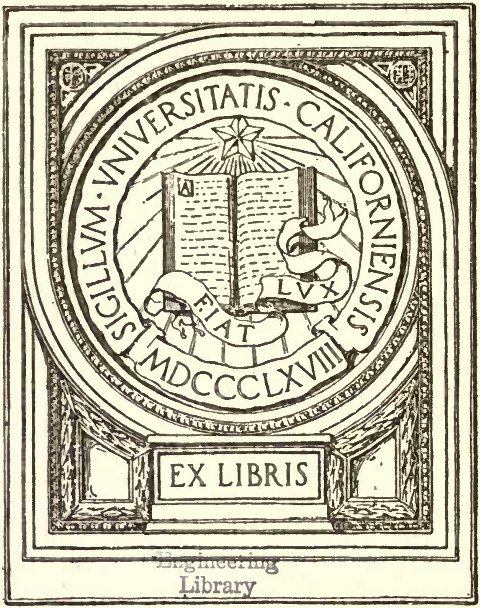
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# CONCRETE GARAGES

## THE FIREPROOF HOME
## FOR THE AUTOMOBILE

PUBLISHED BY
THE ATLAS PORTLAND CEMENT COMPANY
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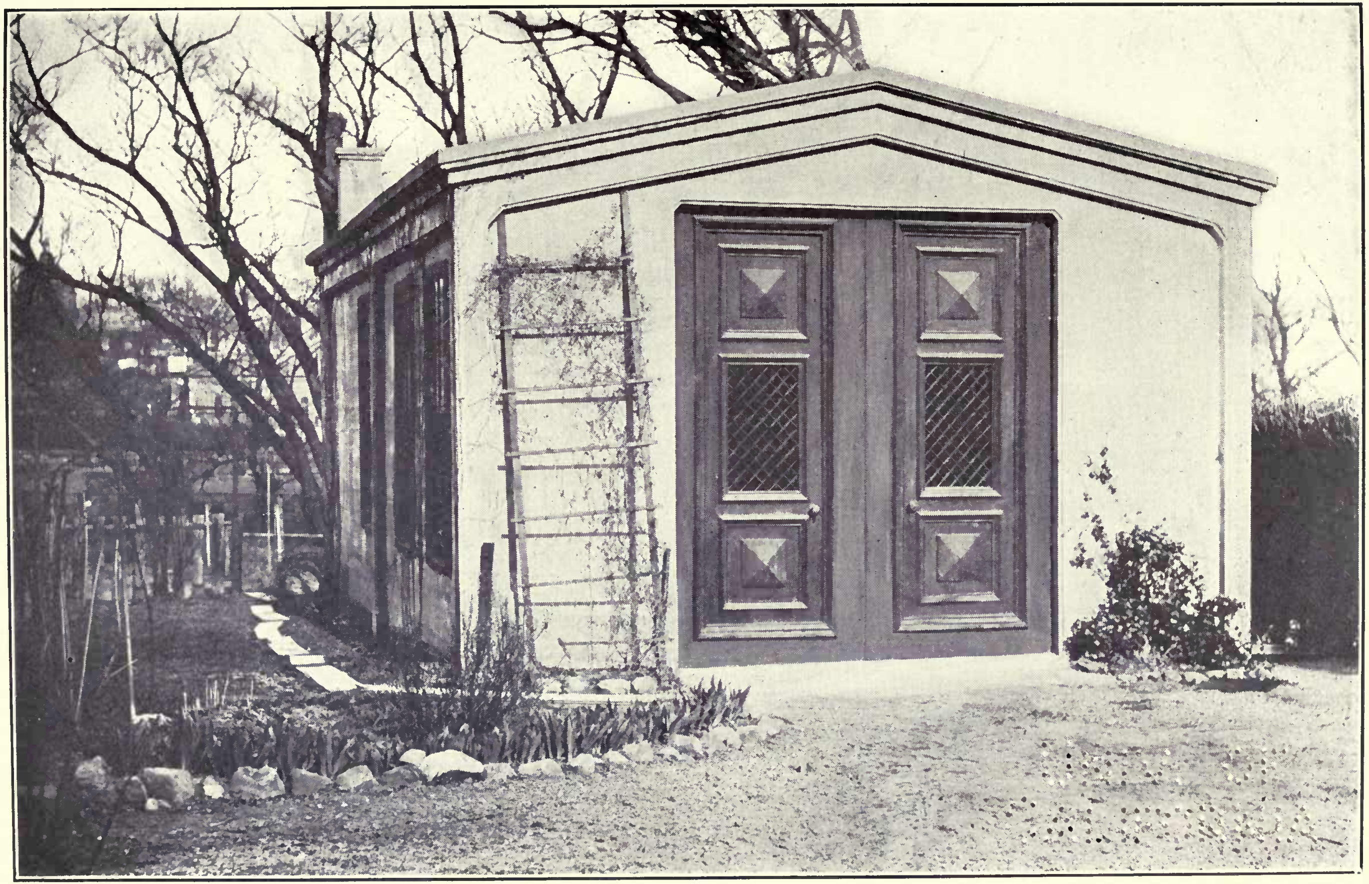
First Edition



Garage at West Brighton, S. I. Solid Reinforced Concrete.

# CONCRETE GARAGES

With the advent of the automobile and its growing popularity, especially among the people living in suburban towns, there has come a demand for a new class of building—the private garage. The necessary storage of oils, gasoline and other combustible materials, makes the garage a veritable firetrap, unless a fireproof building is erected.

Concrete, by reason of its adaptability to varying conditions, is the cheapest satisfactory fireproof building material, and the absurdity of storing a valuable automobile in a building liable to burn at any moment, when, for a small difference in price, a fraction of the cost of the automobile, a fireproof building can be built, is readily apparent.

Many automobile owners have realized this situation, and the illustrations in this book show a few simple designs in concrete garages which have been built for the proper housing of automobiles and the protection of the property.

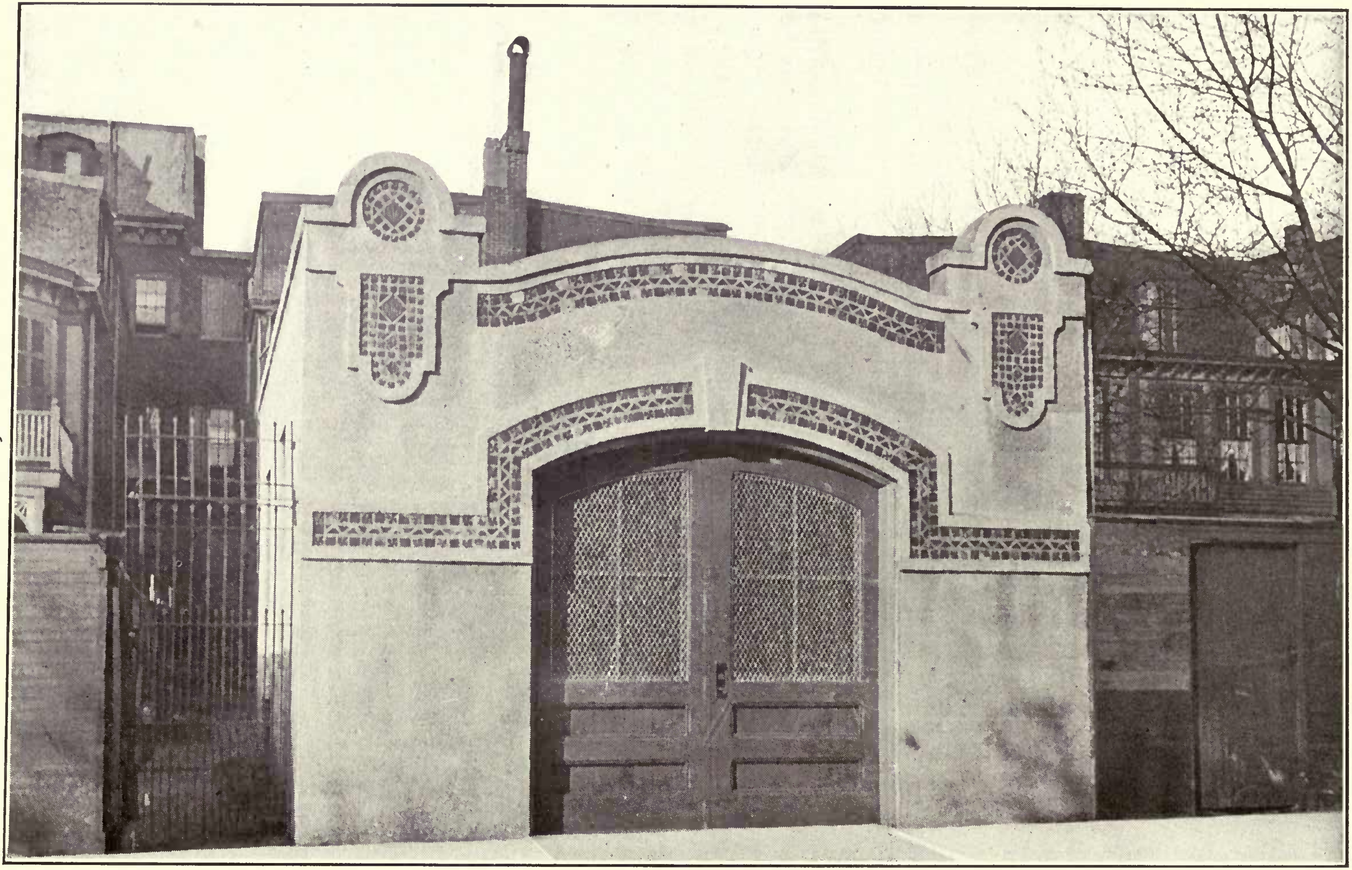
It is hardly necessary to say that wood is not a proper material for the construction of garages. Moreover, wood floors become soaked with oil and quickly rot tires. Aside from being inflammable, the high cost of lumber and of the skilled labor necessary renders the difference in price between wood and concrete a negligible quantity.

Brick work and masonry are as a rule very much more expensive than concrete, while offering no additional advantages.

There are several ways of using concrete in garage construction, each of which will give good results, the best methods being determined largely by local conditions, such as the supply of skilled or unskilled labor and the quality of material to be had. Simple one-story garages can be constructed without difficulty under the direction of a good foreman, but for the more elaborate buildings and those of more than one story, an architect or engineer thoroughly familiar with concrete construction should be employed. This is essential when reinforced concrete floors are to be built.

The following methods of building concrete garages are the most popular, and used either singly or in combination will give satisfactory results.

1.—Mass or reinforced concrete.
2.—Concrete hollow tile.
3.—Concrete block.
4.—Pipe frame with wire lath and stucco.
5.—Wood stud frame and stucco.



Garage at Philadelphia, Pa. Solid Reinforced Concrete.

## GENERAL DIRECTIONS.

*The selection of materials for building with concrete should be carefully undertaken, as without the best material a first class job cannot be expected.

These brief rules should always be kept in mind: 1st—Use clean coarse sand, broken stone or clean screened gravel and Atlas Portland Cement. 2d—Make sure the concrete is thoroughly mixed. 3d—That sufficient water is added to produce a mushy mixture. 4th—The concrete is used before it gets its initial set—the result will be a hard, dense concrete.

The selection of the aggregate (sand and broken stone or gravel) will play an important part in the appearance of the finished work, and where a particular shade or color is desired, it is recommended that a sample batch of concrete be made, using exactly the material that is to be used in the work.

Atlas Portland Cement is particularly light in color, and, therefore, peculiarly adapted to obtaining beautiful effects.

## MASS OR REINFORCED CONCRETE CONSTRUCTION.

Mass concrete, by which is meant solid concrete, built in place between temporary wooden forms, is a most durable and substantial type. Floors may be built of the same material, but must be properly reinforced with steel.

In preparing the footing for a garage, excavate a trench to the depth below the frost line, six inches wider than the proposed wall, and fill to within 8 inches of the ground level with concrete—1 part Atlas Portland Cement, 3 parts clean coarse sand, 6 parts broken stone or gravel. After the concrete is sufficiently hard to withstand the weight build the †forms for the proposed wall in the center of the footing and fill with concrete—1 part Atlas Portland Cement, 2 parts clean coarse sand, 4 parts broken stone or gravel—using a stable or coal fork to work the large pieces of aggregate away from the surface, letting the mortar and fine material through so as to make a dense, smooth, hard surface. The forms for the walls may be taken off in 48 hours in warm weather, but should remain longer if the weather is cool. In cold weather concrete may be handled with excellent results, but all material must be heated including the cement and the water, to fully 80 degrees, and as soon as deposited must be covered and kept warm until thoroughly set. In hot weather concrete should be kept covered, sheltered from the sun as much as possible and continually wet down. You cannot give concrete too much water after it has set.

For a one-story garage, the walls need not be over 8 inches thick. For a

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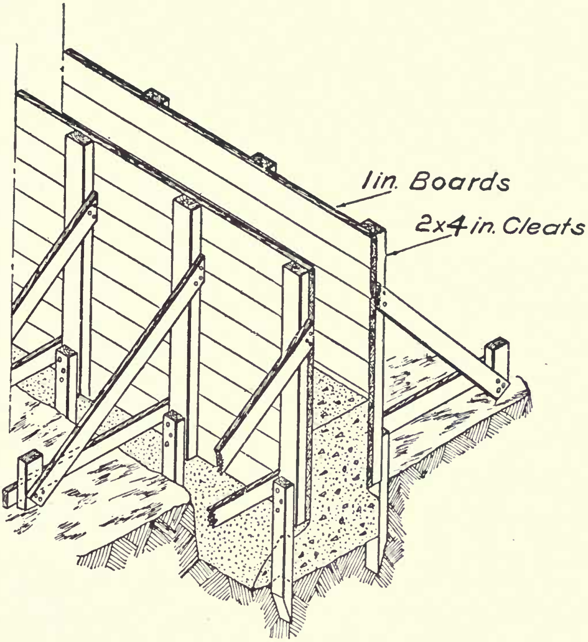
*For detailed information as to the selection of materials and the methods of mixing and depositing concrete, see our "Concrete Construction About the Home and on the Farm," free upon request.

†See forms p. 19—"Concrete Construction About the Home and on the Farm."

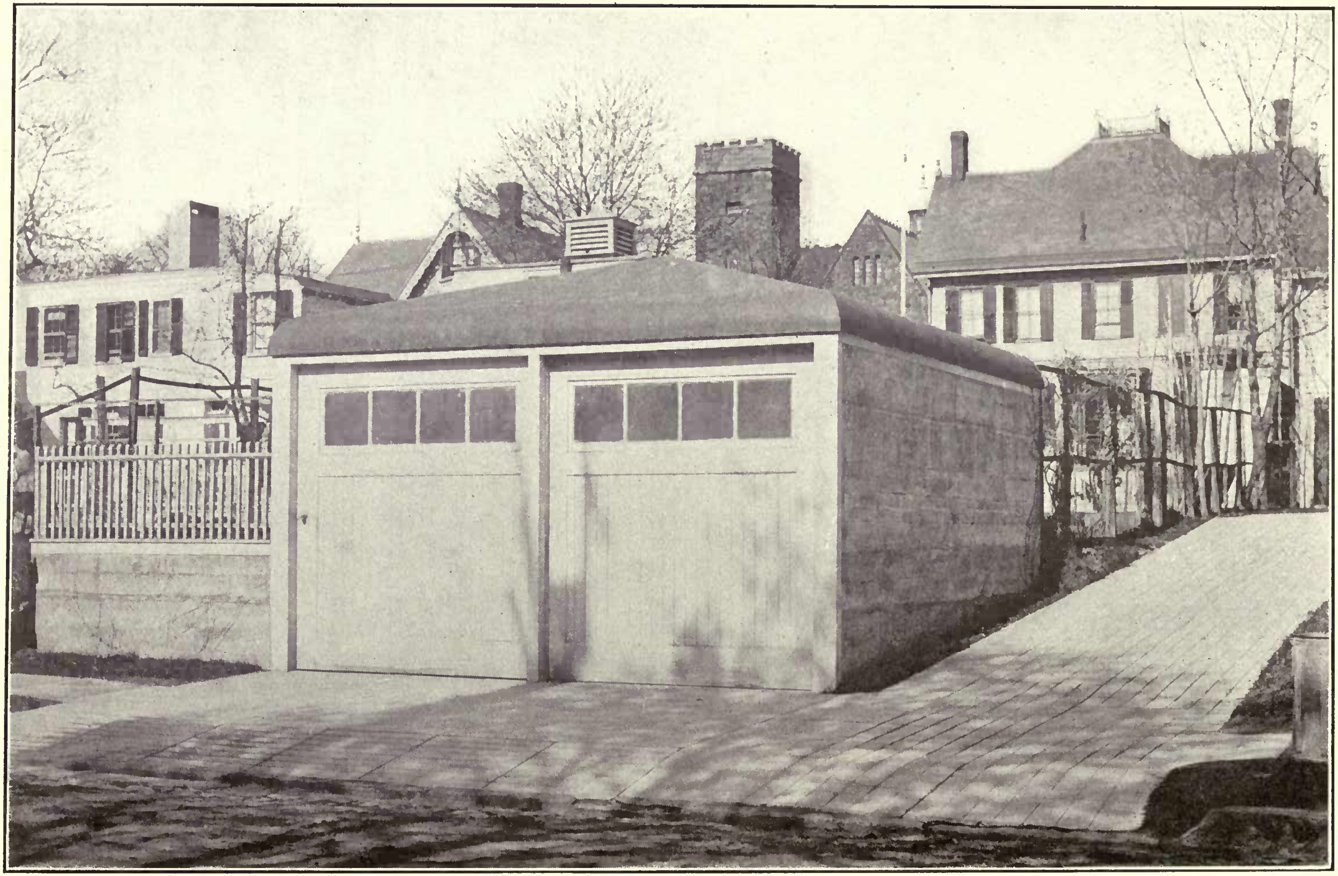
Garage at White Plains, N. Y. Solid Reinforced Concrete.



Forms for Mass Concrete.

two-story building make the first story 10 inches thick and the second story 8 inches thick. After the forms are in place, it is desirable to smear the inner surface with petroleum (crude vaseline), soft soap or other similar material. After the forms are removed and before the surface of the concrete has dried out, the board marks should be removed by rubbing the surface with carborundum brick and washing down with clean water. This method is superior to applying a wash of any kind. A piece of hard sandstone will do for this rubbing, but the carborundum will work faster and cut cleaner.

For mouldings, panels, projections or recesses corresponding moulds should be made in wood and set up rigidly with the wooden form work and filled simultaneously with the rest of the walls. It is best to fill entire sections of the wall in one operation, stopping only at a moulding or other horizontal line, as it is difficult to bond concrete masses and the line of cleavage or demarcation between masses of concrete deposited at different times is likely to show permanently. If a wall is to be stuccoed, it would be desirable to reduce the quantity of the sand and allow more or less honeycombing to appear on the surface of the work to give an additional bond to the mortar, and it is desirable to wait a month or so after the concrete has been poured before the stucco is applied to a concrete wall.

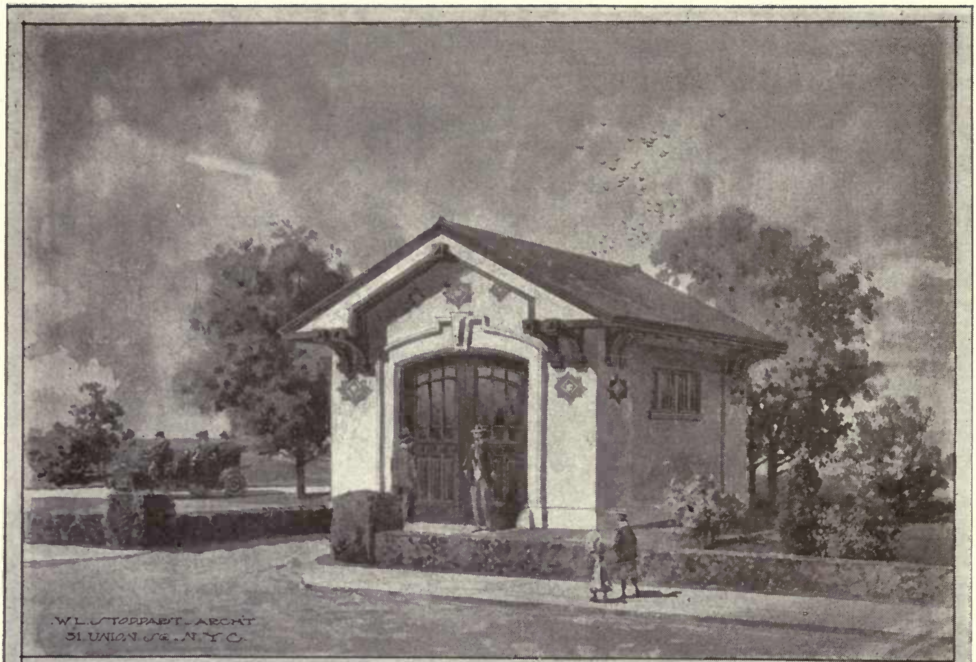


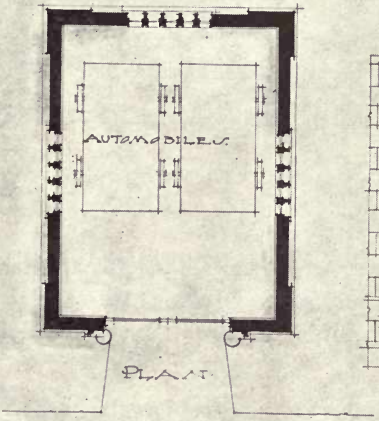
Garage at Paterson, N. J. Solid Reinforced Concrete.

A good combination will be found to be a skeleton of reinforced concrete with piers from 16 ft. to 18 ft. apart, with the panel between the piers made of concrete blocks or tile. The panel wall may be made of solid concrete, the same as the piers, but a more attractive looking building and a more economical construction can be obtained by the first method. If more elaborate effects are desired, much can be done by using facing of fine material of crushed granite or marble, Atlas Portland Cement, and carefully selected sand, and after the concrete has reached a proper hardness, tooling the face so as to bring out the texture of the facing mixture. Stone cutters' tools are used for this purpose, and a great variety of effects may be secured by a judicious choice of material.

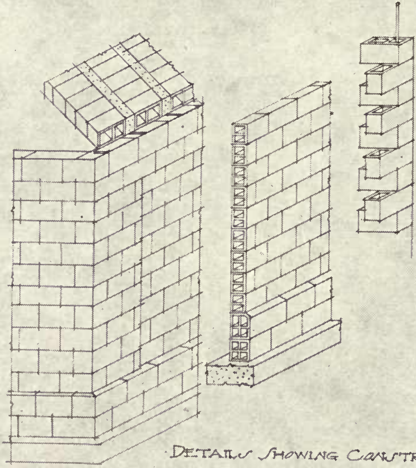
Garage at Beverly Farms, Mass. Solid Concrete.

A sloping or hip roof is not easily managed in fireproof construction and the safest and most economical scheme is to use a wood roof covered with slate, asbestos or tile and sealed on the under side with a metal lath and cement ceiling built in the same manner as the walls of the pipe frame garage described.





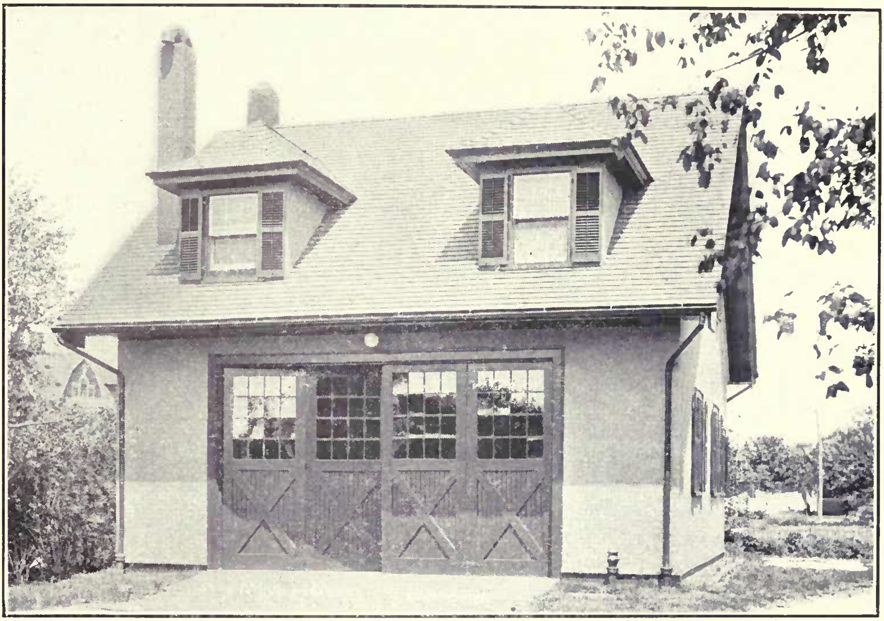
PLAN



DETAILS SHOWING CONSTRUCTION

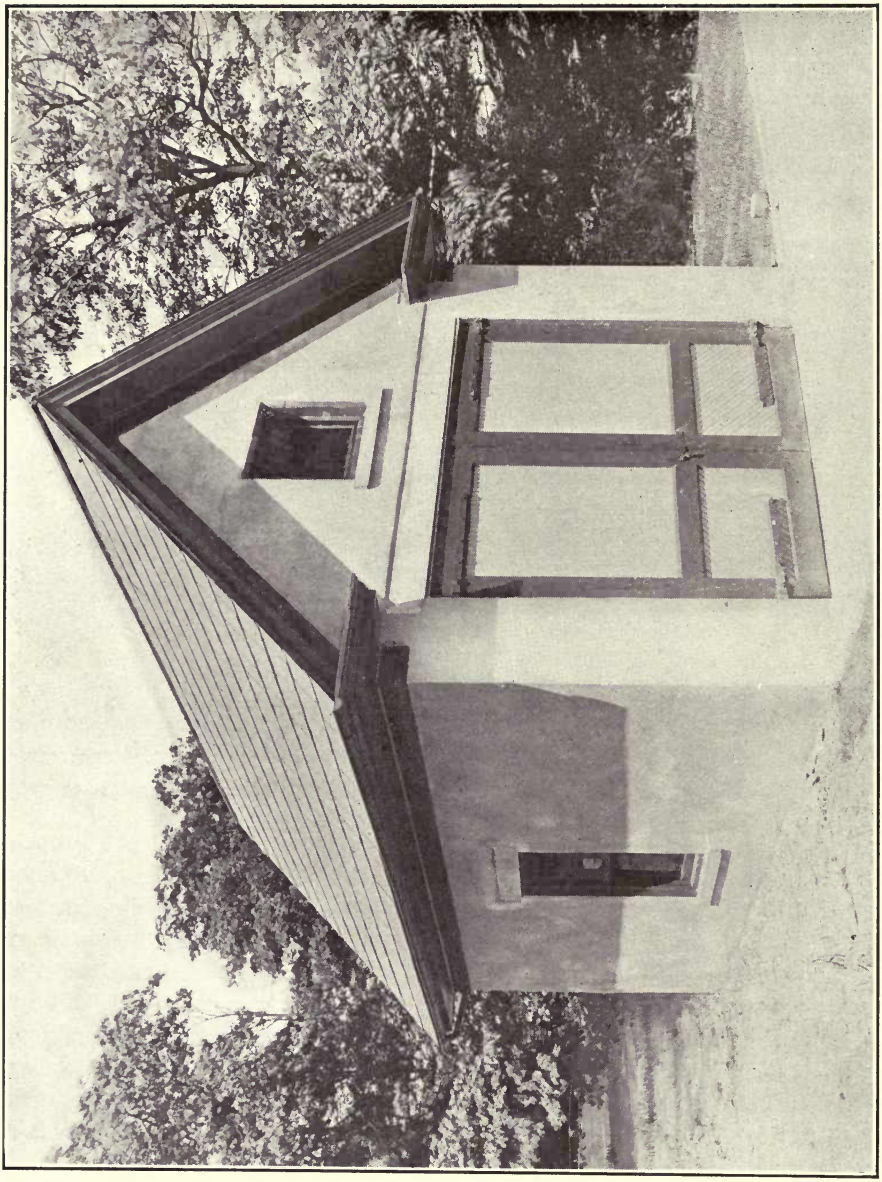
## CONCRETE TILE CONSTRUCTION.

In various parts of the country concrete hollow tile are to be had which are exceedingly economical for wall building. They are made in various shapes and sizes and may be laid up by any brick mason rapidly and efficiently. The accompanying drawing will give some suggestion as to the method of laying these tile.



Garage at Far Rockaway, L. I. Stucco on Wood Stud and Metal Lath.

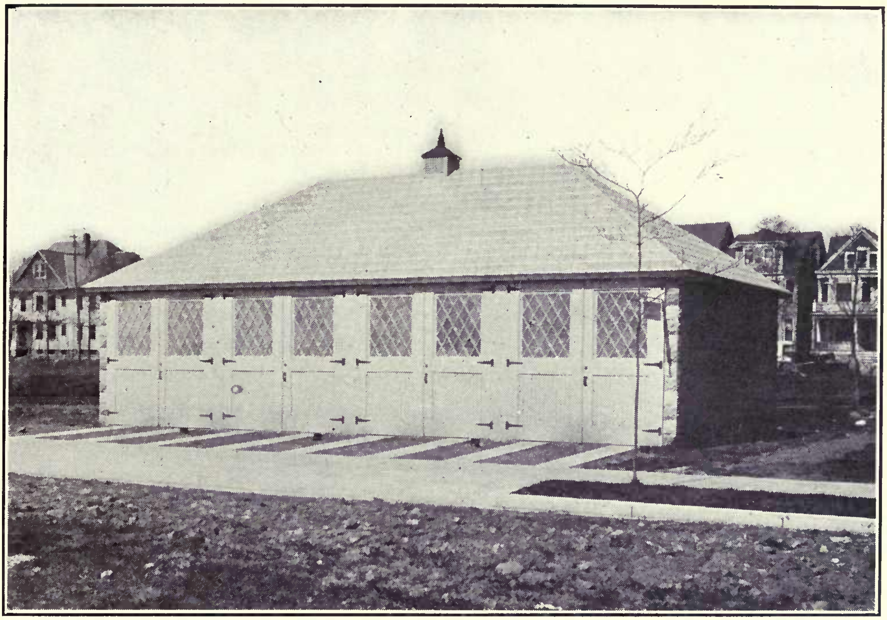
A footing should be laid extending 3 inches on each side of the proposed wall and from 8 inches to 10 inches in thickness. This footing should be carried down below frost line, as in mass construction. The tiles which are to be had usually 10 inches wide and 8 inches high, should be laid on top of this footing and carried up to ground level or above. If the load is not too heavy the smaller tile—6″ x 8″—may be laid up for the rest of the wall. The tile shown in the drawing at the right are corner tile, with the cells running vertically instead of horizontally, and may be used in combination with the regular wall tile for the purpose of turning corners and working around doors and window jambs. If a two-story building is required it is advisable to fill the corner tiles with concrete and reinforce the piers thus formed with steel bars. It will also be found advisable to carry the 8″ x 10″ tile up to the level of the underside of the beams and use the smaller tile for the second story. A large



Garage at Youngstown, Ohio. Stucco on Concrete Tile.

amount of variation is possible with the use of concrete tile, which will readily suggest themselves to anyone desiring to build in this method. An excellent fireproof floor can be made by using the corner tile for floor fillers with concrete ribs between as indicated in the sketch.

*Stucco adheres readily to concrete tile walls, provided the wall is thoroughly wet when the stucco is being applied. The stucco, being of the same material and having the same coefficient of expansion as the tile, does not crack, as is often the case when terra cotta tile is used.



Garage at Paterson, N. J. Concrete Block.

## CONCRETE BLOCK WALL CONSTRUCTION.

Concrete blocks differ from concrete tile in the method of manufacture. They are heavier and less economical than tile, but may be had in almost every locality, and if reasonably well made will do excellent service. They are generally made with rock face or finished surfaces and consequently do not require any surface treatment or stucco. There are many types of blocks on the market and there is little choice between them, although a wall made of two pieces is, as a rule, superior to a wall made of one piece, as these blocks are not as water-tight as wet mixed concrete, and the wall is likely to be damp

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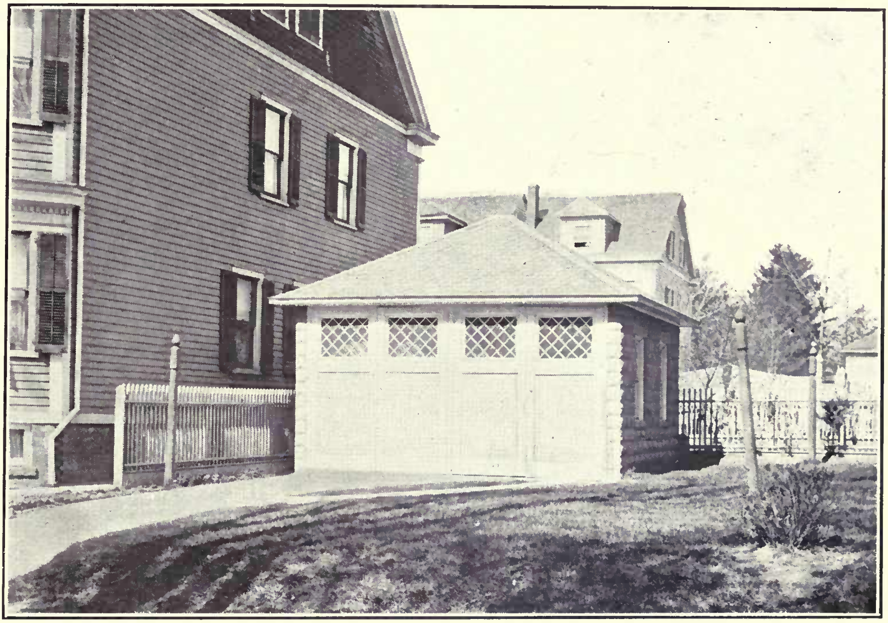
*See Method of Applying Stucco Under Pipe Frame, Wire Lath and Stucco.

Garage at Far Rockaway, L. I., N. Y. Concrete Block.

if made of one-piece blocks. By using good facing material and a rich mixture, however, very good weatherproof blocks can be made. Sills and lintels may be cast in wooden forms to fit window and door openings.

Concrete blocks should be laid as cut stone and any good foreman is competent to superintend the work.

Garages of this construction are very often stuccoed, as will be seen by the illustrations.



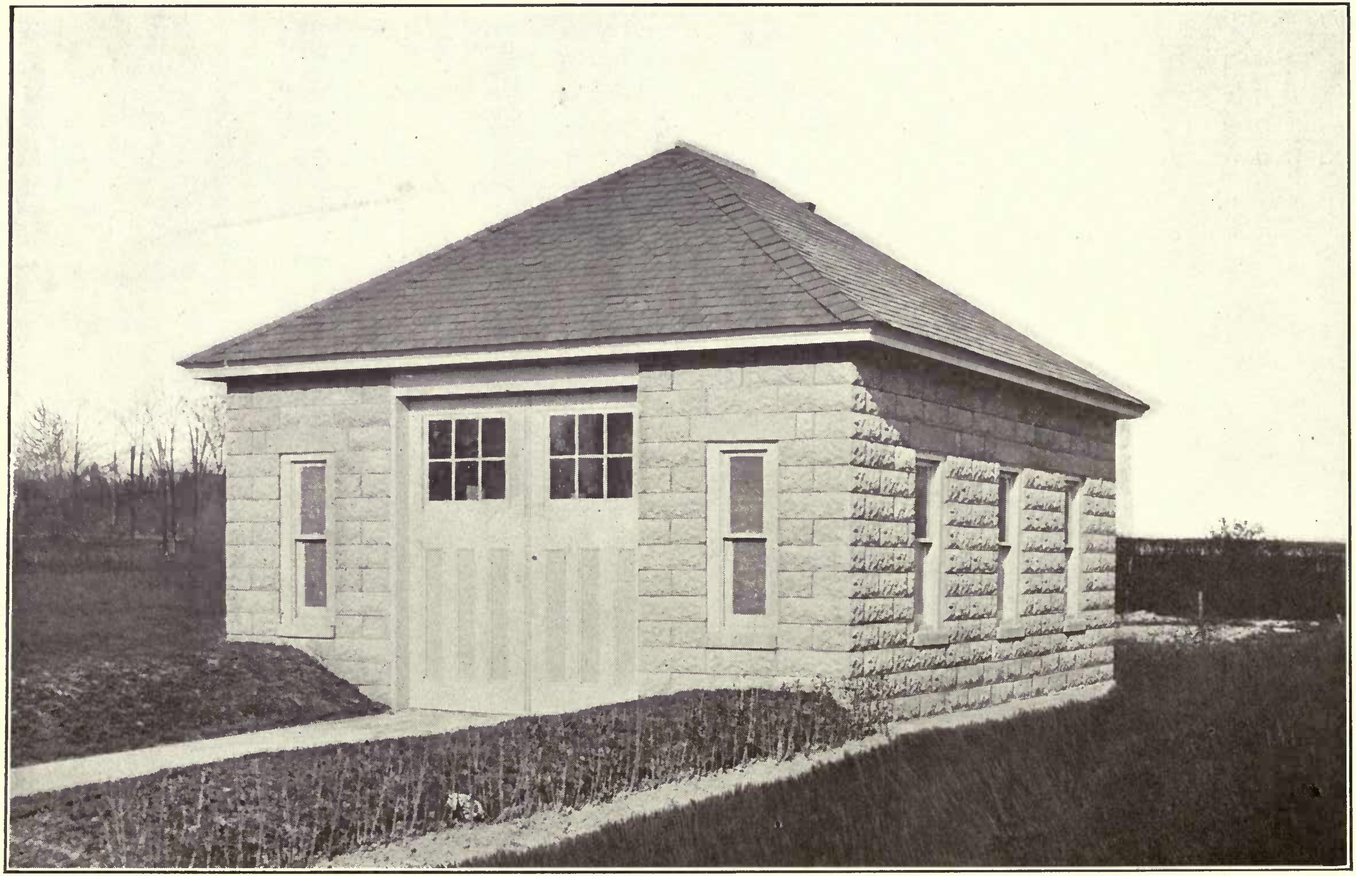
Garage at Paterson, N. J. Concrete Block.

## PIPE WIRE LATH AND STUCCO.

This type of garage will be found very economical where material for concrete making is scarce, and where an owner does not want to go to the expense of solid construction. This construction consists of a frame work of pipe which can readily be had and is simply put together. The frame work is set in a base of concrete and the walls are covered with wire lath and mortar. The method is simple and at the same time is applicable to variation and decoration so as to meet all practical requirements and make an artistic structure.

## FOOTING WALLS.

Excavate and build a footing wall from the surface of the ground to below



Garage at Paterson, N. J. Concrete Block.

frost line. Provide a footing under the wall 6 inches thick extending 3 inches on either side. The wall itself should be 12 inches thick, built between suitable plank forms. Mix the concrete for the wall and footing in the proportion of 1 part Atlas Portland Cement, 2 parts clean, coarse sand and 5 parts gravel or broken stone. Use sufficient water to make a soft concrete and puddle into place until forms are thoroughly filled, flush to the top.

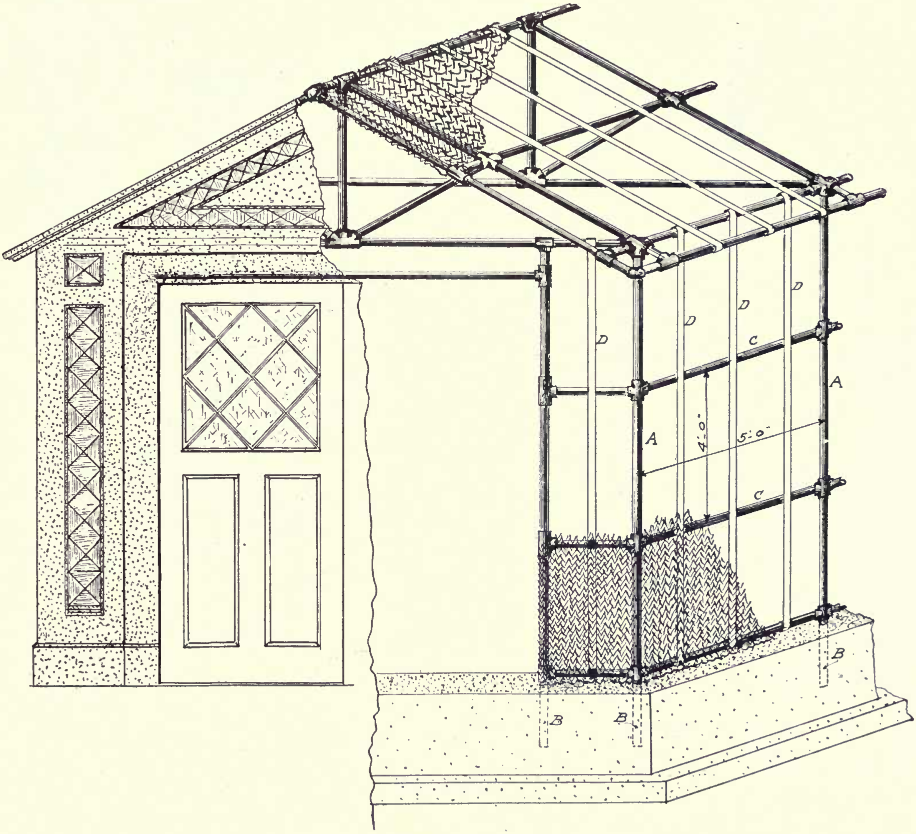
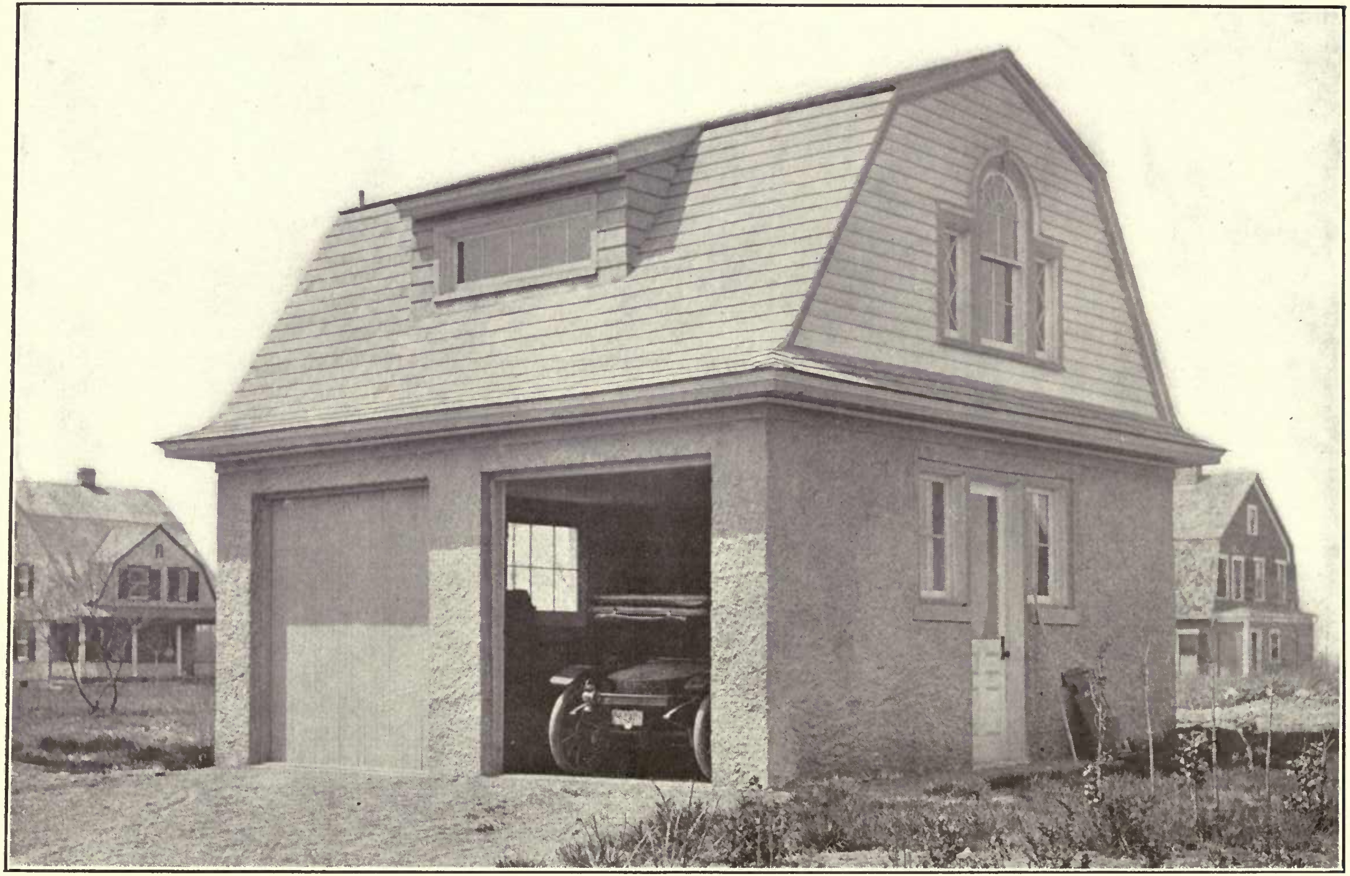


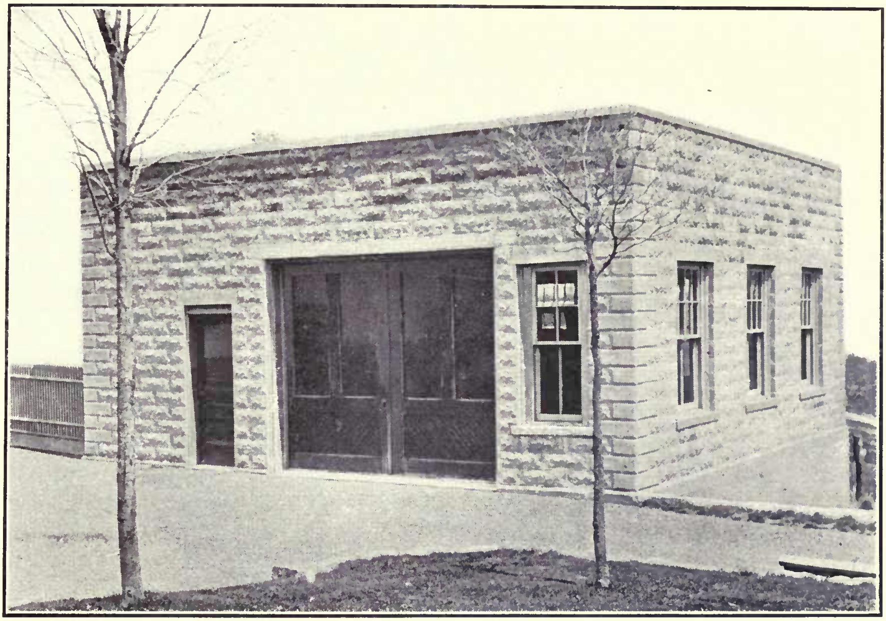
Diagram of Pipe Frame Garage.



Garage at Haworth, N. J.  Stucco on Concrete Block.

## PIPE DOWELS.

Before the concrete has set imbed along the center line of the wall pipe dowels 8 inches long, threaded to receive the standards AA. If angles are used in place of piping, the dowels should be large enough to let the angles down inside so that cement mortar made of 1 part Atlas Portland Cement to 2 parts of sand may be poured down into the dowels to hold the angles rigidly in place.



Garage at Scarsdale, N. Y. Concrete Block.

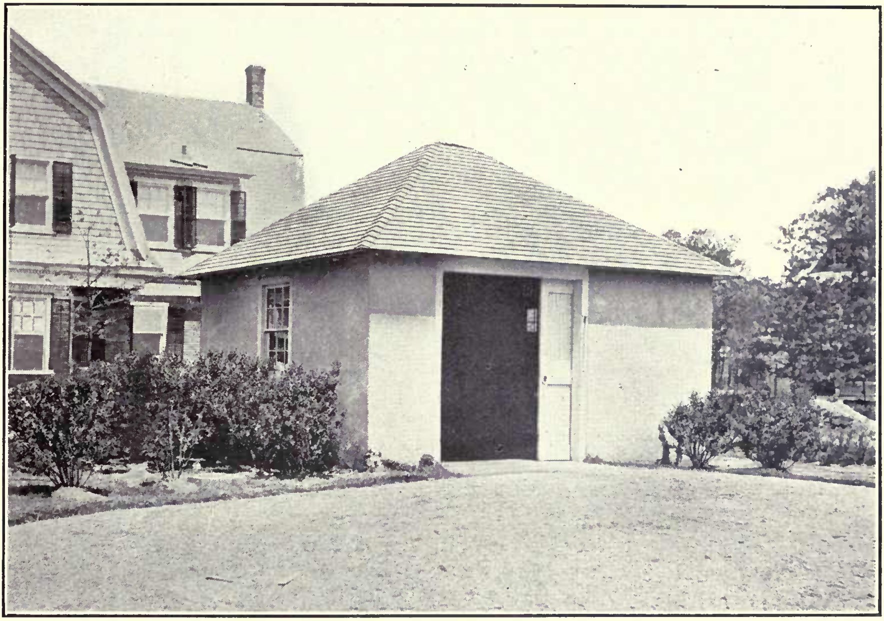
The frame should, of course, be laid out carefully on paper, and all dimensions determined. The local gasfitter or blacksmith can then get out main structural parts and assemble them, only light tools being necessary in either case. For a pipe frame use 2½-inch galvanized uprights, spaced not more than 5 feet on centers and 1½-inch galvanized horizontals about 4 feet apart. The frame, having been set up, fastens on the studs SS of ¾-inch by ¼-inch flatiron bent around the horizontal pipe and stretched well into place. The studs should not be more than 16 inches on centers.

Metal lath should be laced to the studs DD, tied on well with No. 16 wire. There are a number of kinds of lath on the market, some of which are ribbed and provided with clips or fasteners to take the place of wiring. Any of these will do, but it is essential that the ratio of opening in the lath be large

Garage at Paterson, N. J. Concrete Block.

as compared with the area of metal. Wire mesh, expanded metals and the like are best for walls of this kind. Wherever the mortar is to be carried around the pipe frame, as at the edge of the eaves, carry the metal lath well around and wire firmly.

In pipe frame construction three coats of stucco will be required to make a good wall finishing about 1½ inches thick; two coats being applied outside and one, a finishing coat, inside, a single layer of metal being used.



Garage at Woodmere, L. I. Stucco on Wood Frame and Metal Lath.

Small 1½-inch channel iron frames, punched with 1¼-inch holes and provided with bolts, should be set around all door and window openings to receive a wooden buck to which the door or window frame may be fastened. This should be done before stucco is applied.

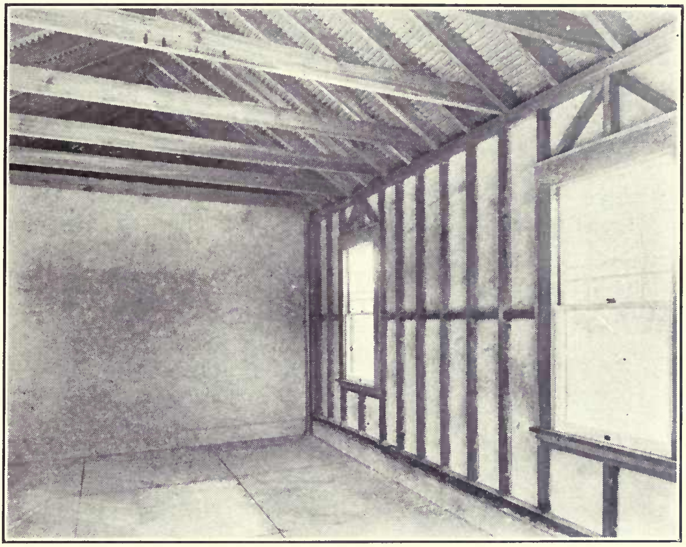
After the scratch coat (see specifications for stucco, p. 29) has been applied to roof and before second coat is put on, set 2-inch by 1-inch beveled wooden strips running parallel with the eaves and wire firmly. The spacing will depend on the kind of roofing to be used, whether slate, asbestos, tiles, etc. After the strips are set fill flush on the top with mortar mixed 2½ parts sand to one part Atlas Portland Cement.

If desired many elaborate and beautiful effects may be secured by the introduction of panels or borders in tile, mosaic, or even pebbles and field

Garage at Allentown, Pa. Stucco on Wood Frame and Metal Lath.

stones. Frames of wood of required outline and thickness should be wired to the lathing and the stucco work finished. After the wall is hard remove the wooden frames carefully and fill the panels by grouting in the tile or other ornament, as desired.

Small angle iron may be substituted for the pipe frame, the angle irons being cut to the proper length, rivetted together and set up in the same manner as for the pipe frame. The furring, metal lath, stucco, etc., will be applied in the same manner as described.



Interior of Garage at Allentown, Showing Wood Frame with Stucco on Both Sides of Metal Lath.

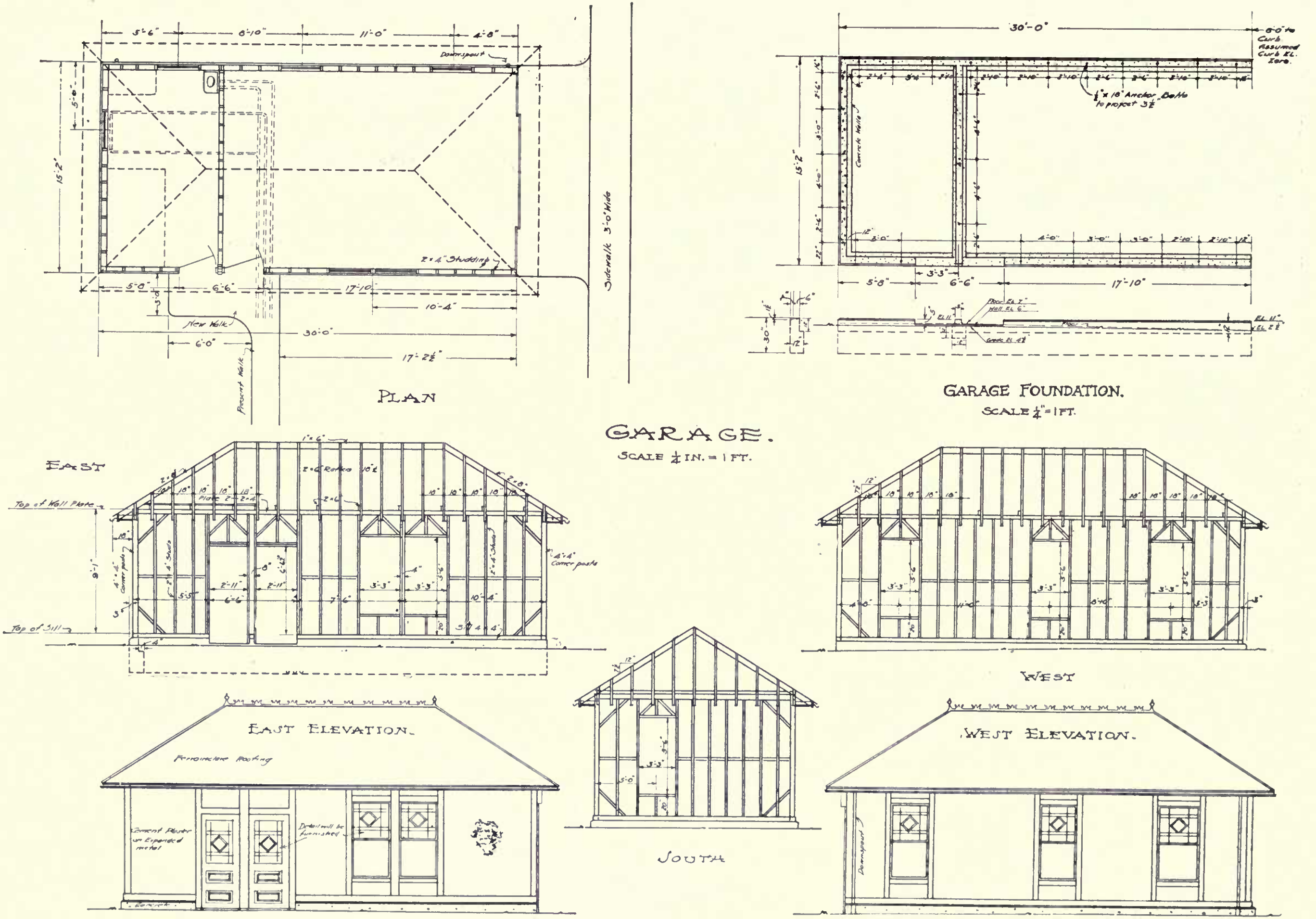
## WOOD STUD FRAME AND STUCCO.

If a still cheaper method is desired, the frame work of the building may be constructed of wood, 2 x 4 wooden studs 16 inches on centers with bridging between being used in place of the pipe or angle iron frame. Staple the metal lath on to the wooden studs, but have the stapling loose to allow a certain amount of play between the lath and the stud.

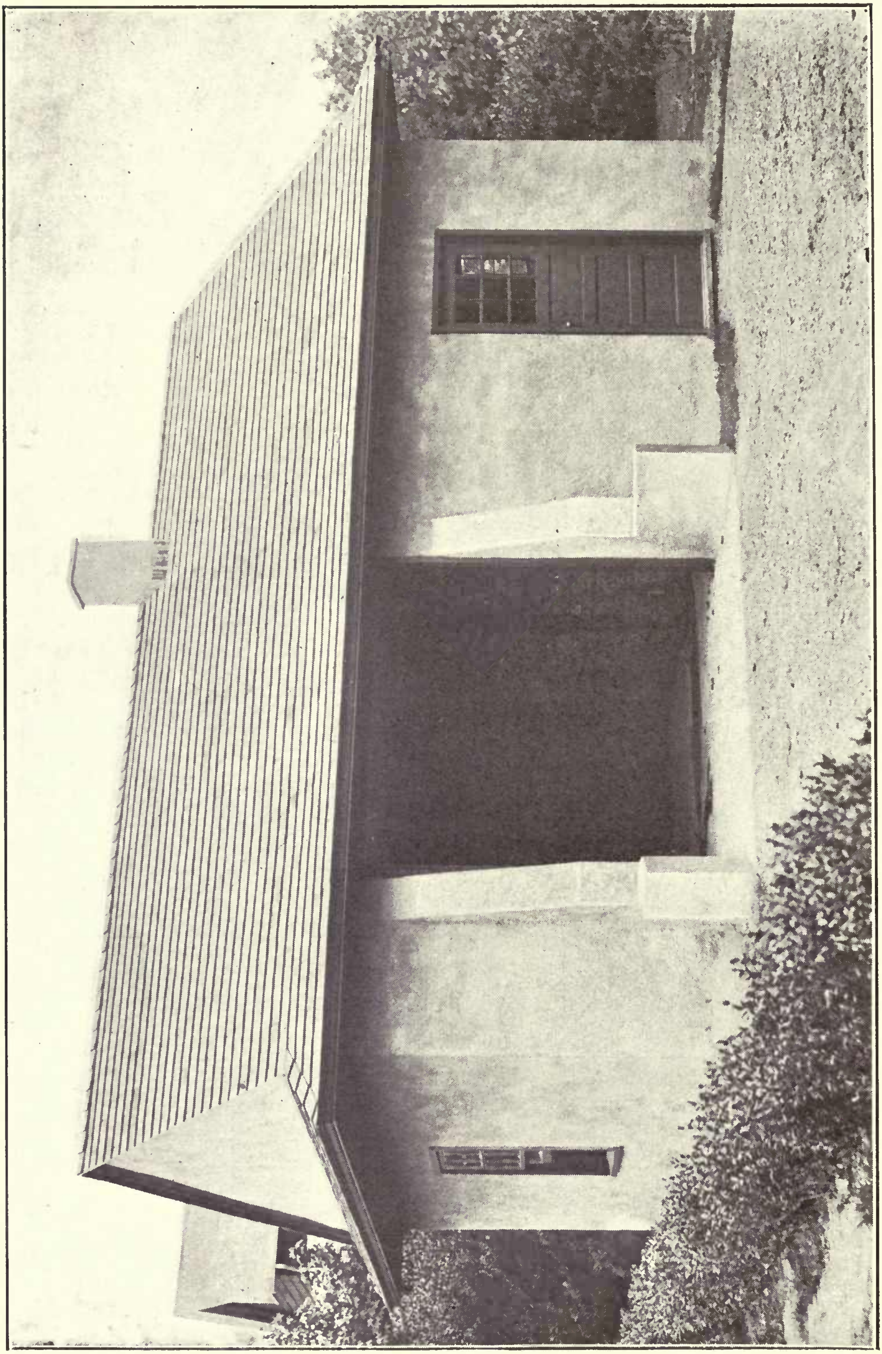
Use two coats of stucco on the outside and apply one coat inside between the 2 x 4 studding. A neater appearing interior can be had, and the garage made more fireproof by lathing and stuccoing the interior in the same manner as the exterior, but in place of making a rough finish the finished coat should be floated smooth.

Detail drawings of a wood stud garage are shown on page 27 and a photo on page 24. The cost of this garage completed was $783.80.

Garage at Far Rockaway, L. I., N. Y.  Stucco on Wood Frame and Metal Lath.



Detail of Garage Shown on Page 24



Garage at Woodmere, L. I., N. Y. Stucco on Brick.

## GARAGE FLOORS.

Garage floors should be laid the same as sidewalks, detailed specifications for which are given in our book "Concrete Construction about the Home and on the Farm," copies of which may be had free upon request.

## SPECIFICATIONS FOR STUCCO.

The instructions given below should be closely followed in building any of the garages described in this book.

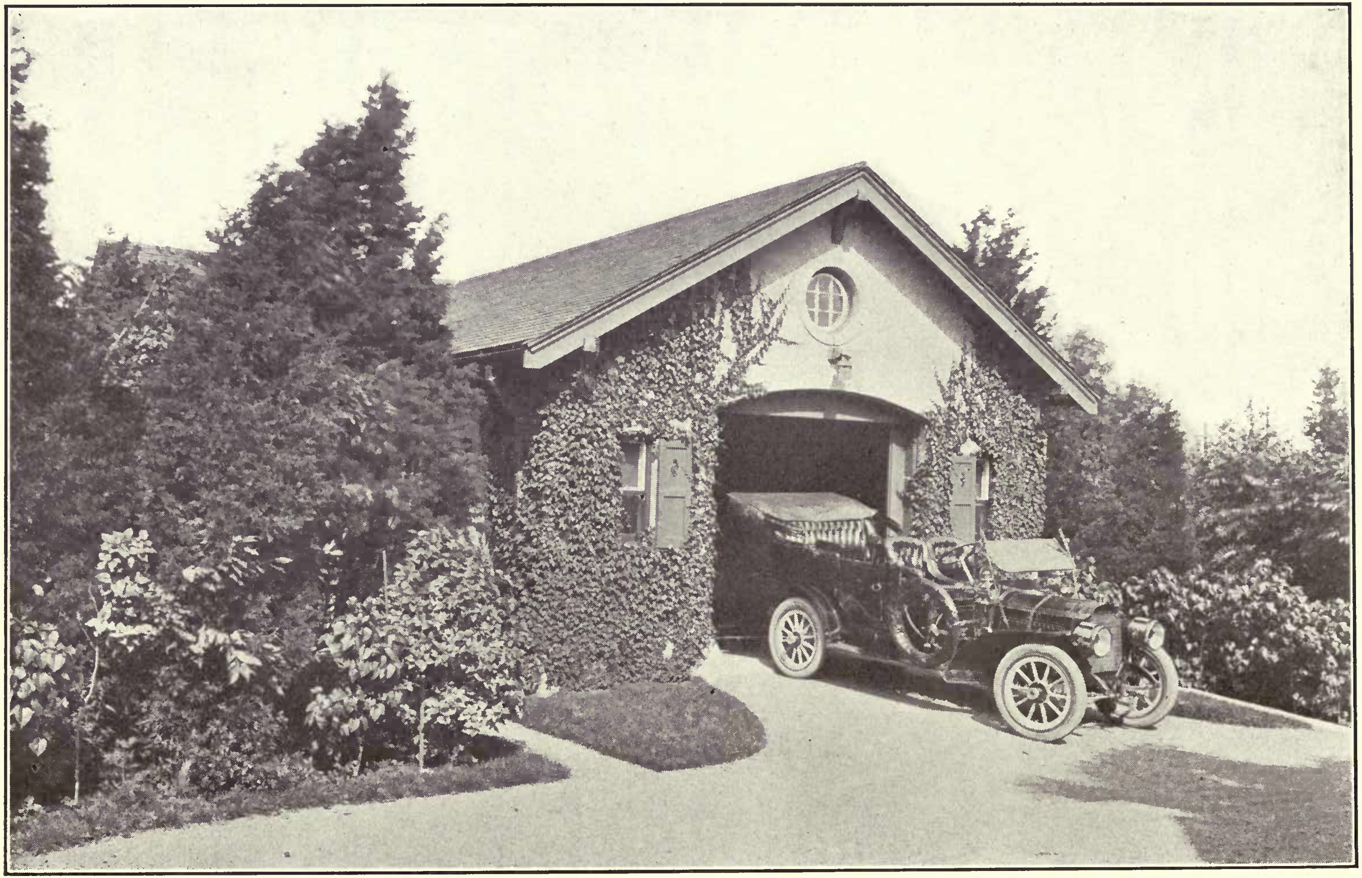
"Stucco work may be used to cover wood, brick, stone or any other building material, provided special precautions are taken in preparing the surface properly so that it will adhere and not crack or scale off. The work should be done by an experienced plasterer.

"As a rule, two coats are used—the first, a scratch coat composed of five parts "ATLAS" Portland Cement, twelve parts clean, coarse sand, and three parts slaked lime putty and a small quantity of hair; the second, a finishing coat composed of one part "ATLAS" Portland Cement, three or even five parts clean, coarse sand and one part slaked lime paste. Should only one coat be desired the finishing coat is used. Some masons prefer a mortar in which no lime is used, but this requires more time to apply.

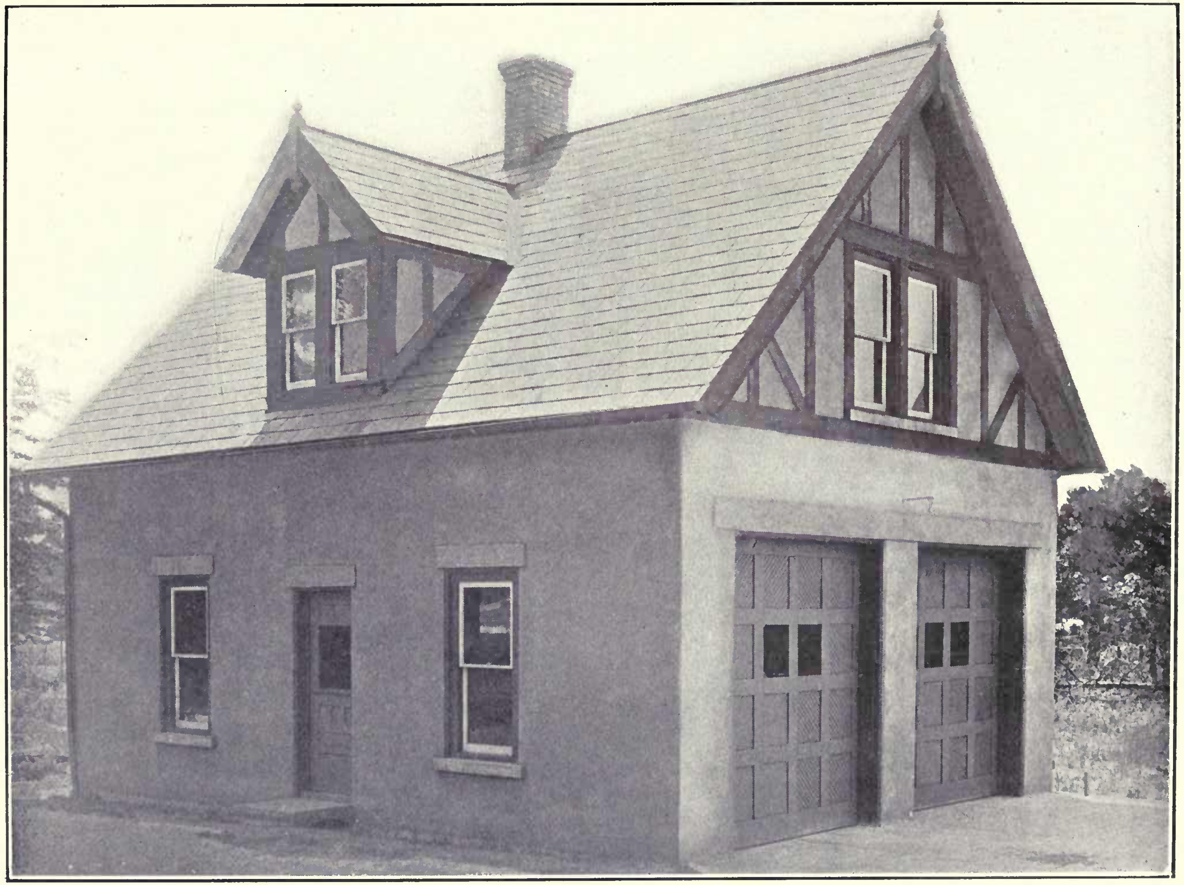
"To apply stucco to brick or stone or concrete, clean the surface of the wall thoroughly, using plenty of clean water so as to soak the wall. If the surface is concrete roughen it by picking with a stone axe. Plaster with a 1½-inch coat and finish the surface with a wood float, or to make a rough surface cover the float with burlap. Protect the stucco work from the sun and keep it thoroughly wet for three or four days; the longer it is kept wet the better.

"In using stucco on a frame structure, first cover surface with two thicknesses of roofing paper. Next put on furring strips about one foot apart, and on these fasten wire lathing. (There are several kinds, any of which are good.) Apply the scratch coat ½ inch thick and press it partly through the openings in the lath, roughing the surface with a stick or trowel. Allow this to set well and apply the finishing coat ½ inch to 1 inch thick. This coat can be put on and smoothed with a wooden float, or it can be thrown on with a trowel or large stiff-fibred brush, if a spatter-dash finish is desired. A pebble-dash finish may be obtained with a final coat of one part "ATLAS" Portland Cement, three parts coarse sand and pebbles not over ¼ inch in diameter, thrown on with a trowel."

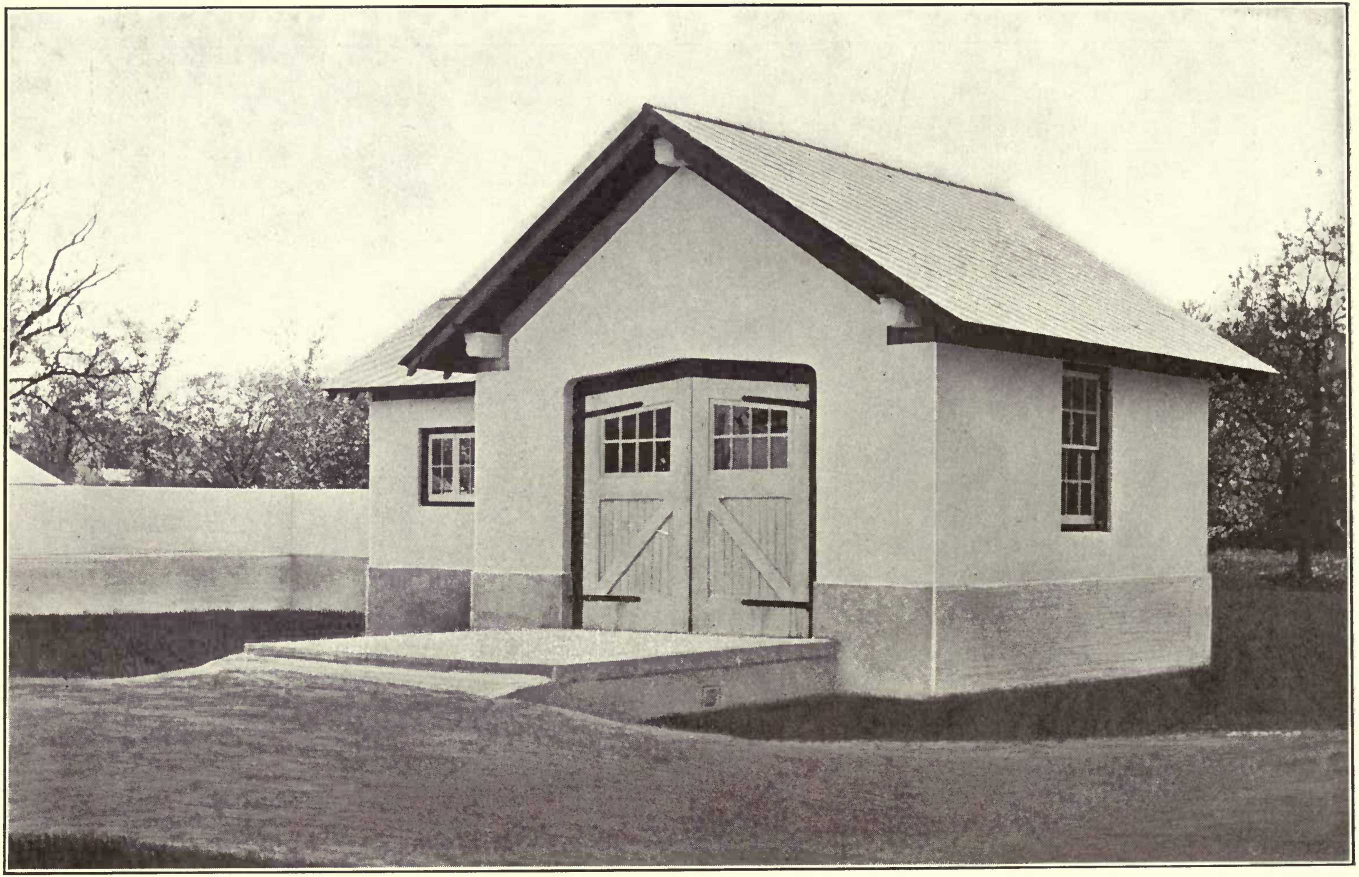
Quoted from copyrighted book "Concrete Construction about the Home and on the Farm," page 156.



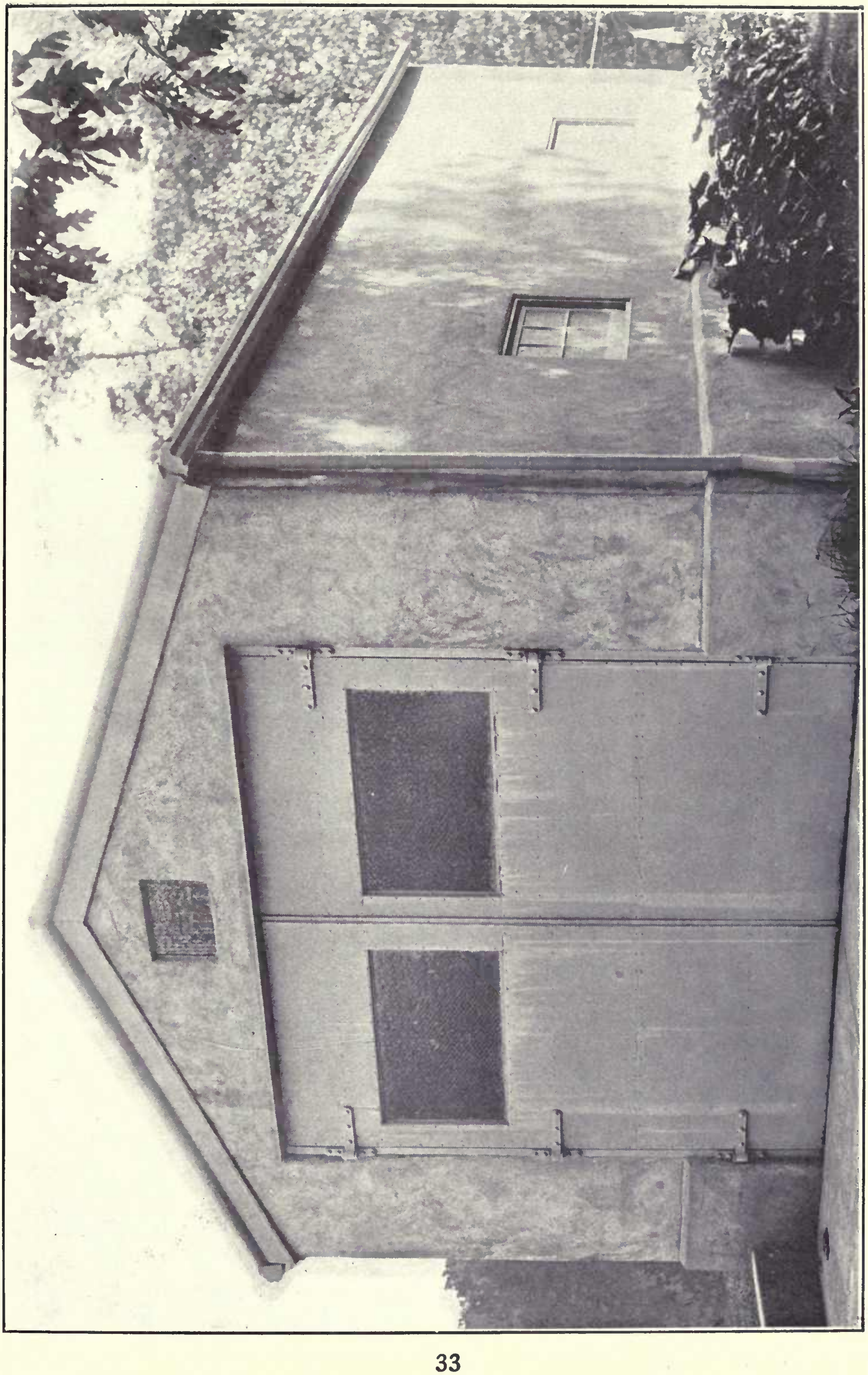
Garage at Cohasset, Mass. Stucco on Wood Frame and Metal Lath.



Garage at Youngstown, Ohio. Stucco on Concrete Tile.

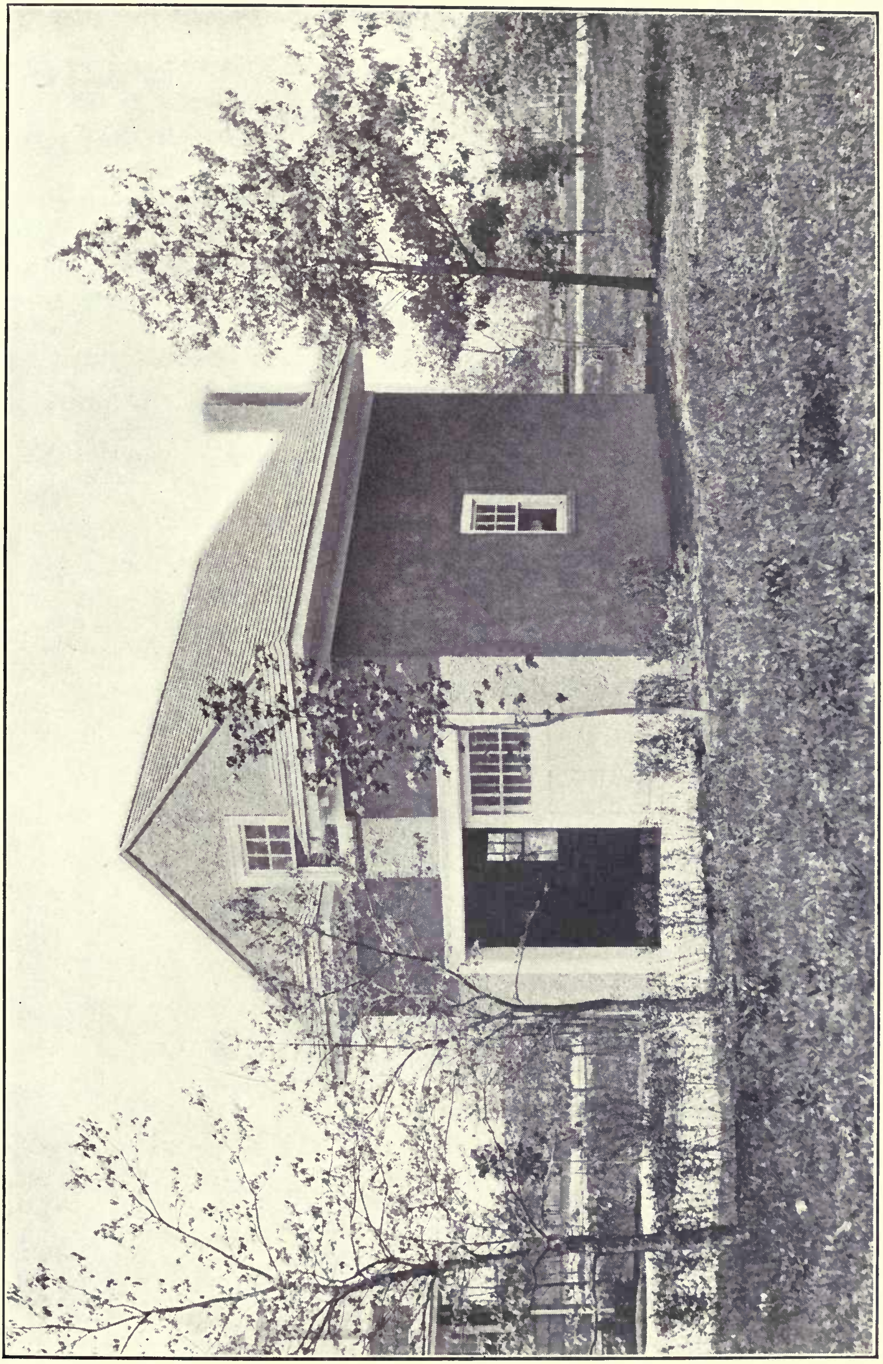


Garage at Islip, L. I., N. Y.  Solid Reinforced Concrete.



Garage at Summit, N. J. Solid Reinforced Concrete.

Garage at Paterson, N. J.  Solid Concrete.



Garage at Woodmere, L. I., N. Y. Stucco on Concrete Block.

Garage at Black Rock, Conn. Solid Reinforced Concrete.

# CONCRETE CONSTRUCTION ABOUT THE HOME AND ON THE FARM

THE RECOGNIZED TEXT BOOK
OF CEMENT USERS

REVISED EDITION
1909

PUBLISHED BY
THE ATLAS PORTLAND CEMENT COMPANY
30 BROAD STREET
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THE ATLAS PORTLAND CEMENT CO.
30 Broad Street, New York

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Eighth Edition

# INDEX.

**Specifications for mixing and handling "Atlas" Portland Cement.**

SPECIFICATIONS FOR MIXING AND HANDLING "ATLAS" PORTLAND CEMENT—*Continued.*

**Specifications for**

SPECIFICATIONS FOR—*Continued.* PAGE

Specifications for—*Continued.* PAGE

# FOREWORD.

The development of the American Portland Cement industry during the past decade has been one of the marvels of the age, and while Portland Cement Concrete has come to be recognized as the ideal building material for heavy work, comparatively little attention has been given to its use in the smaller construction about the home and on the farm. That active interest, however, is taken in this important subject by the suburbanite, the villager, and the farmer, is evidenced by the large number of letters of inquiry received by the agricultural and technical journals.

During the past few years the price of lumber has advanced to almost prohibitive figures, and it is therefore only natural that a substitute material which affords the advantages of moderate cost, durability, and beauty should be looked upon with favor.

It is not our purpose to enlarge upon the uses for which Portland Cement is now considered standard, but rather to direct attention to the economy of supplanting wood, brick, and cut stone in divers ways by the more durable, sightly, and sanitary Portland Cement construction.

In the following pages we shall endeavor to point out, in language free from technical terms, some of the uses for which Portland Cement Concrete is especially adapted.

# CONCRETE CONSTRUCTION.

Concrete construction dates back to the time of the Romans, who secured good results from a mixture of slaked lime, volcanic dust, sand and broken stone. Even this combination, crude in comparison with Portland Cement Concrete, produced an artificial stone which has stood the test of nearly two thousand years, as evidenced by many works in Rome which are to-day in a perfect state of preservation.

"Portland Cement" is an invention of modern times—its universal use the matter of a quarter of a century. The honor of its discovery belongs to Joseph Aspdin, of Leeds, England, who took out a patent in 1824 for the manufacture of "Portland Cement," so called because of its resemblance, in color, to a then popular limestone quarried on the Island of Portland. Manufacture was begun in 1825, but progress was slow until about 1850, when, through improved methods and general recognition of its merits as a building material, commercial success was assured. About this time the manufacture of Portland Cement was taken up in earnest by the French and Germans, and, by reason of their more scientific efforts, both the method of manufacture and quality of the finished product was greatly improved. Portland Cement was first brought to the United States in 1865. It was first manufactured in this country in 1872, but not until 1896 did the annual domestic production reach the million-barrel mark.

EDW. BURNETT, Dairy Expert

ALFRED HOPKINS, Architect

AN ALL CONCRETE DAIRY FARM

GEDNEY FARMS—White Plains, N. Y.

Wonderful as the development of the general industry has been, the growth of the Atlas Portland Cement Company's plants has been even more so. Beginning in 1892 at Coplay, Pa., with the modest capacity of 250 barrels per day, its production has steadily increased through the construction of plants Nos. 2, 3, and 4, at Northampton, Pa., and plants Nos. 5 and 6, at Hannibal, Mo., until now the productive capacity is more than 40,000 barrels each twenty-four hours, or approximately fourteen million barrels per year. This production is greater than the capacity of any other Portland Cement company in the world. "ATLAS" Portland Cement is manufactured from the finest raw materials, under expert supervision in every department of the works. It is of the highest quality, being guaranteed to pass all usual and customary specifications, such as the specifications of the United States Government and those of the American Society for Testing Materials, which latter specifications have been concurred in by The American Institute of Architects, The American Engineering and Maintenance of Way Association, and The Association of American Portland Cement Manufacturers. The quality of eastern and western "ATLAS" is identical. By virtue of its enormous production, The Atlas Portland Cement Company is able to develop and retain in its service the most skilled operating talent in the Portland Cement industry, which insures a thoroughly reliable and uniform product.

"ATLAS" Portland Cement is guaranteed to be "ALWAYS UNIFORM."

**CONCRETE**

Concrete, which is really an artificial stone, is made by mixing pieces of stone, such as broken granite or hard limestone, which may vary in size from a walnut to a hen's egg, with clean, coarse sand and first-class Portland cement, using enough water to make a mushy mixture about like heavy cream.

The cement and water make the mass begin to stiffen in about half an hour, and in from 10 to 24 hours it becomes hard enough so that an impression cannot readily be made by pressing on it with the thumb. In a month's time the entire mass becomes one hard stone.

Conglomerate or pudding stone in nature is really a natural cement concrete, the large and small particles of pieces of stone and sand being cemented together in the course of ages in a similar way to that by which cement is made.

**MORTAR**

Where a very strong mortar is required for laying brick or stone, "ATLAS" Portland cement may be mixed with sand in proportions one part "ATLAS" cement to two and one-half parts sand. A characteristic of "ATLAS" Portland Cement is that it gives an especially *greasy* mortar.

A mortar nearly as strong as the above, and which works still better under the trowel, can be made by mixing one bag "ATLAS" Portland cement with one barrel of clean sand and one-half pail of lime putty. The lime putty is made by thoroughly slaking quick lime. The longer the time the putty can stand before using the better it is. It must never be used when hot or until the lime is thoroughly slaked. When laying up brick and stone with any kind of mortar they must be thoroughly wet.

**CEMENT**

Always use the best Portland cement obtainable. Natural cement is not suitable for concrete. Whatever the kind of cement, unless it is of first-class quality, it may give trouble by not setting up and hardening properly.

Portland cement is manufactured from a mixture of two materials, one of them a rock like limestone, or a softer material like chalk, which is nearly pure lime, and another material like shale, which is a hardened clay or else clay itself. In other words, there must be one material which is largely lime and another material which is largely clay, and these two must

**CEMENT (Cont'd)**

be mixed in very exact proportions determined by chemical tests, the proportions of the two being changed every few hours, if necessary, to allow for the variation in the chemical composition of the materials.

"ATLAS" PORTLAND CEMENT then is made by quarrying each of these two materials, crushing them separately, mixing them in the exact proportions, and grinding them to a very fine powder. This powder is fed into long rotary kilns, which are iron tubes about 5 or 6 feet in diameter, lined with fire brick and over 100 feet long. Powdered coal is also fed into the kilns with the ground rock and burned at a temperature of about 3000 degrees Fahrenheit, a temperature higher than that needed to melt iron to a liquid, and there is formed what is called cement clinker, a kind of dark, porous stone which looks like lava.

After leaving the kiln, the clinker is cooled, crushed and ground again to a still finer powder, so fine, in fact, that most of the particles are less than 1/200 of an inch in size, and this grinding brings it back to the very light gray color characteristic of "ATLAS" Portland Cement.

It is now placed in storage tanks or stock houses where it remains for a while to season before it is put into bags or barrels and shipped. The barrels weigh 400 pounds gross, or 376 pounds net. When shipped in bags, the weight is 94 pounds per bag, four bags being equal to one barrel.

At the "ATLAS" plants, from the time the rock is taken from the quarry until it is packed in barrels or bags, all of the work is done by machinery, and a thorough chemical mixture takes place regulated by the experienced chemists in charge of the work.

PACKING OF CEMENT. Portland cement may be obtained in paper bags, cloth sacks or wooden barrels. The most convenient form for most users is the cloth sack. These sacks can be returned to the dealer from whom the cement was purchased and a rebate obtained for them if they are kept dry and untorn.

HOW TO STORE CEMENT. Portland cement must be stored in a dry place, that is, in a barn or shed, for dampness is the only element which will injure its quality. The cement will become lumpy and even form a solid mass when kept in a damp place, and when in this condition it should not be used.

All lumps which do not crumble at the lightest blow should be thrown out.

Cement stored in a building must not be placed on the bare ground. Make a platform which is at least 6 inches above the ground, and store the cement on this platform. If the building has a concrete floor it is advisable to cover the floor with planking upon which to place the cement.

**SAND (Fine Aggregate)**

Sand, crushed stone or gravel screenings passing when dry a screen having 1/4-inch diameter holes is called the fine aggregate. Sand should be (1) clean, that is, free from dirt like vegetable, loam, and (2) coarse.

If the sand contains vegetable matter, it is difficult to tell whether the sand is good, because a very small quantity—a fraction of one per cent.—may sometimes prevent the concrete from hardening. When the job is small, however, an approximate idea of the quality may be obtained by examining the sand in the bank and making up a specimen of concrete on the job as described below. The ordinary plan of taking a little sand in the palm of one hand and rubbing it with the fingers of the other to see if it discolors is of little value, and little can be learned from dropping sand in water, because it is not so much the quantity as the kind of impurity that counts.

HOW TO TEST FOR A CLEAN SAND. Two rough tests are as follows: (a) Pick up a double handful of moist sand from the bank, open the hands, holding them with the thumbs up, and rub the sand lightly between the hands, keeping them about 1/2 inch apart, allowing the sand to slip quickly between them. Repeat this operation five or six times, then rub the hands lightly together so as to remove the fine grains of sand which adhere to them, and examine to see whether or not a thin film of sticky matter adheres to the fingers; if so, do not use the sand, for it contains loam. A further test is to scrape some of this matter from the fingers on the end of a penknife and take a little of it between the teeth. If it does not feel gritty or sharp it indicates vegetable loam, which is bad. Do not use this sand, or if no other can be obtained test it further to make sure that there is not sufficient loam present to prevent the cement from getting thoroughly hard.

**SAND (Fine Aggregate) (Cont'd.)**

The sand for the test given above must be moist, just as it comes from the bank. When dry the dirt will not stick to the fingers, hence this test cannot be used. Some idea can be obtained, however, by the appearance of the sand, even if it is dry. If it looks "dead," an appearance which is caused by the particles of dirt sticking in little lumps to the grains of sand, sometimes also making the grains of sand stick together in little bunches when picked up, it is almost a sure sign of vegetable matter, and the sand should not be used. Fine roots in a sand will also indicate the presence of vegetable matter.

(b) Make up two blocks of concrete, each about 6 inches square and 6 inches thick, using the same cement and the same sand and gravel or stone as will be used in the structure to be built, and mixing them in the same proportions and of the same consistency. Keep one block in the air out of doors for 7 days and the other in a fairly warm room.

The specimen in the warm room should set so that on the following day it will bear the pressure of the thumb without indentation, and it should also begin to whiten out at this early period. The specimen out of doors should be hard enough to remove from the molds in 24 hours in ordinary mild weather, or 48 hours in cold, damp weather. At the end of a week test both blocks by hitting them with a hammer. If the hammer does not dent them under light blows, such as would be used for driving tacks, and the blocks sound hard and are not broken under medium blows, the sand as a general rule can be used.

HOW TO WASH SAND. Sand cannot be washed simply by wetting the pile of sand with a hose, for this only washes or transfers the dirt to a lower part of the pile. Sand, provided it is not too fine, can be satisfactorily washed, however, by making a washing trough, as shown in Fig. 1. For sands a screen with 30 meshes to the linear inch is necessary to prevent the good particles from passing through it. This must be supported by cleats placed quite near together, or it will break through. The sand is shoveled on to the upper end of the trough by one man, while another one can wash it with a hose. The flow of water will wash the sand down the incline, and as the sand and water pass over the screen the dirty water will drain off through the screen, leaving the clean sand for use. By this arrangement the dirt which is washed out cannot in any way get mixed with the clean sand

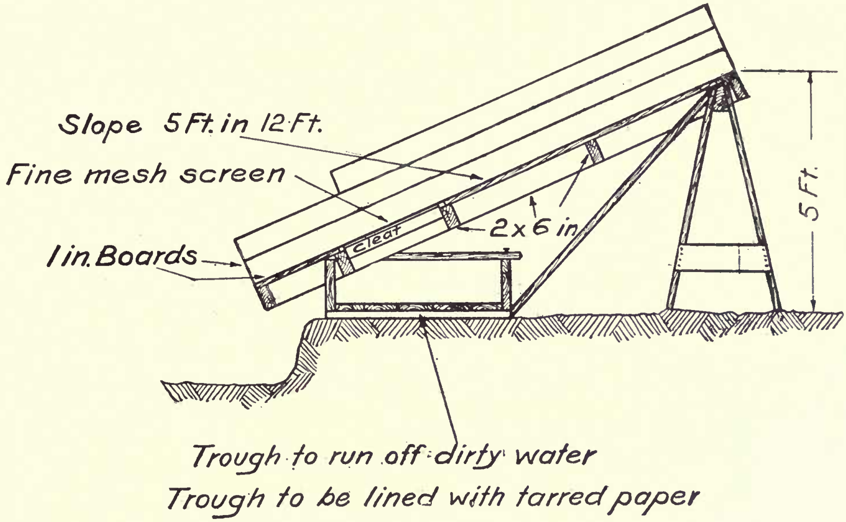

Fig. 1. Washing Trough for Sand or Gravel.

COARSE SAND. Sand should be coarse. By this we mean that a large proportion of the grains should measure 1/32 to ⅛ inch in diameter, and should the grains run up to ¼ inch the strength of the mortar is increased. Fine sand, even if clean, makes a poor mortar or concrete, and, if its use is unavoidable, an additional proportion of cement must be used with it to thoroughly coat the grains.

If the sand is very fine a mortar or concrete made from it will not be strong. Sometimes fine sand must be used because no other can be obtained, but in such a case, double the amount of cement may be required. For example, instead of using a concrete one part cement to two parts sand to four parts stone, a concrete one part cement to one part sand to two parts stone may be used.

NATURAL MIXTURES OF BANK SAND AND GRAVEL. Very often the sand and gravel found in a bank are used by inexperienced people just as it is found without regard to the proportions of the two materials. This may be all right in some cases, but generally there is too much sand for the gravel or stone, so that the resulting concrete is not nearly as strong as it would be if the proportions between the sand and gravel were right. It is better then to screen the sand from the gravel through a ¼-inch sieve, and then mix the materials in the right proportions, using generally about half as much sand as stone. By so doing a leaner mix can be used than where the sand and gravel are taken from the bank direct. The cost of the cement saved will more than pay for the extra labor required to screen the material. For example: Using even a very good gravel bank, a mixture one part cement to four parts natural gravel must be employed instead of one part cement to two parts sand to four parts of screened gravel. So much more cement is thus required with the natural gravel that a saving of one bag of cement in every seven is made by screening and remixing in the right proportion.

CRUSHER SCREENINGS. Screenings from broken stone make an excellent fine aggregate, which can be substituted for sand unless the stone is very soft, shelly or contains a large percentage of mica.

**GRAVEL OR BROKEN STONE (Coarse Aggregate)**

Gravel or broken stone forms the largest part of the mass of a good concrete, and is called the coarse aggregate. If the concrete is to be used simply for filling, or in a low wall against which nothing is to be piled, clean cinders, screened to remove the dust, may sometimes be used for the coarse aggregate. The concrete made from them, however, is not strong and is very porous. Slag or broken brick are sometimes used for the coarse aggregate.

The size of the stone is best graded from fine particles about ¼ inch diameter up to the coarser. The largest size pieces may be 2½ inches where a foundation or a wall 12 inches thick or over is being built, while for thin walls and where reinforcement is used the largest particles had best be about ¾-inch size.

With gravel the danger is apt to lie in the grains being coated with clay or vegetable matter which prevents the cement from sticking to them, and hence a very weak concrete results. The method for washing gravel should be the same as that described for sand (see page 14) and shown in Fig. 1. The screen when washing the gravel should have openings ¼ inch square.

**WHAT NOT TO USE.** Do not use dirty stone or gravel in any case. Avoid soft sandstones, soft freestones, soft limestones, slate and shale.

**WATER**

The water used for concrete must be clean. It should not be taken from a stream or pond into which any waste from chemical mills, material from barns, as manure, or other refuse, is dumped. If the water runs through alkali soil or contains vegetable matter it is best to make up a block of concrete, using this water, and see whether the cement sets properly. Do *not* use sea water.

**PROPORTIONS**

Concrete is composed of a certain amount or proportion of cement, a larger amount of sand, and a still larger amount of stone. The fixing of the quantities of each of these materials is called proportioning. The proportions for a mix of concrete given, for instance, one part of cement to two parts of sand to four parts of stone or gravel, are written 1:2:4, and this means that one cubic foot of packed cement is to be mixed with two cubic feet of sand and with four cubic feet of loose stone.

For ordinary work use twice as much coarse aggregate (that is, gravel or stone) as fine aggregate (that is, sand).

If gravel from a natural bank is used without screening, use the same proportion called for of the coarse aggregate; that is, if the specifications call for proportions 1:2:4, as given above, use for unscreened gravel (provided it contains quite a large quantity of stone) one part cement to four parts unscreened gravel.

If when placing concrete with the proportions specified, a wall shows many voids or pockets of stone, use a little more sand and a little less stone than called for. If, on the other hand, when placing, a lot of mortar rises to the top, use less sand and more stone in the next batch.

In calculating the amount of each of the materials to use for any piece of work, do not make the mistake so often made by the inexperienced that one barrel of cement, two barrels of sand and four barrels of stone will make seven barrels of concrete. As previously stated, the sand fills in the voids between the stones, while the cement fills the voids between the grains of sand, and therefore the total quantity of concrete will be slightly in excess of the original quantity of stone. This point is very clearly shown in Fig. 2.

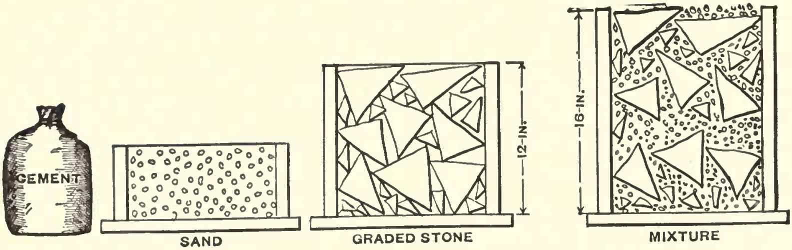

Fig. 2. Diagram Illustrating Measurement of Dry Materials and the Mixture.[*]

**PROPORTIONS (Cont'd)**

The following quotation from Concrete, Plain and Reinforced,[*] by the well-known authorities, Taylor and Thompson, is printed as a guide to those who wish to build any concrete structure for which specific instructions are not given in the following pages.

"As a rough guide to the selection of materials for various classes of work, we may take four proportions which differ from each other simply in the relative quantity of cement."

"(a) A Rich Mixture for columns and other structural parts subjected to high stresses or requiring exceptional water-tightness: Proportions—1:1½:3; that is, one barrel (4 bags) packed Portland cement to one and one-half barrels (5.7 cubic feet) loose sand to three barrels (11.4 cubic feet) loose gravel or broken stone.

"(b) A Standard Mixture for reinforced floors, beams and columns, for arches, for reinforced engine or machine foundations subject to vibrations, for tanks, sewers, conduits and other water-tight work: Proportions—1 : 2 : 4; that is, one barrel (4 bags) packed Portland cement to two barrels (7.6 cubic feet) loose sand to four barrels (15.2 cubic feet) loose gravel or broken stone.

"(c) A Medium Mixture for ordinary machine foundations, retaining walls, abutments, piers, thin foundation walls, building walls, ordinary floors, sidewalks and sewers with heavy walls: Proportions—1:2½:5; that is, one barrel (4 bags) packed Portland cement to two and one-half barrels (9.5 cubic feet) loose sand to five barrels (19 cubic feet) loose gravel or broken stone.

"(d) A Lean Mixture for unimportant work in masses, for heavy walls, for large foundations supporting a stationary load and for backing for stone masonry: Proportions—1 : 3 : 6; that is, one barrel (4 bags) packed Portland cement to three barrels (11.4 cubic feet) loose sand to six barrels (22.8 cubic feet) loose gravel or broken stone."

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[*] Taken by permission from Taylor & Thompson's "Concrete Plain and Reinforced," John Wiley & Sons, New York, publishers.

Green timber is preferable, for, if seasoned, it is likely to swell and warp when brought in contact with moisture from the concrete. White pine is best, but fir, yellow pine or spruce are also suitable. If a smooth surface is desired, the form boards or planks next to the concrete must be planed and the edges tongued and grooved or beveled. Grease the inside of forms with either soap, linseed oil, mixed lard and kerosene, or crude oil, that is, petroleum, otherwise particles of concrete will stick to the forms when they are removed, thus giving an unnecessarily rough surface to the face of the concrete. Forms should not be greased when it is intended to plaster the surface of the concrete, but should be thoroughly wet immediately before placing the concrete.

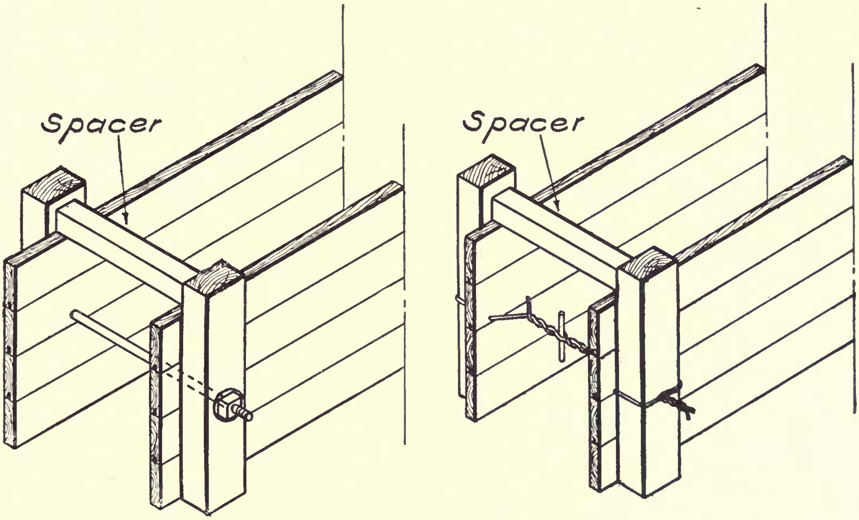


Fig. 3. Section of Forms Showing Method of Holding Sides of Forms.

Lay the sheathing or form boards horizontally. These may be of 1-inch, 1½-inch or 2-inch lumber, the distance apart of the studding being governed by the thickness of sheathing selected. Place the studs not more than 2 feet apart for 1-inch sheathing, nor more than 5 feet apart for 2-inch sheathing. They should be securely braced to withstand the pressure of the soft concrete, also of the ramming and tamping. In building forms do not drive the nails all the way home. Leave the heads out so that it is possible to draw them with a claw hammer. The less hammering done around green concrete the better. Avoid cracks in forms into which the mortar will force itself and form "fins" on the surface of the work.

The length of time the forms should be left in place varies with conditions. Where no pressure is brought to bear on the concrete, forms can be removed within one-half to two days, or as soon as the concrete will withstand the pressure of the thumb without indentation. On very small work, like drain tile, two to four hours is sufficient time, provided it is carefully handled and left in place until thoroughly hard. On large and important walls one to three days are generally required, and if any water or earth pressure comes against the walls the forms should be left in place from three to four weeks. Slab forms can be removed in about one week, but the supporting posts under any beams and slabs must not be touched for a month after laying the concrete.

Concrete forms are kept from separating or bulging either by using bolts or by wiring. Bolts as a general rule are more satisfactory on large work than wire, but as they cannot always be conveniently obtained, wires are used extensively. In Fig. 3 are sketched both methods for holding side forms together. The spacers are only placed between the forms to hold them the proper distance apart, and must be removed after some of the concrete is placed. Where wires are used, the forms are drawn together by twisting, as shown in the figure. This is done with a large nail or a hammer handle.

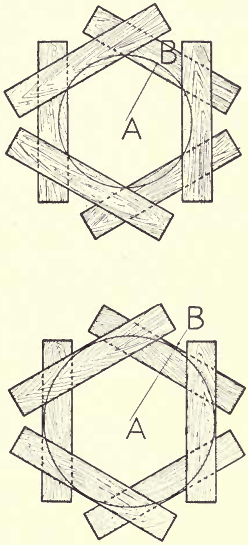
**CIRCULAR FORMS**

For a round structure two sets of circular forms are usually needed, namely, inner and outer forms, "A" and "B," Fig. 5. Both of these come into use when building a silo or other structure having a thin wall, but in the case of a solid column only the outer form is necessary. Both inner and outer forms are made practically the same, except that the radius of the outer one is of necessity greater than that of the inner because of the thickness of the walls between the two forms.

A simple method of drawing the circle for the outer form is as follows: Take a piece of string, attach one end to a long spike, marked "A," Fig. 4, and stick it into the ground. Measure off on the string one-half the diameter of the circle desired, tie a knot, through which force a nail (marked "B," Fig. 4), and, keeping the string stretched between these two points, draw a continuous line. Lay the boards around the line just made, nail them together firmly and then mark the

**CIRCULAR FORMS (Cont'd)**

circle out on them and saw to the line. After making two or more forms, place them at equal distances apart, and put on the sideboards in the manner shown in Fig. 5. These boards are called "Lagging."



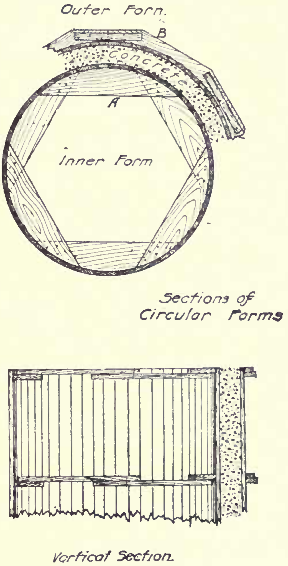
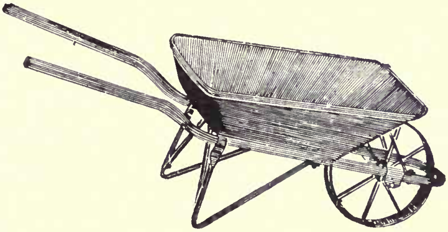


Fig. 4. Laying Out Circular Forms. Fig. 5. Circular Forms.

**TOOLS AND APPARATUS**

The quantity of tools will, of course, vary with the size of the gang of men. The following schedule is based on a small gang of two or three men, making concrete by hand:



Concrete Wheelbarrow.

Square Pointed Shovel

Three No. 3 square-pointed shovels.
Two wheelbarrows (iron wheelbarrows the best).
One tamper, a piece of 2 x 4-inch joist is sufficient.
One garden spade or spading tool.
One water barrel.
Three water buckets.

One sand screen, ¼-inch or ⅜-inch mesh, for screening sand from the gravel.

One measuring box (see Fig. 6).

One mixing platform about 10 feet square built so substantially that it can be moved without coming to pieces, having a 2 x 3-inch strip around the edge to prevent the waste of materials and water. This platform can be made of 1-inch stuff, resting on joists about 2 feet apart, provided it is stiffened by being tongued and grooved.

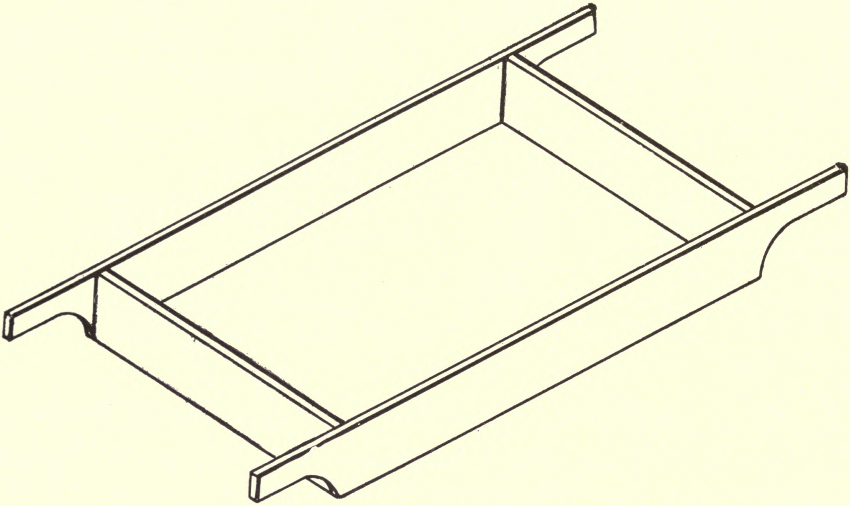


Fig. 6. Measuring Box for Sand and Gravel.*

Concrete should be mixed as near the place where it is to be used as practicable, so as to avoid delay in getting it into place. If left standing any length of time it will set and become useless. To avoid this, mix small batches at a time, using on a small job not more than a half barrel or two bags of cement to the batch. Should the cement take its initial set, i. e., begin to harden, before being placed in the forms, so that it lumps when retempered, discard it, as the hardening qualities of cement are affected if disturbed after it has begun to set.

If sand or gravel require washing, add to the above list of tools and apparatus:

One washing screen for sand with 30 meshes to the linear inch.

One washing screen for gravel with ¼-inch meshes.

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*See footnote, page 18.

**MEASURING**

Too much attention cannot be paid to this important part of concrete making. The best and most convenient way to measure the sand and stone is to make a measuring box or frame as shown in Fig. 6.

The inside dimensions of the box for different mixes of concrete are given in the table below, the size of the box being based on a two-bag batch of concrete; that is, using two bags "ATLAS" Portland Cement to each batch. The use of the box or frame for measuring can be best illustrated by the following example: Assume a 1 :2 :4 mix. From the table a measuring frame or box, 10 inches high by 2 feet 3 inches by 4 feet inside dimensions, must be made. Lay this box on the mixing platform, fill it exactly half full of sand, up to a mark previously made all around it, and level off the sand to make sure that the sand just fills half the frame, and then raise the measuring frame. Dump two bags of cement on the sand and mix it as described under "Mixing," on page 24. Even off the mixed cement and sand, place the measuring box on top of it and fill the frame with stone level with the top. Level off the stone carefully, raise the measuring box and the correct amount of stone is ready to be mixed with the cement and sand.

QUANTITY OF MATERIALS AND SIZES OF MEASURING BOXES.

| Mix | Cement Bags | Sand | Gravel | Concrete Made, Cu. Ft. | Size of Measuring Box Lgth.Dpth.Wdth. |
|---|---|---|---|---|---|
| 1:1½:3 | 2 | 2.8 cu. ft. or ¾ bbl. | 5.6 cu. ft. or 1½ bbl. | 7.0 | 3′ 0″x2′ 0″x10″ |
| 1·2 :4 | 2 | 3.8 cu. ft. or 1 bbl. | 7.6 cu. ft. or 2 bbl. | 9.0 | 4′ 0″x2′ 4″x10″ |
| 1:2½:5 | 2 | 4.8 cu. ft. or 1¼ bbl. | 9.6 cu. ft. or 2½ bbl. | 10.9 | 4′ 6″x2′ 2″x12″ |
| 1:3 :6 | 2 | 5.8 cu. ft. or 1½ bbl. | 11.6 cu. ft. or 3 bbl. | 12.8 | 4′ 6″x2′ 7″x12″ |

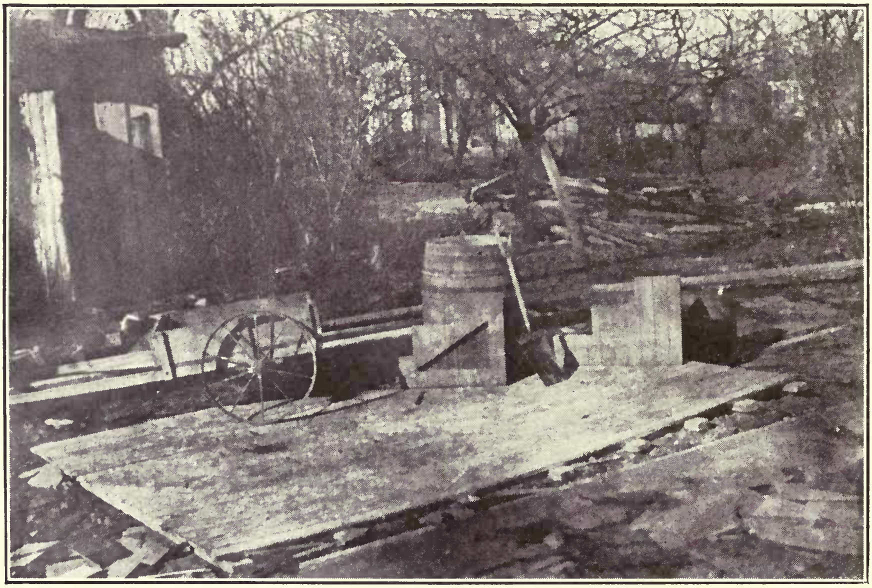
Note.—A cement barrel holds 3.8 cubic feet.

Another way to measure the sand and stone is by using a wheelbarrow. To determine the capacity of the wheelbarrow, dump into it one or two bags of cement and see how much of the wheelbarrow is filled; taking this as a unit, measure the sand and stone accordingly, using perhaps a little less of the sand and stone than would be indicated by the cement measure considered as one part. This method is not nearly so accurate as the first one, and if used the barrow should be filled with the cement two or three times a day to keep the eye trained.

**MIXING**

An essential to thorough mixing is a flat water-tight platform, a convenient size being about 10 feet square, the boards forming which must be laid with tight joints to prevent the cement and water from running through while mixing. If these boards are planed off on top it will make the shoveling easier.

The operation of mixing the materials for concrete is as follows: Measure the sand and spread it in a layer of even depth as shown in Fig. 7. Place the cement on top of the sand. First turn these two materials toward the center of the board (see Fig. 7) and then turn them twice more or until they are thoroughly mixed together, as indicated by a uniform color. Next wet the stone, throw it on top of the mixed cement and sand and turn the whole mass at least three times, water being slowly poured on during the first turning, the quantity varying according to the nature of the work. In general, add sufficient water to give a "mushy" mixture just too soft to bear the weight of a man when in place. Pails are most convenient for measuring the water, and enough pailfuls should be provided in advance for wetting an entire batch. Do not use a hoe. In turning the concrete use square-pointed



IMPROVISED MIXING PLATFORM AND TOOLS USED ON SMALL JOB AT COLUMBIA, MO.

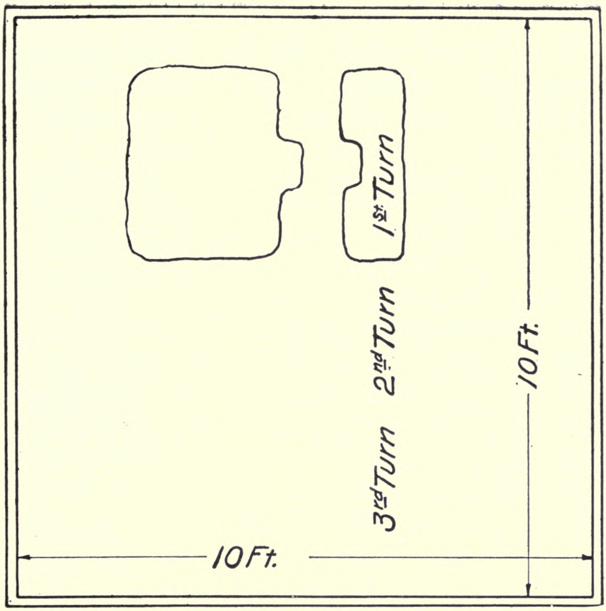


Fig. 7. Position of Piles of Cement and Sand During Mixing.*

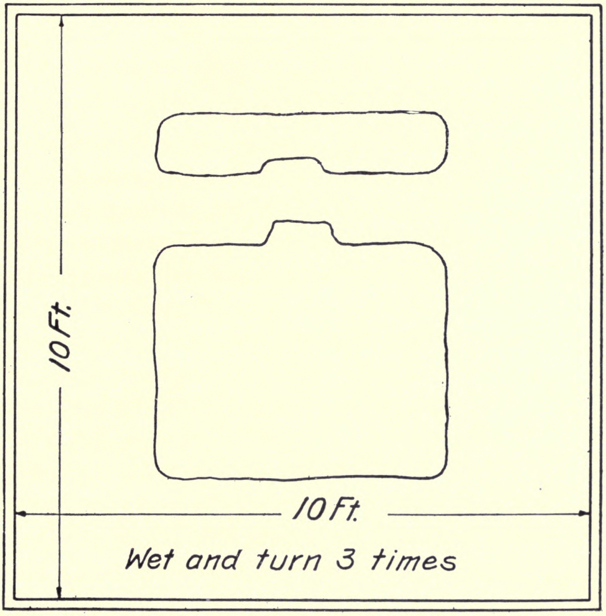


Fig. 8. Position of Materials During Mixing of Concrete.*

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***See footnote, page 18.**

shovels. Push the shovel along the boards under the mass, lift it, then turning the shovel carefully over deposit the material with a spreading motion. Concrete mixing machines should be used on large jobs as a matter of economy.

**PLACING CONCRETE IN FORMS**

Place the concrete in forms in layers about 6 to 12 inches deep and tamp lightly with a rammer or puddle with a piece of 2 by 4-inch joint until the water flushes to the top. Note that the concrete must be well rammed and spaded to avoid pockets of stone forming in the concrete.

The method of obtaining a smooth face on concrete frequently adopted is as follows: Thrust a spade or thin paddle between the concrete and the form, moving the handle to and fro, up and down. This movement forces the broken stone in the concrete away and brings a coating of mortar next to the form, which gives a smooth surface. Care taken in manipulation of concrete along the moulds will be amply repaid by the smooth surface resulting, and the saving in time and expense otherwise made necessary in plastering over cavities and smoothing rough places.

Concrete which is exposed to the sun should be soaked with water each day for a week or two. This will allow the interior of the walls to dry uniformly with the exterior, and thus prevent scaling or cracking.

**PLACING CONCRETE UNDER WATER**

Concrete should never be placed under water if it possibly can be avoided, because the materials are in danger of separating. The danger of the fine material separating from the coarse was illustrated in a little test made by the engineers constructing the Holyoke Dam. A small batch of concrete was mixed in proportions one part cement to two and one-quarter parts sand to five parts stone, and shoveled into a pail of water with a trowel. The surface hardened satisfactorily, and after several months the water was poured off and the material taken out. Instead of being concrete, three layers were found. On top was a thin layer of practically neat cement, then about 2 or 3 inches of mixed sand and cement in a porous mortar, then below this a mixture of sand and stone as separate and clean as before the concrete was mixed.

This experiment and other tests show that if concrete has to be placed under water it must be deposited in large masses and never by shovelfuls.

**PLACING CONCRETE UNDER WATER (Cont'd.)**

On small work put the concrete in pails, place a board over the top of the pail and lower it carefully into the water to the bottom. Turn the pail upside down, carefully remove the board and slowly raise the pail, allowing the concrete to flow out. Great care must be used not to disturb the water in which the concrete is being placed nor to touch the green concrete. Concrete must never be placed under water if there is any current, because the cement will be washed away, leaving only the sand and stone.

Another method for depositing concrete under water is to pass the concrete slowly through a spout or tube which reaches to within a couple of inches of the bottom where the concrete is to be placed. The tube must be kept full and the concrete kept moving continuously and slowly through it. On large work specially designed buckets are used for depositing the concrete under water, but these are generally operated by a derrick.

**SURFACE FINISH**

Surface finish of concrete may be for either of two purposes: To make the concrete more water-tight, or to improve the appearance. It is advisable to leave the outside surface of the concrete just as it comes from the forms, having used care in placing to see that there are no stone pockets or voids; or else to take off the skin of cement so as to expose the sand and stone and leave an even but slightly rough surface.

PURE CEMENT WASH. On exterior surfaces a coat of pure cement will check with fine hair cracks because of the rapid drying out of the mortar. However, for the interior of a tank which will be kept wet while in use, a coat of neat cement may serve to make the concrete more water-tight. Put this on just as soon as the forms are removed, and take off forms as early as possible. In small pieces of concrete, like a small trough, the inner form may be removed within two or three hours, and the wash applied immediately. Leave the outside forms, however, until the concrete is hard. Wet the inside surface thoroughly and apply the pure cement with a brush or a trowel.

REMOVING SURFACE SKIN OF CEMENT WHILE CONCRETE IS GREEN. The best method of obtaining a good outside finish is to rub off the skin of cement which comes to the surface next to the forms and thus expose the sand or stone. There are various ways of doing this. The easiest way is to remove the forms as soon as the concrete is set, which for a wall may be in 24 or 48 hours; just as soon, in fact, as the concrete will bear the pressure of the thumb. Wet the surface thoroughly, and rub it with a brick, or with a board with a plasterer's wooden float, or with a carborundum block. By this plan the surface can be simply smoothed of roughnesses, or the skin of cement can be taken off to leave a sandy finish, or by still further work the stones can be exposed. The resulting finish, while rough, should be uniform and pleasing.

PICKED SURFACE. If the concrete has hardened, the skin of cement can be removed with a tool. A stone cutter's bush hammer can be used for this, or a tool can be made with a toothed edge.

PLASTERING. Plastering on exterior surfaces requires great care and skill to prevent cracking and peeling. The forms in which the concrete is laid must be wet instead of oiled. Roughen the surface, either when the concrete is green, by rubbing off the cement, or by picking the hardened surface with an old hatchet or a stone axe. Wet thoroughly and apply as thin a layer as possible, about 1/16 inch thick is best, of mortar, one part "ATLAS" Portland Cement and one part fine, but very clean, sand. For thick layers, pick and wet the surface, then brush on a thin coat of pure cement grout on a small part of the surface, and before this has begun to stiffen apply the plaster.

## REINFORCED CONCRETE

Reinforced concrete is ordinary concrete in which iron or steel rods or wire are imbedded. Reinforcement is required when the concrete is liable to be pulled or bent, as in beams, floors, posts, walls or tanks, because, while concrete is as strong as stone masonry, neither of these materials has nearly so much strength in tension as in compression. Moreover, concrete alone, like any natural stone, is brittle, but by imbedding in it steel rods or other reinforcements, the cement adheres, and the metal binds the particles together so that the reinforced concrete is better adapted to withstand jar and impact. Even railway bridges are built, not only in arch form, like a stone arch, but in some cases like a steel girder bridge, with a flat reinforced concrete floor supported by horizontal beams of the same material.

Reinforcement may be iron or steel. Steel is nearly always used because it is nowadays cheaper than iron and easier to buy. The ordinary iron rods, so-called, as found in the stores are almost always steel.

Round rods or square twisted rods, or rods with special surfaces designed to better pervent pulling out from the concrete, are used in most of the important work in reinforced concrete. For slabs, metal fabrics like expanded metal or woven wire is frequently used instead of rods. In some of the smaller structures described in the pages which follow, the reinforcement is put in to prevent cracking, and, as stated in the text, almost any kind of wire can often be used. Nearly every farmer has fence wire which is well adapted for reinforcing watering troughs and for small pieces of work.

Concrete, like other materials, shrinks when the weather is cold, and it also shrinks in setting, so that a long wall is bound to have occasional cracks in it unless it is very heavily reinforced or unless joints are placed every 30 feet or so.

An engineer or architect experienced in reinforced concrete design should be employed in preparing the plans for houses, barns or other large structures, but by carefully following the directions and specifications in this booklet small reinforced concrete construction may be safely undertaken by the inexperienced.

The table which follows gives the thickness and reinforcement of slabs, and the dimensions and reinforcement of reinforced concrete beams for a number of conditions which are liable to be met with in common practice. While the values are as low as should be adopted without knowing the local conditions, complete mathematical calculations of dimensions should be made for large structures, not only from the standpoint of safety, but also because of the saving in cost of material which can be effected by fitting each member in its proper place.

Rules, which are written as footnotes to the table, give very important directions.

An invariable rule in placing steel is to insert it in the face where the pull will come. Thus in a beam or slab it must be close to the bottom. In a wall, to withstand earth pressure, it must be in the face nearest the earth. If, for example, a beam were designed according to the table, but the steel placed in

# TABLE FOR DESIGNING REINFORCED CONCRETE BEAMS AND SLABS

PROPORTIONS OF CONCRETE 1:2:4. [See important foot-note.]

| Length or Span of Beam. | Distance apart of Beams. | Dimension of Beams | | | Reinforcement of Beams | | | | | Thickness of Slabs | | Reinforcement of Slabs | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Width | Depth | Depth below Steel | Number of Rods required | Diameter of Rods | Number of Stirrups at each end | Diameter of Stirrup Rods | Spacing* of Stirrups | Total Thickness | Depth below Steel | Diameter of Rods | Spacing of Rods |
| Feet | Feet | Inches | Inches | Inches | | Inches | | Inches | | Inches | Inches | Inches | Inches |
| *Medium Heavy Floor Loading - - - 125 Pounds per Square Foot* | | | | | | | | | | | | | |
| 8 | 4 | 6 | 13 | 1½ | 3 | ½ | 1 | 5/16″ | | 3 | ¾ | 5/16 | 6 |
| | 6 | 7 | 15 | 1½ | 3 | 9/16 | 2 | 5/16″ | 6″ | 3¾ | ¾ | ⅜ | 6 |
| | 8 | 8 | 17 | 1½ | 3 | ⅝ | 2 | ⅜″ | 6″ | 5 | 1 | ½ | 7½ |
| 10 | 4 | 7 | 14 | 1½ | 3 | ½ | 2 | 5/16″ | 8″ | 3 | ¾ | 5/16 | 6 |
| | 6 | 9 | 17 | 1½ | 4 | 9/16 | 3 | 5/16″ | 8″ | 3¾ | ¾ | ⅜ | 6 |
| | 8 | 9 | 20 | 2 | 4 | ⅝ | 3 | ⅜″ | 8″ | 5 | 1 | ½ | 7½ |
| 12 | 4 | 9 | 16 | 1½ | 4 | 9/16 | 2 | ⅜″ | 8″ | 3 | ¾ | 5/16 | 6 |
| | 6 | 10 | 20 | 2 | 4 | | 3 | ⅜″ | 8″ | 3¾ | ¾ | ⅜ | 6 |
| | 8 | 11 | 22 | 2 | 4 | 11/16 | 4 | ⅜″ | 8″ | 5 | 1 | ½ | 7½ |
| 14 | 4 | 10 | 18 | 1½ | 4 | ⅝ | 2 | ⅜″ | 8″ | 3 | ¾ | 5/16 | 6 |
| | 6 | 11 | 24 | 2 | 4 | ¾ | 3 | ⅜″ | 8″ | 3¾ | ¾ | ⅜ | 6 |
| | 8 | 13 | 24 | 2 | 4 | 13/16 | 4 | ⅜″ | 8″ | 5 | 1 | ½ | 7½ |
| *Light Floor Loading - - - - 50 Pounds per Square Foot* | | | | | | | | | | | | | |
| 8 | 4 | 5 | 10 | 1¼ | 3 | ⅜ | | | | 3 | ¾ | ¼ | 5½ |
| | 6 | 6 | 13 | 1½ | 3 | 7/16 | | | | 3½ | ¾ | 5/16 | 7 |
| | 8 | 7 | 13 | 1½ | 3 | ½ | | | | 4 | ¾ | ⅜ | 5½ |
| 10 | 4 | 6 | 12 | 1¼ | 3 | ⅜ | | | | 3 | ¾ | ¼ | 5½ |
| | 6 | 7 | 15 | 1½ | 3 | 9/16 | | | | 3½ | ¾ | 5/16 | 7 |
| | 8 | 8 | 16 | 1½ | 3 | ⅝ | | | | 4 | ¾ | ⅜ | 5½ |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **12** | 4 | 7 | 13 | 1½ | 3 | ½ |  |  |  | 3 | ¾ | ¼ | 5½ |
|  | 6 | 8 | 17 | 1½ | 3 | ⅝ |  |  |  | 3½ | ¾ | 5/16 | 7 |
|  | 8 | 9 | 18 | 1½ | 4 | 9/16 |  |  |  | 4 | ¾ | ⅜ | 5½ |
| **14** | 4 | 7 | 15 | 1½ | 3 | 9/16 |  |  |  | 3 | ¾ | ¼ | 5½ |
|  | 6 | 8 | 19 | 2 | 3 | ⅝ |  |  |  | 3½ | ¾ | 5/16 | 7 |
|  | 8 | 10 | 21 | 2 | 4 | 11/66 |  |  |  | 4 | ¾ | ⅜ | 5½ |
| *Roofs - - - 30 Pounds per Square Foot* |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 8 | 4 | 5 | 10 | 1¼ | 3 | ⅜ |  |  |  | 2¾ | ¾ | 3/16 | 6 |
|  | 6 | 6 | 11 | 1¼ | 3 | 7/16 |  |  |  | 3 | ¾ | ¼ | 5½ |
|  | 8 | 7 | 12 | 1¼ | 3 | ½ |  |  |  | 3¼ | ¾ | ⅜ | 7½ |
| 10 | 4 | 6 | 12 | 1¼ | 3 | 7/16 |  |  |  | 2¾ | ¾ | 3/16 | 6 |
|  | 6 | 7 | 13 | 1½ | 3 | ½ |  |  |  | 3 | ¾ | ¼ | 5½ |
|  | 8 | 8 | 14 | 1½ | 3 | 9/16 |  |  |  | 3¼ | ¾ | ⅜ | 7½ |
| 12 | 4 | 7 | 13 | 1½ | 3 | ½ |  |  |  | 2¾ | ¾ | 3/16 | 6 |
|  | 6 | 7 | 16 | 1½ | 3 | 9/16 |  |  |  | 3 | ¾ | ¼ | 5½ |
|  | 8 | 8 | 17 | 1½ | 3 | ⅝ |  |  |  | 3¼ | ¾ | ⅜ | 7½ |
| 14 | 4 | 7 | 15 | 1½ | 3 | 9/16 |  |  |  | 2¾ | ¾ | 3/16 | 6 |
|  | 6 | 8 | 17 | 1½ | 3 | ⅝ |  |  |  | 3 | ¾ | ¼ | 5½ |
|  | 8 | 9 | 18 | 1½ | 3 | 11/66 |  |  |  | 3¼ | ¾ | ⅜ | 7½ |

**1.** Bend, diagonally upwards, one rod in three, or two rods in four from ¼ points in beam to top of beam and over supports. (See Fig. 9.)

**2.** Stirrups are made U-shaped with bent ends. (See Fig. 9.)

**3.** Slab reinforcement is placed at right angles to supporting beams. (See Fig. 9.)
Cross reinforcement of slightly smaller rods or same rods farther apart is also placed in slabs parallel to beams.

**4.** Wire fabric or expanded metal mesh may be substituted for rods in the slabs, provided the area of section of metal is kept the same as the rods.

5 Cinder concrete should not be used for beams.

6 Cinder concrete may be used for roof slabs if thickness is increased one inch.

7 After setting 30 days, test two of the slabs and one beam by loading two panels with sand to depth of:
18 inches deep for heavy floor loading;
8 inches deep for light floor loading;
5 inches deep for roof loading.

*Place first stirrup in every case 6 inches from support.

the middle or top of the beam instead of in the bottom, it would certainly break under a very light load. There must be only enough concrete outside of the steel to protect it from rusting or fire. In floor or roof slabs of small structures this thickness should be one-half inch to three-quarters inch below the bottom of the steel, and for beams from one to one and one-half inches.

A typical beam with its connecting floor slabs, the concrete of both of which should be laid at the same operation, is shown in Fig. 9. It will be seen that the beam reinforcement consists of rods running lengthwise of the beam—one-half or one-third of these rods being bent up about one-third way from each end and extending over the supports, as shown in Fig. 9 and for the heavier beams U-shaped bars or stirrups are used which pass under the longitudinal rods and up on each side of the beam. The horizontal bars withstand the direct pull in the bottom of the beam due to bending when a load is placed upon it; the U-bars or stirrups and the bent-up bars prevent diagonal cracks, which sometimes occur under loading, and the bars passing over the supports prevent the cracking of the beam on top at the ends.

The steel in the slab is placed just above the bottom surface at the center of the span and then bent upward over the supports as shown in the drawing.

Proportions for all reinforced concrete must not be leaner than one part "ATLAS" Portland Cement, two parts clean, coarse sand and four parts broken stone or clean screened gravel. Maximum size of broken stone or gravel should not be over one inch diameter in order to pass between and under the steel rods. Consistency of concrete should be like heavy cream.

**COST OF CONCRETE WORK**

The cost of concrete work varies considerably on account of the many elements entering into the work. For instance, the cost of building the various structures illustrated in this book may be very small, as the work itself may be done by the owner or farmer at odd times or with comparatively cheap help, while in building with other materials, either brick or wood, it is necessary to employ carpenters or masons. Moreover, even if the lumber for the forms costs nearly as much as the lumber for a wooden structure, as is sometimes the case, it need not be thrown away, but may be used again for other purposes. If hired laborers and carpenters do the work it may be stated as a general rule that concrete is always more expensive in first cost than wood. On the other hand, concrete does not rot, it does not burn, and it does not have to be painted, so that it frequently may be cheaper in the long run. Besides this, more unique and pleasing effects may be produced.

MATERIALS FOR ONE CUBIC YARD OF CONCRETE.

| Proportion by Parts | | | Bbls. Cement in 1 Cubic Yard | Bbls. Sand in 1 Cubic Yard | Bbls. Gravel or Stone in 1 Cubic Yard |
|---|---|---|---|---|---|
| Cement | Sand | Stone or Gravel | | | |
| 1 | 1½ | 3 | 2.00 | 3.00 | 6.00 |
| 1 | 2 | 4 | 1.57 | 3.14 | 6.28 |
| 1 | 2½ | 5 | 1.29 | 3.23 | 6.45 |
| 1 | 3 | 6 | 1.10 | 3.30 | 6.60 |

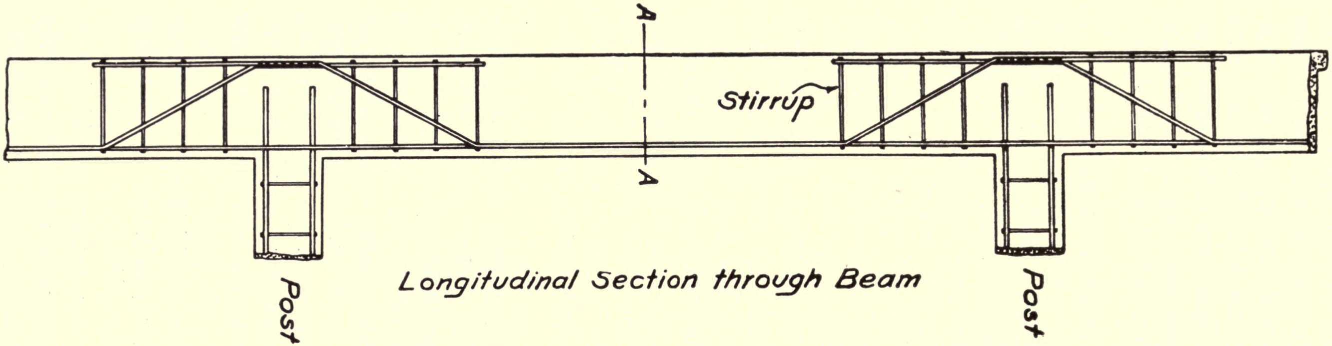
## EFFECT OF EXTERNAL AGENCIES ON CONCRETE

**FIRE RESISTANCE.** Concrete is one of the best fireproof materials known. It resists intense heat better than iron, steel, ordinary brick or stone, and in the San Francisco and Baltimore fires it stood the test better than any other material. It can therefore be depended upon to resist any ordinary fire. Concrete is used extensively as a fire-protective covering for steel, for which purpose about two inches is necessary. In reinforced concrete the iron or steel should be imbedded one or two inches for protection.

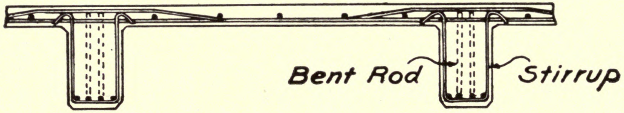
**WATER TIGHTNESS.** By mixing wet and using proportions one part "ATLAS" Portland Cement to one and one-half parts sand to three parts screened gravel and placing in one continuous operation, so that no surface is allowed to harden, or else by forming very good joints as described on page 112, concrete is watertight under ordinary conditions. Long walls to resist water pressure must be well reinforced to prevent cracks due to temperature contraction, since concrete expands and contracts with temperature just like other materials.

**CORROSION OF METAL REINFORCEMENT.** Concrete properly proportioned and mixed wet absolutely prevents any metal imbedded in it from rusting.

**SEA WATER.** Concrete resists sea water, provided it is properly proportioned with first-class materials and is carefully laid.



Longitudinal Section through Beam



Cross-Section at A through Beams & Slab

Fig. 9. Typical Beam and Slab Sections.

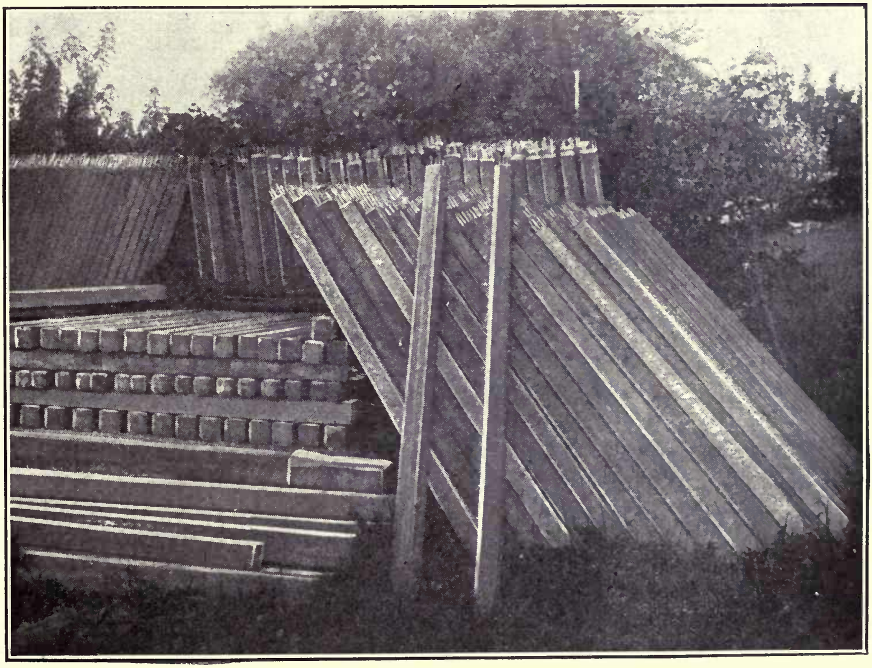
**ACIDS.** After concrete has thoroughly hardened it resists acids better than almost any other material. A substance like manure, because of the acid which it contains, has been known to slightly injure the surface of green concrete, but after the concrete has hardened for at least a week it is proof against injury.

**OILS.** When concrete is properly made and the surface carefully finished and is hardened before the oil comes against the concrete, it can be depended upon to resist the action of almost any oil.

**ALKALIES.** For use in the arid regions where there is alkaline ground water, concrete should be especially rich, dense and water-tight.

**FREEZING.** Concrete work should be avoided so far as possible in freezing weather, as the frost will prevent the bonding of different layers and will cause a thin scale to peel off of the surface of concrete.

It is a good rule to follow, therefore, never to lay concrete if the temperature is below freezing or liable to fall below freezing in a day or two.



CONCRETE FENCE POSTS AT SIOUX RAPIDS, IOWA

# POSTS.

**FENCE POSTS.** The use of concrete fence posts is becoming very general. This is due not only to the scarcity and high price of good straight wood posts, but to the almost unlimited life of the concrete post, its greater strength and more pleasing appearance.

Concrete fence posts should be a little larger than wood fence posts, and may be made either straight for the whole length or slightly tapering. Five or six inches square at the bottom and four or five inches square at the top is an ordinary size, or for convenience in molding they may not be made exactly square, say, 6 inches by 5 inches at the bottom and 5 inches by 4 inches at the top, this size being selected for the form shown in Fig. 10.

As a very slight heaving of a fence post by frost is not objectionable, they do not need to be placed in the ground more than 2½ feet, although if for any reason they should be absolutely rigid the lower end should go below frost line, which in the Northern States is as much as 4 feet down. The length of the post is determined by the height which is desired above the ground.

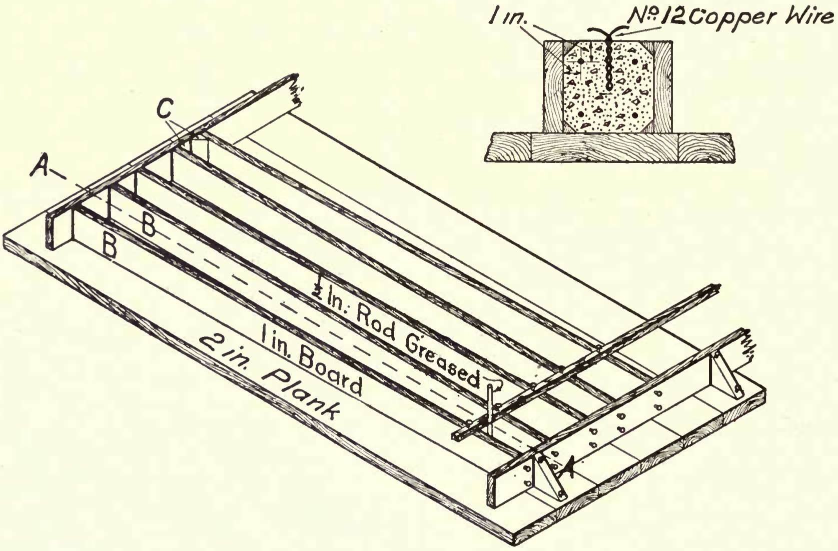
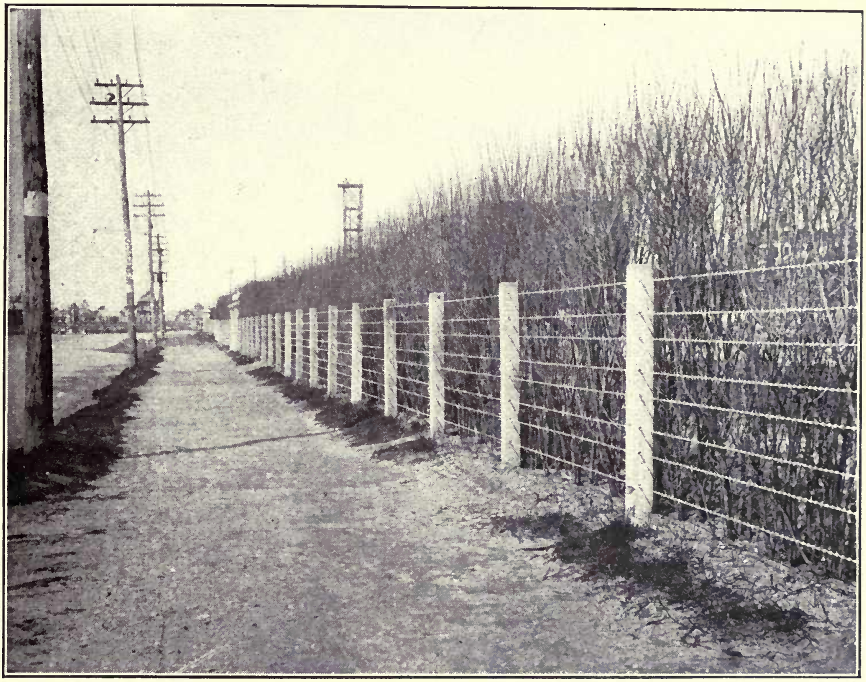


Fig. 10. Design of Forms for Fence Posts.

Posts may be built separately, that is, in a separate form laid on the ground, but the cheapest way is to build forms for a number of posts so that several can be molded at the same time, and then the forms used for another set as soon as the concrete has hardened.

To mold a lot of posts at one time build the forms in the following manner: Select some place where the posts can be left in their original position for at least ten days. Level off the ground and place the bottom planks, which should be of 1½-inch or 2-inch planed lumber, side by side upon 2 or 3 cross sills, making a solid floor upon which to mold the posts. Place two 1-inch by 5-inch boards on edge parallel to each other and the height of the posts apart and brace them on the outside with triangular braces as shown in the figure. To locate the center of first post stretch a line from one side across to the other at right angles to the boards on edge as indicated by line AA. At one end of this line AA measure 3 inches each side of it for the bottom of the post and at the other end measure 2 inches each side of this line for the top of the post. This will locate the boards BB for the sides of the posts. Nail these intermediate boards at the ends with a nail or two to the two parallel boards, allowing the heads to project so they can be pulled out with a claw hammer.



CONCRETE FENCE POSTS AT FAR ROCKAWAY, L. I.

Make the posts, as is shown in the sketch, with every alternate post lying the opposite way. By so doing one intermediate board serves as a side to two posts, thus requiring less lumber per post than by any other arrangement of forms. With this method of construction also the least amount of ground area is required for molding the posts and no bracing is necessary to support the boards for the sides of the posts. Triangular 1-inch bevel strips may be placed on all edges, as shown in the cross section, Fig. 10, which will give the posts a neat and pleasing appearance. These bevel strips can be obtained readily from a mill, or they may be sawed from a 1-inch board by ripping the board lengthwise. If desired the top of the post can be finished with a taper by simply inserting a triangular block, as shown at C in Fig. 10. Never plaster the top of any post; instead, remove the end form when the concrete is green and smooth the surface with a trowel or float.

If straight instead of tapering posts are preferred, the same kind of a form as has just been described can be used for molding them except that the intermediate boards B are placed at right angles to the two long parallel boards instead of at angle to them, as shown, making them 5 inches apart. The forms are now ready to fill and the quantities of material for certain size posts can be taken from the following table.

### QUANTITY OF MATERIAL FOR FENCE POSTS

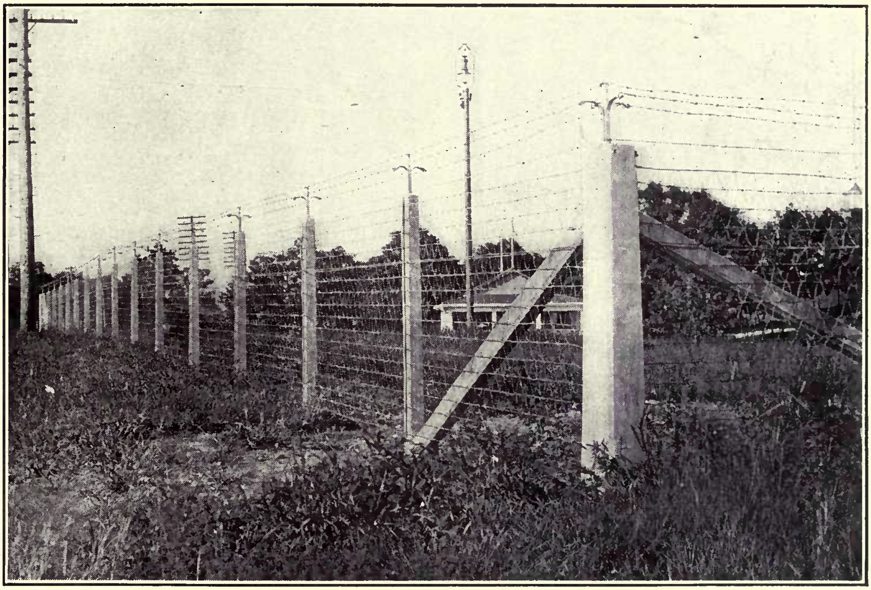
All Posts Are 4 x 5 Inches at Top; All Posts are 5 x 6 Inches at Bottom.
One-Half Small Single Load* of Sand Required per Barrel of Cement; One Small Single Load* of Screened Gravel or Stone Required per Barrel of Cement.
Proportion: 1 Part "Atlas" Portland Cement; 2 Parts sand; 4 Parts Gravel or Stone.

| Length of Posts, Feet | No. of Posts per Barrel (4 Bags) of Cement | Weight per Post, Pounds |
|---|---|---|
| 5 | 20 | 130 |
| 6 | 17 | 160 |
| 7 | 14 | 180 |
| 8 | 12 | 210 |
| 9 | .11 | 234 |

* Small single load = 15 cubic feet.

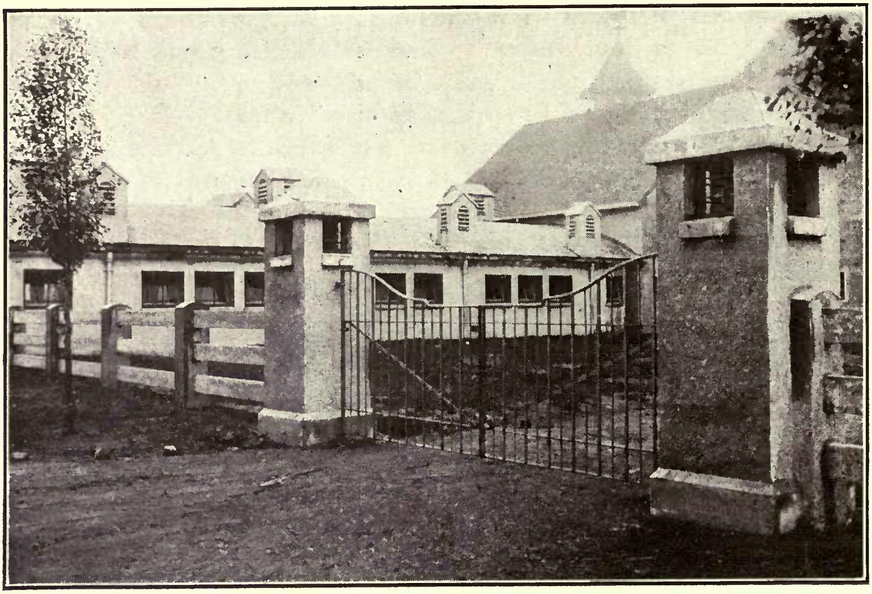
The posts should be made with one part "ATLAS" Portland Cement, two parts clean, coarse sand and four parts broken stone or gravel, about 1 inch diameter particles. Grease or oil the form and fill the bottom of the form with concrete to a depth of 1 inch, upon which place immediately two pieces of ¼-inch round or steel rods or No. 6 wire 1 inch in from each side and running the full length of the post. Then quickly fill the form to within 1 inch of the top with concrete, tamping the wet concrete slightly to drive out any air bubbles. Next place two more rods or wires, each 1 inch from each side and fill in the rest of the concrete, spading the faces of the posts next to the form boards to leave a smooth surface, and lightly trowel the top surface. The end boards and the boards between the posts must not be removed until the concrete is hard and the posts should not be handled or moved for at least ten days without danger of cracking them. They should be left for three or four weeks at least before using and kept damp by sprinkling. The surfaces of the posts do not need to be finished off in any special way, for they should be smooth enough without.

For fastening fence wire to the posts, the following method is suggested: Take a piece of No. 12 copper wire 12 inches long, bend it in two and twist the halves together, leaving the ends free for about 2 inches; these should be made beforehand. While the concrete is being placed in the forms set two or three of these copper wires in the concrete the proper distance for stringing wires so that they will be imbedded in the post about 4 inches and leave the two free ends to project from the post about 2 inches. See cross section of post in Fig. 10.



VIEW OF DELLWOOD PARK FENCE, JOLIET, ILL.

Another very good method is to get a number of ½-inch or 1-inch round rods or wood dowells 6 or 8 inches long and place them vertically in the form the proper distance apart for stringing wires. To hold them in place nail a strip of wood across the top of the form beside the rod and drive a nail into this strip and bend the nail around the rod so as to hold it up against the strip. The rods should be well greased and left in the concrete about 1 day, when they can be removed. If they are not well greased it will be almost impossible to remove them without injuring the concrete. Through the holes



CONCRETE FENCE AT GEDNEY FARMS, WHITE PLAINS, N. Y.

CONCRETE GATE POSTS AT COLUMBIA, MO.

the fence wire can be strung, or a short piece of wire can be run through and the ends twisted around the running fence wire.

There are several other methods of providing the same means of attaching the fence wire to the posts. For instance, insert in place of the copper wire described above a galvanized screw eye and run the fence wire through it or attach it to the screw eye by means of wires.

CORNER POSTS. Corner posts should be made about 10 inches square the full length of the posts and 9 feet long. On account of the weight of such a large post it is easier to mold the posts in place, as they will weigh about 940 pounds, but if desired they can be made in the same manner as the other fence posts just described. Reinforce corner posts with a ⅜-inch rod in each corner of the post instead of the No. 6 wire used for the smaller ones. Set a corner post at least 3½ feet in the ground. If special finish is necessary, refer to method of treating horse blocks, page 43.

### QUANTITY OF MATERIAL FOR CORNER POSTS

**One-Half Small Single Load* of Sand Required Per Barrel of Cement; One Small Single Load* of Screened Gravel or Stone Required Per Barrel of Cement.**

**Proportions: 1 Part "Atlas" Portland Cement to 2 Parts Sand to 4 Parts Gravel.**

| Size of Posts | | | No. of Posts per Barrel (4 Bags) Cement | Weight per Post, Pounds |
|---|---|---|---|---|
| Length, Feet | Top, Inches | Bottom, Inches | | |
| 6 | 12 | 12 | 2¾ | 900 |
| 7 | 12 | 12 | 2½ | 1,050 |
| 8 | 12 | 12 | 2¼ | 1,200 |
| 9 | 12 | 12 | 2 | 1,350 |
| 9 | 10 | 10 | 3 | 940 |
| 9 | 6 | 6 | 8 | 337 |
| 7 | 24 | 24 | ½ | 4,200 |

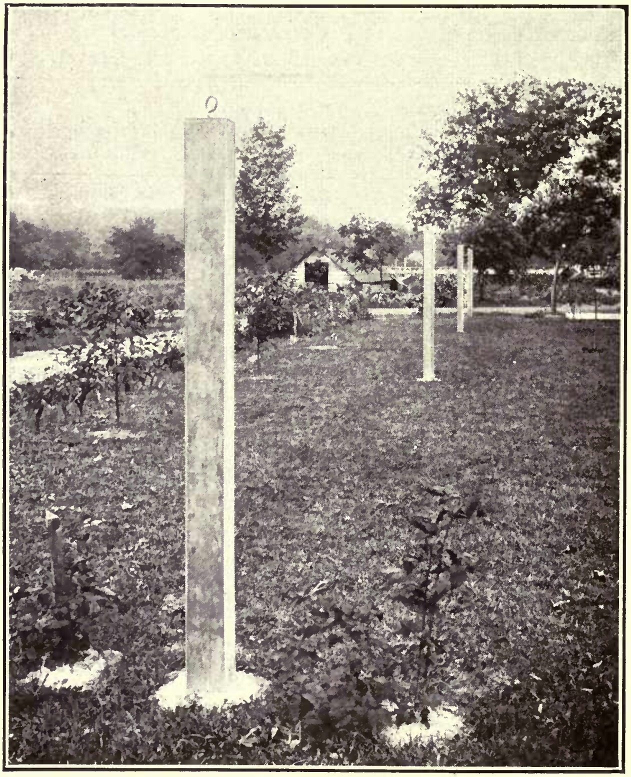
* Small single load = 15 cubic feet.

COST OF FENCE POSTS. Seven-foot fence posts constructed as described on page 36, without hiring outside help so that the cost of labor need not be considered, can be made for about 20c. to 30c. each. They will cost from 10c. to 20c. apiece more if the cost of labor is considered.

HITCHING POSTS. Hitching posts can be built and reinforced in the same manner as finished fence posts. Make a post about 6 feet long so that it will set about 2½ feet in the ground. Make forms and handle the concrete same as described above for fence posts. Cast a long ½-inch diameter iron staple, holding an iron ring, in the top of the post by passing it through a slot in the head of the form before the concrete is poured, just as the staple is placed in the clothes post described on page following.

A neat and inexpensive round hitching post may be designated as the "stove-pipe" hitching post. Dig a hole 18 inches deep and 10 inches in diameter in the ground and fill with one part "ATLAS" Portland Cement, two parts of clean, coarse sand and four parts of screened gravel or broken stone. Place on this base of concrete, before it has set, a section of 7-inch stove pipe. For reinforcement place a 1-inch gas pipe in the center of the stove pipe and push it into the soft base of concrete. Insert in top of post a round hitching post ring. Leave the stove pipe in place and paint it if desired, which makes a very neat and attractive post. When the stove pipe rusts off, the concrete post still remains as attractive as ever.

STOVE-PIPE HITCHING POST AT COLUMBIA, MO.



CONCRETE CLOTHES POSTS AT WESTWOOD, N. J.

## CLOTHES POSTS.

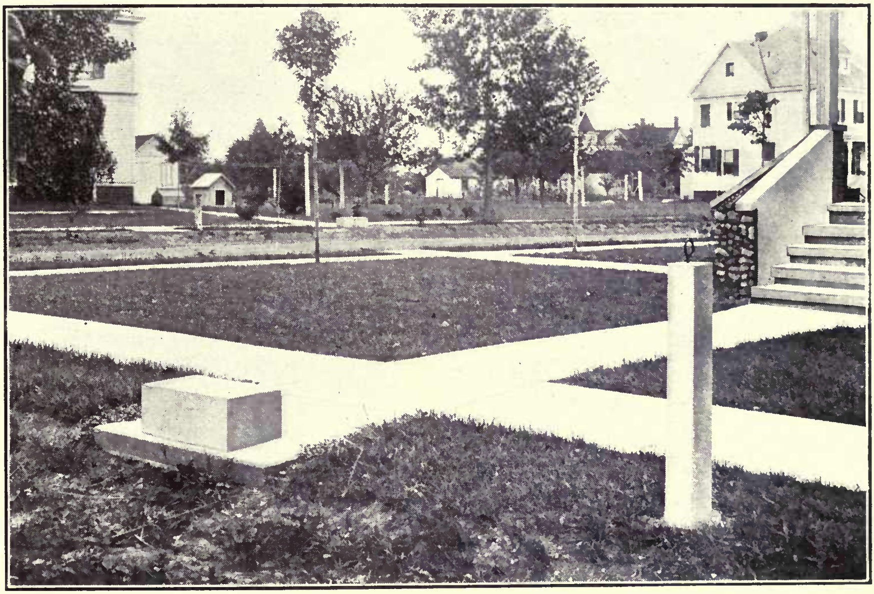
Clothes posts may be made in the same general way as the finished fence posts, except that they should be 6 inches square, 9 feet long, and reinforced with ⅜-inch rods in each corner instead of No. 6 wire. Imbed an iron staple ½ inch in diameter in the top of the post for a clothes line. This can be done by cutting a hole in the head of the form large enough to pass the eye of the staple through, then placing the staple before the concrete is poured and hold it in place by a wad of paper to plug the hole. Another plan is to form a hole near the top of the post by placing a greased dowel in the form before pouring the concrete.

## HORSE BLOCKS.

Horse blocks can be built solid in place.

Make a form or box, without a bottom, 36 inches long, 18 inches wide and 12 inches deep, inside dimensions. Grease this form and fill with concrete, one part "ATLAS" Portland Cement, two and one-half parts clean, coarse sand and five parts screened gravel or broken stone.

It is best not to plaster the top surface or sides of the block, for if it is plastered it is apt to crack or peel off. The top surface should be smoothed off with a trowel when the concrete is first laid, then in a few hours, as soon as it has begun to stiffen, scrape off any light colored scum with a wire brush or horse curry comb, and trowel the surface again, preferably with a wood float, but using no fresh mortar. The form should be removed the next day, or as soon as the concrete is hard enough not to show thumb marks, and while the concrete is green rub down the sides with a wood float or brick. Keep damp by sprinkling for a week. If the surface thus left is not good enough, it may be necessary to plaster it, even though at the risk of checking and cracking. To do this pick the surface with a stone axe, wet thoroughly and trowel on a coat of mortar one part "ATLAS" Portland Cement to one part clean, fine sand, making the layer not over 1-16 inch thick.



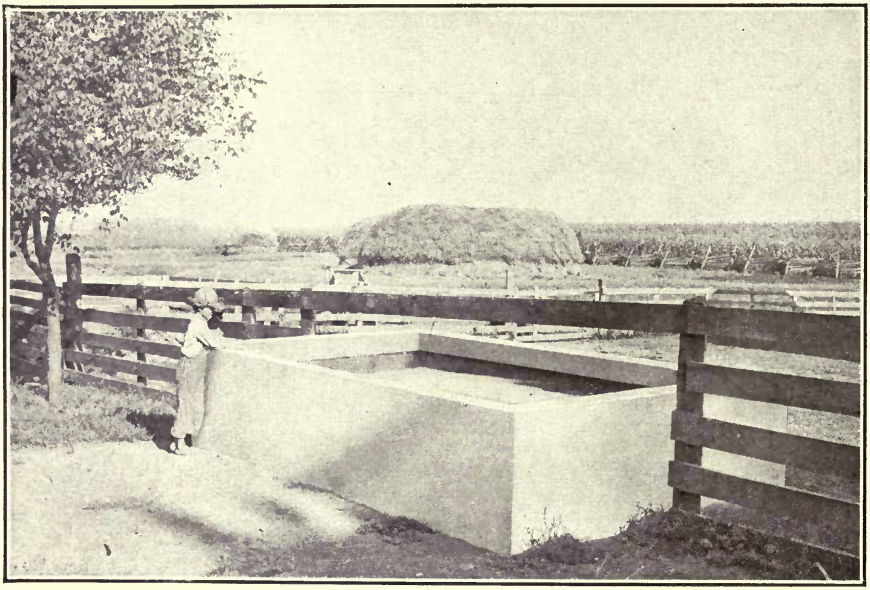
HORSE BLOCK, HITCHING POST AND SIDEWALK AT WESTWOOD, N. J.

The weight of a horse block of the above dimensions is about 675 pounds and about two bags of cement are needed.

## WATERING TROUGHS.

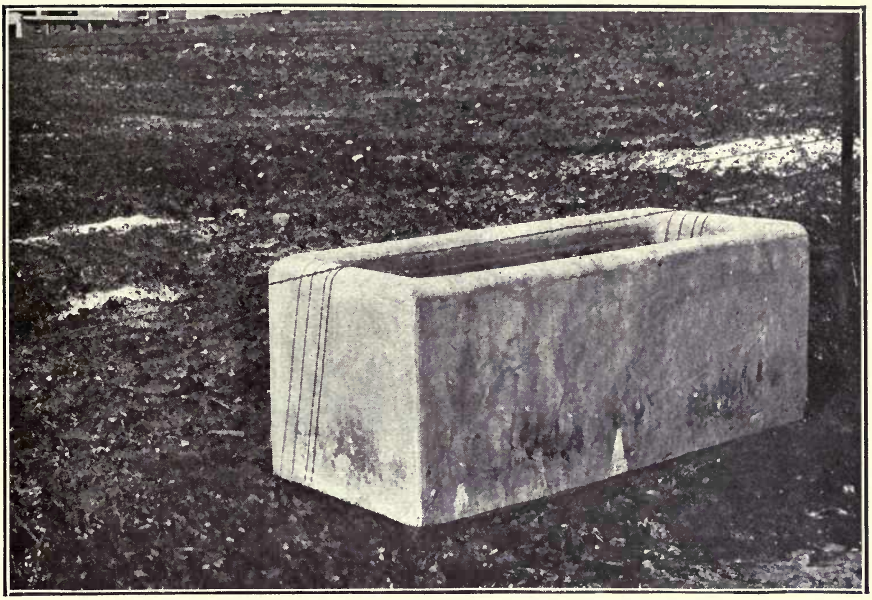
One of the most useful and essential devices about a farm is the small watering trough, and when made of concrete it is not only of pleasing appearance, but is practically indestructible. Moreover, if an inlet pipe with float valve connection has been provided it needs absolutely no attention.

Watering troughs, like many other concrete structures, may be made without steel reinforcement, but if so constructed the walls must be half again as thick as when reinforced, and even then are more apt to crack. The size and capacity of the trough varies with the purpose for which it is used, but for troughs up to about 10 feet long by 2 feet wide by 2 feet deep the thickness of the reinforced walls should be about 5 inches.



WATERING TANK, BOODY, ILL.

It is essential that a watering trough be water-tight. The conditions for obtaining a trough which will not leak are (1) a richer mix of concrete than is required for ordinary work; (2) enough water in mixing to give a sloppy concrete, and (3) the placing of all the concrete at one operation. It is extremely difficult to make any structure water-tight unless all three of the above conditions are complied with.

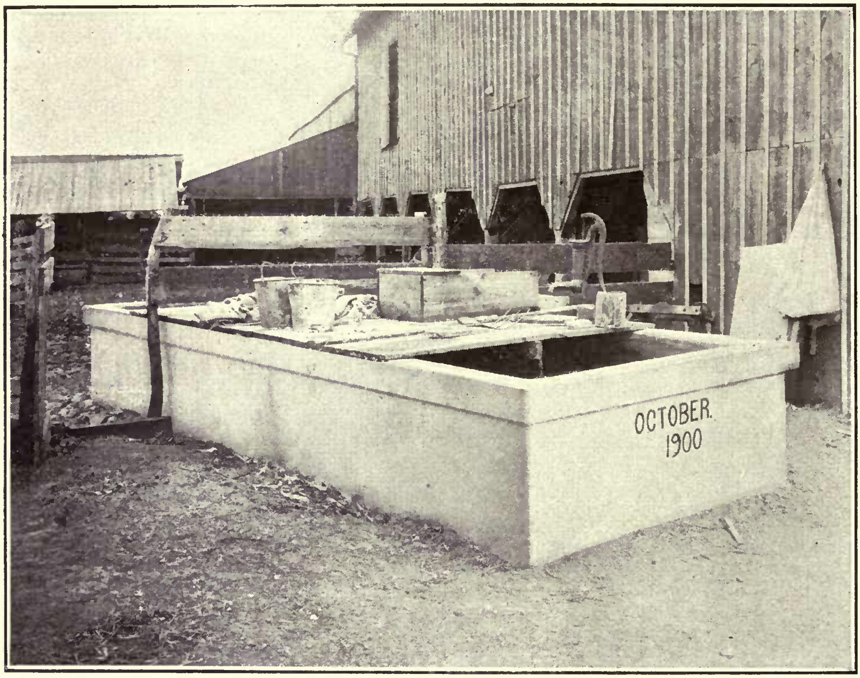


FIELD TROUGH AT GEDNEY FARMS, WHITE PLAINS, N. Y.

WATERING TROUGH AT BERRY HILL, L. I.

The best mix of concrete to use varies with the sand and gravel employed, but generally speaking one part of "ATLAS" Portland Cement to one and one-half parts of clean, coarse sand to three parts of screened gravel or broken stone are advised, or if gravel from the natural bank is used without screening, one part of "ATLAS" Portland Cement to three parts of natural bank run gravel. If sand alone is available use one part "ATLAS" Portland Cement to two parts sand.

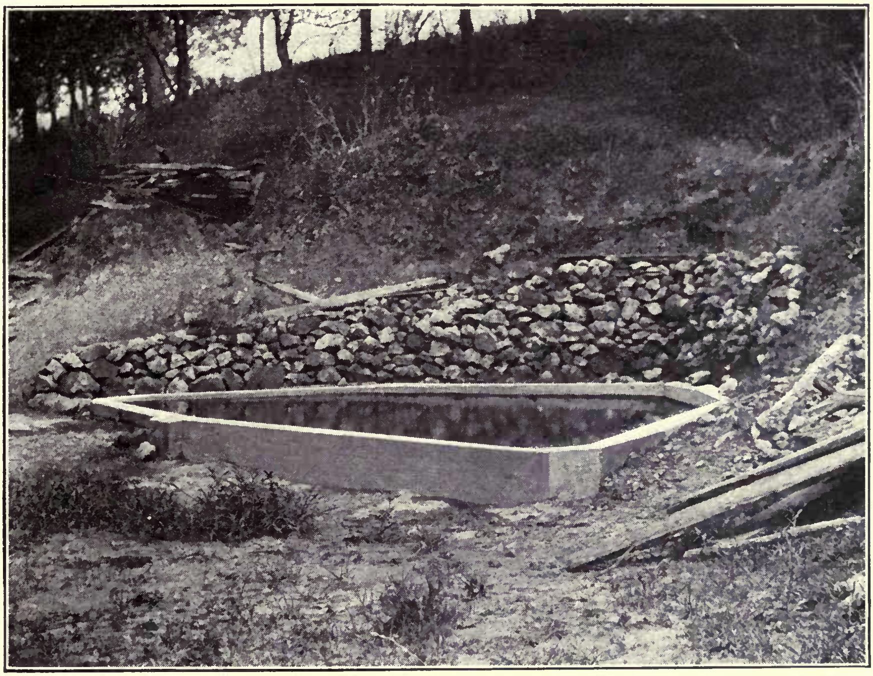
The amount of excavation necessary for the foundation of a trough depends upon the size. For a small trough level off the earth and tamp the ground well before placing any concrete, but for a trough of large capacity a solid foundation should be used. To construct a solid and reliable foundation, excavate about 12 inches and fill in 6 inches with either cinders or gravel from which the sand has been screened, tamp this well and fill in 6 inches of concrete, using only half the proportion of cement to sand and stone that is used for the trough itself.



WATERING TROUGH, DECATUR, ILL.

Next place the outer forms in position, brace and oil them well and mix the concrete according to the directions given on page 24.

Place a 2½-inch layer of concrete in the form, and immediately after placing and before the concrete has set, place a sheet of woven fence wire or some other wire fabric over the concrete, bending it up so that it will come to within one inch of the top of the forms at the sides and ends. Place 2¼ inches more of the concrete in the bottom and ram lightly to bring the mortar to the surface and smooth it off evenly. Have the inner form all ready and as soon as the base is laid and before it has begun to stiffen set it, taking care to keep it at equal distances from the sides, and then immediately fill in the concrete between the outer and inner forms to the required height. The time at which to remove the form depends upon several conditions, such as the wetness of the concrete, the weather and the temperature, but generally such forms can be removed within two days. After removing the forms, wet the concrete thoroughly and paint the inside surface with pure "ATLAS" Portland Cement mixed as thick as cream. Protect the trough from the sun until it is filled with water keeping it wet for about a week. Do not fill with water until a week after laying the concrete.



FIELD WATERING TROUGH, KNOXVILLE, IOWA

The outside surface can be finished off very satisfactory if done as soon as the forms are removed by wetting the surface thoroughly with a whitewash brush, using plenty of water, and rubbing it down with a wood float or board or a brick. This will remove the marks of the form boards and make a very pleasing appearance. (See directions for Finishing Concrete Surfaces, page 27). A long trough is difficult to build because of the great amount of reinforcement required to prevent shrinkage cracks.

Where the trough is to be connected with an inlet and outlet pipe, it is best to place the necessary pipes and connections in the forms before laying the concrete. This will save a great deal of labor and trouble, but where these connections cannot be made before placing the concrete, the holes for them may be provided in the concrete by inserting greased wooden plugs in the forms in place of the pipes. These plugs can be easily withdrawn as soon as the concrete has set.

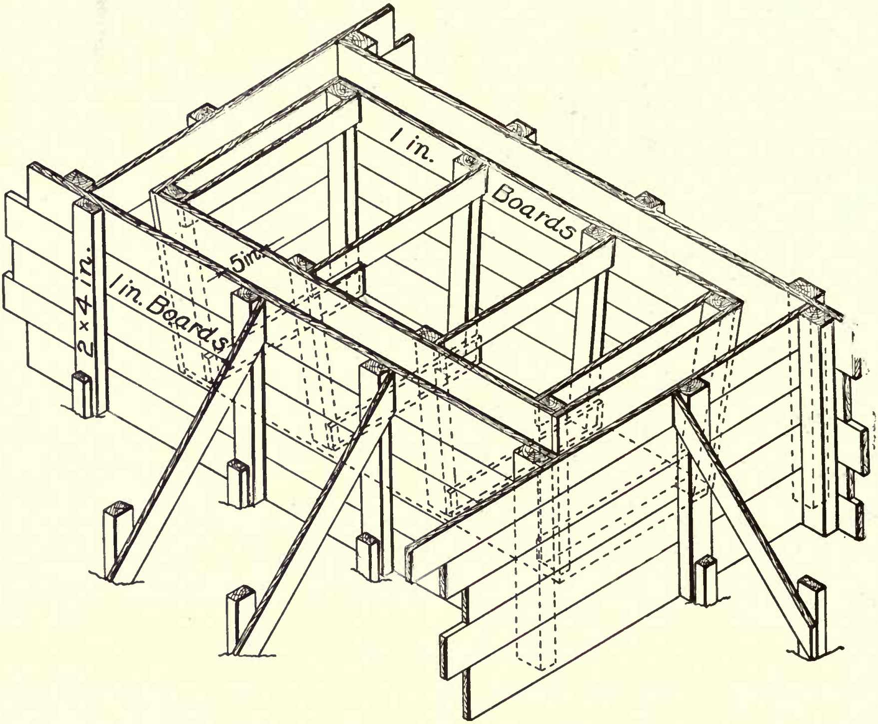
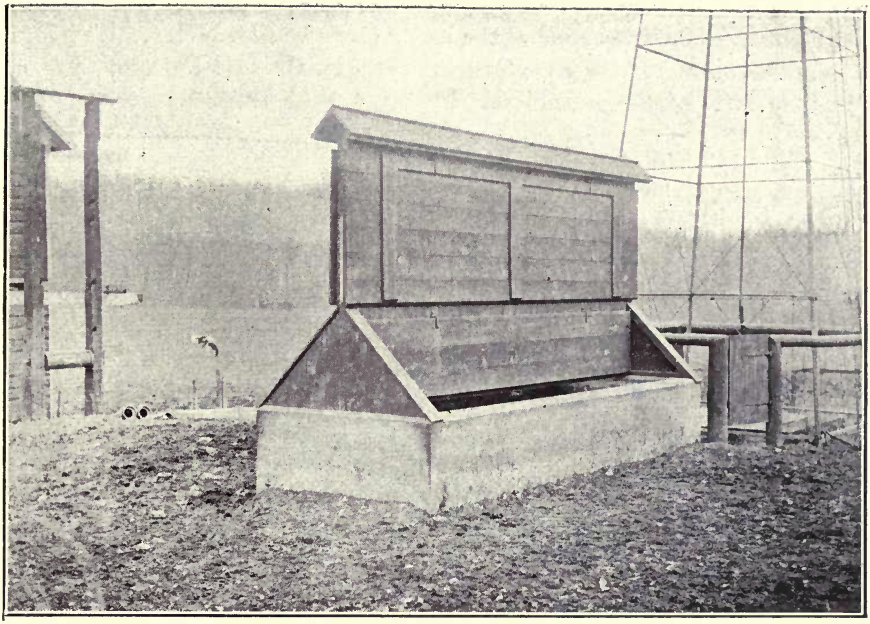
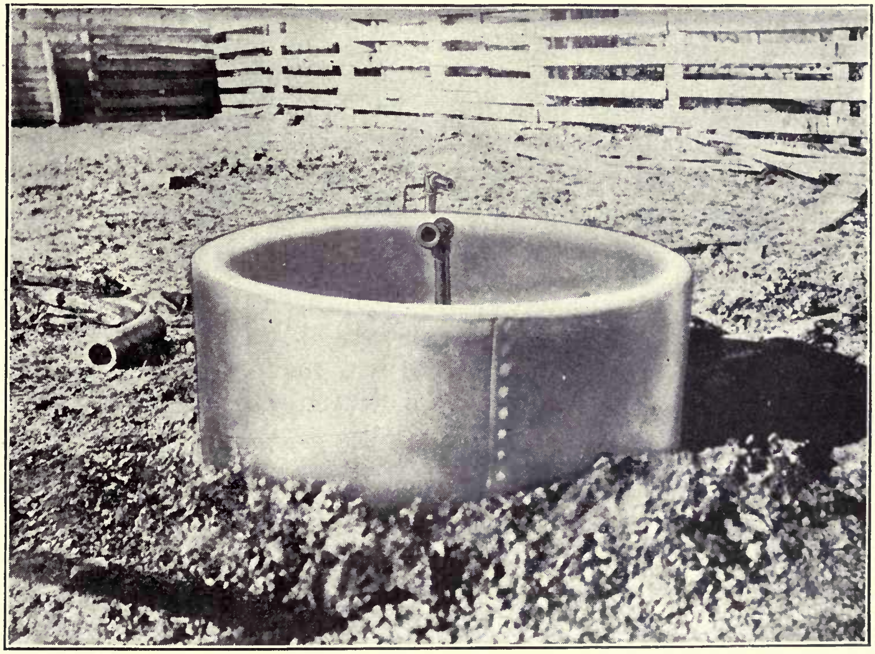


Fig. 11. Design of Forms for Rectangular Trough.

The design of forms for a rectangular trough, shown above, is economical in that the lumber for the outside forms does not need to be cut unless desired, and can therefore be used for any other purpose, being practically as good as new.



WATER TROUGH AT MONROE, N. J.



OLD BOILER TANK WATERING TROUGH AT COLUMBIA, MO.

Were it not for the more complicated form work, the circular shaped tank would be built oftener because of the attractive effects which can be produced.

A simple and attractive circular form for a small watering trough is shown in Fig. 12. It is made as follows:

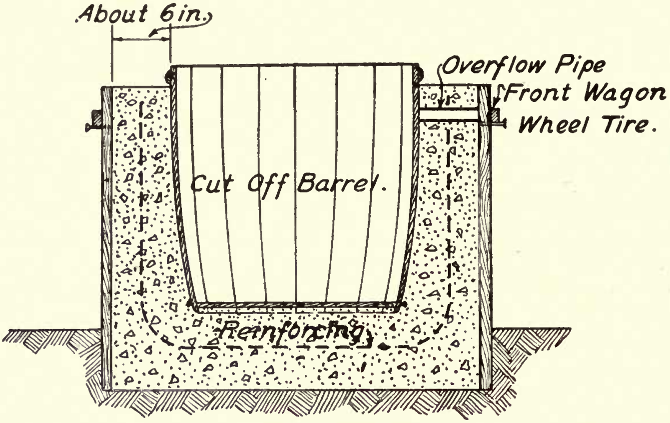


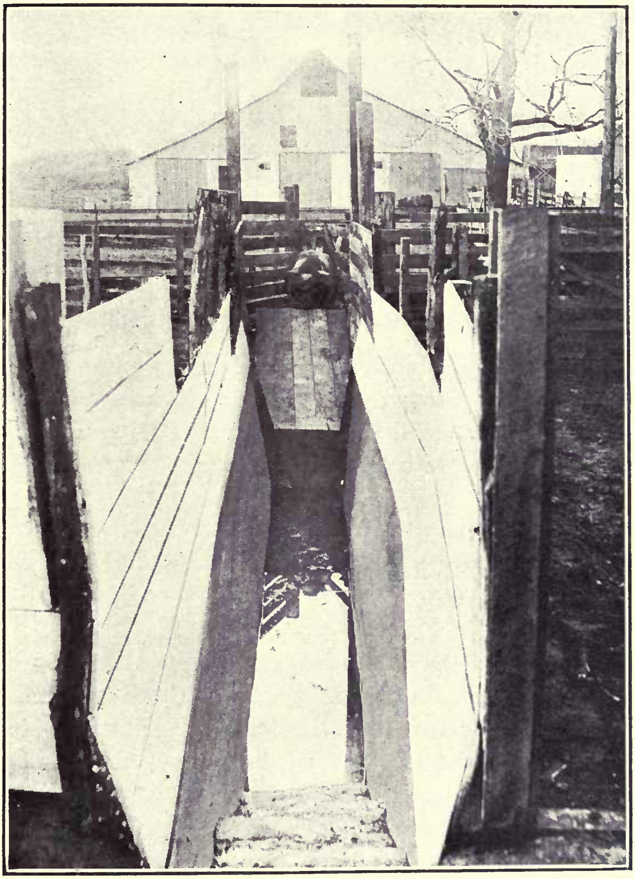
Fig. 12. Design of Forms for Circular Trough.

Take an old wagon or buggy tire, lay it on the ground, and mark a line on the inside of the tire. Excavate inside of tire 6 inches deep and place endwise three 1 by 2-inch stakes about 3 feet long on the inside of the tire. Raise the tire 2 feet above the ground to make the total inside depth of the trough 2 feet, and drive a nail in each of the three stakes under the tire to support it at this height. Fill in the circle between these three stakes with slats or flooring boards set on end and place a nail in each under the tire to hold them at the top. To hold them at the bottom tamp a little sand at the foot of the stakes. Mix one part "ATLAS" Portland Cement to one and one-half parts of clean, coarse sand to three parts of screened gravel or broken stone and lay about 4 inches of concrete. Place the reinforcement as described for rectangular troughs, running it up on the sides so that it is about 2 inches from the outside surface. After placing the reinforcement the rest of the operations are the same as for a rectangular trough. The inside form may be made by sawing a barrel in two, nailing each of the barrel staves to the head of the barrel, and removing all but the top hoop. The construction of the inside barrel form is clearly shown in Fig. 12. Oil the forms well before placing the concrete.

The materials required for a circular trough like this are 3½ bags of "ATLAS" Portland Cement and 1 single load of sand and gravel. Two men can make a trough in about one-half day each, and the cost is approximately $4.00 complete.

A single load of sand or gravel is considered as 20 cubic feet, or ¾ of a cubic yard, and a double load as 40 cubic feet, or nearly 1½ cubic yards.

A method of constructing a circular trough where a cut off section of an old boiler was used, not only for the exterior form, but also as the outside finish, is shown in the photograph above. This style of trough, although rather attractive, is more expensive than the one just described on account of the cut off boiler section, which in this case was about $10.00.



DIPPING TANK AT CHILLICOTHE, OHIO

**HOG TROUGHS.** A desirable hog trough can be made by building a bottomless box 6 feet long and 12 inches broad by 12 inches deep. From a 2-inch plank saw out two triangles having a base of 12 inches and a height of 8 inches. Place these 5 feet 6 inches apart and nail a plank 1 inch thick on each side of the triangle. Place the inverted V-shaped trough thus made inside the bottomless box and put small triangular strips around the edges to make a square edge. (See Fig. No. 13.) Grease the form thoroughly and fill the space left with concrete mixture, one part "ATLAS" Portland Cement and three parts clean sand or sandy gravel, tamp lightly, and smooth off to top of box. Let stand until dry. Remove the inner forms within 3 or 4 hours, and paint the inside with pure "ATLAS" Portland Cement, mixed as thick as cream.

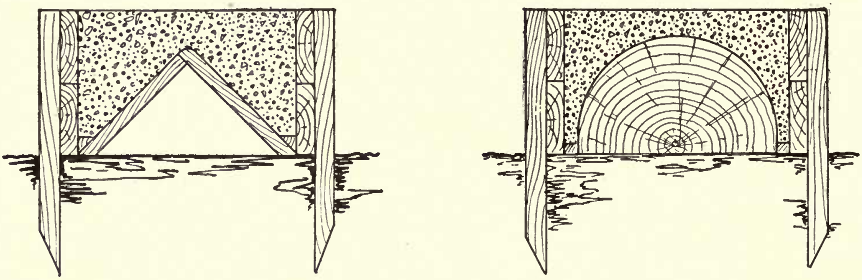


Fig. 13. Forms for Hog Troughs.

Should a trough with a round bottom be desired, an inner form can be made by sawing a log the right length, stripping it of bark, and splitting in half. Put this in the bottomless box described above, flat side down (Fig. No. 25), grease well and proceed as with triangular trough.

## SLOP TANKS.

Every farm should have one or more slop tanks, in order to heat the slop and prevent it from freezing, so that the cattle can be fed no matter how cold it may be.

Slop tanks of concrete have proved satisfactory. A concrete slop tank should be made of one part "ATLAS" Portland Cement to two and one-half parts clean, coarse sand to five parts of screened gravel or stone. The size shown in Fig. 12 will require 12 bags of cement, 1½ single loads of sand (20 cubic feet per single load) and 3 single loads of screened gravel, or better still, clean cinders.

A 36-inch iron kettle, having a capacity of 75 gallons, costs about $7.00 in the city market, to which the freight must be added. The forms are very simple, and can be easily made by a man in a day. The inner form need not be removed, but can be burnt out the first time a fire is built in it. The tank must be well reinforced in order to keep it from cracking, due to the difference in temperature to which the tank is subject. The firing is done from the door left in the front and the stack takes care of the draft. Do not build a fire in the tank until the concrete has set for at least two weeks.

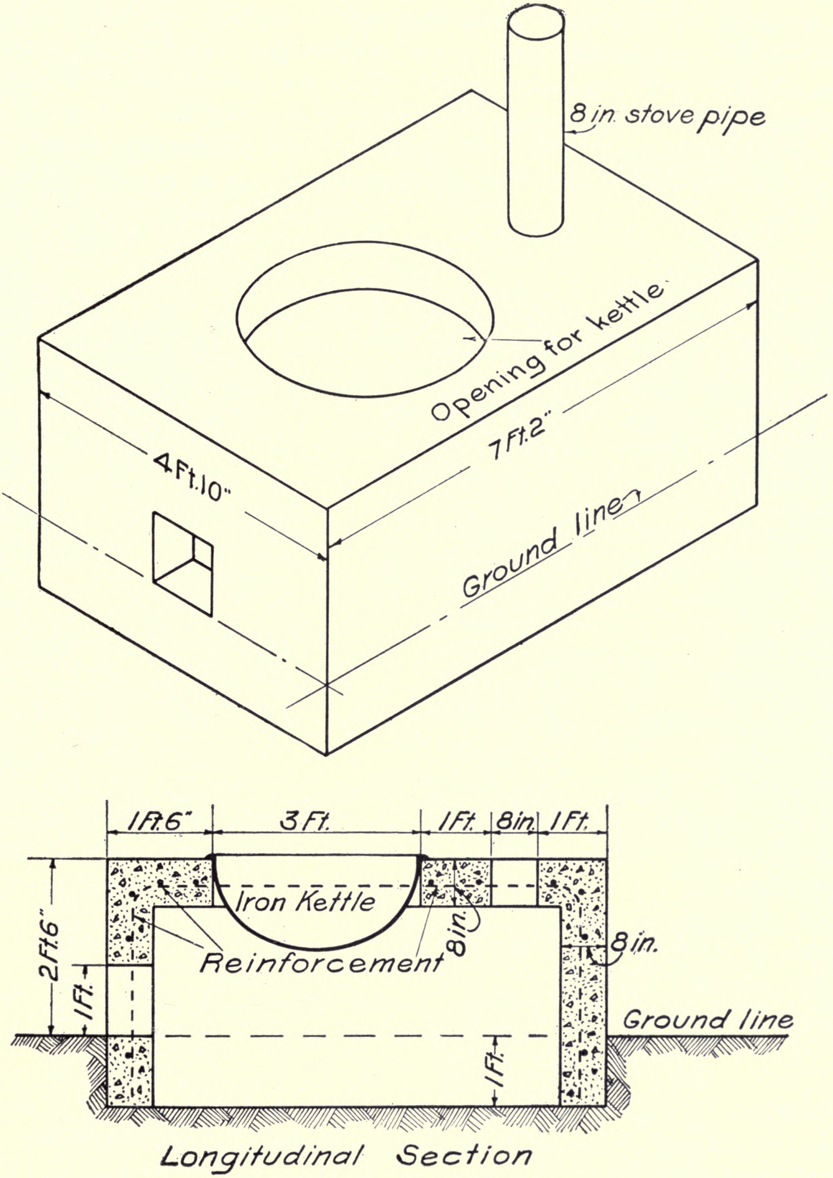
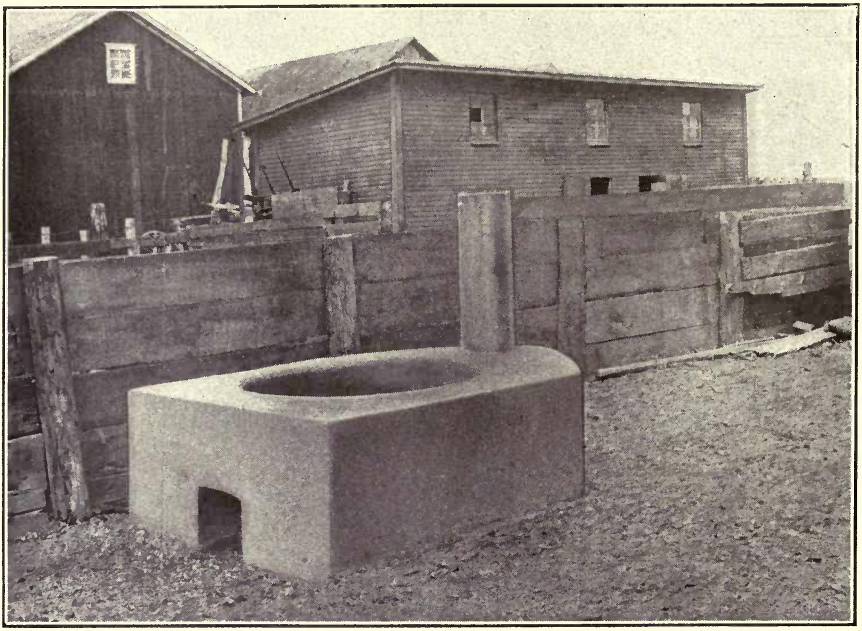


Fig. 14. Concrete Slop Tank.

## FERTILIZING TANKS.

Fertilizing tanks should be made about the shape of and a little larger than a barrel. If carefully made they will withstand the rough usage to which they are subjected by being pulled from place to place on drags, and are unaffected by the fertilizing fluids. Make the tank about 2½ inches thick and well reinforced. As soon as inside form is removed wet and brush with a layer of pure "ATLAS" Portland Cement of the consistency of thin cream to make it water-tight. Keep the inside wet until it is to be used.

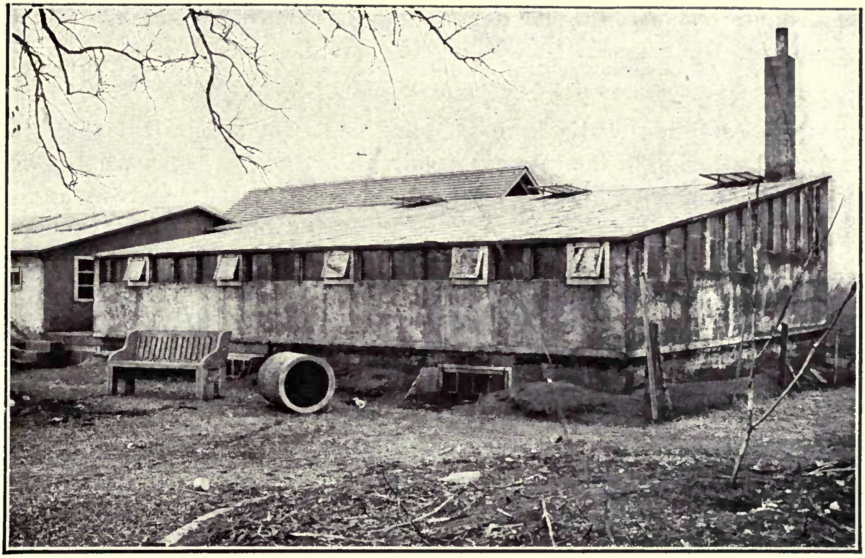


SLOP TANK AT MORTON, ILL.

## RAIN LEADERS.

Rain leaders or gutters are best constructed of concrete because they can be made for a very small cost, need no forms, are indestructible, and very attractive.

Excavate a trench 4 inches deep by 9 inches wide in the sand or dirt from the end of the rain conductor to the required distance from the building. Make a small batch of concrete, in proportions one part "ATLAS" Portland Cement to four parts unscreened sand and gravel, and fill the trench, hollowing out the surface and troweling a little to form the trough. The water may be carried under the surface if desired by digging a deeper trench, placing it in a



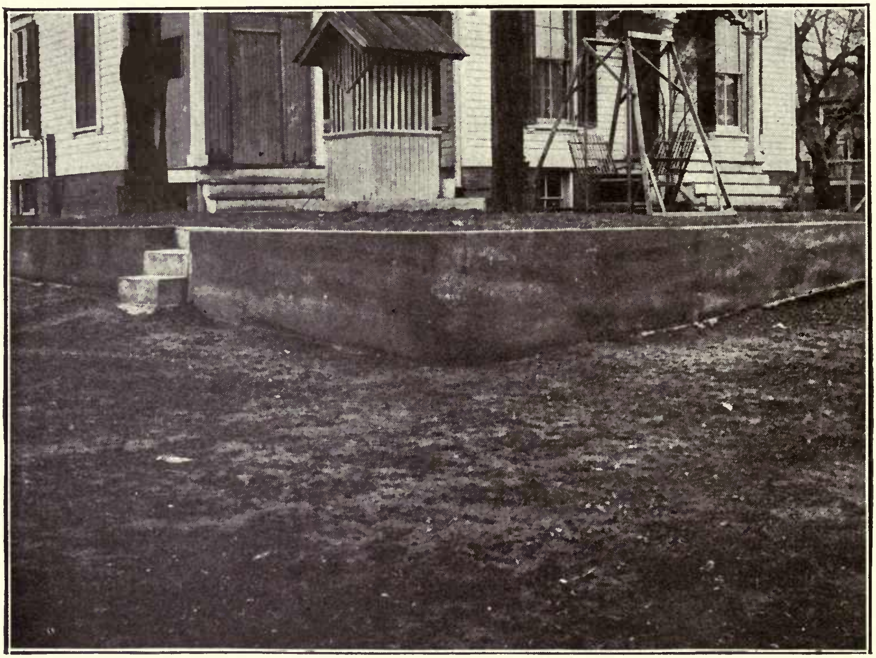
FERTILIZING TANK, GREENHOUSE AND RUSTIC SEAT AT WESTWOOD, N. J.

RAIN LEADERS, DUMONT, N. J.

length of tin or sheet-iron pipe and surrounding this with concrete. When the pipe rusts out, the concrete tube will still remain.

## RETAINING WALLS.

Concrete retaining walls in most localities cost much less than rubble masonry. The design of the retaining walls shown in Fig. 15 is what is known as the gravity section, which means that the earth pressure is resisted by the weight of the wall. The following table gives the necessary dimensions and the amount of materials per foot of length of wall. The amount of material is figured, assuming that the concrete is made of one part "ATLAS" Portland Cement, two and one-half parts of clean, coarse sand, and five parts of screened gravel or stone. The foundation, as shown, is taken 4 feet below the ground level. In the Southern States, 3 feet, or even 2 feet, will be sufficient to get below the frost line.



RETAINING WALL AT DUMONT, N. J.

The exposed side or face of the retaining wall can be finished off in the same manner as described on page 27. The top surface must not be plastered or it will crack and is apt to peel off. The surface should be smoothed off with a trowel when the concrete is first laid, then as soon as it has begun to stiffen scrape off any light-colored scum with a wire brush or old curry comb, wet slightly, and trowel it, preferably with a wood float, but using no fresh mortar.

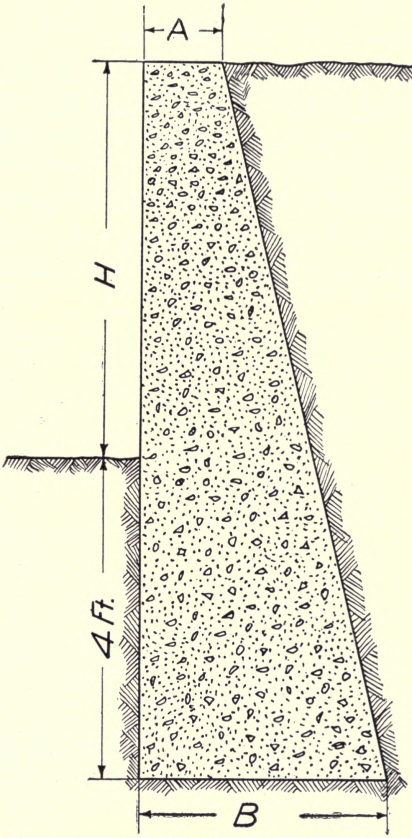


Fig. 15. Design for Retaining Wall.

## DIMENSIONS OF RETAINING WALLS AND QUANTITY OF MATERIALS FOR DIFFERENT HEIGHTS OF WALL.

**Proportions: 1 Part "Atlas" Portland Cement to 2½ Parts Sand to 5 Parts Gravel or Stone. (See Figure 15.)**

| Height of Wall Above Ground H | Total Height of Wall | Thickness at Base B | | Thickness at Ground Level | | Thickness at Top A | Amount of Materials per One Ft. Length of Wall | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Cement | Sand | Gravel or Stone |
| Feet | Feet | Ft. | In. | Ft. | In. | Inches | Bags | Cu. Ft. | Cu. Ft. |
| 2 | 6 | 2 | 2 | 1 | 6 | 10 | 1¾ | 4½ | 9 |
| 3 | 7 | 2 | 5 | 1 | 7½ | 10 | 2½ | 5½ | 11 |
| 4 | 8 | 2 | 9 | 1 | 11 | 12 | 3 | 7 | 14 |
| 5 | 9 | 3 | 2 | 2 | 1 | 12 | 3½ | 9 | 19 |
| 6 | 10 | 3 | 6 | 2 | 4½ | 15 | 4¾ | 11½ | 23 |
| 7 | 11 | 3 | 10 | 2 | 8 | 18 | 6 | 14 | 28 |
| 8 | 12 | 4 | 2 | 2 | 10 | 18 | 7 | 16½ | 33 |

Note:—A large single load of sand or gravel is about 20 cubic feet.
A large double load of sand or gravel is about 40 cubic feet.

## DAMS.

If a dam is to be built more than 4 or 5 feet above the bed of the stream, an engineer should be called upon to design it and look after the construction.

For an ice pond or a pond for watering stock a concrete dam may be built across a brook without difficulty.

If possible, dig a temporary trench so as to carry the water around the dam while it is being built. If this cannot be done, run the water through a wooden trough in the middle of the dam, and after the wall, each side of it, is finished, carry the forms across the opening, and make these tight enough so that the water is quiet between them; then place the concrete as described on page 26.

DAM AT ARLINGTON, VA.

Dig a trench across the stream slightly wider than the width of the base of the dam, carrying it down about 18 inches or 2 feet below the bed of the brook, or if the ground is soft, deep enough to reach good, hard bottom. In case the earth is firm enough for a foundation, but is porous either under the dam or each side of it, sheet piling consisting of 2-inch tongued-and-grooved plank can be pointed and driven with a heavy wooden mallet so as to prevent the water flowing under or around the dam. Build the forms so as to make the wall of the dimensions shown in the table. Wet them thoroughly, then mix and place the concrete as described on page 24.

Use proportions one part "ATLAS" Portland Cement to two parts clean, coarse sand to four parts screened gravel or broken stone.

Take special care to make the concrete water-tight by using a wet mix. If possible, lay the entire dam on one day, not allowing one layer to set before the next one is placed. If it is necessary to lay the concrete on two different days, scrape off the top surface of the old concrete in the morning, thoroughly soak it with water, and spread on a layer about ¼ inch thick of pure cement of the consistency of thick cream, then place the fresh concrete before this cement has begun to stiffen.

If the forms on the lower side of the dam are well braced, the forms on the upstream side may be removed in three or four days, and the pond allowed to fill. The forms on the downstream face should be left in place well braced for two or three weeks. No finish need be given to the surface.

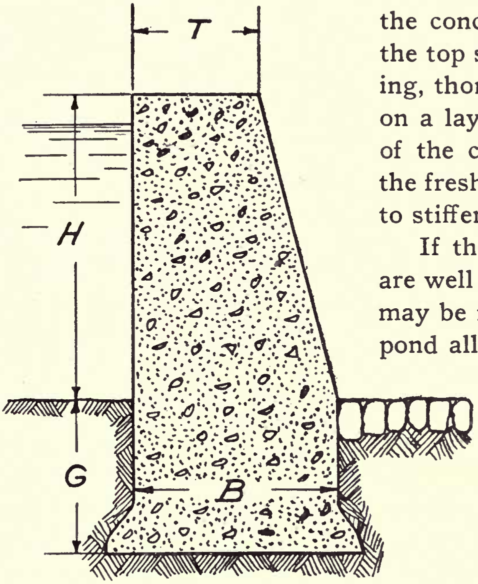


Fig. 16. Design for Dam.

**DIMENSIONS FOR SMALL DAMS AND QUANTITY OF MATERIALS FOR DIFFERENT HEIGHTS OF DAMS.**

**Proportions: 1 Part "Atlas" Portland Cement to 2 Parts Sand to 4 Parts Gravel or Stone. (See Fig. 16.)**

| Height Above Bed of Stream | Depth Below Bed of Stream* | Thickness at Base | Thickness at Top | Amount of Materials per Foot of Length of Dam | | |
|---|---|---|---|---|---|---|
| | | | | Cement | Sand | Gravel or Stone |
| Feet H | Feet G | Feet B | Feet T | Bags | Cu. Ft. | Cu. Ft. |
| 1 | 1½ | 1 | 1 | ½ | ¾ | 1½ |
| 2 | 1½ | 1 | 1 | 1 | 1½ | 3 |
| 3 | 1½ | 2 | 1½ | 1¾ | 4 | 8 |
| 4 | 2 | 2 | 1½ | 2¾ | 5 | 10 |
| 5 | 2 | 2½ | 1½ | 3½ | 6¾ | 13½ |
| 6 | 2 | 3 | 1½ | 4½ | 8¾ | 17½ |

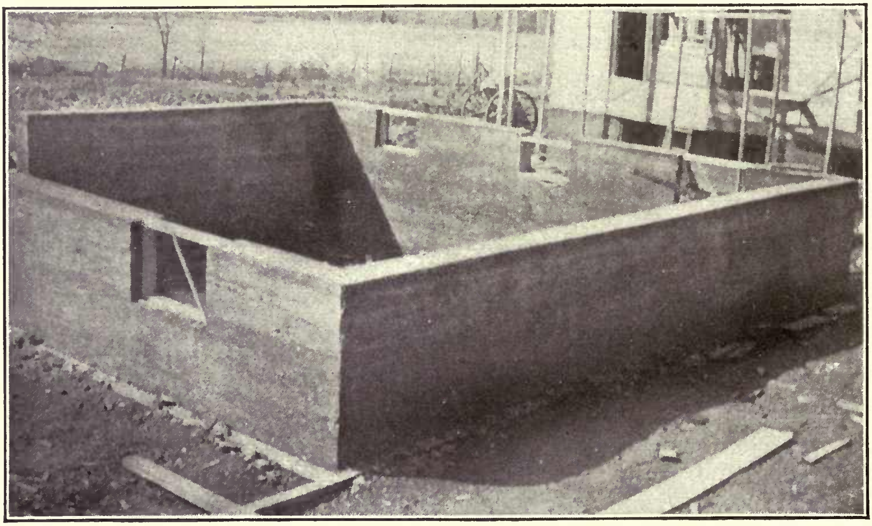
* Make deeper if necessary to get a good foundation.

Note:—A large single load of sand or gravel is about 20 cubic feet.
A large double load of sand or gravel is about 40 cubic feet.

## WALLS.

Concrete walls are everywhere being built in preference to stone, on account of the lower cost and thinner walls which are usually required. Unless stone can be laid at practically no expense, the concrete is cheaper.

Every wall should have a footing, that is, a base wider than the wall it supports, and must be carried down below the frost line. The depth of such footings, therefore, must be varied according to the section of country in which the work is being done. In general, they should be about 4 feet below the ground level in the Northern and Middle States, and about 3 feet in the Southern States, while in very mild climates 2 feet will be sufficient. The footing should be not less than 4 to 6 inches thick and should extend about the same distance each side of the wall.



HOUSE FOUNDATION AT SUMMIT, N. J.

Care must be taken to see that the foundation is not placed on a soft and yielding soil. Where the soil is unsuitable, either excavate until rock or a better material is found, fill in up to frost line with gravel and tamp it well while placing. When there is any danger of this filling of gravel forming a pocket in which the water will accumulate, dig a ditch away from the wall so that the water will run off.

CELLAR AND BASEMENT WALLS. Cellar or basement walls must withstand the earth pressure that comes upon them. This pressure varies with the depth of the cellar or basement, and hence the thickness of the walls

CONCRETE HOUSE AT DECATUR, ILL.

CONCRETE HOUSE NEAR MORTON, ILL.

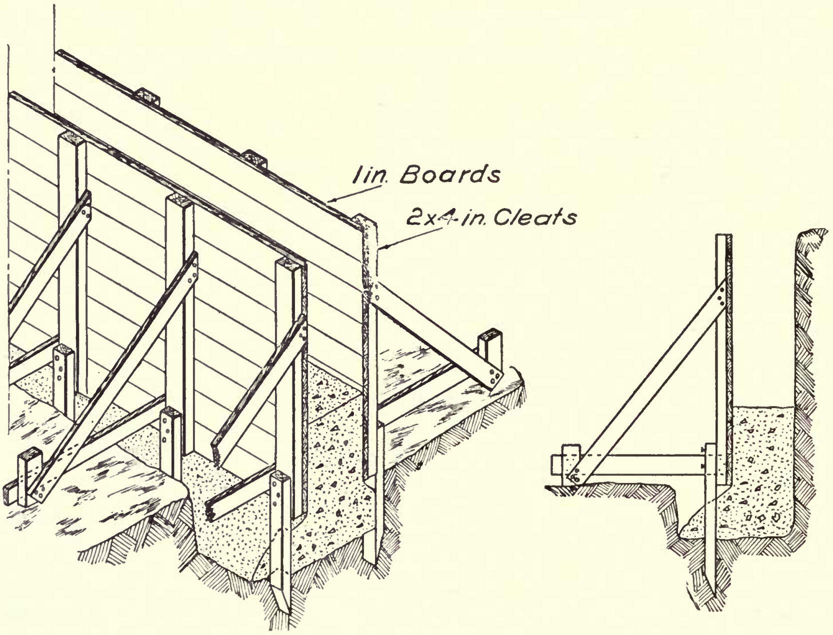
should vary with the depth as shown in the following table:

**THICKNESSES OF WALLS AND QUANTITIES OF MATERIALS FOR DIFFERENT HEIGHTS OF BASEMENTS.**

**Proportions: 1 Part "Atlas" Portland Cement to 2½ Parts of Sand to 5 Parts of Gravel or Stone.**

| Height of Basement | Depth of Foundation Below Ground Level | Thickness of Wall at Bottom | Thickness of Wall at Top | Cement per 10 Ft. of Length of Wall | Sand per 10 Ft. of Length of Wall | Gravel or Stone per 10 Ft. of Length of Wall |
|---|---|---|---|---|---|---|
| Feet | Feet | Inches | Inches | Bags | Cubic Feet | Cubic Feet |
| 6 | 4 | 6 | 6 | 6 | 14½ | 29 |
| 8 | 6 | 10 | 8 | 12 | 29 | 58 |
| 10 | 8 | 15 | 10 | 25½ | 60 | 120 |

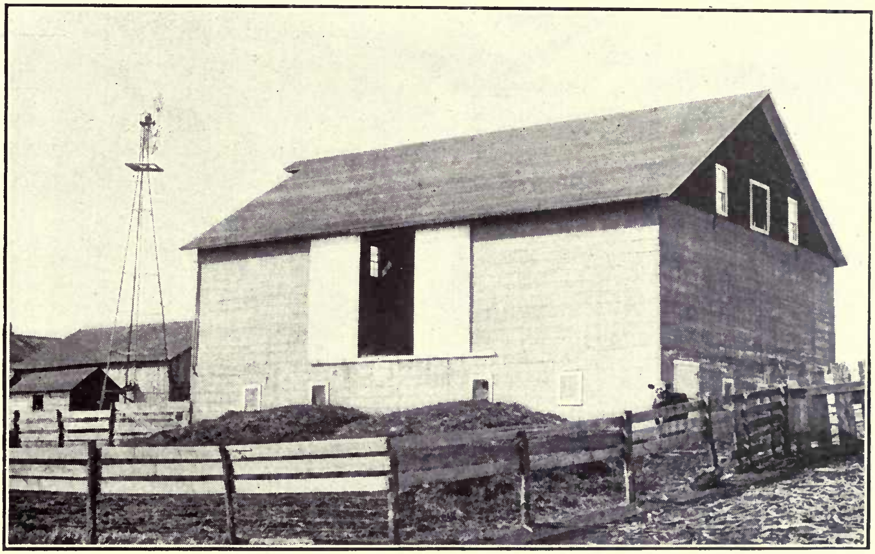
The thicknesses are less than for a retaining wall out of doors because the weight of the building and the floor timbers strengthen it. The back of the wall may batter or slope to save concrete. If vertical use bottom thickness for the full height. The earth must not be filled in against the back of the wall until three or four weeks after placing the concrete unless the forms and bracing are left in place in front.



*a* Fig. 17. Cellar Wall Forms. *b*

Where there is no earth pressure against the wall let the forms remain not less than 24 hours, or until the concrete will withstand the pressure of the thumb.

Fig. 17 illustrates a simple design for cellar or foundation walls: (a) of the figure represents view of an ordinary form, 2-inch by 4-inch braces being attached to the studs as braces; the form sides do not extend to the bottom so as to allow the concrete to flow out and form a spread footing; (b) represents a wall for which the bank of earth serves as one side of the form. This condition may occur when the soil is of a clayey nature, which does not cave in, or where the new wall is being built against an old one.



CONCRETE BARN AT TAMPICO, ILL.

Cellar or basement walls should be laid with one part "ATLAS" Portland Cement to two and one-half parts coarse sand and five parts of broken stone or screened gravel.

As concrete is the best material for cellar walls or footings of any kind, it is often used for this purpose even where the rest of the building is of wood or any other material. The building foundation should be brought up to the required height above the ground level. To attach the wood superstructure to the concrete foundation place on the concrete, imbedding it in mortar, the wood sill, which is made with the ends halved and bolted together. In the West, where the winds are very strong, this sill must be bolted to the concrete; this is done by placing occasional bolts in the concrete when laying it, letting the nut end protrude above the foundation to bolt through the sill. Holes can then be bored in the sill to fit over the protruding bolts and the nuts placed, thus firmly securing it.

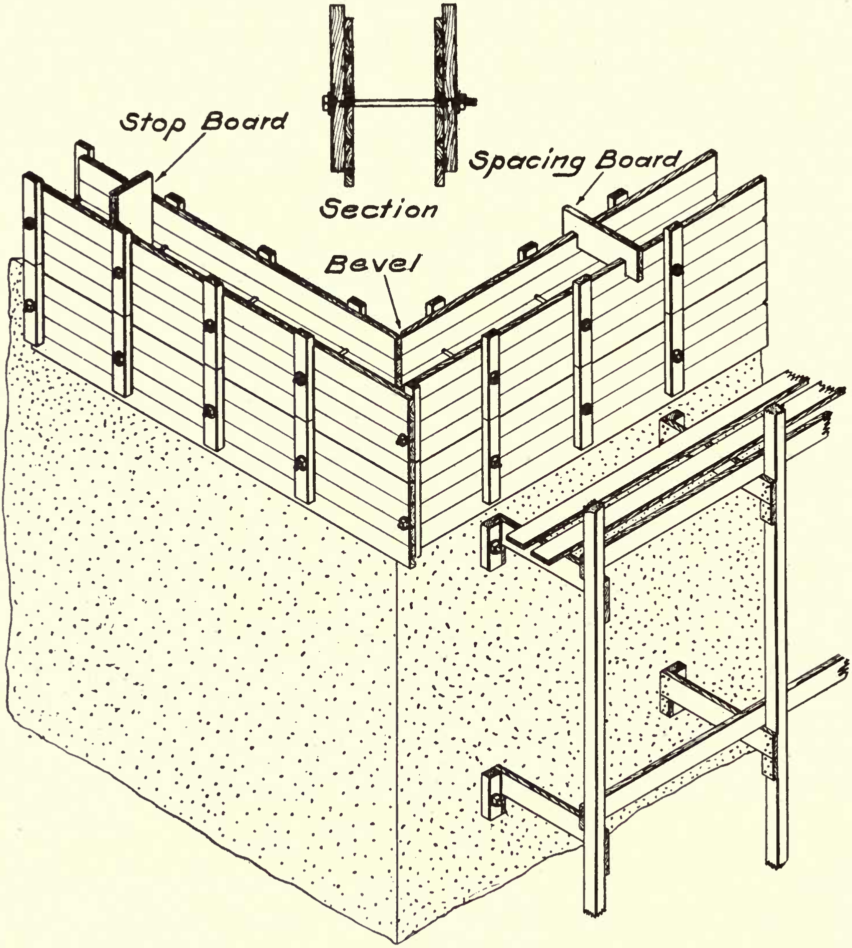


Fig. 18. Wall Forms.

WALLS ABOVE CELLAR OR BASEMENT. Concrete walls above the cellar may be built either as a single solid wall or as two walls with an air space between them. Such an air space renders the building less subject to changes of temperature and more completely moisture proof, but it is more expensive.

A solid concrete wall 6 inches thick is at least equivalent to 12 inches of brick. Walls 6 inches in thickness should be reinforced with vertical rods

¼ inch in diameter placed 18 inches apart and with horizontal rods ¼ inch in diameter placed 12 inches apart. Additional rods must be placed at corners and diagonally across the corners of all openings. Walls of small buildings, such as hen houses, may be made 4 inches thick with the same reinforcement described. Where hollow wall construction is used, make each of the walls 4 inches thick and about 9 inches apart, and tie together with galvanized-iron strips, or place piers of concrete 4 feet apart to connect the two together. Where such piers are used they are built at the same time as the two walls, making practically one wall with air chambers at regular intervals. A very simple method to construct a hollow wall is by using 2-inch planed plank, as shown in Fig. 31 (p. 102).

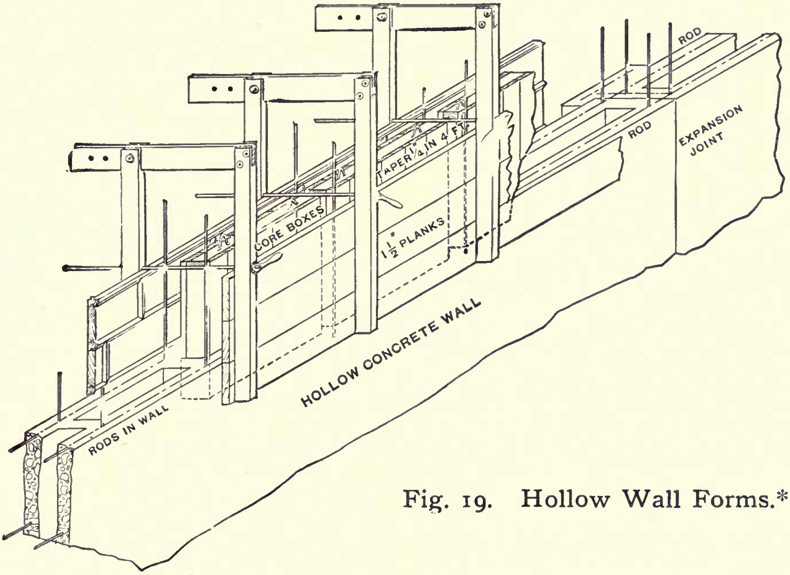
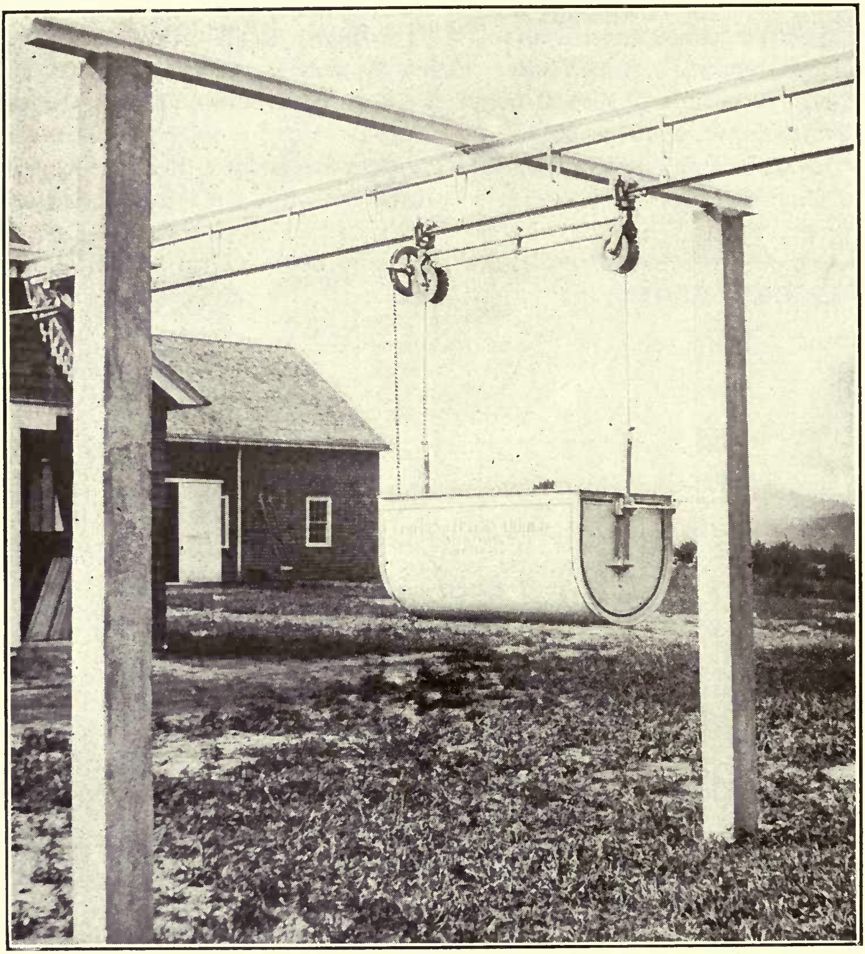


Fig. 19. Hollow Wall Forms.*

Fig. 18 shows a design of wall forms for building a solid wall of any height. The form sections are each made 2 feet high and the length depends upon the length of boards at hand. A 2-foot section made of 1-inch boards 10 feet long weighs 55 pounds, which can therefore be handled easily by one man. The cleats are made to lap over the top of the form 1½ to 2 inches, in order to catch the next section placed on top of the one just filled with concrete. Notice, also, that the cleat at one end projects beyond the form bracing so as to catch the next section and hold it in place. Use bolts for holding the forms together, as they are better than wires, which cut into the cleats and spring the forms apart. The bolt holes left in the wall, as shown in Fig. 15, are a means of constructing a very efficient and cheap scaffolding. All bolts should

*See Footnote, p. 18.



CONCRETE POSTS FOR SUPPORTING TROLLEY FOR LITTER CARRIER AT NEWBURGH, N. Y.

be well greased so that they can be readily removed. After completing the wall the bolt holes can be filled with mortar mixed in the same proportion as the concrete so that the color will be the same as the wall.

Sometimes a building is built with a wood superstructure on top of concrete walls which are only from four to eight feet above the ground. In this case the wood superstructure can be attached to the concrete walls in the same manner as described on page 63 for connecting a wood building to a concrete foundation.

# COLUMNS.

Excavate below frost and build forms 2 feet square to within 6 inches of surface of ground. Fill with concrete, one part "ATLAS" Portland Cement, two and one-half parts clean, coarse sand and five parts broken stone or screened gravel, not over one inch in size, and tamp or puddle carefully. From the center of this foundation build a hollow form one foot square and to desired height, and fill with concrete of same mixture. Before the form is filled—in fact, before setting it—place four steel bars ¾ inch in diameter vertically so that they are about 2 inches inside the corners, and around them, at intervals of one foot, wind loops of ⅛-inch or ¼-inch wire, tying these to the steel rods with fine wire. Make the concrete soft and mushy, so that it will just flow, and, as it is poured into the top of the mold, work a long paddle, made like the oar of a rowboat, against the forms to force the stones away from the surface and drive out bubbles of air which tend to adhere to the boards and form pockets of stone.

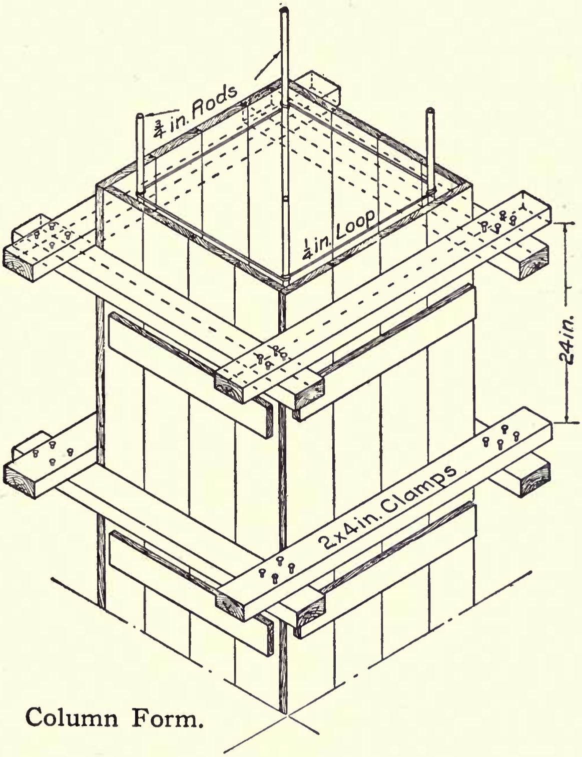
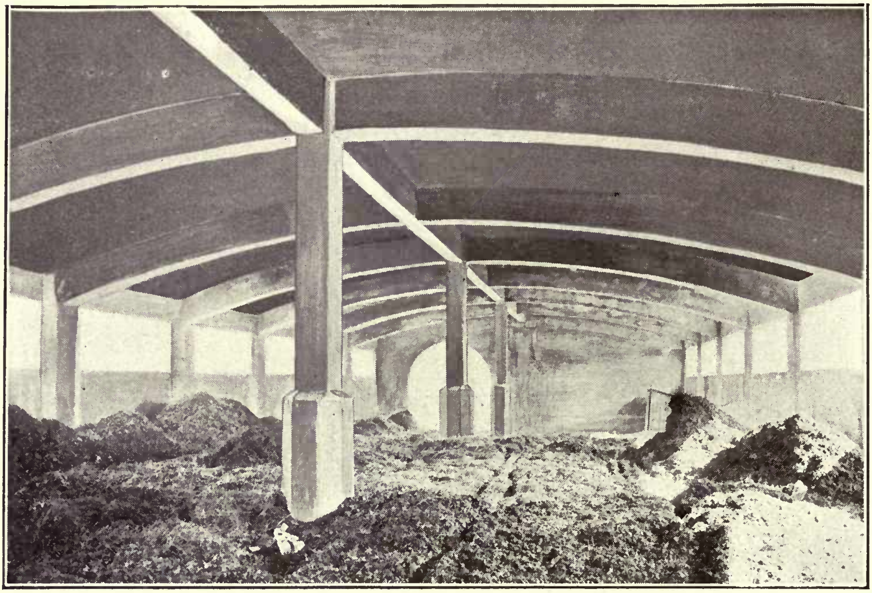
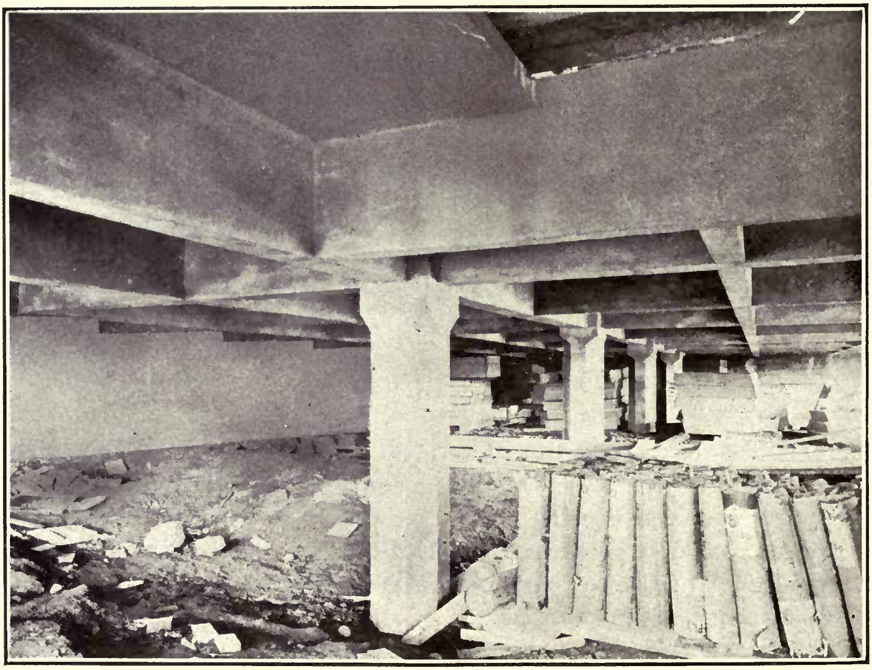


Fig. 20. Column Form.

A column 10 inches square, the smallest size it is usually desirable to build unless it is quite short, will safely support 15 tons, or 30,000 pounds.



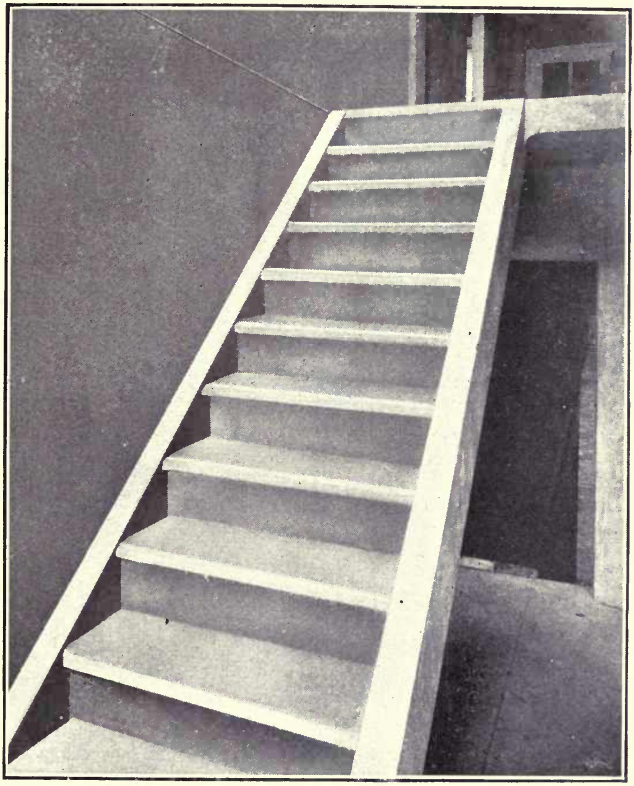
INTERIOR VIEW OF MANURE PIT AT GEDNEY FARMS, WHITE PLAINS, N. Y.



DETAILS OF PIERS AND FLOOR BEAMS UNDER HORSE BARN AT GEDNEY FARMS, WHITE PLAINS, N. Y.

# STEPS AND STAIRS.

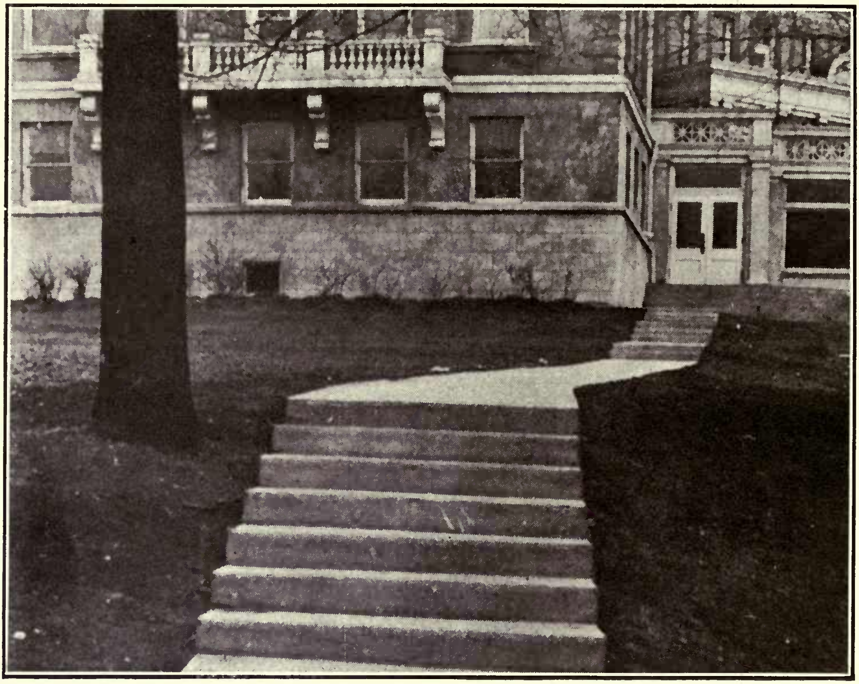
Steps and stairs are of two kinds: those made in one piece, monolithic, and those cast in separate moulds and put into place. There are numerous ways of arriving at the same end, and each man in charge of such work must use his ingenuity in the use of the materials at hand, and adopt the method best suited to his requirements. Specifications are given for four ways of making steps and stairs, all of which have proved successful.



FLYING STAIRS, DAIRY HOUSE AT GEDNEY FARMS, WHITE PLAINS, N. Y.

The rises on all steps and stairs should not be less than 6 inches nor more than 8 inches, while the tread should be from 9 inches to 12 inches, except where it is intended that more than one step should be taken on the tread, in which case 30 inches should be the minimum width.

Foundations for all steps out of doors should extend below frost line or have a porous base with a drain situated at the lowest point to allow the water to run off. Steps should be wider than the walk or opening from which they



SIDEWALK AND STEPS AT WEST HAVEN, CONN.

lead, to avoid looking cramped, and, in order to secure an artistic effect, should have some sort of projection, or moulding, at the upper edge. A slight slope to allow the water to run off is also desirable.

Let us first consider steps to areas or terraced grounds. Excavate the earth on the slope to the desired depth (see Foundations for Sidewalks) and put in

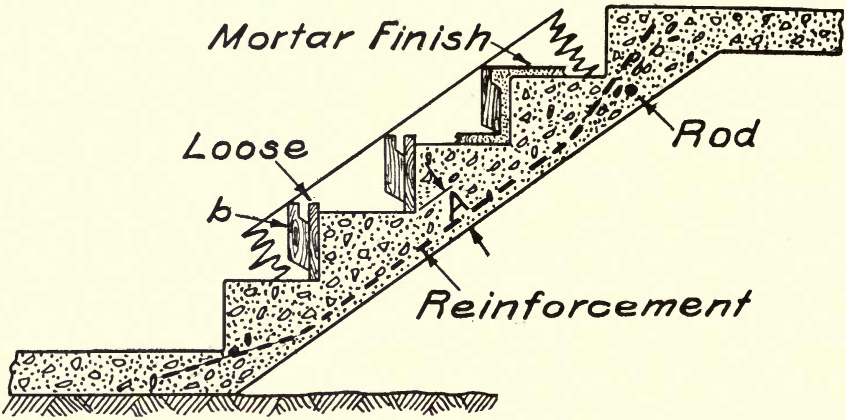
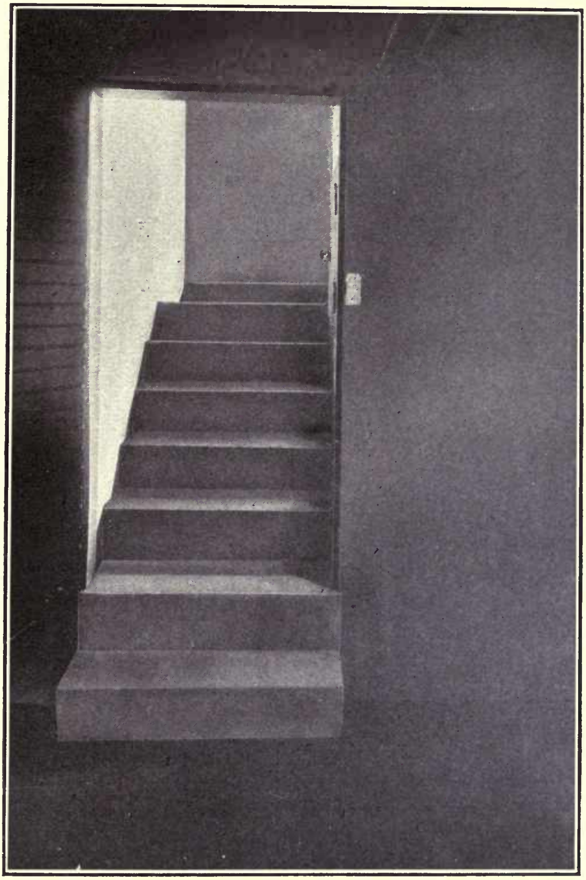


Fig. 21. Concrete Steps.

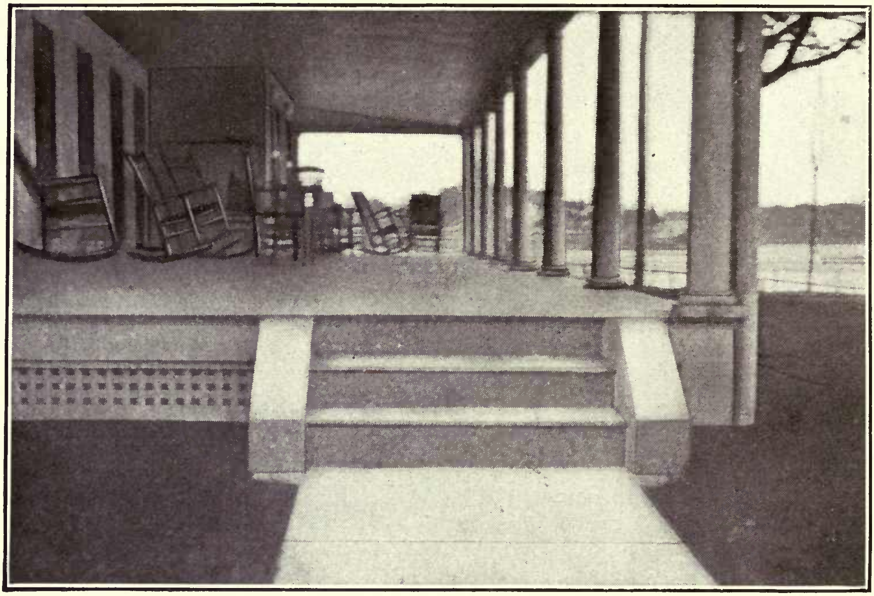
porous foundation with a drain at the lower end to dispose of any water that may accumulate.

Take two planks the length of the flight of steps on the slope, and wide enough to house each step, and mark upon them the location of the riser for each step. Place these planks edgewise on each side on the slope, and brace well on the outside. Place the necessary reinforcement, as given in the table, the full length of the steps on the slope. Now set planks marked (b.) Fig. 21, across these housings to form the rise of each step on the lines previously marked, placing them so that there will be a space below them for a continuous slab of concrete. The thickness of the slab is given in the table under column marked "A." These planks should be arranged with a groove at the top, as shown, to form the projection or moulding at the top of each step. They



CELLAR STEPS AND ICE BOX AT WESTWOOD, N. J.

should be fastened to the housing planks with cleats in such a way that they can be removed without disturbing them. Inside of each of these riser forms place a loose piece of board, well greased, as described for facing curbing on page 79, so as to provide a space which can later be filled with mortar. Now pour into the forms thus made concrete in proportions one part "ATLAS" Portland Cement, two parts clean, coarse sand, and four parts broken stone or screened gravel, filling each step to within 1 inch of the top of the riser. As soon as this concrete has stiffened, but before it has set, carefully draw out the loose facing board and fill the spaces with mortar one part "ATLAS" Portland Cement to one and one-half parts clean, coarse sand, and also cover over the top of the step to the depth of 1 inch with the same mortar, so that it will come flush with the top of the riser plank. Float the surface lightly with a wooden float, and as soon as it has stiffened hard enough to work, trowel it thoroughly. Early next day remove the riser form, the bottom of which, as shown in the figure, is beveled and comes only to the top of the mortar surface, and trowel the face of each riser. A skilled plasterer should be employed for this work, as the surface is likely to crack if not handled in a workmanlike manner.



PORCH STEPS AT GREENPORT, L. I., N. Y.

Porch steps, and other short flights, can be built as follows: Build two 8-inch walls to a depth below frost, the upper surface conforming to the desired pitch of the steps, but 3 inches below the points where the inner edges of the treads meet the risers. Carry the outside form, however, on the same slope to

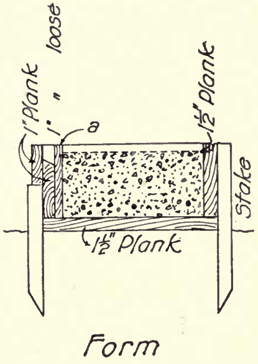


Fig. 22.

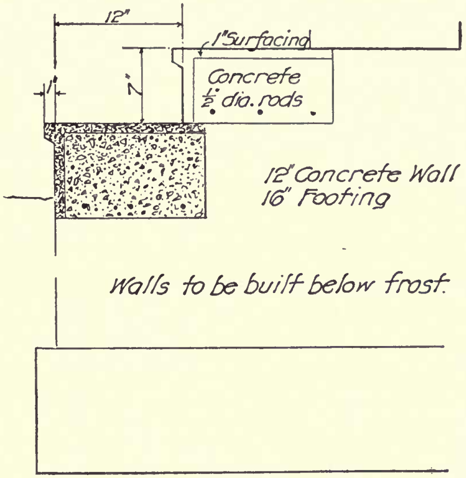


Fig. 23.

Fig. 22. Form for a Single Step.

Fig. 23. Single Steps in Place.

the line of the top of the risers. Between the walls build a sloping platform out of 1-inch boards supported by 2 x 4-inch stuff, well braced and conforming to the slope of the walls. Upon this sloping platform place ¼-inch steel bars 12 inches apart running from top to bottom. Also, crossways place one ⅜-inch bar just at the foot of each rise, and fasten these to the ¼-inch bars by soft wire. Next mark for the location of the risers the side forms which project above the 8-inch walls, place cross plank on each to form these risers, and proceed in the same manner as has been described for area steps. Forms should not be removed from under the steps for 28 days. Should the steps be more than 6 feet wide, a wall similar to the two side walls may be built in the center.

Sometimes it is easier to build a wall at the top and bottom of the steps instead of at the sides, and run the principal rods lengthwise of the flight, so that it is supported at top and bottom. In this case the supporting slab, whose thickness must be considered as the thinnest place in the steps, is designated in Fig. 21 by "A." The span, that is, the "distance apart of the beams," in the table is taken as the length of the horizontal projection of the stairs. The thickness of the slab and the diameter and spacing of the rods are given in the table following.

## DIMENSIONS OF STAIRS.

(See Fig. 21, Page 70.)

| Distance Between Floors Feet | Rise Inches | Tread Inches | A Inches | Size of Rods* Inches | Spacing* Inches | No. of Rods in Top Beam | Size of Rods in Top Beam Inches | No. of Steps |
|---|---|---|---|---|---|---|---|---|
| 10 | 7½ | 10 | 7¼ | ½<br>or ⅝ | 4<br>6½ | 1 | ⅝ | 16 |
| 9 | 7¼ | 10 | 6½ | ½<br>or ⅝ | 4¾<br>7½ | 1 | ⅝ | 15 |
| 8 | 7½ | 10 | 6 | ½<br>or ⅝ | 5½<br>8½ | 1 | ⅝ | 13 |
| 7 | 7 | 10 | 5½ | ½<br>or ⅝ | 5¾<br>9 | 1 | ⅝ | 12 |
| 6 | 7¼ | 10 | 4½ | ⅜<br>or ½ | 4<br>7 | 1 | ⅝ | 10 |
| 5 | 7½ | 10 | 3¾ | ⅜<br>or ½ | 5½<br>9¾ | 1 | ½ | 8 |
| 4 | 7 | 10 | 3¼ | ⅜<br>or ½ | 6<br>11 | 1 | ½ | 7 |
| 3 | 7¼ | 10 | 2½ | ⅜ | 9 | 1 | ½ | 5 |

* Select either size and spacing preferred.

Steps cast separate from supporting walls should be made in advance and allowed to season. The sectional drawing illustrates this form of step. To build a single step, make form shown in Fig. 22, 14 inches x 7 inches inside measurement and 1 inch for projection, and fill as shown to within 1 inch of top with concrete, one part "ATLAS" Portland Cement, three parts clean, coarse sand, and six parts broken stone; tamp hard. As soon as this has stiffened, but before it has set, remove the board "a" next to the face of the concrete, which should not be fastened to the form, but simply set in and well greased. This will leave a space on the side and top of step, also a small mould for the projection at top of step. Fill this with wet mortar, one part "ATLAS" Portland Cement and one and one-half parts clean, coarse sand, and let set. The side forms may then be removed and used again. The two side walls for these steps may be 8 inches wide, spread at the base by allowing the concrete to flow out under the forms. The top is stepped off to conform to the bottom and back of steps (Fig. 23.) Place the steps on the walls thus made, after covering all joints with cement mortar, so that they overlap one another 2 inches. Reinforce all steps and stairs cast separately by iron bars placed about 1 inch above the bottom of the slab.

## SIDEWALKS.

Before laying the concrete a foundation of porous material, such as cinders or screened gravel, must be placed and as much care should be taken in laying this as the walk itself. Foundations should generally be 6 inches to 12 inches deep, depending upon the climate and character of the soil. In sections where there is a porous soil and a mild climate, foundations are sometimes omitted entirely. If the soil is clayey, blind drains of coarse gravel or tile pipe should be laid at the lowest points in the excavation, to carry off any water that might accumulate in the porous material of the foundation. Walks are frequently ruined by water freezing in the foundations and heaving them out of position.

Excavate to the sub-grade previously determined upon, 3 inches wider on each side than the proposed walk, and fill with broken stone, gravel or cinders to within 4 inches of the proposed finished surface, wetting well and tamping in layers, so that when complete it will be even and firm, but porous. Place 2-inch x 4-inch scantlings (preferably dressed on inside and edge and perfectly straight) on top of the cinder foundation, the proper distance apart to form the inner and outer edges of the walk. The outside or curb strips must be 1 inch to 2 inches lower than the inner edge of the walk. This will give a slight incline to the finished surface and allow the water to run off. A good rule to follow is to allow ⅜-inch slope to every foot of width of walk. For wide walks lay off the space between the scantlings into equal sections not larger than 6 feet square, put 2-inch x 4-inch scantlings crosswise and in the center, as shown in Fig. 24—this will make every alternate space, shown in figure by *diagonal line,* the size desired. Fill these spaces with concrete to a depth of 3 inches (this depth should be 4 inches where there is more than ordinary traffic, or where the blocks are 6 feet square)—one part "ATLAS" Portland Cement, two parts clean, coarse sand, and four to five parts broken stone or screened gravel—then tamp until water begins to show on top. On the same day, as soon as the concrete has set, remove crosswise and center scantlings, place a sheet of tar paper on the edges to separate them from all other squares and fill in the spaces thus left with 3-inch concrete as before. Mark the scantling to show where the joints come.

The finishing coat should be 1 inch thick, of one part "ATLAS" Portland Cement and one and one-half parts clean, coarse sand, or crushed stone screenings. This coat should be spread on before the concrete has taken its set, and smoothed off with a screed or straight edge run over the 2 x 4 scantlings, the object being to thoroughly bond the finishing coat to the concrete base. If the bond between the finishing coat and the concrete is imperfect, the walk gives a hollow sound under the feet, and is liable to crack after having been down

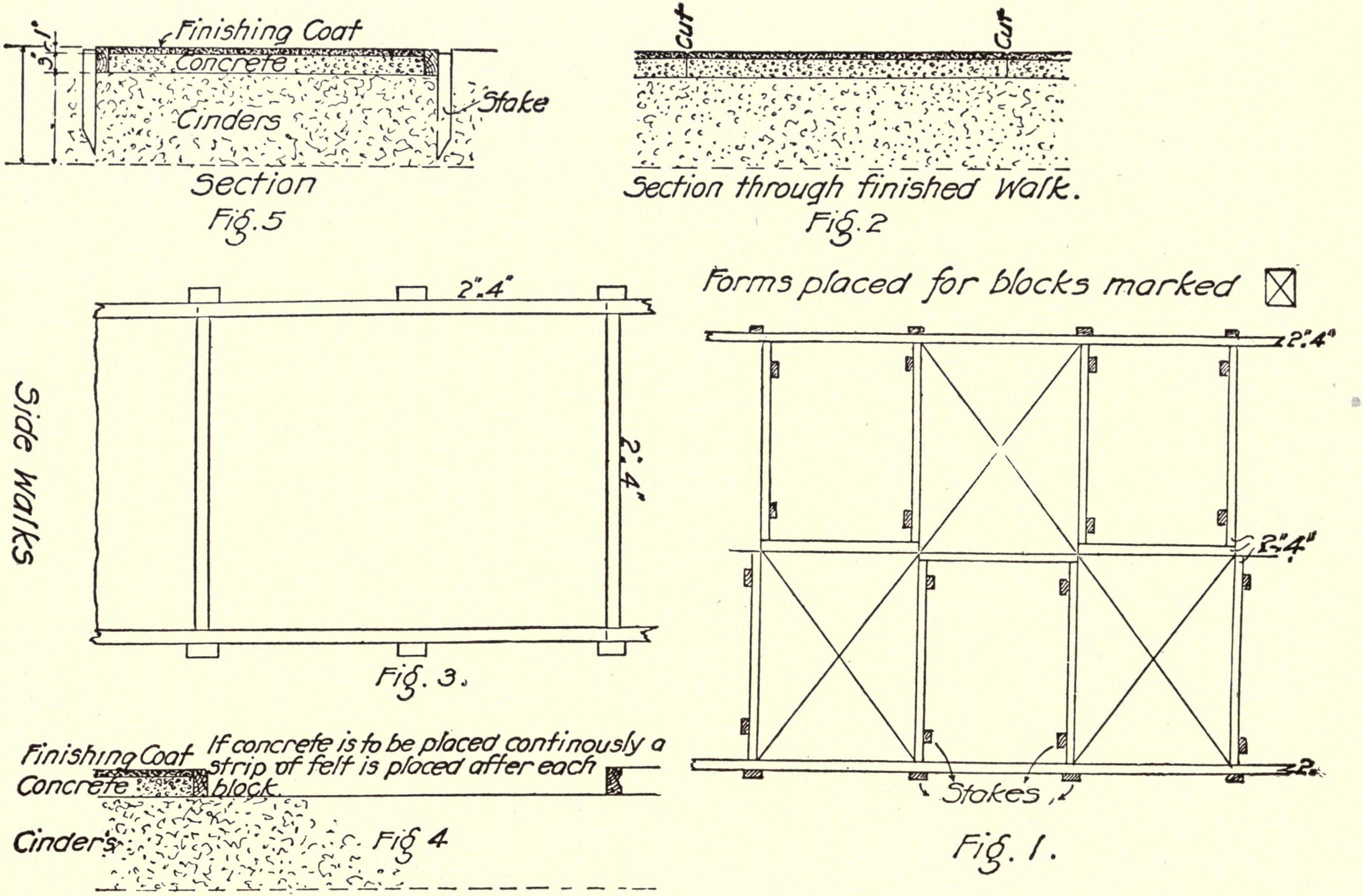


Fig. 24. Sidewalk Construction.

one or two years. Smooth with a wooden float, and groove exactly over the joints between the concrete (Fig. 24), so as to bevel the edges of all blocks. Do not trowel the finishing coat too much, nor until it has begun to stiffen, as this tends to separate the cement from the sand, producing hair cracks, and giving a poor wearing surface. Keep the finished walks protected from dust, dirt, currents of air and the hot sun during the process of setting, and further protect from the sun and traffic for three or four days, and keep moist by sprinkling. The covering may be whatever is most convenient—sand, straw, sawdust, grass, or boards.

MATERIALS FOR 100 SQ. FT. OF CONCRETE.

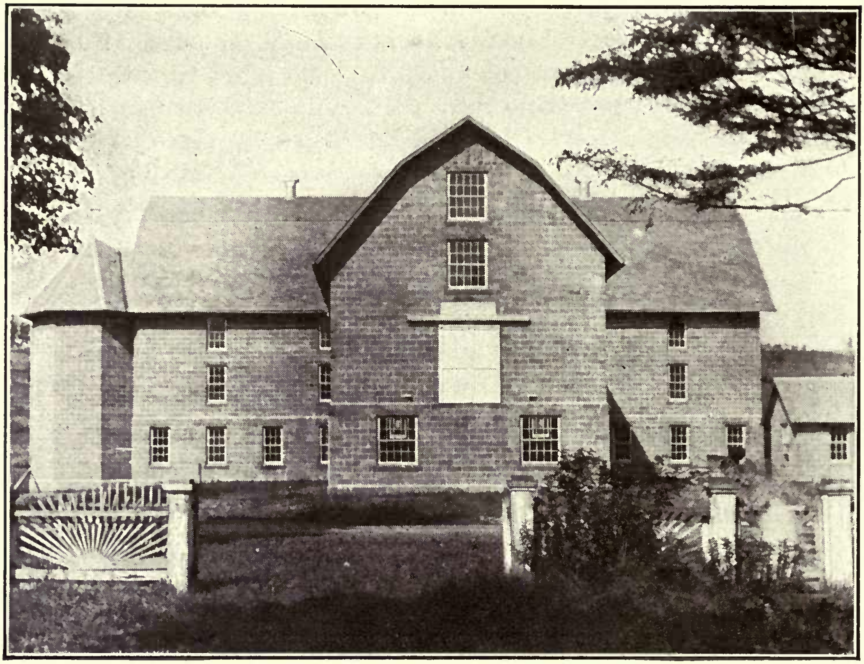
| Bags of Cement to 100 Sq. Ft. of Concrete Surface | | | | Bags of Cement to 100 Sq. Ft. of Mortar Surface | | | |
|---|---|---|---|---|---|---|---|
| Thickness Inches | Proportions | | | Thickness Inches | Proportions | | |
| | 1:1½:3 | 1:2:4 | 1:3:6 | | 1:1 | 1:1½ | 1:2 |
| 3 | 8½ | 6½ | 4¾ | ½ | 3½ | 2¾ | 2¼ |
| 4 | 11 | 8¾ | 6 | ¾ | 5 | 4 | 3½ |
| 5 | 14½ | 11 | 7½ | 1 | 7 | 5¼ | 4½ |
| 6 | 16¾ | 13¼ | 9½ | 1¼ | 8¼ | 6½ | 5¾ |
| 8 | 22¾ | 18 | 12 | 1½ | 10 | 8 | 6¾ |
| 10 | 28¾ | 21½ | 15½ | 1¾ | 12 | 9¼ | 7¾ |
| 12 | 34¾ | 26½ | 18½ | 2 | 14 | 11 | 9 |

SURFACES LAID WITH ONE BARREL OF CEMENT.

| No. of Sq. Ft. of Concrete (Base) Laid with 4 Bags (1 Bbl.) of Cement | | | | No. of Sq. Ft. of Mortar Surface Laid with 4 Bags (1 Bbl.) of Cement | | | |
|---|---|---|---|---|---|---|---|
| Thickness Inches | Proportions | | | Thickness Inches | Proportions | | |
| | 1:1½:3 | 1:2:4 | 1:3:6 | | 1:1 | 1:1½ | 1.2 |
| 3 | 47 | 60 | 83 | ½ | 114 | 146 | 178 |
| 4 | 36 | 46 | 66 | ¾ | 80 | 100 | 114 |
| 5 | 27 | 36 | 52 | 1 | 57 | 73 | 89 |
| 6 | 24 | 30 | 41 | 1¼ | 48 | 60 | 70 |
| 8 | 17 | 22 | 33 | 1½ | 40 | 50 | 59 |
| 10 | 14 | 19 | 26 | 1¾ | 33 | 43 | 52 |
| 12 | 12 | 15 | 21 | 2 | 29 | 36 | 44 |

NOTE.—Four bags of cement equal 1 barrel.
For proportions 1:1½:3 use for every 33 bags of cement 1 large double load of sand and 2 of gravel.
For proportions 1:2:4 use for every 23 bags of cement 1 large double load of sand and 2 of gravel.
For proportions 1:3:6 use for every 15 bags of cement 1 large double load of sand and 2 of gravel.
One large double load contains 40 cubic feet or 1½ cubic yards.

Most walks are made the width of a single block, and should be constructed as shown in Fig. 24. In a walk the width of a single block, make every alternate block and then go back and fill in the blocks between.



CONCRETE BLOCK BARN AT HARPERSVILLE, N. Y.

COW BARN AT U. S. SOLDIERS' HOME, WASHINGTON, D. C.

## CURB AND GUTTER.

The foundation for curbs and gutters, like sidewalks, should be governed by the soil and climate.

Concrete curbing should be built in advance of the walk in sectional pieces 6 feet to 8 feet long, and separated from each other and from the walk by tar paper or a cut joint, in the same manner as the walk is divided into blocks.

Curbs should be 4 inches to 7 inches wide at the top and 5 inches to 8 inches at the bottom, with a face 6 inches to 7 inches above the gutter. The curb should stand on a concrete base 5 inches to 8 inches thick, which in turn should have a sub-base of porous material at least 12 inches thick. The gutter should be 16 inches to 20 inches broad, and 6 inches to 9 inches thick, and should also have a porous foundation at least 12 inches thick.

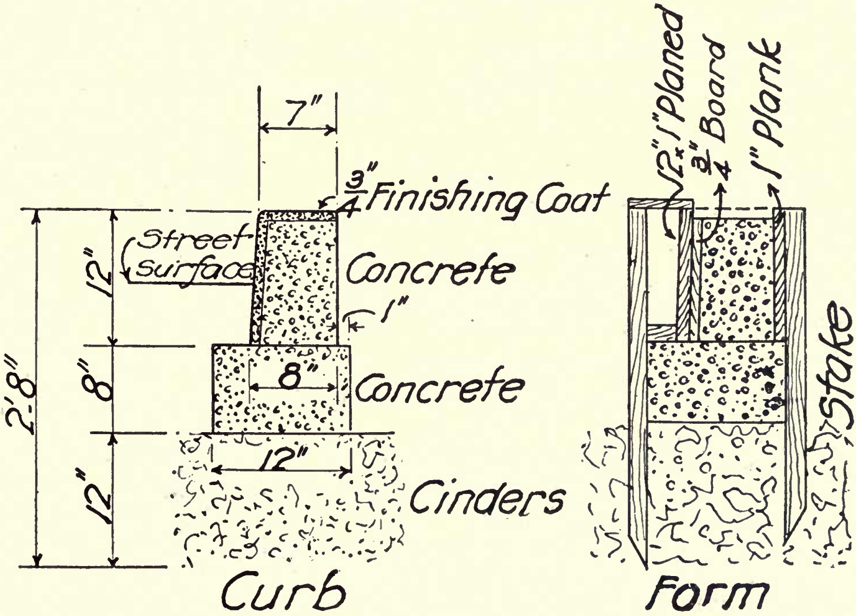


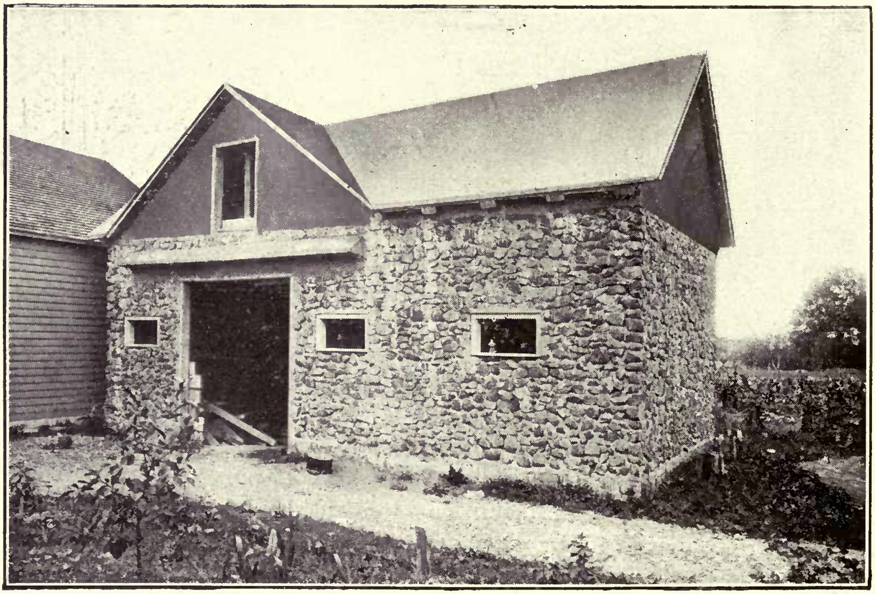
Fig. 25. Concrete Curb and Gutters.

Keeping the above dimensions in mind, excavate a trench the combined width of the gutter and curb and put in the sub-base of porous material. On top of this place forms and fill with a layer of concrete, one part "ATLAS" Portland Cement, three parts clean, coarse sand and six parts broken stone, thick enough to fill the forms to about 3 inches below the street level. As soon as the concrete is sufficiently set to withstand pressure, place forms for the curb, and, after carefully cleaning the concrete between the forms and thoroughly wetting, fill with concrete, one part "ATLAS" Portland Cement, two and one-half parts clean, coarse sand and five parts broken stone. When the curb has sufficiently set to withstand its own weight without bulging, remove the ¾-inch board shown in Fig. 25, and with the aid of a trowel fill in the space between the concrete and the form with cement mortar, one part "ATLAS" Portland Cement and one part clean, coarse sand. The finishing coat at the top of the curb should be put on at the same time. Trowel thoroughly and smooth with a wooden float, removing face form the following day. Sprinkle often and protect from sun.

In making curbs alone, specifications given below and illustrated in sectional drawing should be followed.

Excavate 32 inches below the level of the curb and fill with cinders, broken stone, gravel or broken brick to depth of 12 inches. Build a foundation 8 inches deep by 12 inches broad, one part "ATLAS" Portland Cement, three parts clean, coarse sand and six parts broken stone, and from the top of this and nearly flush with the rear, build a concrete wall 11¼ inches high, 7¼ inches broad at the base and 6¼ inches at the top, the 1-inch slope to be on the face. Forms should be built as in Fig. 25.

Remove the forms as soon as the concrete will withstand its own weight without bulging, and proceed as per directions given on this page (Fig. 25). Keep moist for several days and protect from the sun. The above measurements may be varied to suit local conditions.



RUBBLE CONCRETE BARN AT WESTWOOD, N. J.

## BARNS.

Each year dairymen are realizing more and more the necessity of improving and changing their methods in order to produce a milk which contains less bacteria than that of their neighbor or competitor. A number of factors enter into the accomplishment of this result.

It is stated by experienced dairymen that the material of which the barn is made is of the most vital importance, for this may be the breeding place of germs. With the use of concrete this question is solved, because a building so constructed offers no chance for the germs to nest. If one goes a step further and constructs the floors, troughs, stalls and other fixtures all of concrete, perfect hygienic conditions are realized, and the road is clear to securing a germ-proof milk.

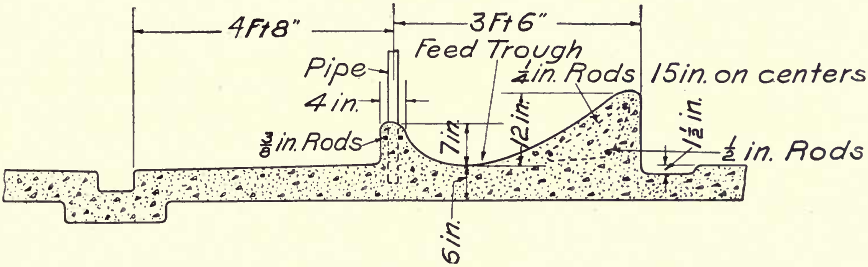
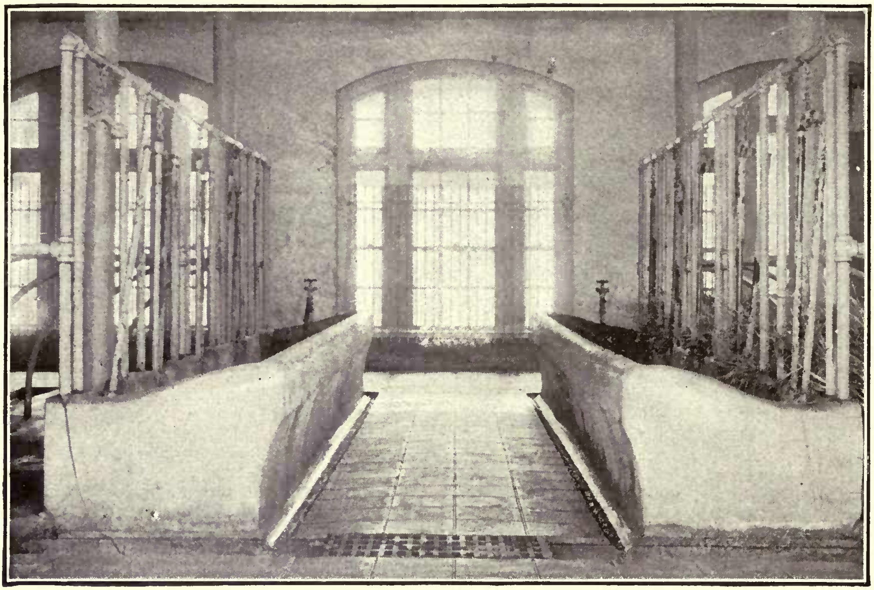


Fig. 26. Section of Cow Barn Floor.

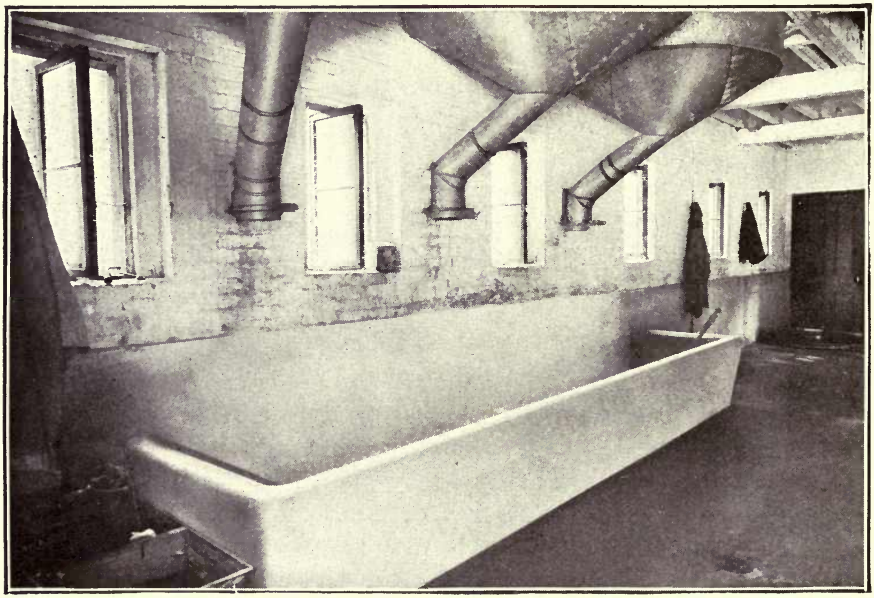
## FEED TROUGHS.

Many designs of feeding troughs have been used, but most of them are objectionable from a hygienic standpoint. A concrete feeding trough, shown in section in Fig. 26, is similar to the trough developed after considerable study by the well-known dairy expert, Mr. S. L. Stewart, and used by him at Somers Center, N. Y., and elsewhere.

This design has a high front end, slanting instead of straight, in order to avoid scratching and bumping it with the carts and to keep them out of the drain in front. Use the same design of forms for the slanting front as that shown in the figure, except place the bottom of the form 8 inches in from the vertical. Make the inside of the trough at the center either on a level with the top of the finished floor or about 2 inches above it, and give it a slope of 3 inches in 50 feet in order to readily drain the water at the lower end.



INTERIOR VIEW OF BARN AT GLEN COVE, L. I.



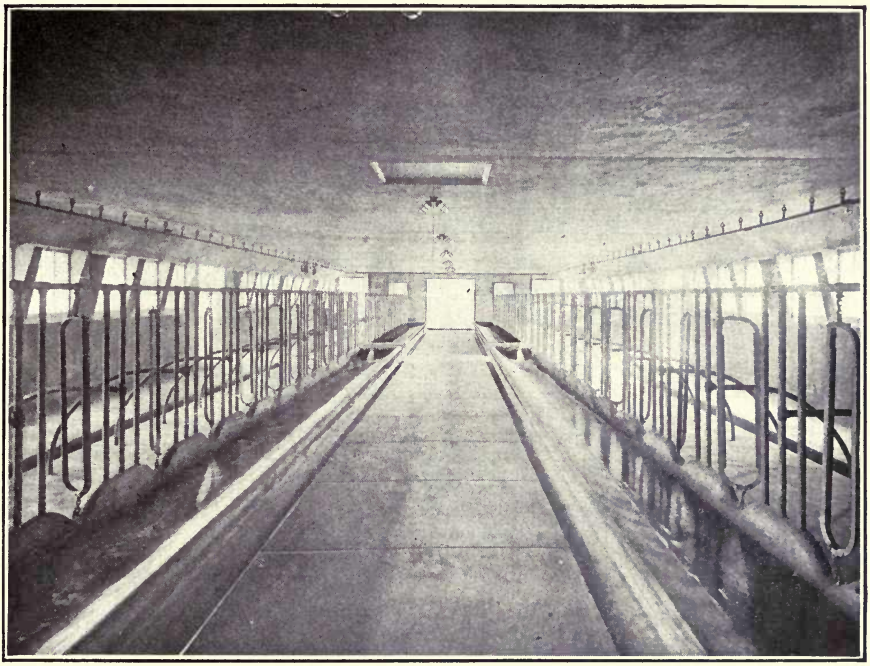
FEED-MIXING TROUGH AT U. S. SOLDIERS' HOME, WASHINGTON, D. C.

Some of the features which this trough incorporates are:

(1) The front of the trough is low so that it does not catch the breath of the cow, and still is high enough to prevent the material from being spilled out unnecessarily.

(2) Only a minimum amount of water need be run into the trough, and still it will be deep enough to allow the cattle to drink freely.

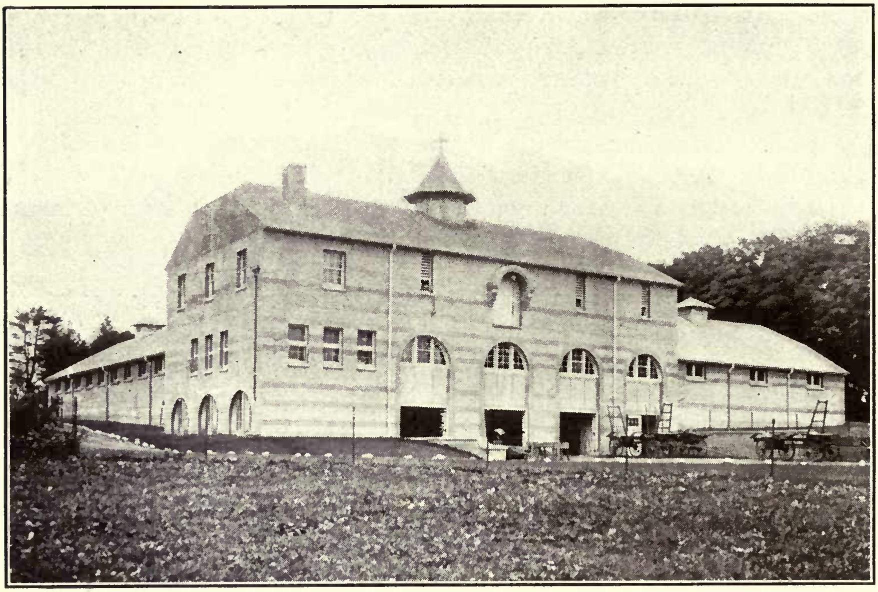
(3) The trough is of such a width that the least amount of material is apt to be thrown out of the trough by the cattle.



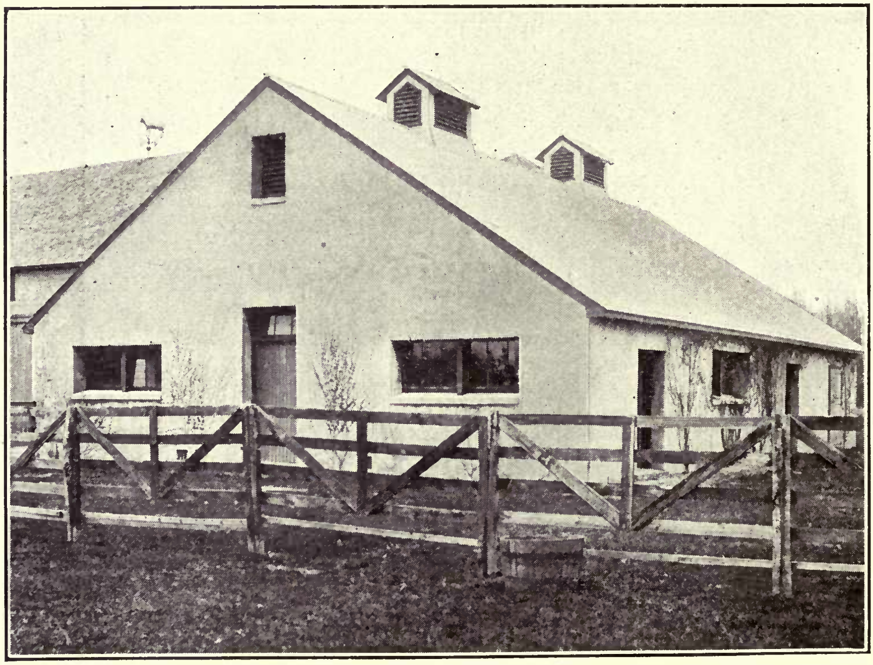
INTERIOR VIEW OF BARN AT BROOKSIDE FARM, NEWBURGH, N. Y.

The following costs of concrete troughs are figured from actual data taken by a contractor on a job in New York. These values checked almost exactly with those given by another contractor in a different section of the country. The comparison was made possible, of course, by assuming the unit cost of material and labor the same for both jobs, thus placing them on the same basis.

A trough such as is shown in Fig. 26 contains about 3½ cubic feet of concrete per running foot of trough. It should be made with one part "ATLAS" Portland Cement to two and one-half parts clean, coarse sand, to five parts of stone, and finished with a one-inch coat of one part "ATLAS" Portland Cement to one and one-half parts of sand. The amount of material needed



CONCRETE HORSE BARN AT GEDNEY FARMS, WHITE PLAINS, N. Y.



COW BARN AT BABYLON, L. I.

per 10 linear or running feet of trough, including the top finish, is ten bags of cement, one single load of sand (reckoning 20 cubic feet per load), and three quarters of a single load of gravel. Thus the cost per running foot of trough for material only is about 70 cents, considering cement at $2.00 per barrel, sand at 75 cents per cubic yard, and gravel at $1.25 per cubic yard. The cost of labor is about 44 cents per running foot, considering labor at $2.00 per day. This makes the total cost for labor and material per linear foot of trough about $1.14. When the price of labor or material is higher, the cost will naturaly be greater, and vice versa. The cost of the stanchions and pipe work is about $8.00 per stall, but this price varies with the local market and the kind of stanchion bought.

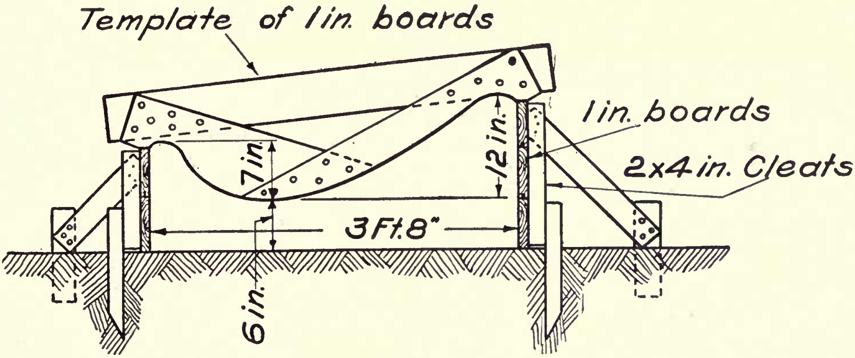
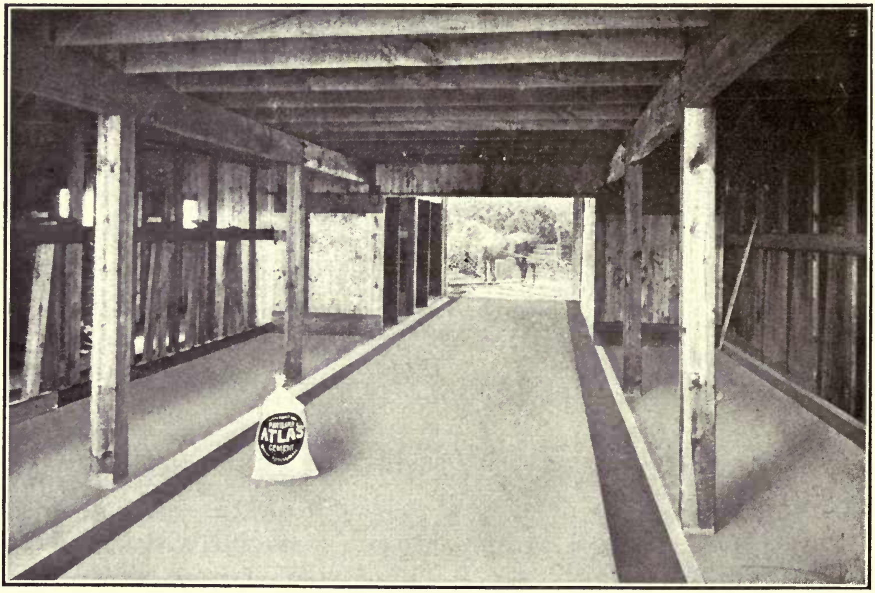


Fig. 27. Forms for Concrete Trough.

The forms for a trough are very simple. Two forms and a screed or templet are all that is required (see Fig. 27). Oil the foms thoroughly, then set up the front and back forms as shown and brace them well. Plaster the forms with a 1-inch coat of one part "ATLAS" Portland Cement to one and one-half parts of sand, and before this has begun to stiffen place the concrete. It is absolutely necessary that the mortar finish does not set before placing the concrete, for otherwise there will be no bond between the body of the concrete and the mortar face, which will be sure to crack off, especially if kicked or jarred. The screed or templet is cut from boards nailed together, as shown in the figure, and is used to screed off the concrete and make it the desired shape. The reinforcement and the pipes for the stanchions are placed as shown.

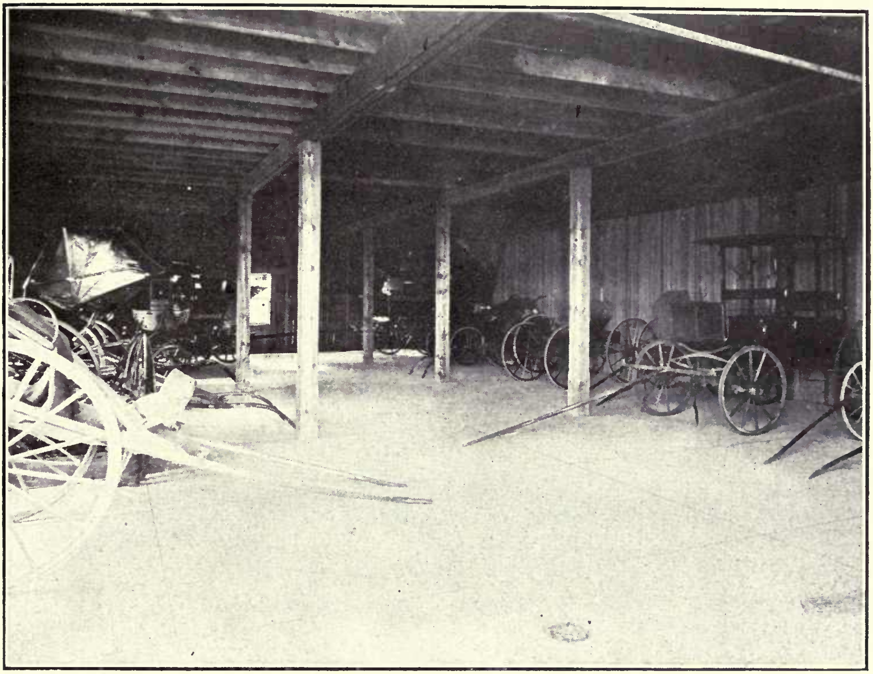
# FLOORS.

**CELLAR FLOORS.** Cellar floors may be laid without foundations, except in places where there is danger of frost getting into the ground below the floor. The dirt should be evened off and tamped hard, and the concrete, one part "ATLAS" Portland Cement, two and one-half parts clean, coarse sand and five parts broken stone, spread over the surface in one continuous slab 3 inches to 4 inches thick and lightly tamped to bring the water to the surface, and screeded with a straight edge resting upon scantlings placed about 12 feet apart. The scantlings are then withdrawn and their places filled with concrete. No finishing coat is needed unless the floor is to have excessive wear. The surface of the concrete, however, should be troweled as soon as it has begun to stiffen. Joints about 12 feet apart should be made if the surface is more than 500 feet long, or if it is to be subjected to extreme temperatures. (See "Side Walks," p. 75.)

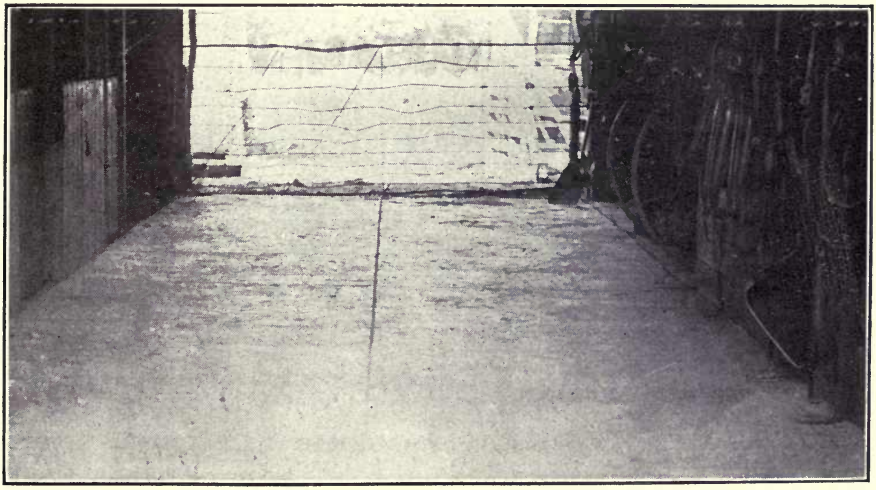


CONCRETE FLOOR IN COW STABLE AT ST. CHARLES, ILL.

**BARN FLOORS.** Barn floors are laid in the same manner as sidewalks. The thickness of the porous sub-base varies with conditions, but generally 6 to 12 inches is sufficient. The floor itself should be about 4 inches thick, of concrete in proportions one part "ATLAS" Portland Cement, two and one-half parts



INTERIOR VIEW OF CARRIAGE HOUSE AT WASCO, ILL.



FLOOR OF HORSE BARN AT HOMER, ILL.

(This floor is a good illustration of the durability of concrete floors. It is 40 x 60 feet, and although it has been in service over five years, no cracks of any kind are visible. This floor was made of one part "ATLAS" Portland Cement, two parts sand and four parts stone, and surfaced with a mortar of "ATLAS" Portland Cement and sand.)

clean, coarse sand, and five parts screened gravel or broken stone, and be finished before the concrete has set with a 1-inch mortar surface of one part "ATLAS" Portland Cement to one and one-half parts clean, coarse sand.

The surface of the floor should have sufficient slope to carry liquids to the drains, and in order to prevent the animals from slipping the floor may be scored or grooved into blocks before the concrete has hardened. These sections may be about 6 inches square.

Some builders make a practice of waterproofing the stable floor. This is not necessary in most cases, but where there is any great danger of the ground water causing the barn to become damp, the floor should be laid as follows:

Place a 2-inch layer of concrete, mop on a 3-ply layer of tar and felt waterproofing, and then upon this the rest of the concrete.

CONCRETE FEEDING FLOOR AND WATERING TROUGH AT EAST NORWICH, L. I.

**FEEDING FLOORS.** The immense advantage of concrete feeding floors over the old method of placing fodder on the ground is apparent to all who have given the subject any thought.

Feeding floors should be built the same as sidewalks (see Walks). The finishing coat is optional, although it has the advantage of being much easier to keep clean. Many farmers prefer an unfinished surface on account of its giving cattle a firmer footing in slippery weather.

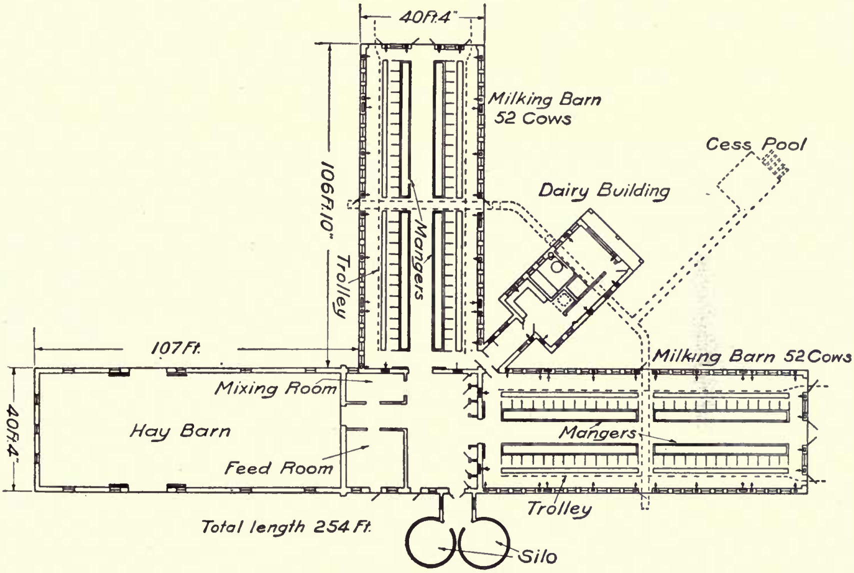


Fig. 28. Plan of the Farm Building at the New York Catholic Protectory, Somers Center, N. Y.

## RUNWAYS FROM STABLES.

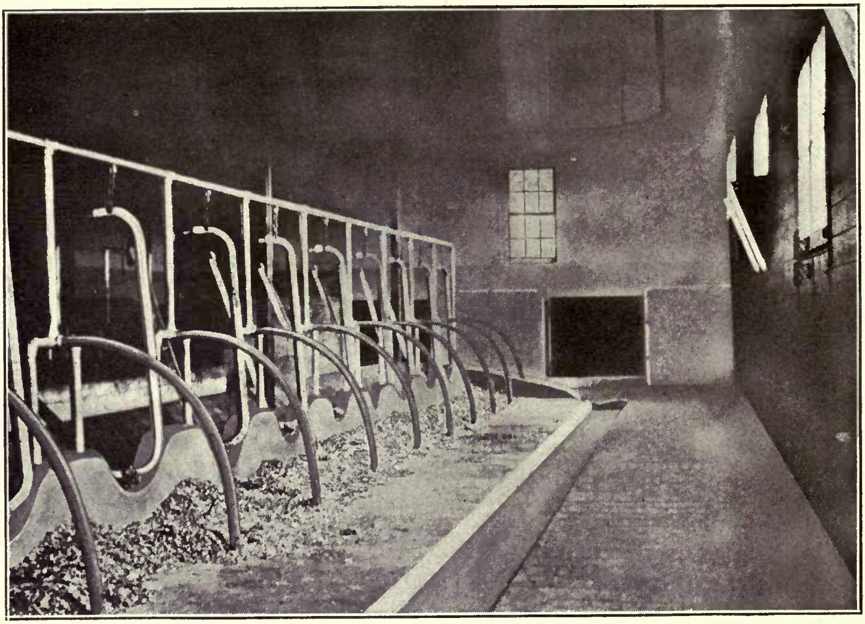
To construct a runway from a stable make up two or three batches of concrete in proportions one part "ATLAS" Portland Cement to two parts sand to four parts gravel or broken stone, spread it in place, and roughly trowel the surface. If a fine, smooth surface is desired, it may be built like a sidewalk (see p. 75) with a 4-inch base of concrete and one inch wearing surface of mortar of one part "ATLAS" Portland Cement to two parts sand.

If the runway is built on a slope which consists of filled ground, care must be taken to see that the fill is well tamped and not liable to settle. If there is any danger of the filling settling from under the runway, it must be designed as a flat slab. In this case the thickness of slab and amount of reinforcement necessary for the width and span of the runway can be taken directly from the table on page 30, using the heaviest loading. For example, if the length to be supported is 8 feet, place ½-inch rods in bottom of slab, 7½ inches apart.

## DRAINS.

Since well-made concrete, after it has hardened, is not injured by manure, concrete is being used to replace wooden or masonry drains which are continually rotting or leaking.

Drains may be made either in place, or tile, described below, may be used. In any case lay the drain with enough slope to flush properly, and if it is to receive material liable to clog, make it open or with a removable cover.



INTERIOR VIEW OF BARN AT EAST NORWICH, L. I.

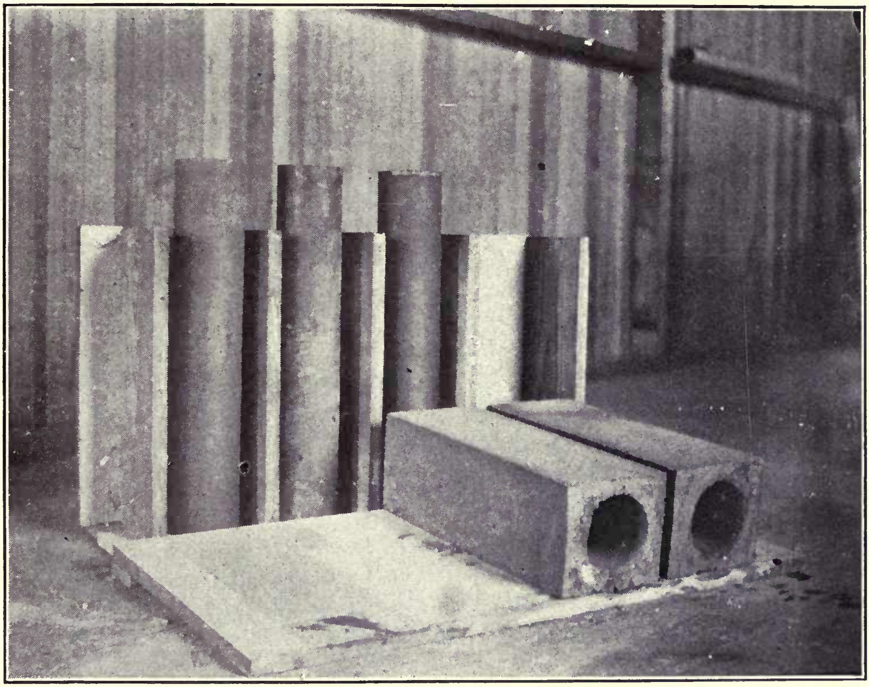
To make a drain in place, dig a trench on the proper slope. Set sections of form the shape of the inside of the drain so that the concrete will be 3 or 4 inches thick. Pour the concrete, mixed in proportions one part "ATLAS" Portland Cement to three parts coarse gravelly sand, into the trench under the form. Remove the form when the concrete has hardened for about one or two hours, and gently trowel the surface to make it smooth and bring the cement to the surface.

If the drain is to have lids, the concrete of the sides is left down so as to leave room for the lid and have the top sunk about ¼ inch below the level of the floor.

## TILE DRAINS

Concrete land tile drains, when made of one part "ATLAS" Portland Cement to three parts clean, coarse sand which has been sifted through a ½-inch mesh screen and of a soft, mushy consistency like mortar used for laying brick, can be depended upon to resist the chemical action of even the most alkaline ground water. The tile may be made 12 or 18 inches long, and the inside diameter anywhere from 4 to 12 inches.

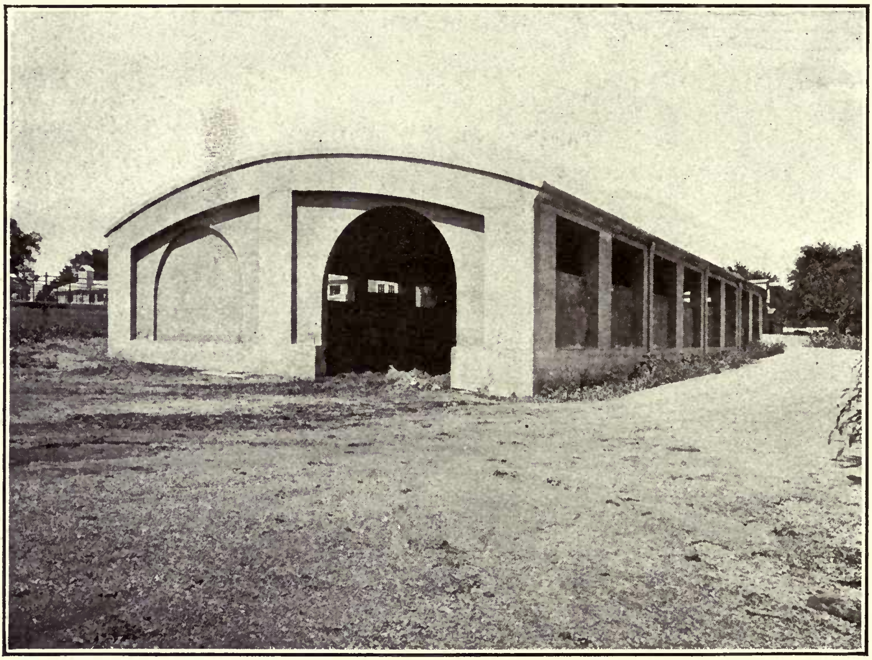
The forms for making concrete land tile are simple and inexpensive. One or two sets of forms with four or six tile each may be made so that they can be filled every morning, and in this way enough tiles can be soon on hand to drain a large acreage of land. The concrete tile should be made with a circular bore, and may be either circular or square on the outside. A photograph of a tier of four forms, with two of the tile on a board, is shown above.



MOLDING TILE DRAINS

Use ordinary stove pipe of the required diameter for the inside mold; this should project far enough above the top of the wood form so that a good grip can be had on it in order to remove it from the concrete. If desired, holes can be punched through the stove pipe near the top and a rod placed through these holes in order to more easily draw the pipes. To keep the pipes in place when pouring the concrete for each tile, drive four nails in the floor or platform on which the tile are to be cast, leaving them projecting so as to locate the end of the pipe and keep it from getting out of position but yet not hindering its removal. The stove pipes must be thoroughly cleaned and greased each time they are used, and must not be dented or have any irregularities on them to make them catch.

As shown in the photograph, the wood partitions are permanently attached to one of the long sides, but the other side is only nailed on temporarily and the heads of the nails left so that they can be readily withdrawn with a claw hammer and without jarring the forms unnecessarily. The wood partitions are spaced far enough apart so that there is one inch of concrete between stove pipe and the wood, hence make the distance between the sides equal to the diameter of the stove pipe, plus 2 inches. In order to readily remove the wood forms, clean and oil them thoroughly before each time using. Mix the concrete to proportions and consistency given above and place in the mold, ramming with a stick. The time to remove the stove pipe core varies with the wetness of the mix and the temperature, but it should be pulled as soon as the top of the concrete begins to harden, which generally is from one-half to one hour; if left too long it is very hard to get them out. The outside forms



MANURE PIT AT GEDNEY FARMS, WHITE PLAINS, N. Y.

can usually be removed after two or three hours, or may be left until the next morning. To remove the wood forms, pull the protruding nails with a claw hammer, and carefully remove this side. Place this sideboard back again in position, and carefully turn the whole tier on the side. Next draw out the other side with the partitions attached. If any of the forms stick, they can generally be started by tapping them lightly with a hammer; this applies as well to the stove pipe cores. Scrape the form carefully, re-oil, attach the long side and they are ready for a second filling.

To save material the outside of the tile may be made round or octagonal. For the latter tack triangular strips in all corners of the mold.

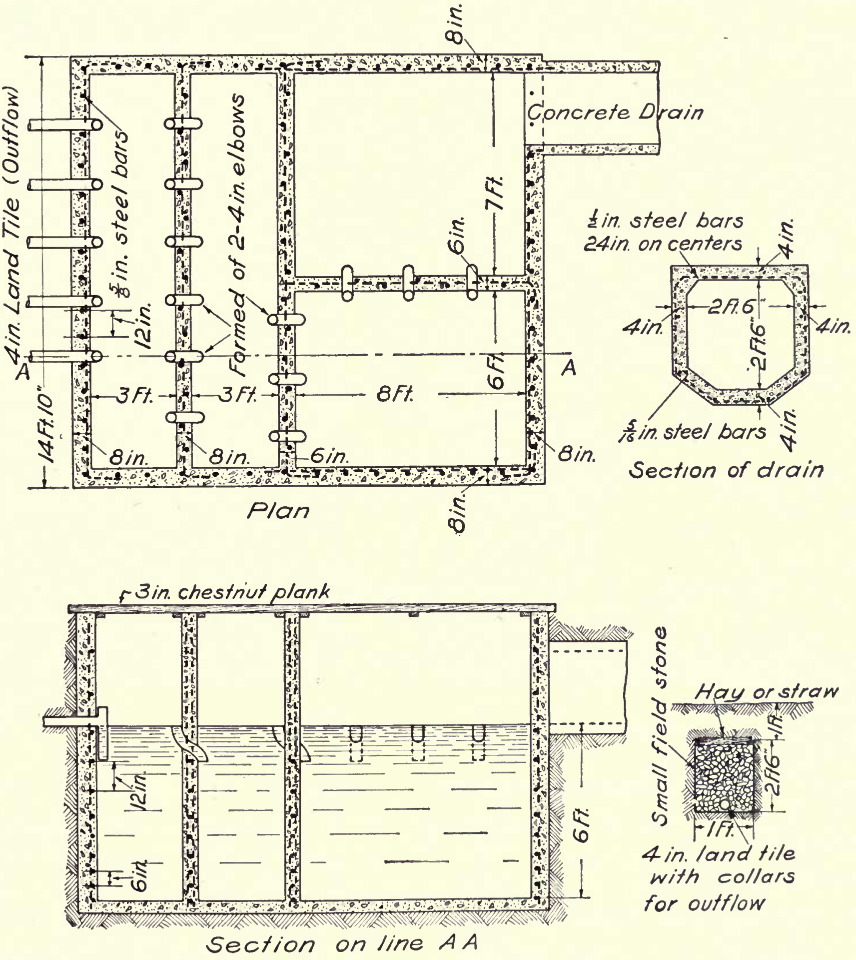
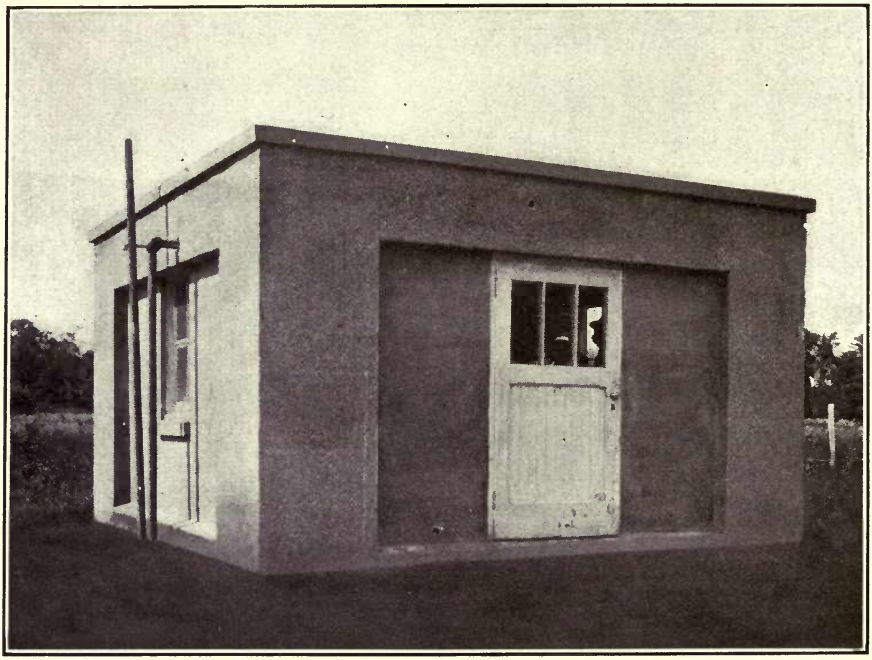


Fig. 29. Concrete Cess Pool and Drains at New York Catholic Protectory, Somers Center, N. Y.

A cess pool for either a house or a barn may be made in the manner described for cisterns on page 119. A single chamber may be made with over-flow drains laid with loose joints and leading under the surface of the ground so as to fertilize the lawn or garden.

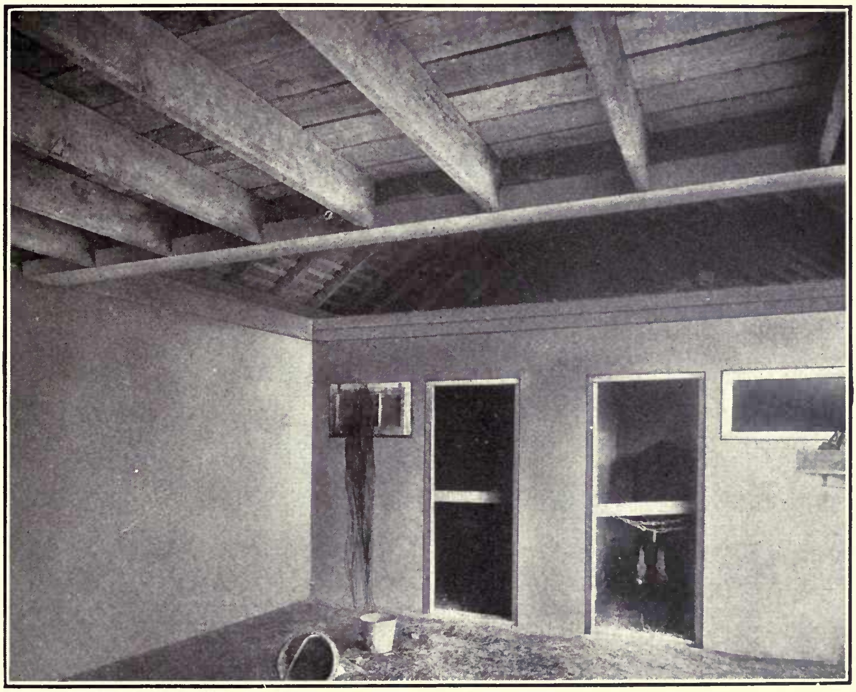
The cess pool shown in Fig. 29 is built in several sections so that the manure may settle and overflow into the series of tanks. The sewage from the drains empties into the first tank where the heavy material settles, leaving the water on top. When the water level rises up to the outlet of the pipes leading from the first to the second chamber, the cleaner water is drained into the second chamber, leaving the heavy material in the first. This same process takes place in each of the other three chambers, the water finally draining into the concrete tile drains, and being distributed by them over a considerable land area. The cess pool is covered with a chestnut plank cover so as to facilitate cleaning if this ever became necessary. A 5-inch concrete slab reinforced in the bottom with ½-inch rods placed 6 inches apart might be used instead, leaving openings in it for trap doors.



PUMP HOUSE AT GEDNEY FARMS, WHITE PLAINS, N. Y.

## BOX STALLS.

Concrete box stalls offer a great advantage over stalls of other material, for they are warmer in winter and cooler in summer, and thus help to prevent horses becoming restive and ill-tempered. They may be built of concrete one part "ATLAS" Portland Cement to two and one-half parts clean, coarse sand to five parts broken stone or screened gravel, and should have walls 4 inches thick and reinforced as described in the wall specifications. The surface can be finished off the same as outer walls.



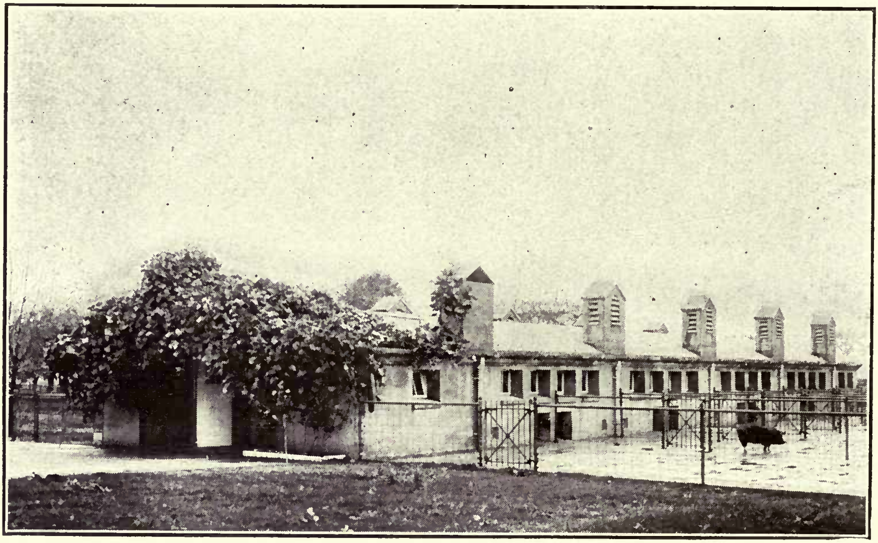
BOX STALLS AT WESTWOOD, N. J.

## VENTILATION.

Concrete barns, like houses, are built either with a single solid wall or with a hollow wall. Each type offers advantages and disadvantages. For instance, it is easier and cheaper to build a single wall on account of having no core to make or handle; but, on the other hand, these openings between the walls may be utilized for the air ducts or vents through which the ventilation in the barn is taken care of.

In designing a barn it is of the utmost importance to secure perfect ventilation, and this means (1) a constant change of air; (2) the introduction and distribution of fresh air without drafts; (3) the introduction of outside air, but not at the expense of the proper temperature, and (4) the removal of foul air without condensation.

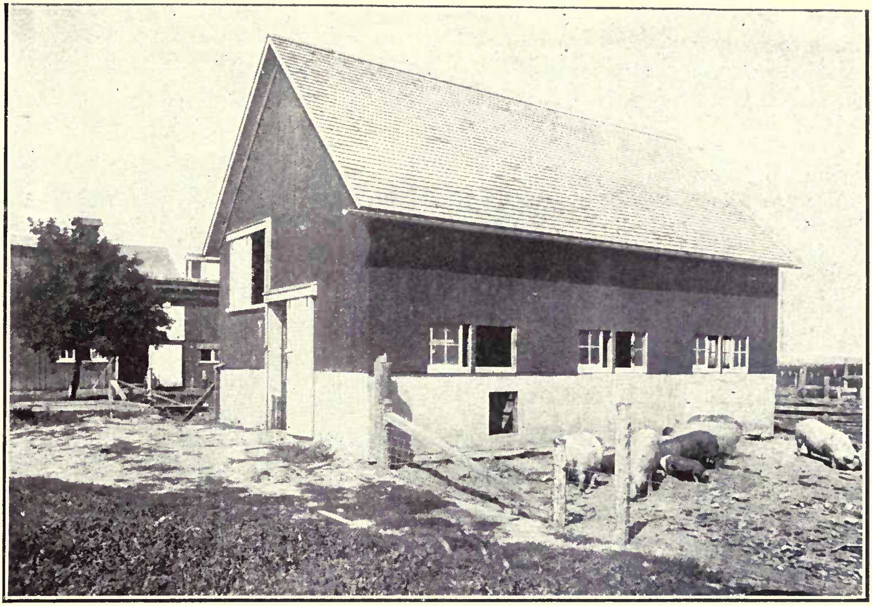
The intake registers for the removal of the foul air should be placed in the walls near the floor. The foul air passes from the registers through the hollow spaces in the walls and from there into the chimney. The chimney is best located near the center of the barn, and should be high enough to extend above the roofs of any nearby building. The fresh air should be admitted by registers located near the ceiling. The air near the ceiling is usually the warmest; hence, the fresh air is heated somewhat before striking the cattle.



PIGGERY AT GEDNEY FARMS, WHITE PLAINS, N. Y.

## HOG PENS.

To construct a concrete hog pen excavate a trench, the size and shape desired for finished pen, 10 inches wide, and to a depth below frost, and fill with concrete mixture, one part "ATLAS" Portland Cement, four parts clean, coarse sand, and eight parts broken stone or screened gravel. On top of this foundation build a wall (See "Walls"), at equal distance from edge, 4 inches thick and 4 feet high, reinforced with wire fabric or else with ¼-inch rods placed about 18 inches apart both ways. The reinforcement must be carefully bent around the corners. Proportions of wall, one part "ATLAS" Portland Cement, two and one-half parts clean, coarse sand, and five parts broken stone.

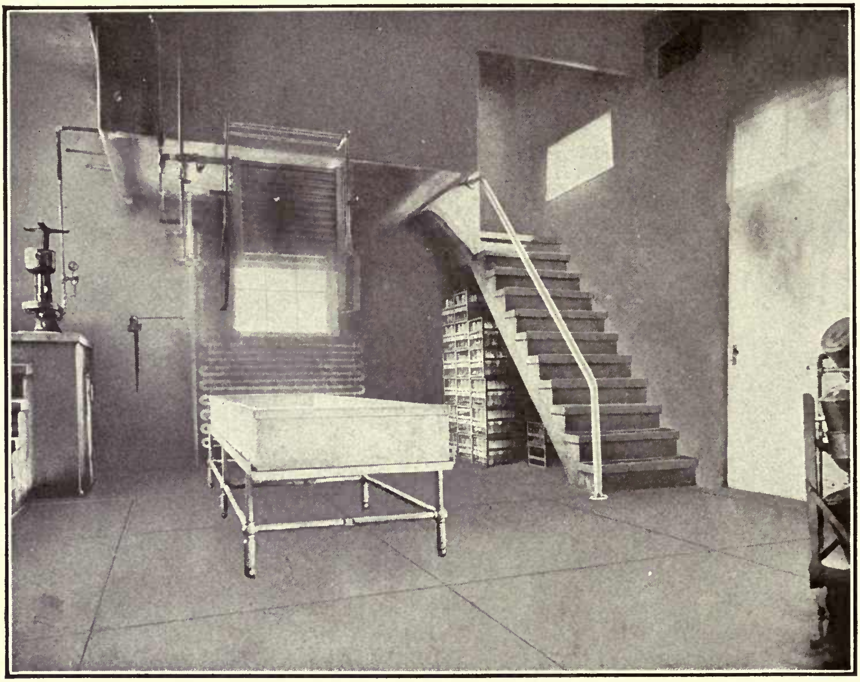


HOG HOUSE AT BRICELYN, MINN.

INTERIOR OF PIGGERY AT GEDNEY FARMS, WHITE PLAINS, N. Y.

Space for a gate should be left, and a trough built similar to the one shown in picture or described in "Hog Troughs."

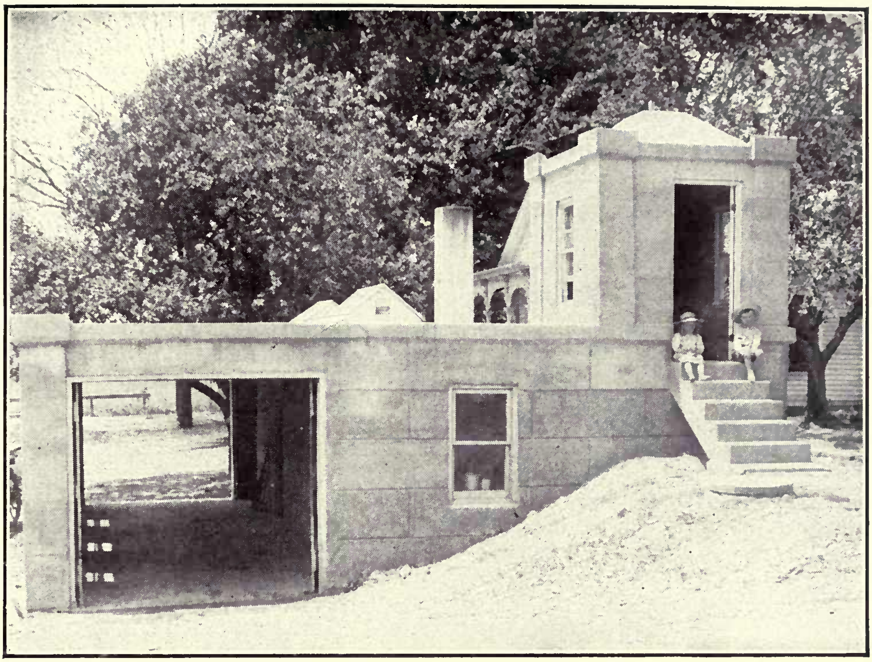
A hog house can be added by building another wall in the corner and roofing the space with 2½ inches concrete, one part "ATLAS" Portland Cement, two parts clean, coarse sand, and four parts broken stone. This slab must be reinforced with wire mesh or steel rods of size and spacing given in Table for Designing Reinforced Concrete Beams and Slabs. Flooring may be put in same as in "Cellar Floors" (see page 86).



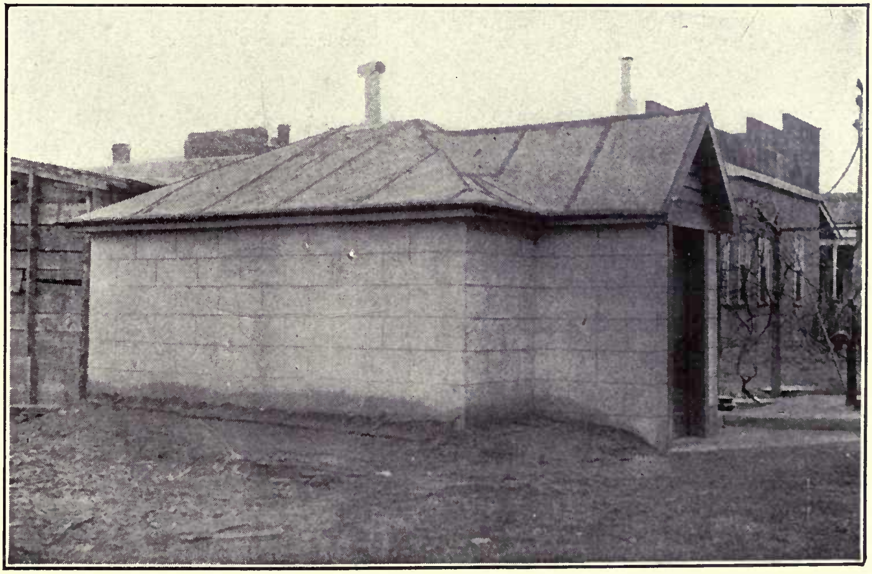
BOTTLING ROOM IN DAIRY HOUSE AT BROOKSIDE FARMS, NEWBURGH, N. Y.

## DAIRIES.

The dairy may be connected by a passage way with the barns or may be in a building by itself. In either case, concrete had best be used throughout for the various rooms: the receiving room, the bottling room, the closets, the refrigerator, the cold storage room, the shower baths and the clothes closet; also for all the various accessories, such as the troughs for the milk cans and bottles.



28 BY 30-FOOT REINFORCED CONCRETE MILK HOUSE AT BEACH FARM DAIRY, AT COLDWATER, MICH.



WELL AND CELLAR AT MARSHFIELD, MO.

## ICE BOXES.

Since concrete is a poor conductor of heat and cold, it is a good material for an ice box. It may also readily be made with one or two air spaces in the walls so as to make an economical storage box. Ice boxes are sometimes built as a part of a new building, and sometimes are built onto an old building. An ice box is not in the least affected by the hard usage it receives by having heavy milk cans thrown against it.

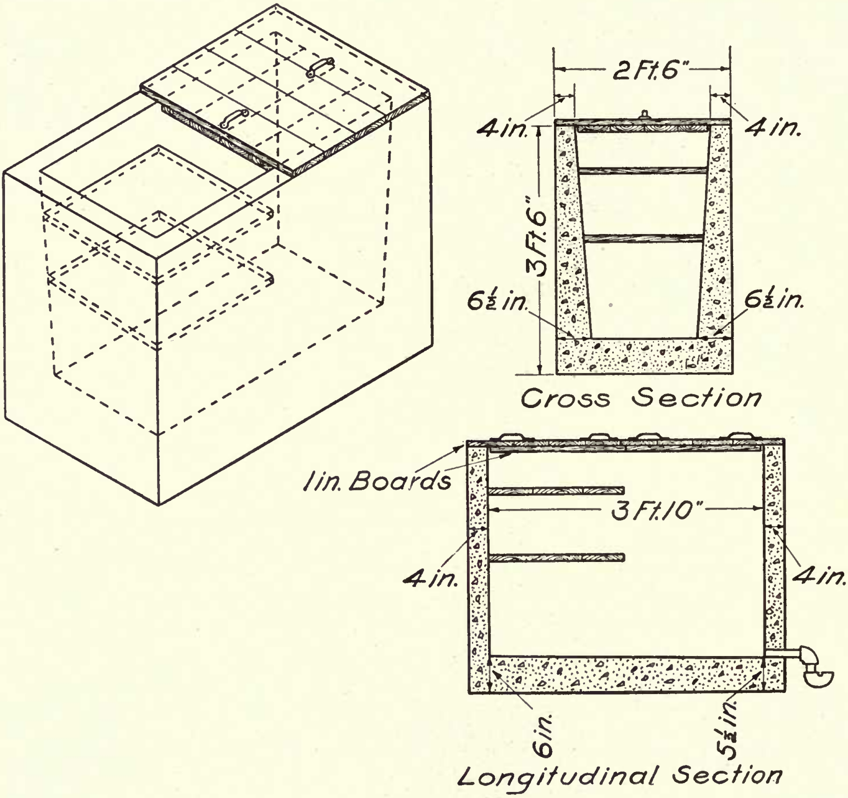
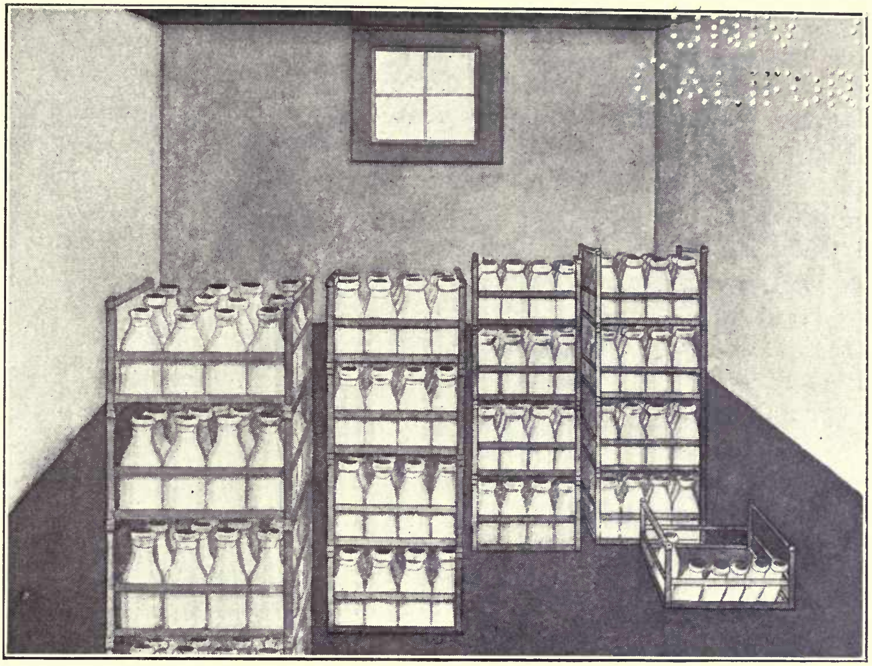
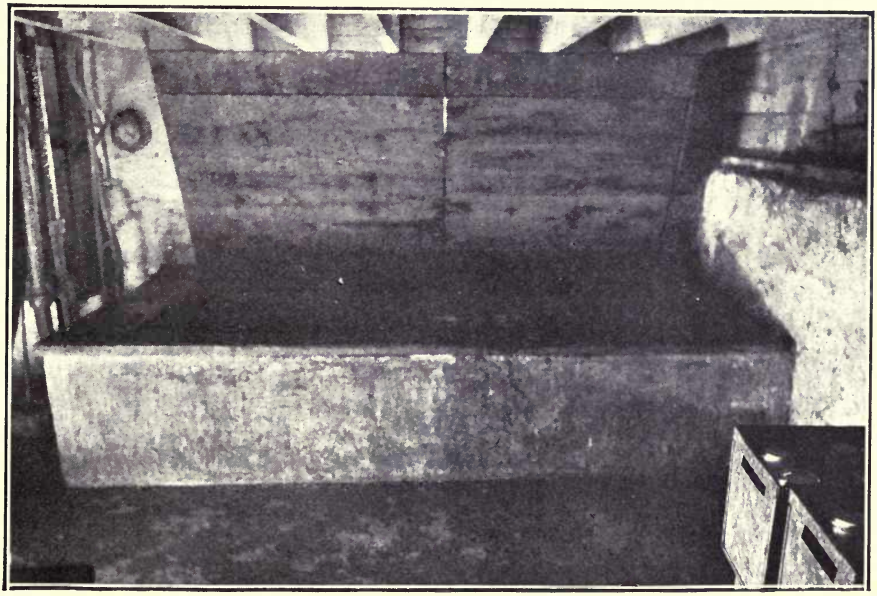


Fig. 30. Solid Wall Concrete Ice Box.

An ice box should be made in the place where it is to set, as it will be too heavy to move. Build outside forms of 1-inch tongued-and-grooved and planed boards. Cleat these lightly together and run a brace back to hold in place. Make a light box or use one already made for the inside forms, oiling or greasing it well before placing the concrete. Make the wall 8 inches thick if one air space is required, or 10 inches thick for two air spaces. To form the air space, place 2-inch plank on end 2 inches from the form and in pairs so that each thickness of wall will be 2 inches and these 2-inch walls will be con-



INTERIOR OF CONCRETE ICE BOX AT BROOKSIDE FARMS, NEWBURGH, N. Y.



CONCRETE ICE BOX IN A DAIRY AT CHICAGO, ILL.

nected by about 4 inches of concrete at the ends of each pair of plank. By greasing the plank thoroughly, they may be pulled out after the concrete has begun to stiffen. The time for doing this will be about an hour after the concrete is placed if it is made about the consistency of mortar for laying brick, or about two hours after placing if it is made thinner than this. Pull plank just as soon as the surface of the concrete has dried off. Leave the inside and outside forms in place for two or three days. To furnish a place for a double cover, which should always be used with a double wall, make the inside section of wall lower than the outside, as shown in Fig. 31. There should be from ½ inch to 1 inch space between the two wood covers. The hollow spaces in the walls may be filled either with cork or mineral wool, which helps considerably to keep the inside of the ice box at a low temperature with the least amount of ice.

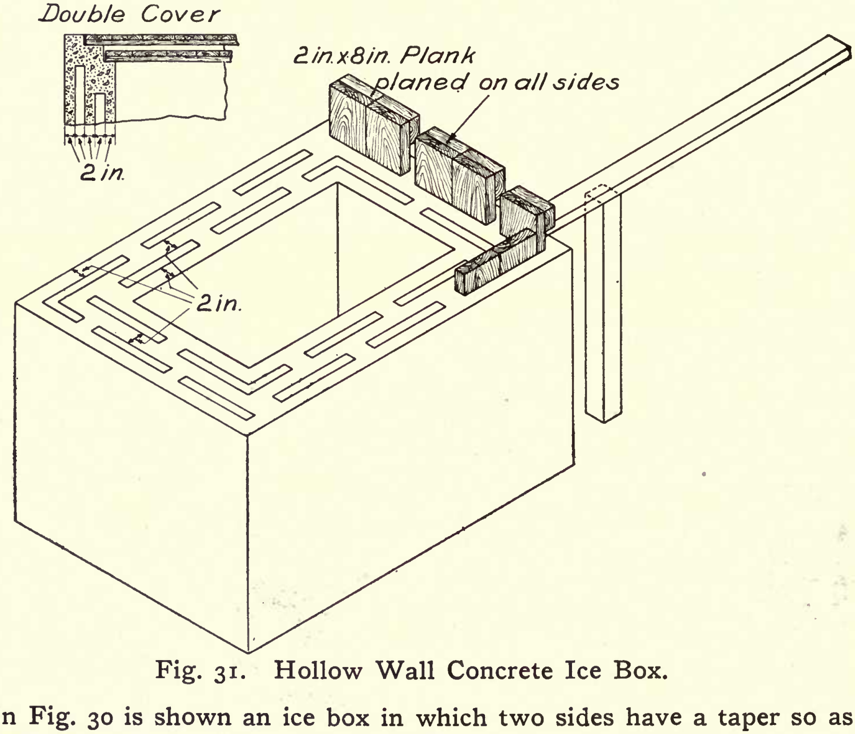


Fig. 31. Hollow Wall Concrete Ice Box.

In Fig. 30 is shown an ice box in which two sides have a taper so as to catch the wood trays. The other two sides need not be tapered. The cover is made in two sections so that only one need be removed in order to place or take anything from the trays. The bottom of the box should be made sloping toward a drain pipe, which may be fitted with an elbow and an upward bend which fills with water and traps the air from entering the ice box, while it allows the water from the melting ice to drain from the box.

## SILOS.

A silo, which is a tank or chamber for preserving fodder or ensilage by the exclusion of air and water, is a practical necessity on every farm.

Concrete silos are without question the most satisfactory, for they are water-tight, practically air-tight and vermin or rat-proof; they cannot shrink, rot, rust or burn up; they will not blow over on account of their weight nor collapse when empty. Concrete is a good non-conductor of heat and cold and the temperature inside such a silo will be fairly uniform so that the ensilage will never freeze to any extent.

ONE OF THE SILOS AT GEDNEY FARMS, WHITE PLAINS, N. Y.

Silos are generally made circular, and the height may be about two or three times the diameter.

There are three ways of building concrete silos: With monolithic or solid walls; with hollow monolithic walls; and with concrete block walls.

Concrete silos are more economical than wood because of their durability. The expense varies, of course, with the prices of the ingredients composing the concrete and the cost of the form work. The cost of the gravel and sand is generally small, for there are comparatively few farms without a gravel pit suitable for making good concrete; hence, it is in the handling of these materials and the making of the forms that the principal outlay is involved. A reinforced silo can be built cheaper than one which is not reinforced, because of the thinner walls which can be used.

A design for forms and staging for a concrete silo is shown in Fig. 32.

The table gives the necessary data for constructing silos of different heights and diameters.

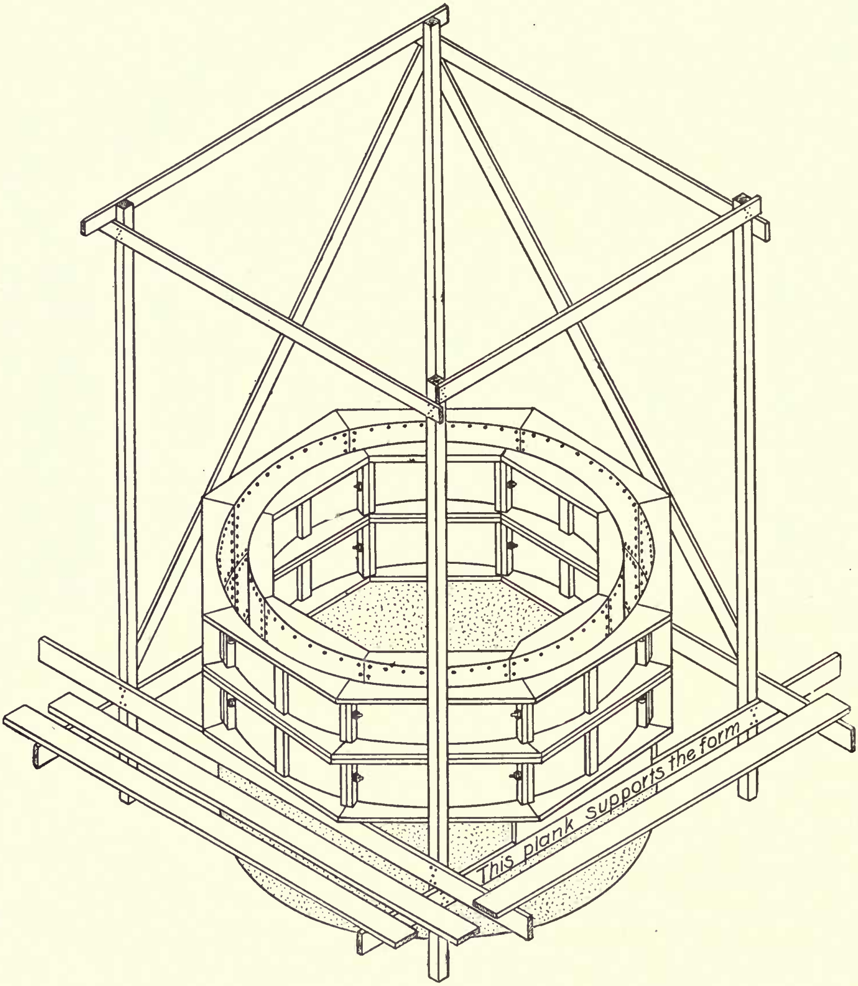


Fig. 32.—Forms and Staging for Silos.

## DATA FOR REINFORCED CONCRETE SILOS.
(Including 6-Inch Floor).

Proportions: 1 Part "Atlas" Portland Cement to 2 Parts Sand to 4 Parts Gravel or Stone

| Height | Inside Diameter | Thickness of Wall | Horizontal Reinforcement | | Cement | Sand | Stone |
|---|---|---|---|---|---|---|---|
| Feet | Feet | Inches | Size Inches | Spacing C. to C. Inches | Bbl. | Cu. Yd. | Cu. Yd. |
| 10 | 5 | 6 | ¼ | 12 | 6½ | 2 | 4 |
| 10 | 10 | 6 | ¼ | 12 | 18½ | 4 | 8 |
| 15 | 5 | 6 | ¼ | 12 | 9½ | 3 | 6 |
| 15 | 8 | 6 | ⅜ | 12 | 14½ | 4 | 8 |
| 15 | 12 | 6 | ⅜ | 12 | 24 | 6½ | 13 |
| 20 | 8 | 6 | ⅜ | 12 | 19½ | 5 | 10 |
| 20 | 12 | 6 | ⅜ | 12 | 29½ | 8 | 16 |
| 20 | 15 | 6 | ½ | 12 | 38 | 10 | 20 |
| 25 | 10 | 6 | ½ | 12 | 27½ | 7½ | 15 |
| 25 | 15 | 6 | ½ | 12 | 45 | 12 | 24 |
| 25 | 20 | 6 | ½ | 12 | 62 | 16½ | 33 |
| 30 | 10 | 7 | ½ | 12 | 37 | 10 | 20 |
| 30 | 15 | 7 | ½ | 12 | 58 | 15½ | 31 |
| 30 | 20 | 7 | ⅝ | 12 | 80 | 22½ | 45 |
| 40 | 15 | 8 | ½ | 12 | 80 | 22½ | 45 |
| 40 | 20 | 8 | ⅝ | 12 | 114 | 30½ | 61 |
| 40 | 25 | 8 | ¾ | 12 | 147 | 38½ | 77 |

Place vertical rods same size as horizontal, 2½ feet apart.
A cubic yard is about 1½ single load or ¾ of a double load.

The method of laying out the curves in order to make a section of the form for a silo shown above is given in Fig. 33.

The complete circles can be laid off in this manner on any level piece of ground or on a barn floor.

After laying out the circles, divide them into a number of equal parts in order that the sections shall be alike, eight divisions generally being the most convenient, for then the sections are not too large to handle easily, nor too small, making too many in number. Make all the joints between the sections on lines with the center of the silo except one inside joint, which is cut on an angle, as shown in the drawing, in order to permit removing the inner forms. This section which is cut at an angle is placed last and removed first.

The curved boards for the frames of the form sections can be cut either from one wide plank, as shown in Fig. 33, or from two narrow planks which are tacked together. The frames may be covered either with sheet iron or with thin boards 3 or 4 inches wide nailed endwise to the frame.

The forms can be made also by riveting angle irons to the sheet iron to stiffen it instead of the wood shapes. While the metal form is more expensive than wood, if a number of silos are to be built, the first cost of the forms can be larger, because it is divided among several. One man making a form of this type can rent it to his neighbors, and in this way more than pay for the extra money spent in making the forms.

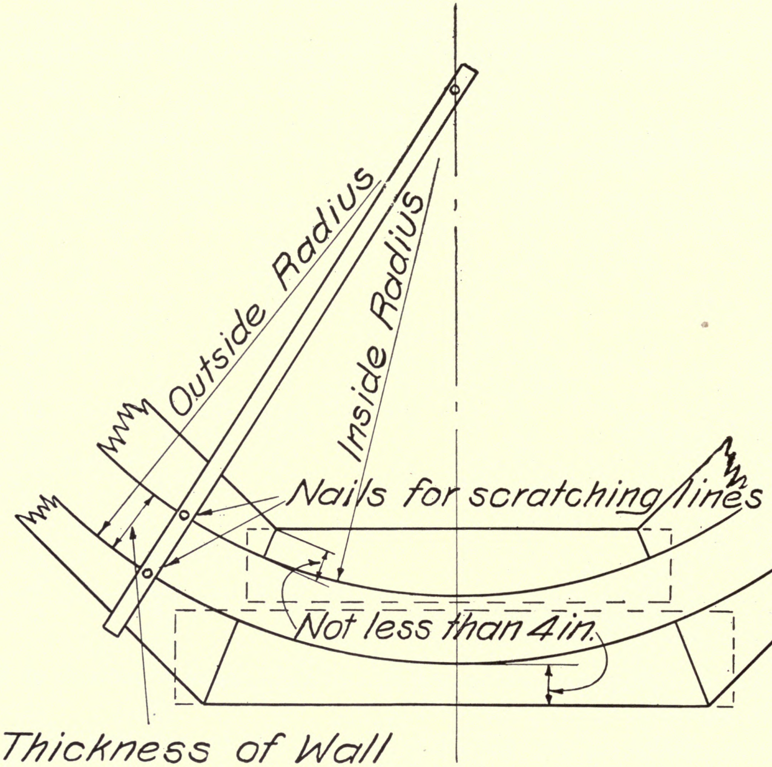
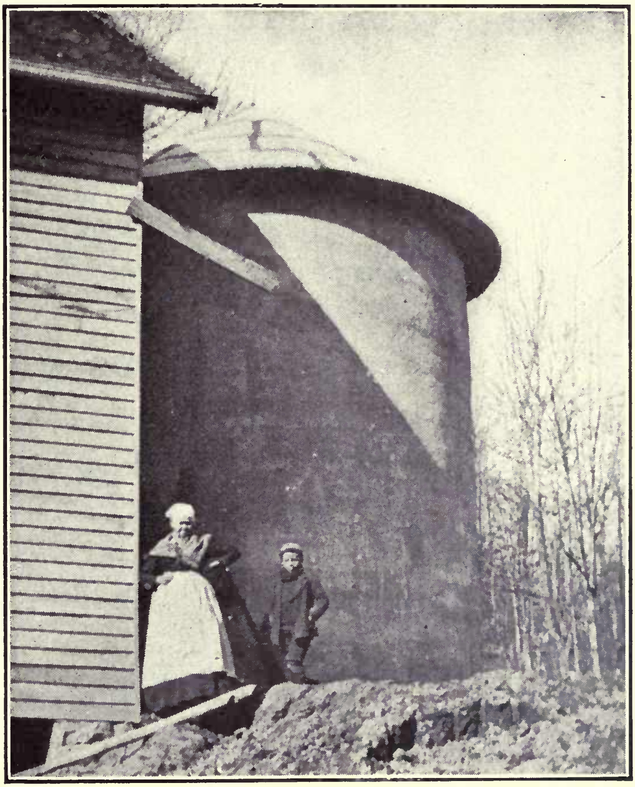


Fig. 33.—Method of Laying Out Silo Forms.

Excavate the earth to a depth below frost, which in the Northern and Middle States is about 4 feet, while in the Southern States 3 feet, or even 2 feet, may be sufficient and of the required diameter. If the earth is hard and will stand alone sometimes it is only necessary to excavate to the outside diameter of the silo. In other cases the diameter of the circle for excavating must be 4 or 5 feet larger than the outside diameter of the silo, so as to allow for a 2 or 2½-foot trench to make room for placing and removing the outer form. Grease the forms thoroughly. A mixture of fat or lard with kerosene makes a good grease for oiling the forms.

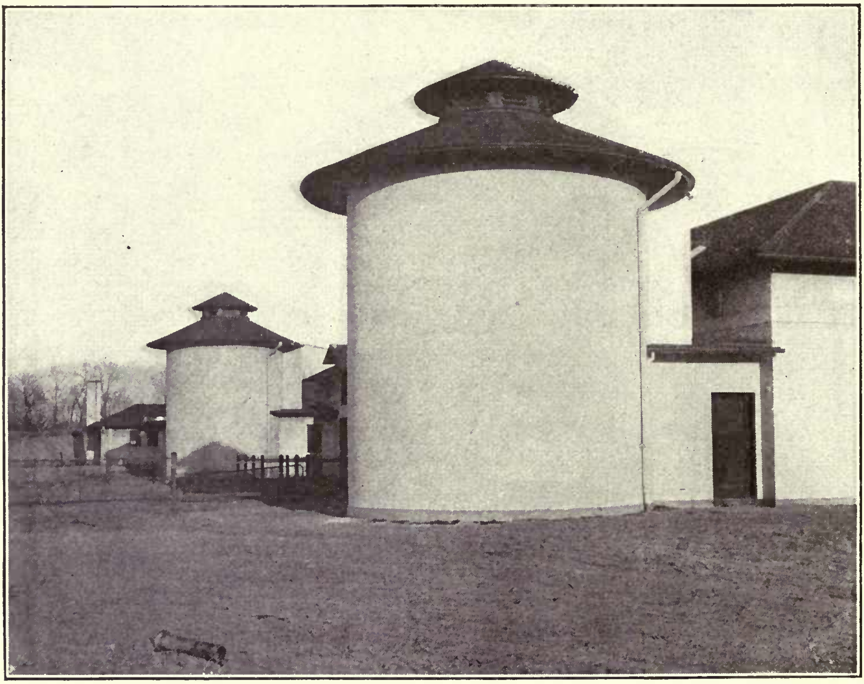
Care must be taken in placing the reinforcement. Locate the horizontal reinforcement by marking on one or two of the 4 by 4-inch upright studs of the scaffolding the location of all the rods; then there will be no question whether or not the reinforcement is in the correct position.

Before mixing the concrete, bend the horizontal rods into rings so that they will go in the middle of the wall. Lap the ends 2 feet. To find the length of rod to go around a silo, add to the inside diameter the thickness of one wall and multiply this sum by 3 1/7. This gives the circumference of the center line of the wall. If the length of this circumference is not too long for one rod, add 2 feet for the lap. If two rods are necessary, add 2 feet for each lap; that is, make every rod 2 feet longer than is required for the actual circumference. By placing the inside form of the silo first, the reinforcement may be set in advance of the concreting, the horizontal rods being tied to the verticals by soft wire about 1/16 inch diameter. This is a better way than to place the horizontal rods as the concrete is being laid. The table gives the distance apart of the horizontal rods at the bottom of the silo. Increase the spacing slightly toward the top so that at the top the rods are double the distance apart they are at the bottom.



CONCRETE SILO AT CHARLOTTESVILLE. VA.

Mix the concrete, using one part "ATLAS" Portland Cement, two parts clean sand and four parts broken stone or screened gravel. For mixing of the concrete, see page 24. Make the mixture of sloppy consistency about like heavy cream, place it in the forms and ram lightly to distribute the mortar and drive out air bubbles. Before removing the forms, clean off the top of the wall with a stiff wire brush or an old horse curry comb, and raise the forms for the next filling. Before placing the new concrete, wet thoroughly the surface and spread a ½-inch layer of mortar mixed about one part "ATLAS" Portland Cement to one part sand and then place the concrete. Care must be used in tamping the concrete, not to push the rods to one or the other side of the form, but to keep them in the center of the wall.



CONCRETE SILOS AT EAST NORWICH, L. I.

(The dimensions of these silos are as follows: Footing, 4 feet below ground; 20 feet inside diameter; 24 feet above ground; 12-inch walls reinforced vertically with 1-inch rods 4 feet c. to c. and horizontally with ½-inch rods 3 feet c. to c. There were 443 bags of "ATLAS" Portland Cement used.)

As soon as the forms are removed roughen the inside surface by scraping off the skin of cement with a wire brush or a brick; as soon as the walls of the silo are completed wet the inside surface thoroughly with clean water, and plaster it with not over a 1/16-inch coat of one part "ATLAS" Portland Cement to one part clean, coarse sand, screened through a fine screen. Protect the surface from the sun and wet twice a day for seven days. It is very important to have this inside surface perfectly smooth, for when the ensilage settles after being packed, any roughness of the walls is liable to cause the cornstalks to catch and prevent them settling evenly. The ensilage around the air space thus formed becomes moldy and must be thrown away. This same thing occurs where the concrete is laid with too little water. The concrete then is porous and sucks out the moisture from the ensilage, forming a dry skin of material next to the wall.

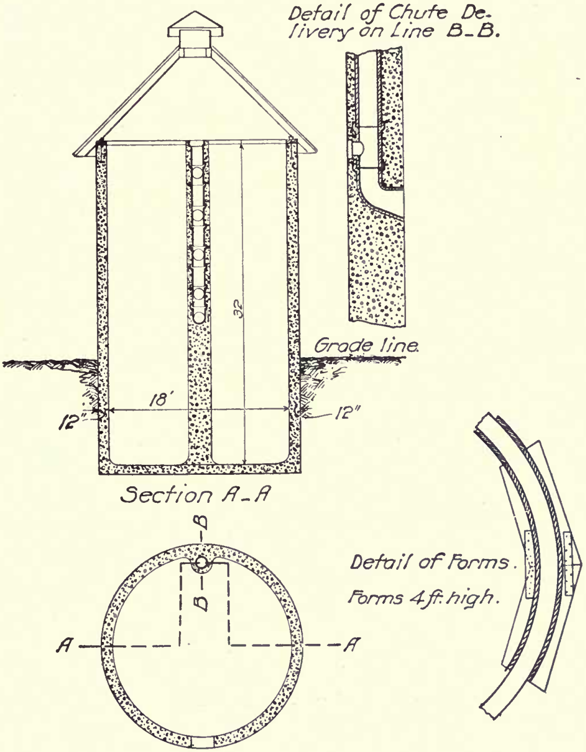


Fig. 34. Details of Silo Built at U. S. Soldiers' Home, Washington, D. C.

The outside surface of the silo is generally good enough if it is rubbed down with a board or a brick, using water with it, immediately after taking off the forms while the concrete is fairly soft so as to take off the joint ridges and leave a uniform surface. By removing the forms the next day after laying the concrete, it is possible then to entirely remove the skin of cement, leaving the sand and stone exposed enough to give a very pleasing finish.

For convenience in handling the ensilage, it is well to leave openings or doors about 20 inches square at least every three feet on one side of the silo.

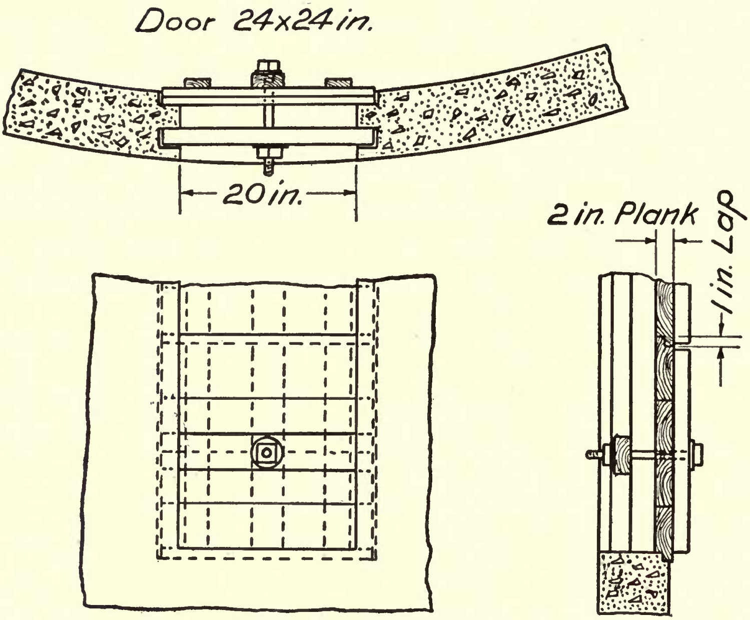
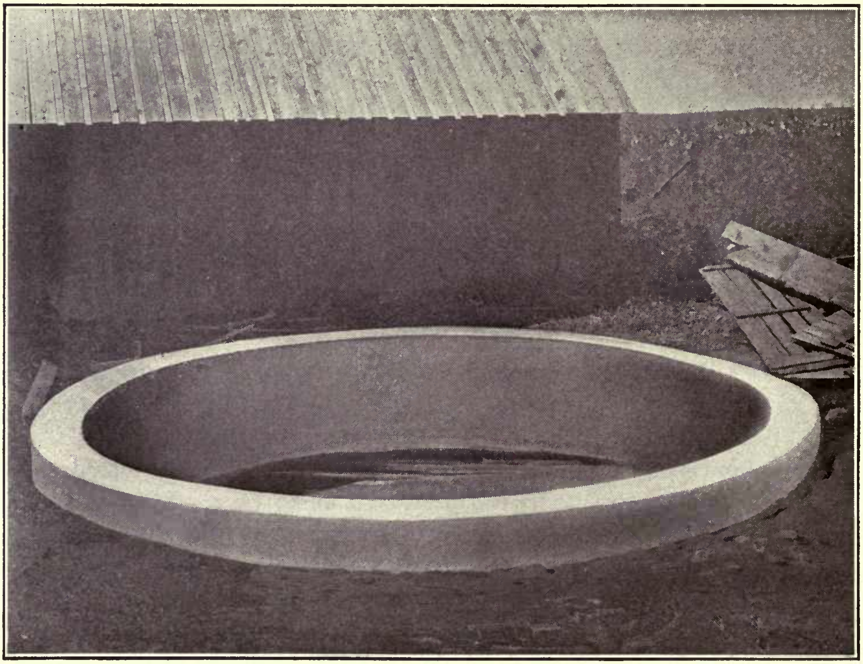


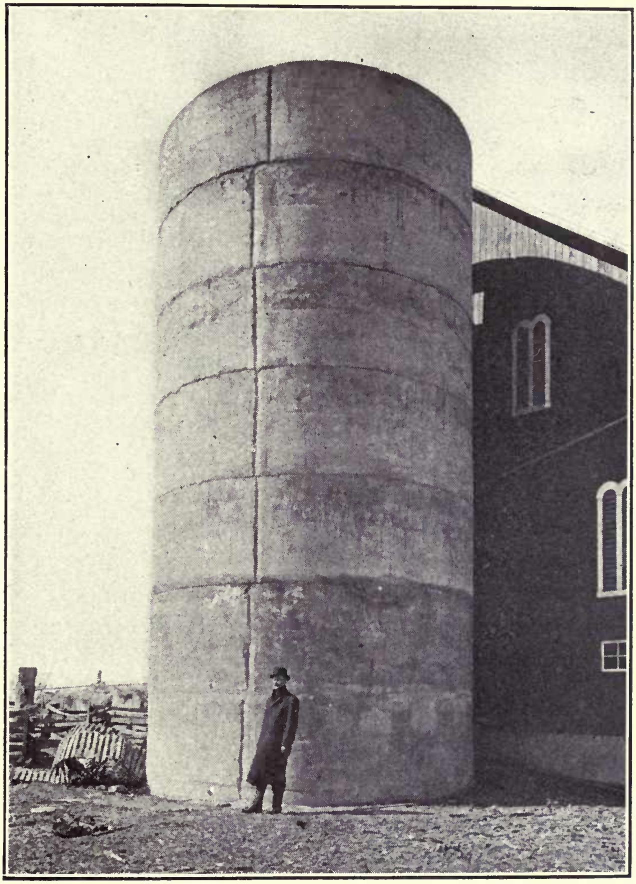
Fig. 35. Door for Silo at East Norwich, L. I., N. Y.



CONCRETE SILO FOUNDATION AT BRICELYN, MINN.

When desired, an opening 20 inches wide may be left the entire height of the silo if a part of the horizontal reinforcement is run across the opening to strengthen it; this opening is to be closed by a series of wooden doors. A good design for a door or a series of doors is shown in Fig. 35.

A chute running to the full height of the silo has sometimes been built around these doors or openings being constructed simultaneously with the walls. Make the walls of the chute 4 inches thick and reinforce them. A convenient size for such a chute is about 4 feet along the face and 2½ feet at the sides.

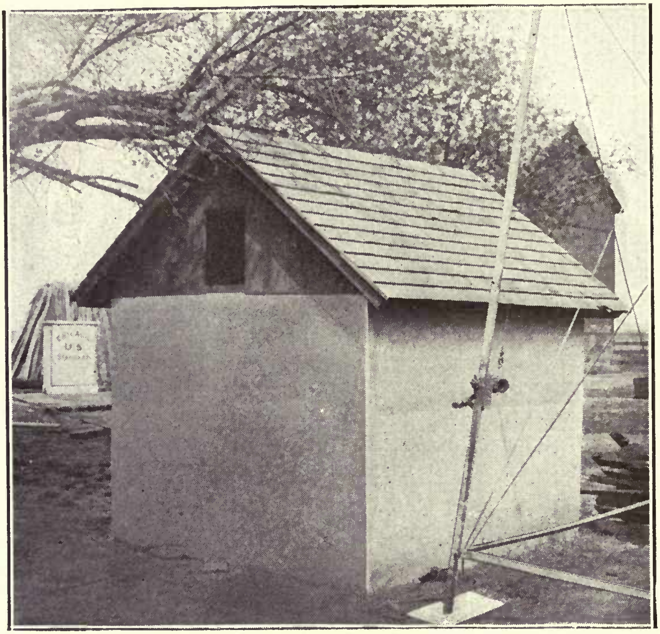


SILO AT SOUTH CHARLESTOWN, OHIO

One method of building a chute is illustrated in Fig. 34. The chute is made of 12-inch tiles and pipe, each length being 24 inches. Alternate lengths of plain pipe and tiles were used so as to bring the openings 4 feet apart.

## HOLLOW WALL SILOS.

If it is desired to make the silo with a hollow wall, the construction can be made similar to the ice-box walls described on page 100. The inside section of the wall of the silo is made the thickness required in the silo table, page 105, and the other walls 3 inches thick with lighter reinforcement. Formerly it was thought necessary to make all silos of hollow wall construction, but this is now practically superseded by the solid wall built with dense wet mixed concrete.



STORAGE WATER TANK AT BOODY, ILL.

## TANKS.

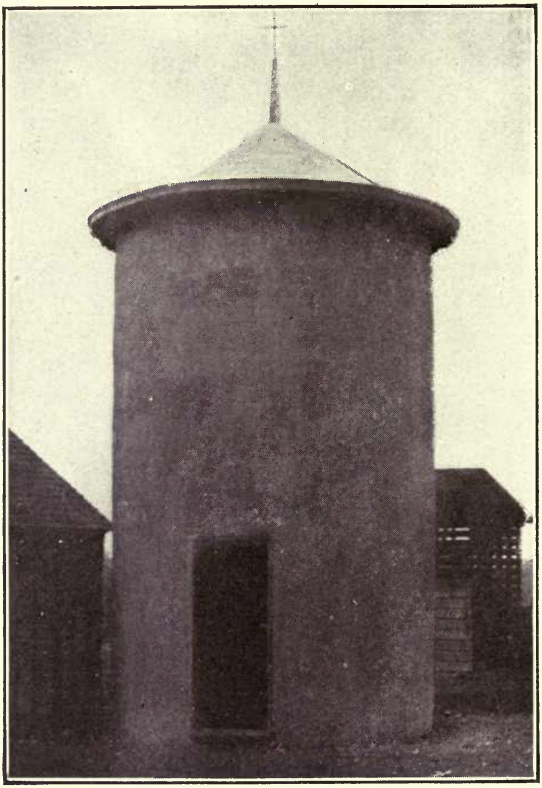
Concrete tanks, if properly built, are superior in all respects to any other kind of a tank for storing water or grain. They are easy to clean, and do not rot or rust. The concrete mixture should be in proportions one part "ATLAS" Portland Cement to one and one-half parts clean but rather fine sand to three parts screened gravel or broken stone.

A tank in order to withstand water pressure and not leak is best built by laying the concrete without stopping. Even then there are other essential things which, if disregarded, will produce a leaky tank. The concrete must be mixed so wet that it will flow over and around the metal reinforcement and against the forms. The materials for the concrete must be very carefully proportioned and the stones small enough to pass a ¾-inch mesh screen. A concrete made by using very clean screened gravel makes a denser concrete than broken stone; it flows into place better and is not so apt to have voids and stone pockets which let through the water.

SQUARE TANKS (Small). Square tanks do not stand water pressure so well as round because the sides tend to bulge, but they are all right if not more than 4 feet deep and 8 feet square. Build outside forms 12 inches wider, 12 inches longer and 6 inches deeper than the inside of the finished tank. Set mesh reinforcement, or else ¼-inch rods running both ways and 6 inches apart, in bottom of tank and the reinforcement given for a 5-foot round tank in the sides. Allow the vertical rods to project down to the bottom and the bottom rods to project up into the sides. Tie horizontal rods to vertical by 1/16-inch soft wire. Place inner form 4 inches from the outside form. This form can rest on iron pins driven into the ground. Grease forms thoroughly. Put concrete into forms at one continuous operation so that there will be no joints between courses, making it of the consistency of heavy cream. As the concrete is placed in the bottom, lift the reinforcement a little to allow the

WATER TANK, NEAR MORTON, ILL.

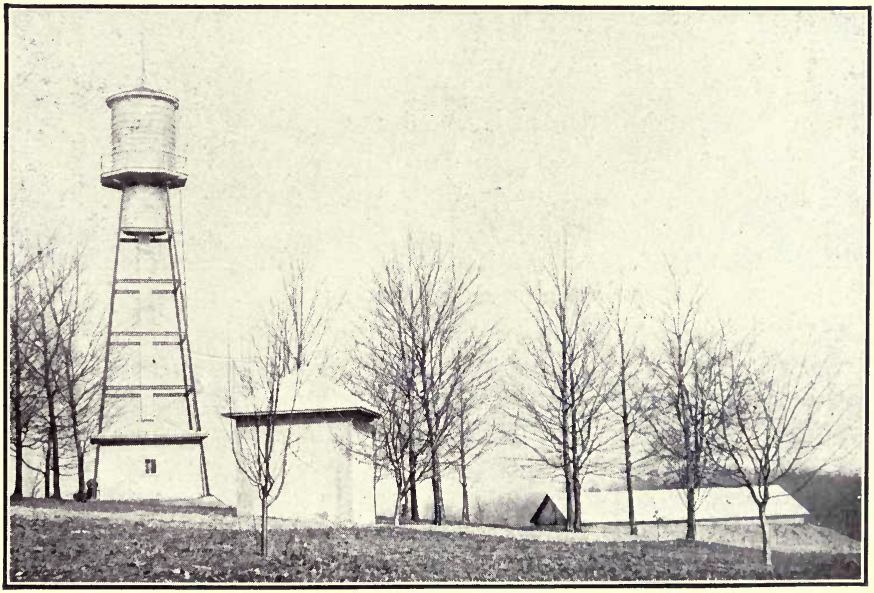
concrete to get in under it. When filling the wall take care to keep the reinforcement in place. By working carefully, the inside form may be removed as soon as the concrete has become dry on top, say, in two or three hours, although a better way is to leave it for two or three days and knock the form to pieces. Leave outside form in place for three or four days. After the concrete has set and the forms are removed, paint inside of the tank with pure cement mixed with water to the consistency of cream and brush in well. This should prevent any leakage. Protect the tank from the sun till ready to use and wet two or three times a day for a week after removing the forms. Do not fill with water until tank is two weeks old.



WATER TANK AT MORTON, ILL.

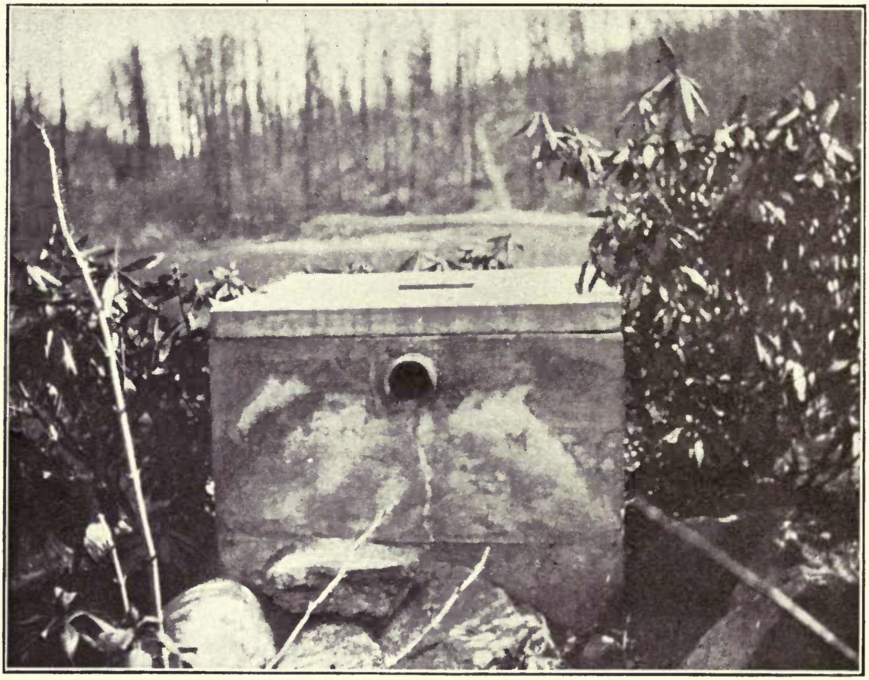
ROUND TANKS. Follow exactly the same methods given for square tanks, except using thicknesses and reinforcement given in the table. Lay out circular forms as described on page 20 or page 106. Set the reinforcement in place and pour the concrete in the same way as for square tanks.

WELL HOUSE WITH HEAVY CONCRETE COLUMNS FOR SUPPORTING STEEL FRAME OF HIGH WATER TANK AT COLUMBIA, MO.



WATER TANK, SO. CHARLESTON, O.

Tanks sometimes have to be constructed by filling one or two sections of forms each day, letting it set over night and continuing the next day. This is bad practice because it is readily seen that a joint is formed on the surface of each layer of concrete which is placed on top of another layer that has set up and hardened; to make the joint as tight as possible the top surface of the old concrete must be specially treated. The operation for treating this surface is as follows: Scrape off all dirt and scum from the old surface, pick it with a pick or scrub it thoroughly with a wire brush or horse curry comb in order to remove all surface mortar and scum and leave a very rough surface. To make the bond between this cleaned surface and the new concrete, wet it thoroughly, soaking it well, place a ¼-inch to ½-inch layer of one part "ATLAS" Portland Cement to one part sand, or, better still, a layer of pure "ATLAS" Portland Cement on the cleaned surface, and before this has set or has begun to stiffen place the new concrete upon it. In some cases a positive bond between the old and new concrete work is used in addition to the above by imbedding in the top of the last mass of concrete laid each day a 4 by 4-inch piece or a V-shaped stick of timber. This timber, which is removed the next morning, will form a groove to bond the new and old concrete together.



WATER TANK AT BERRY HILL, L. I., N. Y.

If the tank is built above ground, remove sod and earth until good firm material is reached. Excavate in any case at least 6 inches below the bottom of the tank and build foundation 6 inches thick of screened gravel or cinders or crushed stone, spreading in 4-inch layers and ramming hard. Be sure that this foundation is drained so that the water cannot collect and freeze in it.

For inlets and outlets to tanks place pieces of pipe in the concrete while it is being deposited.

Tanks may be roofed with either a wooden or concrete roof. For concrete lay the concrete on a very flat slope and reinforce it as described in the table for concrete beams and slabs on pages 30 and 31. A wooden roof is apt to be cheaper and will answer most purposes.

## REINFORCEMENT FOR TANKS.

The table which follows gives a list of sizes of steel required for tanks of several different dimensions, allowing ample factor of safety. It is extremely important that the horizontal steel be placed exactly as given. The entire pressure of the water is assumed, according to the very best practice, to be taken by the steel, as concrete is not reliable in tension unless reinforced. The thickness of concrete is only required to imbed the steel and to make the tank water-tight, and should vary with the height of the tank, but not necessarily with the diameter. A minimum thickness of 4 inches for a 5-foot tank, running up to 10 inches for a tank 15 feet deep, is suggested.

| (1) Depth Ft. | (2) Diameter Ft. | (3) Thickness of Concrete Inches | (4) Diameter Circumferential Rods Inches | (5) Spacing Circumferential Rods at Bottom Inches | (6) Spacing Circumferential Rods at Top Inches | (7) Diameter Vertical Rods Inches | (8) Spacing Vertical Rods Ft. |
|---|---|---|---|---|---|---|---|
| 5 by | 5 | 6 | 1/4 | 6 | 9 | 3/8 | 1 1/2 |
| 5 “ | 10 | 6 | 5/16 | 6 | 9 | 3/8 | 2 1/2 |
| 10 “ | 10 | 8 | 3/8 | 6 | 12 | 3/8 | 2 1/2 |
| 10 “ | 15 | 8 | 1/2 | 6 | 12 | 1/2 | 3 |
| 15 “ | 10 | 12 | 1/2 | 6 | 15 | 1/2 | 2 1/2 |
| 15 “ | 15 | 12 | 5/8 | 6 | 15 | 5/8 | 3 |

NOTE.—Bend circumferential rods in rings, place in center of wall and lap ends 2 feet. Increase, gradually, spacing of circumferential rods from bottom to top.

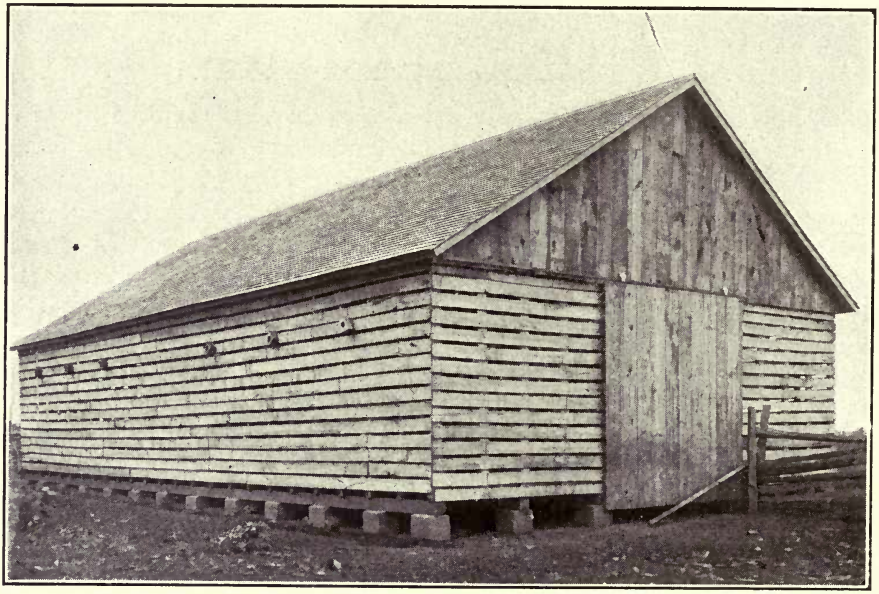
## GRAIN ELEVATORS.

Concrete grain elevators of immense size are being built all over the country by the railroads. For the storage of grain on the farm or in a village grain elevators can be built like silos, and the descriptive matter and amount of reinforcement under silos, pages 103 to 113, will apply. An elevator built in this way is proof against rats and other vermin, and is water-tight.

## CORN CRIBS.

The waste caused each year by rats and mice in corn cribs is enormous. This loss can be prevented by constructing the entire corn crib of concrete, as well as the floor, which makes it also fireproof.

The corn crib may be constructed with 5 x 5-inch concrete posts, spaced 4 feet on centers, and extending from the concrete foundation to the roof plate, which may also be a beam of concrete tying the posts together and supporting the wooden roof. On two of the opposite sides of the posts mold a slot 1 inch deep by 2 inches wide its entire length. The sides of the crib may consist of a series of slats or slabs. Cast or mold these separately 2 inches thick by 5 inches high by 3 feet 8 inches long, and reinforce with two ¼-inch rods in the same way that fence posts are molded. After thoroughly seasoning, place the slats in the slots in the posts so that there is a ½-inch opening between them. To accomplish this place one slat, then throw some mortar in the groove in the post on top of it. Place the next slat, and push it into the mortar at the joint so that a ½-inch space remains between the two slats. Continue in this way up to the plate.

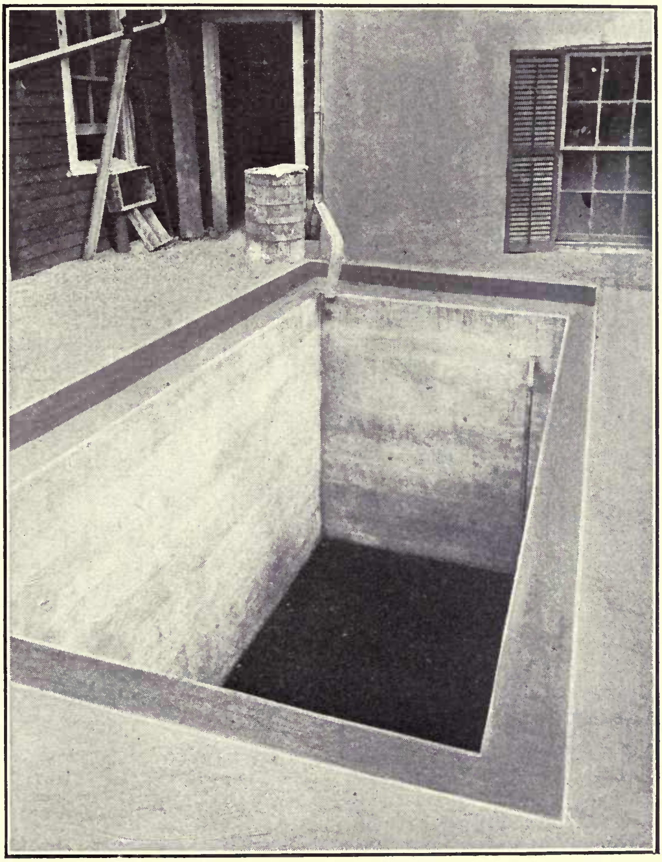


40 BY 60-FOOT STOREHOUSE AT LOWVILLE N. Y., WITH CONCRETE PIERS

The mix of concrete should be one part "ATLAS" Portland Cement to two parts clean, coarse sand to three parts fine screened gravel, or one part "ATLAS" Portland Cement to four parts unscreened gravel or sand.

## CISTERN.

Make a circular excavation 16 inches wider than the desired diameter of the cistern, or allow for a wall two-thirds the thickness of a brick wall that would be used for the same purpose, and from 14 feet to 16 feet deep. Make a cylindrical inner form (see Circular Form) the outside diameter of which shall be the diameter of the cistern. The form should be about 9 feet long for a 14-foot hole, and 11 feet long for one 16 feet deep. Saw the form lengthwise into equal parts for convenience in handling. Lower the sections into the cistern and there unite them to form a circle (Fig. No. 36), blocking up at intervals six inches above the bottom of excavation. (Withdraw blocking after filling in spaces between with concrete and then fill holes left by blocking with rich mortar.)



CONCRETE CISTERN AT ST. CHARLES, ILL.

Make concrete of one part "ATLAS" Portland Cement, two parts clean, coarse sand and four parts broken stone or gravel. Mix just soft enough to pour. Fill in space between the form and the earth with concrete, and puddle it to prevent the formation of stone pockets, using a long scantling for the purpose and also a long-handled paddle for working between the concrete and the form. To construct the dome without using an expensive form, proceed as follows: Across top of the form build a floor, leaving a hole in the center two feet square. Brace this floor well with wooden posts resting on the bottom of the cistern. Around the edges of hole, and resting on the floor described, construct a vertical form extending up to the level of the ground.

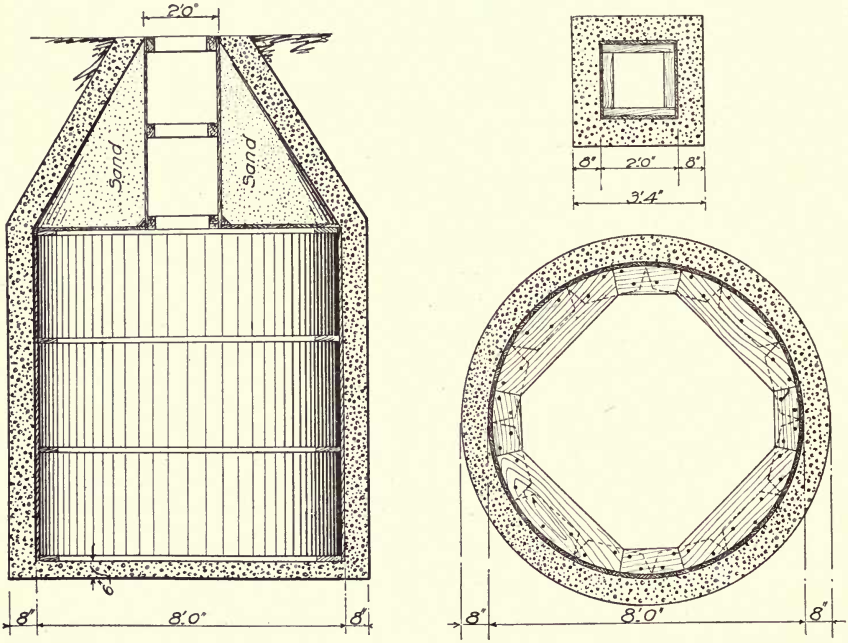


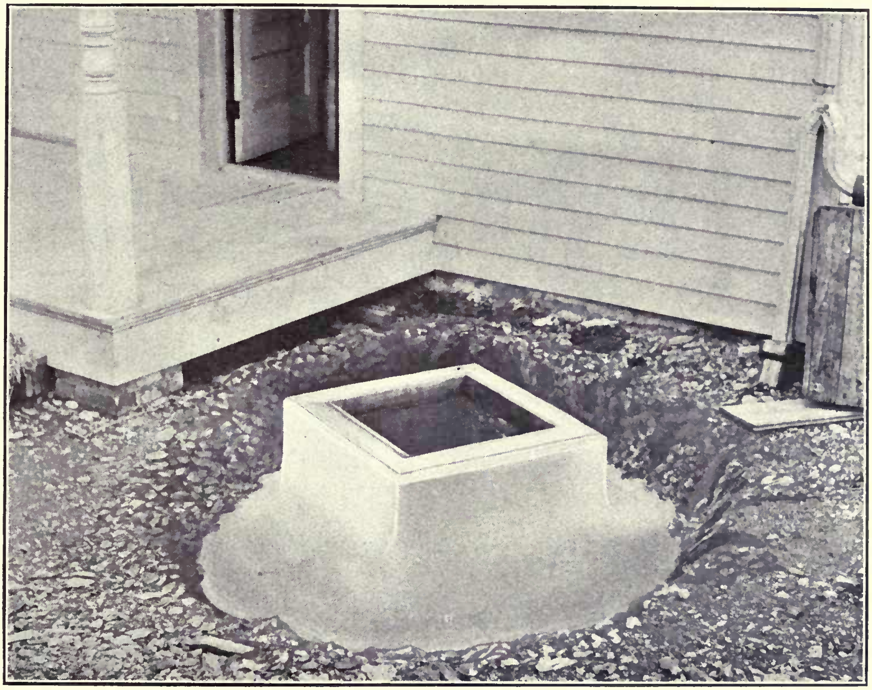
Fig. 36. Concrete Cistern.

Build a cone-shaped mold of very fine wet sand from the outer edge of the flooring to the top of the form around the square hole and smooth with wooden float. Place a layer of concrete four inches thick over the sand so that the edge will rest on the side wall.

Let concrete set for a week, then remove one of the floor boards and let the sand fall gradually to the bottom of the cistern. When all boards and forms are removed they can be easily passed through the two-foot aperture and the sand taken out of the cistern by means of a pail lowered with a rope. This does away with all expensive forms and is perfectly feasible. The bottom of the cistern should be built at the same time as the side walls and should be of the same mixture, six inches thick.

## SQUARE CISTERNS.

Excavate to desired depth and put in 6 inches concrete floor, one part "ATLAS" Portland Cement, two parts sand and four parts broken stone. As soon as practicable, put up forms for 8-inch walls (see Walls) and build the four walls simultaneously. If more than 8 feet square, walls should be reinforced with a woven wire fabric or steel rods.

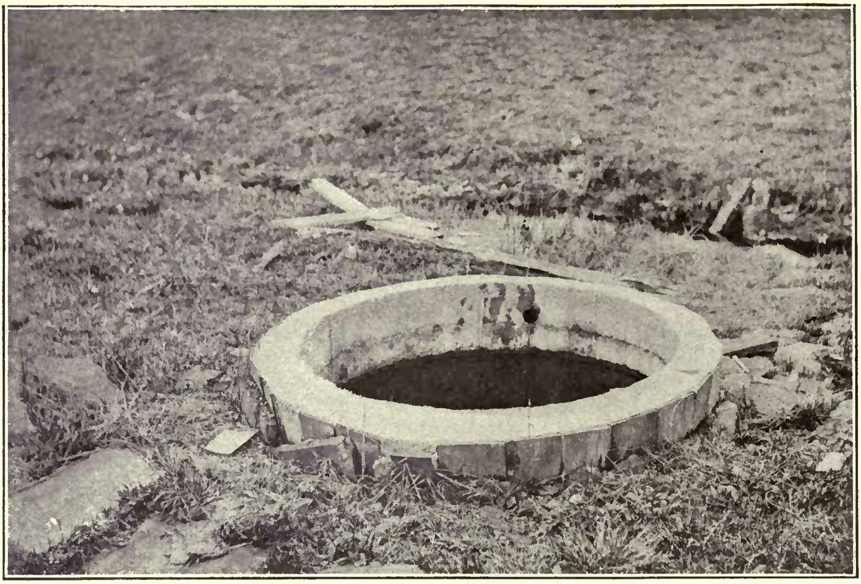


CONCRETE CISTERN AT MONROE, N. J.

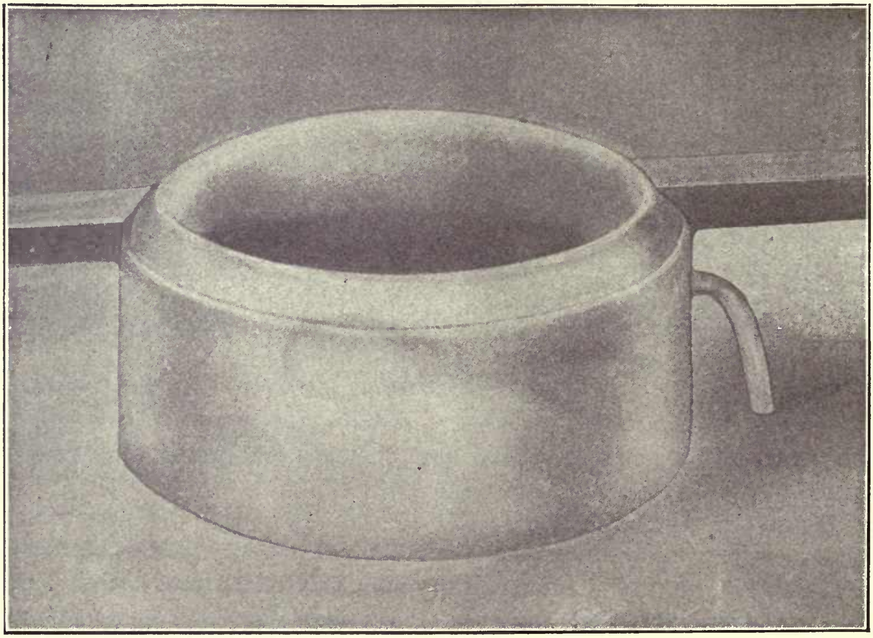
## WELL CURBS.

Concrete makes the best well curb, as it keeps out the surface water and is easily kept clean.

After the well has been dug to the desired depth, and the sides properly braced in short sections so that the earth cannot cave in, build a circular form 8 inches smaller than the diameter of the hole, and 4 feet long. (See Circular Forms.) Lower to the bottom in sections and adjust so that there are 4 inches between the form and the side of the hole. Place concrete mixture, one part "ATLAS" Portland Cement, two and one-half parts clean, coarse sand



SPRING CURB AT MONROE, N. J.



CURB IN INTERIOR OF SPRING HOUSE AT LAKE MASCOMA, N. H.

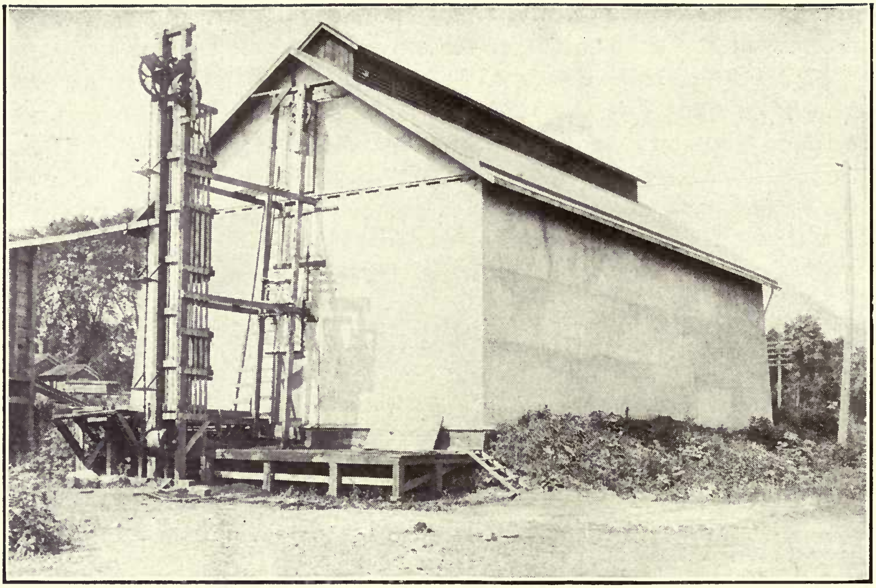
and five parts broken stone or gravel, in this space. To allow the water to get into the well, place a couple of pints of loose, broken stones in "pockets" every few feet until the water level is reached. After filling the form to the top and allowing it to set over night, or until the concrete will bear pressure of the thumb, raise it 3 feet, brace securely and repeat until ground level is reached. A slab 4 inches thick and 8 feet square should be built around the top of the well, first replacing surface soil with a layer of cinders or clean gravel, well rammed, about 12 inches thick.

SPRING CURB AT MONROE, N. J.

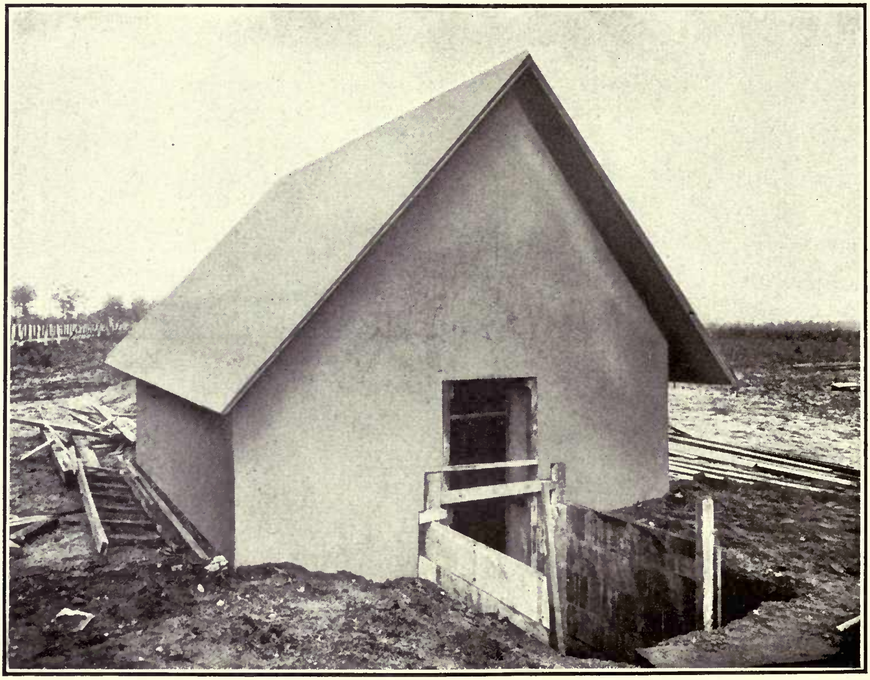
## ICE HOUSES.

There has been considerable discussion as to whether or not concrete ice houses are a success. After thorough investigation the conclusion has been reached that there are none better, if properly built—i. e., with a double wall.

Excavate a foot below the desired depth and put in a layer of coarse gravel or broken stone, ramming hard. This makes a good floor and leaves plenty of drainage. Set up forms in shape finished structure is desired, allowing 16 inches for a wall, and build foundation one part

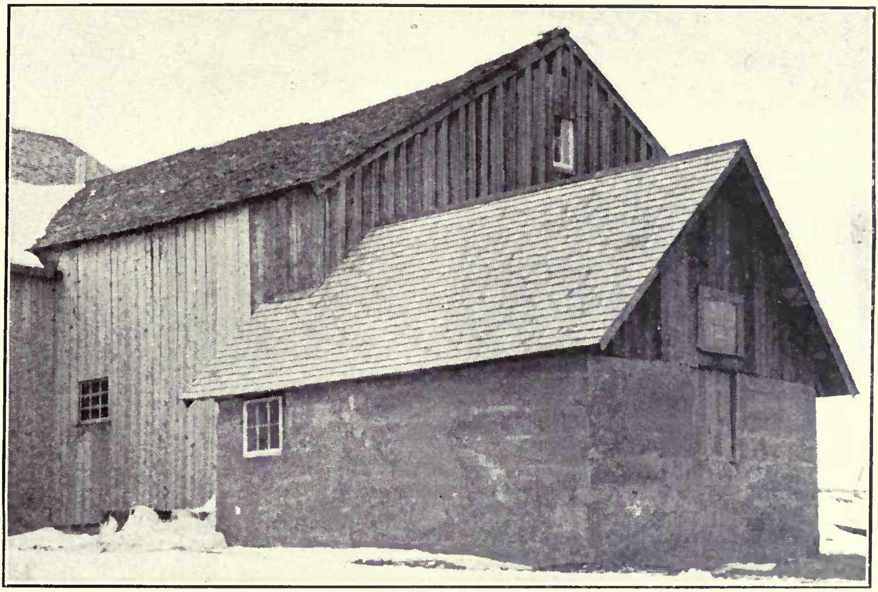


ICE HOUSE AT MONMOUTH, ILL.



ICE HOUSE AT BABYLON, L. I.

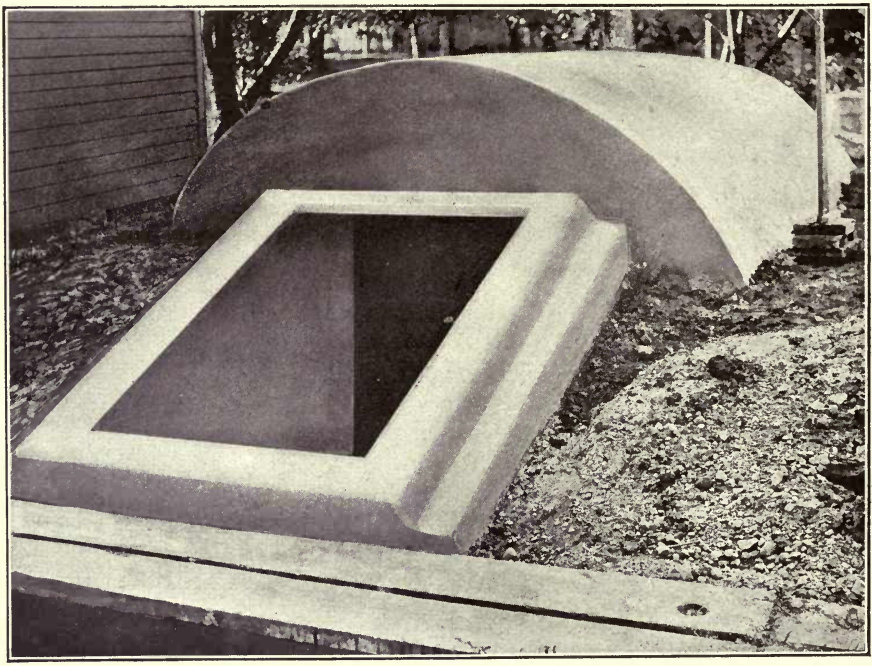
"ATLAS" Portland Cement, three parts clean, coarse sand and six parts broken stone, 16 inches wide by 4 feet deep, or below frost. The wall should be built as shown in Hollow Walls, making two 3-inch walls with a 6-inch space, each reinforced with one-quarter-inch rods placed 12 inches apart in both directions. Mixture: One part "ATLAS" Portland Cement, two parts clean, coarse sand and four parts broken stone. The wall should be built in sections about 2 feet high at a time, and the outer and inner walls should be bound together by placing galvanized iron strips, one inch broad by one-sixth inch, and turned up about an inch at each end between the first and second section, after the first section of the inner form has been removed. These strips will not only strengthen the wall, but will serve as a convenient footing for the second tier of inner forms, etc. The ends and top should be filled in solid to the depth of 6 inches, leaving no openings for the air to circulate.



15 BY 20-FOOT CONCRETE ICE HOUSE ATTACHED TO COW BARN AT LOWVILLE, N. Y.

The roof should be made slanting, and after the lower or inner side is completed 5 inches of sand may be placed on top and leveled off. The upper or outer surface of the roof can then be laid, with suitable reinforcement, directly upon the sand, and carefully trowelled as soon as it is partly set. The sand is let out at an opening left for the purpose at the sides when the concrete has dried for a couple of weeks. There should be several square blocks of concrete placed so as to connect the two, and a strong concrete beam should form the ridgepole. All openings between the walls and roof and the two layers of roof should be sealed up solid, so as to give a dead air space between them. Shrinkage cracks are liable to form on large concrete roof surfaces so that if a surface is over 20 feet square it should be covered with tar and gravel or some other kind of roofing.

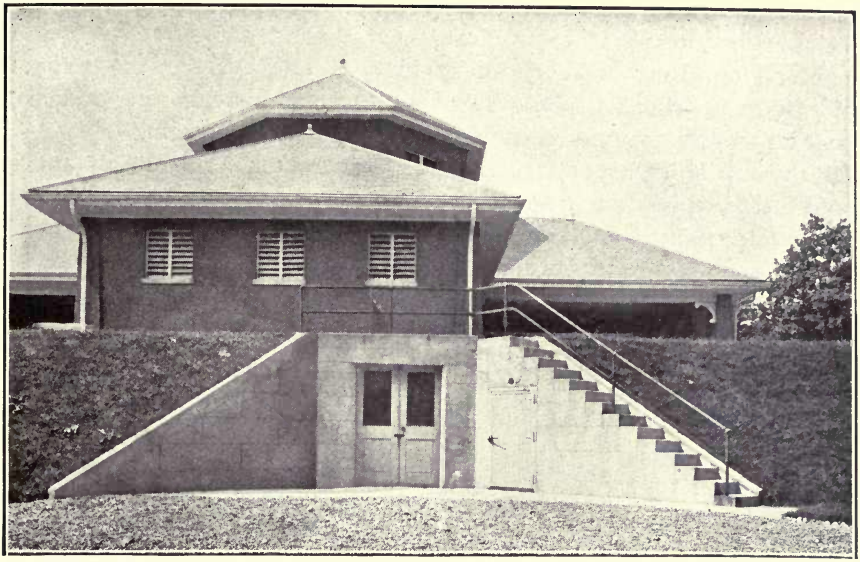
For a small house the dimensions of beams and slabs for roof may be obtained from table of Reinforced Beams and Slabs, but for a large house money will be saved and safety assured by consulting an engineer or architect experienced in concrete design.



ROOT CELLAR AT KNOXVILLE, IOWA

## ROOT CELLARS.

Root cellars are usually built half below and half above the level of the ground. Excavate 16 inches below the desired level of the floor, and around the sides build a foundation 12 inches broad, one part "ATLAS" Portland Cement, three parts clean, coarse sand and six parts broken stone or gravel. Remove the form and fill between the foundations to a depth of 12 inches with porous material, tamping well. On this build a floor as described under Cellar Floors, p. 86. On the foundation and at equal distance from either edge



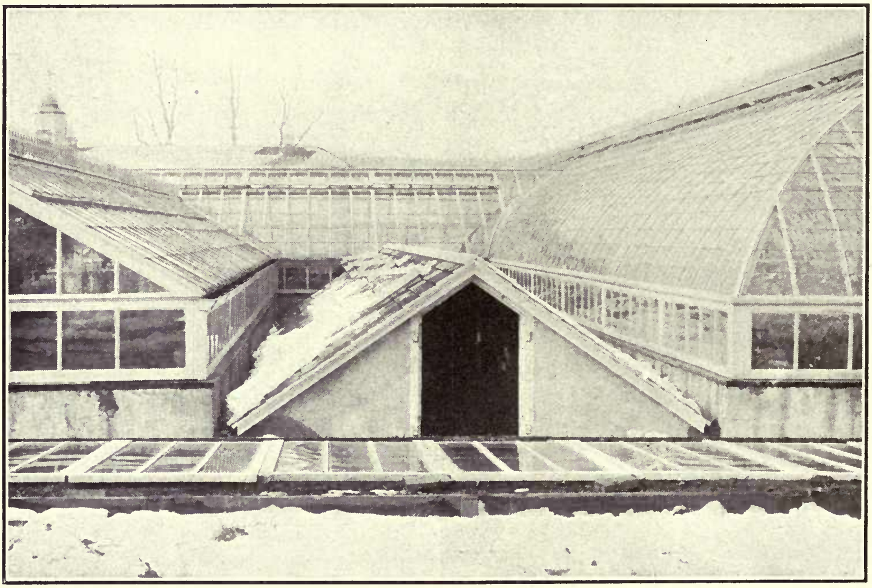
ENTRANCE TO ROOT CELLAR, UNDER WAGON HOUSE, AT U. S. SOLDIERS' HOME, WASHINGTON, D. C.

ROOT CELLAR, BABYLON, L. I.

erect a solid wall 8 inches thick (see Walls), one part "ATLAS" Portland Cement, two and one-half parts clean, coarse sand and five parts cinders, broken stone or gravel, leaving an opening at one end for the steps (see Steps). Build up the end walls so as to form a point in the middle and high enough to give the roof a sufficient pitch to shed the rain.

Near the top at each end, openings for windows should be left and sash fitted and plastered in after the concrete has set and forms have been removed.

Bins should be built of size and height to suit convenience, with walls 4 inches thick and reinforced with one-quarter-inch rods placed 12 inches apart horizontally and vertically.



ROOT CELLAR AT GLEN COVE, L. I.

If a concrete roof is desired, forms should be erected and a roof 3 inches thick laid on. On the top of this, and before the concrete is dry, a layer one-quarter inch thick of one part "ATLAS" Portland Cement and one part sand should be placed, trowelled when partially set, and smoothed with a wooden float. This surface must be wet three times a day for a week or two. Forms should not be removed from roof for at least three weeks.

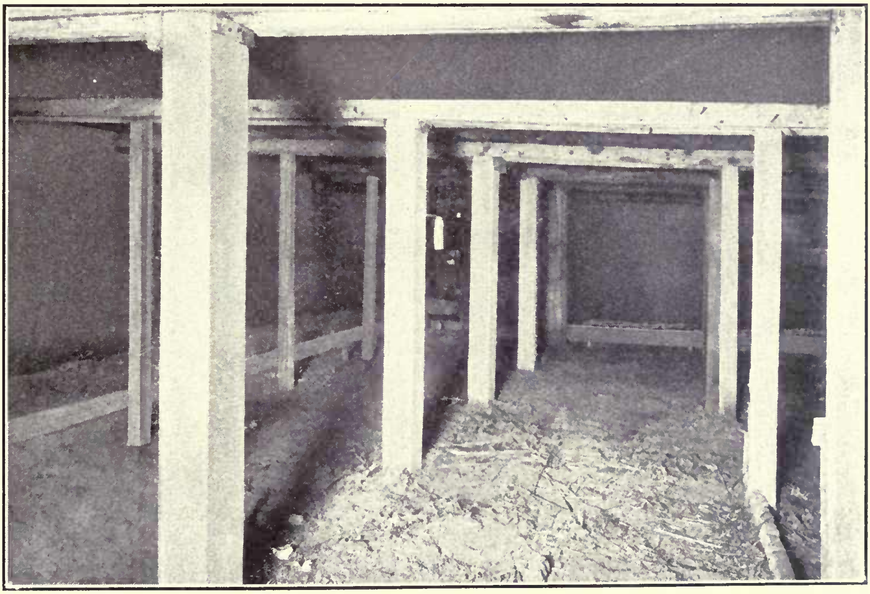
Should the roof be sufficiently long to require support other than the concrete beam that forms the ridge pole (see section on Reinforced Concrete), posts can be built in place 8 inches square.

Roof and steps should be reinforced with a woven wire fabric or with steel rods.

## MUSHROOM CELLARS.

Mushroom cellars should be built at least two-thirds below the level of the ground to obtain the best results.

Excavate to the desired depth, and around the edge dig a trench 12 inches deep and 16 inches broad. In this lay a foundation one part "ATLAS" Portland Cement, three parts clean, coarse sand and six parts broken stone or gravel. On the foundations and at equal distance from either edge build a solid wall (See Walls) 8 inches thick; mixture, one part "ATLAS" Portland Cement, two parts clean, coarse sand and four parts broken stone, gravel or cinders.



INTERIOR OF MUSHROOM CELLAR AT WESTWOOD, N. J.

Build a concrete roof 3 inches thick, supported by concrete beams and posts (see Table, Reinforced Concrete Beams and Slabs). An opening should be left at one side for steps (see Steps). All walls, posts, beams and roof should be reinforced. A coat of grout, one part "ATLAS" Portland Cement to one part fine, clean sand mixed to the consistency of cream, may be applied to the whole exterior with a brush if a very smooth surface is required.

## ARCH DRIVEWAYS.

Every farm or house along a country road must have one or more bridges or culverts where the driveways span the trench or ditch alongside the road. These arches or small bridges should be constructed of concrete, for then they will not continually rot out and need repairing and renewal.

An arch driveway consists of a slab supported on each side by a beam which spans the ditch. The size of the beams, the thickness of the slab, and the amount and spacing of the reinforcement in the beams and slab can be taken directly from the table on page 30. For example, take an arch driveway of 12-foot span, having an 8-foot roadway. The heaviest loading, namely, 125 pounds per square foot, will be taken as given in the table. Beams 9 inches wide and 16 inches deep, reinforced in the bottom with four 9-16-inch rods, are required. The slab must be 3 inches thick, and be reinforced with 5-16-inch rods placed every 6 inches.

ARCH DRIVEWAY NEAR COLD SPRINGS HARBOR, L. I.

The arch or slab should be constructed during a dry spell, in order that little or no water need be taken care of in the ditch. The forms for the slab may be made of wood if desired, or it can be constructed as follows: If the ditch is not entirely dry, place a closed wood trough or a pipe in the bottom of the ditch, to take care of the small amount of water. Throw the earth which is excavated for the side walls into the ditch, and, if necessary, borrow sand from the bank beyond to bring the pile of sand to a height level with the bottom of the new arch or slab to be built and wet it thoroughly. Tamp this fill and level off the top of the pile. Place some boards for the side walls, and brace them. Place the necessary reinforcement, upon which lay the concrete, composed of one part "ATLAS" Portland Cement, with two parts clean, coarse sand and four parts screened gravel or stone. After the concrete has set for a week or two, shovel out the earth from under the arch, and the driveway is ready for use.

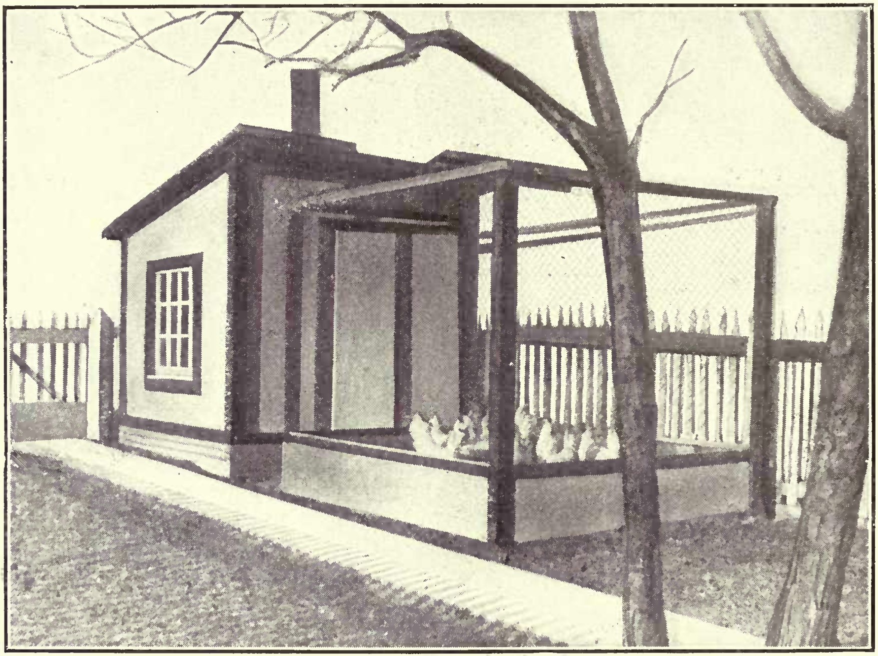
SPILLWAY AT DUMONT, N. J.

## CULVERT DRIVEWAYS.

Culvert driveways are used to span small, shallow runways of water.

The bore or opening through which the water passes is generally built circular, although a square or rectangular opening may be used as well. Line the bottom or invert of the opening with small cobble stones or gravel, from which the sand has been screened. To make a circular bore or opening, get two or three flour barrels or cement barrels, with the heads in, place them end to end on the cobble or gravel base just laid, and brace them in position so that they will not be moved when placing the concrete. If desired, a layer of concrete can first be laid in the bottom of the ditch, on which the barrels can be placed and braced. After placing the barrels and side forms in position, lay the rest of the concrete, which should be composed of one part "ATLAS" Portland Cement to two and one-half parts clean, coarse sand to five parts gravel or broken stone. The walls should be about 10 inches thick and the top of the arch 6 inches thick. To remove the forms, knock in the heads of the barrels and pry out the staves.

WATER PIPES UNDER DRIVEWAYS. Concrete water pipes, which are covered over with earth, furnish a very good means for taking care of water underneath driveways. The pipes are constructed in the same manner as the concrete tile, described on page 91, and may be made up to 12 or 16 inches in diameter.



STUCCO CHICKEN HOUSE AT ALLENTOWN, PA.

## HEN NESTING HOUSES.

Hen nesting houses constructed of concrete are better and if a number are to be built are cheaper than if constructed of any other material. It is impossible to keep vermin from any nesting house, and consequently the nests must be cleaned artificially. The only sure way to clean a nest is by the burning out process. This is impossible, of course, where the nests are constructed of wood, and the only way therefore is to burn them every so often and build new ones.

It is hardly necessary to state the advantages of a concrete nest, but a few of them are: (1) that it is cool in summer and warm in winter; (2) no draughts are possible, hence the hen will not acquire roup; (3) they can be burnt out after each nesting so as to destroy all germs, leaving the nest clean and wholesome; (4) if discolored by the fire the nest can be whitewashed after each firing.

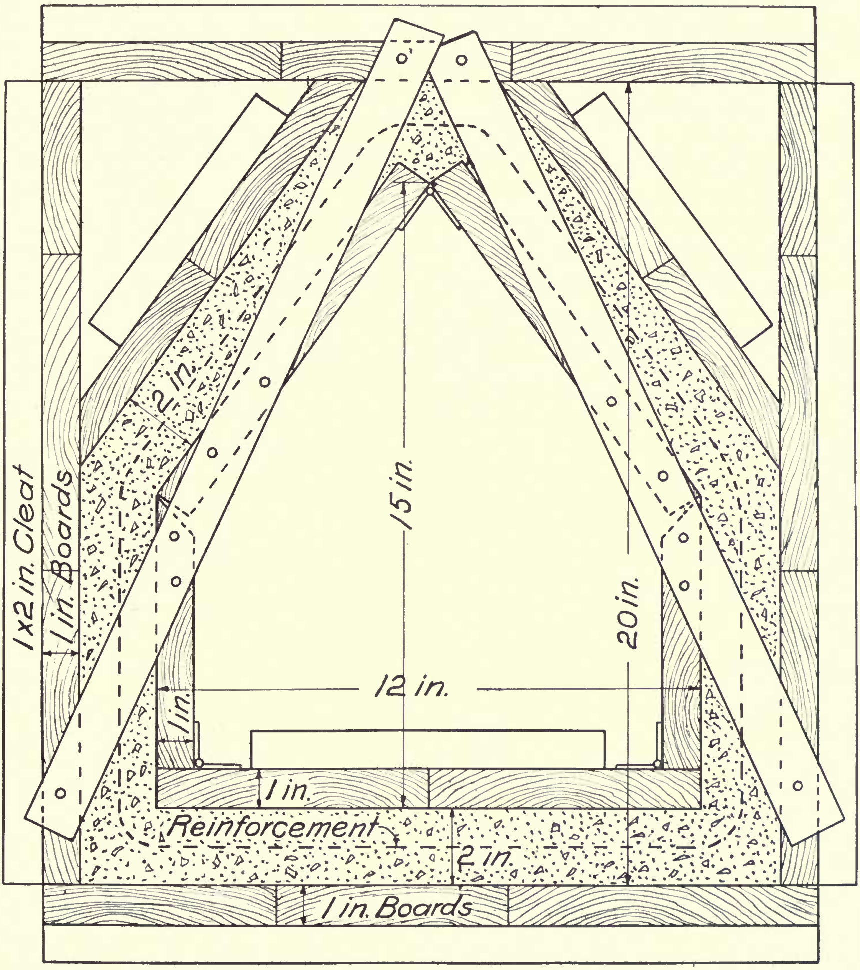


Fig. 37.—Design for Hen Nesting House.

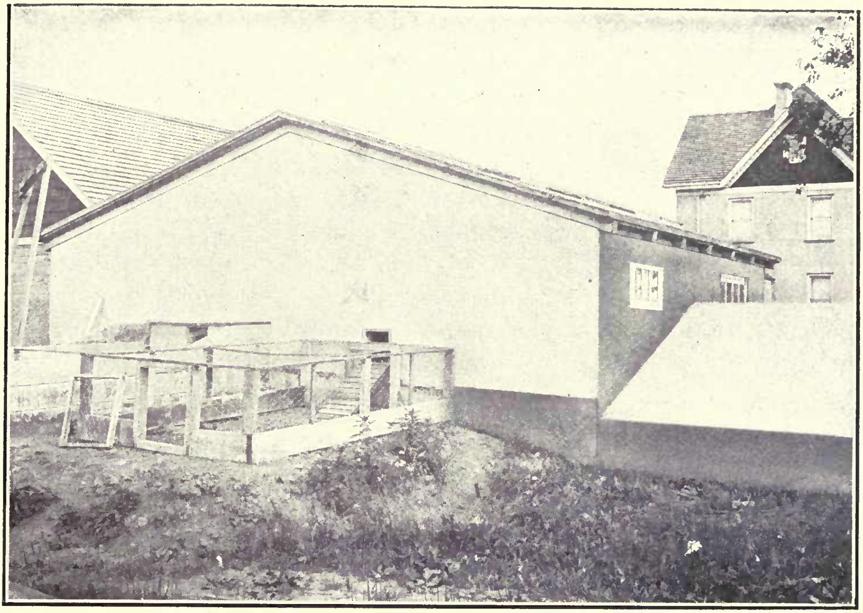
A good size for a hen nesting house is 12 inches wide, 15 inches high and 18 inches deep inside dimensions. The walls and back should be 2 inches thick, while the front is left entirely open, although if desired a lip or ledge can be cast on the front side. The ledge can be made out of wood and cut so that it fits snugly in the concrete and this can be removed very easily when cleaning the nests. The forms, as shown in Fig. 37, are very simple, and are made so that a number of nests can be built with one set of forms. The outside forms consist of a rectangular box without any ends and each side made as a separate member so that they can be easily taken apart after the concrete has hardened. When nailing the sides together do not drive the nails home, but leave the heads so that they can be easily drawn with a claw hammer, or, better still, drive the nail first into a short piece of lath which can be easily split when the sides of the form are to be removed, and thus the heads of the nails will stick out from the form ¼ inch and can be easily pulled out. Nail the outside form together with the two bevel pieces for the top of the nest tacked in and place on either hard level ground or a plank floor or platform. Oil the forms well so that they can be easily removed. The inside form is made as shown in the figure, having a hinge at the peak of the roof and two hinges at the bottom in order to facilitate removing the form. It is made in two separate sections which are held together by nailing on two cleats to serve also to hold them in the outer form and at the right distance, namely, 2 inches from the ground or platform. After placing the forms, which should be well greased, mix one part "ATLAS" Portland Cement with two and one-half parts of clean, coarse sand with five parts of screened gravel or broken stone. Place the layer of concrete in the bottom of the form for the solid back of the nest and then fill in the concrete for the walls. To remove the inside form take off the two top cleats, which allow the two slant boards to swing together on the hinge at the top, and the two side boards swing in on to the base boards, making it possible to remove them very readily.

Thirteen nests can be made from one barrel (4 bags) of cement, one-half of a single load (20 cubic feet per single load) of sand and one load of screened gravel or broken stone. Figuring cement at $2.00 a barrel, sand at 75 cents a cubic yard and gravel at $1.25 per cubic yard, the cost of the material for the concrete for each nest will be about 25 cents.

## CHICKEN HOUSE.

The protection afforded by a concrete chicken house against rats, weasels, and other vermin, and the ease with which such a structure is kept clean, should be sufficient reason to give it preference over every other kind.

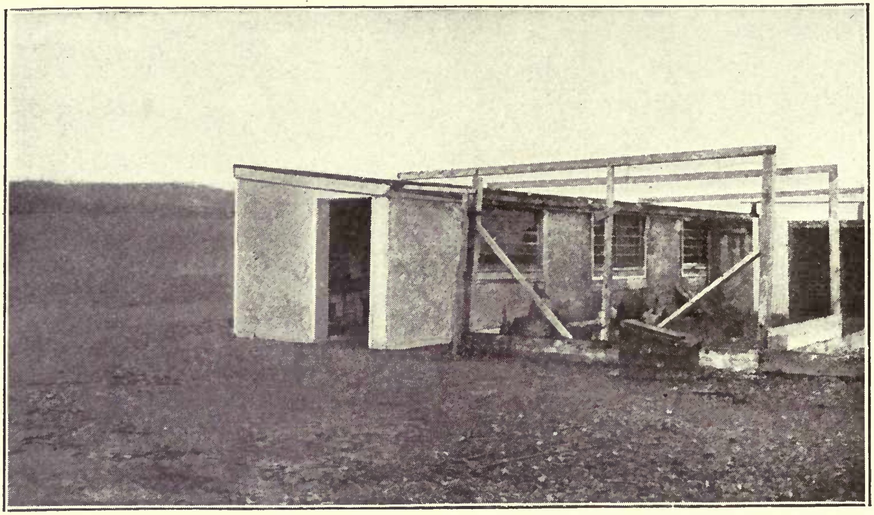
Excavate a trench 10 inches wide, to a depth below frost, and fill with concrete one part "ATLAS" Portland Cement, three parts clean, coarse sand



CHICKEN HOUSE AT WESTWOOD, N. J.

CHICKEN HOUSE AT MONTCLAIR, N. J.

and six parts cinders. On this foundation, and at equal distance from either edge, build a solid wall 5 inches thick (see Walls), one part "ATLAS" Portland Cement, two and one-half parts clean, coarse sand and five parts clean cinders or screened gravel. The roof may be made of wood or of concrete. If the house is not more than 8 feet wide, a roof with slope in one direction may be made of a 4-inch concrete slab reinforced with steel rods or heavy wire mesh of size suggested in the table of Reinforced Beams and Slabs. For a shorter span a less thickness may be adopted. A slope of six inches in eight feet will give sufficient pitch for the water to run off if the surface is well trowelled, as described under Sidewalks. If the width is more than 8 feet, concrete rafters may be placed and slabs upon them of dimensions to be selected from the table of Reinforced Beams and Slabs.



CONCRETE CHICKEN HOUSE AT LAUREL GROVE, N. J.

Concrete shelves and water basins can be put in to suit convenience.

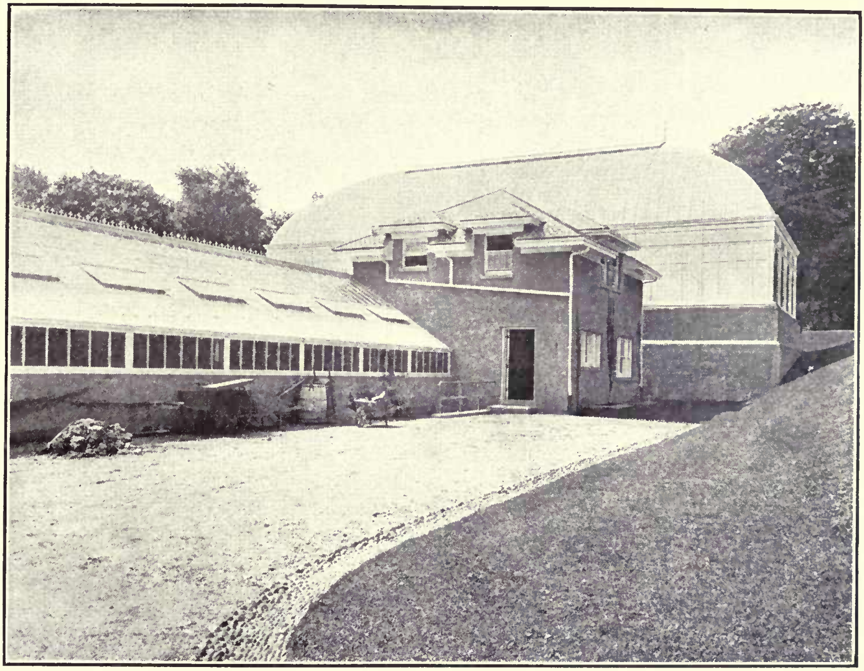
A coat of mortar one part "ATLAS" Portland Cement and one part fine clean sand, mixed as thick as cream, may be applied with a brush to the outside walls as soon as forms are removed, although with careful placing of the concrete, the surface may be wet and rubbed down as soon as the wall forms are removed and before the concrete has hardened, with a board or a brick, to remove the board marks of the forms and leave a pleasing rough surface.

The use of cinders is recommended in this construction, as the voids in the cinders take up the moisture, which is otherwise liable to collect on the inside of the wall in cold weather. The walls may be made with a hollow space, as shown in Fig. 31 (p. 102).

# GREENHOUSES.

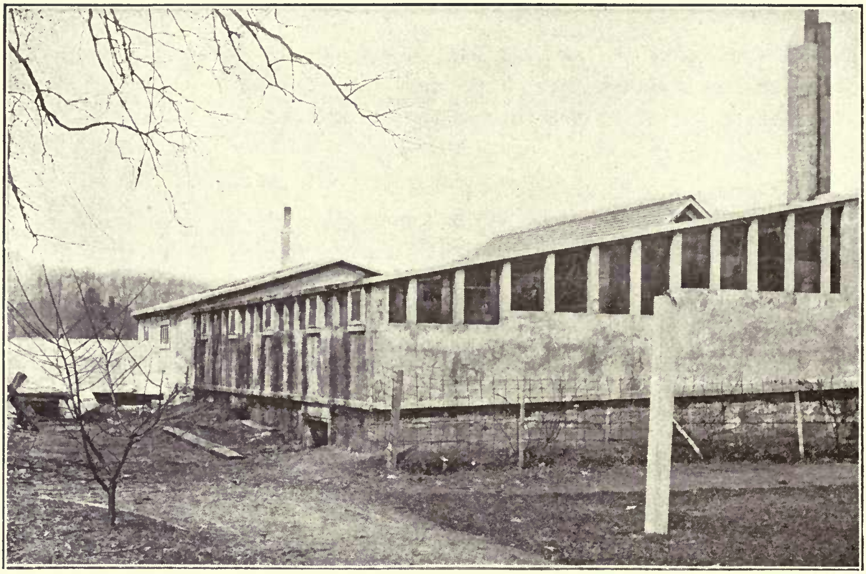
A greenhouse built of concrete not only does not require constant repairs, but saves fuel, as it retains heat and keeps out cold air.

Greenhouses should have a foundation 10 inches broad and 16 inches deep, or below frost, composed of mixture one part "ATLAS" Portland Cement. three parts clean, coarse sand and six parts broken stone. On this, and at equal distance from either edge, erect a wall 7 inches thick, mixture one part "ATLAS" Portland Cement, two parts clean, coarse sand and five parts cinders, to the height required for the walls. A ridgepole can be erected, 6 inches wide by 8 inches deep, of concrete, one part "ATLAS" Portland Cement, two and one-half parts clean, coarse sand and five parts broken stone or gravel not over three-quarters inch in size, reinforced with two steel bars each one-half inch in diameter. If total width of house is not over 16 feet, beams 2½ inches by 5 inches, extending from ridgepole to side wall, reinforced with a ½-inch bar, will be sufficiently strong to support the sashes.



GREENHOUSE AT U. S. SOLDIERS' HOME, WASHINGTON, D. C.

Reinforced concrete posts 8 inches square should be placed at intervals of 10 feet to support the ridgepole.

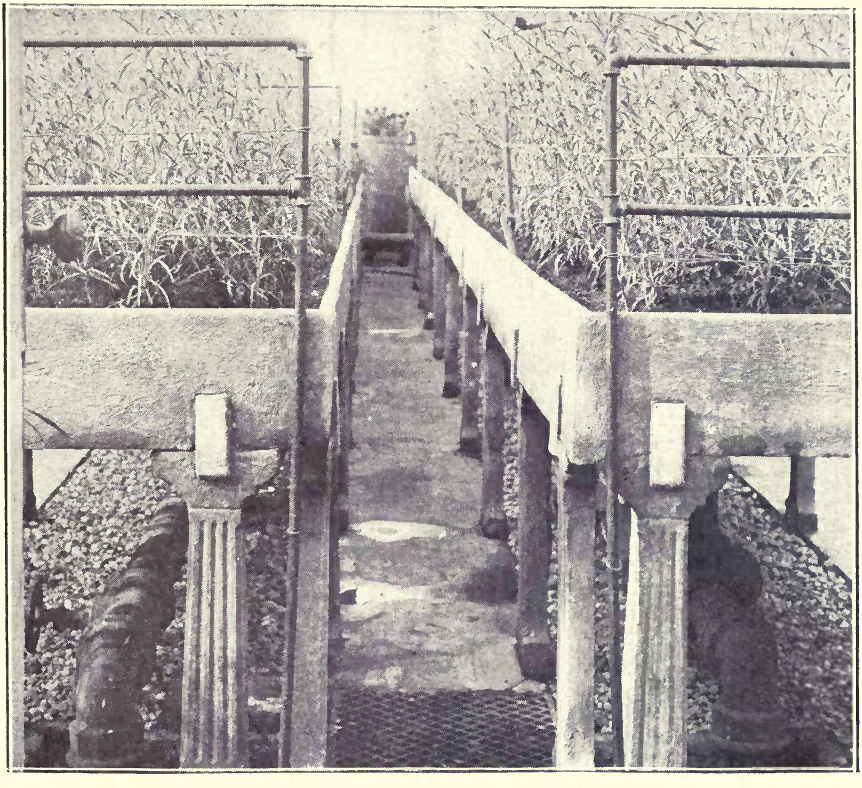


CONCRETE GREENHOUSE WITH CONCRETE SASH AT WESTWOOD, N. J.

INTERIOR VIEW OF GREENHOUSE AT WESTWOOD, N. J.

## GREENHOUSE TABLES.

The tables or benches in greenhouses should be constructed of concrete in order to save the grower the large expense and annoyance of renewing and replacing every few years the old decayed wooden benches. The tables can be made either as one member, in which case the posts, bottom and sides are cast in one continuous piece of concrete, or they can be made by constructing them in parts. In order to facilitate the drainage of the water from the table, holes must be left at the bottom of the benches except when the bottom is cast in a series of slabs, where the cracks between them will be sufficient.



INTERIOR VIEW OF GREENHOUSE AT GLEN COVE, L. I.

Make the concrete tables which are cast in one piece 2½ inches thick and of a mixture composed of one part "ATLAS" Portland Cement to two parts of clean, coarse sand to four parts of cinders, reinforced with a woven wire fabric or ¼-inch round rods spaced 7 inches apart. A design for a table and forms for molding the separate members is shown in Fig. 38. The posts should be 5 inches square, spaced on 6-foot centers, and the table may be made 4 feet wide. If the slab is molded in sections, as shown in the drawing (Fig. 38), the section should be made about 12 inches in width for convenience in handling.

The forms if well planned and greased with oil should leave the concrete surface smooth enough without plastering them, but if desired a coating ⅛ of an inch thick, of one part "ATLAS" Portland Cement to one part of clean, fine sand, may be applied to them. This should be put on after the surface to be covered has been picked with a stone axe or old hatchet and thoroughly wet.

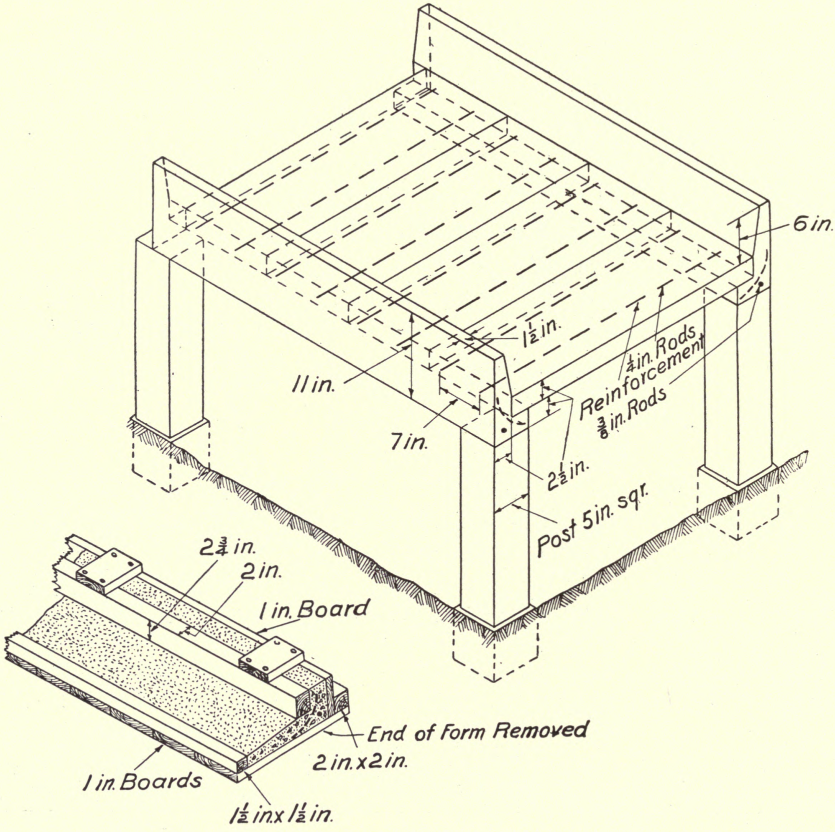
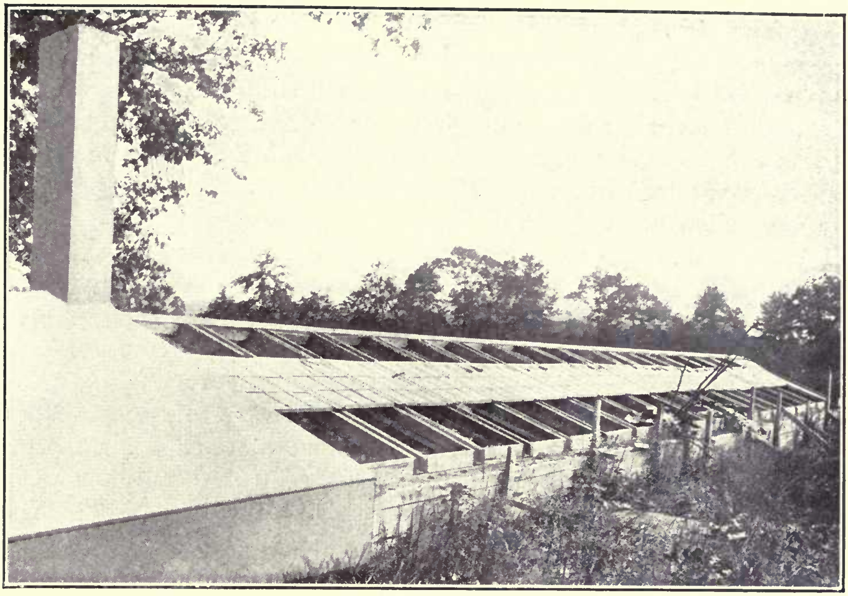
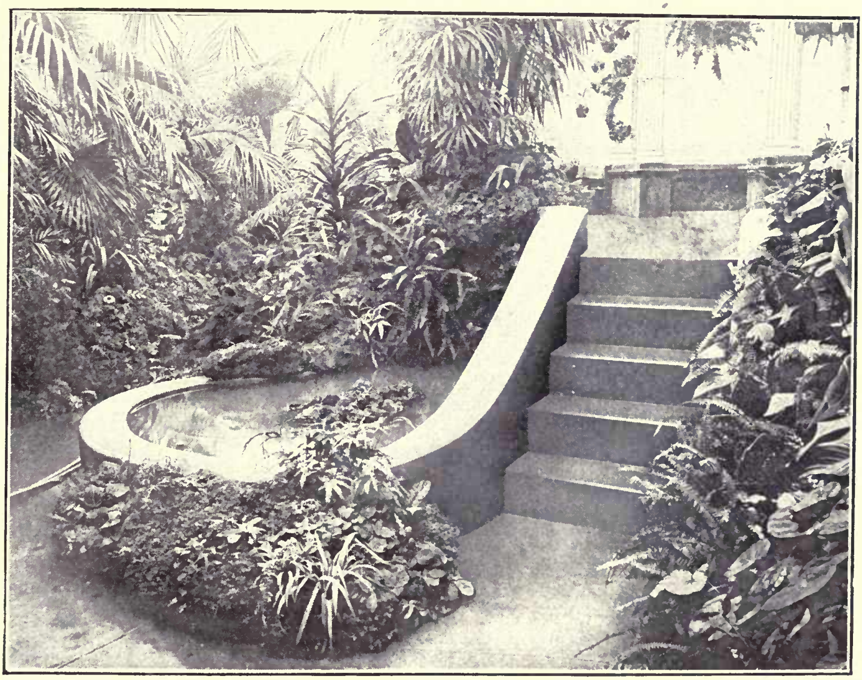


Fig. 38. Design of a Separately Molded Greenhouse Table.



GREENHOUSE AT WESTWOOD, N. J.



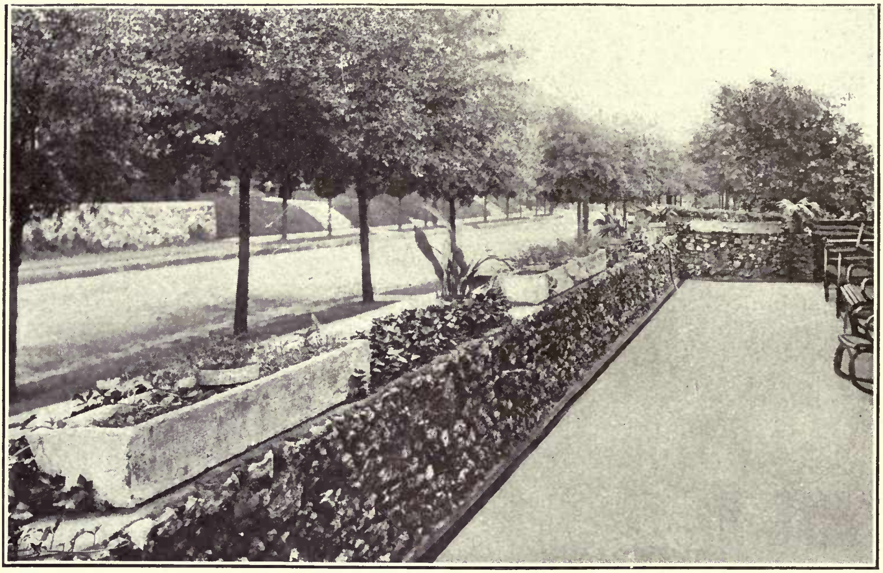
INTERIOR OF GREENHOUSE AT U. S. SOLDIERS' HOME, WASHINGTON, D. C.

## CONCRETE GREENHOUSE TRAYS.

Greenhouses are so warm that the moisture is soon dried out from the air. To supply the necessary amount of moisture, it is frequently advisable to keep a number of trays filled with water about the greenhouse. The larger the surface of these, the greater the evaporation, and hence the better producers of moisture. These trays are most satisfactory if constructed of concrete, because the concrete, unlike the wood ones, do not rot, and do not shrink if allowed to become dry and consequently need little attention to see that they are always filled. The concrete trays can be made very attractive, and are more serviceable than if made of any other material.

Make the trays like the slabs for tables (see page 140), except form a lip all around them to the required height. Brush a layer of pure "ATLAS" Cement, mixed to the consistency of thin cream, over the inner surface two or three hours after the concrete is poured to make them water-tight. Protect from sun and keep wet until they are to be used.

Frequently larger tanks are preferred, which may be made 18 inches wide by 18 inches deep, with 6-inch reinforced walls.



CONCRETE FLOWER BOXES.

## CONCRETE FLOWER BOXES.

Concrete veranda boxes for flowers do not rot and therefore do not have to be renewed every two or three years. They are attractive, too, not only on the porch of any stone, stucco or cement house, but are ornamental to a frame house.

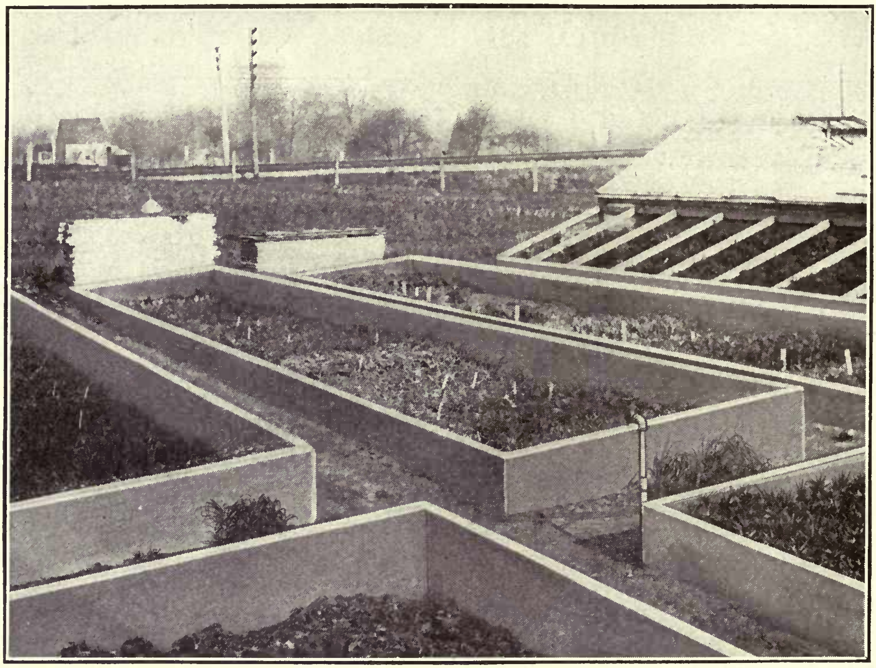
The length of the concrete veranda box is generally determined by the size of the space in which it is to be placed on the veranda. A good size is 5 feet long, 8 inches deep, and 10 or 12 inches wide. The outside forms consist of a long rectangular box, which may have the two long sides tapered if desired, so that the box will be 10 inches at the bottom and 12 inches at the top. This will make the finished concrete box look more attractive than if made with perfectly vertical sides. Use planed lumber in the forms and oil them thoroughly on all the surfaces coming in contact with the concrete. Line the outside form with poultry netting, folding it at the end or corners so as to make a reasonably close fit to the walls of the mold. Place the inside form, which consists of a bottomless frame having dimensions 3 inches smaller each way than the outside one, so as to make the walls 1½ inches thick. Set this inside form on little blocks of wood to keep the form raised 1½ inches from the bottom of the outside form. These wood pieces can be removed when the concrete is hard, and will leave holes in the bottom of the box for draining off the excess water.

CONCRETE FLOWER BOX AT PATERSON, N. J.

Mix a batch of concrete composed of one part "ATLAS" Portland Cement to three parts clean, gravelly sand which has been screened through a ½-inch mesh screen, that is, a screen having openings ½ inch square. Lay the concrete, which should be of the consistency of mortar for laying brick. Remove the inner form very carefully in an hour or two, but leave the outside form at least until the next day. The outside surface generally need not be finished off further than wetting it down thoroughly and rubbing it with a wood float or brick, but if desired it may be finished off as described on page 27. The box must not be moved for at least a week, for fear of cracking it. Wet it occasionally during this time.

## HOT-BED FRAMES.

Excavate a trench to a depth below frost and erect forms for a 4-inch wall. Fill with concrete mixture one part "ATLAS" Portland Cement, three parts clean, coarse sand and six parts broken stone or gravel, to level of the ground. On top of these build forms for a 3-inch wall to height desired, and fill with concrete of the same proportions. Remove the forms in two or three days and keep the walls damp for a couple of weeks.



CONCRETE COLD FRAMES AT WESTCHESTER, N. Y.

## WINDMILL FOUNDATION.

The great danger caused by the rotting of wooden windmill foundations is obviated by the use of concrete.

Excavate four holes at the proper distance apart, 2½ feet square and 5 feet deep; build forms for the sides and grease properly. Fill forms 2 feet deep with concrete, one part "ATLAS" Portland Cement, three parts clean, coarse sand, six parts broken stone or gravel, of a jelly-like consistency, tamping well every six inches. To insure proper location of holding-down

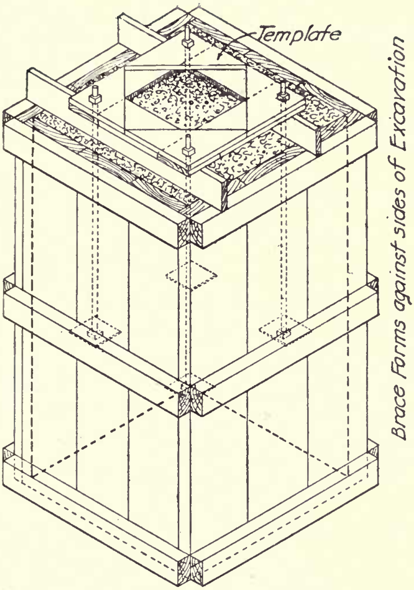
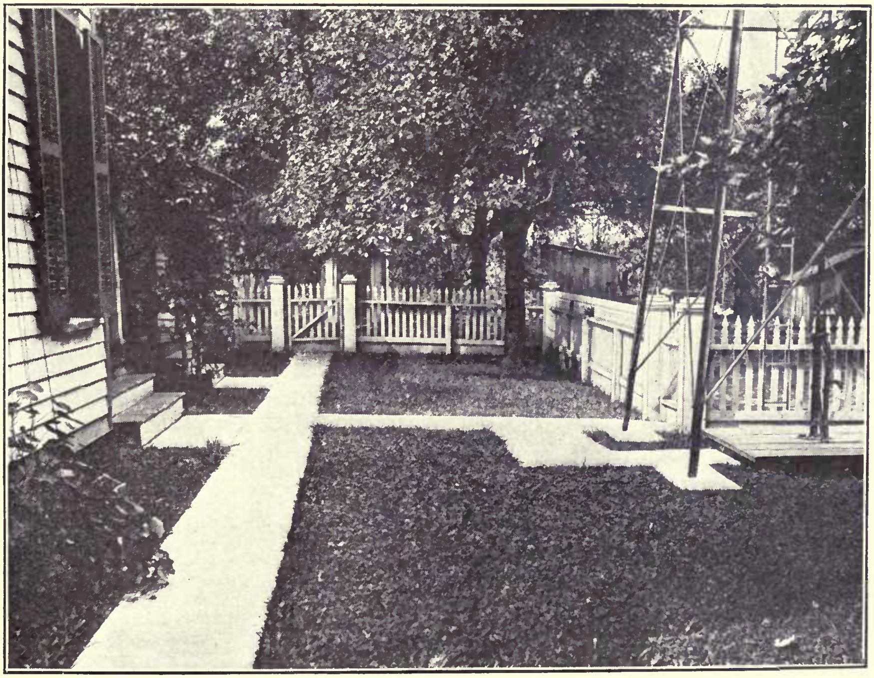


Fig. 39. Form for Windmill Foundation.

bolts, construct template and hang the bolts from it, as shown in Fig. 39, and fill in concrete around them until flush with top of form, and allow to set several days before using. This gives a substantial anchorage for a steel tower.

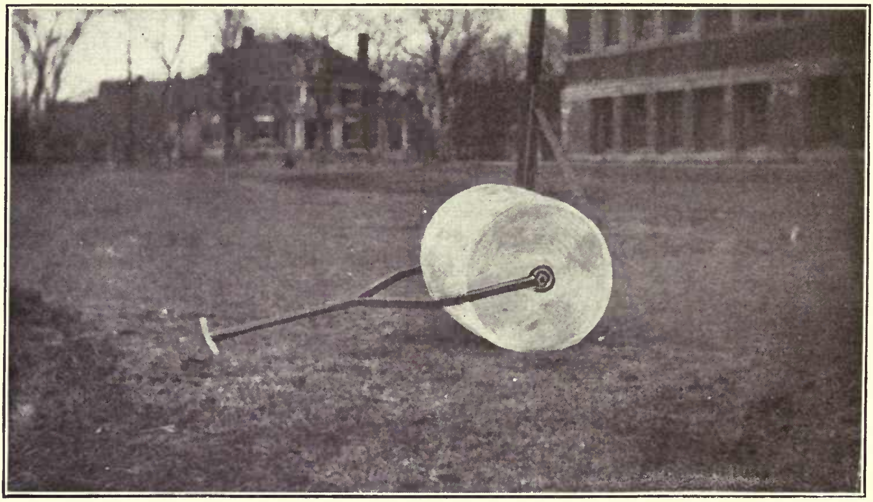
In case a wooden tower is to be used, run projecting bolts up through the timber sills and use large cast-iron washers under the nuts. The anchorage in this case should project at least 6 inches above the ground.



CONCRETE WALK AND WINDMILL FOUNDATION AT CLINTON, IOWA.

## CONCRETE ROLLER.

A concrete roller may be made as a hand roller to be operated by one or two men or as a horse roller, when it is, of course, larger and heavier. A hand roller for two men suitable for rolling lawns should be made about 18 inches in diameter and 24 inches long. This size of roller weighs about 530 pounds or 265 pounds, per foot of length. The roller shown below is of the dimensions first given and has been used very satisfactorily for several years.



CONCRETE ROLLER AT NEWTON, MASS.

A form for making a concrete roller is very easily and cheaply made, as shown in Fig. 40. For a roller 18 inches in diameter and 24 inches long cut a piece of sheet iron 24 inches by 25¼ inches. The edges must be cut even and must be square. Make two sets of wood clamps like the circular forms shown on page 20. The piece of sheet iron cut to the dimensions as given can now be bent in a circle and nailed, if necessary, to the two wood clamps. Wire the iron form or jacket with No. 16 wire to hold the form from opening at the joint when the concrete is placed. Grease or oil the inside of the form thoroughly so that it will not stick to the concrete. To make an opening through the center of the roller for an axle or shaft, place a ¾ or ⅞-inch iron pipe in the center of the form. The axle can be cast in the roller itself if desired instead of casting a ¾ or ⅞-inch pipe in the roller in which to place the axle. The concrete should be made of one part "ATLAS" Portland Cement to two parts of sand to four parts of stone or gravel. It will take a little less than one bag of cement for a roller of the above dimensions.

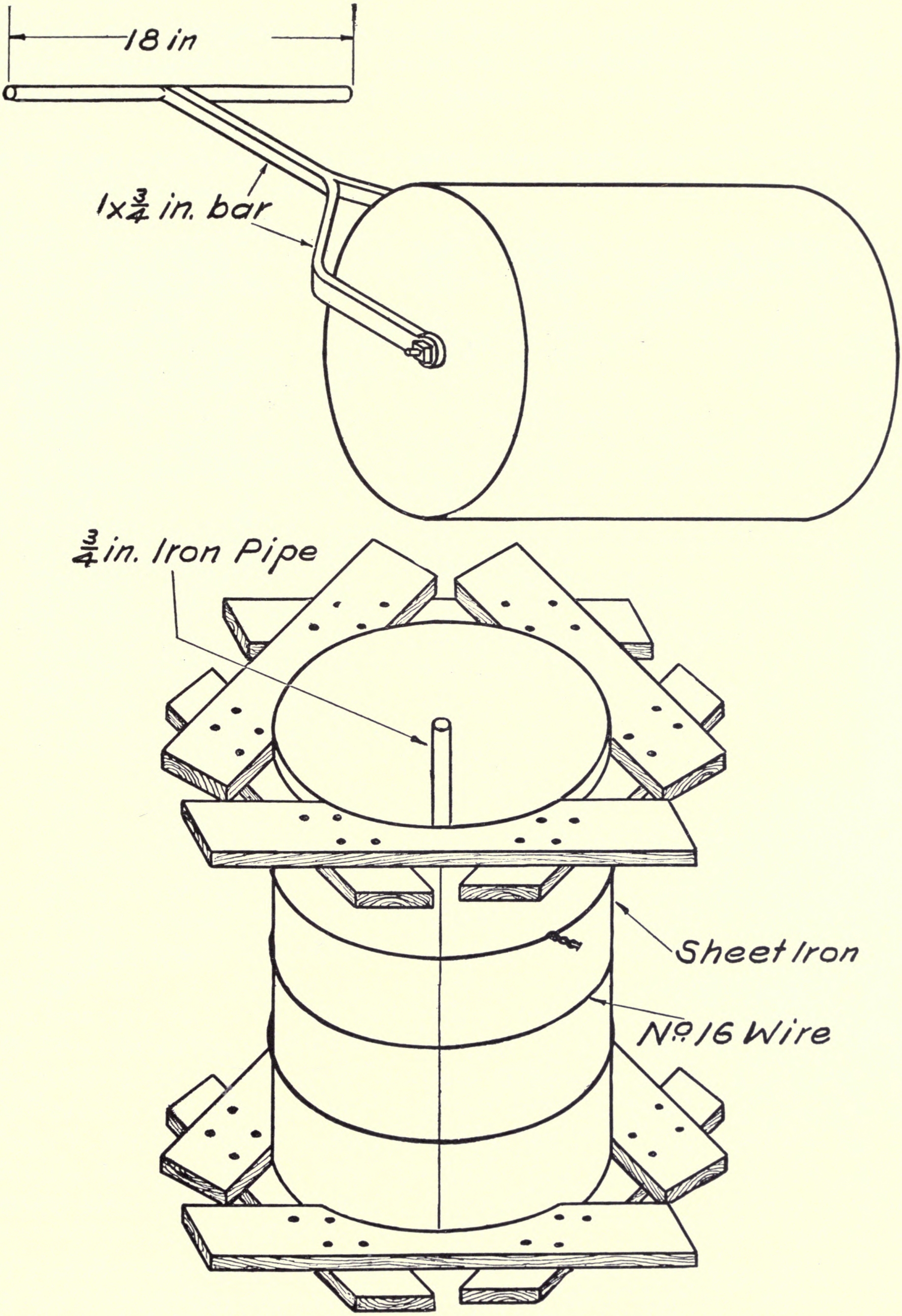


Fig. 40. Form for Concrete Roller.

The handle for a hand roller may be made of ¾-inch by 1-inch iron, bent and welded together as shown in the figure. Where the roller is heavier, or is to be operated by a horse, a heavier handle and different design of handle can be easily made.

A small roller for rolling seeded ground or golf greens may be made by pouring concrete into a piece of pipe which forms the outside surface.

DANCE PAVILION AT TWIN LAKE, HARRISTOWN, ILL.

## DANCE PAVILION.

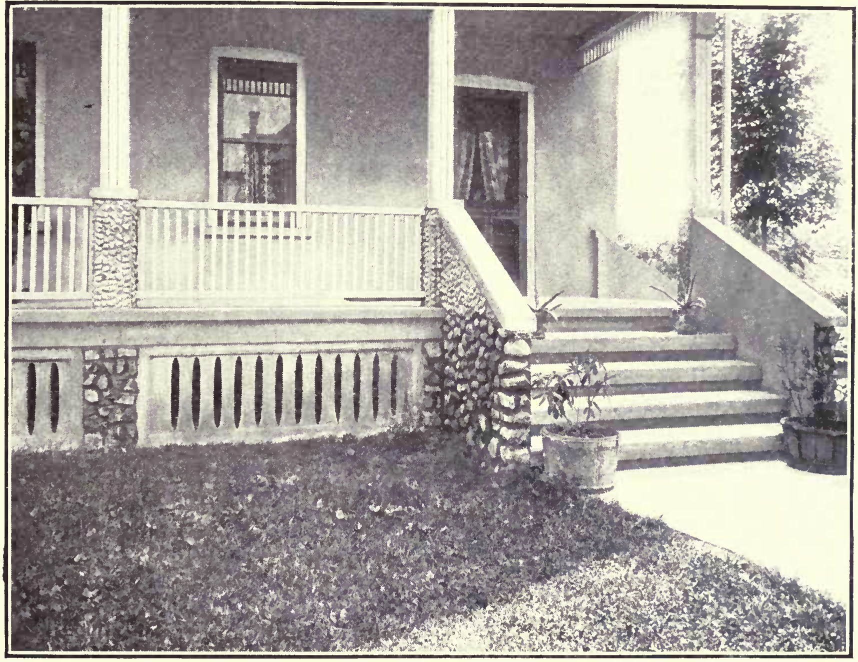
The photograph of the pavilion at Twin Lake, Harristown, Ill., shows what can be accomplished by a farmer and one farm hand who had never before had any experience with concrete. There are 16 posts in the 30 by 40-foot pavilion, each 8 inches by 11 inches, and the walls are 3 feet high and 4 inches thick. The lumber used for the forms was not cut up any more than necessary and was all used for the roof. Thirty-five barrels of "ATLAS" Portland Cement were required in the construction of the posts, walls and floor. Sand and gravel found on the farm was used and the concrete was proportioned one part "ATLAS" Portland Cement to seven parts of aggregates. A 3-inch floor was laid, using the same mix of concrete, and was surfaced with a ¾-inch coat of mortar, one part "ATLAS" Portland Cement to one part of sand.

The time required to make, place and remove forms was two days each for the two men. It took them 10 days to mix and lay the concrete for the entire structure.

## PIAZZA.

In building a concrete piazza the first care should be the supports. Unless these are strong and have a foundation that will not be affected by frost, the piazza is liable to prove a failure.

Erect two lines of 4-inch posts, 8-inch bases, 8 feet apart, extending below frost. The outer line of posts should be slightly lower than the inner line, which is next to the house to allow water to flow off the piazza. On top of and connecting these in both directions, build concrete cross beams and stringers 4 inches by 8 inches. Posts should be reinforced with a ⅜-inch steel bar and beams with two ⅜-inch bars placed one inch above the bottom. For a large piazza, refer to dimension of beams and reinforcement in Table for "Designing Reinforced Concrete Beams and Slabs," pages 30 and 31.



CONCRETE PORCH STEPS AND LATTICE AT WESTWOOD, N. J.

After the concrete has set hard, erect forms and build a solid slab of concrete over the entire framework, allowing it to project slightly over the outer edge. This slab should be reinforced with a woven wire fabric or expanded metal or with steel rods, using the size and spacing given for slabs in the Beam and Slab Table just mentioned.

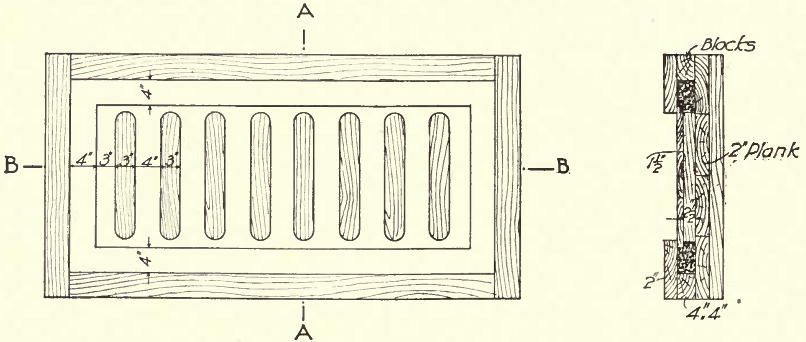
If preferred the forms for the beams and floor may be built at the same time, and the concrete poured in one operation.

A finished surface can be obtained by plastering the surface one-half inch thick with mortar, one part "ATLAS" Portland Cement and one part clean, coarse sand, before the concrete has set and trowelling it hard as the mortar begins to stiffen.

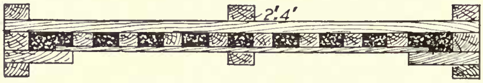
## LATTICE.

In building a lattice, the fact that there are two thicknesses of concrete, i. e., the thickness of the panel or border and the thickness of the lattice itself, should be borne in mind.

Build a form 8 inches higher and 8 inches longer than the size the finished lattice is to be, using 2-inch stuff. Along the top, bottom and at either end, nail a 4-inch by 4-inch scantling, and on these nail a 2-inch by 8-inch plank (see Fig. 41). On the back of the form, at equal distances apart and equal distances from the edge of the 2-inch by 8-inch plank, nail securely blocks of wood of the shape of the holes desired. (See holes in lattice in accompanying cut.) Lay the form thus made on the ground, face up, and block securely. Fill with concrete one part "ATLAS" Portland Cement, two parts sand and four parts fine broken stone or gravel to the level of small blocks for holes, and pack concrete all around under the 2-inch by 8-inch plank to form panel; tamp hard, making sure there are no voids. Smooth off face of concrete and let stand for a week, or until the concrete is thoroughly dry. If the surface is not smooth enough a coating of grout, one part "ATLAS" Portland Cement and one part fine, clean sand, mixed as thick as cream, may be applied with a brush after first roughening surface and wetting it thoroughly. A moderately dry concrete should be used in this form.



*Elevation of Lattice with part of Form removed.* *Section A_A*



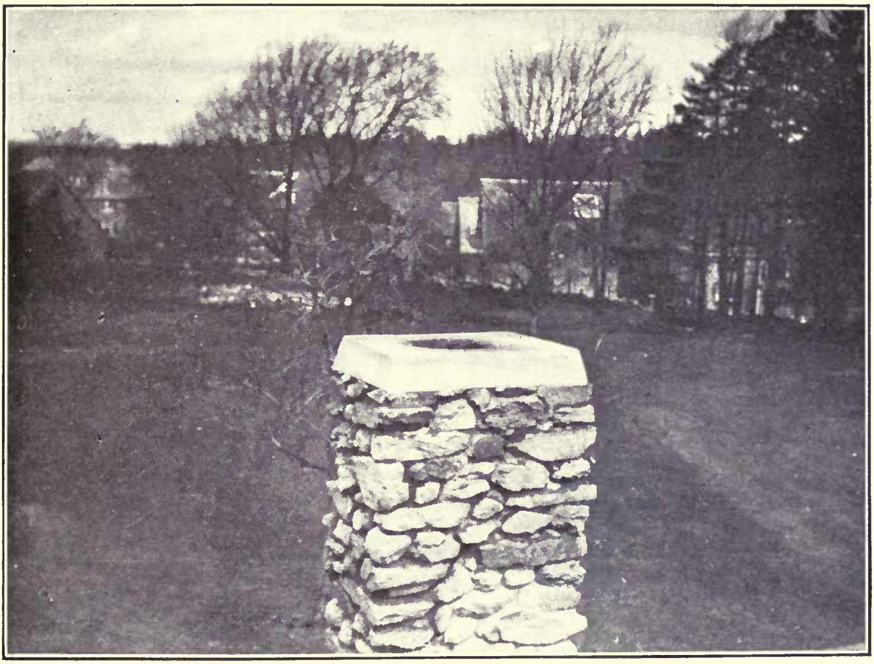
*Section B_B.*

Fig. 41. Forms for Concrete Lattice.

The lattice may be built in place by leaving off the 4 inches by 4 inches at the top of form and boarding up the open space in front of "hole-blocks" with a 1½-inch plank and pouring the concrete in from the top (Fig. 41). A very wet concrete should be used if this plan is followed.

## CHIMNEY CAPS.

Chimney caps of concrete are rapidly supplanting stone, brick or iron, as they are not only cheaper and more durable, but protect the top of chimney better.



CHIMNEY CAP AT CHESTNUT HILL, MASS.

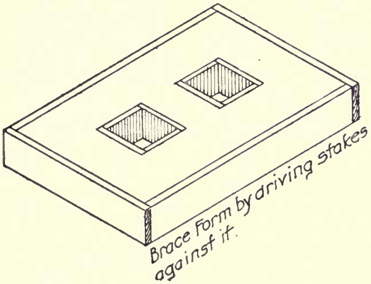
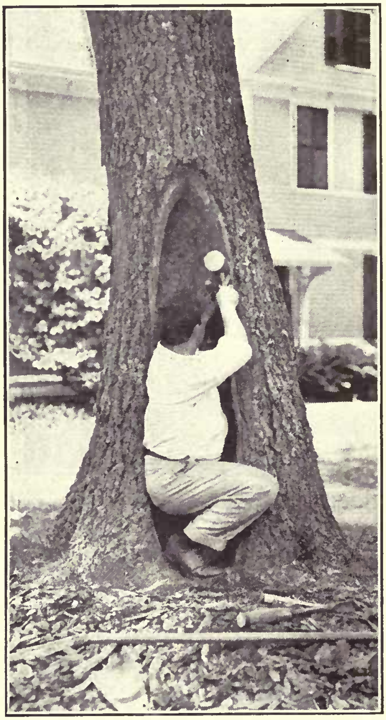


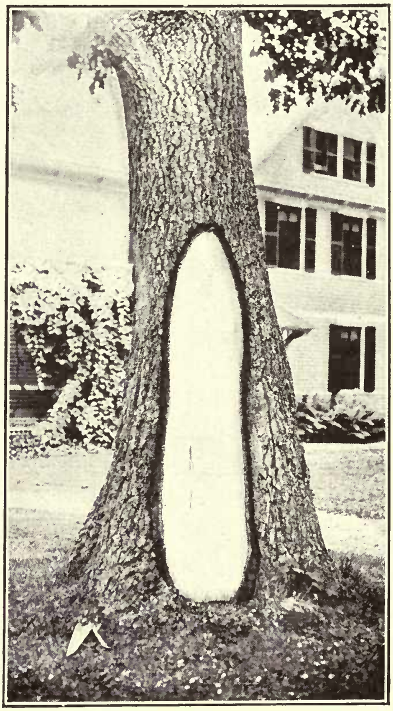
Fig. 42. Forms for Chimney Cap.

Make a bottomless box the size of the required cap, and one or more small bottomless boxes to correspond to the flue or flues of the chimney, and ½ inch higher, so that the surface of the concrete can be sloped to allow water to flow off, and set in place (Fig. 42). The thickness is usually about 4 inches, but this can be varied to suit convenience. Plaster the inside surface of the large mold with ½ inch of stiff mortar and then immediately fill form one-half full with one part "ATLAS" Portland Cement, three parts clean, coarse sand and six parts broken stone, and put in reinforcing, either woven wire, expanded metal or ¼-inch rods, complete, and tamp until water puddles on top. When partly set, trowel smooth.

If it is desired to build the cap in place, the following plan should be adhered to: Place small rods across the chimney between the flues. On these build platform of tongue and grooved board planed on upper side and driven snug together, but not nailed. On this platform place the forms previously described and fill with reinforced concrete. After the concrete has set (at least a week is needed) remove platform and rods by raising each side of chimney cap alternately and knocking platform apart. Remove outer and inner forms. Raise one end of slab, cover all accessible surface of top of chimney with mortar, lower cap on bed thus formed and remove rods under end. Repeat process at opposite end.



REMOVING DECAYED MATTER FROM TREE BEFORE FILLING



TREE WITH CAVITY FILLED WITH CONCRETE

## TREE SURGERY.

Tree surgery not only consists in cutting away all the decaying and dead matter of the tree, but embraces also the pruning and chaining of limbs, scraping, and filling of cavities. Through the skillful methods used by the tree surgeon it is possible to give a new lease of life to trees which apparently have reached their limit of existence. The cavities are caused by poor pruning of limbs, the breaking off of branches and other injuries. While the treatment of the cavities varies more or less in different cases, if the specifications given below are followed closely a good job should result.

The tree grows in girth by the deposit of a thin layer of new wood between the wood and the bark. It is this new layer and others recently formed which are known as the sapwood and form the active section of the trunk and branches. The inner rings are gradually covered by the yearly deposit of this new growth, and in turn the living sapwood becomes heartwood, which is dead, and serves merely as a strong framework for the living parts of the tree. This is the reason why hollow trees may often be found in a flourishing condition when the heartwood has entirely disappeared.

FILLING THE CAVITY. Cut out all the deceased and decaying part of the tree without regard to the size of the wound which is made. This must be cleaned out with the same thoroughness which a dentist uses when cleaning the cavity of a tooth for a filling. If all of the decayed matter is not removed the decay will continue as if the filling had not been placed. Disinfect the freshly cut surfaces with a coat of creosote or crude petroleum oil. Heat some coal tar and apply a thick coat to the disinfected surfaces. This coat of tar applied thick serves as a plastic substance to prevent any cracks between the cement and the wood from shrinkage.*

The cavity, if it is a large one, may be reinforced to better hold the concrete in place with either some woven wire mesh reinforcement or with small steel rods placed across from side to side of the cavity. Cut back the bark for about ⅜ of an inch or so around the entire wound in order to prevent bruising it while the work is in progress, and in order to get the cement perfectly flush with the wood, which cannot be done when the bark is not cut away.

For a large cavity some kind of a form must be used to prevent the concrete from caving out when it is being placed. For this boards may be fitted to the opening, leaving a space at the top to pour in the concrete; or metal, like zinc or tin, may be thoroughly greased and tacked on. When it is ready mix up a batch of concrete composed of one part "ATLAS" Portland Cement, two parts of sand and four parts of screened gravel or stone made up to a rather stiff consistency, about like jelly.

If the opening to the cavity is small, so that no form is required, trowel the surface of the concrete lightly so as to leave it smooth. If the concrete is too soft to make a good vertical surface or if the upper part of the cavity is

---

*Methods similar to these have been used by Mr. G. E. Stone, of the Massachusetts Agricultural College, for a number of years.

not entirely filled, wait for two or three hours until the concrete has begun to stiffen, ram it in again to completely fill the hole and then trowel the surface, adding a little stiff concrete if necessary.

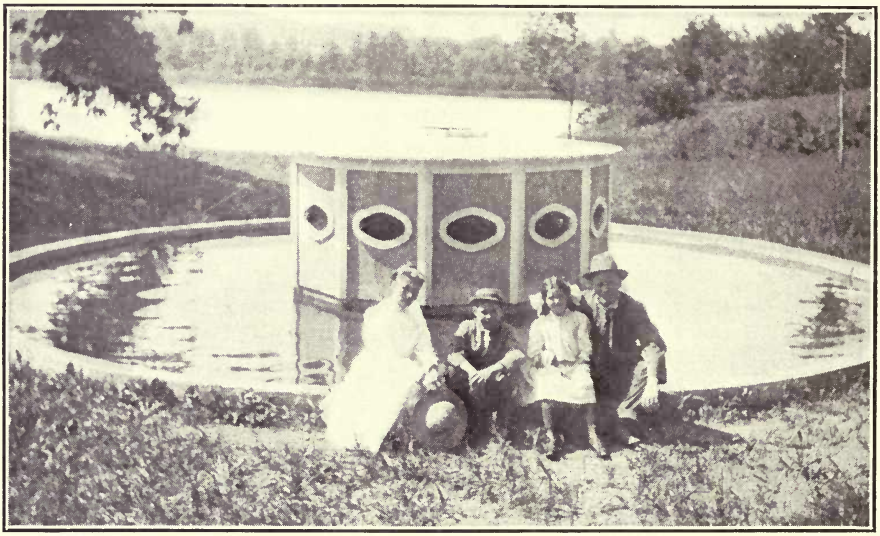
If forms are used, remove them as soon as possible, either in a few hours or else the next day, and go over the surface so as to slightly roughen it and remove the form marks.

The bark on a tree treated in this way will in time grow over the concrete and in some cases not even leave a scar.

## CONCRETE AQUARIUM.

Aquariums constructed of concrete can be made attractive and have been found very serviceable. At the fisheries at Cold Springs Harbor, L. I., some of these concrete aquariums have been in service since 1904 and look as good to-day as when first made.

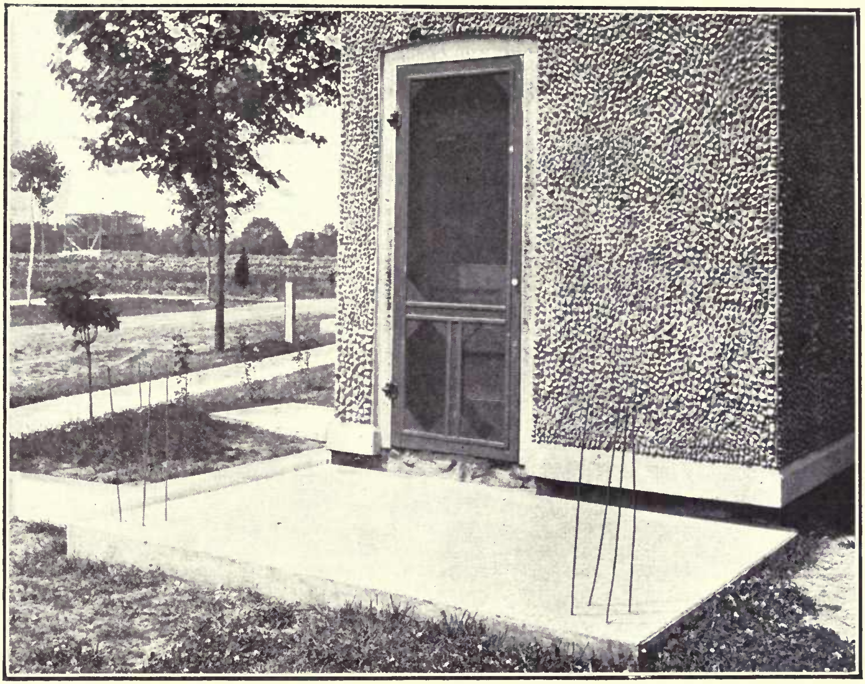
Make the base or bottom of each tank 18 by 31 inches and the vertical sides 13 by 15 inches, all being 2 inches thick. Make the sides with vertical grooves 1¼ inches from the edge in order to set in the glass sides. Leave grooves in the bottom also so that the glass sides can be puttied in and be made water-tight at the joints.



THIRTY-FOOT DIAMETER CONCRETE FOUNTAIN AT UNION, PA.
(1:4 Mix, 6-inch Thick Walls, 10 inches Deep)

## CONCRETE BLOCKS.

During the past few years concrete blocks have been used extensively and many patents have been granted the manufacturers of concrete block



DETAIL OF CONCRETE PEBBLE-FINISHED RESIDENCE AT WESTWOOD, N. J.

STUCCO COTTAGE AT CEDARHURST, L. I.

machines for the various devices and methods employed. Buildings constructed with concrete blocks have proved satisfactory when the blocks have been made with care and with proper materials.

## STUCCO.

Stucco work is cement plastering, and, in one form or another, has been in use for ages. It is durable, artistic and impervious to weather. For veneering new buildings, or protecting old structures, and wherever the cost of solid concrete is prohibitive, Portland Cement Stucco cannot be equaled.

Stucco work may be used to cover wood, brick, stone or any other building material, provided special precautions are taken in preparing the surface properly so that it will adhere and not crack or scale off. The work should be done by an experienced plasterer.

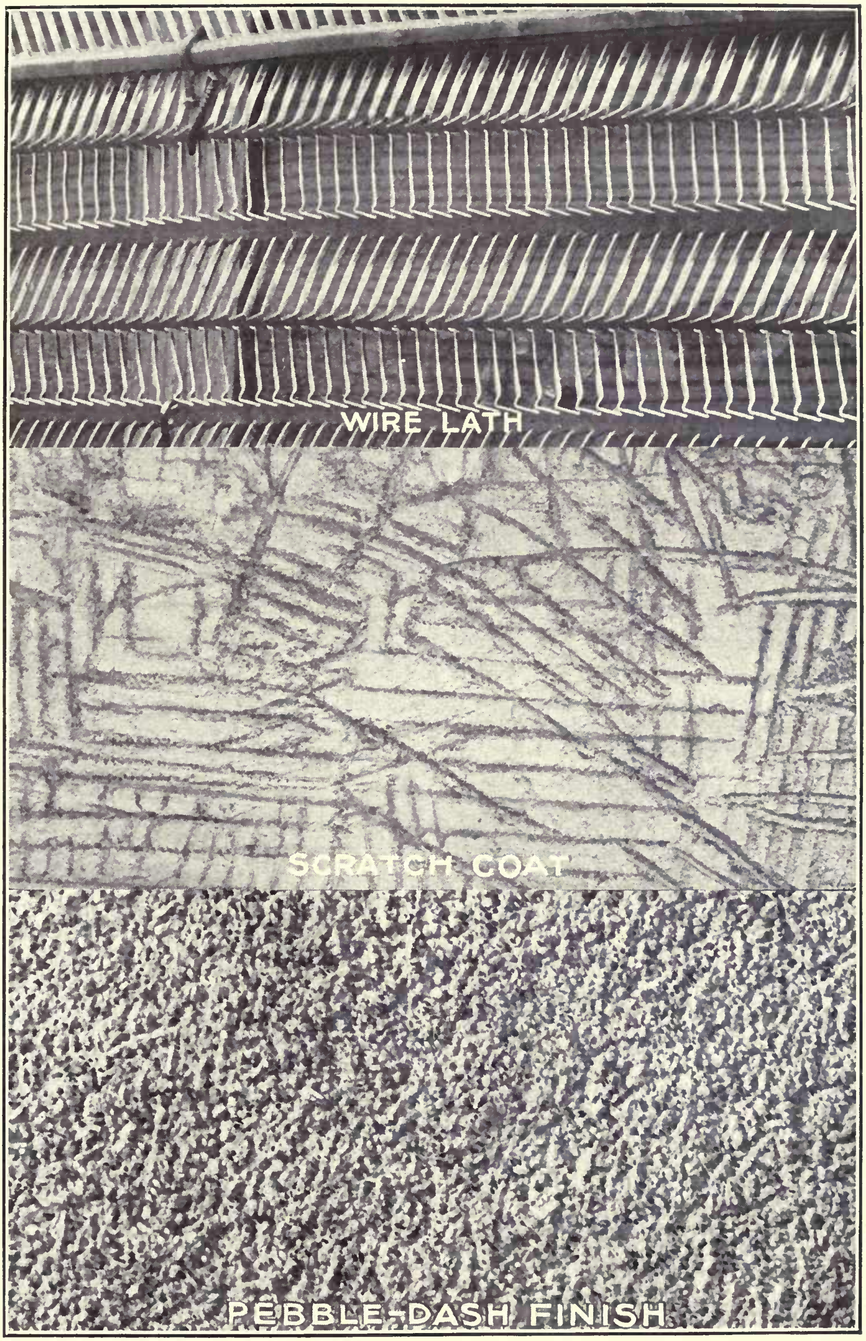
As a rule two coats are used—the first, a scratch coat composed of five parts "ATLAS" Portland Cement, twelve parts clean, coarse sand and three parts slaked lime putty and a small quantity of hair; the second, a finishing coat composed of one part "ATLAS" Portland Cement, three or even five parts clean, coarse sand and one part slaked lime paste. Should only one coat be desired the finishing coat is used. Some masons prefer a mortar in which no lime is used, but this requires more time to apply it.

To apply Stucco to brick or stone or concrete, clean the surface of the wall thoroughly, using plenty of clean water so as to soak the wall. If the surface is concrete roughen it by picking with a stone axe. Plaster with a 1½-inch coat and finish the surface with a wood float, or to make a rough surface cover the float with burlap. Protect the stucco work from the sun and keep it thoroughly wet for three or four days; the longer it is kept wet the better.

In using Stucco on a frame structure, first cover surface with two thicknesses of roofing paper. Next put on furring strips about one foot apart, and on these fasten wire lathing. (There are several kinds, any of which are good.) Apply the scratch coat ½ inch thick and press it partly through the openings in the lath, roughing the surface with a stick or trowel. Allow this to set well and apply the finishing coat ½ inch to 1 inch thick. This coat can be put on and smoothed with a wooden float, or it can be thrown on with a trowel or large stiff-fibered brush, if a spatter-dash finish is desired. A pebble-dash finish may be obtained with a final coat of one part "ATLAS" Portland Cement, three parts coarse sand and pebbles not over ¼ inch in diameter, thrown on with a trowel.

## COLORING FOR CONCRETE FINISH.

The use of colored concrete up to the present time has not been general, and the effect of coloring ingredients upon the strength of concrete is not definitely known.



METHOD OF APPLYING PEBBLE DASH FINISH

In his book on "Cement and Concrete,"* Mr. L. C. Sabin, an eminent authority, states that the dry mineral colors mixed with the water in proportions by weight of from two to ten per cent. of the cement give shades approaching the color used, with no apparent effect on the early hardening of the mortar.

Mr. Sabin also gives the following table, showing the result obtained from a dry mortar (wet mortars give a darker shade):

**COLORED MORTARS**

**Colors Given to Portland Cement Mortars Containing 2 Parts River Sand to 1 Cement.**

| Dry Material Used | Weight of Dry Coloring Matter to 100 Pounds of Cement | | | | Cost of Coloring Matter per Pound, Ct. |
|---|---|---|---|---|---|
| | ½ Pound | 1 Pound | 2 Pounds | 4 Pounds | |
| Lamp Black | Light Slate | Light Gray | Blue Gray | Dark Blue Slate | 15 |
| Prussian Blue | Light Green Slate | Light Blue Slate | Blue Slate | Bright Blue Slate | 50 |
| Ultra Marine Blue | ............. | Light Blue Slate | Blue Slate | Bright Blue Slate | 20 |
| Yellow Ochre | Light Green | ............. | ............. | Light Buff | 3 |
| Burnt Umber | Light Pinkish Slate | Pinkish Slate | Dull Lavender Pink | Chocolate | 10 |
| Venetian Red | Slate, Pink Tinge | Bright Pinkish Slate | Light Dull Pink | Dull Pink | 2½ |
| Chattanooga Iron Ore | Light Pinkish Slate | Dull Pink | Light Terra Cotta | Dull Brick Red | 2 |
| Red Iron Ore | Pinkish Slate | Dull Pink | Terra Cotta | Light Brick Red | 2½ |

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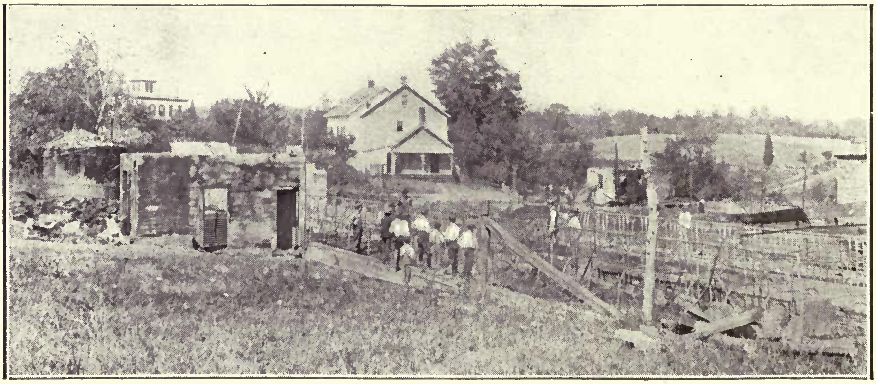
*"Cement and Concrete," Louis Carlton Sabin; McGraw Publishing Company, N. Y.



BURNT BARN AT BROOKSIDE FARM SHOWING CONCRETE BUILDING IN REAR IN WHICH THE LEAD TRAPS ON THE SINKS WERE NOT EVEN MELTED OFF

## CULVERTS.*

Concrete culverts of all sizes and shapes are being constructed not only where the roads have been fully developed, but also on a great many farm roads. They are cheaper than wooden culverts considering that the wooden ones rot out every few years. If desired, they can be made quite artistic.

Culverts vary greatly in size, from those which are nothing more than a large sewer pipe to those which span a wide stream.

CULVERT AT HARRISTOWN, ILL.

The bore or opening through which the water passes may be made either circular or rectangular. Culverts are generally built with a circular bore, although the forms for these are more difficult to make than for the rectangular, so that frequently the latter are much cheaper.

A culvert should be built, if possible, during the dry season or when the water is low. When of such size as to make it impracticable to build it by having the water flow through the center in a trough or flume, then build a dam above the culvert and convey the water around one side of the proposed new structure while the work is in progress by means of a wooden trough or a deep ditch.

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*For further detail information see "Concrete in Highway Construction," published by The "ATLAS" Portland Cement Co.

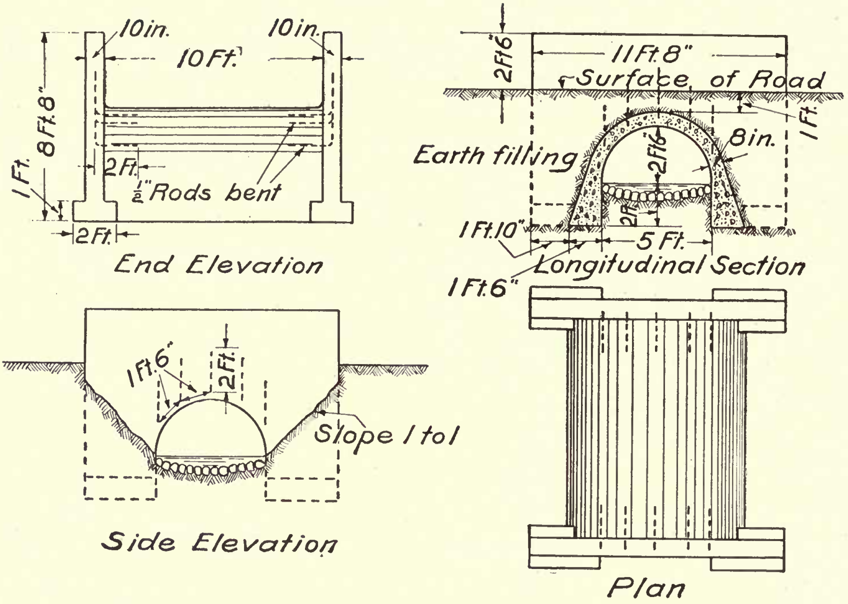


Fig. 43. Design for a 5-Foot Arch Culvert.

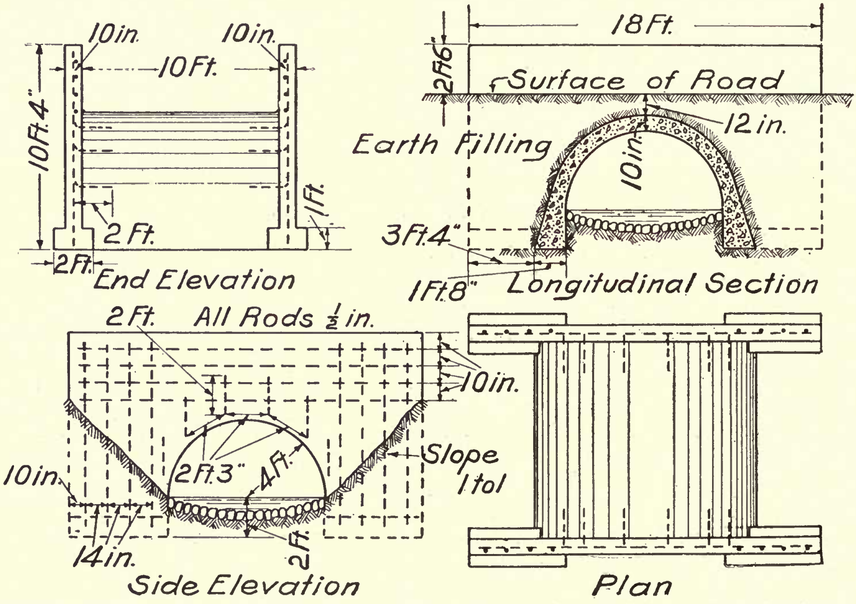
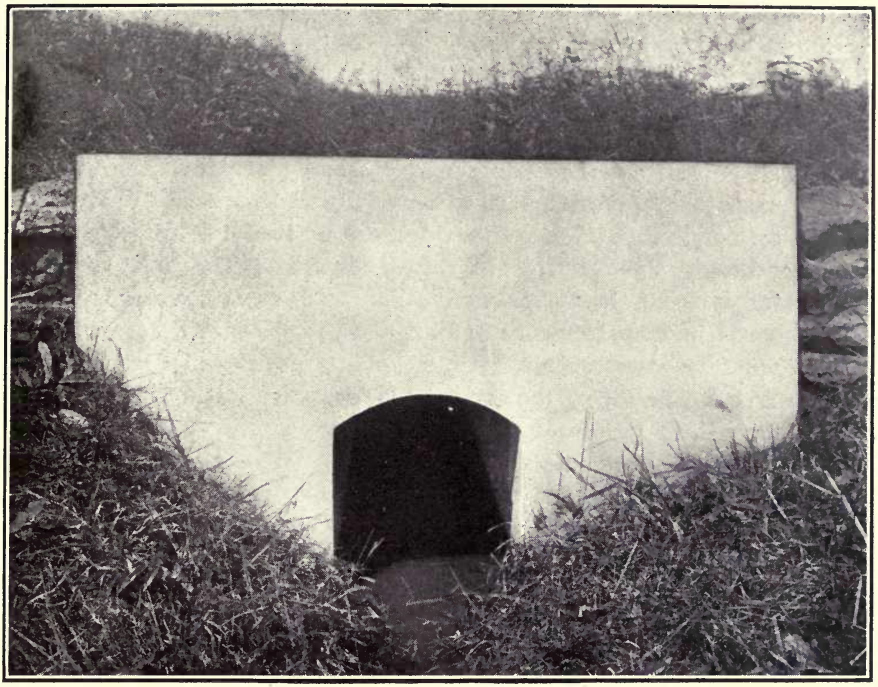


Fig. 44. Design for an 8-Foot Arch Culvert.



CULVERT AT DES MOINES, IOWA.

CULVERT AT MORTON, ILL.

The footings of the culvert can usually be laid directly on the earth in the bottom of the trench dug for them. Where the ground is soft, place wide footings under the culvert, and if deep marsh is encountered excavate to hard soil and fill with gravel well rammed or else drive piles to prevent the settlement.

In a small culvert set the forms complete and place the concrete for the whole culvert in one operation. In a large culvert this is not practicable, in which case set rough forms for the footings and up to the springing line of the arch. After laying the concrete to this level set up the arch centers and wing wall forms. Oil the forms well. The wing wall forms may be built of 1-inch boards laid horizontally against 2 x 4-inch studs. The inner wing wall form must be cut somewhat to the shape of the arch or stepped off around the arch. The top of the arch needs forms from the springing line up to about one-half to three-quarters of the way to the crown, as the wet concrete will not stand on so steep a slope.

The mix of concrete for culverts should be one part "ATLAS" Portland Cement to two and one-half parts of clean, coarse sand to five parts of screened gravel or broken stone. The amount of materials for the culverts given in Figs. 43, 44 and 45, is tabulated in the table below. If the excavation must be deeper than shown, of course more material will be needed.

AMOUNT OF MATERIALS FOR ARCH CULVERTS.

| MATERIALS FOR CULVERT FOR 10-FT. ROADWAY (See Fig. 46) | | | | EXTRA MATERIAL FOR EACH ADDITIONAL FT. WIDTH OF ROAD | | |
|---|---|---|---|---|---|---|
| Span of Culvert Feet | Cement Bags Bbls. | Sand* Double Load | Screened* Gravel or Stone Double Load | Cement Bags Bbls. | Sand Double Load* | Screened Gravel or Stone* Double Load |
| 5 | 50 or 12½ | 3 | 6 | 2 or ½ | ⅛ | ¼ |
| 8 | 80 or 20 | 4¾ | 9½ | 3 or ¾ | $$ | ⅜ |
| 10 | 115 or 28¾ | 7 | 14 | 4 or 1 | ¼ | ½ |

*A double load of sand or gravel is taken as 40 cubic feet or about 1½ cubic yards.

Fig. 46 shows a form for an arch culvert and also the flume box in place to take care of the water during construction. The inside wall form is constructed in the same manner as the wall forms previously explained, except that a 3 by 4-inch or a 4 by 4-inch ranger is set across the top of the cleats on which the wedges are placed to support the arch form. The wedges should separate the two forms at least 3 inches so that when the forms are

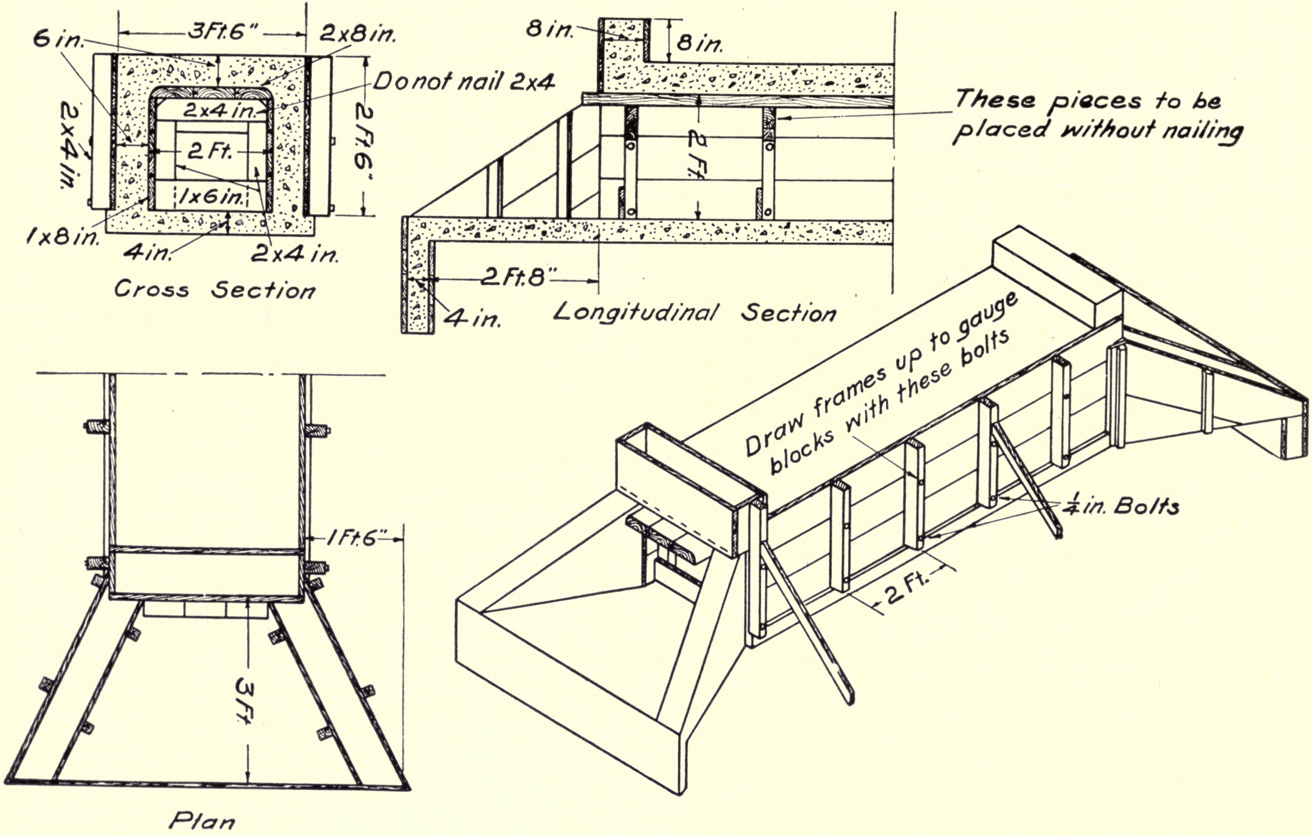


Fig. 47. Form Construction for Square Culvert.

to be removed the arch center can drop this distance and be readily removed. A strip of sheet iron should be nailed to the side forms as shown and lap over on to the arch form to prevent the concrete from getting in between the forms, in which case it would be impossible to remove the arch form without breaking it to pieces. After pulling out the arch form the side forms can be easily removed. The circular forms or braces which support the 1½-inch lagging should be placed on 4-foot centers, or if 1-inch lagging is used space the forms 2 feet apart.

Fig. 47 is the standard type of form and culvert used by the Iowa State Highway Commission. The invert or water table in this case is shown as a concrete slab, but this may be omitted in some cases and can be used if desired in an arch culvert as well. Where an invert or bottom of concrete is used it must be protected at both ends by an apron, as shown in the figure, to prevent the water from washing the earth from underneath it.

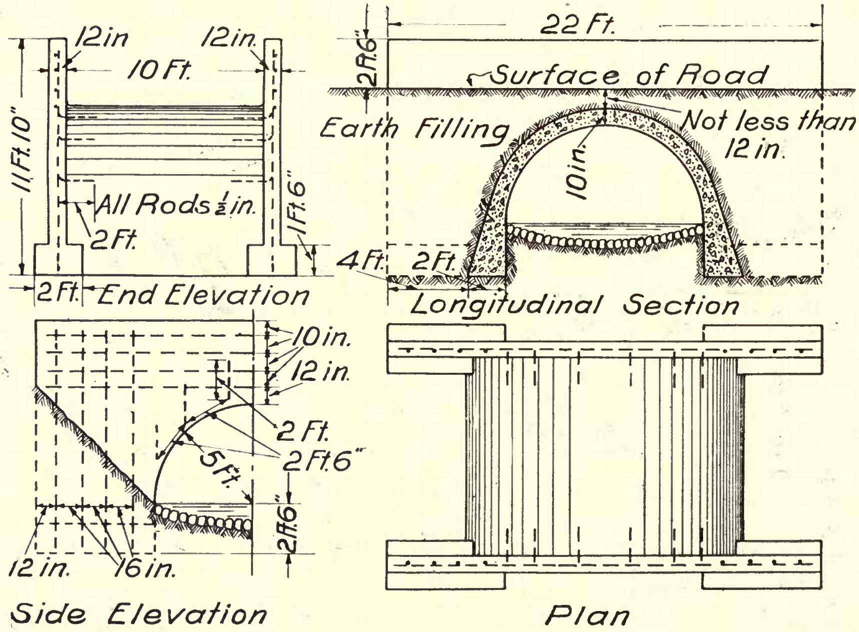


Fig. 45. Design for a 10-Foot Arch Culvert.

A good method of making the invert of a culvert is to lay cobble or field stones as shown in the figures. This can be done even when there is considerable water running through the culvert, and should a dry spell occur the cobbles can be plastered or grouted over, making a very satisfactory and efficient invert.

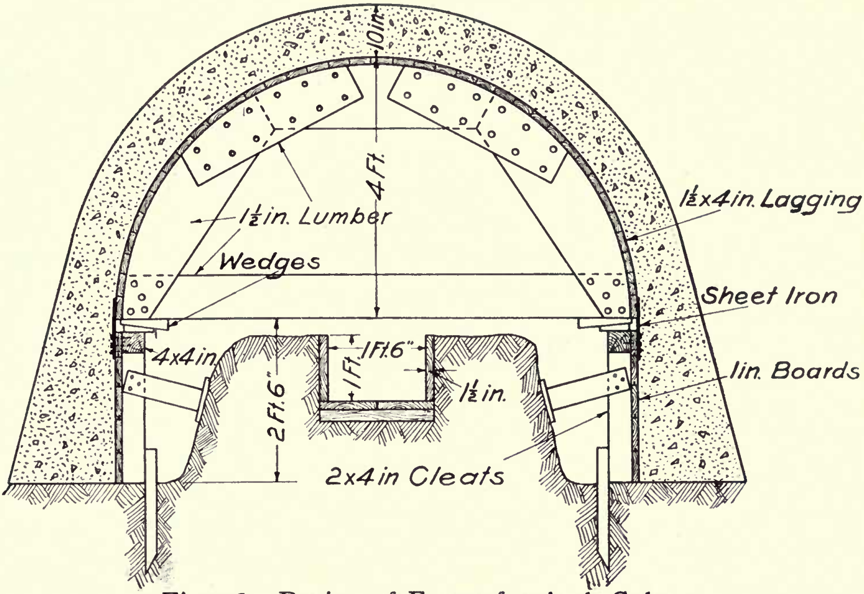
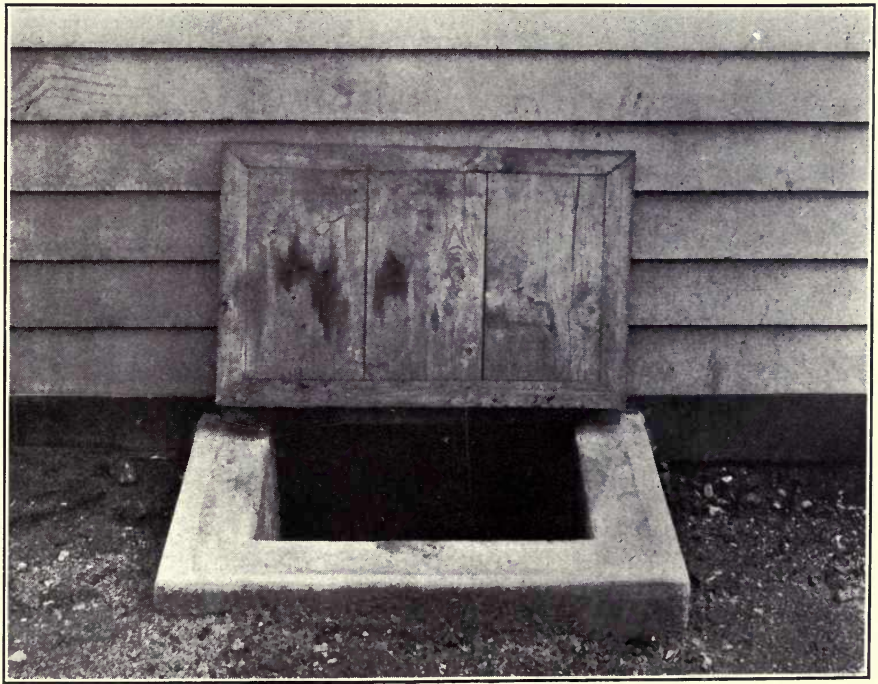
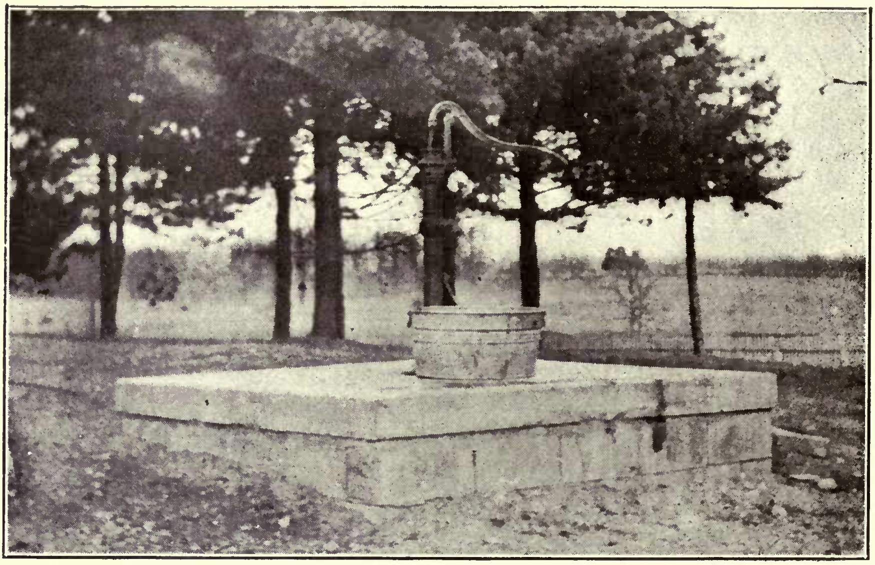


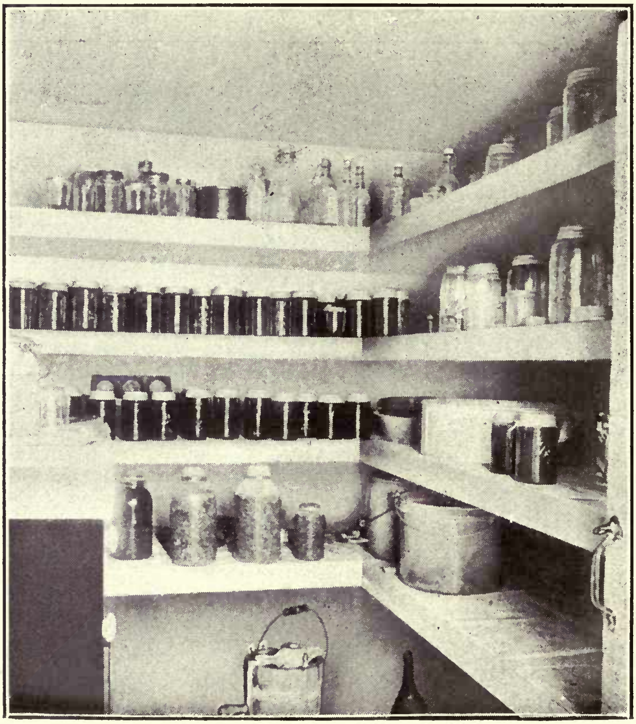
Fig. 46. Design of Forms for Arch Culvert.



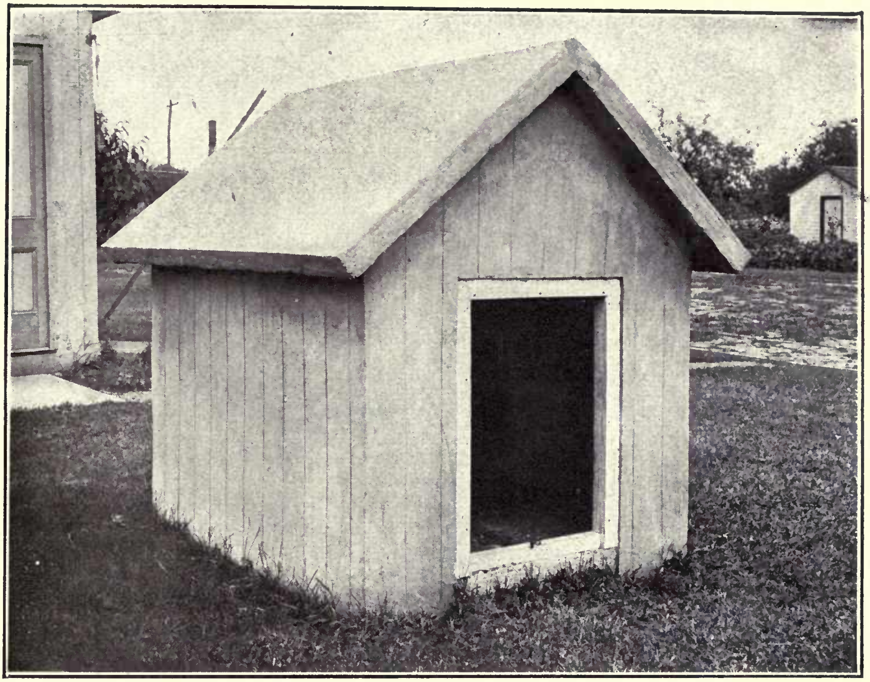
CONCRETE COAL CHUTE, DUMONT, N. J.



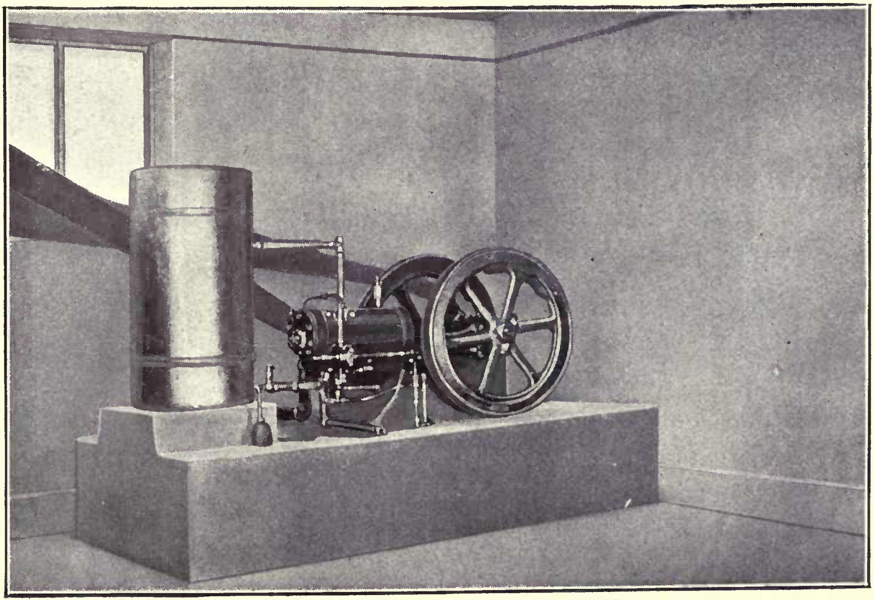
CONCRETE CISTERN COVER, HARRISTOWN, ILL.



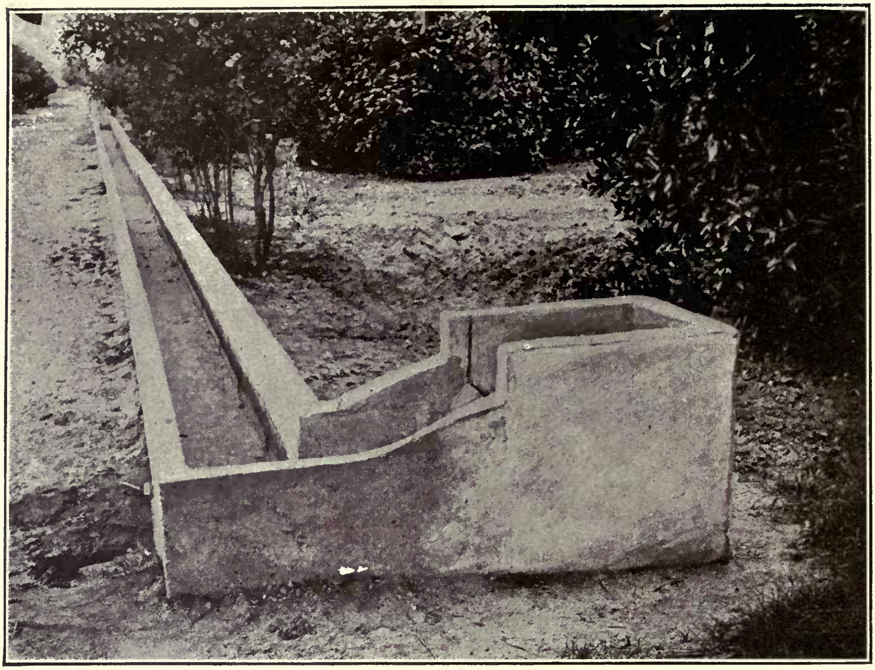
FRUIT CELLAR AT WESTWOOD, N. J.



DOG HOUSE AT WESTWOOD, N. J.



ENGINE BASE IN WELL HOUSE AT COLUMBIA, MO.



CONCRETE FLUME, REDLANDS, CALIFORNIA

CONCRETE BLOCK FIREPLACE AT CEDAR BROOK, N. J.

# CONCRETE IN HIGHWAY CONSTRUCTION

A Text-Book for Highway
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CONCRETE BRIDGE OVER THE YELLOWSTONE RIVER, YELLOWSTONE NATIONAL PARK

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## CHAPTER VII.—RETAINING WALLS.

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# FOREWORD.

The development of manufacture and of agriculture, which require proper transportation facilities not only on the railroads but to the points of shipment and distribution, has stimulated a widespread interest and called national attention to the necessity for better pavements and for highway constructions of a more permanent and durable character.

This demand, as well as the necessity for reducing the expense of repairs incident to automobile traffic, has brought to the forefront the use of concrete to produce permanent construction, not only for sidewalks and pavements, but for highway structures, such as bridges, retaining walls, culverts, and the many smaller details, the repairs to which are continually vexing the City and Town Engineer and the Highway Commissioner.

The purpose of the present volume, then, is to present to those in charge of street and highway construction and maintenance, examples of work which have been satisfactorily performed, and, further, to give drawings and designs made especially for The "ATLAS" Portland Cement Company, either as reproductions of existing structures, from drawings and photographs kindly furnished by the local authorities, or as original designs prepared by expert engineers at the request of the "ATLAS" Portland Cement Company.

The most important matter of sidewalk construction is taken up in considerable detail, while concrete street pavement construction has been thoroughly investigated, and recommendations made of methods which have produced durable and satisfactory results. Numerous examples and suggestions are given in the line of bridge design and construction, both for arches and flat bridges; sewers, culverts and retaining walls are quite thoroughly treated; and such minor structures as drains, brook linings, fences and posts, are illustrated and described.

Although the information in this little volume is more valuable and in much greater detail than is customarily presented by manufacturing companies, the position of The "ATLAS" Portland Cement Company as the leading cement manufacturers in the world has led them to present data which will tend not only toward an increasing use of cement but toward a use of cement according to the best, safest and most economical practice.

This present volume together with the other books of The "ATLAS" Portland Cement Company, namely, "Concrete Construction About the Home and on the Farm"; "Concrete Country Residences"; "Reinforced Concrete in Factory Construction," and "Concrete in Railroad Construction," covers a wide range in the use of concrete.

THE ATLAS PORTLAND CEMENT COMPANY.

New York, June, 1909.

## CHAPTER I.

## CONCRETE.

During the year 1907 the State Highway Commission of Massachusetts spent $468,000 in the construction of new roads and $106,000 for repairs and maintenance of roads in its charge. The State Highway Department of Pennsylvania expended $3,187,000 in the construction of new roads up to January 1, 1908, and in the report of this department for 1907 the sum of $29,225,000 is given as the total cost of roads completed, under contract and to be built. Other States are similarly engaged in building new roads, and improving old ones so that the movement for better roads and streets is almost universal. Such enormous costs of construction and maintenance show the necessity for the selection of materials which, in the long run, are the cheapest and most economical.

Concrete is playing a large part in this construction and re-construction, not so much in the roadbed proper, although as is shown in the pages which follow, concrete street pavements are well adapted to certain conditions, but especially for the various structures which are necessarily incidental to road building.

This class of work includes not only such structures as are necessary in first-class streets or highways, such as culverts, bridges and retaining walls, but also in the roadway itself, either as a foundation for a stone, brick or asphalt surface, or as a complete pavement including foundations and wearing surfaces.

For smaller uses concrete has a still wider field. For sidewalks, curbs and gutters its use is becoming quite universal, while as a material for drain tiles, lamp posts of various styles, hitching posts, fence posts, and many other highway appurtenances, its value is fast being recognized as is shown by the enormous increase in its use for such purposes. As a material for building park structures, such as bridges, buildings, drinking fountains, and seats, concrete is well suited because of its cheapness, durability, and the ease with which it is molded into artistic designs.

In the larger structures such as bridges and retaining walls, especially where steel reinforcement is necessary to give the required strength, a proper design with good working drawings showing the dimensions and the location of the steel is of the utmost importance, and where the structure is of appreciable size a competent engineer familiar with the principles of design and with practical construction in concrete should be employed to prepare plans and specifications, and to superintend the construction. On the other hand, many of the minor details can be built with but little engineering experience, provided directions given by competent authorities are carefully followed, and good judgment is used in the selection of the materials and in the work of construction.

The principal requisites of a material used in building various structures forming the necessary parts of a well-constructed, modern highway are cheapness and durability. If the first cost of the structure is to be small the materials used in its construction must be cheap and must be easily placed in position by ordinary workmen, and if the cost of maintenance is not to be excessive the materials used must possess qualities that will enable them to withstand the elements successfully. Wood, steel, stone, and concrete are in general the principal materials used in the construction of highway appurtenances such as bridges, culverts, sidewalks, curbs, and gutters. Of these four materials wood is usually the cheapest in first cost for small structures and is the least durable of all. The cost of maintenance of ordinary wooden bridges is so great and the life is so short that wood is really no longer considered seriously as a material for first-class construction, especially in those localities where lumber is scarce. Stone is generally a durable material of construction, but its first cost, and in many places its scarcity, tend to limit its use for highway purposes. It is also difficult and expensive to shape stone into desired forms which in many cases are required to secure the best results. The importance of steel in the construction of highway bridges of long spans is well understood, but its cost and the constant heavy maintenance charges, or its rapid deterioration if not properly maintained, have caused builders of bridges to seek some other material which is lower in first cost and which will not require constant painting. Clearly, concrete, or concrete with steel imbedded in it to reinforce it, is the material above all others that combines the advantages of cheapness and durability. Concrete can be made at small expense in practically any locality; can be molded in any desired shape or size; requires no maintenance, and can be placed in position with very little skilled labor.

In making concrete the cement, sand, and stone or gravel should be carefully chosen, thoroughly mixed, and properly laid. If these precautions are taken the mass will begin to stiffen in an hour or so after being laid and will continue to harden until in about one month's time the mass becomes a hard compact stone.

## CEMENT.

Portland cement of first-class reputation should be used to obtain the greatest uniformity, reliability and the highest strength. If the work is small and unimportant and a brand of cement of first-class reputation is purchased from a reliable dealer no testing is necessary, but for important structures the cement should be tested and should meet the requirements of the American Society for Testing Materials.* If it is impracticable to make these complete tests, specimens may be made to see if the cement sets up properly. The following, also, is a simple test for determining the soundness of the cement:

A sound cement will not crumble when placed in the work and a test for soundness is therefore of considerable importance. Oftentimes no other test need be made. Mix, by kneading 1½ minutes, one cupful of Portland cement with enough water to form a paste having a consistency like that of ordinary putty. Place part of this paste on each of 3 pieces of glass about 4 inches square so as to make a pat about 3 inches in diameter and ½ inch thick at the center tapering down to a thin edge. Leave these 3 pats under a damp cloth arranged so that it will not touch them for 24 hours. Then place one pat in air at an ordinary temperature for 28 days, a second pat in water for 28 days, and the third pat in a tightly closed vessel over boiling water for 5 hours. If the cement is of good quality the pats will show no radial cracks and they will not crumble. If the time is limited and the pat placed in steam shows no signs of crumbling the cement may be accepted on this steam test alone.

Portland cement is manufactured from a mixture of two materials, one of them a rock like limestone or a softer material like chalk which is nearly pure lime, and another material like shale, which is a hardened clay, or else clay itself. In other words, there must be one material which is largely lime and another material which is largely clay, and these two must be mixed in very exact proportions determined by chemical tests, the proportions of the two being changed every few hours to allow for the variation in the chemical composition of the materials.

"ATLAS" Portland Cement is made by quarrying each of these materials, crushing them separately, mixing them in the exact proportions, and grinding them to a very fine powder. This powder is fed into long rotary kilns, which are iron tubes about 5 or 6 feet in diameter lined with fire brick and over 100 feet long. Powdered coal is also fed into the kilns and burned at a temperature of about 3,000 deg. Fahr., a temperature higher than that needed to melt iron to a liquid and there is formed what is called cement clinker, a kind of dark porous stone which looks almost exactly like lava.

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*These may be obtained by addressing The Atlas Portland Cement Company.

After leaving the kiln, the clinker is cooled, crushed, and ground again to a still finer powder, so fine, in fact, that most of the particles are less than 1/200 of an inch in size, and this grinding produces the light gray-colored powder characteristic of "ATLAS" Portland Cement.

It is now placed in storage tanks or stock houses where it should remain for a while to season before it is put into bags or barrels and shipped. The barrels weigh 400 pounds gross, or 376 pounds net. When shipped in bags the weight is 94 pounds per bag, four bags being equal to one barrel.

At the "ATLAS" plants from the time the rock is taken from the quarry until it is packed in barrels or bags all of the work is done by machinery, and a thorough chemical mixture takes place regulated by the experienced chemists in charge of the work.

## STORING CEMENT.

Cement should come packed in barrels or in stout cloth or canvas bags and should be stored in a dry place, preferably a house or shed until used, or if no such storage house is available the cement should be placed on a wooden platform raised at least 6 inches above the ground and should be covered so as to exclude water. When used the cement should be free from lumps.

## SAND OR FINE AGGREGATE.

The term aggregate includes the stone and sand in concrete and may be classified as fine and coarse. The fine aggregate may be sand or crushed stone or gravel screenings which will pass when dry a screen having ¼ inch diameter holes. If sand is used it should be clean and coarse, or a mixture of coarse and fine grains with the coarse grains predominating. It should be free from loam, clay, mica, sticks, fine roots, or other impurities. Sand should be coarse, that is, it should have a considerable portion of its grains measuring 1/32 to ⅛ inch in diameter and should the grains run up to ¼ inch the strength of the mortar is increased.

Vegetable loam is frequently very injurious to concrete and great care should be taken in selecting and excavating to see that the sand does not contain any vegetable matter. For all important structures the sand should be tested in a laboratory as described in the following paragraphs:

"Mortars composed of one part Portland cement and three parts fine aggregate by weight when made into briquets should show a tensile strength of at least 70 per cent of the strength of 1:3 mortar of the same consistency made with the same cement and standard Ottawa sand. To avoid the removal of any coating on the grains which may affect the strength, bank sands should not be dried before being made into mortar but should contain natural moisture. The percentage of moisture may be determined upon a separate sample for correcting weight of the sand. From 10 to 40 per cent more water may be required in mixing bank or artificial sands than for standard Ottawa sand to produce the same consistency."*

"The relative strength of mortars from different sands is largely affected by the size of the grains. A coarse sand gives a stronger mortar than a fine one, and generally a gradation of grains from fine to coarse is advantageous. If a sand is so fine that more than 10 per cent of the total dry weight passes a No. 100 sieve, that is, a sieve having 100 meshes to the linear inch, or if more than 35 per cent of the total dry weight passes a sieve having 50 meshes per linear inch, it should be rejected or used with a large excess of cement."*

Crushed stone or gravel screenings, when used in place of sand, should pass when dry a screen having ¼-inch diameter holes or a screen having 4 meshes to the linear inch and if free from impurities may be substituted for a part or the whole of the sand in such proportions as to give a dense mixture.

## COARSE AGGREGATE

Gravel or crushed stone of a hard and durable quality make up the coarse aggregate for concrete. The best materials are trap rock, hard limestone, granite, or conglomerate of size retained on a screen having ¼-inch diameter holes.

Aggregates containing soft, flat, or elongated particles should be excluded from important structures. Stone which breaks into cubical or similar angular forms is much preferable in any case to that which breaks into flat layers because it gives a stronger concrete and one which is more readily placed. Graded sizes of particles, that is, particles varying from small to large sizes, are generally advantageous. Where concrete is used in mass, the crushed stone or gravel may range in size from ¼ inch to that which passes through a 3-inch ring. For reinforced concrete, the particles must be small enough to flow into place around and between the steel bars and into all corners of the forms. For this a maximum size of 1 inch (that is, the largest particle small enough to go through a 1-inch ring), or in other cases a ¾-inch or ½-inch must be used. The material passing the ¼-inch screen may be used as a part of the sand.

If gravel is used instead of crushed stone, it should be of a size to be easily handled and easily placed around the steel if there is steel reinforcement and it should be clean and free from vegetable or other deleterious matter. As in the case of crushed stone, the material below ¼ inch in size should be screened out to be used as sand. Sand and gravel are rarely found mixed in the proper

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*Report of Committee on Reinforced Concrete, 1909, National Association of Cement Users.

proportions in the natural bank, and it is cheaper to screen and remix them in the correct proportions than to use the richer mixture necessary with unscreened material.

Pebbles of graded sizes with the larger sizes predominating are preferable to pebbles of a uniform size because they are more readily mixed and placed.

For important structures and for structures where there will be considerable wear on the concrete, the materials should be carefully selected, but for unimportant structures it is usually sufficient to make two small blocks of concrete, say 6-inch cubes, and place one of these cubes out-of-doors in air for 7 days and the other in a fairly warm room.

The specimen placed in the warm room should be hard enough at the end of 24 hours to bear pressure from the thumb without indentation and it also should whiten out to some extent during this time. The specimen placed out-of-doors should be hard enough to remove from the mold at the end of 24 hours in ordinary mild weather or 48 hours in cold damp weather. At the end of a week test both blocks by hitting them with a hammer. If the hammer does not dent them under light blows such as would be used in driving tacks and the blocks sound hard and are not broken under these blows the sand as a general rule can be used.

## WATER.

Water used in mixing concrete should be free from oil, acids, alkalies, or vegetable matter.

## PROPORTIONS OF MATERIALS.

The following paragraphs relating to the proper proportions of materials for making concrete are taken from "Concrete Construction About the Home and on the Farm": *

"Concrete is composed of a certain amount or proportion of cement, a larger amount of sand, and a still larger amount of stone. The fixing of the quantities of each of these materials is called proportioning. The proportions for a mix of concrete if given, for instance, as one part of cement to two parts of sand to four parts of stone or gravel, are written 1:2:4, and this means that one cubic foot of packed cement is to be mixed with two cubic feet of sand and with four cubic feet of loose stone.

"For ordinary work, use twice as much coarse aggregate (that is, gravel or stone) as fine aggregate (that is, sand).

"If gravel from a natural bank is used without screening, use the same proportions called for of the coarse aggregate; that is, if the specifications call for proportions of 1:2:4, as given above, use for unscreened gravel (provided it

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*Published by The Atlas Portland Cement Company, from whom it can be obtained by making application for same.

contains quite a large quantity of stone) one part cement to four parts unscreened gravel.

"If when placing concrete with the proportions specified, a wall shows many voids or pockets of stone, use a little more sand and a little less stone than called for. If on the other hand, when placing, a lot of mortar rises to the top, use less sand and more stone for the next batch.

"In calculating the amount of each of the materials to use for any piece of work, do not make the mistake so often made by the inexperienced that one barrel of cement, two barrels of sand, and four barrels of stone, will make seven barrels of concrete. As previously stated, the sand fills in the voids between the stones, while the cement fills the voids between the grains of sand, and therefore the total quantity of concrete will be slightly in excess of the original quantity of stone."

The unit of measure is the barrel, which should be taken as containing 3.8 cubic feet. Four bags containing 94 pounds of cement each are equivalent to one barrel. Sand and stone or gravel should be measured separately as loosely thrown into the measuring receptacle.

The following quotation from "Concrete, Plain and Reinforced"* by the well-known authorities, Taylor and Thompson, is printed as a guide to those who wish to build any concrete structure for which specific instructions are not given in the following pages:

"As a rough guide to the selection of materials for various classes of work, we may take four proportions which differ from each other simply in the relative quantity of cement":

(a) A Rich Mixture for columns and other structural parts subjected to high stresses or requiring exceptional water tightness: Proportions—1:1½:3; that is, one barrel (4 bags) packed Portland cement to 1½ barrels (5.7 cubic feet) loose sand to 3 barrels (11.4 cubic feet) loose gravel or broken stone.

(b) A Standard Mixture for reinforced floors, beams and columns, for reinforced engine or machine foundations subject to vibrations, for tanks, sewers, conduits, and other water-tight work: Proportions—1:2:4; that is, one barrel (4 bags) packed Portland cement to 2 barrels (7.6 cubic feet) loose sand to 4 barrels (15.2 cubic feet) loose gravel or broken stone.

(c) A Medium Mixture for ordinary machine foundations, retaining walls, abutments, piers, thin foundation walls, building walls, ordinary floors, sidewalks, and sewers with heavy walls: Proportions—1:2½:5; that is, one barrel (4 bags) packed Portland cement to 2½ barrels (9.5 cubic feet) loose sand to 5 barrels (19 cubic feet) loose gravel or broken stone.

(d) A Lean Mixture for unimportant work in masses, for heavy walls, for large foundations supporting a stationary load, and for backing for stone masonry: Proportions—1:3:6; that is, one barrel (4 bags) packed Portland cement to 3 barrels (11.4 cubic feet) loose sand to 6 barrels (22.8 cubic feet) loose gravel or broken stone.

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*See reference, footnote, page 18.

# QUANTITIES OF MATERIALS IN CONCRETE.

In estimating the quantities of cement, sand, and broken stone or gravel in a given volume of concrete or in estimating the volume of mortar or concrete which can be made from one barrel of cement the three accompanying tables will be found useful. The values given in the tables are computed from results of actual experiments and have been checked with concrete laid in large masses.

### VOLUME OF CONCRETE MADE FROM ONE BARREL OF PORTLAND CEMENT*

Based on a Barrel of 3.8 Cubic Feet

| Proportions by Parts | | | Proportions by Volume | | | Volume of Mortar in Terms of Percentage of Volume of Stone | Average Volume of Rammed Concrete Made From One Barrel of Cement | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Percentages of Voids in Broken Stone or Gravel | | |
| Cem't | Sand | Stone | Cem't | Sand | Stone | | 50%† | 45%‡ | 40%§ |
| | | | bbl. | cu. ft. | cu. ft. | per cent. | cu. ft. | cu. ft. | cu. ft. |
| 1 | 1 | 2 | 1 | 3.8 | 7.6 | 75 | 9.5 | 9.9 | 10.3 |
| 1 | 1 | 3 | 1 | 3.8 | 11.4 | 51 | 11.5 | 12.2 | 12.8 |
| 1 | 1½ | 3 | 1 | 5.7 | 11.4 | 64 | 12.9 | 13.5 | 14.1 |
| 1 | 1½ | 3½ | 1 | 5.7 | 13.3 | 55 | 13.9 | 14.6 | 15.4 |
| 1 | 2 | 3 | 1 | 7.6 | 11.4 | 75 | 14.3 | 14.9 | 15.5 |
| 1 | 2 | 4 | 1 | 7.6 | 15.2 | 57 | 16.3 | 17.2 | 18.0 |
| 1 | 2½ | 4½ | 1 | 9.5 | 17.1 | 60 | 18.7 | 19.6 | 20.6 |
| 1 | 2½ | 5 | 1 | 9.5 | 19.0 | 54 | 19.8 | 20.8 | 21.8 |
| 1 | 3 | 5 | 1 | 11.4 | 19.0 | 61 | 21.1 | 22.1 | 23.2 |
| 1 | 3 | 6 | 1 | 11.4 | 22.8 | 52 | 23.2 | 24.4 | 25.6 |

Note.—Variations in the fineness of the sand and the compacting of the concrete may effect the volumes by 10% in either direction.

†Use **50%** column for broken stone screened to uniform size.

‡Use **45%** column for average conditions and for broken stone with dust screened out.

§Use **40%** column for gravel or mixed stone and gravel.

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*Taken by permission from Taylor & Thompson's "Concrete, Plain and Reinforced," copyright, 1905, by Frederick W. Taylor. John Wiley & Sons, New York, publishers.

## QUANTITIES OF MATERIALS FOR ONE CUBIC YARD OF RAMMED CONCRETE*

Based on a Barrel of 3.8 Cubic Feet

| Proportions by Parts | | | Proportions by Volume | | | Volume of Mortar in Terms of Percentage of Volume of Stone | Percentages of Voids in Broken Stone or Gravel | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | †50 Per Cent. | | | ‡45 Per Cent. | | | §40 Per Cent. | | |
| Cement | Sand | Stone | Packed Cement | Loose Sand | Loose Stone | | Cement | Sand | Stone | Cement | Sand | Stone | Cement | Sand | Stone |
| | | | bbl. | cu. ft. | cu. ft. | per cent. | bbl. | cu. yd. | cu. yd. | bbl. | cu. yd. | cu. yd. | bbl. | cu. yd. | cu. yd. |
| 1 | 1 | 2 | 1 | 3.8 | 7.6 | 75 | 2.85 | 0.40 | 0.80 | 2.73 | 0.38 | 0.77 | 2.62 | 0.37 | 0.74 |
| 1 | 1 | 3 | 1 | 3.8 | 11.4 | 51 | 2.34 | 0.33 | 0.99 | 2.22 | 0.31 | 0.94 | 2.12 | 0.30 | 0.90 |
| 1 | 1½ | 3 | 1 | 5.7 | 11.4 | 64 | 2.09 | 0.44 | 0.88 | 2.00 | 0.42 | 0.84 | 1.91 | 0.40 | 0.81 |
| 1 | 1½ | 3½ | 1 | 5.7 | 13.3 | 55 | 1.94 | 0.41 | 0.96 | 1.84 | 0.39 | 0.91 | 1.76 | 0.37 | 0.87 |
| 1 | 2 | 3 | 1 | 7.6 | 11.4 | 75 | 1.89 | 0.53 | 0.80 | 1.81 | 0.51 | 0.76 | 1.74 | 0.49 | 0.74 |
| 1 | 2 | 4 | 1 | 7.6 | 15.2 | 57 | 1.65 | 0.46 | 0.93 | 1.57 | 0.44 | 0.88 | 1.50 | 0.42 | 0.84 |
| 1 | 2½ | 4 | 1 | 9.5 | 15.2 | 66 | 1.52 | 0.54 | 0.86 | 1.46 | 0.51 | 0.82 | 1.40 | 0.49 | 0.79 |
| 1 | 2½ | 4½ | 1 | 9.5 | 17.1 | 60 | 1.44 | 0.51 | 0.91 | 1.37 | 0.48 | 0.87 | 1.31 | 0.46 | 0.83 |
| 1 | 2½ | 5 | 1 | 9.5 | 19.0 | 54 | 1.37 | 0.48 | 0.96 | 1.30 | 0.46 | 0.92 | 1.24 | 0.44 | 0.87 |
| 1 | 3 | 5 | 1 | 11.4 | 19.0 | 61 | 1.28 | 0.54 | 0.90 | 1.22 | 0.52 | 0.86 | 1.17 | 0.49 | 0.82 |
| 1 | 3 | 6 | 1 | 11.4 | 22.8 | 52 | 1.16 | 0.49 | 0.98 | 1.11 | 0.47 | 0.94 | 1.05 | 0.44 | 0.89 |

Note.—Variations in the fineness of the sand and the compacting of the concrete may effect the quantities by 10% in either direction.
†Use **50%** columns for broken stone screened to uniform size.
‡Use **45%** columns for average conditions and for broken stone with dust screened out.
§Use **40%** columns for gravel or mixed stone and gravel.
*Quoted from Copyrighted Treatise; see footnote on opposite page.

## VOLUME OF PLASTIC MORTAR MADE FROM DIFFERENT PROPORTIONS OF CEMENT AND SAND*

Quantities of Materials per Cubic Yard

| Relative Proportions by Volume† | | Volume of Compacted Plastic Mortar | | Materials for 1 cu. yd. Compacted Plastic Mortar, Based on Barrel of 3.8 Cubic Feet | |
|---|---|---|---|---|---|
| Cement | Sand | From 1 cu. ft. Cement, Based on Portland Cement Weighing 100 Lbs. per cu. ft. | From 1 bbl., or 4 bags, Cement, Based on Barrel of 3.8 cu. ft. | Packed Cement | Loose Sand |
| | | cu. ft. | cu. ft. | bbl. | cu. yd |
| 1 | 0 | 0.86 | 3.2 | 8.31 | ...... |
| 1 | 1 | 1.42 | 5.4 | 5.01 | 0.71 |
| 1 | 1½ | 1.78 | 6.7 | 4.00 | 0.84 |
| 1 | 2 | 2.14 | 8.1 | 3.32 | 0.93 |
| 1 | 2½ | 2.50 | 9.5 | 2.84 | 1.00 |
| 1 | 3 | 2.86 | 10.9 | 2.48 | 1.05 |

Note.—Variations in the fineness of the sand and the cement, and in the consistency of the mortar may affect the values by 10% in either direction.

*See reference, footnote, p. 18.

†Cement as packed by manufacturer, sand loose.

## RUBBLE CONCRETE.

Rubble concrete is ordinary concrete in which are imbedded large stones, usually of a size that can be handled by one or two men, but in very massive work such as large dams, stones of even greater size as heavy as can be handled with a derrick are used. Only in massive structures such as heavy foundations, dams, retaining walls, or similar works is this form of construction possible and when stones are imbedded in the concrete they should be spaced at least 3 inches from one another and also from the outer surface. About 20 per cent of the total volume of the structure may be replaced by "one-man" and "two-men" stones, and thus a considerable saving in cost is effected in large structures.

## MIXING CONCRETE.

Mixing may be done either by hand or machine and the method to be employed is determined principally by the size of the job. If a small amount of concrete is to be made, hand mixing is the more economical, while for large works machine mixers are better and generally cheaper, though in some cases where the mixer must be frequently moved, hand mixing may prove to be the cheaper. A better and more uniform concrete can be made with a good machine mixer than by hand. The type of mixer should be such as to insure a thorough and uniform mixing of the materials. In any case enough water should be used to make a mushy consistency which requires very little tamping to bring the mortar to the surface.

## HAND MIXING.

If hand mixing is employed it should be carefully done on a water-tight platform and should be subjected to thorough supervision. The following directions by Taylor and Thompson for hand mixing will be found useful to those who are inexperienced in this class of work.*

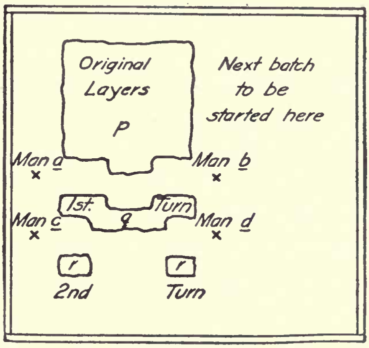

FIG. 1.—POSITION OF MEN AND CONCRETE ON PLATFORM WHILE TURNING.*

"Assume a gang of four men to wheel and mix the concrete with two other men to look after the placing and ramming.

"When starting a batch, two mixers shovel or wheel sand into the measuring box or barrel—which should have no bottom or top—level it and lift off the measure, leveling the sand still further if necessary. They then empty the cement on top of the sand, level it to a layer of even thickness, and turn the dry sand and cement with shovels three times, as described below, after which the mixture should be of uniform color.

"While these two men are mixing sand and cement, the other two fill the gravel measure about half full, then the two sand men take hold with them, and complete filling it. The gravel measure is lifted, the gravel hollowed out slightly in the center, and the mixture of sand and cement shoveled on top in a layer of nearly even thickness.† A definite number of pails are filled with

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*See reference, footnote, page 18.

†"Some Engineers prefer to spread the stone on top of the sand and cement, while others prefer to mix the water with the sand and cement before adding them to the stone."

water, and poured directly on the top of these layers, greater uniformity being thus attained than by adding the water directly from a hose. After soaking in slightly the mass is ready for turning.

"The method illustrated in Fig. 1 of turning with shovels materials which have already been spread in layers is as follows:

"Two men, A and B, with square-pointed shovels, stand facing each other at one end of the pile to be turned, one working right-handed and the other left-handed. Each man pushes his shovel along the platform under the pile, lifts the shovelful, turns with it, and then, turning the shovel completely over, and with a spreading motion drawing the shovel toward himself, deposits the material about 2 feet from its original position. Repetitions of this operation will form a flat ridge of the material, on a line with the pile as it originally lay, and flat enough so that the stones will not roll. As soon as, but not before, a single ridge is complete, two other men, C and D, should start upon this ridge, turning the materials for the second time, as shown in the illustration, and forming as before a flat ridge and finally a level pile which gradually replaces the last. A third mixing is accomplished in a similar way.

"Fig. 1 gives the position of the piles as the concrete is being turned. A portion of the original layers is shown at P, the ridge formed by men A and B shoveling from pile P is shown at Q, and the beginning of the ridge formed by men C and D is shown at RR. The third turning is not shown.

"The quantity of water used must be varied according to the moisture in the materials and the consistency required in the concrete. While the opinions of engineers regarding the proper consistency vary widely, it is advisable, the authors believe, for an inexperienced gang to use an excess of water. The rule may be made in hand mixing to use as much water as can be thoroughly incorporated with the materials. Concrete thus made will be so soft or 'mushy' that it will fall off the shovel unless handled quickly.

"After the material has been turned twice, as described, and as soon as the third turning has been commenced, two of the mixers who have finished turning may load the concrete into barrows and wheel to place. They should fill their own barrows, and after the mass has been completely turned for the third time by the other two men the latter should start filling the gravel measure for the next batch.

"If the concrete is not wheeled over 50 feet, four experienced men ought to mix and wheel on the average about 10½ batches in ten hours. This figure is based on proportions 1:2 1/2:5, and assumes that a batch consists of one barrel (four bags) Portland cement with 9.5 cubic feet of sand and 19 cubic feet of gravel or stone.

"Assuming that 1.29 barrels of cement are required for 1 cubic yard of concrete, one barrel of cement—that is, one batch—will make 0.78 cubic yard of concrete; hence 10½ batches mixed and wheeled by four men in ten hours are equivalent to 8¼ cubic yards of concrete. This is for the very simplest kind of concreting and makes no allowance for the labor of supplying materials to the mixing platform or for building forms."

## PLACING CONCRETE.

In handling and placing concrete, the materials must remain perfectly mixed, the aggregate must not separate from the mortar and the concrete must be rammed or agitated so as to thoroughly fill the forms and surround all parts of the steel reinforcement. Care must be taken to remove all sticks, blocks, shavings, or similar materials from the forms before the concrete is placed and in case new concrete is deposited on a layer that has already set, the old surface should be roughened, cleaned, and drenched with water before the new material is added. In reinforced structures the metal must be placed in the forms and wired or otherwise held rigidly in position before any concrete is laid. It is now generally customary to use wet mixtures and the concrete is usually carried in buckets or in water-tight wheelbarrows. An ordinary whelbarrow load of concrete is about 1.9 cu. ft. If wet concrete is used it can be dropped vertically into place or run through an inclined water-tight chute. Concrete should be wet frequently for a few days after it is laid.

## LAYING CONCRETE IN WATER.

Only in exceptional cases should concrete be placed in water and even then the greatest care must be taken to prevent the cement from being washed out. Under no circumstances should it be thrown or placed into water by shovels. In some cases of small construction, the concrete may be deposited in bags, or it may be placed in pails with a board covering the top of the pail and lowered carefully into the water to the bottom. When this has reached bottom, turn the pail upside down and move the board from underneath and carefully raise the pail, allowing the concrete to flow out. Great care must be taken not to disturb the water in which the concrete is being placed nor to touch the concrete before it has set. Under no circumstances should concrete be placed in running water. In large work, it is sometimes placed by means of a tube extending into the water with the lower end near the bottom. By keeping a continuous flow of concrete passing through the tube, the cement will not be separated from the aggregate.

## LAYING CONCRETE IN SEA WATER.

For use in sea water concrete must be proportioned to secure maximum density and must be so carefully mixed and placed as to secure an impervious mass. Unless proper precautions are taken in choosing the materials, mixing, and in depositing the concrete there is danger of scaling on the surface of the concrete between high and low water levels.

The remarks just made concerning the use of concrete in sea water are equally true of concrete placed in alkaline soils where the mixture must be of maximum density and must be richer than where used in ordinary soils.

## EFFECT OF MANURE.

Manure, because of the acid in its composition, is injurious to green concrete, but after the concrete is thoroughly hardened it satisfactorily resists such action.

## FREEZING.

Concrete for thin walls and reinforced concrete structures should not be laid during freezing weather unless concrete is prevented from freezing by warming the materials before mixing and by covering the concrete after it is placed with a thick covering of clean straw, sand, or other suitable material. Common salt is quite frequently used to lower the freezing point of the water used in mixing concrete. A well known rule requires 1 per cent by weight of the salt to the weight of the water for each degree Fahrenheit below freezing point of water.

As one cannot tell in advance how low the temperature is going to fall, an arbitrary amount of salt must be used. Some engineers specify two pounds of salt to each bag of cement, and in case this is not sufficient, three pounds to a bag.

Another method is to mix warm sand and stone with the cement and water in such manner as will bring the entire mixture up to about 75 degrees Fahrenheit, protecting in the early stages of setting, so far as possible, from cold and currents of air.

Heavy walls and foundations where the appearance of the faces is of no importance may be laid in freezing weather.

Concrete sidewalks must not be laid in freezing weather for the surface will soon scale.

## FORMS.

Forms usually are of wood, though in some cases metal is used. They must be strongly built so as to prevent displacement, deflection, or leakage of mortar and they must not be removed until the concrete has set. The time required for setting varies with the condition of the weather, longer time being required in cold or wet weather; with the quality of the cement; and with the amount of water used in mixing. White pine is the best lumber for forms, but cheaper kinds, such as spruce, fir, Norway pine or softer kinds of Southern pine, are frequently used, and green lumber is on the whole better than dry. To secure a smooth surface on the finished concrete, lumber planed on one side must be used; likewise where the forms are to be removed within a day or two, planed lumber must be used, for then the concrete will not stick to the planks and they may be again used without much cleaning.

Forms usually consist of boards held in place by studs braced so as to remain in place. For the boards one or two-inch planks are commonly used and quite frequently tongued and grooved materials are necessary for tight construction. The studs are spaced at distances apart depending upon the consistency of the concrete, the thickness of the wall, and the character of finished concrete surface desired. Wet concrete in large masses is apt to exert considerable pressure against the forms before the cement sets, but with wet concrete less ramming is necessary than with dry mixtures and therefore the forms are less likely to be knocked out of position. With wet mixtures in comparatively thin walls two-inch planking should be supported not over 5 feet apart, while for one-inch boards 2 feet is about the right spacing.

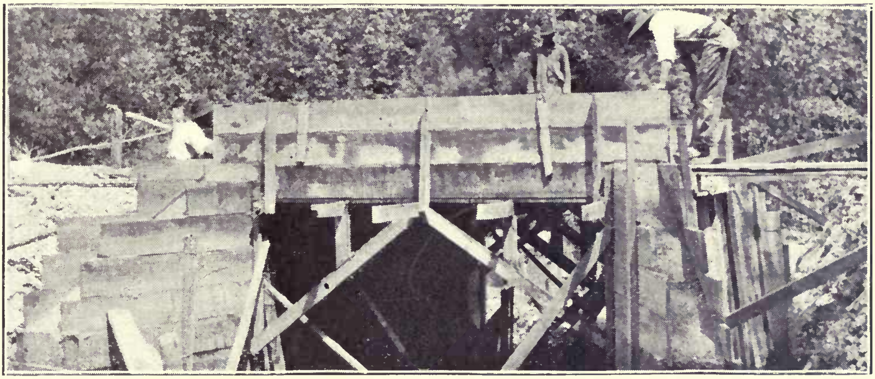

FIG. 2.—FORMS FOR BEAM BRIDGE

Forms are greased by applying to them a coat of crude oil or soft soap, but if the forms are not to be removed for several weeks no greasing is necessary, though in this case the surfaces of the forms which are to come in contact with the concrete must be thoroughly wet.

PAVEMENT IN CITY OF PANAMA.

BRIDGE NEAR WASCO, ILL.

# CHAPTER II.

## SIDEWALKS, CURBS, AND GUTTERS.

Concrete is in universal use for sidewalks, curbs, and gutters, and the excellent and permanent qualities of this material are as well shown in these forms as in any other type of construction in which it is used. Sidewalks should be smooth, durable, cheap in first cost, and should present a pleasing appearance. With proper care concrete can be laid to satisfy all these requirements and therefore make a solid durable walk. For curbs alone or for combined curbs and gutters, especially for the streets in residential districts, parks or similar places where neatness of appearance is especially desirable. concrete is being used in many localities almost exclusively. In this chapter are shown methods of construction which are standard and which if followed will produce good results.

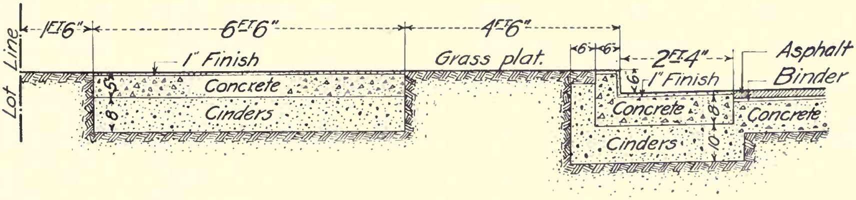

FIG. 3—CROSS SECTION OF SIDEWALK AND COMBINED CURB AND GUTTER.

## DIMENSIONS OF WALKS, CURBS, AND GUTTERS.

A first class walk consists of a foundation of cinders, gravel, or broken stone upon which is laid a layer of concrete called the base and an upper thin layer of mortar called the wearing surface. Granolithic is a common name for concrete walks.

Sidewalks vary in width according to conditions, but the thickness of the concrete is nearly uniform, ranging from four to five inches total thickness including the wearing surface.

In Fig. 3 is shown the section of a sidewalk separated from the curb by a narrow grass plat such as is common in residential streets. The thickness of the concrete is shown as 5 inches, but 4 inches is more commonly used, and if the walk is provided with good foundations and drainage 4 inches is ample in most places. Where the total thickness of the concrete is 4 inches the base should be 3¼ or 3 inches and the wearing surface ¾ or 1 inch, and for a 5-inch walk the base should be 4 inches and the wearing surface 1 inch.

The slope of the surface from the lot line toward the curb should be ¼ or ⅜ inch per foot. For parks and similar locations the walk is usually crowned toward the center.

Curbs are made from 6 to 8 inches wide on top and are generally vertical on the side next to the walk and slightly inclined on the side facing the gutter. The total depth of the curb should be from 12 to 14 inches, and if the street traffic is heavy the curb should set upon a concrete base 12 inches wide and 8 inches thick. Where the curb and gutter are combined, as shown in Fig. 3, the gutter is made 8 inches thick and from 1½ to 3 feet in width. In the case shown the curb has a width on top of 6 inches and tapers down to 6½ inches at the gutter. Sometimes both the inner and outer surfaces of the gutter are made vertical, although it is better to have the front face inclined. The upper outer corner of the curb and the intersection of gutter with face of curb should be rounded off with radii of about 1 inch.

The surface of the gutter should conform to that of the street surface, though in some cities, as for instance Salt Lake City, the upper surface of the gutter is curved in such a manner as to secure greater carrying capacity, the depth of the gutter being 10 inches, whereas it would be only 8 inches were the curve omitted and the slope of the street continued to the curb line. At street corners curbs should be thicker than where straight so as to better withstand shocks from moving vehicles. Where the street traffic is heavy, the upper outer edge of the curb is often provided with a special steel corner imbedded in the concrete as it is laid.

Fig. 4 illustrates a type of concrete curb, gutter, and cross walk construction used considerably in Chicago on streets for ordinary traffic. A cross walk is provided by elevating the street surface near the curbs as shown.

## FOUNDATIONS AND DRAINAGE.

A good foundation properly drained is absolutely essential for successful sidewalk construction, and is best made by excavating the soil to a depth of 10 to 15 inches below the level of the finished sidewalk surface, depending on the kind of soil and the locality, so as to give a foundation 6 to 10 inches thick, and after ramming the bottom of the excavation a layer of coarse material such as broken stone, cinders, or coarse sand is placed in the excavation and thoroughly rammed. Drainage and ramming are of the utmost importance. In some cities no foundation is required in soils of clean coarse sand which is porous enough to afford good drainage, while in soils which retain water a foundation of 6 to 12 inches is specified. Fig. 3 shows an 8-inch foundation of cinders under the walk and one of 10 inches under the curb and gutter. Broken stone or gravel should be screened

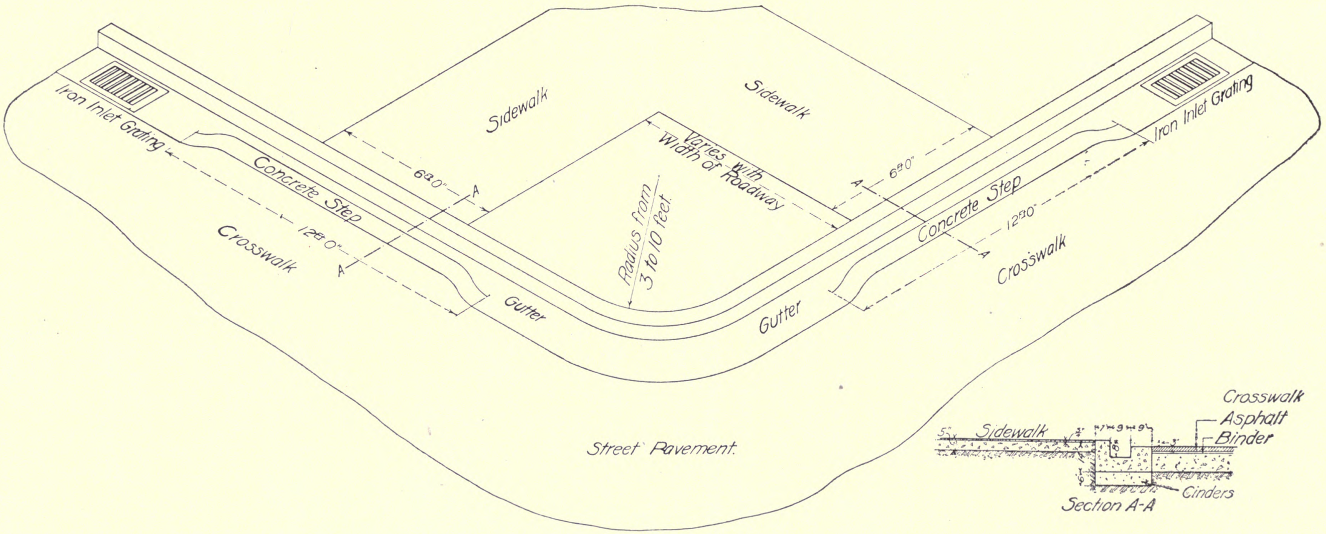

FIG. 4.—CONCRETE CURB, AND GUTTER, AND CROSS-WALK CONSTRUCTION.

to remove all fine material and cinders and sand should be wet while being rammed into place. In soils like clay which retain water the foundation should be drained by running occasional drain tiles underneath the soil from the foundation to the gutter, or other suitable outlet. Instead of tile drains small ditches, say 10 by 10 inches in cross section, filled with broken stone may be used.

## PROPORTIONS FOR CONCRETE.

Portland cement only should be used.

The concrete for the base should be mixed 1 part "ATLAS" Portland Cement, 2½ parts sand or fine stone which will pass a ¼-inch screen, and 5 parts broken stone or gravel larger than ¼ inch size. Where the quality of the sand and stone require it, these proportions must be slightly changed, and if the sand is not very good 1 part "ATLAS" Portland Cement, 2 parts sand and 4 parts stone or gravel had better be used.

The wearing surface should be mixed 1 part "ATLAS" Portland Cement to 1½ parts sand, and should be of such consistency as not to require tamping, but should be simply floated with a straight edge. The sand here referred to may be either natural bank sand or crushed stone which will pass a ¼-inch screen provided it is from a hard stone which has but little dust.

Another excellent plan is to use 1 part "ATLAS" Portland Cement and ¾ part sand and ¾ part fine crushed stone.

Although 1 part cement to 2 parts fine aggregate is quite frequently used for the wearing surface this mixture is liable to make a surface that will wear sandy.

The combined curb and gutter shown in Fig. 3 is laid on a cinder foundation and the concrete base and 1-inch finish are of the same mixtures as specified for the corresponding parts of the walk.

## FORMS.

Forms should be made of clean lumber not less than 2 inches thick, though 1½ may be used if well braced. Fig. 5 shows typical form construction for walks and combined curb and gutter. The walk shown is 5 inches thick and the side forms are 2 by 6 inches, although 2 by 5 inches will do if available. The upper edge must be the exact level of the finished walk. The forms should be of best white pine planed on all sides, should be straight and set to true line and grade. If white pine is too expensive, spruce, fir, or other soft woods may be used. The wooden pegs should be spaced from 4 to 6 feet apart and must be securely driven into the ground so that the forms will not move while concrete is being deposited against them.

The gutter shown as 5 inches thick in the drawing is suitable for streets with light traffic. The curb is 6 inches wide and 11 inches deep with both faces vertical. The side planks are held in place by the wooden pegs and the front plank for the curb is held by clamps and steel dividing plates, the latter serving as spacers as well as dividing plates at the joints. The upper corner of the curb should be rounded to a radius of 1 inch with a tool and the lower corner at the intersection of the gutter and curb should be similarly arranged by rounding off the lower inner edge of the front plank of the curb form.

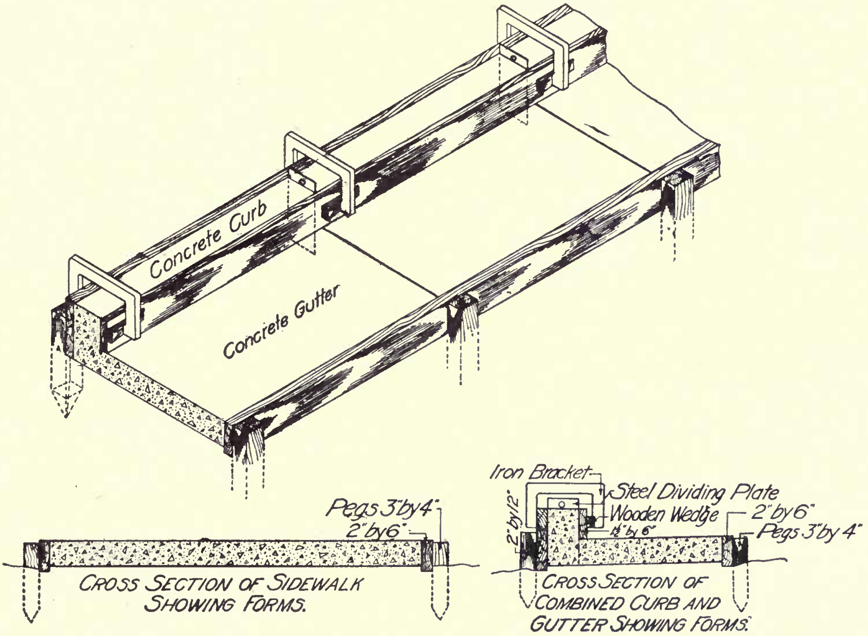

FIG. 5—FORMS FOR SIDEWALK AND COMBINED CURB AND GUTTER

## PLACING CONCRETE.

After having placed and thoroughly rammed the porous foundation, and having carefully set the forms to line, as described above, divide the surface into blocks by cross lines. Mark the dividing lines between the blocks on the side forms by notches and place cross strips from form to form located by these notches. The blocks should be nearly square, and for walks 4 inches in thickness should not be over 6 feet in longest dimension, while for walks 5 inches in thickness 8 feet is about the maximum size. By laying alternate blocks, and then after the concrete has stiffened, removing the cross strips and filling in the blocks between, joints are made so that if the walk heaves

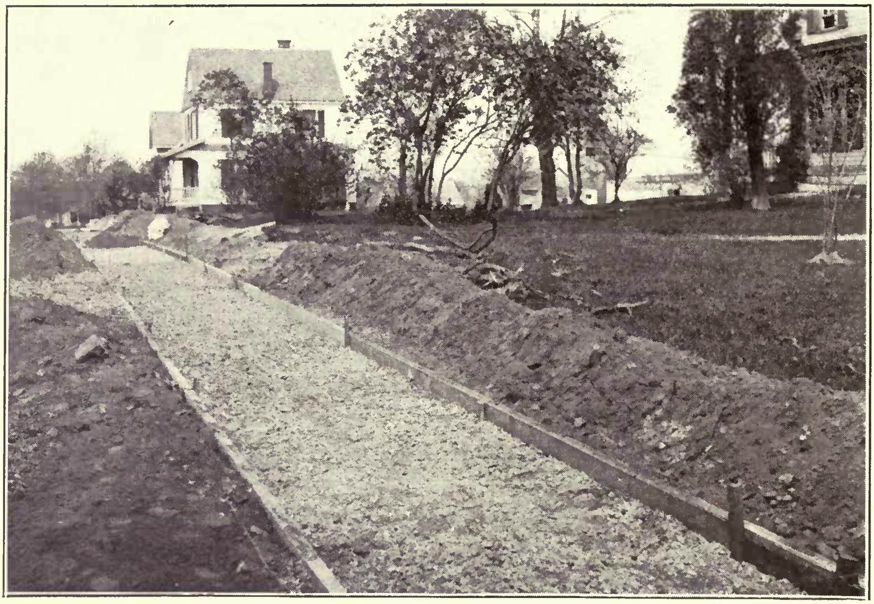

FIG. 6.—CINDER FOUNDATION FOR CONCRETE SIDEWALK.

FIG. 7.—PLACING THE CONCRETE BASE.

slightly, it will crack in the joint and will not show, provided of course the wearing surface is grooved and jointed directly above the joint in the base.

Mix the concrete for the base on a tight platform unless the street pavement is hard and impervious, in which case that can be used for mixing. Make the consistency rather stiff, but wet enough so that the concrete will glisten when it is being mixed, and although holding its shape in a pile, can be compacted and the mortar brought to the surface with comparatively light ramming. See that the surface of the base is exactly one inch below the upper level of the forms, so that the wearing surface will be uniformly one inch thick. To accomplish this, make a straight-edge of 7/8 inch wood notched at each end to fit upon the forms.

As soon as a few blocks of the base have been laid, and before the concrete has set, mix the mortar for the wearing surface. Make this one part "ATLAS" Portland Cement to one and a half parts sand or finely crushed stone and sand mixed. This mortar may be mixed in a mortar box, as it has to be of about the consistency of mortar for laying brick.

To secure good results and prevent the wearing surface from eventually cracking from the base, it is absolutely essential that the mortar be spread before the concrete base has begun to stiffen, for if it is left for several hours or over night the wearing surface is almost sure to peal off in places.

After smoothing the wearing surface with a straight-edge, float it roughly with a plasterer's trowel, and after a few hours, when the mortar has begun to stiffen, float it with a wooden float, and then with a metal float, or, as it is sometimes called, a plasterer's trowel. Neat cement should not be applied to the surface. Just as the final floating is being finished, take a small pointing trowel, and guided by the notches in the side forms and by a straight-edge, placed across the walk, run the trowel down between the blocks so as to form a joint in the wearing surface directly above the joint in the base, and finish this joint with a groover, so as to give it rounded edges. The side edges of the walk are then rounded off with a special jointer, and the surface again finally troweled.

If a roughened surface is desired, a dot roller or a grooved roller may be used. The walk should be protected from the sun for at least four days, and wet down frequently.

Curbs and gutters should be laid in advance of the walk in sections 5 or 6 feet in length and a joint should be left between the curb and the walk. The surface of the gutter and the top and front surface of the curb should be made of a 1-inch layer of mortar the same as used for the wearing surface of the walk. It is important to place the upper part of the curb at the same time with the lower for the perfect union of the two parts is necessary to keep the curb in position.

FIG. 8.—MIXING MORTAR FOR WEARING SURFACE.

FIG. 9.—TROWELING WEARING SURFACE.

## COLORING MATTER.

By selecting a crushed stone of the proper variety a permanent color can be secured for the surface of a walk, some pink granites giving especially pleasing effects. Artificial coloring matter may be secured by the addition of lamp black, ochre, iron oxide, and other materials to the cement, but most of these colors will fade.

### MATERIALS FOR CONCRETE SIDEWALKS, FLOORS AND WALLS

| Bags of Cement to 100 sq. ft. of Surface area of Concrete Base or of Wall | | | | Bags of Cement to 100 sq. ft. of Mortar Surface | | | |
|---|---|---|---|---|---|---|---|
| Thick-ness, Inches | Proportions | | | Thickness, Inches | Proportions | | |
| | 1:1½:3 | 1:2:4 | 1:3:6 | | 1:1 | 1:1½ | 1:2 |
| 3 | 8½ | 6½ | 4¾ | ½ | 3½ | 2¾ | 2½ |
| 4 | 11 | 8¾ | 6 | ¾ | 5 | 4 | 3½ |
| 5 | 14½ | 11 | 7½ | 1 | 7 | 5¼ | 4½ |
| 6 | 16¾ | 13¼ | 9½ | 1¼ | 8¼ | 6½ | 5¾ |
| 8 | 22¾ | 18 | 12 | 1½ | 10 | 8 | 6½ |
| 10 | 28¾ | 21½ | 15½ | 1¾ | 12 | 9¼ | 7¾ |
| 12 | 34¾ | 26½ | 18½ | 2 | 14 | 11 | 9 |

| No. of sq. ft. of Concrete Laid with 4 Bags (1 bbl.) of Cement | | | | No. of sq. ft. of Mortar Surface Laid with 4 Bags (1 bbl.) of Cement | | | |
|---|---|---|---|---|---|---|---|
| Thick-ness, Inches | Proportions | | | Thickness, Inches | Proportions | | |
| | 1:1½:3 | 1:2:4 | 1:3:6 | | 1:1 | 1:1½ | 1:2 |
| 3 | 47 | 60 | 83 | ½ | 114 | 146 | 178 |
| 4 | 36 | 46 | 66 | ¾ | 80 | 100 | 114 |
| 5 | 27 | 36 | 52 | 1 | 57 | 73 | 89 |
| 6 | 24 | 30 | 41 | 1¼ | 48 | 60 | 70 |
| 8 | 17 | 22 | 33 | 1½ | 40 | 50 | 59 |
| 10 | 14 | 19 | 26 | 1¾ | 33 | 43 | 52 |
| 12 | 12 | 15 | 21 | 2 | 29 | 36 | 44 |

## QUANTITIES OF MATERIALS FOR SIDEWALKS.

For the computation of the quantities of cement, sand, and stone required to construct a sidewalk of any given dimensions the accompanying table will be found useful as giving the quantities required to lay 100 square feet of sidewalk. The values given are based on a barrel of 3.8 cubic feet and a coarse aggregate having 45 per cent voids are assumed. In the table allowances have been made for waste. To determine the total volumes required for a walk of given proportions and dimensions the amounts noted for the base and for the wearing surface should be added together. The quantities required will of course vary with the proportions and character of the materials.

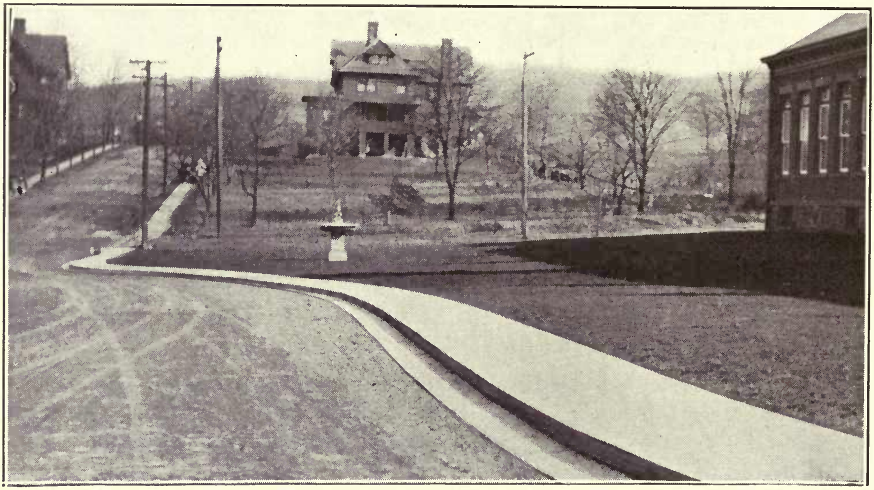

FIG. 10.—CONCRETE SIDEWALK IN SOUTH BETHLEHEM, PA.

## COST.

The cost of sidewalks, curbs and gutters varies with the locality, size of the job, and with the character of the soil and materials used. Work finished recently under contract for Salt Lake City shows the following costs to the city. These figures are based on a day's work of eight hours and laborers at $2 per day, form setters $4 per day. Costs given below are per linear foot:

| | |
|---|---|
| Concrete curb, 6 x 16 inches, without gutter | $0.43 |
| Concrete curb, plain, 6 x 16 inches, with gutter 30 inches wide | 0.79 |
| Concrete curb, plain, 6 x 16 inches, with gutter 30 inches wide and curved to special radius | 0.85 |
| Concrete curb, 6 x 16 inches, reinforced, without gutter and curved to special radius | 0.64 |
| Concrete gutter, 30 inches wide along curb | 0.61 |

Mr. George W. Tillson* gives the cost of concrete walks, 5 inches thick and laid on 7 inches of cinders in Brooklyn, N. Y., as 16½ cents per sq. ft.

Fig. 10 shows a walk built of "ATLAS" Portland Cement in South Bethlehem, Pa., where the current price for walks similar to that shown is from 17 to 20 cents per sq. ft. including curb and gutter. The walk is 4 feet wide, has a 3-inch base of 1:2:4 concrete and a wearing surface of 1:2 mortar, and is laid on an 18-inch cinder foundation. The front face of the curb is 4 inches high and the gutter is 14 inches wide and 4 inches thick. Street traffic is light so that heavy curbs and gutters are not required at this location.

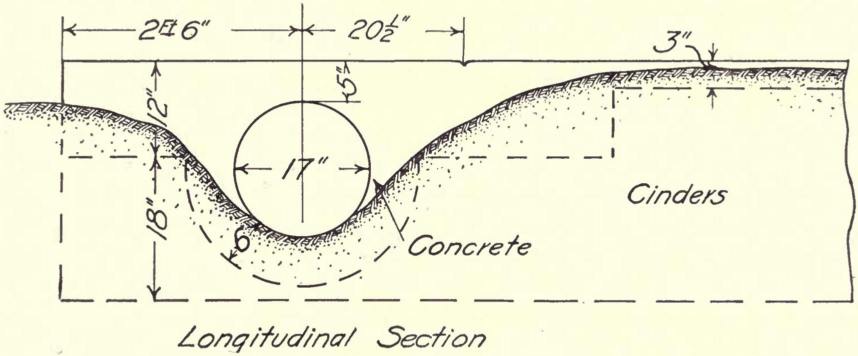

FIG. 11.—CONCRETE CROSS-WALK OVER GUTTER.

Fig. 11 and Fig. 12 show a small cross-walk leading from a front walk in a yard over a gutter to a country road. The walk is 4 feet in width and the total length from house to road is 13½ feet. The walk in the yard is 3 inches

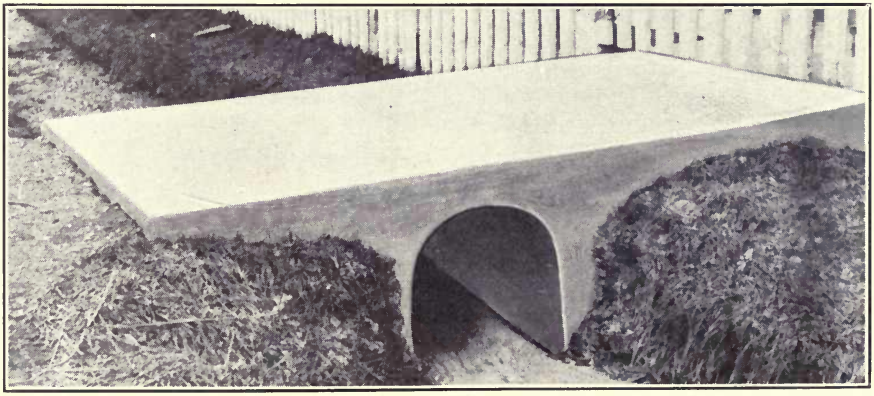

FIG. 12.—CONCRETE CROSS-WALK OVER GUTTER.

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*"Street Pavements and Paving Materials," p. 479.

thick, and on each side of the circular opening is 12 inches thick, while under the opening there is a thickness of 6 inches. An 18-inch cinder foundation underlies the whole work. Two cement barrels were used in place of forms and the total cost of the walk and cross-walk was $13.20, or 24½ cents per sq. ft.

## VAULT LIGHT CONSTRUCTION.

In Fig. 13 is shown a design for vault light construction supported on concrete ribs on steel I beams. The sizes of the concrete ribs and the steel I beams depend on the spans, and it is necessary to construct the concrete ribs and slab at one time. The glass discs are imbedded in the concrete and admit light to the area below.

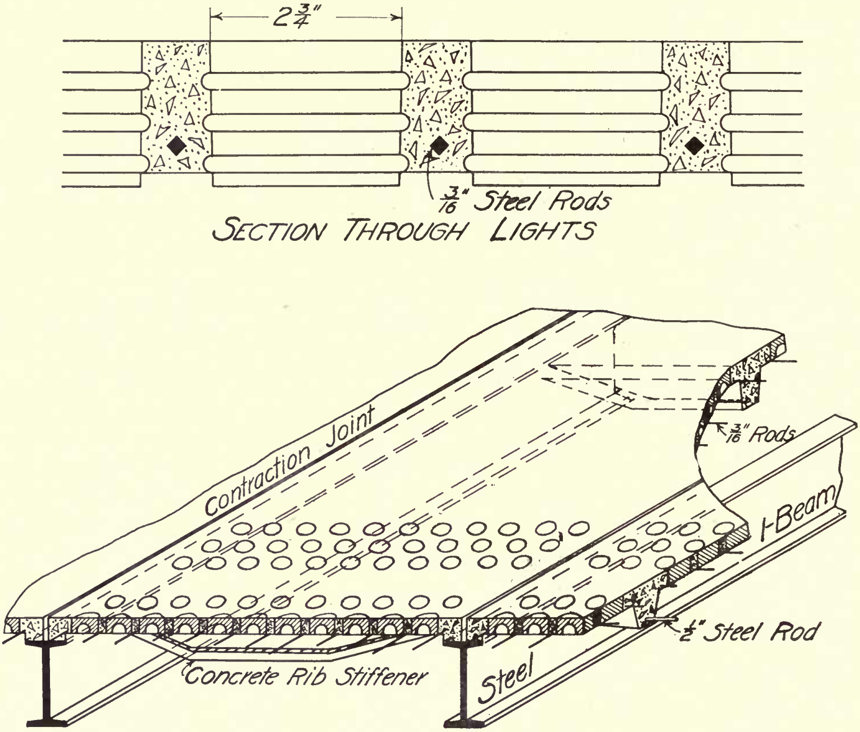

FIG. 13.—TYPICAL VAULT LIGHT CONSTRUCTION.*

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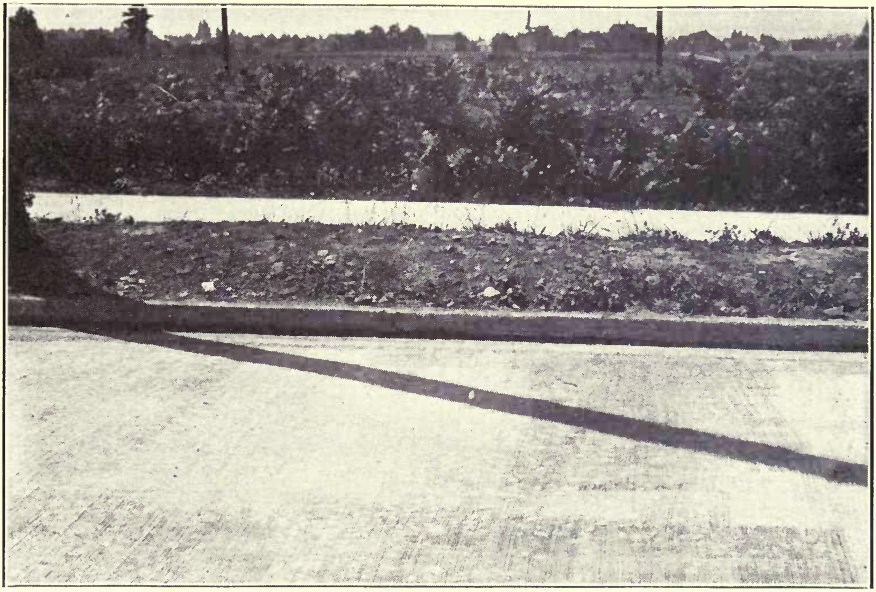
*See reference, footnote, page 18.

# CHAPTER III.

## STREET PAVEMENTS.

The ideal street pavement is durable, noiseless, cleanly, easy to travel on, low in first cost, and built of such material that the maintenance charges are small. Scarcely any material has been found which entirely satisfies these requirements, but some of the pavements of Portland cement concrete which have been built in recent years, where the concrete forms not only the foundation but also the wearing surface, are giving thorough satisfaction and approach closely to the ideal for streets where the traffic is not so excessive as to require a stone block.



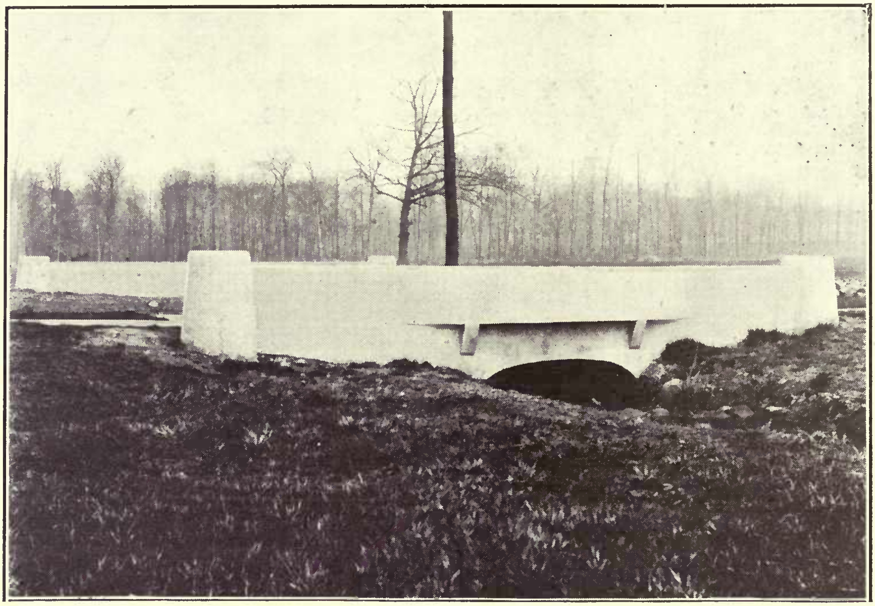
HASSAM PAVEMENT, PORTLAND, OREGON.

For pavement foundations, concrete is used almost universally in city streets where the wearing surface is asphalt, brick, wooden blocks or stone blocks, and there is no material which can be compared with it for this purpose. Its use for the wearing surface is comparatively new, but it is proving its usefulness to a remarkable degree.

Concrete sidewalks made of a concrete base with a granolithic or mortar wearing surface have been in successful use ever since the beginning of the Portland cement industry. As early as 1894 alleys were paved with concrete in Boston, using methods similar to sidewalk construction except slightly thicker layers of concrete and surface divisions into small blocks instead of large ones, so as to give better footing for horses.

Probably the first street pavement of concrete was built in Richmond, Ind., in 1903, on Sailor Street, and in 1906, when it was necessary to cut a trench the entire length of this pavement for telephone conduits, the concrete was found so hard that it could be cut only with great difficulty. On the completion of the conduit the pavement was repaired, and in 1908 it seemed to be as good as when laid in 1903.

An alley pavement in Richmond adjacent to the Wescott Hotel, and built in 1896, in which a very heavy traffic is confined to a small space, proved so satisfactory that the street pavement was an outgrowth of it. An examination of this alley in 1908 showed the surface to be in good condition with very little signs of wear.



BRIDGE AT HAWORTH, N. J.

Concrete street pavements contain the maximum number of desirable qualities as compared with pavements of other materials. They are low in first cost, since the materials of which they are made are within easy reach of all localities desiring good pavements. Practically no section of the country is without stone or gravel good enough for the main body of the pavement, and if local sand is too poor in quality and freight rates prohibit importing good sand, fine crushed stone may be used in its place. "ATLAS" Portland Cement is within the reach of every section of the country.

The quality of materials and workmanship for concrete pavements is of greater importance than in almost any other form of concrete construction. The aggregate must be chosen with extreme care, the cement must be of a first-class standard brand, the proportioning of the materials must be accurate, and the consistency right. Concrete roadways require expert workmanship but no more so than the laying of other forms of pavement. The methods of laying and the materials to employ are best understood by reference to the descriptions given in the pages which follow of pavements which have proved successful. Too great stress cannot be laid upon the matter of a first-class aggregate for the wearing surface; if this cannot be obtained concrete street paving should not be attempted.

The maintenance cost of concrete pavements is very low. They are not injured by the elements or by materials which attack some forms of pavement. The cost of maintenance of a pavement includes the cost of keeping it clean and concrete can be easily cleaned by flushing the street with water, since this does not in the least injure the quality of the concrete whereas with some other pavements constant flushing is extremely injurious.

The item of smoothness is to a large degree within the control of the builder of the concrete pavement; for the surface can be made perfectly smooth or it can be left with any degree of roughness by grooving the surface or otherwise. Clearly, on a steep grade the pavement should be left so that horses can get a foothold and on curves so that automobiles will not slip. Both of these conditions can be met by grooving or roughening the wearing surface of the concrete.

A wagon running over a concrete pavement makes less noise than running over a stone block or other similar pavement having many joints. Another advantage of these pavements is that there are very few places where dust and dirt can collect.

Summing up then the advantages of concrete pavements it is seen that they offer very little resistance to moving vehicles, afford good foothold for horses and prevent slipping of fast moving automobiles, are clean, can easily be kept free from dirt, and are not very noisy. A pavement combining all these desirable qualities is certainly one that should commend itself to those in charge of construction and maintenance of our city streets.

## CONCRETE STREET PAVEMENT FOUNDATIONS.

Concrete was first used in foundations for street pavements in New York City in 1888. At the present time nearly all cities require that concrete foundations shall be laid under all classes of pavements. It is well understood that the success of any pavement depends largely upon its foundation. To insure a good foundation the subsoil should be properly shaped and graded and then thoroughly rolled with a steam roller weighing not less than 10 tons. When rolling the sub-grade care should be taken to remove all timbers or other matter which may decay and leave space underneath the foundation. All ditches or holes must be filled and any soft material removed and replaced by good, dry gravel or similar materials.

## PROPORTIONS OF CONCRETE FOR STREET FOUNDATIONS.

The proportions of materials for concrete to be used in foundations for pavements such as granite blocks or asphalt depend upon the local conditions. The heavier the traffic the stronger should be the foundation. The proportions most common are 1 part "ATLAS" Portland Cement, 3 parts sand, and from 5 to 7 parts broken stone or gravel. In most cases 1 part "ATLAS" Portland Cement, 3 parts sand, and 6 parts broken stone or gravel makes a first class foundation. The thickness of foundations of Portland cement concrete should be 6 inches. The surface of the concrete should be kept wet for a few days.

One square yard of concrete foundation 6 inches thick will require 1/6 of a cubic yard of concrete. If the mixture is 1:3:6, as previously specified, the quantity of cement, sand, and broken stone in a square yard of foundation can easily be determined from the tables of quantities in Chapter I, page 19, by dividing the quantities given by 6. Thus, for 1 square yard of 6-inch foundation made of a 1:3:6 mixture there will be required 0.185 barrels of cement, 0.078 cubic yards of sand, and 0.157 cubic yards of stone. These figures are based on average conditions, that is, 45 per cent of voids in the broken stone. Quantities may also be found still more directly from table in Chapter II, page 27.

## COST OF CONCRETE FOUNDATIONS IN PLACE.

The cost of concrete foundations for pavements varies greatly with the proportions used and with the cost of the materials and labor. The cost ranges from 75 cents to $1.50 per square yard for the usual thickness of 6 inches. The following is an estimate for the cost of 1 cubic yard of 1:3:6 concrete in place making 6 square yards of finished foundation. For other prices of materials and labor the items may be varied accordingly.

| | |
|---|---|
| Portland Cement, 1.11 barrels, $2.00 | $2.22 |
| Sand, 0.47 cu. yd., 75 cents | 0.35 |
| Broken Stone, 0.94 cu. yd., $1.75 | 1.65 |
| Labor with wages at 20 cents per hour | 1.15 |
| Cost of 1 cubic yard, that is, 6 square yards of foundation of 1:3:6 concrete in place | $5.37 |
| Cost of 1 square yard of 6-inch foundation | 0.90 |

## MIXING OF CONCRETE.

Machine mixing gives a better quality of concrete than hand mixing, but unless a large area is to be concreted and the machinery is very carefully selected and arranged, hand mixing is apt to be cheaper and is therefore more commonly used. For hand mixing a tight matched board or metal platform should be used, and the methods should conform to those outlined in Chapter I. The consistency of the concrete may be somewhat dryer than for reinforced concrete work, but should be wet enough so that the mortar will flush the surface with a very little ramming.

FIG. 14.—CONCRETE ROAD AT FLUSHING, L. I., N. Y

## GANG FOR HAND MIXED CONCRETE.

To illustrate the arrangement of a gang in street pavement foundation work, the following example is taken from actual practice:*

Gang for a 6-inch foundation for a street pavement, where the sand and cement were made into a mortar and spread on to the stone, and where two mixing platforms were used, one on each side of the street, with a mortar box between them.

"One foreman.

"Two men mixing mortar in one mortar box.

"Four men shoveling stone alternately into two measuring boxes.

"Four men working alternately on the two mixing platforms, spreading mortar on stone, mixing concrete, and shoveling to place.

"Three men leveling and ramming concrete, and also assisting to shovel to place.

"One man carrying water and doing other odd work.

"The total quantity of concrete in proportions 1:2:5 laid per day of ten hours averaged from 40 to 46 batches or 29 to 33 cubic yards per day for the gang.. The gang was not quite up to the average, for under given conditions they ought to have turned out regularly 34 cubic yards per day of ten hours."

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*See reference, footnote, page 18.

## CONSTRUCTION OF FOUNDATIONS.

The whole operation of mixing and depositing concrete in pavement foundations should be carried on as quickly as is possible with thoroughness. Concrete which has been mixed and has set or hardened to any extent should not be allowed to be used in the foundation. Wherever possible the concrete should be laid entirely across the street without longitudinal joints. Boards set to proper elevation and curved on the upper edge to conform to the cross section of the foundation are set across the street and between these forms the concrete is laid.

When connection is to be made with any section which has been previously laid and which is partially or wholly set the edge of such section must be broken off so as to be vertical, and must be freed from dirt and properly wet before fresh concrete is laid against it. No carting, wheeling, walking or bicycle riding should be allowed on the concrete until it has hardened.

The top surface of all concrete foundations should be left rough so as to better hold the wearing surface which is placed upon it. Expansion joints may be left at intervals not over 100 feet lengthwise of the street. They can be made best by setting in the concrete a 1-inch board upright on its edge across the street from the curb to curb and after the concrete is sufficiently hardened the board is removed and the space filled with coarse or fine gravel. Expansion joints are especially necessary near a change in grade of the street where expansion from heat may cause the pavement to buckle upward.

## CROWNING OF ROADWAYS.

The finished surface of all roadways should be higher at the center than at the gutters to afford good drainage. Although engineers do not entirely agree as to the proper amount of this crowning, practically all agree that the upper surface of the sub-grade and of the foundation should be crowned to conform to the upper finished surface of the street pavement. Crowning is necessary on all streets and for all materials and the smallest crown which will properly drain the street surface is best.

The top of the sub-grade is always below the surface of the finished pavement by an amount equal to the thickness of the pavement and its cushion, if any, plus the thickness of the concrete foundation.

In addition to crowning of the surface the street should have a longitudinal grade so that water can be carried off. This grade should not be less than 0.3 feet or 4 inches in 100 feet for hard materials such as pavements of concrete or good macadam. Where the street is level the longitudinal drainage must be secured by giving a grade to the gutters between catchbasins. This necessitates varying the crown along the street.

For widths of roadways between curbs of 24, 30, 36, 48, and 60 feet the crown should be 3, 4, 5, 6, and 8 inches respectively; the inches given being the difference in elevation of the finished wearing surface at the center of the street and at each curb.

The cross section of the street surface is curved and points on this curve can most easily be located by driving stakes at the center of the street, at each curb and at points 1/3 and 2/3 distant from the center to the curb on either side. The tops of these stakes can be located in the following manner: Stretch a string across the street so that it will be level at the proper elevation of the upper finished surface of concrete foundation at the center of the roadway. Compute the ordinates from the string to the elevation of the finished surface of foundation at points 1/3 and 2/3 of the distance from the center toward each curb. The ordinate to be measured down at the 1-3 point nearest the center is equal to 1/9 of the amount of crown determined upon and the ordinate to be measured down at the 2/3 point from the center is 4/9 of the total crown. This is illustrated in the accompanying table. Thus, for a roadway 24 feet wide having a crown of 3 inches the elevation of the finished surface of foundation at points 4 feet on either side of the center should be 1/9 of 3 inches, that is, 1/3 inch below the level string, which corresponds with the elevation of the upper surface of concrete foundation at the center. At points 8 feet out on either side of the center of the roadway the elevations of the finished surface of foundation should be 4/9 of 3 inches, or 1 1/3 inches, below the string. The gutter of course would be 3 inches below the surface at the center where the crown is 3 inches as here assumed. The grade of the sidewalk next to the property line is frequently made the same as the center of the street.

TABLE OF OFFSETS FOR CROWNING STREETS OF VARIOUS WIDTHS.

| Width of Roadway Between Curbs | Crown | Distance From Center of Roadway | Vertical Offset | Distance From Center of Roadway | Vertical Offset |
|---|---|---|---|---|---|
| Feet | Inches | Feet | Inches | Feet | Inches |
| 24 | 3 | 4 | $\frac{1}{3}$ | 8 | $1\frac{1}{3}$ |
| 30 | 4 | 5 | $\frac{4}{9}$ | 10 | $1\frac{7}{9}$ |
| 36 | 5 | 6 | $\frac{5}{9}$ | 12 | $2\frac{2}{9}$ |
| 48 | 6 | 8 | $\frac{2}{3}$ | 16 | $2\frac{2}{3}$ |
| 60 | 8 | 10 | $\frac{8}{9}$ | 20 | $3\frac{5}{9}$ |

Transverse rows of stakes similar to those just described are placed every 10 to 25 feet apart lengthwise of the street. Of course, these stakes should be driven in after the sub-grade is thoroughly rolled and shaped so that they will be parallel to the finished surface of street.

The curbs should always be set to line and grade before the foundation for the pavement is laid.

## FOUNDATIONS UNDER STREET RAILWAY TRACKS.

When a street or a portion of a street under improvement is occupied by street railway tracks and the tracks are removed during construction work, the excavation of that portion of the street occupied by the tracks should be made to a depth of 6 inches below the bottom and 6 inches beyond the ends of the ties. The remainder of the excavation must correspond in depth to that required for the ordinary pavement. The concrete along the track is then laid to a thickness of 6 inches below the bottom of the ties. The ties and rails are set in place upon this layer and brought to true line and grade. Additional concrete should be tamped under and around the rails and thoroughly grouted with a grout made of 1 part "ATLAS" Portland Cement to 2 parts clean, sharp sand. In case concrete beam construction is used, that is, where a rectangular beam of concrete is laid longitudinally under each rail, the excavation must conform to special plans for the track construction.

For sheet asphalt pavements the top of the concrete foundation should be parallel with and 3 inches below the finished surface grade. For stone block pavements to allow for 6-inch block and 2-inch sand cushion the top of the concrete is 8 inches below the finished surface of the pavement. Brick pavements are usually 4 inches thick and are laid with a 2-inch sand cushion between the bottom of bricks and top of concrete foundation so that the concrete is 6 inches below the finished grade.

## CONCRETE PAVEMENTS.

The use of concrete for the wearing surface of a pavement as well as for the foundation is comparatively recent. The examples of these pavements already built have proved so successful that the increase in this class of construction will undoubtedly be very rapid. If, as has been indicated, proper care is used in the selection of the materials and in the workmanship, such pavements will prove satisfactory and durable.

Concrete pavements have been successfully built by several cities as described in the pages which follow, and patented types of pavement, the Blome and the Hassam, have also been laid in various places. Pavements built in Richmond, Ind., and other cities, have been made by similar methods to those employed for first-class sidewalk construction, using a compacted and well drained foundation of concrete and a mortar wearing surface. The Blome pavement is similarly made with a concrete foundation and a concrete wearing surface, using specially selected materials and having the surface divided into blocks.. The Hassam pavement usually consists of well compacted layers of broken stone with the voids filled with Portland cement grout and thoroughly rolled.

FIG. 15.—BLOME GRANITOID PAVEMENT, OHIO STREET, CHICAGO.

## ESSENTIALS OF A CONCRETE PAVEMENT.

In order that a concrete pavement shall prove satisfactory the following essentials must be adhered to:

(1) Thoroughly compacted sub-foundation.
(2) Foundation (unless the soil is very porous) of porous materials rolled or otherwise compacted.
(3) A base of first-class Portland cement concrete.
(4) A wearing surface composed of a standard Portland cement and a carefully selected aggregate.
(5) Expert and very careful workmanship.

The fine aggregate for the surface layer is of the utmost importance. Perhaps the best material is crushed granite or crushed trap whose particles pass a ¼-inch sieve and which contains scarcely any dust. Sand may be used provided it is of exceptionally good quality, coarse, clean, free from clay or other fine matter, and absolutely free from vegetable loam. In natural sand the percentage of dust passing a sieve having 100 meshes per linear inch might well be limited to 3 per cent.

## BLOME CO. GRANITOID CONCRETE PAVEMENT.

Pavements made entirely of concrete are coming more and more into general use as the true strength and worth of concrete is becoming better known and understood. One of the all-concrete pavements is known as the Blome Co. Patented Granitoid Pavement and is laid under patents owned by the Rudolph S. Blome Company of Chicago. As previously stated the Blome Co. Granitoid pavement consists of a lower layer of concrete serving as a base and an upper thinner layer of richer concrete forming a wearing surface; the two layers being laid so as to secure a perfect union, thus forming a monolith. The upper surface is grooved to give a good foothold for horses.

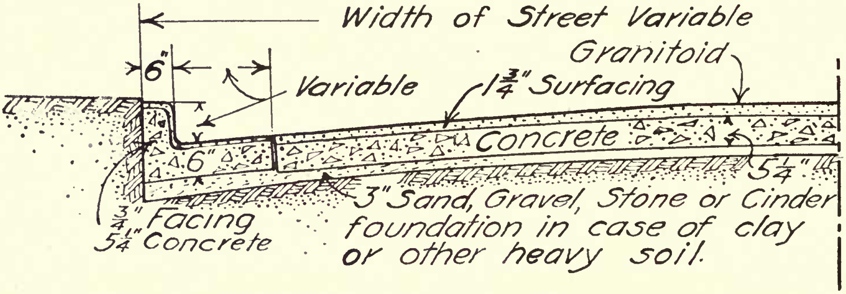

FIG. 16.—STANDARD SECTION BLOME CO. PATENTED GRANITOID PAVEMENT.

Fig. 16 shows a standard section of the Blome Co. Granitoid Pavement. It consists of a 5¼-inch thickness of concrete with a 1¾-inch surface of a richer concrete, the two layers being laid so as to give it thorough union. The drawing shows a foundation of sand, gravel, broken stone or cinders which is necessary where the soil is clay or hard pan or in fact in any soil except a porous sand or gravel. Expansion joints, ½ inch wide, are left along the gutters or curbs.

The granitoid pavement has been laid in many places and has given very good satisfaction. It presents a gritty surface and affords an excellent foothold for horses. On wet slippery streets horses travel more freely and easily on the granitoid pavement than on other more smooth and equally hard pavements. Granitoid has been used successfully on 8 per cent grades at Knoxville, Tennessee; on streets in Michigan where the temperature falls at times to 40 degrees below zero; and on streets in the South where the pavement is subjected to intense heat. Granitoid pavements have demonstrated that when properly laid concrete is not seriously affected by temperature.

## GENERAL SPECIFICATIONS FOR THE BLOME COMPANY GRANITOID CONCRETE BLOCKED PAVEMENT.

The following general specifications have been furnished through courtesy of the Rudolph S. Blome Company of Chicago.

PREPARATION OF SUB-GRADE.—The street shall be graded (excavated or filled as the case may be) to sub-grade, including compacting and rolling by means of a heavy steam roller, and all slopes, contours and other shaping required in the finished pavement shall be formed and provided for in said sub-grade, so that the foundation and pavement hereinafter specified will be uniformly of the same thickness throughout. The contractor to use extreme care to remove all spongy material or other unsuitable or vegetable matter that may be in the way of making this improvement a permanent one.

The contractor will bid with the strict understanding that he or they must use all necessary precautions in preparing the sub-grade, so as to support the pavement permanently, and so that the pavement shall remain at the original grade for a period of five years. This clause shall not be waived on account of any trenches or holes dug in the street by any corporation or private party, prior to the laying of the pavement.

FOUNDATION.—Where the natural soil is of sandy or gravelly nature, no other foundation will be required, but where the natural soil is clay, the contractor shall grade for and provide a foundation of sand, gravel, crushed stone or other suitable material, and which foundation after having been flooded and compacted, satisfactory to the engineer, shall be not less than 3 inches thick.

MATERIALS.—Samples of the cement which is proposed to be used in the work shall be submitted to the engineer in such quantities and at such time and place as will enable him to make all required tests.* The engineer reserves the right to reject without recourse any cement which is not satisfactory, whether for reasons mentioned in these specifications or for any good and sufficient cause.

All the cement to be used must be delivered on the work in approved packages, bearing the name, brand or stamp of the manufacturer. It shall be thoroughly protected from the weather until used in such manner as may be directed.

SAND.—All sand shall be clean, dry, free from dust, loam and dirt, of sizes ranging from ⅛ inch down to the finest, and in such proportions that

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*Specifications for the cement are also included.

the voids, as determined by saturation, shall not exceed 33 per cent of the entire volume, and it shall weigh not less than 95 pounds per cubic foot. No wind drifted sand shall be used.

CRUSHED STONE.—All crushed stone used in making the concrete shall be of the best quality of limestone, trap rock or granite, clean, free from dirt, broken so as to measure not more than 1½ inches and not less than ¼ inch in any dimension. The stone when delivered on the street shall be deposited on flooring and kept clean until used.

GRAVEL.—If gravel is used, same to be perfectly clean gravel, free from all loam and foreign substances, and the same size as that specified herein for crushed stone.

## MIXING AND LAYING OF CONCRETE AND FORMATION OF THE BLOME COMPANY GRANITOID BLOCKING.

The concrete and blocking hereinafter specified shall be constructed and manipulated according to the Blome Company patents and processes, using materials mixed in the proportions and laid as hereinafter specified.

The pavement shall consist of 5¼ inches of concrete, and surface blocking 1¾ inches, making a total of 7 inches, exclusive of foundation.

After the sub-grade and foundation have been prepared as hereinbefore specified, there shall be deposited concrete composed of 1 part of Portland cement, 3 parts sand, and 4 parts of crushed limestone, trap rock, or clean gravel. These materials to comply with the requirements hereinbefore set forth and shall be mixed by special mixing machine suitable for the purpose to be approved by the engineer and shall be mixed at least five times before being removed from the mixer. The concrete shall be thoroughly tamped in place, and shall be 5¼ inches thick, uniformly at all points, after having been compacted, shall be laid in sections with expansion joints, all as per the Blome Company patents and shall follow the slopes of the finished pavement so that the surface blocking is and shall be uniformly of the same thickness at all points.

SURFACING MATERIAL.—After the concrete has been placed and before it has begun to set, there shall be immediately deposited thereon the Granitoid Blocking which shall be 1¾ inches in thickness to be composed of two parts of the hereinbefore specified Portland cement and three parts of clean, crushed granite, trap rock, hard stone, crushed gravel, crushed boulders, or other similarly hard materials shall be screened with all the dust removed therefrom utilizing the following composition of this material.

Fifty per cent of the granite, trap rock, hard stone, crushed gravel, crushed boulders or other similarly hard materials to be what is known as ¼-inch size, 30 per cent of the ⅛-inch size, and 20 per cent of the 1-16-inch size with all finer particles removed. These proportions of sizes are extremely essential and must be kept absolutely accurate as in this lies one of the essential requirements to produce proper results. This material to be mixed with cement thoroughly and after being wetted to a proper consistency and deposited on the concrete shall be worked into brick shapes of approximately 4½ inches by 9 inches with rectangular surface similar to paving blocks, all as per special method and utilizing grooving apparatus as employed under the Blome Company patents. The pavement shall be sloped in a manner as required by the City Engineer.

Should there be any part or parts of this pavement when completed where the slopes, contours, etc., have not been carried out in true manner then under this specification the contractor will be required to take up such part or parts down to the foundation and replace same to the proper level without expense of any kind to the city.

EXPANSION JOINTS.—The contractor for the work above specified shall also be required to provide for expansion joints across the pavement at such locations as may be necessary, which expansion joints shall extend through the blocking and concrete and shall be filled with a composition especially prepared for the purpose according to the Blome Company patents. These expansion joints shall be constructed in an extremely careful manner under specific direction of the City Engineer.

PATENTS.—All fees for any patent invention, article or arrangement or other apparatus that may be used upon or in any way connected with the construction, erection, or maintenance of the work or any part thereof, embraced in the contract on these specifications shall be included in the price stipulated in the contract for said work, and the contractor or contractors must protect and hold harmless the city against any and all demands for such fees or claims.

GUARANTY.—Upon the completion of the contract, the contractor shall furnish a satisfactory surety company bond executed by one of the Surety Companies in good standing in the State of ————, guaranteeing the pavement mentioned against settlements, upheavals, disintegration and the results of faulty workmanship, and the use of materials of improper quality for and during the period of five years from and after the date of completion of the pavement.

It is to be expressly understood that the above-mentioned pavement shall satisfactorily withstand all severe usage to which same will be subjected during and for the period named above.

BIDDERS' ATTENTION.—The attention of the bidders is called to the following copy* of agreement in the offices of the City Clerk for furnishing

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*Not here given.

necessary materials and mixtures for laying the surfacing material of the contemplated pavements and for the allowance of the uses of certain patented processes owned and controlled by the Blome Company and for the expert advice which will be furnished, which agreement forms a part of these specifications and which must be considered as a requirement by prospective bidders in the making up of their proposals on the contemplated work.

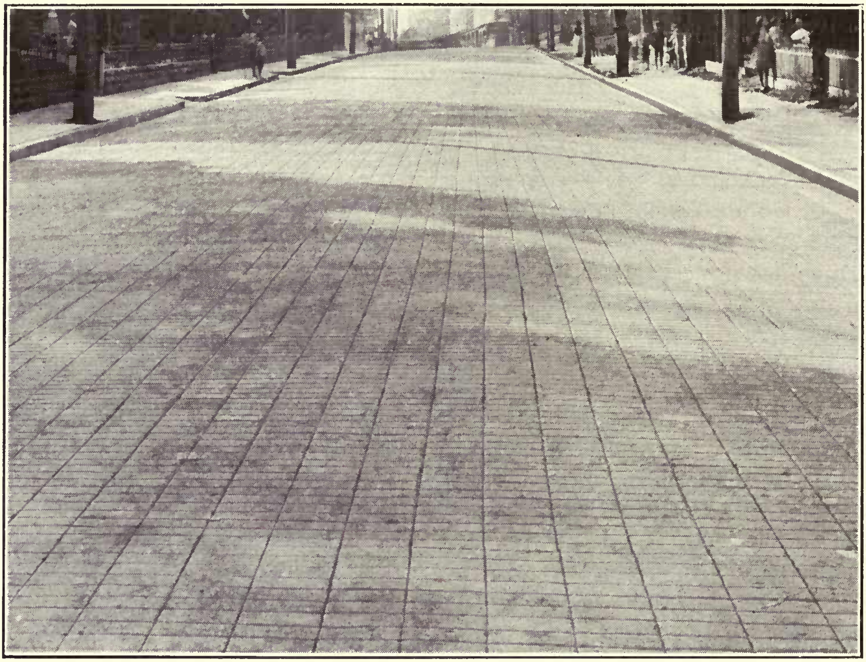


FIG. 17.—BLOME CO. GRANITOID PAVEMENT, KNOXVILLE, TENN.

## COST OF BLOME CO. GRANITOID PAVEMENT.

The cost of this pavement varies greatly, depending upon location, quantity of work, costs of the various materials and labor. The price ranges from $1.50 to $3 per square yard, not including excavation or grading. Its use compares favorably in cost with brick, asphalt, or creosote or wooden blocks on concrete foundations.

In Knoxville, Tenn., the same granitoid laid in accordance with methods previously described cost $1.88 per square yard in place, exclusive of the grading, which varied from 15 to 20 cents per square yard of pavement, making the total cost of finished pavement from $2.03 to $2.08 per square yard.

In New Haven, Conn., the Blome pavement has been laid at $2.25 per square yard.

A piece of granitoid block laid on 48th Avenue, Hawthorne, Ill., in the fall of 1904, was in very good condition when examined in January, 1909. This pavement is 7 inches thick and cost $3 per square yard exclusive of excavation or grading.

## HASSAM PAVEMENT.

Hassam pavements are laid in the form of a grouted macadam street or as a granite block pavement on a grouted macadam foundation. In each case the work is done in a manner peculiar to this type of pavement.

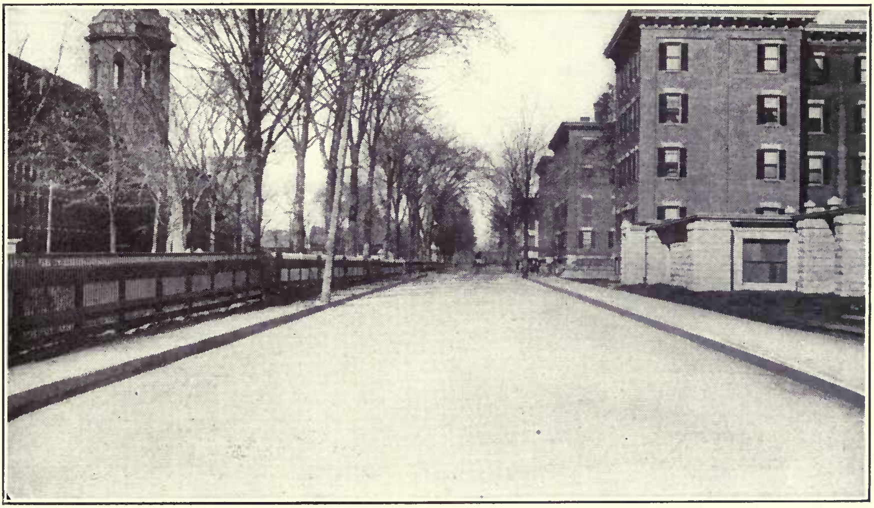


FIG. 18.—HASSAM PAVEMENT, BIDDEFORD, MAINE.

## HASSAM GROUTED CONCRETE PAVEMENT.

The Hassam pavement as usually laid consists of a properly compacted sub-grade upon which is placed a layer of broken stone thoroughly rolled to a thickness of six inches and made to conform to the grades and contour of the street. After this stone has been firmly compacted by rolling and the voids reduced to a minimum it is grouted with a Portland cement grout made of one part cement and two parts sand. This grout is poured upon the stone until all the voids are filled and the grout flushes to the surface. The rolling is continuous during the process of grouting. Upon this surface is placed a very thin layer of pea stone which is spread over the entire area of the roadway, grouted and rolled, the rolling to continue until the grout flushes to the surface. Expansion joints are left along the curbs. The data given above was taken from the specifications of the Hassam Paving Company who have a patent on this pavement.

Hassam pavement has been laid upon a grade of 7 per cent in Biddeford, Maine.

## LONG ISLAND MOTOR PARKWAY.

The automobile is rapidly changing the conditions governing the building of improved streets and highways. This is particularly noticeable along the suburban highways where it is possible to run automobiles at high speeds. Concrete pavement seems to be well adapted to meet the conditions imposed by this particular class of traffic. An example of the Hassam type of pavement for automobile traffic is the Long Island Motor Parkway. The paved portion of this parkway is several miles in length and "ATLAS" Portland Cement was used throughout.

FIG. 19.—CONSTRUCTION OF LONG ISLAND MOTOR PARKWAY.

The method of construction was as follows: The sub-grade was shaped and rolled with a 10-ton roller. A 2½-inch layer of broken stone 1½ to 2½ inches in size was then spread upon the sub-grade and upon this broken stone a wire fabric reinforcement was laid over the entire width of the roadway and the separate sheets overlapped as shown in the photograph. A layer of broken stone was then spread upon the fabric so as to conform to the cross section of the roadway and to give a pavement five inches in thickness after rolling.

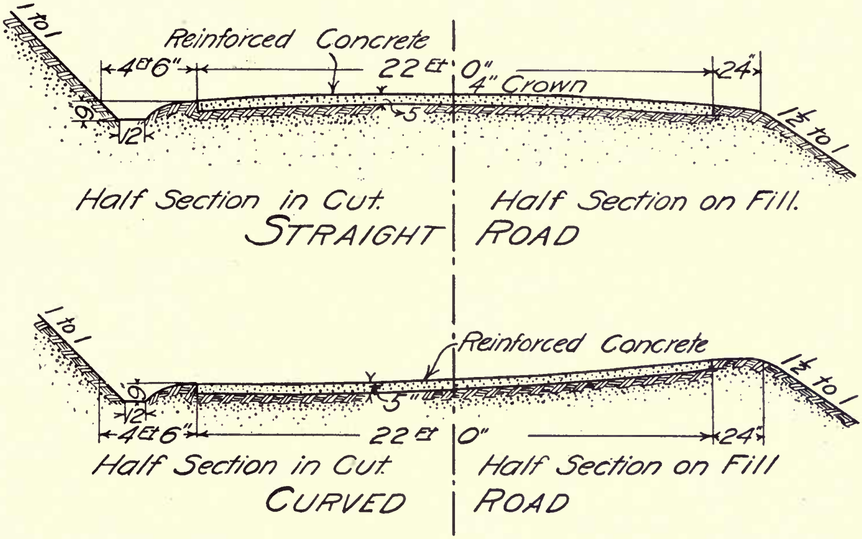


FIG. 20.—TYPICAL CROSS SECTION OF LONG ISLAND MOTOR PARKWAY.

After the ballast was placed on the reinforcement it was thoroughly rolled and compacted with a 10-ton roller. Portland cement grout made with one part of "ATLAS" Portland Cement and two parts sand was mixed in a mechanical mixer and poured upon the surface of the rolled ballast until all the voids were filled and until the grout flushed to the surface after rolling. The grout was colored with lampblack to slightly darken the finished pavement. After the grout had been poured and rolled a thin layer of pea stone was spread, grouted, and the surface again rolled as before.

The finished pavement was given a rough surface by brooming so as to form very small ridges at right angles to the length of the roadway. Care was taken to complete all rolling after grouting each section before a sufficient period of time had elapsed to allow the cement to take its initial set. Automobiles were allowed on the finished pavement ten days after completion.

This pavement was laid by the Hassam Paving Company of Worcester, Mass. No provision was made for expansion or contraction, but as previously stated the roadway was reinforced with wire fabric. Fig. 20 shows typical sections of the parkway. The upper drawing represents construction where the road is straight, and the lower where the road is on a curve.

## COST OF HASSAM PAVEMENT.

A Hassam pavement was completed in Watertown, Mass., during October, 1908, at a cost of $1.85 per square yard. The pavement consists of a 6-inch thickness of rolled broken stone grouted with one part "ATLAS" Portland Cement and two parts clean, fine, sharp sand. The grout was mixed in a Hassam grout mixer. The surface of broken stone after the first grout was placed was covered with a pea grade of broken stone, and this finer stone in turn was covered with a grout of the proportion of one part "ATLAS" Portland Cement and one part sand, and rolled with a steam road roller before the first grout had time to set.

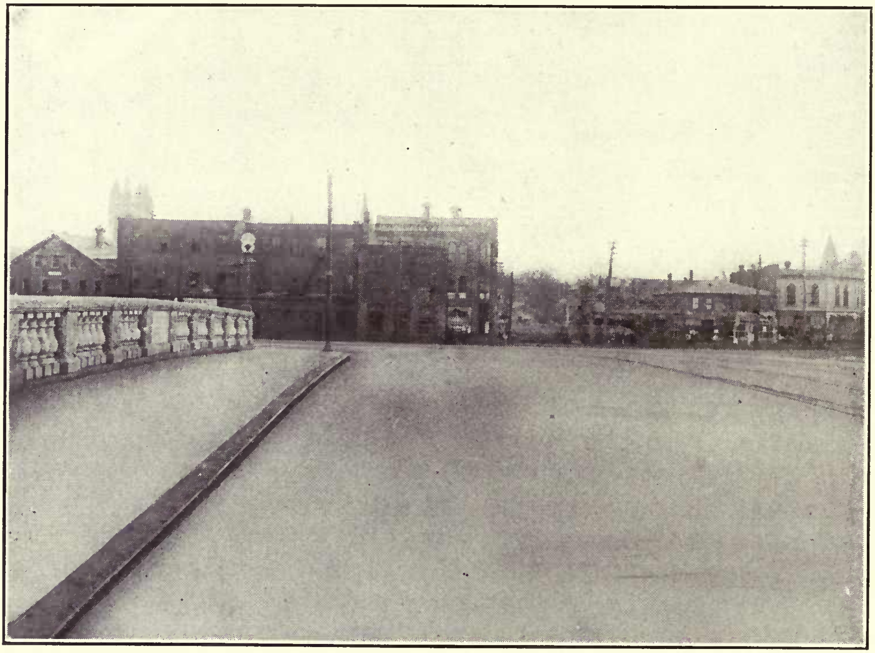


FIG. 21.—HASSAM PAVEMENT, WATERTOWN, MASS.

## HASSAM GRANITE BLOCK PAVEMENT.

River Street, in Troy, N. Y., is paved with a Hassam Granite Block Pavement on a Hassam foundation. The foundation in this pavement consists of a 6-inch layer of broken stone grouted with one part "ATLAS" Portland Cement and four parts sand. Grout was mixed in a Hassam grout mixer, was poured upon the broken stone until all voids were filled and the grout flushed to surface. This foundation was rolled during the process of grouting as well as being thoroughly compacted by rolling before the grout was applied.

The pavement proper consists of granite paving blocks having dimensions 4 to 4½ inches deep, 3½ to 4½ inches wide and 6 to 12 inches long, laid on edge across the street on a sand cushion 1½ inches in thickness placed on the Hassam foundation. Pea stone was sprinkled upon the surface of the blocks and swept into the joints with wire brooms, the pavement rolled to an even surface or rammed when roller could not be used, and the surface was then swept clean and the joints filled with a grout made of one part "ATLAS" Portland Cement and one part clean, sharp sand. The grout was spread upon the paving and brushed into the joints, the stone blocks having previously been wet by sprinkling, and the grout was then broomed to a fine smooth surface. The blocks were laid with joints not to exceed ½ inch.

The sand cost $1.25 per cubic yard delivered upon the street in bags. Crushed stone cost $1.45 per cubic yard delivered. Day labor cost $1.75 per day of 8 hours. Contract price including all materials and labor was $3 per square yard. Fig. 22 shows a cross section of this street.

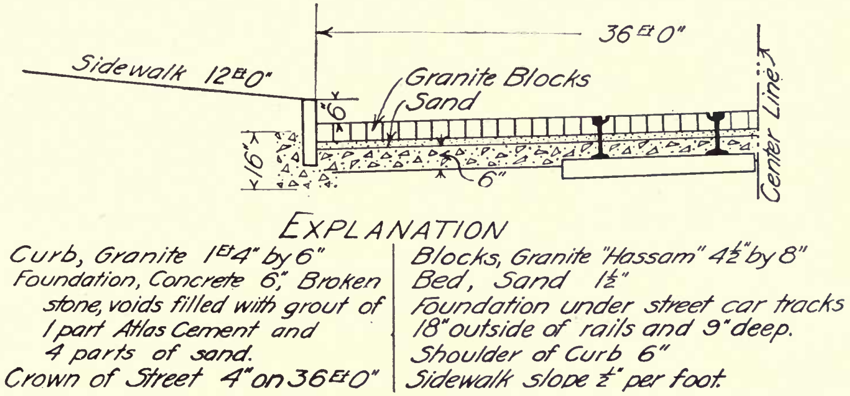


FIG. 22.—CROSS SECTION OF GRANITE BLOCK PAVEMENT ON RIVER STREET, TROY, N. Y.

## CONCRETE PAVEMENT IN RICHMOND, IND.

Numerous streets and alleys have been paved with concrete in Richmond as previously stated in this chapter. The first concrete street pavement in Richmond was laid in 1896 at a cost of $1.62 per square yard, since then the cost has been still further reduced.

The usual pavements for streets of ordinary traffic in Richmond have a concrete base 5 or 6 inches thick with a top wearing surface 1 or 1½ inches thick.

For such pavements, that is, those requiring a thickness of 6 or 7 inches, a foundation consisting of 8 inches of rubble, field cobble stone, the refuse from quarries, or coarse gravel is placed. On this layer is spread sufficient gravel to fill the spaces, and, after flooding and ramming, to make a total thickness of the foundation of 10 inches.

On this foundation 5 inches of thoroughly rammed 1:2:5 concrete is laid in blocks 10 feet by 15 feet.

The wearing surface, 1½ inches in thickness, and composed of one part cement and two parts clean, coarse sand; or else of one part cement, one part sand, and one part clean, crushed stone screenings, must be placed on the 5-inch base before the latter has set. This wearing surface is troweled down to insure contact, then leveled off with a straight edge. When hard enough it is floated or troweled to a smooth, continuous surface.

The surface is finally pitted with a brass roller except for marginal strips two inches wide around the edges of the blocks. The wearing surface is cut into blocks the same size as the base.

For streets having heavy traffic a concrete base is laid in addition to the regular pavement so that the total thickness is the same as a brick pavement on a concrete foundation or about eleven inches total. These pavements are constructed as follows:

Where necessary an 8-inch layer of gravel thoroughly wet and consolidated is used for sub-drainage and upon this gravel foundation is placed a 6-inch layer of 1:3:6 Portland cement concrete. When this concrete foundation is strong enough to sustain the roadway pavement it is covered with a coating of fine sand, raked off with a flat board rake so as to remove all sand except that which may remain in low places and voids in the concrete foundation. Upon this sand is placed a thin layer of tar paper and upon the paper a 1:2:5 concrete layer four inches thick.

Upon the above concrete is placed a wearing surface one inch in thickness composed of one part cement, one part clean, sharp sand, and one part clean stone or granite screenings, mixed with water to form a rather wet facing mixture. In some cases this wearing surface is placed in two layers, each one-half inch thick, the first to be thoroughly rammed to insure perfect contact; the second applied immediately after and troweled and worked over, and made to conform to the finished surface of the street. When sufficiently hard, the surface is floated and steel troweled and finished with a cork float.

## CONCRETE PAVEMENTS IN THE CITY OF PANAMA.

Fig. 23 shows West Fifteenth Street in the city of Panama being paved with 1:2½:5 "ATLAS" cement concrete five inches thick; after tamping in place it is finished with a straight edge and trowel. The surface is smooth but not slippery. The concrete, hand mixed, was placed with wheelbarrows. Broken stone was obtained by crushing old cobble stones. The sand was obtained from Panama Beach. In 1906 and 1907 over two miles of this pavement was laid in the city of Panama at a cost of $2 per square yard on streets having grades as high as 8 per cent. It was laid in alternate blocks or sections about 10 feet long lengthwise of the street and extending all of the way or one-half way across the street between curbs. The streets vary in width from 13 feet to 20 feet between curb lines.

FIG. 23.—CONCRETE PAVEMENT IN THE CITY OF PANAMA.

## GROUTING STONE BLOCK AND BRICK PAVEMENTS.

For filling the joints in stone block or brick pavements the cement grout should be mixed one part "ATLAS" Portland Cement and one part clean sand with enough water to make the grout flow easily. The materials must be thoroughly mixed with hoes in a tight box at the place of using. As soon as the mixing is completed the grout must be immediately poured out of the box upon the surface of the pavement and broomed into the joints before the cement sets.

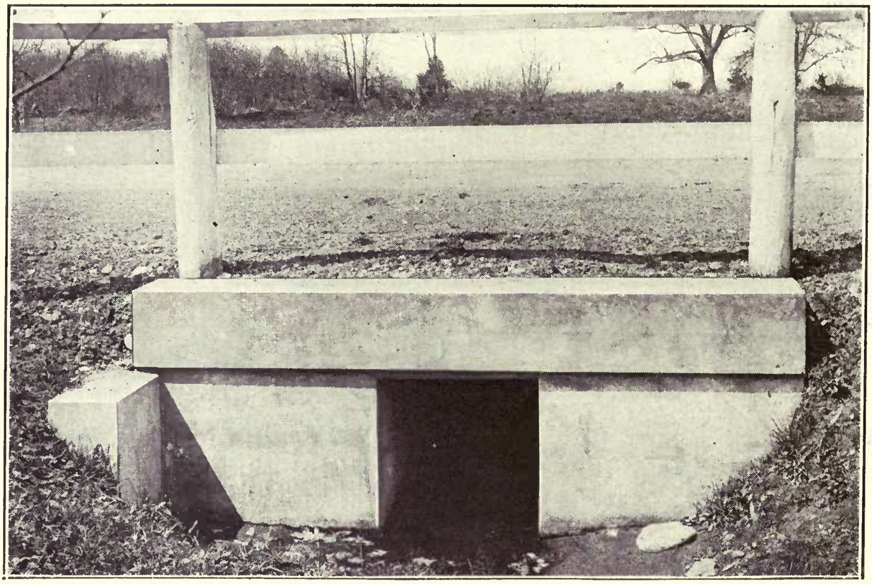
Every twenty-five feet, measured lengthwise of the street, one or two transverse joints should be filled with tar to provide for expansion. The joint next to each curb should also be filled with tar.

# CHAPTER IV.

## SEWERS, DRAIN TILES, BROOK LININGS, CONDUITS.

### SEWERS.

While formerly all large sewers were built of brick and the smaller ones of vitrified clay or cast-iron pipe, in recent years concrete has entered this field of construction and through a process of expansion and adaptation has been gradually supplanting all of these materials. At first its use was limited to foundations and the lower part of side walls, then to lining the inverts of brick sewers, and finally increasing experience and additional confidence has led to its use for the construction of entire concrete sewers and also sewer pipes.



BOX CULVERT, AMHERST, MASS.

The larger concrete sewers, molded in place, are practically monolithic, while the smaller ones, constructed by joining short lengths of concrete pipes together and sealing the joints, make one continuous pipe.

Aside from being generally cheaper than brick, concrete sewers are more permanent and water-tight, have a much smoother surface and therefore a greater carrying capacity, and are less liable to damage and collapse through excessive loads, vibrations and unsuitable foundations.

## CONCRETE PIPE SEWERS.

While monolithic sewers molded in place are entirely satisfactory for diameters of more than 30 inches, owing to the difficulty of devising suitable forms they are impractical and less economical for smaller diameters. Concrete pipe, on the other hand, can be made economically and easily in sizes ranging from 3 inches to 36 inches inside diameter.

Concrete pipes can be made wherever gravel, sand and cement can be brought together, and at a cost considerably lower than cast-iron pipe and usually less than vitrified clay. They can be molded as desired into sectional forms which are more conducive to stability and efficiency than the circular cross-section which is necessary with cast iron or vitrified clay. By giving concrete pipe a broad, flat level base, they are made to rest firmly and securely on a continuous, flat earth foundation, while to secure such a bearing for a circular pipe requires tamping the earth filling into the space beneath the two sides of the pipe and also cutting out a depression in which the bells can rest.

In localities where there are great variations in the amount of sewage flowing through the pipes an oval form of cross section is better than a circular one. For this concrete must be used, since vitrified pipe cannot be made into these forms on account of the warping due to burning.

This warping also prevents the finished section of vitrified pipe from being truly circular so that when these pipes are fitted together there are rough projections at many points on the inside of the pipe which tend to collect solid matter in the sewage and thus to reduce its carrying capacity.

Concrete pipes can be given a tapering butt joint, instead of the bell and spigot joint common for vitrified and cast-iron pipe, which considerably reduces both the cost of manufacture and of joining the pipe with mortar in the trench.

That concrete pipes without reinforcement possess sufficient strength for use as sewers is shown in the accompanying table* which gives the results of

### TESTS OF PLAIN CONCRETE SEWER PIPE IN BROOKLYN.

| Kind | Diameter, Inches | Thickness, Inches | Age | Breaking Load, Lb. per Lin. Ft. |
|---|---|---|---|---|
| A | 12 | $1\frac{3}{16}$ | 32 days | 1,689 |
| B | 15 | $1\frac{7}{16}$ | 33 days | 1,800 |
| B | 18 | $1\frac{3}{8}$ | 29 days | 1,767 |
| A | 12 | $1\frac{3}{16}$ | 1 month 29 days | 1,622 |
| B | 15 | $1\frac{1}{2}$ | 2 months 3 days | 1,617 |
| B | 18 | $1\frac{7}{16}$ | 1 month 29 days | 1,522 |
| C | 6 | $1\frac{5}{16}$ | | 2,600 |
| A | 9 | $1\frac{3}{16}$ | Several years over 3 years | 2,011 |
| A | 12 | $1\frac{1}{4}$ | 2 years 9 days | 1,983 |
| B | 15 | $1\frac{1}{2}$ | 1 year 7 months 20 days | 1,962 |
| B | 18 | $1\frac{5}{8}$ | 2 years 7 days | 2,022 |
| B | 24 | $2\frac{1}{8}$ | 2 years 1 month 28 days | 1,978 |

A, circular pipe with flat base. B, egg-shape with flat base. C, circular pipe.

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*Part of table from Engineering Record, Vol. 58, Nov. 21, 1908, p. 591.

tests on pipes made in the testing laboratory of the Bureau of Sewers of Brooklyn, N. Y.

The pipes which, as seen from the accompanying table, varied in diameter from 6 to 24 inches, were made of a mixture of 1½ parts cement to 1 part sand to 3 parts trap rock screenings, and were tested at ages varying from twenty-nine days to over two years. The 6-inch pipes were made 24 inches long while the larger diameters were 36 inches in length. They were tamped into molds, and then subjected to heat to dry them immediatly after molding, the forms being removed within half an hour after the work on a length was started.

CULVERT, DUMONT, N. J.

In testing a section of the pipe it was laid on a sand bed so that the lower one-sixth of its circumference was in contact with the sand and then the pressure was applied from the testing machine along the upper surface of the pipe until the pipe broke. In order to secure an even distribution of the pressure along the length of the pipe, the pressure was applied through a strip of plaster of Paris one inch wide and not over one-quarter inch thick, held in place by strips of wood.

The accompanying table shows the sizes of the pipe in inches together with the thickness of the walls, the age, and the breaking load in pounds per linear foot. In order to break a 12-inch pipe 32 days old, for example, a load of 1,689 pounds on each foot of length of the pipe was required, the total load for the 3 feet of pipe being thus three times 1,689, or 5,067 pounds.

The pipes, it must be remembered, were of plain concrete without reinforcement.

## LARGE CONCRETE SEWERS.

Large sewers and conduits are built of plain concrete and also of reinforced concrete. For diameters of 3 to 4 feet the thickness required for good construction is usually sufficient without reinforcement as they can be reckoned as strong as a brick sewer of the same diameter which is half again as thick. For large diameter, reinforcement is generally advisable, and the saving in material will more than counterbalance the added cost of reinforcing. The reinforcement adds to the strength of the sewer during construction, and when completed enables it to withstand a larger pressure after the earth is filled in around and on top of the pipe, and also renders it less liable to damage where there is danger of settlement.

### THICKNESS OF CONDUITS*

| Diameter of Conduit | Thickness of Crown, Inches | Thickness of Haunch, Inches | Thickness of Invert, Inches |
|---|---|---|---|
| 2 | 4 | 6 | 5 |
| 6 | 7 | 18 | 8 |
| 12 | 13 | 23 | 14 |

"If reinforcement is used, the thickness for conduits for ordinary sizes is usually determined by the minimum thickness of concrete which can be laid so as to properly imbed the metal. This minimum for the large diameters where steel is advisable may be taken as 6 inches."

As a guide for determining the thickness of concrete required for both plain and reinforced concrete sewers, the general rule used by Mr. William B. Fuller* is given as follows:

"If concrete is not reinforced and ground is good—able to stand without sheeting—make crown thickness a minimum of 4 inches, and then one inch thicker than diameter of sewer in feet. Make thickness of invert same as crown plus one inch except never less than 5 inches.. Make thickness at haunches two and a half times thickness of crown, but never less than 6 inches.. If ground is soft or trench is unusually deep, these thicknesses must be increased according to experienced judgment."

## SIZES OF CIRCULAR CONCRETE SEWER PIPE.

Fig. 24 shows one form of concrete circular pipes suitable for sewer con-

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*See reference, footnote, page 18.

struction. The pipes are shown 2 feet 6 inches in length over all, the inside diameters can be anything from 12 to 48 inches, and the thickness of the pipe from 2 to 6 inches. The joints are beveled so that when laid with Portland cement mortar the joints will be practically water tight, and will present a smooth surface so that solid matter will not be deposited, as is apt to be the case in vitrified pipe sewers.

In laying these pipes a little mortar mixed 1 part "ATLAS" Portland cement and 2 parts clean sharp sand is placed inside of the pipe in the inner beveled surface. The pipe is then pushed hard against the beveled end of the length of pipe already laid, and the motar smoothed off inside and outside of the pipe so as to make a smooth joint.

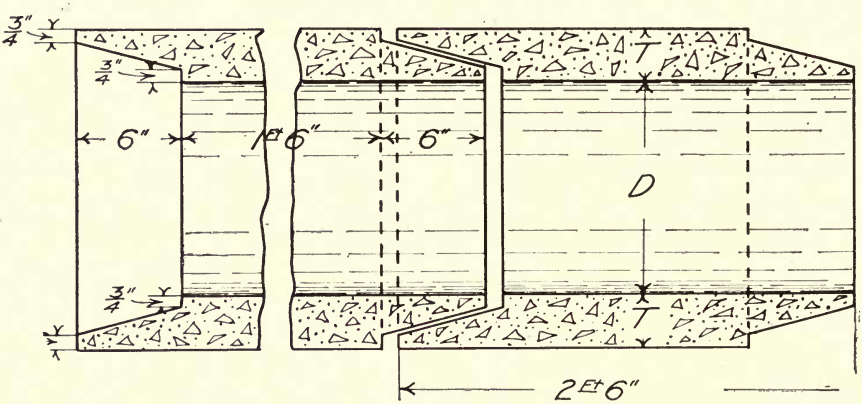

FIG. 24.—LONGITUDINAL SECTION OF SEWER PIPES.

The inside diameter of the pipes, D in Fig. 24, are 12, 18, 24, 30, 36, 42, and 48 inches, and the thickness T in the figure corresponding to these diameters should be 2, 3, 4¼, 4½, 4¾, 5¾, and 6 inches. That is, for a 12-inch pipe the thickness should be 2 inches; for an 18-inch pipe, 3 inches, and so on. For drain tile, which need not be so thick as sewer pipe, thinner pipe may be used.

## PROPORTIONS OF CONCRETE FOR SEWER PIPE.

Concrete used in the construction of sewer pipe, that is, in the construction of pipes having diameters of 12 or more inches, should be mixed in the proportions of 1 part "ATLAS" Portland Cement, 2 parts clean, sharp sand, to 4 parts crushed stone or clean coarse gravel not more than 1 inch in diameter.

## CONCRETE DRAIN TILE.*

Tiles are used for draining roadways and farms.* A roadway of even the best material needs some drainage and for roadways made of poor materials drainage is absolutely essential. Concrete drain tiles are the best for the under drainage of any roadway or sidewalk. Oftentimes in the construction of roads and sidewalks one or more longitudinal lines of drain pipes are laid underneath the surface of the road or sidewalk and at convenient places are carried to proper outlets. Frequently a drain 4 inches in diameter is sufficient for draining sidewalks or roadways.

## SIZE OF CONCRETE DRAIN TILES.

Concrete drain tiles are made in sizes of 4 inches to 30 inches inside diameter. Ordinarily the sizes from 4 to 12 inches are molded by machine, although they may be made in simply constructed molds as described in "Concrete Construction about the Home and on the Farm," while the larger sizes are usually made by hand. Although concrete sewer pipes have either bell shaped or other similar joints, concrete drain tiles are nearly always made with plain ends.

The thickness of the shell for tiles varies from 1 inch or even thinner for the 4-inch pipes to 3 inches for the 36-inch pipes. The sizes under 10 inches in diameter are made 1 inch or less in thickness; the 12 to 24-inch, from 1 to 2 inches thick; the 24 to 36-inch, 3 inches.

Usually sizes under 10 inches in diameter are made 18 inches long and those 10 inches or more are made 2 feet long.

## MIXTURES FOR TILES.

The best mixture for tiles is 1 part "ATLAS" Portland Cement to 3 parts clean coarse sand, or sand and gravel passing a ½-inch screen.

A 1:3 mixture for drain tiles to be used in roads, either for longitudinal or cross drains, gives the proper strength to the pipes. For farm drainage and other similar locations where there is not much pressure exerted upon the pipe a 1:4 mixture is sometimes used.

## CURING.

For ordinary drain tiles the concrete should be mixed with enough water so that the moisture will show at the surface when the concrete is tamped. As a general thing, the molds can be removed as soon as the concrete is thor-

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*See also "Concrete Construction about the Home and on the Farm," p. 91. This book may be obtained by writing to The Atlas Portland Cement Co., New York.

oughly rammed into them. After the molds are removed, the tiles should be placed in the shade, and wet down as soon as the concrete will stand the water without washing, which is ordinarily from 8 to 10 hours after molding. It is of the utmost importance that they should not be allowed to dry out for at least 4 days, and they should also be kept in the shade for 8 or 10 days, being wet once or twice each day during this period. If the weather is very dry or hot, 3 or 4 wettings for the first few days are desirable. A pretty good rule to follow is that the pipes must not be allowed to dry "white" until they are at least 8 days old. After this treatment the tiles should be stored in an open yard to season and harden. In ordinary weather the pipes are ready for shipment in 30 days.

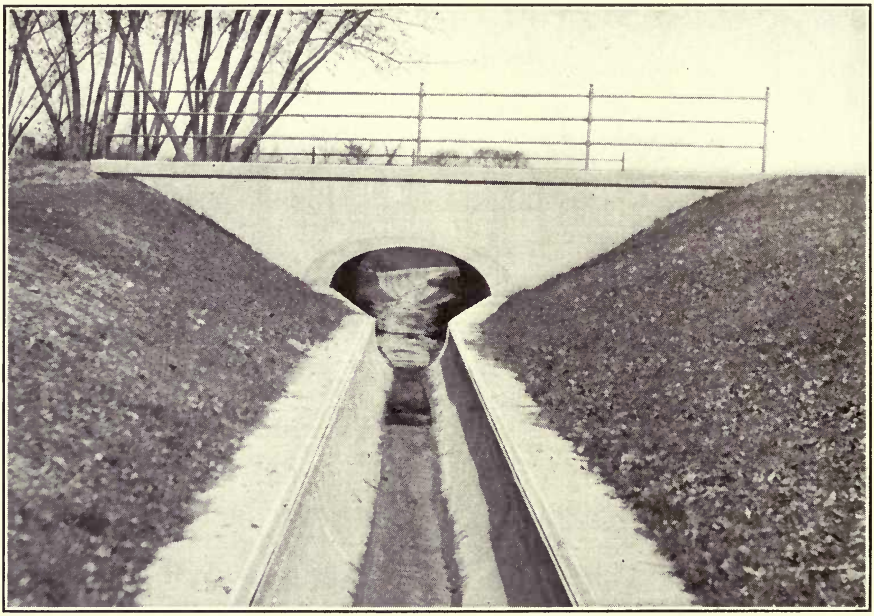


FIG. 25.—CONCRETE BROOK LINING IN NEWTON, MASS.

## LAYING DRAIN TILES.

Concrete drain tiles under roads must have at least 1 foot of earth on the top of the pipe and they must be laid on a grade of at least 1 foot in 100 feet, that is, one foot fall of the pipe in 100 feet of distance.

The pipes should be laid with open joints, that is, with the ends simply abutting without any mortar.

## BROOK LININGS.

A small stream of water running through a town or through the flats adjoining a town often is the cause of a great deal of trouble. If the adjoining lands are to be divided into house lots the brook must be properly taken care of. Usually the best solution for this problem is to change the course of the brook so that it will flow under a street through a concrete conduit. If the stream is not within the limits of a street the banks can be lined with concrete, the top thus being left open. The concrete lining prevents the nuisance caused by the breeding of mosquitoes and other insects along the edges of the open brook. Fig. 26 shows typical drawings of a brook lining in Newton, Massachusetts. The concrete lining, throughout most of the length is curved to a radius of 18 inches, inside diameter, and for the most part is 8 inches in thickness, the invert being 8 inches and the thickness at the upper

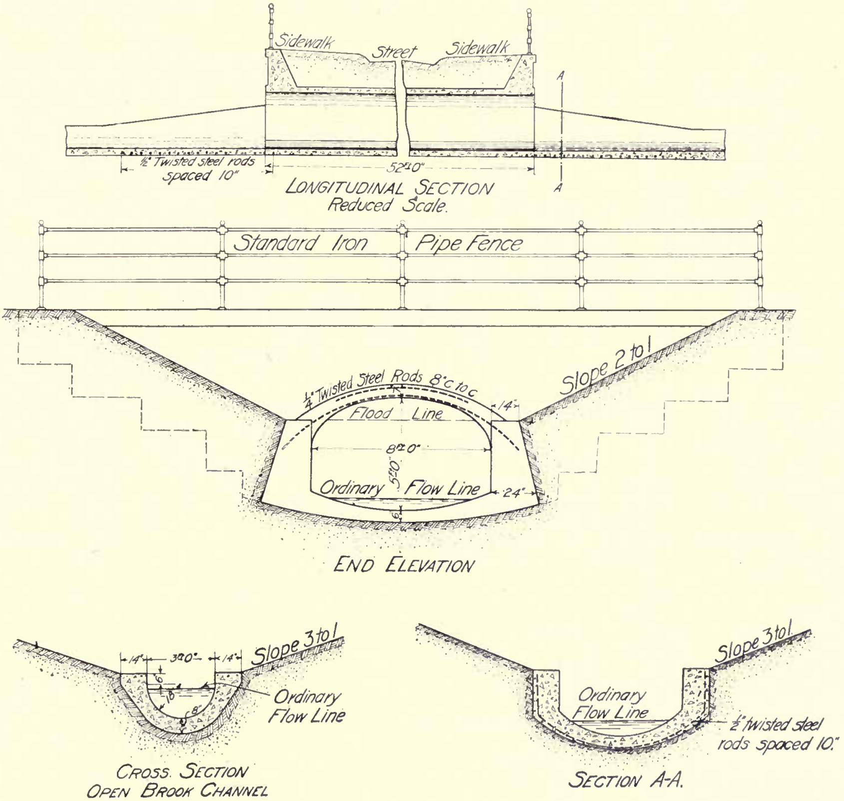


FIG. 26.—CONCRETE BROOK LINING IN NEWTON, MASS.

surface of the concrete being 14 inches. Under the ordinary flow the concrete channel does not run full. During extreme high water the cross section of the channel is not sufficient to carry the entire flow so that once in a great while the water overflows the normal cross section.

Fig. 26 shows, in addition to the normal cross section of the channel, the sections where it enlarges to pass under a small culvert which carries a street over the brook. At section A-A the concrete is reinforced with half-inch rods spaced 10 inches apart. The culvert itself has a clear span of 8 feet and a total depth of 5 feet. The thickness of the invert of the culvert is 6 inches at the middle, gradually enlarging towards the abutments while the arch is 7 inches thick at the crown and increases gradually towards the abutments and is reinforced with ¼-inch steel rods 8 inches apart on centers.

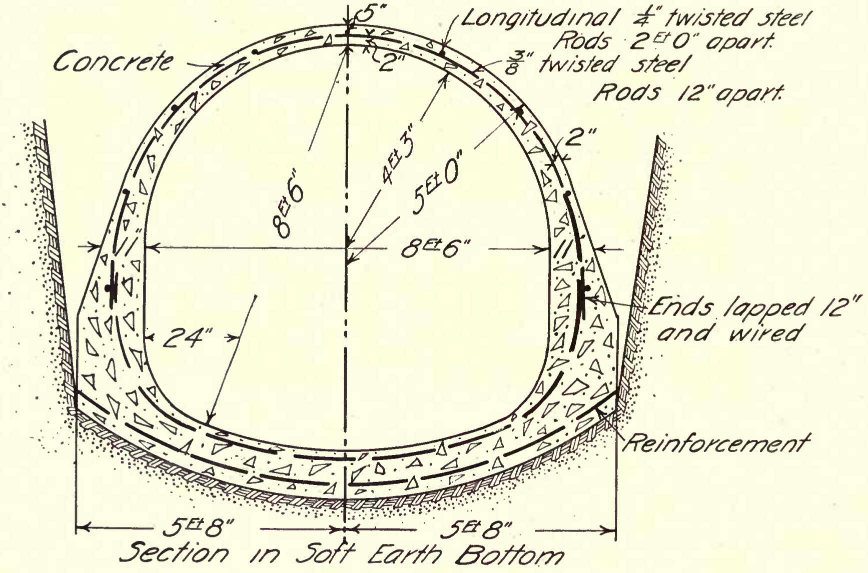


FIG. 27.—TYPICAL CROSS SECTION, JERSEY CITY CONDUIT.

Fig. 25 is an illustration of the brook shown in detail in Fig. 26. The photograph was taken at a very low stage of the water.

For brook linings the concrete should be mixed 1 part "ATLAS" Portland Cement, 2½ parts sand and 5 parts broken stone or screened gravel. Concrete linings should be laid in sections not over 20 feet in length, and the end of one section should be built into the adjacent section in a tongued and grooved manner.

Sometimes these concrete brook linings are connected with nearby sewers so that the sewers are automatically or continuously flushed by some water passing from the brook into the sewer.

## CONDUITS.

Oftentimes a covered conduit is necessary to carry the water of a brook located under a street surface. Such conduits may be made rectangular or circular in cross section. They are also frequently used for water supply lines where there is little or no pressure within the concrete conduit.

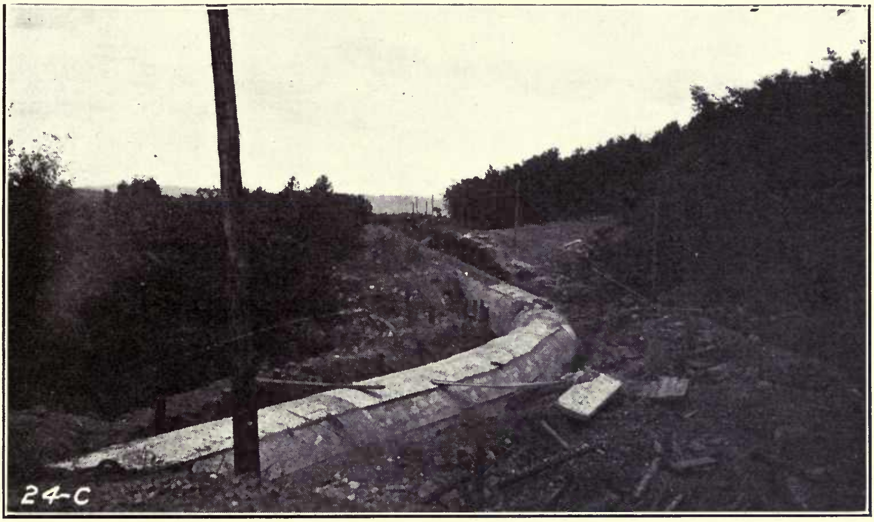


FIG. 28—JERSEY CITY CONDUIT.

Fig. 27 shows a typical cross section and Fig. 28 a photograph of a concrete conduit of the Jersey City Water Supply Company built to carry a water supply. This conduit is approximately 8 feet 6 inches inside diameter and for a length of about 20,000 feet is made of concrete. About 30,000 barrels of "ATLAS" Portland Cement were used in this conduit.

The thickness of the conduit at the crown varies from 5 to 8 inches depending on the kind of material in which the pipe is placed and the depth of the filling over the pipe. The section shown in Fig. 27 is typical of those used in soft earth.

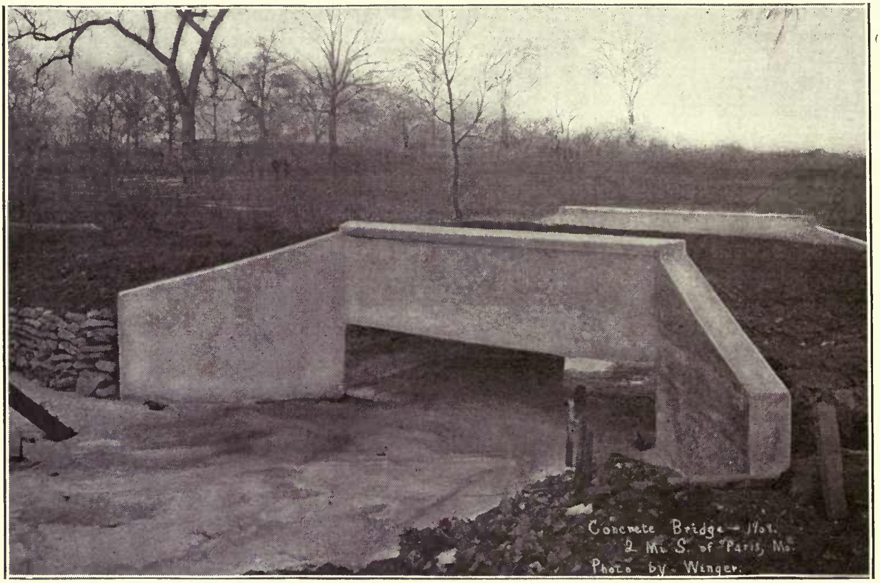
For sections laid in open trench the concrete was mixed 1 part "ATLAS" Portland Cement and 7 parts sand and ballast. The ballast was broken trap rock, the run of the crusher being used. All concrete was machine mixed and was very wet.

# CHAPTER V.

## CULVERTS.

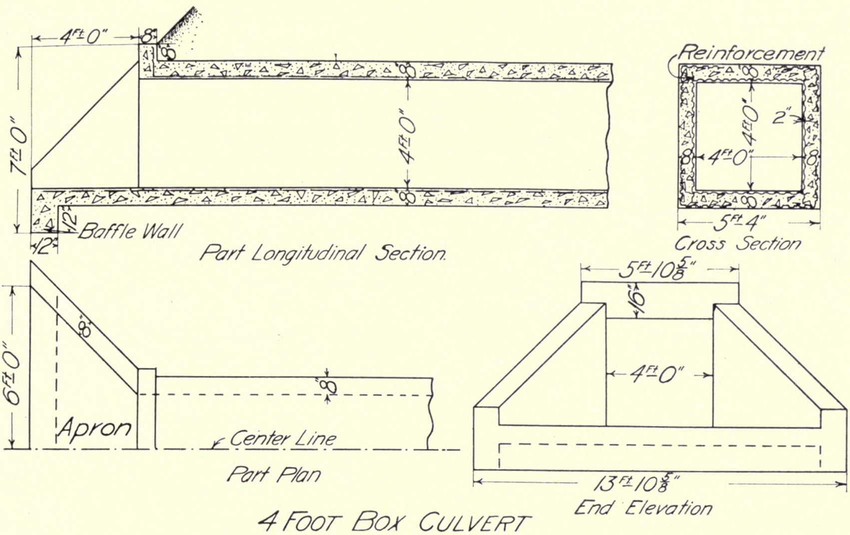
Concrete is an excellent material for the construction of culverts as is shown by the great number of concrete culverts now being built for highways and railways. As the entire culvert is made of concrete there is nothing to decay and the excessive maintenance charges in timber construction are entirely lacking.

Culverts vary greatly in size and shape. The best way to determine the required size for an opening so that the waterway will be sufficient is to measure the width and depth of the stream at some narrow point near by during the high water stage, and if possible compare this size with that of culverts over the same stream in the neighborhood. With this information the width and depth of the culvert opening may be chosen.

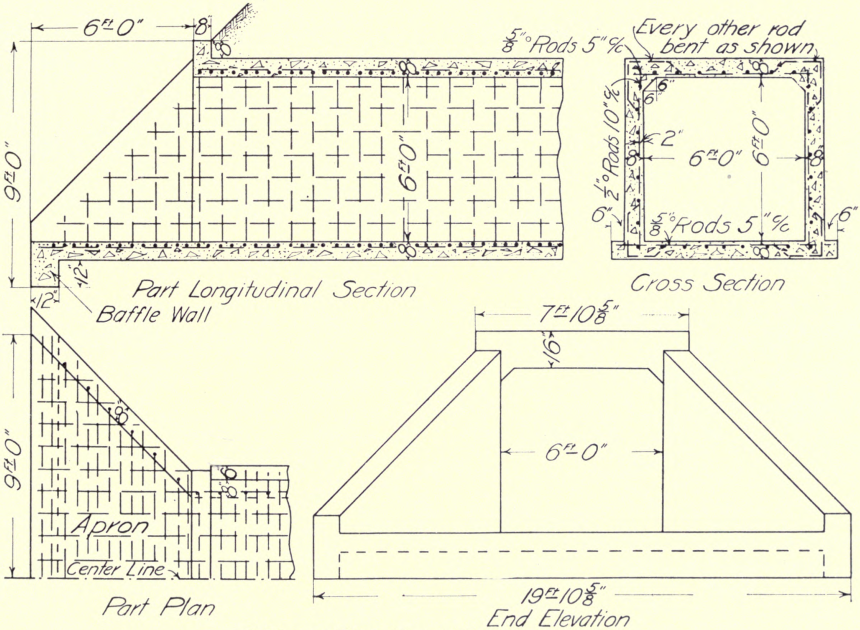


BEAM BRIDGE NEAR PARIS, MO.

Culverts may be either square, rectangular, circular, or arched in cross section. Generally the rectangular section is best because it conforms more nearly to the cross section of the water way and is cheaply and easily built. Where the appearance is of more importance than the cost, arch culverts are preferable to other styles. Whatever the form of cross section the construc-

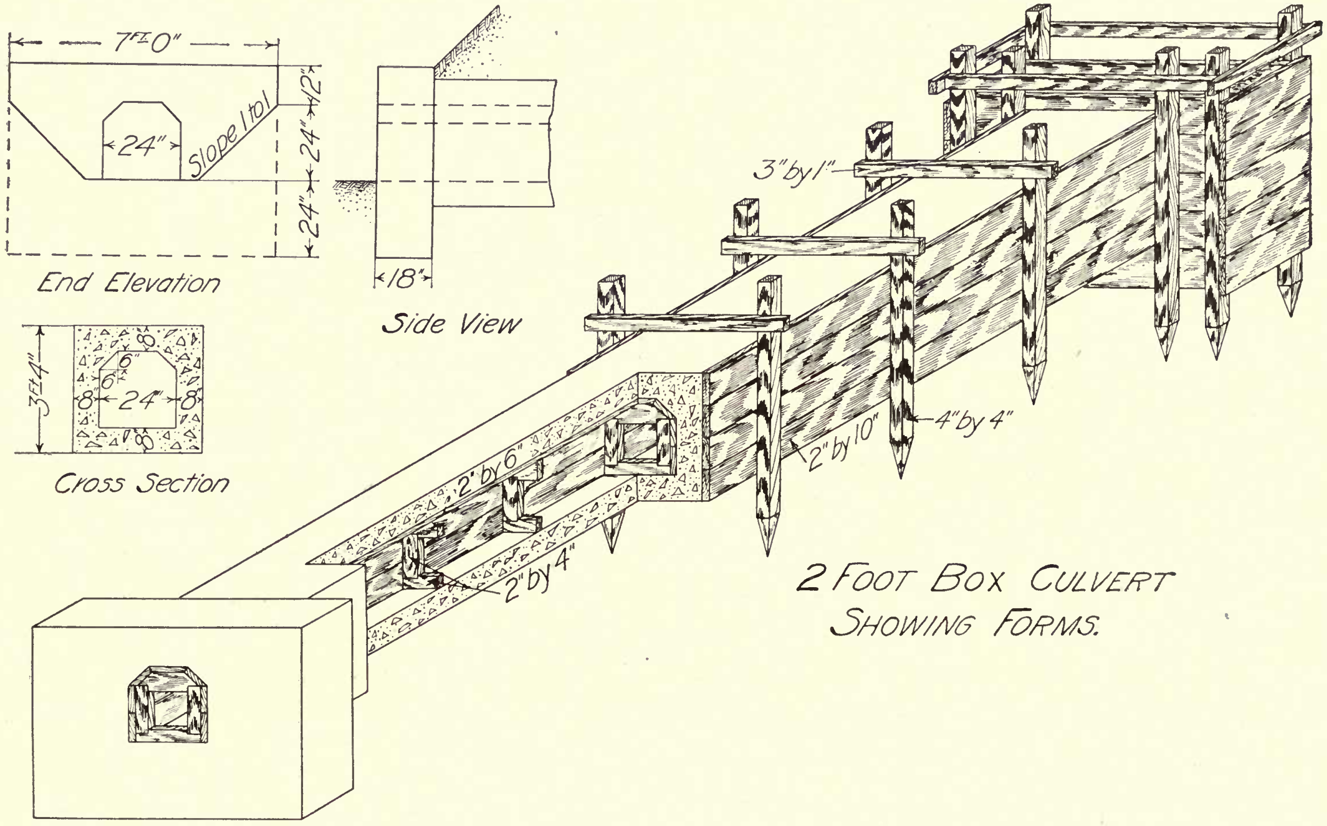


4 FOOT BOX CULVERT



6 FOOT BOX CULVERT

FIG. 29.—REINFORCED CONCRETE BOX CULVERTS.



FIF. 30.—SMALL CNNCRETE BOX CULVERT WITH FORMS.

tion should be such as to prevent undermining, that is, to prevent the water from running along the outside of the culvert and thus washing out the earth embankment.

Culverts with square or rectangular openings are called box culverts, and those with circular sections are called pipe or circular culverts. Pipe culverts are made entirely of concrete or else of tile or iron pipe with a concrete head wall at each end of the pipe where it projects from the sides of the road.

BEAM BRIDGE.

Concrete for culverts should be made one part "ATLAS" Portland Cement, two and a half parts sand, and five parts broken stone.

## BOX CULVERTS.

Box culverts may have square or rectangular sections as in Fig. 29 or Fig. 32 or a section similar to that shown in Fig. 30. For small culverts, the last is a neat design, having an arch effect and yet being cheaply and easily constructed. The cost of the small box culvert shown in Fig. 30 may be slightly reduced if the cross section is made square, omitting the bevels at the upper corners.

Fig. 29 shows a good design for a 4-foot box culvert of ample strength to carry a highway.. To prevent undermining, a concrete invert or bottom is used and a baffle wall and apron at each end should be constructed as shown although some culverts where the soil is hard do not need the apron, baffle wall or bottom. Cobble stones or paving bricks may be used instead of concrete for covering the bottom between the side walls. They may be laid even in running water and in case a dry season should occur the spaces between the stones or bricks may be filled with cement grout.. Concrete must not be laid in running water for the cement will be washed out from the aggregate. This 4-foot box culvert has top, bottom and sides 8 inches in thickness and is reinforced with expanded metal No. 10 gage having 3-inch meshes, or with other similar reinforcement placed not less than 1½ and not more than 2 inches from the inner surface of the culvert. The sheet reinforcement should also be placed in the apron and in the wing walls.

The lower part of Fig. 29 shows a design for a box culvert with opening 6 by 6 feet similar to the 4-foot box culvert above described except that round steel rods are used instead of sheet reinforcement. In the bottom of the culvert proper the rods running at right angles to the length of the culvert should be ⅝ inch in diameter and spaced 5 inches apart. For the top they should be ⅝ inch in diameter, spaced 5 inches apart and alternate rods should be bent, as shown in Fig. 29, to reinforce the side walls extending within three inches of the bottom surface of the concrete. This bending of the alternate rods in the top results in the vertical rods of the sides being spaced 10 inches apart. In the apron the ⅝-inch rods should be spaced 5 inches apart and should be bent up alternately so that the vertical rods in the wing walls are spaced 10 inches.

In addition to the rods above mentioned there should be a set of ½-inch diameter rods running parallel to the length of the culvert spaced 10 inches apart which should extend into the apron and wing walls at each end.

Fig. 31 and Fig. 32 show a reinforced box culvert built in Lenox, Massachusetts, in 1896, for the Massachusetts Highway Commission. The body of the culvert is reinforced with ⅞-inch square twisted steel rods 8 inches c. to c. at each corner where the side walls meet the top and bottom, those at the bottom corners being 24 inches long and bent, while those at the top corners are straight and 14 inches in length. Four counterforts for bracing the side walls are shown in the plan and also in section C1C, Fig. 32, are used in this culvert.

Forty cubic yards of broken stone, 16 cubic yards of sand, 55 barrels of cement, and 778 pounds of steel were used.. One hundred twenty-one cubic yards of earth were excavated. The concrete mixture was about one part "ATLAS" Portland Cement, two and one-half parts sand, and five parts crushed stone, and the 44 cubic yards in the structure cost $660, or $15 per cubic yard. The earth excavation cost 75 cents per cubic yard. The total cost of the culvert to the Commission, exclusive of the macadam roadway was

$809.67. The cement cost the contractor $1.85 per barrel, plus 50 cents for hauling, making the price at the culvert $2.35 per barrel. The contractor paid $2 per load of about 1 cubic yard for the sand delivered at the culvert and about $1.15 per cubic yard for the stone. About 3½ or 4 days were required for excavating and the concreting extended over 24 days including delays.

A small box culvert with an opening 2 by 2 feet is shown in Fig. 30 in which the head wall, culvert proper, and arrangement of forms are all clearly illustrated. If the soil is compact material like hard clay, where the excavation can be made to the exact size and shape of the culvert, the outer forms may be omitted, the concrete being deposited directly on the bottom of the trench to form the invert of the culvert, then the inner form set in place and the concrete deposited between it and the walls of the trench.

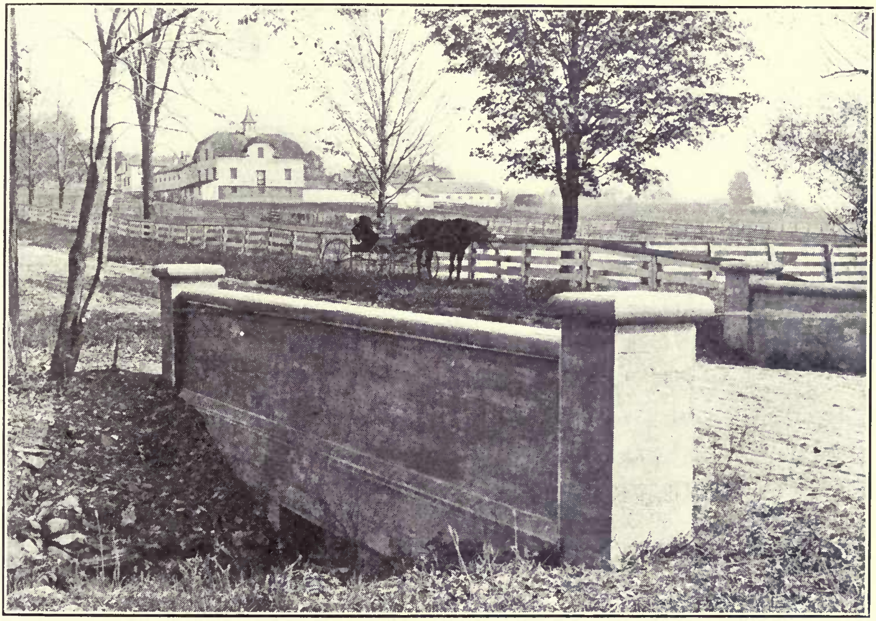
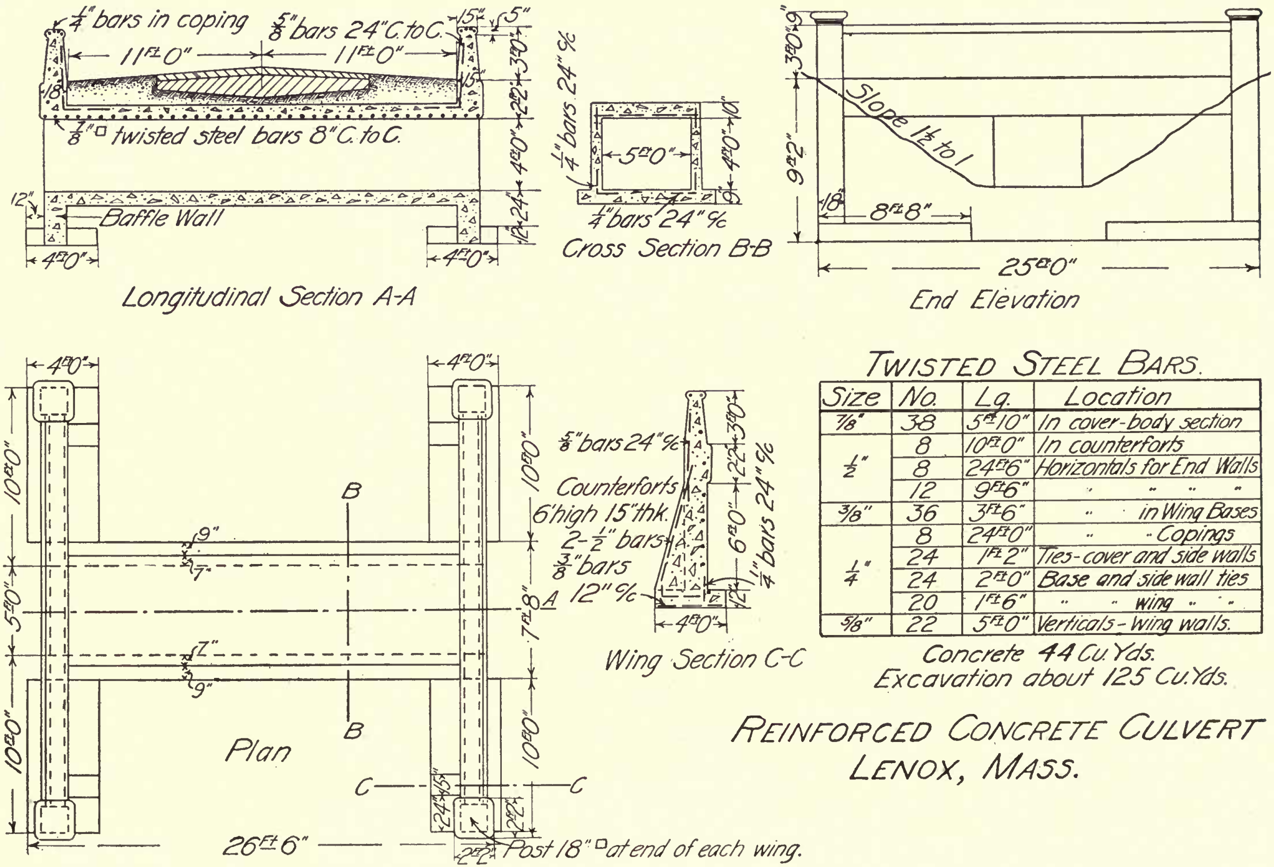


FIG. 31.—REINFORCED CONCRETE BOX CULVERT AT LENOX, MASSACHUSETTS.

The inner forms consist of frames made of three pieces of 2 by 4 inch and one piece of 2 by 6-inch joists, notched as shown. Around these frames boards are set. The upper 2 by 6 piece is not nailed so that in removing the inner forms after the concrete has hardened this upper piece is first knocked out and then the 2 by 4-inch pieces and finally the boards.

Another type of small culvert and form as used by the Iowa State Highway Commission is shown in Fig. 33.



TWISTED STEEL BARS.

| Size | No. | Lg. | Location |
|---|---|---|---|
| 7/8" | 38 | 5 Ft 10" | In cover-body section |
| 1/2" | 8 | 10 Ft 0" | In counterforts |
| | 8 | 24 Ft 6" | Horizontals for End Walls |
| | 12 | 9 Ft 6" | " " " |
| 3/8" | 36 | 3 Ft 6" | " in Wing Bases |
| 1/4" | 8 | 24 Ft 0" | " Copings |
| | 24 | 1 Ft 2" | Ties-cover and side walls |
| | 24 | 2 Ft 0" | Base and side wall ties |
| | 20 | 1 Ft 6" | " " wing " " |
| 5/8" | 22 | 5 Ft 0" | Verticals-wing walls. |

Concrete 44 Cu. Yds.
Excavation about 125 Cu. Yds.

REINFORCED CONCRETE CULVERT
LENOX, MASS.

FIG. 32.—REINFORCED CONCRETE BOX CULVERT AT LENOX, MASSACHUSETTS.

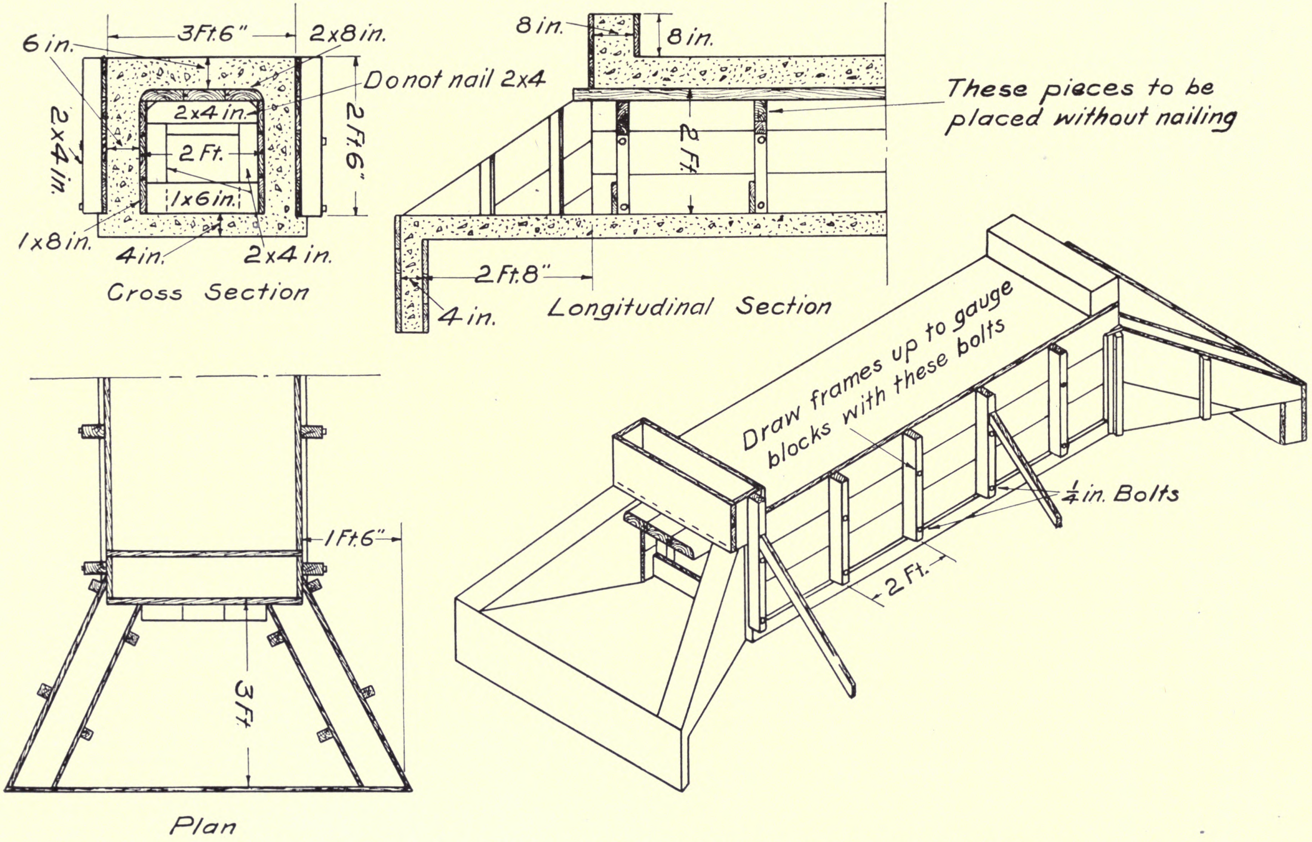


FIG. 33.—SMALL BOX CULVERT AND FORMS, IOWA STATE HIGHWAY COMMISSION.

## CIRCULAR OR PIPE CULVERTS.

Circular or pipe culverts are made of concrete as in Fig. 34, or of metal with concrete head walls as in Fig. 35. The concrete culvert shown is 3 feet in diameter and is not reinforced. An apron with a baffle wall on each side as well as on the outer end is provided to prevent the water from running along the outside of the culvert and thus washing out the earth.

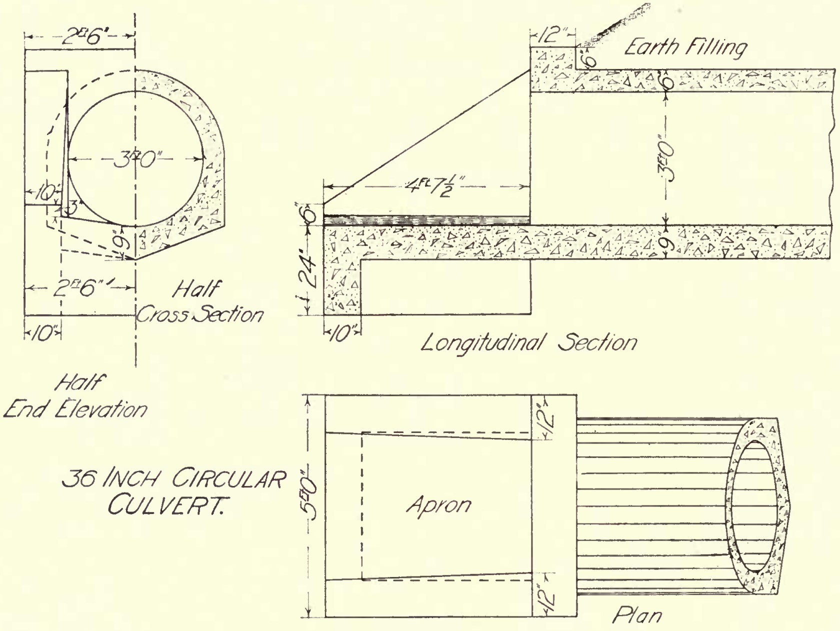


FIG. 34.—CONCRETE CIRCULAR CULVERT.

Pipe culverts are made of cast iron or sheet iron or of tiles. They should have fall enough so that water will not stand in them, a slope of ¼ inch per foot being generally sufficient. They should also have at least 12 to 18 inches of earth over the top of the pipe and the earth should be thoroughly compacted around the outside of the pipe.

To prevent undermining, head walls should always be used with pipe culverts. In Fig. 35 head walls for four sizes of metal pipes are shown and they are all similar except that for the 24-inch pipe the head wall has a coping 6 inches deep projecting 2 inches from the face of the wall, and the head wall for the 3-foot pipe has a concrete apron 6 by 24 by 48 inches in size. This apron should slope up at the inlet and down at the outlet.

The number of cubic yards of concrete in one head wall for the 12, 18, 24, and 36-inch pipe is 0.64, 1.04, 1.47, 2.57 respectively. The 2.57 cubic yards in the headwall for the 36-inch pipe includes the concrete in one apron.

If the proportions are one part "ATLAS" Portland Cement, two and one-half parts sand and five parts broken stone or screened gravel, 1 1/3 bbls. cement (each barrel being the same as four bags) will be required for a cubic yard together with about ½ cubic yard of sand and a cubic yard of broken stone or screened gravel.

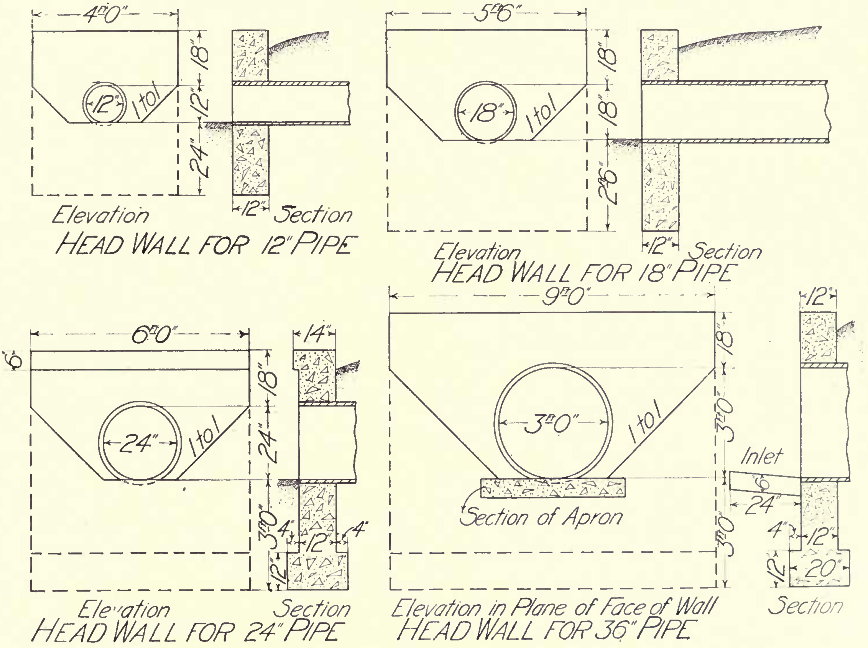


FIG. 35. —CONCRETE HEAD WALLS FOR METAL CULVERTS.

## ARCH CULVERTS.

As previously stated, arch culverts are more expensive and more difficult to build than box culverts, but nevertheless they are frequently used where an artistic design is desirable. The culvert of 5-foot span, illustrated in Fig. 36, is very similar to the design for the 5-foot span shown in Fig. 39, and was built in Bureau County, Illinois, by the Illinois Gravel Company of Princeton, Illinois. It contains 11.4 cubic yards of concrete mixed one part "ATLAS" Portland Cement to six parts sand and gravel, using gravel as the large aggregate with coarse sand to fill the voids. The cost of the cement delivered at the bridge was $1.35 per barrel. Actual cost of the culvert was $75.00, which included long haul charges for gravel.

Figs. 37, 38 and 39 show designs for arch culverts of 5, 8, and 10-foot clear spans respectively, suitable for highway construction where the soil is firm, as compact sand or hard clay. If the soil is soft clay or loam, the footings should be made wider so as to give a larger bearing area for the walls as well as for the arch proper. Of course, if the soil is too soft, box instead of arch culverts should preferably be used, or else the bearing power of the soil should be increased as indicated below under "Preparing the Bed."

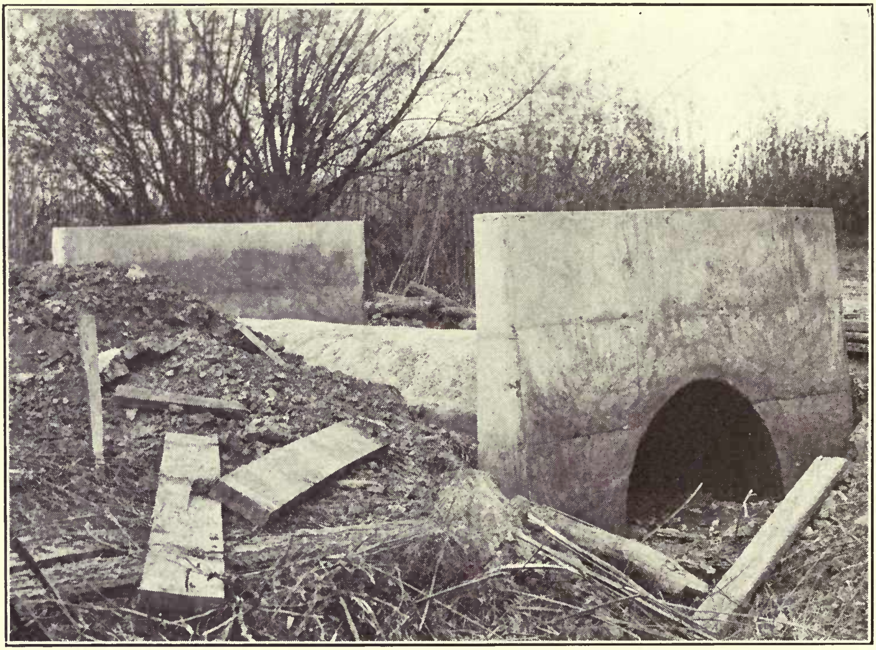


FIG. 36.—CONCRETE ARCH CULVERT IN BUREAU COUNTY, ILLINOIS.

As shown in Fig. 38, each end wall of the 10-foot span should be reinforced with 14 long vertical rods and with 8 short bent rods, the latter extending horizontally two feet into the arch and vertically two feet into the end walls; and in addition there should be 4 long horizontal rods in each end wall. All rods are ½ inch in diameter. The 5-foot span has no reinforcement except 5 bent rods to tie each end wall to the arch.

The designs show a width of 10 feet between the walls, but this can be increased to any distance desired.

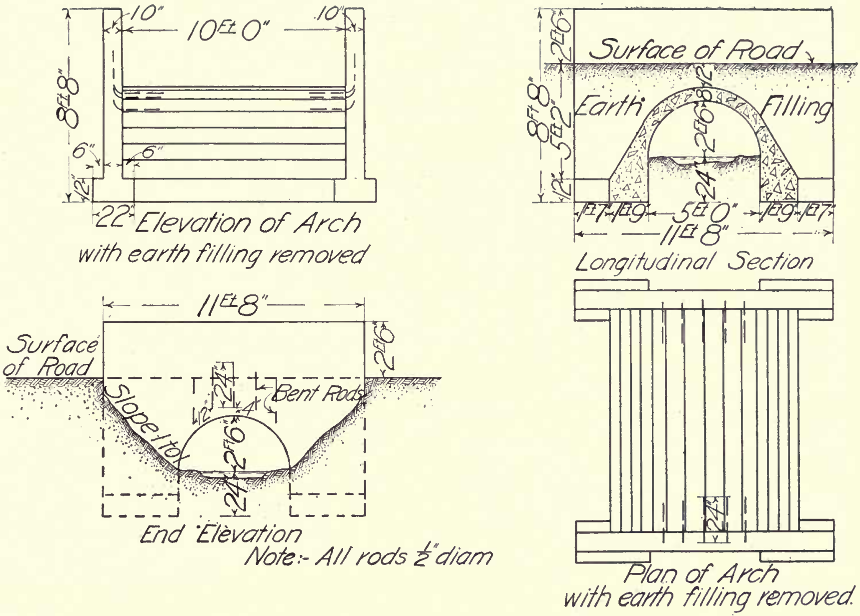


FIG. 37.—ARCH CULVERT FOR FIVE-FOOT SPAN.

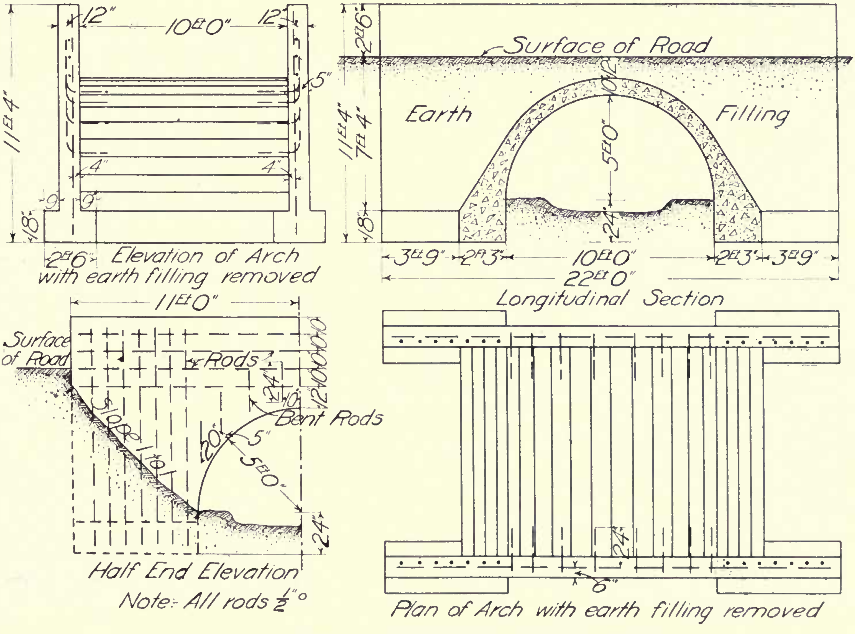
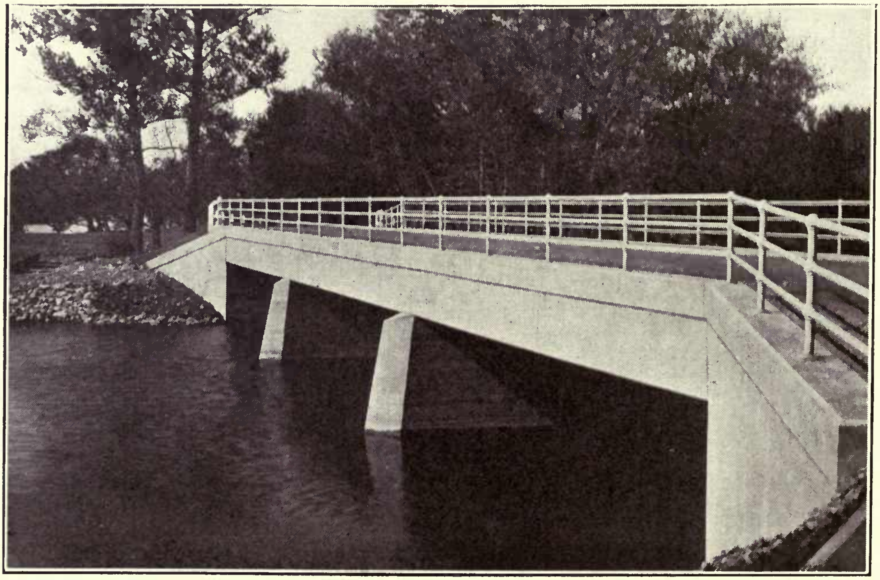


FIG. 38.—ARCH CULVERT FOR TEN-FOOT SPAN.

ARCH IN BUREAU CO., ILLINOIS.



BEAM BRIDGE, GROTON, MASS.

In the 5-foot span there are 4.25 cubic yards in each end wall and 4.73 cubic yards in the arch between the end walls, making a total of 13.23 cubic yards of concrete in the structure. In case the roadway is wider than here assumed, the total number of cubic yards of concrete in the structure may be computed by adding to 8.5 the product of 0.473 times the distance in feet between the end walls; 8.5 being the cubic yards of concrete in the two walls and 0.473 the number of cubic yards of concrete in one foot length of arch.

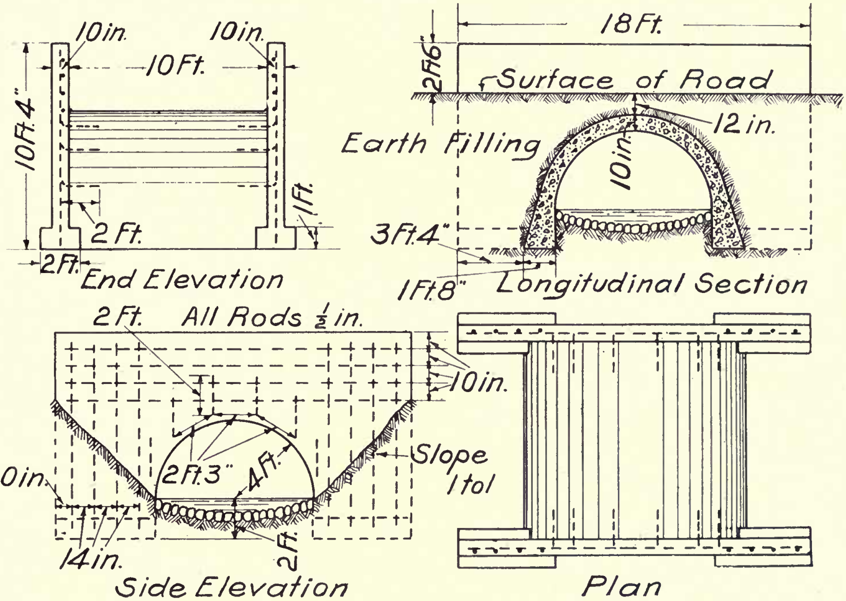


FIG. 39.—ARCH CULVERT FOR EIGHT-FOOT SPAN.

Thus, if the roadway were 16 feet wide instead of 10 feet the total volume of concrete in the culvert is 8.5 plus 0.473 multiplied by 16; that is, 8.5 plus 7.57 or 16.07 cubic yards.

The quantities of materials for arch culverts, 5, 8 and 10-foot span, are given in the following table.

### QUANTITY OF MATERIAL FOR ARCH CULVERTS

Proportions: 1 Part "ATLAS" Portland Cement to 2 1-2 Parts Sand to 5 Parts Gravel or Stone

| | Materials for Culvert for 10-ft. Roadway (See Figs. 37, 38 and 39) | | | Extra Material for Each Additional Foot Width of Road | | |
|---|---|---|---|---|---|---|
| Span of Culvert | Cement | Sand | Screened Gravel or Stone | Cement | Sand | Screened Gravel or Stone |
| feet | | cu. ft. | cu. ft. | | cu. ft. | cu. ft |
| 5 | 50 bags or 12 ½ bbls. | 120 | 240 | 2 bags or ½ bbl. | 5 | 10 |
| 8 | 80 " " 20 " | 190 | 380 | 3 " " ¾ " | 7 ½ | 15 |
| 10 | 115 " " 28 ¾ " | 275 | 550 | 4 " " 1 " | 10 | 20 |

## PREPARING THE BED.

Culverts should be built when the water is low in the brook at the site of the culvert. In many cases the water will cause no trouble if in excavating for the foundation the earth is thrown up into two parallel dams so that the brook can flow between them, the foundation for the culvert being then laid outside of these piles of earth. Sometimes the stream can be carried in a new trench around the side. If there is considerable water in the brook and it cannot be carried around, it may be necessary before excavating to drive a row of closely fitting boards parallel to the stream in front of each of the proposed trenches in which the foundations are to be laid and then bank the earth against the boards to make two tight dams between which the brook flows and behind which the work may be carried on. Sometimes the water may be carried in a box trough as shown in Fig. 41.

In some cases a hand pump may be needed to keep down the water in trenches. Trenches for foundations of whatever kind should in all cases be excavated to a depth below frost, but if the brook is never dry two or three feet below the bed of the stream will be sufficient.

The preparation of the bottom of the trenches to receive the concrete footings of the culvert as a rule should not be difficult, for the concrete can be laid directly on the soil when it is hard clay, compact sand or gravel. If the soil is soft sand or soft clay or loam it should be compacted by ramming, but if too soft to be rammed the bearing power of the soil can be increased by adding a layer of clean sand, cinders, or broken stone before ramming. In extreme cases, where the soil is very soft, it may be necessary to increase the width of the base of the culvert walls or to build these walls on a layer of 4-inch planks to distribute the weight over a considerable area of the soil.

Occasionally, piles may be necessary. Where the soil is as soft as here indicated a box culvert is preferable to an arch.

Planking should never be used under a foundation unless it will at all times be covered with water.

## FORMS FOR ARCH CULVERTS.

The forms are set after the soil has been prepared to receive the concrete. Outer wing wall forms are generally constructed of 1-inch boards laid horizontally and braced with 2 by 4-inch or 2 by 6-inch studs. The forms on the inner side of the wing walls are laid horizontally and cut to fit approximately the shape of the arch. The outer surface of the arch proper needs forms from the bottom up to about ½ to ¾ of the way to the top and should be made of 1 by 4-inch or 1 by 6-inch boards, attached at their ends to the inside wing wall forms.

Centering for circular arch culverts is shown in Figs. 40 and 41. The sills should be set first and braced; then the circular forms, spaced 2 feet apart for 1-inch lagging, 3 to 4 feet apart for 2-inch stuff, should be set upon the wedges resting on the upper sills. The lagging shown in the drawings, which should be of narrow width to fit the circle, is then fastened to the circular centers. The outer forms must be braced by tieing across the top of the culvert or by using braces against the earth on either side.

In Fig. 41 the inside wall forms have a 3 by 4-inch or a 4 by 4-inch ranger set across the top of the cleats on which the wedges are placed to support the arch forms. The wedges should separate the two forms at least 3 inches in order to facilitate the removing of the arch forms. A strip of sheet iron may be nailed to the side forms, as shown, and lap over on to the arch form to prevent the concrete from getting in between the forms. After removing the arch forms the side forms can be readily removed.

The forms should be oiled before placing the concrete.

The concrete for culverts should be of a mushy consistency and should be deposited and lightly tamped in layers 6 or 8 inches thick. If possible the concrete of the whole arch and wing walls should be deposited at one time, but where the work is so large as to make it impossible to do this, the arch should be divided into circular sections, and one section laid at a time. Twenty-eight days should be allowed for the concrete to set, after which time the wedges are knocked out and the centers removed. The earth filling can be placed as soon as the connecting is completed.

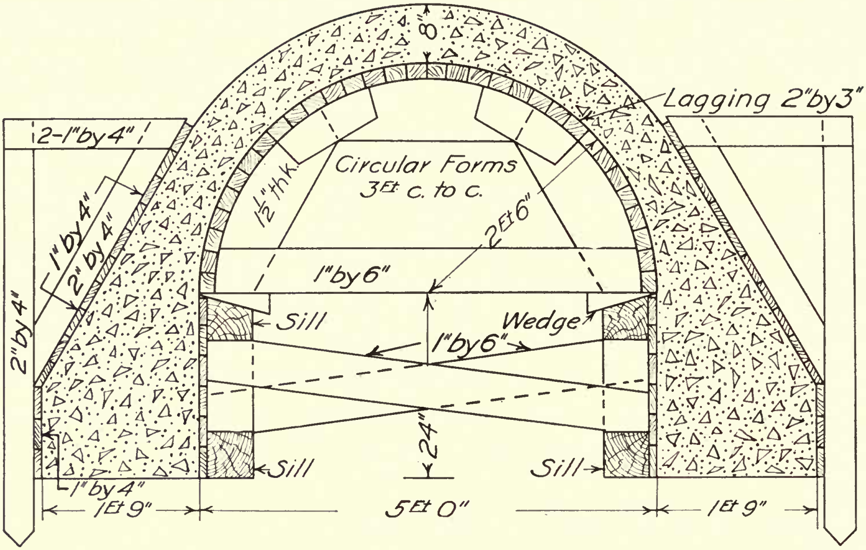


FIG. 40.—FORMS FOR FIVE-FOOT CIRCULAR ARCH.

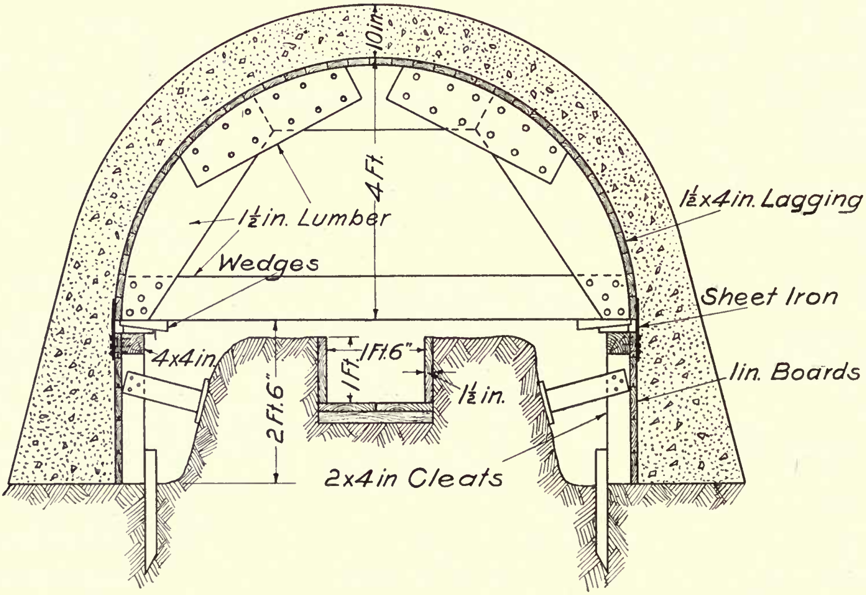


FIG. 41.—FORMS FOR EIGHT-FOOT CIRCULAR ARCH.

## CHAPTER VI.

## BEAM BRIDGES

Owing to the demand for more permanent bridges, concrete is fast replacing wood and steel for structures of all types, especially for spans under 100 feet. Not only is concrete an excellent material for these short spans, but where the foundations are good, concrete arches are well suited even for structures 200 feet in length or even longer. The average life of a wooden bridge is only about 9 years, and of a steel bridge not over 30 to 40 years, and even during this time there is a continual outlay for repairs and painting. A concrete bridge will last indefinitely and with practically no maintenance.

FIG. 42.—CONCRETE BEAM BRIDGE.

In the State of Illinois alone $1,888,724 was expended for highway bridges in the year 1905, a considerable part of this being devoted to repairing and replacing wooden or metal structures. It is evident that more attention should be given to the design and construction of highway bridges.

In addition to their natural permanence, concrete bridges are cheap in first cost and are absolutely proof against tornadoes, high water, and fire. *Further-*

*more, by employing local labor the money spent in their construction remains almost entirely in the community in which the bridge is built,* there is less difficulty in securing the necessary skilled labor during times when the building trades are active and there is no waiting for structural steel since rods can be had at short notice.

The greatest care should be taken in the design and construction of concrete bridges. Designs must be made by an engineer familiar with concrete construction except for small arched structures where the designs given in this book may be used by one who thoroughly understands the use of concrete.

## KINDS OF CONCRETE BRIDGES.

Concrete bridges may be classified as flat bridges and arch bridges. Flat bridges are those in which the pressure from the bridge acts vertically on the supports and consist either of straight flat slabs or of combined beams and slabs of concrete reinforced with steel. Arch bridges are curved and the pressures upon the supports are not vertical but inclined.

Flat construction is suitable in level countries for short spans, generally not exceeding 30 or 40 feet, and for locations where the foundation is soft material. Arches are especially economical in localities where the roads can be built considerably above the streams and where there is rock, firm sand or gravel or other similar hard soils which afford good foundations.

## TYPES OF FLAT BRIDGES.

Flat bridges may be divided into three types, slab, combined beam and slab, and girder bridges. The first two types are used for short spans and the girder type is preferably used for spans from 25 to 40 feet.

A slab bridge, Fig. 43, consists essentially of a flat slab of concrete of uniform thickness reinforced with steel and resting on the supporting walls. In some cases, as shown in Fig. 44, the slab is supported by two longitudinal girders. The macadam roadway is laid directly on the slab—or by employing method and materials described in Chapter III the slab may form a concrete pavement.

Combined beam and slab bridges, Fig. 45, consist of a series of reinforced concrete beams, laid parallel to the roadway, and a flat slab of concrete upon which the roadway is laid. These beams rest on, and are usually thoroughly united with, the abutment walls. The beams and slab must be laid at one time so as to form a homogeneous structure.

Girder bridges, Fig. 48, are usually composed of two large reinforced concrete beams, called girders, one on either side of the roadway supporting intermediate cross beams which in turn carry the slab upon which the roadway is laid. A weight on the roadway, as from a wagon wheel for example, is therefore transmitted from the roadway to the slab, then to the beams, then to the girders and finally from the girders to the supports.

## PROPORTIONS FOR CONCRETE.

For bridges such as described in this chapter, the concrete should be mixed one part "ATLAS" Portland Cement, two parts sand, and four parts broken stone or gravel for slabs, beams, girders, and other parts of the deck. For abutment walls and foundations use one part "ATLAS" Portland Cement, two and one-half parts sand, and five parts broken stone or gravel.

The materials must be thoroughly mixed and must not be separated in handling.

Care must be taken to work the concrete in between and around the steel rods without displacing them.

The forms must be strong and under the bridge they must be left in place 28 or 30 days or even longer in the fall and spring.

## STEEL REINFORCEMENT.

The reinforcement shown in the designs of this chapter is medium steel, either with round or deformed surfaces, the latter giving better bond with the concrete.

## SLAB BRIDGES.

A slab bridge similar to that shown in Fig. 43, representing a design practically the same as the standard design of the Pennsylvania State Highway Department, is of simple construction and permanent character. This bridge, which has a clear span of 16 feet, consists of a reinforced slab 15 inches thick connected rigidly to two abutment walls of the same thickness. The side walls serve only as protecting parapets. The principal reinforcement in the slab consists of steel rods ¾ inch square, spaced 5 inches apart on centers, running lengthwise of the roadway and bent at the abutments. The design shown differs from the standard of the Pennsylvania State Highway Department in that alternate bars are bent upward at the junction of the slab and abutment walls so as to lie near the outer surfaces of the slab and wall. Rods placed in these positions at the upper corners prevent cracks from forming in the concrete at the top of the slab near the abutment wall. In addition ½-inch square rods are used in the slab, abutments, and side walls as shown in the cut. The distance from the bottom of slab to top of upper footing course is shown as 6 feet, but this may be increased to 10 feet if necessary to give the proper waterway. For greater heights than 10 feet, the thickness and reinforcement of the walls and footings should be increased. The total length of each side wall also must be increased 3 feet for every 1 foot increase in the height over that shown in the cut.

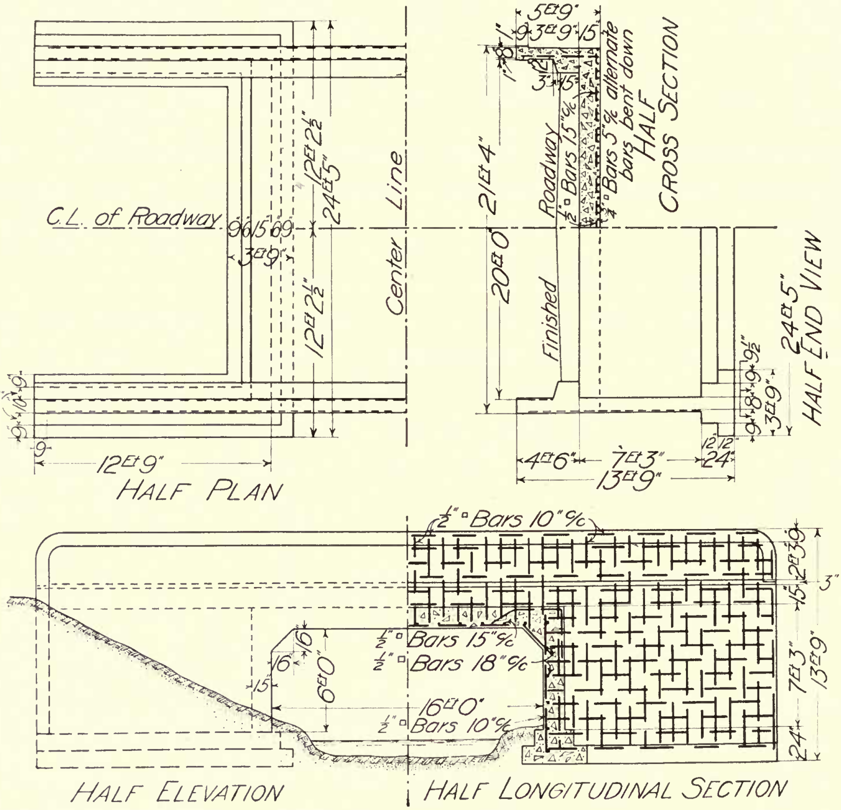


FIG. 43.—SLAB BRIDGE WITH SPAN OF 16 FEET.

The designs for spans other than 16-foot, differ in the thickness of the concrete and in the amount of reinforcement. Each span is a special design in itself and it is just as necessary to have exactly the correct amount of concrete and steel rods for each individual design as it is to use the right size of I-beams or trusses in a steel bridge.

The clear width of the roadway in the design illustrated is 20 feet, but this may be changed to suit local conditions, using for a 16-foot span the same thickness of slab and the same size and spacing of reinforcement. There are 73 cubic yards of concrete and 4,375 pounds of steel rods in this bridge. For every 1-foot increase or decrease in width of roadway, there will be an increase or decrease in the volume of concrete of 1.91 cubic yards, and in the weight of steel rods of 125.7 pounds. With the aid of these figures, the total quantities may be computed for a bridge having a roadway whose width differs from that shown in the drawing.

The accompanying table shows the proper dimensions and quantities of materials for slab bridges similar to that illustrated in Fig. 43. The quantities of materials given in the table are for the entire bridge, including abutments, sidewalls and slab.

PRINCIPAL DIMENSIONS AND QUANTITIES OF MATERIALS FOR SLAB BRIDGES SIMILAR TO BRIDGE IN FIG. 43

| Clear Span in Ft. | Thickness of Slab in Inches | Longitudinal Bars |  | Abutment Walls |  | Length of Side Walls, Feet |  | Cu. Yds. of Concrete |  | Pounds of Steel Rods |  |
|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  | Size of Square Bars, Inches | Distance c. to c., Inches | Thickness, Inches | Width of Footing, Inches | 6 Ft.* | 8 Ft.* | 6 Ft.* | 8 Ft.* | 6 Ft.* | 8 Ft.* |
| 8 | 9 | 5/8 | 6 | 8 | 20 | 32.0 | 38.0 | 43 | 53 | 2715 | 3440 |
| 10 | 11 | 3/8 | 5 | 11 | 23 | 34.5 | 40.5 | 49 | 60 | 3195 | 3880 |
| 12 | 13 | 5/8 | 5 | 13 | 27 | 37.0 | 43.0 | 57 | 69 | 3420 | 4100 |
| 16 | 15 | 3/4 | 5 | 15 | 45 | 41.5 | 47.5 | 73 | 87 | 4375 | 5035 |

*Distance in feet from top of footing course to bottom of slab.

A slightly different style of design for a slab bridge from that just described is shown in Fig. 44, which represents a standard design of the Illinois State Highway Commission for a 24-foot span carrying a roadway 16 feet wide. Here the slab is supported by the side girders which at the same time serve as side railings or parapets. The wing walls are set at an angle with the abutments and are reinforced with ½-inch rods laid horizontally near the front face and vertically near the back face. The main abutment walls are 14 inches thick and have a maximum height of 14 feet 4 inches from the bottom of the foundation. These walls as well as their foundations are reinforced with ½-inch bars as indicated in the figure.

The floor slab is 11 inches thick and is reinforced with ¾-inch bars, 4 inches apart on centers running across the roadway and bent up into the gir-

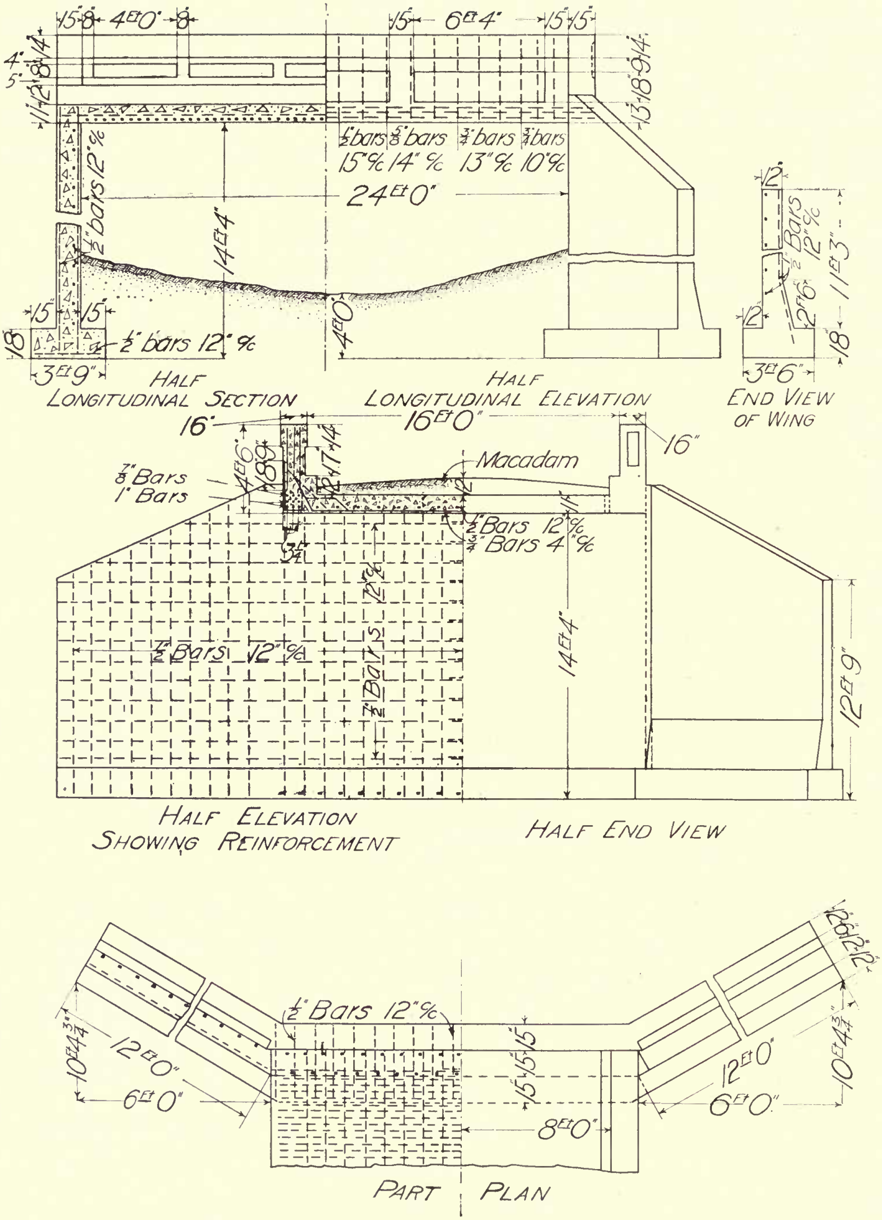


FIG. 44.—SLAB BRIDGE WITH SPAN OF 24 FEET.

ders, also with ½-inch bars spaced 12 inches apart on centers running lengthwise of the bridge. The reinforcement of the girders consists of nine horizontal bars imbedded in the lower part and several U-shaped bars placed vertically at short intervals throughout the length of the beam.

Care must be taken to set the steel rods in the places called for by the plans; thus, in the footings of the abutment walls the horizontal rods must be near the bottom, not the top of each footing. Rods are placed in concrete to perform certain definite purposes and too much care cannot be taken to see that they are set right and that they do not get moved out of place during the progress of the work.

In this 24-foot span, shown in Fig. 44, there are 82.7 cubic yards of concrete and 7,584 pounds of steel.

## COMBINED BEAM AND SLAB BRIDGES.

Combined beam and slab bridges are more complicated in design and in construction than are slab bridges. Inexperienced persons should not attempt the design of structures of this type and those ignorant of the use of concrete should not attempt to build beam and slab bridges.

Combined beam and slab bridges are well adapted to spans of 15 to 30 feet where the width of roadway is more than 16 or 18 feet. Fig. 45 shows such a structure built of reinforced concrete in 1906 by the Massachusetts Highway Commission and represents a skew bridge of 28-foot span. The slab on which the macadam roadway is laid is 4 inches in thickness and is reinforced with ¼-inch square twisted steel rods spaced 8 inches apart. The slab is supported by eight reinforced concrete beams spaced 3 feet 2 inches apart on centers. These beams are 28 inches deep under the slab and vary in width from 13 inches on the bottom to 14 inches just under the slab. The reinforcement for each beam consists of three longitudinal 1¼-inch square twisted rods placed near the bottom with ten ⅜-inch and six ¼-inch stirrups placed as shown in the longitudinal section of beam.

In the construction of concrete beams, such as that shown in Fig. 45, running parallel with the roadway and resting upon the abutment cross walls, the best design demands that one or more bent bars be placed in each end of each beam running vertically into the wall near the back face and horizontally into the beam near the top surface of the beam. Bent rods of this kind tend to prevent the formation of cracks in the upper surface of the beam near the ends. In the longitudinal beams in Fig. 45, this can be done by bending up the center 1¼-inch bar about 3 feet from the face of each abutment and

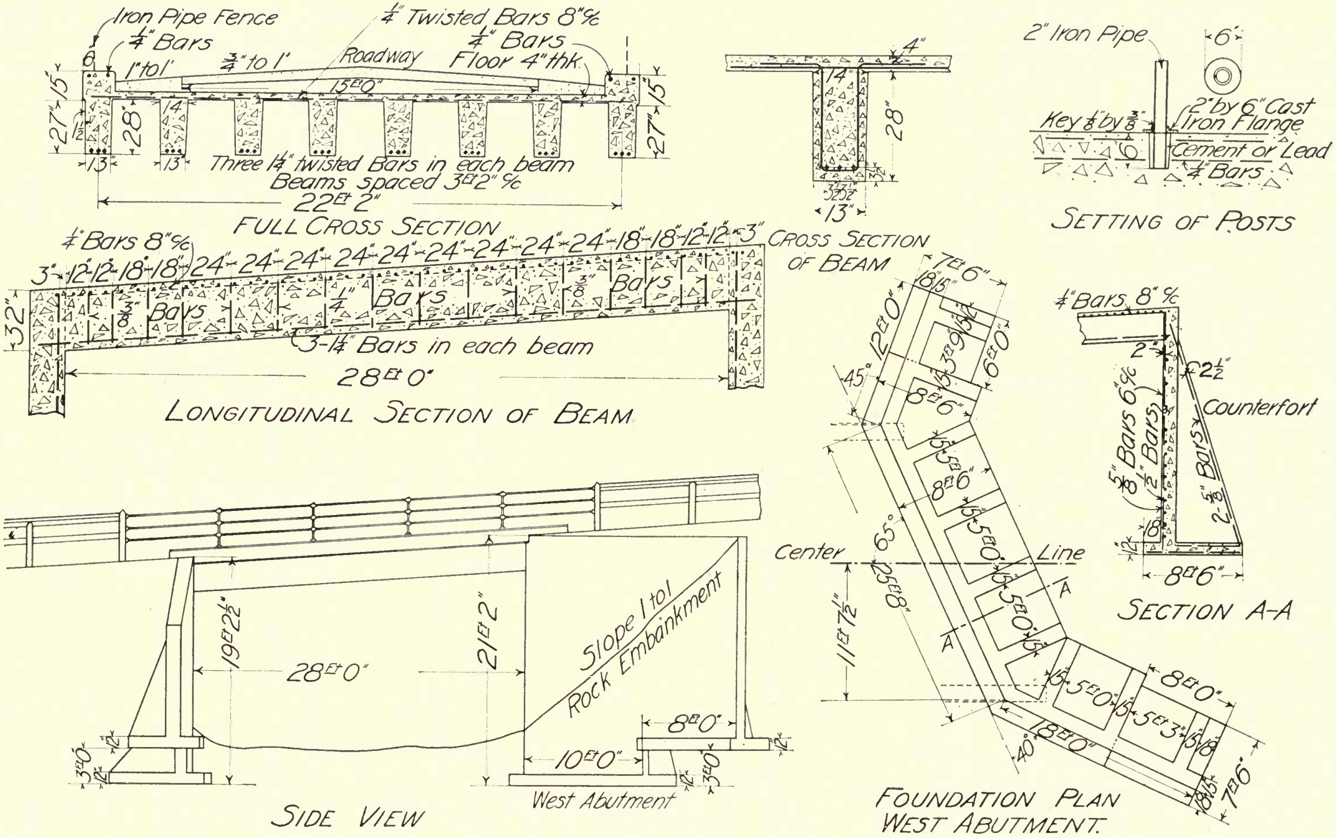


FIG. 45.—COMBINED BEAM AND SLAB BRIDGE WITH SPAN OF 28 FEET AT BECKET, MASS.

continuing this bar near the upper horizontal surface of the beam thence around the corner down into the abutment walls about 4 feet.

The abutments, Fig. 45, which are irregular in shape on account of the skew on which the bridge crosses the stream, are braced with counterforts 15 inches thick spaced about 5 feet apart. Each counterfort has two 5/8-inch tie bars imbedded 2½ inches in from the back surface and bent down into the footing so as to form a secure tie. The footing is also reinforced with 3/8-inch bars running perpendicular to the face of the abutment and spaced 12 inches apart on centers. The abutment and wing walls are 15 inches thick and have ½-inch horizontal bars spaced from 12 to 24 inches apart on centers and 5/8-inch vertical bars 6 inches apart on centers.

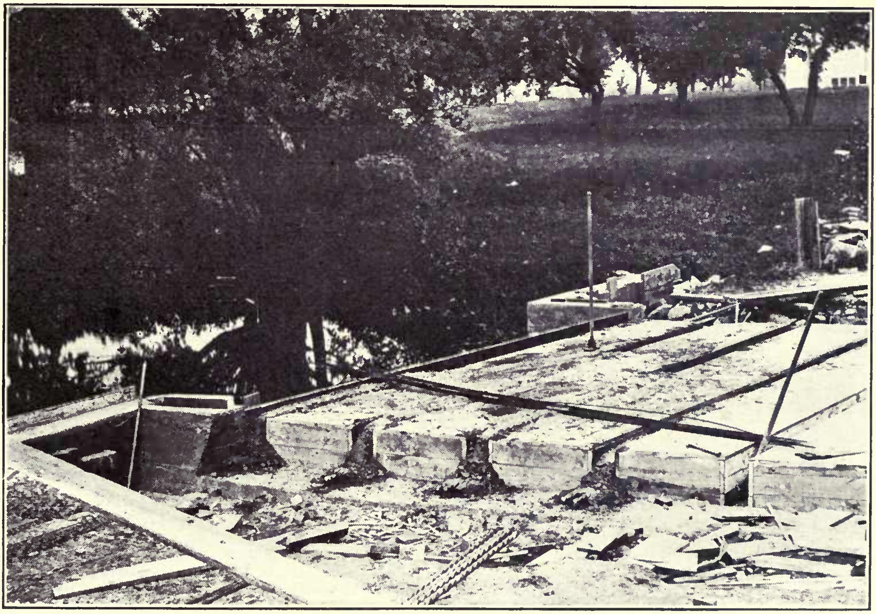


FIG. 46.—FORMS FOR SLAB AND BEAM BRIDGE.

One hundred and seventy-seven cubic yards of 1:2:5 "ATLAS" Portland Cement concrete were used in the construction of this bridge. The total cost of the bridge was $2,286.50, the cement costing $2.30 at the nearest railroad station. The actual time of construction was 54 days, although the total time elapsing from start to finish of the work was 86 days.

In concreting a combined beam and slab bridge, the work must be continuous so that the beam and slab are placed at one time, thus forming a monolith. This is a very important matter and utmost precautions must be taken to see that it is carried out in the construction of beam and slab bridges.

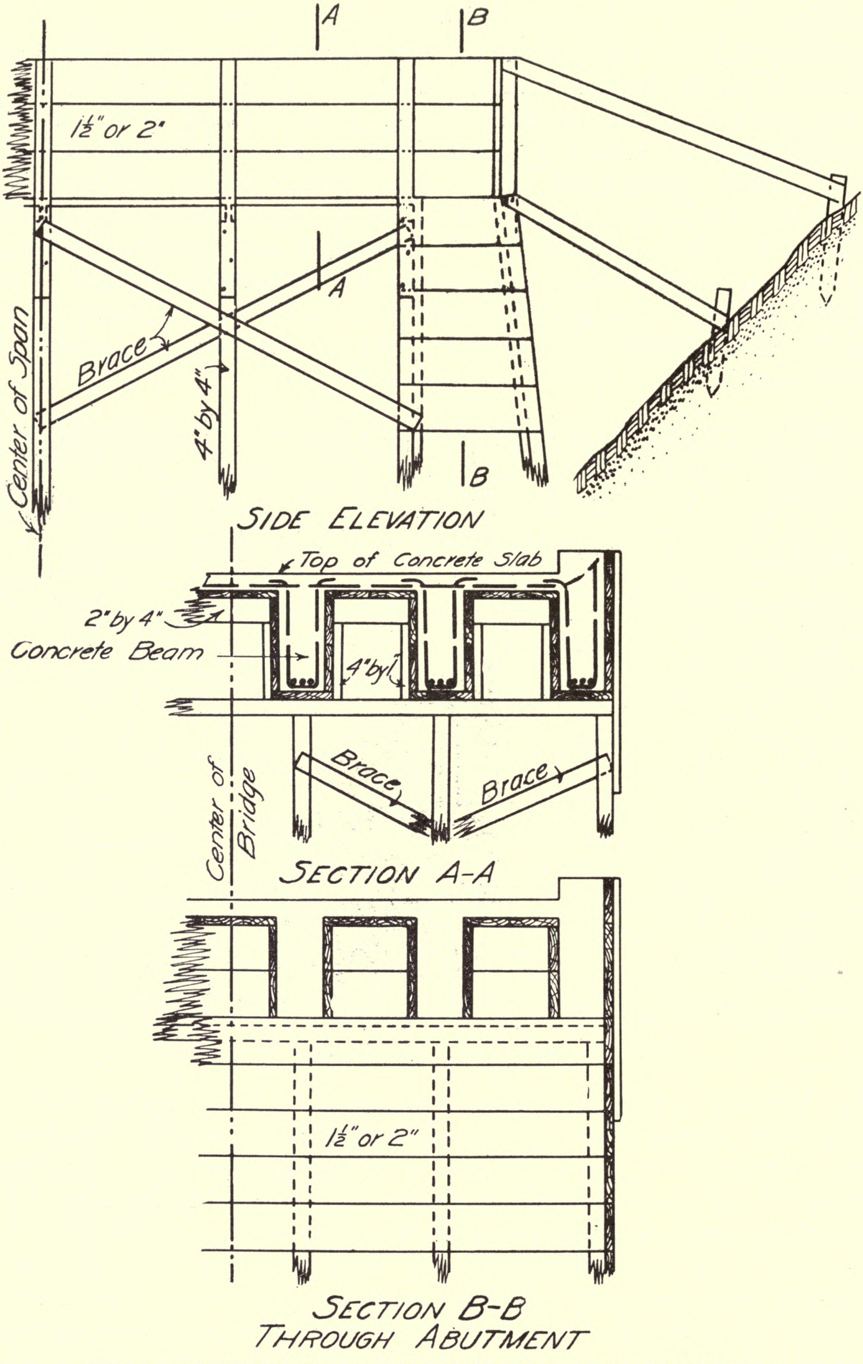


FIG. 47.—FORMS FOR DECK OF COMBINED BEAM AND SLAB BRIDGE.

## METHOD OF CONSTRUCTION OF COMBINED BEAM AND SLAB BRIDGES.

Fig. 47 shows the arrangement of forms for the deck of a combined beam and slab bridge. Generally the abutment forms are first set and the concrete placed to the grade of the bottom of the beams in the deck. The forms for the deck are then put into position and after the reinforcement is placed the concrete for the beams and slab is laid, the concrete for the slab being placed immediately after filling the beam form below it and before the cement begins to set. In some cases where the beams underneath the slab are designed heavy enough to act alone without the aid of the slab the beam reinforcement is first placed and the concrete for the beams poured into the forms. Then the slab reinforcement is placed in position and the concreting of the slab started. If, however, the beams are designed as T-beams in the more usual and the cheapest way, it is absolutely essential that the beams and slab be laid at the same operation. The deck forms should be thoroughly braced underneath so that they will not deflect as the concrete is poured.

In Fig. 47 the bracing is only partially shown, since it will vary considerably with the location of the structure. The stirrups shown in section A-A can best be held in place temporarily with small wooden strips which are removed as soon as there is enough concrete in the beam to hold the stirrups in place.

## GIRDER BRIDGES.

Concrete girder bridges are not so common as slab or combined slab and beam bridges, but they are suitable for spans longer than is proper for the slab bridges and for locations where there is not head room enough to use an arch span. Fig. 44 is in one sense a girder bridge since it has two main girders which carry the slab, but Fig. 48 gives a better idea of this type of structure. In Fig. 48 the slab is 8 inches in thickness at the center and 7 inches at the girders and is reinforced with ¾-inch twisted square bars spaced 7 inches apart on centers running parallel to the roadway. At the center of each panel, that is, midway between the cross floor beams, these bars must be laid 1½ inches from the bottom of the slab, but at the cross-beams they should be 1½ inches from the top of the slab, being bent to conform to these requirements. Another way is that shown in Fig. 48, where the rods in the bottom of the slab are run through straight over the floor beams and another set of ¾-inch bars 4 feet long spaced 7 inches apart on centers is laid parallel with the length of the roadway and imbedded in the top of the slab over the floor beam. At the end of the bridge where the slab connects with the end

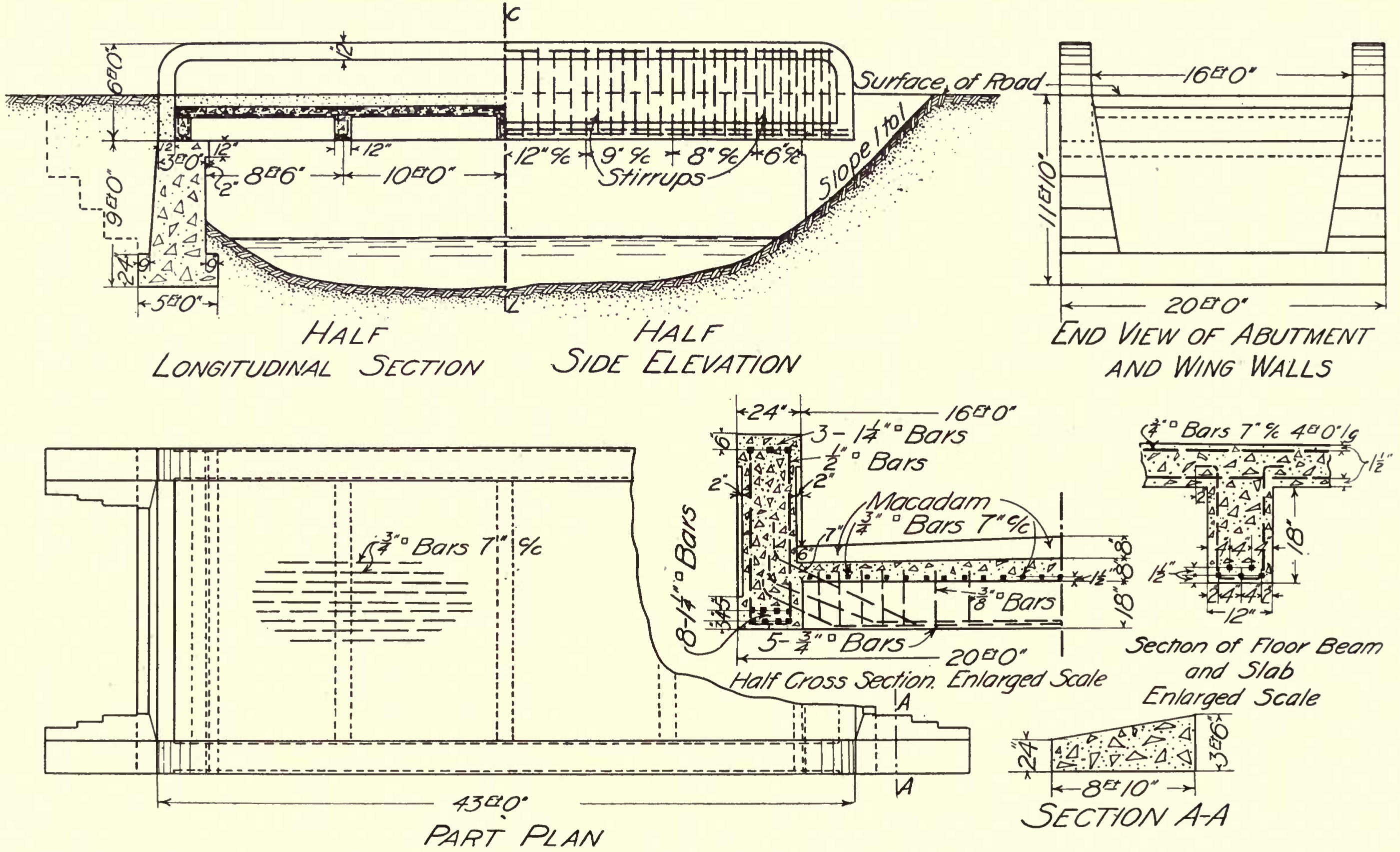


FIG. 48.—GIRDER BRIDGE WITH SPAN OF 37 FEET.

floor beam, the rods in the top of the slabs should be bent to extend downward into the floor beam.

The floor beams, which are the cross-beams running from girder to girder, are spaced 10 feet apart on centers and are reinforced with five ¾-inch longitudinal bars and with ⅜-inch stirrups. These longitudinal rods must be bent up at each of the floor beams as shown and must extend into the girder.

The main girders have a clear span of 37 feet and a depth of 5 feet. They are reinforced with eight 1¼-inch square bars in the bottom and three 1¼-inch square bars in the top and are provided with vertical stirrups. The stirrups are ½-inch bars bent U-shaped and placed close together near the ends of the girder and further apart near the center.

The surface of the roadway must be drained and this can best be done by making a slab with a curved upper surface so that the water may run to the gutters and thence through the drain pipes placed in the slab.

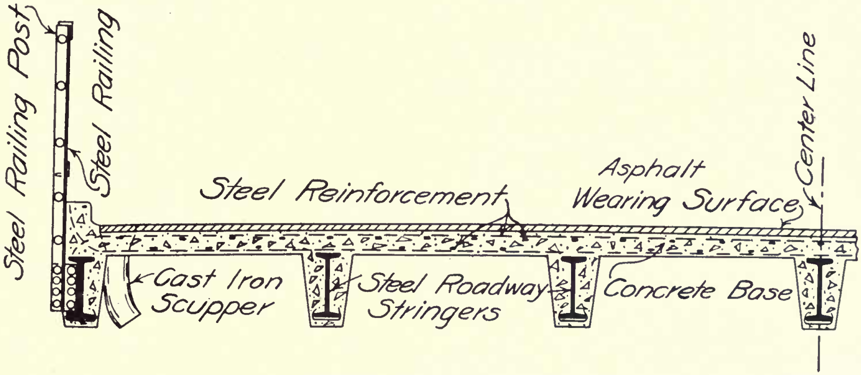


FIG. 49.—REINFORCED CONCRETE ROADWAY FOR STEEL SPANS.

## CONCRETE FLOORS FOR STEEL BRIDGES.

On long span highway bridges where steel trusses are necessary, plank flooring has until recently been used, but as this planking only lasts from one to five years there is a demand for something more durable than wood and reinforced concrete slabs on steel beams are being used.

Fig. 49 shows a typical cross section of a concrete slab construction carried on steel I-beam stringers which in turn are supported by the steel floor beams running from truss to truss. A 30-foot roadway without sidewalks is here provided for, but where sidewalks are necessary the construction may be easily modified to suit. The wearing surface of the roadway is shown as asphalt, which usually is laid 2 inches thick on a binder of small thickness. In some cases the binder has been omitted and the upper surface of the concrete left very rough to give a good union between asphalt and concrete. Proper crown must be given the roadway to take care of the drainage; this being easily done by setting the I-beam stringers on high levels towards the center of the roadway or else by making the concrete slab level and using a greater thickness of wearing surface at the center than at the gutters.

The I-beam stringers should be encased in concrete as shown, for by so doing a stronger floor is obtained and the steel beams are protected against rust. Railing posts made of two steel angles and connected to the outside I-beam by a plate and small angles, give the necessary support to the railings.

## COST OF BEAM AND SLAB BRIDGES.

There is considerable variation in the cost of concrete bridges and any data given regarding the cost is at the best only approximate. The cost of a bridge is affected by the span, width, height, character and depth of foundations, the type of structure, the magnitude of the loads to be carried, the style of finish, and by several other elements of a similar nature.

The cost of several reinforced concrete bridges recently built and similar to those shown in this chapter, was $9.00 per cubic yard for the reinforced concrete where the expense of hauling was considerable, and $6.75 per cubic yard for abutments without reinforcement. The abutment foundations extended about 3 feet into the ground.

For reinforced concrete bridge work similar to that shown in Fig. 43, the contract price frequently paid by the Pennsylvania State Highway Commission is $10.00 per cubic yard.

A bridge of 30 feet span similar to the one shown in Fig. 44 and designed by the Illinois Highway Commission cost $995 not including the crushed stone which was furnished free. The price of the bridge would have been $1,125 had the contractor furnished everything. There were 90 cubic yards of concrete and 8,600 lbs. of steel in the structure.*

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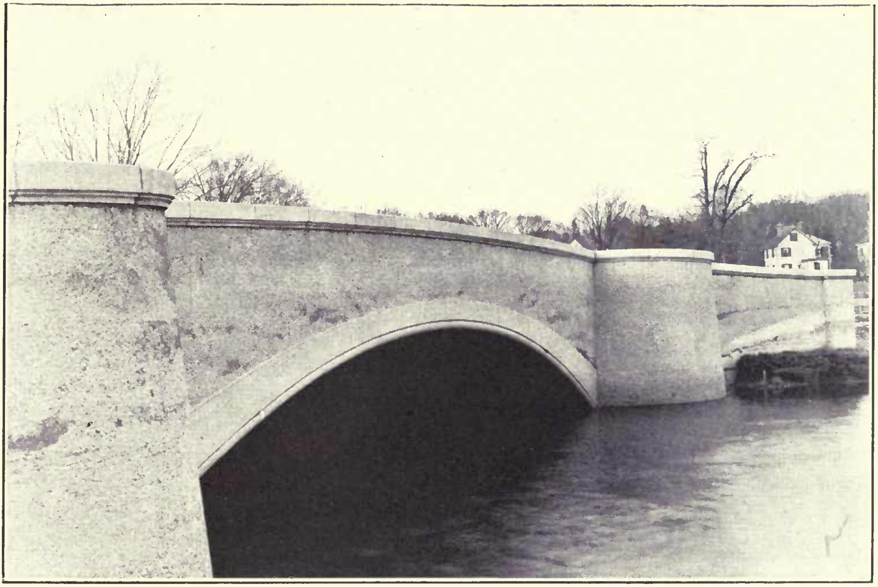
*Illinois Highway Commission Report, 1906, p. 59.

# CHAPTER VII.

## ARCH BRIDGES.

Arches include that class of curved bridges varying from simple culverts of 5 or 10-foot spans to the wonderful structures like the Walnut Lane Bridge in Philadelphia which has an arch of 232 feet, clear span. The advantage of using concrete in bridges was clearly set forth in Chapter VI. and therefore it is needless to further emphasize in this chapter on arch bridges, its value wherever ultimate economy, beauty and durability are of importance. Suffice it to say that in many locations a good concrete arch bridge can be built cheaper than a good steel bridge, and when the durability of the concrete and the enormous cost of maintaining the steel bridge are considered there is no question as to which is the better investment for a town or county to make. The concrete structure is more durable, more beautiful, and in every way superior to steel construction for spans of ordinary length. Where the foundations are good, a series of arches may be used in place of a steel bridge with long spans, and the advantages already enumerated for short spans apply equally well in this case. The pressures which the arch exerts on its foundations are



AUBURN ST. BRIDGE, MEDFORD, MASS.

inclined and this pressure or outward thrust must be provided for in the design and construction of the bridge.

## PLAIN AND REINFORCED CONCRETE ARCHES.

Arches may be built either with or without steel reinforcing bars; where there is no steel the arch is of plain concrete, and if steel rods or steel in other forms are used to reinforce the concrete the structure is then called a reinforced concrete arch bridge.

Steel reinforcements should always be used in arches, for while it adds very little to the cost, it increases the strength considerably. In the last few years there has been a remarkable increase in the number of reinforced concrete arch bridges, and they are giving perfect satisfaction. In most cases the quantity of steel used is really very small in proportion to the quantity of concrete, and as this steel is entirely imbedded in the concrete it cannot rust and therefore is not open to the same objections that are raised against steel where it is exposed to the action of the elements. In many arches the cross-sectional area of the steel used is only about 1/100 of the area of the concrete as measured at the crown of the arch, which is the highest part of the span. This means that for every 100 square inches of concrete there is only 1 square inch of steel at that section.

BRIDGE IN DELLWOOD PARK, JOLIET, ILL.

Under ordinary conditions bridges of spans from 20 or 30 feet to 100 feet can be readily constructed of reinforced concrete, while for even greater spans where the foundations are good, the proper combination of steel and concrete makes a strong, graceful and economical bridge, a type which is being widely adopted in country districts as well as in the larger towns.

## HISTORY OF CONCRETE ARCHES.

The first plain concrete arch built was the 116-foot span at Fontainebleu Forest in France, which was finished in 1869, and is known as the Grand Maitre bridge. In the United States the first plain concrete arch of which there is any record was one of 31-foot span built in 1871 in Prospect Park, Brooklyn. The earliest reinforced concrete arch in the United States was constructed in Golden Gate Park in San Francisco in 1889, and several years even before this date concrete bridges reinforced with iron had been built in Europe. This type of construction is not an experiment. It represents the highest art of modern bridge construction. As a material for highway bridges of spans from about 30 feet to 100 feet reinforced concrete has no equal.

As has already been stated, a span of 232 feet has been completed in Philadelphia. The new Rocky River Bridge in Cleveland, Ohio, is being constructed with a span of 280 feet and a proposed bridge in New York City has a span of over 700 feet. These large spans show the rapid development in the art of building bridges with concrete.

## TYPES OF CONCRETE ARCHES.

Arches are classified in various ways, but the most simple classification is that which deals with the method of the construction of the spandrels which are the spaces above the upper surface of the arch ring and below the roadway level. These spaces may be either filled in solid with earth filling or they may be left open by supporting the roadway above on slabs and beams, which in turn are supported on columns or cross-walls resting on the arch ring.

Where the spandrel spaces are filled in solid with earth, this earth is prevented from flowing out sidewise by side walls, also called spandrell walls, which run lengthwise of the bridge, one on either side of the roadway. The earth rests directly on the outer surface of the arch ring and the road or street pavement is laid directly on this earth filling. These bridges are said to have solid spandrels.

In the second type, where the spandrels are left more or less open, the roadway is usually laid on a slab of reinforced concrete having a thickness of from 4 to 8 inches which rests upon a series of reinforced beams supported on columns, or upon transverse concrete walls which, being spaced at distances of from 10 to 20 feet lengthwise of the bridge, give the appearance of open spandrels. These columns or walls rest on top of the arch ring.

For small arches the solid spandrel type is the most common, while for the large bridges with spans over 100 feet the open spandrels are better, because they lessen the weight to be carried.

Arches are often also classified as to the style of reinforcement or as to whether there are any hinges used in the arch ring. A hinge is made by inserting a joint in the concrete arch ring, and usually, when they are used, one is placed at the crown of the arch and also one at each end where the arch ring rests upon the abutment or support. These hinges are made of steel and act very much in principle like the hinges on an open door, that is, the concrete arch ring can move a little by turning around the steel hinges. This movement is of course very small. Hinges are used with an idea of simplifying the design of the arch, but they have been employed in only a few cases in the United States.

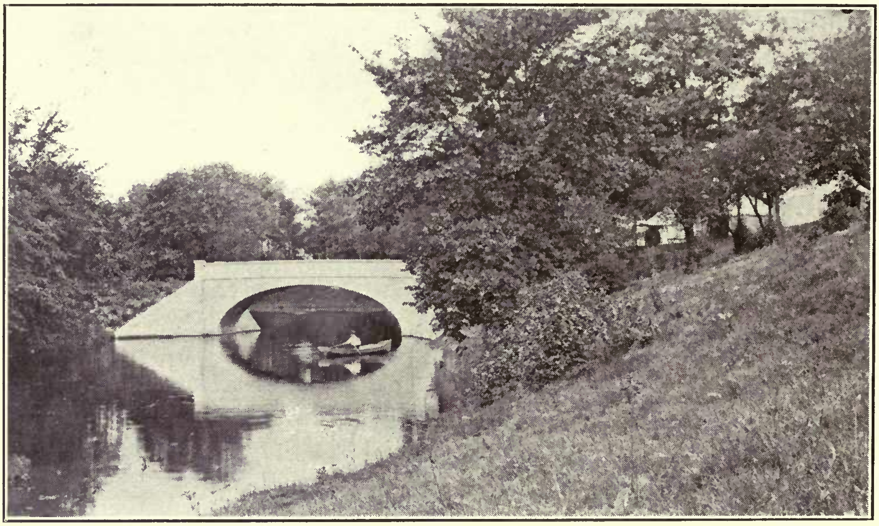


FIG. 50.—ARCH BRIDGE, DELLWOOD PARK, JOLIET, ILLINOIS.

## PREPARATION OF PLANS.

An arch bridge is too important a structure to be placed in charge of an inexperienced man. The only safe way is to employ a competent engineer to prepare plans and specifications and to superintend the construction. Before the contract for the bridge is let, the plans should be complete and should show not only the principal dimensions of the structure, but they should also show all important details which may in any way affect the strength or the cost. Unless the plans and specifications are complete and accurate, unnecessary delays in construction and extra charges for changes and additions will inevitably occur. If the engineer is not to be on the ground continually during the construction, he should be allowed a competent assistant or inspector whose duty it should be to see that the plans and specifications are followed and that the work is carried on in a proper manner.

## DESIGN FOR A 40-FOOT SPAN.

Fig. 51 shows a design for a reinforced concrete highway arch for a 40-foot span with a rise of 8 feet. The principal parts are the arch ring, the spandrel or side walls, the abutments, the wing walls, the parapets and the earth filling. The cross section at crown shows a 20-foot roadway with a 6-foot sidewalk on either side. At the crown of the arch the earth filling has a thickness of 18 inches at the center of the roadway.

The arch ring is 12 inches thick at the crown and 2 feet 6 inches thick at the abutments, the latter being the radial not the vertical thickness. The dimensions of the abutments are shown in the drawing and have been determined on the assumption that the soil under the foundations is good compact sand and gravel or other similar materials capable of safely sustaining 4000 to 6000 lbs. per square foot.

The arch ring is reinforced with round medium steel rods ¾ inch in diameter running lengthwise of the span, arranged in two layers, one layer 2 inches in from the outer curved surface of the concrete ring and the other 2 inches from the inner curved surface. These layers, therefore, are 8 inches apart at the crown and 2 feet 2 inches apart at the abutments. The rods in each layer are 8 inches apart on centers as shown in the cross section.

In addition to the ¾-inch rods there are two sets of ½-inch diameter rods running at right angles to the length of the roadway as shown in the one-half longitudinal section. In each layer the ½-inch rods are 15 inches apart on centers. Stirrups made of ⅜-inch diameter round rods are frequently used in bridges of this type to connect the outer layer with the inner. They should be hooked at the outer and inner ends to pass around the transverse and longitudinal rods at their intersections. In the bridge shown, this arrangement would space them 15 inches apart. Where no stirrups are used, the transverse and longitudinal rods should be connected by wires at their intersections.

Where the design calls for rods longer than can be obtained in one length, splices must be used and this can be done by simply lapping the two bars to

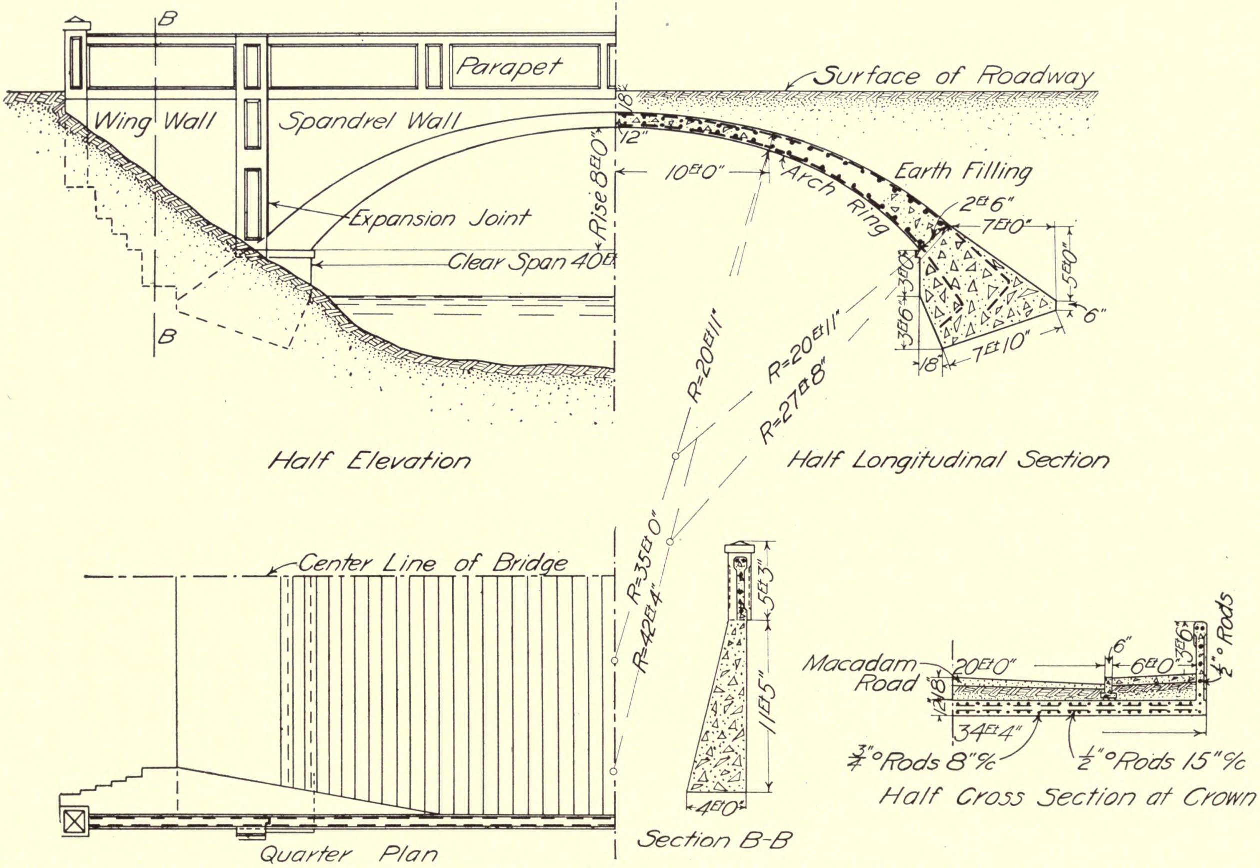


FIG. 51.—REINFORCED CONCRETE ARCH BRIDGE WITH SPAN OF 40 FEET.

be spliced a distance equal to 20 diameters of the rod if it has deformed surfaces or 30 diameters if it has smooth surfaces. Sometimes the rods are lapped and then wound with heavy wire. Some designers thread the rods and splice them by means of sleeve nuts, but usually it is sufficient to lap the rods as indicated.

As shown in the cross section at the crown, Fig. 51, six ½-inch diameter rods should be placed in the parapet wall between the expansion joints.

The design shown is suitable for ordinary highway traffic.

## EXPANSION JOINTS.

Each spandrel wall and parapet is provided with an expansion joint at the abutments. This is to allow for the change in length of these parts due to changes in temperature. Concrete changes its length about ⅜-inch for every 100 feet of length due to the change in temperature from a mean temperature to extreme heat or to extreme cold in a climate such as that of New England, Michigan or similar sections. Unless the wall is properly reinforced, expansion joints should be left at distances apart not much over 40 feet or even less to prevent cracking due to these changes in temperature. These joints should be made from the upper surface of the arch ring to the top of the parapet and should be made wedge-shaped or dove-tailed so that one part fits into the other.

## REINFORCED CONCRETE ARCH, ELM STREET, CONCORD, MASS.

Figs. 52 and 53 show a highway bridge of 75 feet clear span built of "ATLAS "Portland Cement in Concord, Massachusetts, by the Massachusetts Highway Commission. The rise of the arch is 12 feet or about 1/6 of the span length. At the crown the arch ring is 16 inches in thickness and increases towards the abutments as shown.

The reinforcement in the arch ring consists of 1-inch longitudinal twisted steel bars spaced 17 inches apart on centers and ¼-inch transverse twisted steel bars spaced 24 inches apart on centers. The centers of the 1-inch rods are 2¼ inches from the face of the concrete and these rods are in lengths of about 16 feet lapped 40 inches at each splice as shown in Fig. 55. Reinforced side walls braced with counterforts shown in Fig. 53 serve to retain the earth filling. Although there is a comparatively small amount of concrete used in the construction of this type of wall, the saving due to this is probably more than offset by the increase in cost due to the expensive forms necessary for the counterforts. Several sections of these side walls are shown in the upper right hand corner of the drawing over the half section of the arch, and the locations of these sections are indicated by distances on the half section and by letters upon the plan of the arch. The steel in the side walls consists of ⅝-inch horizontal rods spaced 12 inches apart on centers near the bottom and ½-inch rods spaced 24 inches apart on centers near the top of the wall. In the coping there are also two ¼-inch longitudinal rods. The counterforts are provided with tie rods as indicated.

As shown in Fig. 53, the coping overhangs the face of the arch ring and the face of the wing walls by 1½ inches, the faces just mentioned being in the same vertical plane; the spandrel walls are set back 1½ inches from the face of the arch ring, hence 3 inches back from the surface of the coping. This gives a neat design and one which is easily carried out.

Four hundred and fifty-eight cubic yards of concrete were used in this structure.

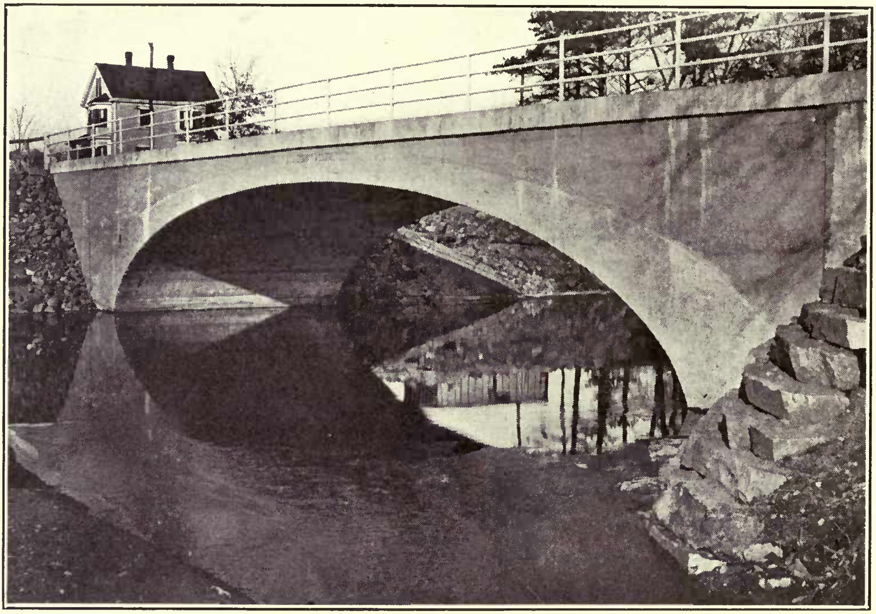


FIG. 52.—ARCH BRIDGE WITH SPAN OF 75 FEET, ELM STREET, CONCORD, MASS.

Fig. 54 on page 110 is a view taken just after the falsework and centering were in place and before the lagging was placed on the centering. The photograph on page 110 shows the arch ring under construction with the longitudinal rods partially imbedded in concrete. One of the small transverse rods may be seen just beyond the top of the transverse stop boards. These stop boards serve as temporary forms for the concrete and also as spacers for the longitudinal rods. After these boards are removed the next section of the concrete

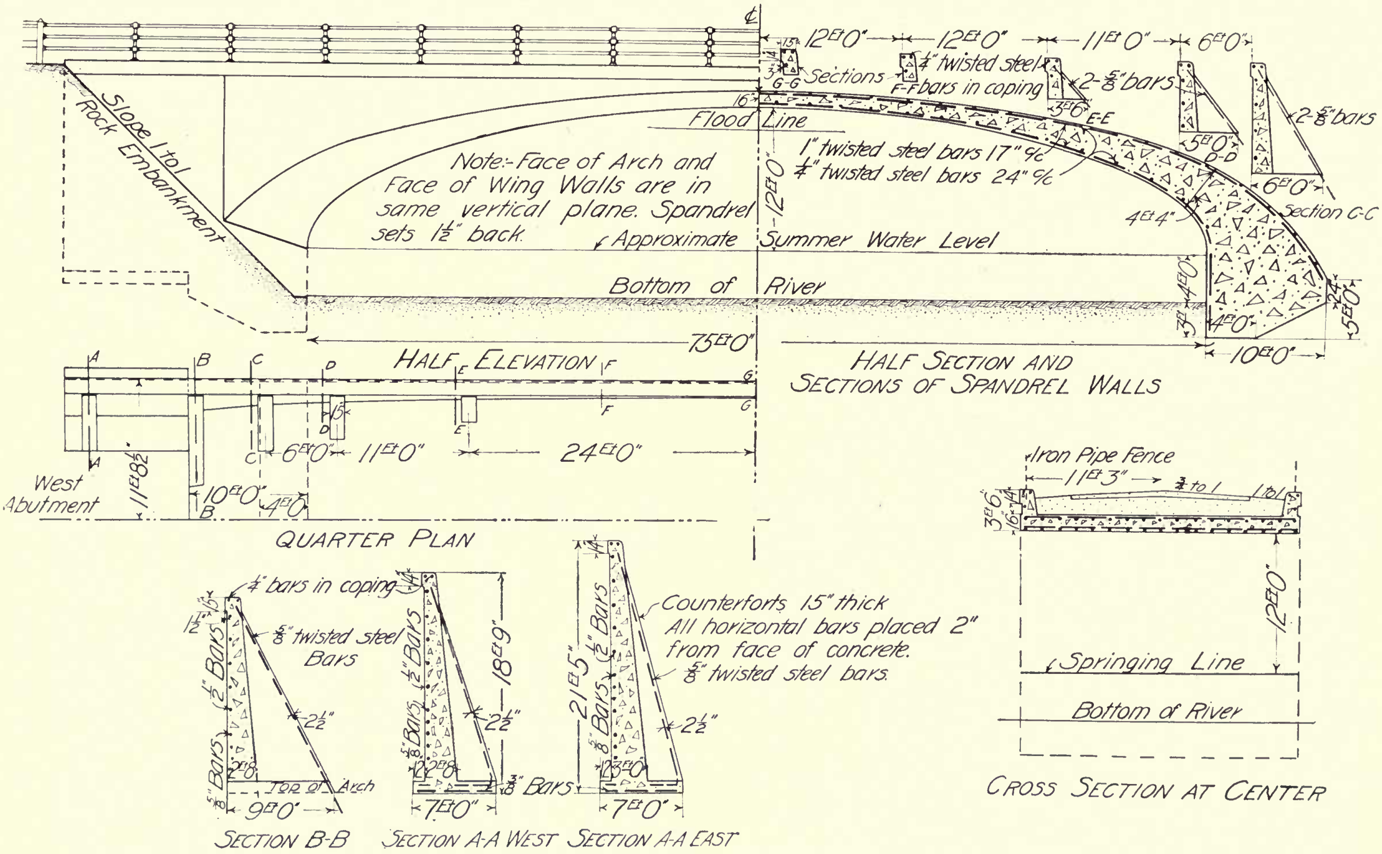


FIG. 53.—ARCH BRIDGE WITH SPAN OF 75 FEET, ELM STREET, CONCORD, MASS.

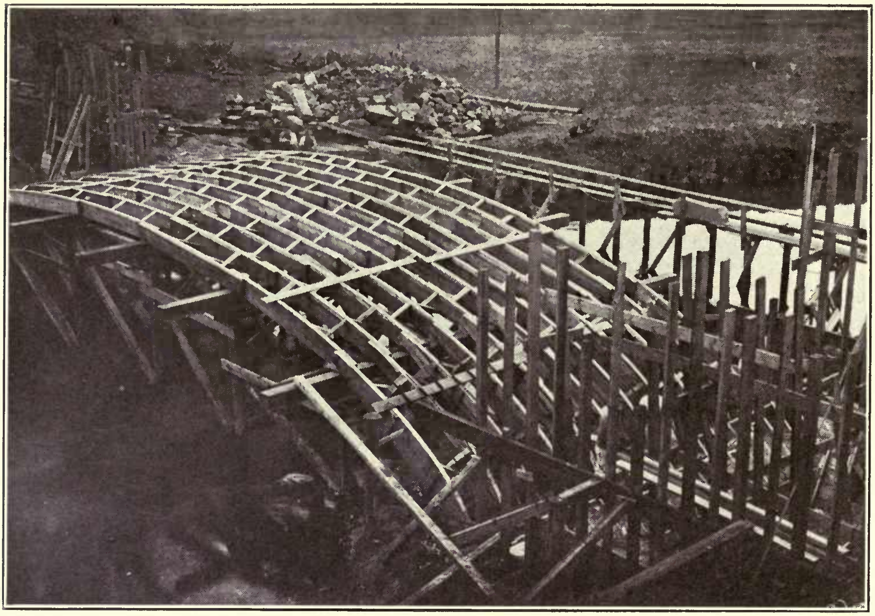


FIG. 54.—CENTERING OF ARCH BRIDGE, ELM STREET, CONCORD, MASS.

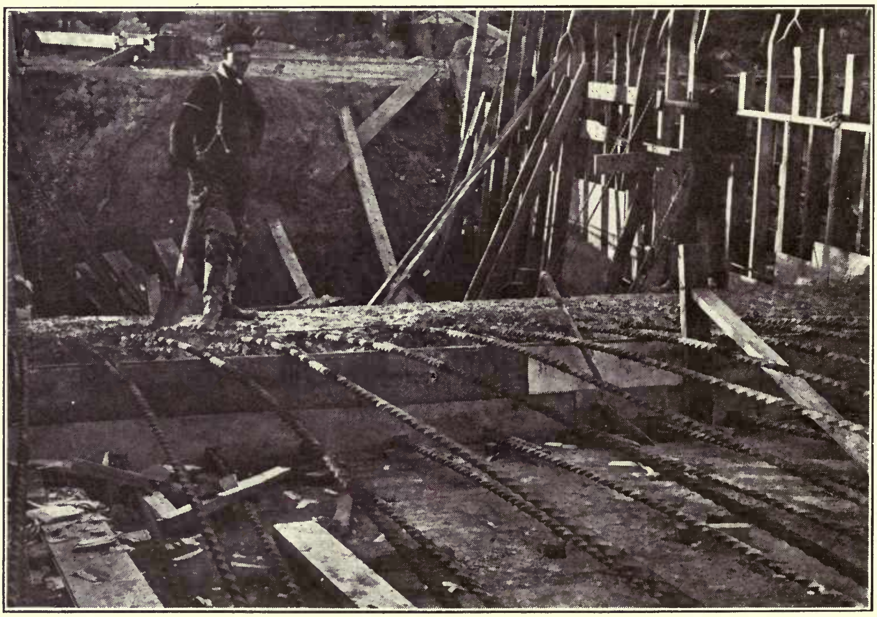


FIG. 55.—CONSTRUCTION OF ARCH BRIDGE, ELM STREET, CONCORD, MASS.

for the arch ring is deposited against the finished section. The form of arch here shown is suitable for locations where the foundation is of the hardest material, like hard pan or rock.

## FALSEWORK AND CENTERING.

The falsework and centering, Fig. 56, constitute that part of the temporary wood work which supports the concrete while it is being laid and until it has hardened. The falsework consists of vertical timbers braced transversely and longitudinally upon which rest the centering or curved platform forming the support for the concrete arch ring. The vertical supports may be either piles driven into the ground or river bottom underneath if the bottom is soft, or framed trestle bents resting on horizontal timbers if the bottom is hard. The piles must be placed close enough to carry the weight above with practically no settlement and must be braced with 2 by 8-inch or 2 by 10-inch diagonal timbers spiked or bolted to the piles.

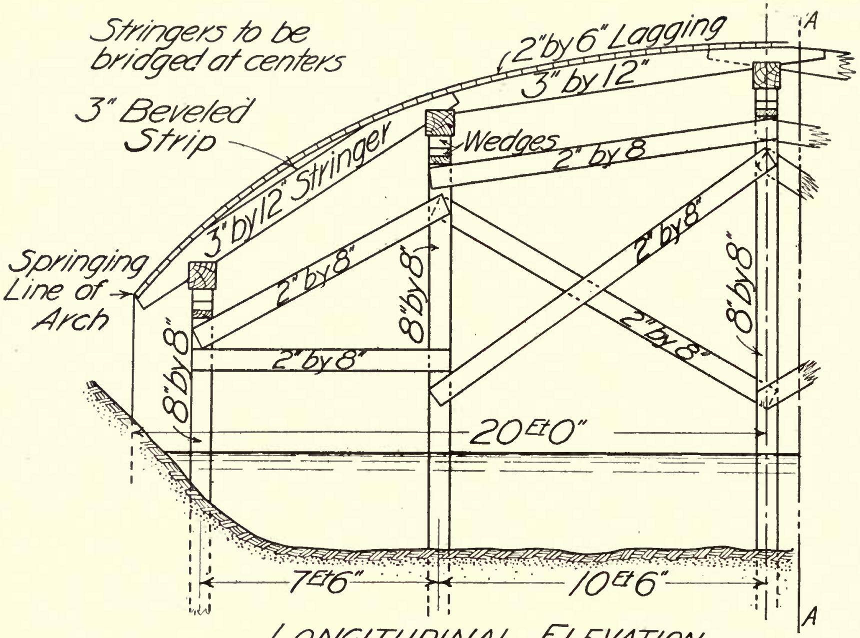
Transversely to the length of the bridge and spiked or bolted to the tops of the piles, a cap must be set and upon these caps rest wooden wedges supporting the weight of the centering above.

The centering consists usually of a set of caps or cross timbers resting on the wedges above the pile caps, some longitudinal stringers notched on and supported by the upper caps and finally of a closely laid flooring or lagging resting on the stringers. The caps for the centers are usually 10 by 10 inch or 12 by 12 inch timbers. The stringers are of varying size, depending on the distance between piles and the weight to be carried. For arches having spans up to 100 feet, these stringers are from 2 to 4 inches wide and from 12 to 14 inches deep, spaced from 1½ to 3 feet apart on centers. The upper surface of the stringers must be curved to fit the curvature of the under surface of the arch; this is frequently done by nailing a curved piece to the top of the stringers as in the centering of the Concord Arch in Fig. 54 and also in Fig. 56. The stringers must be braced to one another by 1 by 6-inch bridging as is common in ordinary house floors.

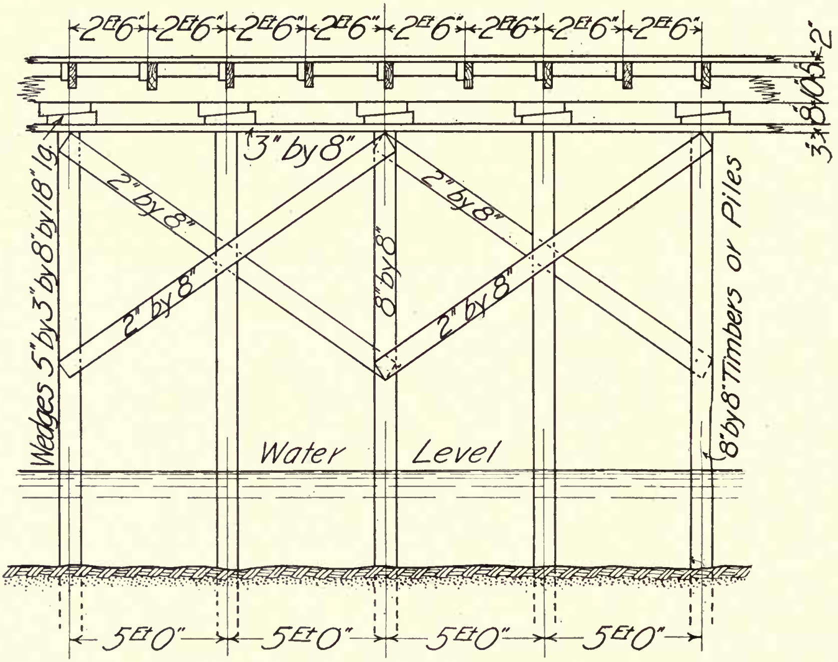
Lagging, consisting of ⅞-inch tongued and grooved pine or 2-inch spruce with beveled edges, must be nailed to the stringers and must be planed on the top side to give a smooth finish to the under surface of the arch ring. Sometimes where the stringers are quite far apart 4-inch lagging is used.

## PLACING CONCRETE.

Before concreting is begun, the forms for the foundations and wing walls should be in place and thoroughly braced and the steel reinforcement set and wired in place. The forms and steel for the spandrel walls and the arch ring



LONGITUDINAL ELEVATION



SECTION A-A

FIG. 56.—FALSEWORK AND CENTERING FOR ARCH WITH SPAN OF 40 FEET.

may be placed while the concrete is being deposited for the foundations. As soon as the concrete in the foundations is up to the arch, the arch may be begun and laid in one or two days.

First, the arch ring may be divided longitudinally into parallel rings or sections having a width of from 3 to 5 feet, or even more if the span is not too large, and one of these sections laid at a time. This is generally the best plan to follow.

Or, secondly, the arch ring is divided into sections as shown in Fig. 55, which shows the Concord Arch being laid in large, separate blocks across the bridge, having a width equal to that of the arch ring and a length equal to a fraction of the span length.

FIG. 57.—CENTERING FOR ARCH IN PLACE.

Whichever of these methods is used, care must be taken to avoid undue settlement or distortion of the centers as the concreting progresses. If the second method of laying concrete is used, that is, in large transverse blocks, the work is usually begun at each abutment at the same time, and if the centering is not well supported underneath it will rise at the crown, due to the weight at the two ends. To avoid this the best way is to begin concreting at the two abutments and as this work progresses load the centering at the crown temporarily, adjusting this load if needs be to keep the centers in proper position. The loading at the crown is frequently done by laying a part of the arch ring there after a part is laid at each abutment. Then the spaces between these blocks are filled in.

For small arches the entire ring can be laid in one day's work, and of course this should be done whenever possible.

## EARTH FILLING.

After the concrete is placed in position and thoroughly hardened and before the centers are removed, the earth filling should be added. As the earth is placed, it should be compacted by ramming or rolling, and even if the centers are still in place it is better to deposit the earth in layers over the whole length of the span so that the arch is loaded nearly uniformly till the entire filling is in place.

If the filling is placed after the centers are removed, it is absolutely necessary to place the earth uniformily over the span length and not pile a large weight on one side leaving the other side unloaded.

In case the finished roadway is to have a surface such as macadam or concrete, great care should be taken in compacting the earth filling, for otherwise settlement will take place in the filling and the roadway surface will also settle.

## STRIKING CENTERS.

By striking centers is meant the lowering of the centers so that the arch becomes self supporting. The centers are usually lowered by removing the wooden wedges already mentioned under the head of Falsework and Centering. These wedges, Fig. 56, placed between the caps of the falsework and those of the centers, can be removed by a sledge hammer, thus lowering the centers. Care must be taken to lower the centers gradually and without jarring the structure by allowing a part to get its load suddenly.

## SURFACE FINISHING.

In many structures the appearance of the surface of the finished concrete is of no importance, but most structures, such as bridges, which are constantly exposed to view, need some treatment to render the outer surfaces neat in appearance. Oftentimes the structure is such that proper selection of good tongued and grooved planking smoothly laid, together with care in placing the concrete against the forms is all that is required to give a fairly presentable surface. This surface is obtained by simply forcing a spade down the side of the forms and pushing back the stones so that the mortar will flow against the face of the forms and fill all stone pockets or voids.

If a better finish is desired, good results can be obtained by removing the forms before the concrete has set very hard, generally from 12 to 48 hours, depending upon the cement, weather and amount of water used in mixing, and after floating the green concrete with water by rubbing the surface with a circular motion with carborundum bricks or with bricks composed of 1 part "ATLAS" Portland Cement to 2 parts sand. If the concrete can be worked when quite green, a very satisfactory finish can be obtained by rubbing the surface with stiff wire brushes.

When the surface of the concrete has set so hard as to prevent its being treated by rubbing with a brush, it still may be surfaced with a carborundum block, or an excellent finish may be gained by picking the concrete surface with a hand or pneumatic tool after the forms are removed. If further treatment is deemed necessary the tooled surface may be washed with a weak solution of acid and then with an alkali solution to neutralize the effect of the acid.

If a very smooth surface is desired, a veneer of mortar is sometimes placed between the main body of the concrete and the forms. This mortar facing is usually composed of 1 part "ATLAS" Portland Cement to 2 or 3 parts sand and may be applied in several ways. Perhaps the cheapest and easiest method is to trowel a layer of mortar an inch in thickness against the face of the forms and immediately deposit the concrete against it, thus causing the two parts to become thoroughly united. Another method is to hold the concrete away from the forms about 1 inch by means of sheet iron plates while the mortar is being placed between the plates and the forms.

A granolithic finish is given the exposed surfaces of bridges in Philadelphia by applying a 1-inch layer composed of 1 part cement to 2 parts sand to 3 parts broken stone to the inner surface of the forms slightly in advance of the concrete body. After 24 or 48 hours the forms on the faces of the bridge are removed and the concrete surface is immediately rubbed, using a wood block with sand and water and then washing with clean water.

Plastering on concrete surfaces exposed to the weather should be avoided as the plaster is sure to peel off and leave the surface in an unsightly condition unless extraordinary precautions are taken. If plastering is unavoidable the forms must be wet instead of greased. The surface of the concrete should be picked or bush hammered to make it rough, thoroughly wet and then covered with a thin coat of neat cement paste upon which the plaster must be applied in as thin a layer as possible and before the neat cement paste has set.

## COST.

There are so many variable items in bridge building that to give accurate figures regarding costs is practically impossible. Frequently the cost is given for a bridge based on a cubic yard of concrete as a unit, while in other cases the cost per horizontal square foot of roadway surface is taken as a unit. In a paper read by Mr. Henry H. Quimby before the National Association of Cement Users in Cleveland, Jan. 11-16, 1909, he states that the average cost per cubic yard of 18 concrete bridges recently built in Philadelphia was $9.75, with a minimum of $6.50 and a maximum of $11.25 per cubic yard. Basing the cost on a horizontal area equal to the clear span times the width, he gives as an average cost for these bridges $6.50 per square foot, with a range of from $3.11 to $9.74 per square foot. These figures include all the concrete in the arches and abutments.

The cost of the O'Connor Street reinforced concrete skew arch bridge in Ottawa*, Canada, was $8.02 per cubic yard as an average cost for the total of 620 cubic yards including some plain and some reinforced concrete. The cost of the reinforced concrete was $9.80 per cubic yard. This bridge has a span of 20 feet; a length of 46 feet; thickness at crown 18 inches; a rise of 4 feet 10 inches.

The cost of two concrete arches, one of 50-foot and the other of 44-foot span, built by the Pennsylvania State Highway Department in 1907 is given by Mr. G. A. Flink† as $7.50 per cubic yard for the 44-foot span which contains 243 cubic yards of concrete, and $9.50 per cubic yard for the 50-foot span containing 268 cubic yards. The 50-foot span has a rise of 6 feet 9 inches, which is quite small for a bridge of this length.

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*The Concrete Review, Vol. 3, Nov. 1, 1908, p. 23.
†Good Roads Magazine, April, 1908, p. 111.

# CHAPTER VIII.

## RETAINING WALLS.

Retaining walls are frequently required to hold back an adjoining mass of earth from sliding upon a highway or for supporting the lower side of a highway on a side hill. In fact, where the highway is cut in the side of a hill it may be necessary to use a retaining wall on the up-hill as well as the down-hill side of the road. Walls are also necessary in many cases where an embankment is confined to a limited width as, for instance, where the highway is carried up to and over a railroad on an inclined embankment which is confined on either side of the roadway by a wall running parallel with the roadway.

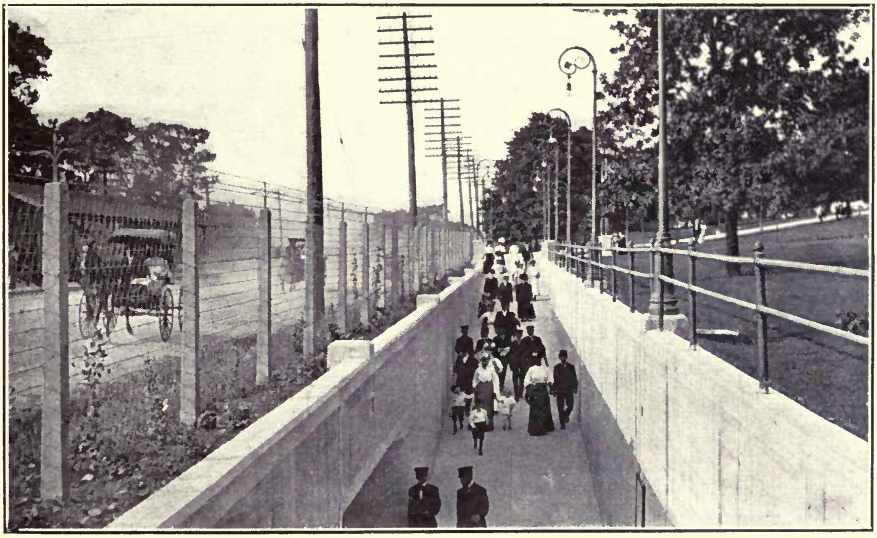


FIG. 58.—RETAINING WALLS AT DELLWOOD PARK, JOLIET, ILL.

Fig. 58 illustrates a use of retaining walls which is quite common. The two walls shown hold back the earth on either side of an inclined passage way leading to the subway entrance in Dellwood Park, near Joliet, Illinois. In the left of the picture is a highway and on the right the park. These walls were built of concrete made of "ATLAS" Portland Cement.

Retaining walls are needed in many places in addition to the uses already cited.

Concrete retaining walls are built either with or without steel reinforcement and they have come into prominence because they are more economical than the stone masonry walls so universally used until a few years ago. Concrete has already demonstrated its usefulness as a material for wall construction, not only because of its low first cost, but also because no maintenance is necessary. A stone retaining wall must be pointed from time to time to keep the joints closed or the masonry will soon be disintegrated by frost. Concrete walls have practically no joints and hence no maintenance charges.

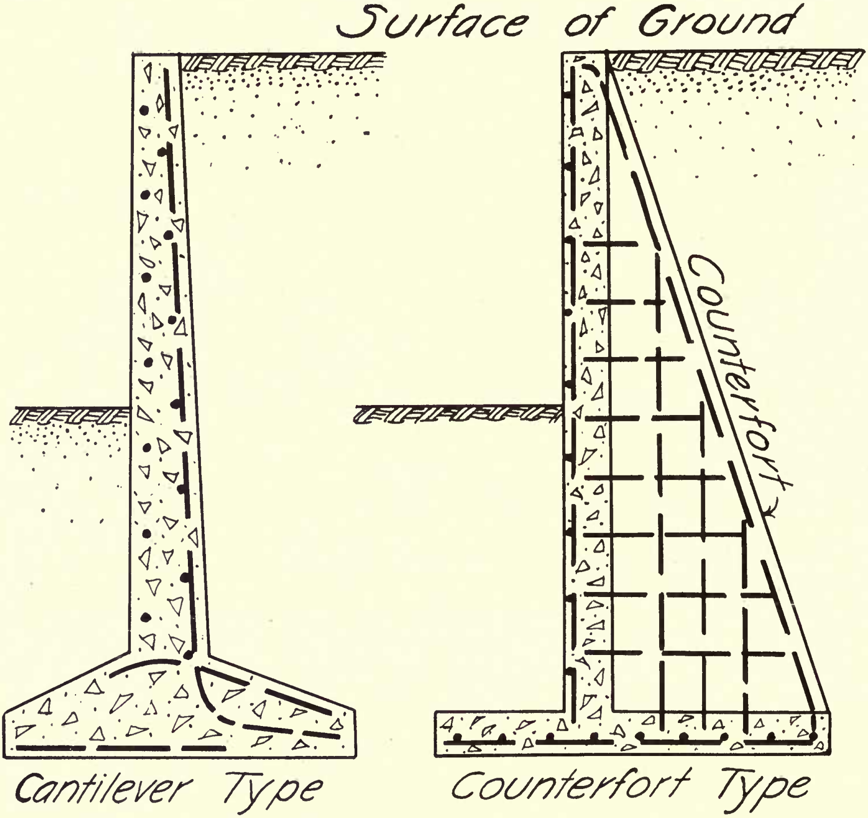


FIG. 59.—TYPES OF REINFORCED CONCRETE RETAINING WALLS

## KINDS OF RETAINING WALLS.

Retaining walls are built in the form of thin reinforced concrete walls or as gravity walls of plain concrete containing little or no steel reinforcement.

Gravity walls are designed to withstand the earth pressure behind them by being made sufficiently heavy to prevent sliding or overturning. They do not utilize the weight of the earth behind them to add to their strength.

Reinforced concrete walls, however, depend to a considerable extent on the earth sustained to add to their stability. The earth behind the walls presses against it, but at the same time the wall is of such a shape that this earth pressure helps to some extent to prevent sliding or overturning. Reinforced walls can be made much thinner than gravity walls and for this reason reinforced walls are usually cheaper.

Reinforced walls as usually built consist of a thin vertical wall attached to a horizontal base and braced either by counterforts on the back or by buttresses on the front side. In more recent designs no buttresses or counterforts are used and the wall then is a vertical slab of reinforced concrete attached to a horizontal base.

RETAINING WALLS, BIRMINGHAM, ALA.

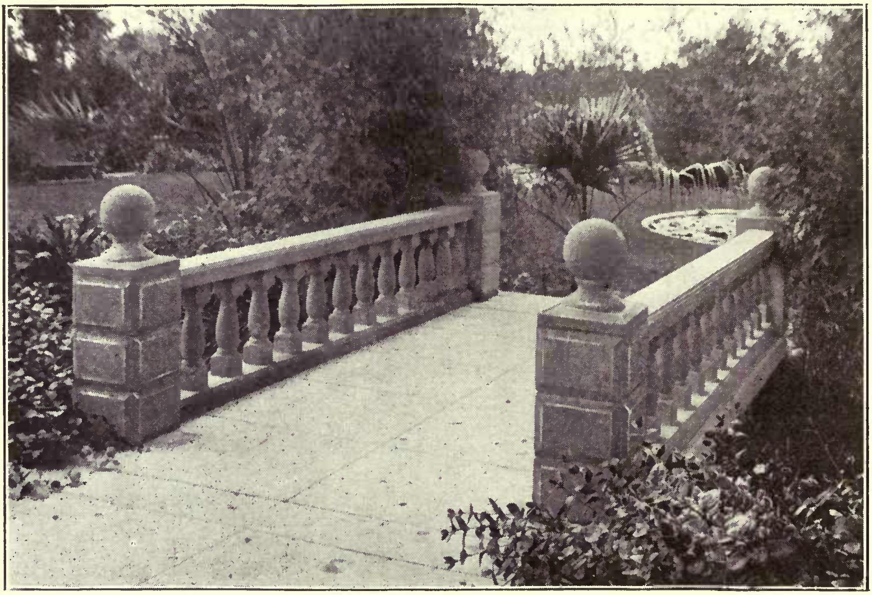
Fig. 59 illustrates the two more usual types of reinforced concrete walls, cantilever and counterfort types.

Buttresses projecting out in front of the wall are not often used, for they take up too much space which in many cases must be utilized for other purposes. In addition they give a very unsightly appearance to the face of the wall.

Counterforts are thin walls running back into the earth behind and serve to brace the main vertical wall. They are quite frequently used, but the inverted T-shaped cantilever type is so much more easily and cheaply constructed that it should be used unless the wall is at least 18 feet high above ground, in which case the counterfort type may be more economical. Counterforts rest on and are connected to the horizontal base of the wall, and, being reinforced with steel bars, they really act as ties on the back of the wall.

## GRAVITY RETAINING WALLS.

With a gravity type of construction, the weight of the wall is relied upon to sustain the earth pressure and the wall must not only be of sufficient weight but also must have the proper shape.



BEAM BRIDGE ON PRIVATE ESTATE, REDLANDS, CAL.

In the construction of retaining walls of any shape or kind, care must be taken to get good foundations. If the material under the wall is compact sand or gravel, there should be no trouble with the foundation. In some cases, where it is necessary to build a wall on rather soft ground, the sub-soil must be thoroughly drained and in addition it must be compacted by ramming sand or gravel or stone into it. Where the soil is very soft, piles are required to sustain the weight of the wall with the earth pressure behind it. In building walls upon rock which has an inclined surface, this surface must be made horizontal, stepped, or roughened by blasting to prevent the wall from sliding down the inclined rock surface. Several large retaining walls have failed because this was not regarded. By taking the precautions just mentioned no trouble will be experienced.

Gravity walls are usually made with a coping on top of the main body of the wall. The front or exposed face of the wall is sometimes made vertical and is sometimes given a batter, that is slightly inclined, and the back side of the gravity wall is either sloped or stepped so that the base of the wall is thicker than the top. A slight batter on the face adds to the appearance of the construction, but too large a batter makes the wall look as if it were leaning backwards. For low walls, say those under 12 or 15 feet in height, the face may be made vertical, although a batter of ½ inch per foot while not absolutely necessary is desirable. In heavy construction this batter is sometimes exceeded, but should never be more than 1½ inches per foot.

## COPINGS.

The coping for a gravity wall should overhang the front surface of the wall 2 or 3 inches and should be from 12 to 18 inches deep, depending on the height of the wall. For heights of less than 15 feet a coping 12 inches deep should be used, while for walls of greater heights the coping should be 15 to 18 inches deep.

The top surface of the coping should be sloped backward so that dirt will not be washed towards the front edge of the coping and thus will not drop on the front face of the wall and discolor it. The back edge of the top surface should be ¼ inch below the front edge. The front surface of the coping should be vertical and the back is sometimes, though not always, made so. The two upper corners and the front lower corner should be beveled off so that there will be no sharp corners of concrete exposed. This beveling can be best done by nailing in the forms strips of molding having triangular cross sections.

Copings may be laid on top of the wall after the concrete in the wall is hardened or they may be laid at the same time as the body of the wall. The top and front surface of the coping to a depth of 2 inches may be made of a mortar of 1 part "ATLAS" Portland cement and 2 parts clean sand laid between the forms and the inner body of the concrete. In no case should the mortar be plastered on the concrete after the latter has hardened. The upper surface of the coping should be "floated' or finished in the same manner as is the wearing surface of side walls.

Copings should be laid with vertical joints to match the vertical joints in the body of the retaining wall.

## FORMS FOR GRAVITY WALLS.

In Fig. 60 is shown a good arrangement for the construction of forms for a gravity wall and a movable form* for building the coping in sections 12 feet long is likewise shown in the same figure.

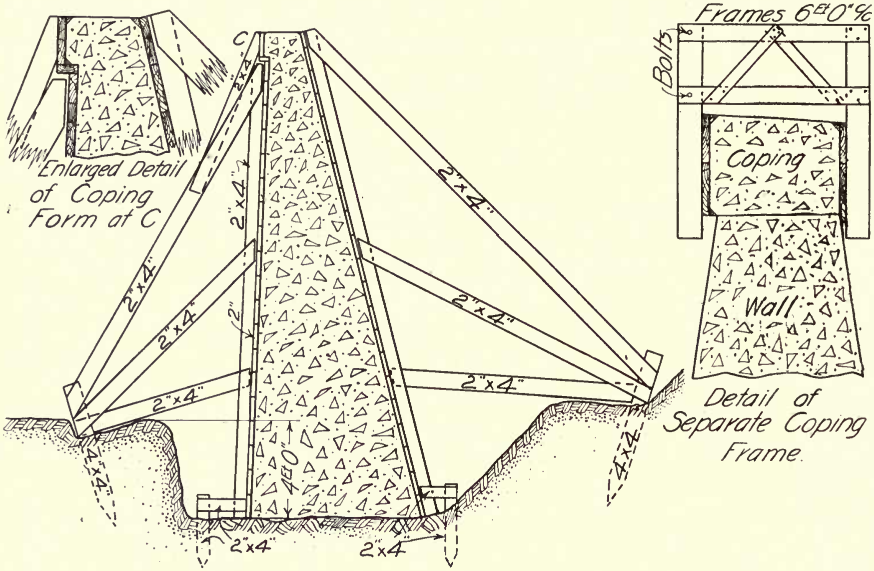


FIG. 60.—FORMS FOR GRAVITY RETAINING WALL

The forms for the wall consist of sheeting made of 1½ or 2-inch lumber braced by 2 by 4-inch studs and 2 by 4-inch inclined struts spiked to a post driven in the ground. The front and back forms are separated by means of 2 by 4-inch braces or by ½-inch bolts running through both of them and also through a piece of 1 or 1½-inch pipe between them, these pipes serving as spacers for the two forms as well. Wires are sometimes used in place of the bolts, but they are apt to stretch or break and bolts are better.

In placing concrete in the forms, care must be taken to avoid any longitudinal joints on the front face of the wall. To this end the wall should be divided into short sections such that the work in one section can be completed without leaving any horizontal joints. Of course in such an arrangement the forms have to be planked up at the outer end of the section, these end boards being removed when the adjoining section is begun.

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*"Engineering News," Vol. L., July 9, 1903, p. 37.

The movable form shown in Fig. 60 is useful where the coping is built after the body of the wall. These forms are made in sections 12 feet in length with 3 of the bracing frames, one at each end and one in the middle of the 12-foot section. They are held in place on top of the wall and the coping concrete is deposited within the form and after the concrete has set the bolts at the points shown are removed so that the forms can be taken off.

## DIMENSIONS OF GRAVITY WALLS.

The accompanying table shows dimensions and quantities of concrete for gravity walls shown in Fig. 60, with heights varying from 6 feet to 20 feet, the heights being the difference in elevation between the upper and lower levels of the earth.

DIMENSIONS AND QUANTITIES OF GRAVITY RETAINING WALLS

| Height Above Ground Level, Feet | Width of Base | Total Height Feet | Batter on Face Inches | Cubic Yds. Concrete in Wall 1 Foot Long |
|---|---|---|---|---|
| 6 | 2 ft. 3 in. | 10 | 4 ½ | 0.64 |
| 8 | 3 " 0 " | 12 | 5 ½ | 0.92 |
| 10 | 3 " 9 " | 14 | 6 ½ | 1.26 |
| 12 | 4 " 6 " | 16 | 7 ½ | 1.65 |
| 14 | 5 " 3 " | 18 | 8 ½ | 2.10 |
| 16 | 6 " 0 " | 20 | 9 ½ | 2.61 |
| 18 | 6 " 9 " | 22 | 10 ½ | 3.17 |
| 20 | 7 " 6 " | 24 | 11 ½ | 3.78 |

The bottom of the wall should in all cases go well below the frost line. Four feet has been taken in this case, though of course this will vary with different localities. Four feet, however, is usually enough, even in the coldest climates. The coping is shown 12 inches high and 18 inches wide on top and the top surface should have at least a ¼-inch slope towards the back.

The width of the base must of course be made larger as the height of the wall increases. For highway work where the upper surface of the ground is horizontal and level with the top of the wall it is customary to make the base ⅜ of the height of the wall, the height being taken as the distance between the upper and lower levels of the ground, thus: if the height of the wall is 20 feet the base would be ⅜ of 20, that is 7½ feet. The batter on the front face is ½ inch per foot of vertical distance under the coping, that is, ½ times 23 or 11½ inches. In this case the amount in 1 foot length of wall is 3.78 cubic yards.

Where the earth to be sustained is rather wet and slopes up from the top of the wall instead of being horizontal, the thickness of the base should be ½ of the height of the wall.

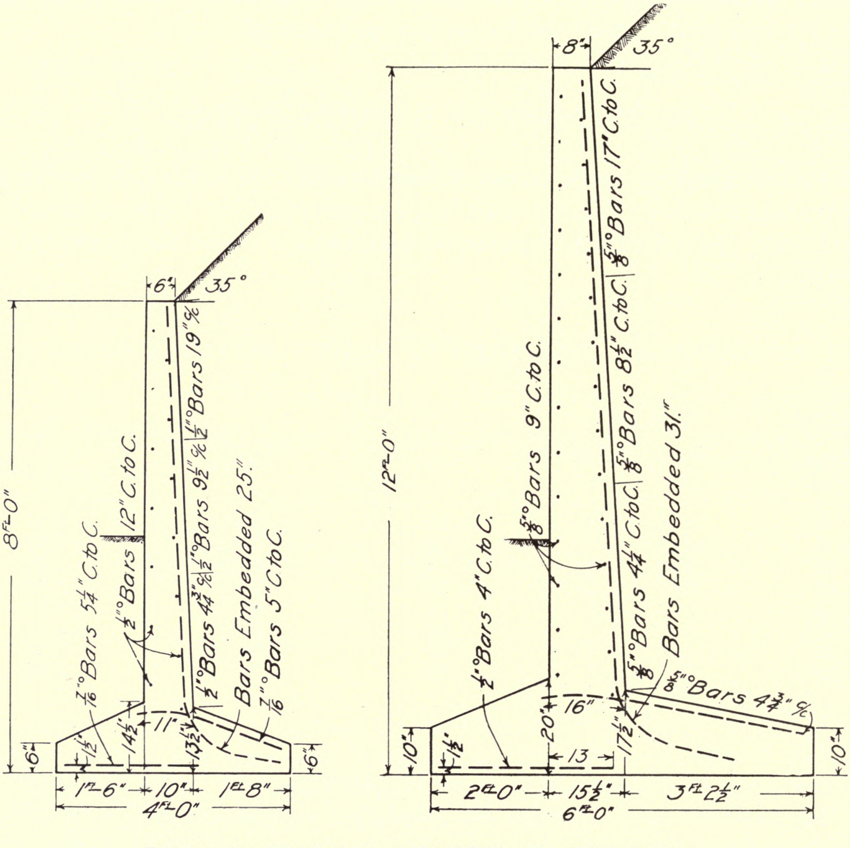


FIG. 61.—SECTIONS FOR REINFORCED RETAINING WALLS.

## REINFORCED RETAINING WALLS.

The cantilever retaining walls shown in Fig. 61 consist of a vertical slab of reinforced concrete attached to a reinforced concrete base, the whole section being really an inverted T. The figure shows designs for 2 walls, one for a total height of 8 feet, the other 12 feet. In severe climates the bottom of these walls should be placed 4 feet below the surface of the ground in front of them, thus making the visible height of the finished wall 4 feet and 6 feet respectively. Maximum pressure on soil from these walls is 2 tons per sq. ft.

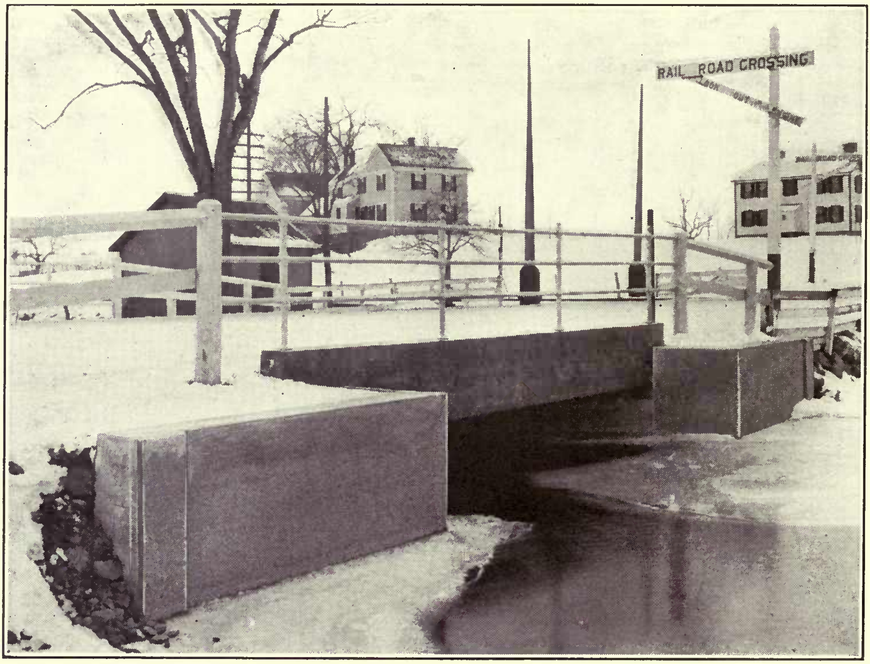
Great care must be taken to place the steel reinforcement in the exact positions called for by the drawing. In each wall the reinforcement consists of 5 sets of reinforcing bars. In the base of the 12-foot wall there is one set of horizontal half-inch round bars spaced 4 inches apart and 1½ inches above the lower edge of the base. Near the upper surface of the base there is a set of ⅝-inch round rods spaced 4¾ inches apart and slightly inclined as shown in the drawing. In the vertical parts of the wall there are two sets of ⅝-inch round horizontal rods, one set near the front face and one near the rear face of the wall. Also in the vertical part there is a set of ⅝-inch round vertical rods near the back of the wall. These vertical rods must be imbedded in the base as shown. In this set of vertical rods every fifth rod should extend from the bottom to the top of the wall, these rods being 17 inches apart. Then midway between each pair of these long rods a shorter rod extends from the bottom of the wall 2/3 of the way to the top, making the rods in the middle third of the height 8½ inches apart. In the lower third of the height there are in addition to the rods mentioned short rods running from the base up 1/3 of the height of the wall, thus making the rods in this lower third 4¼ inches c. to c.

ARCH IN PHILLIPS PARK, AURORA, ILL.

Although ⅝-inch round rods are shown in the figure, other bars having the same cross sectional area can be used instead.

## PROPORTIONS OF CONCRETE.

For gravity walls similar to those described in this chapter for the body of the wall and for the body of the coping the concrete should be mixed 1 part "ATLAS' Portland Cement, 3 parts sand and 6 parts broken stone or gravel. For the upper and front surfaces of the coping a 2-inch veneer of mortar mixed 1 part "ATLAS" Portland Cement and 2 parts sand may be used, built on a part of the coping at the same time that the concrete is placed. For a gravity wall having a height of more than 12 feet "one-man" stones may be imbedded in the concrete as indicated in Chapter I under the head of Rubble Concrete.



BEAM BRIDGE, SUDBURY, MASS.

For reinforced concrete walls similar to those described in this chapter concrete should be mixed 1 part "ATLAS" Portland Cement, 2½ parts sand and 5 parts broken stone or gravel.

In depositing the concrete against the forms, care must be taken to prevent the larger stones from collecting in pockets against the forms and thus making voids which will show when the forms are removed.

## EXPANSION JOINTS.

When concrete is subjected to changes in temperature it will expand or contract. Therefore, in long retaining walls vertical cracks will form in the concrete unless the wall is either reinforced with steel or vertical joints are made at frequent intervals. For plain concrete walls vertical joints should be left at intervals not exceeding 30 feet; these joints allowing the sections of concrete to expand or contract without forming unsightly cracks in the face of the wall. While 30 feet is the maximum distance between expansion joints in plain concrete walls, 20 feet is the proper distance, and walls provided with joints 20 feet apart will not crack. Frequently these joints are run straight through the wall from front to back. It is better, however, to have the two adjacent sections of the wall tongued-and-grooved or V-shaped in plan.

## DRAINAGE.

Unless provision is made for removing the water, it will in most cases collect behind the retaining wall and considerably increase the pressure on the back of the wall. With clayey soils or other material of similar nature, some provision must be made for removing this water by drainage. If the wall is short, a broken stone drain laid lengthwise behind the wall and properly graded so that the water will flow along the back and then away from the wall will serve every purpose. In the case of long walls, drainage holes must be placed through the wall so that the water may pass from the back to the front where it can be drained off. These drainage holes can be made by placing cement or clay tile pipes 3 or 4 inches in diameter in the concrete, sloping downward toward the front of the wall. Wooden forms of 1-inch planks can be used to make a square hole, but the planks are hard to remove after concreting. The outlet in the front face should be 6 inches above the surface on the ground in front of the wall. Two or three barrow loads of cobble stones and gravel should be placed at the upper end where the pipe pierces the back surface of the wall.

In very wet soils loose stones 10 to 15 inches in thickness should be piled up against the back of the wall from the bottom to within 2 feet of the top. This arrangement together with the weep holes just described will afford perfect drainage even in very wet material.

Weep holes should be placed from 10 to 20 feet apart lengthwise of the wall, depending on the nature of the soil. They should be placed 10 feet apart in wet ground.

# CHAPTER IX.

## MISCELLANEOUS.

### FENCE POSTS.

Reinforced concrete fence posts are better than wooden ones because they will not decay, are more uniform in size and shape, and in the long run are cheaper. Fence posts of wood are cheaper in first cost than those made of concrete, but ordinary wooden posts decay in a comparatively short time while concrete construction lasts indefinitely. Cast iron posts last very well, but their cost prohibits their use except in a few cases. Concrete posts properly reinforced with steel rods possess the necessary strength and durability and at the same time may be obtained in any locality at a reasonable cost.

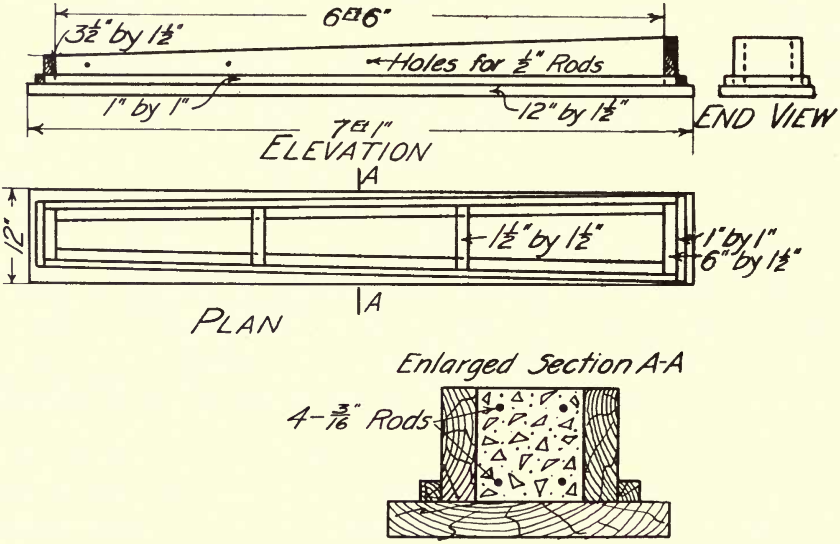


FIG. 62.—FORMS FOR CONCRETE FENCE POSTS.

Fence posts for farms and for division fences in city suburbs should generally be 7 feet long, 6 inches square at the lower and 4 inches square at the upper end. These posts are usually made to support wire fences.

For fences adjoining streets in towns the posts should be from 5 to 6 feet in length with ends the same size as for farm posts. These posts carry wire fences or wooden fences. If a wooden fence is supported by concrete posts the street side of the posts should be set vertical, the lower wooden stringer of the fence being bolted to the front vertical face of the post and the upper stringer bolted on top of the post.

A form for making an individual post is shown in Fig. 62 and consists of a base board 1½ inches thick and 12 inches wide. Upon this are set two beveled pieces of 2-inch lumber 6 inches wide at one end and 4 inches wide at the other. The two side boards, connected with 2 or 3 cross braces on top, are set against, but not nailed to, the two small strips, the latter being nailed to the base board. The blocks at the ends are nailed in place.

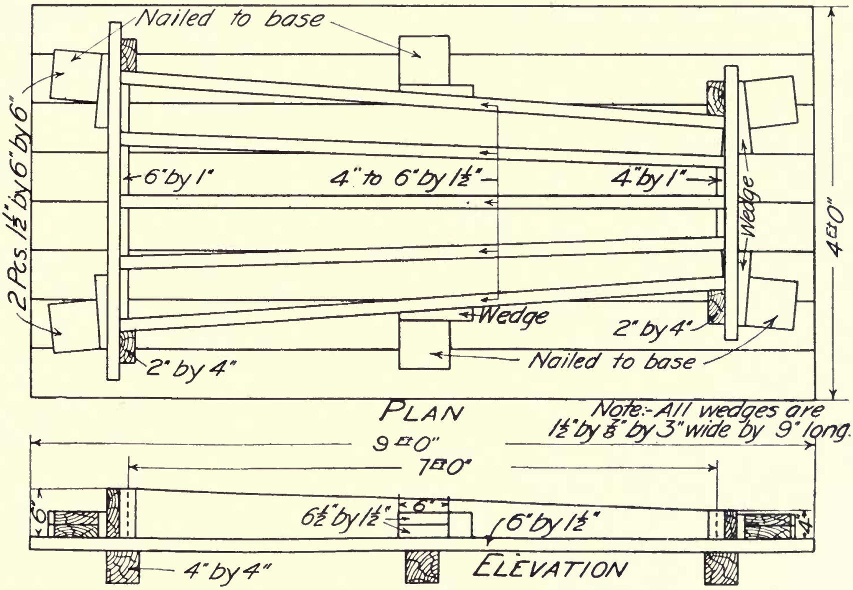


FIG. 63.—MULTIPLE FORM FOR CONCRETE FENCE POSTS.

Short pieces of ½-inch greased round rods should be placed through the side boards before the concrete is placed in the forms and allowed to remain four or five hours till the concrete is hardened enough so that they can be pulled out. The fence wires can be run through these holes or can be run in front of the post and tied to the same with No. 12 or 14 galvanized wire. These holes for fence wires do not decrease the strength of the post and afford a better method of attachment than staples placed in the front surface of the post. If staples are used they must be galvanized.

With the form in place, concrete, made one part "ATLAS" Portland Cement, two parts clean coarse sand, and four parts broken stone or screened gravel of about one inch diameter particles, should be placed in the form and tamped to a thickness of one inch. Then two pieces of wire about 3/16 inch in diameter and 6½ feet long are placed on the layer of concrete, each one inch from the side forms. Another layer of concrete must then be tamped on the first layer until the concrete is within one inch of the top edge of the side forms and two more wires like the first ones then laid and the forms filled with concrete. After the concrete is tamped and smoothed off on the upper surface, the post is set aside and allowed to lie ten or twelve hours before the side forms are removed. The base board must be left in place ten days during which time the post must be sprinkled daily and must not be disturbed. After this time the posts should be allowed to harden for four weeks more before being used.

Fig. 63 shows a mold for casting four posts at a time. The boards separating the posts are slipped in between cleats at each end and are either screwed to the end pieces or held in place by tightening up the wedges at the ends. Wedges bearing against blocks nailed to the base board prevent the side boards from spreading. Staples pressed in the upper face of the concrete before the concrete sets afford an easy connection for the fence wires.

Forms should be made of dressed lumber and should be oiled or greased with soft soap before using.

Fence posts such as here described should cost from thirty to fifty cents each.

Corner posts must be larger than the side posts, 10 by 10 inches at the base and 10 by 10 inches at the top, and 9 feet long being good dimensions. Use four ⅜-inch round rods for reinforcement of 3/16-inch.

## CONCRETE FENCE POSTS AT DELLWOOD PARK.

In Fig. 64 are shown some concrete fence posts around Dellwood Park, four miles from Joliet, Ill. This fence* encloses a tract of land approximately 1,320 feet wide by 2,200 feet long and has 1,500 concrete posts varying in length from 7 to 9 feet. At the top the posts are 4 inches square and at the bottom they are 4 by 6 inches in cross section. The concrete was made one part "ATLAS" Portland Cement and one part stone screenings passing a ¼-inch screen. The reinforcement consists of four rods, one in each corner.

The forms used were similar to the single form shown in Fig. 62 and were left on the posts twenty-four hours, the side boards being removed after this period. The posts were then left for an additional twenty-four hours lying

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*Engineering Record, Vol. 55, March 23, 1907, page 377.

on the base boards after which the bases together with the post were moved to a platform where they remained a week. They were then laid out to harden till used, being kept wet for the first three weeks after they were made. Two men, each paid $2 per day, could make about forty posts in one day. The cement cost $2 per barrel, the reinforcement 3½ cents per pound and the screenings 75 cents per cubic yard. The posts, 9 feet long, cost 65 cents each, a rather high cost because of the design and the richness of the proportions. Posts at angles of the fence were heavier than the others and were braced.

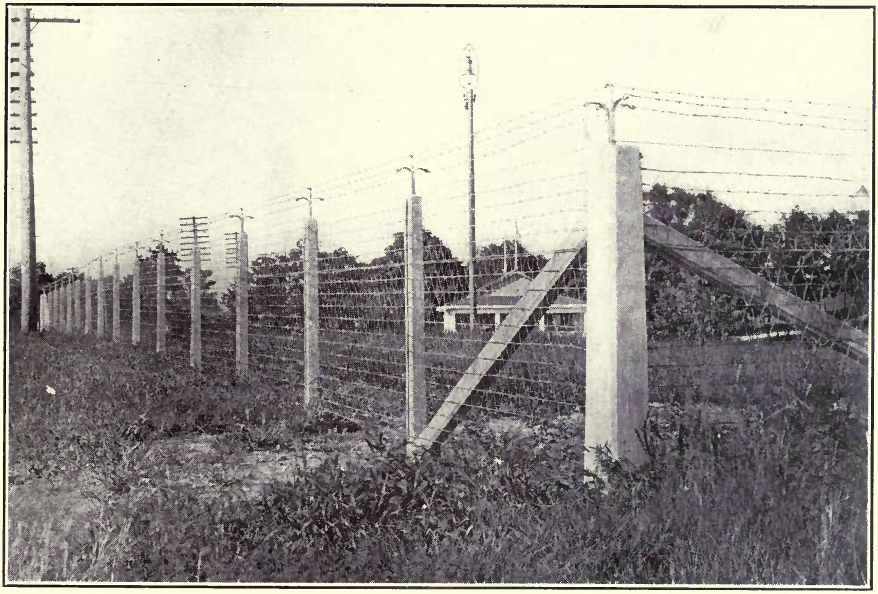


FIG. 64.—CONCRETE POSTS AT DELLWOOD PARK, JOLIET, ILL.

## HITCHING POSTS.

Concrete hitching posts without reinforcement do not have sufficient strength. They must be reinforced with a ⅜-inch diameter rod imbedded in each corner. Hitching posts should be set at least 2½ feet in the ground if they are surrounded by a concrete sidewalk. If set in earth without the surrounding walk they should be placed 3 feet in the ground. The outer surface must be at least 6 inches, or still better, 8 inches from the edge of the curb.

Posts similar to that shown at the left side of Fig. 65 are made in the same manner as fence posts except that there is a 2-inch ring attached to a staple in the top.

The post shown in the right half of Fig. 65 is neat but is more difficult to make than the plain post. The depressed surfaces on the sides are one-half inch deep and are best formed by nailing one-half-inch wooden pieces to the inside of the forms. Tamp the concrete into the corners of the molds well and after the forms are removed give the surfaces of the posts a coating of cement mixed with water, applied with a brush.

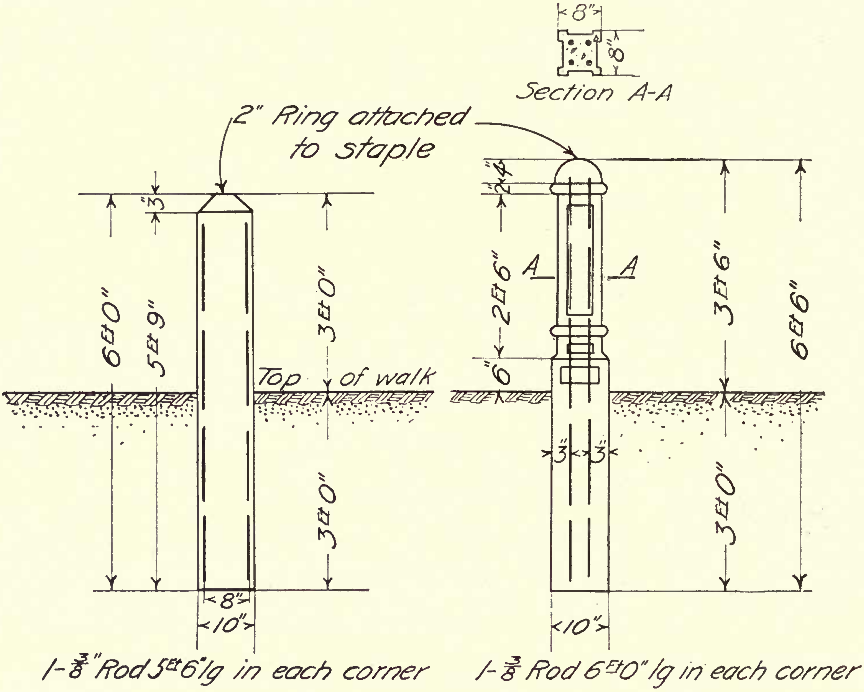


FIG. 65.—CONCRETE HITCHING POSTS.

## LAMP POSTS.

Concrete is being used for lamp posts to support electric lights in parks and other similar places. These posts are usually about 20 to 24 feet in length and are set 5 or 6 feet into the ground. They should be 6 or 8 inches in diameter at the bottom and 4 or 5 inches at the top, the larger diameters being required for the highest posts. A piece of 1-inch gas pipe is placed in the center of the post throughout its length to carry the wires from the lamp to the bottom of the post where the wires then connect with the underground electric system. The lamp can be set directly on top of the post or it can be suspended from the outer end of a curved pipe which is connected to the pipe passing down through the post. The methods of construction are similar to those used in making fence posts.

One rod one-half inch in diameter in each corner of a square post is sufficient for reinforcement. A square post with beveled edges is simpler to make than a round post, but is not quite so neat in appearance.

BRIDGE AND DRINKING FOUNTAIN, LINCOLN PARK, CHICAGO, ILL.

## DRINKING FOUNTAINS.

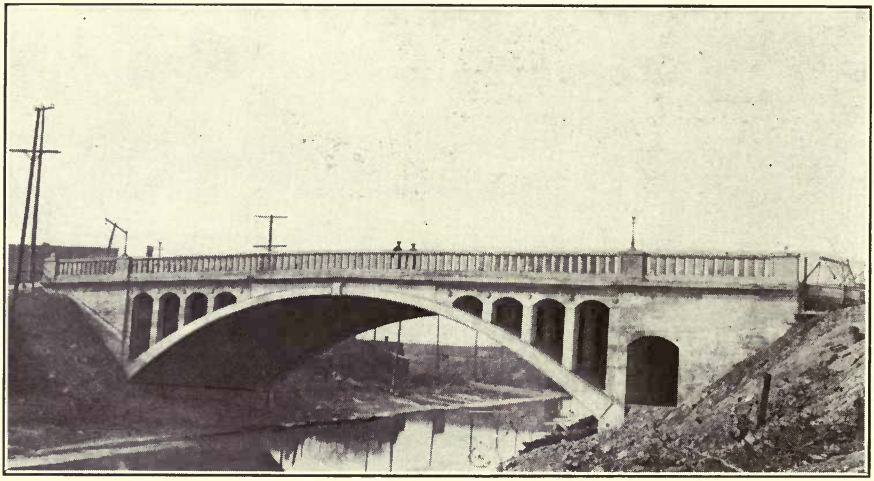
Drinking fountains of concrete are giving good satisfaction in parks even where the climate is severe. These fountains are generally made with a circular base about 3 feet in diameter and a circular stem and bowl on top; the stem gradually diminishing in diameter from the base and then enlarging into the bowl which is from 3½ to 4 feet in diameter.

Reinforcement must be used in fountains to give them sufficient strength to withstand shocks. Wire mesh of any kind bent to shape and imbedded in the concrete is all that is necessary.

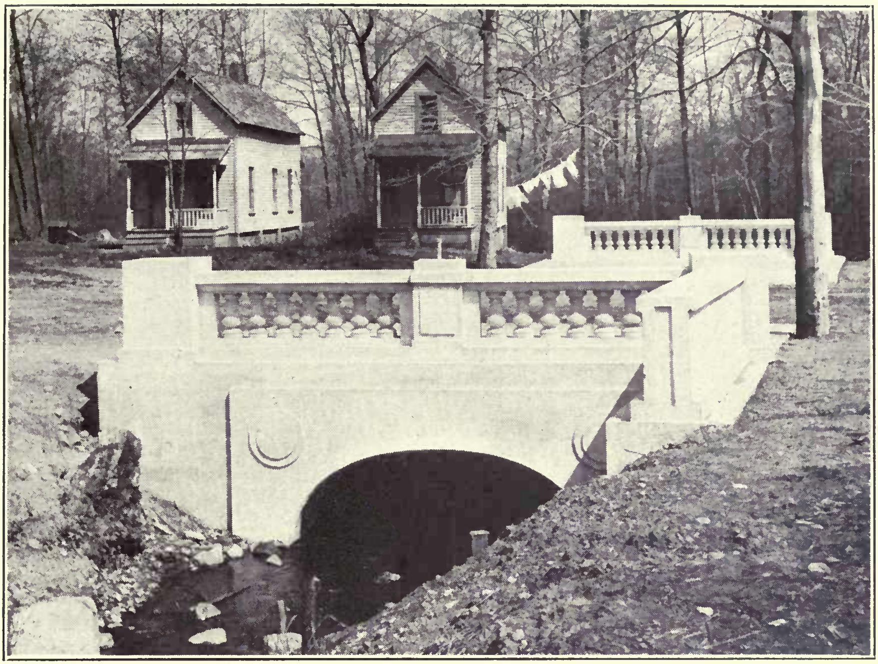
The concrete must be mixed quite wet, about the consistency of thick cream and in the proportions of 1 part "ATLAS" Portland Cement, 1½ parts clean, coarse sand, and 3 parts broken stone or screened gravel of about 1 inch diameter.

The bowl must be cast at one operation and as quickly as possible so that it will be water tight.

Good drinking fountains of this kind have been built for $12 with $5 for the setting.

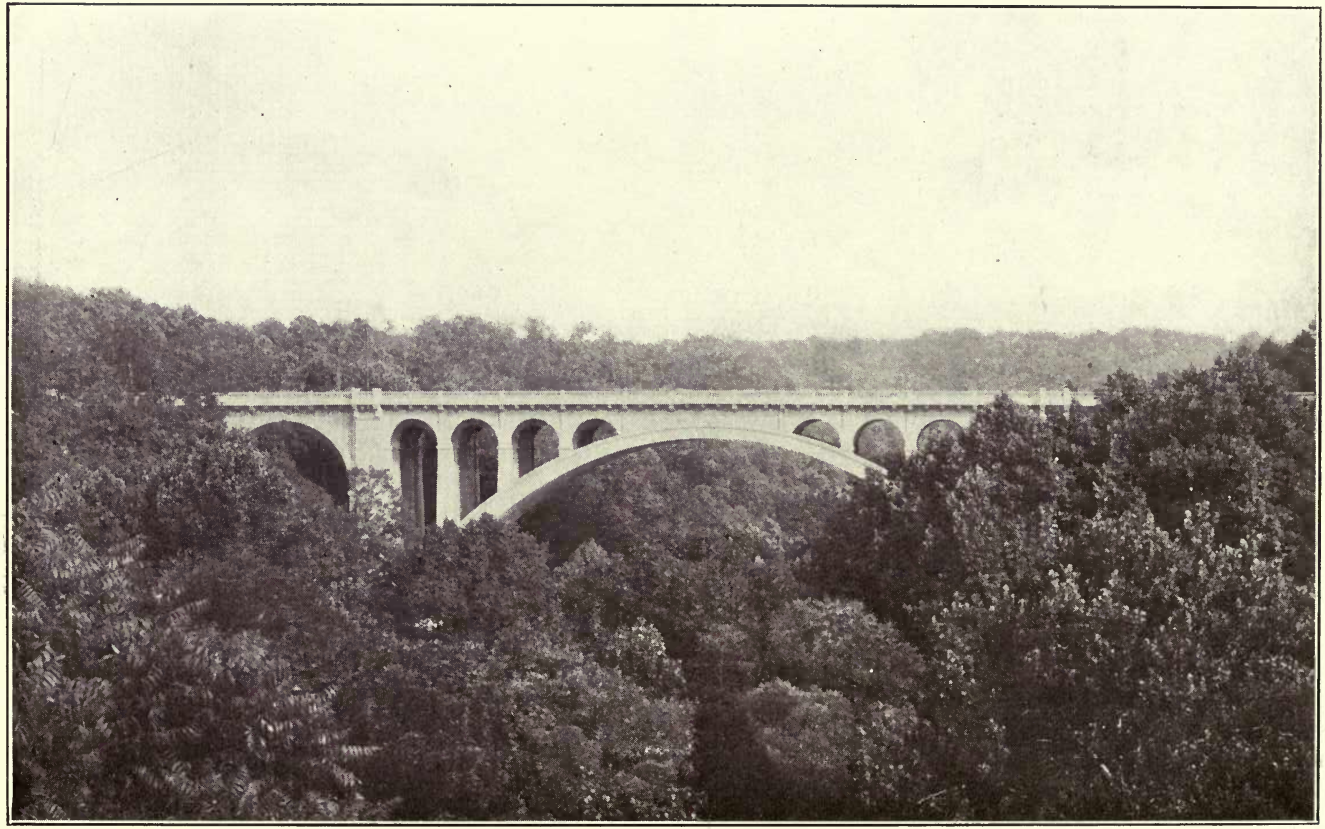


BRIDGE WITH OPEN SPANDRELS, CHICAGO, ILL.



BRIDGE AT HAWORTH, N. J.

PARKWAY BRIDGE, MEDFORD, MASS.



WALNUT LANE BRIDGE, PHILADELPHIA.

# CONCRETE
# IN
# RAILROAD
# CONSTRUCTION

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A TREATISE ON CONCRETE
FOR
RAILROAD ENGINEERS AND CONTRACTORS

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PRICE, $1.00

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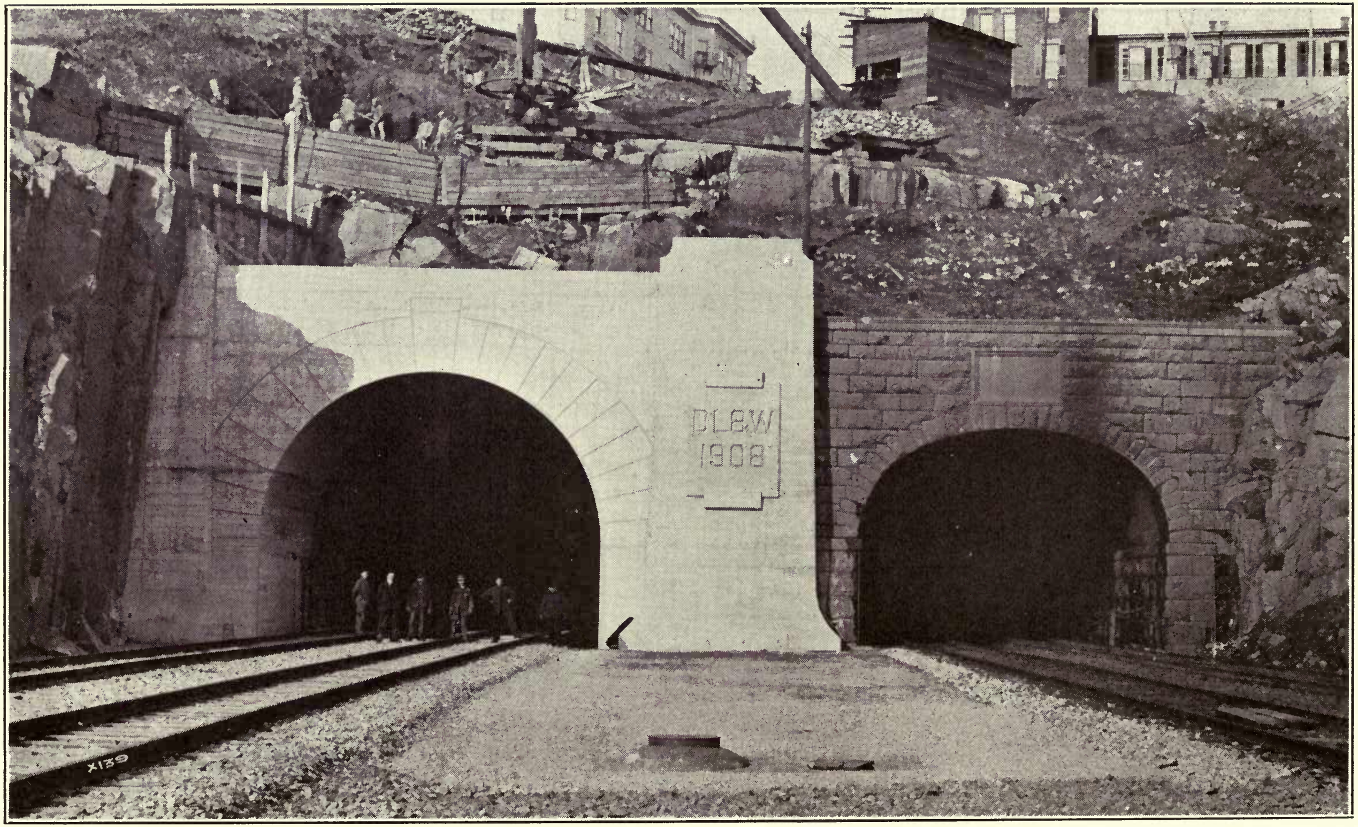

ENTRANCE TO OLD AND NEW BERGEN HILL TUNNELS.

## INTRODUCTION.

Economy in railroad construction demands permanent structures. Materials must be used therefore which as far as possible are proof against the deteriorating and destructive influences of the elements and of vibration, so as to resist corrosion, decay and fire, and the gradual weakening due to continual, severe and constantly growing service. At the same time the materials must possess requisite strength for present and future traffic combined with cheapness and facility of construction.

The advent of reinforced concrete, possessing as it undoubtedly does in a marked degree all these qualities combined with a wide range of possible uses and versatility of design, has been of the greatest importance to railroad engineers.

To illustrate the best of present day practice, The Atlas Portland Cement Company takes this opportunity to present to the railroad world at large a brief treatise on concrete in railroad construction, with a view of giving a comprehensive idea of the diversity of the concrete structures in actual existence on railroad lines throughout the country and of the future possibilities of this material in the field of railroad engineering.

Realizing that the treatment of this subject demanded the attention of an expert authority the work was entrusted to Mr. Sanford E. Thompson, M. Am. Soc. C. E., one of the foremost concrete experts in the country. The Atlas Portland Cement Company, occupying as it does a somewhat unique position among cement manufacturers, with its wide reputation for a thoroughly uniform and standard product, its selection by the United States government to furnish 4,500,000 barrels for use in building the Panama Canal, and its immense production—over 40,000 barrels per day—commends the book to its readers with the hope that it may prove a fitting sequel to the former publications of the company—"Concrete Construction About the Home and on the Farm," "Concrete Cottages," "Concrete Country Residences," "Reinforced Concrete in Factory Construction" and "Concrete in Highway Construction."

THE ATLAS PORTLAND CEMENT COMPANY.

New York, July, 1909.

# PREFACE.

In compiling this book it has been the aim of the author and of the publishers to cover as thoroughly as possible the entire field of the uses of concrete in railroad construction. Although it is very fully illustrated, the photographs and drawings are presented not as mere pictures but to illustrate in detail the many points which are continually occurring to the railroad officials and their engineers and designers. With this in view, typical structures of nearly every class are shown, with a short description of the essential features of design and construction of each.

The first chapter contains a brief review of the qualities of concrete in comparison with other materials for railroad construction and this is followed by a chapter on design and construction designed to serve as a guide to the intelligent use of concrete. In the descriptive portion of the book, which embodies fifteen chapters, the following subjects have been treated: Bridges, Culverts, Piers and Abutments, Retaining Walls, Stations, Train Sheds, Platforms, Coal and Sand Stations, Coal Trestles, Ash Handling Plants, Roundhouses, Turntable Pits, Signal Towers, Water Tank Supports, Bumping Posts, Power Stations, Shops, Warehouses, Grain Elevators, Storage Reservoirs, Docks, Tunnels and Tunnel Lining, Cross Ties and Road Beds, Telegraph Poles, Transmission Towers, Posts and Fences. A number of miscellaneous illustrations of general interest are shown at the end of the book.

All illustrations have been prepared especially for this book, the half-tones being made from original photographs while the drawings were reproduced in the office of the author from the original plans furnished by the chief engineers of the various railroads.

In certain cases, where none of the designs of existing structures were sufficiently representative in character, special designs have been prepared.

The descriptive matter and drawings have been compiled under the immediate direction of Mr. Chester S. Allen of the author's engineering staff. The author also acknowledges the assistance of Prof. Frank P. McKibben in reviewing the original designs.

The text and the drawings of each structure have been referred to the officials of the railroad for their approval.

The Atlas Portland Cement Company, and the undersigned, desire to express their appreciation of the courtesies extended by the engineers of the various railroads and by the contracting companies who have so kindly furnished plans and data for incorporation into the descriptive chapters of this book.

SANFORD E. THOMPSON,
1909. Newton Highlands, Mass.

# CHAPTER I.

## RAILROAD CONSTRUCTION.

While the policy of European railroad engineers always has been to build permanent structures, the necessity in the past of practising the strictest economy in the original building of many of the railroads of this country has led American engineers to exactly the opposite course, and as a result railroad structures built not many years ago were largely of timber; bridges were of the Howe truss and lattice type, trestles of pile and timber construction, and stations, roundhouses and freight sheds veritable wooden fire traps.

The increasing importance with the attendant increase of incomes of the railroads and the need for more permanent structures coupled with the improvements in iron manufacture resulted in the substitution of wrought iron structures in place of the wood, and this material in turn was replaced by steel. But it was soon found that steel was by no means perfect, since structures built of it required careful inspection and continual repairs and even then rust and gases had such a deteriorating effect that the life of a steel bridge or building would probably be not over 30 or 40 years.

In the past few years concrete has had a marvelous growth, and in railroad construction perhaps more than in any other branch of engineering it has been universally adopted as a building material. Not only is it replacing steel construction, but perhaps still more it has taken the place of stone and brick masonry not only for foundations but also for various structures above ground, such as retaining walls, bridges, coaling stations, signal towers, and in fact many of the smallest details.

## COST.

While the cost of concrete construction is invariably higher than wood, it is almost always considerably less than stone masonry and will not greatly, if at all, exceed steel in first cost.

The maintenance costs of a concrete structure are practically neglible and it has been estimated that the elimination of painting costs alone warrants an initial expenditure of from 10 per cent to 15 per cent over the first cost of a steel structure.

## SAFETY.

When well designed and properly constructed, a reinforced concrete structure will be safe for all time, since its strength increases with age, the concrete growing harder and the bond with the steel becoming stronger.

In building such a structure, it is of the utmost importance that the plans and specifications should be followed absolutely and that work should be entrusted only to men of undoubted experience in this line of construction.

## DURABILITY.

While steel and wooden structures grow weaker from rust and decay a concrete structure as stated above grows stronger with time and its life is measured by ages rather than years. In addition to its natural permanence, such a structure is proof against tornadoes, high-water, fire and earthquakes. A number of concrete buildings in San Francisco withstood the shock of the earthquake, while those around them of terra cotta brick and stone were destroyed.

## FREEDOM FROM VIBRATION.

Concrete is especially adapted for railroad construction owing to the fact that its solidity and entire lack of joints render it free from the excessive vibrations often experienced in steel structures. In riding over a structure built of concrete it is particularly pleasing to the passenger to note the absence of the familiar roar and the lurching of the train which is so often endured in crossing a steel bridge. Only where there is direct contact, as in ties, is there danger of the jar disintegrating the concrete. In such cases either cushions of wood or earth should be provided to deaden the shock, or the concrete should be placed in large mass.

## FIRE RESISTANCE.

In addition to its permanence and strength, concrete is especially suited to the construction of warehouses, terminal buildings, bridges, stations, coal pockets and similar structures on account of its undoubtable fire-resisting qualities. Actual fires and fire tests have demonstrated time and again the ability of reinforced concrete to withstand even extraordinary fires. This is a valuable asset not only for buildings and warehouses, but particularly for structures to be used for the storage of coal, since the railroads of this country have suffered in the past much inconvenience and expense through the use of inferior bins of timber or steel. The spontaneous combustion to which coal is subject when stored in great quantities not only results in the loss of the coal itself and the damaging of much valuable machinery, but also in the destruction of the bin if it is constructed either of wood or steel.

As a result of the lessons taught by the recent terrible fires along the waterfront of Hoboken, the new piers designed to replace those burned down in the fire of 1904 are to be built entirely of concrete and steel construction.

## VERSATILITY OF DESIGN.

Concrete enjoys a wider range of possible use and varieties of design than any known building material. An evidence of its adaptability to the endless variety of uses in railway design is shown by the thirty-five classes of construction described in the text of this book.

## WATER-TIGHTNESS.

It was formerly thought necessary to waterproof a structure where it came in contact with ground water. But now by using a proper amount of reinforcement to prevent cracks due to shrinkage from temperature and by properly forming the joints, concrete is used in many cases with no surface waterproofing. In the Philadelphia subway after experimenting with various methods of waterproofing it was decided to depend entirely on the concrete itself, and in the New York subway no waterproofing is now being used above high-water level. Concrete is especially adapted for use in the construction of conduits, dams, tanks, reservoirs and other structures which, to accomplish their purpose, must be essentially water-tight.

## ALTERATIONS.

Owing to the difficulty in tearing it down concrete is not suitable for a temporary structure. While radical changes in construction are not readily made, holes may be cut in walls and floors, at greater expense than in wood, but without serious difficulty.

## STRENGTHENING OLD MASONRY.

Concrete from its very nature is well adapted for reinforcing or strengthening and protecting old stone masonry which is being disintegrated by the action of the weather.

## FOUNDATIONS.

Concrete has been used for foundations in railroad construction for years; in fact, until recently this was practically the only use. With the development of design, reinforcement has been introduced which often saves much material.

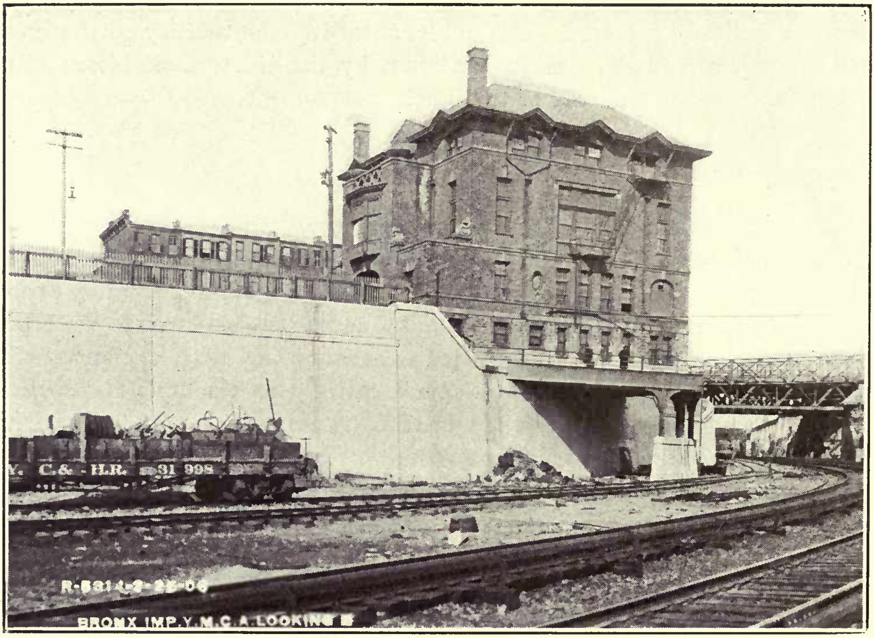

FIG. 1.—RETAINING WALL AND PROTECTION PIER, BRONX IMP., N. Y. C. & H. R. R.R.

# CHAPTER II.

## DESIGN AND CONSTRUCTION.

Although the use of reinforced concrete is comparatively recent, there have been sufficient tests and the theory is far enough developed to design with absolute security not only masonry structures like foundations, bridges, retaining walls, abutments and piers, but structures embodying beams and slabs, such as girders, bridges, coaling stations and power plants.

Numerous tests have been made during the last few years on almost all the details of concrete construction not only at nearly all the universities, but the Structural Materials Testing Laboratories at St. Louis under the direction of the United States Geological Survey has been taking up the subject in a scientific manner.

Besides this experimental work, the use of reinforced concrete is so widespread that practice is rapidly confirming the theoretical demonstrations.

## CEMENT.

While brief specifications for cement may be sufficiently comprehensive for work of minor importance, the standard specifications adopted by the American Society for Testing Materials* are generally adopted for important work throughout the country.

## SAND.

The selection of sand for use in concrete work is quite as important as that of the cement and it should be carefully tested for all important structures. As a guide for the proper selection of the aggregates the following is quoted from the Progress Report of the Joint Committee on Concrete and Reinforced Concrete, 1909.†

> "a. FINE AGGREGATE consists of sand, crushed stone, or gravel screenings, passing when dry a screen having ¼-inch diameter holes. It should be preferably of silicious material, clean, coarse, free from vegetable loam or other deleterious matter.

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*These may be obtained by addressing The Atlas Portland Cement Company.

†Affiliated Committees of American Society of Civil Engineers, American Society for Testing Materials, American Railway Engineering and Maintenance of Way Association, Association of American Portland Cement Manufacturers.

"A gradation of the grain from fine to coarse is generally advantageous.

"Mortars composed of one part Portland cement and three parts fine aggregate by weight when made into briquets should show a tensile strength of at least 70 per cent of the strength of 1:3 mortar of the same consistency made with the same cement and standard Ottawa sand."

## BROKEN STONE AND GRAVEL.

"b. COARSE AGGREGATE consists of inert material, such as crushed stone, or gravel, which is retained on a screen having ¼-inch diameter holes. The particles should be clean, hard, durable, and free from all deleterious material. Aggregates containing soft, flat or elongated particles should be excluded from important structures. A gradation of size of the particles is generally advantageous.

"The maximum size of the coarse aggregate shall be such that it will not separate from the mortar in laying and will not prevent the concrete from fully surrounding the reinforcement or filling all parts of the forms. Where concrete is used in mass, the size of the coarse aggregate may be such as to pass a 3-inch ring. For reinforced members a size to pass a 1-inch ring, or a smaller size, may be used.

"Cinder concrete is not suitable for reinforced concrete structures, and may be safely used only in mass for very light loads or for fireproofing.

"Where cinder concrete is permissible the cinders used as the coarse aggregate should be composed of hard, clean, vitreous clinker, free from sulphides, unburned coal, or ashes."

Owing to the presence of vegetable loam or other deleterious matter, it is often necessary to wash the aggregates, and the drawing in Fig. 2 shows an apparatus designed by Mr. Allen Hazen and Mr. William H. Ham and used with good success by the contractors, Messrs. Tucker and Vinton.

## STEEL.

There is frequently a question as to the use of high or low carbon steel. High carbon steel is very apt to be brittle unless it is made so as to pass severe tests,* when it can be depended upon.

It is generally economical to use ordinary medium steel unless perhaps for temperature reinforcement, when steel with high elastic limit and deformed section is especially good.

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*See Specifications in Taylor & Thompson's "Concrete Plain and Reinforced," Second Edition, 1909. John Wiley & Sons, New York, publishers.

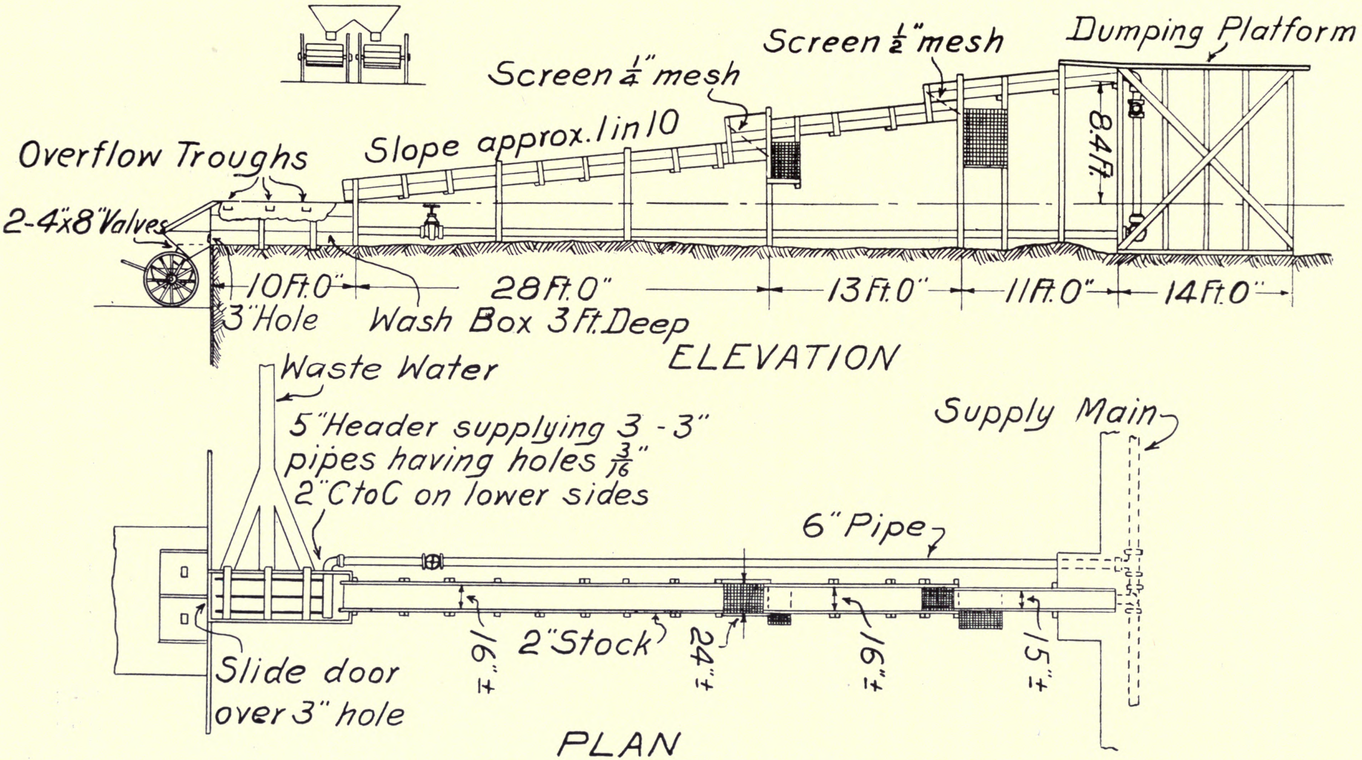

FIG. 2.—SAND AND GRAVEL WASHER, ETC.

For ordinary uses, deformed bars, that is, bars with irregular sections, while satisfactory and in some cases better than ordinary round bars, are usually not absolutely necessary.

## PROPORTIONS.

In such a broad field of construction as is found in railroad work, it is impossible to give any general recommendations as to the proper proportions to use, as this depends so much on the structure itself. For any specific structure, the reader is referred to the proportions adopted in the construction of similar structures described in the text.

The standard method for measuring parts is to assume one part as equal to 4 bags of cement, or one barrel. In measuring the sand and stone a barrel is assumed as 3.8 cubic feet. The actual volume of a cement barrel averages about 3.5 cubic feet, but the 3.8 cubic feet has been adopted generally in practice as corresponding to a weight of 100 pounds of cement to the cubic foot, which is that of the cement partially compacted; thus proportions 1:2:4 means one barrel (or 4 bags) Portland cement, 7.6 cubic feet sand measured loose and 15.2 cubic feet of broken stone or gravel measured loose.

## MIXING.*

"The ingredients of concrete should be thoroughly mixed to the desired consistency, and the mixing should continue until the cement is uniformly distributed and the mass is uniform in color and homogeneous, since maximum density and therefore greatest strength of a given mixture depends largely on thorough and complete mixing.

"(a) Measuring Ingredients. Methods of measurements of the proportions of the various ingredients, including the water, should be used, which will secure separate uniform measurements at all times.

"(b) Machine Mixing. When the conditions will permit, a machine mixer of a type which insures the uniform proportioning of the materials throughout the mass should be used, since a more thorough and uniform consistency can be thus obtained.

"(c) Hand Mixing. When it is necessary to mix by hand, the mixing should be on a water-tight platform and especial precautions should be taken to turn the materials until they are homogeneous in appearance and color."

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*From Joint Committee's recommendations, see footnote, page 15.

## CONSISTENCY.

The required consistency varies with the class of work. Concrete is strongest when not too wet, but of a medium jelly-like consistency. For reinforced concrete it must be softer, so that it can just flow sluggishly around the steel and into the forms. At the same time it should be stiff enough to be conveyed from the mixer to the forms without separation of the coarse aggregate from the mortar.

## PLACING.*

"(a) Methods. Concrete after the addition of water to the mix should be handled rapidly, and in as small masses as practicable from the place of mixing to the place of final deposit, and under no circumstances should concrete be used that has partially set before final placing. A slow setting cement should be used when a long time is liable to occur between mixing and final placing.

"The concrete should be deposited in such a manner as will permit the most thorough compacting, such as can be obtained by working with a straight shovel or slicing tool kept moving up and down until all the ingredients have settled in their proper place by gravity and the surplus water forced to the surface.

"In depositing the concrete under water, special care should be exercised to prevent the cement from being floated away, and to prevent the formation of laitance which hardens very slowly and forms a poor surface on which to deposit fresh concrete. Laitance is formed in both still and running water, and should be removed before placing fresh concrete.

"Before placing the concrete care should be taken to see that the forms are substantial and thoroughly wetted and the space to be occupied by the concrete free from debris. When the placing of the concrete is suspended, all necessary grooves for joining future work should be made before the concrete has had time to set.

"When work is resumed, concrete previously placed should be roughened, thoroughly cleansed of foreign material and laitance, drenched and slushed with a mortar consisting of one part Portland cement and not more than two parts fine aggregate.

"The faces of concrete exposed to premature drying should be kept wet for a period of at least seven days.

"(b) Freezing Weather. The concrete for reinforced structures should not be mixed or deposited at a freezing temperature, unless special precau-

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*From Joint Committee's recommendations, see footnote, page 15.

tions are taken to avoid the use of materials containing frost or covered with ice crystals, and in providing means to prevent the concrete from freezing after being placed in position and until it has thoroughly hardened.

"(c) Rubble Concrete. Where the concrete is to be deposited in massive work its value may be improved and its cost materially reduced through the use of clean stones thoroughly embedded in the concrete as near together as is possible and still entirely surrounded by the concrete."

## JOINTS.

In walls of any considerable length it is necessary to provide against shrinkage and temperature cracks. The general practice for walls of plain concrete is to place contraction joints at intervals of from 30 to 50 feet, but in many instances this has not been sufficient and the author recommends a spacing of from 20 to 30 feet. Walls can be built with no joints by providing sufficient reinforcement to so distribute the temperature stresses that the cracks will be very minute and scarcely noticeable on close inspection.

## SURFACES.

The proper treatment to give a pleasing appearance to exposed surfaces is one of the most difficult problems in concrete construction and a number of different methods have been employed, all of which are illustrated by different structures described in the text.

## FORMS.*

"Forms should be substantial and unyielding, so that the concrete shall conform to the designed dimensions and contours, and should be tight to prevent the leakage of mortar.

"The time for the removal of forms is one of the most important steps in the erection of a structure of concrete or reinforced concrete. Care should be taken to inspect the concrete and ascertain its hardness before removing the forms.

"So many conditions affect the hardening of concrete that the proper time for the removal of the forms should be decided by some competent and responsible person, especially where the atmospheric conditions are unfavorable."

## WATERPROOFING.

While many expedients have been used to render concrete impervious to water, experience has shown that, where the concrete is proportioned to realize

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*See footnote, page 15.

the greatest practicable density and is mixed to a rather wet consistency, it is sufficiently impervious itself, for ordinary purposes, without further treatment. The proportions generally used to resist the percolation of water range from 1:1:2 to 1:2:4, the latter being the most common mixture. Sometimes, where the mass of the concrete is considerable, or where the walls are thin, a material like hydrated lime or dry powdered clay may be efficient for void filling and permit the use of leaner proportions. In subways, long retaining walls, and reservoirs, cracks can be prevented by horizontal reinforcement properly proportioned and located. In any case, for water-tight work the concrete should be mixed wet enough to entirely surround the reinforcing metal and flow against the forms.

Asphaltic or coal tar preparations applied either as a mastic or with paper or felt are used to good advantage where it is deemed unadvisable to rely upon the natural imperviousness of the concrete itself.

## DESIGN OF PLAIN CONCRETE.

In the design of plain concrete, sections should be so proportioned as to avoid tensile stresses, and while this may be accomplished in the case of rectangular shapes by keeping the line of pressure within the middle third of the section, in very large structures a more exact analysis may be required.

Inasmuch as structures of massive concrete are able to resist any unbalanced later forces by reason of their weight, a relatively cheap and weak concrete is often suitable for such conditions.

## BENDING MOMENTS.

In reinforced concrete design as much variation may be had in the results by the selection of the bending moments as in the choosing of working stresses. If the members are continuous beams or slabs, special care must be taken in the design at the supports, since there is much and frequently more stress there than at the middle of the span. It is not safe practice to design a continuous beam in the center as though it was simply supported and then pay no attention to the design over the supports.

Good practice and the recommendations also of the Joint Committee on Concrete and Reinforced Concrete (1909) sanction the following formulas for bending moments:

Let $P$ = concentrated load in pounds
$w$ = unit distributed load in pounds per square foot (including the dead load)
$l$ = length of member between centers of support in feet
$M$ = bending moment in foot pounds.

*To transform the bending moment to inch pounds, multiply by 12.*

For beams and slabs simply supported at the ends and not continuous:

$$M = 1/8\ wl^2 \text{ for distributed load} \qquad (1)$$

and

$$M = 1/8\ wl^2 + \tfrac{1}{4}\ Pl \text{ for distributed load plus a load concentrated at the center} \qquad (2)$$

For beams and slabs truly continuous and thoroughly reinforced over the supports:

$$M = 1/12\ wl^2 \text{ at the center of the member} \qquad (3)$$

$$\text{and } -M = 1/12\ wl^2 \text{ at the ends of the member} \qquad (4)$$

For beams and slabs partially continuous, as end spans, or for continuous members of 2 or 3 spans:

$$M = 1/10\ wl^2 \text{ at the center of the member} \qquad (5)$$

The negative bending moments which exist at the supports must be provided for by steel rods carried over the top of the support for tension and by a sufficient amount of concrete at the bottom of the beam near the support to take the compression.

If a part of the tension rods are bent up on an incline from about one-quarter points in the beam so as to pass horizontally through the top of the beam at the supports they must extend over the supports for a sufficient distance to transmit the compressive stress there, or must be firmly connected with corresponding rods in the adjacent bay. The total steel in the top must be sufficient to resist the tension due to negative moment, and the concrete and steel in the bottom next to the support, sufficient to resist the compression.

For cantilever beams, that is, beams with one end fixed and the other end free, where the maximum bending moment is at the point of support and the tension is in the top of the beam, the following formulas hold:

With a uniformly distributed load over the length of the beam:

$$-M = \tfrac{1}{2}\ wl^2 \text{ at the support}$$

If also a live load is concentrated at the end

$$-M = Pl + \tfrac{1}{2}\ wl^2$$

## DESIGN OF REINFORCED CONCRETE.

In designing a reinforced concrete member it is not sufficient to simply determine the amount of steel required to resist the tensile stresses, but a most careful analysis must be made of all parts of the structure.

The correct design of reinforced concrete beams and girders involves the following studies:

(1) The bending moments due to the live and dead loads.

(2) Dimensions of beams which will prevent an excessive compression of the concrete in the top and which will give the depth and width which is otherwise most economical.

(3) Number and size of rods to sustain tension in the bottom of the beam.

(4) Shear or diagonal tension in the concrete.

(5) Value of bent-up rods to resist shear or diagonal tension.

(6) Stirrups to supplement the bent-up rods in assisting to resist the shear or diagonal tension.

(7) Steel over the supports to take the tension due to negative bending moment.

(8) Concrete in compression at the bottom of the beam near the supports due to negative bending moment.

(9) Length of rods to prevent slipping.

(10) End connections at wall.

## WORKING STRESSES.

The working stresses for static loads given below follow the recommendations of the Progress Report of the Joint Committee on Concrete and Reinforced Concrete, 1909.*

> "General Assumptions. The following working stresses are recommended for static loads. Proper allowances for vibration and impact are to be added to live loads where necessary to produce an equivalent static load before applying the unit stresses in proportioning parts.
>
> "In selecting the permissible working stress to be allowed on concrete, we should be guided by the working stresses usually allowed for other materials of construction, so that all structures of the same class, but composed of different materials, may have approximately the same degree of safety.
>
> "The stresses for concrete are proposed for concrete composed of one part Portland cement and six parts aggregate, capable of developing an average compressive strength of 2,000 pounds per square inch at twenty-eight days, when tested in cylinders 8 inches in diameter and 16 inches long, under laboratory conditions of manufacture and storage, using the same consistency as is used in the field. In considering the factors rec-

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*The form of the tabulation is as given in the Report of the Committee on Reinforced Concrete of the National Association of Cement Users, 1909, Sanford E. Thompson, Chairman.

ommended with relation to this strength, it is to be borne in mind that the strength at twenty-eight days is by no means the ultimate which will be developed at a longer period, and therefore they do not correspond with the real factor of safety. On concretes in which the material of the aggregate is inferior, all stresses should be proportionally reduced, and similar reduction should be made when leaner mixes are to be employed. On the other hand, if, with the best quality of aggregates, the richness is increased, an increase may be made in all working stresses proportional to the increase in compressive strength at 28 days, but this increase shall not exceed 25 per cent.

"Diagonal Tension. In beams where diagonal tension is taken by concrete, the vertical shearing stresses should not exceed

2 per cent of compressive strength at twenty-eight days, or 40 pounds per square inch for 2,000 pound concrete.

"Bond for Plain Bars. Bonding stress between concrete and plain reinforcing bars,

4 per cent of compressive strength at twenty-eight days, or 80 pounds per square inch for 2,000 pound concrete.

For drawn wire,

2 per cent, or 40 pounds on 2,000 pound concrete.

"Bond for Deformed Bars.* Bonding stress between concrete and deformed bars may be assumed to vary with the character of the bar from

5 per cent to 7½ per cent of the compressive strength of the concrete at twenty-eight days or from

100 to 154 pounds per square inch for 2,000 pound concrete.

"Reinforcement. The tensile stress in steel should not exceed 16,000 pounds per square inch. The compressive stress in reinforcing steel should not exceed 16,000 pounds per square inch, or fifteen times the working compressive stress in the concrete.

"Modulus of Elasticity. It is recommended that in all computations the modulus be assumed as 1/15 that of steel; that is, that a ratio of fifteen be employed.

"Bearing.† For compression on surface of concrete larger than loaded area,

32.5 per cent of compressive strength at twenty-eight days or 650 pounds per square inch on 2,000 pound concrete.

"Plain Columns. Plain columns or piers whose length does not exceed twelve diameters,

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*No recommendation for deformed bars is given in the report of the Joint Committee.

†For beams and girders built into pockets in concrete walls the lower compressive stress of 450 pounds per square inch should not be exceeded.

22½ per cent of compressive strength at twenty-eight days, or 450 pounds per square inch on 2,000 pound concrete.

"Reinforced Columns. (a) Columns with longitudinal reinforcement only, the unit stress recommended for plain columns.

(b) Columns with reinforcement of bands or hoops, as specified below, stresses 20 per cent higher than given for (a).

(c) Columns reinforced with not less than 1 per cent and not more than 4 per cent of longitudinal bars and with bands or hoops, stresses 45 per cent higher than given for (a).

(d) Columns reinforced with structural steel column units which thoroughly encase the concrete core, stresses 45 per cent higher than given for (a)."

"In all cases, in addition to the stress borne by the concrete given above, longitudinal reinforcement is assumed to carry its proportion of stress in accordance with the ratio of its elasticity to concrete. For example, with a working stress in concrete of 450 pounds per square inch, the longitudinal reinforcement may be assumed to carry $15 \times 450 = 6{,}750$ pounds per square inch.

"The hoops or bands are not to be counted upon directly as adding to the strength of the column.

"Bars composing longitudinal reinforcement shall be straight and shall have sufficient lateral support to be securely held in place until the concrete is set.

"Where bands or hoops are used, the total amount of such reinforcement shall be not less than 1 per cent of the volume of the column enclosed. The clear spacing of such bands or hoops shall be not greater than one-fourth the diameter of the enclosed column. Adequate means must be provided to hold bands or hoops in place so as to form a column, the core of which shall be straight and well centered.

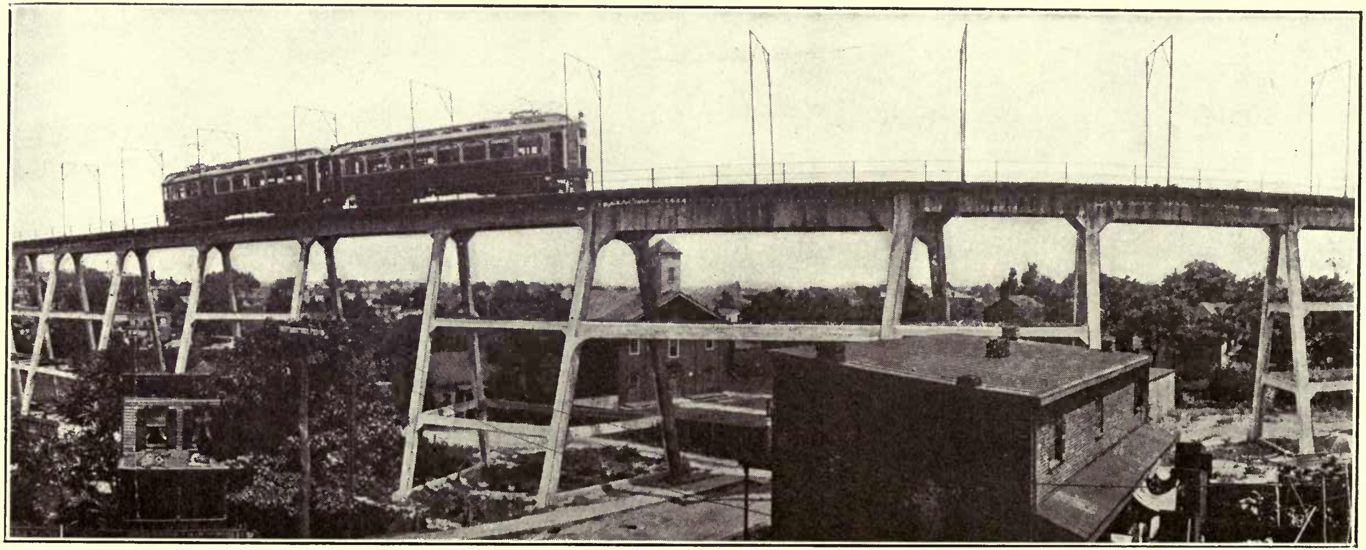
"Bending stresses due to eccentric loads must be provided for by increasing the section until the maximum stress does not exceed the values above specified.

"Compression in Extreme Fiber. For extreme fiber stress of beams calculated for constant modulus of elasticity.

32.5 per cent of the compressive strength at twenty-eight days, or 650 pounds per square inch for 2,000 pound concrete.

"Adjacent to the support of continuous beams, stresses 15 per cent greater may be allowed.

"Shear. Pure shearing stresses uncombined with compression or tension. 6 per cent of compressive strength at twenty-eight days, or 120 pounds per square inch for 2,000 pound concrete."



RICHMOND VIADUCT, RICHMOND AND CHESAPEAKE BAY RY.

## CHAPTER III.

## BRIDGES.

One of the most important applications of concrete to railroad construction is in the building of bridges. By the intelligent use of reinforced concrete, bridges are being designed which are superior to similar steel, masonry or wooden structures from an artistic, structural and economic standpoint.

While the life of a wooden bridge is about 9 years and of a steel bridge probably not over 30 to 40 years, and even then with a continual outlay for repairs and painting in addition to careful inspection, a concrete bridge will last almost indefinitely and with practically no maintenance. In addition to its natural permanence, such a bridge is proof against tornadoes, high water and fire.

Steel and wooden bridges grow weaker from rust and decay and in a few years the day comes when the bridge of decreasing strength is overloaded by the increasing weight of rolling stock and requires either strengthening or replacing. Concrete bridges on the other hand grow stronger with age and in probably as rapidly an increasing ratio as the increase of traffic.

A concrete bridge is free from the excessive vibrations often experienced in steel bridges and from disagreeable noise.

Track is easily maintained on such a structure, since the ordinary track ties and ballast take the place of the more expensive bridge ties of a steel structure.

In the construction of a concrete bridge there is no obstruction of traffic from swinging booms as is the case when setting stone of large dimensions in masonry bridges, nor so much difficulty in securing the necessary skilled labor during times when the building trades are active. The materials used can generally be obtained in the immediate vicinity of the bridge site.

The cost of a reinforced concrete bridge in almost all cases will be considerably less than that of a stone masonry structure and will not greatly, if at all, exceed that of a steel bridge, when the cost of piers and abutments is included in the comparison. Even when the cost of the steel is less, the difference is more than counteracted by the practically negligible maintenance costs of the concrete structure.

## ARCH BRIDGES.*

While arch bridges may be constructed of either plain or reinforced concrete, the latter type is usually the most satisfactory, as the steel reinforcement not only permits the use of less material, but it also adds to the safety against settlements of foundations or centerings, and temperature stresses. The Wallkill River bridge shown in Fig. 3 is an interesting example of plain concrete construction, while the Jackson Street arch, the Paulins Kill viaduct and the Vermillion River Bridge, shown in Figs. 4, 8 and 9, are types of reinforced arch bridges.

Arches are classified in various ways, but the most simple classification is in reference to the method of the construction of the spandrels, or spaces above the upper surface of the arch ring and below the road-bed level. These spaces are either filled in solid with loose filling or are left open by skeleton spandrel construction consisting of slabs and beams supported on columns or cross-walls resting on the arch ring.

SOLID FILLED SPANDRELS. This type of construction is generally employed for arches of spans under 100 feet. While the solid-filled spandrels usually consist of an embankment of earth, sand or cinders enclosed between solid spandrel walls having the common trapezoidal retaining-wall section, or between reinforced spandrel walls, sometimes a filling of very lean concrete is used in place of the loose material, when the spandrel walls become an integral part of the filling. The loose filling between spandrel walls is deposited in thin layers and thoroughly tamped by ramming, rolling or flooding it in with water.

The Jackson Street arch, described on page 30, is an example of the solid fill spandrel type of construction.

SKELETON SPANDREL CONSTRUCTION. For spans of about 100 feet or over the skeleton spandrel construction is, on account of its reduced weight and cost, found most advantageous.

In addition to the advantage resulting from a reduction of the load on the main arch ring and foundations this type of construction when well handled furnishes an opportunity to introduce architectural effects of great beauty. By doing away with the long and heavy solid spandrel walls the trouble with temperature strains is greatly lessened in this type of construction.

The Paulins Kill Viaduct and the Vermillion River Bridge, described on pages 34 and 36, are examples of skeleton spandrel construction.

Another form of skeleton spandrel construction, an example of which is found in the Connecticut Avenue Bridge, Washington, D. C., consists of hol-

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*For theory and methods of design see Taylor & Thompson's "Concrete Plain and Reinforced," Second Edition, 1909, or Howe's "Symmetrical Masonry Arches." John Wiley & Sons, New York, publishers.

FIG. 3.—WALLKILL RIVER VIADUCT, ERIE AND JERSEY R. R.

low spandrels with curtain walls forming a cellular spandrel construction in which the roadway is carried on a system of braced columns and beams enclosed by thin curtain walls on each side of the bridge.

EXPANSION JOINTS. To provide for the action of temperature strains, expansion joints are generally constructed in the spandrels where they meet the abutments and usually also at one or more points between the abutments and crown of the arch. Some engineers place a vertical expansion joint over each springing line and at a point about 10 feet each side of the crown. These joints which cut the spandrels vertically from the coping of the parapet wall to the arch ring are either constructed as mere planes of weakness in the concrete or as actual joints filled with one or more layers of felt, corrugated paper or some other partially elastic material.

Another method which is sometimes adopted is to entirely omit the expansion joints and resist the temperature strains by providing sufficient reinforcing metal throughout the structure.

WATERPROOFING. The top of the arch and the lower parts of the spandrel walls are usually waterproofed in order to facilitate drainage and keep accumulated water from penetrating the arch ring.

In addition to the structures described below, a number of other arch bridges are shown among the miscellaneous photographs in the back of the book.

JACKSON STREET ARCH, C. R. R. OF N. J. As will be seen by the drawings in Fig. 5, page 32, which show the essential features of design and construction, this bridge consists of a reinforced concrete arch of 54 ft. 3 inch clear span with axis on a skew of 22° 2′ with the axis of the street. The photograph in Fig. 4 shows the finished arch.

The abutments and wing walls rest on 10-inch piles, the last three rows in each abutment being driven with a batter to correspond with the inclination of the line of pressure. These piles were cut off below water level, which is about 10.87 feet below the surface of the street, and a bed of broken stone 3 feet thick was rammed around them to within 6 inches of the tops where the concrete work started.

With the exception of an open expansion joint, like a vertical tongue and groove, between the ends of the abutments and the ends of the wing walls the bridge was constructed as a monolith. For the arch ring the concrete was mixed in the proportions of 1 part Atlas Portland Cement, 2 parts sand and 4 parts 1-inch screened broken stone, while for the abutments and wing walls the proportion was 1:3:6 with 1½-inch stone and for the spandrel walls 1:3:5, with 1-inch stone.

The main reinforcing for the arch consists of 1¼-inch curved round rods in both intrados and extrados placed about four inches from the upper and

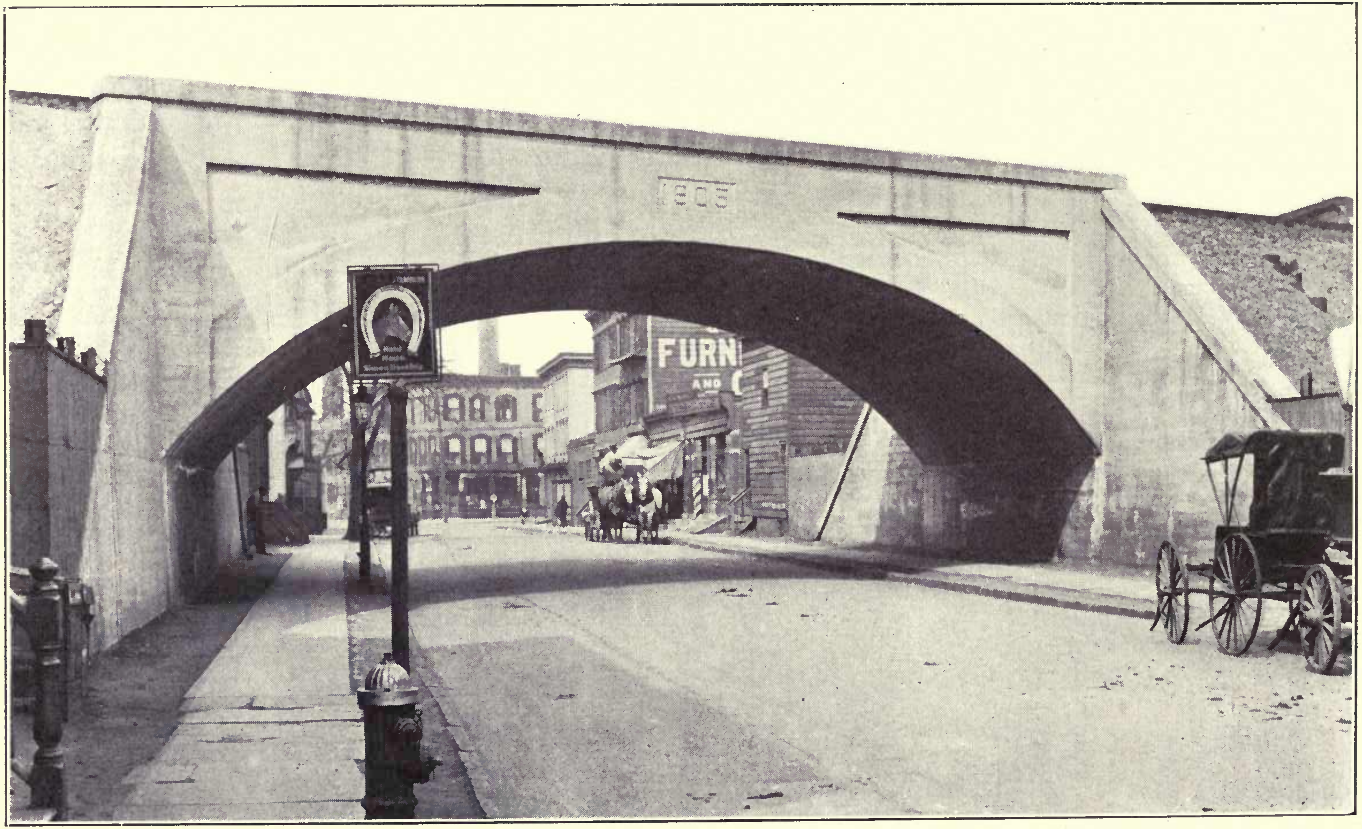


FIG. 4.—JACKSON STREET ARCH, NEWARK, N. J., C. R. R. OF N. J.

lower surfaces. In the intrados they are spaced 12 inches apart at the springing line and extend 5 feet past the center, thus giving a spacing of 6 inches for 32 feet at the crown. In the extrados they are 12 inches apart at the abutments and carry 2½ feet beyond the center line, thus giving a 5 foot lap for bond. At the haunches auxiliary rods about 26 feet long are placed in all the spaces between the main rods. Above and below both the intrados and extrados rods, horizontal transverse ¾-inch rods are spaced 24 inches apart and extend the full length of the arch.

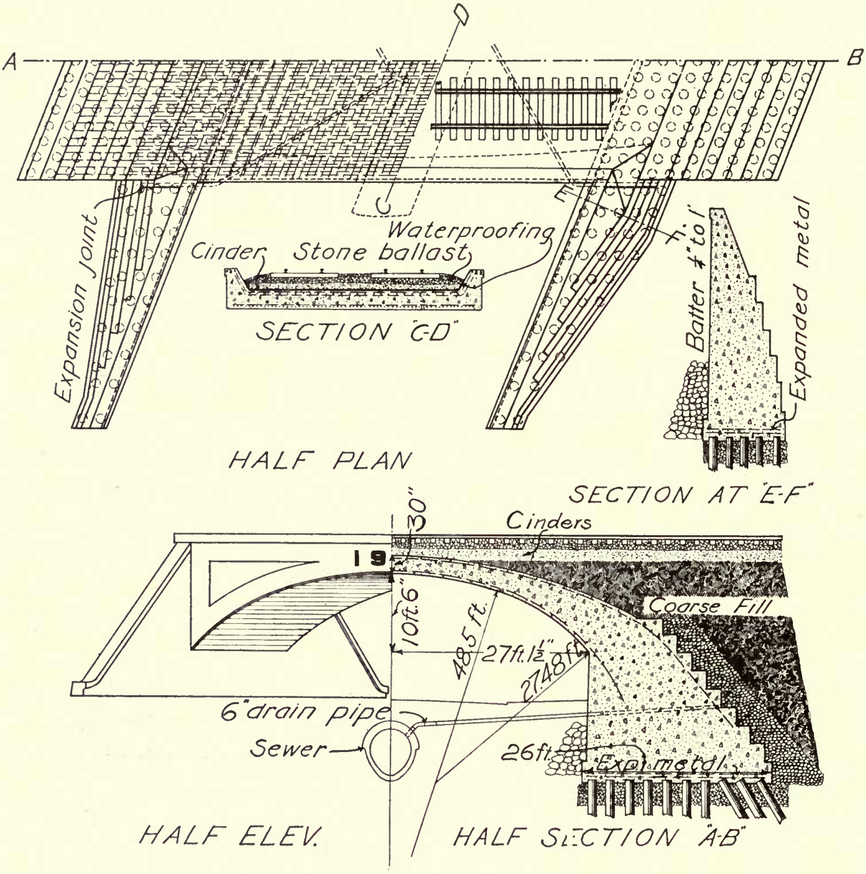


FIG. 5.—JACKSON STREET ARCH, C. R. R. OF N. J.

In designing the bridge the stress in the arch ring was computed by the graphical method of Prof. W. A. Cain, the live load assumed being the standard loading of the Central Railroad of New Jersey or 700 pounds per square foot of surface while the dead load was figured as follows: Rails, ties, ballast, 140 pounds per square foot of surface; filling, 100 pounds per cubic foot, and concrete, 160 pounds per cubic foot. Including temperature stresses the maximum stress in the concrete was 600 pounds per square inch compression and 50 pounds per square inch shear, while the maximum stress in the steel was 18,000 pounds per square inch in tension and 5,000 pounds per square inch in compression, the latter value being fixed of course by the permissible stress in the concrete times the ratio of elasticity of steel to concrete.

During the construction of the bridge, railroad traffic was maintained uninterruptedly on temporary trestles on either side of the bridge.

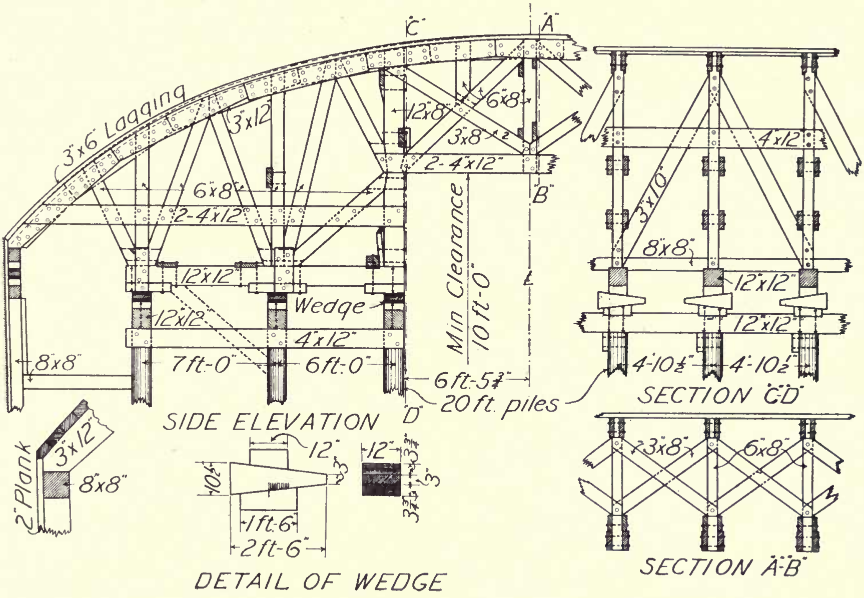


FIG. 6.—FORMS FOR JACKSON STREET ARCH.

The arch forms were assembled on the ground, and after the abutments were well under way they were swung into place from an erection car on the temporary trestle. The photograph in Fig. 7 shows the method of placing these centers. The concrete in the abutments and the filling behind them was carried to a point about 2 feet above the spring line of the arch, when the arch ring was put in at one operation, concreting commencing simultaneously at the springing lines of both abutments.

The concrete was mixed in a 1 cubic yard Ransome Mixer on one side and a 1 cubic yard Smith Mixer on the other, and was deposited from ordinary iron wheelbarrows.

With the exception of the tops of the spandrel and wing walls, which were finished with a 1-inch trowelled surface of cement mortar applied simultaneously with the last course of concrete, the finish of the concrete was obtained by simply spading back the concrete from the forms.

The upper surface of the arch is waterproofed with four coats of Hydrex felt mopped on with Hydrex compound applied hot, and the backfill is drained from the ends of the abutments by two 6-inch cast-iron pipes connecting with the city sewer in the center of the street as shown.

The bridge was designed by the engineering department of the railroad. Mr. J. O. Osgood, Chief Engineer, and was constructed under their supervision in the spring of 1904 by Holmes and Coogan of Jersey City.

FIG. 7.—SETTING ARCH CENTERS.

PAULINS KILL VIADUCT, D., L. & W. R. R. This bridge, under construction in 1909, is approximately 1100 feet long and 115 feet high and consists of five 120-ft and two 100-ft. reinforced arches with skeleton spandrel arches supporting the track.

The drawings in Fig. 8 show the details of construction of a typical arch span and pier, together with one of the reinforced abutments. The design of these abutments furnished a rather novel and economical feature inasmuch as

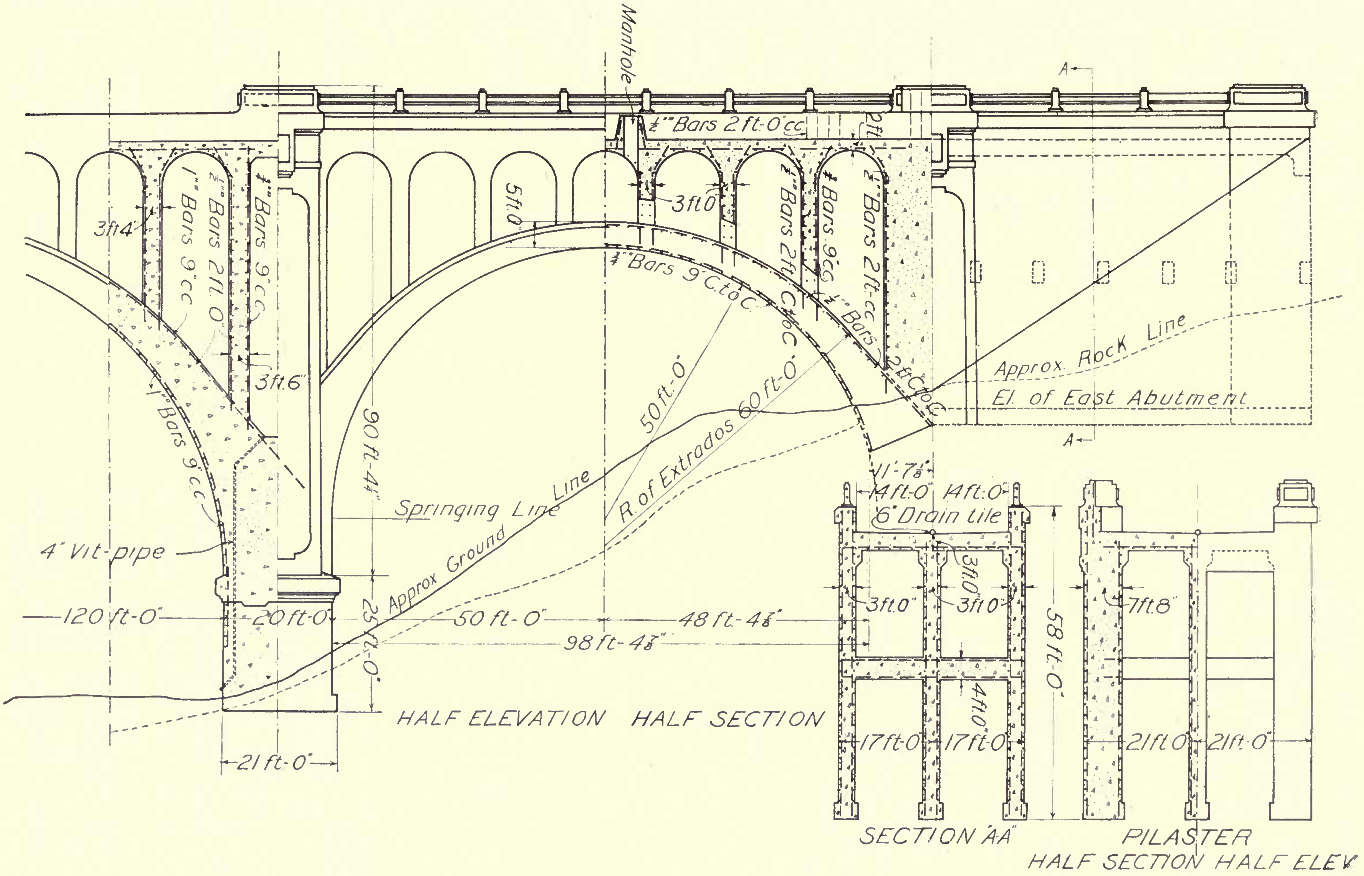


FIG. 8.—TYPICAL ARCH SPAN, PAULINS KILL VIADUCT, D., L. & W. R. R.

they are composed of three longitudinal reinforced walls carrying a reinforced slab which supports the track and ballast. This skeleton construction allows the embankment to take its natural slope between the walls as well as on the outside of them, and by thus balancing the earth pressure does away with the bulky section which would have been necessary had they been designed as retaining walls.

With the exception of the copings and ornamental railings, which are of 1:2:4 proportions, the concrete throughout the structure is mixed in the proportions of 1 part cement, 3 parts sand and 5 parts broken stone. In the abutments and piers for the arches and foundations below the ground line, large quarry stones are bedded in the concrete so as to form a rubble concrete and reduce the most of materials.

In designing the viaduct a ratio of elasticity of steel to concrete of 15 was assumed and the concrete was figured at 600 pounds per square inch safe working fiber stress, 500 pounds per square inch direct compression and 50 pounds per square inch shear, while the steel was given a working tensile stress of 16,000 pounds per square inch.

The structure was designed by the engineering department of the Delaware, Lackawanna and Western Railroad under the supervision of Mr. Lincoln Bush, Chief Engineer, with Mr. B. H. Davis, Assistant Engineer in charge of masonry design, and Mr. F. L. Wheaton, Engineer of Construction in charge of work in the field.

VERMILLION RIVER BRIDGE, C., C., C. & ST. L. RY. In its essential features this bridge is similar in type and design to the Paulins Kill Viaduct illustrated in Fig. 8 and consists of three arches, the central span being 100 feet and the two side spans 80 feet, with rises of 40 and 30 feet respectively.

The photograph in Fig. 9 is of the completed structure, while Fig. 10 is a view taken during the construction showing the false work for the main arches and the location of the derricks.

The arch rings are 3½ feet thick at the crown, deepening out toward the spring lines, and are reinforced near the extrados and intrados with 1-inch corrugated bars 12 inches apart and overlapped 4 feet at their ends, thus giving a bond of 40 diameters. Below these rods at the extrados and above them at the intrados there is a series of ⅞-inch transverse bars 33 feet long.

Above the arch rings of the main arches the channel piers are hollow, the pilasters being carried up as reinforced facing slabs 15 feet wide and 3½ feet thick. The transverse walls are formed by the piers of the spandrel arches next to the springings, which have brackets at the top projecting 12 inches on the inside. These brackets carry reinforced concrete slabs 2 feet thick, which,

FIG. 9.—VERMILLION RIVER BRIDGE, BIG FOUR RY.

being freely supported on rails embedded in the tops of the piers and bearing against similar rails projecting from the underside of the slabs, act as expansion joints. A similar transverse expansion joint is placed over the top of each abutment.

The concrete in these joints was made as smooth and flat as possible and finished so that contact between the adjacent faces at the point is made only through the embedded rails. To further separate the division two layers of felt are placed between the two surfaces of concrete and carried up to within 2 inches of the top of the vertical joints, the remaining space being filled with asphalt.

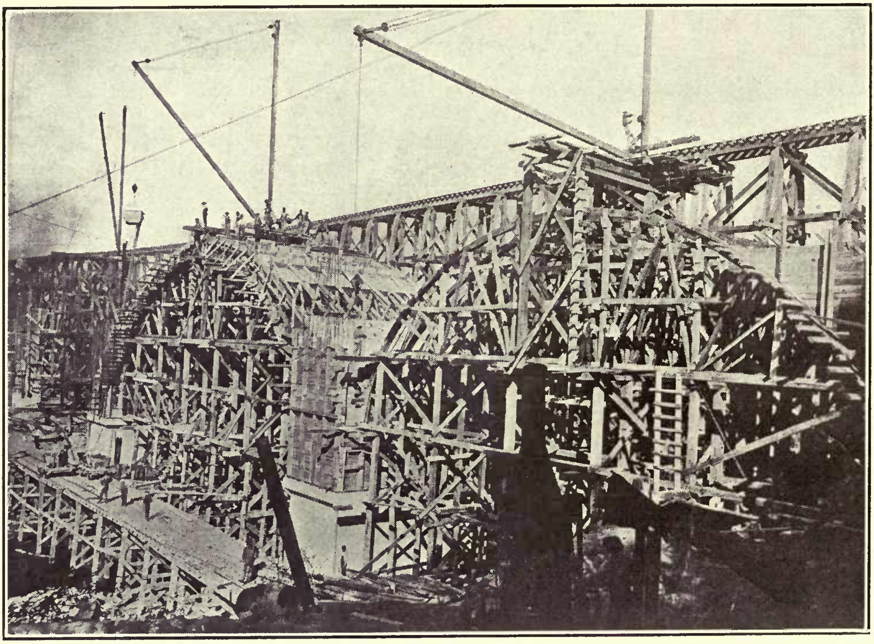


FIG. 10.—FALSE WORK FOR MAIN ARCHES.

The concrete for the reinforced portions was mixed in the proportions of 1 part cement to 2 parts clean sand to 4 parts of broken stone; that for the abutments and main piers of 1:3:6 and the footings of 1:4:8 proportions.

The bridge was designed in the construction department of the Cleveland, Cincinnati, Chicago and St. Louis Ry. and was built by the Bates and Rogers Construction Company of Chicago in the fall of 1905.

WALLKILL RIVER VIADUCT, E. & J. R. R. This is a very heavy unreinforced concrete bridge 388 feet long, having a width of 32 feet between outside of parapet walls, and consists of four 60-ft. and two 40-ft. circular arches. The photograph in Fig. 3, page 29, is of the finished structure, while the drawings in Fig. 11 show the plan, elevation and section of the 60-ft. arches, together with details of the expansion joints, which occur at each pier, extending from the top of coping to top of haunch. The starkweather is also drawn in detail.

The bridge, which contains 7500 cubic yards of concrete, was designed by the engineering department of the Erie Railroad under the supervision of Mr. F. L. Stuart, Chief Engineer, and was built by Lathrop, Shea and Henwood Company of Scranton, Pa.

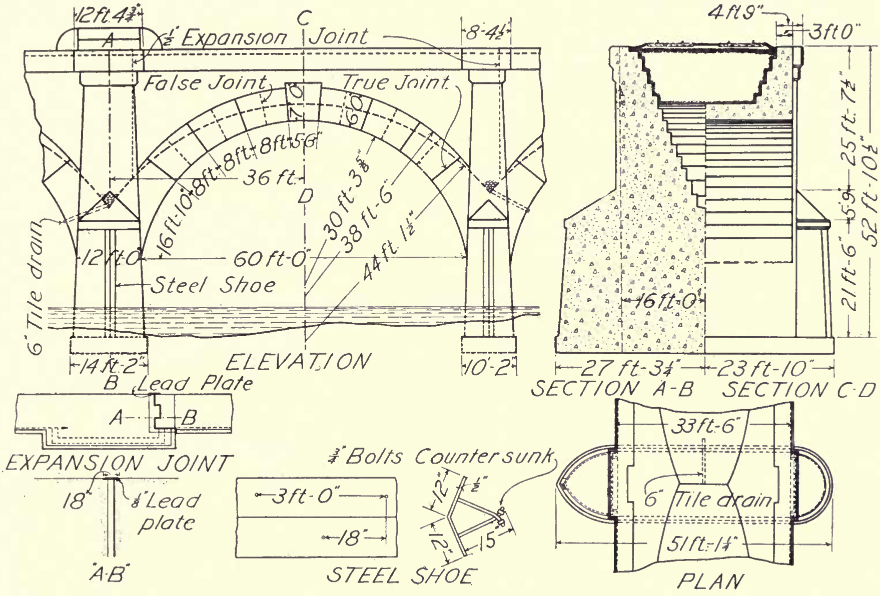


FIG. 11.—DETAILS OF 60-FT. ARCH, WALLKILL RIVER VIADUCT.

## GIRDER BRIDGES.

When constructed of concrete, girder bridges are designed either as entire reinforced concrete structures or as a combination of structural steel and reinforced concrete. In the latter case the main girders and cross beams are generally composed of structural shapes encased in concrete with the floor slabs of reinforced concrete. An example of the former type, which contains a number

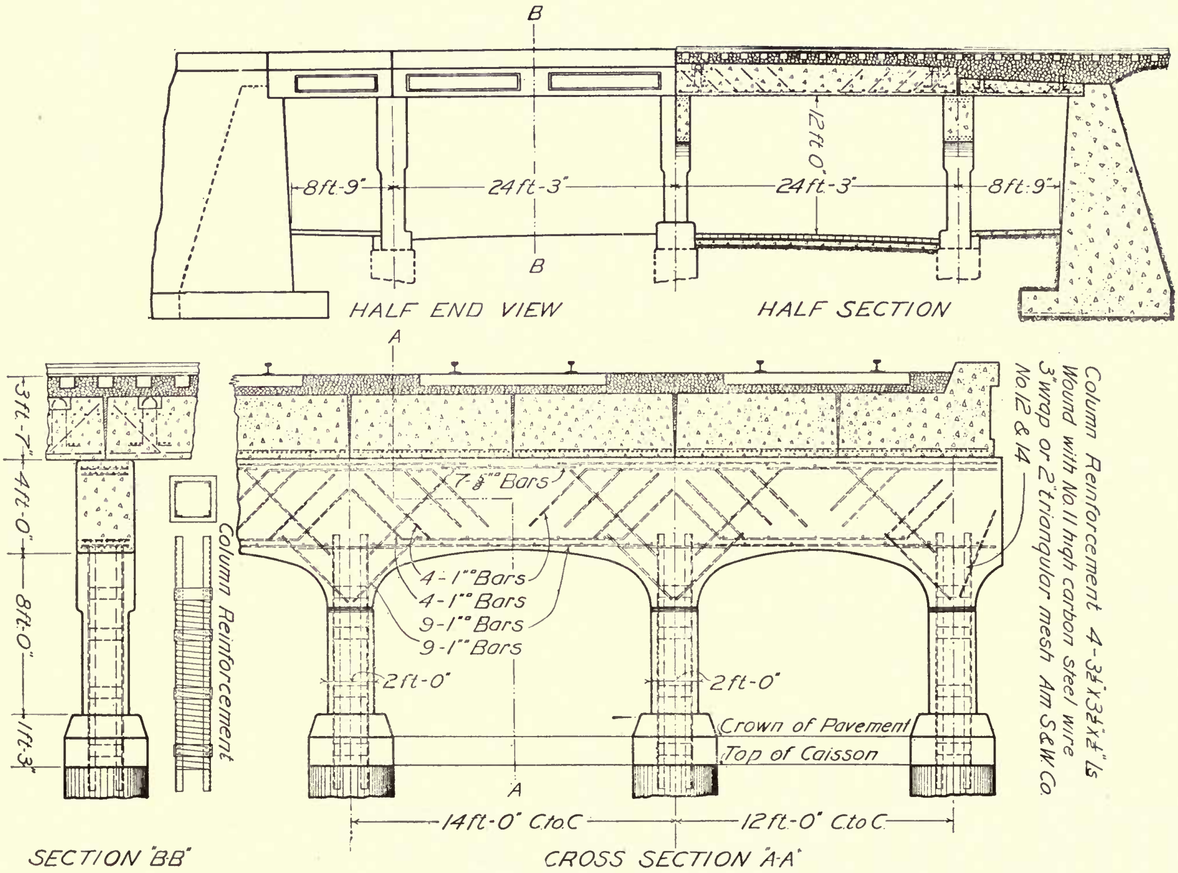


FIG. 12.—TYPICAL DETAILS, C., B & Q. R. R. TRACK ELEVATION.

of advanced and novel features, is described below, while the First Avenue Viaduct described on page 57 is an interesting example of the latter type.

Among the miscellaneous photographs in the back of the book are shown other girder bridges of both types.

In designing reinforced concrete girder bridges, care should be taken to see that there is sufficient concrete and steel provided for shearing stresses, as with short spans and heavy loads this will be found in many cases to be the determining factor.

TRACK ELEVATION WORK, CHICAGO, ILL., C., B. & Q. R. R. In connection with the track elevation work which the Chicago, Burlington & Quincy Railroad is carrying on between Canal Street and Blue Island avenue, Chicago, there are a number of reinforced concrete girder bridges forming subways similar in type and design to the drawings shown in Fig. 12. These bridges are notable because of their extremely large size and capacity and for their methods of construction. As will be seen from the drawings in Fig. 12, the essential features of design and construction of a typical bridge consist of reinforced concrete columns and cross girders cast in place and carrying reinforced deck slabs which were moulded in sections away from the bridge site and when properly cured were transported on flat cars and set in place by a wrecking crane. After being thoroughly waterproofed the ballast and track was laid directly on these slabs. Fig. 13 shows the details of a typical slab.

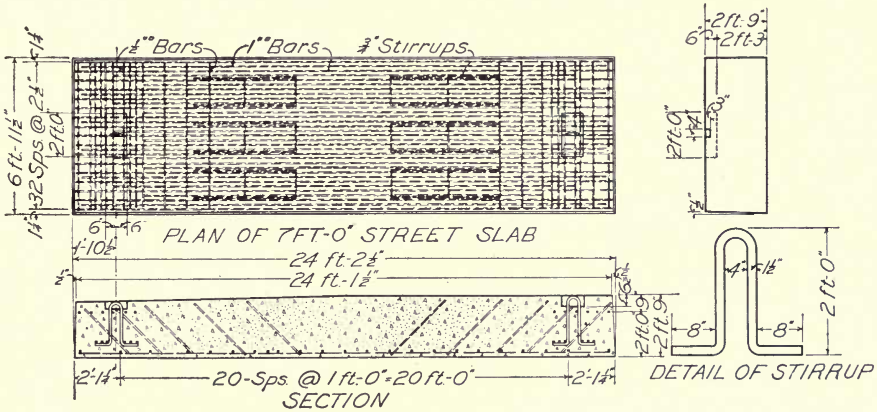


FIG. 13.—DETAILS OF TYPICAL SLAB, C., B. & Q. R. R. TRACK ELEVATION.

The columns and cross girders are composed of concrete mixed in the proportions of one part cement to four parts pit-run gravel. The columns are reinforced with four 3½ by 3½ by ½ inch angles hooped spirally with high carbon steel wire. The girders and slabs are reinforced with corrugated bars.

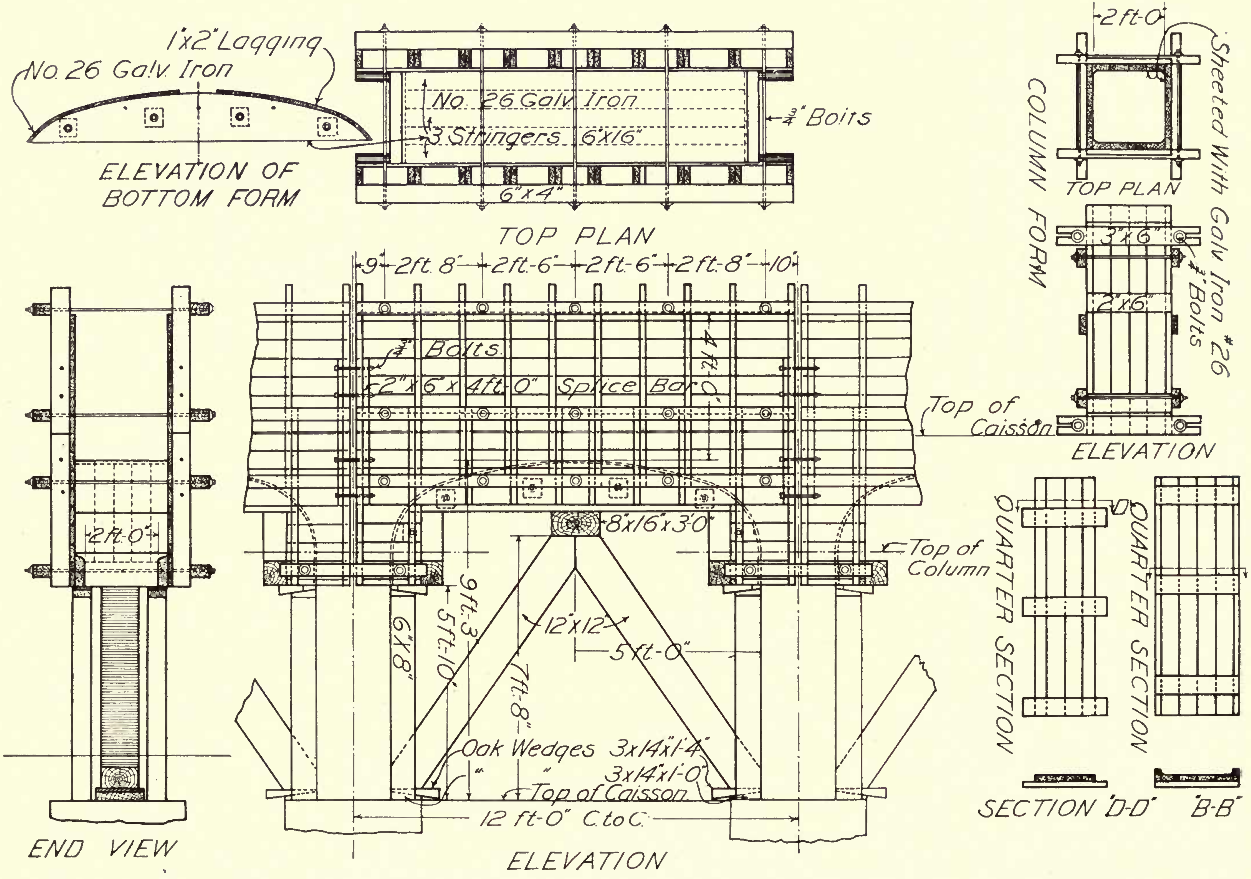


FIG. 14.—FORMS FOR COLUMNS AND GIRDERS, C., B. & Q. R. R. TRACK ELEVATION.

Fig. 14 shows the forms used in the construction of the girders and columns.

The slabs were built along both sides of a switch track in one of the railroad yards near the city limits and after curing ninety-days were picked up by a locomotive crane and placed on flat cars and hauled to a convenient storage place where they were piled three high until required at the bridge site.

Each slab was built in a separate form and after being cast was wet thoroughly every evening for two weeks. The slabs were made with the ends and sides battered so as to have a clearance of 1/4 inch between them at the bottom and 1 inch at the top on both sides and both ends. These spaces were filled with waterproofing, thus making the whole bridge floor water tight. A mixture of one part cement to four parts gravel was used in their construction. The slabs for the long spans contain approximately 19.2 cubic yards of concrete and weigh 36 tons each.

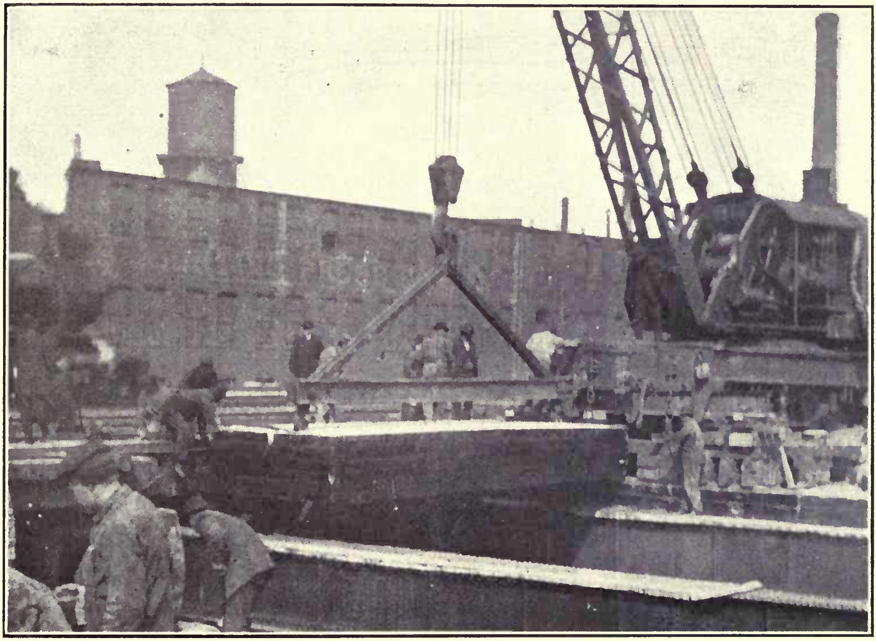


FIG. 15.—SETTING CONCRETE SLABS, C., B. & Q. R. R. TRACK ELEVATION.

In handling and setting the slabs, a 100-ton locomotive crane equipped with a special toggle frame was used. The photograph in Fig. 15 shows this crane in the act of setting one of the long span slabs.

This work is designed and constructed by the Engineering Department of the railroad under the supervision of Mr. C. H. Cartlidge, Bridge Engineer.

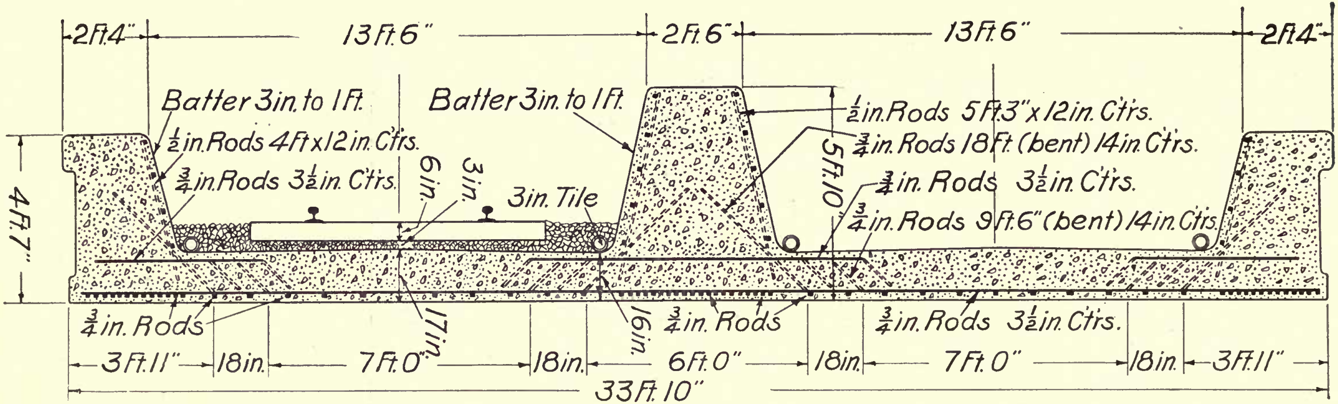


FIG. 16.—CROSS SECTION OF THROUGH GIRDER BRIDGE, C., B. & Q. R. R.

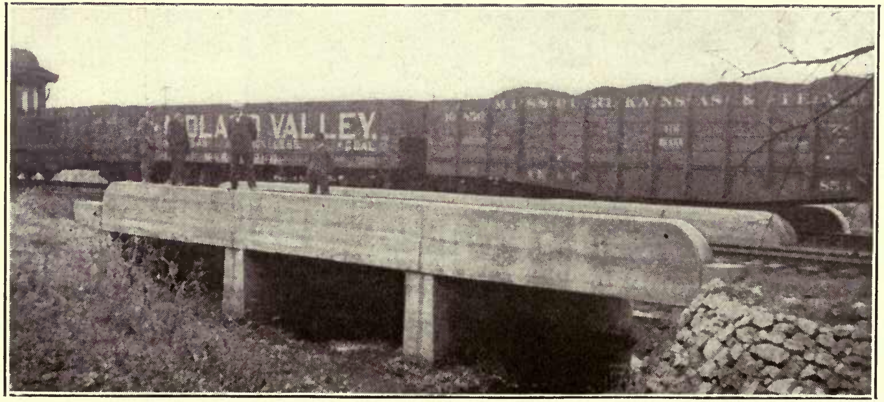


FIG. 17.—THROUGH GIRDER BRIDGE, C., B. & Q. R. R.

THROUGH GIRDER BRIDGE, C., B. & Q. R. R.—In Fig. 16 is shown the cross section of a reinforced concrete double track through girder bridge of 20 feet 3 inch skew span, which is of interest since this form of construction is employed to good advantage where the headroom is limited and a deck girder could not be placed. It will be seen that the two outer girders act as parapets and that the ballast is laid directly on the suspended floor slab. The photograph in Fig. 17 is of a similar type of construction of 18 foot skew span.

## TRESTLES.

Reinforced concrete is being used for trestles of every class. In the majority of cases these are conservative and safe, but a few of the designs along the lines commonly employed in steel construction with very high bents are considered by many conservative engineers to be extreme.

In structures of this type the utmost caution should be employed in the mechanics of design to see that all parts are symmetrical, that the column design is conservative and that proper provision is made for temperature stresses.

While the cost of a reinforced trestle is greater than that of a timber structure, this difference is often more than offset by the temporary character and the danger from conflagration of the latter type. As compared to steel construction, reinforced concrete is generally cheaper and possesses the additional advantage of being free from constant inspection, painting and general maintenance.

A number of very long and high trestles have been constructed during the past few years of reinforced concrete, one of the largest being the Richmond and Chesapeake Bay Viaduct described below.

The Chicago, Burlington & Quincy Railroad are changing over all the wooden pile trestles on their line to similar reinforced concrete structures, a typical example of which is shown on page 22.

A number of other reinforced concrete trestles are shown among the miscellaneous photographs at the back of the book.

RICHMOND VIADUCT OF THE RICHMOND AND CHESAPEAKE BAY RAILWAY.—The Richmond and Chesapeake Bay Electric Railway enters Richmond over a reinforced concrete viaduct 2,800 feet long, ranging in height from 18 feet at either end to 70 feet at its highest point. A riveted steel girder viaduct was first contemplated, but was rejected on account of the high initial cost and cost of maintenance, as well as the difficulty of double tracking such a structure should it become necessary. A wooden trestle was then planned, and some of the timber ordered and partially delivered, when considerations of fire protection as well as the necessarily temporary character of wood construction persuaded the company to adopt a reinforced concrete structure.

Bids for the design of such a structure were then called for, the railroad company submitting only the general location, profile and prescribed loads. Under these conditions the design of the New York branch of the Trussed Concrete Steel Company, Mr. B. J. Greenhood, Engineer, was accepted and the contract for the construction of the viaduct awarded to Mr. John T. Wilson, of Richmond, Va.

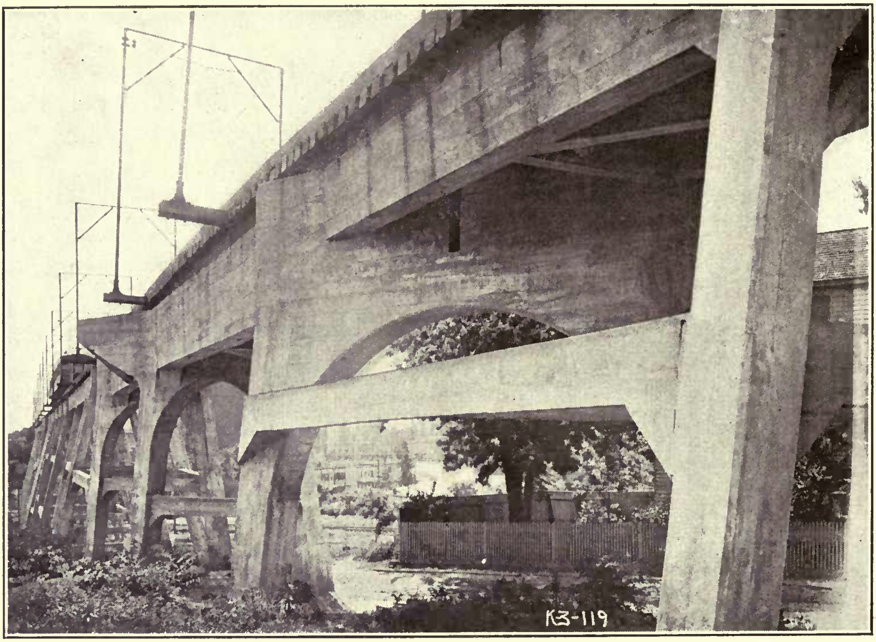


FIG. 18.—VIEW AT CURVE, RICHMOND VIADUCT.

The viaduct was designed to carry a 75 ton car, 54 ft. long on four-wheeled trucks placed 33 ft. apart, each truck consisting of two axles 7 ft. on centers. In computing the sizes of the various members it was assumed that the viaduct should carry its dead load and the entire live load plus 50 per cent of the live load for impact. The longitudinal thrust due to the braking of trains was assumed as 20 per cent of the live load. At the curves, overturning moments were allowed for at the rate of 2 per cent for each degree of curvature. Wind pressure was figured at 30 pounds per square foot on the surface of train and viaduct.

For the superstructure, it was decided to use concrete mixed in the proportions of 1 part Atlas Portland Cement, 2 parts granite dust and 4 parts ¾-inch crushed granite, and in the footings a 1:2½:5 mixture of the same materials. The columns were designed for a compressive stress of 500 pounds per square inch on the concrete and 6,000 pounds per square inch on the longitudinal reinforcing steel. In designing the girders, continuous beam action was assumed and the concrete was figured at 600 pounds per square inch extreme fiber stress and 50 pounds per square inch shear, while the steel was given a tensile stress of 16,000 pounds per square inch. In proportioning the footings, which bear on either hard clay or compact gravel, a bearing value of 3 tons per square foot was figured on for all possible stresses including future double tracking. Kahn trussed bars were used as reinforcing for the entire structure.

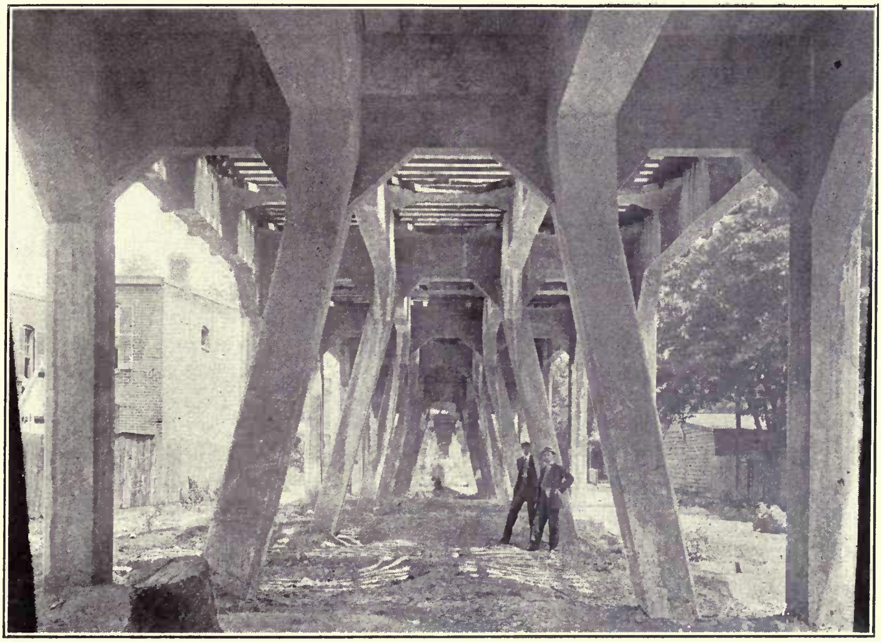


FIG. 19.—VIEW FROM GROUND, RICHMOND VIADUCT.

The viaduct is comprised of a system of girders of rectangular cross section varying in span from 23 to 68 feet supported by a series of interbraced and battered bents varying from 14 to 70 feet in height. The general features of design and construction of the different types of cross section of the viaduct are readily understood from the accompanying drawings shown in Fig. 20.

As will be noted by the photograph in Fig. 19, the diagonal bracing which is generally seen on structural steel towers is replaced by transverse and longitudinal struts, the intention being to design all joints and all members so that they will have the rigidity to withstand bending. Provision has been made for double tracking the viaduct, when traffic warrants such an extension, by building the footings for all bents over 20 feet in height, with an offset column base to which new columns can be attached and by leaving cored holes in the girders for connecting the new work. Both of these features are shown clearly in Fig. 20.

Expansion joints have been provided where the short girders rest on the column brackets, at intervals of about 200 feet, consisting of a grooved steel plate on top of the bent, on which a planed steel plate on the bottom of the girder slides; together with steel toggle connections at the upper part of the girder which prevent any tendency to turn the girder. Fig. 21 shows the details of construction of one of the 49 ft. girders.

An idea of the massive proportions of the trestle can be obtained by a study of the photographs in Fig. 18 and Fig. 19.

The track consists of 80 pound rails spiked to 8 x 8 inch cross ties 12 inches on centers which are notched 1½ inch over and bolted to 6 x 12 inch sleepers embedded in and attached to the concrete girders by means of anchor bolts as shown in Fig. 20. On the curves, heavier sleepers are used under the outside rail as shown in Fig. 20 in order to gain the necessary outer elevation.

The guard rail is made of 8 x 10 inch hard pine notched 2 inches between the ties. By extending every fifth tie four feet beyond the concrete girder and covering this extended tie with planking, a footway 40 inches wide is provided. In a similar manner the poles for carrying the trolley wires are supported.

Work on the structure was started in the spring and finished in the fall of 1906.

In the construction of the viaduct, one mixing plant, transferable from one place to another, consisting of one No. 2½ rotary mixer, hoisting engine, elevator, buckets, etc., was used. After the erection of the forms the columns and struts up to the bottom of the girders were poured at one continuous operation. The column forms were built in three sides forming a U-shape, and the fourth side built up in sections as the concrete was poured. The girders and floors were also put in at one operation.

The forms were made of 2-inch lumber dressed on one side, supported by falsework consisting of a 4 by 4 inch and 6 by 6 inch timbers. The girder sides were removed at the end of a week while the remaining forms and supporting falsework were left in place for at least thirty days. After the removal of the forms the entire surface of the viaduct was given a finish of sand and cement applied with a brush.

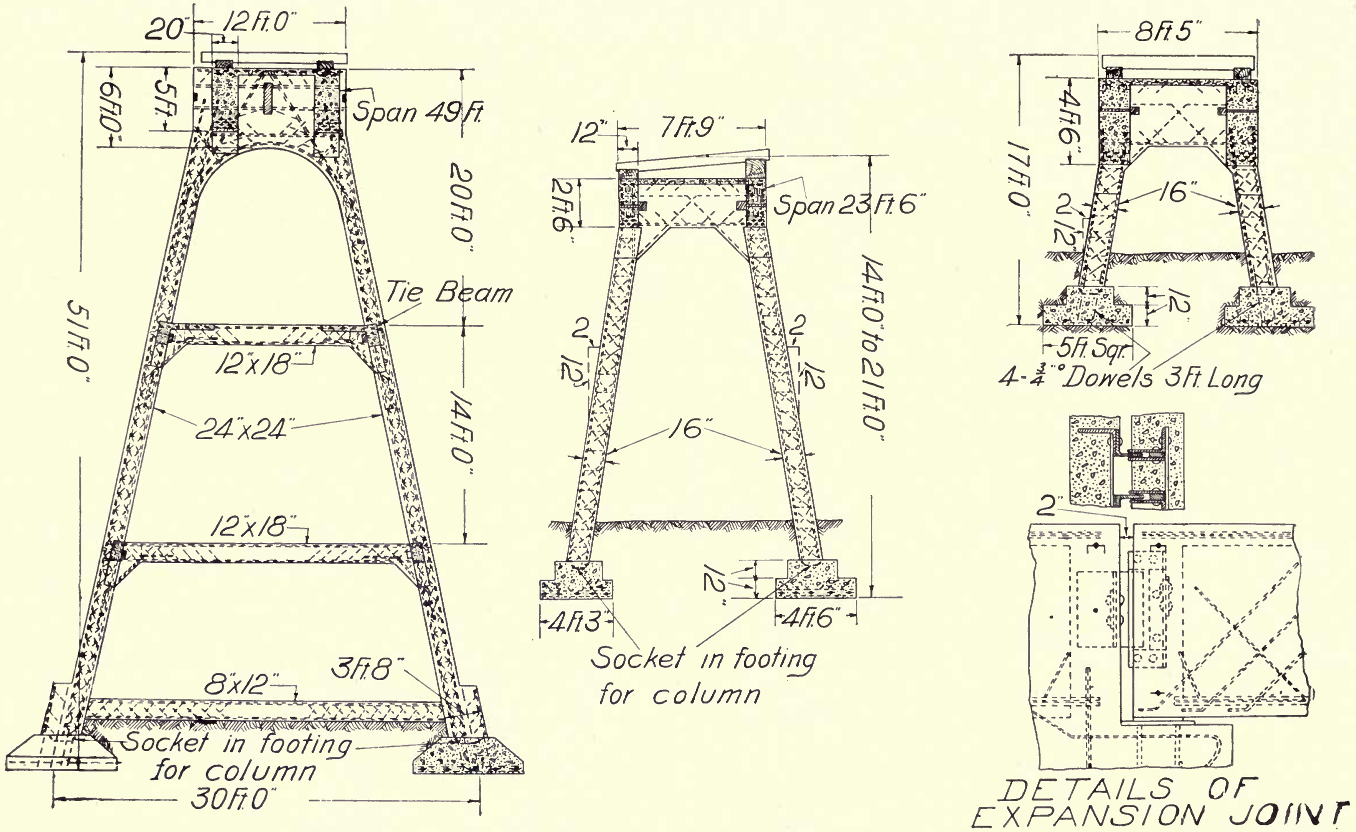


FIG. 20—TYPICAL BENTS, RICHMOND VIADUCT.

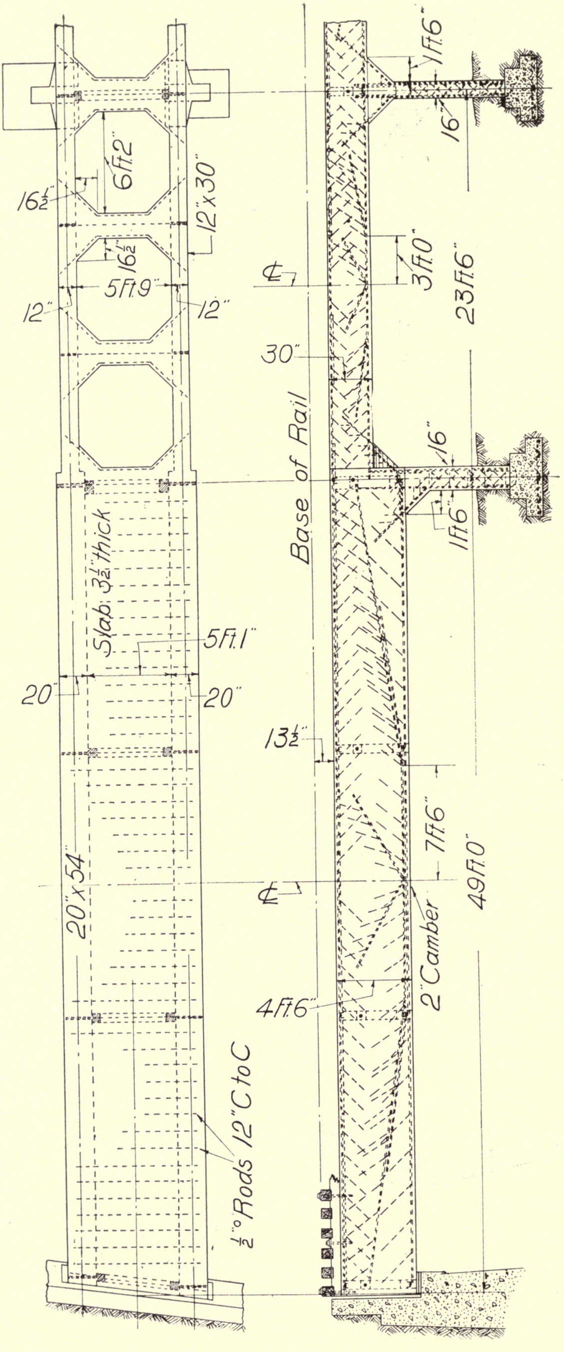


FIG. 21.—PLAN AND ELEVATION OF RICHMOND VIADUCT.

CONCRETE PILE TRESTLES, C., B. & Q. R. R.—These trestles, which replace similar wooden structures, possess a number of features comparatively new to the field of concrete construction. In general, the construction consists of six pile bents spaced 14, 15 or 16 feet center to center, and with an average height of 10 feet. The essential details of design and construction are shown by the drawings in Fig. 21, while the photograph in Fig. 20 shows a typical trestle.

FIG. 22.—CONCRETE PILE TRESTLE, C., B. & Q. R. R.

Two types of piles are used, namely, rectangular cast piles and Chenoweth rolled piles. The cast or molded rectangular piles are made in lengths up to 30 feet, and are 16 inches square at the top with 4-inch chamfers. The reinforcement consists of eight ½-inch bars wired to a spiral coil of wire of varying pitch. The Chenoweth rolled pile, which is the type shown in Fig. 21, is circular in section, 16 inches in diameter, and is reinforced with ½-inch corrugated bars wound spirally with a ½-inch mesh No. 16 wire netting.

The piles are driven vertically by an ordinary railroad pile driver with a 3,000-pound hammer, with cushioned cap, falling 24 feet.

The piles are capped by deep reinforced concrete cross girders, which support the slabs forming the floor or deck.

Each span consists of two reinforced concrete slabs or girders, each slab forming half the width of the floor and having a curb wall to retain the ballast.

For trestles of over 5 or 6 feet spans in length, longitudinal rigidity is obtained by the use of double bents at suitable intervals, consisting of two rows of piles carrying a single cap twice the usual width.

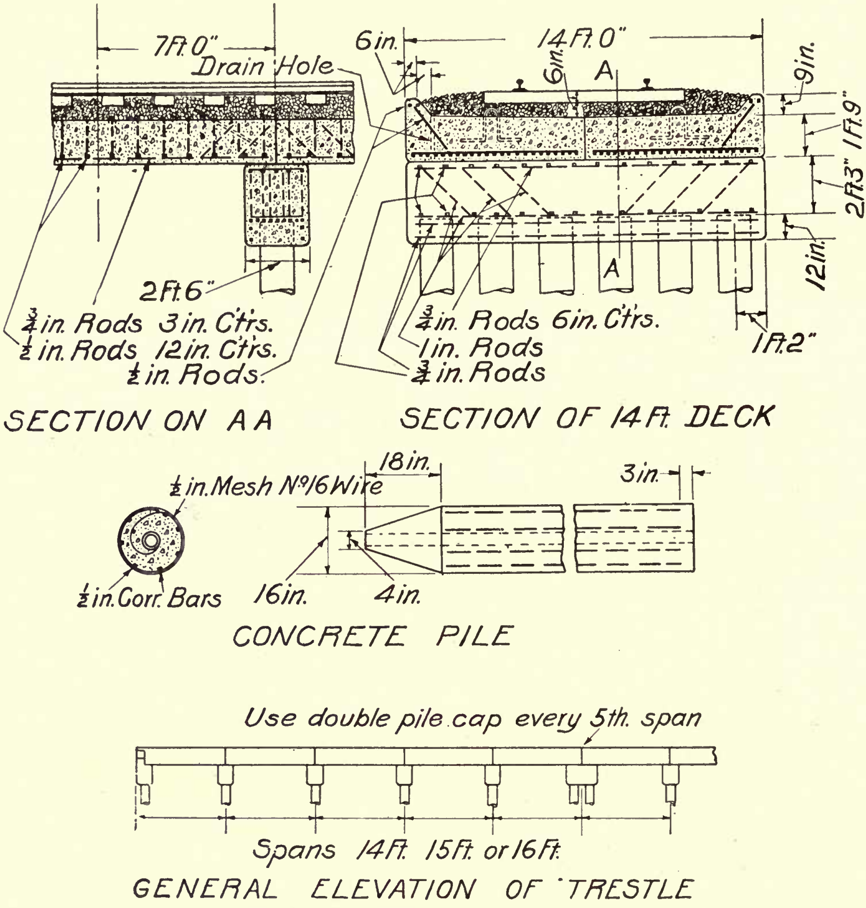


FIG. 21.—PILE TRESTLE, C., B. & Q. R. R.

In the first of these trestles to be built, a solid pier was used in place of the piles and cap at every sixth bent, but the double bent construction is now considered preferable.

The deck slabs are cast in the railway company's yards, and after seasoning about sixty days are carried to the bridge site and placed in a similar manner to the deck girder slabs described on page 41. The ballast and track are laid directly on these slabs.

Different proportions of concrete are used for different parts of the trestle. The concrete for the piles is mixed in the proportions of one part cement to three parts fine screened gravel, while for the caps and girder slabs a mixture of 1:4½ with gravel, or 1:2:4 with sand and stone is used.

In constructing these trestles traffic is not interfered with. The floor of the existing timber trestle is partly dismantled and concrete piles are driven to form bents intermediate with the old timber bents. The forms for the caps are then put in place and filled, the concrete being allowed to set about thirty days. Part of the timber trestle is then torn out by a derrick car or wrecking crane and the girder slabs set in place.

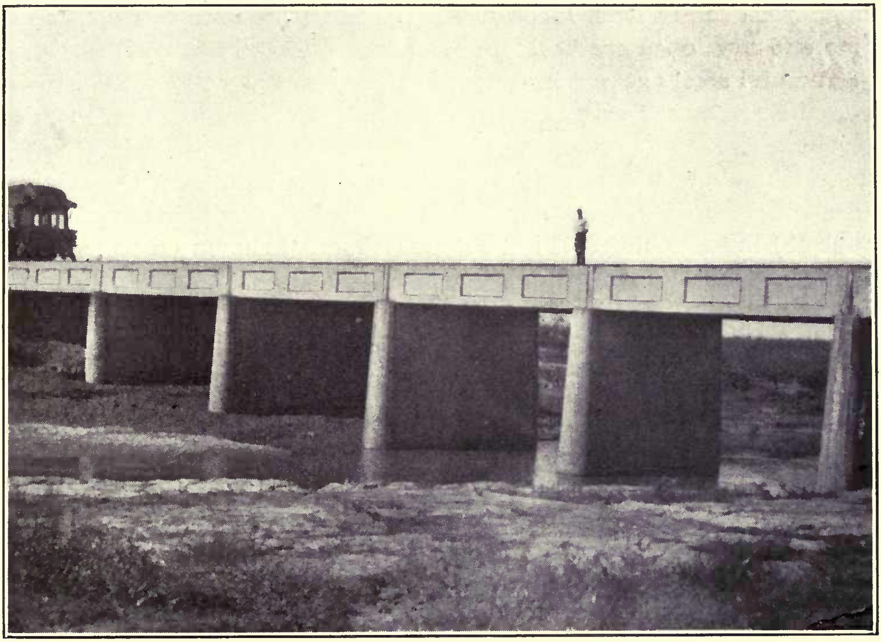


FIG. 22.—PIER TRESTLE, C., B. & Q. R. R.

CONCRETE PIER TRESTLES.—Where longer spans are used and where the trestles cross streams in which floating ice is apt to occur, thin concrete piers are used in preference to the pile bents. The photograph in Fig. 22 shows a typical structure of this type of 25 foot spans. The piers are carried down to footings on a solid foundation or are supported by wooden or concrete piles.

These trestles are designed and constructed by the Engineering Department of the railroad under the supervision of Mr. C. H. Cartlidge, Bridge Engineer.

# OVERHEAD HIGHWAY BRIDGES.

Owing to the deteriorating influence of locomotive gases upon the under surface of bridge floors, the construction of overhead highway crossings is one of the greatest problems which railroad engineers are called upon to solve.

There are numerous cases where after a few years steel girders and stringers, even when presumably protected by brick arches, have rusted to one-half their original thickness, thus endangering many lives.

Steel girders, when unprotected, have to be painted very frequently, and, as the accumulated rust formed by the locomotive gases has to be removed, this is a much more expensive operation than under ordinary circumstances. To do away with the high maintenance expense and to overcome the effect of the sulphurous fumes from locomotives, old structures are being encased in concrete and new ones are being built either entirely of reinforced concrete or of structural steel encased in concrete. Bridges thus constructed are absolutely unaffected by ordinary rust, rot or fire, and can be designed economically along artistic lines.

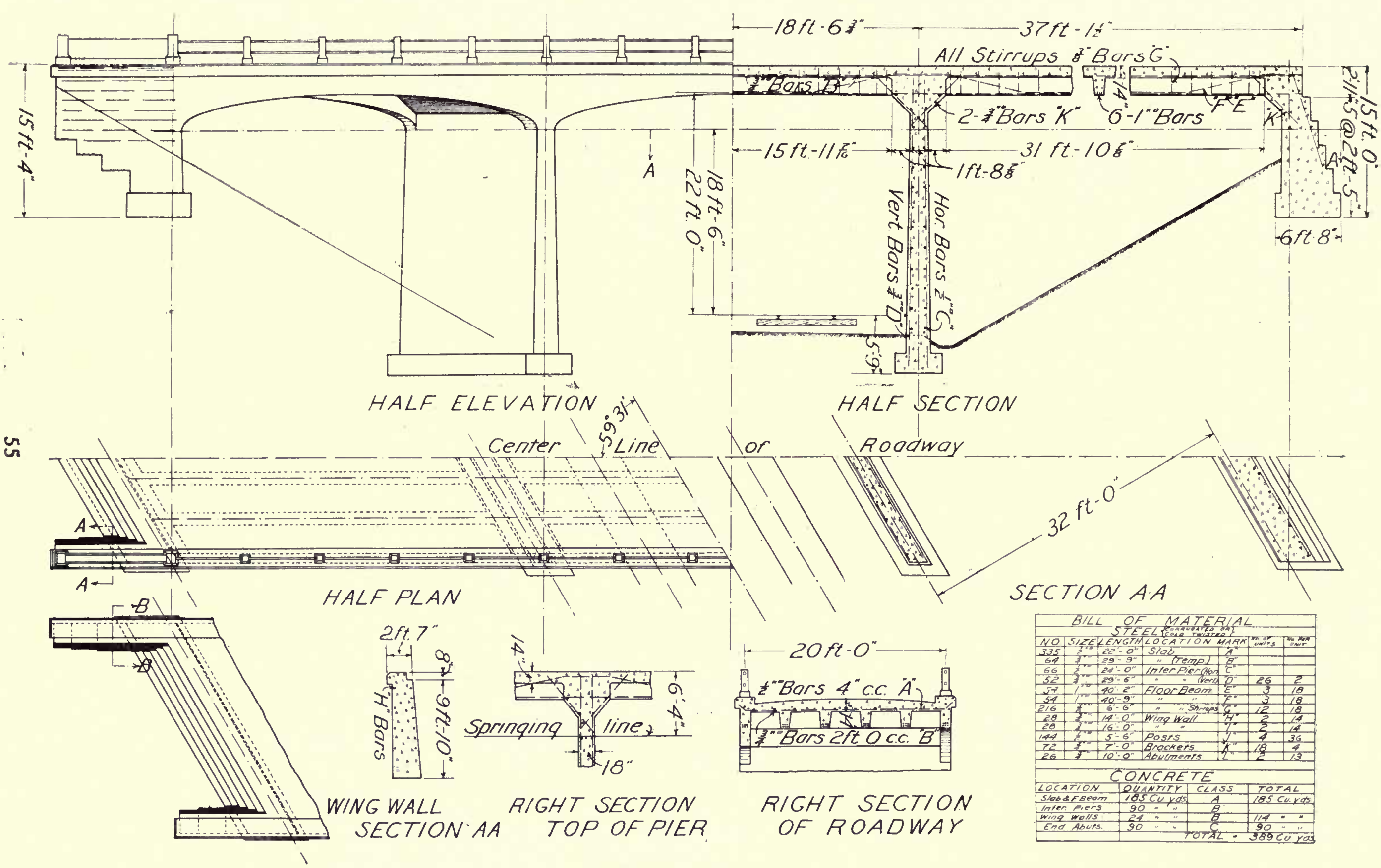
The Blairstown Bridge, described on page 55, is an entirely reinforced concrete structure which is particularly commendable on account of its light and graceful lines, while the First Avenue Viaduct, shown on page 56, is an interesting example of an overhead highway bridge composed of structural steel girders and cross beams encased in concrete.

Other overhead highway bridges are shown among the miscellaneous photographs at the back of the book.

OVERHEAD HIGHWAY BRIDGE, NO. 19.31, D., L. & W. R. R.—As will be seen from the drawings in Fig. 23, which show a half elevation and half section together with details of construction, this bridge consists of two reinforced piers and abutments supporting reinforced girders and floor slab. The two exterior girders are built with the bottoms slightly arched, thus giving the bridge the appearance of being a light arched structure of graceful lines.

The roadway wearing surface is formed by a two inch excess of concrete which is built as a part of the floor slab. A mixture of 1 cement, 2 sand and 4 broken stone was used throughout the structure and the finish obtained by floating the green concrete with water, immediately after removing the forms, and rubbing with wire brushes.

In designing the bridge a ratio of elasticity of 15 was assumed and the concrete was figured at 600 pounds per square inch fiber stress, 500 pounds per square inch compression, and 50 pounds per square inch shear, while the steel was given a tensile stress of 16,000 pounds per square inch and a compressive stress of 7,500 pounds per square inch.



BILL OF MATERIAL

STEEL {CORRUGATED OR COLD TWISTED}

| NO | SIZE | LENGTH | LOCATION | MARK | NO. OF UNITS | NO. PER UNIT |
|---|---|---|---|---|---|---|
| 335 | ½" | 22'-0" | Slab | "A" | | |
| 64 | ¾" | 29'-9" | " (Temp.) | "B" | | |
| 66 | ½" | 24'-0" | Inter Pier (Hor.) | "C" | | |
| 52 | ¾" | 29'-6" | " " (Vert.) | "D" | 26 | 2 |
| 54 | 1" | 40'-2" | Floor Beam | "E" | 3 | 18 |
| 54 | 1" | 40'-9" | " " | "F" | 3 | 18 |
| 216 | ⅜" | 6'-6" | " " Stirrups | "G" | 12 | 18 |
| 28 | ¾" | 14'-0" | Wing Wall | "H" | 2 | 14 |
| 28 | ¾" | 16'-0" | " " | "I" | 2 | 14 |
| 144 | ½" | 5'-6" | Posts | "J" | 4 | 36 |
| 72 | ¾" | 7'-0" | Brackets | "K" | 18 | 4 |
| 26 | ¾" | 10'-0" | Abutments | "L" | 2 | 13 |

CONCRETE

| LOCATION | QUANTITY | CLASS | TOTAL |
|---|---|---|---|
| Slab & F Beam | 185 Cu yds | A | 185 Cu. yds |
| Inter. Piers | 90 " " | B | |
| Wing Walls | 24 " " | B | 114 " " |
| End Abuts. | 90 " " | C | 90 " " |
| | | TOTAL - | 389 Cu yds |

FIG. 23.—HALF ELEVATION, HALF SECTION, OVERHEAD HIGHWAY BRIDGE, NO. 19.31, D., L. & W. R. R.

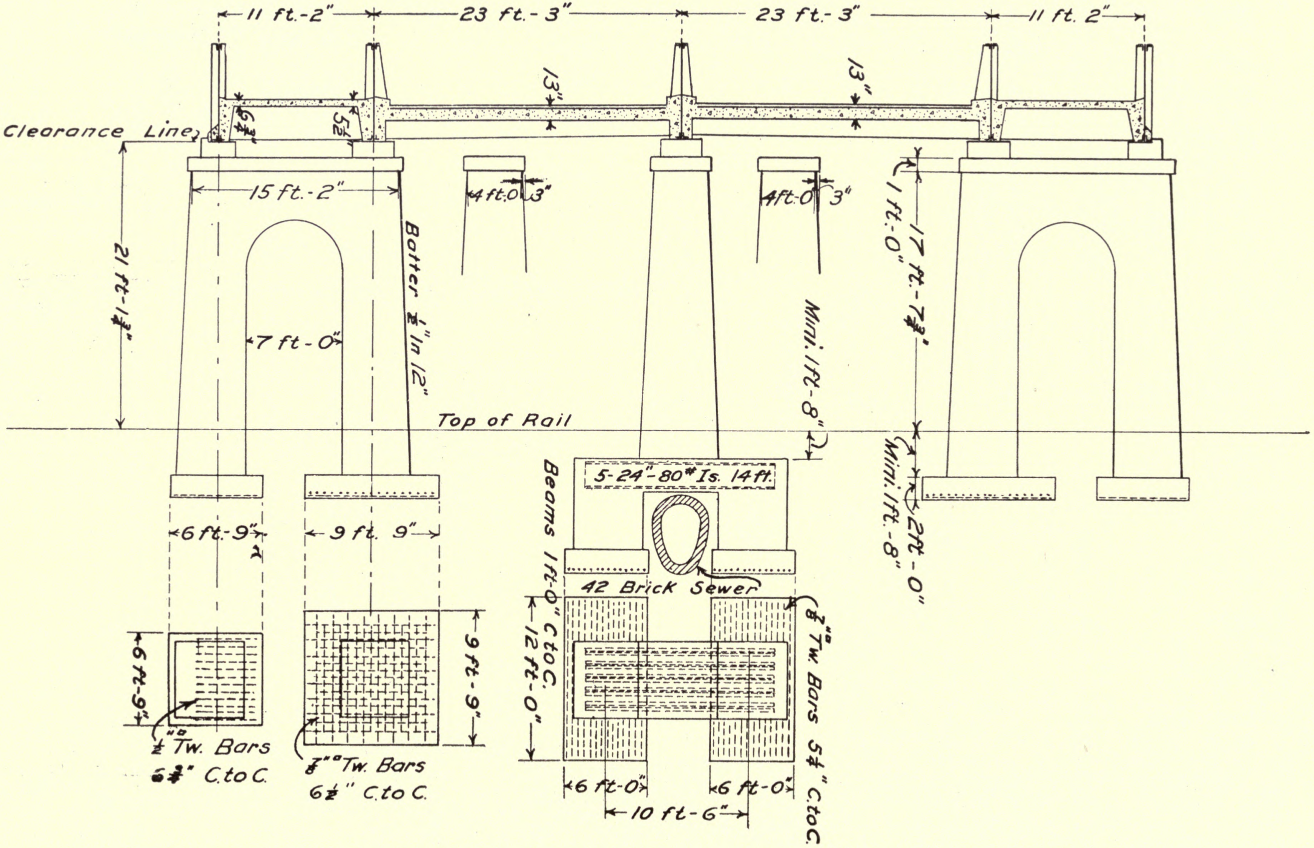


FIG.—24. CROSS SECTION, FIRST AVENUE VIADUCT, L. I. R. R.

The bridge, which was constructed in 1909, was designed by the engineering department of the Delaware, Lackawanna and Western R. R., under the supervision of Mr. Lincoln Bush, Chief Engineer, with Mr. B. H. Davis, Assistant Engineer, in charge of masonry design, and F. L. Wheaton, Engineer of Construction, in charge of work in the field.

FIRST AVENUE VIADUCT, L. I. R. R.—This viaduct, 788 feet long, carries First Avenue over the tracks of the Long Island Railroad at Bay Ridge, Long Island. It is 68 feet 10 inches wide, and, as will be seen from Fig. 24, showing a cross section of the viaduct, is divided by the main girders into two roadways 23 feet 3 inches wide and two sidewalks 11 feet 2 inches wide.

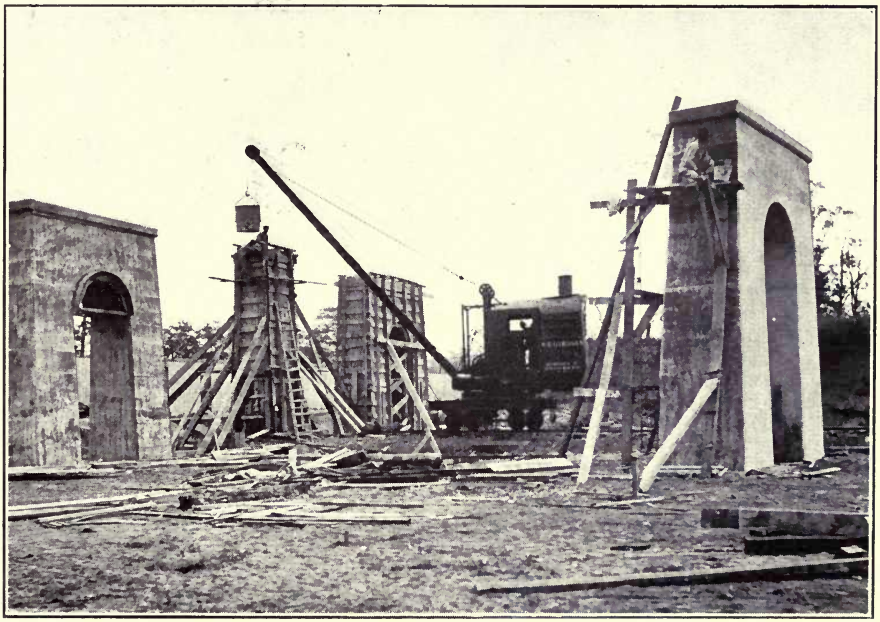


FIG. 25.—FILLING PIER FORMS, FIRST AVENUE VIADUCT.

The main girders, which are supported for about half the viaduct on concrete piers, and the remainder of the distance on steel columns and girders, are riveted steel plate girders encased in concrete to a level a little above the roadway and sidewalk. The drawings in Fig. 24 show the manner in which these girders are encased, with details of the bolster protection, and the photograph in Fig. 26 gives a view of the encased girders from below. Fig. 24, mentioned above, gives the general dimensions and essential features of design

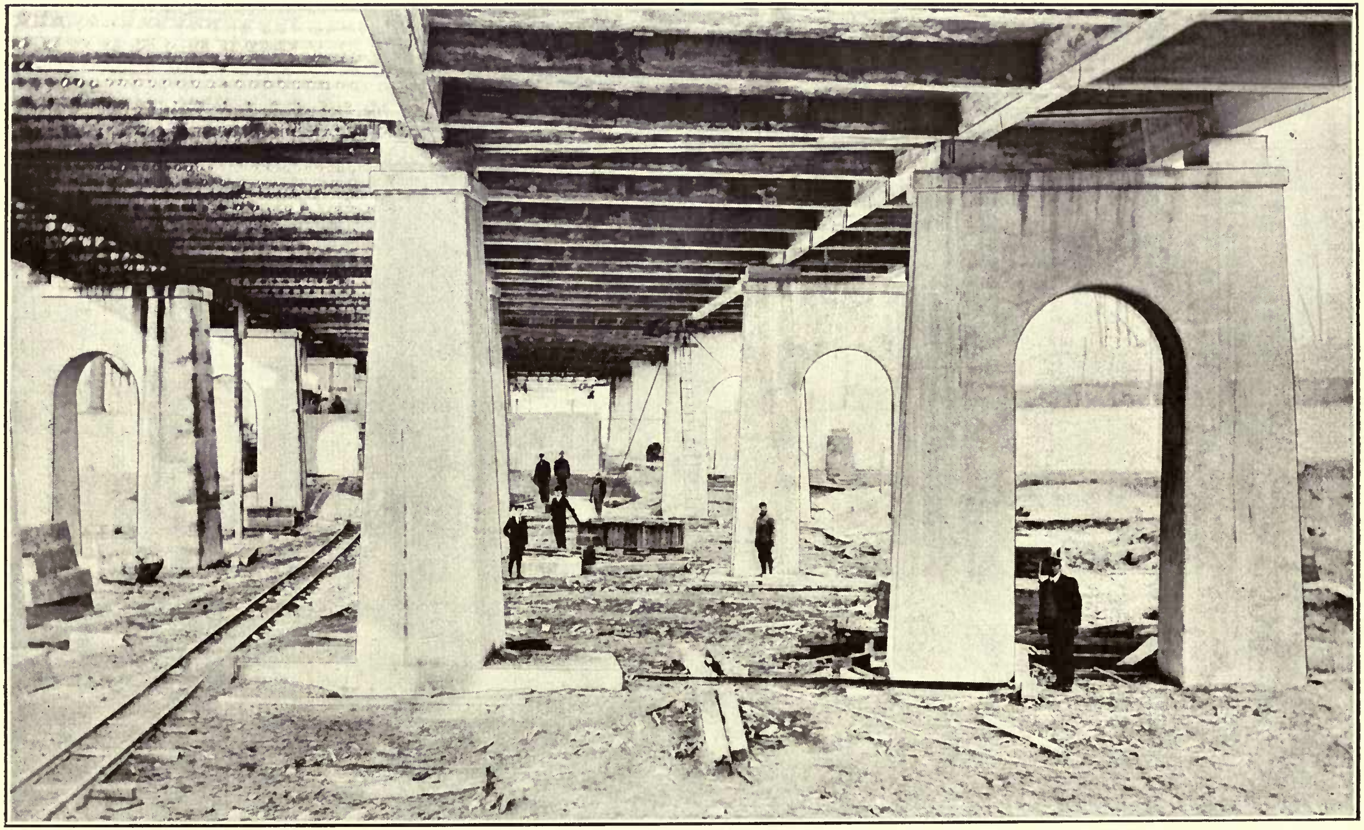


FIG. 26.—STEEL GIRDERS ENCASED IN CONCRETE, FIRST AVENUE VIADUCT, L. I. R. R.

of the piers and footings, while the photograph in Fig. 25 is a view taken of them during construction and shows the forms in place and the method of depositing the concrete.

The floor system, the details of which are shown in Fig. 27 (see below), consists of 24 inch 80 pound I-cross beams, 11 feet on centers, entirely encased in concrete, carrying a reinforced concrete floor slab. Twisted rods are used as reinforcement.

The concrete for the piers was mixed in the proportions of 1 part Atlas Portland Cement to 3 parts sand to 5 parts 1½ inch broken stone, and for the other parts of the structure, in the proportions of 1:2:4 with ¾ inch broken stone.

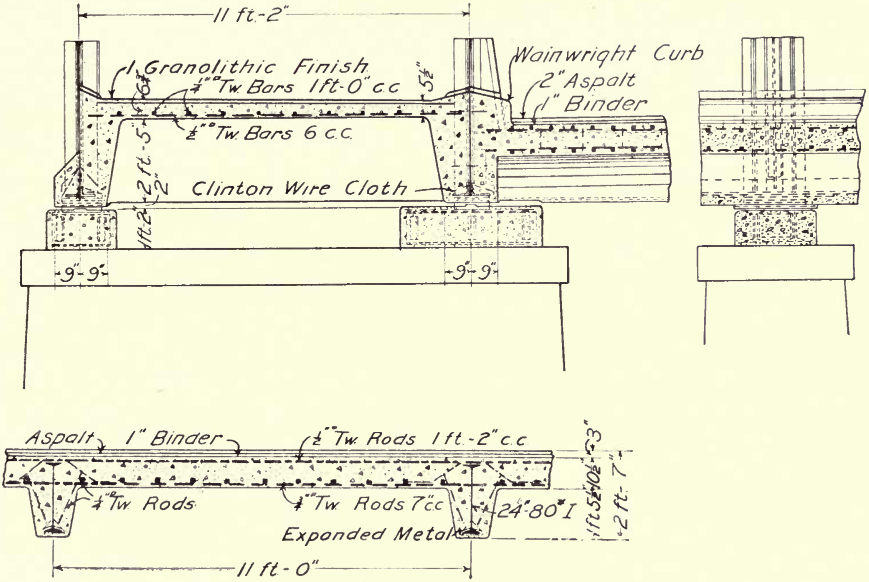


FIG. 27.—DETAILS OF FLOOR CONSTRUCTION, FIRST AVENUE VIADUCT.

Before the concrete of the sidewalk slabs had time to set, a granolithic finish 1 inch thick consisting of 1 part cement to 2 parts trap rock screenings was applied and worked until it became an integral part of the concrete and had a dense and smooth surface.

The pavement for the roadways consists of a 1-inch binder course with a 2-inch wearing surface of asphalt.

By using hangers suspended from the bottom flanges of the cross beams, the forms for the floor slabs and haunches around the bottom flanges of the steel beams were supported without the use of shoring. Fig. 28 shows this method of construction in detail.

The forms for both piers and floors were treated with car journal oil. Immediately after removing the pier forms, which was on an average about 48 hours after filling, the green concrete was floated with water and rubbed by carborundum bricks.

The construction plant consisted of a 5-ton locomotive crane, a ½ cubic yard mixer, two 24-inch gauge cars carrying two ¼ cubic yard buckets and ordinary iron barrows.

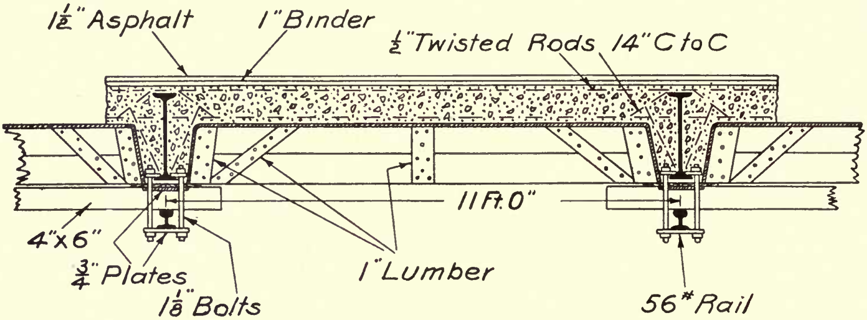


FIG. 28.—FORMS FOR FLOOR SLABS.

The viaduct was designed by the engineering department of the Bay Ridge Improvement Company under the supervision of Mr. L. V. Morris, Chief Engineer, and the concrete work was done by W. H. Gahagan, contracting engineer, of Brooklyn, N. Y., during the fall of 1908 and the winter and spring of 1909.

## BRIDGE FLOORS.

Since railroad engineers came to the conclusion a few years ago that the most satisfactory form of bridge floor was a ballasted solid floor, a great many types of wooden and steel floors have been tried. The best of these floors have been very expensive, and while satisfactory for a limited time have proved comparatively short lived.

A number of railroads throughout the country have designed bridge floors, using reinforced concrete in the form of a slab, that have given absolute satisfaction. The reinforced concrete slab usually rests either directly upon the top flange of the girders when used for a deck bridge, or upon floor beams and girders when used on a through bridge. Both types are illustrated, the former by Fig. 29, and the latter by Fig. 31.

A reinforced concrete bridge floor of considerable proportions,—being in reality a railway yard supported on plate girders—which has given marked satisfaction during the period it has been under traffic, is described on page 62.

C., B. & Q. R. R. BRIDGE FLOORS.—Fig. 29 shows the cross section, including construction forms, of a reinforced slab of trough section used by the Chicago, Burlington & Quincy R. R. for deck bridges. The photograph in Fig. 30 shows a typical deck bridge floor.

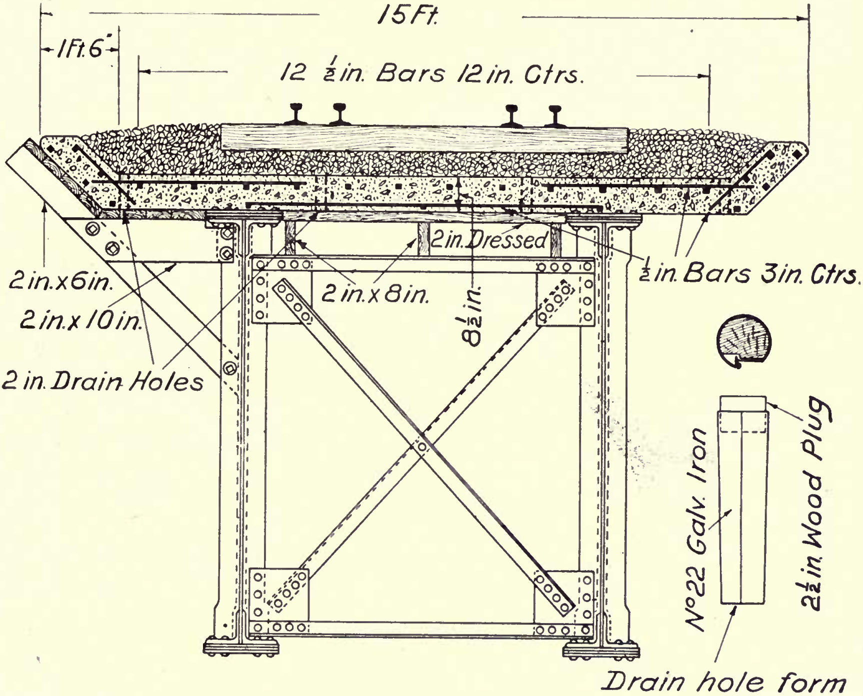


FIG. 29.—CROSS SECTION, DECK GIRDER BRIDGE FLOOR, C., B. & Q. R. R.

The concrete slab, which is 8½ inches thick, has the outer edges inclined upward at an angle of 30 degrees to make flanges 9 inches deep which retain the standard ballast, the cross ties being placed in the usual manner.

Before putting in the ballast, the top of the deck is painted with tar paint composed of one part oil, four parts cement and sixteen parts tar. Drip pipes are placed in such a position as to keep the drip clear of the iron structure.

As will be seen from the cross section in Fig. 29, the top lateral system and the top angles of the sway brace frames are lowered clear of the top flange angles of the girders to allow the forms for the concrete to be set with greater ease and to be supported on the transverse frames and lateral angles. The outstanding flanges of the vertical web stiffener angles in the girders are punched for connecting bolts to the 2 by 6 inch knee braces of the concrete forms.

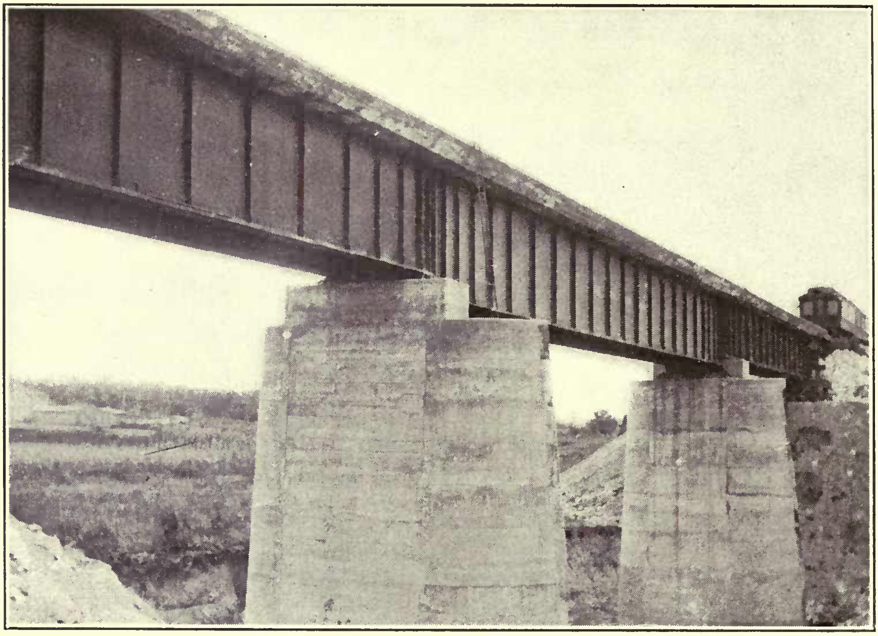


FIG. 30.—DECK GIRDER BRIDGE FLOOR, C., B. & Q. R. R.

Fig. 31 shows a typical floor of a through-girder bridge. The reinforced slab rests upon the floor beams and extends up to form curb walls against the girder, enclosing the gusset plates. The slab is 4½ inches thick and is reinforced transversely with ½-inch corrugated bars 6 inches apart and longitudinally with ½-inch bars 1 foot apart. These floors are designed by the engineering department of the railroad under the supervision of Mr. C. H. Cartlidge, Bridge Engineer.

REINFORCED CONCRETE BRIDGE FLOORS, D., L. & W. R. R.—This mammoth bridge floor, 81 by 349 feet, containing 26,269 square feet of floor space is shown in detail in Fig. 33. The concrete is mixed in the pro-

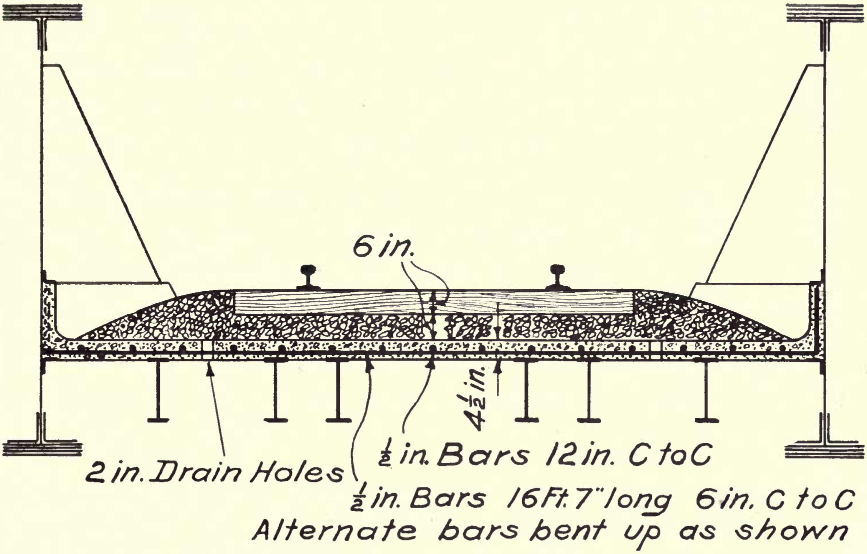


FIG. 31.—CROSS SECTION, THROUGH-GIRDER BRIDGE FLOOR, C., B. & Q. R. R.

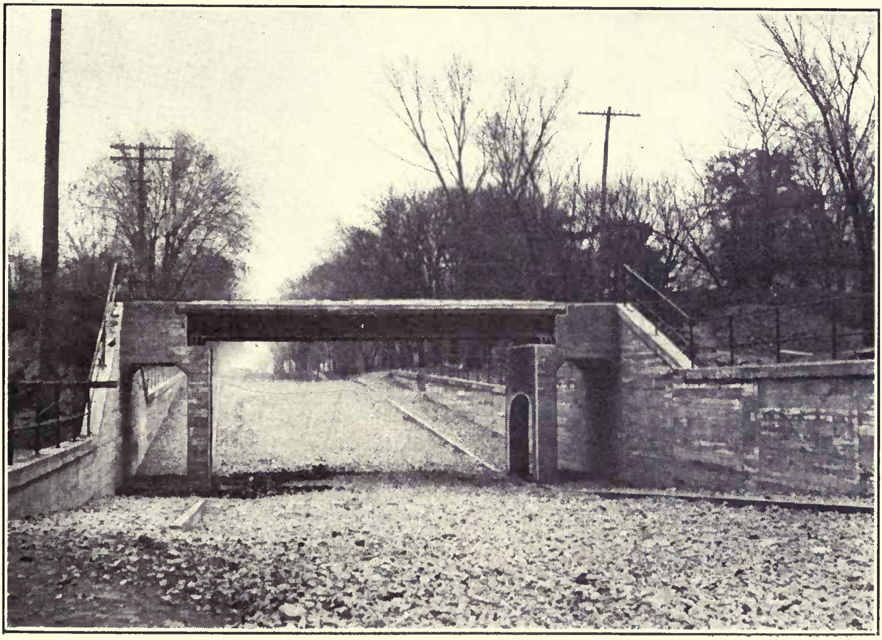


FIG. 32.—DECK GIRDER BRIDGE FLOOR, C., B. & Q. R. R.

portions of 1 part Portland cement, 2 parts clean sharp sand and 4 parts 1½ inch broken stone. The top layer, which acts as waterproofing, consists of a 1-inch coating of mortar composed of 1 part Portland cement to 2½ parts sand troweled smooth on top. After this layer had thoroughly set the entire surface was given a heavy coat of pure cement grout.

The floor slab is designed so that switches and cross overs may be made anywhere.

In the construction of the floor, it was found that the economy involved as to material and labor resulted in a saving of from 30 to 40 per cent from the cost of steel channel floor for the same purpose. A square 10 ft. by 10 ft. contains 3,704 cubic yards of concrete and 718.4 pounds of steel, while a standard channel floor composed of 15-inch channels protected by 4 inches of concrete would contain 1,234 cubic yards of concrete and 2,640 pounds of steel.

This floor was designed by the engineering department of the railroad under the supervision of Mr. Lincoln Bush, chief engineer, and Mr. B. H. Davis, assistant engineer in charge of masonry design.

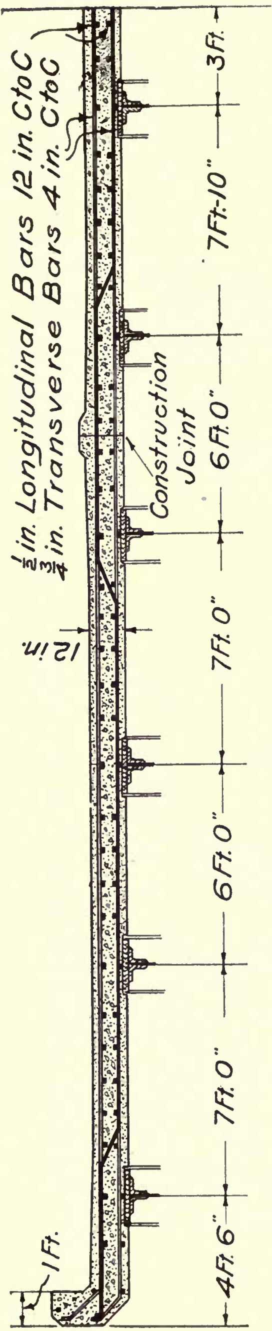


FIG. 33.—HALF-SECTION, BRIDGE FLOOR, D., L. & W. R. R.

# CHAPTER IV.

## CULVERTS.

Concrete is used to advantage in the construction of all classes of culverts from the small pipe to the large reinforced arch and box types.

On account of its greater simplicity and the less expensive abutments required, the reinforced flat top culvert, with abutments of reinforced concrete, is more economical for short spans than the arch type.

The variation in the designs of the different railroads, together with the fact that none appears entirely satisfactory, has led to the making of special designs for this book. The drawing in Fig. 35 with the accompanying original table give the requisite dimensions for reinforced culverts of 4, 6, 8, 10, 12, 14, 16, 18 and 20 foot spans.

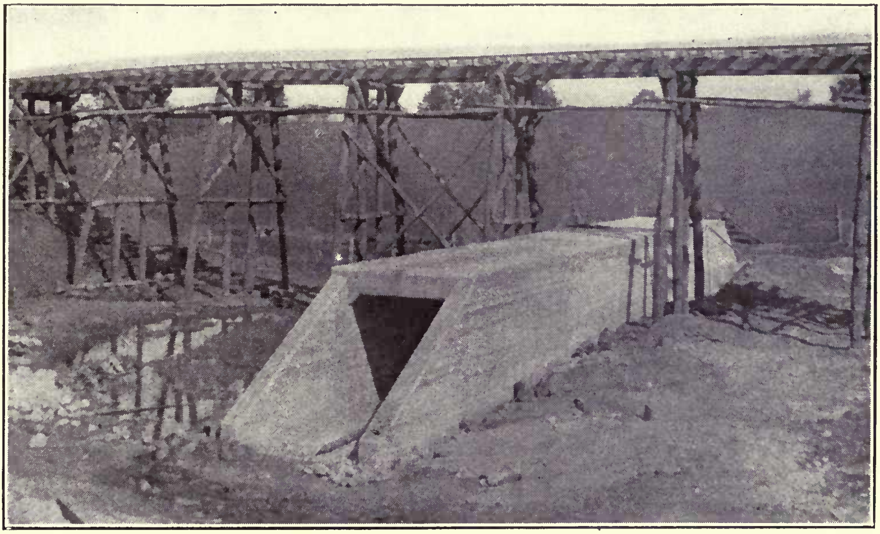


FIG. 34.—5 FT. x 7 FT. BOX CULVERT, C., B. & Q. R. R.

As an aid to the design of concrete arch culverts, without reinforcement, a committee of the American Railway Engineering and Maintenance of Way Association submitted to that association in 1908 a composite design embodying a combination of details of construction of plain concrete-arch culverts with the necessary dimensions, selected from the standards of railroads in the United States and Canada, and for this data the reader is referred to Bulletin No. 105 of that Society.

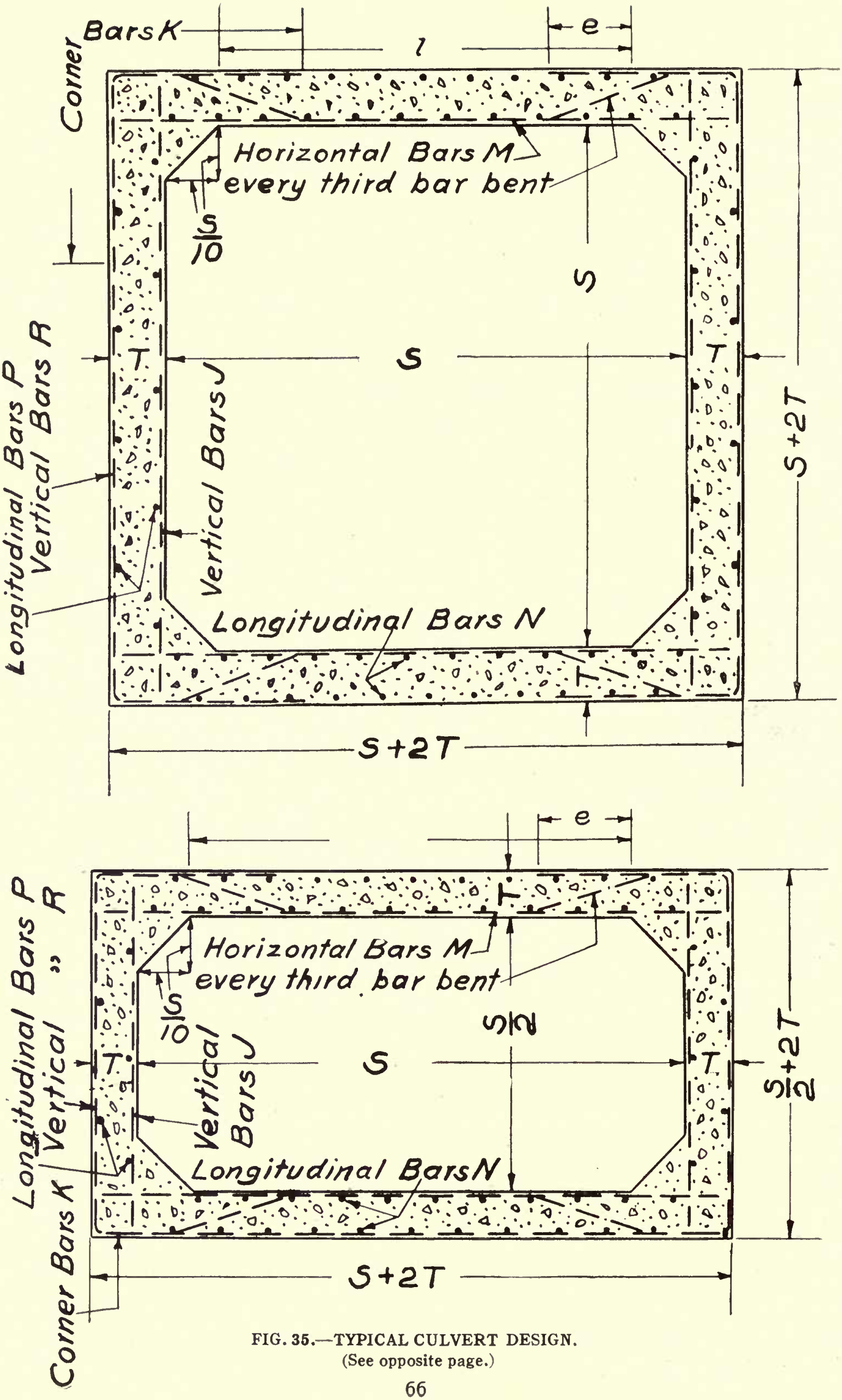


FIG. 35.—TYPICAL CULVERT DESIGN.
(See opposite page.)

## DIMENSIONS AND REINFORCEMENT FOR BOX CULVERTS

### Square Culverts

| Item | Span | Thickness of Wall | Horizontal Walls | | | | | | | Vertical Walls | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Horizontal Bars M | | Corner Bars K | | | Longitudinal Bars N | | Vertical Bars R | | Vertical Bars J | | Longitudinal Bars P | |
| | S | T | Size | Spacing | Size | Spacing | L'gth e | Size | Spacing | Size | Spacing | Size | Spacing | Size | Spacing |
| | ft. | in. | in. | in. | in. | in. | in. | in. | in. | in. | in. | in. | in. | in. | in. |
| 1 | 4 | 8 | ½ | 6 | ½ | 12 | At least 50 diam. for plain and 36 diam. for deformed bars. | ½ | 18 | ½ | 24 | ⅜ | 6 | ½ | 24 |
| 2 | 6 | 8½ | ¾ | 8 | ¾ | 16 | | ½ | 18 | ¾ | 32 | ½ | 8 | ½ | 24 |
| 3 | 8 | 10½ | ¾ | 6 | ¾ | 12 | | ½ | 16 | ¾ | 24 | ½ | 6 | ½ | 24 |
| 4 | 10 | 12½ | ⅞ | 7 | ⅞ | 14 | | ½ | 16 | ⅞ | 28 | ½ | 7 | ½ | 20 |
| 5 | 12 | 14½ | ⅞ | 6 | ⅞ | 12 | | ½ | 14 | ⅞ | 24 | ⅝ | 12 | ½ | 20 |
| 6 | 14 | 17½ | 1 | 6¼ | 1 | 12 | | ½ | 14 | 1 | 24 | ¾ | 11 | ½ | 20 |
| 7 | 16 | 19½ | 1 | 5¾ | 1 | 11½ | | ½ | 14 | 1 | 23 | ⅞ | 11½ | ½ | 16 |
| 8 | 18 | 21½ | 1⅛ | 6½ | 1⅛ | 13 | | ½ | 12 | 1 | 26 | 1⅛ | 13 | ½ | 16 |
| 9 | 20 | 23½ | 1⅛ | 5½ | 1⅛ | 11 | | ½ | 12 | 1 | 22 | 1⅛ | 11 | ½ | 16 |

### Oblong Culverts

| Item | Span | Thickness of Walls | Horizontal Walls | | | | | | | VerticalWalls | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Horizontal Bars M | | Corner Bars K | | | Longitudinal Bars N | | Vertical Bars R | | Vertical Bars J | | Longitudinal Bars P | |
| | S | T | Size | Spacing | Size | Spacing | L'gth e | Size | Spacing | Size | Spacing | Size | Spacing | Size | Spacing |
| | ft. | in. | in. | in. | in. | in. | in. | in. | in. | in. | in. | in. | in. | in. | in. |
| 2 | 6 | 8 | ¾ | 9½ | ¾ | 12 | At least 50 diam. for plain and 36 diam. for deformed bars. | ½ | 18 | ¾ | 12 | ⅜ | 12 | ½ | 24 |
| 3 | 8 | 10 | ¾ | 6½ | ¾ | 13 | | ½ | 18 | ¾ | 13 | ½ | 22 | ½ | 24 |
| 4 | 10 | 11½ | ¾ | 5¾ | ¾ | 7¼ | | ½ | 16 | ¾ | 7¼ | ½ | 20 | ½ | 20 |
| 5 | 12 | 13½ | ⅞ | 6½ | ⅞ | 8¼ | | ½ | 16 | ⅞ | 8¼ | ½ | 18 | ½ | 20 |
| 6 | 14 | 16 | 1 | 7 | 1 | 9 | | ½ | 14 | 1 | 9 | ½ | 16 | ½ | 20 |
| 7 | 16 | 17½ | 1 | 6¼ | 1 | 8 | | ½ | 14 | 1 | 8 | ½ | 14 | ½ | 16 |
| 8 | 18 | 19½ | 1 | 5½ | 1 | 7¼ | | ½ | 12 | 1 | 7¼ | ½ | 12 | ½ | 16 |
| 9 | 20 | 21½ | 1 | 5 | 1 | 6½ | | ½ | 12 | 1 | 6½ | ½ | 10 | ½ | 16 |

NOTE—The culverts are designed for following stresses:

Compression in concrete, **650** lb. per sq. in. · Tension in steel, **16,000** lb. per sq. in. The weight of earth is taken as **100** lb. per cu. ft. The live load is based on Cooper's standard loading, E 40. The effect of vibration is provided for by increasing the moments due to dead load **50** per cent. All bars are figured as round

DIMENSION AND REINFORCEMENT FOR CULVERTS FROM 4 TO 20 SPAN.
(See Fig. 35, page 66).

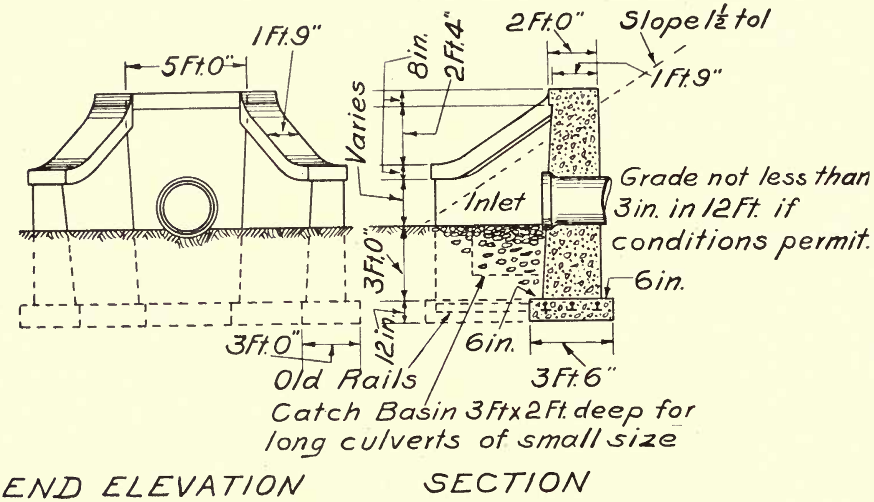


FIG. 36.—STANDARD PIPE CULVERT, WING TYPE, N. Y. C. & H. R. R. R.

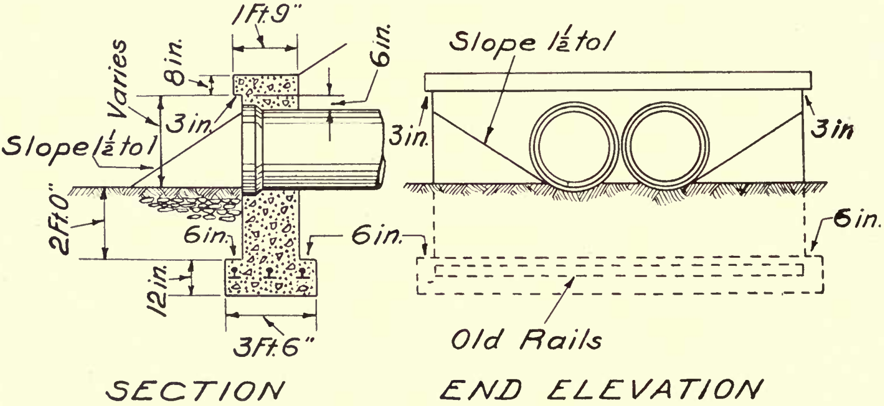


FIG. 37.—STANDARD PIPE CULVERT, STRAIGHT TYPE, N. Y. C. & H. R. R. R.

STANDARD PIPE CULVERTS, N. Y. C. & H. R. R. R.—Fig. 36 shows the standard pipe culvert of the wing type and Fig. 37 the standard pipe culvert of the straight type of the New York Central & Hudson River Railroad. In both types the footings of the end walls are composed of 1:4:7½ concrete, the main body of the walls of 1:3:6 concrete, while the copings are mixed in the proportions of 1:2:4.

STANDARD 3-FOOT ARCH CULVERT, D., L. & W. R. R.—In Fig. 38 is shown a cross-section of the standard 3-foot semicircular arch culvert for 75-feet fills on the Delaware, Lackawanna & Western Railroad. As will be seen from the cross-section, the invert is reinforced with ¾-inch bars, 12 inches on centers transversely, and 2 feet on centers longitudinally, while the arch itself is reinforced in a longitudinal direction with ¾-inch bars 18 inches on centers. In case rock or shale is found, the invert reinforcement is left out, and the concrete in the invert reduced to a thickness of one foot throughout. In the body of the culvert there are 0.628 cubic yards of 1:2:4 concrete per linear foot.

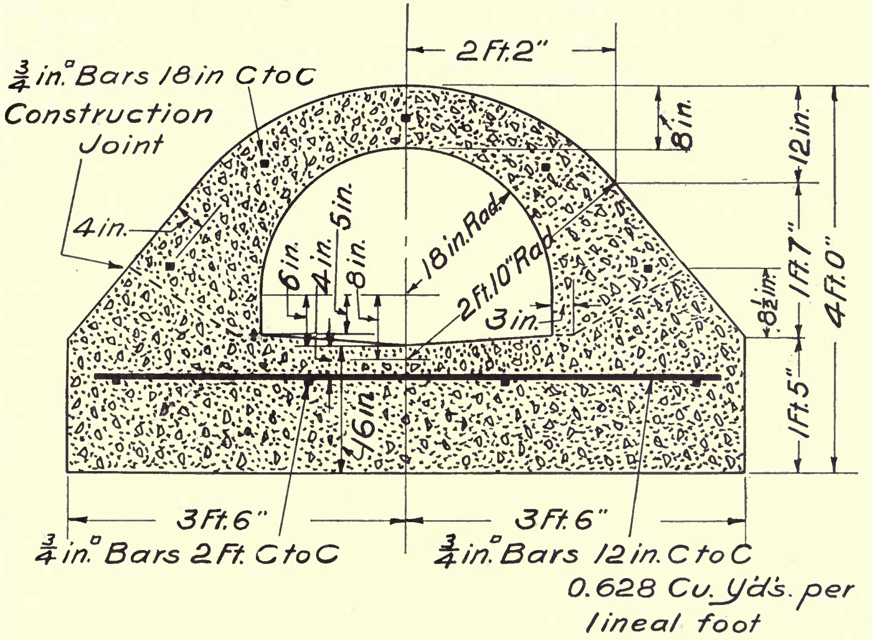


FIG. 38.—CROSS SECTION, 3-FOOT CULVERT, D., L. & W. R. R.

INDIAN CREEK CULVERT, K. C., M. & O. RY.—The drawings in Figs. 39 and 40 give the essential features of design and construction, while the photographs in Figs. 41 and 42 show the finished culvert before and after filling. As will be seen from the drawings, this is a reinforced box culvert 14 by 15 feet and about 250 feet long. An interesting feature in the design of the culvert is the use of reinforced struts spaced 8 feet on centers instead of a solid concrete invert.

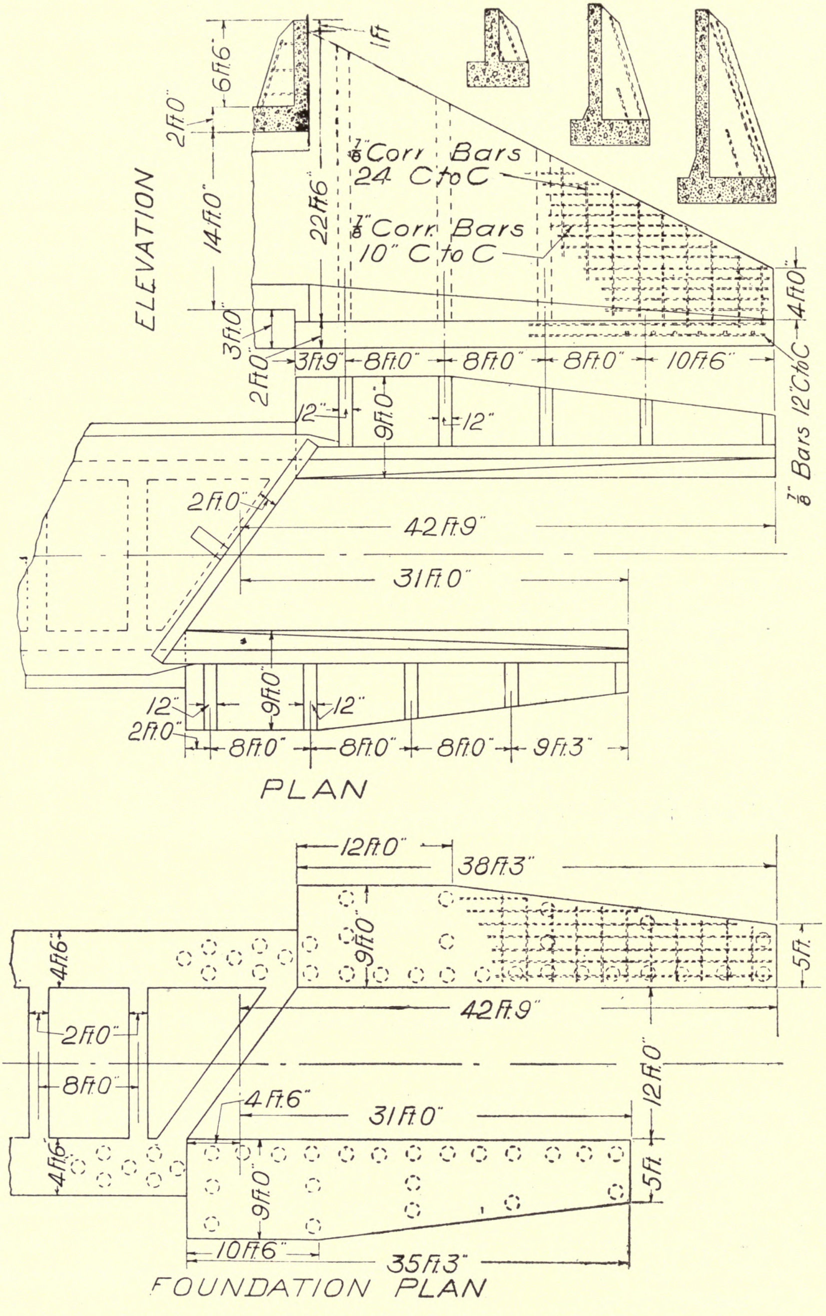


FIG. 39.—PLAN AND ELEVATION, INDIAN CREEK CULVERT.

In the construction of the culvert, the concrete was mixed in the proportions of 1 part cement to 3 parts Kansas River sand to 5 parts crushed limestone, passing a 2-inch ring and freed from dust by screening. The mixing was done by a No. 1 Rotary mixer. The forms were constructed of 1-inch lumber with 2 by 6-inch studs 12 inches on centers. All excavation and pile-driving was performed and the reinforcing bars furnished by the railroad company, who also bore one-half the cost of keeping the foundations dry while the forms were being built and the concrete placed.

The following figures* give the unit cost to the contractor and the unit cost to the railroad company, who let the contract on the basis of $9.00 per cubic yard. The costs given covered all labor and materials necessary other than the exceptions mentioned above:

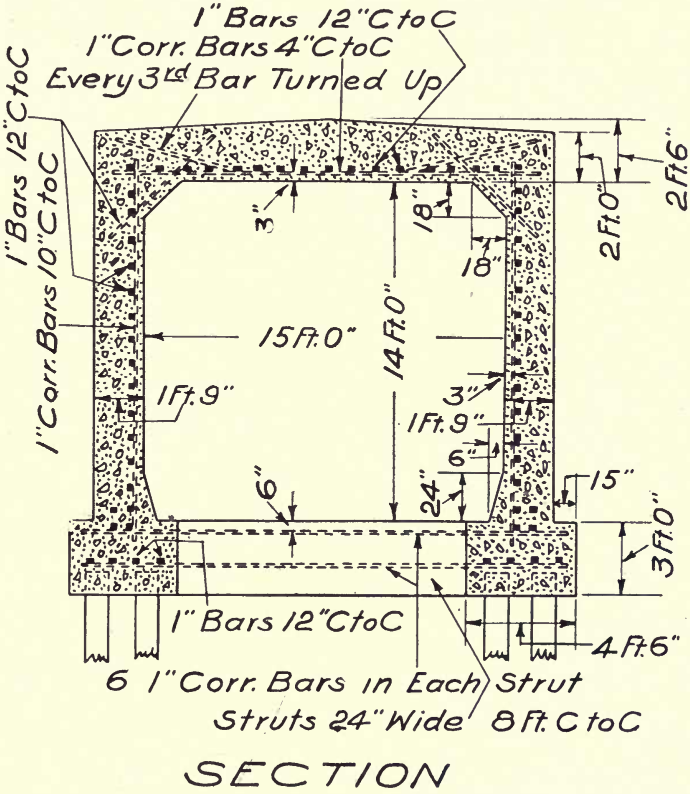


FIG. 40.—CROSS SECTION, INDIAN CREEK CULVERT.

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*W. W. Colpitts in "Railway Age," Aug 2, 1907, p. 143.

Unit Cost to Contractor.

| | | |
|---|---|---|
| Cement | $1.37 | per cubic yard of concrete |
| Sand | 0.34 | " " " " " |
| Stone | 1.10 | " " " " " |
| Labor | 2.48 | " " " " " |
| Lumber | 0.76 | " " " " " |
| Miscellaneous | 0.18 | " " " " " |
| | $6.23 | |

Unit cost to Railroad.

| | | |
|---|---|---|
| Excavation, pumping, etc | $1.84 | per cubic yard of concrete |
| Piles (389) 8,647 linear ft | 2.71 | " " " " " |
| Reinforcing bars, 113,600 lb | 2.56 | " " " " " |
| | $7.11 | |

Total unit net cost, not including profit.................... $13.34 per cubic yard

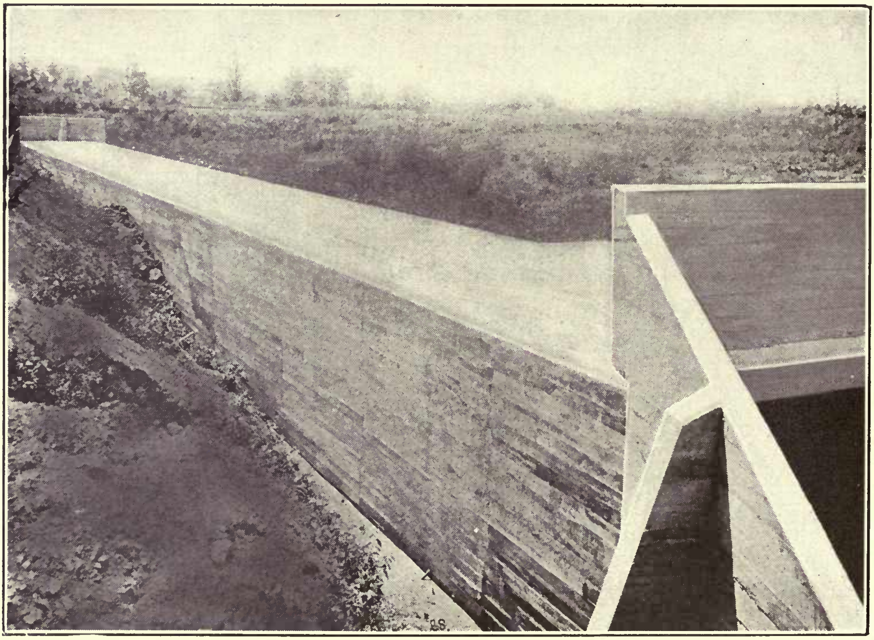


FIG. 41.—INDIAN CREEK CULVERT BEFORE FILLING.

The culvert was designed by Mr. W. W. Colpitts, Assistant Chief Engineer of the Kansas City, Mexico & Orient Railway, and was built by Mr. L. J. Smith, General Contractor, of Kansas City, in the fall of 1905.

FIG. 42.—INDIAN CREEK CULVERT, K. C., M. & O. RY.

EIGHTEEN FOOT ARCH CULVERT, BANGOR & AROOSTOOK R. R.—The drawing in Fig. 43 and the photograph in Fig. 44, page 74, are of an 18-foot arch culvert on the Bangor & Aroostook R. R., of very simple and at the same time artistic lines. An interesting feature of the design of this culvert is the method employed to protect the soil under the culvert from wash or undertow. This is done by extending the paving, which is of concrete with a minimum thickness of one foot, to the ends of the wing walls, where it makes a vertically downward return to the depth of the bottom of the foundation 5 feet below the bed of the stream or top of paving.

The concrete was mixed in the proportions of one part Atlas Portland Cement to 3 parts sand to 6 parts gravel, and cost, everything included, \$6.42½ per cubic yard.

The culvert was designed and constructed by the engineering department of the Bangor & Aroostook Railroad in 1904 under the supervision of Mr. Moses Burpee, Chief Engineer.

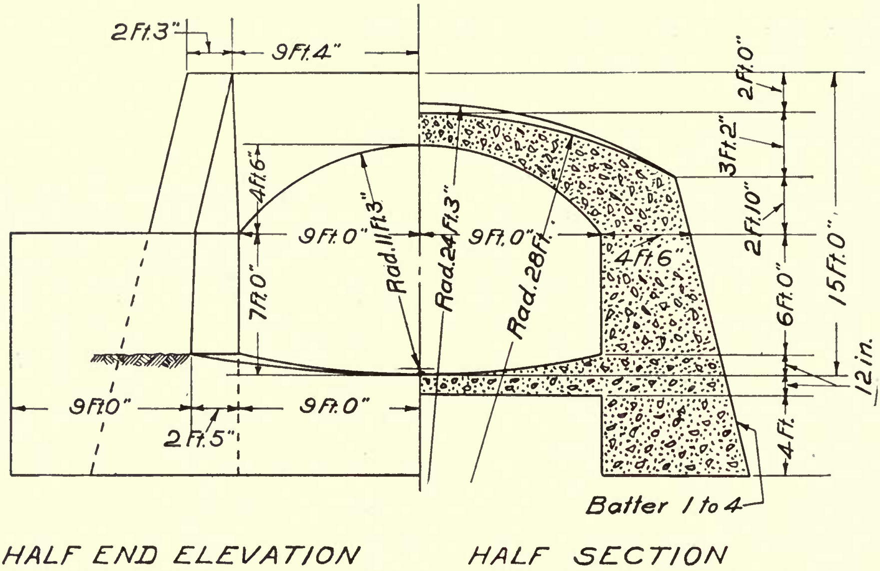


FIG. 43.—CROSS SECTION OF 18-FT. CULVERT, BANGOR & AROOSTOOK R. R.

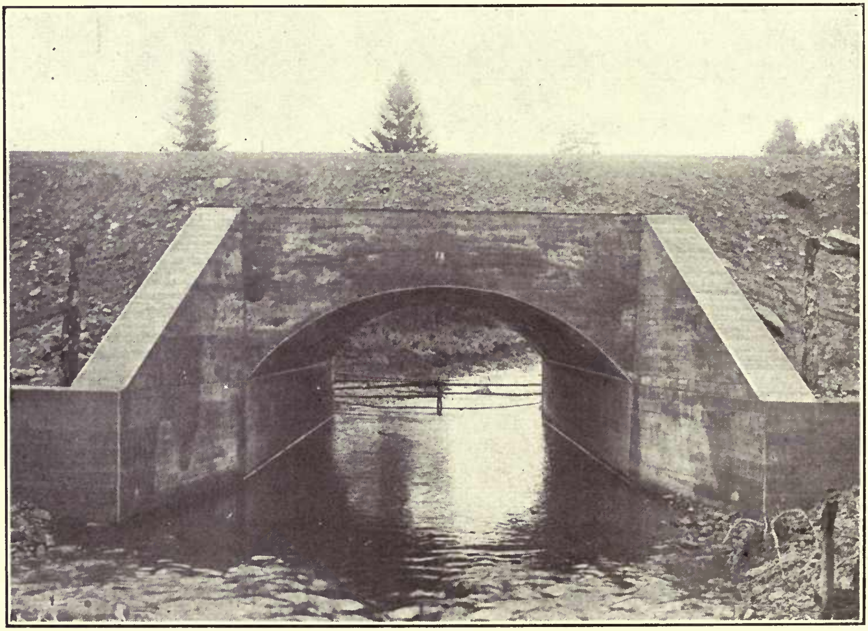


FIG. 44.—EIGHTEEN FOOT CULVERT, BANGOR & AROOSTOOK R. R.

THIRTY FOOT CULVERT, C., M. & ST. P. RY.—This culvert, which is shown by the photograph in Fig. 45, is of interest owing to the fact that it serves as a footing for trestle bents as well as a culvert. As will be seen from the accompanying picture, footings are built upon the back of the arch on which two of the trestle bents rest. The culvert, which is near Farson, Iowa, was designed and built by the Engineering Department of the Chicago, Milwaukee and St. Paul Railway, under the supervision of Mr. C. F. Loweth, Engineer and Superintendent of Bridges and Buildings, in 1908.

FIG. 45.—THIRTY FOOT CULVERT, C., M. & ST. P. RY.

HORSESHOE CULVERT.—The photograph in Fig. 46, page 76, is of special interest, as it shows a rather unique and very efficient form of heading for culverts where the slope of the embankment is not particularly steep. Instead of perpendicular end walls, a horseshoe heading is formed by cutting the barrel of the culvert to conform to the slope of the fill and by forming a shoulder over the crown to hold the toe of the slope. The culvert is at Runnells, Iowa, and was designed and built by the N. M. Stark Bridge Company of Des Moines, Iowa.

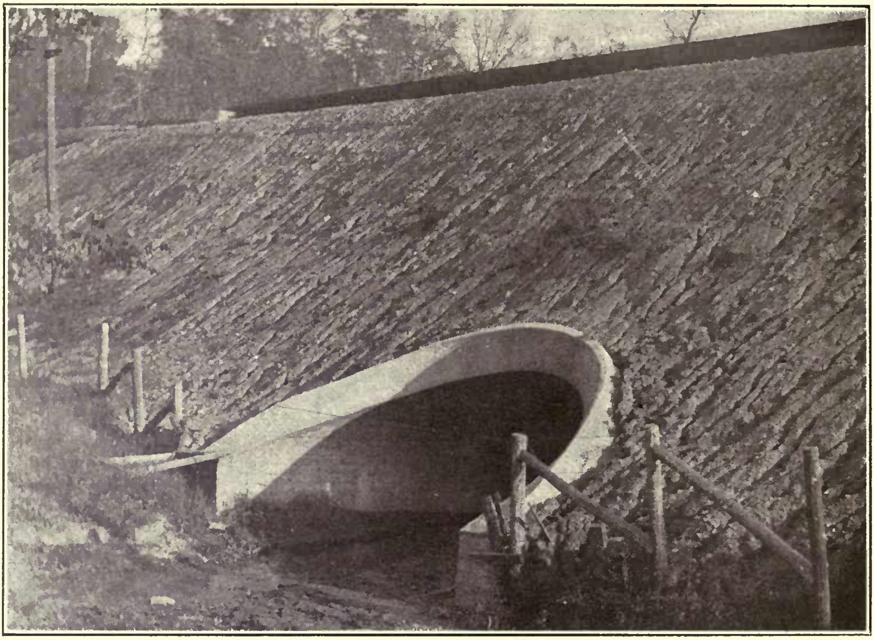


FIG. 46.—HORSESHOE CULVERT, RUNNELLS, IOWA.

FIG. 47.—DOUBLE ARCH CULVERTS, ILL. CENTRAL R. R.

# CHAPTER V.

## PIERS AND ABUTMENTS.

### PIERS.

Concrete is employed for bridge piers either as filling for ashlar or cut masonry, or for the entire pier, in which case it may be of either plain or reinforced concrete. When of plain concrete, the sizes and general proportions are practically the same as for stone piers, the quantity of masonry used for the two not differing materially. If reinforced concrete is used, there may be quite a saving of concrete with a corresponding reduction in the cost of the structure. This is obtained either by reducing the size of the pier or by using the ordinary size of pier and making it hollow with reinforced walls, in which case the open space is either filled with sand, broken stone or gravel, or if the pier is designed so that it possesses sufficient stability it is left open, thus making a considerable reduction in the load on the foundation. The

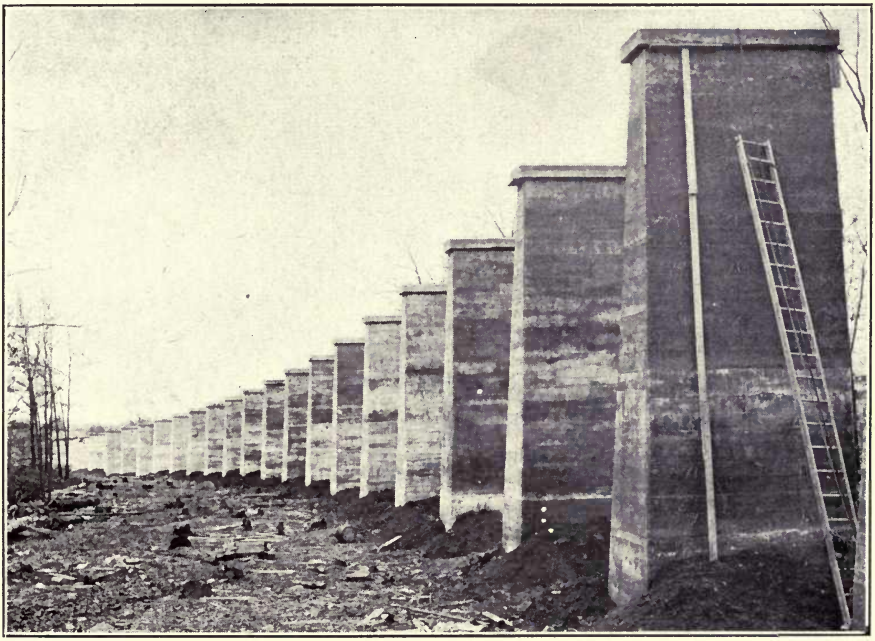


FIG. 48.—CONCRETE PIERS, PATERSON AND SUFFERN RY.

top slab forming the coping is designed strong enough to support the loads brought upon it and transmit them to the side and interior walls, which in turn carry the loads to the foundation. Fig. 52 shows the design of a typical reinforced pier.

Concrete is also used very advantageously in raising the grade of old masonry piers, as is very often necessary, an interesting example of which is described on page 79.

FIG. 49.—CONCRETE PIERS DURING ICE JAM, C. R. R. OF N. J.

STANDARD PIERS, N. Y. C. & H. R. R. R.—The standard pier of this railroad, adapted to any height up to 40 feet, is shown by the drawing in Fig. 50. The width, which is dependent upon the length of span, is as follows:

Spans up to 40 feet width, A, = 4 feet 0 inches
Spans 40 to 60 feet width, A, = 4 feet 6 inches
Spans 60 to 80 feet width, A, = 5 feet 0 inches
Spans 80 to 100 feet width, A, = 5 feet 6 inches
Spans 100 to 125 feet width, A, = 6 feet 0 inches
Spans 125 to 150 feet width, A, = 6 feet 6 inches
Spans 150 to 200 feet width, A, = 7 feet 0 inches
Spans 200 to 250 feet width, A, = 7 feet 6 inches

The foundation which is of 1:3:6 concrete, except where local conditions make stone cheaper, is varied to suit local conditions, but is not less than 4 feet deep unless good rock is found. The pier itself is constructed of 1:3:6 concrete while the coping, which is reinforced with galvanized wire netting or wire cloth is of 1:1:2 concrete, as is the starkweather cap which is two feet above high water. The charts and tables in Fig. 50 give the quantities in these standard piers.

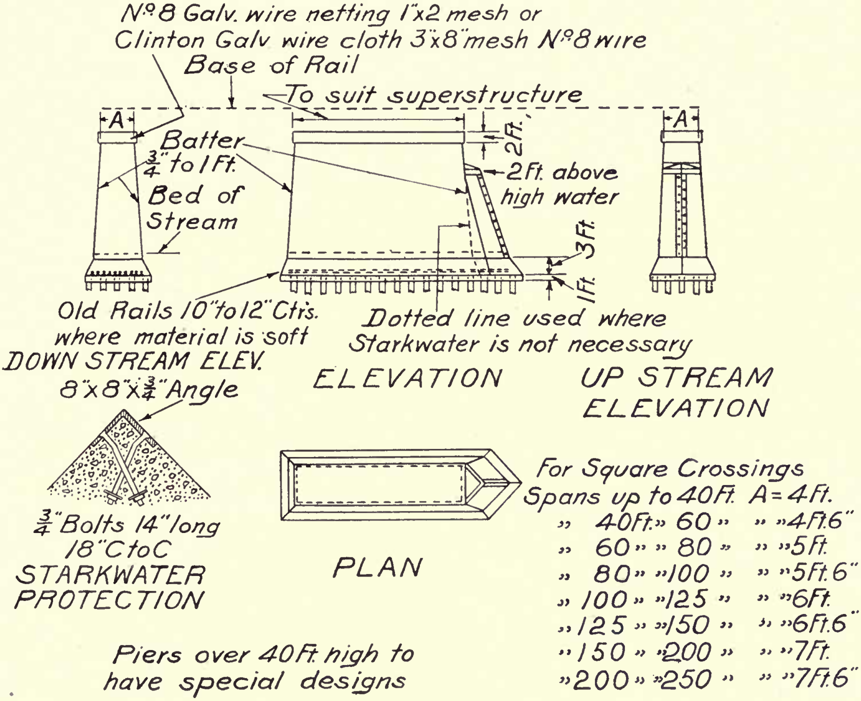


FIG. 50.—STANDARD PIER, N. Y. C. & H. R. R. R.

RAISING GRADE OF OLD MASONRY PIERS.—The photograph in Fig. 51 shows a three span plate girder bridge on the Chicago, Milwaukee and St. Paul Railway which originally rested on piers and square wing abutments of cut stone across which the grade was raised 7½ feet by means of concrete. The girders were raised to grade and the concrete built in place, the rounded ends being formed by means of steel shells held in place by rods which were left in the concrete to give additional strength to the piers. A short span was added at either end of the bridge to take the slope and a rectangular concrete pier of the proper height to bring the masonry up to grade was built on each abutment.

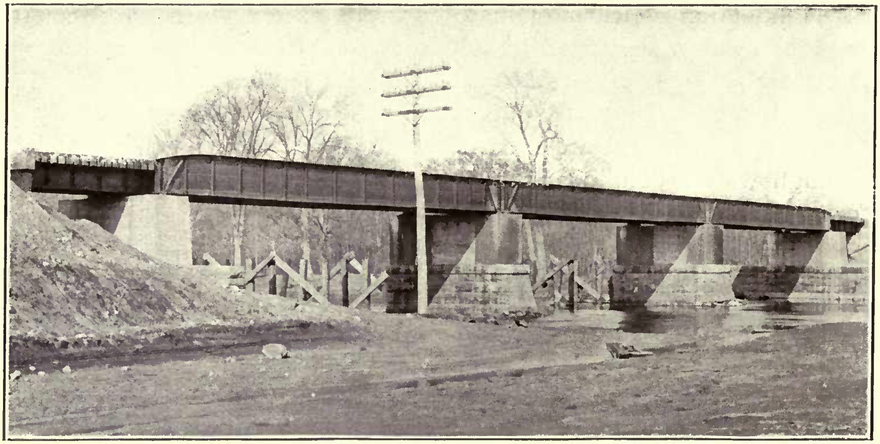
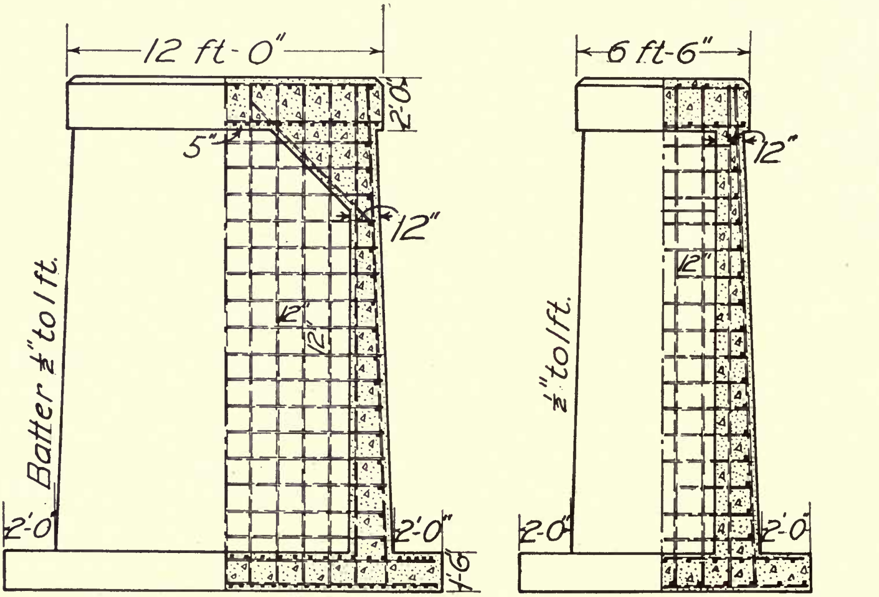


FIG. 51.—RAISING GRADE OF OLD MASONRY PIERS, C., M. & ST. P. RY.

REINFORCED PIER, K. C., M. & O. RY.—In Fig. 52 is shown the design of a standard reinforced concrete pier of the Kansas City, Mexico & Orient Ry.



FRONT ELEV & SECTION END ELEV & SEC.

FIG. 52.—STANDARD REINFORCED CONCRETE PIER, K. C., M. & O. RY.

## ABUTMENTS

PLAIN ABUTMENTS. Abutments for bridges can be designed of either plain or reinforced concrete. When plain concrete is used the general details are essentially the same as those employed for stone abutments.* The Van Cortlandt Avenue abutments on the N. Y. C. & H. R. R. R., described on page 83 and shown in plan, elevation and section in Fig. 53, are fine examples of this type, not only as to details of construction, but also on account of the architectural treatment of the design.

REINFORCED ABUTMENTS. By using reinforced concrete there is generally a considerable saving in materials which in some instances has been so great as to reduce the cost as much as 40 per cent.

The general features of design and method of reinforcing will be understood from a study of the drawings of the Third Street abutment, K. C., M. & O. Ry., shown in Fig. 56, page 85. It will be seen that the construction, with the exception of the bridge seat and supporting buttresses, closely resembles that of reinforced buttressed retaining walls described in Chapter VI.

The bridge seat consists of a heavy reinforced concrete slab extending over the tops of the supporting buttresses, thus securely knitting the structure together.

These supporting buttresses are located directly under the bridge girders, thus eliminating bending in the slab forming the bridge seat. In designing the buttresses the width must be taken at least equal to that of the bed plate.

In order to resist the overturning moment, vertical bars are placed in the back and extend through the base hooking under the horizontal bars in the bottom. A sufficient number of horizontal bars are placed in the buttresses as shown in Fig. 56, so as to transfer the total load from the face wall to the buttresses without depending upon the tensile strength of the concrete. The diagonal shear in the buttresses is taken care of by the diagonal rods which hook under the bottom bars in the rear of the base and over the longitudinal bars in the face wall.

A face wall, heavy enough to resist the earth pressure and live load transferred through the earth, is placed in front of, and constructed monolithic with, the buttresses, the two being firmly tied together by means of the reinforcing bars with hooked ends. This face wall is continued beyond the bridge seats to form wings, and is supported by buttresses at intervals of about 8 feet.

At the back of the bridge seat there is a parapet wall forming the back or mud wall, as in a stone abutment, which is provided with returns at the ends

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*The design of abutments for arches is treated in Taylor & Thompson's "Concrete Plain and Reinforced," Second Edition, 1909, and in Baker's "Masonry Construction."

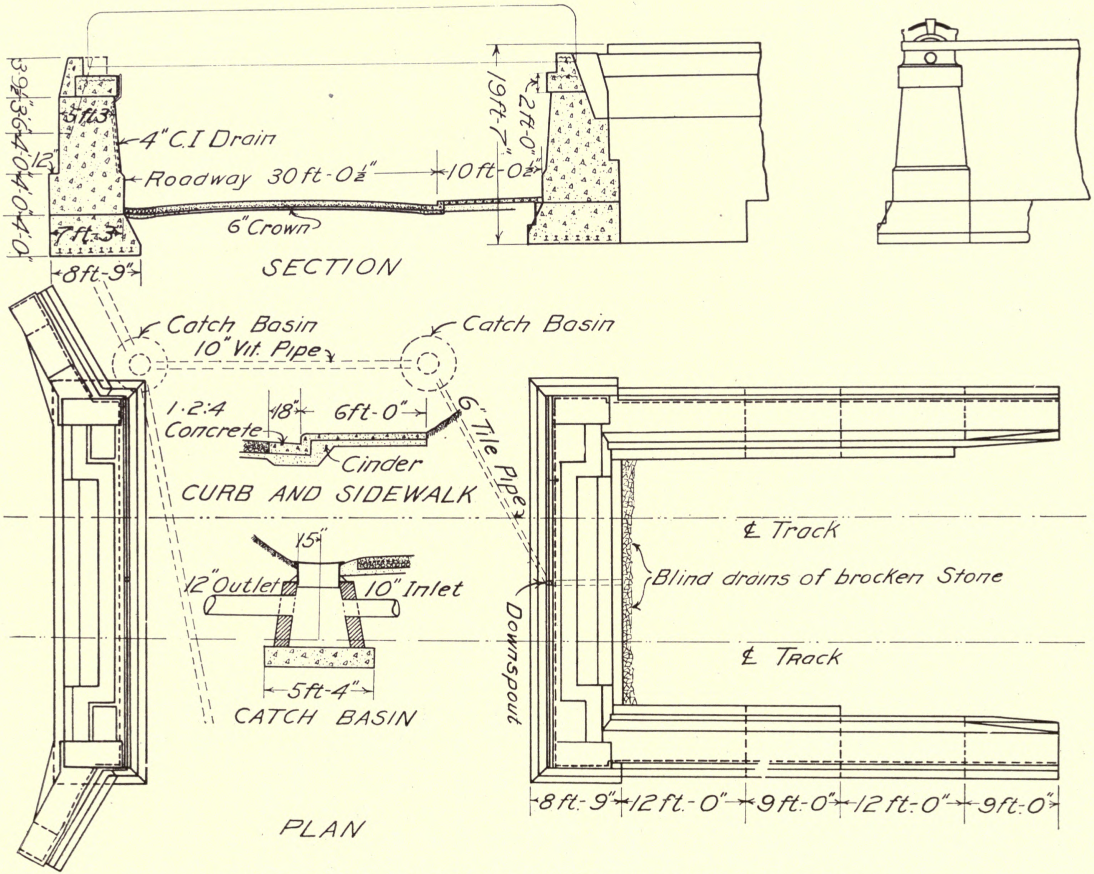


FIG. 53.—VAN CORTLANDT AVE. ABUTMENTS, N. Y. C. & H. R. R. R.

to the face walls and is supported by buttresses similarly to the front wall, and in addition by the vertical bars extending into the bridge seat.

The base consists of a rectangular slab sufficiently reinforced to distribute over the foundation the load transmitted by the buttresses under the bridge seat. Usually, as is the case in the design mentioned above, the width of the base is not taken less than one-half the height of the abutment. To minimize the eccentricity of the load, the base extends about two feet beyond the face wall.

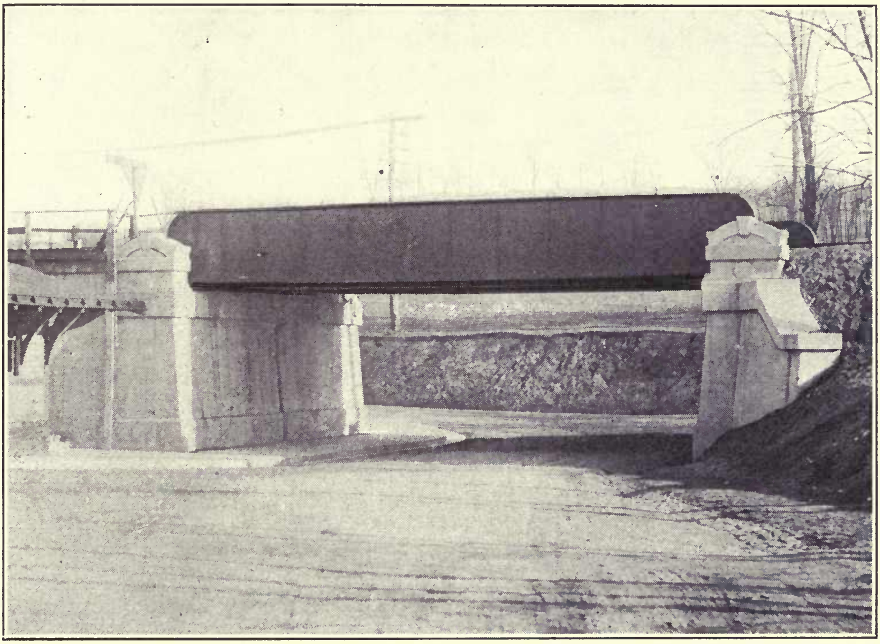


FIG. 54.—VAN CORTLANDT AVE. ABUTMENTS, N. Y. C. & H. R. R. R.

VAN CORTLANDT AVE. ABUTMENTS, N. Y. C. & H. R. R. R. These abutments, which were designed and constructed by the engineering forces of the New York Central Railroad during the fall of 1904, are noteworthy examples of the adaptability of concrete to architectural treatment in structures of this nature, which are frequently crude to the extreme.

The drawings in Fig. 53 show the essential features of design and construction, while the photograph in Fig. 54 gives an idea of the artistic effect which is derived from the moulded pylons and the graceful lines of the wing walls.

In the construction of the abutments four different proportions of

Atlas cement, sand and broken stone were used as follows: Footings 1:4:7½; main wall and wing walls, 1:3:6; bridge seats and pylons, 1:1:2, and copings, 1:2:4.

Old rails with joints staggered and bolted together with two angle bars were laid in the footings 12 inches on centers and 6 inches from the bottom. The bridge seats were reinforced with Clinton Galvanized Wire Cloth, 3 by 8 inch mesh No. 10 wire.

Each abutment is provided with a 4-inch cast iron down spout which is hidden in a 6 by 8 inch chase in the center of the face of the wall and connects with a 6-inch tile drain on one side and discharges into the gutter on the other.

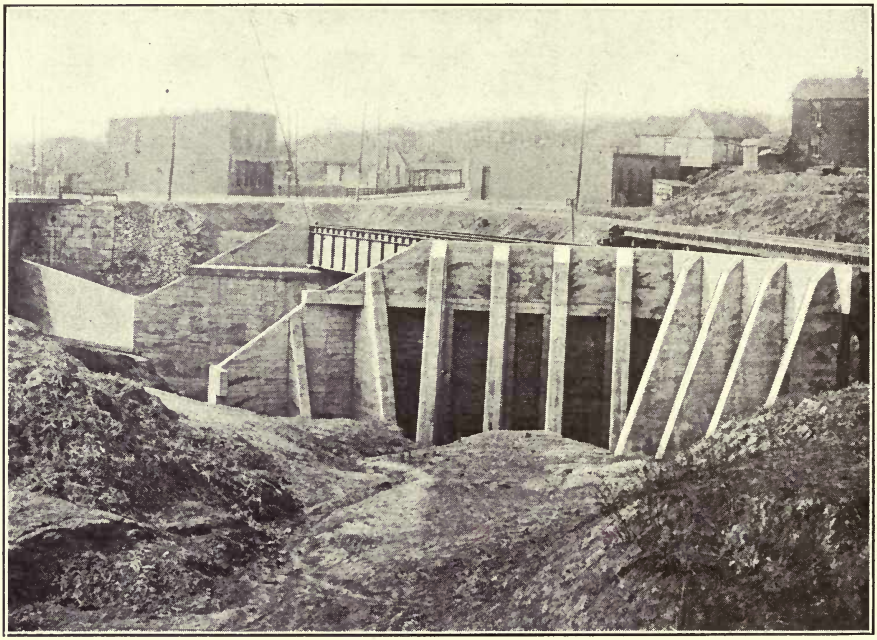


FIG. 55.—THIRD STREET ABUTMENTS, K. C., M. & O. RY.

THIRD STREET ABUTMENTS, K. C., M. & O. RY. These reinforced concrete abutments are on the Kansas City Outer Belt and Electric Railroad, which furnishes an entrance into Kansas City and terminal facilities for the Kansas City, Mexico and Orient Railway, and were designed by Mr. W. Colpitts, Assistant Chief Engineer of the road, and built by Mr. L. J. Smith, general contractor, of Kansas City, in the fall of 1906.

The general dimensions, arrangement of reinforcing and principal features of design are shown clearly on the drawings in Fig. 56, while the photograph in Fig. 55 shows the finished structure.

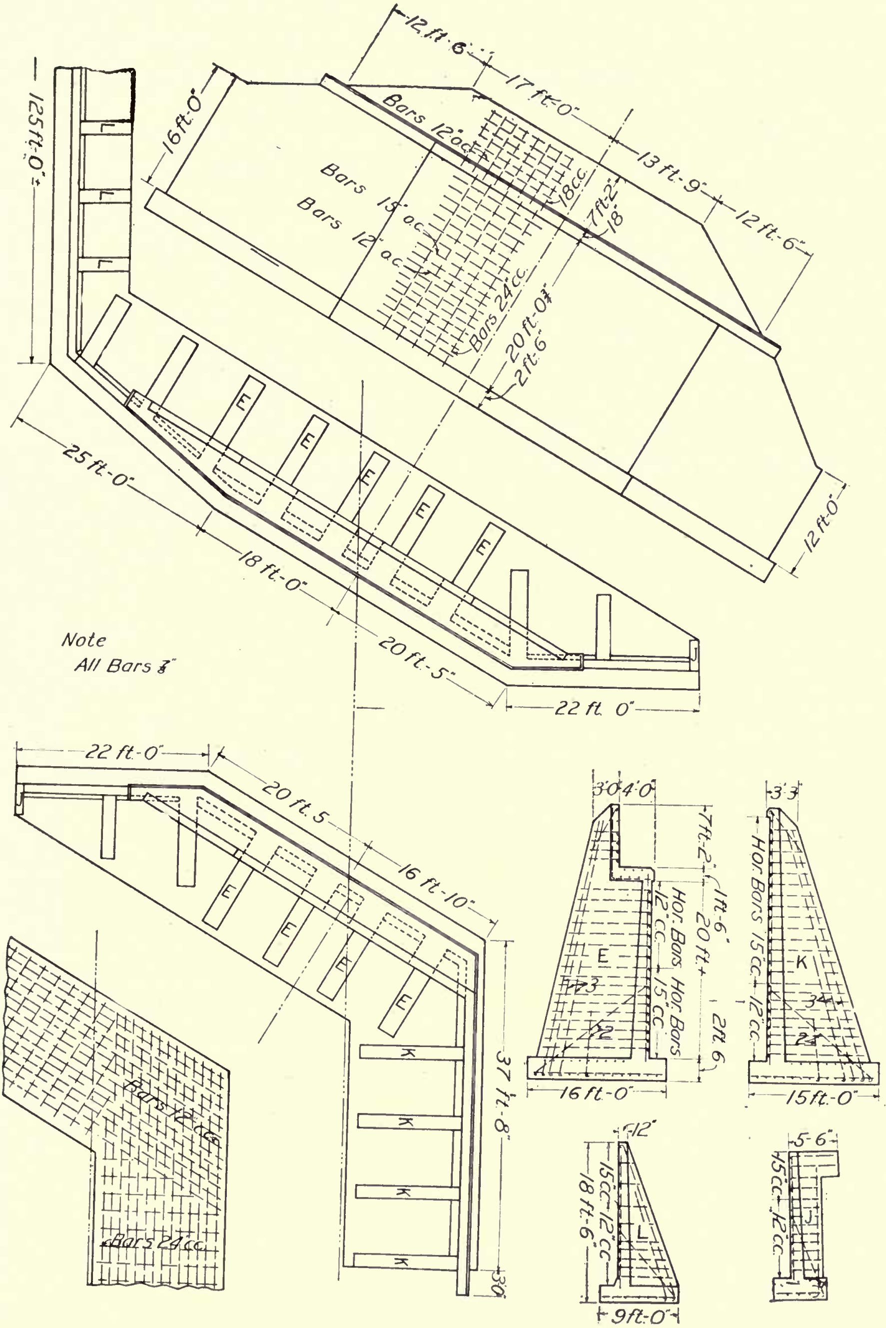


FIG. 56.—THIRD STREET ABUTMENTS, K. C., M. & O. RY.

With the exception of the bridge seats, which are of 1:2:4, all the concrete was mixed in the proportion of 1 part Portland cement to 3 parts Kansas river sand to 5 parts crushed limestone, passing a 2-inch ring and freed from dust by screening.

Seven-eighths-inch corrugated bars were used for reinforcing throughout the abutments and adjoining retaining walls. All bars were lapped 3 feet with joints broken. The supporting piles extend 6 inches into the base slab and were covered with three inches of concrete before the reinforcing bars were put in place. In both abutments and retaining walls the face walls were trenched six inches into the base slab.

The forms were constructed of 1-inch lumber with 2 by 6 inch studs 12 inches on centers and the concrete was mixed by a No. 1 Rotary Mixer.

All excavation and pile driving was done and the reinforcing bars furnished by the railroad company, who also bore one-half the cost of keeping the foundations dry while the forms were being built and the concrete placed.

The following figures* give the unit cost to the contractor and the unit cost to the railroad company who let the contract on the basis of $9 per cubic yard, which covered all labor and materials necessary except the items under "unit cost to railroad."

*Unit cost to contractor:

| | | |
|---|---|---|
| Cement | $1.78 | per cubic yard concrete |
| Sand | 0.35 | " " " " |
| Stone | 1.35 | " " " " |
| Lumber | 0.74 | " " " " |
| Labor | 2.75 | " " " " |
| Miscellaneous | 0.16 | " " " " |
| | $7.13 | " " " " |

Unit cost to railroad:

| | | |
|---|---|---|
| Excavation (total) | $3.80 | per cubic yard concrete |
| Piles (214) 5,228 lin. ft. | 1.84 | " " " " |
| Reinforcing bars | 1.82 | " " " " |
| | $7.46 | " " " " |
| Total unit cost, not including profit | $14.59 | " " " " |

## CHAPTER VI.

## RETAINING WALLS.

The use of both plain and reinforced concrete for retaining wall construction in track elevation and depression work has become general throughout the country. The plain concrete walls are designed of gravity section, that is, they are made sufficiently heavy to prevent sliding or overturning by their own weight. Reinforced walls consist either of a thin vertical wall attached to a horizontal base and braced either by counterforts on the back or by buttresses on the front side, or they are designed as cantilevers, in which case the wall is attached to a spreading base, the whole section being in the form of an inverted T.

Reinforced concrete retaining walls usually are more economical than plain concrete walls, since in the latter type the material cannot be fully utilized because the section must be made heavy enough to prevent overturning by its own weight. In reinforced concrete retaining walls, on the other hand, a part of sustained material is used to prevent overturning, and the section need be made only strong enough to withstand the moments and shears due to the earth pressure. The wall is lighter and exerts smaller pressure on the soil, which with the possibility of extending the base of the wall sometimes enables the constructor to get along with ordinary foundations in cases where for masonry walls piles would have been indispensable. They also admit the use of a more scientific design, since the behavior of reinforced concrete is even better known and more reliable than that of plain concrete.

The common practice among railroad engineers of using arbitrary ratios of width of base to height of walls in designing retaining walls, leads to a neglect of the study of the distribution of the pressure on the foundation. Since it is well established that movements from the original alignment due to unequal settlement from a defect more common than any other, this question is of great importance and each case should be carefully studied and the amount and distribution of the pressure on the bed or foundation determined.

Also, by a careful analytical treatment, the most effective section and the minimum amount of material will be attained, whereas many of the walls thus far designed have embodied a great waste of material with a resulting lack of economy in design.

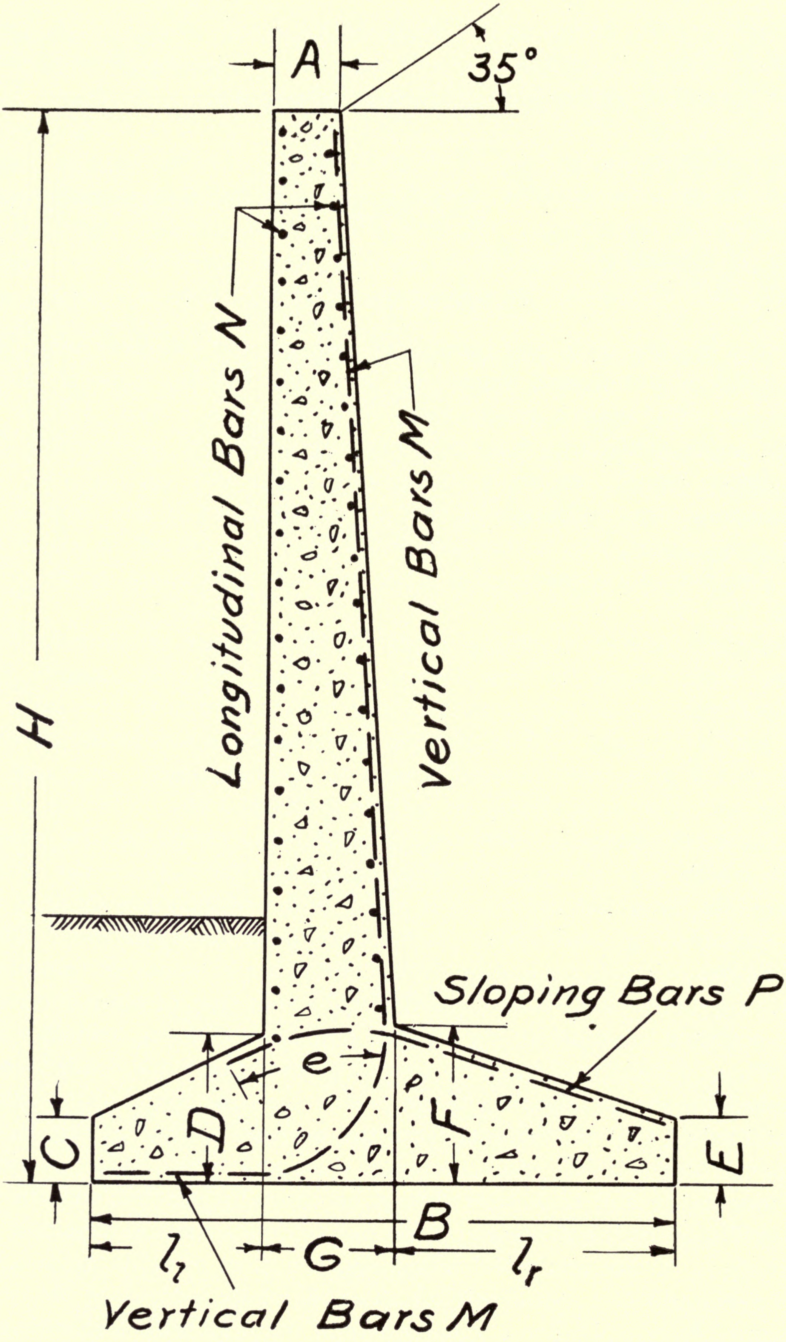


FIG. 57.—DESIGN OF T-SECTION RETAINING WALLS

## DIMENSIONS AND REINFORCEMENT FOR T-TYPE RETAINING WALLS.

| Item | Total Height | Length of Base | Length of Right Cantilever | Length of Left Cantilever | Upright Beam | | | | | | | | Left Cantilever | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Dimensions of Slab | | Reinforcement | | | | | | For Round Plain Bars | | For Square Deformed Bars | |
| | | | | | | | Plain Round Bars M | | Deformed Square Bars M | | Horizontal Bars N | | | | | |
| | | | | | Thick-ness at Top | Thick-ness at Bottom | Size | Spac-ing | Size | Spac-ing | Size | Spac-ing | Thick-ness at End | Max. Thick-ness | Thick-ness at End | Max Thick-ness |
| | H | B | $l_r$ | $l_l$ | A | G | | | | | | | C | D | C | D |
| | ft. | ft. | in. | in. | in. | in. | in. | in. | in. | in. | in. | in. | in. | in. | in. | in. |
| 1 | 8 | 4 | 20 | 18 | 6 | 9½ | ½ | 4¾ | ⅜ | 4¾ | ½ | 12 | 6 | 12 | 6 | 9 |
| 2 | 12 | 6.5 | 39 | 24 | 8 | 15½ | ⅝ | 4¼ | ½ | 5 | ⅝ | 9 | 8 | 17 | 8 | 13½ |
| 3 | 16 | 8.75 | 50 | 31 | 10 | 23½ | ⅞ | 5½ | ⅝ | 5⅜ | ⅝ | 9 | 10 | 27 | 10 | 18 |
| 4 | 20 | 11 | 62 | 39 | 12 | 31½ | ⅞ | 4 | ¾ | 5 | ⅝ | 8 | 12 | 30 | 12 | 23½ |

| Item | Total Height | Right Cantilever | | | | | | | | | | Unit Pressure on the Soil | | Tangent of Angle of the Resultant Pressure with the Vertical |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | For Plain Round Bars P | | | | | For Deformed Square Bars P | | | | | | | |
| | | Dimensions of Slab | | Size of Round Bars | Spac-ing | Length of Imbed-ment | Dimensions of Slab | | Size of Square Bars | Spac-ing | Length of Imbed-ment | Maxi-mum | Mini-mum | |
| | | Thick-ness at End | Max. Thick-ness | | | | Thick-ness at End | Max. Thick-ness | | | | | | |
| | H | E | F | | | e | E | F | | | e | | | |
| | ft. | in. | in. | in. | in. | in. | in. | in. | in. | in. | in. | lbs. per sq. ft. | lbs. per sq. ft. | Tang. φ |
| 1 | 8 | 6 | 13½ | 7/16 | 5 | 11 | 6 | 8¼ | ⅜ | 4½ | 12 | 2,450 | 0 | 0.60 |
| 2 | 12 | 10 | 18½ | ⅝ | 4¾ | 20 | 8 | 14 | ⅝ | 6¼ | 21 | 3,700 | 0 | 0.59 |
| 3 | 16 | 12 | 28½ | ¾ | 5 | 29 | 10 | 19½ | ¾ | 6¼ | 24 | 5,000 | 0 | 0.59 |
| 4 | 20 | 14 | 35½ | ⅞ | 4¼ | 36 | 12 | 29½ | ⅞ | 5½ | 29 | 6,100 | .300 | 0.59 |

NOTE 1.—When the maximum unit pressure on the soil given in the table is too excessive, it may be reduced by extending the left cantilever of the footing. Following formula

$$b = \frac{B}{2}\left[-(2+m)+\sqrt{m(m+8)}\right]$$

gives the necessary length of extension, b, of the base, B, to reduce the maximum pressure to $\frac{1}{m}$ of its previous value. The left cantilever should be then re-designed for the new forces acting on it, using the common reinforced concrete beam formulas.

NOTE 2.—In the retaining wall design the following working stresses and conditions are assumed:

Compression in concrete, **500** lb. per sq. in. Tension in steel, **16,000** lb. per sq. in. Bond of plain bars to concrete, **80** lb. per sq. in. Bond of deformed bars to concrete, **120** lb. per sq. in. Shear involving diagonal tension, **40** lb. per sq. in. Angle of internal friction, **35°**; slope of earth above wall **35°**; weight of earth, **100** lb. per cu. ft. All bars are figured as round except the deformed bars as specified.

DIMENSIONS AND REINFORCEMENT FOR T-TYPE RETAINING WALLS.

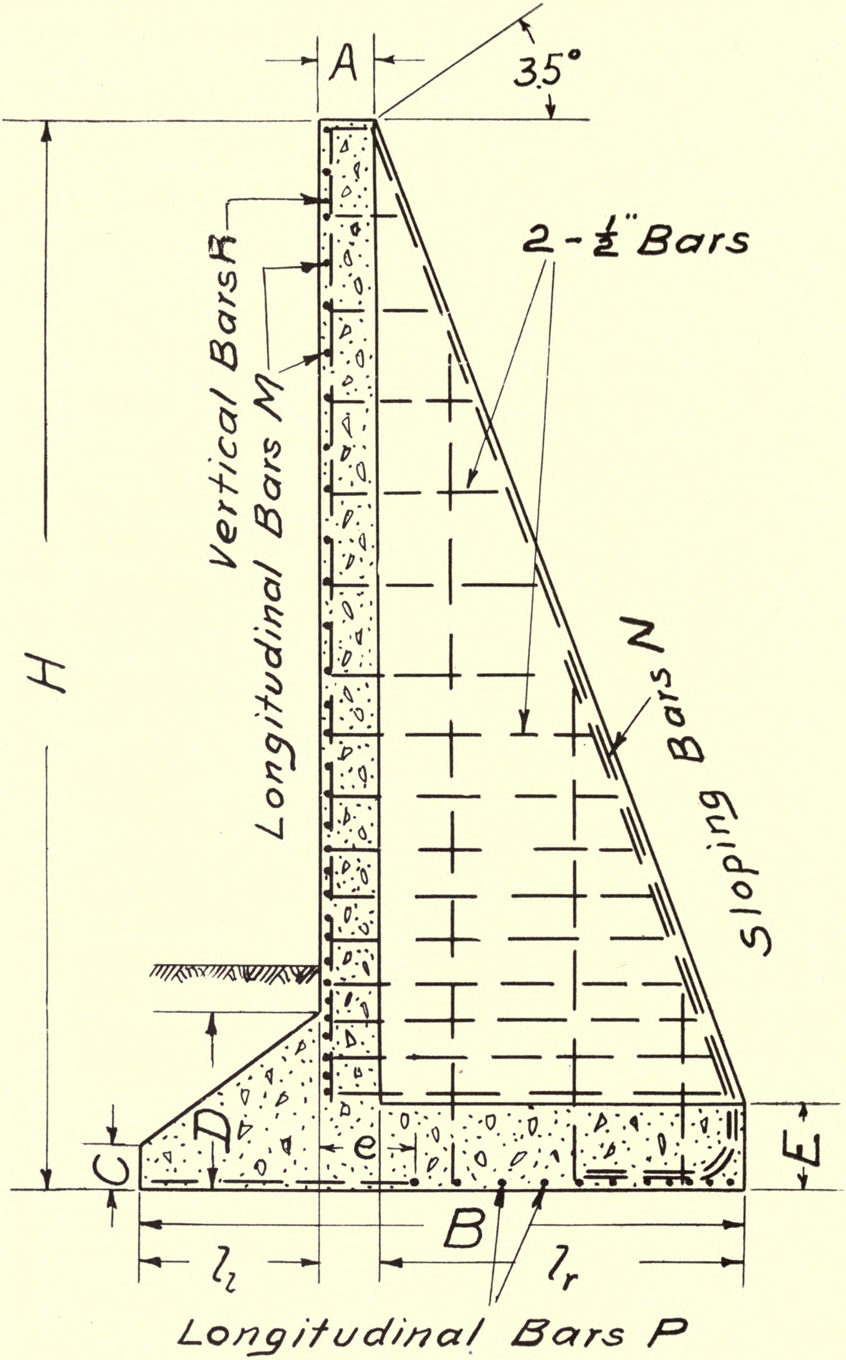


FIG. 58.—DESIGN OF COUNTERFORT TYPE OF RETAINING WALLS.

## DIMENSIONS AND REINFORCEMENT FOR RETAINING WALLS WITH COUNTERFORTS

| Item | Height of Wall | Length of Base | Length of Right Cantilever | Length of Left Cantilever | Left Cantilever of Footing | | | | | | | | | | Vertical Slab | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | For Plain Bars | | | | | For Deformed Bars | | | | | Thickness of Slab | Reinforcement | |
| | | | | | Dimensions of Slab | | Reinforcement | | | Dimensions of Slab | | Reinforcement | | | | | |
| | | | | | Thickness at End | Max. Thickness | Size Round | Spacing | Length of Imbedment | Thickness at End | Max. Thickness | Size Square | Spacing | Length of Imbedment | | Size of Bars | Number and Spacing of Bars |
| | H | B | $l_r$ | $l_l$ | C | D | | | e | C | D | | | e | A | | M |
| | ft. | ft. | ft. | ft.' | in. | in. | in. | in. | in. | in. | in. | in. | in. | in. | in. | in. | |
| 1 | 20 | 11 | 6.7 | 3.25 | 12 | 34½ | ¾ | 4 | 24 | 12 | 23½ | ¾ | 5 | 16 | 13 | ⅝ | 6, 6″ o.c., 4, 10″ o.c.<br>4, 8″ o.c., balance 12″ o.c. |
| 2 | 24 | 13.5 | 8.3 | 4 | 14 | 48 | ⅞ | 4⅜ | 26 | 14 | 31 | ⅞ | 5½ | 26 | 13½ | ⅝ | 8, 5″ o.c., 5, 8″ o.c.<br>6, 6″, balance 12″ o.c. |
| 3 | 28 | 15.5 | 9.45 | 4.75 | 16 | 57½ | 1 | 4½ | 36 | 14 | 39½ | 1 | 5¾ | 30 | 14 | ⅝ | 6, 4″ o.c., 8, 8″ o.c.<br>12, 6″ o.c., balance 12″ o.c. |
| 4 | 32 | 18 | 11.45 | 5.33 | 16 | 58½ | 1 | 4 | 38 | 14 | 41 | 1 | 5 | 32 | 14½ | ⅝ | 8, 4″ o.c., 6, 6″ o.c.<br>8, 8″, balance 12″ o.c. |

Table Continued

| Item | Height of Wall | Horizontal Slab Footing | | | Counterforts | | | | Unit Pressure on the Soil | | Tangent of angle of the resultant pressure with the vertical. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Thickness | Reinforcement | | Spacing of Counter forts | Reinforcement | | | Maximum | Minimum | |
| | | | Size | Number and Spacing of Bars | | Thickness | Number and Size of Bars | Length of Imbedment | | | |
| | H | E | | P | | | N | e | | | |
| | ft. | in. | in. | | ft. | in. | | in. | lbs. per sq. ft. | lbs. per sq. ft. | Tang. % |
| 1 | 20 | 21½ | ⅞ | 4, 6″ o.c., 3, 9″ o.c., balance 12″ o.c. | 7½ | 14 | 1, 1″ bar, 23 ft. long<br>2, 1″ " 17 " "<br>3, 1¼″ " 11 " " | 50<br>50<br>62 | 6,100 | 300 | 0.59 |
| 2 | 24 | 23½ | ⅞ | 5, 5½″ o.c., 3, 9″ o.c., balance, 12″ o.c. | 8 | 16 | 1, 1¼″ bar, 29 ft. long<br>2, 1¼″ " 23 " "<br>1, 1¼″ " 17 " "<br>2, 1¼″ " 11 " " | 62 | 7,500 | 000 | 0.59 |
| 3 | 28 | 26½ | ⅞ | 4, 4¾″ o.c., 5, 9″ o.c., balance, 12″ o.c. | 8½ | 18 | 2, 1¼″ bars, 33 ft. long<br>2, 1¼″ " 23 " "<br>2, 1¼″ " 17 " "<br>3, 1¼″ " 11 " " | 62 | 8,420 | 000 | 0.60 |
| 4 | 32 | 28½ | ⅞ | 5, 4″ o.c., 6, 9″ o.c., balance, 12 o.c. | 9 | 18 | 2, 1¼″ bars, 37 ft. long<br>3, 1¼″ " 28 " "<br>3, 1¼″ " 20 " "<br>4, 1¼″ " 11 " " | 62 | 8,300 | 1,100 | 0.59 |

NOTE—In the retaining wall design the following working stresses and conditions are assumed:
Compression in concrete, **500** lb. per sq. in. Tension in steel, **16,000** lb. per sq. in. Bond of plain bars to concrete, **80** lb. per sq. in. Bond of deformed bars to concrete, **120** lb. per sq. in. Shear involving diagonal tension, **40** lb. per sq. in. Angle of internal friction, **35°**; slope of earth above wall **35°**; weight of earth, **100** lb. per cu. ft. All bars are figured as round except the deformed bars as specified.

DIMENSIONS AND REINFORCEMENT FOR RETAINING WALLS WITH COUNTERFORTS.

As to which of the two types of reinforced concrete retaining walls is for a specific case the more economical depends upon the height of the wall, the intensity of earth pressure and the relative cost of concrete and steel. As a general thing the construction of the inverted-T type is simpler and the placing of the steel easier, requiring less skilled labor and experience.

The least height at which the counterfort type may be economical has been found by special studies for this chapter to be in general about 18 feet.

In retaining walls of any considerable length it is necessary to provide against shrinkage and temperature cracks.

The general practice for walls of unreinforced concrete is to place contraction joints at intervals of from 30 feet to 50 feet. It is possible to provide enough horizontal reinforcement to so distribute the temperature stresses that the cracks will be very minute and scarcely noticeable. For this 0.3 per cent of horizontal steel based on the vertical section of the wall is sometimes used and this should be placed near the surface and in small sized rods. It is quite common practice to introduce a smaller quantity of horizontal reinforcement and in addition provide occasional contraction joints to allow for movement and to localize any cracking.

In constructing retaining walls it is of the utmost importance that careful attention be given to the earth filling and to its drainage. The drainage is most easily accomplished by filling close to the back of the wall with some porous material such as gravel, crushed stone or cinders and by placing weep holes through the wall at suitable distances apart to carry the water from behind the wall. The distance apart of these weep holes is dependent upon local conditions, and should be decided after careful examination of the ground. The standard retaining wall specifications of a number of railroads call for weep holes not more than 15 feet apart with vertical blind drains extending to the top of the wall.

It is not within the scope of this book to go into a discussion of the various methods of determining the pressure exerted on retaining walls or to give a theoretical treatment of the designs of the different types of walls, but the tables in Figs. 57 and 58 give the necessary dimensions for the T-section and counterfort types of retaining walls for heights and pressures ordinarily met with. These have been prepared especially for this book. For a complete analysis of the subject of concrete retaining walls the reader is referred to Taylor and Thompson's "Concrete, Plain and Reinforced," second edition, 1909, and to "Walls, Bins and Grain Elevators," by Milo S. Ketchum.

In designing the walls given in the tables referred to above, the earth pressure was computed by Rankine's formula for a fill weighing 100 pounds per cubic foot and an angle of repose of 35 degrees. The filling was assumed as sloping behind the wall at the angle of repose.

The unit stresses assumed were: Compression in the concrete, 500 pounds per square inch; tension in the steel, 16,000 pounds per square inch; shear in the concrete involving diagonal tension, 40 pounds per square inch; bond, 80 pounds per square inch for plain and 120 pounds per square inch for deformed bars.

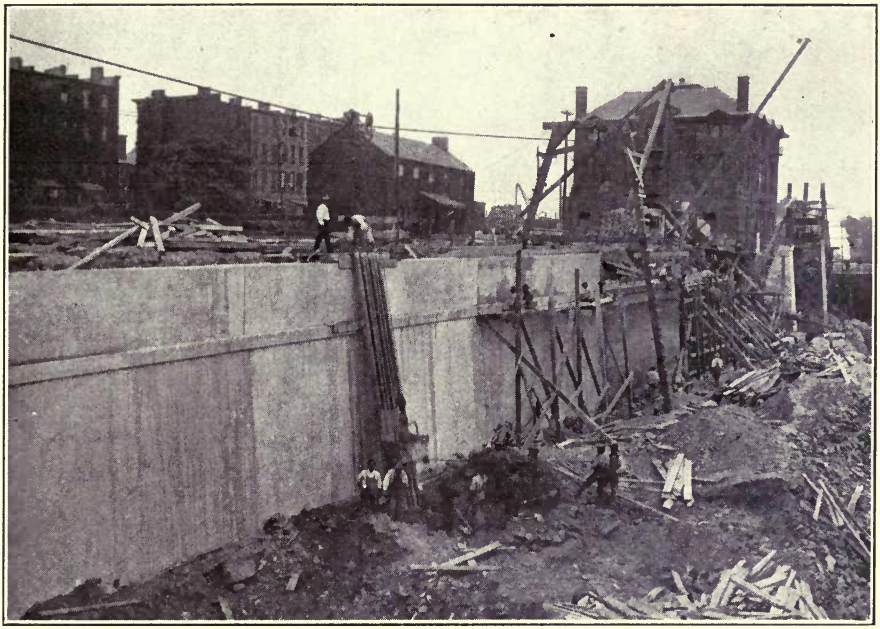


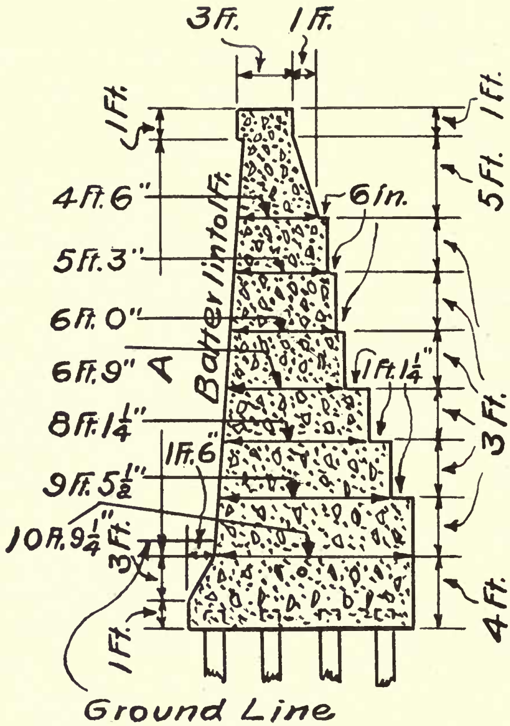
FIG. 59.—BRONX IMPROVEMENT RETAINING WALL, N. Y. C. & H. R. R. R.

## EXAMPLES OF RETAINING WALLS.

### STANDARD GRAVITY RETAINING WALL, N. Y. C. & H. R. R. R.

Fig. 60 shows the cross section and table of contents per running foot of this type of wall. The concrete below the ground line is mixed in the proportions of 1:4:7½, from the ground line to the coping, in the proportions of 1:3:6, and for the coping, in the proportions of 1:2:4. Expansion joints filled with one layer of tar paper with the edge ¼-inch back from the face of the masonry are provided every 50 feet. The back filling consists of cinders or other porous material and the drainage is taken care of by 4-inch weep holes not more than 15 feet apart, with vertical blind drains extending to the top of the wall. Along side walls these weep holes are placed 9 feet below the top of the side walls and are piped to the gutter.

The photograph in Fig. 59 is an example of a gravity retaining wall on the Bronx improvement work carried on by the New York Central and Hudson River Railroad.



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| Height A | Cu. yds per running ft. | | |
|---|---|---|---|
| | Coping | Body Wall | Found. 4 ft deep |
| 5 Ft. 0 | 0.111 | 0.671 | 0.833 |
| 6-0 | ” | 0.858 | 0.920 |
| 7-0 | ” | 1.048 | 0.932 |
| 8-0 | ” | 1.241 | 0.944 |
| 9-0 | ” | 1.455 | 1.032 |
| 10-0 | ” | 1.673 | 1.044 |
| 11-0 | ” | 1.894 | 1.056 |
| 12-0 | ” | 2.136 | 1.143 |
| 13-0 | ” | 2.381 | 1.155 |
| 14-0 | ” | 2.630 | 1.167 |
| 15-0 | ” | 2.922 | 1.343 |
| 16-0 | ” | 3.217 | 1.355 |
| 17-0 | ” | 3.516 | 1.367 |
| 18-0 | ” | 3.858 | 1.544 |
| 19-0 | ” | 4.204 | 1.556 |
| 20-0 | ” | 4.553 | 1.568 |
| 21-0 | ” | 4.946 | 1.744 |
| 22-0 | ” | 5.341 | 1.756 |
| 23-0 | ” | 5.740 | 1.768 |
| 24-0 | ” | 6.183 | 1.946 |
| 25-0 | ” | 6.628 | 1.958 |
| 26-0 | ” | 7.078 | 1.970 |
| 27-0 | ” | 7.571 | 2.146 |
| 28-0 | ” | 8.068 | 2.158 |
| 29-0 | ” | 8.567 | 2.170 |
| 30-0 | ” | 9.110 | 2.346 |

FIG. 60.—STANDARD GRAVITY RETAINING WALL, N. Y. C. & H R. R. R.

REINFORCED RETAINING WALLS, C., B. & Q. R. R.—Fig. 61 shows the essential features of design and construction of a typical track elevation retaining wall of the Chicago, Burlington and Quincy Railroad, which is in reality a compromise between the plain monolithic and the cantilever types of walls. In designing, no attempt was made to use the full compressive strength of the concrete, as such a condition would have required a much greater amount of reinforcement and at the same time would have developed an excess of strength beyond requirements. Sections at the top of the footing, at the angle in the back of the wall, and at points both above and below this angle were analyzed and the stresses computed by Prof. Howe's formulas and a sufficient amount of reinforcement was provided to take care of the total tensile strength at every point which, however, was very small because of the comparatively heavy section. Owing to the difficulty in constructing reinforced abutments, plain concrete was used; the footings, however, have a reinforced projection in front to increase the bearing area. As a general thing the walls are supported on piles closely spaced under the toe and more widely apart under the heel. The concrete was mixed in the proportions of 1 part cement to 6 parts pit run gravel.

In Fig. 62 are shown the forms used in constructing these walls, together with the method of bracing and tying down the forms. They comprise a combination of continuous and sectional forms, the sectional portion consisting of studs, coping and bottom forms for the face, and entire sectional forms for the back of the wall.

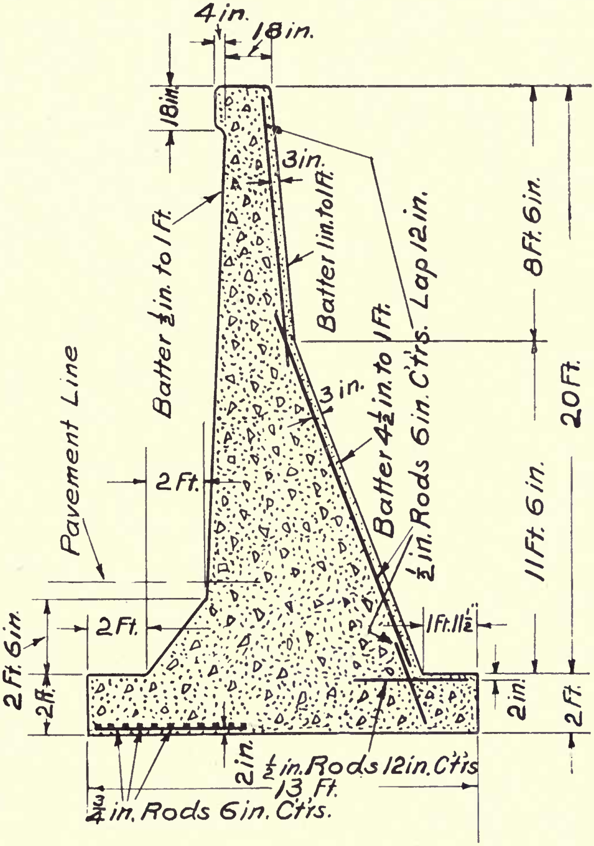

FIG. 61.—CROSS SECTION TYPICAL RETAINING WALL, C., B. & Q. R. R.

As the cross section of the wall is such that in filling the concrete showed a tendency to lift the forms off the footing, ½-inch bars were placed in the footing, as shown in Fig. 62, and the forms tied to them with wires. The wall forms are tied together by ¾ rods which pass through pieces of 2-inch scrap pipe cut to fit loosely between the forms, the ends of the pipes being stuffed with waste to keep the grout from filling them.

In regard to the cost of walls of this type, Mr. C. H. Cartlidge, Bridge Engineer of the C., B. & Q. R. R., under whose supervision, with Mr. L. J. Hotchkiss, Assistant Bridge Engineer, the walls were designed, writes as follows:*

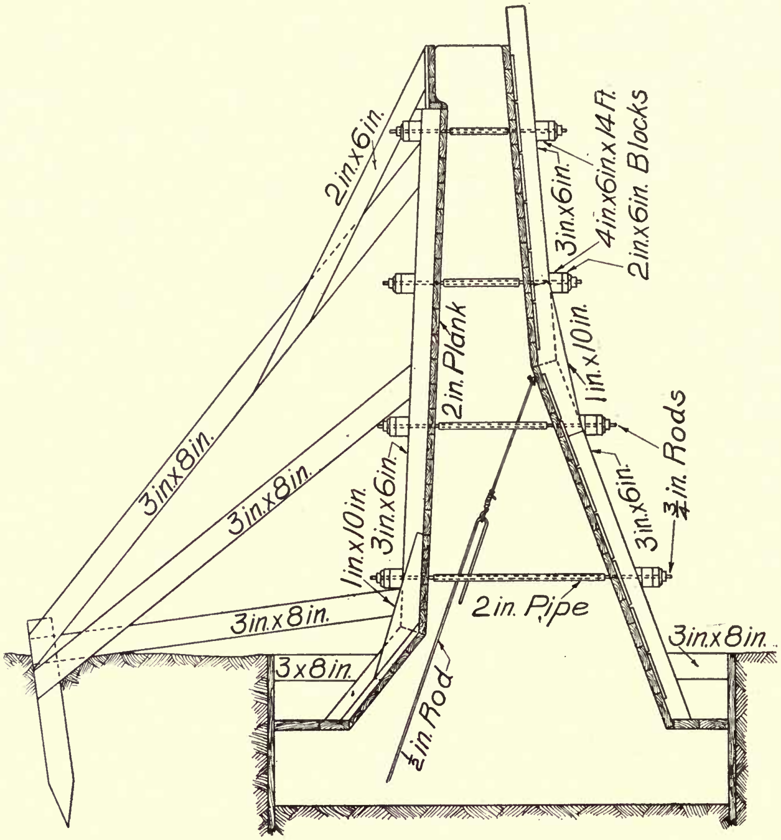

FIG. 62.—FORMS FOR RETAINING WALL, C., B. & Q. R. R.

"This wall (reinforced concrete) will show an economy over a gravity wall of solid concrete. The cost of a large amount of work, including everything, has been a little less than $9 per yard. For the concrete only, exclusive of excavation and piling, $6.23 per yard. Our abutments are solid concrete without any reinforcing. These cost us per cubic yard $5.55, including everything. The high cost per yard of the retaining

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*Bulletin No. 108, p. 426, American Railway Engineering and Maintenance of Way Association.

walls for excavation and piling is, of course, due to the fact that comparatively little concrete is used per yard of excavation. The true comparison, therefore, is between the concrete in the two, being for the retaining walls as stated above, $6.23 and $5.03."

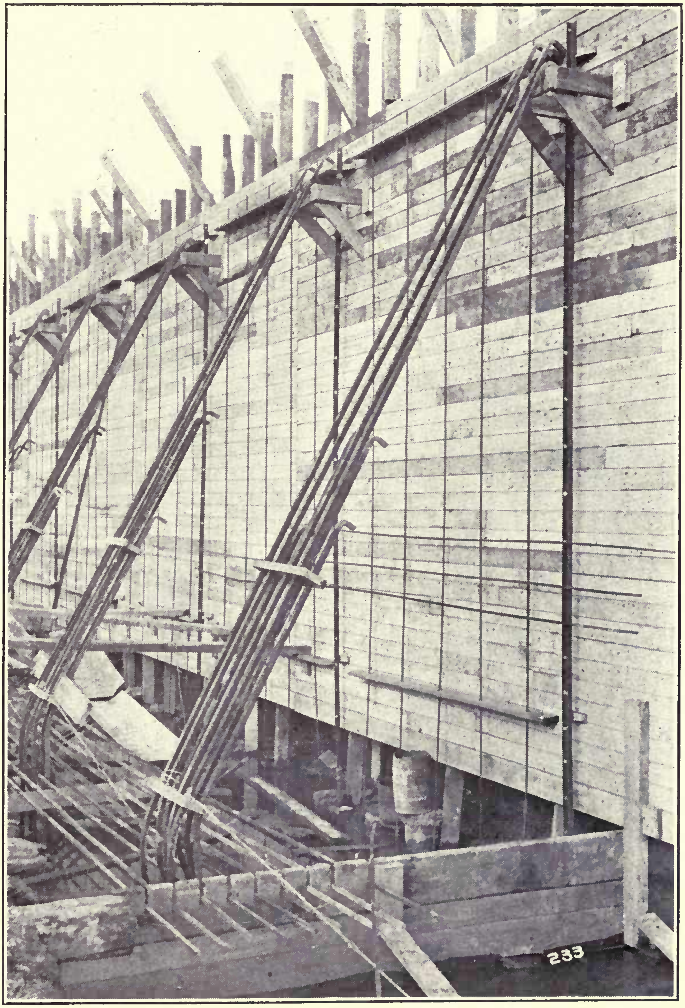

FIG. 63.—REINFORCEMENT IN PLACE, BUFFALO RETAINING WALL.

REINFORCED BUTTRESS RETAINING WALLS, D., L. & W. R. R. The photograph in Fig. 63 shows the method of constructing and reinforcing the counterforts of the retaining wall at Buffalo, New York, while the photograph in Fig. 64 is of the finished wall.

In addition to the retaining walls just described, there are a number of illustrative examples of different types of walls among the miscellaneous photographs at the end of this book.

FIG. 64.—BUFFALO RETAINING WALL, D., L. & W. R. R.

## CHAPTER VII.

## STATIONS, TRAIN SHEDS AND PLATFORMS.

Railroads throughout the country are adopting the use of concrete in the construction of railway stations of every class, in many cases for the entire structure and in others for integral parts such as foundations, platforms, smoke ducts, stairways, and often for architectural features, such as cornices, belt courses and platform columns. Its permanence, fire resisting qualities and adaptability to architectural treatment renders it a most satisfactory building and structural material for both large and small stations. In addition to the Marathon Station, the O'Fallon Station and the Bush Train Shed, a number of other concrete stations are shown among the miscellaneous photographs at the end of the book.

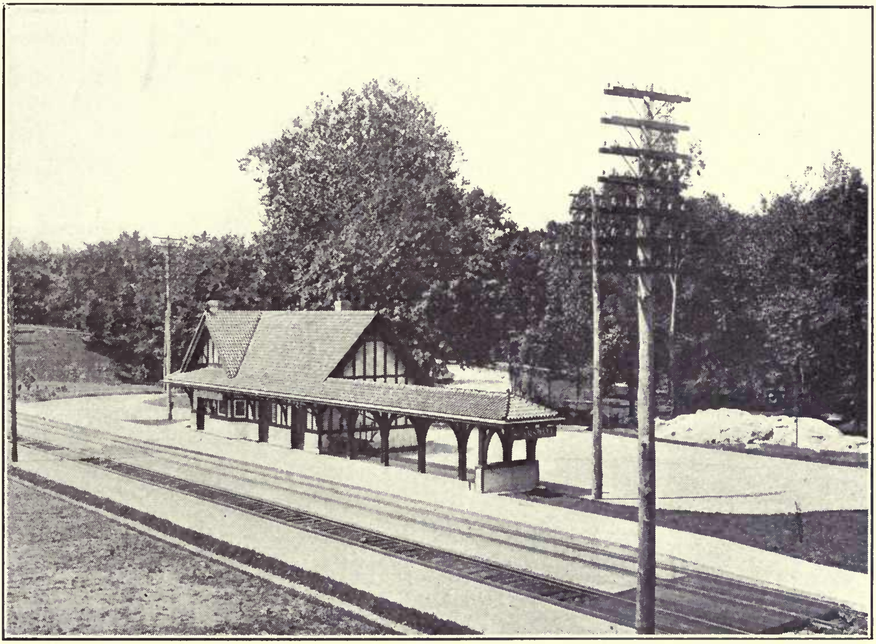

FIG. 65.—SCARSDALE STATION, N. Y. C. & H. R. R. R.

SCARSDALE STATION, N. Y. C. & H. R. R. R. The photograph in Fig. 65 shows a very artistic concrete station at Scarsdale, on the Harlem division of the New York Central and Hudson River Railroad.

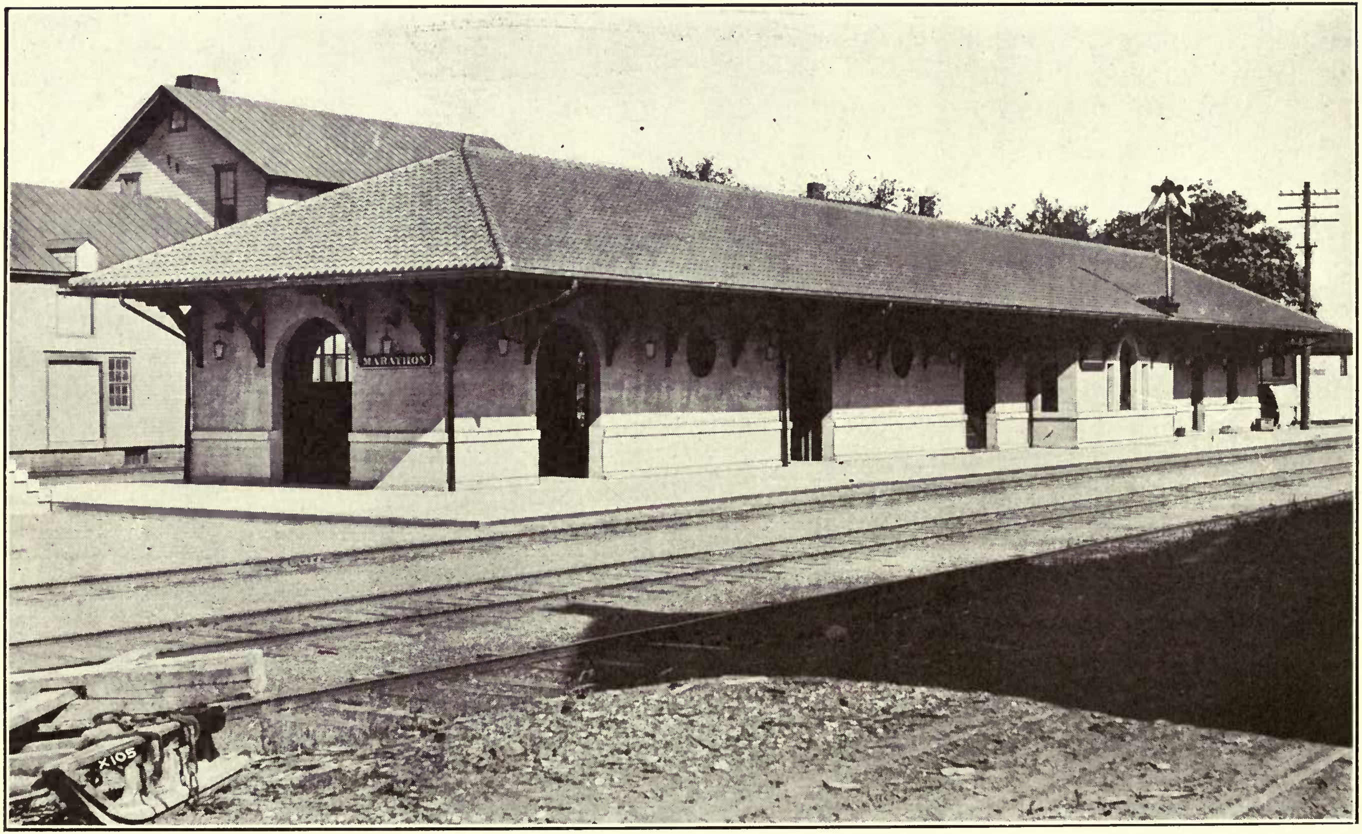

FIG. 66.—MARATHON STATION, D., L. & W. R. R.

MARATHON STATION, D., L. & W. R. R. This structure, a photograph of the track side of which is shown in Fig. 66, is a combination passenger station and freight house of simple, yet artistic design and substantial construction.

With the exception of the roof, which is of Ludowici Celadon tile on wooden rafters, and the trusses and brackets, the building is of concrete construction throughout. The foundations and main walls are of plain concrete, except over square openings where reinforced lintels are formed by placing three ¼-inch square rods near the soffit, while the floors and platforms are of plain concrete laid directly on a cinder base and surfaced with a 1½-inch granolithic finish.

The walls are tool finished up to the water-table, and above that, with the exception of the belt course, are finished by floating the green concrete with water and rubbing with wire brushes immediately after removing the forms.

All the concrete was mixed in the proportions of 1 part Atlas Portland Cement to 2 parts sand and 4 parts broken stone.

The station was designed by Mr. F. J. Nies, architect for the railroad, under the supervision of Mr. Lincoln Bush, Chief Engineer, and was built by A. E. Badgely, general contractor, of Binghamton, N. Y.

O'FALLON STATION, WABASH R. R. This station, a photograph of which is shown in Fig. 67, is typical of a class of small fireproof stations which the Wabash Railroad are erecting to take the place of the ordinary combustible frame building formerly used.

They are built in three sizes, 20 by 40 feet, 20 by 52 feet, and 20 by 62 feet, and consist of plastered walls with floors, platform, foundations and chimney of concrete. These stations are erected at about the cost of the ordinary frame building, and in addition to being fireproof present a better appearance than the former type of structure.

In furring for the outside plastering of the walls, pieces of ½-inch diameter plain round rods 4 inches long are fastened to the studs every 12 inches and against these are wired ½-inch round rods placed longitudinally every 12 inches. To these horizontal rods, sheets of spiral expanded metal lath, No. 26 gauge, 16 inches wide by 96 inches long, are wired, the long dimension being placed vertically. After this is plastered, the inside of the building is furred in a similar manner, except that the horizontal rods are nailed directly to the studding.

The plaster for the first coat consists of a mixture of three cubic feet of well slacked lime mortar to one bag of Atlas Portland Cement. This scratch coat is applied to both sides of the expanded metal attached to the outer side of the studding and to the exposed surface of the expanded metal on

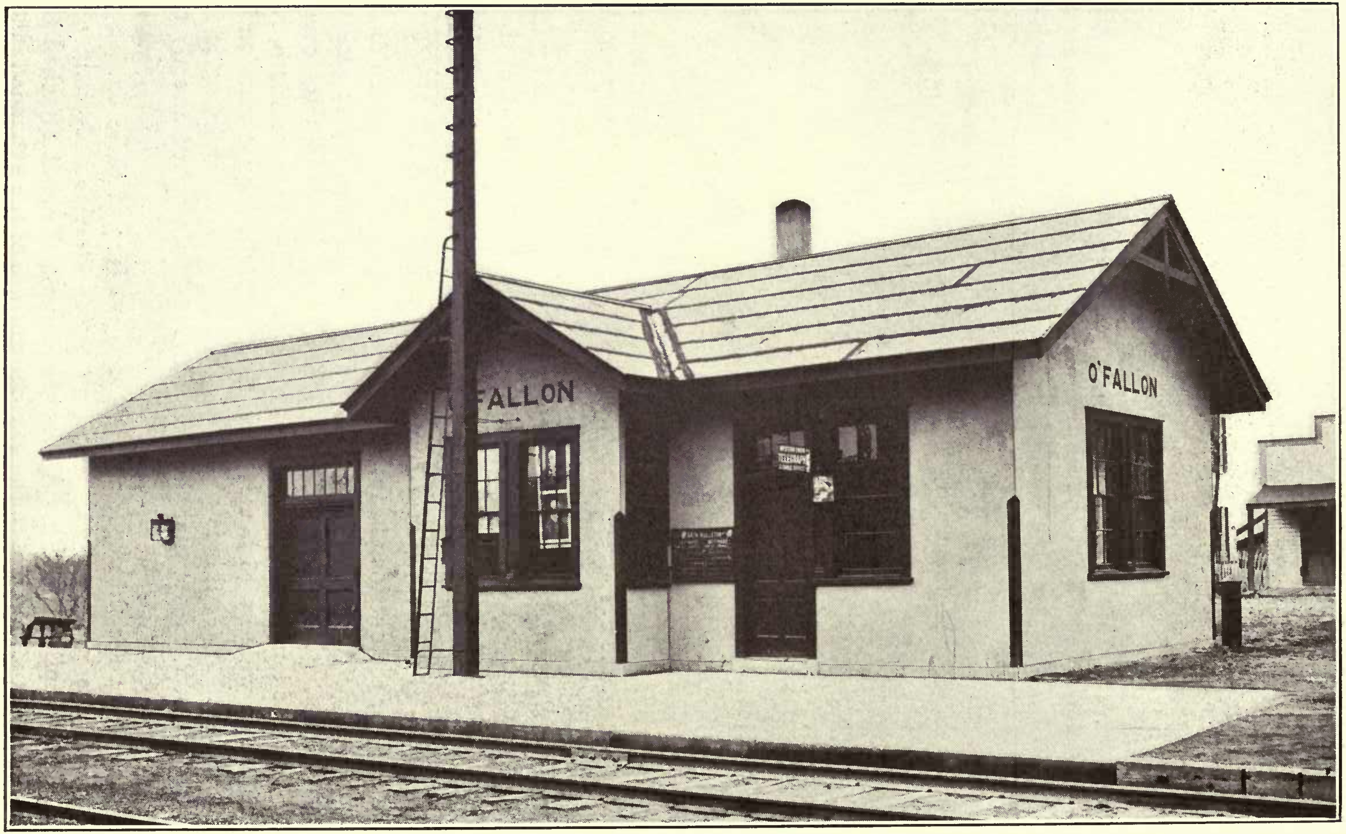

FIG. 67.—O'FALLON STATION, WABASH R. R.

the inside. When this coat has become sufficiently hard both sides of the outer metal lath are plastered until a thickness of 1½ inches is attained, and the inner metal lath is plastered to a thickness of 1 inch, using for the finishing coat cement mortar in proportions one bag of Atlas Portland Cement to 2 cubic feet of sharp, clean sand.

After the walls are dried the outside surface is painted with two coats of waterproofing compound put on thick enough to fill in and hide all joints and hair cracks.

In the new depots of this type the walls up to the window sills are built of solid concrete, which greatly improves the strength and general appearance of the structure.

These stations are designed by and built under the supervision of the Engineering Department of the Wabash Railroad, Mr. A. O. Cunningham, Chief Engineer.

FIG. 68.—HOBOKEN TERMINAL TRAIN SHED, D., L. & W. R. R.

## TRAIN SHEDS.

HOBOKEN TERMINAL TRAIN SHED, D., L. & W. R. R. The train shed for the new Lackawanna passenger terminal at Hoboken, N. J., a part section of which is shown in Fig. 69, is an entirely new departure from the hitherto considered standard type of structure for this purpose. Instead of comprising a series of high arches, which in the common type of train shed are continually enveloped in a haze of smoke and gases from the locomotives, it consists essentially of a system of low arched short span longitudinal sections, just high enough to clear the largest locomotive in use on the line, with smoke ducts of reinforced concrete through which the locomotive gases are discharged directly into the open air. As will be seen from the section in Fig. 69 and from the photograph in Fig. 68, each of these sections cover two tracks and the sides of the smoke ducts are built high enough to prevent driving rain or snow from reaching the platforms. In addition to the smoke ducts the roof, platforms and fence footings are of concrete construction.

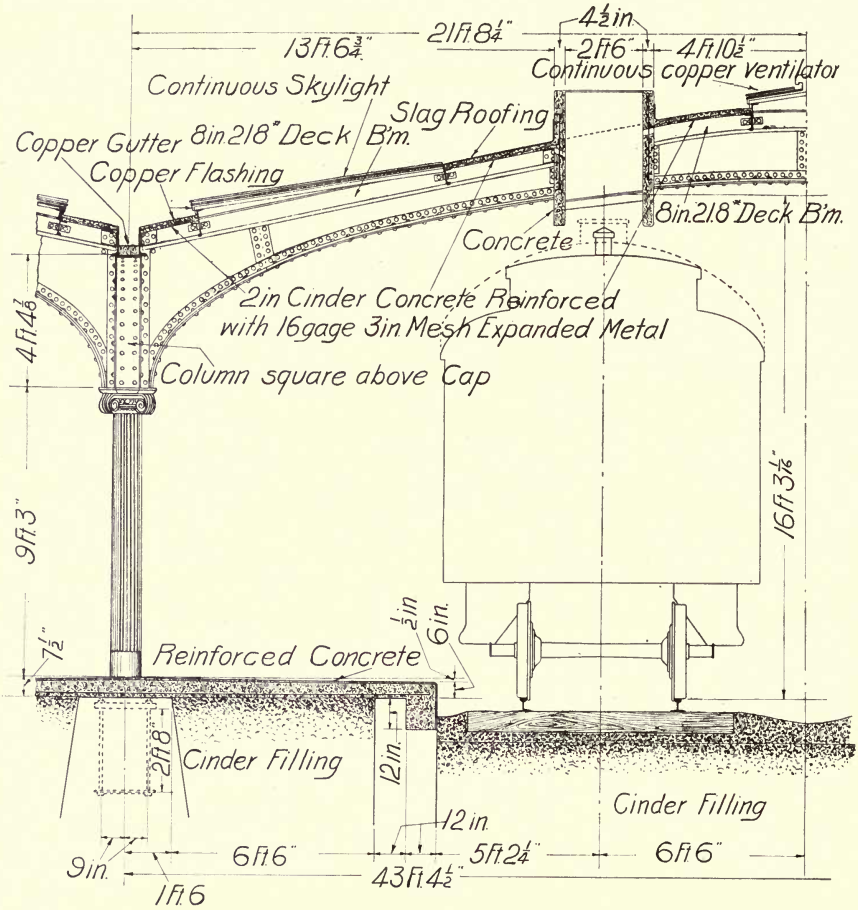

FIG. 69.—PART SECTION, HOBOKEN TRAIN SHED, D., L. & W. R. R.

This shed was designed and patented by Mr. Lincoln Bush, Chief Engineer of the Delaware, Lackawanna and Western Railroad, and erected under his supervision by the company forces in 1907.

The same type of train shed has also been used by the Lackawanna Railroad at the new Scranton station and by the Chicago and Northwestern Railway Co. at its new terminal in Chicago.

FIG. 70.—COHOES STATION AND PLATFORM, N. Y. C. & H. R. R. R.

## PLATFORMS.

While plain concrete has been used for many years in the construction of low platforms at main stations the adoption of high platforms on rapid transit and suburban lines during the past few years has opened up a new field for reinforced concrete. A typical ground platform is shown in Fig. 71, while two types of high platforms of reinforced concrete are illustrated and described on pages 106 to 111.

STANDARD CONCRETE GROUND PLATFORMS AT STATIONS, N. Y. C. & H. R. R. R. These platforms, a typical one of which is shown in cross section and plan in Fig. 71, and by the photograph in Fig. 70 are usually constructed 200 feet long and 12 feet wide and are divided into blocks of not more than 40 square feet area. The platform illustrated in Fig. 71 is for only one passenger track, but if more than one track is used another 12-foot platform is provided opposite and outside of the additional passenger track or tracks.

The concrete is mixed in the proportions of 1 part Portland cement to 3 parts sand to 6 parts broken stone and the granolithic finish in the proportions of 1 part cement to 1½ parts sand.*

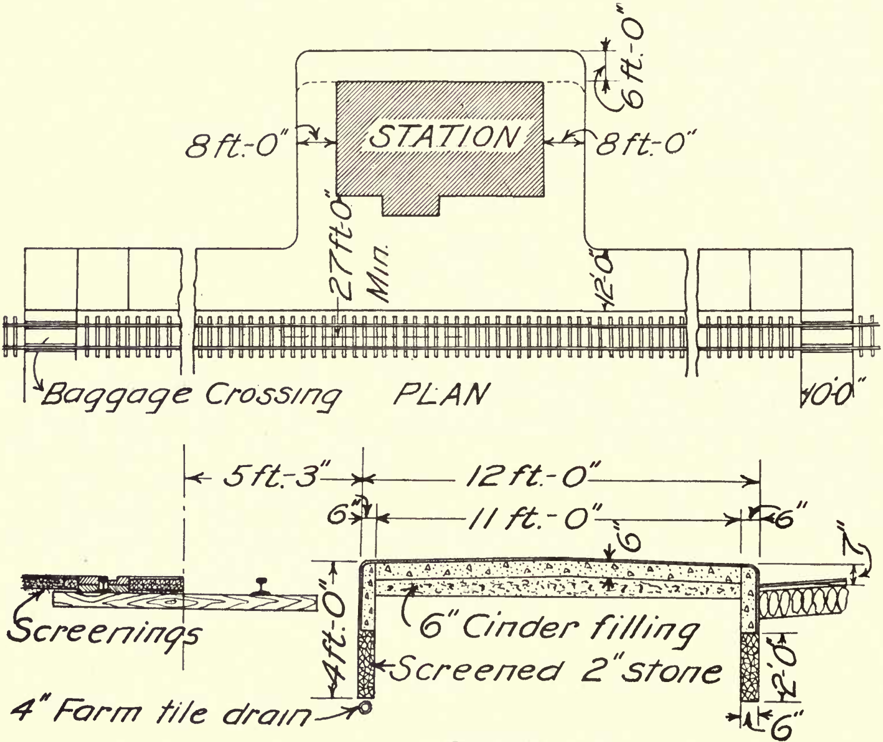

FIG. 71.—STANDARD GROUND PLATFORM, N. Y. C. & H. R. R. R.

STATION PLATFORMS, BROOKLYN RAPID TRANSIT CO. The platforms on either side of the tracks are about 240 feet long and 8 feet wide and are constructed of a reinforced concrete slab carried by girders of the same material which are in turn supported by concrete piers placed about every 20 feet. The photograph in Fig. 72 shows the track side of one of the platforms while the drawings in Fig. 73 show the essential features of design and construction.

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*The details of sidewalk and platform construction are discussed in "Concrete in Highway Construction," published by the Atlas Portland Cement Company.

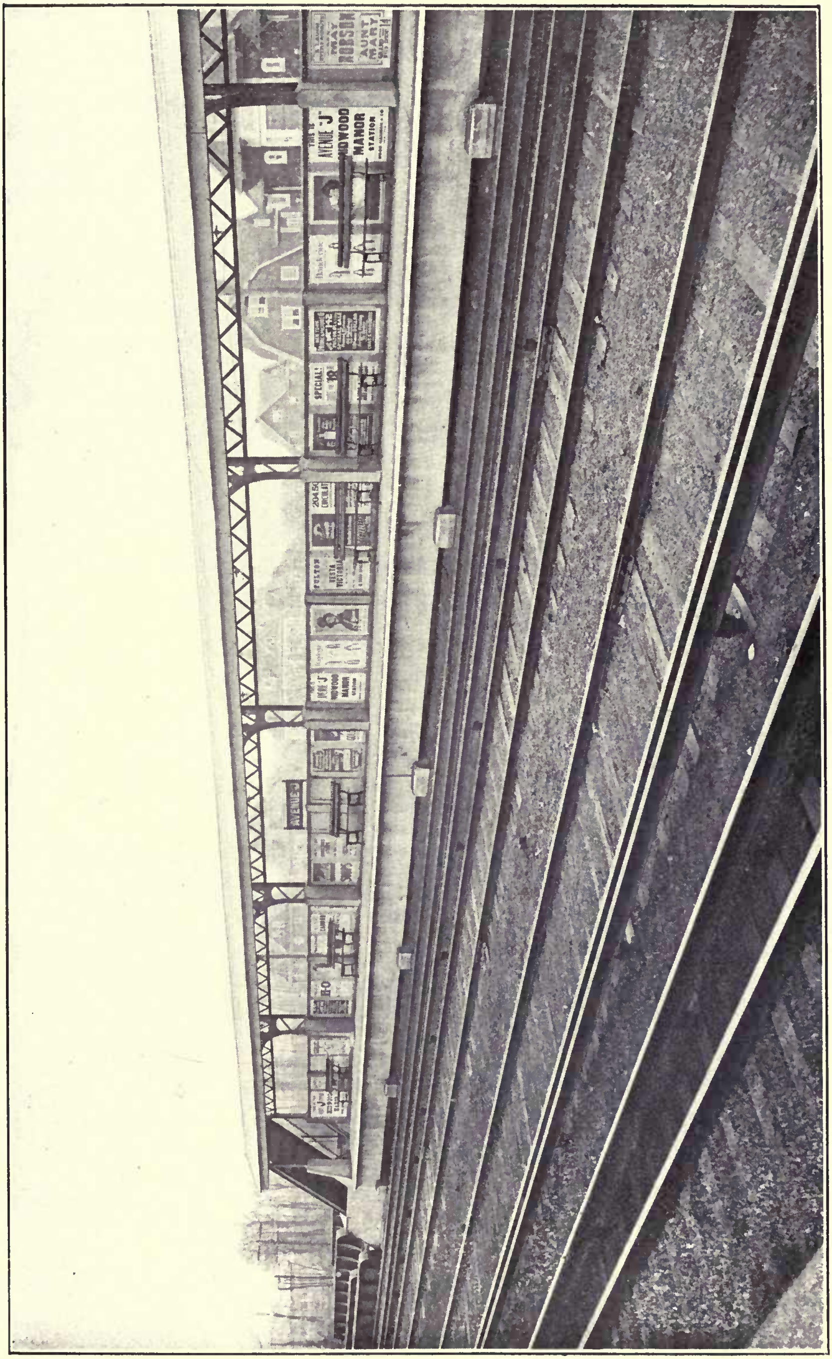


FIG. 72.—AVENUE J STATION PLATFORM, B. R. T. CO.

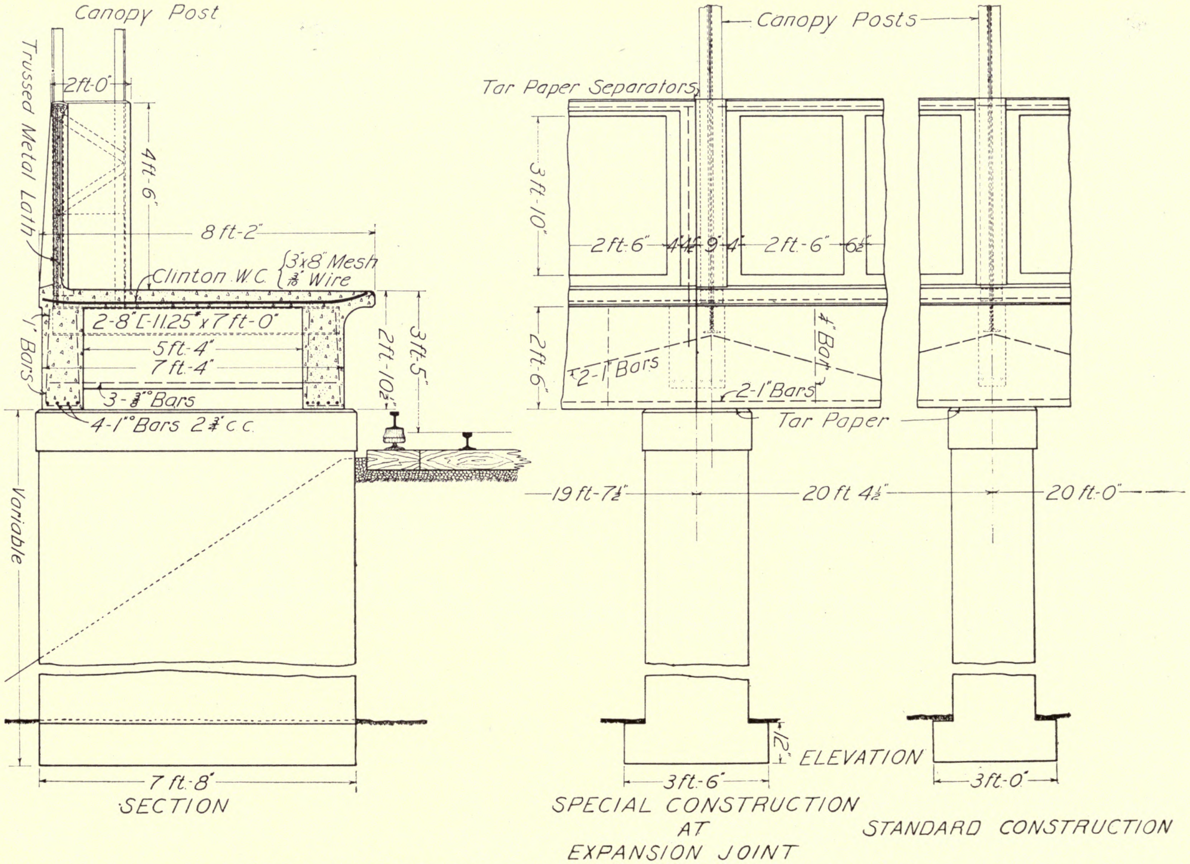


FIG. 73.—DETAILS OF CONSTRUCTION, STATION PLATFORMS, B. R. T. CO.

Expansion joints are provided every 60 feet by separating the construction entirely with tarred paper.

The outside edges of the platform are equipped with patent bulb nosing.

The fences running the length of the platform and forming the guard railings on the outside and ends of the platforms are constructed of cement plaster on metal lath and are described in detail in Chapter XVI.

For the concrete work a mixture of 1 part Atlas Portland Cement to 2 parts sand to 4 parts ¾-inch broken stone was used throughout. The 1-inch granolithic surface of the platforms was mixed in the proportions of 1 part Atlas cement to 1 part sand and 1 part pebble grit and was applied simultaneously with the last course of concrete.

In designing the platforms, a live load of 150 pounds per square foot was assumed and the concrete was figured at 500 pounds per square inch extreme fiber stress while the steel was allowed 16,000 pounds per square inch in tension.

The platforms were designed by the Engineering Department of the Brooklyn Rapid Transit System, Mr. W. S. Menden, Chief Engineer, and were constructed under his supervision by Mr. Thomas G. Carlin of Brooklyn, in 1907.

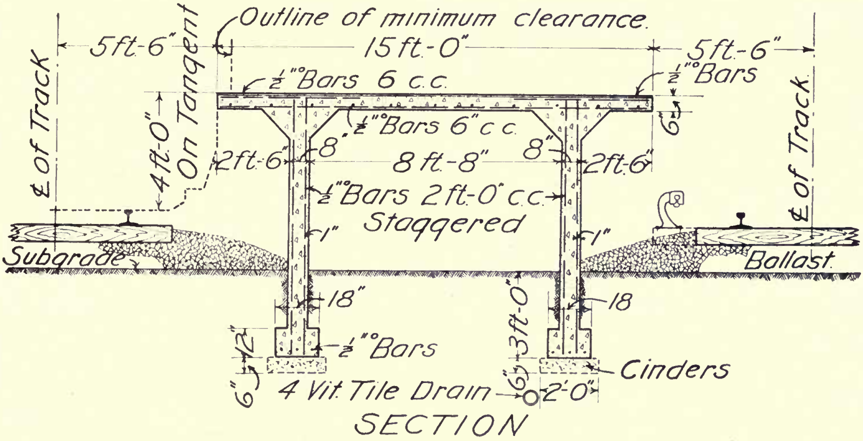


FIG. 74.—CROSS SECTION OF STANDARD ISLAND PLATFORM. N. Y. C. & H. R. R. R.

## ELECTRIC ZONE STANDARD PLATFORMS, N. Y. C. & H. R. R. R.

One of the most important features of the Electric Zone improvement work of the New York Central and Hudson River Railroad is the adoption of high platforms on the suburban side of all local stations within the Zone. This not only enables greater ease in the interchange to and from trains, but greatly increases the rapidity of the service.

As will be seen from the cross-sections in Figs. 74 and 75, which show the details of construction of an island and outside platform, the type adopted comprises two longitudinal reinforced 8-inch walls with a 6-inch reinforced deck or floor plate spanning the walls and overhanging 2 feet 6 inches on either side. The width varies from 12 to 15 feet, while the height is determined by the elevation of the rails according to the degree of curve, which is four feet above the rails on tangents and curves up to three degrees and thirty minutes.

In plan the arrangement of the platform varies greatly according to the location. The suburban stations have high platforms about 350 feet long, on either side, outside of the group of four tracks, and the combination stations have two high outside platforms and a middle low platform between the express tracks on both sides, with a high platform at one end for a distance of 350 feet and a low one of the same length adjoining it.

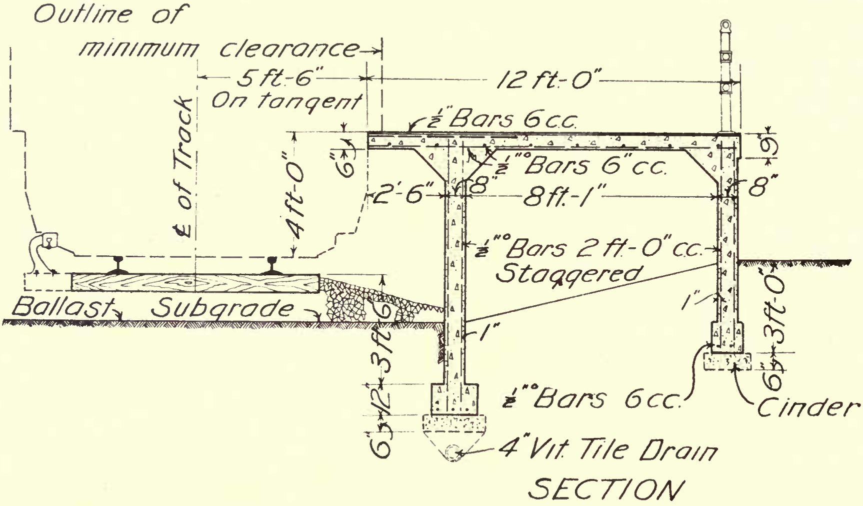


FIG. 75.—CROSS SECTION OF STANDARD OUTSIDE PLATFORM, N. Y. C. & H. R. R. R.

All stations are provided with overhead bridges or subways connecting with the various platforms.

The concrete is of 1:3:6 proportions, with exposed surfaces faced with ½-inch cement finish mixed in the proportions of 1 cement to 1½ sand. All exposed edges are rounded to a 1-inch radius.

The platforms are divided into blocks of not more than 40 square feet area and expansion joints are to be provided every 25 to 40 feet.

These platforms are designed by the engineering force of the N. Y. C. & H. R. R. R. under the supervision of Mr. George A. Harwood, Chief Engineer of Electric Zone Improvements.

## CHAPTER VIII.

## COAL AND SAND STATIONS AND ASH HANDLING PLANTS.

Reinforced concrete is peculiarly adapted to the construction of structures which are to be used for the storage of coal on account of its undoubtable fire-resisting qualities, permanence and strength.

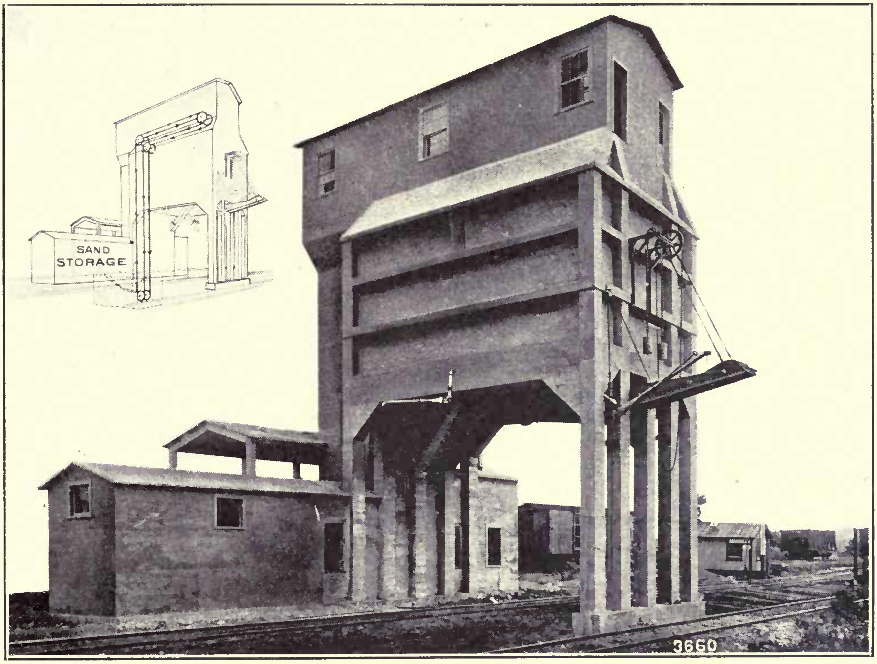


FIG. **76**.—COAL AND SAND STATION, N. & W. RY.

Through the use of inferior bins such as have been constructed of timber or steel, the railroads of this country have suffered much inconvenience and heavy expense. The spontaneous combustion to which coal is subject when stored in great quantities not only results in the loss of the coal itself and the damaging of much valuable machinery, but also in the destruction of the bin, if it is constructed of either wood or steel.

This condition has led to entirely reinforced concrete structures, even though the initial cost is higher than for wood or steel. The coal and sand stations which have thus far been constructed of reinforced concrete have given entire satisfaction.

CONCORD COAL AND SAND STATION, N. & W. RY. This combination coaling and sand station, shown by the photograph in Fig. 76, was built and entirely equipped for the Norfolk and Western Railway by the Link Belt Co. of Philadelphia during the summer of 1907. The reinforced concrete details were designed and worked out by Mr. Walter Loring Webb, Consulting Engineer, of Philadelphia, and the concrete work was sublet to McLaughlin Brothers, of Baltimore, Md.

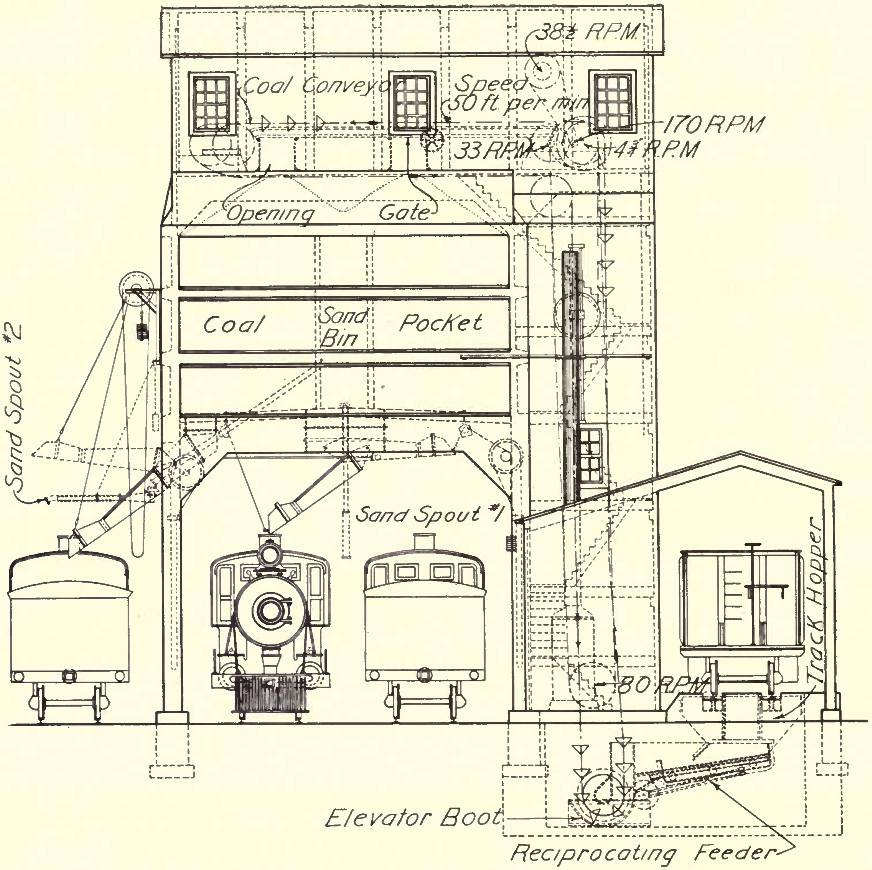
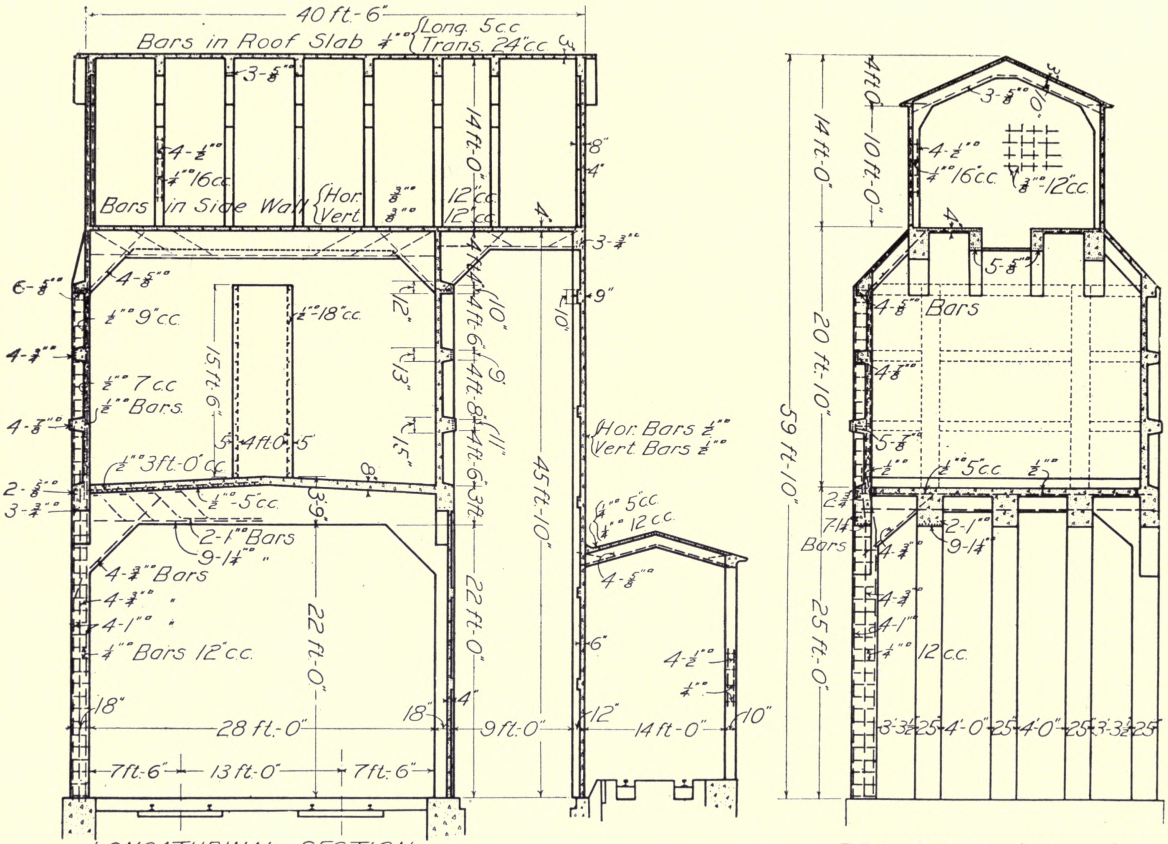


FIG. 77.—CROSS-SECTION SHOWING MECHANICAL EQUIPMENT OF CONCORD COAL AND SAND STATION.

In general the station consists of an elevated coal pocket having a capacity of 260 tons of coal, and a wet sand storage house on the ground with an elevated dry sand bin. From a study of the drawing in Fig. 77, showing the mechanical equipment of the plant, it will be seen that the coal is brought to



LONGATUDINAL SECTION

TRANSVERSE SECTION

FIG. 78.—LONGITUDINAL AND TRANSVERSE SECTIONS, CONCORD COAL AND SAND STATION.

the pocket on a side track, and dumped through a 10 by 12 foot track hopper into a reciprocating feeder which delivers it into a steel bucket elevator discharging into a conveyor trough above for distribution into the pocket. The photograph in Fig. 79 shows the conveyors and the conveyor trough over the pocket. The coal is fed to the engine tenders through hinged gates and over counterweighted coaling chutes, two directly under the pocket and two over the track in front of the pocket. The wet sand passes into a dryer emptying into a sand pit underneath, where it is scooped up and carried by a sand elevator which dumps it from above into the dry sand bin. From this bin it is fed to the engines through two telescopic sand spouts.

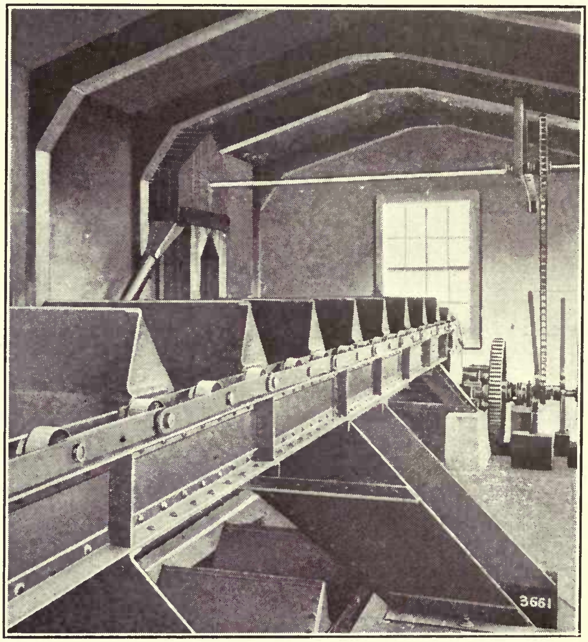


FIG. 79.—CONVEYORS OVER COAL POCKET, CONCORD COALING AND SAND STATION.

In designing the structural features of the station, the unit compression in the concrete was taken as 500 pounds per square inch, and the tension in the steel as 16,000 pounds per square inch. The side walls were designed on the basis of the computed lateral pressure exerted by bituminous coal weighing 47 pounds per cubic foot. This gave a maximum lateral pressure of 248 pounds at the bottom of the pocket, and a vertical pressure on the bottom slab of nearly 1,000 pounds per square foot. The essential features of design and construction are shown very clearly by the longitudinal and transverse sections in Fig. 78.

In the construction of the building, concrete mixed in the proportion of 1 part Atlas Portland Cement to 2 parts sand to 4 parts broken stone, was used throughout and was mixed in a cube mixer equipped with hoisting engine and elevator and delivered over the work in batch carriers. The cost of the concrete work was $8,600.

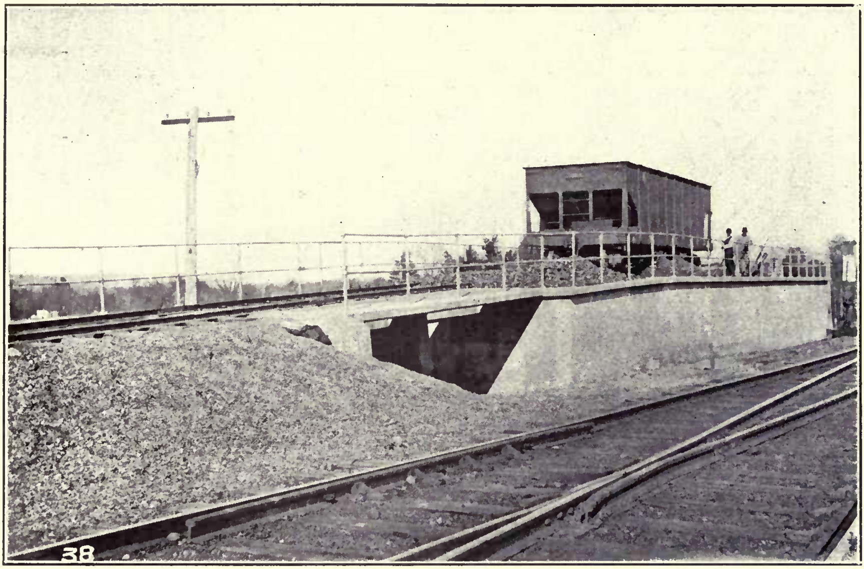
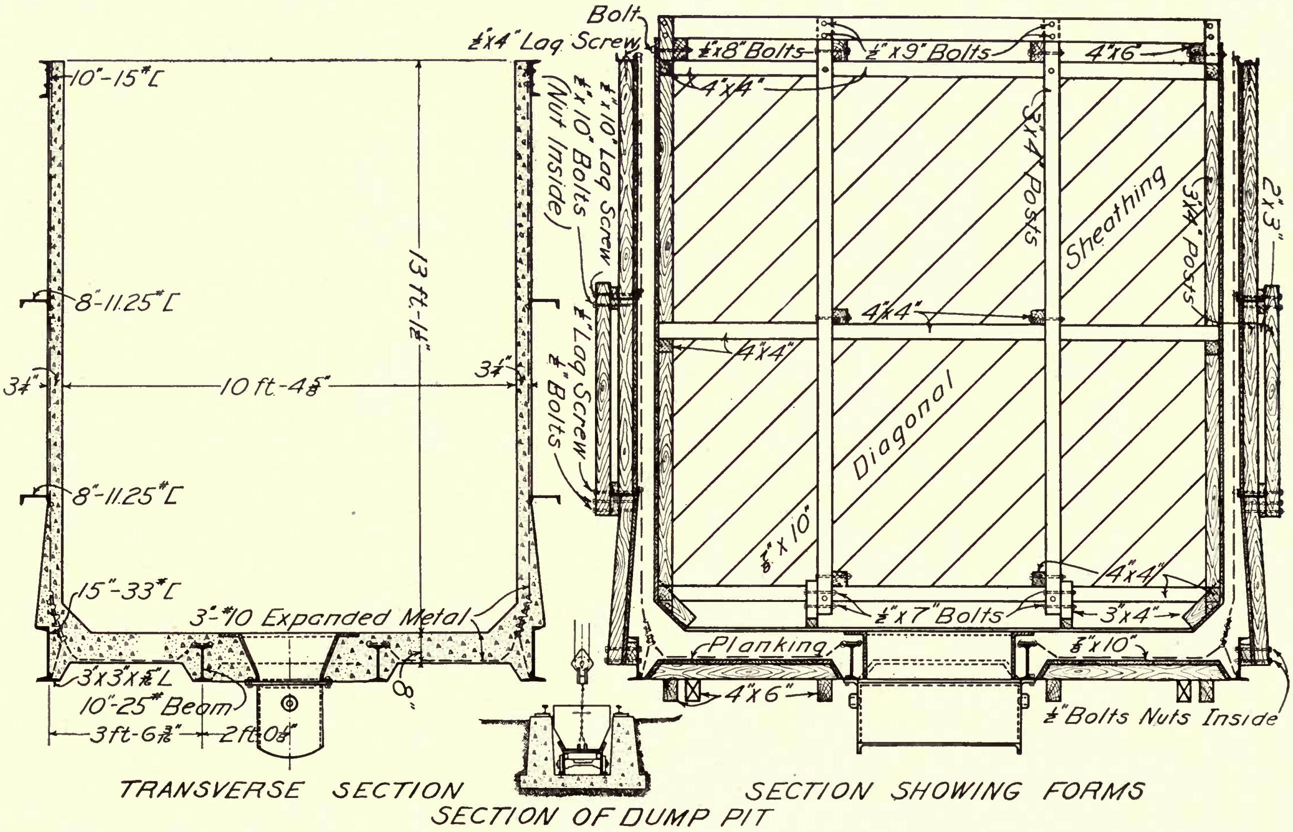


FIG. 80.—MURRAY HILL RETAIL COAL POCKET, D., L. & W. R. R.

## ASH HANDLING PLANTS.

Inasmuch as wood burns and steel corrodes, it has long been a problem as to how to build ash handling plants capable of withstanding the destructive effect of ashes quenched with water. The advent of reinforced concrete into the field of railroad construction has successfully solved this problem. At the present time most of the plants being built throughout the country consist of a steel framework which support bins constructed of reinforced concrete. The accompanying photograph in Fig. 82 is a good example of such a plant designed and erected in 1905 by the Link Belt Company for the Norfolk & Western Railway at Bluefield, W. Va.

The ash bin has a storage capacity of 30 tons. Ashes are dumped from the engine into 1-ton tubes which rest on trucks in the dump pit below, with their tops flush with the rails, and are raised, dumped into the bin and returned automatically by an electric hoist. In the photograph one of the skips is seen in action, while on the drawing in Fig. 81 is shown a cross section of the dump



TRANSVERSE SECTION

SECTION OF DUMP PIT

SECTION SHOWING FORMS

FIG. 81.—SECTION OF ASH BIN SHOWING FORMS, BLUEFIELD ASH HANDLING PLANT.

pit. The ashes are emptied from the bin through a discharge gate into cars on a track directly beneath.

The details of construction of the concrete work of the bin are shown in Fig. 81 together with the forms and the manner in which they were supported by the steel framework of the building. The cost of the concrete work including the forms was about $700.

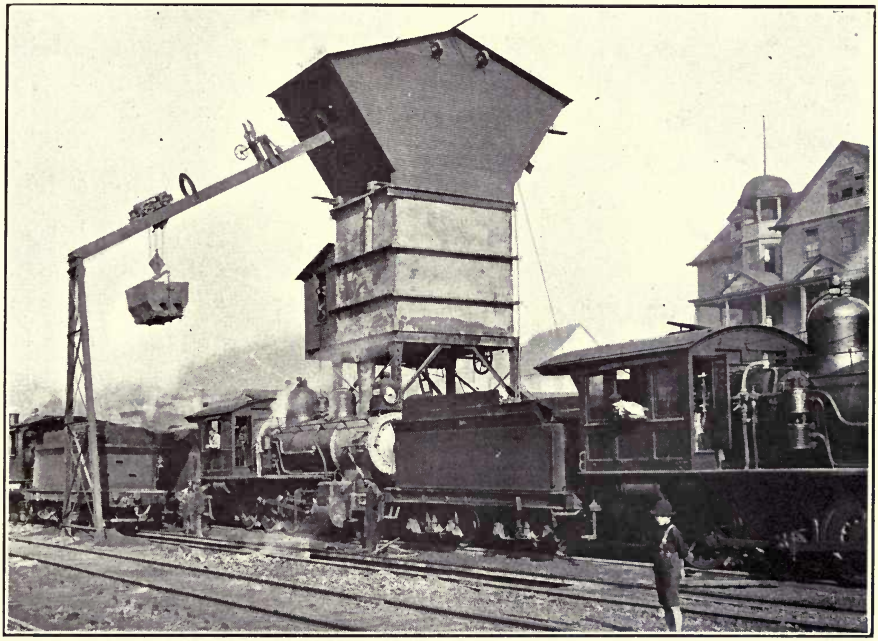


FIG. 82.—ASH HANDLING PLANT, BLUEFIELD, W. VA., N. & W. RY.

HOBOKEN COAL TRESTLE, D., L. & W. R. R. As shown by the photograph in Fig. 83, this trestle forms an approach by which loaded coal cars may be taken to the level of the second floor of the power house where the coal is dumped to the space in front of the boilers. It will be seen that the trestle proper, which is 226 feet 3 inches long, comprising 18 bents on piers spaced 12 feet on centers, has for an inner abutment the wall of the power house and for the outer abutment the end of an approach 112 feet 4 inches long.

From out to out the trestle is 16 feet wide, about one-half this width being taken up by a walk each side of the track.

The footings, which rest on piles, are 4 feet 9 inches wide and 3 feet thick.

Each pier is 19 feet wide and 18 inches thick at the top with a batter of 1 inch per foot in cross section of the trestle and ½ inch per foot in longitudinal section, and is reinforced vertically with ¾-inch square bars placed in two rows 3 inches from the outside of the pier, 5 inches on centers underneath the stringers, and 9 inches on centers between the stringers. In addition to these vertical bars, similar ones are placed horizontally 18 inches apart.

The beams or stringers resting on these piers are 18 inches by 27 inches, and are reinforced with three 1¼-inch square bars, two being bent up at the quarter points to take care of the diagonal tension. Over each pier the top of the stringer is also reinforced with four 1½-inch square bars 8 feet 4 inches long. Every two feet, ¾-inch bolts 12 inches long are embedded 9¼ inches in the top of the stringer to which are secured clamps for holding the rails in place.

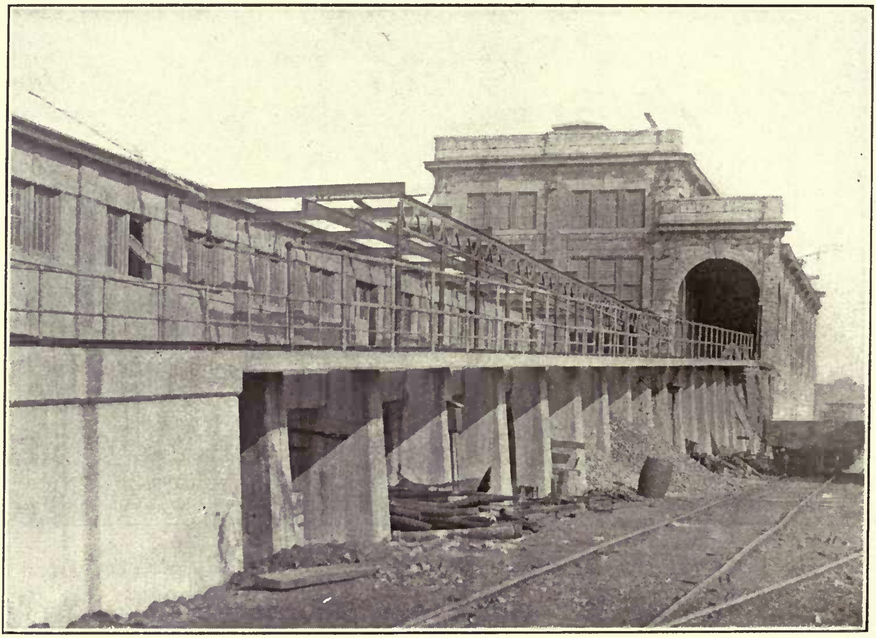


FIG. 83.—COAL TRESTLE, HOBOKEN, N. J., D., L. & W. R. R.

As will be seen from the photograph in Fig. 84, the sidewalks are carried by an inverted rail at each bent which extends the width of the trestle. To these rails clips are attached every 6 inches with openings in each leg through which the rods forming the reinforcement of the sidewalk are passed.

A mixture of 1 :2 :4 was used throughout.

The trestle was designed and constructed by the Engineering Department of the Delaware, Lackawanna and Western Railroad in 1907 under the supervision of Mr. Lincoln Bush, Chief Engineer, and Mr. George T. Hand, Assistant Engineer, with Mr. E. I. Cantine as Division Engineer.

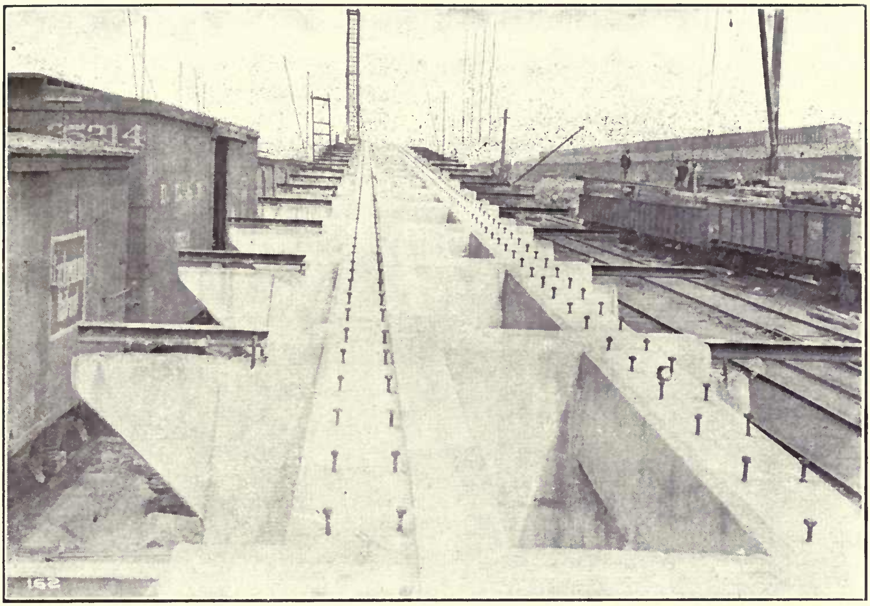


FIG. 84.—HOBOKEN COAL TRESTLE UNDER CONSTRUCTION, D., L. & W. R. R.

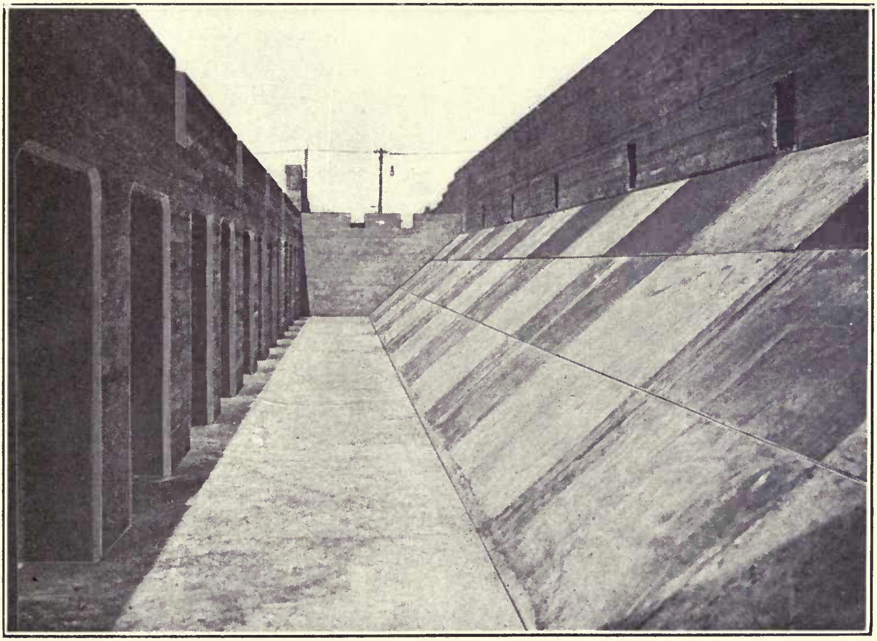


FIG. 85.—REINFORCED CONCRETE CINDER PIT, PITTSBURG SHOPS OF KANSAS CITY SOUTHERN RY.
Built by Arnold & Co., of Chicago.

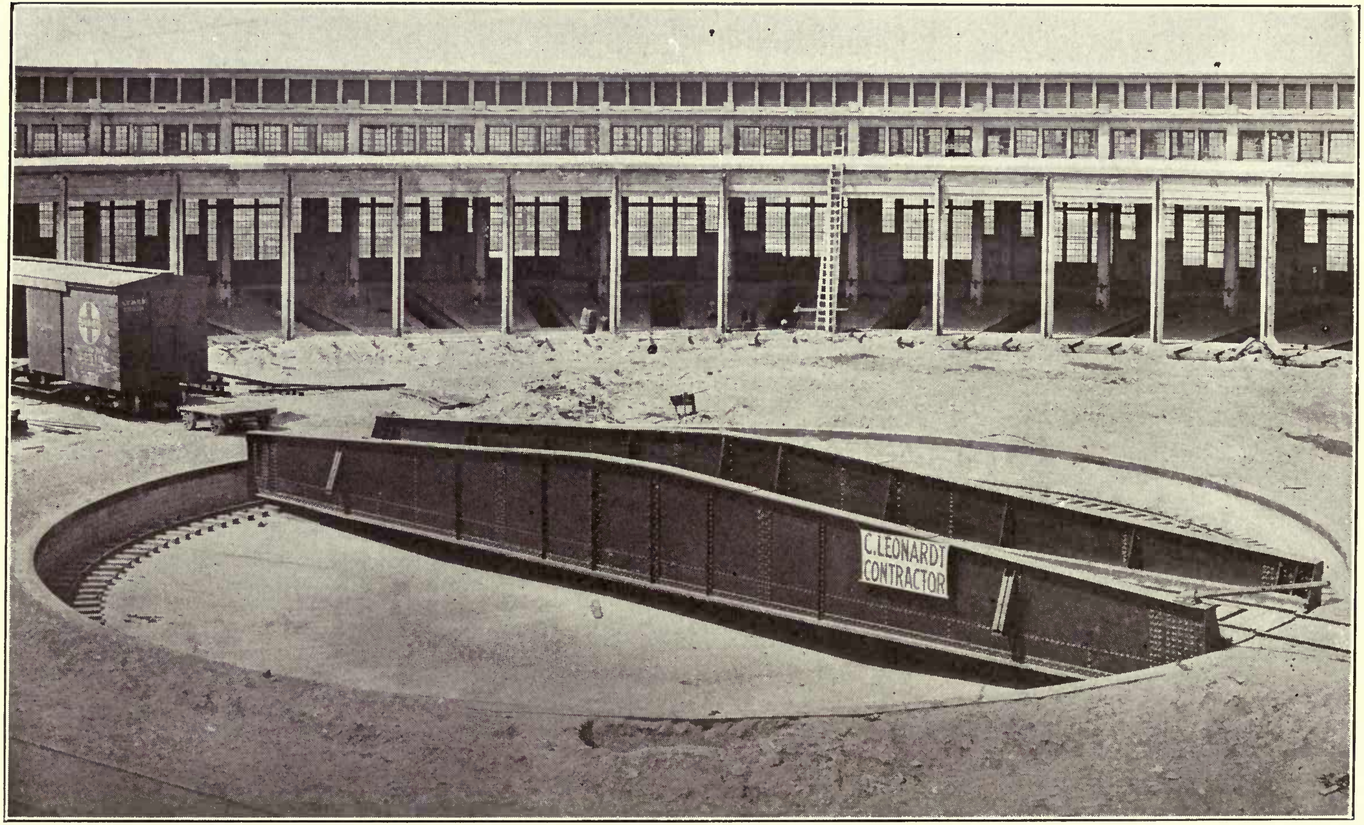


FIG. 86.—TURNTABLE PIT, ATCHISON, TOPEKA AND SANTA FE RY. (See page 127.)

# CHAPTER IX.

## ROUNDHOUSES AND TURNTABLE PITS.

### ROUNDHOUSES.

The adaptability of concrete to roundhouse construction is clearly demonstrated in the report* submitted on that subject by the Committee on Buildings of the American Railway Engineering and Maintenance of Way Association before the annual convention of that society held in Chicago, March, 1908.

For the purpose of discussion, the roundhouse was considered divided into Foundations and Pits, Roof, Supporting Columns and Outer Walls; and excerpts from the report are given below in the order named.

FOUNDATIONS AND PITS. "While in some cases local conditions may favor the use of stone or brick for foundations and pits, it may be stated, as a general proposition, that good practice in roundhouse construction now requires the use of concrete for these parts of the structure. When a solid foundation cannot be obtained within a few feet below the floor level of the building a considerable saving may be effected by the use of reinforcement."

ROOF. "In economy of first cost, durability and fire-resisting qualities, there is no other fireproof roof construction which is equal to reinforced concrete. Steel except as a reinforcement for concrete is not a satisfactory material for engine house roof construction."

SUPPORTING COLUMNS. "If the roof is of reinforced concrete, it should be supported by columns of the same material in the outer and end walls, as well as in the interior of the building. These columns should be concreted with the roof, the concrete being run into the forms from above. The columns on the inner circle to which the doors are attached should be of some other material than concrete, preferably steel or cast iron."

OUTER WALLS. "For a structure roofed with reinforced concrete, the curtain walls may be of brick, plain concrete, reinforced concrete or plaster. Concrete will, if properly made, give good service and local costs of materials and labor would ordinarily determine which of the first three styles of curtain walls named above should be built. The plaster curtain wall may be used where it is desirable or necessary to reduce the first cost to a minimum.

"To build such a wall Portland cement is mixed with enough lime so that it can be worked with a trowel and is plastered on expanded metal. The lat-

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*Proceedings of the Ninth Annual Convention, Vol. 9, p. 166.

## COSTS OF REINFORCED CONCRETE ROUNDHOUSES COMPARED WITH OTHER TYPES

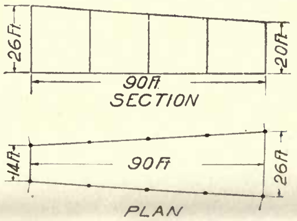
| Type | | First Cost | | | | | | | Average Annual Charges for First Ten Years | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Roof | Walls | Roof Covering | Front Post | Roof, Beams and Posts | Walls | Mill Work, Includ'g Painting | Contingencies 5% | Total | Interest and Depreciation 10.4% | Insurance | Maintenance | Total |
| Reinforced Concrete, 25-50 stalls. | Concrete... | 18 squares, @ $4.00.<br>$72 | Cast iron..<br>$20 | 43.3 cu. yds. rein. conc. @ $13.<br>$563 | 5.5 cu. yds. concrete @ $10.<br>$55 | $250 | $48 | $1,008 | $105 | .......... | $25 | $130 |
| Reinforced Concrete, 25-50 Stalls. | Brick...... | 18 squares @ $4.00.<br>$72 | Cast iron...<br>$20 | 42 cu. yds. rein. conc. @ $13.<br>$546 | 5,000 brick @ $16.<br>$80 | $250 | $48 | $1,016 | $106 | .......... | $25 | $131 |
| Reinforced Concrete, 25-50 Stalls. | Plaster..... | 18 squares @ $4.00.<br>$72 | Cast iron...<br>$20 | 43.3 cu. yds. rein. conc. @ $13.<br>$563 | 16 sq. yds. plaster @ $1.75.<br>$28 | $250 | $47 | $980 | $102 | .......... | $27 | $129 |
| Reinforced Concrete, 15-25 Stalls. | Plaster..... | 18 squares @ $4.00.<br>$72 | Cast iron...<br>$20 | 43.3 cu. yds. rein. conc. @ $14.<br>$606 | 16 sq. yds. plaster @ $1.75.<br>$28 | $250 | $49 | $1,025 | $107 | .......... | $27 | $134 |
| Wood................ | Brick...... | 18 squares @ $4.50.<br>$81 | Wood.....<br>$15 | 9,000 feet lumber @ $40.<br>$360 | 5,300 brick @ $16, Steel Lint'l<br>$125 | $250 | $42 | $873 | $81 | 1% on total cost.<br>$22 | $25 | $138 |
| Wood................ | Plaster..... | 18 squares @ $4.50.<br>$81 | Wood.....<br>$15 | 9,500 feet lumber @ $40.<br>$380 | 40 sq. yds. plaster @ $1.25, 200 ft. lumber @ $40.<br>$58 | $250 | $39 | $823 | $86 | 1% on total cost.<br>$21 | $30 | $137 |
| Wood................ | 4 ft. conc. to window sills, wood above. | 18 squares @ $4.50.<br>$81 | Wood.....<br>$15 | 9,500 feet lumber @ $40.<br>$380 | 4 cu. yds. concrete @ $7, 300 ft. lumber @ $40.<br>$40 | $250 | $38 | $804 | $83 | 1.2% on total cost.<br>$26 | $32 | $141 |

Costs shown are in dollars per stall and include structures only above foundations without jacks, pits, ventilators, piping, etc. Windows to occupy all available space above doors on inner circle and between pilasters in outer circle, and dimensions to be as shown on accompanying sketch.

Insurance is figured on the total cost of the house.

The estimates are based on the following prices of material.

| | | | |
|---|---|---|---|
| Brick...................... | $9.00 per M. | Cement.................... | $1.50 per bbl.. |
| Lumber form................ | 23.00 " | Sand...................... | 0.75 per cu. yd. |
| Lumber, permanent.......... | 28.00 " | Stone..................... | 0.60 " |
| Reinforcing Steel.......... | 2¼c. per lb. | | |



COMPARISON OF COST OF DIFFERENT TYPES OF ROUNDHOUSES.

ter is stiffened with rods and channel irons, which are used to support the window frames. A wall of this character can be built more quickly than a concrete wall, is efficient and should be durable. If damaged by a locomotive or otherwise, it is easily repaired, and alterations can be readily made. Used with concrete columns, it should not crack, and its first cost is but about half that of a brick wall."

COST. "The cost of concrete construction in roundhouses depends largely upon the number of times the forms can be used. It follows, therefore, that where the structure is large and the forms for each unit or stall can be used many times in the same roundhouse, the cost per stall is much less than in a small building. Consequently reinforced concrete construction is more economical in large than in small roundhouses, when compared with brick or frame construction."

The costs of the different types of construction are compared in the table* on page 122.

This table gives in detail a comparative statement of the cost and annual charges per stall of six types of roundhouses, the first three being roofed with reinforced concrete and having outer walls of concrete, brick and plaster, respectively, in the order named. The fourth given is the same type as the third and merely shows the increase in unit cost for the reinforced type when the building is reduced in size.

With these figures as a basis it is evident that the concrete house is in the long run more economical, because of its greater permanency and the lesser chance of damage to it and the equipment it contains, by fire and other causes.

In addition to the roundhouse described below a number of different types of concrete roundhouses are illustrated by the photographs in the back of the book.

WATERBURY ROUNDHOUSE, N. Y., N. H. & H. R. R. While this roundhouse as designed includes 22 stalls, the part constructed at the present time consists of 10 stalls, each comprising about 8 degrees of the circle, and is connected at one end to a machine shop.

As will be seen from the radial section in Fig. 89 the house consists of four circumferential rows of hooped concrete columns carrying beams and roof slabs of reinforced concrete.

The entrance, as shown by the stall elevation in Fig. 87, is closed in by large round slat rolling doors between the columns, while the outer circle is encompassed by a brick wall with large glass windows with concrete sills directly in line with the tracks.

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*Proceedings American Railway Engineering and Maintenance of Way Association, Vol. 9, p. 182.

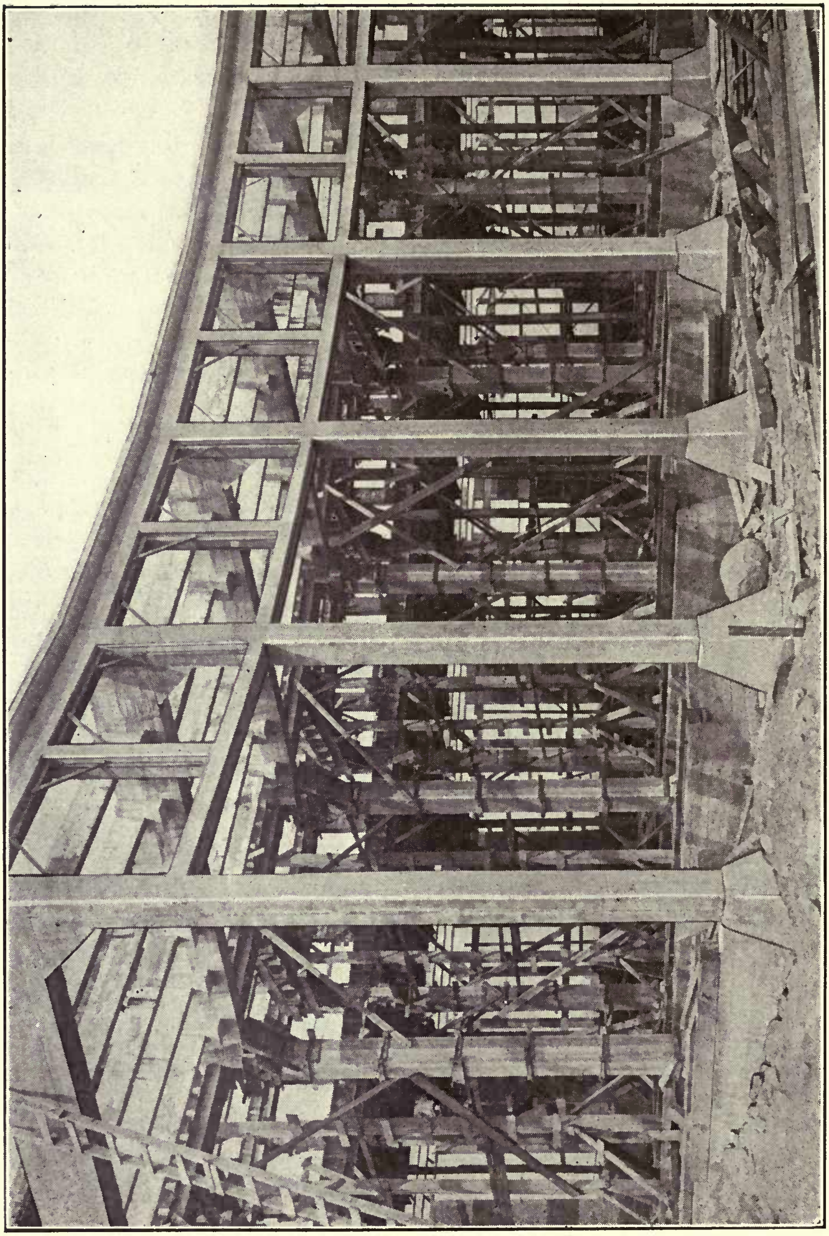


FIG. 87.—WATERBURY ROUNDHOUSE UNDER CONSTRUCTION.

Each stall is equipped with an asbestos lumber smoke-jack and each pit is provided with steam pipes for removing ice and snow from the locomotives. Fig. 88, which is a cross section of a stall pit, shows the arrangement of these pipes.

Permanent compressed air jacks are installed in drop pit under the tracks of two of the longitudinal pits to remove trucks which can then be slid into a transverse pit and thence into the machine shop.

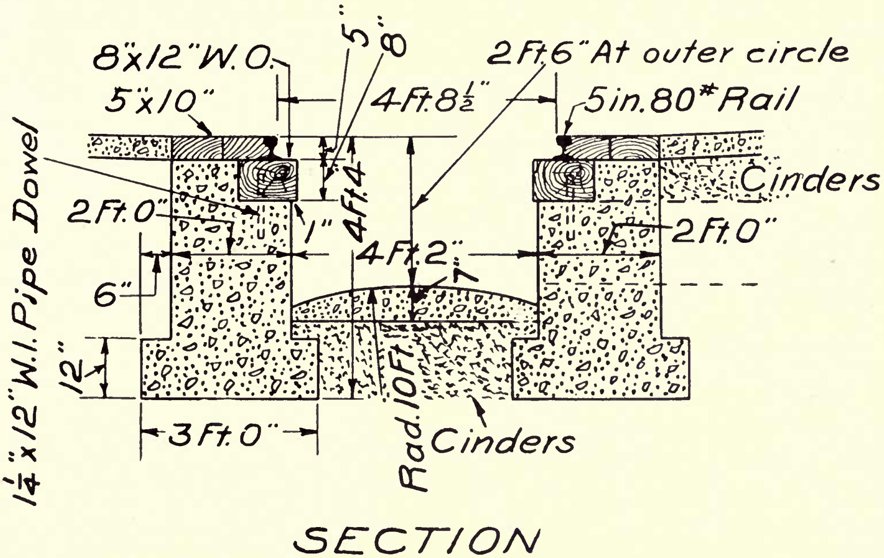


FIG. 88.—CROSS SECTION STALL PIT, WATERBURY ROUNDHOUSE.

The drawings in Fig. 89 show the essential details of design and construction of the columns and roof construction.

The columns are of square section 14 by 14 inches and are reinforced with six ⅝-inch plain square bars hooped with ⅝-inch round hooping ½-inch pitch.

The method employed in constructing the roof presents a rather unique and interesting feature. While the main girders were cast in place in the usual manner the intermediate beams and roof slabs were moulded on the ground, cured and hoisted to their required position and grouted in place. The intermediate beams, set in reinforced bracketed pockets on the main girder to which they are rigidly connected, were locked by extending the reinforcement from both beam and packet and filling the joints with wet concrete. The photograph in Fig. 87 of the roundhouse during erection, shows this form of construction very clearly.

As will be seen from Fig. 89 the slabs which are made in widths of about four feet rest directly on top of the intermediate beams and main girders.

These slabs are 3 inches thick and are reinforced with woven wire mesh fabric.

After the slabs were set, the roof was covered with pitch and slag.

A mixture of 1:2:4 concrete was used throughout in the construction of the roundhouse.

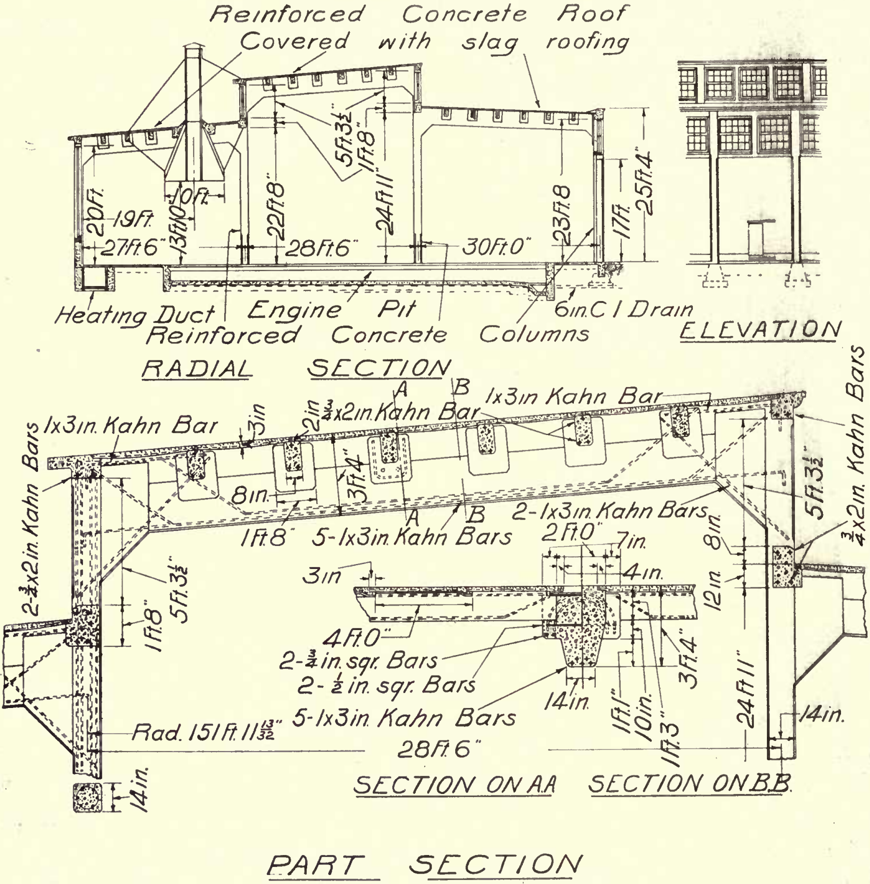


FIG. 89.—RADIAL SECTION WITH DETAILS OF ROOF CONSTRUCTION, WATERBURY ROUNDHOUSE.

The roundhouse was designed by the engineering department of the New York, New Haven and Hartford Railroad, Mr. Edwin Gagel, Chief Engineer, under the direction of Mr. E. H. McHenry, Vice-President, and was built in 1909 by the O'Brien Construction Company of Waterbury.

HURON ROUNDHOUSE, C. & N. W. RY. The photograph in Fig. 90 shows the 40-stall engine house of the Chicago and Northwestern Railway at Huron, S. D., under construction. This is a combination brick and concrete structure with all of the foundations, pits and underground work of concrete construction. It was built for the Chicago and Northwestern Railway by the Charles W. Gindele Co. of Chicago in 1907.

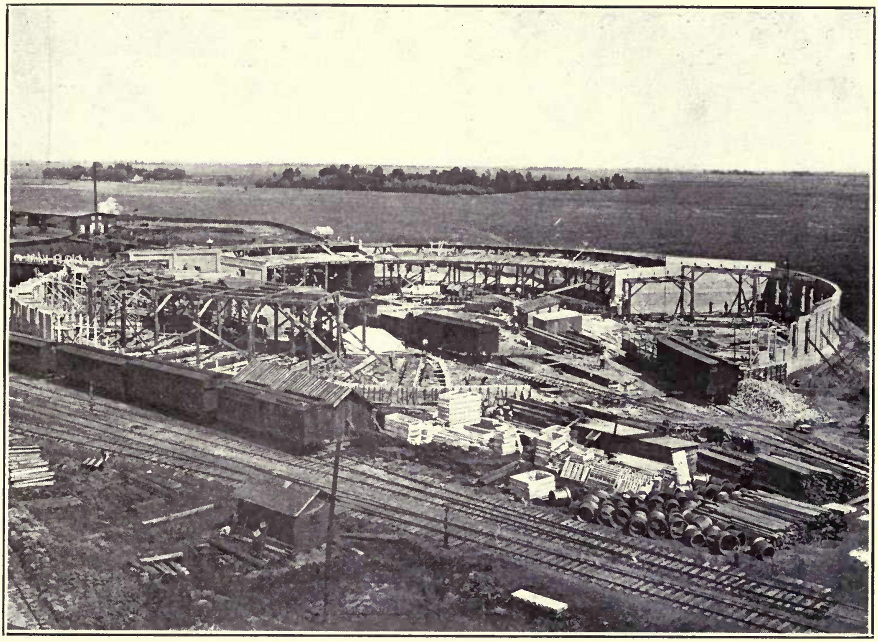


FIG. 90.—HURON ROUNDHOUSE DURING CONSTRUCTION.

## TURNTABLE PITS.

In connection with roundhouse construction the subject of turntable pits is of special interest. The facility and cheapness with which concrete pits can be built is so generally recognized that practically all turntable pits constructed to-day are built of concrete.

The photograph in Fig. 86, page 120, is of a standard turntable pit on the Santa Fe System, while the drawings in Fig. 91 show the standard pit for a 30-foot turntable on the N. Y. C. & H. R. R. R.

STANDARD PIT, N. Y. C. & H. R. R. R. Fig. 91 shows the essential details of design and construction of this pit, together with a drawing of the turntable itself.

As will be seen from the drawings in Fig. 91, the turntable is supported by a center pier surmounted by a complete templet 5 feet by 5 feet by 1 foot 6 inches. The concrete for the pier itself is mixed in the proportion of 1 part

Portland cement to 3 parts sand to 6 parts broken stone and the templet or cap in the proportions of 1 :1 :2.

The floor of the pit consists of 4 inches of 1 :2 :4 concrete laid on 8 inches of well tamped cinders.

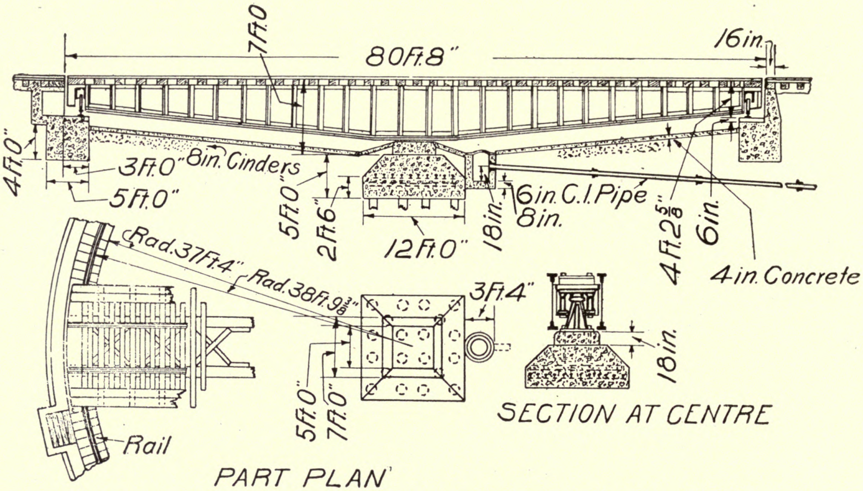


FIG. 91.—STANDARD 80-FT. TURNTABLE PIT, N. Y. C. & H. R. R. R.

The circular run rail is carried on a seat of 1 :3 :6 concrete resting on a foundation 5 feet wide and 4 feet high composed of 1 :4 :7½ concrete.

All exposed corners and edges of the concrete work are rounded to a 1-inch radius.

# CHAPTER X.

# SIGNAL TOWERS, WATER TANK SUPPORTS AND BUMPING POSTS.

## SIGNAL TOWERS.

Railroads throughout the country are experiencing a period of architectural Renaissance. Structures which have in the past been built of temporary construction, apparently regardless of outward appearance, are being replaced by permanent buildings of artistic design. This is particularly true in the case of signal towers, the old unsightly and necessarily temporary wooden structures being superseded either by entire concrete or combination concrete and brick towers of pleasing appearance and permanent construction.

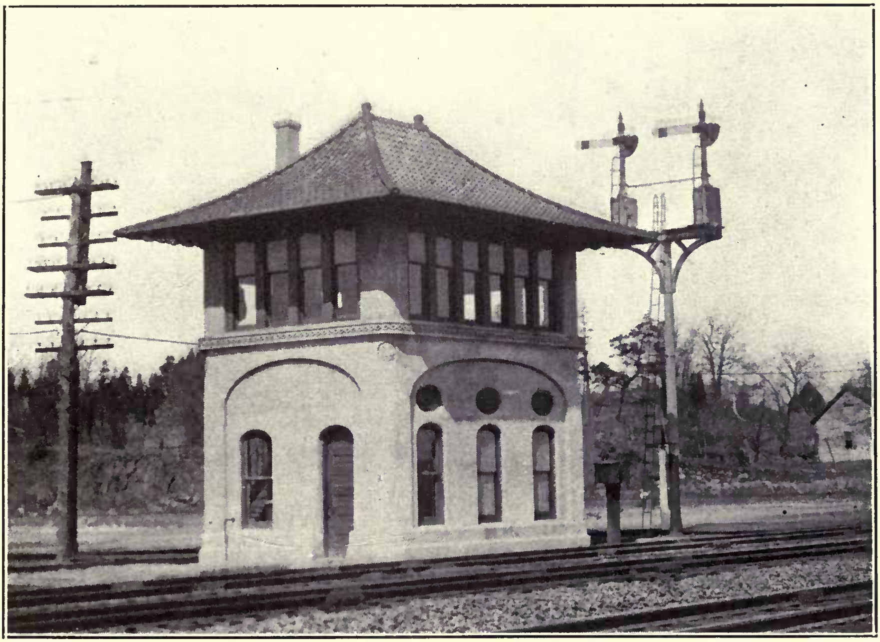
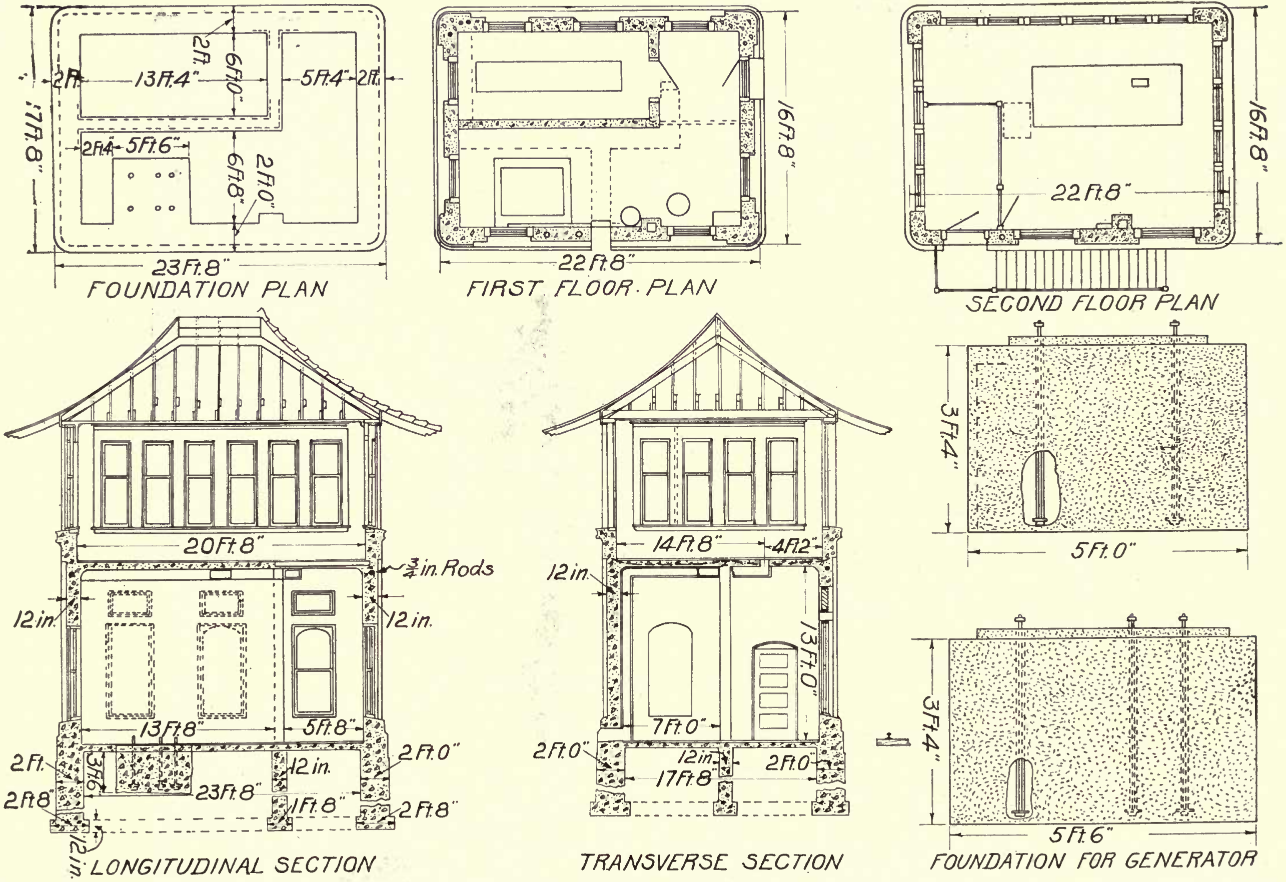


FIG. 93.—SIGNAL TOWER, NAUGATUCK, CONN., N. Y., N. H. & H. R. R.

NAUGATUCK JUNCTION TOWER, N. Y., N. H. & H. R. R. With the exception of the roof, which is of Ludowici Celadon tile on wooden rafters, this tower is of concrete construction throughout. The foundation and both ex-



FOUNDATION PLAN

FIRST FLOOR PLAN

SECOND FLOOR PLAN

LONGITUDINAL SECTION

TRANSVERSE SECTION

FOUNDATION FOR GENERATOR

FIG. 94.—DETAILS OF CONSTRUCTION, NAUGATUCK SIGNAL TOWER, N. Y., N. H. & H. R. R.

terior and interior walls are of plain 1:3:5 gravel concrete, while the floors are of 1:2:4 gravel concrete reinforced with No. 16 2½-inch expanded metal. The general features of design and construction are shown very clearly by the drawings in Fig. 94.

As will be seen from the photograph in Fig. 93, the architectural treatment of the building is enhanced by the use of indented arches over the lower windows, and by a projecting ornamented belt course which runs around the entire building and serves as a lintel for the upper windows. The roof is designed along pagoda lines with a very pleasing result.

The tower was designed by the engineering department of the railroad and built by its building department in 1906.

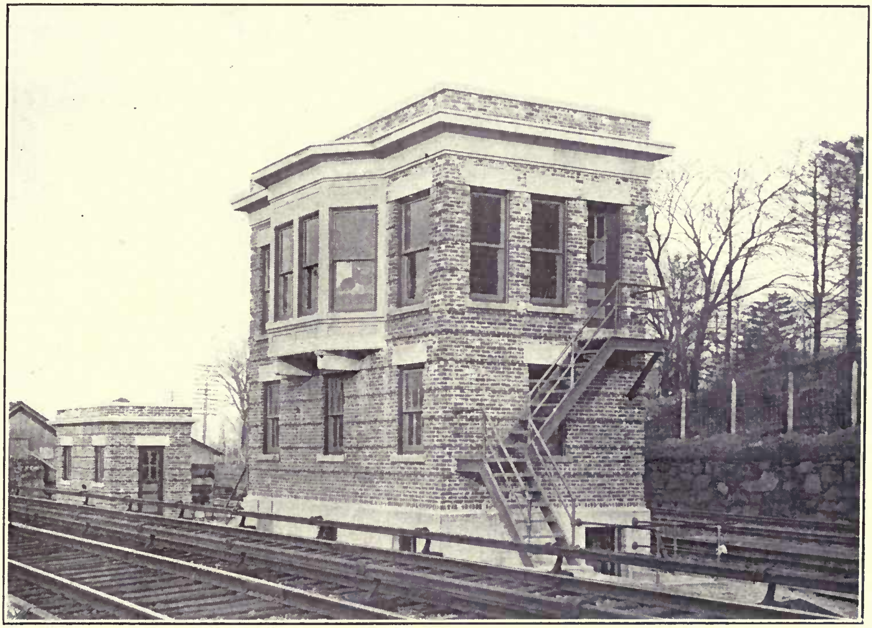


FIG. 95.—KINGSBRIDGE SIGNAL TOWER, N. Y. C. & H. R. R. R.

KINGSBRIDGE TOWER, N. Y. C. & H. R. R. R. The standard signal towers of the electric zone of the New York Central and Hudson River Railroad are combination brick and concrete structures, a typical example of which is shown by the photograph of the Kingsbridge Tower in Fig. 95. The footings and foundation walls below grade are of 1:4:7½ concrete, and the walls above grade up to the first floor level are of 1:3:6 concrete. All the sills and lintels, the coping, the overhanging bay window and supporting brackets and the cornice are of 1:2:4 concrete, the details of construction of which are shown by the drawings in Fig. 96.

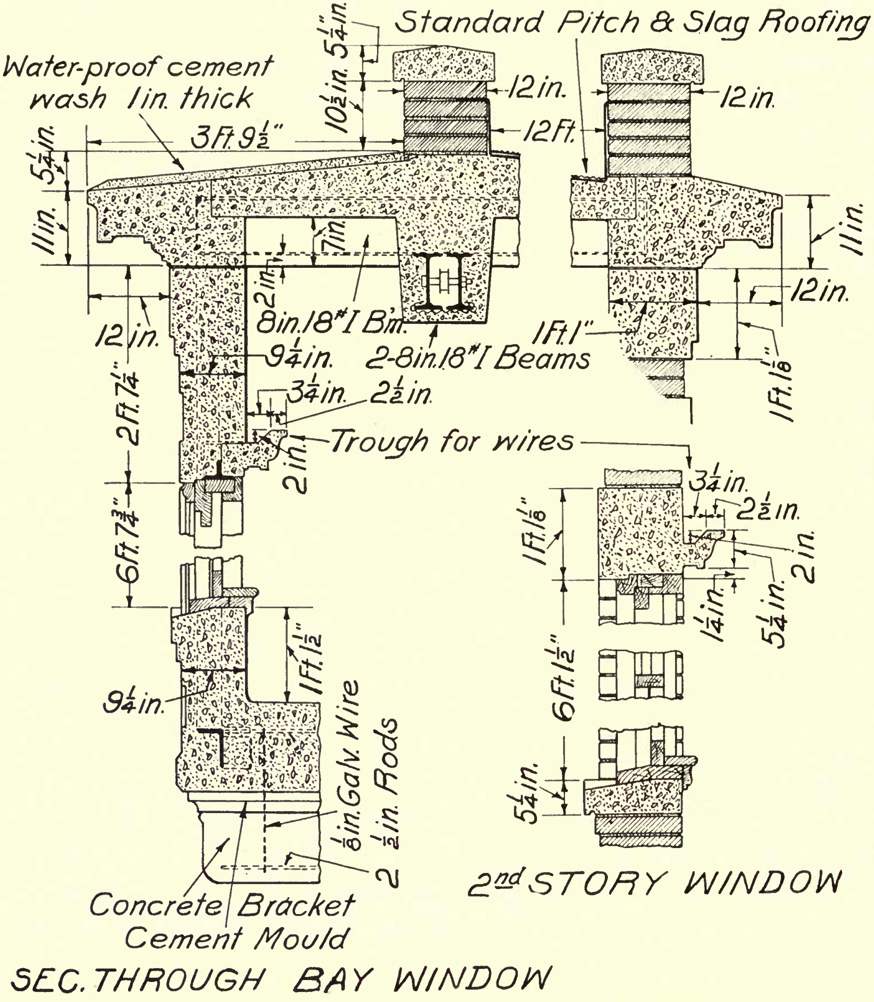


FIG. 96.—DETAILS OF CONSTRUCTION, KINGSBRIDGE SIGNAL TOWER, N. Y. C. & H. R. R. R.

The excellent finish of this work was obtained by floating the green concrete with water and rubbing it with a mortar brick composed of 1 part cement to 2 parts sand. The floor and roof construction consists of 1:2:4 concrete slabs, reinforced with ½-inch round rods, supported by steel I-beams.

GROVE ST. SIGNAL TOWER, D., L. & W. R. R. This tower, located about 250 feet west of Grove Street, Hoboken, is built entirely of reinforced

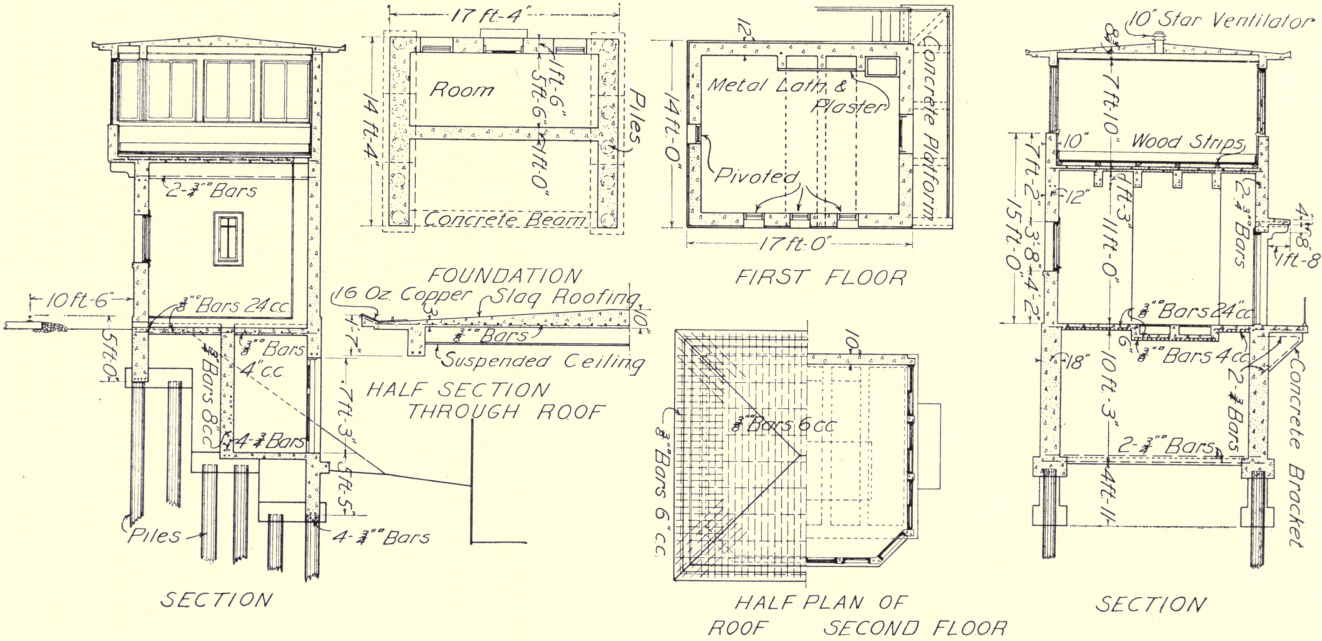


FIG. 97.—DETAILS OF CONSTRUCTION, GROVE ST. SIGNAL TOWER, D., L. & W. R. R.

concrete and was designed and constructed by the engineering department of the Delaware, Lackawanna and Western Railroad, Mr. Lincoln Bush, Chief Engineer, and Mr. F. J. Nies, architect. The general details and essential features of design and construction are shown in Fig. 97, while the photograph in Fig. 98 is of the finished structure.

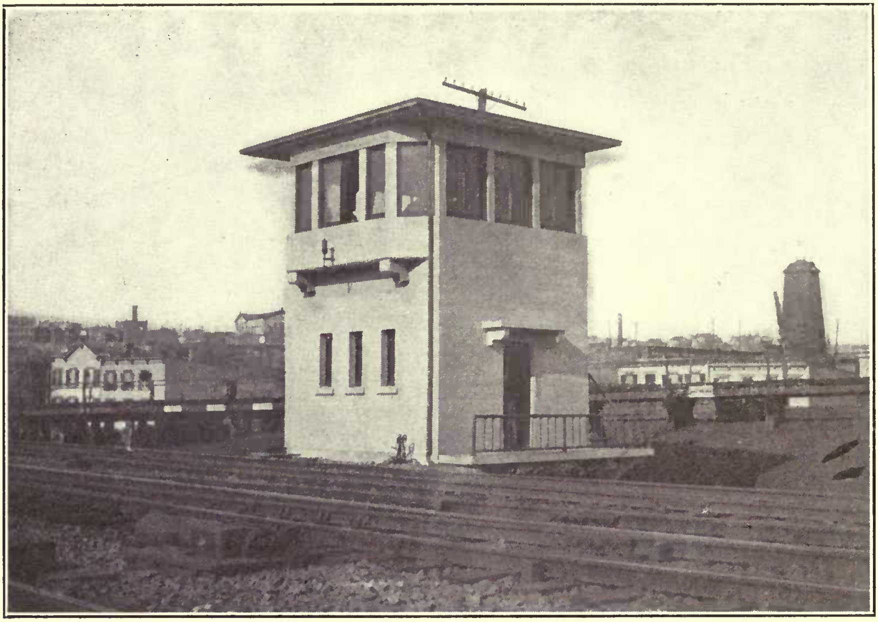


FIG. 98.—SIGNAL TOWER, GROVE STREET, HOBOKEN, D., L. & W. R. R.

There are several interesting features of construction in connection with the tower which are somewhat out of the ordinary. The side walls rest on creosoted piles spaced 2 feet 8 inches apart, while the front and rear walls are carried by reinforced concrete girders spanning from side wall to side wall. At the first floor level there is a concrete platform leading to the iron stairs in the rear which is supported on reinforced concrete brackets cantilevering 3 feet from the side wall of the building. The roof, which overhangs 1 foot 10 inches, and appears from the ground to be flat, is a reinforced concrete slab pitching from a thickness of 3 inches at the walls to 10 inches at the center. With the exception of the overhang, which is flashed with 16-ounce copper, the concrete slab is covered with slag roofing.

The concrete for the entire building was mixed in the proportions of 1:2:4, and all exposed surfaces were rubbed.

In designing the tower a ratio of elasticity of 15 was assumed, and the concrete was figured at 600 pounds per square inch fiber stress, 500 pounds per square inch direct compression, and 50 pounds per square inch shear, while the steel was given a tensile stress of 16,000 pounds per square inch.

## WATER TANK SUPPORTS.

Owing to its strength, rigidity and resistance to fire and decay, reinforced concrete is aptly suited for the construction of water tank supports.

In addition to the support described below, other examples of this form of construction are illustrated among the miscellaneous photographs in the back of the book.

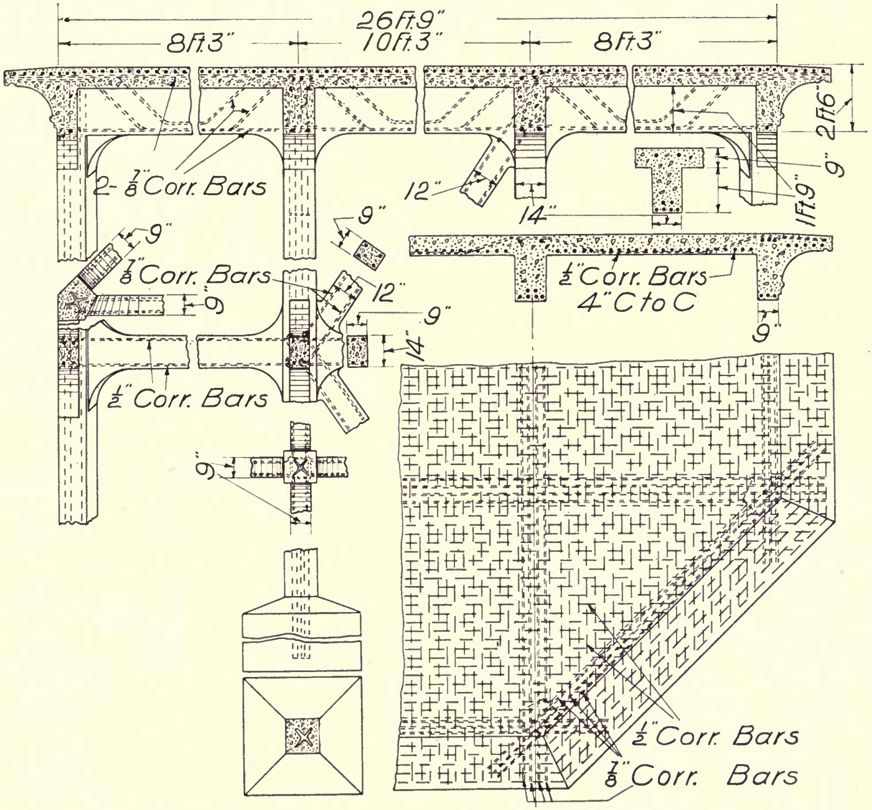


FIG. 99.—DETAILS OF CONSTRUCTION, WATERBURY WATER TANK SUPPORT.

**WATER TANK SUPPORT AT WATERBURY, N. Y., N. H. & H. R. R.** This tank support, octagonal in form, is 30 feet 9 inches wide, with the platform carrying the water tank 40 feet above the ground line. It is designed to carry a 55,400 gallon wooden tank.

The essential details of design and construction are shown clearly by the drawings in Figs. 99 and 100, while the photograph in Fig. 101 is of the finished support.

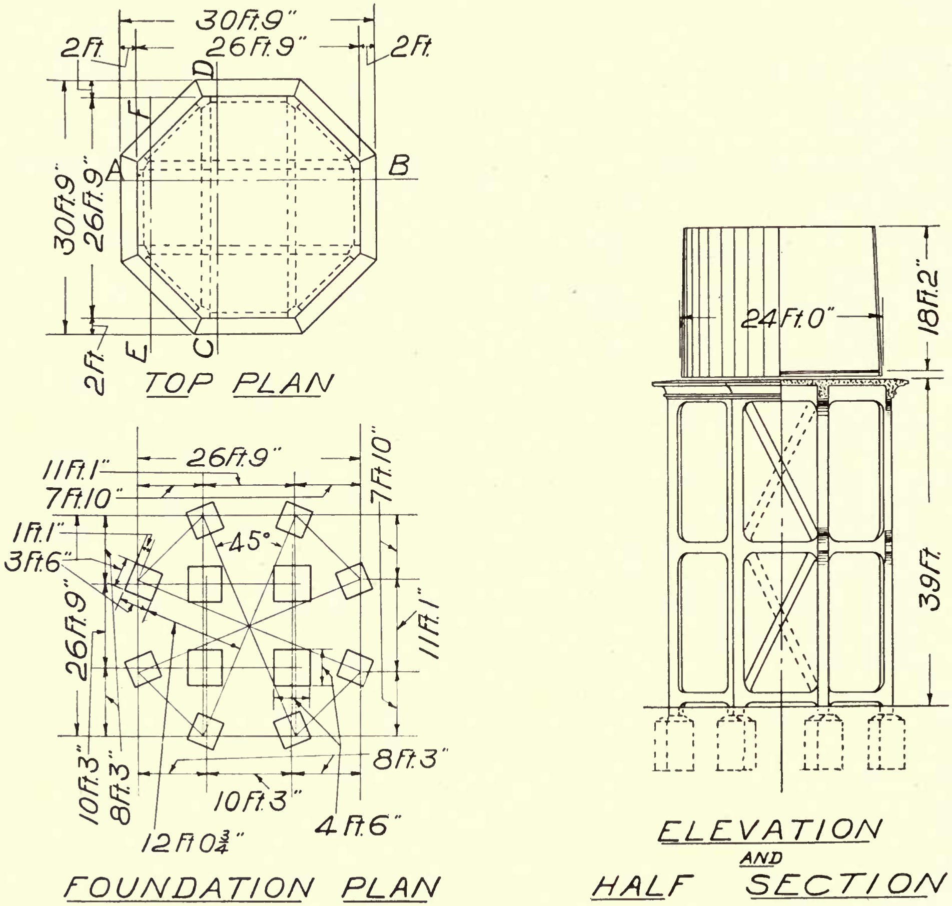


FIG. 100.—PLAN, HALF SECTION AND HALF ELEVATION, WATER TANK SUPPORT, N. Y., N. H. & H. R. R.

The method of reinforcing the supporting columns presents a rather unique and interesting feature. This reinforcement consists of two 95-pound third rails placed back to back and riveted every 3 feet, making a section in the form of a star strut.

The platform which is 9 inches thick is reinforced with ½-inch corrugated bars 4 inches on centers in both directions while the beams and diagonal braces are reinforced with ⅞-inch corrugated bars bent and hooked as shown in Fig. 99.

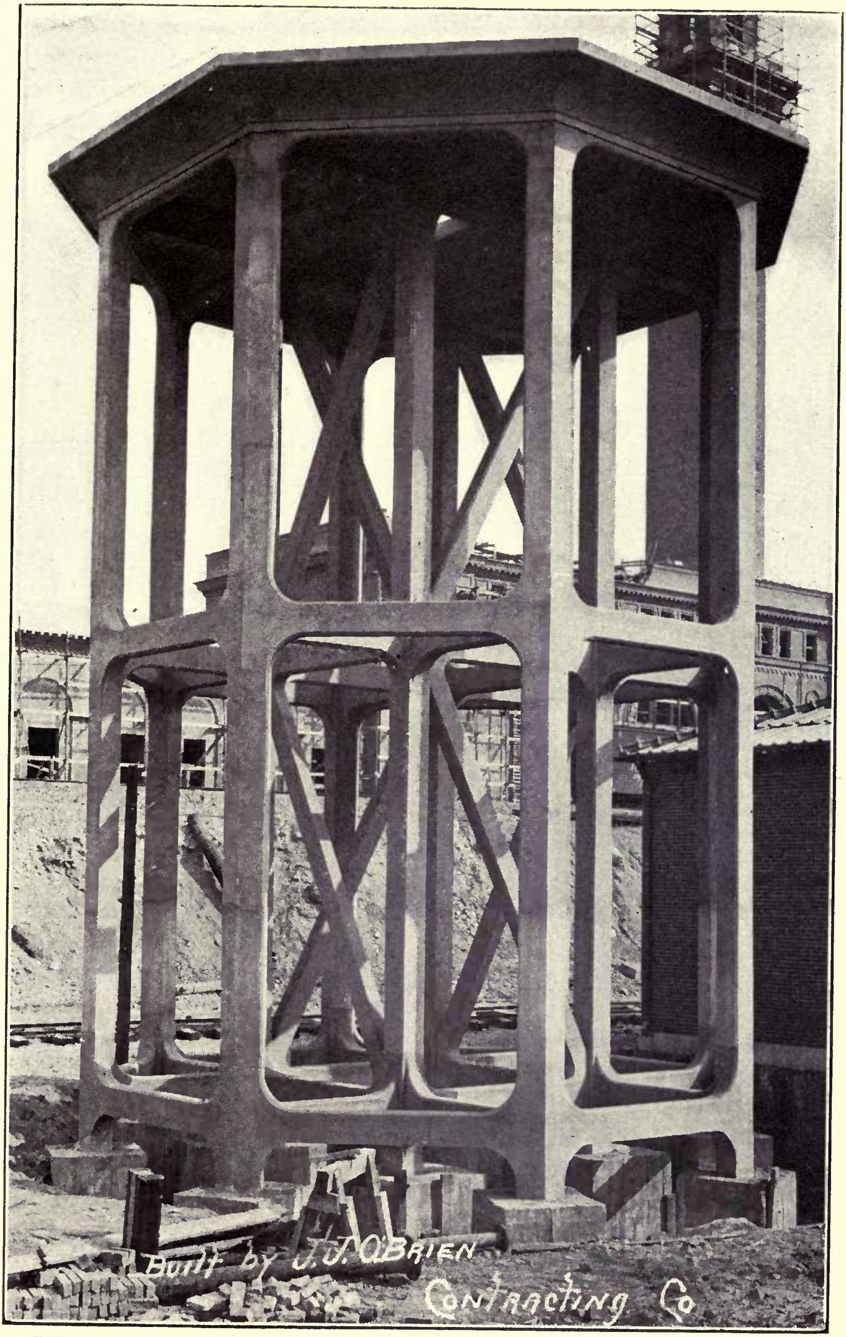


FIG. 101.—WATER TANK SUPPORT, WATERBURY, CONN., N. Y., N. H. & H. R. R.

Concrete for the support was mixed in the proportions of 1 part Portland Cement to 2 parts sand and to 4 parts screened gravel.

The structure was designed by the Engineering Department of the railroad and built by the O'Brien Construction Company of Waterbury, Conn., during the fall of 1908.

FIG. 102.—CONCRETE BUMPING POSTS, D., L. & W. R. R.

## BUMPING POSTS.

A bumping post, to insure safety against rotating or breaking down under constant buffing, must be constructed so as to be anchored in the earth direct rather than attached to the track itself, as is the case with practically all of the patented posts now in use on railways in this country. By the use of concrete, bumping posts can be constructed economically so as to meet the conditions of stability and permanence.

STANDARD CONCRETE BUMPING POSTS, D., L. & W. R. R. This post is given in detail by the drawings in Fig. 103, while the photograph in Fig. 102 shows three of the posts in service at Newark, N. J. As will be seen from the drawings, the buffer block is of granite and the reinforcement of the post consists of 80-pound rails connected with 1¼-inch tie rods. The footing of the post is carried down to solid foundation.

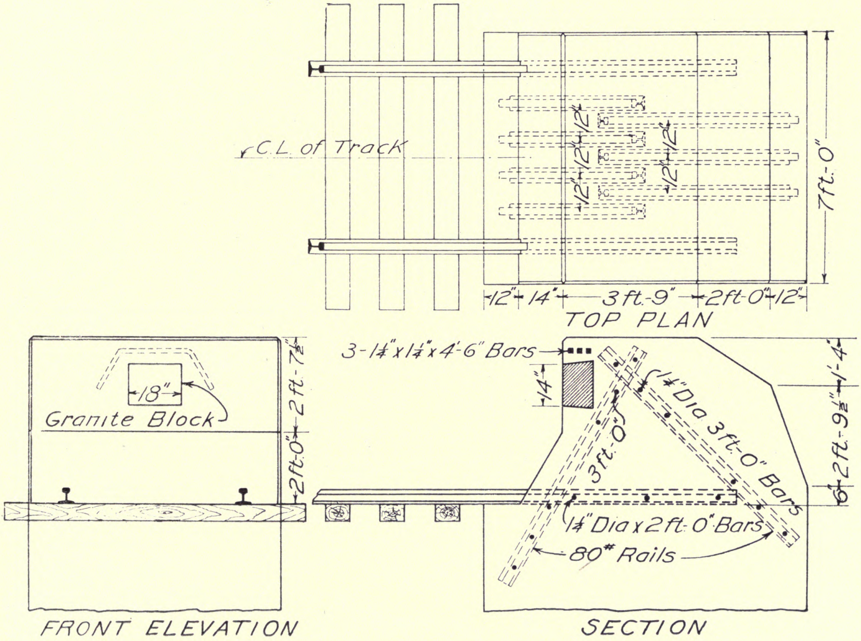


FIG. 103.—STANDARD CONCRETE BUMPING POSTS, D., L. & W. R. R.

FIG. 104.—COS COB POWER PLANT FROM RIVER.

# CHAPTER XI.

# POWER STATIONS, SHOPS, WAREHOUSES AND GRAIN ELEVATORS.

## POWER STATIONS.

The electrification of railroad systems, which bids fair to be a thing of the near future, will necessitate the construction of a large number of power stations along the lines of the railroads adopting this form of motive power.

Concrete construction in addition to its low first cost, facility of erection and fireproof character is especially adapted to the building of power plants on account of its inherent strength, resistance to vibrations and freedom from deterioration.

The New York, New Haven and Hartford Railroad, one of the earliest pioneers in the field of heavy electric traction, has installed electric equipment on its lines from Woodlawn, N. Y., to Stamford, Conn., with the power station for this twenty miles of road located at Cos Cob, about three miles from Stamford. This power house described below is of concrete construction and is a noteworthy example of the pleasing appearance which can be given to a purely utilitarian structure by engineers who pay special attention to the architectural treatment of their designs.

COS COB POWER PLANT, N. Y., N. H. & H. R. R. The power house is located at Cos Cob, three miles west from Stamford, on the Mianus River, about a mile from Long Island Sound. The engineers in charge of the design and construction of the plant adopted the Spanish Mission style of architecture for the exterior of the building, with a very pleasing result. The interior is divided into a turbine room 60 feet wide by 112 feet long, with a switchboard occupying an additional space of 25 feet by 110 feet and a boiler room 160 feet long by 110 feet wide.

The photograph in Fig. 105 shows the track side, while Fig. 104 is of the water side of the power house.

The foundations, column footings and walls up to the water table are monolithic concrete mixed in the proportions of 1 part Atlas Portland Cement, 3 parts sand and 5 parts 2-inch crushed granite. All exposed surfaces of the walls have a bush-hammered finish. For the water-table, window

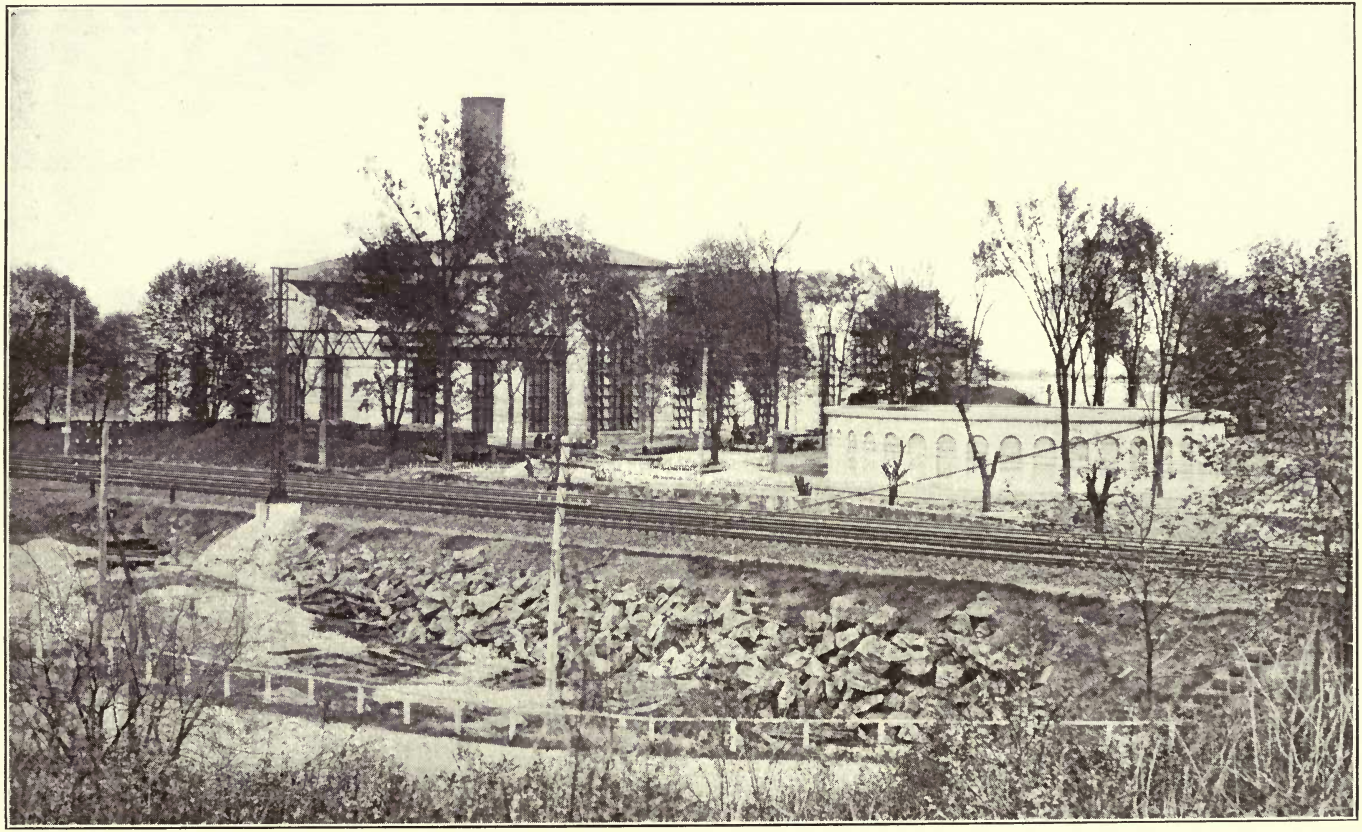
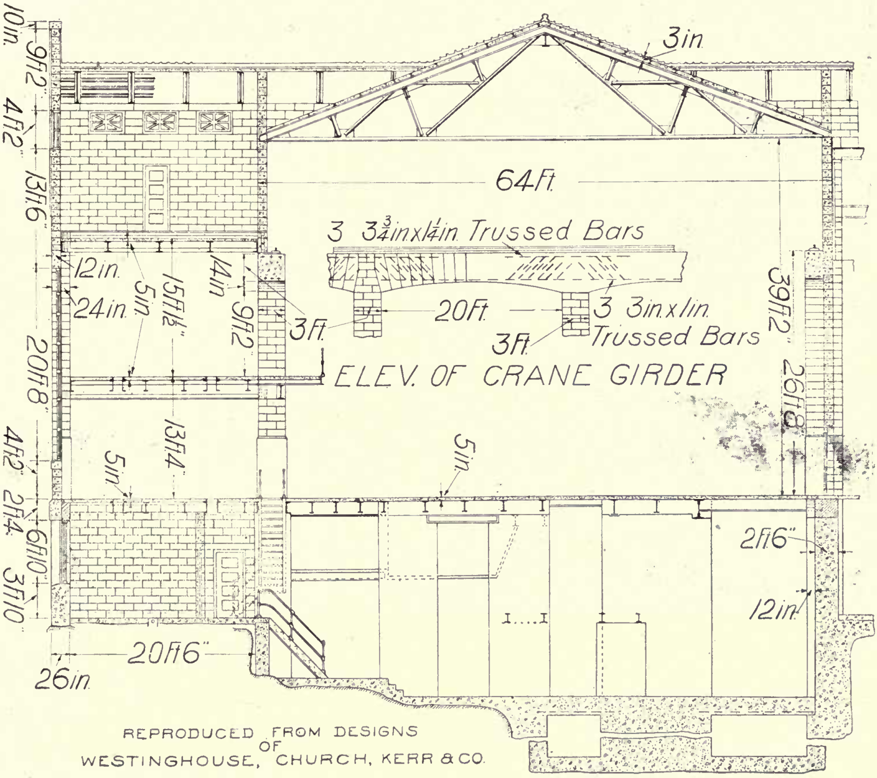


FIG. 105.—COS COB POWER PLANT FROM TRACK.

arches, coping and window sills, monolithic blocks are used. These blocks, are built in special shapes and are made of concrete of the same proportions as the other monolithic work, and have the inner and outer surfaces faced with a mixture of 1 part cement to 2 parts sand.

The walls above the water-table are of hollow blocks, 10 in. by 12 in. by 24 in., composed of a mixture of 1 part cement, 3 parts sand and 3 parts 1¼-inch crushed granite, faced on the exterior surface with a mixture of 1 of cement to 2 of sand, and where the inner surface of the wall is exposed with a mixture of 1 part cement to 4 parts sand. All the window lintels were cast in place, and consist of 1:3:5 concrete reinforced with two ¾-trussed bars.



REPRODUCED FROM DESIGNS OF WESTINGHOUSE, CHURCH, KERR & CO.

FIG. 106.—CROSS SECTION THROUGH TURBINE ROOM, COS COB POWER PLANT.

In designing the structural features of the building, the following live loads per square foot were used: Coal bin floor, 550 pounds; engine room and gallery floors, 400 pounds; boiler room floor, 340 pounds; fan room floor, 200 pounds; roof, 30 pounds. With the exception of the roof slabs, which are of cinder concrete, the stresses allowed for the concrete are 600 pounds per square inch extreme fiber stress, 400 pounds per square inch direct compression, and 60 pounds per square inch shear, and for the steel a tensile stress of 16,000 pounds was assumed.

The columns in the boiler room are of structural steel, but all other columns in the building are composed of concrete blocks made by filling the cored air spaces of the hollow blocks with concrete of the same mixture as the blocks themselves. Over the turbine room where there are no steel columns the steel roof trusses are carried by the concrete block wall, the blocks being solid for several courses below trusses to properly distribute the load. Over the boiler room the trusses are supported in the same way and also by the interior steel columns.

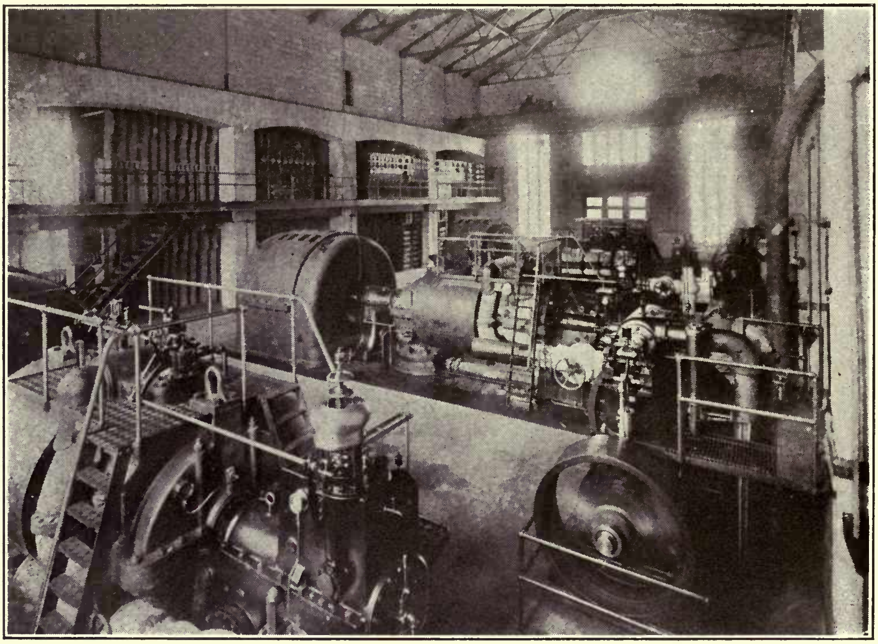


FIG. 107.—TURBINE ROOM, COS COB POWER PLANT.

The front of the switchboard gallery, at one end of the turbine room, is carried on concrete block columns, which also support a reinforced concrete girder forming one of the crane runways, which carry an electric traveling crane, provided with two 17½-ton trolleys. The other crane runway is formed by a similar girder built into the partition wall between the engine room and boiler room, and is carried by pilasters formed in this wall. These girders furnish a rather unique feature, for while they are essentially concete girders

36 by 36 inches reinforced with trussed bars, they are built with the bottom slightly arched and the sides and bottoms ribbed to imitate keystone and voussoirs, the whole giving the appearance of a segmental arch. The girders are shown clearly in the photograph of the turbine room in Fig. 107 and by the drawings in Fig. 106, which are of a cross section taken through the turbine room.

With the exception of the basement floor, which is 1:3:5 concrete laid directly upon the foundation rock, the floor system consists of concrete slabs, reinforced with twisted steel rods, carried on the top flanges of I-beams. These slabs were mixed in the proportions of 1 part cement, 3 parts sand and 5 parts ¾-inch broken stone with a 1-inch granolithic finish applied before the underlying concrete had time to dry. After the floors had dried out they were given two coats of linseed oil and lampblack. In the engine room the floor finish is carried up at the side walls and columns to form a base 10 inches high and 1¾ thick for a 6 foot wainscoting of Faience tile. Above this wainscoting the walls are unfinished except for a cement wash.

The roof, which has a pitch of 4½ inches per foot, is of 1:2:4 cinder concrete laid between 3-inch 5½-pound I-beam purlins 3 feet on centers, and is finished on the exterior with red Ludowici interlocking tiles set on 1 inch by 2 inch strips 24 inches on centers, and secured thereto by means of staples and copper wire. Between the tiles and the concrete there is one thickness of tarred paper.

A self-supporting steel stack 13 feet 6 inches in diameter and 46 feet high is carried by the steel columns which support the fan room floor, thus leaving the space below, in the boiler room, entirely clear.

Work on the power house was started Feb. 3d and steam was turned on Nov. 4, 1906. The construction plant consisted of one ¾ and one 1½-yard mixers, a stone crusher, 3 boom derricks, a temporary power plant, buckets, etc., and two block machines. The material excavated was a gneiss rock, and furnished after crushing and screening all the broken stone for the building, and a sufficient quantity of screenings to take the place of sand for the exterior walls. For the wall forms 2-inch matched spruce was used and for the floor and roof slab forms 1-inch matched spruce. The monolithic blocks which were molded in pine forms, well greased, were mixed very wet, and after the removal of the forms were stored under canvas 24 hours and then left in the open for three weeks. After the hollow blocks were turned out of the machine they were cured in the same manner.

The plant was designed, erected and equipped by the Westinghouse, Church-Kerr Company under the direction of Mr. E. H. McHenry, Vice-President of the New York, New Haven and Hartford Railroad.

## SHOPS AND WAREHOUSES.

The same advantages which reinforced concrete possesses over other materials for the construction of power houses are equally enjoyed by it as a material for shop and warehouse buildings for railway purposes.

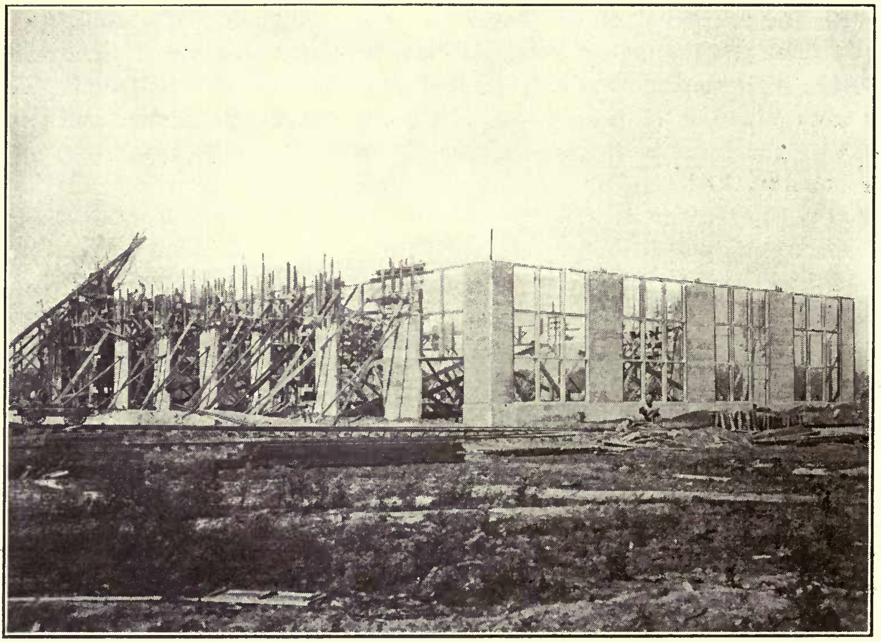


FIG. 108.—BOGALUSA SHOPS DURING CONSTRUCTION, N. O. & G. N. R. R.

The field of reinforced concrete in shop and warehouse construction is so vast that it is impossible to even attempt to cover it in this chapter, but the reader is referred to "Reinforced Concrete in Factory Construction," published by The Atlas Portland Cement Company, as a more complete treatise on the subject.

In addition to the structures described and illustrated below, there are a number of shops, freight sheds, warehouses and inspection sheds shown among the miscellaneous photographs in the back of the book.

N. O. & G. N. R. R. SHOP AND STORE HOUSE, BOGALUSA, LA.—The photograph in Fig. 108 shows one of the shops during construction and Fig. 109 is of the finished store house of the New Orleans and Great Northern Railroad at Bogalusa, La. With the exception of the roof, these buildings are of concrete construction throughout. They were designed and erected by the Arnold Company of Chicago in 1907.

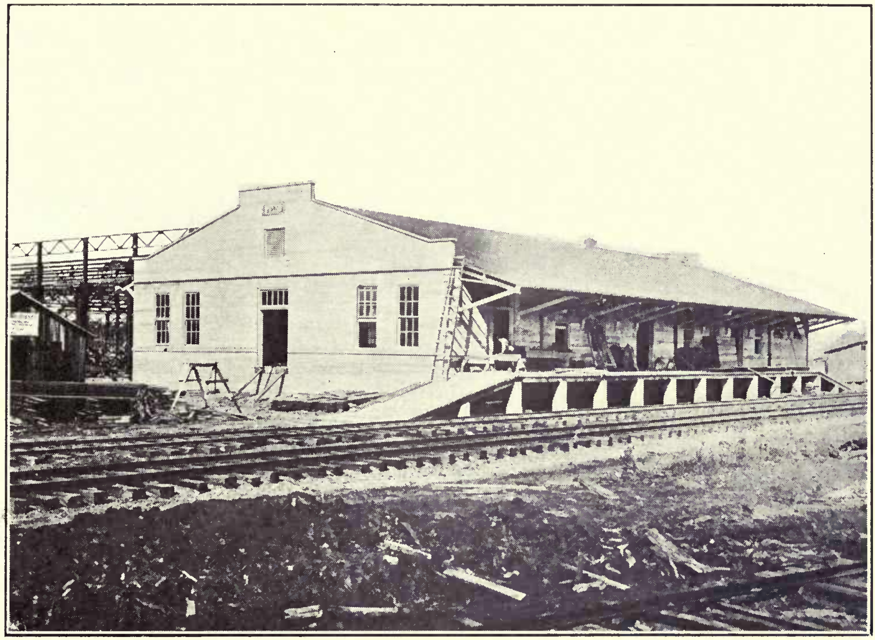


FIG. 109.—STOREHOUSE, BOGALUSA, LA., N. O. & G. N. R. R.

MOTT HAVEN CAR SHOPS, N. Y. C. & H. R. R. R.—The Mott Haven shops are 250 feet long, 43 feet 10 inches wide, and, as will be seen from the photograph in Fig. 110, they are built in alternate high and low bays, the former 25 feet high and the latter 19 feet 4 inches. As windows are provided in each side of the high bays above the roof of the low ones, this construction takes the place of the ordinary saw-tooth roof.

In general, the buildings consist of 2½-inch cement mortar curtain walls reinforced with truss metal lath, No. 28 gage, resting on a concrete foundation wall rising 4 feet above the ground level. The roof is carried on light angle trusses supported by I-beam columns placed every 16 feet 8 inches at the division between the adjoining high and low sections. Between the columns and window frames steel girts are placed to form a support for the truss metal lath reinforcement of the walls.

The metal lath was kept in place and held rigidly by means of temporary 1 by 1 inch angles spaced about 2 feet apart. The mortar, which was mixed in the proportion of one part Atlas Portland Cement to three parts sand, was placed in the same manner as plaster for an ordinary wall.

The shops were designed and erected in 1908 under the supervision of the engineering department of the New York Central & Hudson River R. R., Mr. G. W. Kittredge, Chief Engineer. The Truss Metal Lath Company, New York City, furnished the reinforcing material and built the walls of the building.

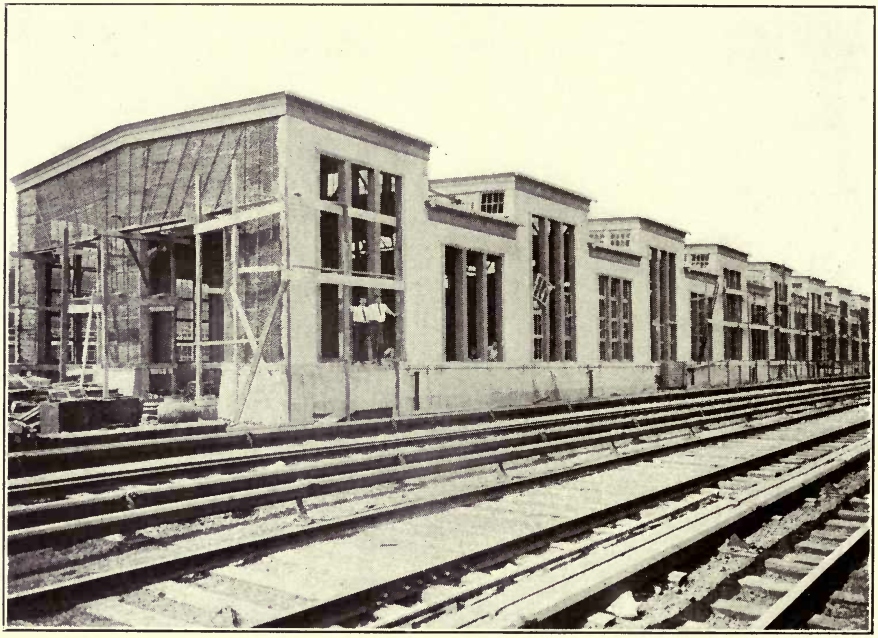


FIG. 110.—CAR SHOPS, MOTT HAVEN, N. Y. C. & H. R. R. R.

NEWARK WAREHOUSE, C. R. R. of N. J.—This mammoth seven-floor warehouse, a photograph of the track side of which is shown in Fig. 111, is 360 feet long with a width varying from 130 to 165 feet, and has a storage capacity of about 1,200 carloads of freight. The first floor is devoted to teaming, the second to the freight tracks, and the basement and four top floors to storage.

In general, the building consists of a steel frame and concrete walls, with steel columns and girders carrying floor slabs of reinforced concrete. Owing to the presence of quicksand, an exceptionally wide spread of footings was required, which resulted in the engineers making the foundation one continuous plate of concrete 15 inches thick reinforced with extra heavy expanded metal.

The walls, which are embellished with rustications, moldings, dentils and cornices, are 20 inches thick to the second story, 16 inches thick to the third story, and 12 inches thick from there up to the top. The reinforcement for the walls consists of expanded metal and ¾-inch rods laid horizontally about 4 feet apart.

The concrete for the walls, floor slabs, column covering and roof slabs, was mixed in the proportions of one part Atlas Portland Cement, to 2 parts Cowe Bay washed sand, to 4 parts ¾-inch crushed stone.

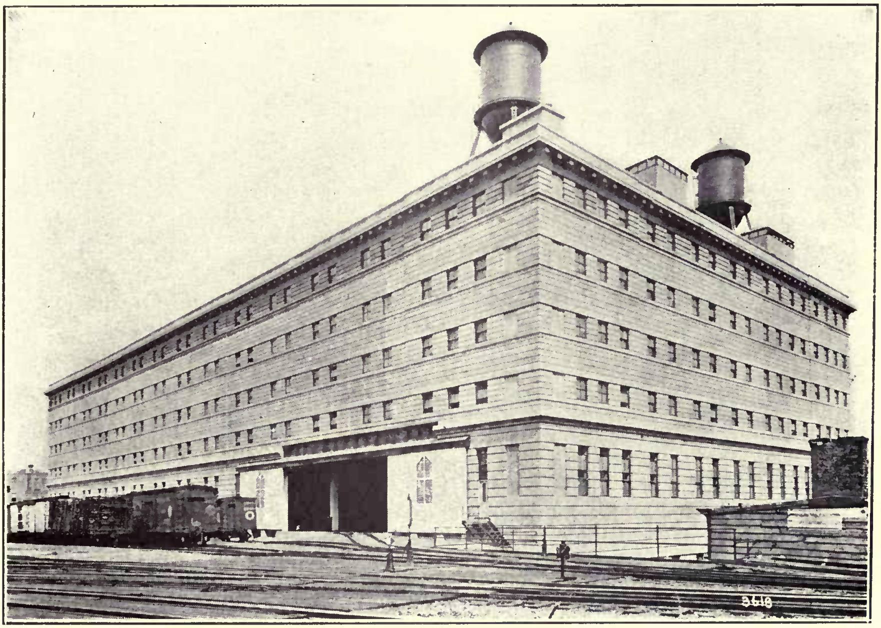


FIG. 111.—NEWARK WAREHOUSE, C. R. R. OF N. J.

The warehouse was designed and constructed under the general direction of Mr. Jos. O. Osgood, Chief Engineer of the C. R. R. of N. J., by the John W. Ferguson Co., Paterson, N. J., in 1907.

PORT MORRIS BOILER HOUSE, D., L. & W. R. R.—The photograph in Fig. 112, page 150, shows a boiler house of heavy concrete construction built at Port Morris, N. J., for the Deleware, Lackawanna & Western R. R.

LOADING PLATFORM, SIOUX CITY, IA.—In connection with warehouses and storage sheds, the construction of loading platforms is of special interest. The photograph in Fig. 113, page 150, shows a reinforced concrete platform 164 feet long and 14 feet wide, which was constructed in 1908 at a cost of $2,500.

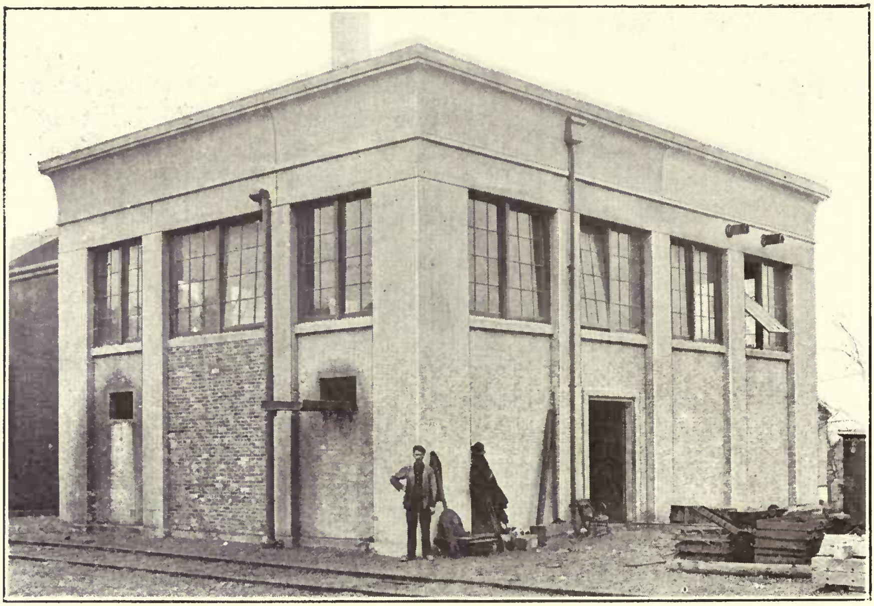


FIG. 112.—PORT MORRIS BOILER HOUSE, D., L. & W. R. R.

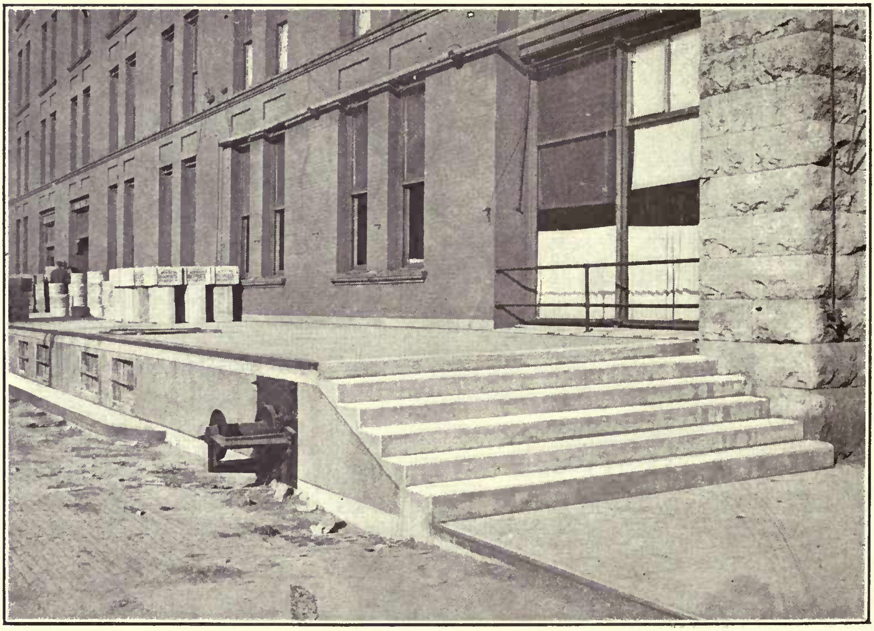


FIG. 113.—LOADING PLATFORM, SIOUX CITY IA.

## GRAIN ELEVATORS.

Reinforced concrete is especially adapted to the construction of grain elevators or other structures to be used for the storage of grain on account of its being absolutely proof against fire, water or dampness, dust and vermin; which are all important and essential qualities of the ideal grain elevator.

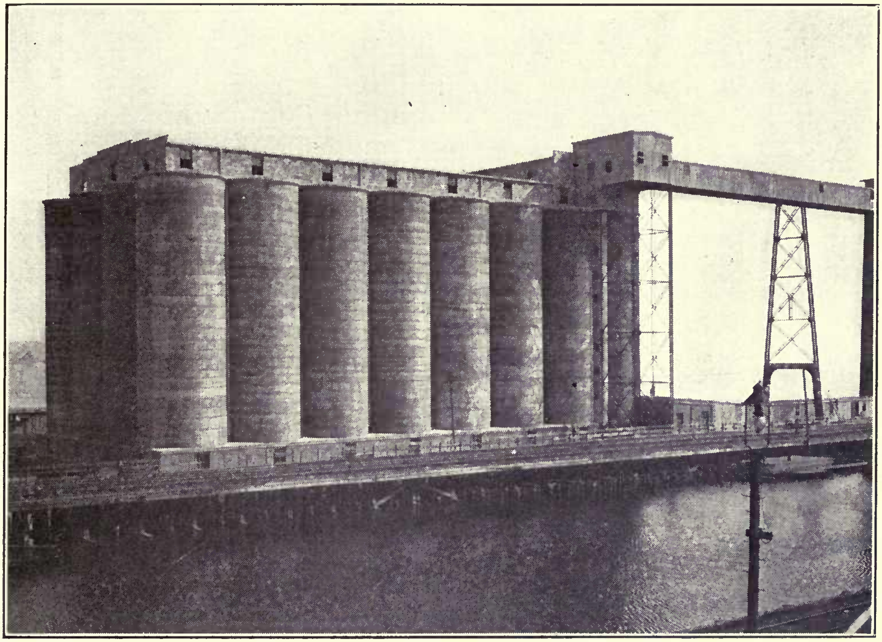


FIG. 114.—TYPICAL CONCRETE GRAIN ELEVATOR.

Grain elevators may be grouped into two classes according to the arrangement of the bins and elevating machinery; viz., elevators which are self-contained, with all the storage bins in the main elevator or working house; and elevators consisting of a working house which contains the elevating machinery and storage bins connected with the working house by conveyors. Reinforced concrete elevators are commonly built of the latter type, with a working house that is generally rectangular in shape with either square or circular bins connected with the independent storage bins, which are usually circular. The photograph in Fig. 114 is of a reinforced concrete elevator of the type built by the James Stewart & Co., of Chicago.

In elevators of this type the storage bins are reinforced both horizontally and vertically. The horizontal reinforcement is either single when it is placed in the center of the wall, as in Fig. 115, or double when the bars are placed near the surface. This reinforcement may be continuous, rising from the bottom to the top as a spiral, in which case high steel wire is generally used, or may be placed in separate rings, as in Fig. 117. The vertical reinforcing bars are equally spaced, and are wired or clamped to the horizontal rods at intersections.

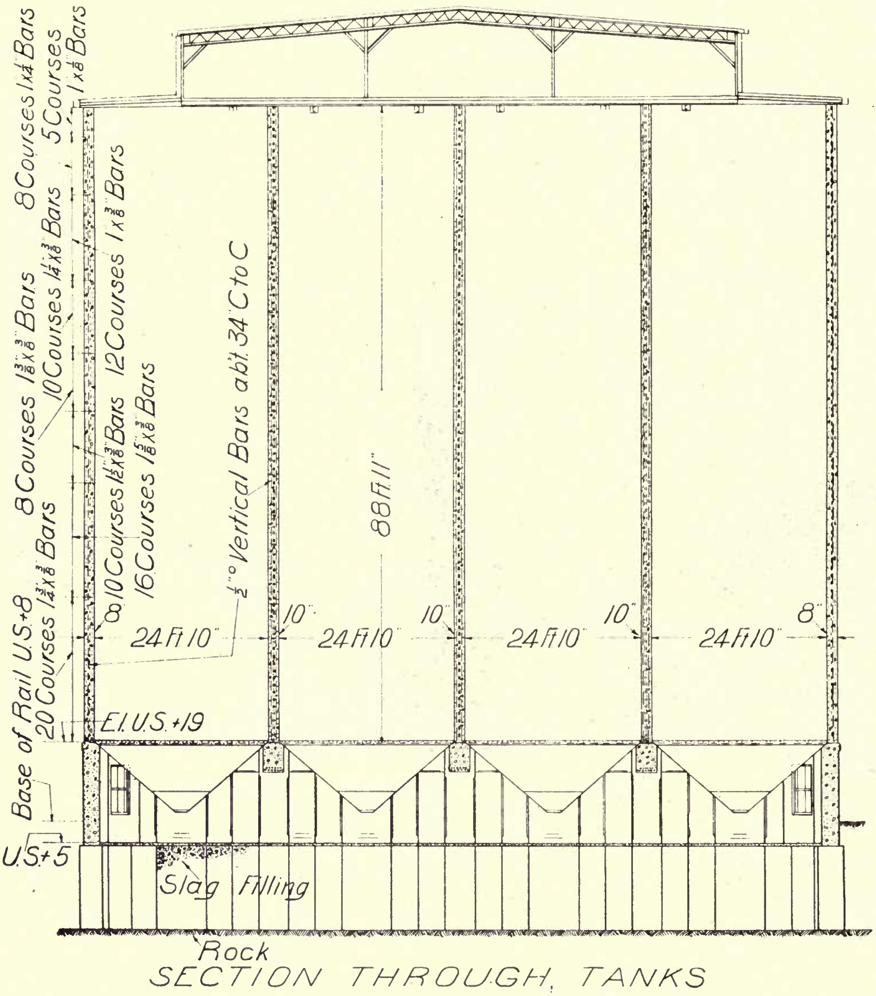


FIG. 115.—CROSS SECTION OF TYPICAL REINFORCED CONCRETE GRAIN ELEVATOR.

The horizontal reinforcement is generally designed to take all the tensile stresses resulting from the pressure of the grain, while the vertical reinforce-

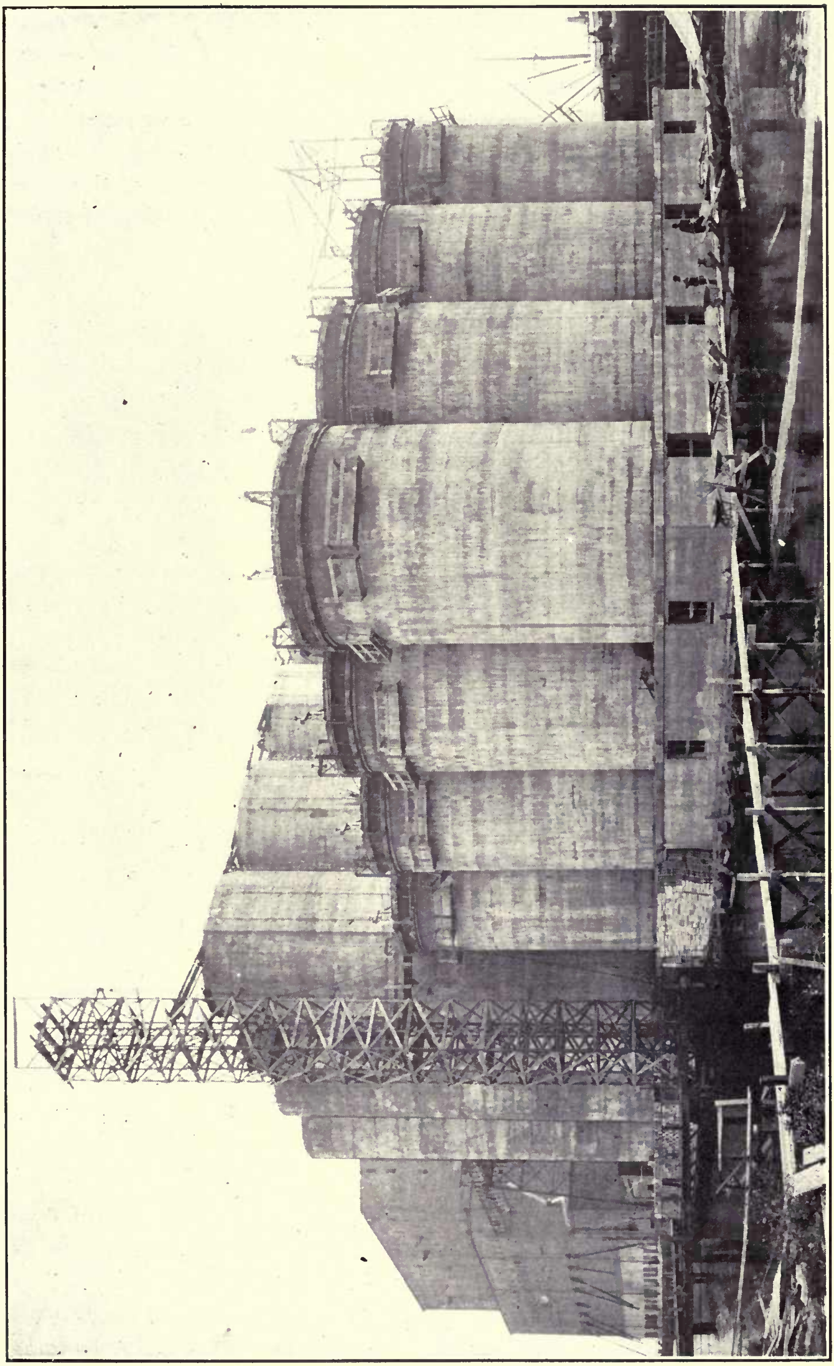


FIG. 116.—GRAIN ELEVATOR BEING CONSTRUCTED

ment carries the load between the horizontal reinforcement, and takes its proportion of the vertical load. The walls have a negative bending moment at the points of horizontal reinforcement, and a positive bending moment halfway between the horizontal reinforcement. The pressure on any horizontal section equals the weight of the wall plus the weight of the grain carried by the walls, and this pressure is carried by both the concrete and the steel.

While the space here is too limited to go into the discussion of the theory of the pressure in grain bins or to give the methods employed in designing the structural features of reinforced concrete grain elevators, the reader is referred to "The Design of Walls, Bins and Grain Elevators," by Milo S. Ketchum, as a complete treatise on the subject.

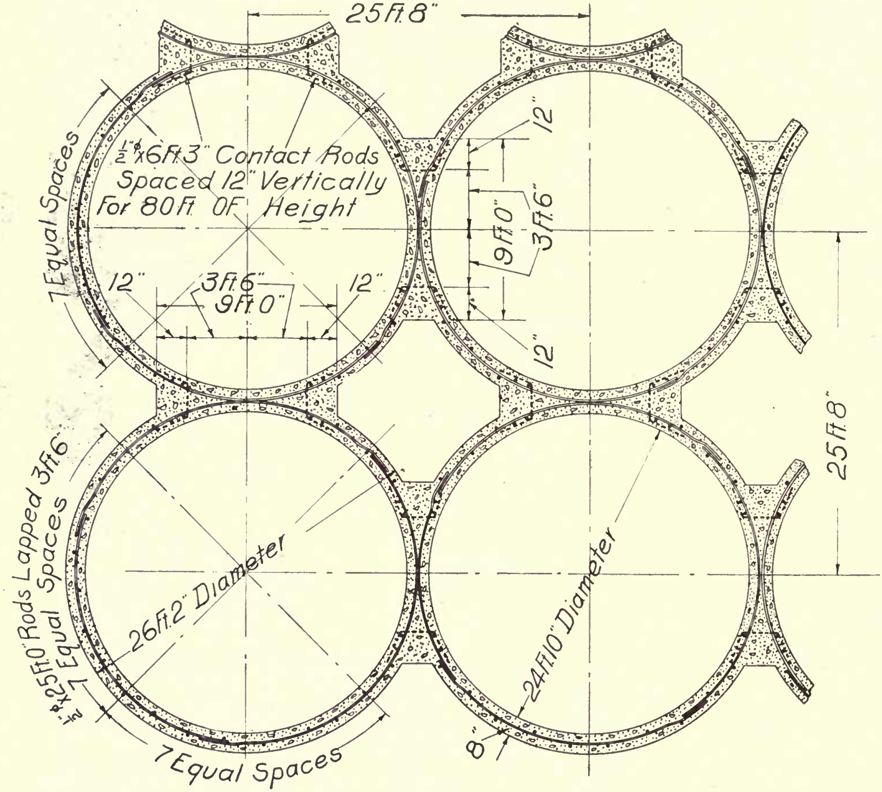


FIG. 117.—SECTION THROUGH BINS, TYPICAL CONCRETE GRAIN ELEVATOR.

Among the miscellaneous photographs in the back of the book are shown a number of reinforced concrete grain elevators of different types.

## CHAPTER XII.

## STORAGE RESERVOIRS.

The advent of power construction into the field of railroad engineering incidentally introduces another problem for railroad engineers in the subject of storage reservoirs for supplying these plants with water.

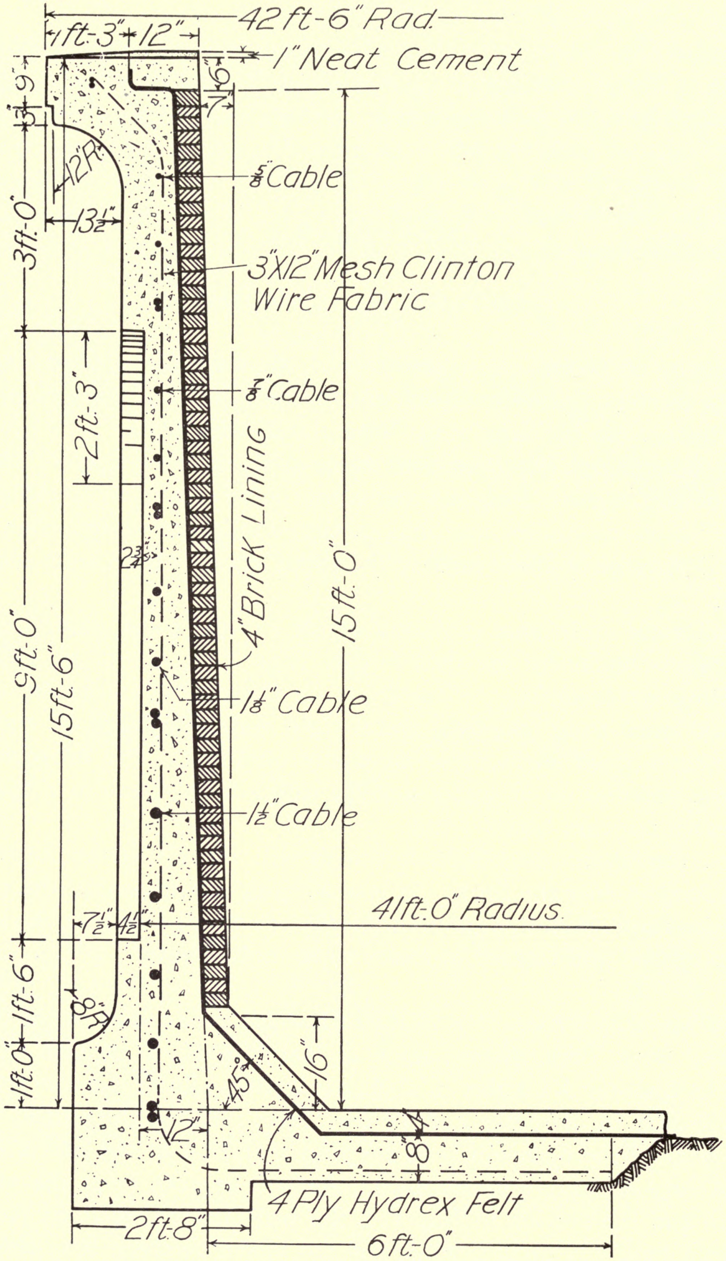
Reinforced concrete has been used extensively in the construction of reservoirs and when properly designed and constructed is a most suitable material on account of its durability and adaptability to lighter design than common masonry. For large or small tanks it is usually cheaper than steel and requires no repairs.

Reservoirs are built most economically of circular form, and all the tensile stresses must be taken by the steel hoops.

In buildng water tanks, the materials for the concrete must be very carefully proportioned so as to give a water-tight wall and the stone should be of such size that a good surface can be easily obtained. The proportions used to resist the percolation of water usually range from 1:1:2 to 1:2½:4½, the most common mixture being 1:2:4.

The concrete should be mixed so that it will entirely cover the reinforcing metal and flow against the form. It is absolutely essential that the concreting for the entire tank should be done in one operation, or else that the surface be specially prepared and treated to make water-tight joints.

COS COB STORAGE RESERVOIR.—In connection with the power plant of the New York, New Haven & Hartford R. R. at Cos Cob, Conn., described in Chapter XI, there is a 564,000 gallon reinforced concrete storage reservoir 80 feet in diameter and 15 feet deep. The architectural treatment of the exterior of the reservoir is in keeping with that of the power house and presents a very attractive appearance. As will be seen from the photograph in Fig. 119 and the section in Fig. 118, the wall has a cornice projecting 13½ inches and a base 7½ inches, while the flat space between is relieved with a series of forty arched indented panels. To further the effect of these arched panels, the face of the concrete of the indented surface is roughened, and the remainder of the exterior is given a smooth cement mortar finish.



REPRODUCED FROM DESIGNS
OF
WESTINGHOUSE, CHURCH, KERR & CO.

FIG. 118.—SECTION THROUGH WALL, COS COB STORAGE RESERVOIR.

All the concrete was mixed in the proportions of 1 part Atlas Portland Cement, 3 parts sand and 5 parts ¾-inch crushed granite. The wall is reinforced circumferentially with the cast steel transmission rope, varying in diameter from 1½ inches at the base to ⅝ inches at the top, forming a continuous spiral with 12 foot splices made with 16 clips where the ends of different sizes of cable are joined. Wired to the inside of this rope spiral is a continuous sheet of 3 by 12-inch mesh wire cloth, placed in vertical strips and extending 6 feet into the floor of the reservoir. The wall and floor is waterproofed with 4-ply felt cemented together with a patented compound. On the floor of the tank a 4-inch protective covering of concrete was laid on top of the waterproofing, and carried up the wall 16 inches at an angle of 45°, to form a footing for a 4-inch lining of brick laid up in cement mortar that protects the waterproofing coat of the wall. The dimensions and general features of design of the reservoir are clearly shown in Fig. 118.

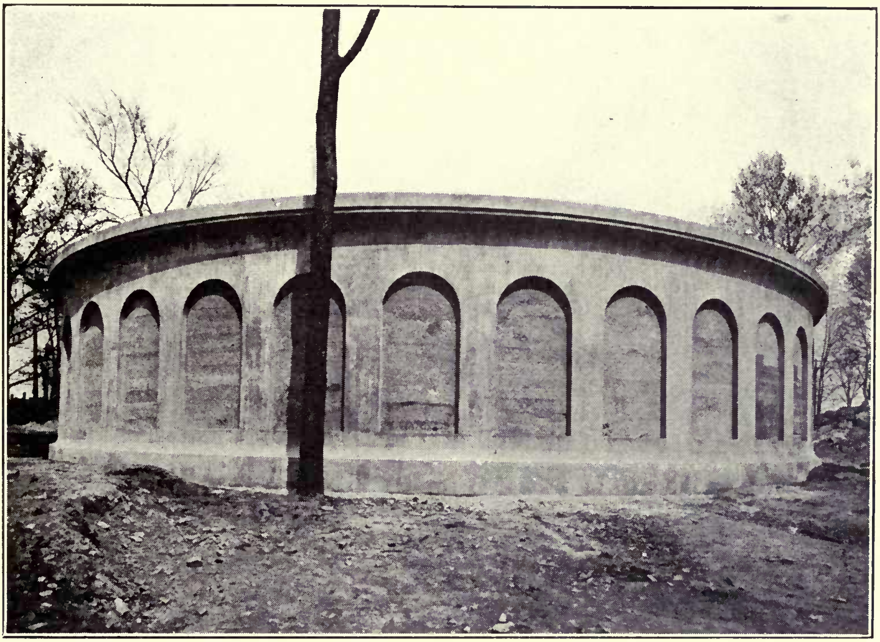
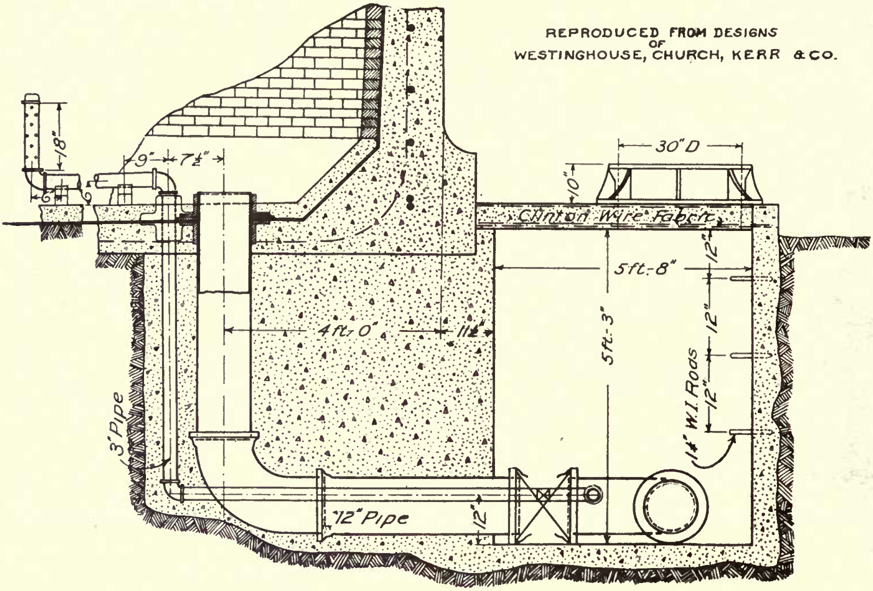


FIG. 119.—COS COB STORAGE RESERVOIR, N. Y., N. H. & H. R. R.

A 10-inch inlet and a 12-inch outlet pipe enter through the floor of the tank, and where they pass through the waterproofing, watertight connections are secured by clamping a sheet of soft copper between two flanged screw sleeves, as shown in Fig. 120. About a foot outside the reservoir wall these pipes run into a concrete valve chamber 11 feet 4 inches long, 5 feet 8 inches wide, and 5 feet 3 inches high, in the top of which is a 30-inch manhole having an American Brake Shoe and Foundry Company's standard manhole frame and cover. A 3-inch steam pipe runs from the power house through the valve chamber and into the tank where it is carried half way across the floor on small brick piers 6 feet on centers. This pipe has a perforated upturned end so as to keep the water above the freezing point in cold weather.

In building the tank, the forms for the exterior wall were erected complete from the foundations to the coping. The spiral rope reinforcing was then hung on screw hooks driven into the inner surface of these forms and the wire cloth was wired to the spiral. The inside forms were built up a few feet at a time, and were wired through the vertical supports to the outer forms. The concrete was mixed in a ¾ yard rotary mixer located just outside the reservoir, and was carried inside in 1 yard skips by a guyed derrick placed in the center of the tank and operated by a hoisting engine standing outside. The derrick cables were run through holes in the wall which were filled in after the forms were removed. Two weeks after concreting the walls the forms were removed, the derrick taken out, and the waterproofing was applied as described above.



REPRODUCED FROM DESIGNS OF WESTINGHOUSE, CHURCH, KERR & CO.

FIG. 120.—SECTION THROUGH VALVE CHAMBER, COS COB STORAGE RESERVOIR.

The reservoir was designed and erected by Westinghouse, Church, Kerr & Co., of New York, the engineers and constructors of the power plant.

PITTSBURG STORAGE RESERVOIR, KANSAS CITY SO. RY.—This reservoir, 85 feet in diameter, which serves as a storage supply for the Kansas City Southern Railway shops at Pittsburg, Kan., is shown by the photograph in Fig. 121. The reservoir rests on a puddle clay bottom, on which a 6-inch cinder fill is placed, and has a concrete wall 4 inches thick mixed in the proportions of one part Atlas Portland Cement to 2 parts sand to 4 parts broken stone, with a ½-inch 1:1 mortar finish. The total cost of the reservoir, which included 1,500 yards of mass concrete in addition to 66 cubic yards of 1:2:4 concrete, was $736. The Arnold Company of Chicago were the engineers in charge of the design and construction.

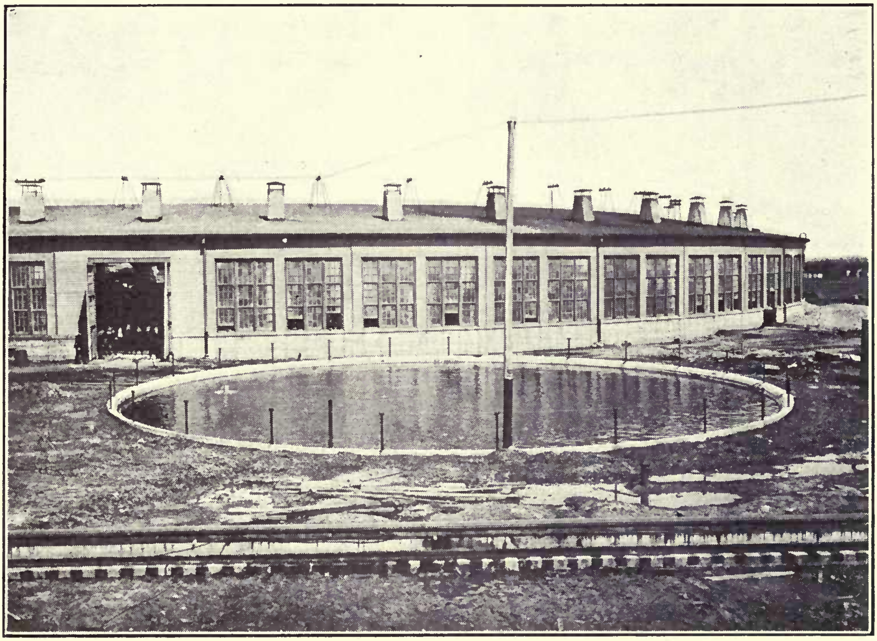


FIG. 121.—PITTSBURG STORAGE RESERVOIR, K. C. S. RY.

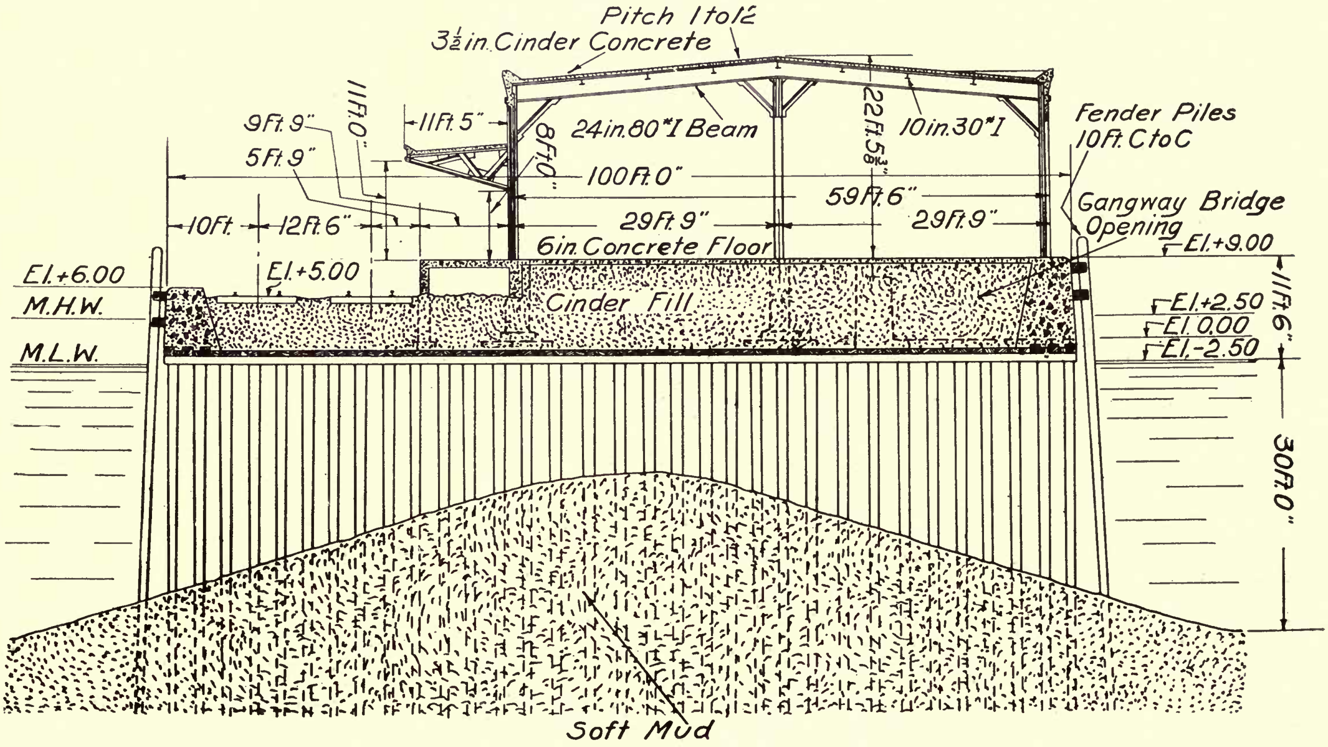


FIG. 122.—CROSS SECTION, HOBOKEN PIER NO. 7, D., L. & W. R. R.

## CHAPTER XIII.

## DOCKS.

Inasmuch as practically every railroad system in the country owns valuable water front the question of dock construction is a most important one. The recent terrible fires with their attendant devastation along the water fronts of Hoboken and of Boston have demonstrated only too clearly the absolute necessity of positive fire protection in structures of this nature. The new piers which the Delaware, Lackawanna and Western Railroad have designed to replace those burned down in the Hoboken fire of 1904 are to be built entirely of concrete construction from the cut-off of the piles. This type of pier, which is described below, is proof against fire and decay and should be practically free from maintenance.

In the tropics where the waters are infested with limnoria and teredos which destroy a wooden pile in a few years and where the very atmosphere itself eats away unprotected wooden and steel structures reinforced concrete is especially adapted to the construction of wharves and warehouses. Practically all the docks of any magnitude now being constructed in South and Central America and the Philippines are designed as entire concrete structures.

The Almirante wharf of the Changuinola Railroad at Bocas del Toro, Panama, described on page 163, is an interesting example of this type of construction.

HOBOKEN PIER, NO. 7, D., L. & W. R. R.—This pier, which is the first of a series to be built on the same general scheme along a railway yard ship canal, is 100 feet wide and 600 feet long.

As will be seen from the transverse section of the pier, shown in Fig. 122, the construction in general consists of a 6-inch concrete floor carried on a cinder fill retained between concrete face walls and supported on a solid timber of grillage carried on piles cut off at low water level.

These piles, which are from 85 to 95 feet in length, are driven 3 feet apart in transverse rows 5 feet apart. Each pile is proportioned for a maximum load of 12 tons. At mean low water they are capped with continuous, 12 by 12-inch transverse timbers, drift bolted to them. Spiked to these caps are longitudinal 6 by 12-inch planks laid close to form the deck. On either side of the pier the outer planks alternate with three 12 by 12-inch longitudinal timbers which project above the top of the deck and form ribs to prevent the concrete side walls from slipping or transverse displacement.

The steel shed and platform are carried on concrete piers and longitudinal walls which are built about 11 feet high to the level of the pier floor. The photograph in Fig. 123 shows one side wall and one row of intermediate piers during construction.

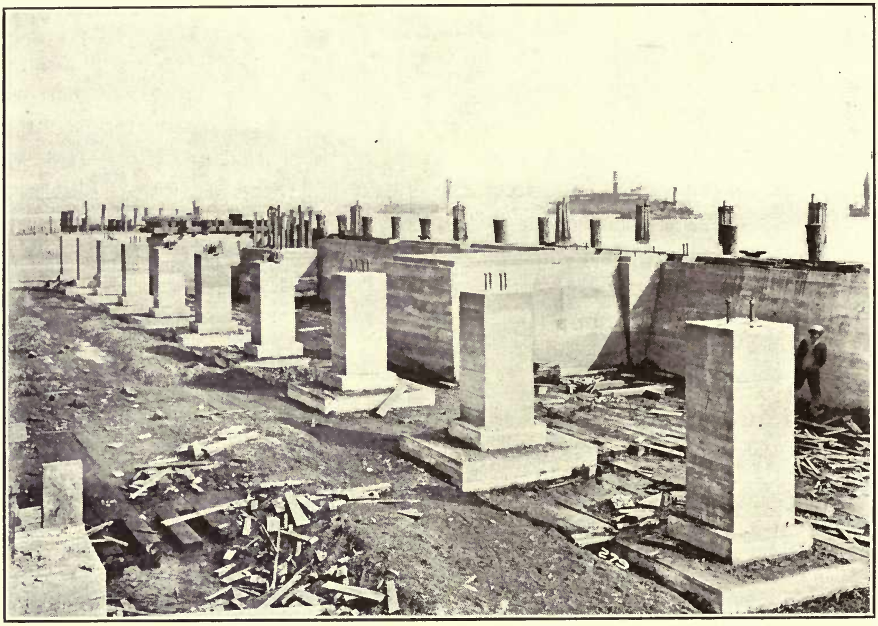


FIG. 123.—HOBOKEN PIER DURING CONSTRUCTION.

The space between the side walls is filled with rolled cinders about 9½ feet deep under the shed and 6 feet deep outside where the railroad tracks are laid directly on it.

The pier shed shown in elevation by the photograph in Fig. 124, and in section by the drawings in Fig. 122, is 59½ feet wide and 594 feet long, and consists of a 6-inch concrete floor without surface finish laid directly on the cinder fill with a superstructure of steel framework carrying reinforced concrete walls and roof.

In connection with the side walls, the provision made to allow for the future adjustment of the walls presents an interesting and important feature in construction of this type where settlement of foundation is liable to occur.

The foot of the wall, which is 6 inches thick, is built in a slot in the concrete floor 6 inches deep and 7 inches wide. Two thicknesses of tarred paper separate the wall from the floor thus preventing the possibility of adhesion between the two concrete surfaces, so that the wall, although having a clearance of ½-inch on each side of the slot, is held securely against transverse displacement and forms a closed point at the bottom, the upper edges of the ½-inch crack being caulked with oakum and pointed with cement mortar.

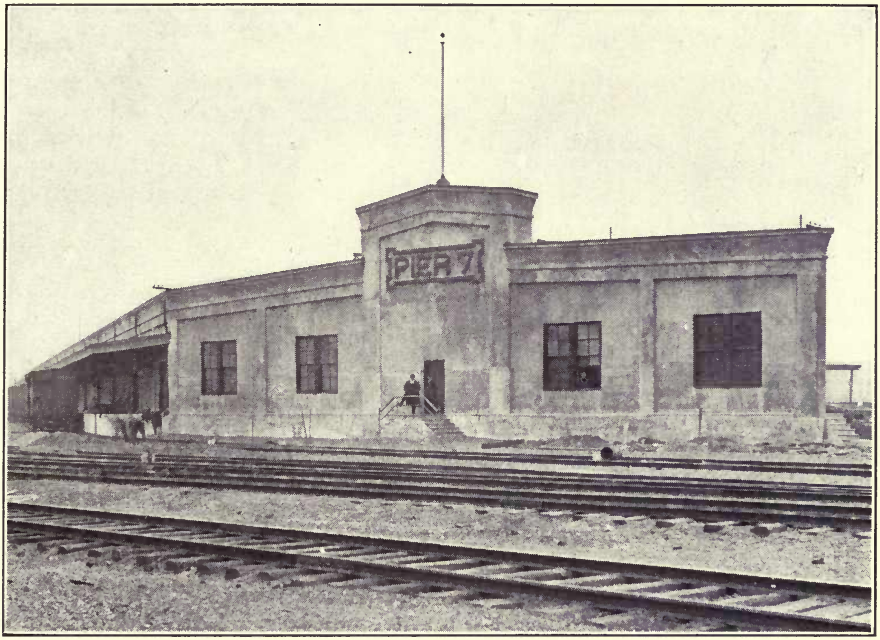


FIG. 124.—PIER SHED, HOBOKEN PIER, D., L. & W. R. R.

If settlement occurs, the wall and the steel superstructure will be jacked up to level the roof and the openings on each side of the slot in the floor will be recaulked and repointed thus restoring the ordinary appearance of the wall.

The shed is divided approximately into equal parts by a transverse reinforced concrete fire wall 12 inches thick.

The pier and shed were designed by the engineering department of the Delaware, Lackawanna and Western Railroad, Mr. Lincoln Bush, Chief Engineer, and Mr. G. T. Hand, assistant engineer in charge of design, and the general contractor was Mr. Henry Steers, of New York City.

ALMIRANTE WHARF, BOCAS DEL TORO, PANAMA.—This wharf which is at the terminus of the Changuinola Railroad, Almirante, Bocas del

Toro, Panama, is of special interest owing to the fact that it is of reinforced concrete throughout and that in its construction the problem of pile protection in the tropics has been successfully solved.

It is approximately 700 feet long and 54 feet wide and is connnected with the mainland by a creosoted timber trestle approach about 800 feet in length. The photograph in Fig. 125 shows one-half of the shore side of the wharf.

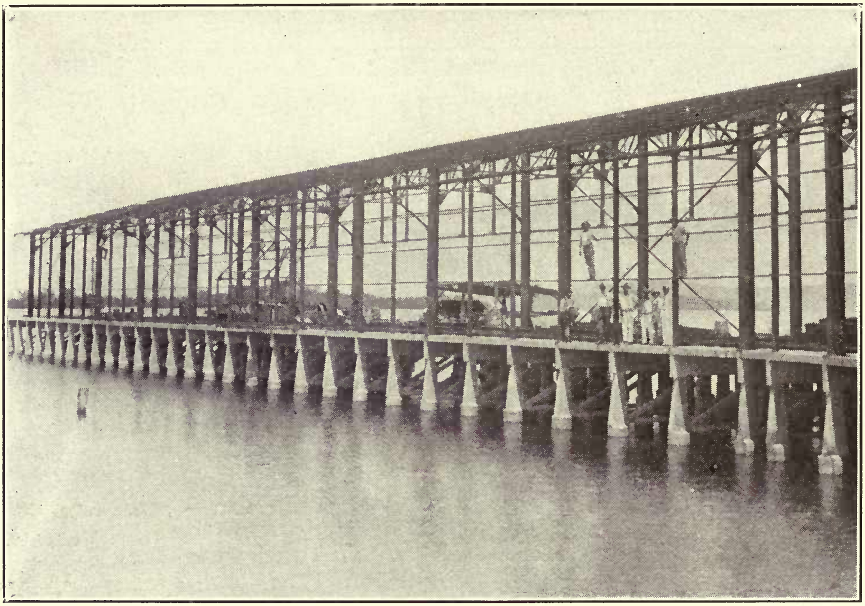


FIG. 125.—ALMIRANTE WHARF, BOCAS DEL TORO, PANAMA.

As the purpose of the wharf is the loading of bananas onto the outgoing, and the temporary storage of general merchandise received from the incoming, steamers, the front of the wharf for a distance of 23 feet is open to allow the free use of automatic loading machines, while the remainder is covered with a steel storage shed, open 6 feet from the bottom in the rear and 14 feet in the front. The bananas are carried to the loading machines by a 3-foot gauge track in front connected by cross-overs to two similar tracks running the length of the storage shed.

As will be seen from the cross section in Fig. 126, which shows the essential details of design and construction, the wharf consists of a series of reinforced concrete columns supporting a system of main girders and cross beams which in turn carry a 7-inch floor slab. The columns rest on wooden piles spaced 10 feet on centers, protected by a four-inch covering of concrete.

This method of protecting the wooden piles from the attacks of teredos consisted in driving a 2-inch concrete shell—20 inches in diameter at the top and 16 inches at the bottom reinforced its full length with 4-inch by 12-inch wire cloth over the wooden pile and into the harbor bottom two feet. The shell was then sealed at the bottom with concrete, the water pumped out and the intermediate space between the shell and the pile filled with concrete to the level of the top of the shell which was about 2 feet above the top of the pile and 1 foot above high water. The shells were made in lengths varying from 32 feet to 12 feet according to the depth of water and were composed of concrete mixed in the proportions of 1 part Portland cement to 2 parts of crusher dust to 3 parts of ½-inch broken stone, and the filling consisted of concrete mixed in the proportions of 1 :2 :4.

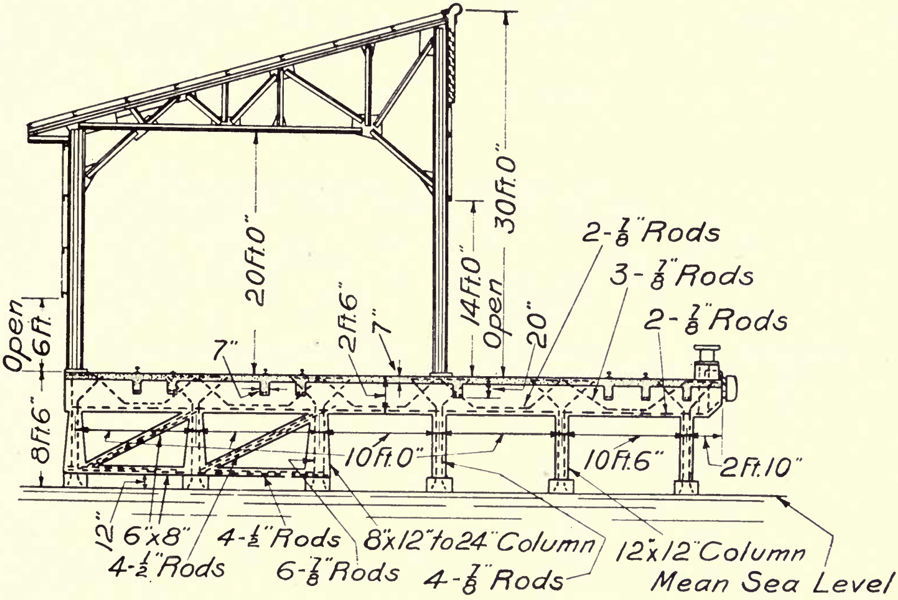


FIG. 126.—CROSS SECTION, ALMIRANTE WHARF.

In constructing the columns, girders and beams, a mixture of 1 of cement to 2 of sand to 2 of crusher dust to 3 of 1-inch broken stone was used and for the floor slabs a mixture of 1 :2 :1 :3 of the same materials.

The reinforcing rods for the columns were embedded four feet in the filling between the shells and the piles and were carried up through the main girders and into the floor slab, thus securely tieing together the entire structure. For the columns, main girders and railroad beams, ⅞-inch round rods were used for reinforcing, and for the floor slab, ½-inch round rods.

Fig. 127 shows in detail the ship buffer, which consists of two 8 by 12-inch creosoted timbers protected by 2 by 10-inch wearing strips every 3 feet 4 inches with a railroad car spring of 19,000 pounds resistance, resting in a cast steel socket embedded in the concrete at each bent to take the shock.

Every 50 feet, hollow steel mooring bits were placed on, and bolted to, concrete pedestals and were then filled with concrete as shown by the detail in Fig. 127.

With the exception of general foremen, native and Jamaican labor was used throughout, both for building the forms, placing the concrete and erecting the steel shed.

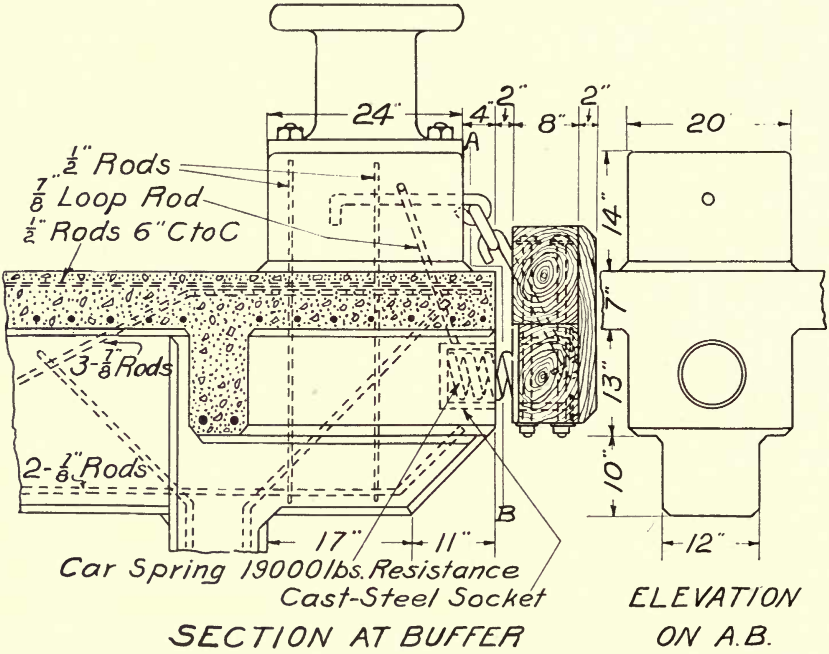


FIG. 127.—DETAIL OF SHIP BUFFER, ALMIRANTE WHARF.

The mechanical equipment consisted of a stone crusher, a ¾-yard rotary mixer with hoist, a floating pile driver with a No. 3, 4,500-pound steam pile hammer, 6 charging carts, an improvised machine for bending the rods cold, and a number of narrow gauge cars on which the shells were made.

The wharf was designed by Mr. T. Howard Barnes with Mr. J. R. Worcester as consulting engineer, and was constructed under his supervision in the fall of 1907 and the winter of 1908, with Mr. Chester S. Allen as resident engineer and Mr. Robert V. O'Brien as superintendent for the United Fruit Company.

## CHAPTER XIV.

## TUNNELS AND TUNNEL LINING.

One of the most common uses of both plain and reinforced concrete is in the construction of tunnels and subways. The term tunnel as generally understood by railroad engineers is applied to construction under cover, in which the tunnel bore is advanced by drifting, the surface of the ground above the work not being disturbed. The term subways is applied to open cut construction. A tunnel for heavy and fast railroad traffic should be built with the entire lining, and for still greater economy with the roadbed of concrete. The old Bergen Hill tunnel on the Lackawanna Railroad is lined with brick for a portion of its length, yet fourteen men are at work every night in the year inspecting the lining and repairing the track. This expensive and dangerous maintenance work, which costs annually approximately $6,000, is prac-

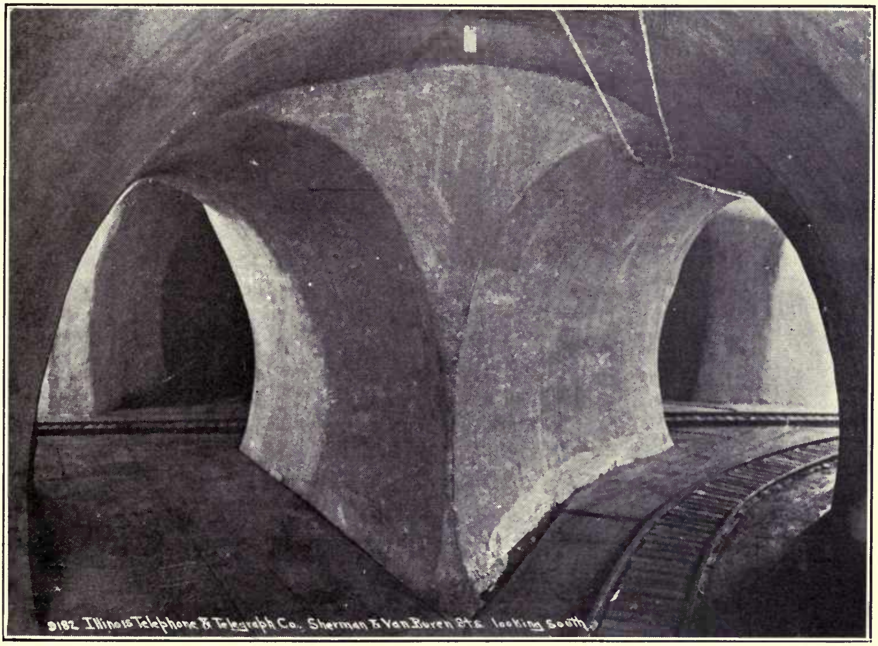
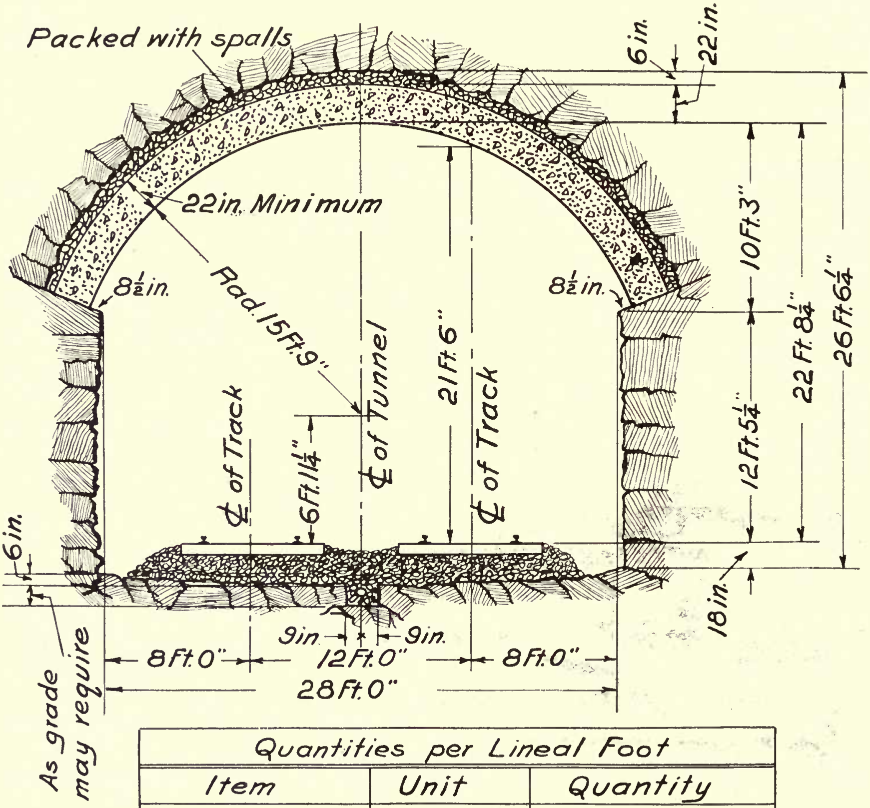


FIG. 128.—ILLINOIS TELEPHONE AND TELEGRAPH TUNNEL, CHICAGO, ILL.

tically eliminated in the new tunnel described on page 173, which is built with the entire lining and roadbed of concrete.

The standard tunnel sections of the New York Central and Hudson River Railroad described below and illustrated by the drawings in Figs. 129, 130, 131, 132, 133, show the methods of construction employed in building tunnels through the different kinds of material encountered in this class of work.

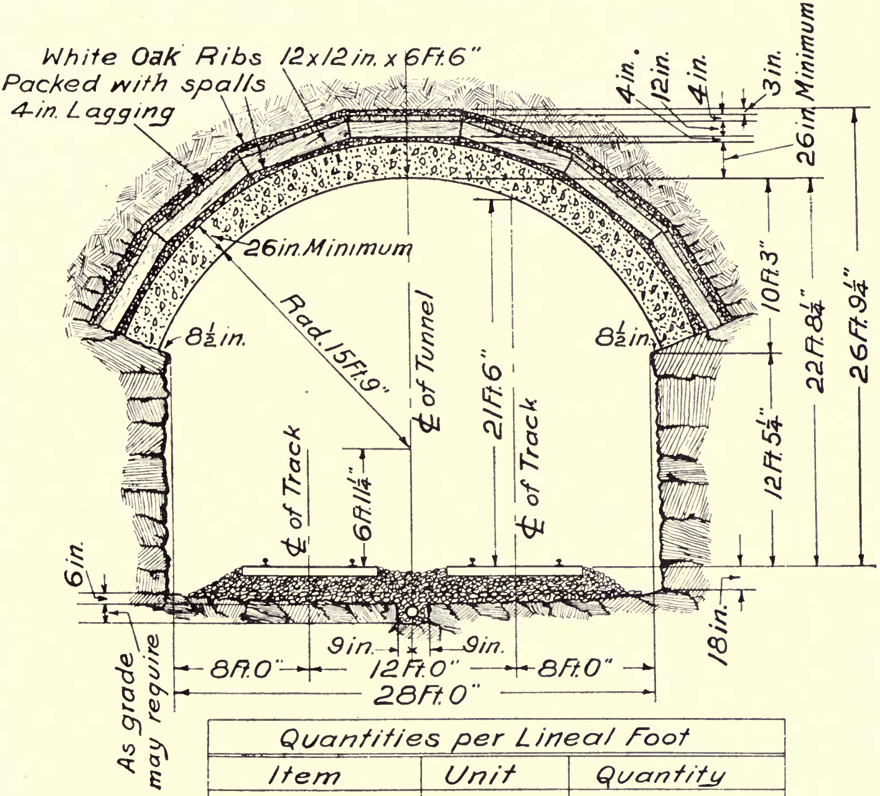
At the end of the book are shown photographs of a number of representative types of tunnels constructed by various railroads throughout the country.



| Quantities per Lineal Foot | | |
|---|---|---|
| Item | Unit | Quantity |
| Excavation | Cu. Yds. | 26.493 |
| Roof Masonry | Cu. Yds. | 2.232 |

FIG. 129.—STANDARD TUNNEL, N. Y. C. & H. R. R. R., TYPE B, SOLID ROCK, FIRM SIDES AND ROOF, DANGER FUTURE FALLS.

STANDARD TUNNEL SECTIONS, N. Y. C. & H. R. R. R.—Type B, Fig. 129 shows a cross section of the standard tunnel designed to meet the condition of solid rock with firm sides and roof but with danger from future falls. The lining for the arch is 22 inches thick and is composed of plain concrete mixed in the proportions of 1 part Portland cement to 2 parts of sand to 4 parts of broken stone. While the distance given between the tracks is 12 feet, this may be increased to 13 feet without changing the width of the tunnel. Vitrified pipe, whose size depends upon the length and amount of water to be carried off, is laid in the drain with open joints.

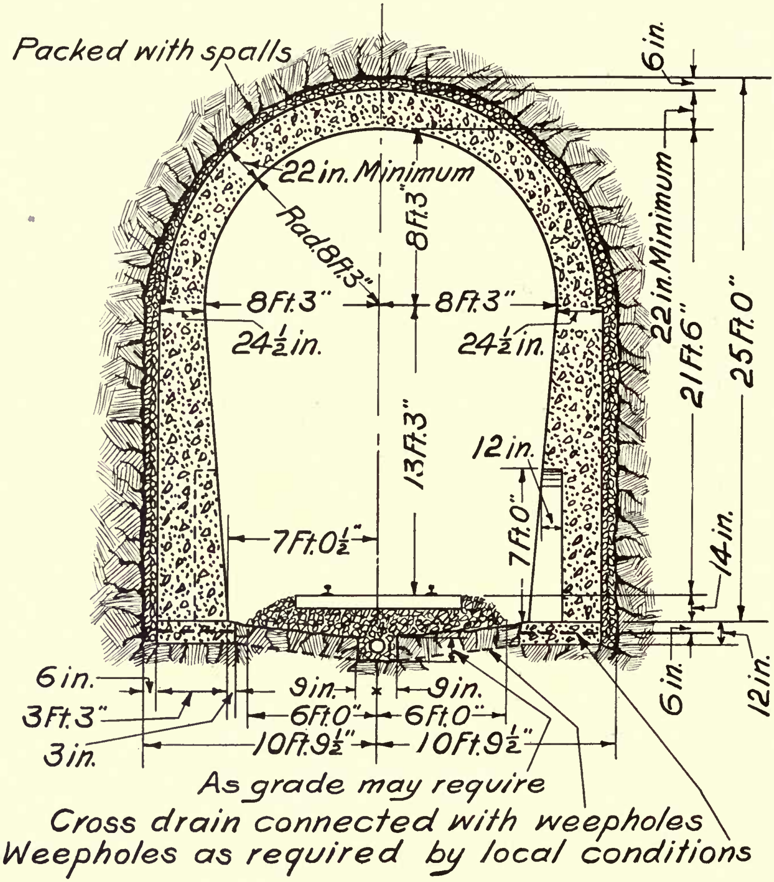


| Quantities per Lineal Foot | | |
|---|---|---|
| Item | Unit | Quantity |
| Excavation | Cu. Yds. | 29.493 |
| Roof Masonry | Cu. Yds. | 3.233 |
| *Timbering | Ft. B.M. | 306. |

*Based on Rib spacing of 5 Ft. C to C

F G. 130.—STANDARD TUNNEL, N. Y. C. & H. R. R. R., TYPE C, SOLID ROCK, YIELDING ROOF, FIRM SIDES.

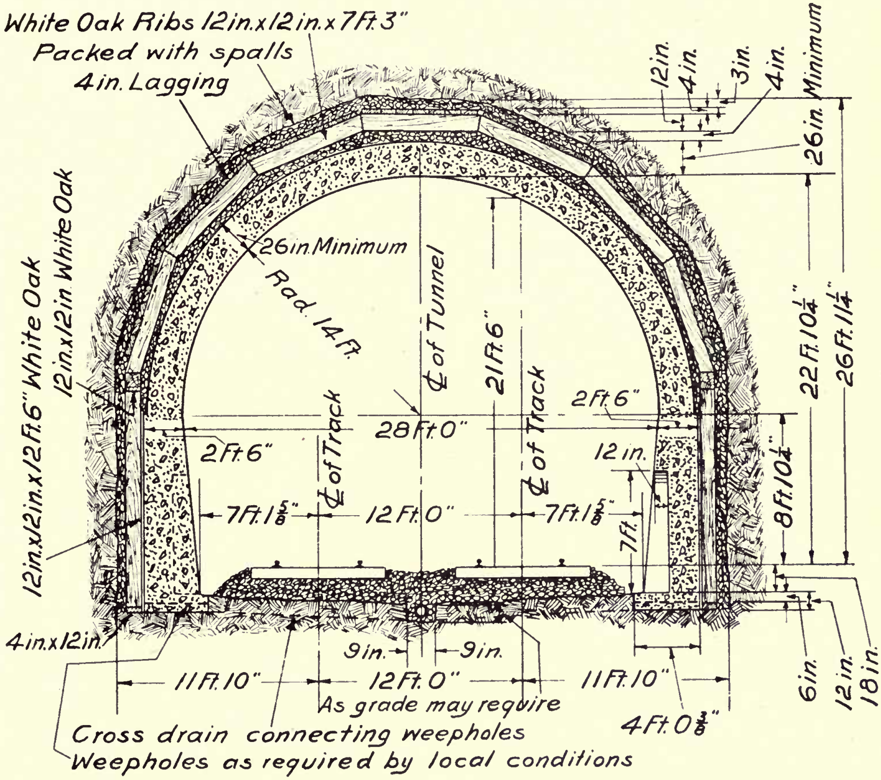
Type C, Fig. 130, shows a cross section of the tunnel where the lining is through solid rock and the tunnel is designed with firm sides and yielding roof. The concrete lining for the arch is 22 inches thick and is mixed in the proportions of 1:2:4. The 12 by 12-inch oak ribs carrying the 4 by 8-inch lagging are spaced 5 feet center to center. The quantities per lineal foot are given in tabulated form in Fig. 130.



| Quantities per lineal Foot | | |
|---|---|---|
| Item | Unit | Quantity |
| Excavation | Cu. Yds. | 18.537 |
| Arch Masonry | Cu. Yds. | 1.955 |
| Side Wall | Cu. Yds. | 3.085 |

FIG. 131.—STANDARD TUNNEL, N. Y. C. & H. R. R. R., TYPE D, FIRM BUT NOT SELF-SUSTAINING MATERIAL.

Type D, Fig. 131, is a cross section of a tunnel through firm but not self-sustaining material. The lining is composed of 1:3:6 concrete. Every 200 feet, staggered on each side of the tunnel, are placed refuge niches as shown in Fig. 131. These niches are 7 feet high and 3 feet wide, with semicircular tops. All exposed corners and edges are rounded to a 1-inch radius. While the section given in Fig. 131 is for a single track the same methods of construction and general clearance distances apply to double track construction.



| Quantities per Lineal Foot | | |
|---|---|---|
| Item | Unit | Quantity |
| Excavation | Cu. Yds. | 33.568 |
| Arch Masonry | " " | 3.803 |
| Side Wall " | " " | 2.547 |
| *Timbering | Ft. B.M. | 425. |

*Based on Rib Spacing of 5Ft. C to C

FIG. 132.—STANDARD TUNNEL, N. Y. C. & H. R. R. R., TYPE E, YIELDING MATERIAL.

Type E, Fig. 132, shows a cross section designed to meet the condition of yielding material. The concrete lining is mixed in the proportion of 1:2:4 and is provided with refuge niches similar to those described in Type D.

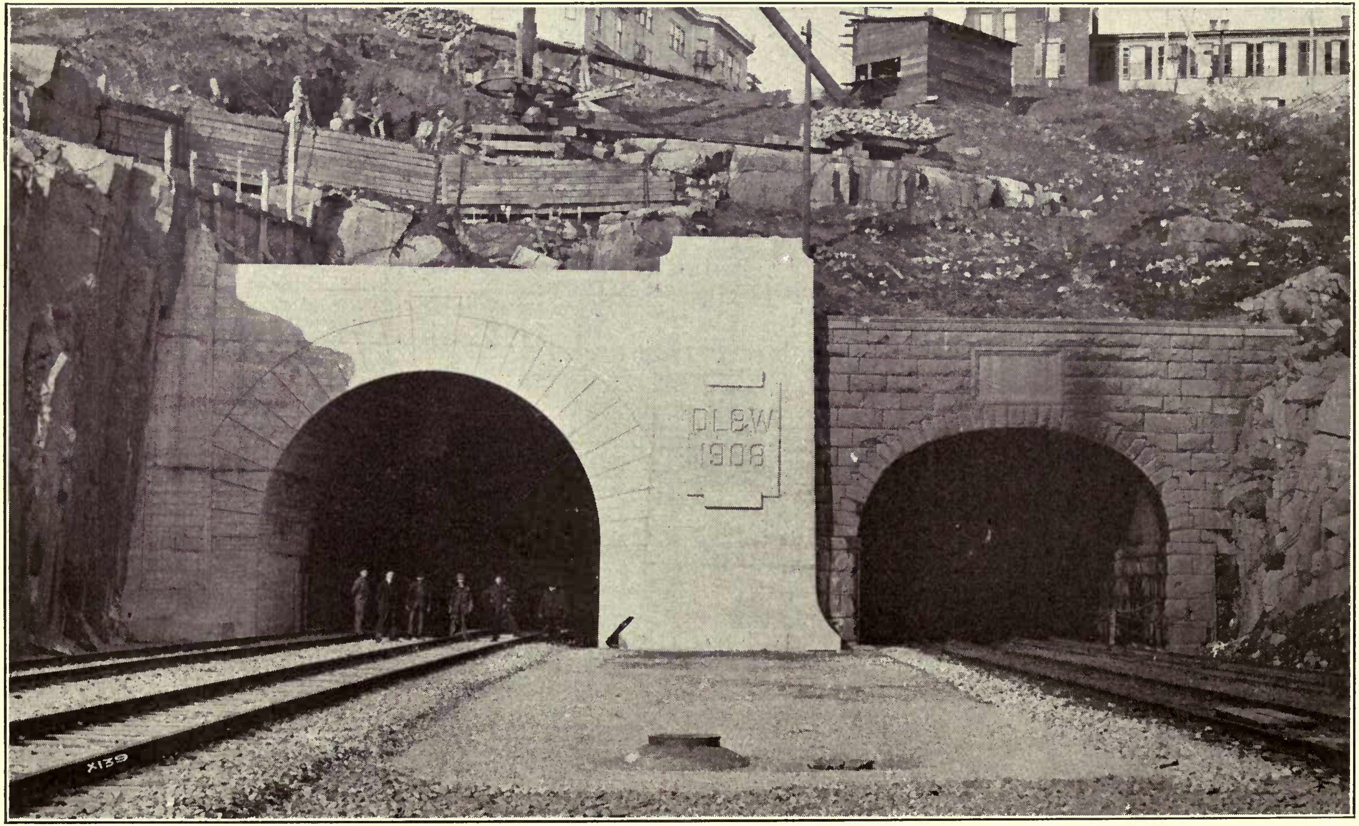


FIG. 133.—ENTRANCE TO OLD AND NEW BERGEN HILL TUNNELS.

The 12 by 12-inch white oak ribs carrying the lagging are spaced 5 feet on centers. The quantities per lineal foot are tabulated in Fig. 132.

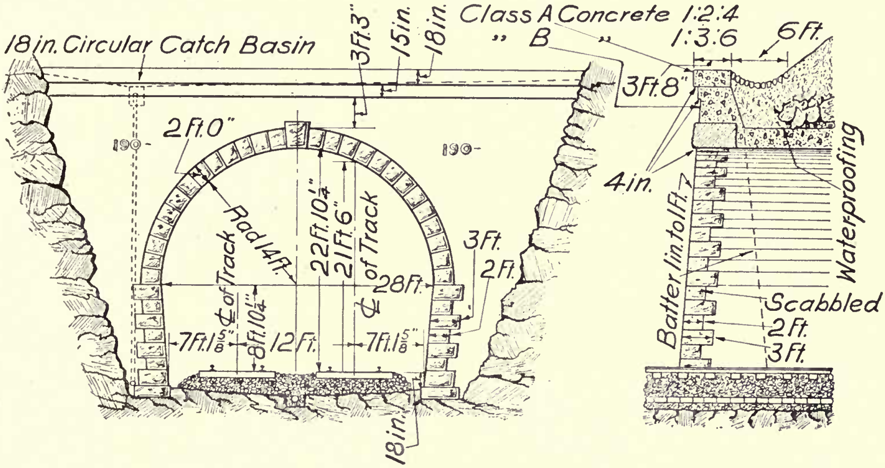


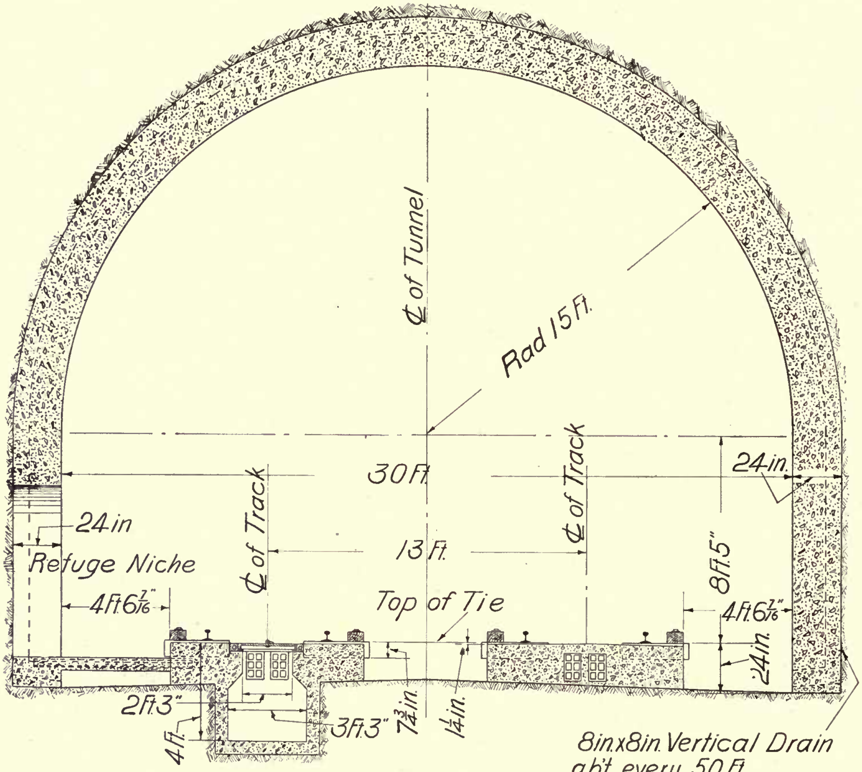
FIG. 134.—STANDARD DOUBLE-TRACK TUNNEL FACADE, N. Y. C. & H. R. R. R.

STANDARD TUNNEL FACADE.—The standard facade for the different types of tunnels described above is shown in Fig. 134. With the exception of the arch ring, which is of scabbled granite, the entire facade is of concrete mixed in the proportions of 1:3:6 for the main body and of 1:2:4 for the coping.

NEW BERGEN HILL TUNNEL, D., L. & W. R. R.—As will be seen from the cross section in Fig. 135, this tunnel is 30 feet wide in the clear, 23 feet 5 inches high from the base of the rail to the crown of the roof arch, and has a concrete lining of a minimum thickness of two feet. The length of the tunnel is 4,280 feet and at two points located at about one-third the length of the tunnel from each portal it is connected to the old tunnel, which is immediately alongside the new one, by an open cut extending across the four tracks, 100 feet long and 80 feet wide.

At about the center of each of the sections, into which these open cuts divide the tunnel, shafts 10 feet long and 30 feet wide were sunk to the new tunnel. These shafts and open cuts were used to good advantage in moving the waste material from the headings and they also greatly facilitated the work of placing the concrete lining.

The concrete, which was mixed in the proportions of 1:2½:5, was placed so as not to require tamping and was carefully spaded from the face of the forms which were lined with No. 20 gauge sheet steel well greased. This resulted in giving the exposed surface of the concrete a smooth metallic appearance which required no further finishing.



SECTION AT MANHOLE TYPICAL SECTION

FIG. 135.—CROSS SECTION, NEW BERGEN HILL TUNNEL.

The development of the portals is shown by the photograph in Fig. 133, and the roadbed construction is described in detail on page 178, Chapter XV.

The tunnel was designed and built, during years 1906 to 1908, under the direction of the engineering department of the Delaware, Lackawanna and Western Railroad, Mr. Lincoln Bush, chief engineer, and the lining was put in by Arthur McMullen & Company, contractors, New York.

# CHAPTER XV.

## CONCRETE TIES AND ROADBEDS.

### TIES.

One of the most serious and perplexing questions which confronts the railroad engineer of to-day is the tie problem. As an evidence of this, during the year 1907 the railroads of the United States used approximately 118,000,000 ties, a very large percentage of which were renewals.

FIG. 136.—CONCRETE TIES ON INTERNATIONAL RY., BUFFALO.

This vast inroad upon the limited and rapidly decreasing supply of timber has caused wooden ties to become poor in quality and high in price, with a result that railroad engineers realize the necessity of procuring a substitute and have been experimenting with concrete ties of various designs for the past few years. While none of these ties have been tested long enough under heavy and high speed traffic to warrant selecting any one as a proper substitute for the wooden ties under all conditions, the success of some of the ties

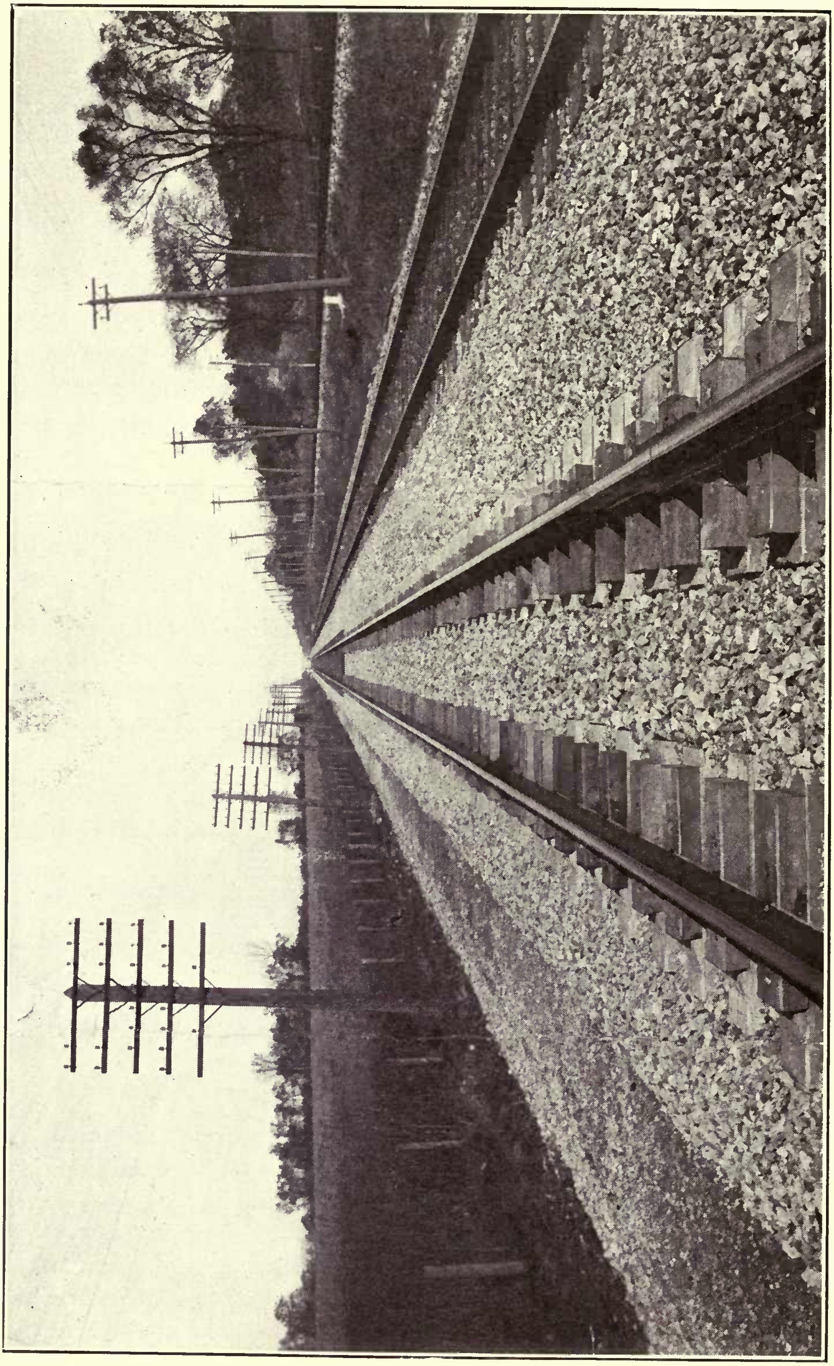


FIG. 137.—CONCRETE TIES ON CHICAGO AND ALTON R. R.

tested thus far has been great enough to convince railroad engineers who have given the most study to the subject that a properly reinforced concrete tie with proper fastenings is a practical and economical tie, at least for tracks where the speed is low and where conditions are adverse to the life of wood or metal. There is no question but what concrete ties are entirely suitable and economical for use in yards and sidings and that there is an enormous place for their introduction into this field alone.

Concrete ties possess certain natural advantages over either timber or steel inasmuch as dampness, drawn fires and insects have absolutely no effect upon them. In addition, they are practically independent of the steel and timber market, and can be made along the line of the railroad, and, as compared with the chemically treated timber or the steel tie, at a reasonable cost.

Concrete ties have been in successful use in Indo-China, where a very peculiar species of ant destroys wooden ties in a few months, for about ten years. At the present time it is estimated that there are over 1,000,000 of these ties in service. They are of an inverted T-section, the flange of which is laid on the ground, the stem being vertical. The rails are fastened by bolts which are imbedded in an enlargement of the stem where the rails pass. In Italy concrete ties have been tried with such success that the Italian government has recently placed an order with various manufacturers in Italy for 300,000 concrete ties.

In the design of a successful tie there are a number of important functions that seem to be more or less overlooked in many of the ties thus far built.

Cushion blocks, if used, should be removable, and the fastenings be of such a nature that they will neither have a tendency to shake loose nor be inaccessible, and may be renewed if injured.

Inasmuch as automatic block signalling is being extended very rapidly upon practically all of the railroads, it is important that the rails should be insulated, and therefore it is necessary to place sufficient concrete between the metal in contact with the rails and the longitudinal reinforcement.

Many long ties have failed from the fact that they were not designed to act as cantilever beams, thus being unable to withstand the severe shocks coupled with the sinking of the tie under passing loads on center bound track. The difficulty experienced with tie blocks has been in keeping them in longitudinal position and maintaining them so that the vertical deflection of one rail will not greatly exceed that of the other, thereby causing rolling and pounding of the equipment.

Finally, ties should be of sufficient strength to support derailed cars and engines until they are off the ends of the ties and actually into the ditch; otherwise, an ordinary derailment may become a serious wreck.

# CONCRETE ROADBEDS.

While the original cost of a solid concrete roadbed is greater than the ordinary cross-tie construction, it is undoubtedly more economical in the end for tunnels and subways; especially so where space is cramped, traffic heavy, and a track cannot be temporarily abandoned, and where with the running rails, guard rails and third rails attached to the long ties—as in the case of electrified lines—it is extremely difficult and very expensive to maintain and tamp up track to surface and make tie renewals.

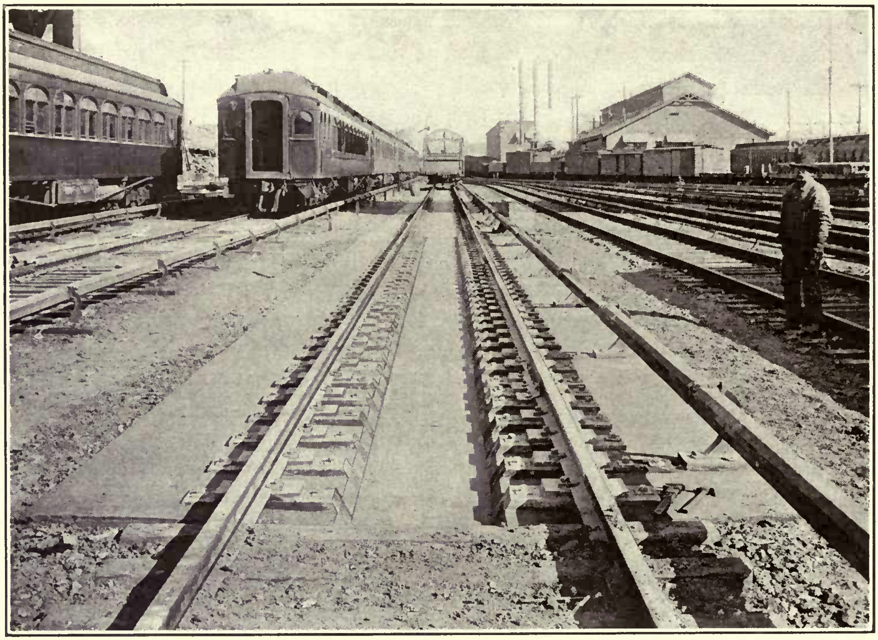


FIG. 138.—EXPERIMENTAL CONCRETE ROADBED, N. Y. C. & H. R. R. R.

Also, it can be used to great advantage and economy in rock and earth cuts where there is always a large maintenance expense to keep ditches open and track in good surface.

In addition to the question of ultimate economy, the solid concrete roadbed is especially commendable for tunnel and subway construction from a hygienic standpoint; for in most tunnels and subways ventilation is difficult and the accumulation of grease, dirt and débris, which is readily held by the ballast of the cross-tie track construction, is a serious menace to the health of the passengers. This can be eliminated in the solid concrete construction

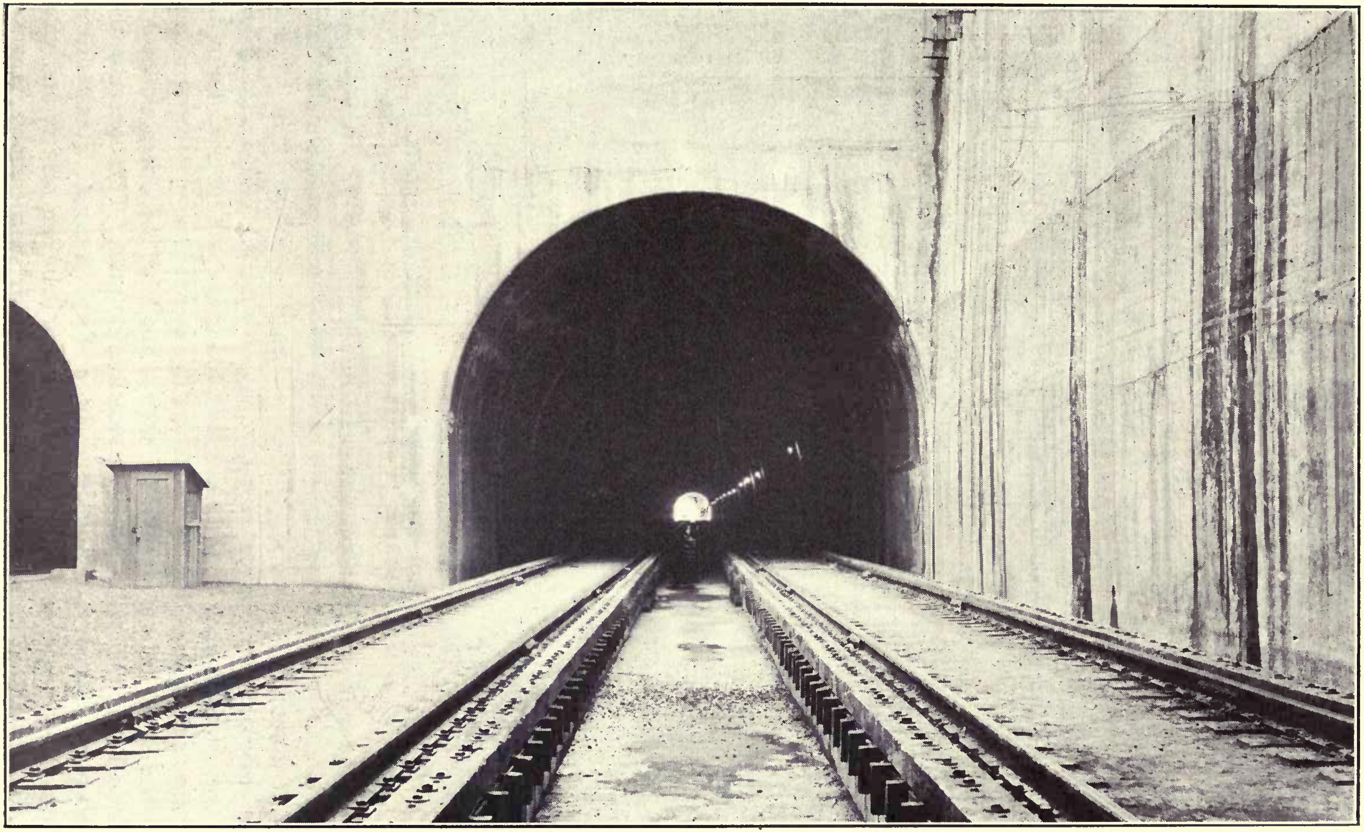


FIG. 139.—VIEW TAKEN AT ONE OF THE TWO OPEN SHAFTS IN THE INTERIOR OF TUNNEL SHOWING FINISHED ROADBED.

as the entire roadbed can be flushed with water and kept in a neat, clean and sanitary condition.

**ROADBED CONSTRUCTION OF THE NEW BERGEN HILL TUNNEL, D., L. & W. R. R.**—The drawings in Fig. 140 show the essential features of design and construction, while the photograph in Fig. 139, which is a view taken at one of the two open shafts in the interior of the tunnel, shows the finished roadbed.

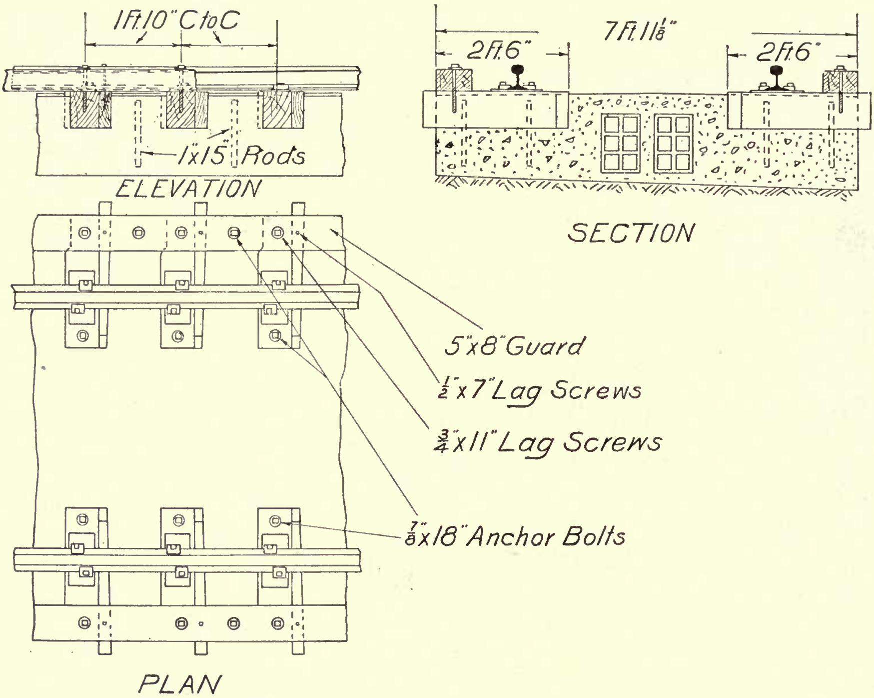


FIG. 140.—CONCRETE ROADBED, NEW BERGEN HILL TUNNEL.

This construction consists of a roadbed of concrete laid on the rock bottom of the tunnel with 8 in. by 8 in. creosoted timber tie blocks 2 feet 6 inches long set in the concrete and spaced 1 foot 10 inches apart on centers for supporting the rails. These tie blocks leave a notch at the outer end to form a shoulder, and are set in the concrete when it is built. The concrete fills the space made by the notch in the tie block, and prevents the lateral shifting of the block and railroad rail, which is attached to it by lag screws and wrought iron clips. A tapered creosoted wedge block holds the tie block tight against the concrete, and can be driven in to take up any looseness due to shrinkage or wear. The wedge is held in place by a lag screw extending about 2 inches into it through the guard rail. As will be seen from the drawings, the guard rail is fastened to the tie blocks by lag screws, and is also anchored to the concrete by anchor bolts.

To replace the tie blocks, the lag screws are removed, the wedge withdrawn, the tie block moved forward until the shoulder of the block clears the shoulder in the concrete, and the tie block is then pulled out laterally without disturbing the adjacent tie blocks or rail fastenings and without raising the rail, thus not interfering with traffic.

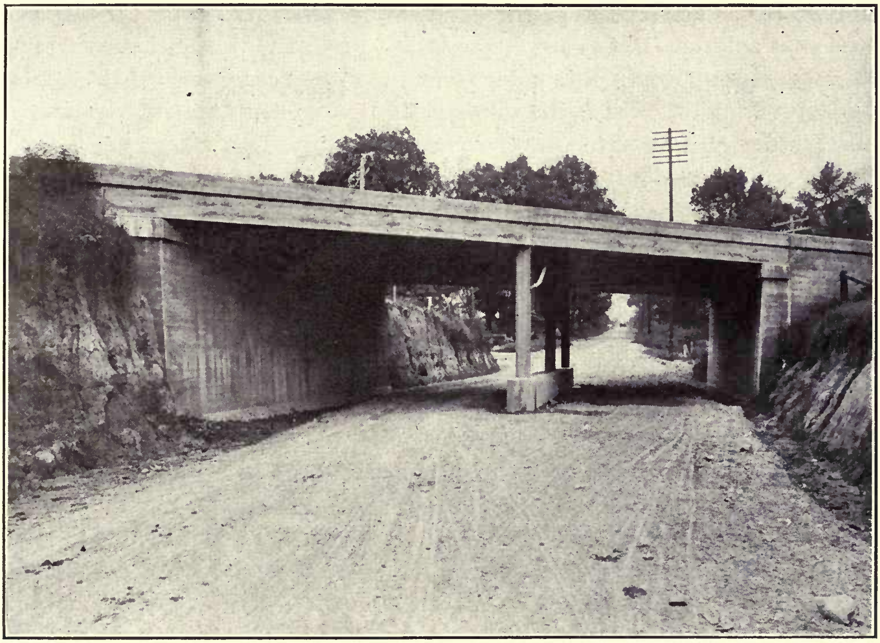


FIG. 141.—BRIDGE WITH CONCRETE FLOOR, ILL. CENTRAL R. R.

One man can replace these tie blocks and wedges, while with the ordinary type of ballast track construction it is necessary for a gang of men to dig out the ballast in order to replace a tie, and it also is necessary to protect traffic while the work is being done.

The proportions used in the track superstructure were one part of cement to 6 parts of Cowe Bay gravel and sand, and in the sub-base the proportions were 1 part of cement to 12 parts of crushed stone and sand for bringing the sub-base up to proper level.

The table on page 183 gives an estimated cost of the ballasted roadbed construction for double track. So far as the amount of tunnel excavations and the cleaning up of muck under the roadbed are concerned, the cost would be the same whether ballasted track or concrete roadbed were used, but with the concrete roadbed the tile drains and trenching for ditches for the drains are eliminated. The estimated total cost, including the conduits, tile drains, creosoted ties, etc., as detailed, for the ballasted double track, for a length of 4,280 feet amounts to $62,568.87, which would be at the rate of $14.62 per lineal foot of double track. If the conduit construction is eliminated from consideration, the total cost amounts to $43,429.87, or $10.15 per lineal foot of double track.

On page 184 is given a detailed statement of the actual cost of the concrete roadbed construction, which does not include any estimate for the concrete sub-base under the finished track superstructure. The statement in detail shows the actual cost for 4,280 lineal feet of double track as taken from the company's invoices and records. It will be noted that this statement includes the two lines of 12-hole conduits.

The railroad furnished sand, stone and cement for the concrete work, and the price of $6.25 per cubic yard given in the detailed statement for concrete roadbed includes the contractor's price, plus the cost of material. The contract provided that the contractor would lay the conduits, the railroad company to furnish the material and the contractor to receive the same price per cubic yard for the work as he received for the balance of the concrete work. for tunnel lining, namely $3.50 per cubic yard. This price of $3.50 per cubic yard included everything excepting sand, stone and cement. The company assembled the tie blocks and rail and the cost of these items is included in the detailed statement. The cost thus figures $14.26 per lineal foot of double track. Eliminating the conduit construction from consideration, the cost per foot of double track for concrete roadbed amounts to $13.18 per lineal foot of double track as against $10.15 per lineal foot of ballasted double track. Had the conduits been eliminated from the concrete roadbed construction, the superstructure could have been made about 4 inches less in height, which quantity would have practically made up for the area of concrete occupied by the conduits.

So far as the maintenance cost is concerned, the concrete roadbed construction has resolved itself into a question of simply track inspection, and one inspector during the night and one during the day is all that is necessary. When a tie block must be renewed, it can be done without disturbing in any way the rail fastenings to the tie blocks on either side of the one to be renewed, and no removal of rail will be necessary. One man can readily replace a tie block 8 inches by 8 inches by 2 feet 6 inches, and no interference whatever would occur with traffic during such renewal, as an inch board could be placed underneath the rail on top of the concrete, either side of the block to be renewed, for temporary support.

Still another detailed statement is given below showing the actual cost to the company per annum to maintain ballasted track in the present old Bergen Hill Tunnel, which is of the same length as the new tunnel, the traffic through it being very heavy. Capitalizing the investment for ballasted track construction and for concrete roadbed construction (includng conduits) at 4 per cent, and taking into consideration the difference in cost of maintaining, shows from these figures that the saving per annum in cost per mile of double track (with conduits) amounts to $7,107.32, and without conduits the saving per annum per mile of double track concrete roadbed would be $6,389.42.

## ESTIMATED COST OF BALLASTED TRACK CONSTRUCTION FOR DOUBLE TRACK THROUGH NEW BERGEN HILL TUNNEL OF THE DELAWARE, LACKAWANNA & WESTERN R. R. AT JERSEY CITY, N. J.

Length of tunnel—4,280 feet.

| | | | | |
|---|---|---|---|---|
| 232 | Gross tons 91-lb. special open hearth rail, | @ | $34.00 | $7,888.00 |
| 520 | Pairs of angle bars | @ | 1.07 | 556.40 |
| 3120 | Spliced bolts | @ | .03 1/3 | 104.00 |
| 3120 | Nut locks | @ | .009 | 28.08 |
| 8835 | Tie plates, 6″ × ½″ × 9″ | @ | .131 | 1,157.38 |
| 520 | Joint tie plates, 6″ × ½″ × 11″ | @ | .171 | 88.92 |
| 18710 | Spikes | @ | .01¾ | 327.40 |
| 4677 | Creosoted Y. P. ties, 7″ × 9″ × 8 ft. 6″ | @ | 2.10 | 9,821.70 |
| 6737 | Cu. yd. stone ballast, delivered | @ | 1.00 | 6,737.00 |
| 17976 | Lin. ft. of vitrified 6-hole conduits, 5% allowed for breakage | @ | .225 | 4,044.60 |
| 5720 | Yd. drilling for wrapping conduit joints | @ | .095 | 543.40 |
| 2035 | Cu. yd. rock excavation for tile drains | @ | 7.00 | 14,245.00 |
| 8988 | Lin. ft. 8″ drain tile, 5% added for breakage | @ | .085 | 763.97 |
| 2000 | Cu. yd. of extra concrete for conduits | @ | 6.25 | 12,500.00 |
| 8560 | Lin. ft. single track laying and surfacing | @ | .20 | 1,712.00 |
| 586 | Cu. yd. concrete voids occupied by conduit | @ | 3.50 | 2,051.00 |
| | | | | $62,568.87 |

$62,568.87 4280 = $14.62 per foot of double track.
If conduits are eliminated from consideration, cost would be $43,429.87.
$43,429.87 ÷ 4280 = $10.15 per foot of double track.

# DETAILS OF ACTUAL COST OF CONCRETE ROADBED CONSTRUCTION FOR DOUBLE TRACK THROUGH NEW BERGEN HILL TUNNEL OF THE DELAWARE, LACKAWANNA AND WESTERN RAILROAD AT JERSEY CITY, N. J.

Estimate includes electric wire conduits. Length of tunnel, 4280 feet.

| | | | |
|---|---|---|---|
| 232 | Gross tons 91-lb. special open hearth rail, | $34.00 | $7,888.00 |
| 520 | Pairs of angle bars, | 1.07 | 556.40 |
| 3120 | Splice bolts | .03 1/3 | 104.00 |
| 3120 | Nut locks, | .009 | 28.08 |
| 8835 | Tie plates, 6″ × ½″ × 9″, | .131 | 1,157.38 |
| 520 | Joint tie plates, 6″ × ½″ × 11″, | .171 | 88.92 |
| 17976 | Lin. ft. vitrified 6-hole conduit, 5% allowed for breakage, | .225 | 4,044.60 |
| 5720 | Yd. drilling for wrapping conduit joints, | .095 | 543.40 |
| 9360 | Creosoted yellow pine tie blocks, 8″ × 8″ × 2 ft. 6,″ | 45.00 | 5,616.00 |
| 9360 | Creosoted yellow pine wedges, 2¼″ × 8″ × 2 ft. 6″, | 45.00 | 1,579.50 |
| 17680 | Intermediate rail clips, | .039 | 689.52 |
| 18720 | Pieces round iron 1″ × 15″ for reinforcement, | .06 1/3 | 1,185.60 |
| 1040 | Joint rail clips, | .051 | 53.04 |
| 18720 | Lag screwspike, ⅞″ × 7½″, | .046 | 861.12 |
| 9360 | Lag screws for guard rail, ¾″ × 11″, | .034 | 318.24 |
| 9360 | Washers for guard rail, ⅜″ × 3″, | .03 | 280.80 |
| 9360 | Wedge lag screws, ½″ × 7″, | .013 | 121.68 |
| 18555 | Lin. ft. of Y. P. creosoted guard rail, 5″ × 8″, | 45.00 | 2,783.25 |
| 4680 | Guard rail anchor bolts, ⅞″ × 18″, | .08 2/3 | 405.60 |
| 4680 | Guard rail washers, ⅜″ × 3″, | .03 | 140.40 |
| 4680 | Anchor nuts, 2¼″ sq. × 1¼″ thick, | .08 | 374.40 |
| 4680 | Paraffine tubes for anchor bolts, | .005 | 23.40 |
| 3754.4 | Cu. yd. concrete, | 6.25 | 23,465.00 |
| 1019.2 | Cu. yd. concrete voids occupied by tie blocks, wedges and conduits, | 3.50 | 3,567.20 |
| | Labor and engineering for assembling and fastening complete, the tie blocks, wedges, guard rail, rail, rail joints, screws, spikes, etc., 8560 lin ft., | .60 | 5,136.00 |
| | | | $61,011.53 |

$61,011.53 — 4280 = $14.26 per linear foot of double track with conduits and wrapping.

$56,423.53, total cost, exclusive of conduits.

$56,423.53 — 4280 = $13.18 per linear foot of double track.

### COST PER ANNUM BALLASTED TRACK (With Conduits)

| | |
|---|---|
| \$62,568.87, @ 4% | \$2,502.75 |
| Track maintenance,<br>\$565.00 per mo. × 12 | 6.780.00 |
| Length of 4280 ft. | \$9,282.75 |
| $\$9{,}282.75 \times \dfrac{5280}{4280}$ | \$11,451.57 per mile |

### COST PER ANNUM BALLASTED TRACK (Without conduits)

| | |
|---|---|
| \$43,429.87, @ 4% | \$1,737.19 |
| Track maintenance,<br>\$565.00 per mo. × 12 | 6,780.00 |
| Length of 4280 ft. | \$8,517.19 |
| $\$8{,}517.19 \times \dfrac{5280}{4280}$ | \$10,507.20 per mile |

### COST PER ANNUM CONCRETE ROADBED (Without Conduits)

| | |
|---|---|
| \$61,011.53, @ 4% | \$2,440.46 |
| Track maintenance,<br>\$90.00 per mo. × 12 | 1,080.00 |
| Length of 4280 ft. | \$3.520.46 |
| $\$3{,}520.46 \times \dfrac{5280}{4280}$ | \$4,344.25 per mile |

### COST PER ANNUM CONCRETE ROADBED (Without conduits)

| | |
|---|---|
| \$56,423.53, @ 4% | \$2,256.94 |
| Track maintenance,<br>\$90.00 per mo. × 12 | 1,080.00 |
| Length of 4280 ft. | \$3,336.94 |
| $\$3{,}336.94 \times \dfrac{5280}{4280}$ | \$4,117.78 per mile |

This roadbed construction was designed and patented by Mr. Lincoln Bush, who was at the time Chief Engineer of the Delaware, Lackawanna and Western Railroad.

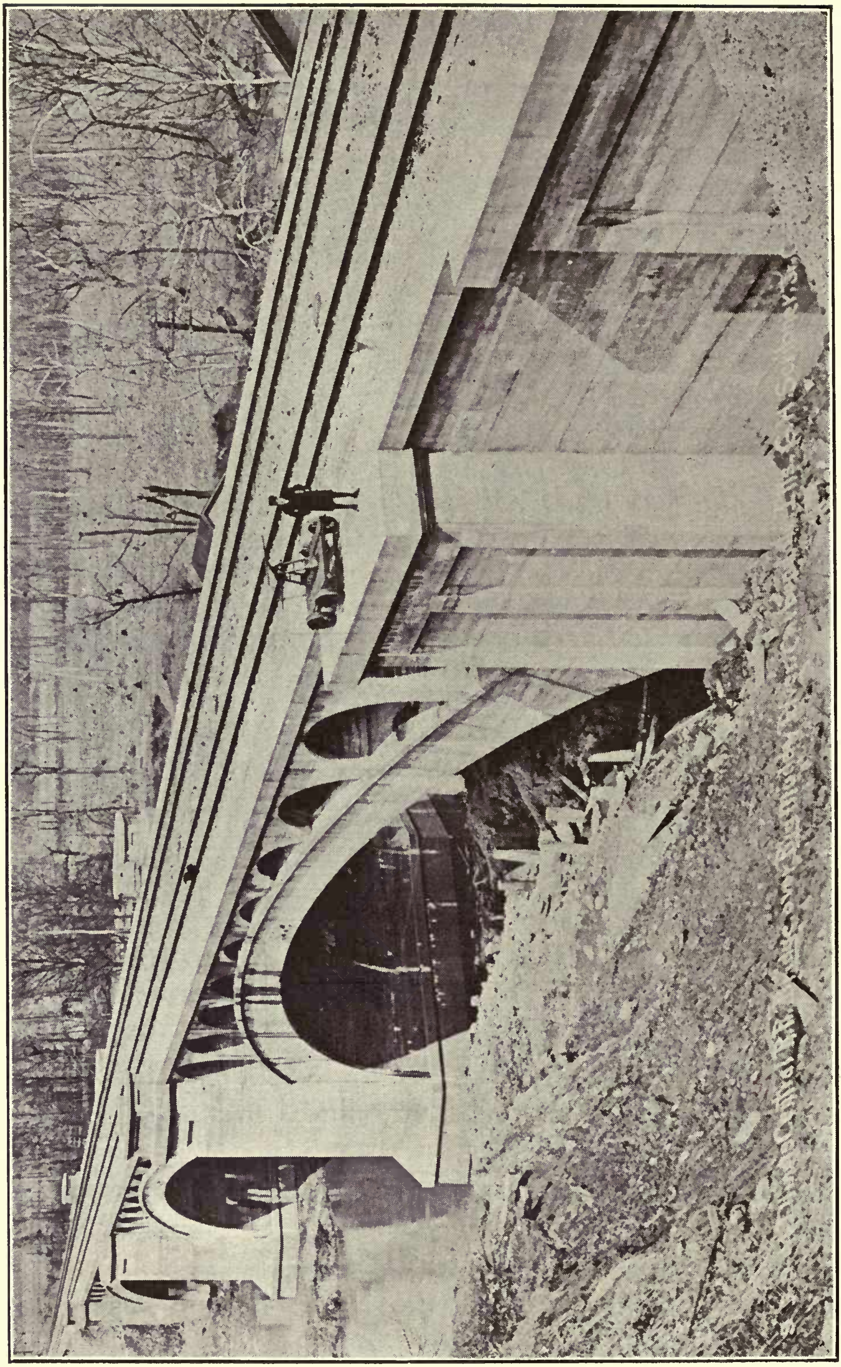


FIG. 142.—BIG MUDDY RIVER BRIDGE, ILL. CENTRAL R. R.

# CHAPTER XVI.

## TELEGRAPH POLES, POWER TRANSMISSION POLES AND TOWERS.

### TELEGRAPH POLES.

Owing to the increasing scarcity and inferior quality of wood, which has heretofore been used exclusively for telegraph and trolley poles, engineers have been experimenting with reinforced concrete for a number of years with the result that poles have been designed which are meeting the requirements in every way.

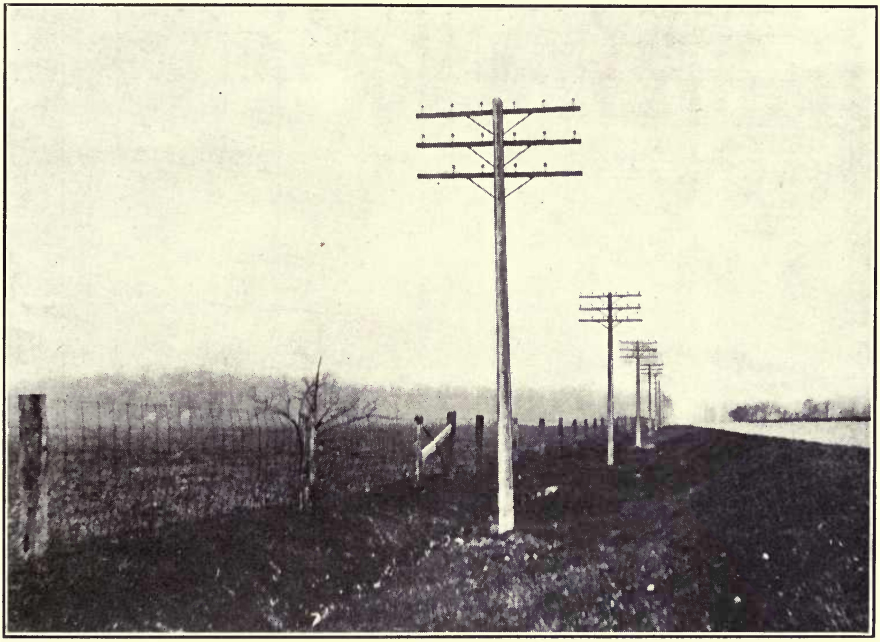


FIG. 143.—CONCRETE TELEGRAPH POLES, P., L. W. OF P.

Among the advantages of the reinforcd concrete pole, the facts are that lines thus equipped have practically no trouble from lightning, the reinforcing rods apparently acting as conductors of electricity; that the pole requires no preservative or paint to protect it from the ravages of weather, as is the case with wood or steel; and that it is elastic enough to withstand all ordinary shocks.

That a reinforced concrete pole of economical dimensions possesses the requisite strength has been demonstrated both in this country and abroad by experiments* on concrete and wooden poles of the same sizes.

In 1907 Mr. Robert A. Cummings† made some comprehensive tests for the Pennsylvania lines west of Pittsburg on reinforced concrete and white cedar poles, which resulted in showing that the concrete pole was not only stronger than the wooden poles but also that, after breaking, the end was held in a

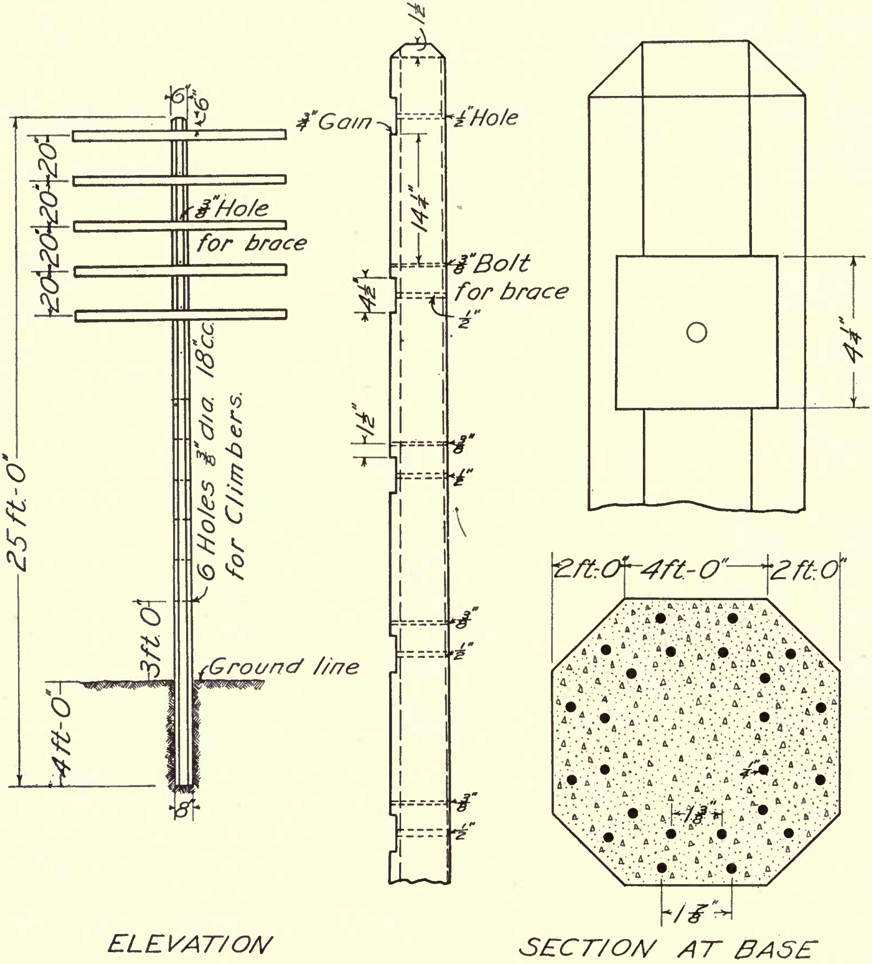


FIG. 144.—CONCRETE TELEGRAPH POLES, P., L. W. OF P.

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*Cement Age, August, 1907, p. 84; Cement, July, 1903, p. 168; Concrete, March, 1907, p. 40.

†Cement Age, August, 1907, p. 84.

slightly inclined position by the reinforcement, while the wooden pole fractured completely and fell to the ground.

Mr. W. W. Bailey* made some very thorough tests in 1908 of reinforced concrete and of cedar poles 30 feet long and embedded 5 feet in the ground. Both poles were 7 inches at the top and 12 inches at the ground line. The concrete pole was reinforced with four ⅝-inch twisted steel rods bound together with No. 9 binding wire. With a horizontal pull at the top of 1,780 pounds, the concrete pole deflected 17 inches and broke from a horizontal pull of 7,200 pounds with a deflection of over 6 feet before falling, while the wooden pole, with a pull of 1,780 pounds, deflected 33 inches and broke at 2,200 pounds.

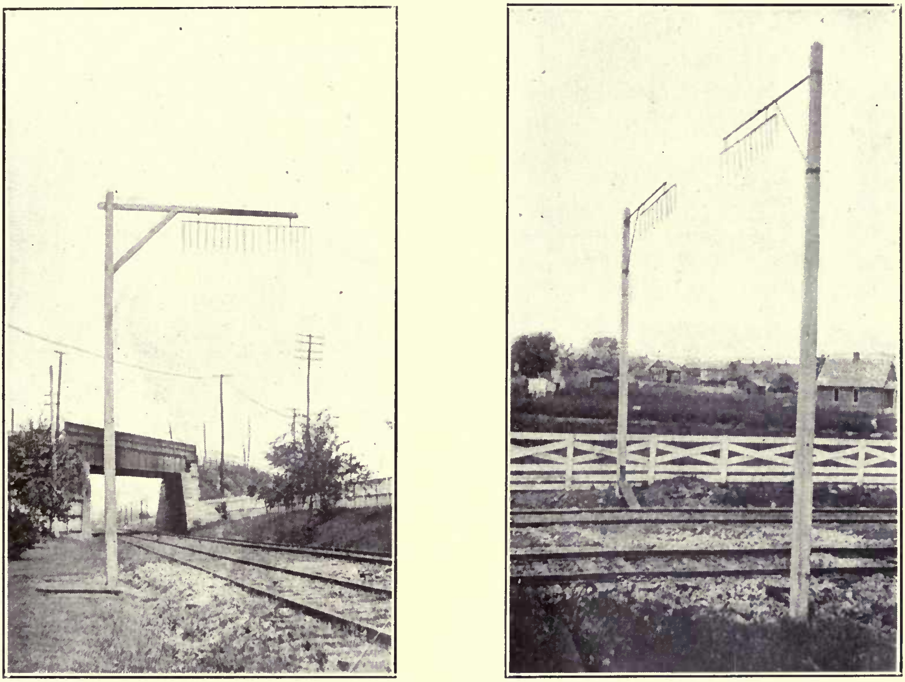

FIG. 145.—TICKLER POLES, N., C. & ST. L. RY.

In general concrete poles are designed with a square section, with the corners chamfered off, tapering from bottom to top and with tapering reinforcement, thus meeting the condition of the decreasing strain, which is of course greatest at the ground line and decreases toward the top where the strain is applied. Aside from telegraph poles such as are described below, concrete has been used to good advantage in the construction of tickler poles, a successful type of which is described on page 191.

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*Concrete Engineering, March, 1909, p. 67.

TELEGRAPH POLES, P., L. W. OF P.—The drawing in Fig. 144 shows the details of poles designed by Mr. F. M. Graham, Engineer, Maintenance of Way, which the Pittsburg, Ft. Wayne and Chicago division of the Pennsylvania Railroad are installing along their lines. These poles range in height from 25 to 34 feet and are 8 inches square at the bottom, tapering to 6 inches square at the top, with the corners chamfered two inches. The reinforcement consists of 24 ¼-inch wires running the full length of the poles. Holes are left in the poles for the brace and cross arm bolts and also for the climber steps. The poles are built at gravel pits along the line and a wet mixture of 1 cement to 3 sand to 3 of gravel is used. After the poles have cured, they are hauled out on cars to the point of erection where they are set four feet in the ground and bedded in stone screenings. The photograph in Fig. 143, page 187, shows these poles in actual service.

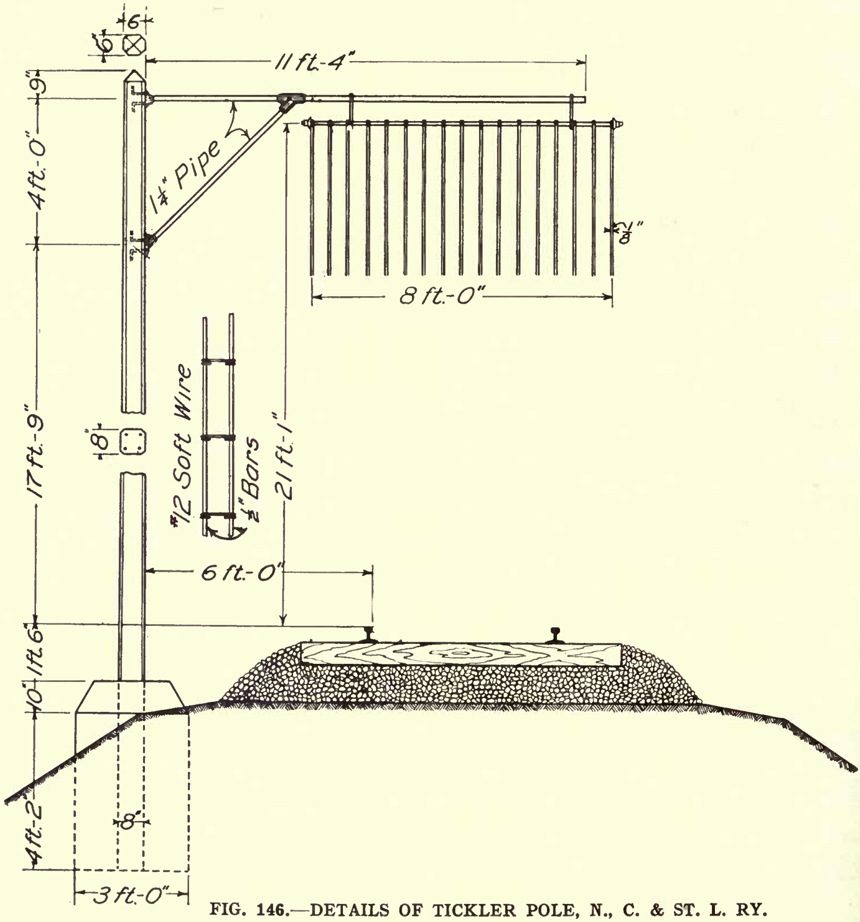

FIG. 146.—DETAILS OF TICKLER POLE, N., C. & ST. L. RY.

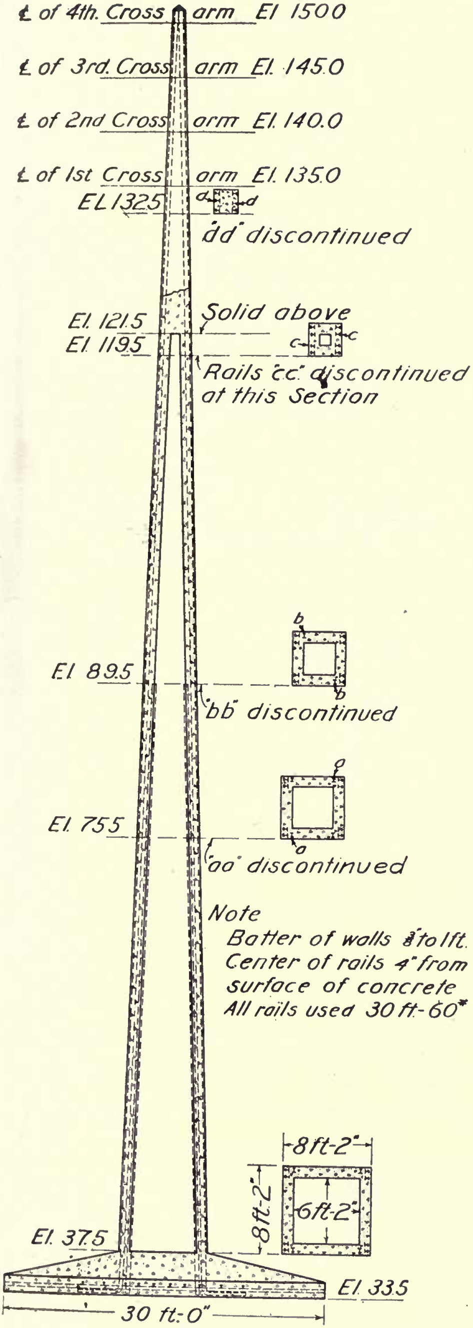

FIG. 147.—DETAILS OF CONSTRUCTION, BROWNSVILLE TRANSMISSION TOWERS.

TICKLER POLES, N., C. & St. L. RY.—In 1904 the Nashville, Chattanooga and St. Louis Railway, Mr. Hunter McDonald, Chief Engineer, erected four bridge warnings using concrete poles for supporting the warning straps or ticklers which have given such satisfaction that they have been adopted as standard for that purpose. These poles, the details of which are shown by the drawings in Fig. 146, and by the photographs in Fig. 145, are 8 inches square at the bottom and 6 inches square at the top, and are reinforced for the full length of 29 feet with four ½-inch round rods banded every foot with No. 12 soft wire. The ticklers on two of the poles are carried by cross-arms and braces of concrete cast with the pole, but since it was found that the concrete cross-arms were expensive as well as so heavy as to cause the pole to bend to an unsightly extent, gas pipe cross-arms were used instead and found satisfactory in combination with the concrete pole.

## POWER TRANSMISSION POLES AND TOWERS.

In the long distance transmission of electrical energy from one point to another, it is necessary from an economical standpoint to use longer spans than wooden poles can safely carry. This condition led first to the adoption of steel structures which not only had the effect of increasing the initial cost and cost of maintenance, but also necessitated a wider right of way than single pole construction. To eliminate these disadvantages and at the same time obtain a pole of sufficient strength for long span construction engineers turned to reinforce concrete with the result that poles have been designed which after several years of trial are proving entirely satisfactory.

In constructing concrete power transmission poles, both hollow and solid sections are employed. An example of the former type is the Brownsville tower described below, while the poles which the Lincoln Electric Light and Power Company* use to carry their wires over the old Welland Canal at St. Catherines, Ontario, are noteworthy examples of the latter type. These consist of reinforced concrete poles 150 feet high, 142 feet being above the ground. They are 31 inches square at the base and 11 inches square at the top and are reinforced with four 2½-inch round rods. The poles were made horizontally on the ground and raised into upright position by means of a pair of shear legs.

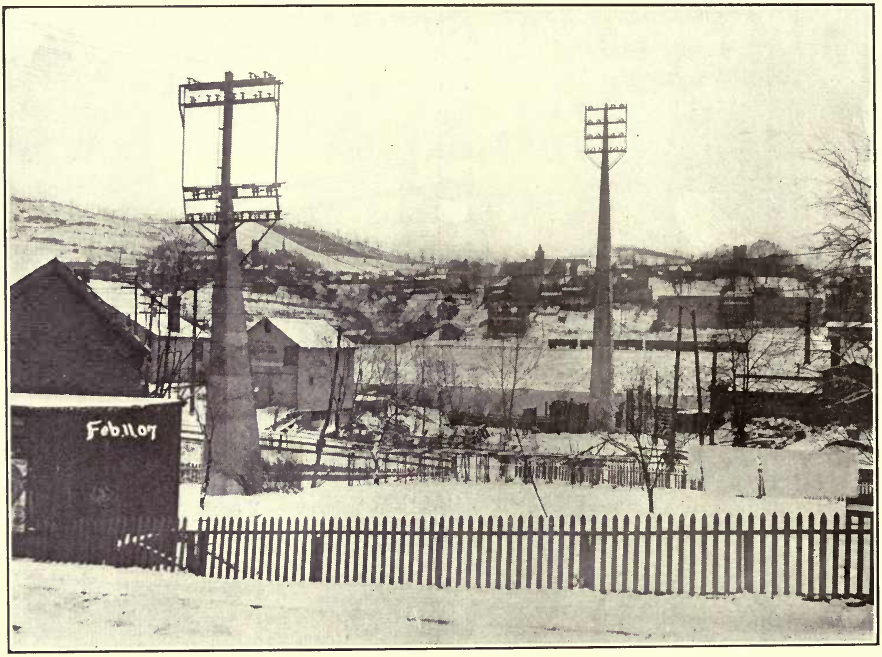

FIG. 148.—BROWNSVILLE TRANSMISSION TOWERS, WEST PENN. RAILWAYS CO.

BROWNSVILLE TRANSMISSION TOWERS.—In the spring of 1907 the West Pennsylvania Railways Company was confronted with the problem of supporting a high potential power transmission line across the Monongahela River at Brownsville, Pa., a distance of 1,014 feet, and at the same time

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*Transactions American Society Civil Engineers, Vol. LX., p. 160.

of keeping the cable 79½ feet above the low water mark, as required at that point by government regulations.

On the Brownsville side of the river no tower was necessary, as a firm anchorage could be obtained in the sub-station of the company. On the opposite side, where a tower was found necessary, it was decided to build a main tower, as close to the river as possible, designed to carry only the weight of the cables and the wind pressure against the cables and the tower itself, and 230 feet back of this a shorter tower designed to serve as an anchorage taking the direct strain of the main span.

In order that the main tower, the general details of design and construction of which are shown by the drawings in Fig. 147, might be designed for practically the wind stress alone, a special roller bearing saddle was devised for carrying the cables over the tower without a rigid connection. Both towers were designed as cantilever beams. The wind pressure considered in connection with the wind stress on the cables was taken as 40 pounds per square foot and the load on the cables as 20 pounds per square foot of projected ice-coated section. The cables themselves were treated as catenaries, the maximum unit load therefore being the resultant of the weight of the cable and the ice in a vertical direction and the wind load in a horizontal direction. With a maximum allowable sag of 36.6 feet and a minimum sag of 33.4 feet, there is assumed to be a pull of 122,000 pounds exerted on the anchorage tower at an average height of 38½ feet above its base.

The photograph in Fig. 148 shows both the main and the anchorage towers. The main tower, which rises 115 feet above its foundations, is pyramidal in form, being 8 feet 2 inches square at the base and 1 foot square at the top and has hollow walls 1 foot thick up to a point 84 feet above the base, where the section becomes solid. The anchor tower, which is of solid section throughout, is 4 feet by 10 feet at the base and batters up to a section 1 foot square at 41 feet 1 inch above the base, from which point it is of uniform section up to the full height of 55 feet.

In addition to the vertical reinforcing rails shown in Fig. 147, two spirals each of ⅜-inch cable, were wound 1 foot apart, thus making a 2-foot pitch for each cable. Gravel concrete mixed very wet was used throughout, the footing being mixed in the proportions of 1:2 ½:5 and the walls in the proportions of 1:2½:4.

Falsework 12 feet square was built for both towers sufficiently in advance of the wooden form so that both the forms and the 30-ft. reinforcing rails might be raised into position. For the exterior forms, three sections 6 feet high were made for each tower. One section was filled each day, and on the third day the bottom section was removed, cut down to the proper section and used above. Before filling the form, each was given a thin coat of motor grease. The interior forms for the main tower consisted of hemlock sheathing backed up by 2 by 4 inch bracing and were left in the tower.

The concrete was mixed in a No. 1 mixer, driven by a 10-horse power belt connected electric motor and was hoisted to the required elevation by a friction hoist operated by a 7½ horse power single phase motor.

The towers were designed and constructed by the West Penn. Railways Company under the general direction of Mr. W. E. Moore, General Manager, and Mr. J. S. Jenks, Superintendent of Transmission, with Mr. F. W. Scheidenhelm, Structural Engineer, in direct charge of design and construction.

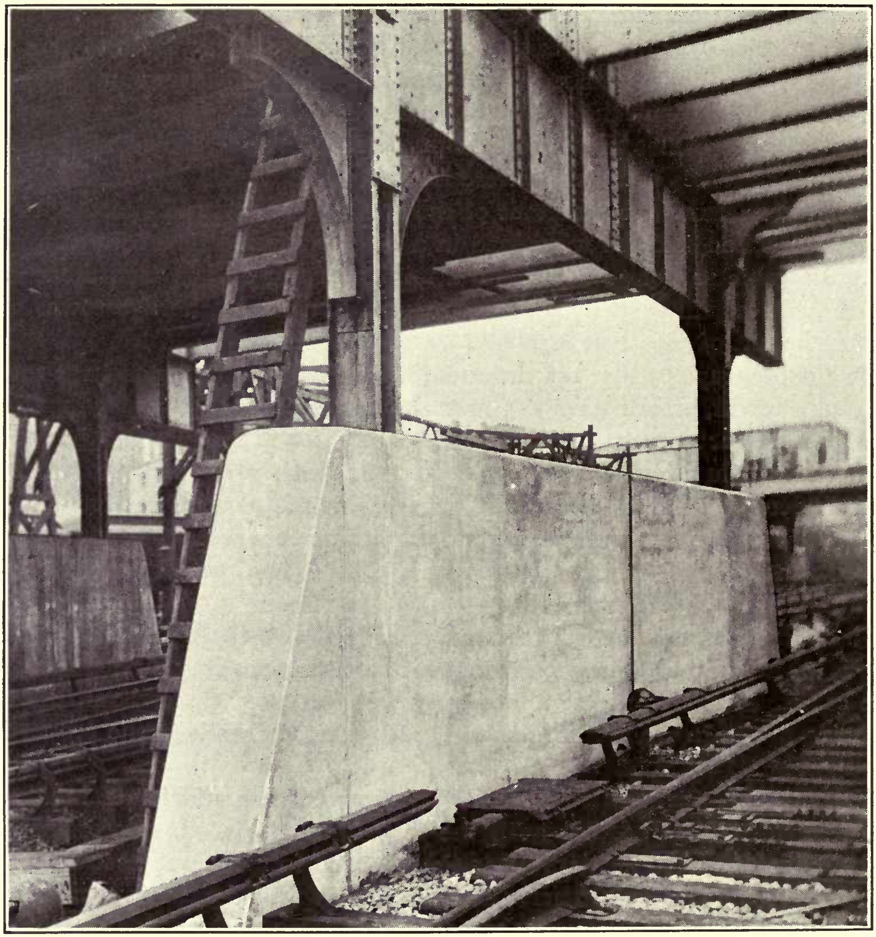

FIG. 149.—CONCRETE PROTECTION PIER, N. Y. C. & H. R. R. R.

## CHAPTER XVII.

## POSTS AND FENCES.

The growing scarcity and the increasing cost of suitable timber for posts has brought concrete into quite general use. Concrete posts possess the advantage over wooden ones not only of unlimited life, greater strength and resistance to the action of fire and decay, but also they present a more pleasing appearance.

As to the adaptability of the concrete post to railroad use, the committee appointed by the American Railway Engineering and Maintenance of Way Association* to investigate this subject reported to the annual convention at Chicago in March, 1909, in part as follows:

> "From observation of concrete fence posts your Committee considers that the concrete fence post will heave very little or not at all, as posts set from two to five years are at present in almost perfect alignment, and not a loose or broken post was found. They appear sufficiently strong for all practical purposes after being properly cured and set. The claim that concrete posts, reinforced with steel, form lightning protectors appears reasonable. They will, of course, resist the action of fire and decay. They will not float and cannot be displaced so easily as wood posts. On the other hand, concrete posts must be carefully handled in loading and unloading and well cured before using. Fence wire in contact with their surfaces should be well galvanized.
>
> "The concrete post is much heavier than the wood post and the cost of distributing is about 25 per cent greater.
>
> "It would seem that the concrete post is particularly adapted to railroad use. Most of the post machines are cheap and portable and the materials used are in daily use on all roads using concrete. The materials are cheap and easily obtained."

In regard to the various types and methods of making such posts the same committee after corresponding with over twenty manufacturers of posts and post-making machinery in the United States and Canada reported that:

> "A majority of these firms use or advise the use of Portland cement and gravel ranging from the size of sand to pebbles which will pass a wire

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*Bulletin No. 107, January, 1909, p. 323.

screen having meshes of from ½ to 1 inch square. The ratio of cement and gravel is as 1 to 4. The methods of reinforcing and tamping concrete posts vary almost as much as those of fastening the fence wire to the posts. The machines are of various capacities and design—from the one post hand mold to the 'post per minute' power machine, with continuous mixer attachment. The average total cubic contents of the 7-foot post is 0.825 cubic feet, of the 8-foot post, 0.95 cubic feet. The weights vary from 65 pounds to 95 pounds, according to methods of manufacture and reinforcement used. Concrete posts retail for from 25 cents to 35 cents per post. End and gate posts are of about three times the volume and cost of intermediate posts. In section concrete posts vary from square or rectangular to triangular, half round and circular. Reinforcements are of wire, wood, strap steel, steel and wire truss, wood and wire truss, chain scrap strips and expanded metal. Fence wire fastenings are also of various forms, from the wire loop around the post to the patent staple encasement.

"All the posts observed taper from a smaller top to a larger base. Some have very wide concrete bases."

## FENCE POSTS.*

Concrete fence posts are either constructed in advance and put in place after they have set sufficiently hard as not to be injured by handling or are moulded in place. The posts in Dellwood Park described on page 197 are examples of the former type of construction, while the posts along the Harlem division of the New York Central and Hudson River Railroad, described on page 197, exemplify the latter. Fig. 150 is a suggested design of forms for fence posts when constructed in advance. As will be seen from the sketch, the posts are made with every alternate post lying the opposite way, thus making one intermediate board serve as a side to two posts.

As stated in the excerpt from the committee report given above, there are a variety of means for fastening fence wire to the post. Two methods are illustrated in Fig. 150, one being by embedding in the concrete a piece of No. 12 copper wire, 12 inches long bent in half with the halves twisted together and with the ends projecting from the post about two inches, to which the fence wires are connected, while the other consists in leaving a hole in the concrete through which the fence wire can be strung. This is done by placing well greased round rods or wood dowels in the post forms at the desired spots and leaving them in the concrete about a day, when they can be readily removed. A very simple and satisfactory method is to use large galvanized

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*Methods of making concrete posts are treated in "Concrete About the Home and on the Farm," published by The Atlas Portland Cement Company.

staples having their ends bent so as to hook into the concrete, while still another way is by bolting a galvanized iron strip to the post as was done in the case of the Dellwood Park posts described on page 197.

STANDARD CONCRETE FENCE POSTS, N. Y. C. & H. R. R. R.—Fig. 152 gives the details of design and construction of these posts while the photograph in Fig. 151 shows the forms in place preparatory to pouring the concrete.

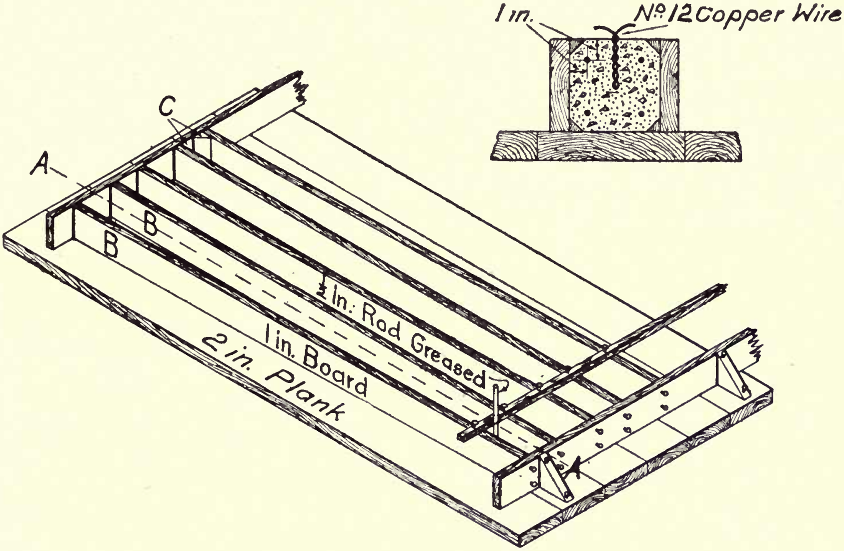

FIG. 150.—FORMS FOR FENCE POSTS.

The main posts are made of 1 :3 :6 concrete poured very wet, while the footings for the intermediate iron posts are mixed in the proportions of 1 :4 :7½. The forms are taken down 12 hours after being filled and the green concrete is floated with water and rubbed with a 1 :2 cement and sand brick until the desired finish is attained.

In making these posts all the material is unloaded from a work train in advance of the job and a gang of six men do the work, two men excavating holes, two setting up the forms and two mixing and placing the concrete.

DELLWOOD PARK FENCE POSTS, C. & J. RY.—The posts shown in detail by the drawings in Fig. 154 and by the photograph in Fig. 153 were built by the Chicago and Joilet Electric Railway to support the galvanized iron woven wire fencing which encloses its amusement resort at Dellwood

FIG. 151.—FORMS IN PLACE, FENCE POSTS, N. Y. C. & H. R. R. R.

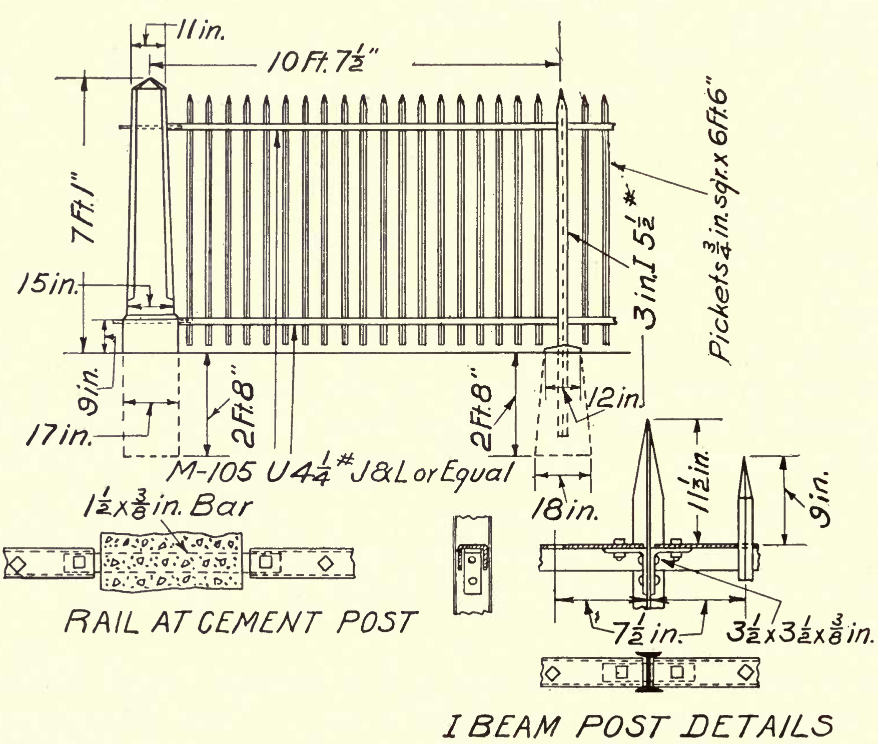

FIG. 152.—CONCRETE FENCE POSTS, N. Y. C. & H. R. R. R.

Park. They are spaced 10 feet on centers and are 7 and 9 feet long, 4 inches by 6 inches at the bottom and 4 inches by 4 inches at the top and are reinforced by four ¼-inch corrugated bars, one at each corner. The wire fencing is attached to them by a ⅛ by 1 inch galvanized iron strip bolted to each post through holes cast in the latter as it was made. Each post was cast in a separate wooden mould laid flat on a 2 by 8 inch plank, as shown in Fig. 154, and was allowed to season at least a month before being set in place. They were made of 1 part Atlas Portland Cement to 2 parts stone screenings, ranging from dust to ¼-inch pieces.

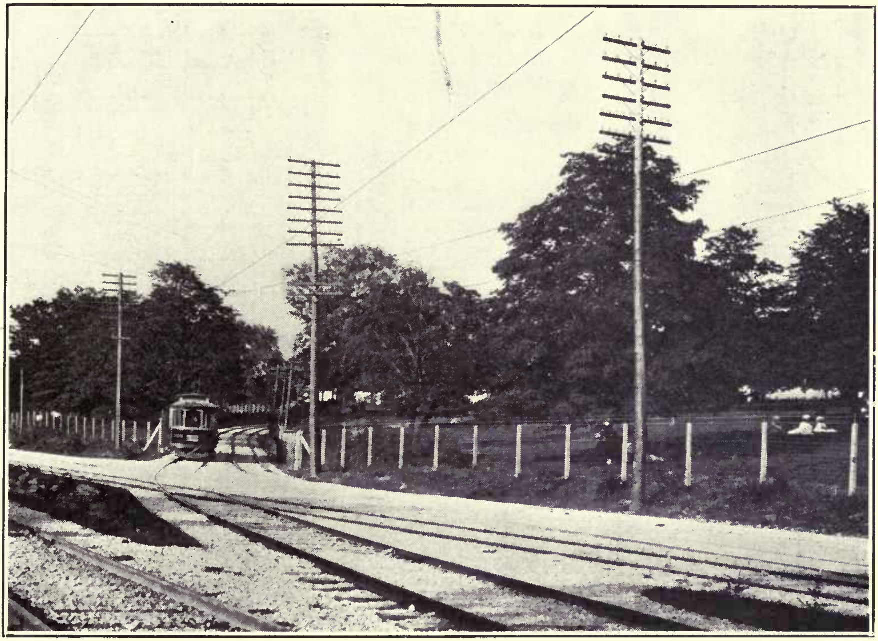

FIG. 153.—CONCRETE FENCE POSTS, DELLWOOD PARK.

The posts in the corners and at angles in the fence are made of larger sections than the others and are reinforced with a 2½ by 2½ by ¼ inch angle. A concrete brace is extended from each of these posts to the base of the adjoining regular posts which are set in concrete, all other posts being simply set in the ground and tamped around. Two men were engaged in making these posts and could produce about forty a day at an average cost of 65 cents for the 9-foot posts. The price is rather high owing to the expensive fittings, the cost of materials and methods of fastening the wire to post.

CONCRETE FENCE POSTS, B. & O. R. R.*—The Baltimore and Ohio Railroad concrete fence posts are of uniform size, 5 by 5 inches, and are reinforced with four ¼-inch rods. Wires are built into the back of the post projecting four inches, to which the woven wire fence is attached by means of pliers. These posts placed cost 44½ cents each.

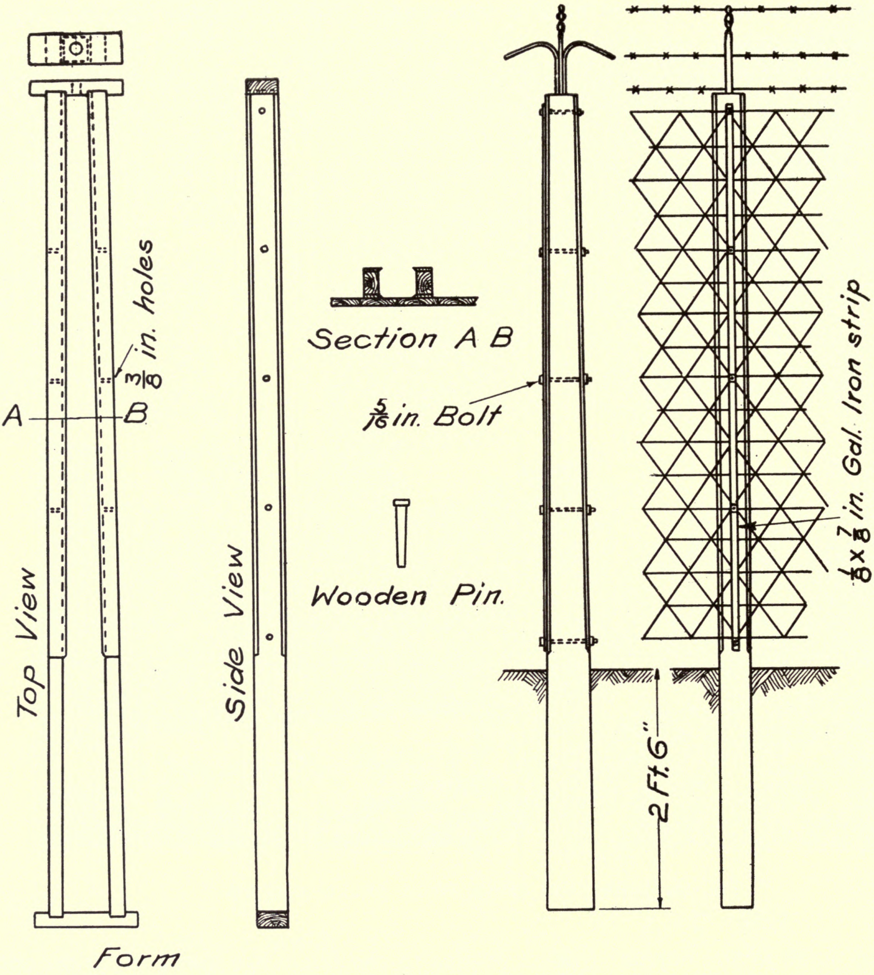

FIG. 154.—DETAILS OF CONSTRUCTION, DELLWOOD PARK FENCE POSTS.

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*Proceedings Association of Railway Superintendents of Bridges and Buildings, October, 1906, p. 69.

## MILE POSTS.

Fig. 155 shows a type of concrete mile posts in use on the lines of the Chicago and Eastern Illinois Railroad that is meeting with success from a standpoint both of maintenance and permanence. As will be seen from the drawing the post is 8 by 8 inches square and 8 feet long, with 4 feet 6 inches above ground.

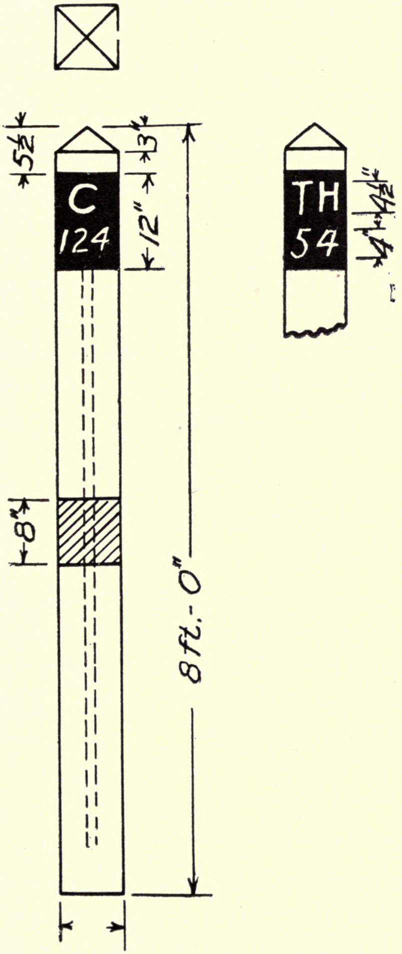


FIG. 155.—MILE POSTS, C. & E. I. R. R.

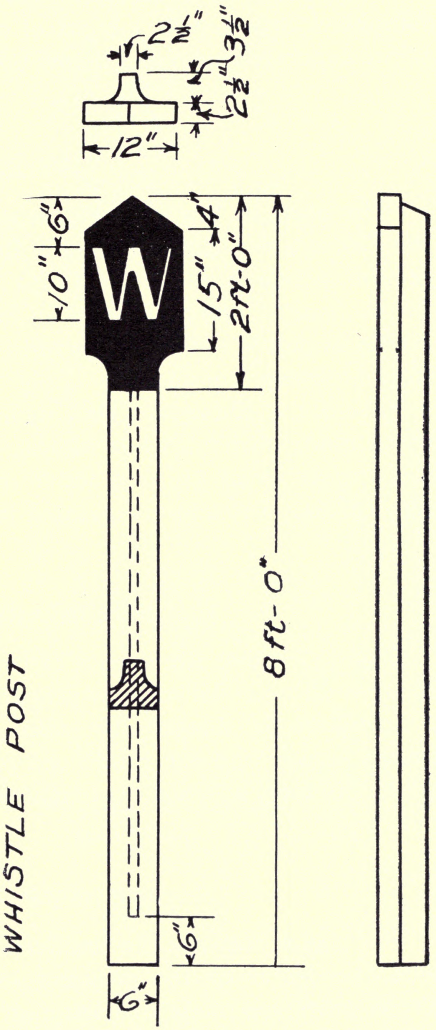


FIG. 156.—WHISTLE POSTS, C. & E. I. R. R.

The post, which weighs 498 pounds, is composed of concrete mixed in the proportions of 1 part cement to 1 part sand to 2 parts crushed stone and is reinforced for the entire length with one 1-inch corrugated bar placed in the center.

In moulding the posts the form is laid with the letters on the bottom, and the sides are plastered with mortar to a thickness of ½ inch before the ordinary concrete is put in.

The black face concrete of the lettered panel is colored with ¼ pound of lampblack mixed with 1 quart of cement in water, and is separated from the white concrete above and below by two recesses across the face of the post.

## WHISTLE POSTS.

The posts in Fig. 156 represents a typical concrete whistle post in use on the Chicago and Eastern Illinois Railroad. Aside from the shape of the cross section, which is in the form of a T, the essential details of construction are the same as for the mile-posts on the same road described above. These posts are set at points 10 feet to the right of the track center and 2,000 feet each way from highway crossings.

The Lake Shore and Michigan Southern Railway use concrete whistle posts, made in moulds like blocks, which are 3½ inches thick, 12 inches wide and are set about 5½ feet above the ground. The letters and signs are cast right in the post and are painted black.

## CLEARANCE POSTS.

Fig. 157 shows the design of concrete clearance posts on the Chicago and Eastern Illinois Railroad, which are set between main track and siding at a point where the distance between centers is 10 feet. These posts are 6 by 6 inches square and are reinforced for the entire length with either a ¾-inch scrap gas pipe, a ½-inch corrugated bar or four No. 9 wires.

## PROPERTY LINE POSTS.

Fig. 158 represents the standard concrete property line posts which are set with the center on the property line and with the letters facing the track. These posts are made in triangular section and are reinforced for the entire length with a ¾-inch scrap gas pipe or a ½-inch corrugated bar or four No. 9 wires.

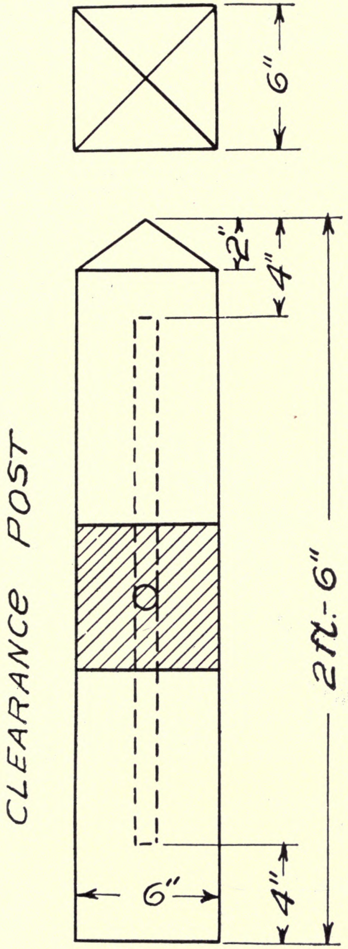


FIG. 157.—CLEARANCE POSTS,
C. & E. I. R. R.

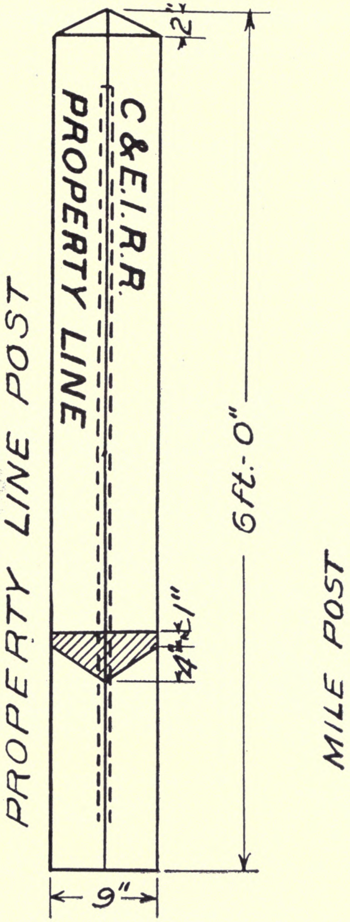


FIG. 158.—PROPERTY LINE POSTS,
C. & E. I. R. R.

## FENCES.

In places where a substantial fence is required ultimate economy, strength, durability and a pleasing appearance can be attained by the use of reinforced concrete. Two types of concrete fences have been tried with success, viz.: solid reinforced concrete and cement plaster on metal lath.

The solid type of fence generally consists of a vertical slab of reinforced concrete about 3 inches thick with a rounded moulding like a hand rail on the upper horizontal edge.

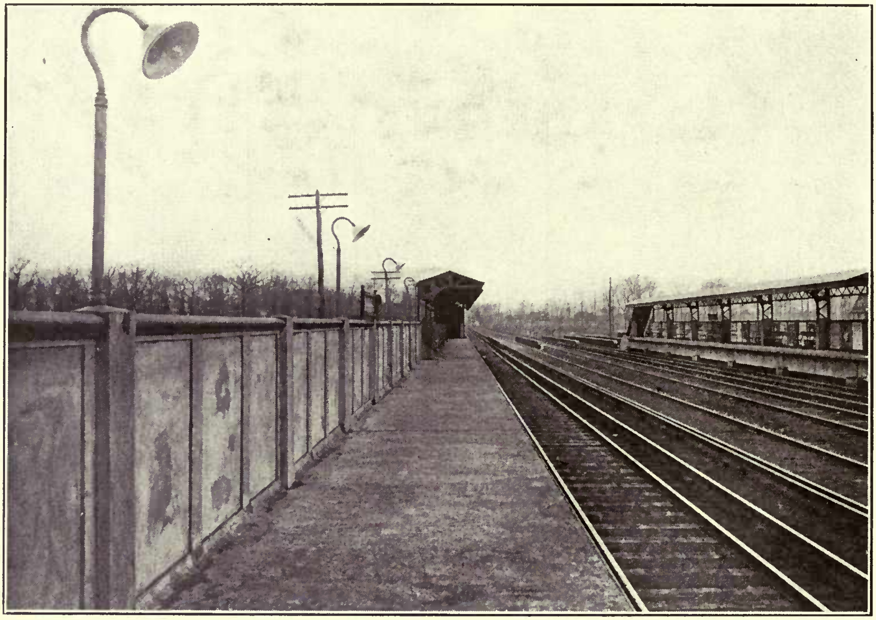


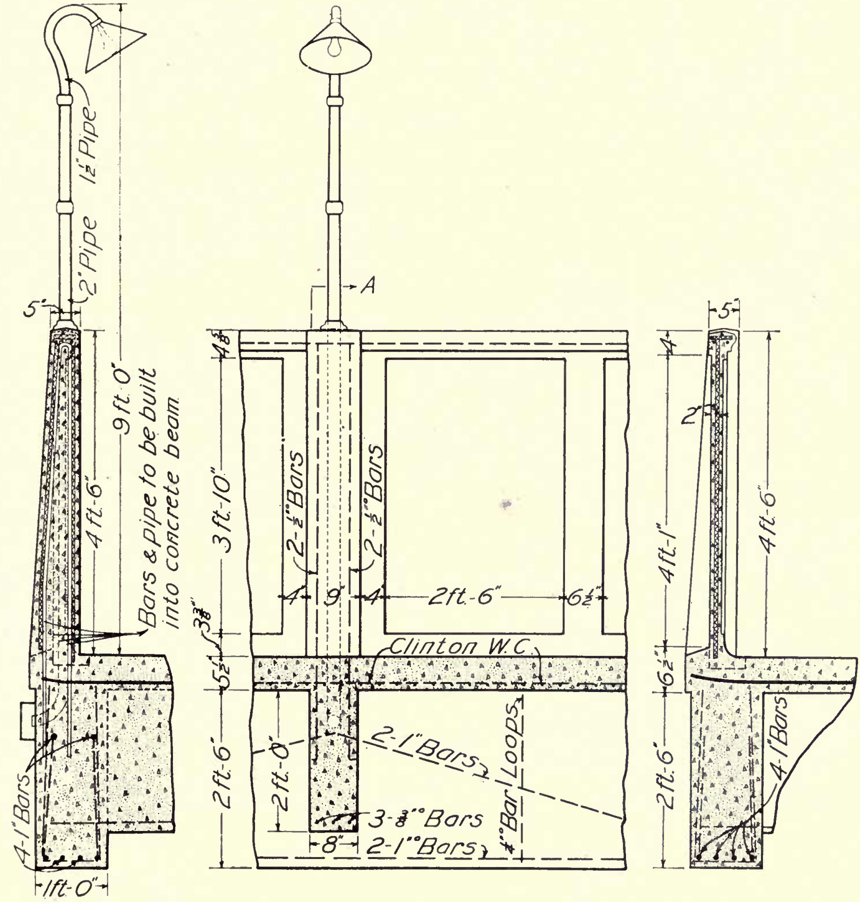
FIG. 159.—FENCE AT AVENUE J, B. R. T. CO.

## PLATFORM FENCES.

An example of the plaster type of fence is described below:

PLATFORM FENCES, BROOKLYN RAPID TRANSIT CO.—These fences, which form guard railings on the outside and ends of the platforms described on page 106, Chapter VII., are 240 feet long, 4 feet 6 inches high, and 2 inches thick and are surmounted by a railing 4⅝ inches high and 5 inches wide. The drawings in Fig. 160 show the essential details of design and construction while the photograph in Fig. 159 shows the fence at Avenue J Station.

The reinforcement consists of metal lath of No. 28 gauge and is carried in continuous sheets through the entire length of the fence, except at expansion joints. The posts, which are 10 feet on centers, are reinforced with four ½-inch rods set deep in the concrete platform and the railing has two ⅜-inch rods running longitudinally with a strip of lath laid horizontally. The posts are formed by two short pieces of lath put in the shape of channels and placed around the reinforcing rods, one channel being on each side of the reinforced sheet of the panels.



SECTION "A-A" ELEVATION SECTION B-B

FIG. 160.—DETAILS OF CONSTRUCTION, PLATFORM FENCE, B. R. T. CO.

In constructing the fences the lath was held in place by 1-inch angle studding supported at the top by a 2 x 4 inch horizontal, braced to the platform. The scratch coat consisted of dry mixed 1:2 Atlas Portland Cement with an addition of 6 per cent. of hydrated lime and the finish coat was made of 1 part Atlas Portland Cement and 2 parts sand.

The lath reinforcing was erected by the Truss Metal Lath Co., New York, sub-contractors of Thos. G. Carlin, who had the general contract for the work under the supervision of the Brooklyn Rapid Transit Co., Mr. W. S. Menden, Chief Engineer.

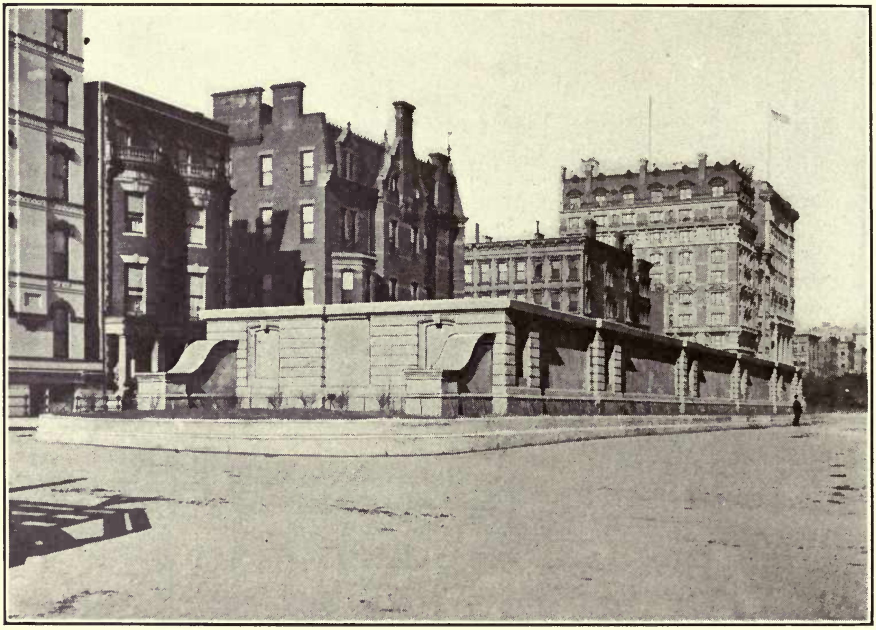
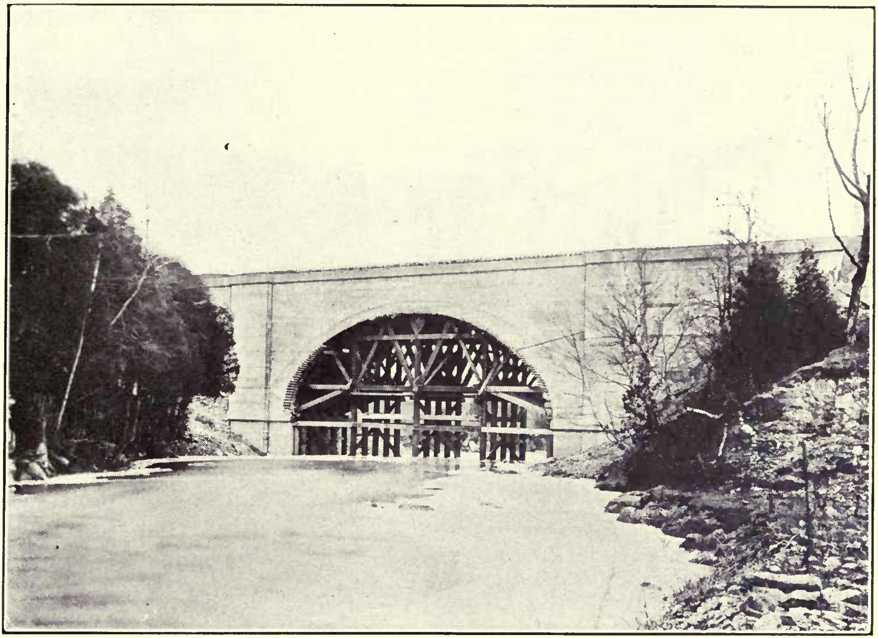
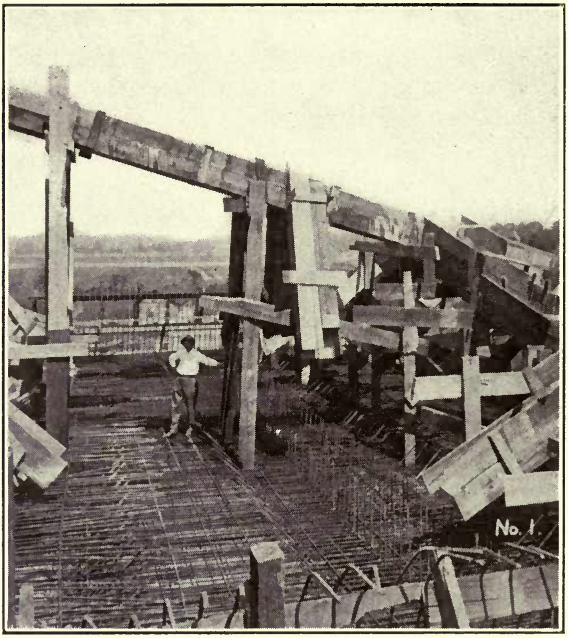


FIG. 161.—MASKED TRUSS, 56TH STREET, NEW YORK, N. Y. C. & H. R. R. R.

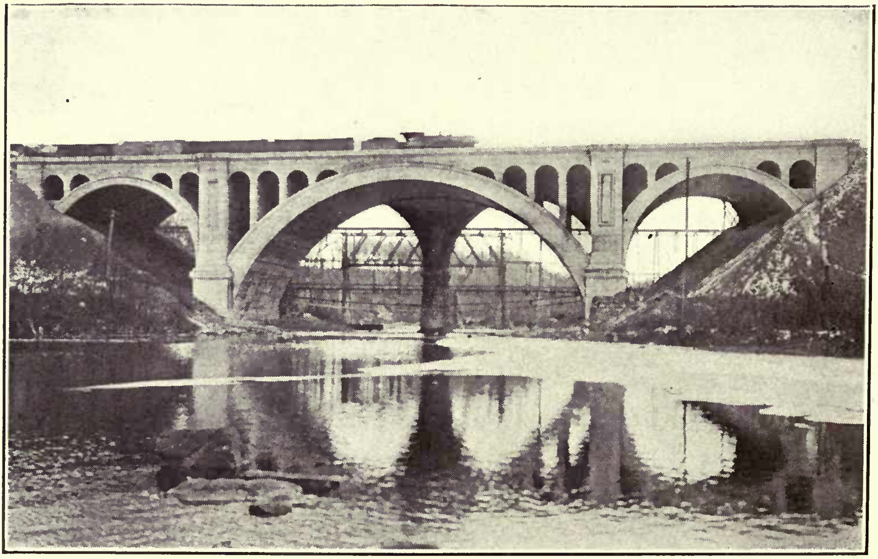


BRIDGE U 44, C., M. & ST. P. RY.

TRIPLE ARCH BRIDGE, ILL. CENTRAL R. R.

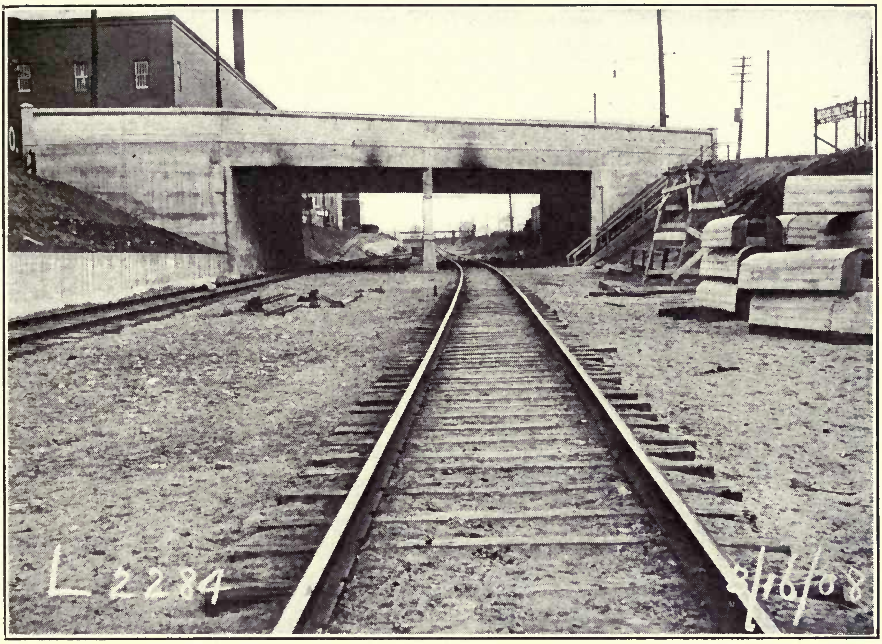


CHUTE FOR DEPOSITING CONCRETE, PAINSVILLE BRIDGE.

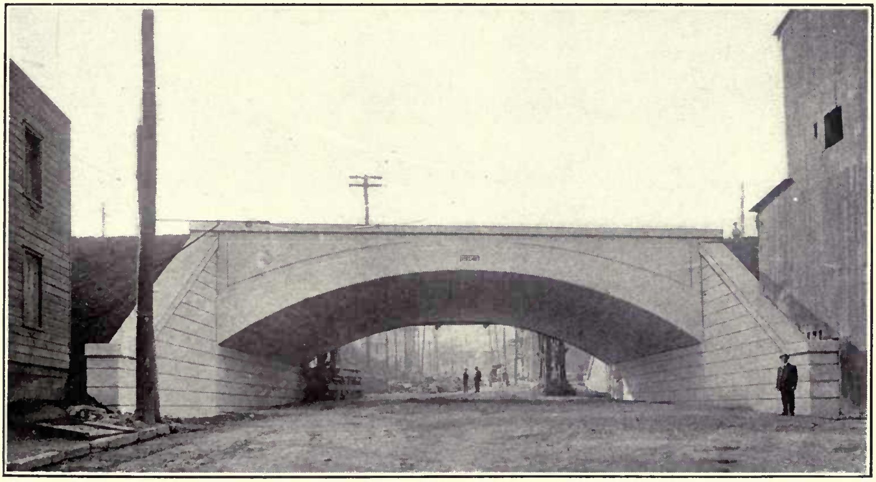


FOUR-TRACK REINFORCED CONCRETE ARCH OVER GRAND RIVER, PAINSVILLE, OHIO, LAKE SHORE & MICHIGAN SOUTHERN RY.

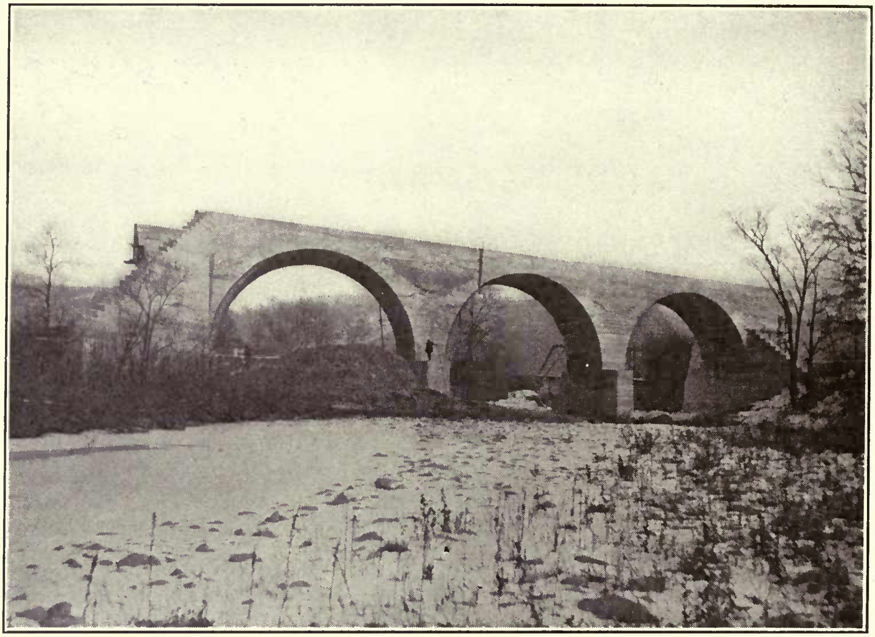
Span of center arch, **160** ft. **0** in. Total length of bridge, **382** ft. **0** in. Rise of center arch, **58** ft. **3** in. Total width of bridge, **65** ft. **0** in. Span of each end arch, **70** ft. **0** in. Cubic yards of concrete, **25,150.**



OVERHEAD HIGHWAY BRIDGE, L. I. R. R.



ARCH BRIDGE, SCHENECTADY, N. Y., N. Y. C. & H. R. R. R.



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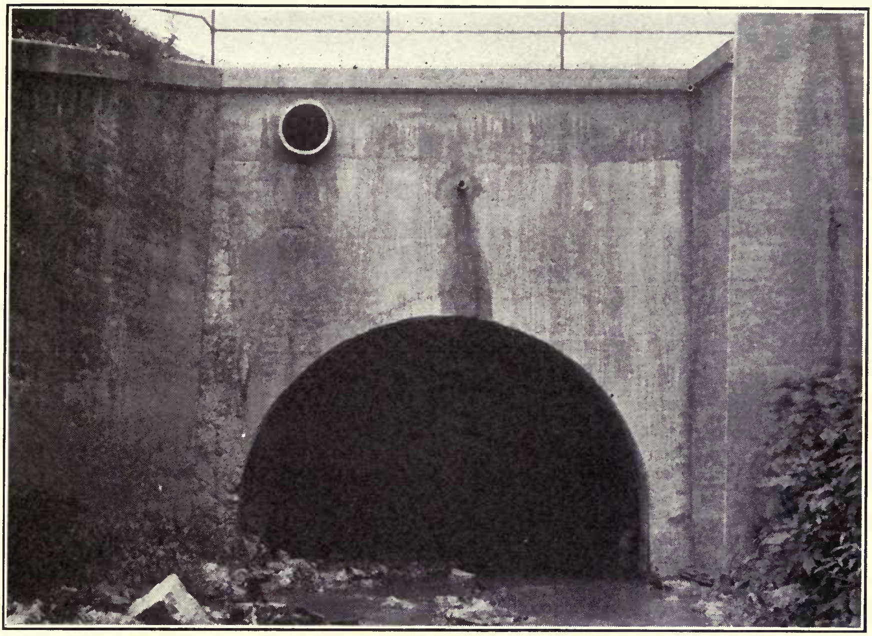
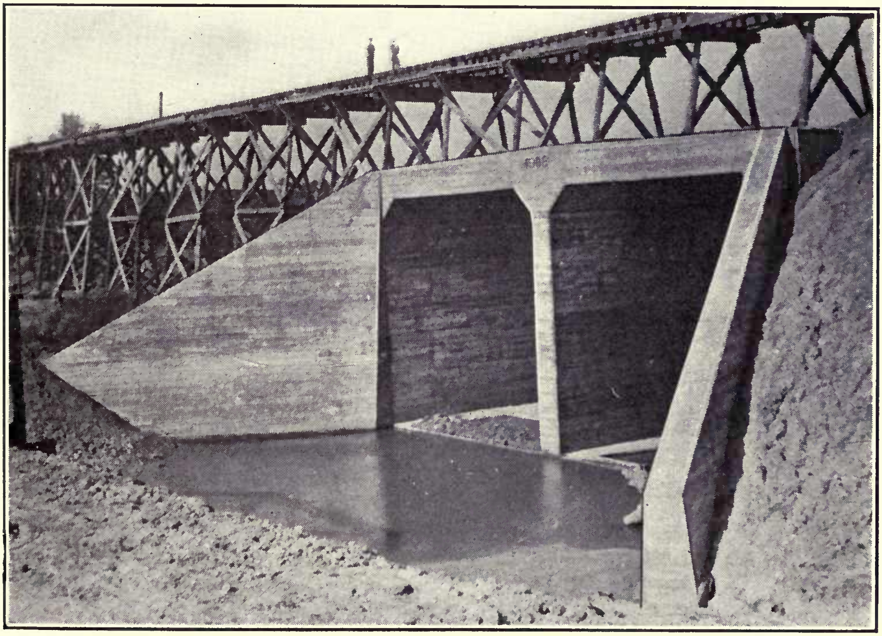
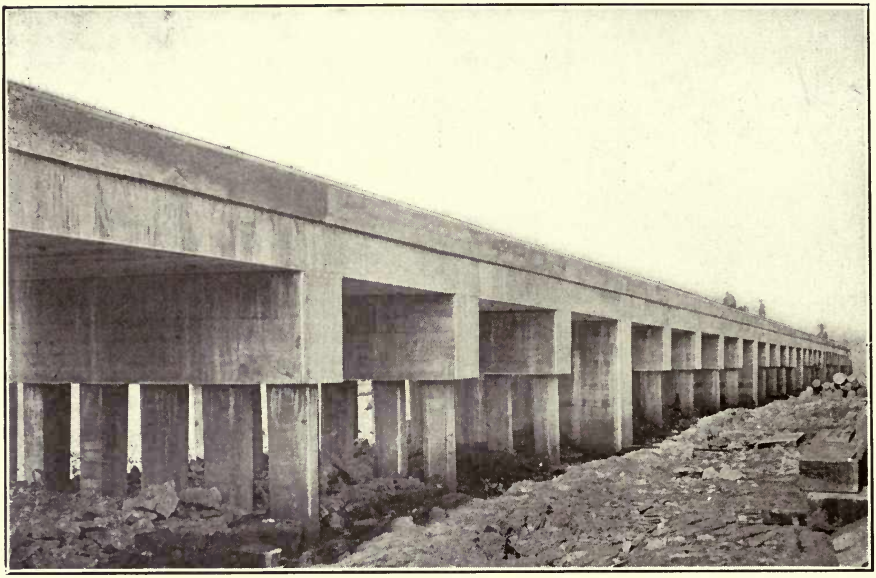


CULVERT UNDER LOUISVILLE & NASHVILLE R. R. FREIGHT DEPOT, KNOXVILLE, TENN.

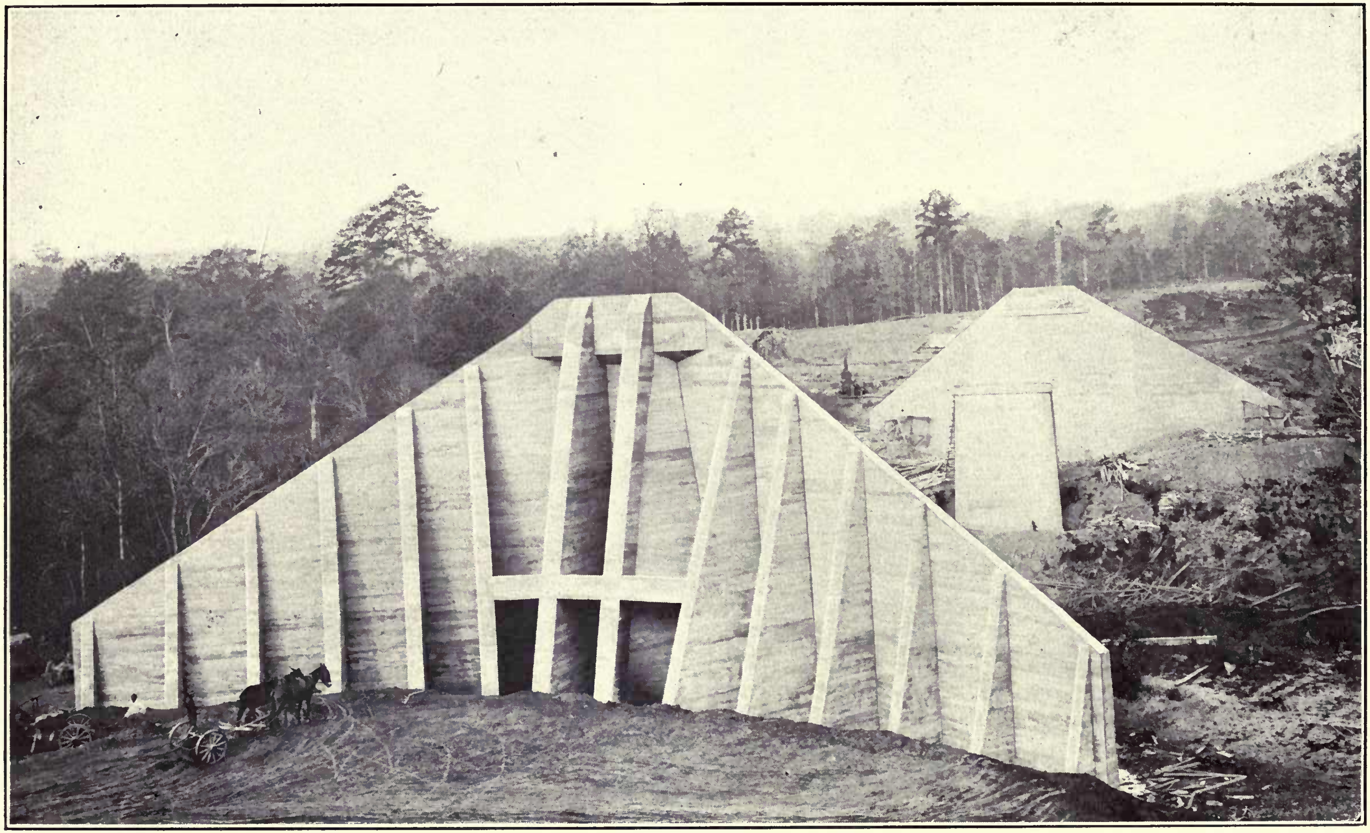


DOUBLE BOX CULVERT, C., B. & Q. R. R.

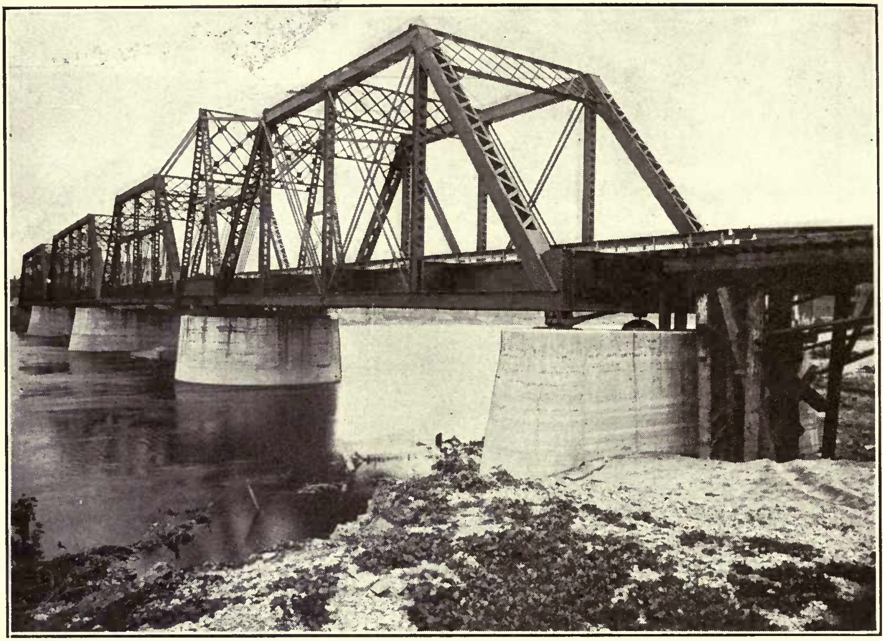


PILE TRESTLE OVER SALT RIVER, C., B. & Q. R. R.

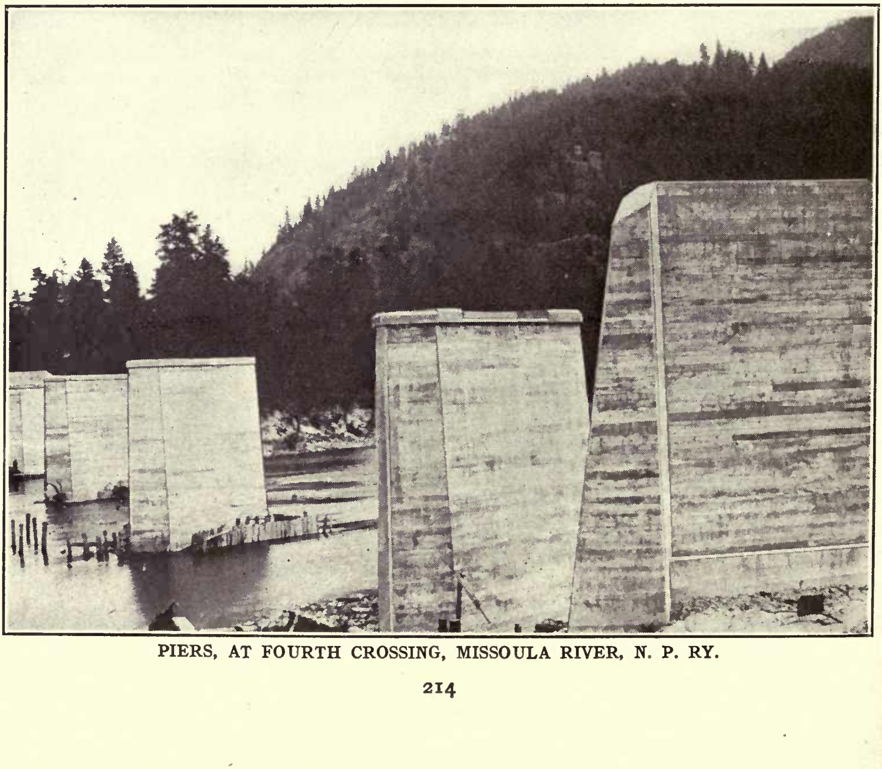
NARROW GAUGE TRESTLE, CATSKILL MOUNTAINS, OTIS R. R. CO.



REINFORCED CONCRETE ABUTMENTS, CAHABA RIVER CROSSING, ATLANTA, BIRMINGHAM AND ATLANTIC R. R.
Height from the base to the top of the parapet, **61** ft. **6** ins.



PIERS, GRAND RIVER BRIDGE, PERE MARQUETTE R.R.



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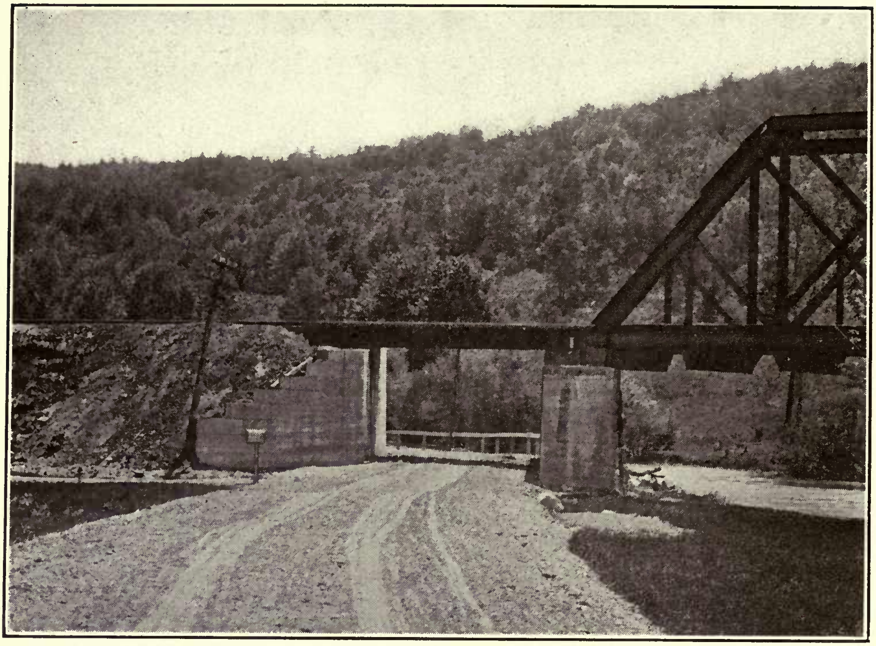
PIERS, SOUTH LEG, DAVENPORT "Y" BRIDGE, C., M. & ST. P. RY.



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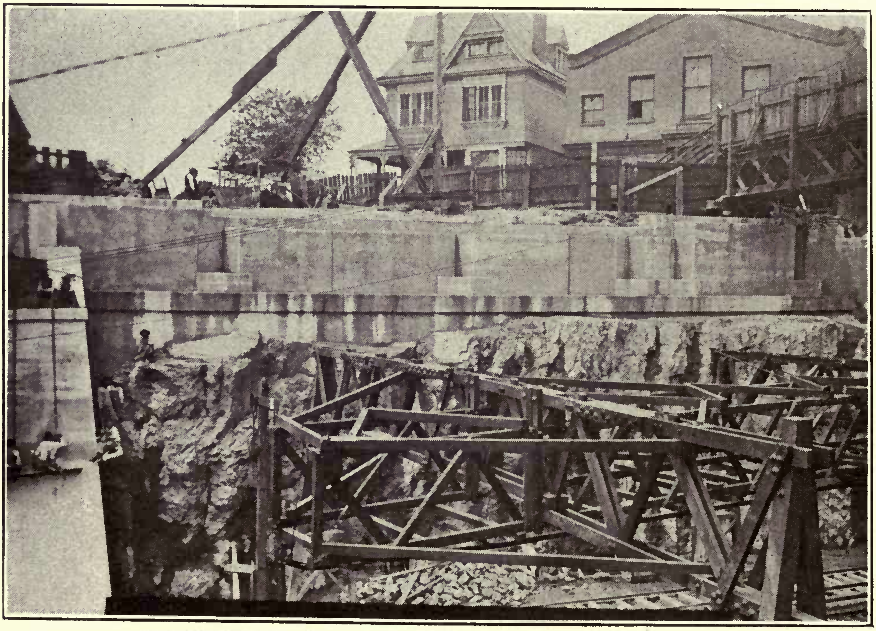

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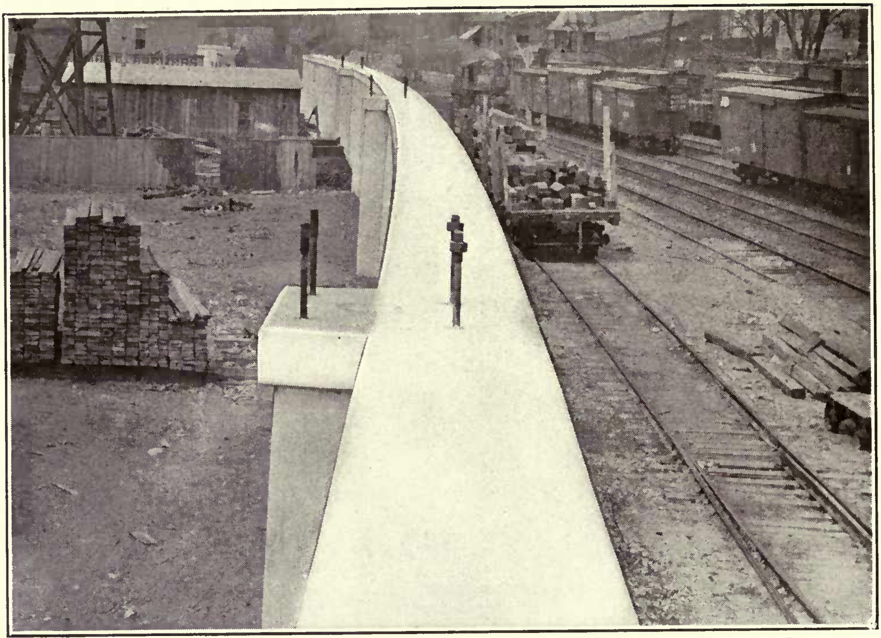
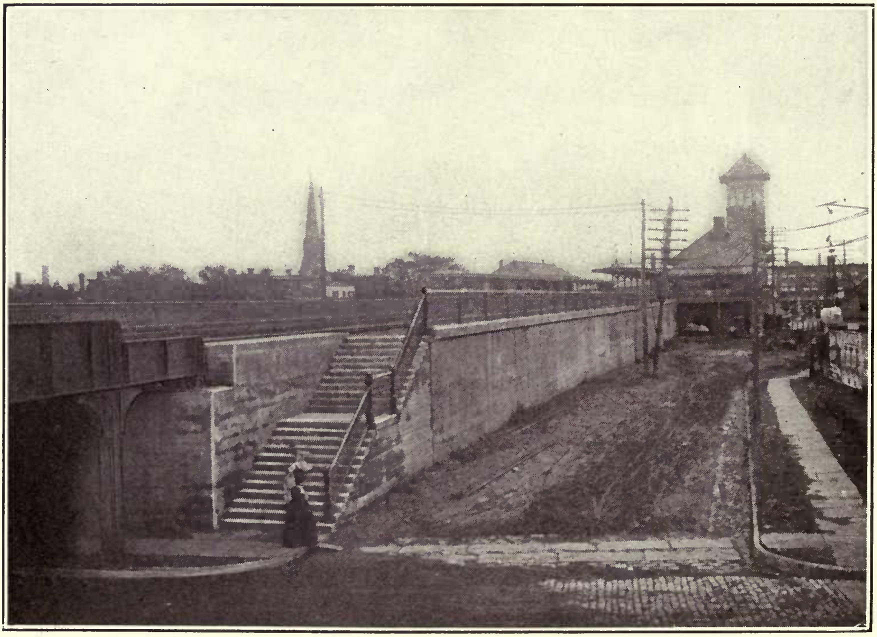
SANTA BARBARA, CAL., STATION, SOUTHERN PACIFIC RY.



YONKERS IMP. RETAINING WALL BEFORE FILLING, N. Y. C. & H. R. R. R.



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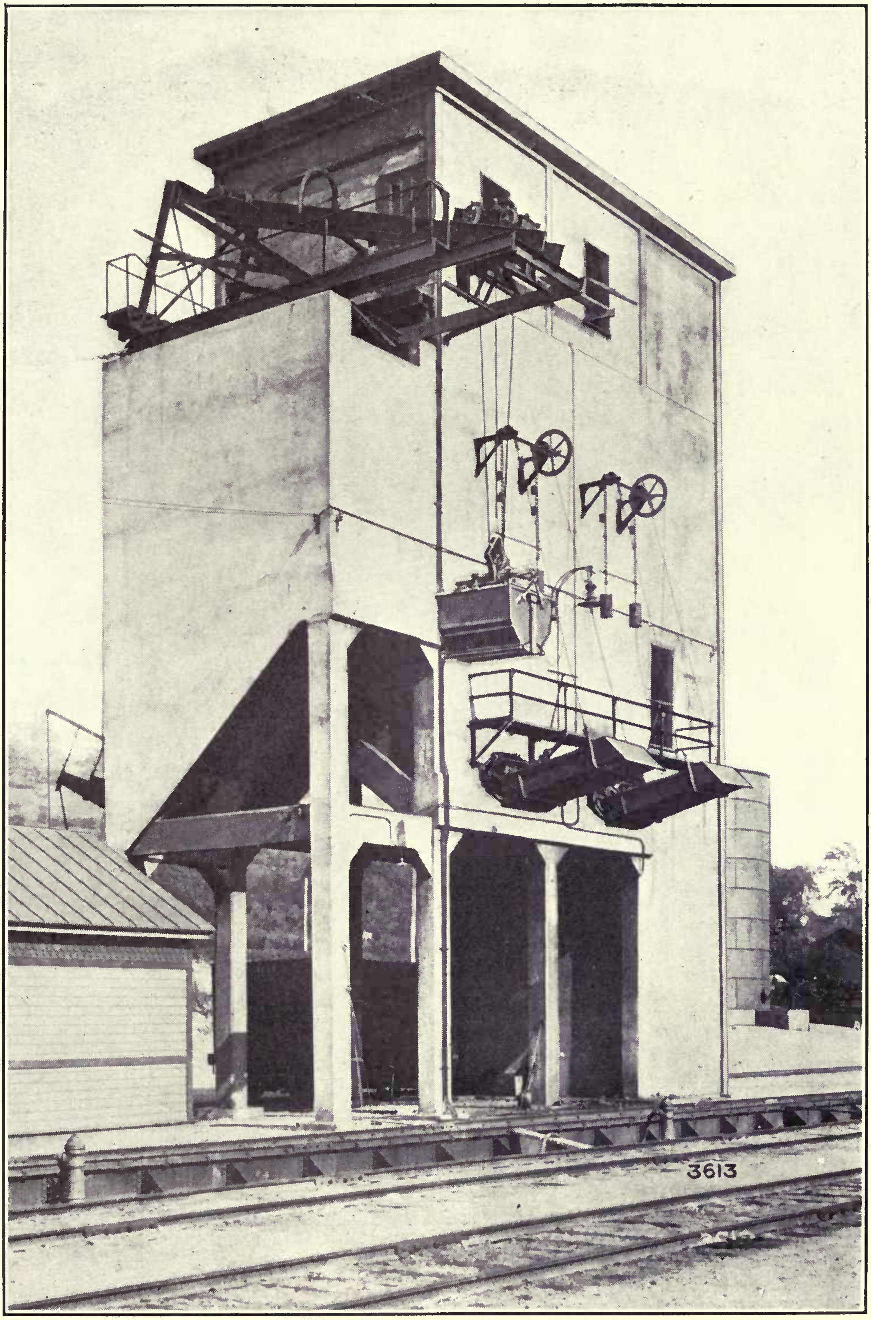

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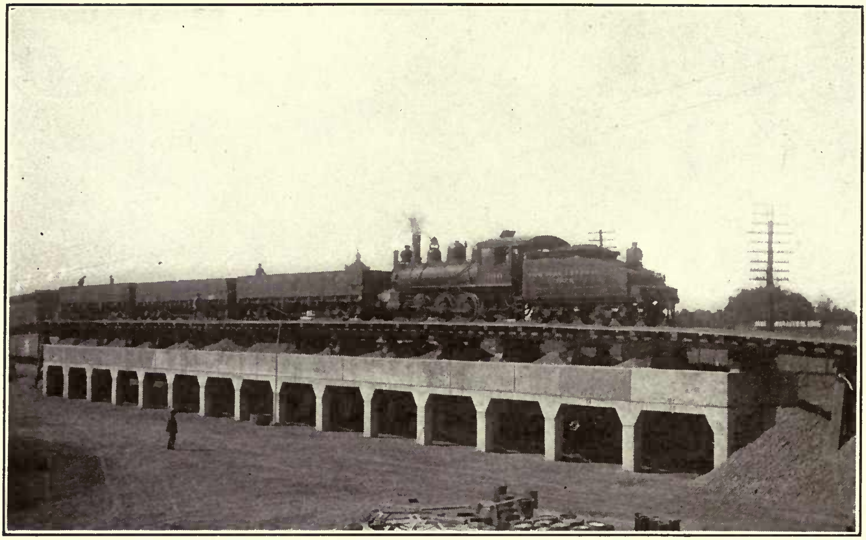
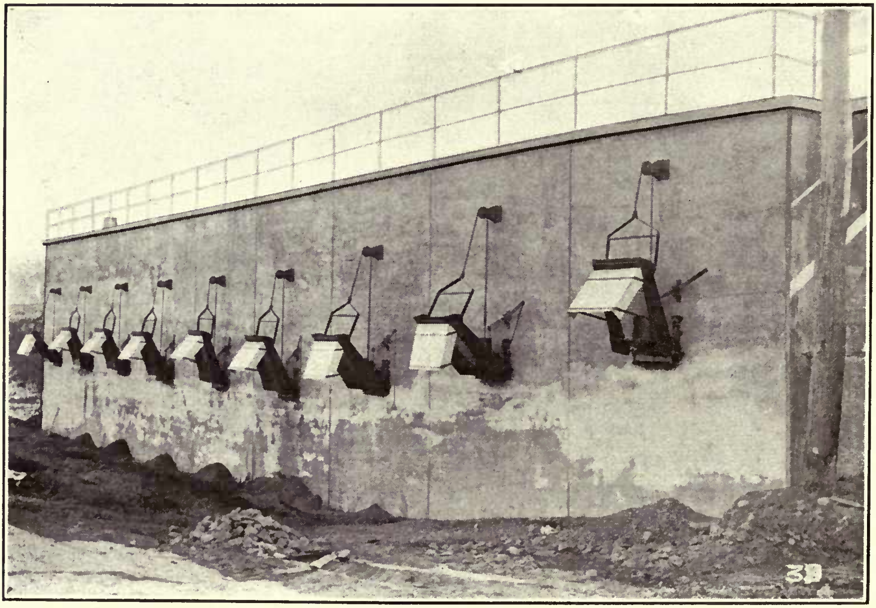


CRUSHED STONE HANDLING TRESTLE, SPRINGFIELD, MASS.



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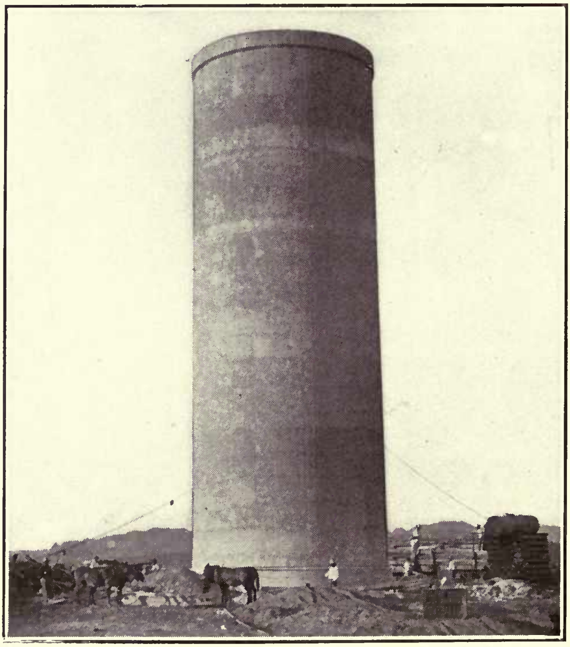

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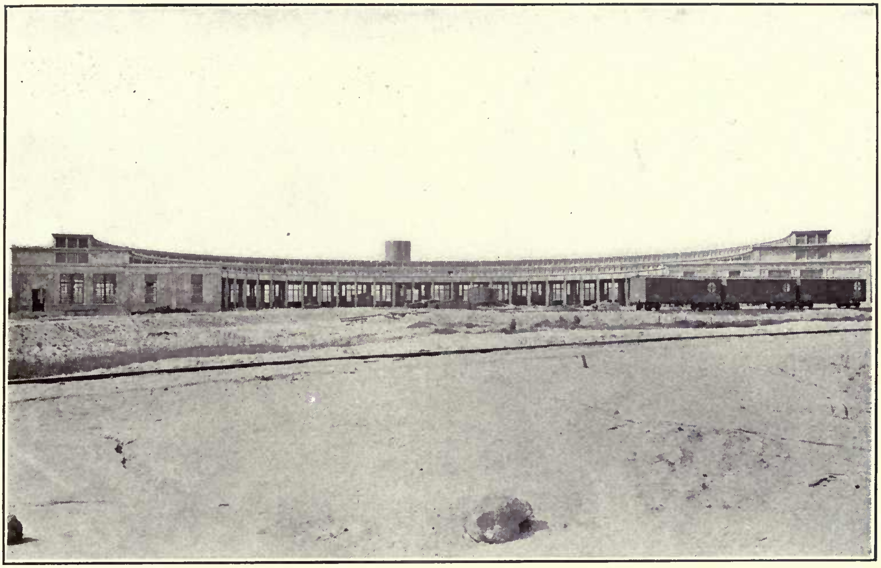

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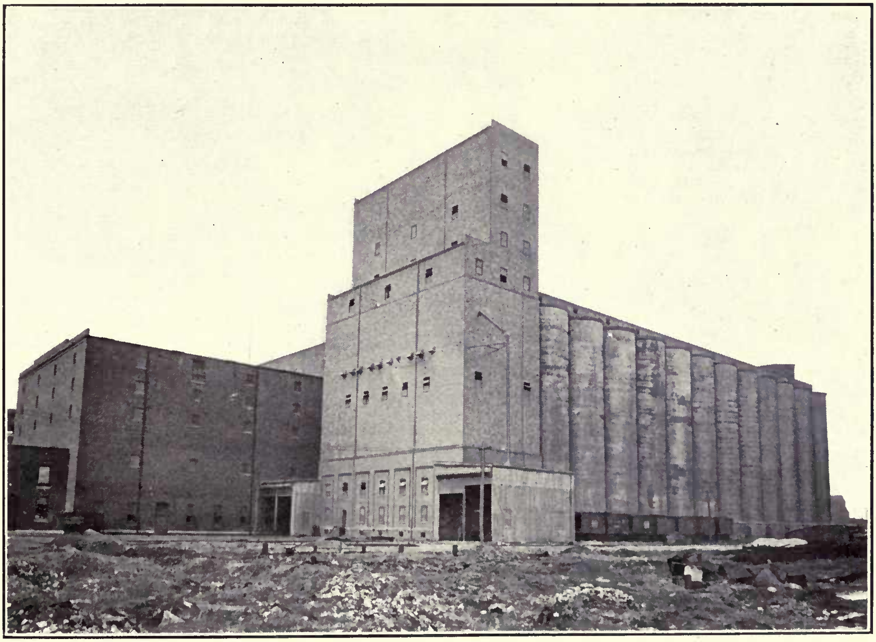

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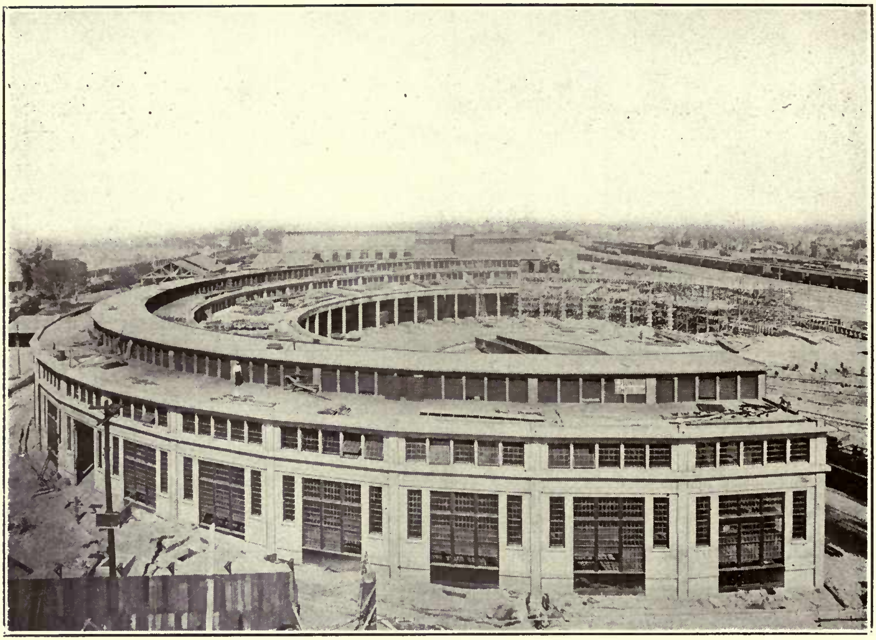

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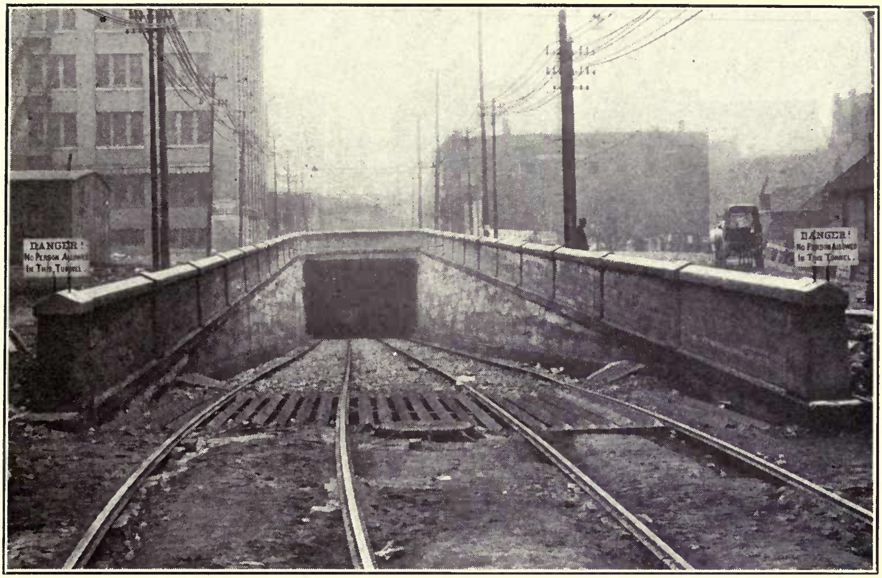
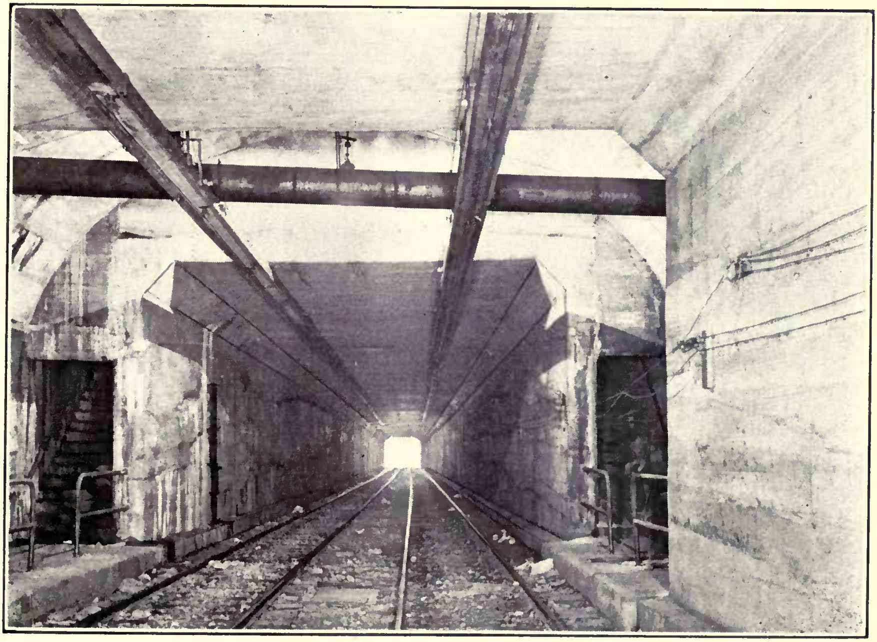
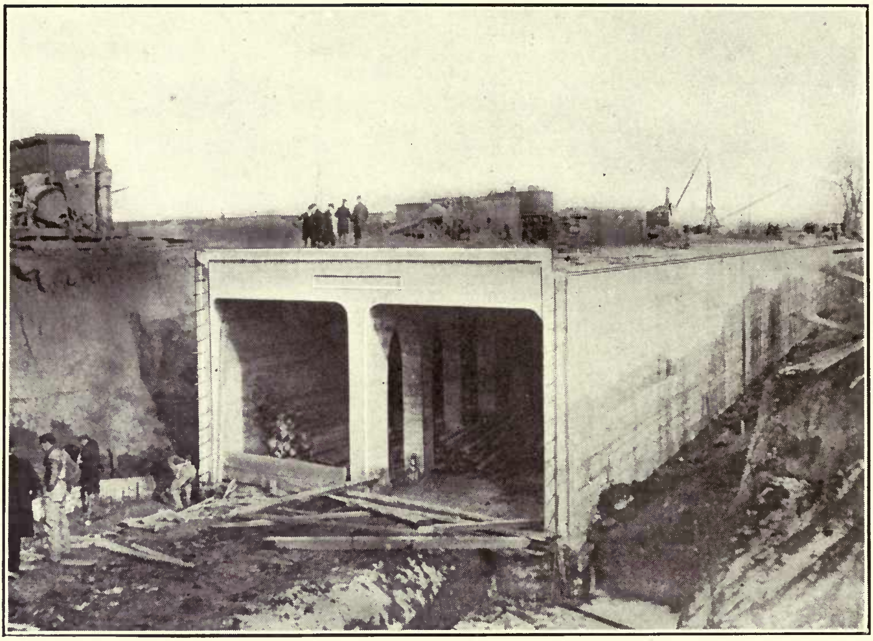


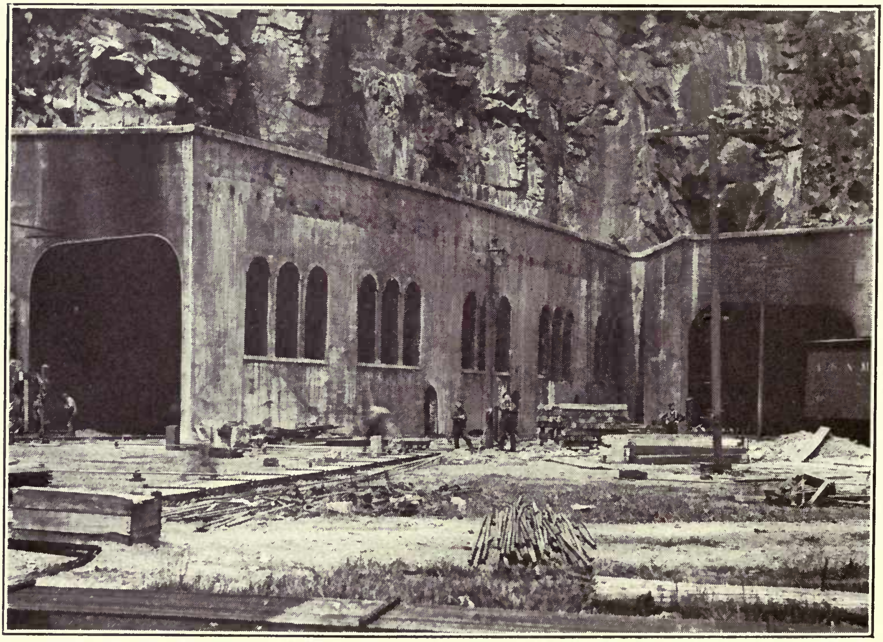
PORTAL 8TH STREET TUNNEL, KANSAS CITY, MO.



INTERIOR 8TH STREET TUNNEL, KANSAS CITY, MO.



GALESBURG SUBWAY, C., B. & Q. R. R.



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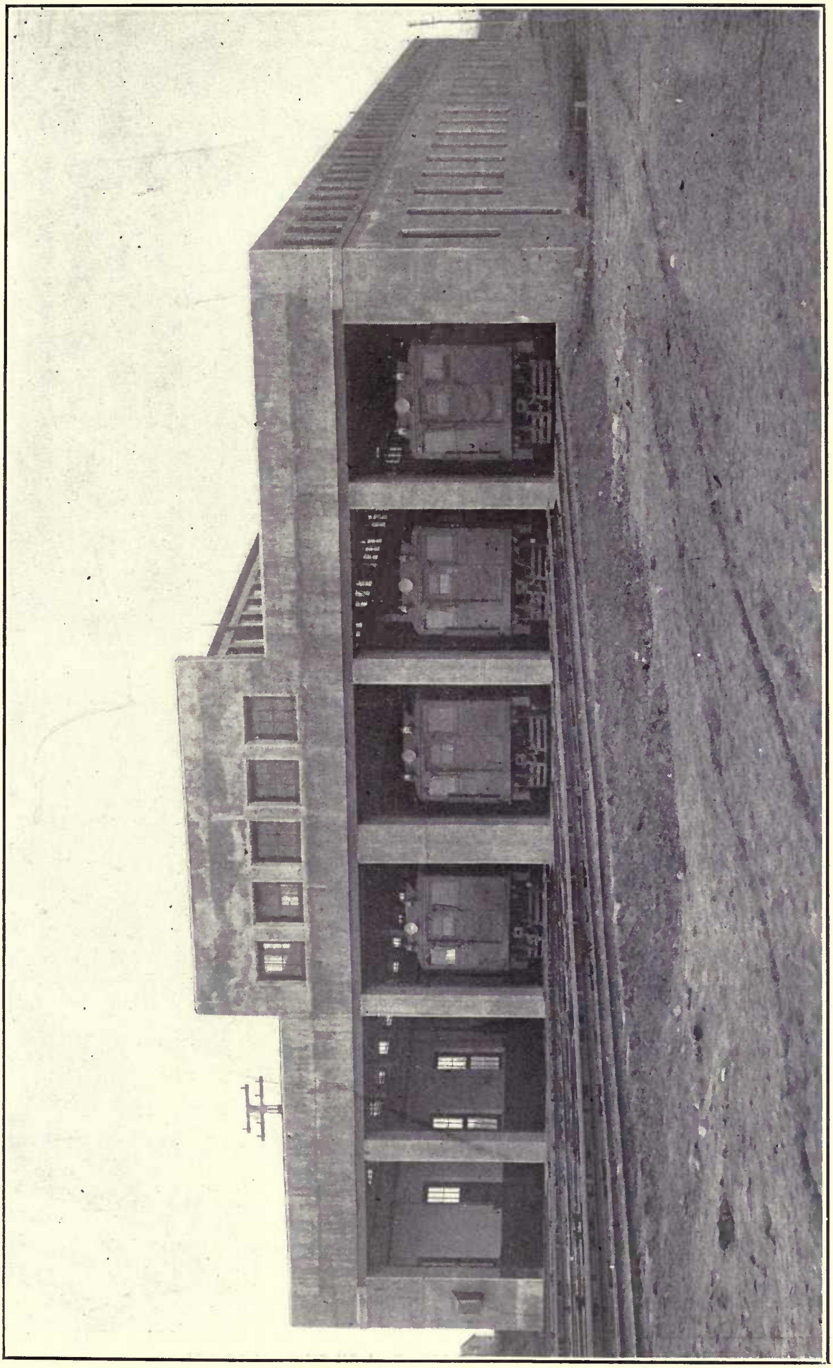

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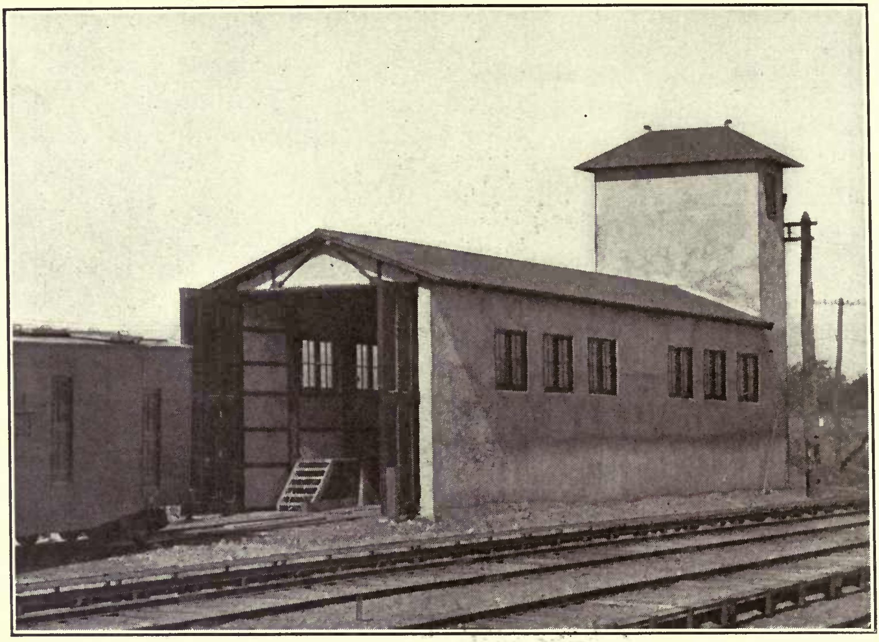

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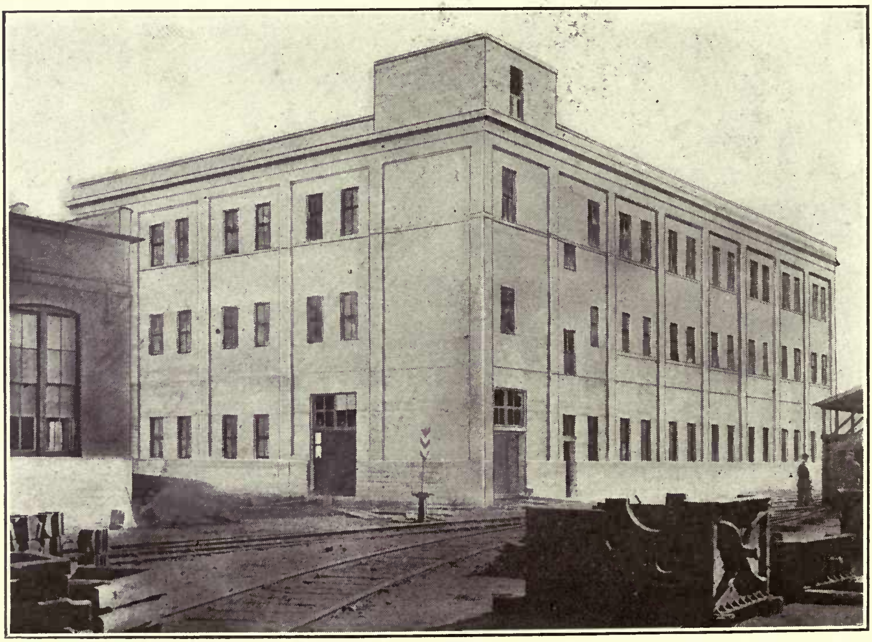

PATTERN STORAGE BUILDING, C., M. & ST. P. RY.

# Reinforced Concrete in Factory Construction

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Published by
The Atlas Portland Cement Company
30 Broad Street, New York, N. Y.

# INTRODUCTION

Reinforced concrete has provided for the manufacturer an entirely new building material. Indestructible, economical and fireproof, it offers under most conditions features of advantage over every other type of construction. The development has naturally been greatest in the larger centers of population, but it is extending rapidly to the remoter districts, and, indeed, wherever new buildings are contemplated.

This widespread interest demands an authoritative treatment, and The Atlas Portland Cement Company has embraced this opportunity to present to the manufacturer, and also to the architect and the engineer who are not concrete specialists, a brief treatise on reinforced concrete for factory construction, with a view of giving a comprehensive idea of the advantages and limitations of the material as adapted to the factory, and a demonstration of its value as illustrated in a variety of buildings in different localities.

The work has been prepared by a consulting engineer, Mr. Sanford E. Thompson, who is well qualified to treat the subject as an expert authority. The Atlas Portland Cement Company, occupying, as it does, a somewhat unique position among cement manufacturers, with its wide reputation for a thoroughly uniform and satisfactory product, and its immense production—greater in 1907 than that of any other four cement manufacturers in the world—commends the book to its readers with the hope that it may prove a fitting sequel to the former publications of the company—"Concrete Construction About the Home and On the Farm" and "Concrete Country Residences."

THE ATLAS PORTLAND CEMENT COMPANY.

New York, November, 1907.

# PREFACE.

This book may not be regarded as a complete treatise on concrete factory construction, but it has been the aim to present details of this type of construction and a careful description of typical examples of concrete buildings selected from various sections of the country and erected by representative builders. Suggestions are thus offered to the factory owner who contemplates building in reinforced concrete, while at the same time the practical details may prove of value to architects, engineers and builders.

The first chapter presents to the manufacturer a brief review of the qualities of reinforced concrete in comparison with other materials for factory buildings, and this is followed by a chapter giving in considerable detail the general principles of design with information in regard to methods of construction. Chapter III treats of the selection of the aggregates. These general chapters are followed by ten chapters, each describing in full some one shop, factory or warehouse of reinforced concrete, selected with a view of presenting a variety of the more usual types of factory and warehouse construction.

Chapter XIV outlines with illustrations many of the styles and systems of reinforcement in common use in building construction, and briefly refers to examples of concrete block walls, surface finish, concrete pile foundations and tanks, each illustrated by photographs.

All illustrations, excepting a part of those in Chapter XIV, have been prepared especially for this book. The half-tones are made from original photographs, and the designs from drawings furnished by the engineers and contractors, or reproduced in the office of the author from the original plans. In this way a number of details are shown which seldom appear in print. Care has been taken throughout to give complete measurements so that the figures may be used as a guide to new construction work.

The Atlas Portland Cement Company, and the undersigned, desire to letters received by them from the owners of the plants described in the various chapters. A number of photographs of other reinforced concrete factories are also reproduced.

The Atlas Portland Cement Company, and the undersigned, desire to express their appreciation of the courtesies extended by individuals and companies who have kindly furnished plans and data for incorporation into the descriptive chapters.

SANFORD E. THOMPSON,
Newton Highlands, Mass.

November 1, 1907.

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# CHAPTER I.

## FACTORY CONSTRUCTION.

A manufacturer about to build a factory or warehouse must choose between several types of construction. In this selection the governing considerations are cost, safety, durability, and fire protection, while many minor factors enter into each individual case.

In this opening chapter the qualities of the different materials available for factories are discussed with special reference to the reinforced concrete.

Types of buildings for mills, factories, and warehouses may be classified as follows:

(1) Frame construction;
(2) Steel construction;
(3) Mill or slow burning construction;
(4) Reinforced concrete construction.

The first and cheapest type of frame construction may be neglected as unsuitable for permanent installation because of its lack of durability and its fire risk. Board walls, narrow floor joists, board floors and roofs, not only do not protect against fire, but in themselves afford fuel even when the contents of a factory are not combustible.

Steel construction with concrete or tile floors, provided the steel is itself protected from fire by concrete or tile, is efficient and durable, but its first cost alone will usually prohibit its use for the ordinary factory building.

Mill, or "slow burning," construction, as it is sometimes called to distinguish it from fireproof construction, consists of brick, stone, or concrete walls, with wooden columns, timber floor beams and thick plank floors, which although not fireproof, are all so heavy as to retard the progress of a fire and thus afford a measure of protection.

Reinforced concrete, through the reduction in price of first-class Portland cement and the greater perfection of the principles of design, has lately become a formidable competitor to both steel and slow burning construction, a competitor of steel, not only for factories and warehouses, but also for office buildings, hotels and apartment houses, because of its lower cost, shorter time of construction, and freedom from vibration; a competitor of slow burning construction because of its greater fire protection, lower insurance rates, durability, freedom from repairs and renewals, and even in many cases, its lower actual cost.

## COST.

As a fundamental principle in mill and factory construction, the cost must be such that the outlay for interest on construction, running expenses, and maintenance, shall be at the lowest possible minimum consistent with conservative design and the requirements of operation. A wooden building is cheap in first cost, and therefore in interest charges, but is expensive in insurance and repairs, while the risk of the loss in production after a fire, for which no insurance provides, may far counterbalance any theoretical saving.

As a general proposition, reinforced concrete is almost invariably the lowest priced fireproof material suitable for factory construction. The cost is nearly always lower than that for brick and tile, and with lumber at a high price, it is frequently even lower than brick and timber, with the added advantage of durability and fire protection.

In comparing the cost of different building materials, one must bear in mind that the concrete portion of the building is only a part of the total cost. Since the cost of the finish and trim may equal or exceed that of the bare structure, even if the concrete itself cost, say, 10 per cent. more than brick and timber, the cost of the building complete may not be 5 per cent. greater than with timber interior. The lower insurance rates will partly offset this even if there is no other economical advantage for the fireproof structure.

The exact cost of a building in any case is governed by local conditions. In reinforced concrete, the design, the loading for which it must be adapted the price of cement, the cost of obtaining suitable sand and broken stone or gravel, the price of lumber for forms, the wages of the laborers and carpenters, are all factors entering into the estimate. Reinforced concrete is largely laid by common labor, so that high rates for skilled laborers affect it less than many other building materials.

## APPROXIMATE COST PER CUBIC FOOT.

As a general proposition, it may be stated that the cost of reinforced concrete factories finished complete with heating, lighting, plumbing, and elevators, but without machinery may run, under actual conditions, from 8 cents per cubic foot of total volume measured from footings to roof, to 12 cents per cubic foot. The former price may apply where the building is erected simply for factory purposes with uniform floor loading, symmetrical design—permitting the forms to be used over and over again—and with materials at moderate prices. Several of the buildings of simple design described in the chapters which follow come in this class. The higher price will usually cover such a manufacturing building as the Ketterlinus, described in Chapter V, located in a restricted district, and where the appearance both of the exterior and interior must be pleasing. This does not include in either case interior plastering or partitions.

## SAFETY OF REINFORCED CONCRETE CONSTRUCTION.

In any type of building there is more or less danger of accident during erection. It may be stated, however, that with ordinary skill in design and construction there is no more liability of failure with reinforced concrete than with other structural materials. Accidents which have occurred can be traced invariably to a disregard of elementary principles of design or construction.

Every little while failures of steel structures occur through neglect of such details as proper riveting, sufficient bracing, or competent design. Even brick buildings are by no means immune from accidents through poor workmanship or ignorance. For example, on a single night in the spring of 1905, the walls of several apartment houses in process of building in different parts of New York city fell down, the cause being undoubtedly the freezing and thawing of the mortar. Yet one does not condemn either steel or brick as a building material. Such failures, whether in steel, brick or concrete, have simply emphasized the fact, and it cannot be too strongly insisted upon, that a thorough knowledge of the theory of design is essential as well as experience and vigilant inspection during erection.

For reinforced concrete buildings it is especially important that the designer be competent, and that the builder be of undoubted experience and with a knowledge of the fundamental principles of this particular type of construction. By this it is not meant that the builder be an expert mathematician, but he should be able to recognize the necessity for placing the steel near the bottom surface of the beams and slabs, of accurately placing all the steel exactly as called for on the plans, uniform proportioning of the concrete, of breaking joints at the proper places, of laying beams and slabs as a monolithic floor system, and of determining the hardness of the concrete before removing forms and shores.

The safety of a well designed reinforced concrete building increases with age, the concrete growing harder and the bond with the steel becoming stronger.

## DURABILITY.

There is scarcely any class of manufacture which is not now being carried on in a reinforced concrete building. It is adaptable to any weight of loading to high speed and heavy machinery, as well as to light machine tools, and to almost any style of design.

Recent scientific experiments, as well as actual experience, are favorable to the use of concrete under repeated and vibrating loads.

The use of concrete in brackets for supporting crane runs, as in the Bullock shop, Chapter VII, is an interesting example of severe application of loading. Several concrete buildings in San Francisco withstood the shock of the earthquake, while those around them of brick and stone and wood were destroyed.

While most materials tend to rust or decay with time, concrete under proper conditions continues to increase in strength for months or even for years.

Concrete expands and contracts with changes of temperature. Its coefficient of expansion, that is, its expansion in a unit length for each degree of increase in temperature, is almost identical with steel, and on this account there is no tendency of the steel to separate from the concrete, and they act together under all conditions. As in building with other materials, provision must be made in long walls or other surfaces for the expansion and contraction due to temperature, by placing occasional expansion joints or by adding extra steel. In factories of ordinary size, no special provision need be made, as the regular steel reinforcement will prevent cracking.

Special precautions are necessary for laying concrete in sea water. A first class cement must be selected, rich proportions used—at least 1:2:4—a coarse sand, and well proportioned aggregate which will produce a dense impervious mass.

## FIRE RESISTANCE.

Reinforced concrete ranks with the best fireproof materials, and it is this quality perhaps more than any other which is responsible for the enormous increase in its use for factories.

Intense heat injures the surface of the concrete, but it is so good a nonconductor that if sufficiently thick, it provides ample protection for the steel reinforcement, and the interior of the mass is unaffected even in unusually severe fires.

For efficient fire protection in slabs, under ordinary conditions the lower surface of the steel rods should be at least ¾ inch above the bottom of the slab. In beams, girders and columns, a thickness of 1½ to 2½ inches of concrete outside of the steel, varying with the size and importance of the member, and the liability to severe treatment, is in general sufficient. In columns, whose size is governed by the loads to be sustained, an excess of sectional area should be provided so that if, say, one inch of the surface is injured by fire, there will still be enough concrete to sustain any loads which may subsequently come upon it.

One of the advantages of concrete construction as a fireproof material is that the design may be adapted to the local conditions. For example, in an isolated machine shop where scarcely any inflammable materials are stored, it is a waste of money to provide a thick mass of concrete simply to resist fire. On the other hand, for a factory or warehouse storing a product capable of producing not merely a hot fire—a hot short fire will not damage seriously—but an intense heat of long duration, special provision may be made by using an excess area of concrete perhaps two or three inches thick.

Actual fires are the best test of a material. One of the most severe on record occurred in the Pacific Coast Borax Refinery described in Chapter IV, and the concrete there, as well as in the Baltimore and San Francisco fires, made an excellent record.

The best fire resistance materials for concrete are first-class Portland cement with quartz sand and broken trap rock. Limestone aggregate will not stand the heat so well as trap, while the particles of gravel are more easily loosened by extreme heat. Neither of these materials, however, if of good quality, need be rejected for building construction unless the demands are especially exacting and the liability to fire great. Cinders make a good aggregate for fire resistance, but the concrete made with them is not strong enough for reinforced concrete construction except in slabs of short span or in partition walls.

The fire resistance of concrete increases with age, as the water held in the pores is taken up chemically and is evaporated.

## INSURANCE.

When reinforced concrete first came to the front for factories and warehouses, the insurance companies hesitated to assume such buildings as first-class risks. However, examination and tests have gradually convinced the most skeptical of their true fire resistance, until now structures of this material are sought after and given the lowest rates of insurance.

Mr. L. H. Kunhardt, Vice-President and Engineer of one of the oldest of the Factory Mutual Insurance Companies, which have for years played a leading part in the development of mill construction, and the science of fire protection engineering and the consequent reduction of fire losses, presents in an Appendix to this chapter (p. 21) very instructive figures comparing the costs of insurance upon several types of factories for various classes of manufacture. Mr. Kunhardt also indicates the means by which concrete may be utilized in reducing even the present low rates of insurance upon buildings protected by efficient fire apparatus.

From the statements there given by so eminent an authority on mill insurance, we may conclude that a well-designed reinforced factory with continuous floors (1) offers security against disastrous fires and total loss of structure; (2) reduces danger to contents by preventing the spread of a fire; (3) prevents damage by water from story to story; (4) makes sprinklers unnecessary in buildings whose contents is not inflammable; (5) reduces danger of panic and loss of life among employees in case of fire.

## STIFFNESS.

A reinforced concrete building really resembles a structure carved out of a single block of solid rock. It is monolithic throughout. The beams and girders are continuous from side to side and from end to end of the building, while even the floor slab itself forms a part of the beams, and the columns are also either coincident with them or else tied to them by their vertical steel rods.

All this accounts for the extraordinary stiffness and solidity of a reinforced concrete structure, and differentiates it from timber construction where positive joints occur over every column; and even from steel construction, in which the deflection is greater.

## FREEDOM FROM VIBRATION.

This solidity and entire lack of joints, and particularly the weight of the material, especially adapts it to both high speed and heavy machinery. The vibrations are deadened and absorbed in a way which is impossible in steel structures.

An interesting example of this fact is furnished in the Ketterlinus building described in Chapter V, where the vibration and jar in the new concrete building are remarkably less than in the adjacent steel and tile structure carrying the same type of machinery.

## VERSATILITY OF DESIGN.

Steel rods are set in the concrete, to provide tensile strength, in such quantity and location as is needed for special loading for which it is designed. Consequently, spans can be constructed of any reasonable length, either long or short, and column spacing may be adapted to the requirements of operation. Because of the weight of the concrete, which must itself be borne by the strength of the member, very long beam and girder spans are relatively more expensive than the more ordinary spans of 15 or 20 feet. Similarly, the cost of floor slabs per square foot increases appreciably with their span. These limitations are economical rather than theoretical, and every design should therefore be studied thoroughly to produce the best results at least cost, and to adapt the structure to the class of manufacture or storage for which it is intended.

The rule applies to reinforced concrete as well as to other structures, that the industrial portion of the plant, the arrangement of the machines, and of the transmission machinery, should be first designed and the structure adapted to give a minimum operating expense.

## LIGHT.

A special feature of reinforced concrete construction is the possibility of building practically the entire wall of glass, so as to afford a maximum amount of light. Concrete is so strong that the columns can be made of small size and the windows carried by shallow beams. The window area may thus cover a very large percentage of the wall surface.

## WATERTIGHTNESS.

In some classes of manufacture where water is freely used, as in paper and pulp mills, it is essential that the floors shall be tight so that water cannot fall into the product on the floor below or on to the belting. In case of fire a watertight floor prevents damage from water to the machinery and materials in the stories below. A concrete floor with granolithic surface is practically impervious to water.

## CLEANLINESS.

Concrete floors may be laid on a slight slope with a drain along the sides of the room so as to carry off all water and permit flushing with the hose. Concrete is vermin proof.

## RAPIDITY OF CONSTRUCTION.

The speed with which a reinforced concrete building can be completed is due in a great measure to the fact that there need be no waiting for materials. Sand and stone are always available; Portland cement is now supplied by large mills with immense storage capacity; and steel rods are kept in stock, so that a building can be commenced as soon as the plans are completed and no delays need be incurred in ordering special shapes and awaiting their shipment from the mills.

In general, under good superintendence the rate of progress of a reinforced concrete factory may be as fast as one-half story or even one story per week.

## ALTERATIONS.

Reinforced concrete is not suitable for a temporary structure. It is too difficult a matter to tear it down. Radical changes in construction are not readily made, but holes may be cut in walls and floors at greater expense than in wood, but without serious difficulty.

## HANGING SHAFTING.

Provision may be made for shafting by placing bolts or sockets, in the beams to connect with pillow blocks for special lines of shafting, or such connections may be made at regular intervals so that timbers or steel frames may be bolted and shafting, or tracks for conveying material, supported at any positions subsequently specified.

## BEDDING MACHINERY.

All ordinary machinery can be directly bolted to the concrete floors by drilling holes into them and setting lag-screws or through-bolts. If a concrete foundation is built for a special machine or engine, it may be bedded directly upon the concrete. To level the machine on a permanent base, it may be leveled an inch or two above the foundation proper and grouted. A dam of sand is built around the machine, and grout, made of Portland cement mortar in proportions one part cement to one or two parts of sand mixed to the consistency of thick cream, is poured into it so as to run under the casting, and then as this mortar hardens it is continually rammed with a rod to prevent shrinkage and form a solid, permanent base.

## AUXILIARY EQUIPMENT.

Not only the factory itself, but many of its accessories are built of concrete:

## FOUNDATIONS.

Foundations for engines, boilers and heavy machines are of course made of concrete, this being customary long before its introduction for building construction. The method of setting and bedding machinery has been referred to in a preceding paragraph.

## POWER DEVELOPMENT.

Dams either of plain gravity section or of reinforced designs, flumes, pen stocks and wheelpits, are all built of this material. Every individual development requires a special design.

## PARTITIONS.

In the factory itself, partitions may be made of reinforced concrete walls four inches thick, or of concrete blocks, as in the Wholesale Merchants' Warehouse at Nashville, Tenn., described in Chapter VIII. For solid partition walls and elevator wells, it is convenient to pour the concrete after the floors are laid, and this may be done according to the plan adopted by the Turner Construction Company in the Bush Model Factory No. 2 (see Chapter IX), by leaving a slot in the floor at the proposed location for the partition.

## ROOF.

Naturally, the roof of a reinforced concrete building is of the same material, designed to carry the weight of roof covering and snow which may come upon it. It is advisable to cover with some form of roofing, as the sun beating down upon the concrete surface will tend to crack it.

If the building is erected with a view to adding one or more stories, it is well to build the roof of wood or light steel construction so that it may be readily taken down or raised.

## TANKS.

The making of durable tanks is one of the problems in many factories. This is being solved in numerous cases by the use of reinforced concrete, designed with sufficient steel to resist the water pressure. In paper and pulp mills the adoption of concrete tanks is especially advisable because of the frequent repairs and renewals required in wood construction. Sulphuric acid and bleach liquor in pulp mills will attack any known substance, even eating into phosphor bronze. Concrete is by no means exempt from this action, but is undoubtedly the best material except copper or bronze, which is of course too expensive to consider.

Special attention should be given to the watertightness of the concrete so that acids cannot work through it, and in a small tank not over 10 or 12 feet high the watertightness can be increased by a coating of rich mortar on the interior, troweled to a hard glassy surface.

Limestone aggregate should not be used in a tank to be filled with acid, and the steel reinforcement should be imbedded at least three inches or more. Sometimes it may be well to provide an excessive thickness of concrete to allow for subsequent wear.

## LETTING THE CONTRACT.

The contract for the construction of a reinforced concrete factory should be let only to responsible builders with practical experience in this class of work. A man who has simply laid concrete foundations is not competent to erect a factory building. This matter of experience cannot be too strongly emphasized, since every one of the failures in reinforced concrete can be traced directly to poor design or to an ignorance and disregard on the part of the builder of the fundamental principles of reinforced concrete construction.

If day labor is employed, as in the case of the Textile Machine Shop, Chapter XI, it must be under the direct superintendence of an engineer skilled in concrete construction.

The plan is frequently followed of requesting estimates from different contractors without specifying the requirements of the design. As a consequence, the man who dares to figure with the smallest factor of safety, and who thus would build the poorest and weakest structure, presents the lowest bid. Such a possibility may be precluded by having at least the general plans and specifications prepared in advance by a competent engineer or architect, so that the estimates may be compared with fairness.

Concrete building construction is frequently performed on the cost-plus-a-fixed-sum or cost-plus-a-percentage-basis. These methods are apt to result in a somewhat higher cost for the structure than competitive bidding, although they offer less temptation to the builder.

Whatever plan is followed, one or more competent inspectors should be employed by the owners independent of the contractor to see that the work is properly performed in all its details.

## GROWTH OF REINFORCED CONCRETE CONSTRUCTION.

One of the first uses of reinforced concrete in building construction was in the house erected by W. E. Ward in 1872 at Port Chester, N. Y. Some twenty years earlier than this, in France, the first combinations of iron imbedded in concrete were made in a small way. However, not until the very end of the last century, since 1895, has concrete been employed commercially in the construction of buildings. Previously to this it had attained a wide use in foundations, and at this time its development was beginning for such structures as dams, sewers and subways.

Two principal reasons may be offered for this comparatively slow growth followed by such marvelous activity. In the first place, Portland cement manufacturers, beginning in Europe about the middle of the 19th century and in the United States about 1880, finally produced a grade of cement which, with the inspection necessary for all structural materials, could be depended upon to give uniform and thoroughly reliable results; furthermore, along with the perfection of the process of manufacture, the price gradually fell from the high cost per barrel in 1880 for imported cement, to a figure for domestic Portland cement of equally good, if not better, quality, at which concrete in plain form could compete with rough stone masonry, and with steel imbedded could compete with other building materials.

In the second place, theoretical studies and practical experiments have now produced rational and positive methods for computing the strength of concrete reinforced with steel so that absolute dependence can be placed upon it.

A conservative estimate places the number of reinforced concrete buildings built in the United States during the year 1906 as not less than two hundred, while at least as many more have gone up in concrete blocks and combinations of concrete with other materials.

Briefly, reinforced concrete such as is used for factory construction consists of Portland cement, sand, and gravel or broken stone, mixed with water to a consistency that will just flow sluggishly, and in which steel rods are imbedded so as to produce an artificial stone with many characteristics of steel.

In the earlier stages of reinforced concrete and even up to the present time, many patents of a more or less fundamental character have been granted. These have taken the line of special forms of reinforcing metal as well as methods of design. The principal styles of reinforcement are illustrated in Chapter XIV. While it is not necessary to encroach on any of these inventions in building, the field is worth careful consideration, from the viewpoint of economy and durability, as to whether or not it may be advisable to make use of them.

# APPENDIX.

## FIRE INSURANCE ON FACTORIES OF REINFORCED CONCRETE.

By L. H. Kunhardt, Vice-President.

Boston Manufacturers Mutual Fire Insurance Co.

In consideration of the question of insurance on reinforced concrete factories, the problem simply resolves itself into a determination of what the fire and water damage will be in the event of fire compared with that in other types of factory buildings.

For this purpose concrete factories may be divided into two classes:

1st. Those having contents which are not inflammable or readily combustible. In this class, if wooden window frames and partitions, etc., have been eliminated, the building as a whole becomes practically proof against fire, provided there are no outside exposures, protection against which would require special precautions.

2nd. Those having contents which are more or less combustible, and which have in their construction small amounts of inflammable material, such as wooden window frames and top floors. In this class the burning of contents is the cause of damage to the building, the extent of which is determined by the character of the contents.

Of the two, the latter class is the one ordinarily met, and with which the question of insurance cost is therefore usually concerned. The character of the occupancy, details of construction and conditions of various kinds inside and outside the factory, and in the various communities, have such direct bearing on rates that any statement as below of comparative cost must be extremely approximate, but perhaps of value as showing somewhat the relative costs. These in the following table are made upon the basis of a building without a standard fire equipment, which condition is, however, now rare in the case of first-class factories and warehouses, even if of fireproof construction.

## CONCRETE FACTORIES VS. THOSE OF WOOD OR BRICK.

### Approximate Yearly Cost of Insurance Per $100.

Exposures, none; area not large; good city department; no private fire apparatus except such as pails and standpipes.

| | All Concrete. | | Brick Mill Construction or Open Joists. | | Wood Mill Construction or Open Joists. | | Add for Brick or Wood Buildings in Small Towns and Cities Without Best of Water and Fire Departments. |
|---|---|---|---|---|---|---|---|
| | Bldg. | Contents. | Bldg. | Contents. | Bldg. | Contents. | |
| General Storehouse | 20c. | 45c. | 60c. | 100c. | 100c. | 125c. | 25c. |
| Wool Storehouse | 20c. | 35c. | 40c. | 60c. | 75c. | 100c. | 25c. |
| Office Building | 15c. | 30c. | 35c. | 50c. | 100c. | 125c. | 25c. |
| Cotton Factory | 40c. | 100c. | 100c. | 200c. | 200c. | 300c. | 50c. |
| Tannery | 20c. | 40c. | 75c. | 100c. | 100c. | 100c. | 25c. |
| Shoe Factory | 25c. | 80c. | 75c. | 100c. | 150c. | 200c. | 50c. |
| Woolen Mill | 30c. | 80c. | 75c. | 100c. | 150c. | 200c. | 50c. |
| Machine Shop | 15c. | 25c. | 50c. | 50c. | 100c. | 100c. | 25c. |
| General Mercantile Building | 35c. | 75c. | 50c. | 100c. | 100c. | 150c. | 25c. |

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Note.—These costs are based on the absence of automatic sprinklers and other private fire protective appliances of the usual completely equipped building. They are not schedule rates, but may be an approximation to actual costs under favorable conditions based on examples in various parts of the country.

The table in a general way illustrates the gain by the use of the better type of construction, but in factory work it has long been recognized that there is a distinct hazard in the manufacturing operations and inflammable contents which is greater in degree than in other classes of property. The science of fire protection with automatic sprinklers and auxiliary apparatus has therefore attained such a degree of perfection that the brick or stone factory with heavy plank and timber floors is obtaining insurance at rates which are lower than those which are possible on any of the fireproof buildings without sprinklers. The real reason for this lies in the fact that the contents, including machinery, stock in process, and finished goods, constitute by far the larger part of the value of the plant, and these the building alone cannot be expected to protect when a fire occurs within, except in so far as the absence of combustible material in construction may assist in so doing. Fire protection is therefore needed for safety of contents, even if the building itself is practically fireproof.

As illustrating the value of fire protection, I would state that in the Boston Manufacturers' Mutual Fire Insurance Company, and others of the older of the Factory Mutual Companies, the average cost of insurance on the better class of protected factories has now for some years averaged, excluding interest, less than seven (7) cents on each one hundred dollars of risk taken, and on first-class warehouses connected with them, one-half this amount. These figures can be compared with the table as illustrating the gain by the installation of proper safeguards for preventing and extinguishing fire.

In these same protected factories and warehouses the actual fire and water loss is less than four (4) cents on each one hundred dollars of insurance, and, being so small, it would seem that they must be almost impossible of reduction, but nevertheless it is possible.

How can this be accomplished? This is the problem of the designer and builder of the concrete factory.

1st. By avoiding vertical openings through floors—a common fault in many factories with wooden floors. To be a perfect fire cut-off, a floor should be solid from wall to wall, with stairways, elevators and belts enclosed in vertical fireproof walls having fire doors.

2nd. By provision for making floors practically waterproof, that water may not cause damage on floors below that on which fire occurs. Scuppers of ample size to carry water from floors to outside are an essential part of the design. In the ordinary factory with wooden floors, loss from water is almost invariably excessive as compared with the loss by actual fire.

3rd. By making the buildings as incombustible as possible, thus reducing the amount of material upon which a fire may feed. Also by provision for sufficient thickness of fireproofing to thoroughly insulate all steel work, the fireproofing being sufficiently substantial that it may not scale off ceilings or columns at a fire or from other causes, thus allowing failure of steel work, by heating or deterioration. An owner is thus more secure if the fire protection or any parts of it fail at a critical moment.

4th. By good judgment as to the extent or amount of fire protection required in each individual case. While the value of the automatic sprinkler is recognized and the general rules specify its installation, the Factory Mutual Companies do not require it in the concrete building, except where there is sufficient inflammable material in the contents to furnish fuel for a fire. An essential feature of good factory construction includes not only consideration of the building, but protection adequate to its needs only.

The extent to which the above is faithfully carried out will eventually be the determining feature in the cost of insurance.

September 9, 1907.

# CHAPTER II.

## DESIGN AND CONSTRUCTION.

Concrete is an artificial stone, and if it contains no steel, that is, if it is not reinforced, it is brittle like stone. Just as stone can be used to support enormous loads, as in foundations, bridges and dams, provided it is so placed as to receive no tension or pull, so can concrete stand heavy loading in compression with no reinforcement.

Concrete, however, has the advantage of stone, because when built in place, steel, which is especially adapted for withstanding pull, may be introduced at just the right position in the beam or other member to take this pull. In an ordinary beam the upper surface is in compression and the lower surface in tension; the natural arrangement of materials is therefore to design the beam so that the upper part is composed of concrete, which takes the compression, while steel is embedded near the bottom to resist the pull or tension. The concrete by surrounding the steel protects it from rust and fire, and because concrete and steel expand and contract almost exactly alike when heated and cooled, they may be used thus in combination with no danger of separation from changes in temperature.

It is evident that to make a safe combination of concrete and steel, it is necessary to know just how much load each can stand, and just where the steel must be located to take every bit of the tension which may occur in any part of the beam. While in a beam supported at the ends, the pull is in the bottom and the principal steel must be as near to the bottom as is consistent with rust and fire protection, on the other hand, when the beam is built into a column or into another beam, a load upon it produces also a pull at the top of the beam over its supports which tends to crack it there. Furthermore, there are other secondary stresses in the interior of the beam, partly shear or tendency to slide and partly tension or pull, which must be guarded against by locating steel rods in the proper places. Hence the necessity, because of the complication in the action of the stresses even in a simple beam, that the designers have a knowledge of the principles of mechanics and the theories involved.

It is not the purpose of this book to dwell upon the theory of design, but instead to give practical principles of construction to supplement the theory which can be obtained readily from other sources.

## CEMENT.

Portland cement should always be used for concrete building construction because it is not only stronger than natural cement but is more reliable and hardens more quickly.

The standard specifications adopted by the American Society for Testing Materials† are generally adopted for important work throughout the country. Brief specifications may be sufficiently comprehensive for work of minor importance.

## BRIEF SPECIFICATIONS FOR PORTLAND CEMENT.

*A cement shall be a first-class Portland cement of a standard brand bearing a good reputation, sound—i. e., not liable to expansion or disintegration,—fine and of uniform quality. It shall be free from lumps and shall be packed in sound barrels, or, if stored in a dry place to be used immediately, it may be packed in stout cloth or canvas bags.

## SPECIFICATIONS FOR MATERIALS.

The following specifications are of so general a character as to be applicable to nearly all kinds of concrete construction. Local requirements limiting the sizes of the particles and giving further information may be added.

Sand.*—The sand shall be clean and coarse, or a mixture of coarse and fine grains with the coarse grains predominating. It shall be free from clay, loam, mica, sticks, organic matter, and other impurities.

Screenings.—*Screenings or crusher dust from broken stone—in which term is included all particles passing a quarter-inch screen—by slightly altering the proportions of the ingredients, may be substituted for the whole or a portion of the sand in such proportions as to give a dense mixture and the same relative volumes of total aggregates.

Gravel. ‡—*The gravel shall be composed of clean pebbles free from sticks or other foreign matter and containing no clay or other materials adhering to the pebbles in such quantity that it cannot be lightly brushed off with the hand or removed by dipping in water. It shall be screened to remove the sand, which shall afterwards be remixed with it in the required proportions.

Broken Stone. ‡—*The broken or crushed stone shall consist of pieces of hard and durable rock, such as trap, limestone, granite, or conglomerate. The dust shall be removed by a quarter-inch screen, to be afterwards mixed with and used as a part of the sand, if desired, except that if the product of the crusher is delivered to the mixer so regularly that the amount of dust

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* Paragraphs designated by an asterisk are quoted from Taylor & Thompson's "Concrete, Plain and Reinforced."

† These may be obtained by addressing The Atlas Portland Cement Company.

‡ The maximum size of stone for building construction is customarily limited to 1 inch or 1¼ inch, so that the concrete may be carefully placed around the steel and into the corners of the forms. In certain cases ½-inch or ¾-inch stone is specified, but the larger size is better, provided it can be properly placed.

(as determined by frequently screening samples) is uniform, the screening may be omitted and the average percentage of dust allowed for in measuring the sand.

Water.—The water shall be free from acids or strong alkalies.

Reinforcing Steel.[†]—*Steel for reinforcement shall have an "ultimate tensile strength of 55,000 to 65,000 pounds per square inch, an elastic limit of not less than one-half the ultimate strength (i. e., not less than 27,000 pounds) and a minimum elongation in 8 inches of 1,400,000 divided by the ultimate strength per cent." Metal reinforcement shall be of such shape or so anchored as suitably to assist its adhesion to the concrete.

## PROPORTIONS OF MATERIALS.

In building construction, the proportions most generally adopted are 1 part cement to 2 parts sand to 4 parts broken stone or gravel (this being customarily indicated by the expression 1:2:4), or 1 part cement to 2½ parts sand to 5 parts broken stone or gravel (i.e., 1:2½:5). One part is assumed to be equal to 4 bags of cement, or one barrel, holding 3.8 cubic feet; thus proportions 1:2:4 mean one barrel (or 4 bags) Portland cement, 7.6 cubic feet sand measured loose and 15.2 cubic feet of broken stone or gravel measured loose.

On a small job, where tests cannot be made so economically it is well to be conservative and require proportions 1:2:4. On the other hand, if an engineer is constantly present, it is often best not to definitely specify the relative amount of sand to stone, but to permit the proportion to vary with the material; thus, in laying the concrete if there is an excess of mortar the quantity of sand should be slightly reduced and the quantity of stone correspondingly increased, while if there is insufficient mortar to cover the stone and prevent stone pockets, the sand may be increased and the stone decreased. The proportion of cement to the sum of the parts of sand and stone may thus be kept constant.

## MACHINE MIXING.

*If the concrete is mixed in a machine mixer a machine shall be selected into which the materials, including the water, can be precisely and regularly proportioned, and which will produce a concrete of uniform consistency and color with the stones and water thoroughly mixed and incorporated with the mortar.

## CONSISTENCY.

For building construction and for other reinforced concrete work it is absolutely necessary that the concrete shall be mixed wet enough to flow

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* See footnote page 25.

[†] For specifications for high carbon steel, see Taylor & Thompson's "Concrete, Plain and Reinforced," page 38.

around and thoroughly imbed the steel, but it must be no wetter than is required to attain this result. If mixed too dry, air voids will be left around the stone, and stone pockets will appear on the face of the concrete after removing the forms. If, on the other hand, too much water is added, the surface may have a similar appearance because of the water running away from the stone.

## PLACING.

*Concrete shall be conveyed to place in such a manner that there shall be no distinct separation of the different ingredients, or, in cases where such separation inadvertently occurs the concrete shall be remixed before placing. Each layer in which the concrete is placed shall be of such thickness that it can be incorporated with the one previously laid. Concrete shall be used so soon after mixing that it can be rammed or puddled in place as a plastic homogeneous mass. Any which has set before placing shall be rejected. When placing fresh concrete upon an old concrete surface, the latter shall be cleaned of all dirt and scum or laitance and thoroughly wet. Noticeable voids or stone pockets discovered when the forms are removed shall be immediately filled with mortar mixed in the same proportions as the mortar in the concrete. For horizontal joints in thin walls, or in walls to sustain water pressure, or in other important locations, a joint of mortar in proportions designated by the engineer may be required.

## SURFACES.

The proper treatment to give a pleasing appearance to exposed surfaces is one of the most difficult problems in concrete building construction. The surfaces of columns, beams and the under sides of floors can be made sufficiently smooth by carefully spading, and by seeing to it that the mortar comes to the face and that the forms are tight enough to prevent the mortar running out.

The treatment of outside surfaces is described and illustrated in Chapter XIV on Details of Construction, and the methods adopted in different buildings are taken up in the descriptive chapters which follow.

## FORMS.

*The lumber for the forms and the design of the forms shall be adapted to the structure and to the kind of surface required on the concrete. For exposed faces the surface next to the concrete shall be dressed. Forms shall be sufficiently tight to prevent loss of cement or mortar. They shall be thoroughly braced or tied together so that the pressure of the concrete or the movement of men, machinery or materials shall not throw them out of place. Forms shall be left in place until in the judgment of the engineer the concrete

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* See footnote page 25.

has attained sufficient strength to resist accidental thrusts and permanent strains which may come upon it. Forms shall be thoroughly cleaned before being used again.

The time for removal of forms is determined by the weather conditions and actual inspection of the concrete. The following approximate rules may be followed as a safe guide to the minimum time for the removal of forms:*

Walls in Mass Work.—One to three days, or until the concrete will bear pressure of the thumb without indentation.

Thin Walls.—In summer, two days; in cold weather, five days.

Slabs up to Six Feet Span.—In summer, six days; in cold weather, two weeks.

Beams and Girders and Long Span Slabs.—In summer, ten days or two weeks; in cold weather, three weeks to one month. If shores are left without disturbing them, the time of removal of the sheeting in summer may be reduced to one week.

Column Forms.—In summer, two days; in cold weather, four days, provided girders are shored to prevent appreciable weight reaching columns.

A very important exception to these rules applies to concrete which has been frozen after placing, or has been maintained at a temperature just above freezing. In such cases the forms must be left in place until after warm weather comes, and then until the concrete has thoroughly dried out and hardened.

## FOUNDATIONS.

In a reinforced concrete building, the floor loads are carried by the slabs to the beams and girders, and thence to the columns, which concentrate the weight upon small areas of ground. The footing of each column must therefore be spread over a large enough area of ground so as not to over compress the soil and cause appreciable settlement.

Mr. George B. Francis† suggests the following loading for materials which can be clearly defined, at the same time calling attention to the necessity for varied and ample experience when fixing allowable pressures in any particular case:

Ledge rock, 36 tons per square foot.
Hard pan, 8 tons per square foot.
Gravel, 5 tons per square foot.
Clean sand, 4 tons per square foot.
Dry clay, 3 tons per square foot.
Wet clay, 2 tons per square foot.
Loam, 1 ton per square foot.

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* From paper on "Forms for Concrete Construction," by Sanford E. Thompson, before National Association of Cement Users, 1907.

† Taylor & Thompson's "Concrete, Plain and Reinforced," page 473.

To illustrate the use of these rules: If a column 20 inches square carries a load from above of 80 tons, the footing over a soil of dry sand must cover an area of $\frac{80}{4} = 20$ square feet; that is, the footing must be about 4 feet 6 inches square.

Not only must the area be calculated to distribute the load over a proper area of soil, but the thickness of the footing must be computed so as to prevent the column punching or shearing through it, and a sufficient amount of reinforcing steel must be placed in the bottom of the concrete footing to prevent its buckling and breaking from the concentrated load of the column. The size of the rods is calculated from the bending moment produced by the upward pressure of the soil against the projection of the footing, which may be assumed to be a beam supported upon a line running through the center of the column. If, as is customary, the footing projects in both directions and the rods run in both directions, both projections may be taken into account as resisting the pressure.

In certain cases where a very large footing is required, especially when the footing rests on piles, stirrups may be needed to resist shear or diagonal tension, as in an ordinary beam.

Proportions of concrete for reinforced footings may be 1:2½:5, i. e., one part Portland cement to 2½ parts sand to 5 parts broken stone or gravel, or the same proportions may be used as in the building above them.

Foundations in dry ground which do not require reinforcement and sustain only direct compression may be laid in proportions of 1:3:6 or 1:3:7. If laid under water the concrete should not be leaner than 1:2½:5, while for sea water construction a mixture at least as rich as 1:2:4 is advisable, with very careful testing of the cement and aggregates.

For a building with no basement, foundation walls between the columns are unnecessary. The walls may be started just below the surface of the ground, and each wall slab will form of itself a beam supported at each end by the column foundation. When a basement is included in the design, its wall is apt to act as a retaining wall to resist the pressure of earth, and it may be necessary to calculate the thickness and reinforcement required to resist the earth pressure. Frequently, the bottom of the wall is held by the basement floor, and the top by the first floor of the building. In this case it may be considered as a slab supported at the bottom and top, and the principal reinforcing rods should be vertical and placed about one inch from the interior face of the wall. If there is no support at the top, the footing may be enlarged by careful computation, and a cantilever design made with the principal tension rods vertical but near the exterior face of the wall; or the vertical slab may be supported at the ends by columns or buttresses of proper design, and the tension rods, computed to resist the earth pressure, run horizontally near the interior face.

For an ordinary cellar wall supported at bottom and top, a thickness of 8 inches with ⅜ inch vertical rods about one foot apart will be strong enough to hold the earth, but it is best to actually compute the thickness and reinforcement for any given case. Even if the principal rods are vertical, occasional horizontal rods, spaced about 18 inches or 2 feet apart, should be placed in the wall to tie it together and prevent contraction cracks.

## BASEMENT FLOOR.

The earth under a basement floor must be well drained. If necessary, drains of tile pipe or of screened gravel or stone may be placed in trenches just below the concrete, or the entire level may be covered with cinders or stone. If the basement is below tide water or ground water level, it is not safe to depend upon the concrete itself being water-tight, and a layer of water proofing consisting of four to six layers of tarred paper, mopped on, may be spread on the concrete and carried up in continuous sheets on the walls to above water level, and the whole surface covered with another layer of concrete. In some cases, it may be necessary to make the concrete extra thick, or to add reinforcement, to resist the upward pressure of the water.

For a basement floor in dry ground a 3-inch or 4-inch thickness of ordinary 1:3:5 concrete,—that is, concrete composed of 1 part Portland cement to 3 parts sand to 5 parts broken stone or gravel,—may be laid and the surface screeded to bring it to the required level. As it sets, this concrete should be troweled just as the wearing surface of a sidewalk is troweled, but without the mortar or granolithic finish which is customarily laid upon a walk. If the floor is to have a great deal of wear or trucking, the usual ¾-inch or 1-inch layer of 1:2 mortar may be laid upon the concrete before it has set, forming a part of the total thickness of 4 inches; but usually this is an unwarranted expense in a basement, as the plain concrete will give as good service.

It is well in any case to divide the floor into blocks, say, 8 or 10 feet square, so that any shrinkage cracks will come in the joints. This is readily accomplished by laying alternate blocks, and then filling in the intermediate ones the next day.

## DESIGN OF FLOOR SYSTEM.

LOADING.—In designing a reinforced concrete building, the first consideration is the loading which the various floors must sustain; in other words, the strength which each floor must have to support the weights which may come upon it under all conceivable conditions. In a factory or warehouse it is frequently possible to accurately calculate the maximum weight which will come upon a given area of floor. For the very heaviest loading the problem is frequently the simplest, since the heavy weights are apt to be due to the storage of merchandise whose weight per cubic foot, and therefore per square foot of floor, can be readily calculated. Sometimes the underside of the floor must support tracks which carry certain definite weights, and the beams or girders must be calculated for these concentrated loads in addition to the uniform loads upon the floor.

In computing the strength of the floor system, the weight of the concrete itself must always be allowed for. In very long spans the concrete frequently weighs more than the load which will be placed upon it.

In many cases the loading must be assumed without actual computation. A maximum load must frequently be selected to support machinery whose weight is slight but whose vibrations require a stiff floor system.

The various conditions met with in warehouse or factory construction may thus necessitate loadings varying from 100 to 500 pounds per square foot of floor area, very wide limits and yet not more than occur in practice. As a guide to the selection of floor loads, the following values are suggested:

| | |
|---|---|
| Office floors | 100 pounds per square foot |
| Light running machinery | 150 pounds per square foot |
| Medium heavy machinery | 200 pounds per square foot |
| Heavy machinery | 250 pounds per square foot |
| Storage of parts or finished products, depending upon actual calculated loads, | 150 to 500 pounds per square foot |

When the loads are apt to occur only over a part of the floor, the slabs and beams are calculated for the full load, and when computing the girders and columns a slightly smaller load is sometimes used. For example, if the slabs and beams are figured for 200 pounds per square foot of floor area, it might be assumed that the whole of the total area supported by a girder or column would never be loaded at once, and the load per square foot actually reaching the girder and column at any one time would be therefore not more than 150 pounds per square foot of floor area.

LAYOUT.—The general layout of the beams and girders and columns depends upon the loading, the uses to which the building is to be put, and the ground area. Frequently in a large building, it will be worth while to require the engineer to make several comparative estimates with different spacings of columns and sizes of panels, so as to determine that which is most economical consistent with the floor area required for the machinery.

Common spacings of columns in a reinforced concrete building are from 12 feet to 20 feet. Longer spans are not usually so economical, but may frequently be necessary to give the floor space required for machinery or storage. Several of the buildings described in the chapters which follow are designed for long spans, but it will be noticed that very heavy beams and girders are required for them.

Taking a general case, if the spacing of the columns is 20 feet each way, the columns are connected by girders running in one direction, usually the long way of the building, and into these girders run beams spaced 6 feet to 8 feet apart. Other arrangements will suggest themselves from the descriptive chapters which follow.

FLOOR SLABS.—The thickness and reinforcement of the floor slabs is determined by the distance beween the beams, and by the loading which will come upon them. The most usual thicknesses are 3½ inches to 5 inches, with reinforcement calculated from the bending moment produced by the loads. An economical quantity of steel is apt to be from 0.8 per cent. to 1 per cent. of the sectional area of the slab above the steel.

A few rods are usually placed at right angles to the main bearing rods of the slab to assist in preventing contraction cracks, and these also add to the strength of the slab.

In a factory or warehouse the most economical floor surface is generally a granolithic finish, consisting of a layer of 1:2 mortar about three-quarter inch thick, spread upon the surface of the concrete slab before it has begun to set, and troweled to a hard finish just like a concrete sidewalk.

Machines are readily bolted to the concrete by drilling small holes in the concrete at the proper points for the standards and grouting the lag screws in place, or else bolting them through the slab.

If for any reason a wood floor is required, stringers may be laid upon the top of the concrete and spaces left between them or filled with cinders or with cinder concrete.

BEAMS AND GIRDERS.—As already indicated, the sizes and reinforcement of the beams and girders must be accurately computed by one who thoroughly understands the theories involved in reinforced concrete design. Even if tables are used the designer must have a knowledge of mechanics and of the way in which the stresses act.

It is a simple matter to determine the amount of steel required in the bottom of the beam to sustain the pull due to a given loading, but while this is an important determination it is by no means the only one.

The weak points in reinforced concrete structures are not usually due to insufficient steel for tension, but more often to an ignorance of other smaller details not less important. It is thus absolutely dangerous, and in fact criminal, for a novice to design or pass upon drawings for a reinforced concrete structure.

The design of reinforced concrete beams and girders involves the following studies:

(1) The bending moment due to the live and dead loads, this involving the selection of the proper formula for the computation.

(2) Dimensions of beams which will prevent an excessive compression of the concrete in the top and which will give the depth and width which is otherwise most economical.

(3) Number and size of rods to sustain tension in the bottom of the beam.

(4) Shear or diagonal tension in the concrete.

(5) Value of bent-up rods to resist shear or diagonal tension.

(6) Stirrups to supplement the bent-up rods in assisting to resist the shear or diagonal tension.

(7) Steel over the supports to take the tension due to negative bending moment.

(8) Concrete in compression at the bottom of the beam near the supports due to negative bending moment.

(9) Horizontal shear under flange of slab.

(10) Shear on vertical planes between beams and flanges.

(11) Distance apart of rods to resist splitting.

(12) Length of rods to prevent slipping.

(13) End connections at wall.

Although it is not the province of this book to go into the mathematical treatment of these various points, many of them are as yet so inadequately treated in literature on the subject that it will be advisable to touch upon them in a general way.

BENDING MOMENT.—The first important computation for an engineer to make is the determination of the bending moment. In a beam which is merely supported at the ends like a steel beam or a timber girder resting upon columns, the calculation is very simple, and can be readily made by drawing a load diagram, or in the simple case of a uniformly distributed load by using the formula

$$M = \frac{1}{8} WL \qquad (1)$$

in which

M = bending moment in inch pounds.

W = total load in pounds supported by the beam or girder (including the dead load).

L = length of span of beam or girder in inches.

When a beam is continuous or is more or less fixed at the ends, as is the case in reinforced concrete construction, where the entire floor system is laid as one unit, the conditions are changed, the stress in the center of the beam is less, and there is also a reverse action, termed the negative bending moment, at the supports.

It is, therefore, conservative practice to use in general for slabs, and for beams and girders which are built into each other or into heavy columns, the formula

$$M = 1/10\, WL \qquad (2)$$

For the end spans, that is, for beams and girders running into a wall, formula (1) is generally used instead.

These values for the bending moment, as stated, are conservative and eventually it will probably be considered safe to slightly increase them.

The negative bending moment at the end of the beams must be provided for by steel rods carried over the top of the support for tension, and by a sufficient quantity of concrete at the bottom of the beam near the support to take the compression. Using formula (1) or (2) for the design at the center gives a very stiff beam so that for the negative moment at the ends it is safe to use

$$-M = 1/12\ WL$$

Since the pull in the bottom of the beam decreases toward the supports a part of the tension rods may be bent up on an incline from about one-quarter points in the beam, if the load is uniformly distributed, and pass horizontally through the top of the beam at the supports. The rods must extend over the supports for a sufficient distance to receive the compressive stress there, or must be firmly connected with corresponding rods in the adjacent bay. The total steel in the top must be sufficient to resist the tension due to the negative moment.

In slabs it is good practice to bend up all of the rods at the quarter points toward the supports.

STEEL.—City building laws are apt to limit the tension in steel to 16,000 pounds per square inch. Many engineers adopt the value, slightly more conservative and therefore preferable, of 14,000 pounds per square inch.

CONCRETE.—If the concrete is made of first-class materials mixed not leaner than 1 part cement to 2 parts sand to 4 parts stone, so as to have a compressive strength of at least 2,000 pounds per square inch at the age of 28 days, a value as high as 600 pounds per square inch for the extreme fiber compression in beams and slabs may be used with safety, provided the computation is based on what is termed the straight line distribution of stress, and the ratio of the modulus of elasticity of steel to concrete is taken at 15. To guard against the possibility of poor workmanship, building departments frequently fix a limit of 500 pounds per square inch.

In computing the compression, the beam is usually considered of T-section, that is, the slab for a certain distance on each side of the beam is assumed to act as part of the beam. The width of slab to use in computing the beam is usually taken from one-fifth to one-third the span of the beam, and not more than two-thirds the distance between beams. In order to take advantage of the strength of the slab, it is absolutely necessary that the concrete be laid in the slabs at the same time as in the beams, so as to prevent any joint between them. The disregard of this important rule has contributed to more than one failure of reinforced concrete.

STIRRUPS.—Besides the ordinary compression and pull in a beam, there are secondary stresses of shear or diagonal tension, which, if not provided for, will produce diagonal cracks. These will run in a general direction from the bottom of the beam near the supports on an incline toward the top of the beam, and may cause the beam to fail. To prevent this cracking, unless the beam is so wide that the concrete can take the whole of the stress without exceeding 60 pounds per square inch in shear, vertical or inclined steel bars, of sizes accurately computed, must be placed. The bent-up tension rods take care of a part of this shear, or diagonal tension, but if these are not sufficient, stirrups, which are usually made in the form of a U, must be inserted at the proper locations to take the remainder.

## COLUMNS.

The most important of all the members of the building are the columns, for if a column fails the entire building is liable to go down.

If columns as ordinarily built in building construction are made of 1:2:4 proportions, it is safe in an ordinary building to allow a direct compressive strength of 450 pounds per square inch, provided the columns are at least 12 inches square. A customary manner of designing is to figure the entire compression upon the concrete to the full size of the column, but to place four or possibly six rods of ⅝-inch or ¾-inch diameter near the corners or sides of the column, with ¼-inch wire loops around these rods at occasional intervals in the height, say, from 8 to 12 inches apart.

Vertical steel-rods of larger size may be introduced when it is necessary to decrease the size of the columns. These may be computed to bear a portion of the compressive load, but they cannot be figured at their full safe value of 16,000 pounds per square inch because they have a different modulus of elasticity and compressive strength from concrete and can only shorten the same amount as the concrete. Under ordinary circumstances, therefore, they cannot be assumed to bear more than the safe compressive stress in the concrete times the ratio of elasticity of steel to concrete, or about 7,000 pounds per square inch. Because of this small amount of compression which they can bear, it is always cheaper to enlarge the column rather than to insert steel of larger diameter to assist in taking the load.

Another means of increasing the strength of the column is to use a richer mixture. This is legitimate provided the same mixture is carried up through the floor system at the column so that there will be no weak places. By using proportions 1:1:3 a safe working compression in the concrete of 700 pounds per square inch may be adopted.

Hooped columns, that is, columns reinforced with bands placed near together or with spirals, are frequently adopted to reduce the size of the column. It is a serious question in the minds of conservative engineers as to whether it is good practice to assume that a large proportion of the load can be borne by such hoops. Although tests have shown that hooped columns have a high ultimate strength, these same tests prove that the concrete within the hoops is overstrained before the hoops begin to take any of the tension which must reach them in order to strengthen the columns.

Composite columns, which are virtually steel columns surrounded by concrete, have been used in a number of buildings. An instance of this is the Ketterlinus building, described in Chapter V. This construction, although more expensive than plain concrete, is advantageous where the floor space is so valuable that the dimensions of the columns must be kept small.

## WALLS.

The walls of reinforced concrete factories are sometimes built up with the columns, but it is generally considered more economical to erect the skeleton structure and fill in the wall panels, as described in Chapters VI and IX.

Slots in the columns are made by nailing a strip on the inside of the column forms. In this way the panels are mortised into the columns.

Ordinary concrete walls require light reinforcement to prevent shrinkage and give them stiffness while setting. All that is required for, say, a 4-inch or 6-inch wall are 1/8-inch rods spaced from 12 to 24 inches apart, according to the size and importance of the wall. At window and door openings a larger amount of reinforcement is of course necessary, and in these cases the amount of steel must be calculated just as though the lintels were reinforced concrete beams.

## ROOFS.

Reinforced concrete roofs are designed like floors. A roof load commonly assumed in temperate climates, to provide for roof covering, snow and wind pressure, is 40 pounds per square foot, in addition to the weight of the concrete itself.

It is not safe to assume that the concrete roof of itself will be water-tight unless special provision is made in the construction. Although tanks and walls can readily be made to hold water, a roof is under extraordinarily disadvantageous conditions because of the rays of the sun. Usually, therefore, a tar and gravel or other form of roof covering must be provided.

## CONSTRUCTION.

The details of construction are treated at length for individual buildings in the chapters which follow. Chapter XIV also takes up many special points and treats as well of different methods of reinforcing.

A reinforced concrete building must have careful inspection while in process of erection, the special points to be observed being:

(1) Exact proportioning of materials.
(2) Placing the concrete so as to prevent separation of ingredients.
(3) Placing concrete to avoid joints except where called for.
(4) Exact placing and imbedding of the reinforcement.
(5) Proper securing of the forms.
(6) Maintenance of the forms in position until the concrete is sufficiently strong.

# CHAPTER III.

## CONCRETE AGGREGATES.*

The term "aggregate" includes not only the stone, but also the sand which is mixed with cement to form either concrete or mortar; in other words, it is the entire inert mineral material. This definition, now generally accepted, has replaced the one restricting the term to the coarse aggregate alone. It is the object of this chapter to enumerate the general principles which should be followed in the selection of sand and stone for mortar and concrete, and to describe briefly the method of testing aggregates and determining proportions which the author has found to give good results in practice.

At the outset, it may be said that a concrete of fair quality, if rich enough in cement, can be made with nearly any kind of mineral aggregate, but there is, nevertheless, a wide variation in the results produced. For the fine aggregate, sand, broken stone, screenings, pulverized slag or the fine material from cinders may be used separately or in combination with each other. For the coarse aggregate, broken stone, gravel, screened gravel slag, crushed lava, shells, broken brick, or mixtures of any of these may be employed. However, the very fact of the adaptability of concrete to so wide a range of materials, every one of which really consists of a large class varying in size, shape and composition, tends to blind one to the economies which often may be effected and the improvement in quality which almost always will result by a careful selection and proportioning of the aggregates.

In many cases, especially where the cost of Portland cement is low, it may be cheaper to use whatever materials are nearest at hand, and insure the quality of the concrete or mortar by making it excessively rich in cement. If the structure is small and of little importance this course is properly followed, but, on the other hand, if a large amount of concrete is to be laid, and especially if the process is to be carried on in a factory, as in concrete block manufacture, it pays from the standpoints of both quality and economy to use great care in the selection of the aggregates, as well as of the cement, and to provide means for maintaining uniformity.

To illustrate the variation which different aggregates may produce even when they are mixed with cement in the same proportions, the author has selected a few comparative tests of mortar and concrete.

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* Read by the author before the National Association of Cement Users, June, 1906.

## EFFECT OF DIFFERENT AGGREGATES UPON THE STRENGTH OF MORTAR AND CONCRETE.

Tests by Mr. Rene Feret,* of France, with mortar made from different natural sands show a surprising variation in strength, which is evidently due simply to the fineness of the sand of which the different specimens are composed. Selecting from his results proportions 1:2½ by weight—that is, 1 part cement to 2½ parts sand—and converting his results at the age of five months from French units to pounds per square inch, the average tensile strength of Portland cement mortar made with coarse sand is 421 pounds per square inch, with medium sand 368 pounds per square inch, and with fine sand 302 pounds per square inch. In the crushing strength, usually the most important consideration, the difference is even more marked. In round numbers, at the age of five months the mortar of coarse sand gave 5,200 pounds per square inch; of the medium sand, 3,400 pounds per square inch, and of the fine sand 1,900 pounds per square inch. Note that the different sands were not artificially prepared, but were taken from the natural bank and correspond to those which every day are being used for concrete and mortar.

The effect of different mixtures of the same kind of material is shown by tests made by the author in 1905.† By varying the sizes of the particles of the aggregates, but using in all cases stone from the same ledge and the same proportion of cement to total aggregate by weight, namely, 1:9 (or approximately 1:3:6), it was found possible to make specimens the resulting strengths of some of which were two and a half times the strength of others.

The effect of the hardness or strength of the stone used for the coarse aggregate is shown in tests of George W. Rafter, ‡ which, for proportions about 1:26½, gave 50 per cent. greater compressive strength of concrete where the coarse aggregate was a hard sandstone than with similar proportions where a shale was substituted. In some of his tests the harder stone gave a concrete even double the strength of the concrete with softer stone.

## GENERAL PRINCIPLES FOR SELECTING STONE.

The quality of concrete is affected by the hardness of the stone, the shape of the particles, the maximum size of the particles and the relative sizes of the particles.

If broken stone is used, and there is an opportunity for choice, the best is that which is hard; with cubical fracture; with particles whose maximum size is as large as can be handled in the work; with the particles smaller than, say, ¼ inch, screened out to be used as sand; and with the sizes of the remaining coarse stone varying from small to large, the coarsest predominating.

If gravel is used it must be clean. The maximum size of particles should be as large as can be handled in the work; grains below, say, ¼ inch, should

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* Taylor & Thompson's "Concrete, Plain and Reinforced," page 136.
† Proceeding American Society of Civil Engineers, March, 1907.
‡ Second Report on Genesee River Storage Project, 1894.

be screened out to be used as sand, and the size of the stone should vary, with the coarsest predominating.

As already stated, the size of the coarsest particles of stone should be as large as can be handled in the work. This is because the strength of the concrete is thereby increased and a leaner mixture can be used than with small stone. In mass concrete the stones if too large are liable to separate from the mortar unless placed by hand or derrick, as in rubble concrete, and a practical maximum size is 2½ or 3 inches. In thin walls, floors and other reinforced construction, a 1-inch maximum size is generally as large as can be easily worked between the steel. In some cases where the walls are very thin, say 3 or 4 inches, a ¾-inch maximum size is more convenient to handle.

It is a little more trouble but almost always best to screen out the sand from gravel or the fine material from crusher stone, and then remix it in the proportions required by the specifications, for otherwise the proportions will vary at different points, and one must use and pay for an excess of cement to balance the lack of uniformity.

If the gravel is used, it is absolutely essential that it shall be clean, because if clay or loam adheres to the particles, the adhesion of the cement will be destroyed or weakened. Tests of the Boston Transit Commission* give an average unit transverse strength of 605 pounds per square inch for concrete made with clean gravel as against 446 pounds per square inch when made with dirty gravel.

## COMPARATIVE VALUES OF DIFFERENT STONE.

Different stones of the same class vary so widely in texture and strength that it is impossible to give their exact comparative values for concrete. A comparison by the author of a large number of tests of concrete made with different kinds of stone indicates that the value of a broken stone for concrete is largely governed by the actual strength of the stone itself, the hardest stone producing the strongest concrete. This forms a valuable guide for comparing different stones. Comparative tests indicate that different stones in order of their value for concrete are approximately as follows: (1) Trap, (2) granite, (3) gravel, (4) marble, (5) limestone, (6) slag, (7) sandstone, (8) slate, (9) shale, (10) cinders. Although as stated above, the wide difference in the quality of the stone of any class makes accurate comparisons impossible—and this difficulty is increased by the fact that the proportions and age of the specimens affect their relative value—an approximate estimate drawn from actual tests gives the value for concrete of good quality sandstone as not more than three-fourths the value of trap, and the value of slate as less than half that of trap. Good cinders nearly equal slate and shale in the strength of concrete made with them.

The hardness of the stone grows in importance with the age of the concrete. Thus gravel concrete, because of the rounded surfaces, at the age of one month may be weaker than a concrete made with comparatively soft

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* Seventh Report of Boston Transit Commission, 1901, page 39.

broken stone; but at the age of one year it may surpass in strength the broken stone concrete, because as the cement becomes hard, there is greater tendency for the stones themselves to shear through, and the hardness of the gravel stones thus comes into play. Gravel makes a dense mixture, and if much cheaper than broken stone, can usually be substituted for it.

A flat grained material packs less closely and generally is inferior to stone of cubical fracture.

## GENERAL PRINCIPLES FOR SELECTING SAND.

The only characteristics of sand which need be considered are the coarseness of its grains and its cleanness. These qualities affect the density of the mortar produced, and therefore the test of the volume of mortar, or "yield" determines which of two or more sands is best graded. The "yield" or "volumetric" test is considered by the author of greater value for quick results than all others put together. The methods of employing it are described farther along in the paper.

The best sand is that which produces the smallest volume of plastic mortar when mixed with cement in the required proportions by weight.

A high weight of sand and a corresponding low percentage of voids are indications of coarseness and good grading of particles; but because of the impossibility of establishing uniformity in weighing or measuring, they are merely general guides which cannot under any conditions be taken as positive indications of true relative values. The various characteristics of sands are separately considered in the following paragraphs:

WEIGHT OF SAND.—A heavy sand is generally denser, and therefore better than a light sand. However, this is not a positive sign of worth, because the difference in moisture may affect the weight by 20 per cent., and when weighed dry the results are not comparable for mortars, since fine sand takes more water than coarse.

As an illustration of the variation in weight of natural sands having different moisture, the author found that the weight per cubic foot of Cowe Bay sand, which dry averaged 103 pounds, when placed out of doors and after a rain shoveled into a measure and weighed in exactly the same way (although it was allowed to drain for two days) averaged 83 pounds.

VOIDS IN SAND.—The voids, like the weight, are so variable in the same sand, because of different percentages of moisture and different methods of handling, that their determination is of but slight value. In the Cowe Bay sand just mentioned, the voids were 38 per cent. in the sand, dry, and 52 per cent. in the same sand, moist.

Because of such discrepancies, the author prefers to mix the sand with the cement and water, and determine the voids in the fresh mortar, as described later. This gives a true comparison of different sands, since with the same percentage of cement, the mortar having the lowest air plus water voids is the strongest.

COARSENESS OF SAND.—A coarse sand produces the densest, and, therefore, the strongest mortar or concrete. A sufficient quantity of fine grains is valuable to grade down and reduce the size of the voids, but in ordinary natural material, either sand or screenings, there will be found sufficient fine material for ordinary proportions, such as 1:1, 1:2, or 1:2½. For leaner proportions, such as 1:4 or 1:5, and sometimes 1:3, an addition of fine particles will be found advantageous to assist the cement in filling the voids. A dirty sand, that is, one containing fine clay or other mineral matter, up to say, 10 per cent., is actually found by tests to be better than a clean sand for lean mortars.

For water-tight work it is probable that a larger proportion of very fine grains may be employed than for the best results in strength. This is a question, however, which has not yet been thoroughly investigated.

Feret's rule for sand to produce the densest mortar is to proportion the coarse grains as double the fine, including the cement, with no grains of intermediate size. There is difficulty in an exact practical application of this rule, but it indicates the trend to be followed in seeking maximum density and strength.

CLEANNESS OF SAND.—An excess of fine material or dirt, as has just been noted, weakens a mortar which is rich in cement. It may also seriously retard its setting. The author's attention was recently called to a concrete lining, one portion of which failed to set hard for several weeks, although the same cement was used as on adjacent portions of the work. The difficulty proved to be due entirely to the fact that the contractor substituted, in this place, a very fine sand, the regular material happening to run low.

SHARPNESS OF SAND.—Notice that the quality of sharpness has not been mentioned among the essential characteristics of sand. This omission was intentional. The majority of specifications still call for "sharp" sand, and yet the writer has never known a sand to be rejected simply because of its lack of sharpness. As a matter of fact, if two sands have the same sized grains, and contain an equal amount of dust, the one with rounded grains is apt to give a denser and stronger mortar than the sharp grained sand. A sand with a sharp "feel" is preferable to another, not to any extent because of its sharpness, but because the grittiness indicates a silicious sand which is apt to have no excess of fine material.

SAND VS. BROKEN STONE SCREENINGS.—Many comparative tests of sand and screenings have been made with contrary results. While frequently crusher screenings produce stronger mortar than ordinary sand, the author in an extensive series of tests has found the reverse to be true.

This disagreement is probably due to the grading of the particles, although in certain cases the screenings may add to the strength because of hydraulicity of the dust when mixed with cement.

## TESTING SAND.

In the previous paragraphs are shown the defects in the more common methods of examining sand.

Tests made by the author in 1903 proved the value of the principles of the density of mortars laid down by Feret, and in the winter of that year similar plans for testing aggregates were introduced by Mr. William B. Fuller and the author at Jerome Park Reservoir, New York City. The object of the test is to determine which of two or more sands will produce the denser, and therefore the stronger, mortar in any given proportions.

The different results in strength which Mr. Feret found with coarse, medium and fine sand respectively have already been given, these relative strengths in compression being respectively 5,200, 3,400 and 1,900 pounds, with proportions 1:2½ by weight in each case. An examination of the tests shows that the strongest mortar was also densest; that is, the smallest volume or yield of mortar was produced with a given weight of aggregate.

The mortar of medium sand occupied a volume 7½ per cent. in excess of the volume of the mortar with coarse sand; and the mortar of fine sand, a volume 17 per cent. in excess of the mortar with coarse sand.

Following these principles, two sands may be compared and the better one selected by determining which produces the smallest volume of mortar with the given proportions by weight. Using the method described below, the author has been able to increase the strength of a mortar about 40 per cent. by merely changing the sizes of grains of the aggregate.

The method of making the test is as follows: If the proportions of the cement to sand are by volume, they must be reduced to weight proportions; for example, if a sand weighs 83 pounds per cubic foot moist, and the moisture found by drying a small sample of it at 212° Fahr. is 4 per cent., which corresponds to about 3 pounds in the cubic foot, the weight of dry sand in the cubic foot will be 83—3=80. If the proportions by volume are 1:3, that is, one cubic foot dry cement to 3 cubic feet of moist sand, and if we assume the weight of the cement as 100 pounds per cubic foot, the proportions by weight will be 100 pounds cement to 3x80=240 pounds sand, which correspond to proportions 1:2.4 by weight.

A convenient measure for the mortar is a glass graduate, about 1½ inches in diameter, graduated to 250 cubic centimeters. A convenient weight of cement plus sand, for a test, is 350 grams. For weighing, the author employs Harvard Trip scales, which weigh with fair accuracy to one-tenth of a gram.

The sand is dried and mixed with cement, in the calculated proportions, in a shallow pan about 10 inches in diameter and 1 inch deep. The mixing is conveniently done with a 4-inch pointing trowel. The dry mixed material is formed into a circle, as in mixing cement for briquets, and sufficient water added to make a mortar of plastic consistency, similar to that used in laying brick masonry. After mixing five minutes, the mortar is introduced about 20 c.c. at a time into the graduate, and to expel any air bubbles, is lightly tamped with a round stick with a flat end. The mortar is allowed to settle in the graduate for one or two hours until the level becomes constant, when the surplus water is poured off, and the volume of the mortar in cubic centimeters is read. For greater exactness, a correction may be introduced for mortar remaining on pan and trowel. The other sands, which are to be compared with this one, are then mixed with cement in the same proportions by dry weight, and sufficient water added to give the same consistency. The percentage of water required will vary with the different aggregates, the finer sand requiring the more water. After testing all the mortars, the sand which produces the strongest mortar is immediately located as that in the mortar of lowest volume. By systematic trials, the best mixture of two or more sands may also be found.

In some cases a correction must be introduced for the specific gravity of the sand; for example, ordinary bank sand has an average specific gravity of 2.65, but if this is to be compared with broken stone screenings having a specific gravity of, say, 2.80, the proportions of the two must be made slightly different. For these particular specific gravities, proportions 1:3, by weight, with sand, correspond in absolute volume to proportions 1:3.2, by weight, of the screenings.

In making these tests, it is also important to notice the character of the mortar as it is being mixed. It should work smooth under the trowel and be practically free from air bubbles.

## CALCULATING RELATIVE STRENGTHS OF MORTARS.

From the results of the tests described, it is possible to very closely estimate the relative strength of different mortars made with the same cement. A formula is given by Mr. Feret* for calculating the strength from absolute volumes of the ingredients of the mortar, but, wishing to avoid the calculation of the absolute volumes and obtain the result directly from the weights of the materials and the volume of the mortar made from them, the writer has found it possible to evolve from Feret's formula one which makes use only of the data from the tests in the graduates above described.

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* Taylor & Thompson's "Concrete, Plain and Reinforced," page 139.

The formula is as follows:

Let

$P$ = compressive strength of mortar in pounds per square inch.
$K$ = a constant.
$Q$ = measured volume or quantity of mortar in cubic centimeters.
$C$ = weight of cement used in grams.
$S$ = weight of sand used in grams.
$Gc$ = specific gravity of cement.
$Gs$ = specific gravity of sand.

Then

$$P = K\left(\frac{G_s}{G_c}\right)^2 \left(\frac{C}{G_s Q - S}\right)^2$$

This formula may be readily altered to apply to the English system of weights and measures.

The value of K varies with different cements and different ages of the same mortar, hence, it is simplest to disregard the actual strength, and consider the relative strengths of any two or more mortars as in direct proportion to the values of the square of the quantities in brackets.

If the aggregates to be compared have similar specific gravity, as in the case with different natural sands, the relative strengths of the mortars will be in proportion to the values of

$$\left(\frac{C}{G_s Q - S}\right)^2$$

To illustrate the practical value of the formula, aside from the theory, it may be of interest to refer to a recent series of comparative tests made in the author's laboratory. A mixture of sand and cement in proportions 70 grams cement to 276 grams sand produced in the graduate a volume of mortar of 178 c. c. After making a number of trial tests, using in every case the same proportions by weight, a new mixture of sizes of the same aggregate was obtained, whose volume when mixed with the cement and water was 165 c. c. The specific gravity of the sand, which in this instance was crushed rock, in both cases was 2.88. Substituting these values in the formula, we find the ratio of the two tests to be 1 to 1.40, that is, the mortar having the smallest volume ought to be 1.40 times (or 40 per cent.) stronger than the other. Actual tests of the two mortars,—afterwards made in similar proportions into long prisms,—gave at the end of 14 days an average of 832 pounds per square inch for one and 1,153 pounds per square inch for the other, thus showing an actual excess of strength of 39 per cent., which is substantially identical with the estimated increase.

## TESTING CONCRETE AGGREGATES.

For concrete in any given proportions, the best sizes of stone and of sand may be determined by similar methods to those described for testing sand mortars, although larger quantities of materials must be used and the measure must be strong to withstand the light ramming which is necessary. A short length of cast iron pipe, closed at one end, may be used for this.

The aggregates, which mixed with cement in the required proportions produce the smallest volume of concrete, are usually the best, although, as already indicated, the shape of the particles and their hardness must also be taken into consideration.

## PROPORTIONING CONCRETE.

A general principle of practical use in determining the relative proportions of two or more aggregates in a concrete is that, the weight of material and the percentage of cement remaining the same, the mixture producing the smallest volume of concrete is the best.

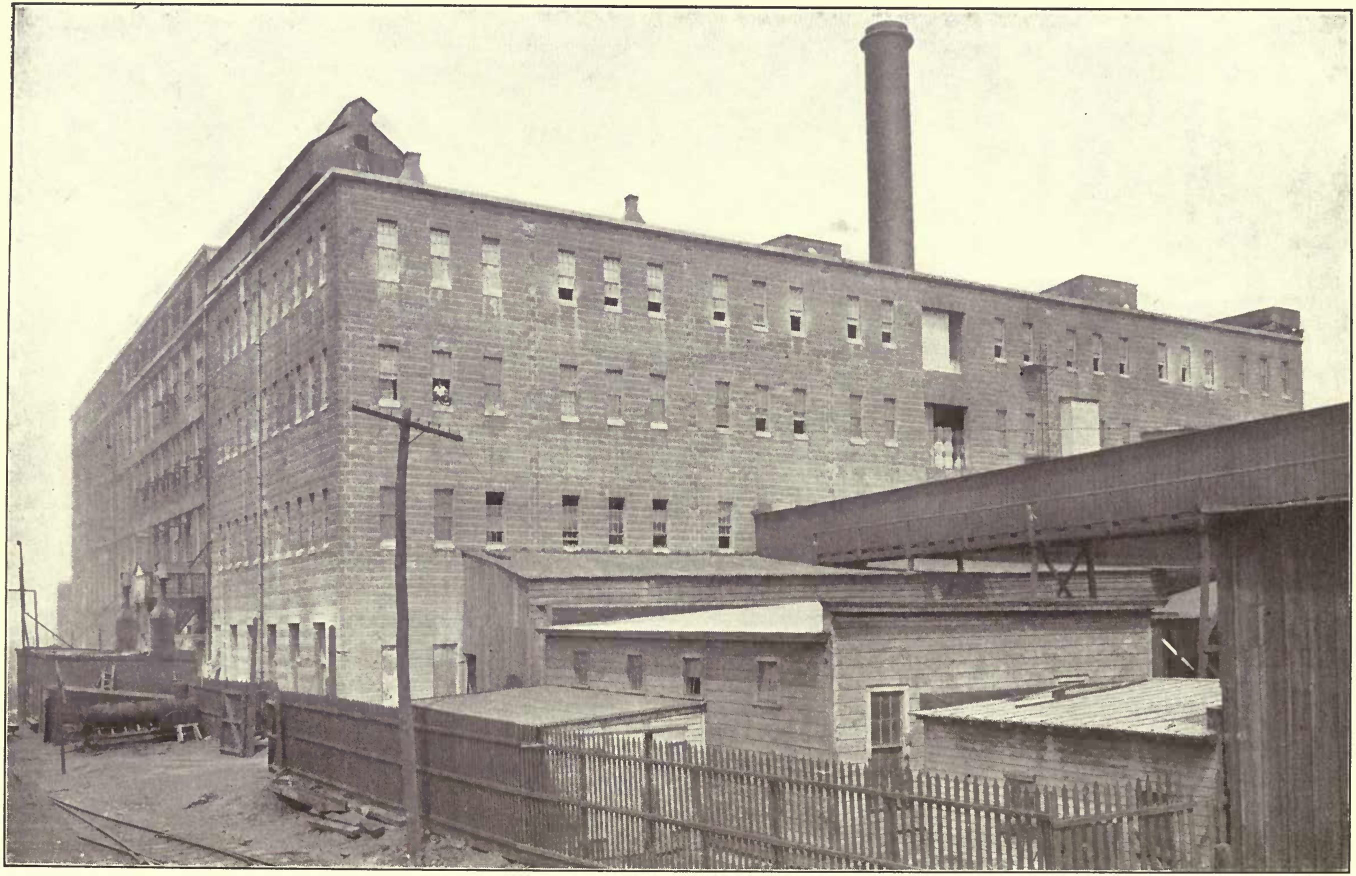

Fig. 1.—Pacific Coast Borax Refinery. *(See p. 47.)*

# CHAPTER IV.

## PACIFIC COAST BORAX REFINERY.

The distinction of being the designer and builder of the first two reinforced concrete factory buildings in the world undoubtedly belongs to Mr. Ernest L. Ransome, of the Ransome & Smith Company. Of these the Pacific Coast Borax Refinery at Bayonne, N. J., a few miles from Jersey City, deserves special attention not only as one of the earliest examples of this type of construction, but for its notable record in passing through a terrific fire without structural injury. Moreover, the fact that it was not erected until 1897-8 serves to emphasize the marvelous growth in reinforced concrete construction.

The time is so recent and reinforced concrete buildings are now so common that it is difficult to appreciate the boldness of the conception to construct a 4-story building, to sustain actual working loads of 400 pounds per square foot besides heavy machinery even on the top floor, out of a material until recently used almost exclusively for foundations, and considered capable of resisting only compressive loads. Of course, the principle of steel reinforcement in concrete had been understood for a number of years previous to 1897. In fact, a house of reinforced concrete was built in Port Chester, N. Y., as early as 1871, and a few other similar structures appeared between this date and 1897. But with the exception of the factory at Alameda, Cal.,* also designed and built by Mr. Ransome, the Pacific Coast Borax Building appears to be, as above intimated, the first attempt at concrete factory construction.

While it is not claimed that the design of this factory is in all respects typical of the up-to-date concrete factory building as now erected by the Ransome & Smith Company and other contractors, many of its features and the methods employed in its construction are well worth consideration.

As built to-day, double walls are not regarded as essential for factories, but instead the wall surface is usually taken entirely by windows separated by concrete columns which support the floors above. In the floor system, slabs of longer span with correspondingly heavier beams are now more common, while expansion joints in floors are not usually specified unless the building covers an extremely large area.

### DESIGN.

The main building is 200 feet long by 75 feet wide, and four stories

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* Illustrated on page 210.

high, rising 70 feet above the ground. Connected with this and forming a part of it is a section which was built first only one story high, and then after the fire carried up to the full four stories, as shown in Fig. 1. The area of ground covered by the combined buildings is 50,000 square feet.

The plan of the first story is shown in Fig. 2, the junction between the four-story and the one-story portion being indicated by the dot and dash line AA. In order to show the plan on a large scale, the first floor of the four-story building is drawn in full and a part of the one-story portion is omitted as indicated by the irregular lines BB.

The bays in general are 24 ft. 8⅞ inches x 12 ft. 4⅝ inches; the columns in the first story are 21 inches square, in the second story 19 inches, in the third story 17 inches, and in the fourth story 12 inches. They are computed by a maximum compression of 500 pounds per square inch.

The sectional elevation in Fig. 3 shows the columns and also the column footings which are reinforced in the bottom with horizontal rods. The footings were designed so that the compression upon the soil, which is of a marshy character, should not exceed 2,500 pounds per square foot.

Fig. 3 also illustrates the construction of the floor system, and, taken in connection with a plan of a portion of the second floor in Fig. 2, gives a good idea of the type of design. Girders connect the columns which are 12 ft. 4⅝ inches on centers. Between the girders and at right angles to them, run the concrete floor beams about 3 feet apart and so thin and deep that they resemble timber joists in appearance. As these beams are nearly 25 feet long in the clear, a stiffening web crosses them in the middle designed to serve the same purpose as bridging in wooden floor joist construction, that is, to assist in preventing tendency to buckle under heavy loads. The girders are of rather peculiar construction, being made thicker in the panels next to the columns so as to save expense in forms. (See Fig. 2).

Originally, the columns in the fourth story of the main building and also the roof were of wood, while the one-story part was of similar construction. After the fire the wood was all replaced by concrete, as shown in the plans. The roofs were then built as reinforced slabs of 12 ft. 4⅝ inches span from centre to centre of the beams, the latter being 24 ft. 8⅞ inches long between column centres. Still later the roof of the low part formed the floor for the second story when this portion of the building was raised to full height, as shown in the finished photograph, Fig. 1.

The reinforcement of the beams and girders and stiffeners of the principal floors is shown at the lower part of the diagram, Fig. 3. The slabs were built of such short span that they received no reinforcement, the depth being 4 inches in addition to the 1-inch cement finish.

The floors with the beams and girders were laid as separate panels about 24 feet square, a vertical contraction joint being carried down through the beams on a line with alternate columns; that is, every eighth beam was built double. As stated above, it is not now customary to insert contraction joints

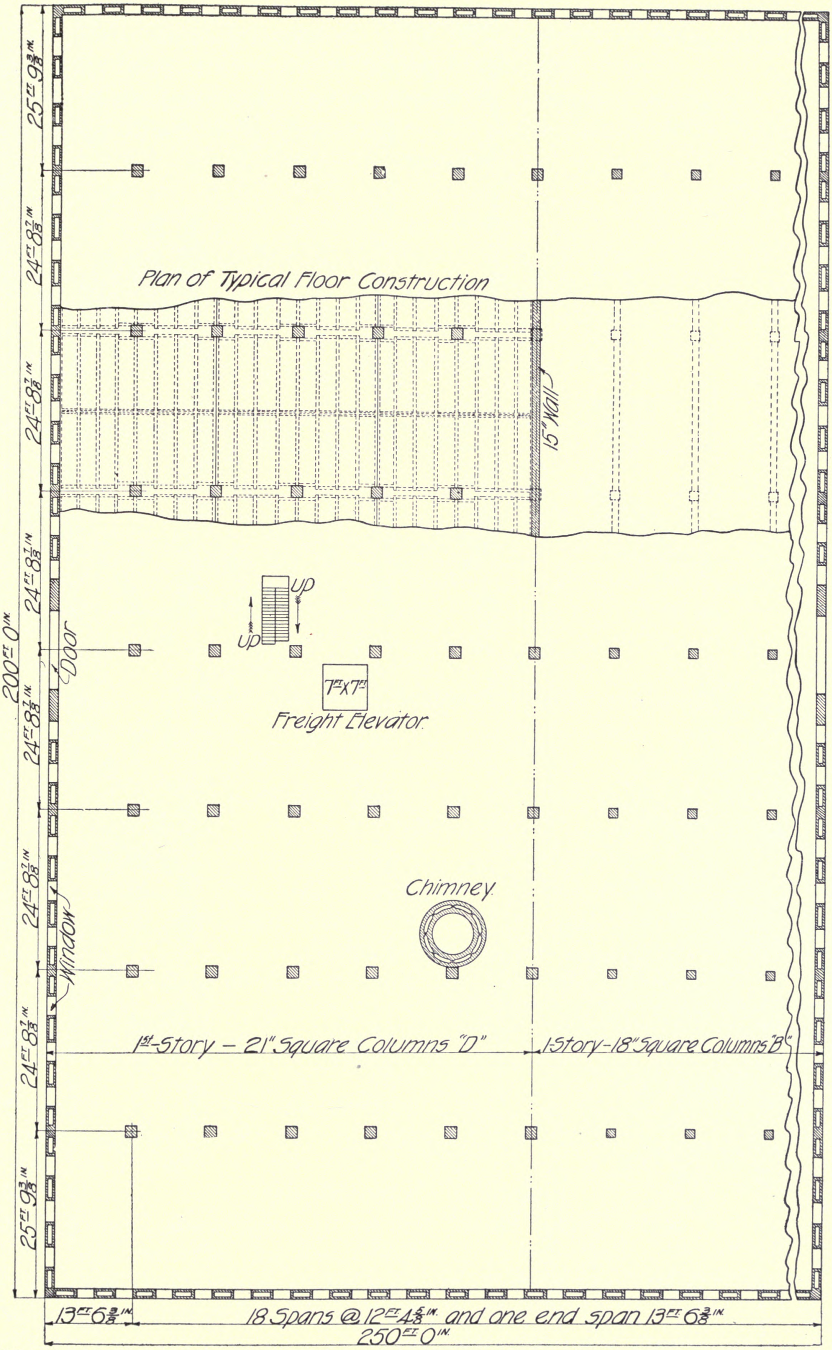

Fig. 2.—Plan of First Story of Pacific Coast Borax Refinery. (*See p. 48.*)

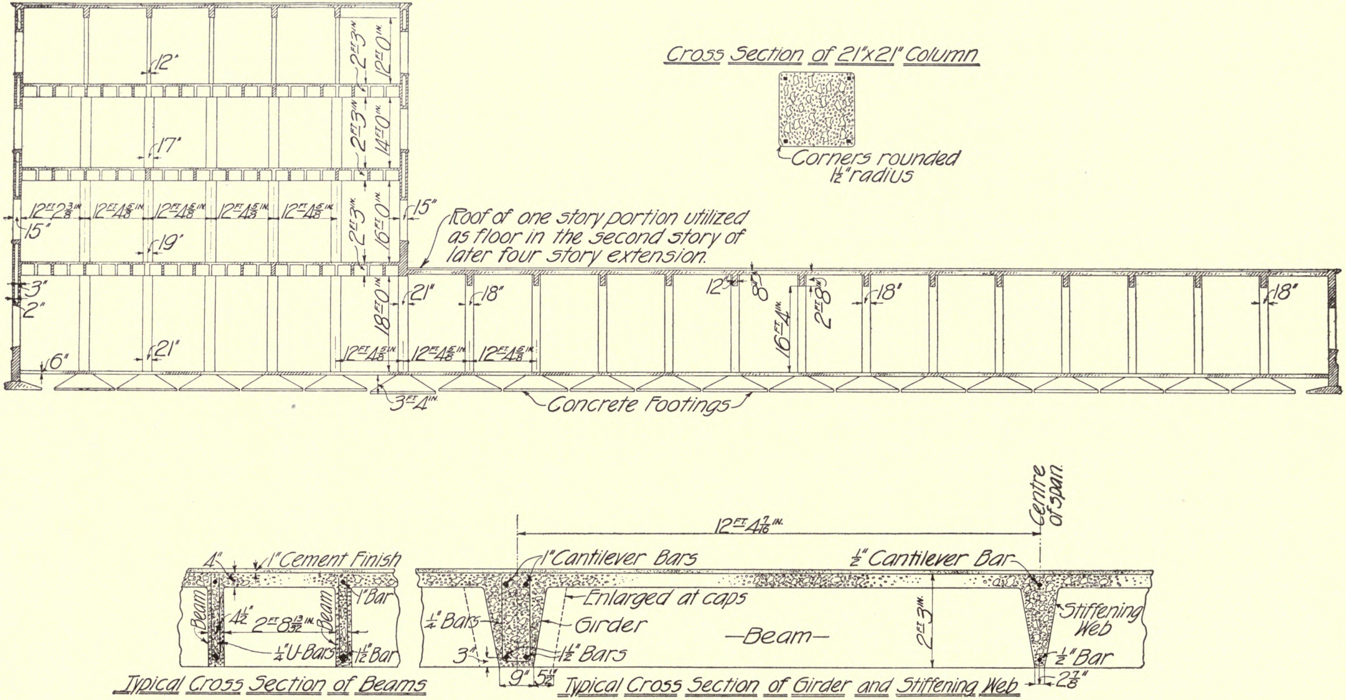

Fig. 3.—Cross Section of Pacific Coast Borax Refinery. (*See p. 48.*)

except on extraordinarily large surfaces, the contraction being provided for instead by the steel reinforcement in the beams and slabs.

Details of the hollow wall construction are presented in Fig. 4. The total thickness of all the walls is 16 inches for the entire height of the building, the outer surface being only 2 inches thick, and the inner surface varying from 4 inches in the first story to 1½ inches in the fourth story. The length of the hollow spaces in the walls is variable, depending upon the number and location of the windows. The webs connecting the two walls are 3 1/16 inches thick on the north and south sides of the building and 4½ inches thick on the east and west. This hollow construction has proved satisfactory and given a good roomy building with no condensation on the inner walls; but, as previously stated, it is not now considered necessary in factory construction to incur the expense of coring out the walls, and it is more usual to build them solid.

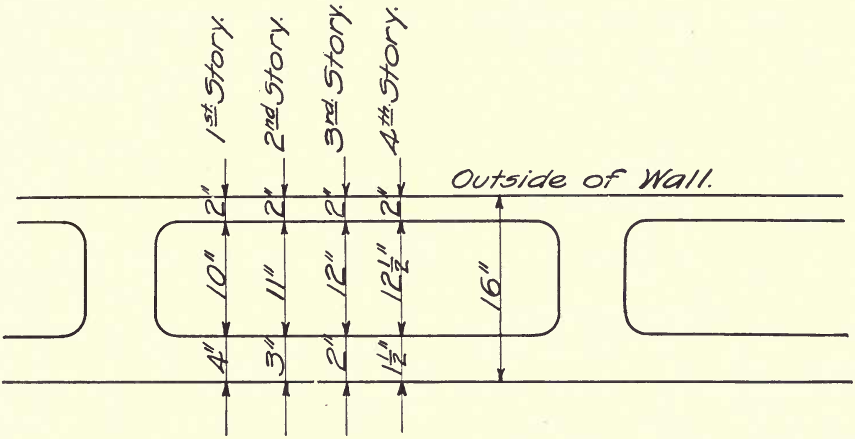

Fig. 4.—Typical Horizontal Section of Wall. (*See p. 51.*)

The exterior walls were finished by picking the surface with a sharp tool which removed the outside skin of cement so as to show the stone and mortar between and resemble pean hammered masonry. A part of this work was done by hand and part with pneumatic hammers. Although a pneumatic hammer averaged about 400 square feet in ten hours, while by hand 100 to 150 square feet was a fair day's work for a man, the actual cost with the power tool was but slightly less than by hand because of the higher grade of men required, the extra men for shifting air pipes, etc., and the wear and tear on the tools.

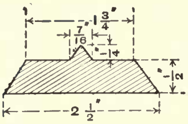

Fig. 5.—Molding of Wall Joints.* (*See p. 52.*)

The surface was also divided into blocks by wood moldings nailed to the inside of the form. A section of the molding is shown in Fig. 5.

The stairs are also of reinforced concrete, typical details being given in Fig. 6.

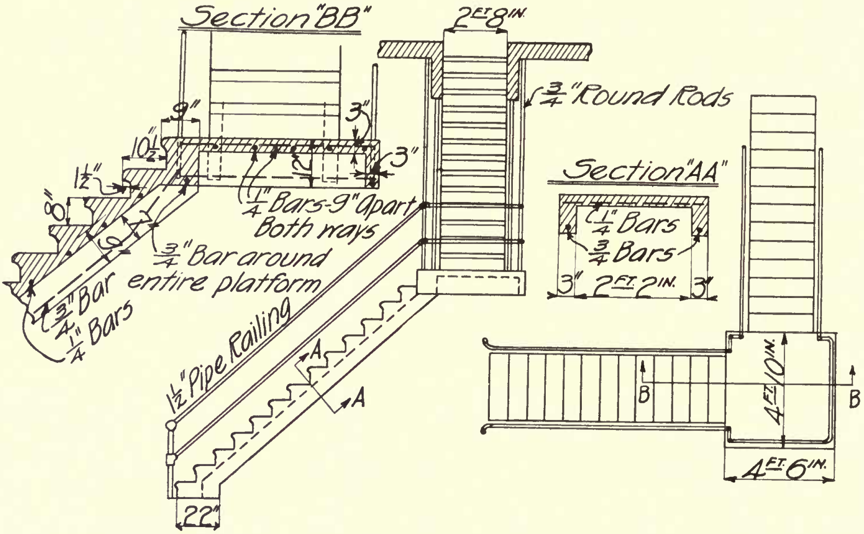

Fig. 6.—Sketches of Stair Construction. (*See p. 52.*)

In Fig. 7 is shown the 150 foot concrete chimney which is located in the middle of the building. (See Fig. 2). It was built with two independent shells of concrete.

## PROPORTIONS OF THE CONCRETE.

The proportions of cement to aggregate in the concrete varied in different parts of the work. For the aggregate, broken basaltic rock brought down from the Palisades of the Hudson was chiefly used. The size was limited to

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* Reproduced by permission from Taylor & Thompson's "Concrete, Plain and Reinforced."

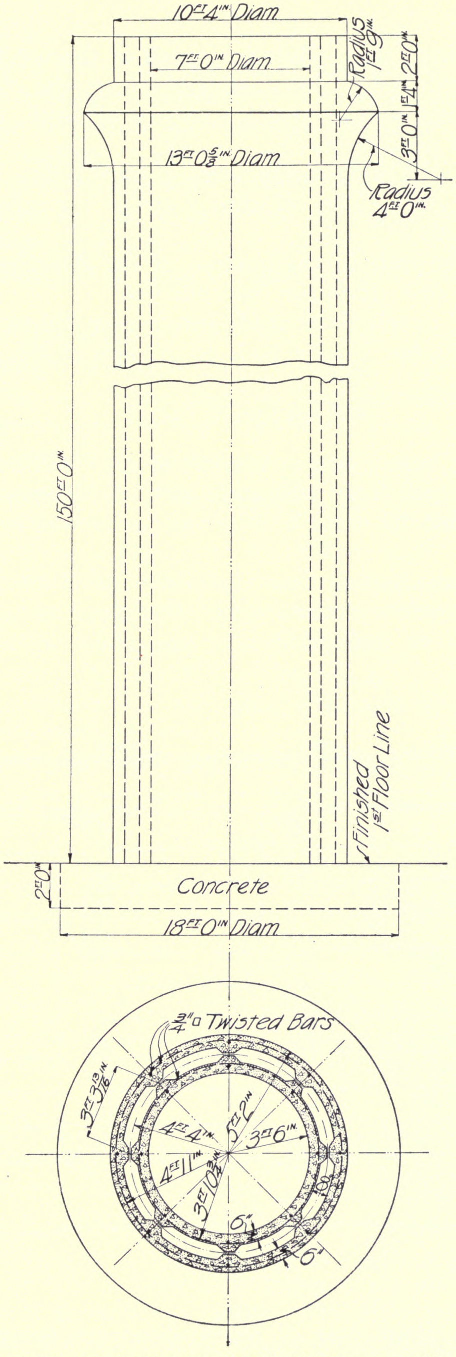


Fig. 7.—Plan and Elevation of Chimney. *(See p. 52.)*

particles passing a 2-inch ring, while for much of the work that which passed a 1-inch ring was employed. The dust was left in the rock and provided so much fine material that only a small quantity of sand, averaging not more than 10 per cent., was needed.

The proportions of the footings were 1 part Atlas Portland cement to 10 parts of this aggregate. The columns were of 1:5 mixture, and the walls, floors and stairs of 1:6½.

For imbedding the rods in the bottom of the floor beams a 1:6 mix was employed, using very fine stone for the concrete.

Concrete of 1:6½ proportions made into 3-inch cubes gave a compressive strength of 900 pounds per square inch at the age of 7 days.

## CONSTRUCTION.

Construction was begun late in the fall of 1897 and completed in October 1898. The usual time per story was 40 to 50 days, whereas now such a building would be put up by the same builders at the rate of a story in one or two weeks.

The materials for the concrete included 10,000 barrels of cement and nearly as many cubic yards broken stone, the stone being brought in scows down the Hudson River and piled near the shed, in which 1,000 bags of cement were stored.

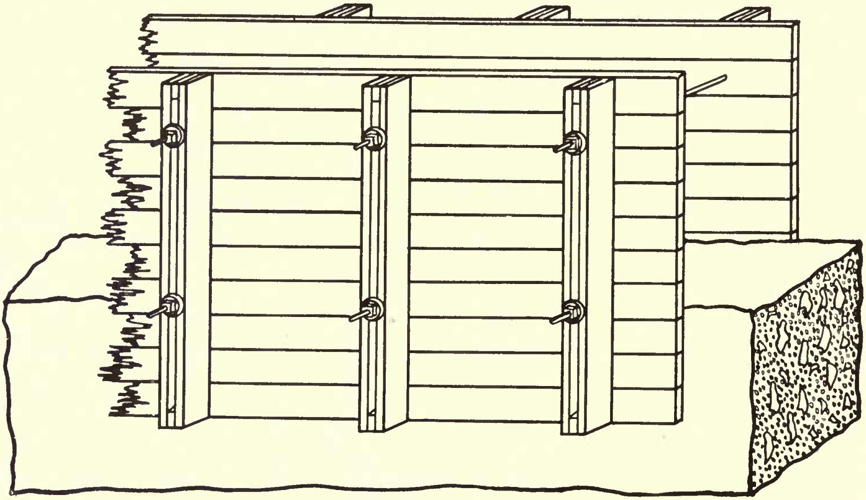


Fig. 8.—Type of Wall Molds. (*See p. 55.*)

The construction plant was of quite elaborate design. The cement having been wheeled from the shed and the stone measured in barrows, both materials were dumped into a hopper which discharged into a car. This car was hauled by cable through a subway and then up an incline to about 30 feet above the hopper and about 400 feet distant, where it was automatically tipped into a chute leading to the mixer. The mixer, of substantially the same type as the Ransome machines now in general use, discharged into a trough containing a screw conveyor which delivered the wet concrete to a vertical bucket elevator and this hoisted the material to the story where it was required, and dumped it upon a platform which held about one cubic yard.

A steam engine operated the car, mixer and elevator, and also ran a twisting machine, bolt cutter and two or three other tools. The column forms were built in the usual way with vertical boards paneled together, and held with clamps surrounding them. The wall forms were ⅞ inch dressed boards, designed in general like Fig. 8.

These forms, patented by Mr. Ransome in 1885, are still extensively used in wall construction. The special feature is the vertical standard made of two 1 by 6 inch boards on edge with a slot between, through which passes the bolts. By loosening the nut, the plank behind the standards may be loosened and the standards raised. The walls were built in sections 4 feet high with central cores to form the hollow walls.

White pine was used for forms, and the salvage on the lumber probably did not amount to more than 10 per cent., although by present methods the builders usually figure about 30 per cent.

The total cost of the building was in the neighborhood of $100,000.

## THE FIRE.

Some four years after completion, in the spring of 1902, the Refinery was subjected to one of the most severe fires to which a manufacturing building is liable. Although the building itself is of concrete, it contained a large amount of wood in the form of partitions, window frames and bins, in addition to the wooden roof, and at the time of the fire one room happened to be completely filled with empty wooden casks which provided yet more fuel for the flames. Some of the material used in the manufacturing process was also extremely inflammable.

To illustrate the heat of the fire, an insurance man called attention to the fact that the plank roof was entirely gone, with no charred wood remaining, the brass in the dynamos was melted, and at least in one case a piece of cast iron was fused into a misshapen mass. A photograph of the melted cast iron is shown in Fig. 9.

This fusing of the iron is especially remarkable since cast iron melts at the high temperature of about 2,200° Fahr. The piece appears to be a portion of a pulley which was probably located near an opening in the floor through which there was a tremendous draft of flame.

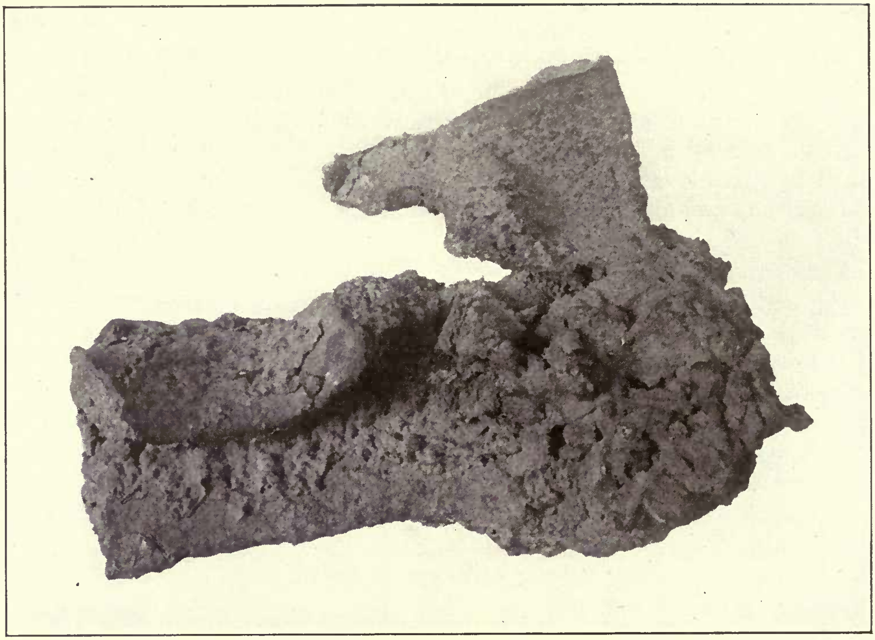


Fig. 9.—Photograph of Cast Iron Melted by the Fire. (*See p. 55.*)

The chief structural damage to the building at the time of the fire was caused by the fall of an iron tank which was located on the wooden roof and supported by timbers from the fourth floor. This weight coming suddenly upon the floor broke the slab and tow or three of the floor beams, but did not pass through to the floor below, being caught by the damaged floor.

In several places throughout the building the concrete had been split off by the fire to a depth of 1/4 to one inch, and on one of the exterior walls a few cracks showed over a doorway. The total cost of repairs, including the portion of the floor broken by the tank, was in the neighborhood of $1,000. The broken beams were repaired by inserting new concrete in the central portion and supporting it by bolts run down through the ends of the beams which still remained in place.

As a result of the fire the structure was completely gutted, nothing remaining but the reinforced concrete and a mass of charred wood, with the machinery, shafting, dynamos, etc., melted or twisted out of shape. A photograph taken directly after the disaster before any repairs were made is given in Fig. 10. This photograph also presents a very good view of the Refinery itself with the main building and the one-story addition.

In contrast with the durability of the reinforced concrete under the action

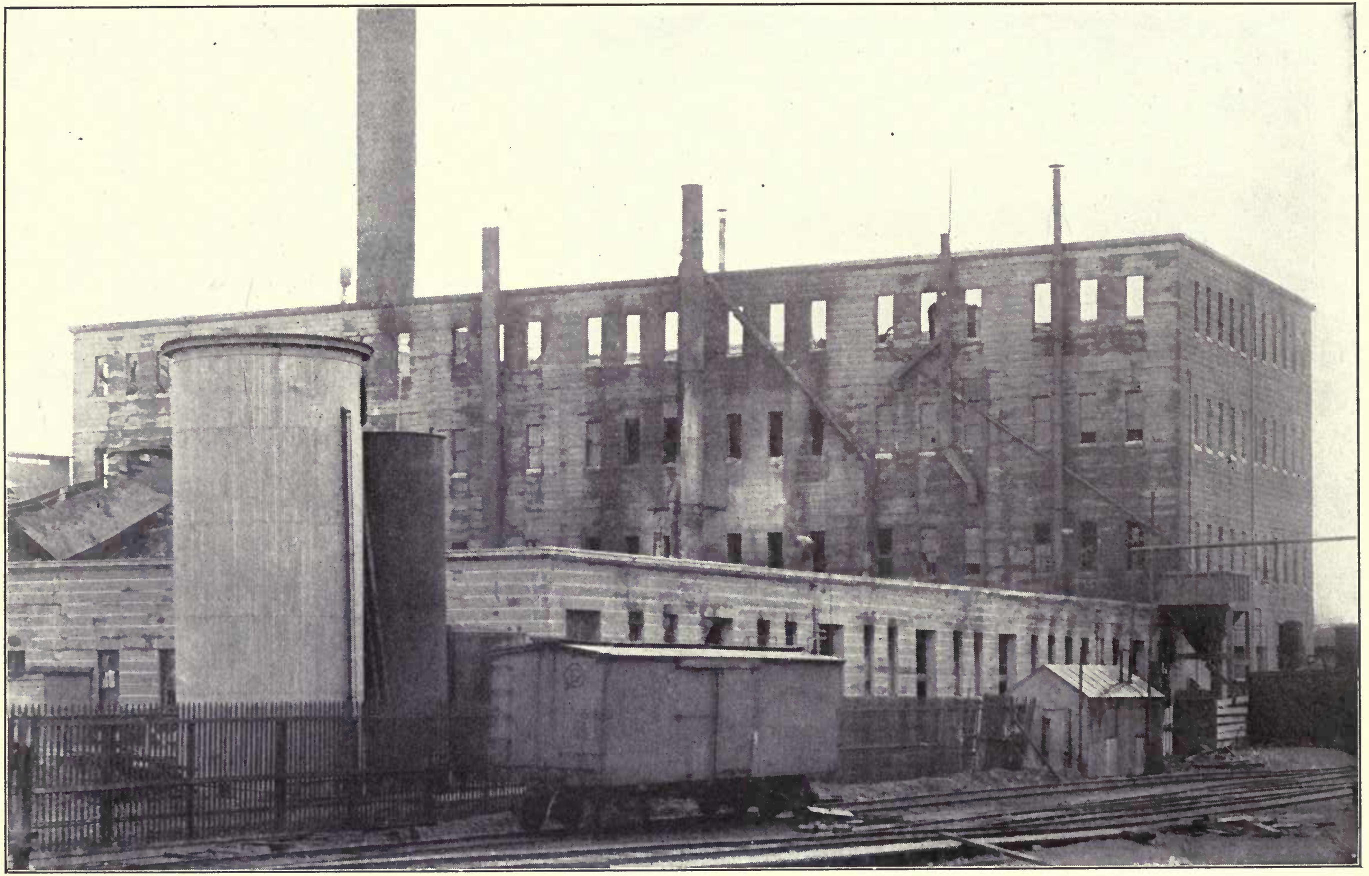


Fig. 10.—View of Refinery After the Fire. (*See p. 56.*)

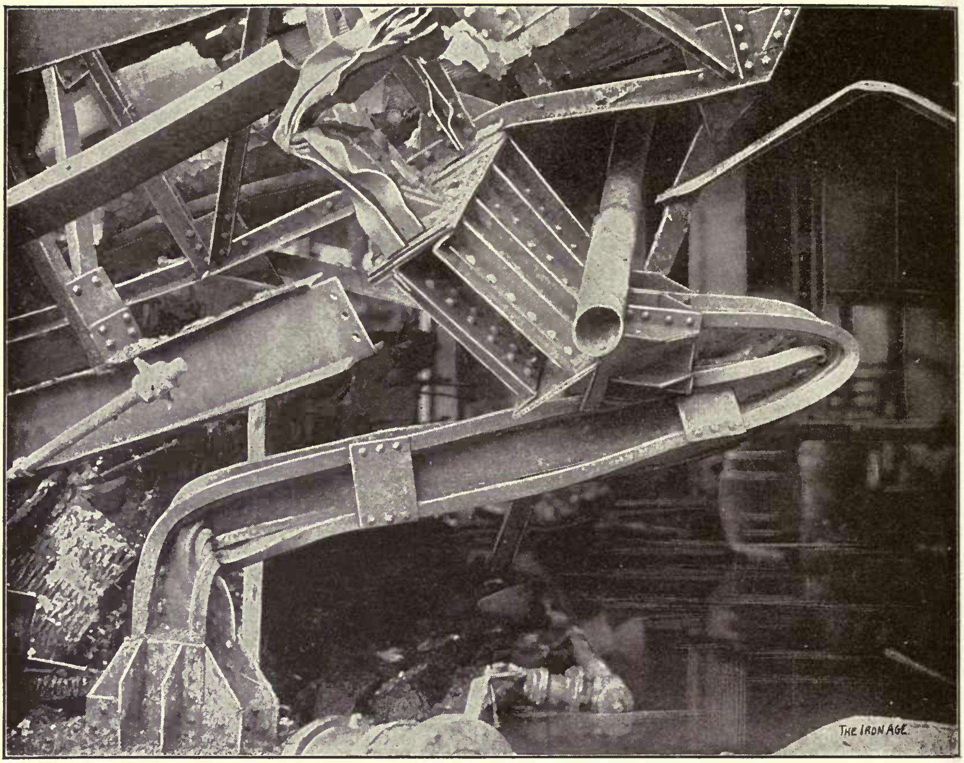


Fig. 11.—Effect of Fire Upon Steel Tank House. (*See p. 58.*)

of the fire is a steel tank house adjoining the building. This was built with steel columns and roof girders, and the effect of the heat upon the steel structure is graphically shown in Fig. 11.

A photograph of the Refinery, taken in 1907 and shown as Fig. 1 on page 46, presents one view of the buildings, and in Fig. 12 is another 1907 view, showing in the foreground the new part also built by Ransome & Smith and the older structure in the background.

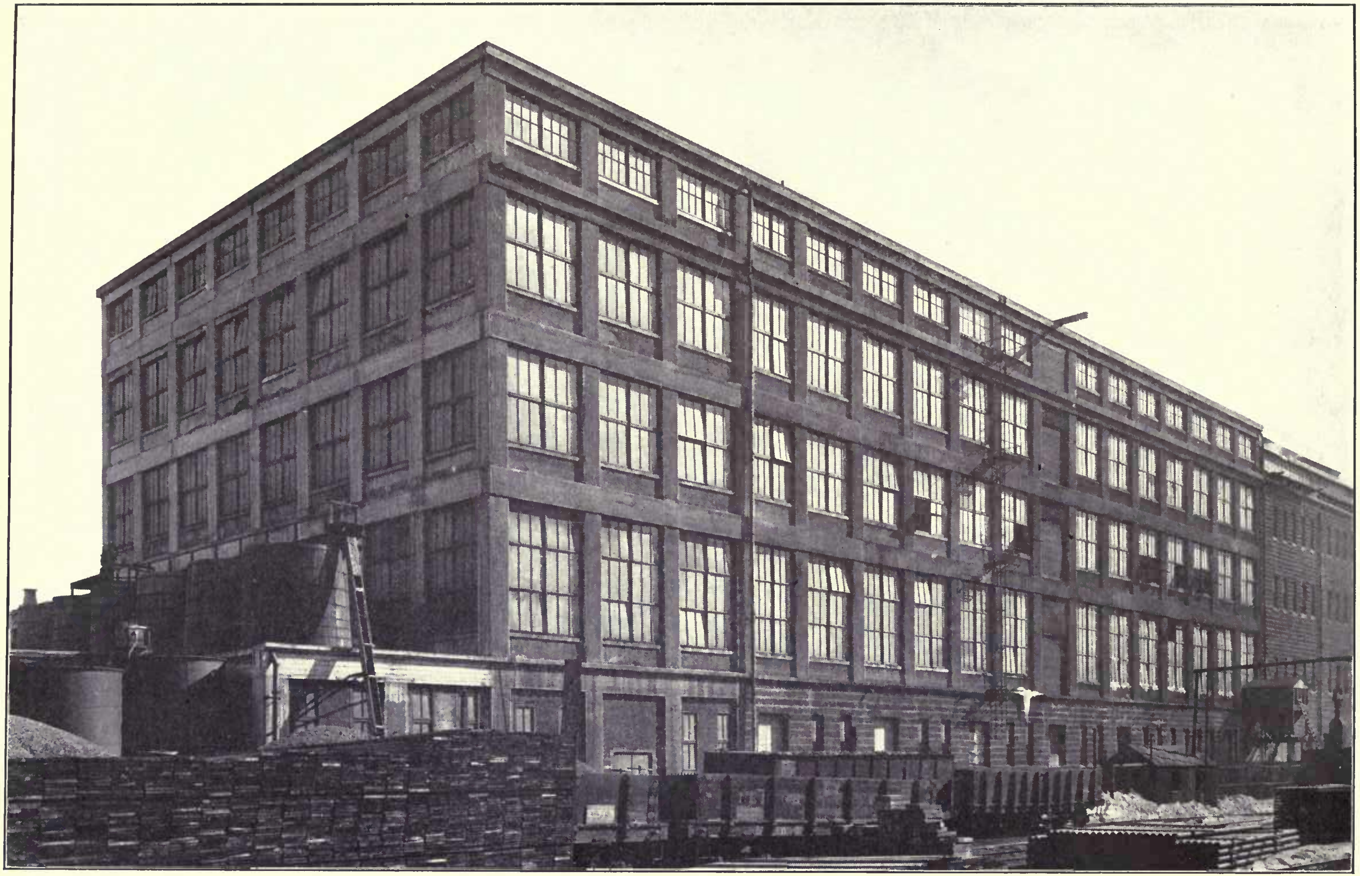


Fig. 12.—View of Refinery, Including New and Old Structures. (*See p. 58.*)

Fig. 14.—The Ketterlinus Building. (*See p. 61.*)

# CHAPTER V.

## KETTERLINUS BUILDING.

The plant of the Ketterlinus Lithographic Manufacturing Company is located in Philadelphia at the northwest corner of Fourth and Arch streets, and the reinforced concrete portion of the structure built in 1906 represents a type of building adapted to city manufacturing establishments limited to a comparatively small ground area. The building illustrated on the opposite page as Fig. 14 is eight stories high besides the basement, and its dimensions are 80 by 67 feet. The architects and engineers were Ballinger & Perrot, of Philadelphia, and they also supervised the erection, which was done by day labor with no general contractor.

This new building adjoins and forms a part of the old plant of the Ketterlinus Company, which is of steel frame construction, fireproofed with terra cotta.

In both buildings heavy machinery is now running, and many large printing presses are at work on the third, fourth and fifth floors. Because of the proximity of the old and new types of construction the advantages of the reinforced concrete from the point of view of the manufacturer are particularly evident. In the building of steel and terra cotta construction the vibration from the machinery is noticeable as soon as one enters, while, on the other hand, in the new structure the concrete because of its greater mass and inertia, absorbs the vibrations, and it is difficult to appreciate the speed and power of the machines. As a result, too, of this reduction in the vibration the noise of the machinery is effectually deadened.

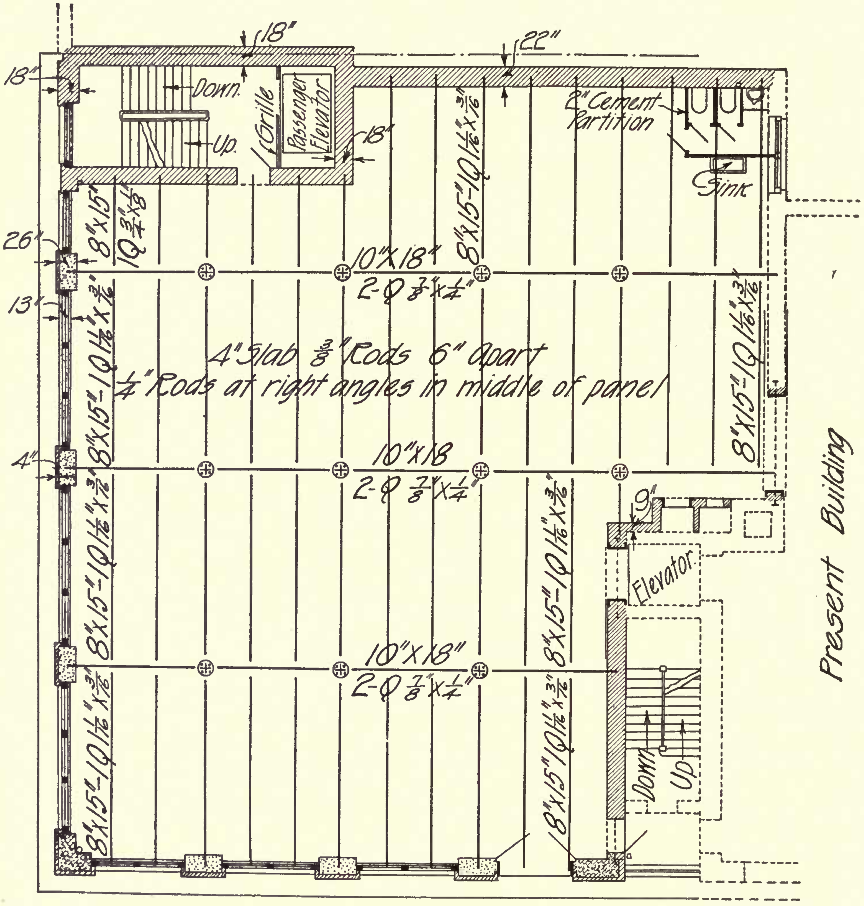
The building is designed for a working load of 400 pounds per square foot. The concrete for practically the whole of the work was proportioned 1:2½:5, equivalent by actual measurement to one barrel (4 bags) Atlas Portland cement to 9½ cubic feet of sand to 19 cubic feet broken stone, the basis of proportioning is in a barrel of 3.8 cubic feet. The sand was well graded coarse material, frequently termed in the region of Philadelphia "Jersey gravel"; the stone was trap rock broken to a size at which all the particles would pass a one-inch ring excepting the stone in the concrete immediately surrounding the steel, which was of a size to pass through a half-inch ring.

To harmonize with the old adjoining building of which it forms a part, the exterior walls are faced with brick with terra cotta trimmings.

## DESIGN.

Several features in the design of the Ketterlinus building are of unusual interest. The columns below the fifth floor, instead of the usual solid concrete construction with four or more round rods for reinforcement, are essentially steel columns surrounded by concrete. The beams and girders are reinforced with the unit frame system in which the steel is all put together in the shop and brought to the job ready to place in the form. The sawtooth roof is also a novel feature for reinforced concrete.

The columns are spaced 13 feet 6 inches apart in one direction and 19 feet 2 inches in the other. The girders follow the shorter span, and the bays are divided into three panels by the cross beams, as shown in Fig. 15. The vertical section, Fig. 16, also illustrates the arrangement of the columns and beams, the window lintels and the sections of brick wall below the windows.



THIRD FLOOR PLAN

Fig. 15.—Typical Floor and Roof Plans of the Ketterlinus Building. (*See p. 62.*)

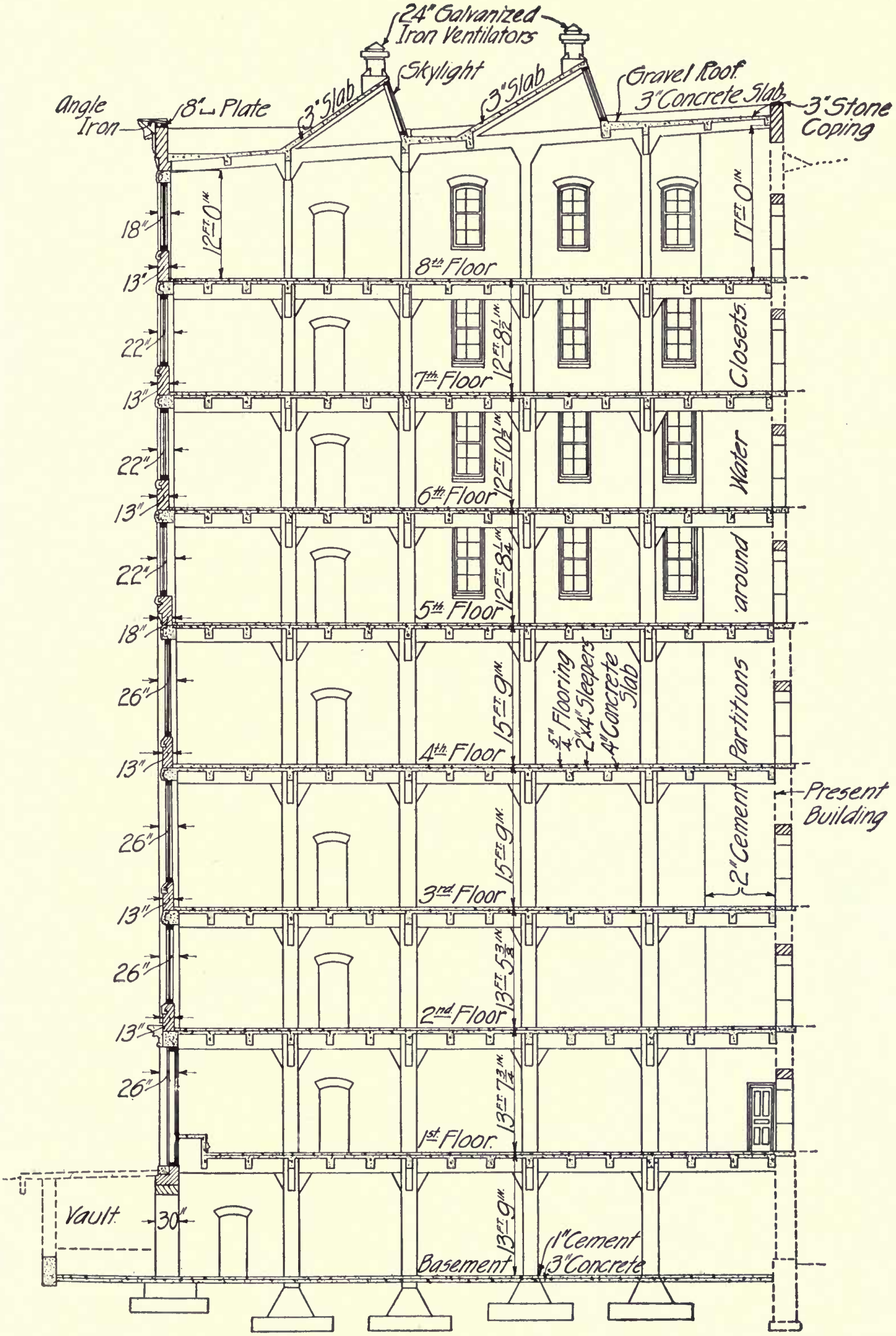
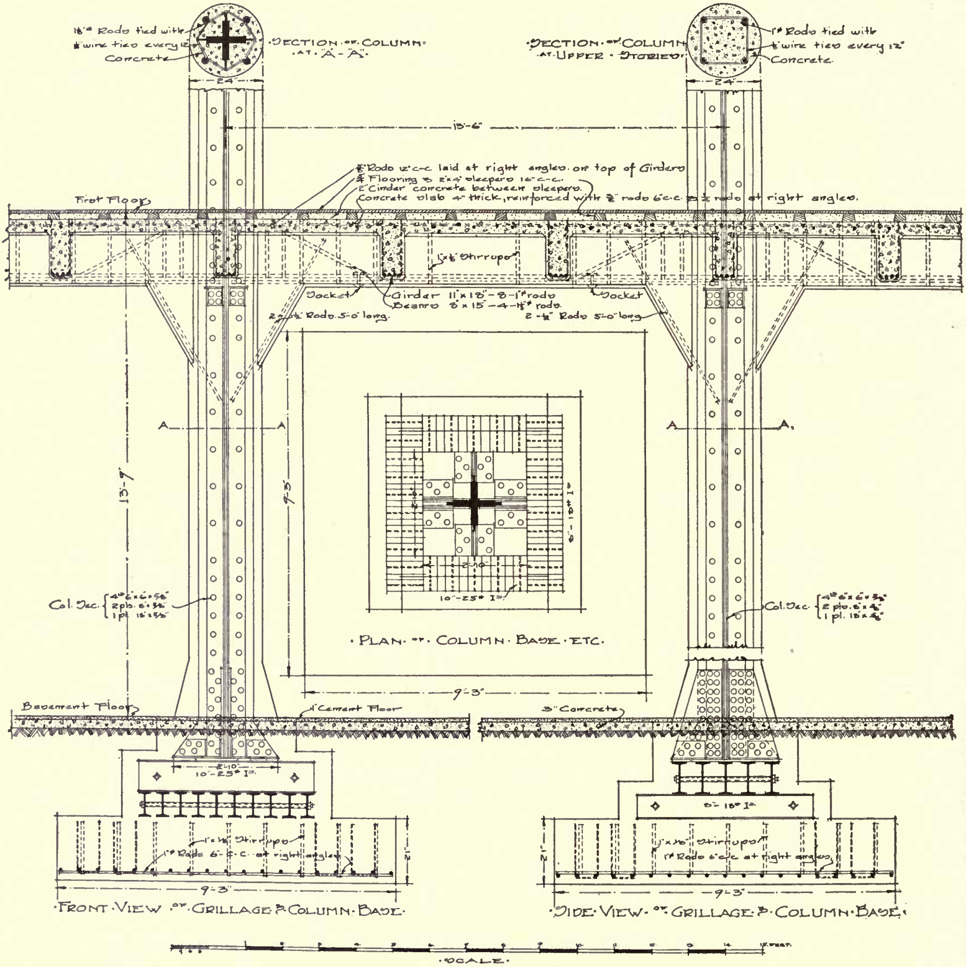


Fig. 16.—Cross-Section of Ketterlinus Building. (*See p. 62.*)

## COLUMNS.

One of the problems in concrete building construction where the loads are heavy or the building is several stories high is to build the columns small enough to satisfy the requirements of the occupants and owners without overloading the concrete. Its solution is especially difficult in a city building where the land area is so valuable that every square inch of floor space is at a pre-



·DETAIL·OF·UNIT·GIRDER·FRAME·CONSTRUCTION·
WITH STAR SHAPED STEEL REINFORCEMENT IN COLUMN
BALLINGER & PERROT
ARCHITECTS & ENGINEERS
1200 CHESTNUT ST. PHILA. PA.

Fig. 17.—Details of Columns and Girders. (*See p. 65.*)

mium, and where there must be more stories than are economical under other conditions. Moreover, the building laws of many cities require more conservative loading than might be warranted if it were certain that the conditions of construction were in all cases the best.

In a number of recent instances the difficulty has been met by the use of composite columns, a combination of concrete and structural steel, and this is the plan followed by the designers of the Ketterlinus building. Full details of the column construction are presented in Fig. 17.

The interior columns in the building up to the fifth floor are 23 inches in diameter. In the basement and the four lower stories, the core of the column is formed of steel plates and angle irons riveted together in the form of a cross. Around this cross 1/8 inch wire ties were placed every 12 inches and looped around four vertical round rods which increased the reinforcement. In the basement, for example, the centre steel is made up of a plate 18 inches wide and 5/8 inch thick with two plates of similar thickness but 8 inches wide at right angles to it, and four angle irons 6 by 6 by 5/8 inch all riveted together. The four round rods, which complete the so-called "Star" reinforcement are 1 1/8 inch diameter.

The columns in the three stories nearest the top are designed to carry the full dead and live loads of floors and roof. In each lower story the columns are designed to carry the full dead load and a smaller proportion of the full live load than can be carried by the floor construction, this live load factor being reduced proportionately to the number of floors carried; for example, the basement columns were calculated on a basis of carrying on the steel cores alone three-fourths the live load plus the full dead load with a factor of safety of 4.

The steel is designed to bear the computed load without exceeding a maximum compression of 16,000 pounds per square inch. The compressive strength of the concrete in these columns is not considered, though almost sufficient to carry the dead load.

The weight of the girders is borne in part by brackets of steel riveted to the angle irons and partly by the concrete knees or enlargements of the column which run out obliquely from the columns and which are reinforced on each side by two 1/2-inch rods.

Above the fourth story the columns are of the same diameter but with the more ordinary reinforcement of four round rods.

## COLUMN FOOTINGS.

To transmit the compressive load from the steel in the columns to the soil, a special design of footing was prepared. A large base was necessary to prevent too great loading of the soil beneath the building, and in order that the pressure from the column might not break or crush the concrete over this large area a grillage of steel I-beams was placed under each column (See Fig.

17), and the concrete below these I-beams further strengthened against breakage and shear by 1-inch horizontal round rods placed 6 inches apart, and ⅛ by 1-inch stirrups.

## FLOOR SYSTEM.

Each girder was designed as an independent beam supported at the ends by the enlargement of the columns and the steel brackets. The area of the reinforcing steel was calculated in the usual way, but instead of placing each rod separately in the form, girder frames were made from quadruple or twin webbed bars, which were cut, bent to shape and stirrups fastened thereto in the shop. The girder frame reinforcement was brought to the building in the form of a truss, and the work of placing consisted simply of setting this truss in the form upon cast steel sockets, each having a ¾-inch threaded stud projecting upward through the frame. A nut screwed down on this stud over the frame holds it rigidly in position. Every rod and every member could not help but be in exactly the right location in the beam. This girder frame and socket were the invention of Emile G. Perrot, one of the firm of architects who designed the building, the object being to insure the exact amount and arrangement of tension and shear members in the exact location as designed, and to afford opportunity for inspection of the steel in position before the pouring of the concrete.

In the various plans the letter "Q" is entered as a part of the description of the reinforcement. This stands for the word "Quadruple" and indicates a group of four rods held at intervals by special sockets.

The rods are rolled in sets of four connected by a web, and this web is sheared and bent down in 2-inch lengths at intervals of 3 inches to give greater grip in the concrete. These 2-inch lengths are bent back over stirrups, where they occur, to clinch them in position on the frame. The outside bars are also cut loose at each end and bent upwards to reinforce the top of the beam near the supports. The sockets (Fig. 17) are shaped so that they support the rods 1½ inches above the bottom of the beam or girder, and are held in place by a ¾-inch bolt passing up through the bottom of the wood mold. These threaded sockets afterwards are used for securing shafting, hangers or other fixtures.

In the various dimensions of beams on the plan the width and depth is given first, followed by "1 Q" or "2 Q" (the latter meaning 8 rods), then the diameter of rod, and finally the thickness of the web forming a part of the rods. Thus 10″x18″-2Q⅞″x¼″ means that the beam is 10 inches wide by 18 inches deep, reinforced with two groups of four rods ⅞ inch diameter, connected longitudinally by webs ¼ inch thick. The depth of the beams and girders is given from the under side of the slab instead of from the top of the slab, the more usual form. The area of cross-section of each of such "Q" bars is about 3 square inches.

The slabs are of usual construction, being 4 inches thick and reinforced for the net span of 3 feet 10 inches with 3-inch No. 10 expanded metal, this mesh having been substituted instead of ⅜-inch rods spaced 6 inches apart and occasional ¼-inch rods running in the other direction, as originally shown on the drawings, at an increase of about one per cent. of the cost of the building.

The wearing surface is a 1¼-inch maple wood floor on 2 by 4 inch sleepers 16 inches apart. The sleepers are placed on the concrete slab and cinder concrete in proportions 1:3:7 filled in between them.

## STAIRS.

The stairs are carried up in brick towers, as required at date of construc-

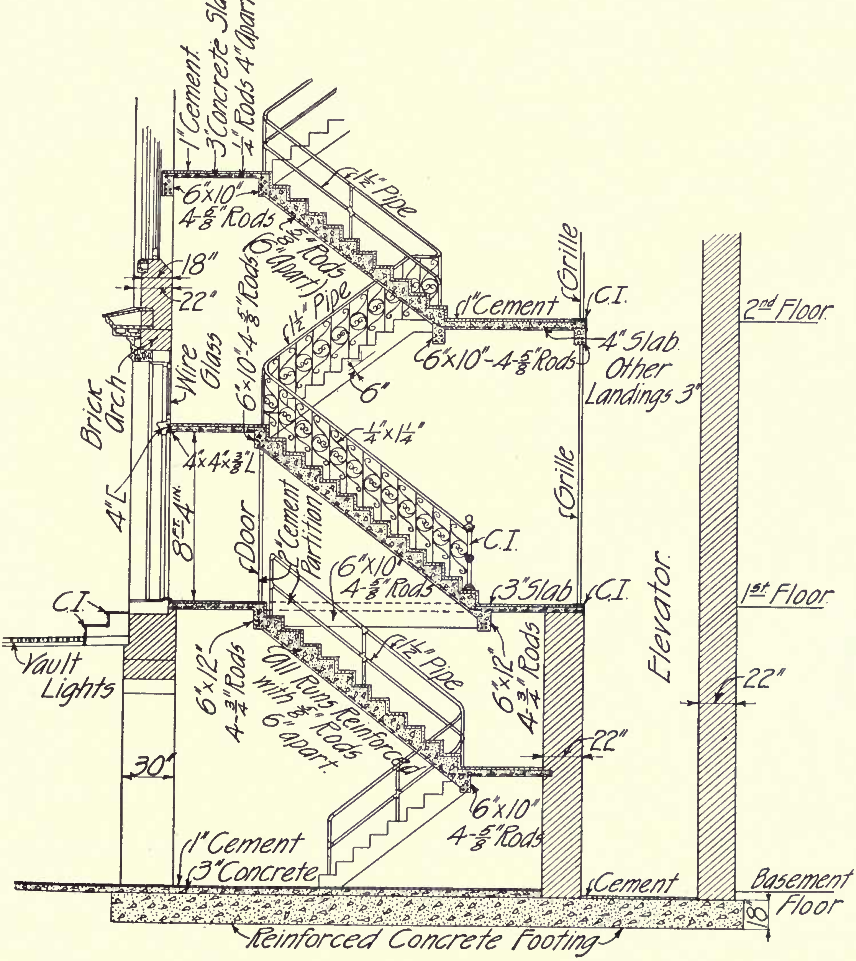


Fig. 18.—Stairs in Ketterlinus Building. (*See p. 67.*)

tion by the Philadelphia building laws. The details of the design and reinforcement are illustrated in Fig. 18.

The treads are formed by 1 inch thickness of 1 to 1 mortar or granolithic finish, and the reinforcement consists of ⅝-inch rods placed 6 inches apart.

## WALLS.

The walls are essentially reinforced concrete columns, veneered on the outside with 4 inches of brickwork and separating the windows. The window lintels are of concrete faced with terra cotta to match the red sandstone of the older building adjoining and anchored to the concrete. The lintels form reinforced concrete beams and support a brick wall 13 inches thick, which is run up to the bottom of the terra cotta window sills.

The method of connecting the brick with the concrete of the columns is shown in Fig. 19, copper wall ties 1/16 by ¾ by 7 inches being set in the concrete at intervals, and, after the removal of the forms, bent out and laid into the joint of the face brick, which is separated from the concrete by a ¾-inch mortar joint for purposes of alignment.

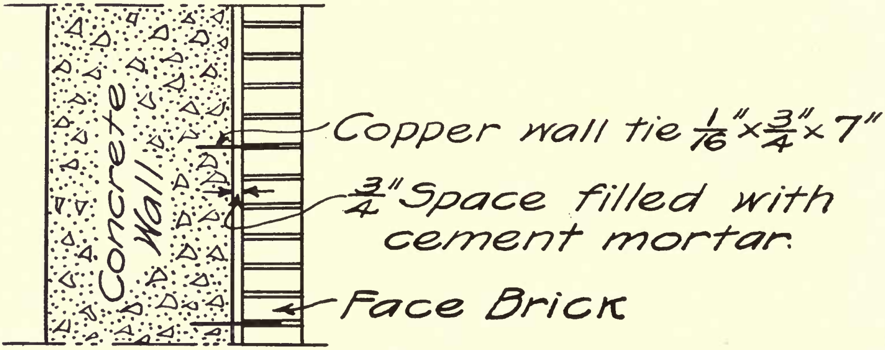


Fig. 19.—Brick Wall Ties. (*See p. 68.*)

## ROOF.

The general design of the saw-toothed roof appears on the full cross-section, Fig. 16 (p. 63). In Fig. 20 the details are illustrated. Inclined girders extend across the building, and above these project the saw teeth, which rest upon concrete beams running into the girders. Saw-tooth construction in reinforced concrete is, of course, expensive, because of the irregularities of the forms, but with the aid of the unit reinforcing system, which accurately locates the steel, the design is satisfactorily worked out.

As in the other plans, the letter Q indicates a quadruple bar whose web thickness is designated by the final fraction in the dimensions. In the roof, instead of the four bars being on one plane and rolled all together with a single web, they are arranged in pairs with a web connecting the two bars of each pair.

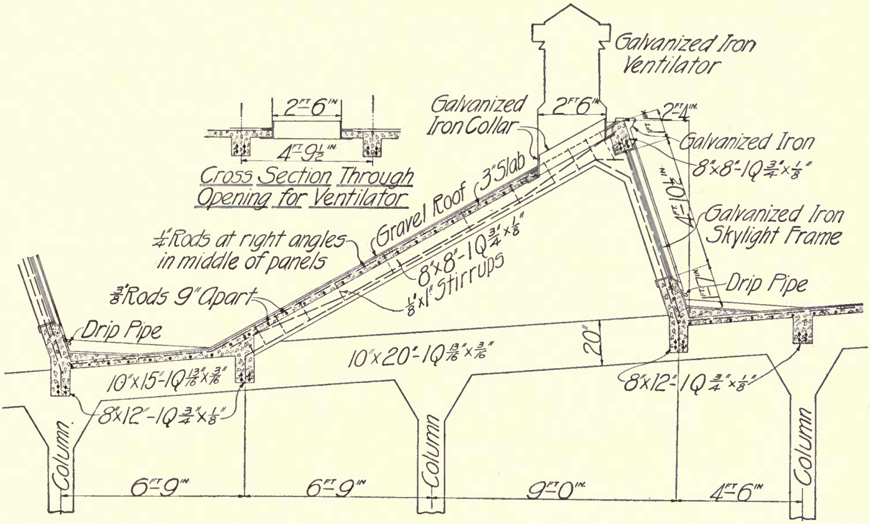


Fig. 20.—Cross-Section Detail of Saw-Tooth Roof. (*See p. 68.*)

## CONSTRUCTION.

The concrete was mixed in the basement by a Smith machine, dumped from the mixer into wheelbarrows and raised on a platform elevator located in the stair tower to the floor in process of construction, when it was wheeled in the same barrows and dumped directly into the columns or floor.

A boom derrick was employed to handle the steel columns, lumber and brick. This derrick was also used for demolishing and excavating before the concrete was started.

A photograph of one of the floors ready for the concrete is shown in Fig. 21. The wood forms for the beams, girders and slabs are in place, and the steel of the columns is set and temporarily braced with plank. In different places on the floor the unit girder frames are seen, some of them in place in the mold and some lying on the floor ready to be carried and lowered to position.

Fig. 22 shows the exterior of the building in a later stage of the construction. The column forms have not yet been removed from some of the columns, and many of the braces are still in place. The framework of the platform elevator projects above the structure at the left of the photograph, while the boom derrick is seen to be located on the roof of the old part of the building.

The progress per story varied from eleven days to three weeks. The forms were left in place two weeks or more and were used three times, the approximate salvage on the lumber for the next job being 25 per cent.

The interior of the building is photographed in Fig. 23 (p. 72), and shows one of the 20-ton lithographic presses.

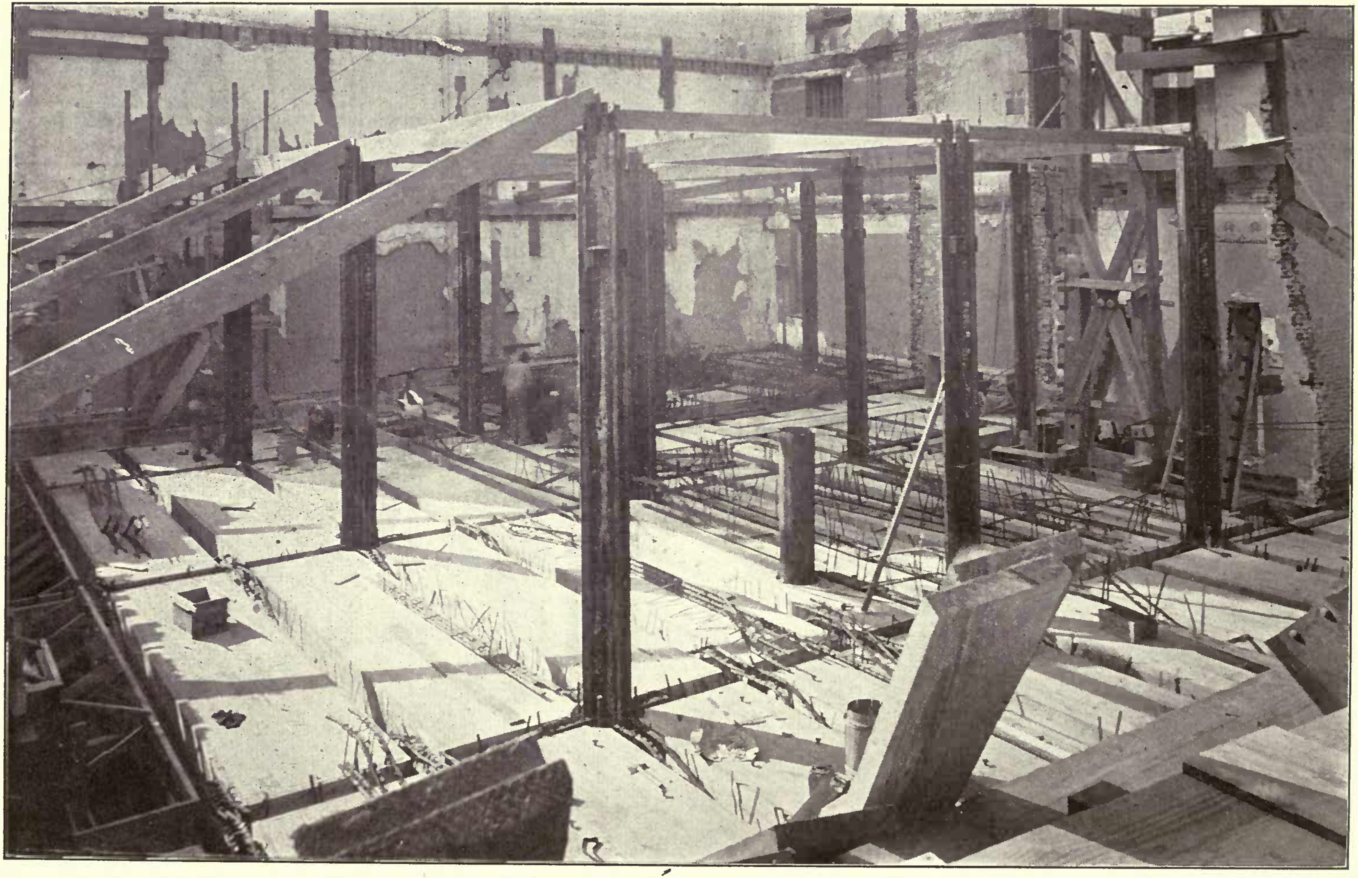


Fig. 21.—Placing the Reinforcement in the Ketterlinus Building. (*See p. 69.*)

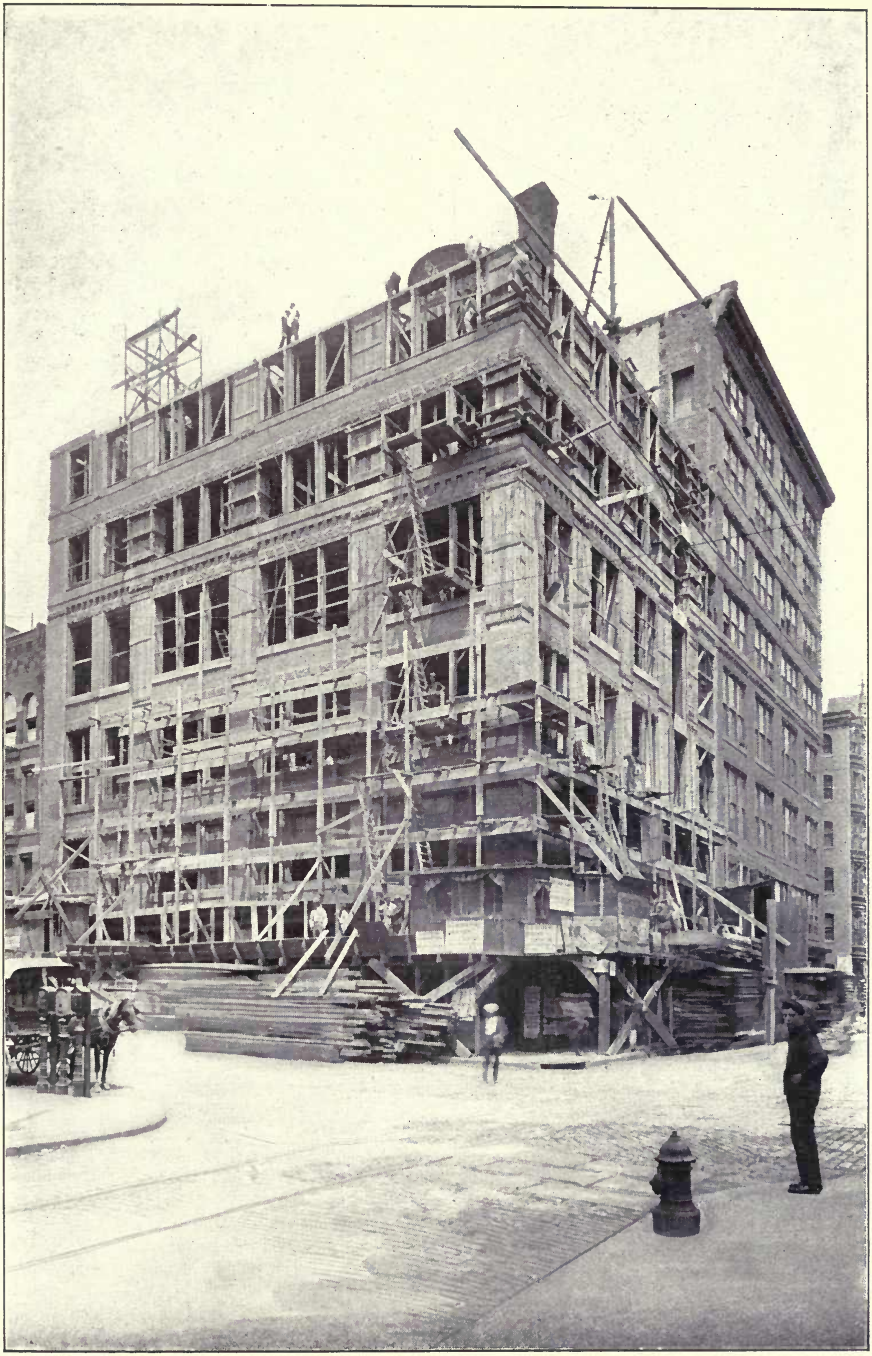


Fig. 22.—Exterior of the Ketterlinus Building During Construction. (*See p. 69.*)

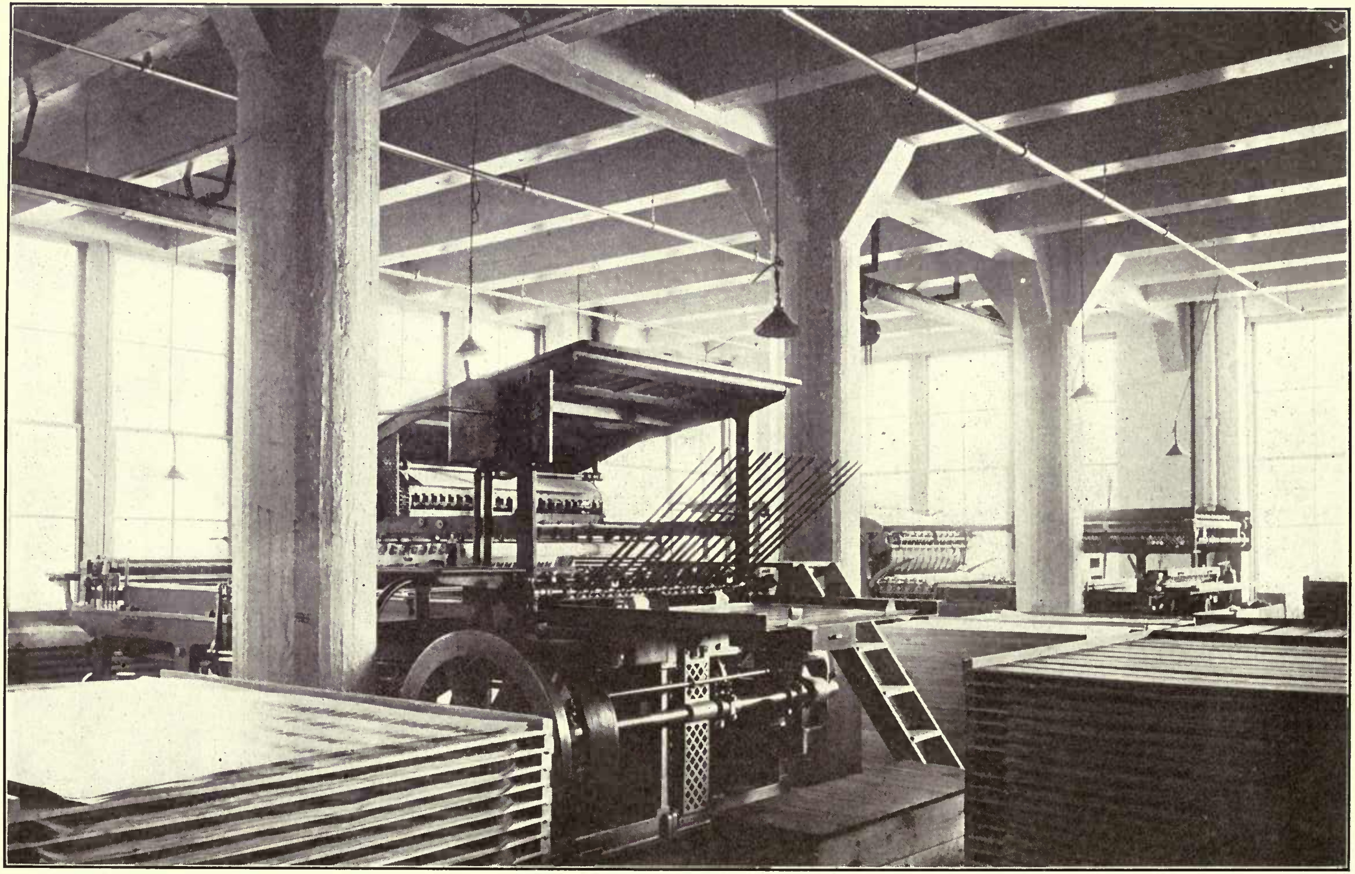


Fig. 23.—Interior of Ketterlinus Building, Showing 20-Ton Lithographic Press. (*See p. 69.*)

## COST.

The concrete portion of the building cost $27,000. This sum included the form work and steel reinforcement, except the column cores and grillage beams, which cost $5,500 additional. The total cost of the structure, including the inside finish, amounted to nearly $90,000.

The unit girder construction is somewhat more expensive than the ordinary system of bending and placing separate rods, but the result is a sure location for every member with no danger of a rod being left out or placed so high as to lose a large part of its efficiency. In this particular building the cost of the unit girder reinforcement was 4 cents per pound after bending ready to place.

## INSURANCE.

It is of interest to observe that the building is insured by the Associated Factory Mutual Insurance Companies, and at the time of completion was the only building in the congested portion of Philadelphia which was insured by them.

As a protection against fires in neighboring structures, the building is fitted with wire glass windows with metal frames, except in the first story, which has plate glass windows with metal frames. Openings in the division wall between the old and new parts of the plant are closed with automatic fire doors on both sides of the fire wall. Furthermore, the building is equipped with automatic sprinklers supplied by a tank located 20 feet above the roof. The sprinklers are also connected with a 750-gallon Underwriters' fire pump supplied by two independent 6-inch connections from the distribution system of the city waterworks, and the tank above the roof and standpipes in the building are also supplied from this pump. In addition to this private fire system, a standpipe extending to a nozzle monitor on the roof is also provided, which is connected with the Underwriters' pump and also with the high-pressure city mains by means of hose.

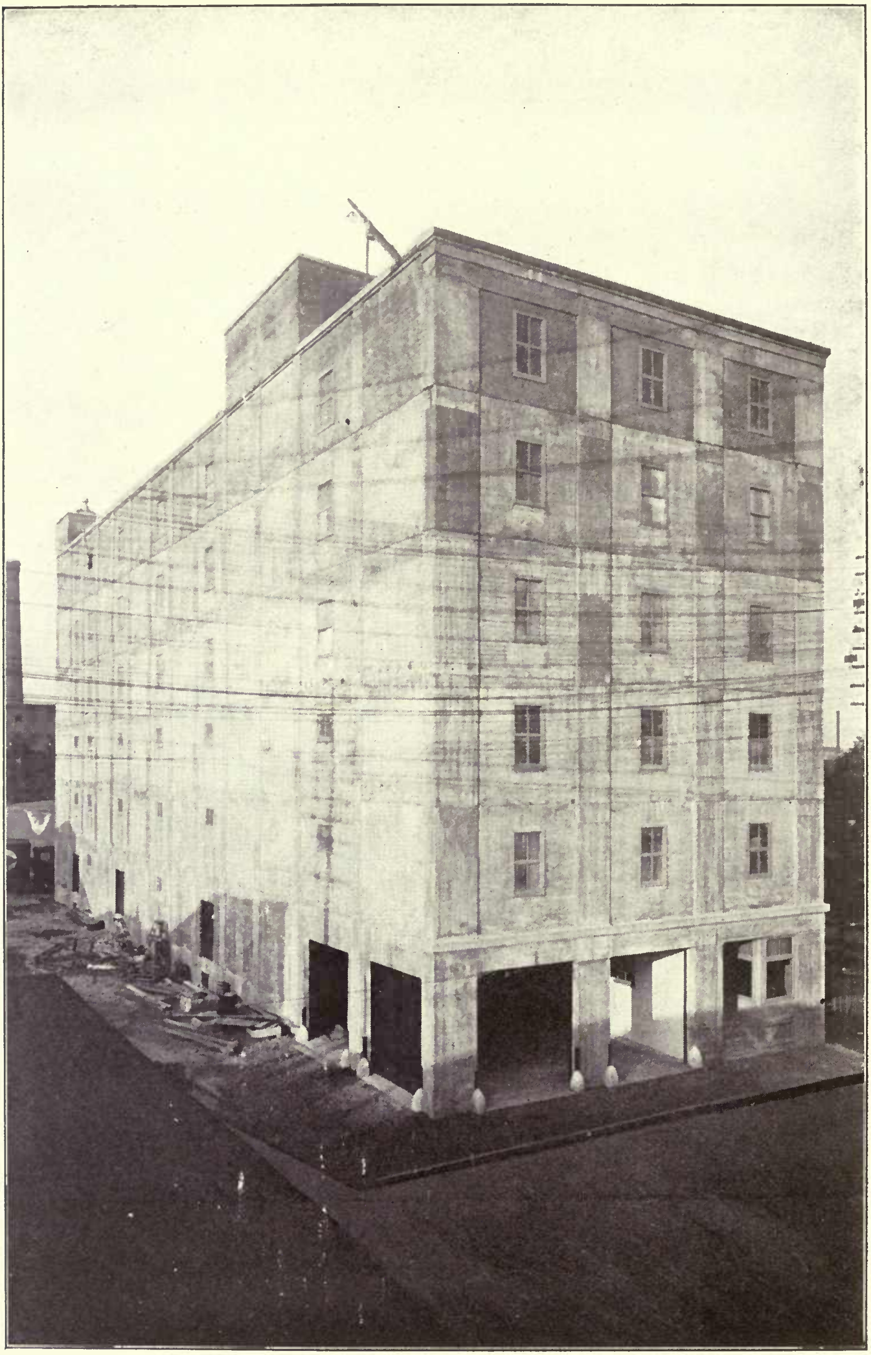


Fig. 24.—Lynn Storage Warehouse. (*See p. 75.*)

# CHAPTER VI.

## LYNN STORAGE WAREHOUSE.

The Lynn Storage Warehouse, at Lynn, Mass., is built for the storage of general merchandise and furniture, reinforced concrete having been selected as the most economical fireproof construction. To provide for the variable character of its contents, the several floors are designed to sustain different loading; the three lower floors are each planned for the rather heavy loading of 250 pounds per square foot, while on the fourth floor 200 pounds per square foot of loading is to be allowed, and on the fifth and sixth floors 150 pounds. A possible weight of 50 pounds per square foot is provided for in the roof design.

The building shown in Fig. 24 is six stories high besides the basement, being 50 feet wide by 165 feet long. Although not strictly speaking a factory building, the design is typical of first-class factory construction.

An interesting feature of the layout is the omission of the first floor in the corner of the building near the large elevator, in order to provide sufficient head room for teams to drive in and deposit their load upon the elevator, or else, if preferred, to drive directly on to the elevator, which is 11 x 12 feet in area, so that the wagon and horses can be elevated to the floor where the goods are to be placed and hauled to the proper point.

The designers of the reinforced concrete and also the builders are the Eastern Expanded Metal Company, of Boston, Mr. J. R. Worcester being consulting engineer. The architect is Mr. D. A. Sanborn, of Lynn.

A full cross-section of the warehouse, showing the dimensions of the members and the general scheme of design, as shown in Fig. 25. Fig. 26 gives typical floor plan and also detail plan and sections of the stairs.

## FLOOR CONSTRUCTION.

Round rods are used for reinforcement of the beams, girders and columns, while expanded metal* forms the slab reinforcement.

The designs were carefully worked up by the Eastern Expanded Metal Company and checked by Mr. Worcester as consulting engineer. The sectional view (Fig. 25) clearly illustrates the general scheme of reinforcing. Complete details of a typical girder, beam and slab, designed to safely sustain 150 pounds per square foot of the floor load in addition to the weight of the concrete, are drawn in Fig. 27 (page 79). The slab, as indicated, is 6 feet in

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* See illustration, Fig. 108, page 182.

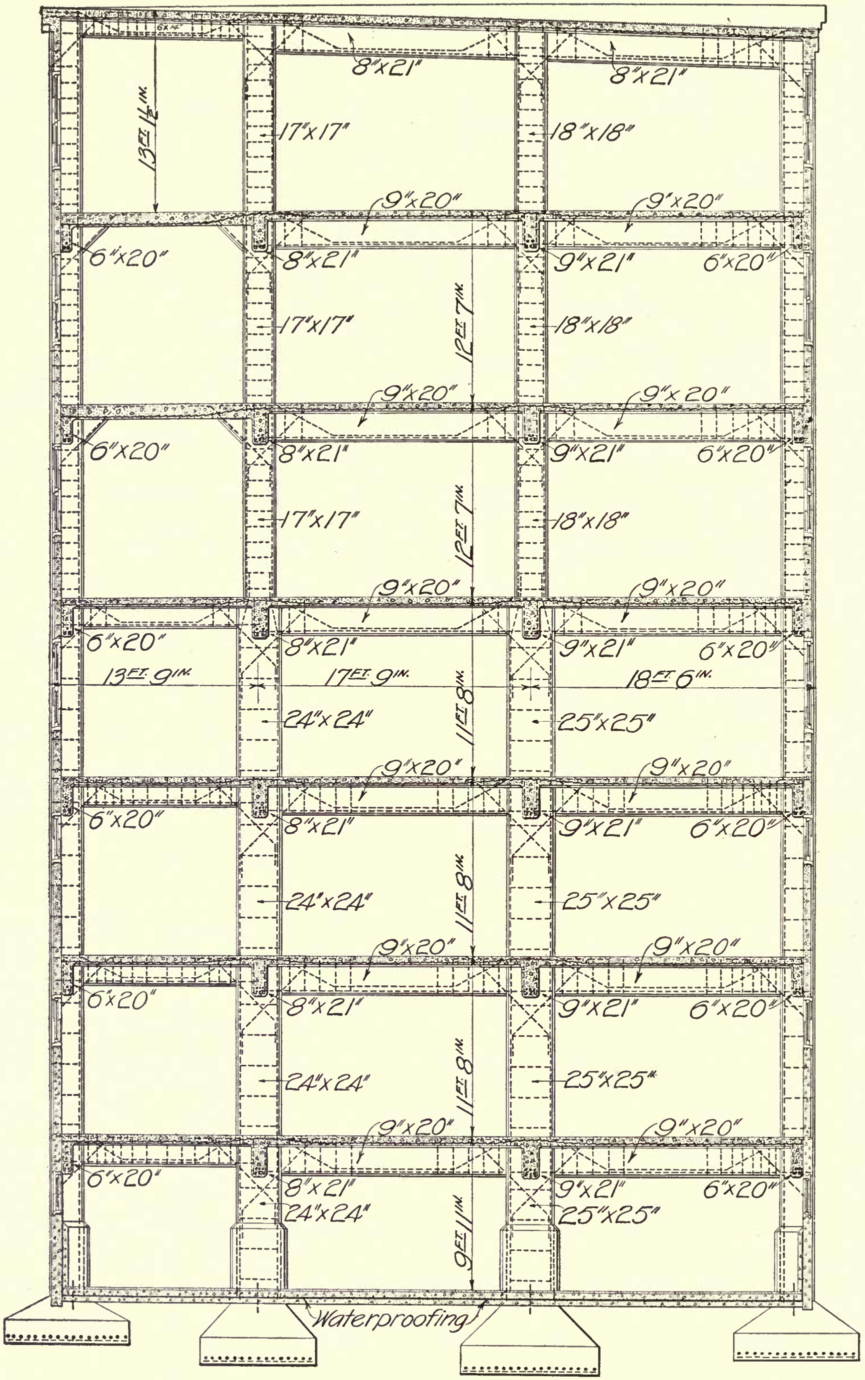

Fig. 25.—Cross-Section Through Lynn Storage Warehouse. (*See p. 75.*)

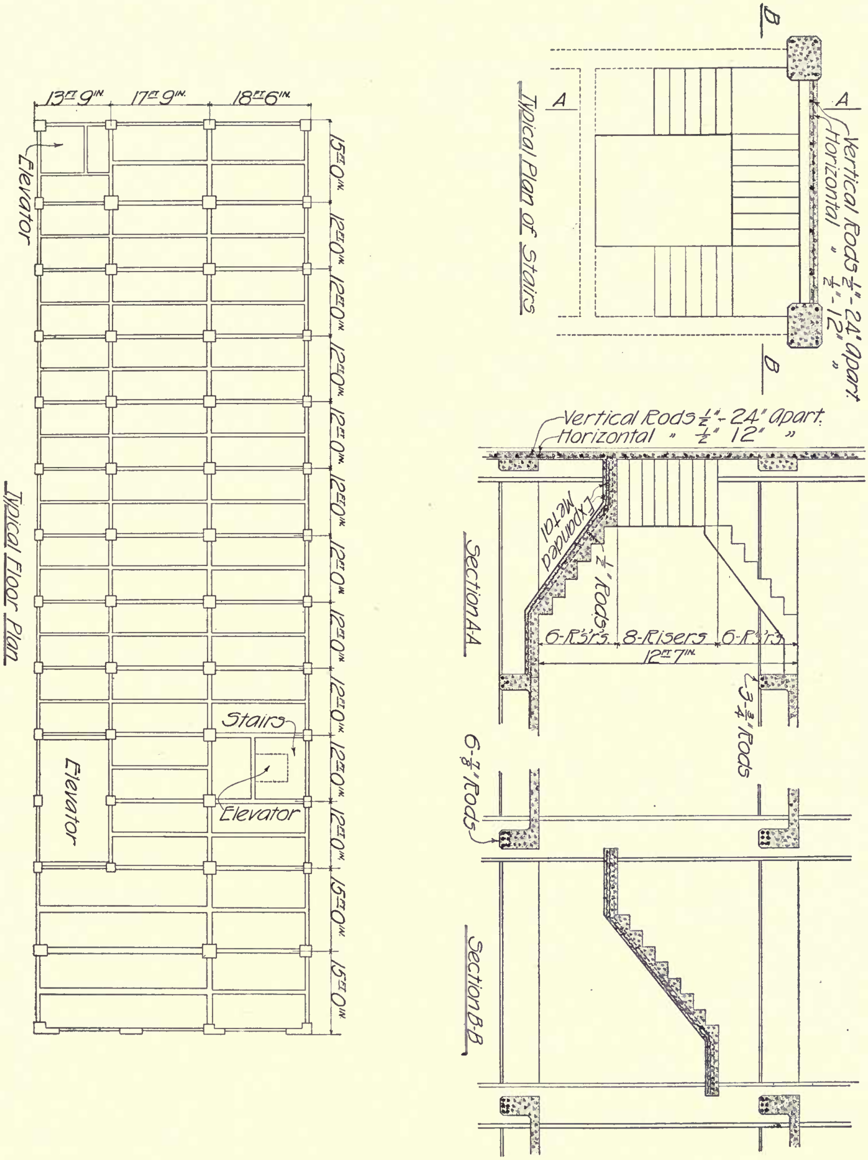

Fig. 26.—Typical Plan and Typical Stair Details of Lynn Storage Warehouse. (*See p. 75.*)

width from center to center of beam or 5 feet 3 inches in net span. The beams are 17 feet 9 inches from center to center of girders or 17 feet net span. The girders are 12 feet between centers of columns or 10½ feet net span.

The expanded metal reinforcement is placed near the bottom of the slab in the center of its span, and rises up to the top of the slab over the beams to provide for negative bending moment. The metal used is 3-inch mesh, No. 10 gage, this being equal to a cross-section of 0.175 square inches per foot of width of slab, or 0.5 per cent. of the cross-section of the slab area above the steel.

In the beams three 1-inch rods are imbedded, one of them bent up at the quarter points and running horizontally over the supports so as to lap by the rod from the next bay, thus giving two-thirds as much reinforcement over the supports as in the center of the beam. The stirrups are flat steel ¼ inch by 1 inch. Notice from Fig. 25 that in the three lower stories, where the loading is heavier, there are five stirrups in each end of the beam instead of two. The beams in these lower stories are made the same size, 9 inches by 20 inches, in order to use the same forms throughout the building, but the reinforcement is heavier.

The typical girders in Fig. 27 have five ⅞-inch rods at the center, two of them bent up and running on an incline from the center of the span. The incline starts at the center of the girder instead of one-quarter way from each end, because the girder having its greatest load at the center, the shear is nearly uniform throughout the entire span.

Instead of the more usual practice of forming the wall girders as a part of the wall, they are built independently of the wall slab, as indicated in Fig. 25.

## FLOOR SPECIFICATIONS.

There are several points of particular interest in the floor specifications, and without copying them entire a brief outline is worth noting, as the data are quite full and the requirements conservative.

The slabs are calculated with a bending moment 1/10 WL in cases where three or more slabs are continuous, while for the wall slabs ⅛ WL is employed. The working strength of the concrete in compression is limited in the slabs to 500 pounds per square inch if computed by the parabolic method of stress, which is equal to about 600 pounds by the more usual straight line method. The slab steel is limited to 16,000 pounds per square inch in tension, the ratio of the modulus of steel to that of concrete being taken as 15. At right angles to the length of the span 1/10 square inch of steel is required per foot of length of slab, which with the 4-inch slab is equivalent to about 0.25 per cent. A thickness of ¾ inch of concrete is required below the metal in the slabs.

The bending moment in the beams and girders is considered as ⅛ WL. The beams are considered as T-beams in computing their strength, and it is specified that the width of the flange shall not exceed one-third the span, and

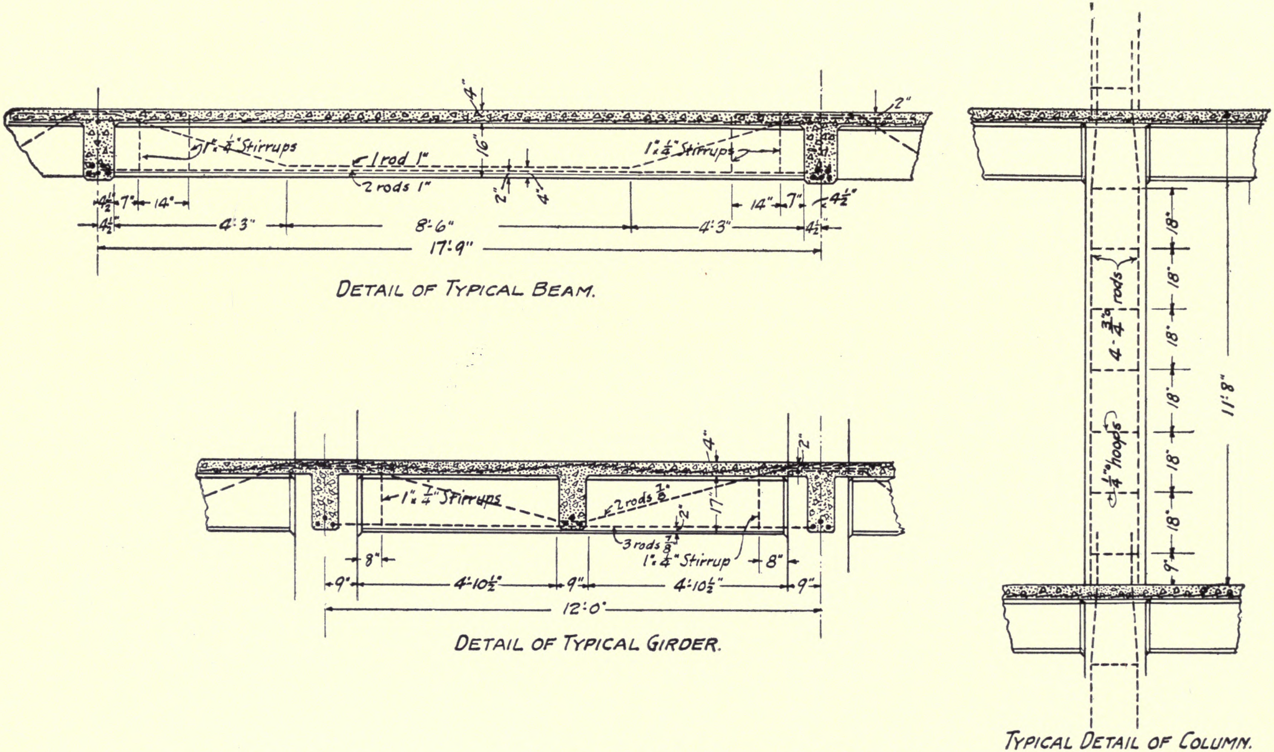

Fig. 27.—Details of Typical Beam, Girder and Column. (*See p. 75.*)

that the average compression in the flange shall not exceed two-thirds of the extreme fiber stress.

The vertical shear in the concrete in beams which are not reinforced for shear is limited to one-tenth the extreme compressive working stress in the concrete, and it is assumed that this vertical shear is distributed over a section whose area is the width of the stem, that is, the width of the beam multiplied by the distance from the center of the steel to the center of the slab, the latter being considered as approximately the center of compression. In any case even when the beam is reinforced for shear the unit shear stress is limited to three-tenths of the extreme compressive unit fiber stress. Thus, if the allowable compressive fiber stress is 500 pounds per square inch, the shear in beams not reinforced for shear must not exceed 50 pounds, and in any case the section must be large enough so that even if reinforced there is sufficient area of concrete to keep the total shear stress within a limit of 150 pounds per square inch.

When all of the shear cannot be taken by the concrete, the vertical component of the diagonal bent-up tension rods is figured to take it, and, in addition, if necessary vertical or diagonal stirrups are introduced.

The specifications require for the coarse material of the aggregate trap stone ranging in size of particles from 1/4 inch to 1 1/4 inches. The proportions for the floor system are 1:2½:5, or by exact volume one barrel (4 bags) cement to 10 cubic feet sand to 20 cubic feet stone.

## FLOOR SURFACE.

The floors are all finished with a granolithic surface 1 inch in thickness, and this is included as a part of the slab thickness. Thus, if the plans require a 4-inch slab the lower three inches are 1:2½:5 concrete, and the top inch is granolithic. The granolithic surface, which is composed of one part cement to 1 part sand to 1 part 1/4-inch stone, is laid before the concrete below it has set, so as to form one homogeneous slab.

## TEST OF FLOOR.

At an age of thirty days it is specified that a test may be made upon the floor panels with a total load two and one-half times the live plus the dead load.

## COLUMNS.

The columns are spaced 12 feet apart lengthwise of the building and 17 feet 9 inches on centers across the building. The interior columns supporting the lower floors are 24 by 24 inches and 25 by 25 inches (the larger size supporting the greater spans), and in the three upper stories the sizes are reduced to 17 by 17 inches and 18 by 18 inches. This arrangement was used to avoid remaking the column forms, this saving, in the opinion of the builders, being enough to more than offset the slight excess of concrete required.

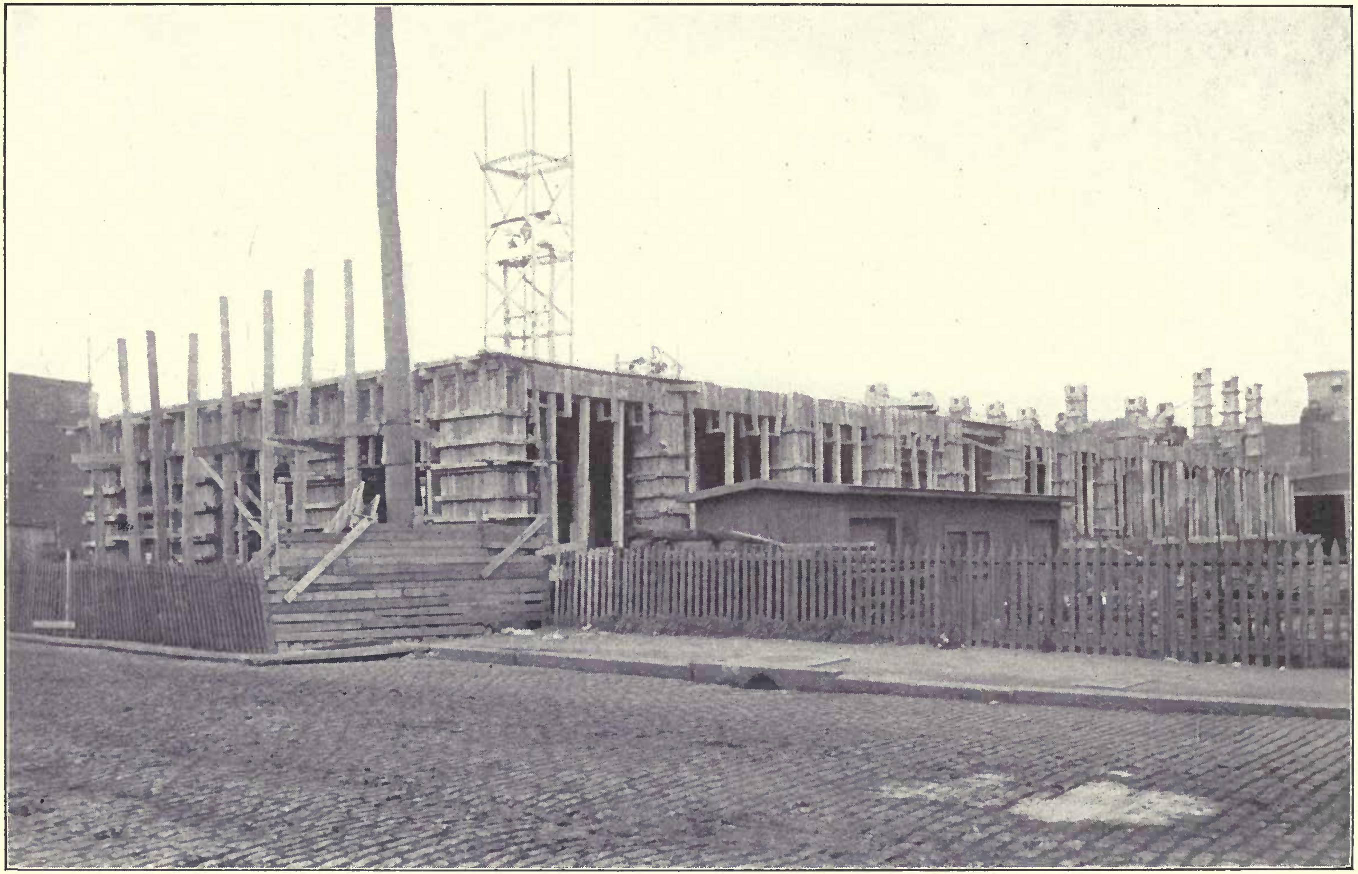

Fig. 28.—Lynn Storage Warehouse at Second Floor Level. (*See p. 82.*)

The columns are outlined in Fig. 27 (p. 79) and also quite distinctly in the general cross-section in Fig. 25 (p. 76). In the latter the diagonal rods will be noticed at the head of each column running into the beams and providing diagonal reinforcement against wind pressure. The building is so high in proportion to its width that this reinforcement was considered advisable.

The ordinary reinforcement of the columns is four ¾-inch vertical rods, with occasional hoops ¼ inch in diameter. In the wall columns, which are oblong in plan and which because of their location are subjected to a greater wind pressure, four larger vertical rods are inserted. The rods are of such length as to project above the next floor level, and the next set rests upon this floor so as to lap and transfer the stresses.

The columns are laid with a richer concrete than other parts of the building, being mixed in proportions 1:1½:3. The compressive stress allowed is 700 pounds per square inch figured on the area of the column, or 600 pounds per square inch on the concrete if the steel is computed to take a proportion of the compression.

## CONSTRUCTION.

Four very good views are presented in Figs. 28, 29, 30, 31, showing the progress from the first story to the stage where the roof is laid and wall panels are nearly completed.

Fig. 28 (p. 81) shows the first story columns and beam molds in place, and in the distance the setting of the second-story column molds. The framework for the elevator which hoists the concrete to place also appears on the farther side of the building.

Fig. 29 is taken after the completion of the concrete work of the fifth floor. The forms are removed from the columns and floor of the lower stories, but the supports are still left under the beams and girders of the fourth floor. The wall panels are completed in the first story and the forms for the second story panels are in place on the side of the building.

The view in Fig. 30 was taken when the building was one story higher, and shows more clearly the elevator for hoisting the concrete, the mixer being located just at the foot of it. The reinforcement for wall panels is quite clearly shown, this being set in place before the panel forms are adjusted.

Fig. 31 shows the building with the roof on and most of the panel work complete.

A photograph of the building complete is shown in Fig. 24 at the beginning of the chapter.

The construction was begun about July 1, 1906, and was practically complete December 1st, although the cold weather caused some delay beyond this time in completing the panels. The average rate of progress on the forms and structural concrete after the work was well started was ten days per story.

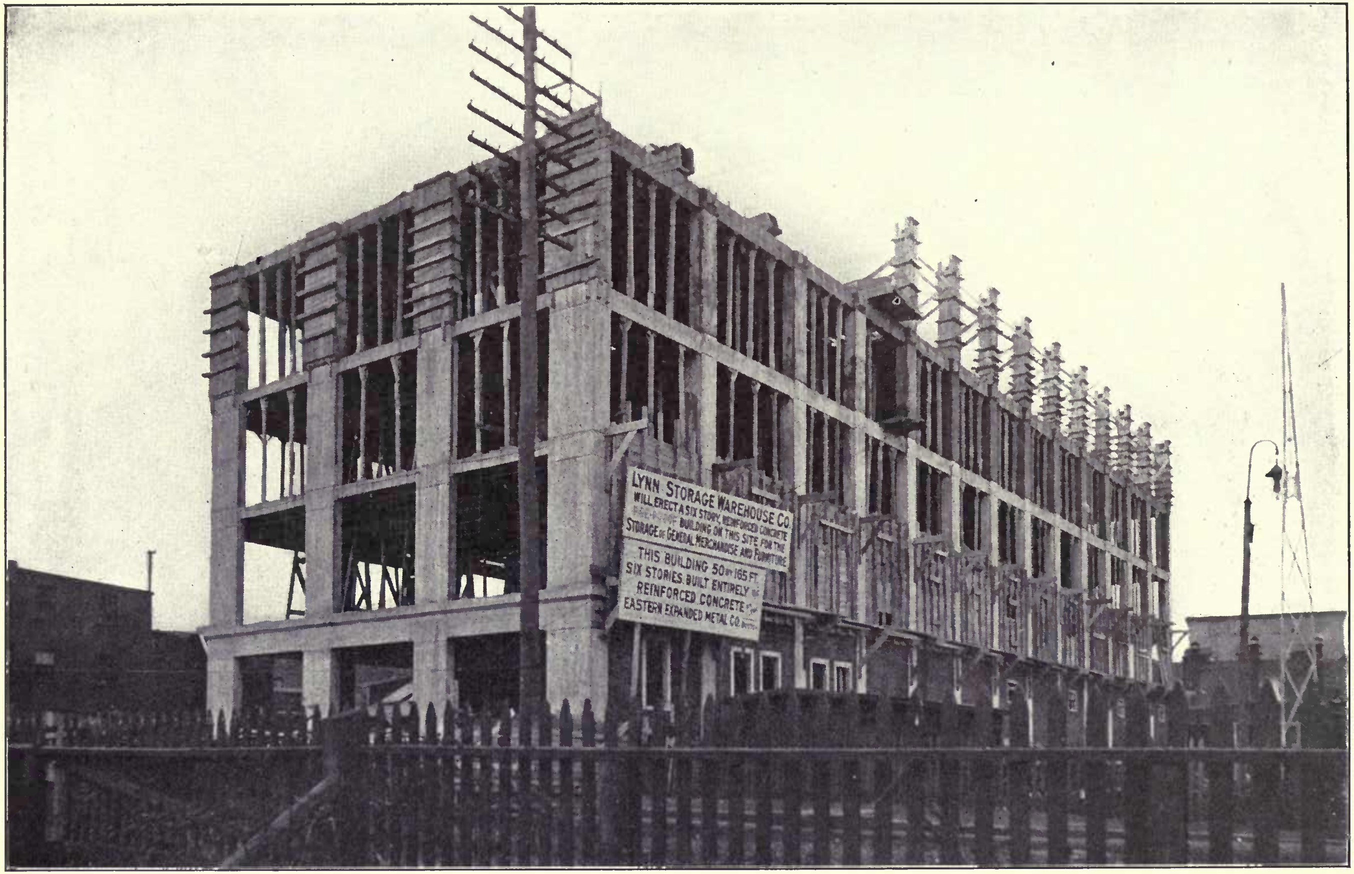

Fig. 29.—Lynn Storage Warehouse at Fifth Floor Level. (*See p. 82.*)

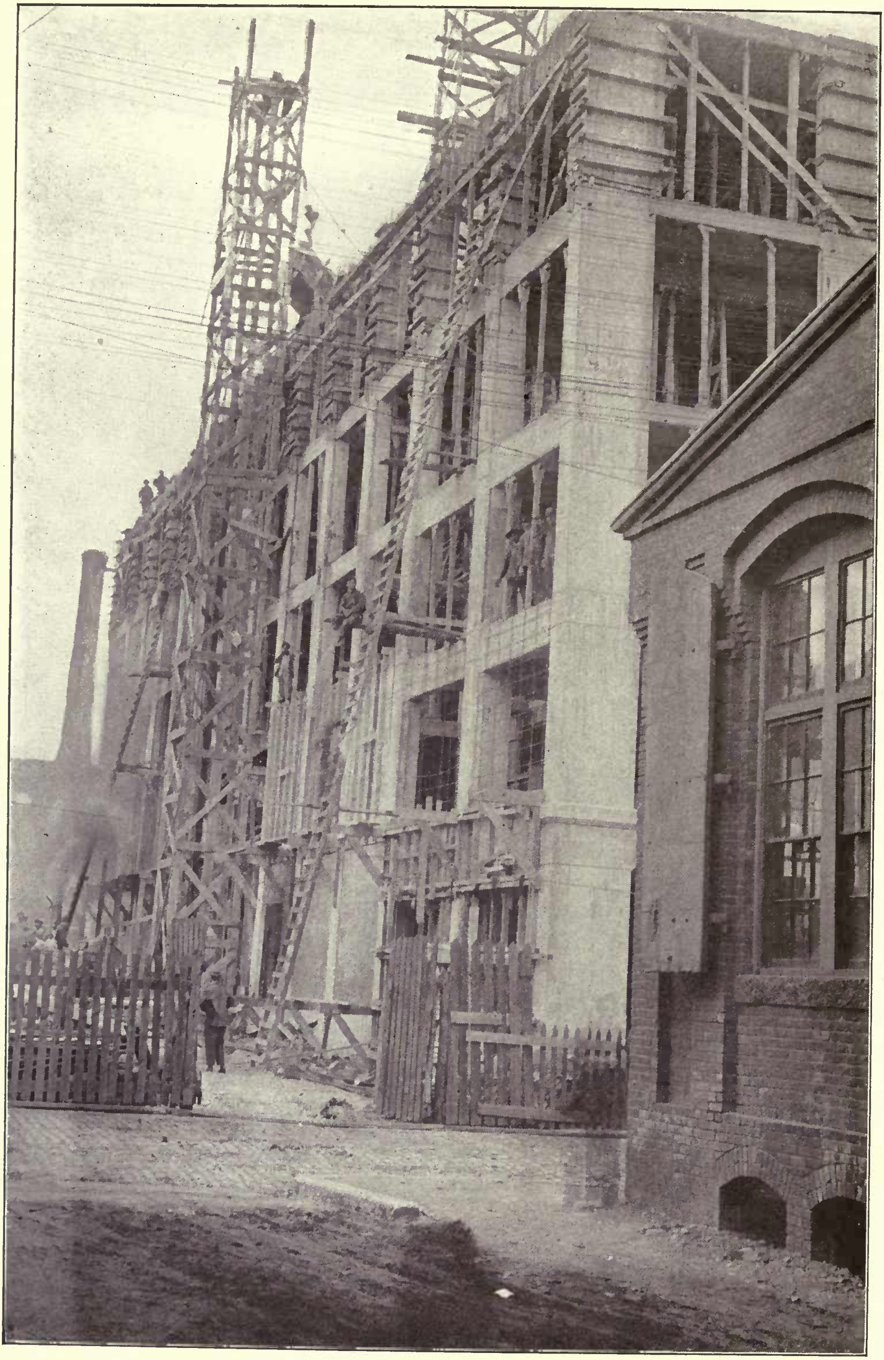

Fig. 30.—Lynn Storage Warehouse at Sixth Floor Level. (*See p. 82.*)

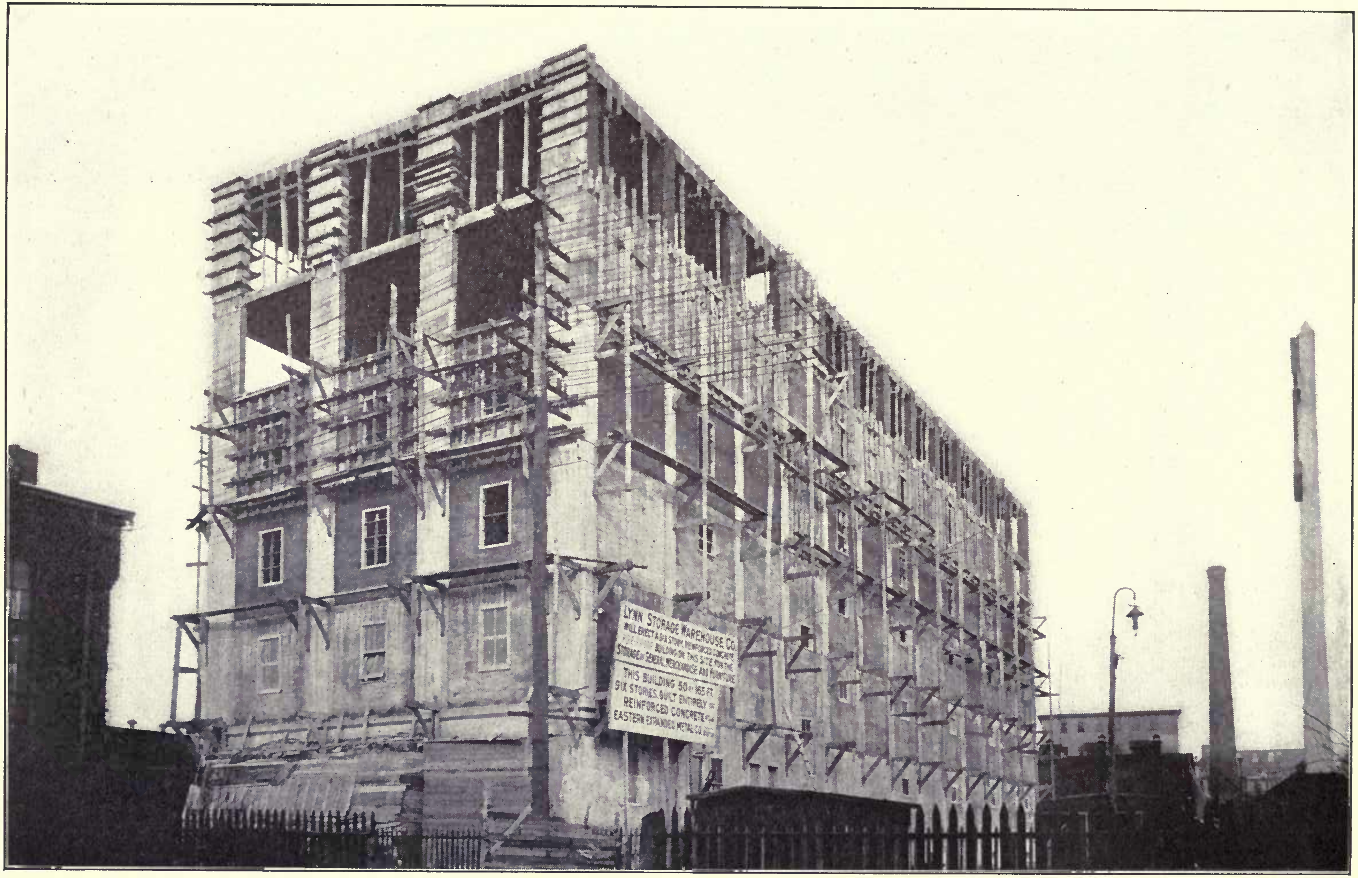

Fig. 31.—Lynn Storage Warehouse with Roof in Place. (*See p. 82.*)

The concrete was mixed on the ground in a rotary mixer (see Fig. 30), and a hoist elevated the concrete and dumped it into the hopper, from which it was conveyed by large two-wheel barrows and dumped in place. Approximately 2,000 cubic yards of concrete were laid in the structure and 136 tons of steel were used in the reinforcement. This was delivered at the factory of the builders, where it was bent to the shape required, the ends of the tension rods being also bent hot at right angles to give a better grip in the concrete.

In placing the steel the stirrups were set first, and as these were in the shape of a U with the ends bent over on a curve, these ends rested upon the slab forms, thus forming a rest for the tension rods which were placed within them and supported at the proper distance above the bottom of the beam.

## FORMS.

For the forms spruce lumber was generally employed. However, a good quality of North Carolina pine, tongued and grooved, was used for the panels, this being preferable to spruce because less apt to warp and having a harder surface, which splinters less and does not soak so much water. In all about 182,000 feet board measure of lumber were used in the construction of the building.

Only one set of forms was required above the first floor, the forms thus being used six times. Although a story was completed on the average in ten days, the work was carried on from end to end of the building, so that one end of the floor system had hardened sufficiently to allow removal of the forms for use in the floor above, while the other end of the floor was being laid. The beams and girder forms were constructed as U units, that is, the sides and bottom were fastened together, and by slightly beveling the sides the form was easily lowered.

By reference to the plan in Fig. 25 (p. 76) it will be seen that although the allowable loading varied on different floors, the dimensions of the beams were maintained the same throughout except for those supporting the roof, the difference in the strength being provided for by varying the reinforcement.

The general plan followed in removing the forms was to leave column forms two days, slab forms six days and beam forms six days. The shoring however, was left under the beams and girders for three or four weeks to guard against possibility of accident. Of course these periods were varied according to the conditions of the weather and the hardening of the concrete, but they represent the ordinary minimum time.

Petrolatum was used for greasing the forms.

The usual gang consisted of one superintendent, 3 foremen, 8 men at the mixing, one engineman, 12 men placing concrete, 3 steel men and 30 to 60 carpenters, the larger number being required for the first set-up of the forms. while the smaller number was sufficient for simply raising them to a floor above when there was no appreciable change in the design.

## WALL CONSTRUCTION.

Panels were built as a separate operation from the rest of the concrete work, as shown in the photographic illustrations. The exterior columns were carried up at the same time as the floors, and the wall panels afterward filled in between them. The wall panel reinforcement consisted of ½ inch diameter rods, the horizontal rods being spaced 12 inches apart and the vertical rods 24 inches apart. This steel was first placed, as shown in Figs. 29 and 30, and after setting the window frames, the forms, consisting simply of 2 inch by 4 inch studs with 1-inch boards nailed to them, were set, and the concrete poured, running into grooves left in the columns. In Fig. 31 the difference in the color of the freshly laid and the old concrete is apparent, the concrete becoming lighter as the water dried out. The walls were completed with slapdash or stippled finish, illustrated in Fig. 129, page 198.

## PARTITIONS.

Around the elevators and stairs and also to enclose the offices on the first floor and storage rooms on the fifth floor, expanded metal partitions were employed. Expanded metal lathing, No. 24 gage, was wired to 1-inch channel bars placed vertically 12 inches on centers, and the lathing then plastered with five coats so as to form a solid partition 2 inches thick.

The first or scratch coat consisted of one part cement to 3 parts of lime with the usual quantity of sand and hair. This pressed through the lathing, so that it could be plastered on both sides with a brown coat of lime and cement mortar in proportions 1 part cement to 3 parts of lime mortar and followed by a finishing coat of the same mortar on both sides.

## WATERPROOFING.

To meet the requirement that the basement should be very dry, asphaltum waterproofing was laid, as indicated by the solid black line in Fig. 25 (p. 76) to prevent penetration of ground water. The ground having been thoroughly tamped, a layer of concrete was spread upon it and the wall slab placed. Then on top and inside of this layer of concrete, five-ply asphaltum waterproofing was spread and upon this 3 inches of concrete with granolithic surface.

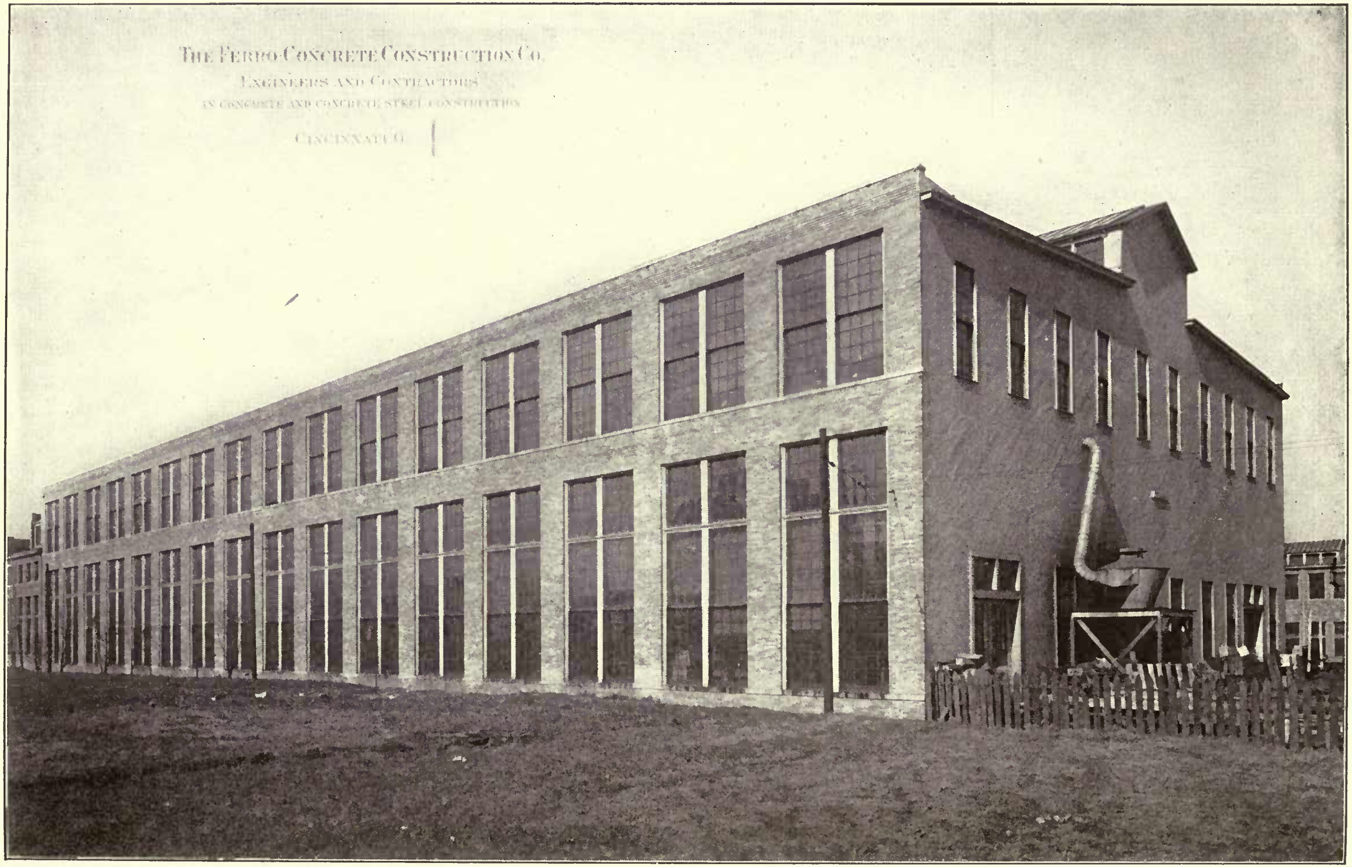

Fig. 32.—Bullock Electric Machine Shop. (*See p. 89.*)

# CHAPTER VII.

## BULLOCK ELECTRIC MACHINE SHOP.

A novel feature of the reinforced concrete machine shop of the Bullock Electric Company, at Norwood, Ohio, a branch of the Allis Chalmers Company, is the supporting of 10-ton cranes upon concrete brackets which form a part of the concrete column. It is customary even in reinforced concrete shops to place the crane runs upon steel columns independent of the rest of the structure, but we have here an example of the transmission of the load directly from the runways, which are steel plate girders, to the reinforced concrete columns. The machine shop, illustrated in Fig. 32, was only fifty-eight and a half days in building and has been in successful and continuous operation since its completion early in 1906.

The building under consideration is an extension to Shop No. 3, which is of the regular type of steel frame with brick walls. The extension was first designed in similar steel construction, but an alternate proposal to substitute reinforced concrete made by the Ferro Concrete Construction Company, of Cincinnati, was adopted at substantially the same cost.

### DESIGN.

The general design of the building is shown in the cross-section in Fig. 33, and a partial elevation in Fig. 34.

The lower story is devoted to the manufacture of the heavier part of the electric machinery and in the assembling of dynamos. In the upper story are the lighter machine tools for the making of the smaller parts. The roof is of 2-inch plank upon steel trusses (see Fig. 33), being built in this way instead of in reinforced concrete so that it can be raised and a third story added when needed. One end of the building, as shown in the photograph of the completed shop, Fig. 32, is also of temporary construction, so that it can be lengthened without tearing down a brick and concrete wall.

Twisted steel was used for reinforcement. The proportions of the concrete were 1:2:4 throughout, using 4 bags Atlas Portland cement to 8 cubic feet of good coarse sand to 16 cubic feet of broken stone, which was the run of the crusher, screened through a 1¼-inch screen.

The floors (see Fig. 33) consist of three longitudinal bays running the entire length of the building, a distance of 256 feet. The total width is 107 feet 7½ inches, thus allowing the two outer bays to be each 42 feet 11½ inches and the inside bay 21 feet 8½ inches. In the other direction, that is,

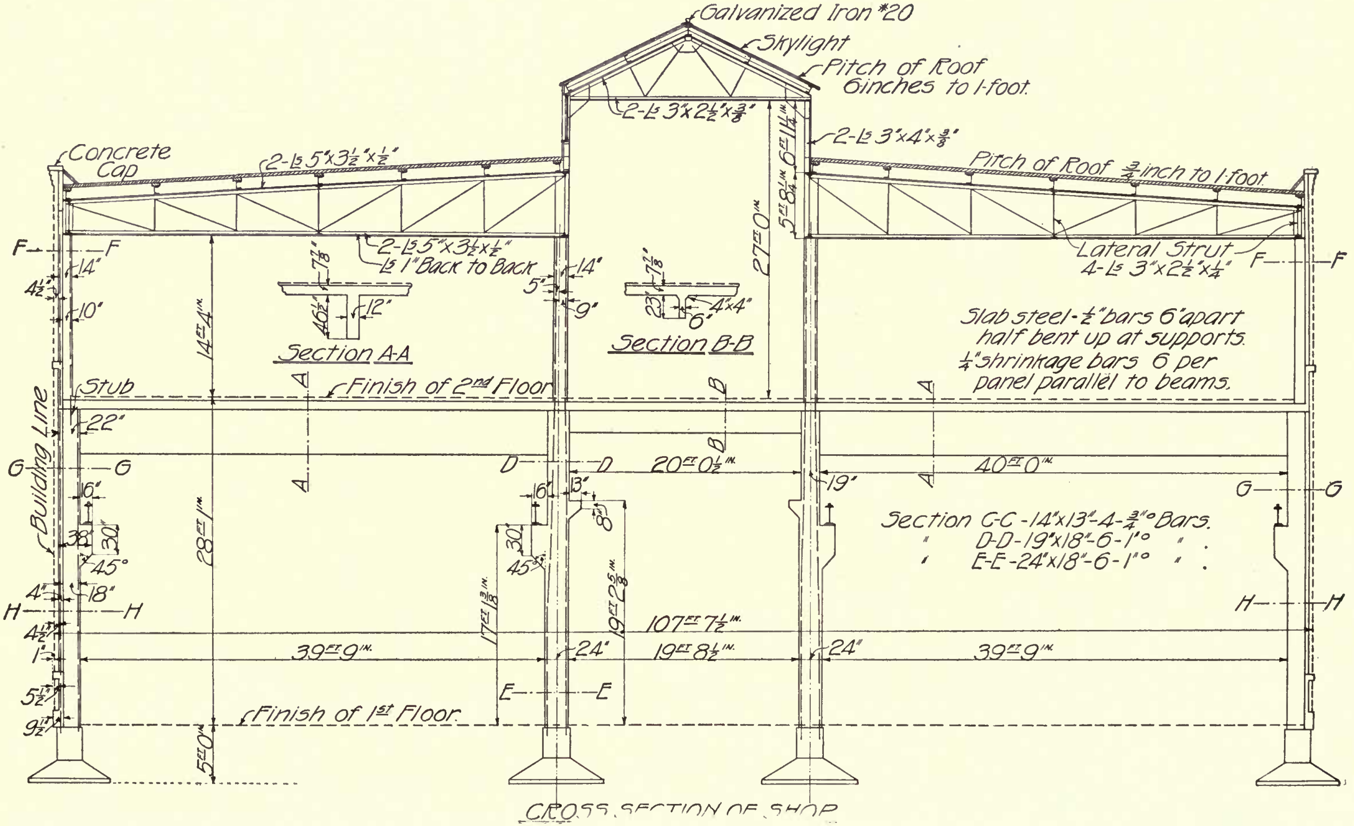

Fig. 33.—Cross-Section of the Bullock Machine Shop. (*See p. 89.*)

lengthwise of the building, the columns are 16 feet apart on centers. The long open floor spaces afford ample room for the machine tools and the handling and distributing of the parts and the finished machines. A view of the shop in operation is photographed in Fig. 35.

The height of the first story, 27 feet in the clear from the floor to the ceiling and 23 feet in the clear to the bottom of the girders, provides the head room necessary for the 10-ton cranes which are located in the outside bays, and also permits very large high windows.

The center bay is designed so that another crane may be installed there when required, but for the present its place is occupied by an intermediate floor. This floor is of light steel I-beam and wood construction, resting upon channel irons running across between the two rows of columns. The channels are bolted at the ends to the concrete columns and their weight also supported by straps suspended from the crane brackets. Had the floor been intended for permanent use it would have been built of reinforced concrete, but the difficulty and expense of tearing down a floor of concrete when the space was needed for the crane made this impracticable.

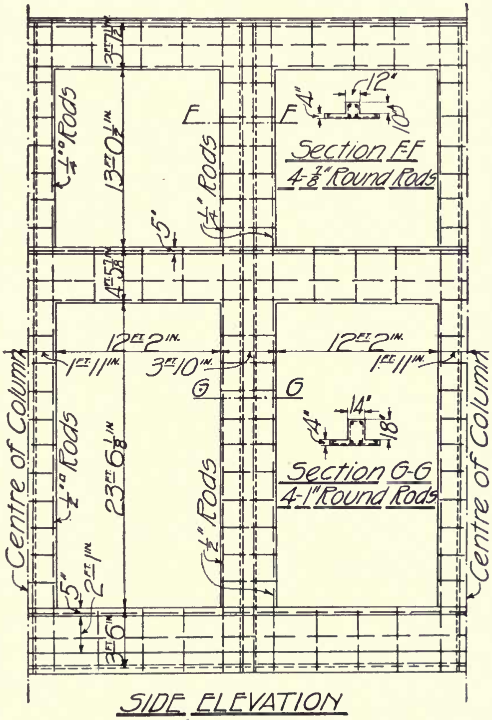

Fig. 34.—Side Elevation of the Bullock Machine Shop. (*See p. 89.*)

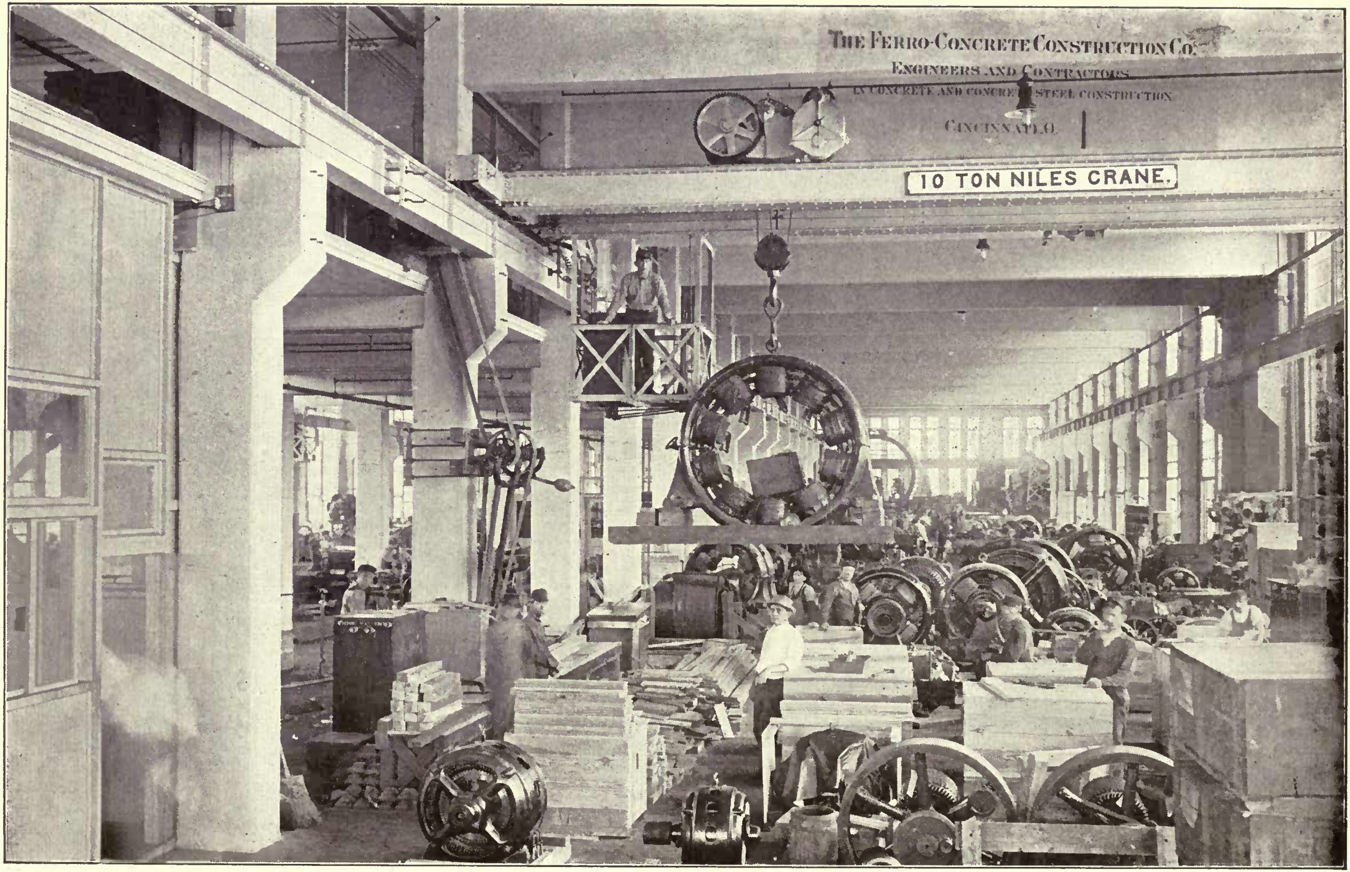

Fig. 35.—Bullock Electric Company Machine Shop in Operation. (*See p. 89.*)

# COLUMNS.

Footings of the interior columns are shown in Fig. 36. These illustrate a typical reinforced concrete footing with two layers of rods at right angles to each other in the bottom. In this case the rods are ¾ inch diameter, while in the footings for the wall columns, which are not shown in our drawings, ½-inch rods fulfil the requirements. The rods in each layer are shorter than the dimensions of the footing in the interior columns (Fig. 36), being 6 feet 8 inches long and placed with one end 2 inches from the edge of the footing and the other end 18 inches from the opposite edge, the alternate rods being staggered to allow for the decrease in the bending moment from the column toward the edges of the footing. As the footing is square, while the column is oblong, 10 bars run in one direction, while 12 bars are placed in the other layer to provide for the greater bending moment.

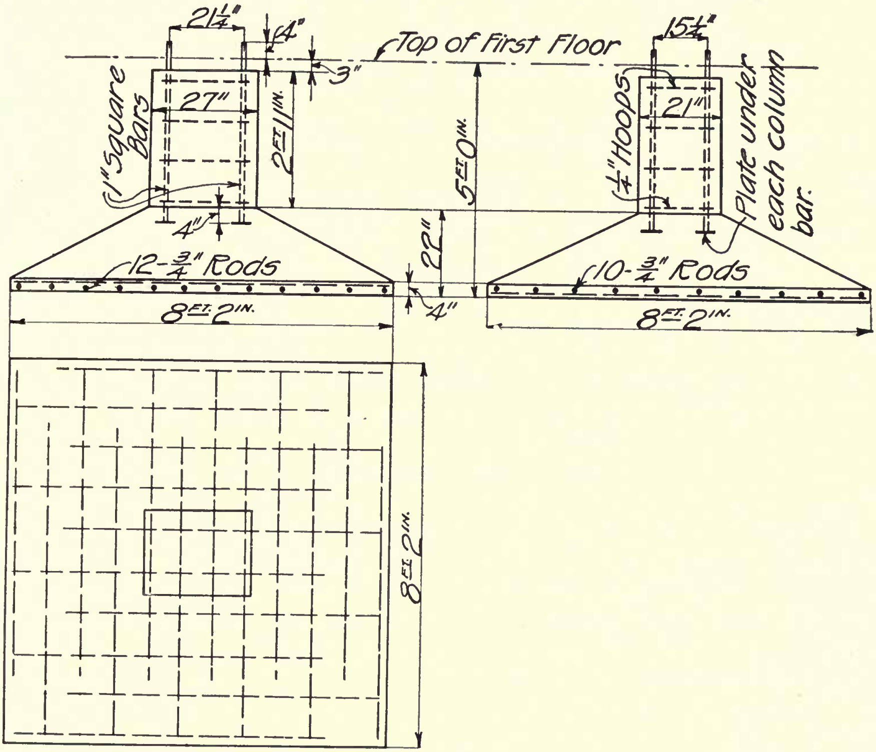

Fig. 36.—Reinforced Footings for Interior Columns. (*See p. 93.*)

The footings really extend up to within 3 inches of the first floor level, the short vertical section of 2 feet 11 inches being built at the same time as the footing proper in order that the first floor can be laid entire and the first story columns started above it. These short vertical lengths are reinforced with six 1-inch rods which extend 4 inches down into the main part of the footing and project 7 inches above the concrete so as to pass through the floor and connect with the column above. These vertical rods rest upon steel plates 3 inches square, which distribute the compression from the steel to the concrete. Four 1/4-inch horizontal hoops are placed around the vertical rods. The columns above the first floor are of slightly smaller dimensions, as shown by the offsets in Fig. 33. Thus, the portion below the first floor is 21 by 27 inches, which reduces to 18 by 24 inches with a further reduction above the crane brackets. The reinforcement in the columns in the first story is the same as below the floor, six 1-inch rods butting upon the ends of the rods below and connected with them by a short pipe sleeve. One-quarter-inch hoops were spaced, double, every 12 inches.

The wall columns have footings similar to those of the interior columns, except of smaller dimensions and lighter reinforcement. The base is 7 feet 4 inches, reinforced with sixteen 1/2-inch rods in each layer. Below the first floor the column is 20 inches by 26 inches, reinforced simply with a 3/8-inch rod in each corner and four 1/4-inch horizontal hoops.

Above the first floor the exterior columns are of T-shaped cross-section, as described in the paragraphs which follow, the column proper being 14 by 22 inches in the first story and 12 by 14 inches in the second story.

## CRANE BRACKETS.

The brackets, shown in Fig. 33 (p. 90), which support the cranes are of particular interest. To provide for the shear, it was considered advisable to loop the reinforcing rods into the bracket, running them out horizontally and then bending them down on an incline back into the column. The steel I-beams supporting the track for the crane rest directly upon these brackets and run the full length of the building.

## FLOOR SYSTEM.

The floor of the first story was laid directly upon the ground after filling in around the columns and thoroughly puddling the earth. This floor is of 1:2:4 concrete with sleepers upon it and a 2-inch oak floor.

The second floor is supported in the two bays by girders about 40 feet long in the clear, 12 inches wide and 54 1/2 inches deep from top of slab. In the bottom of the girder, to take the tension, are ten 1-inch square twisted rods and, to provide for the negative bending moment, five 1-inch rods were placed at the top of the beams over the supports. The shear or diagonal tension is provided for by these bent-up rods, together with sixteen 1/2-inch and ten 1/4-inch U bars. The reinforcement was rigidly located before the concrete was poured, so that it could not be displaced.

In the central bay the net span is about 20 feet and the girders are smaller, being 6 by 31 inches. The thickness of the slab is included in the depth of the girders in both cases, since the concrete for the girders and slabs was poured at one operation.

The girders extend across the building from column to column, and are thus 16 feet apart on centers, giving a net span for the concrete floor slab of 15 feet in the outside bays and 15 feet 6 inches in the middle bay. The slabs, which are designed by a load of 225 pounds per square foot, are 7⅞ inches thick, reinforced with ½-inch bars spaced 6 inches on centers. In addition ¼-inch rods about 2 feet apart run across the building parallel to the girders to prevent contraction cracks.

The wearing surface of the floor is ⅞-inch maple flooring upon 3 by 4-inch sleepers spaced 16 feet apart on centers and filled between with cinder concrete.

## WALLS.

The window area comprises a large percentage of the wall surface, the openings in the concrete being 12 feet 2 inches wide and in the lower story 23 feet 8 inches high. The walls, 4 inches in thickness, were carried up at the same time as the columns, thus forming with them T-sections, as shown in Section GG, Fig. 34. Below and above the windows, the wall was also 4 inches thick, with water table and sills, as in Fig. 33. The window sills, which are 5 inches thick, were poured as a part of these walls and were thoroughly

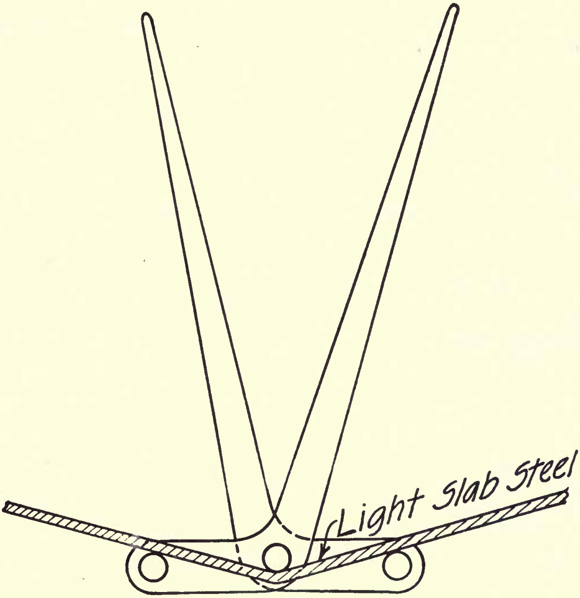

Fig. 37.—Tongs for Bending Light Steel Bars. (*See p. 96.*)

troweled on the top before the concrete had set hard, so as to form a surface like that on a sidewalk.

Each vertical section of wall was reinforced with two ½-inch square bars in the first story and two ¼-inch bars in the second story. Horizontal loops of ¼-inch wire were also placed about 2 feet apart. Above the windows the walls were reinforced with three horizontal rods and with vertical rods spaced about 3 feet apart. Fig. 34 (p. 91), which is a side elevation of two bays, illustrates more clearly the placing of the wall reinforcement.

In order that the exterior of the new building should harmonize with the older shops in the same plant, the walls were surfaced with a single thickness of light-colored pressed brick. These were tied to the wall by the wires which were used in keeping the forms together. These ties were No. 8 galvanized iron wire about 12 inches long, which projected from the concrete about 6 inches. They were spaced every 18 inches horizontally and every six courses of brick vertically. The projecting ends were turned in a hook by the bricklayer and bedded in the mortar joints just like regular brick anchors.

## CONSTRUCTION PLANT

In accordance with their usual plan in building construction, the contractors erected near the site a carpentry shop about 20 feet by 42 feet, with an adjoining tool room. In the shop, wood working tools, including a circular saw and a planer, were installed and driven by electric motor from power furnished by the town plant. Here all the forms were prepared.

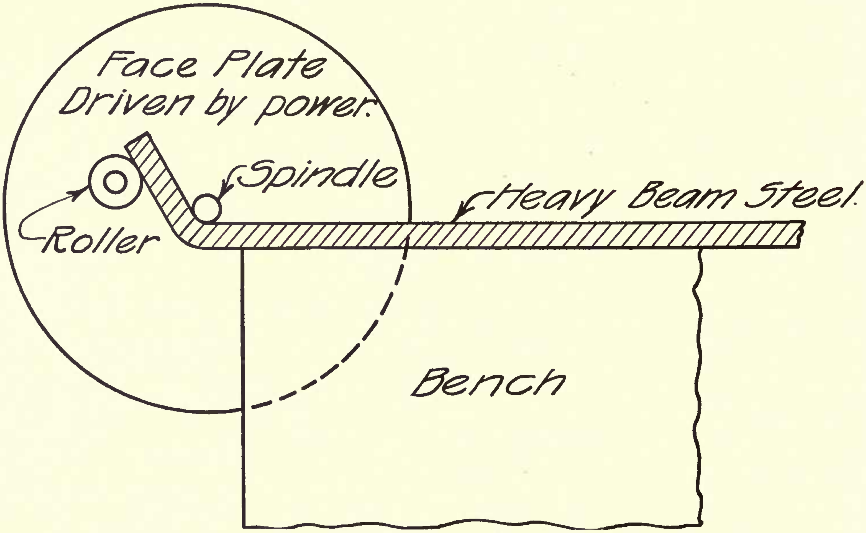

Fig. 38.—Power Bender for Large Steel Bars. (*See p. 98.*)

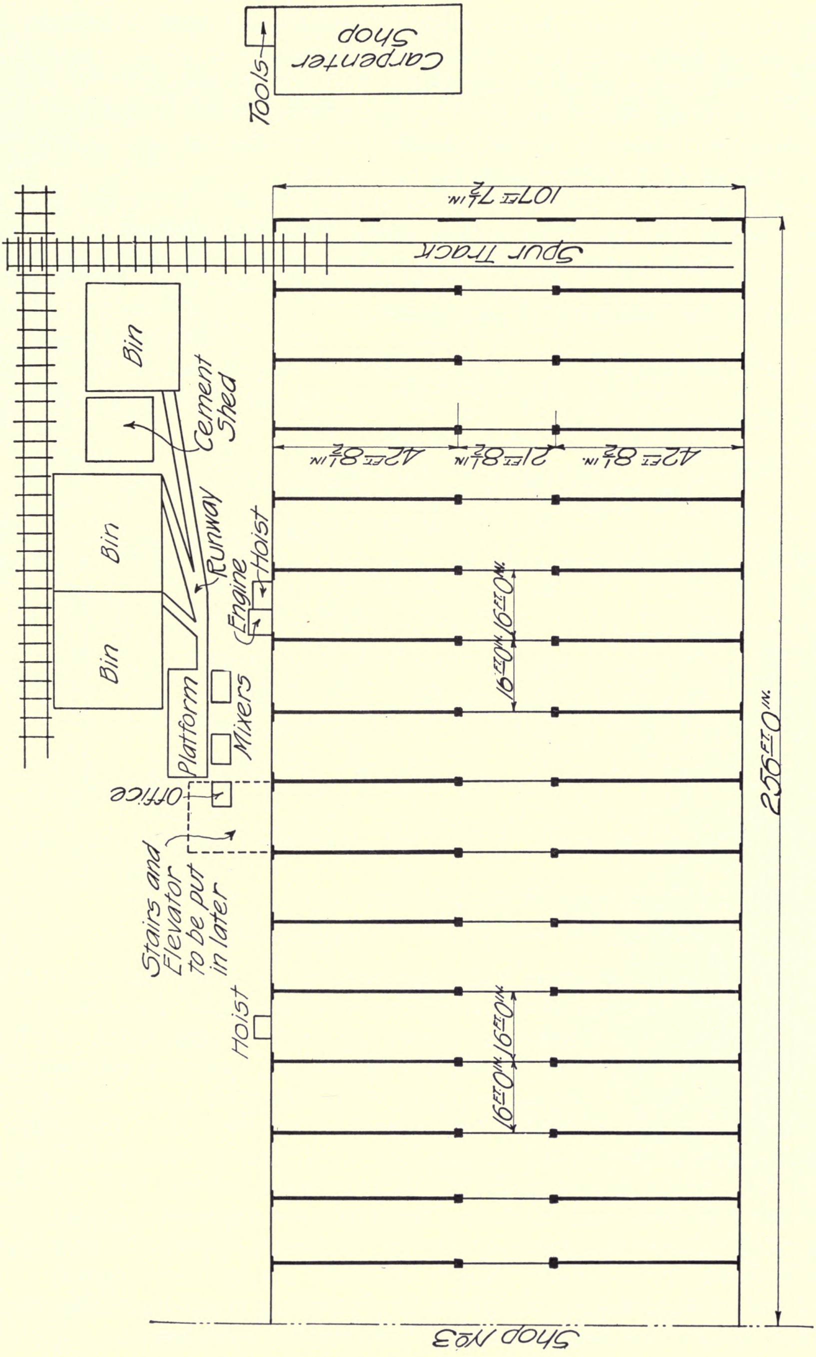

Fig. 39.—Plan of Machine Shop, with Construction Plant. (*See p. 96.*)

The steel was also bent in this shop. For the small rods of the floor slabs a heavy pair of tongs was used, with three projecting lugs, as shown in Fig. 37 (p. 95). The heavy steel for the beams and girders was bent by power in a machine consisting essentially of a face plate with a roller projecting from it, which, when the power is applied, bends the bar around the spindle. The sketch in Fig. 38 (p. 96) illustrates the operation.

The layout of the construction plant and its relation to the machine shop are illustrated in Fig. 39. The broken stone, sand and cement were brought in railroad cars and stored in bins close to the tracks. The mixing plant was provided with both a Ransome and a Smith mixer, although most of the time one of these machines was of sufficient capacity to supply the concrete. The materials were wheeled along the runway on the platform, from which they were dumped into the mixers. From the mixers the concrete was brought to the place where used, in two-wheel barrows of Ransome type, but with staggered wheel spokes, these having been found to be better than the single row of spokes. Each of these held about 5 or 6 cubic feet of concrete. The hoist consisted of a single platform double-barrow hoist, taking two barrows up at one time, and from the hoist the concrete was wheeled to place upon a runway raised above the steel, so as not to interfere with it, and dumped directly in place.

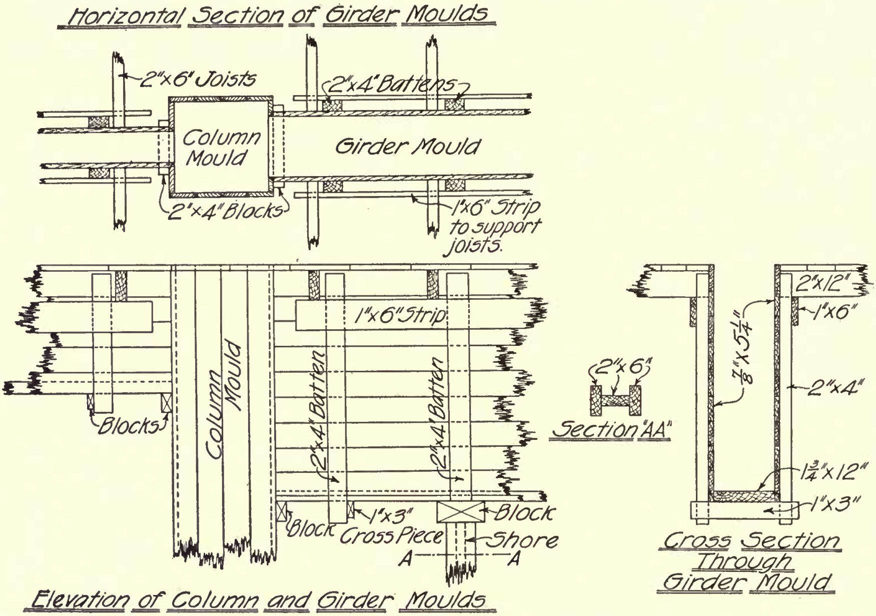

**Fig. 40.—Sectional Plan and Elevation of Girder Molds.** (*See p.* 100.)

The cost of the construction plant, not including small tools, shovels, etc., was $4,350. In the building 2,300 barrels of cement were used.

## GANG.

The usual gang consisted of about fifty laborers and fifty carpenters. The men engaged directly upon the building were distributed approximately as follows:

Four foremen.
Twelve men mixing concrete.
Six men hoisting concrete.
Fifteen men placing concrete.
Seven men bending and placing steel.
One engineman.
Fifty carpenters.

The regular rate of pay for the laborers, who were experienced concrete men, was $2 per day of ten hours.

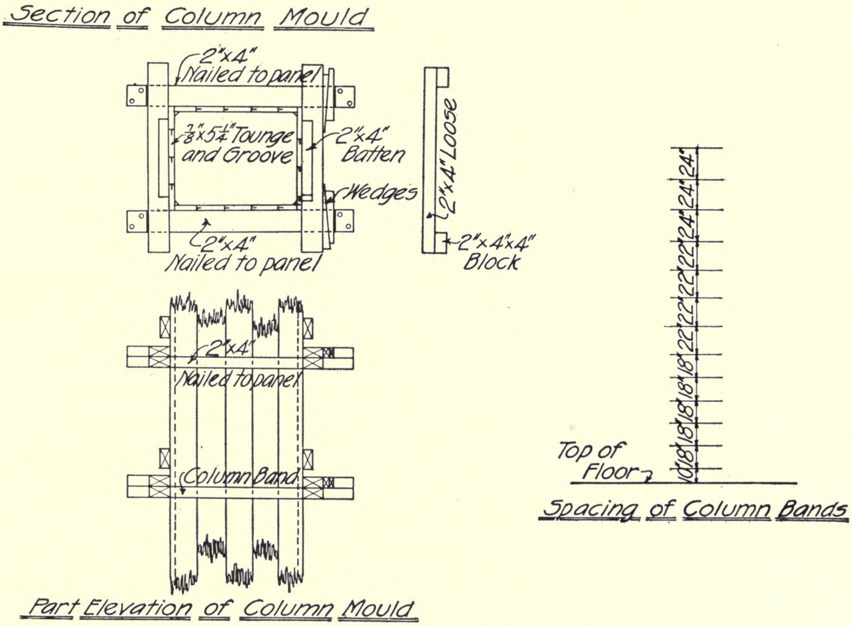

Fig. 41.—Details of Column Molds. (*See p. 100.*)

## FORMS.

The forms were built of yellow pine, which cost $20 per thousand. As the building was only two stories high, much of the lumber could be used only once, although some of the wall and column forms were used twice. The lumber cut to such good advantage, however, that much of it could be used on another job, and the builders estimated the salvage at about 30 per cent., that is, it might be assumed that three-fifths of the lumber could be used to good advantage on another building, and that the value of this was one-half of its original price.

The panel boards were planed one side and on the edges. For the beam and column molds 1 by 6-inch tongued and grooved stock was employed.

The construction of the girder molds is shown in Fig. 40 (p. 98), and the column molds more in detail in Fig. 41. The column bands or clamps were 2 by 4-inch stuff, held together by blocks and wedges, as shown in the drawing. On one side the piece was loose, so that the same clamp could be used for a narrower column by changing the position of the blocks. The clamps were spaced 18 inches apart near the bottom of the column, reducing to 24 inches apart near the top.

The girder forms consisted essentially of 1-inch paneled sides, the boards battened together with pieces of 2 by 4-inch stuff, and a bottom of 1¾-inch plank, which was supported in part by 1 by 3-inch cross pieces nailed to the end of the batten strips, and in part by the shores or struts resting upon the floor below. A 1 by 6-inch strip nailed to the upper part of the battens supported 1 by 6-inch joists, upon which rested the slab flooring.

The shores or struts, instead of being a single piece of lumber, were made of I-section by nailing together three pieces of 2 by 6-inch plank, as shown in section AA, Fig. 40. This plan was followed because the first story was so high that an ordinary 4 by 4-inch post would have been liable to spring unless braced very frequently in its height. An exterior view of the building during construction, showing the column and girder forms and bracing, is given in Fig. 42.

The forms of the walls, columns and panels were left in place about two weeks and the shores six weeks. This time was longer than is customary, but in this building the spans were so long that the dead weight of the concrete was exceptionally large, and this threw a large proportion of the total load upon the concrete when the forms were first taken down.

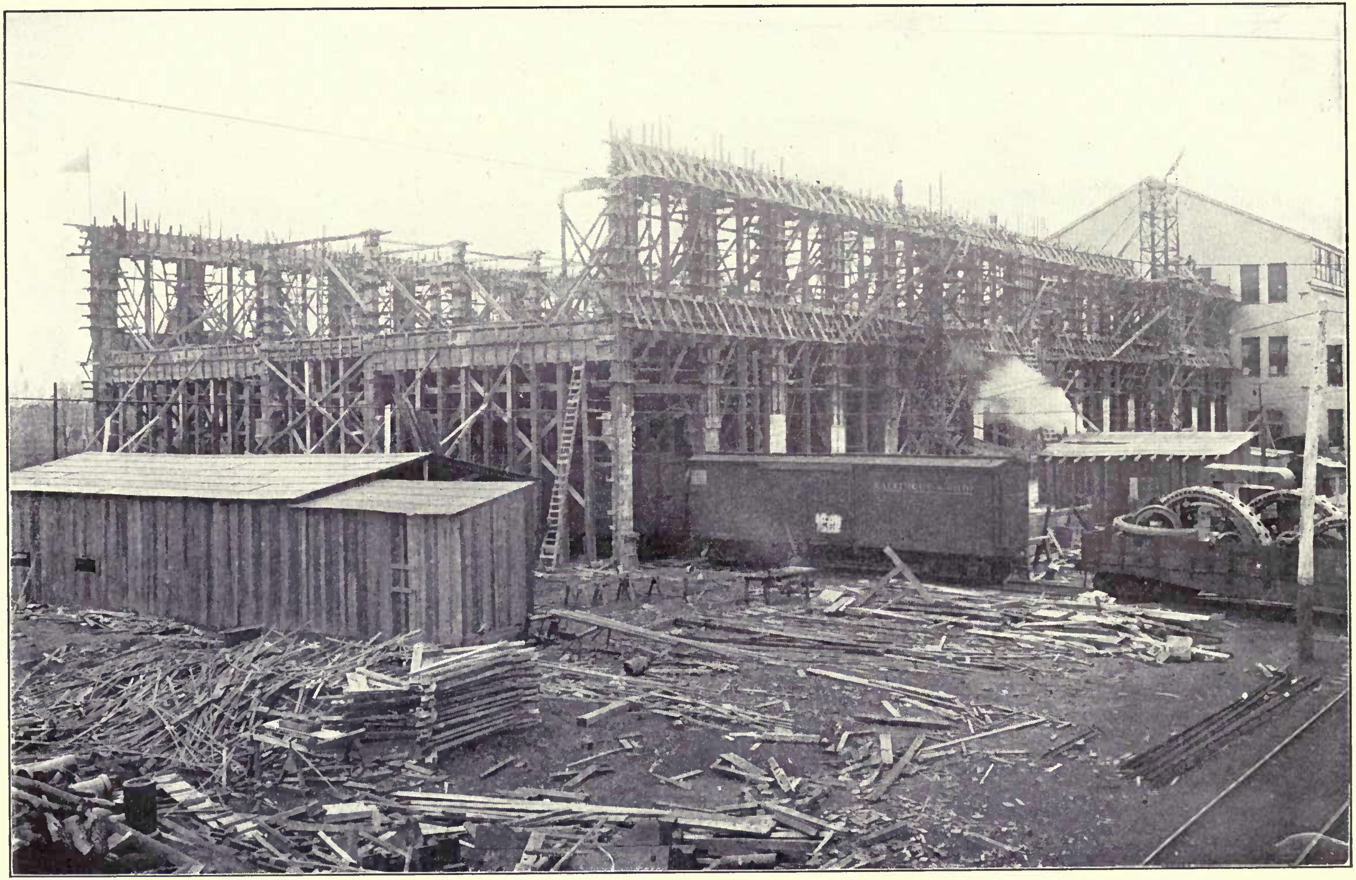

Fig. 42.—Photograph Showing Form Construction. (*See p.* 100.)

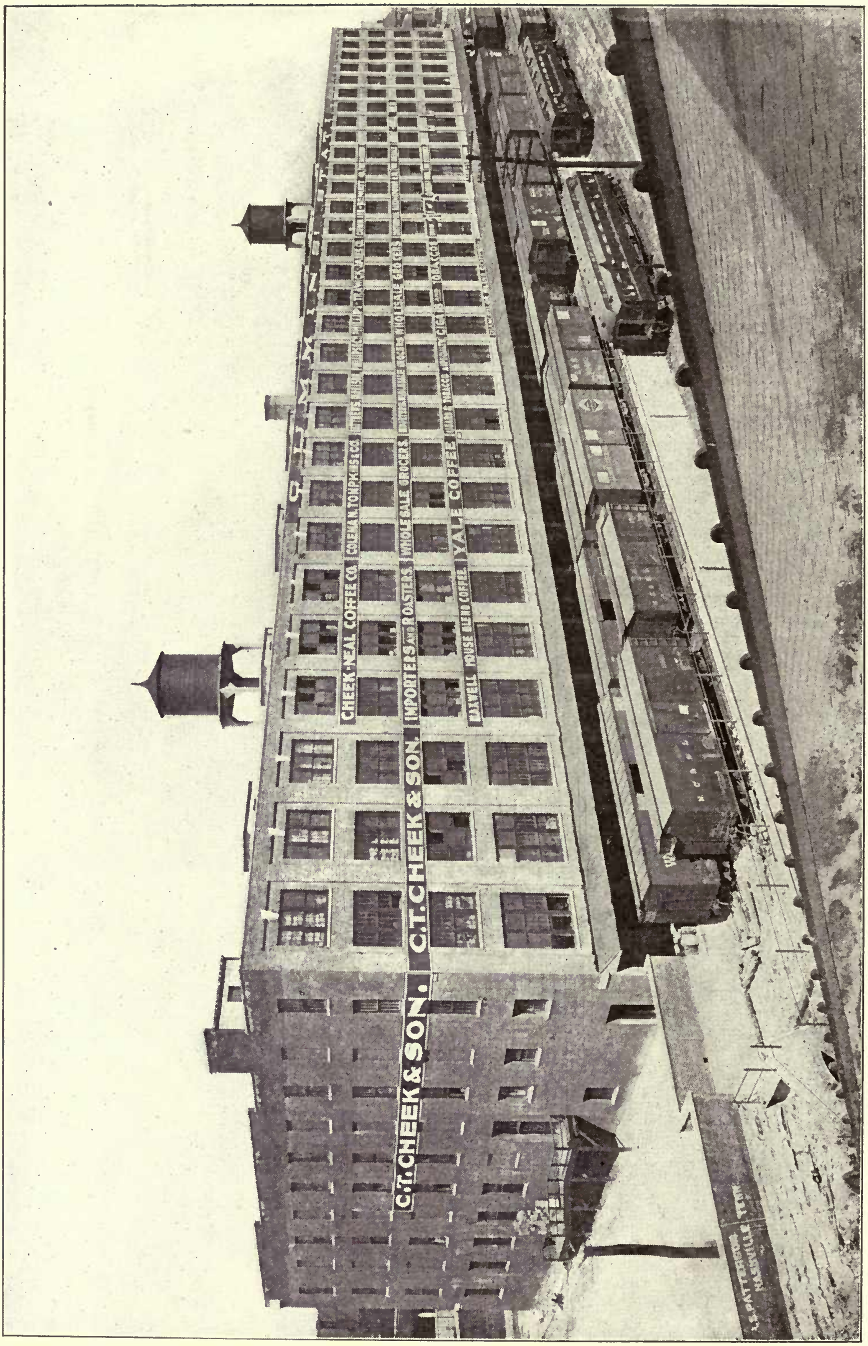

Fig. 43.—Wholesale Merchants' Warehouse, Nashville. (*See p. 103.*)

# CHAPTER VIII.

## WHOLESALE MERCHANTS' WAREHOUSE.

The immense reinforced concrete warehouse at Nashville, Tenn., illustrated on the opposite page, is the result of a scheme of co-operation of a number of the most prominent merchants of that city. They previously had conducted their business in various individual warehouses in the business section of the city and some distance from the railroad. To better their condition the idea was conceived of forming the Wholesale Merchants' Warehouse Company to erect a fireproof building alongside of the tracks, and thus save the large expense of hauling and at the same time obtain greatly reduced insurance rates.

Insurance on the stock carried by the merchants in the old type of frame buildings ranged from $1.80 to $2.20 per hundred while in the new fireproof, reinforced concrete structure the rates were reduced to $0.40 per hundred.

To provide enough floor space not only for storage but also for carrying on the wholesale shipments, the building is 500 feet long by 132 feet deep and four stories high, with basement and sub-basement. It is divided by walls of concrete blocks into compartments entirely separate one from the other, each compartment comprising a complete wholesale warehouse, and as the building is located not only near the railroad but in the central part of the city as well, it constitutes the sole place of business in the city for each firm.

The basement is paralleled by two railroad tracks, an extension of the basement floor forming the unloading platform. A wide trucking platform also runs through the basement, reaching all the elevators.

Reinforced concrete was adopted because of the estimated economy in cost and in time of construction. The designing architects were Messrs. McDonald & Dodd; the supervising architect, Mr. Hunter McDonald, and the engineer, Mr. W. H. Burk. The Oliver Company were the builders.

Corrugated bars* were used throughout the building, and the Expanded Metal and Corrugated Bar Company approved the plans as drawn.

## LAYOUT.

The general plan, Fig. 44 (p. 105), is a framing plan showing the layout of the beams and also illustrating the division of one of the floors into the compartments for the different firms. The interior columns are spaced 12 feet

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* See Fig. 103, page 179.

apart in one direction and 16 feet 7½ inches in the other. In general, the beams run lengthwise of the building from column to column, with no supporting girders, while cross beams are placed at intervals to tie the building together and to support the partitions.

These cross beams and their partitions are not spaced uniformly, but at different distances apart, so as to afford a merchant a choice of several sizes of rooms, each of which extends the full depth of the building. For example, the spacing of the partitions is three bays in a large number of cases, while in one portion of the building the spacing is one and a half bays; in another, two bays; and in still another four bays. The widths of the compartments thus vary from about 24 feet to 66 feet, with a uniform depth of about 130 feet.

The beam design is somewhat different from usual along the front and rear of the building. Here the cross span is 18 feet instead of 12 feet, and short cross girders are introduced, each of which supports a floor beam at its center. The projecting girders at the rear of the building, that is, at the top of the plan in the figure, support the roof over the loading platform in the basement.

A cross section of the building is given in Fig. 45 (p. 106), showing the columns and the outline of the beams and slabs. In order to take advantage of the full width of the lot, and yet not encroach upon the loading platform with the basement columns, the rear wall of the building from the first floor up to the roof is supported by the ends of the floor girders which project at each story about 30 inches, thus acting as cantilevers.

Because of the variety in the weights of the goods to be stored, the floors were designed for different loadings. The first floor was calculated for 350 pounds loading per square foot of surface, the second floor for 300 pounds and the third and fourth floors for 250 pounds. The roof was figured for a snow load of 40 pounds per square foot. These figures in each case represent live loads, and do not include the weight of the concrete itself.

## BEAMS AND SLABS.

Details of the construction of a typical beam and slab are drawn in Fig. 46 (p. 107). These are designed for the first story to support a floor load of 350 pounds per square foot in addition to the weight of the reinforced concrete itself.

Inspection of the plans shows that three of the six bars in the beam are bent up on an incline and run across over the supports, lapping there a distance of one-quarter of the span length. Several 3/16-inch round stirrups are also provided to assist in taking the shear. The dimensions of the beams, 12 by 20 inches for the longitudinal beams of which the details are shown, and 10 by 16 inches for the cross beams supporting the partitions, are given in the customary way, measuring the depth from the top of the slab to the bottom of the beam, and assuming, of course, that the standard practice is

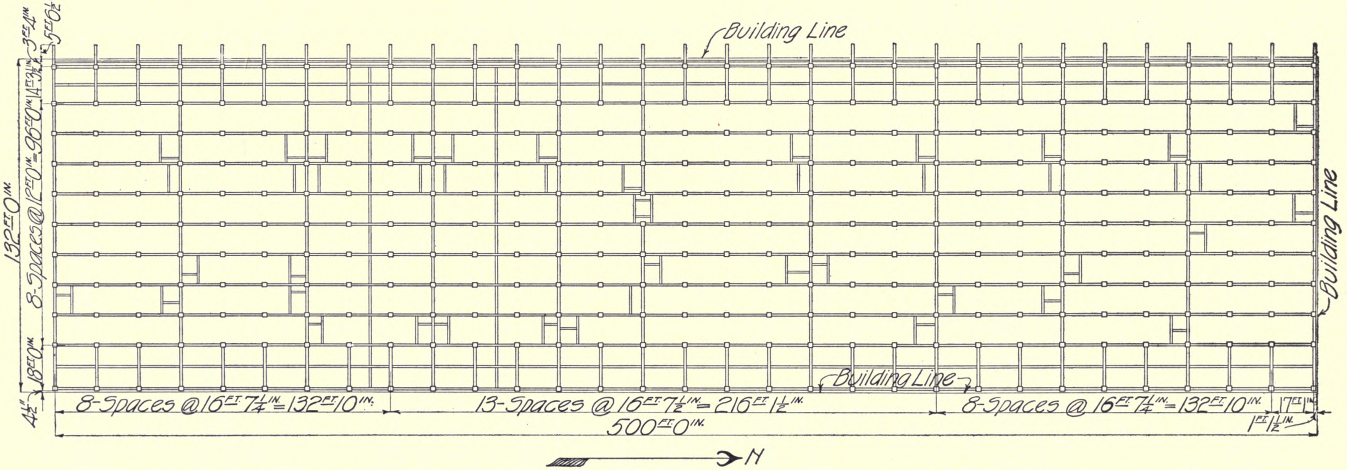


Fig. 44.—Typical Floor Plan of Wholesale Merchants' Warehouse. (*See p. 103.*)

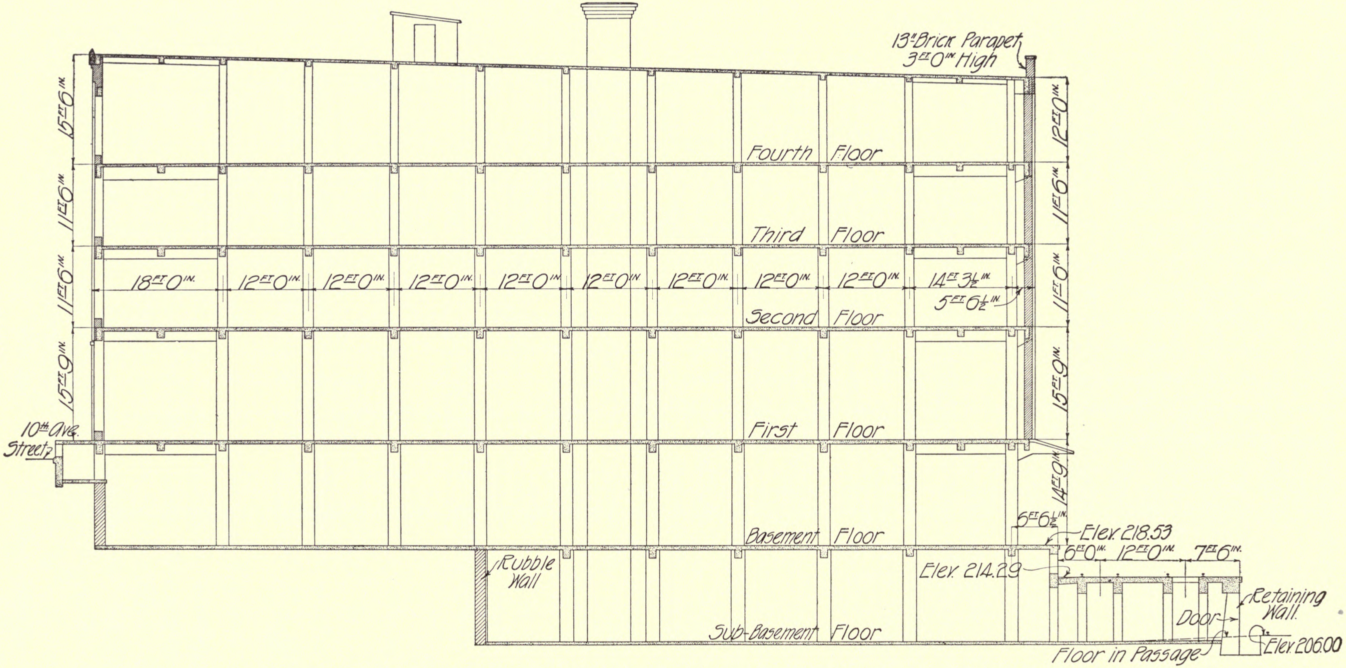


Fig. 45.—Cross-Section of Wholesale Merchants' Warehouse. (*See p.* 104.)

followed of placing the concrete in the beams and slabs at one time, so as to form a monolithic T-section. The rods in the bottom of the beam are placed in two layers, so as to bring them far enough apart to prevent the concrete splitting between them.

It will be noticed in the floor sketched, that ½-inch bars 5 inches apart to form the reinforcement for the slab, are placed in the bottom of the slab at the center of its span, but that all run up toward the supporting beam, and thus in the longitudinal section of the beam at the top of the diagram these rods, which are shown by so many dots, are close to the upper surface. This plan is somwhat easier to follow than where rods are alternately horizontal and bent up, and it is preferable to the latter because the negative bending moment at the ends of a continuous slab is at least as great as the positive moment in the center, so that fully as much reinforcement is required to take the pull at the top of the slab over the supports as is necessary in the bottom at the middle of the span.

The roof is of concrete of lighter design, and the slab, which is 3 inches thick, is laid on a slope of ¼-inch per foot and is covered with tar and gravel roofing.

A detail of the beams around elevator walls is drawn in Fig. 47.

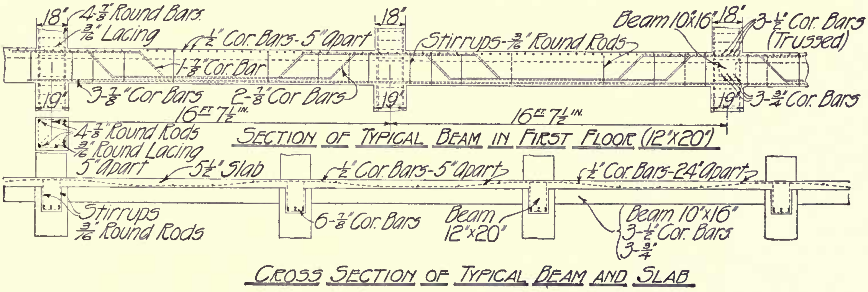


Fig. 46.—Details of Reinforcement of Typical Beam and Slab. (*See p. 104.*)

## COLUMNS.

Although the floor loads are heavy, the columns are only 19 inches square in the basement and less than this in the stories above because the spacing between them is comparatively small. The general type of reinforcement is four ⅝-inch vertical bars near the corners with 3/16-inch horizontal loops at intervals of 5 to 12 inches, varying with the dimensions of the columns. In the first story ¾-inch vertical bars were used with loops 4 inches apart.

The columns are designed for a loading of 750 pounds per square inch, a seemingly high stress for the proportions of cement to aggregate used, 1:2¼:4½, but in making the calculations no account is taken of the area of concrete outside of the steel loops nor of the strength of the vertical steel, so that the loading is really conservative.

## WALLS.

For the walls a skeleton structure of columns and beams is carried up, as shown in the photographs, and filled in with brickwork, the outside face of the columns being veneered with brick so as to give a uniform surface. The exterior trimmings and the doors and widow sills are all artificial stone.

The interior or partition walls, which separate the compartments into which the floors are divided, are of concrete blocks supported upon reinforced beams.

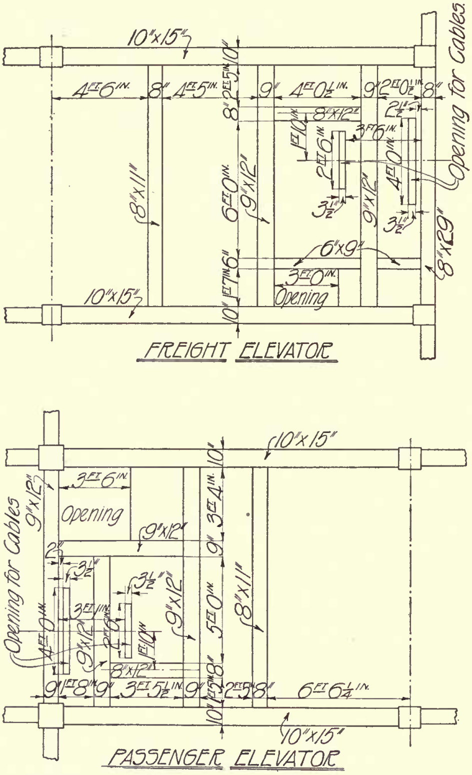


Fig. 47.—Detail of Framing at Elevator. (*See p. 108.*)

The concrete blocks were made of 1 part cement to 1½ part sand to 4½ part crusher dust. They were made in Hercules facedown machines and were faced on both sides during the process of the making with a layer of 1 to 2½ mortar. The standard size blocks in the partition walls were 8 by 8 by 24 inches, with two hollow spaces; the blocks around the elevators were 4 by 4 by 6 inches solid. Rabbets were formed in each end and in top and bottom surfaces, and filled with cement mortar as the blocks were laid, in order to secure as perfect a bond as possible. No interior plastering was used in the building except in the offices of each warehouse, which usually occupied only a small part of the first floor. The first two floors of the building outside of the offices were whitewashed by machines. The rest was left without any finish.

## STAIRS.

Stair details are shown in Fig. 48. The stairways are of straight run from story to story, and consist of a slab with the upper surface formed into steps. The bottom of the slab is reinforced with ½-inch bars placed 2 inches apart, and ½-inch rods also run across the steps at occasional intervals. The foot and head of each flight is especially reinforced, as shown, to strengthen it at the ends and connect it with the floor system.

## COAL TRESTLE.

Reinforced concrete coal trestles are occasionally built, but comparatively few designs have been published, and the trestle erected in connection with this building is therefore shown in considerable detail. Its elevation is given in Fig. 45 (p. 106) and the details in Fig. 49.

Two railroad tracks are carried by the trestle and most of the surface is floored over, the slabs being sloped to drains.

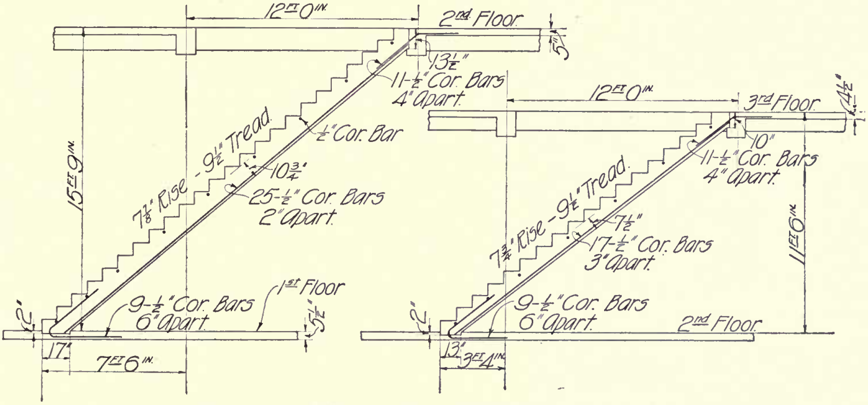


Fig. 48.—Details of Stairs. (*See p. 109.*)

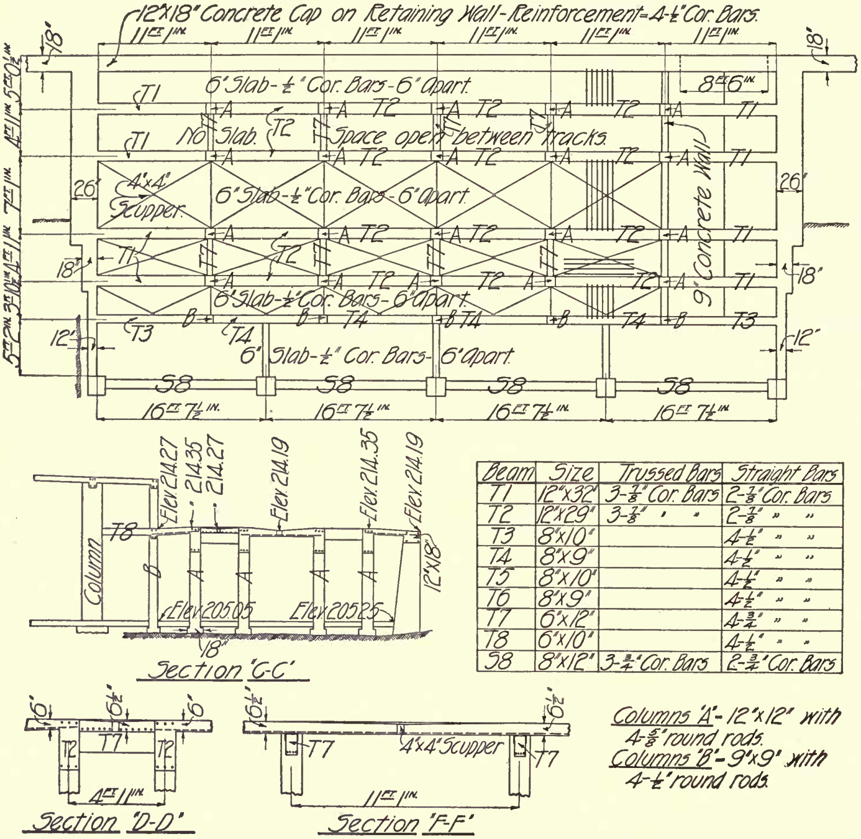
## CONSTRUCTION.

The warehouse was about eight months in building, and during this period 11,830 cubic yards of concrete were placed; of this 8,398 cubic yards were reinforced and 3,432 cubic yards plain. The latter figures included the blocks. The mortar finish for the floors measured in addition 510 cubic yards.

Amount of cement required was as follows:

Reinforced concrete, 10,365 barrels.
Floor finish, 1,690 barrels.
Artificial stone, 99 barrels.
Plain concrete, 1,770 barrels.
Concrete blocks, 4,051 barrels.
Total, 17,975 barrels.

The work in progress is shown in photographs, Figs. 50 and 51. These were taken on the same date, but from different points of view, the former from the rear of the building next to the railroad track and the latter from the unfinished end, showing also the front in process of construction.



| Beam | Size | Trussed Bars | Straight Bars |
|---|---|---|---|
| T1 | 12"x32" | 3-⅞" Cor. Bars | 2-⅞" Cor. Bars |
| T2 | 12"x29" | 3-⅞" " " | 2-⅞" " " |
| T3 | 8"x10" | | 4-½" " " |
| T4 | 8"x9" | | 4-½" " " |
| T5 | 8"x10" | | 4-½" " " |
| T6 | 8"x9" | | 4-½" " " |
| T7 | 6"x12" | | 4-¾" " " |
| T8 | 6"x10" | | 4-½" " " |
| S8 | 8"x12" | 3-¾" Cor. Bars | 2-¾" Cor. Bars |

Columns "A"-12"x12" with 4-⅝" round rods.
Columns "B"-9"x9" with 4-½" round rods.

Fig. 49.—Details of Coal Trestle. (*See p. 109.*)

The concrete was supplied to the different parts of the building by a cableway which is clearly seen in Fig. 50.

The cable was supported by the two towers located at each end of the

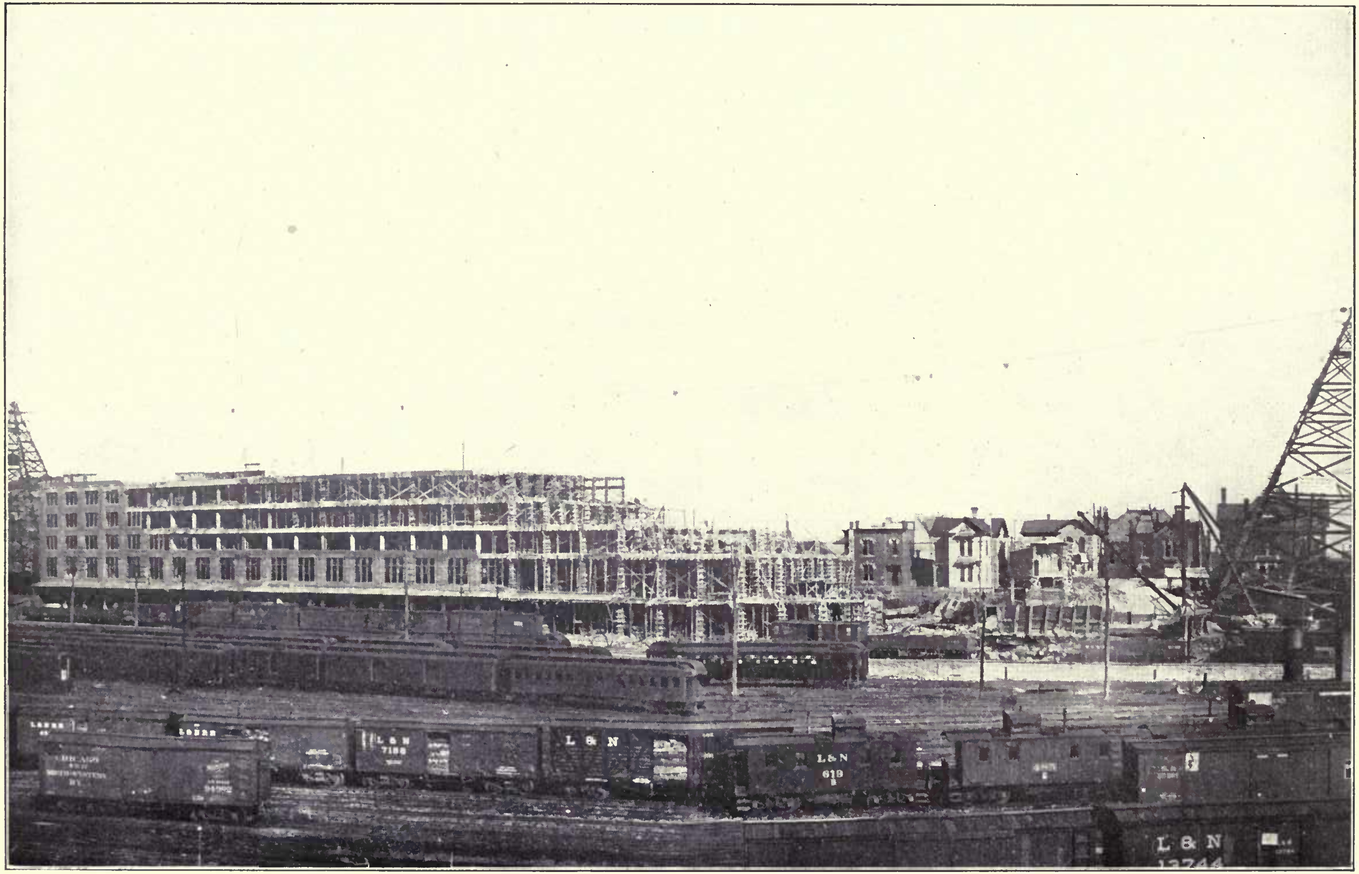


Fig. 50.—Rear View of Wholesale Merchants' Warehouse During Construction. (*See p. 110.*)

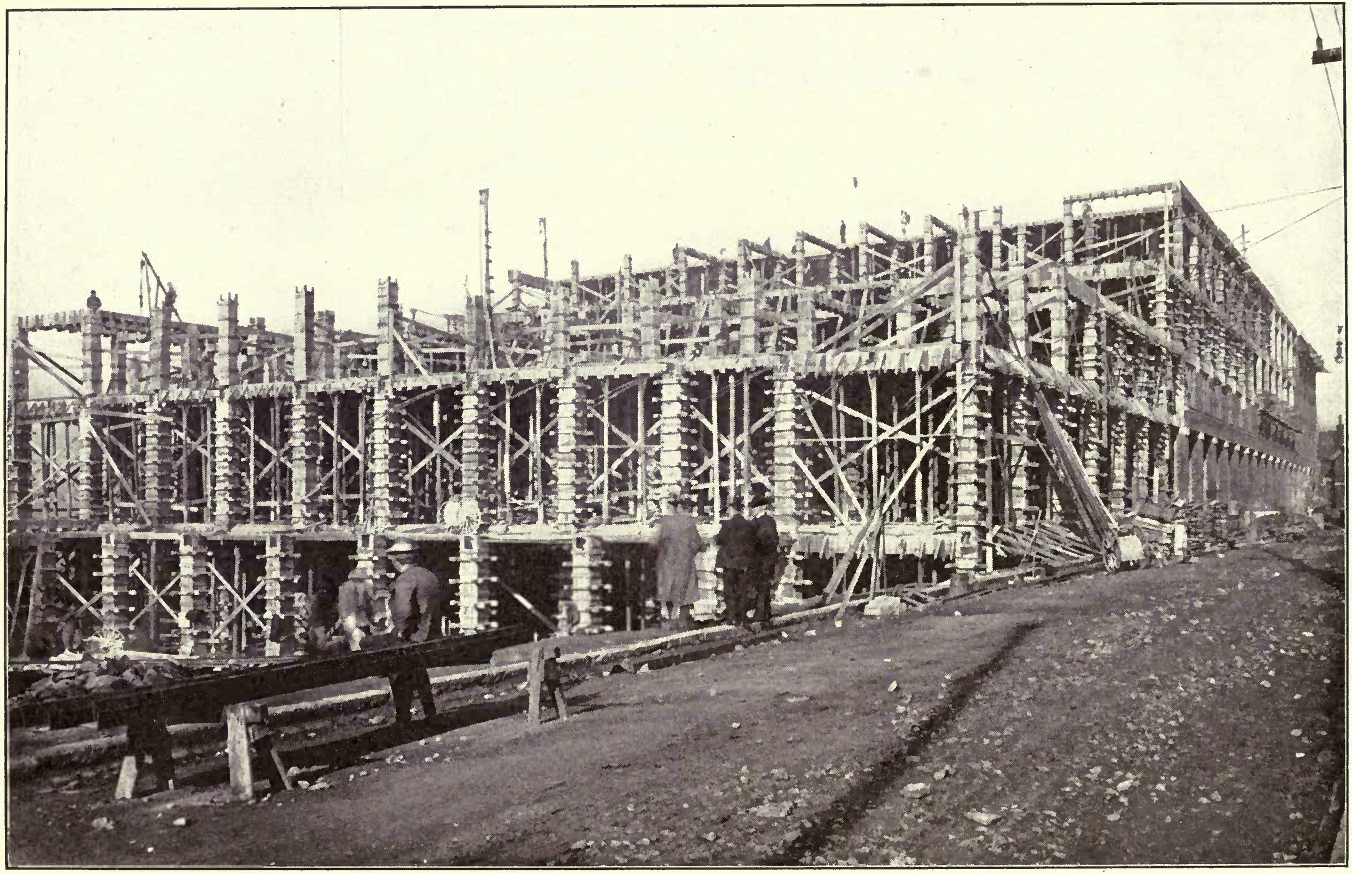


Fig. 51.—End View of Wholesale Merchants' Warehouse Under Construction. (*See p. 110.*)

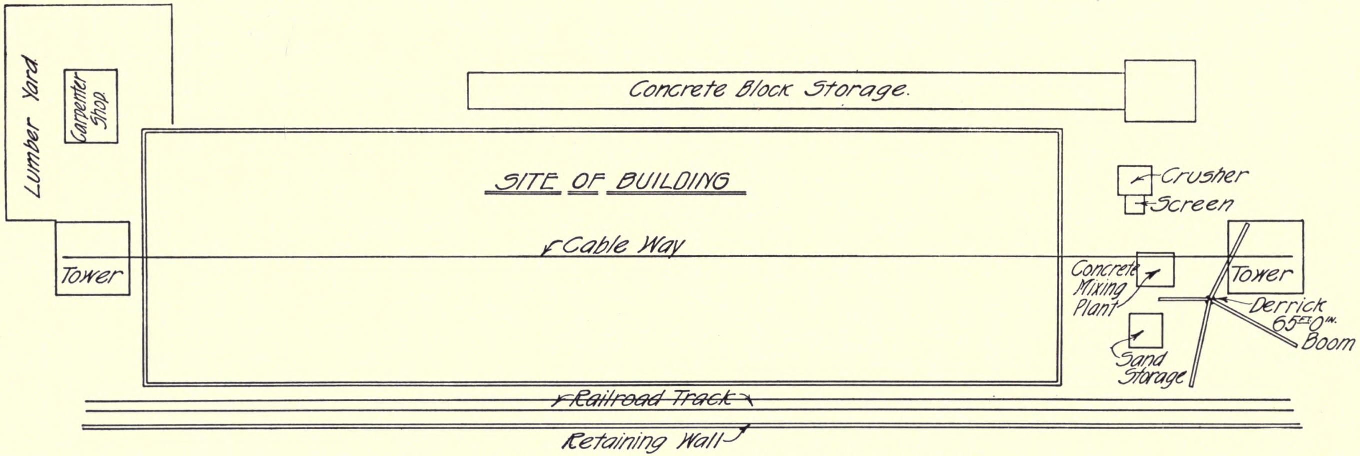


Fig. 52.—Plan of Construction Plant. (*See p.* 110.)

building and far enough away from it to leave room for the construction plant between.

The outline of the building with the cableway and construction plant is sketched in Fig. 52. The building rests on ledge, so that it was necessary to excavate a large quantity of rock, and the stone taken out was utilized in the concrete and also in the concrete blocks. This necessitated the installation of a crushing plant, a somewhat unusual feature in building construction, but which was made possible by the large amount of ground space and by the fact that the broken stone and screenings not only could be utilized for the building, but because there was a demand for the sale of the surplus coarse material for railroad ballast.

Crushers were set to crush the stone to maximum size of 1½ inch and the dust up to ¼-inch was screened out for use in the concrete blocks. All the rest of the crushed material was used in the concrete without further grading. Sand used on the work was brought in from Memphis in cars, while for the floor finish the aggregate was crushed granite.

A No. 4 Smith mixer made the concrete, and this was fed with material by a stiff-legged derrick having a 65-foot boom and operated by a 4-drum Lambert engine. The bucket was of a 1½-yard clamshell type, and dumped the material into charging bins which measured the materials automatically. The concrete fell from the mixer into buckets which were taken by cable and transported to steel portable bins located on the floor of the building where the concrete was laid, and whence it was finally delivered by Ransome 2-wheel carts. The highest run of the plant was 383 cubic yards in ten hours. A diagram of the mixing plant is given in Fig. 53.

The cableway also handled lumber for the forms and mortar for the floor finish, which was put on as the concrete was laid.

The plan of the plant also locates the lumber yard and carpenter shop at the other end of the building from the concrete plant. The forms were all made here, as much of the work as possible being done by machinery.

The cost of the lumber for the forms, which were used from four to eight times, was $5,400 and the salvage is figured at about 20 per cent., i. e., it is estimated that the value of the lumber left over which would be suitable for another job was about 20 per cent. of the original cost or about $1,100 and that this amount could be deducted when charging up the lumber to this building. Pine lumber was used throughout, and for panels it was tongued-and-grooved. The forms were left in place for about 25 days.

At one end of the building all of the reinforcement was stored, and forges operated by compressed air from the signal plant of the N. C. & St. L. Ry. were so arranged that they could be set at required points and the girder bars which required bending thus heated and bent in four places at the same time. Special benders were used for shaping the small rods. The column reinforcement was assembled and wired together before being placed in the form, special care being taken to accurately place it. The cost of bending and placing the steel was 0.4 cents per pound.

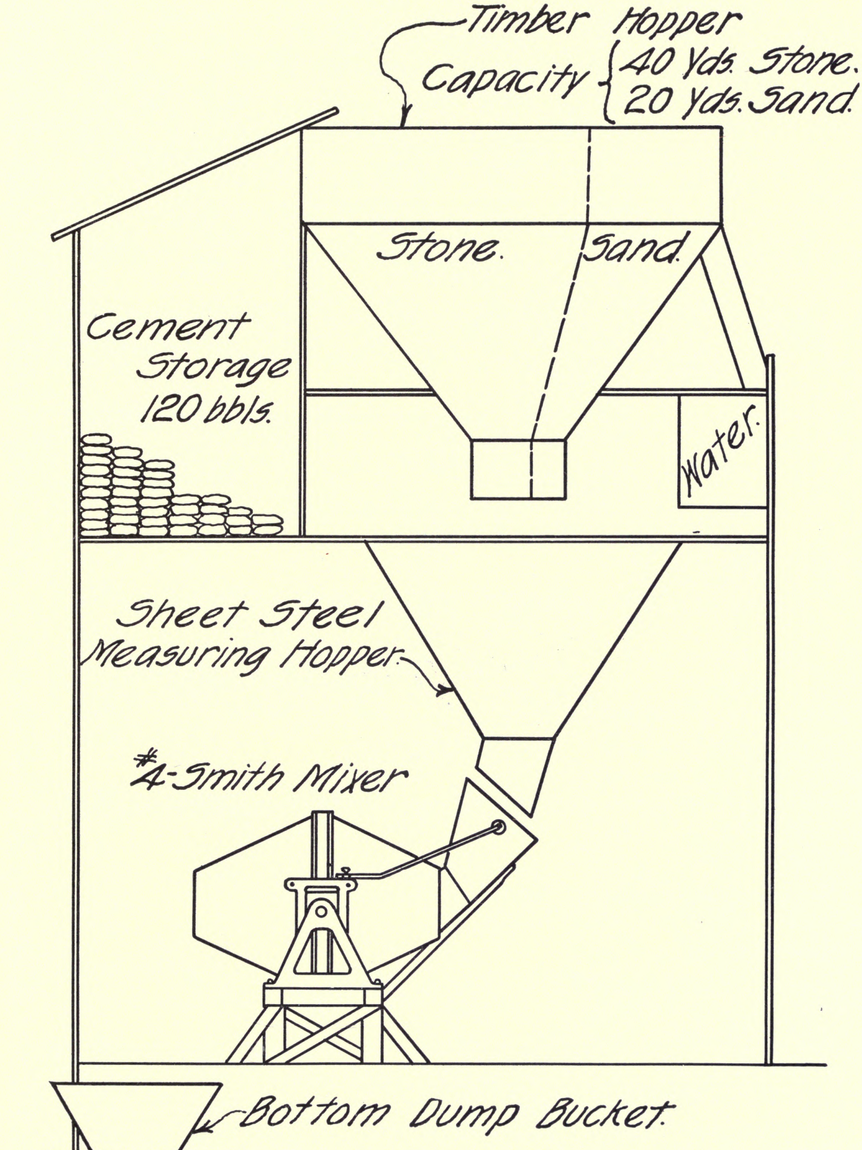


Fig. 53.—Mixing Plant. (*See p. 114.*)

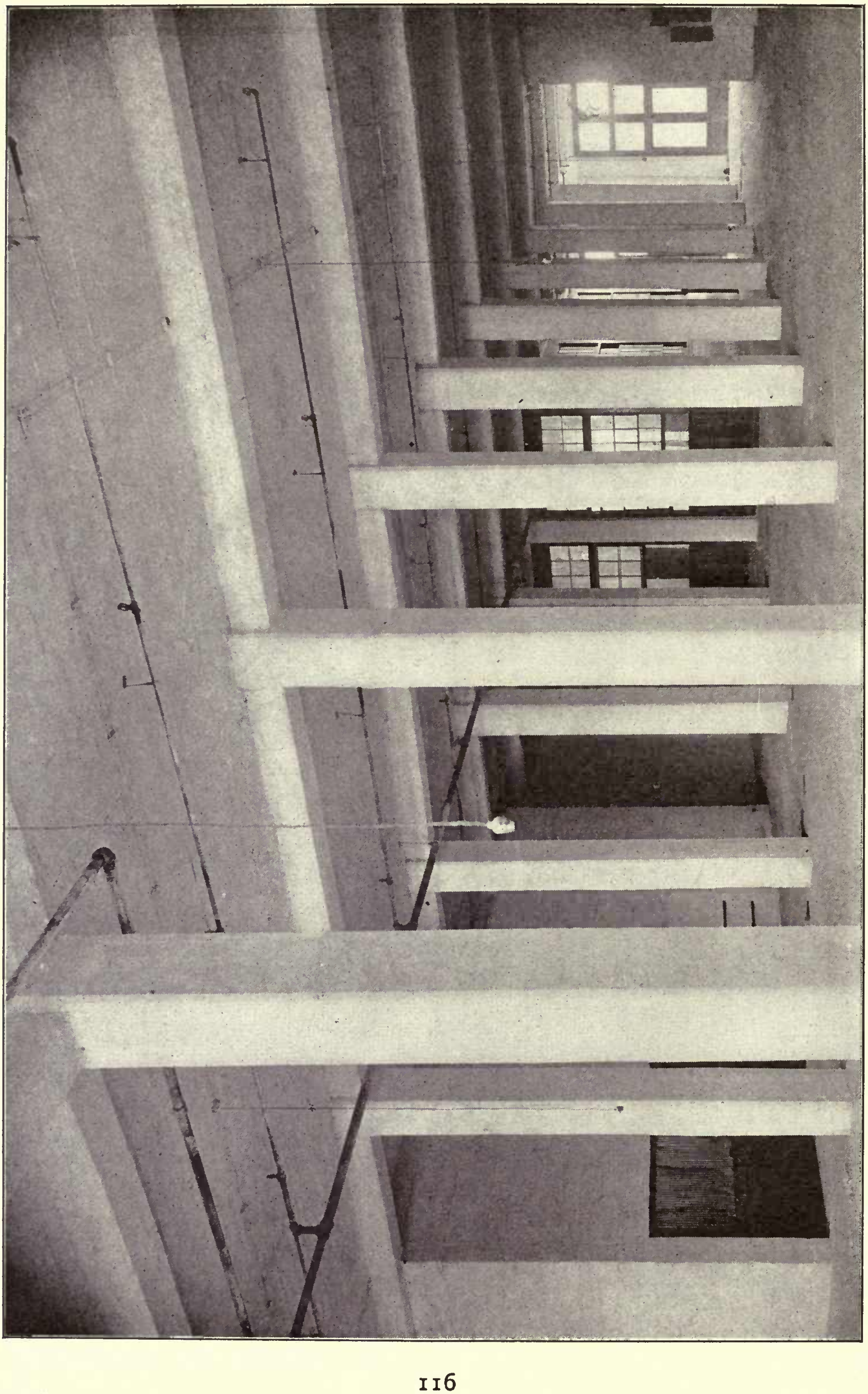


Fig. 54.—Interior of Wholesale Merchants' Warehouse. (*See p. 117.*)

The construction gang consisted in general of three foremen, 3 men mixing, 32 men placing, 45 carpenters, 20 steel men, 9 enginemen, besides some 60 to 150 men on the excavation and from 10 to 40 men on the stone crushing.

A photograph of the interior, showing the columns and floor system, is given in Fig. 54.

## COST.

The entire cost of the building was about $357,000 including finish, of which $192,000 was for the reinforced concrete and the excavation. The cost of the construction plant, which is included in these sums, was $19,000, an unusually large amount, but probably warranted in this case by the size of the building and the need of a crusher plant.

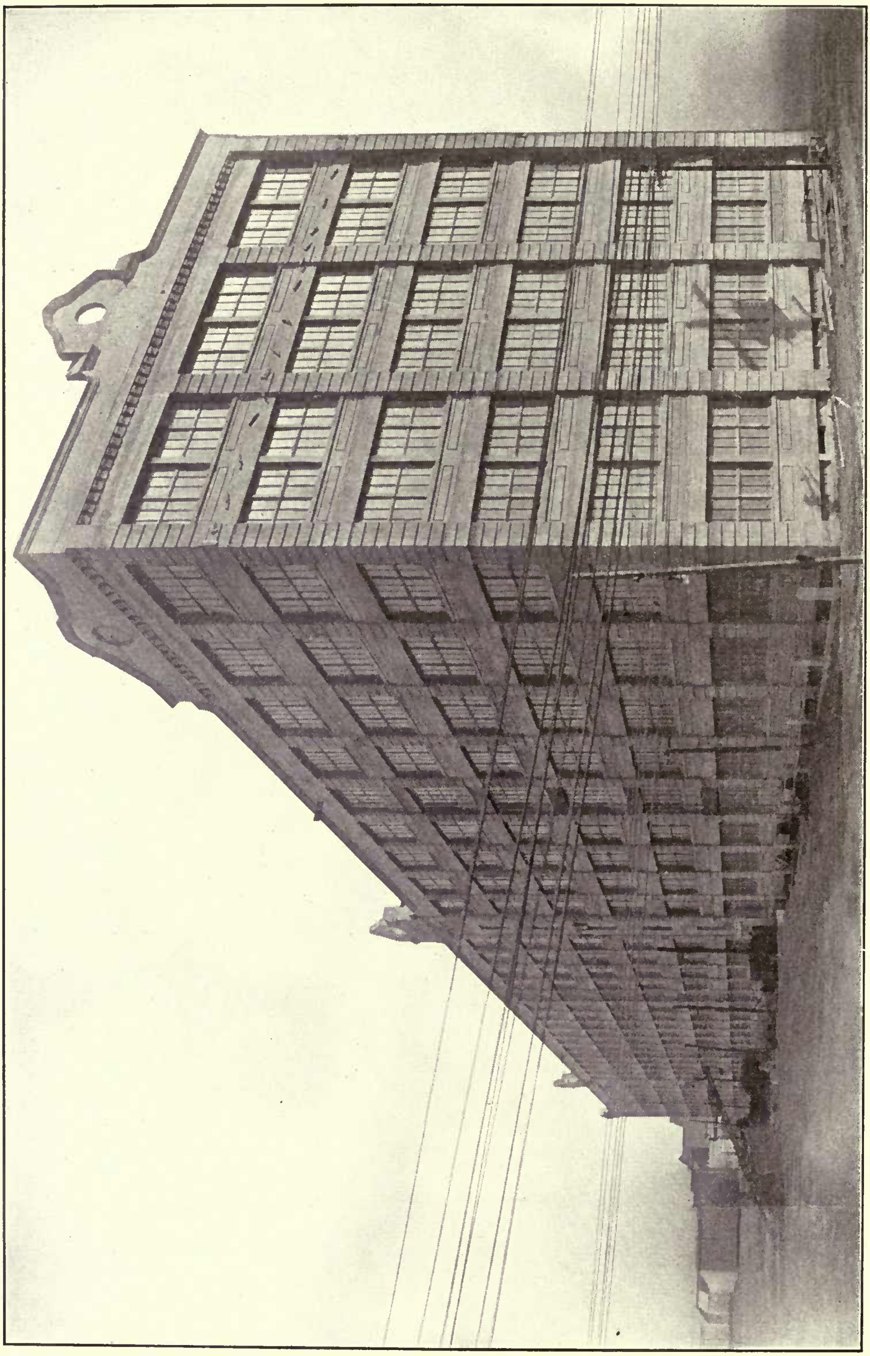


Fig. 55.—Bush Model Factory No. 2. *(See p. 119.)*

# CHAPTER IX.

## BUSH MODEL FACTORY.

The plant of the Bush Terminal Company, located in South Brooklyn on the east shore of New York Bay on Thirty-sixth street, between Second and Third avenues, will cover when completed an immense area and comprise some hundred and fifty warehouses and factories. Many of the more recent of these buildings are of reinforced concrete construction, the factory selected from this group for description being 75 ft. wide by 599 ft. long, and six stories high above the basement. Several features of the design are of unusual types.

The Terminal Company owns some 160 acres of land with nearly three-quarters of a mile of water front. A number of piers, each one-quarter of a mile in length, with wide docks between, permit the largest ocean steamers to discharge and load without interference. The large warehouses, 50 by 150 feet, and from four to seven stories high, provide the steamship lines renting the piers with unusual facilities for both storage and trans-shipment of freight.

In addition to this storage and shipping business handled by the piers and warehouses, a plan is already being carried out to erect eighteen fireproof factories or loft buildings, their floor space to be rented for manufacturing purposes. The first of these factories, built in 1905, and the second, called the Bush Model Factory No. 2, built in 1906, offer unusually attractive features because of the excellent facilities afforded. The details of the latter, which is shown complete in Fig. 55, form the subject of this chapter.

The builder of this concrete factory was the Turner Construction Company. Mr. E. P. Goodrich, formerly chief engineer for the Bush Terminal Company, prepared the structural design, and Mr. William Higginson was the architect.

## DESIGN.

Instead of the usual system of beams, girders and slabs, the floors consist essentially of heavy girders directly supporting ribbed slabs, designed so that the under surface presents a corrugated or ribbed appearance, the purpose being to use for the necessarily long spans a minimum quantity of concrete, placed most effectively to take the loads upon it.

An idea of the general plan of the structure is gained from Fig. 56. In order to present it on a fairly large scale, only one end of the building, a length of about 225 feet in a total of 599 feet, is shown.

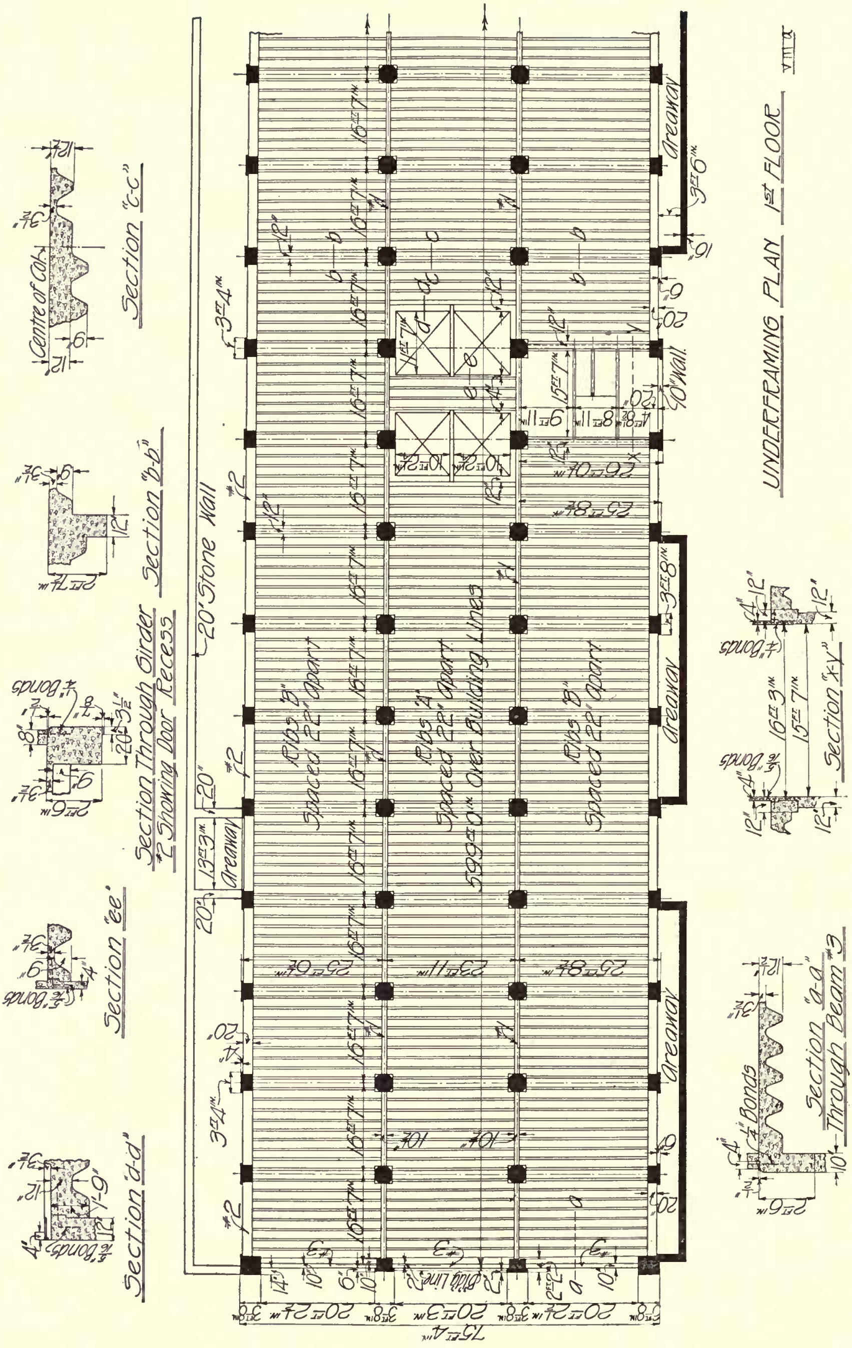


Fig. 56.—General Floor Plan of Bush Factory No. 2. (See p. 119.)

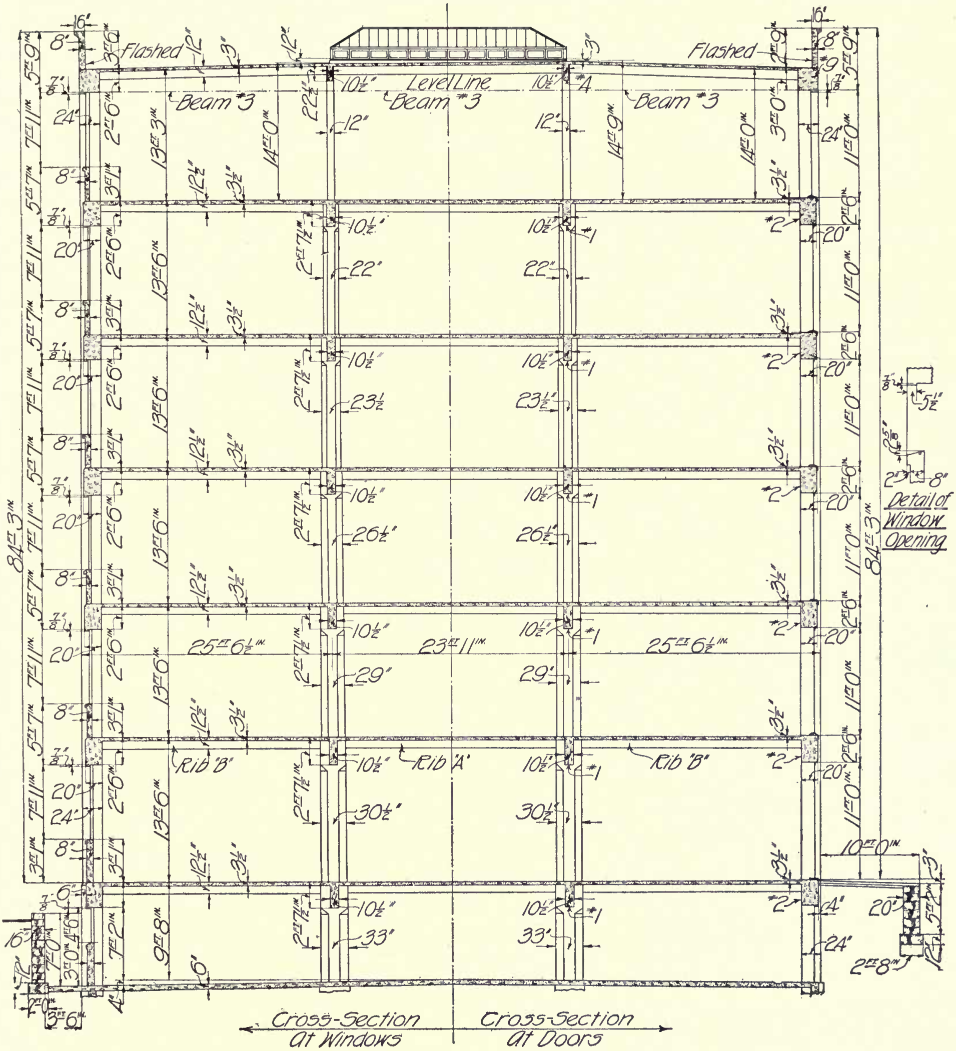


Fig. 57.—Sectional Elevation of Bush Factory No. 2. (*See p.* 119.)

The sectional elevation may be seen in Fig. 57.

Two lines of columns 16 ft. 7 in. on centers divide the factory into aisles about 24 ft. in width, thus giving exceptionally good floor space for either storage or manufacturing. Heavy girders run lengthwise of the building from column to column, while spanning the distance between these two lines or girders and the walls is the ribbed floor system.

Two groups of four elevators each are located one-quarter way from each end of the building, and in adjoining bays on each side of both groups of elevators are the stair wells. The first floor plan, Fig 56 (p. 120), shows the stairs to the basement only on one side of the elevators, but an additional flight is provided for the stories above. Except for the location of the stairs, the floor system of the different stories is identical, thus simplifying the design and permitting the use of the same forms throughout.

The roof is surrounded by a fire wall 3 feet 6 inches high. A series of skylights over the center aisle afford additional light to the top story.

Round rods formed into trusses on the ground and raised to place ready to drop into the forms provide the reinforcement. The proportions of the concrete used throughout were one part Portland cement, 2 parts sand, 4 parts stone, being equivalent in actual volume to one barrel (4 bags) cement, 7.2 cubic feet of sand, and 14.4 cubic feet of broken stone. The aggregate consisted of sand excavated by dredges from Cowe Bay, and washed gravel of a size passing a ¾-inch sieve.

## COLUMNS.

The column footings are supported by wooden piles, and the area of the footing is so large in proportion to the size of the columns as to require a special design of heavy horizontal rods and vertical stirrups.

In Factory No. 1 the interior columns are cylindrical and composed of an outside shell of cinder concrete 2½ inches thick. These cinder concrete cylinders were prepared in advance in 2-foot lengths in a zinc mold, with spiral hooping and expanded metal forming the inner surface. After hardening, they were set one upon another in the building, and filled with concrete.

In Factory No. 2 the columns are octagonal in shape, and composed wholly of gravel concrete. Just below the girders the section was made square (see Figs. 56 and 57), these square caps being of the same size on all the stories so as to avoid altering the rib and girder molds.

The columns were spirally reinforced with round high carbon steel ⅜ to ½ inch in diameter, the pitch varying in the different stories. The loading upon the columns was graduated from 500 pounds per square inch of their section for the upper floor to 1,000 pounds per square inch in the basement. This, however, assumed full loads on all the floors at the same time, which would not ordinarily occur, so that the columns in the lower stories are liable to be stressed much less than the nominal figures. The spiral hooping is computed to assist in bearing the load.

## FLOOR SYSTEM.

The general scheme of design has been referred to in paragraphs above. Longitudinal girders of 13 feet 4 inches net span, supported by columns 16 feet 7 inches on centers, carry the ribbed slabs which run across the building with a net span of about 23 feet.

The details of design of the beams and ribbed slabs are drawn in Fig. 58. The ribs are V-shaped in cross-section, as shown in Sections aa and bb. Two 1-inch round rods, one bent up at the points determined by moment diagram, and the other extending horizontally to the girders, provide for the tension, and ¼-inch stirrups are bent around and wired on to the horizontal rods. Ribs A, which are shown in the diagram, connect the two girders, while ribs B, which run from the girders to each wall, are similar in design except that the upper rod cannot project beyond the support, and is therefore anchored by bending it with a quarter turn around another rod which runs at right angles to it in the wall.

The steel is designed for a maximum pull of 16,000 pounds per square inch when the full allowed load is on the floor, and stirrups are provided wherever the shear exceeds 50 pounds per square inch. The floors are designed for a loading of 200 pounds per square foot besides the dead weight of the concrete.

The design of the principal girders is also shown in Fig. 58. The stirrups are close together at the ends of the girders where the shear is the greatest, and each stirrup is looped around the tension rods, then passes up on each side of the girder and across, as shown in the sections. The stirrups are ½-inch in diameter near the end of the beam, then at the points where the large rods are inclined and thus take a portion of the shear, the size is reduced to 5/16 inch, and this is continued to the center of the beam, the spacing gradually becoming wider as the shear decreases. The tensional reinforcement in the girders consists of four 1¼-inch rods, two of which are bent up just beyond the one-quarter points, and extend nearly to the center of the column, where each is connected with the reinforcement in the next girder by an oval link of ⅞ inch round steel.

In the bays around the elevators, the rib forms were dropped 8½ inches, so as to make the slabs between the ribs 12 inches thick, as shown in Section CC, Fig. 56.

No reinforcement was placed longitudinally of the building at right angles to the ribs. In the floors first laid with the V-shaped rib, slight shrinkage cracks occurred between the ribs and parallel to them. These, however, did not open or indicate any structural weakness, and they were eliminated by more thorough roding of the surface.

The underside of the floor construction, and also the columns, are shown in the photograph, Fig. 59 (p. 126).

The reinforcement was according to the Bertine Unit Girder Frame system as modified by Mr. Goodrich. This work of bending and placing was

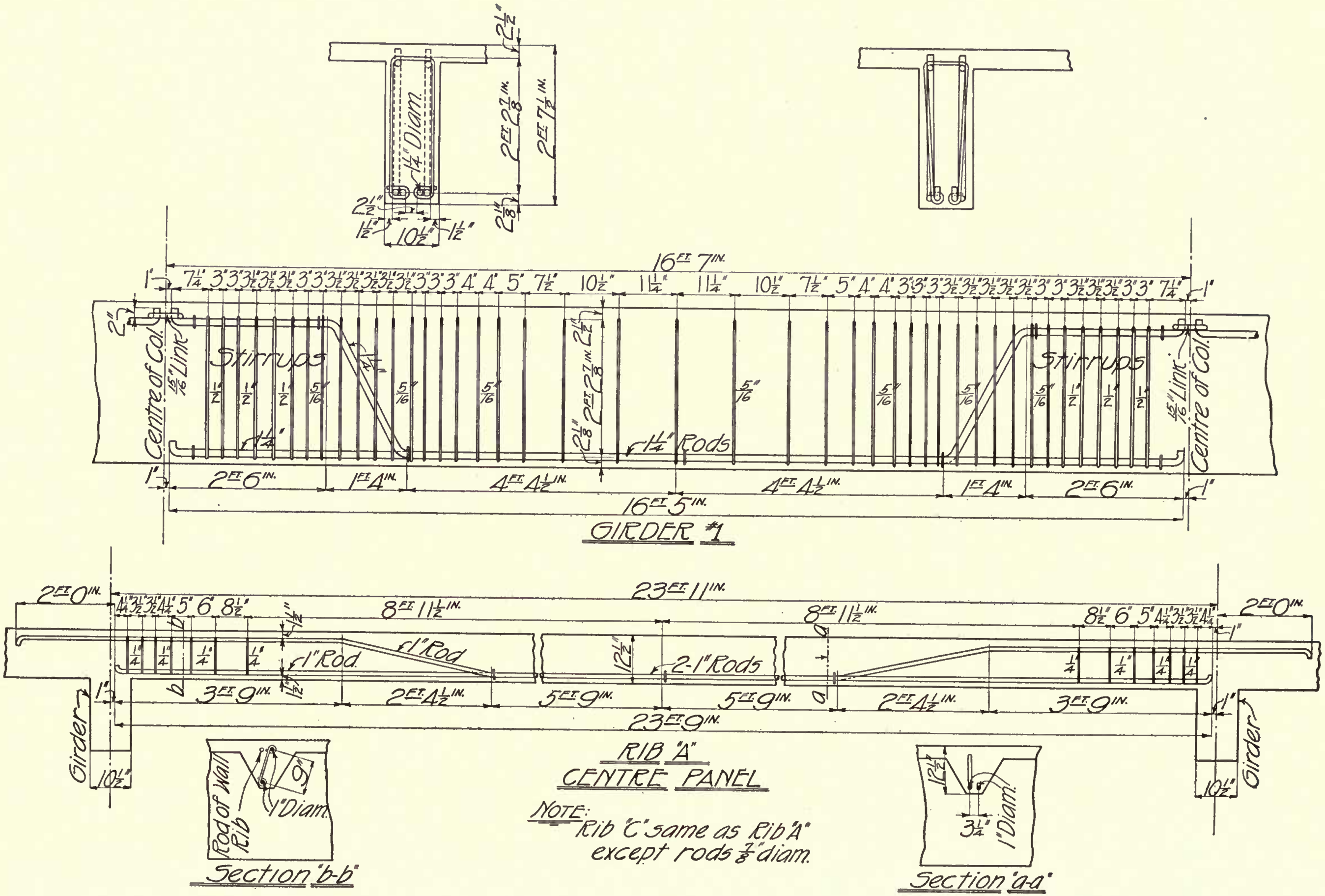


Fig. 58.—Details of Floor Design. (*See p.* 123.)

performed under a separate contract by Mr. M. S. Hamsley in an open shed near the building. To the wooden posts supporting the roof of the shed, brackets were fastened at the exact locations to support the horizontal and the bent-up rods of the truss. These principal members were bent in the special bending machine provided for the purpose, then were brought to the shed and hung upon the brackets, when the stirrups were sprung upon them, and wired to the large rods by ordinary stove pipe wire. The system of rods for each rib or girder thus formed a truss, as shown in Fig. 58, and was taken by the general contractors, elevated to the floor where it was to be used, and dropped into the form. The girder frame or truss rested upon blocks of concrete placed in the bottom of the form, and the rib truss was held upright by wiring each end to the steel in the girder truss.

On the girder trusses, four men worked in a gang, and could put together, after the large rods were bent, from twenty-five to thirty frames per day.

The spirals for the column reinforcement in Factory No. 1 were formed around a horizontal skeleton drum by two men who wound the ¼-inch wire around it and wired it to the ½-inch longitudinal rods. In Factory No. 2 a special machine was used for bending.

## WALLS.

The walls consist essentially of glass between concrete columns. The window lintels are reinforced concrete beams and above the floor level 8-inch walls were carried up from the floor to the window sills, which formed a part of the wall and were troweled hard while setting. These low walls were put in after the structural part of the concrete was several stories above them, as shown in Fig. 60, page 128.

The building is without partitions except around the elevator and stair wells. These were built after the floors were completed, and instead of being located directly under the beams or ribs they were placed alongside of them, slots being left in the floor slab so that they could be poured from the floor above directly into the forms built for them. The reinforcement of these partition walls consists of ⅜-inch round rods 15 inches apart both horizontally and vertically.

The exterior columns are divided into blocks by horizontal moldings attached to the inside of the form. After completing the building, the walls were given a wash of Lafarge cement.

## CONSTRUCTION.

Two mixing plants were located in the basement of the building near the two elevator shafts. The arrangement of the entire plant was according to the Ransome design. Each mixer was located on a platform about 3 feet above the floor level, and the raw material supplied to it by wheelbarrows. An electric motor supplied the power. The hoist, driven by a separate motor,

Fig. 59.—View of Interior of Bush Model Factory No. 2. (*See p. 123.*)

received the concrete directly from the mixer, and raising it to the floor where the concrete was being laid, dumped it into a hopper, from which it was fed by a gate into 2-wheel carts and conveyed to place. Each construction plant cost in the neighborhood of $2,500.

The building was completed in seventy-four working days, the average progress being 10.4 days per story. During this time 16,000 cubic yards of concrete were placed and 950 tons of steel. The usual gang consisted of 80 carpenters and 180 laborers.

Fig. 60 illustrates the work in progress on the fifth floor, where the column and girder forms are also being set for the floor above. The forms and braces are removed from the first, second and third floors, and they are being raised from the fourth floor to the floor above by falls carried by a triangular frame, which is seen projecting above the work. The photograph also shows the bracing and alignment of the faces of the exterior column forms. On the second floor the panels below the windows are being poured, a part of the forms being still in place. From the panel next to the corner and also from the panels of the first story the forms have been removed and show the finished surface. The molding of the columns also distinctly appears.

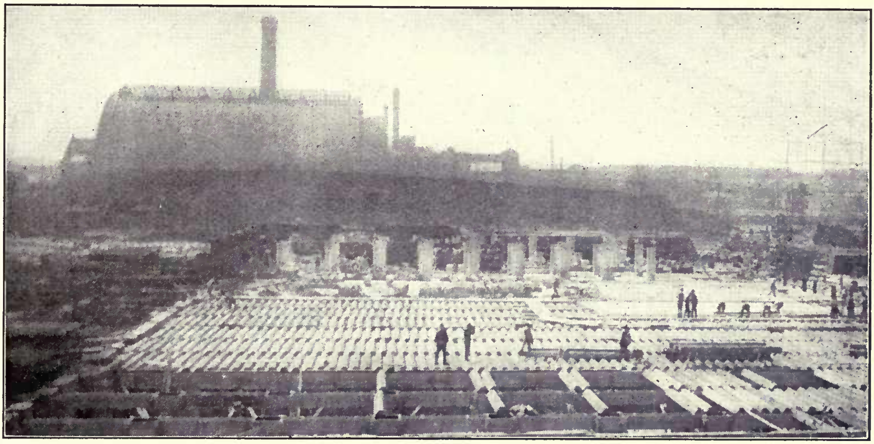


Fig. 61.—View Illustrating Form Construction for Bush Terminal Factory. (*See p. 127.*)

The photograph, Fig. 61, shows the general layout of the forms, the girder forms extending lengthwise of the view with the ribs at right angles to them. The rib forms, which are approximately triangular, rest directly upon the sides of the girder molds, and narrow pieces of plank are dropped between them to form the bottom of the rib.

Fig. 60.—Bush Terminal Factory No. 2 Under Construction. (*See p. 127.*)

The total cost of the building complete was approximately $450,000. It has automatic sprinklers, steam heat, ample toilet rooms, heavy freight elevators, wire glass windows in metal frames, standard automatic fire doors, hard wood floors, and so forth, to make really a model factory.

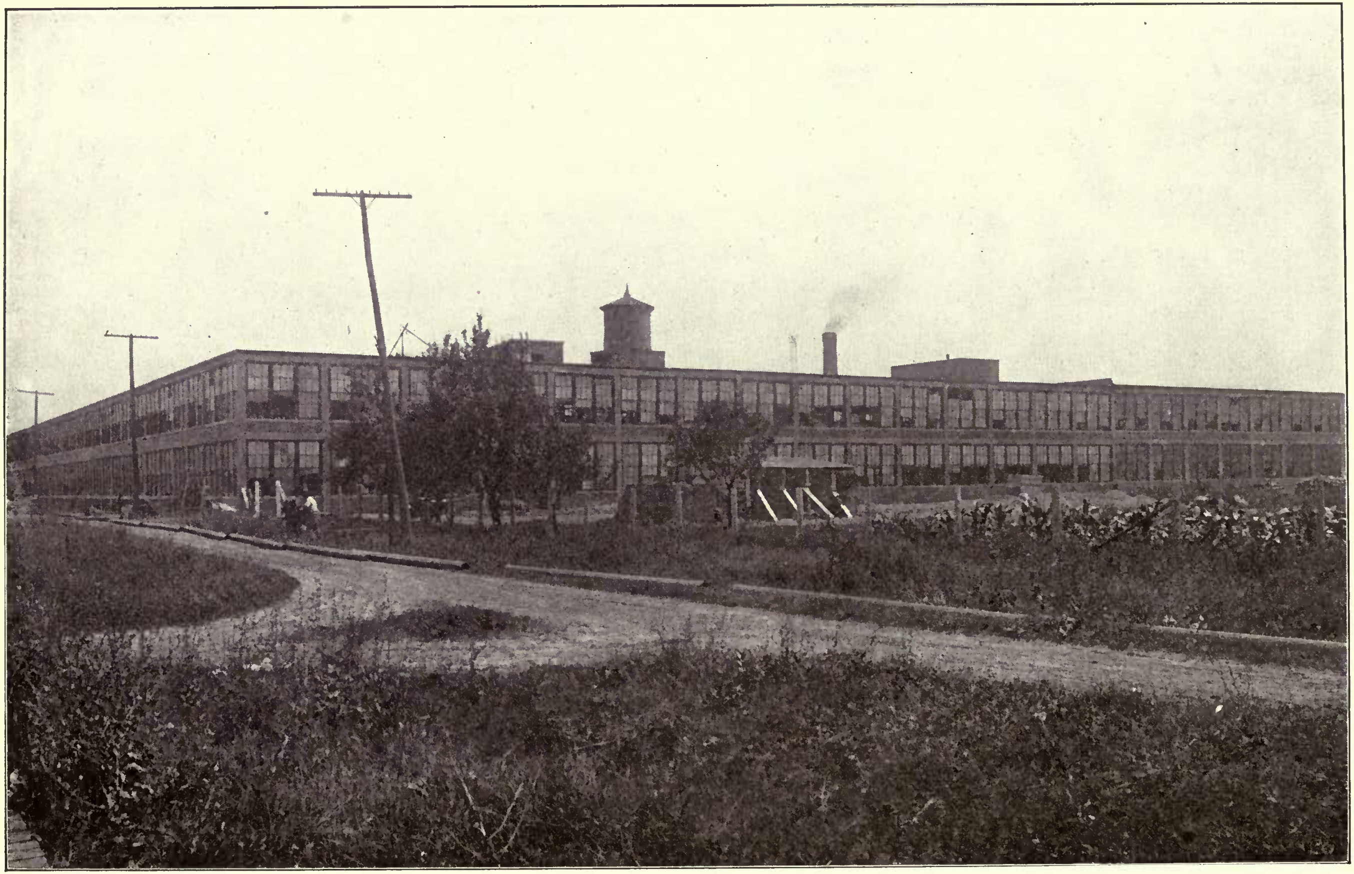


Fig. 62.—Packard Motor Car Factory. *(See p. 131.)*

# CHAPTER X.

## PACKARD MOTOR CAR FACTORY.

The Packard Motor Car Company at Detroit, Michigan, turned out in 1905 700 automobiles. The demand for these cars necessitated an enlargement of the plant, and in the spring of 1906, after careful consideration of the various types of construction, it was decided to build the new factory of reinforced concrete. The building illustrated on the opposite page is the result.

Plans were drawn at once by Mr. Albert Kahn, architect, and the contract was let to the Concrete Steel and Tile Construction Company, of Detroit, the Trussed Concrete Steel Company acting as engineers.

The structure, as is shown on the plans, is long and narrow, and in the form of an L, so that all parts of the floor are well lighted. It is proposed at some future time to extend the building by carrying out another wing. At present there are two stories, and the roof is designed as a floor with a temporary covering, as described below, so that another story can be added at a later date. The first floor is laid upon the ground with no basement.

The building is designed to provide very large floor area without interference of columns. A single row of columns runs through the center of the factory, and these are 32 feet apart on centers, a distance slightly greater than the space between the line of columns and the walls on each side.

Although a motor car appears to be a heavy machine in itself, the parts are comparatively light, and by placing the heavier machinery on the ground floor, it was possible to allow a floor load of only 100 pounds per square foot, in addition to the dead load or weight of the structure itself. In certain parts of the floor, this load is increased, around the elevators especial care being taken to give an excess of strength. This comparatively light live load together with the type of floor construction selected, a combination of tile and concrete, permitted the rather unusually long spans.

The general plan, Fig. 63, shows the layout of the floor, with an outline of the location of the beams, girders and columns.

Fig. 64 presents elevations and sections taken lengthwise of the building, and also, at the right, a typical or transverse section.

## FLOOR SYSTEM.

The first floor is built directly upon the ground. The top soil was removed and the surface thoroughly tamped, then covered with 6 inches of cinders rammed hard to receive the concrete. On top of this porous layer, a

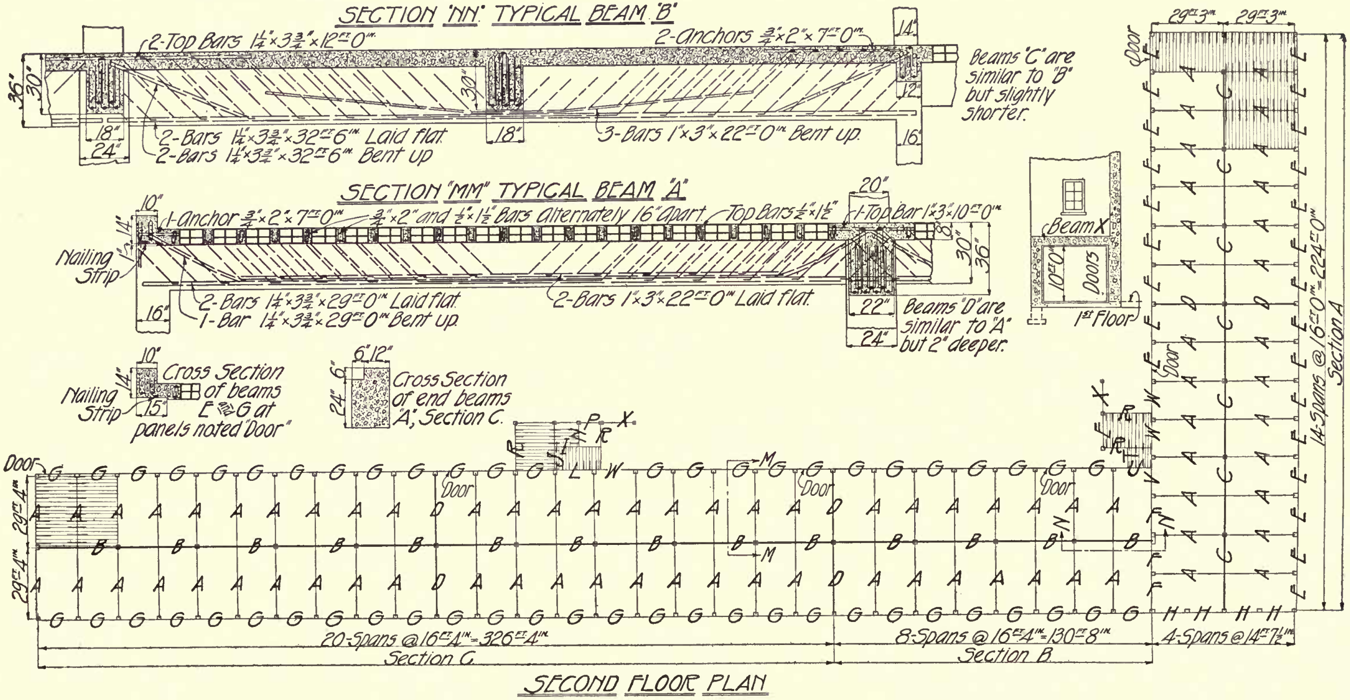


Fig. 63.—Floor Plan and Beam Details in Packard Factory. (*See p. 131.*)

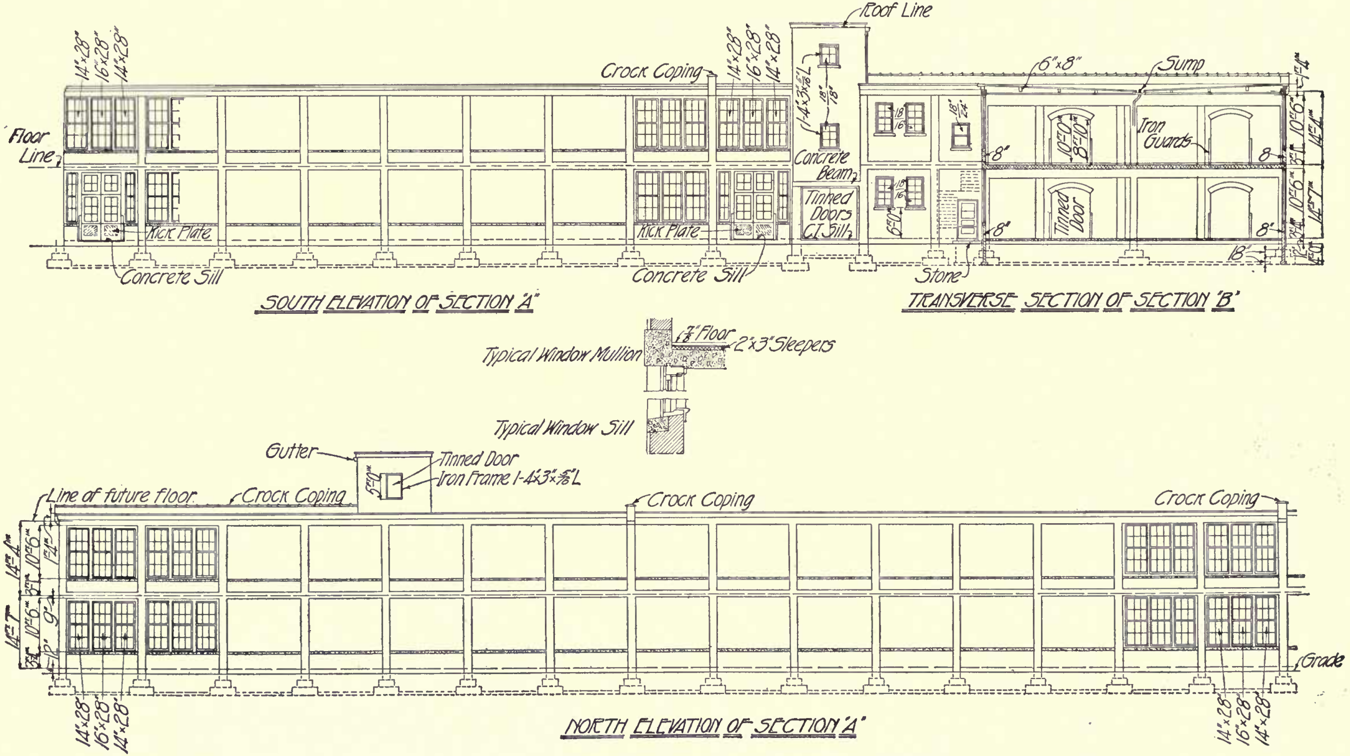


Fig. 64.—Longitudinal Elevations and Sections of Packard Factory. (*See p. 131.*)

5-inch thickness of concrete in proportions 1 part cement to 2 parts sand to 5 parts broken limestone was spread, and covered with a 1-inch mortar surface, laid before the concrete below had set, in proportions 2 parts cement to 3 parts sand, and thoroughly troweled with a steel trowel to a smooth surface. This was divided into sections as it was being laid to provide contraction joints.

In the floor above, the wide spacing of the columns, already mentioned, necessitated beams and girders of unusual length, and consequently of unusual width and depth. The girders (see Fig. 63) are 30 feet 8 inches in net length between columns, or 32 feet 8 inches on centers, and measure 22 inches wide by 36 inches deep from top of slab. Each girder supports one beam at the center of its span, the alternate beams running directly into the columns. The reinforcement, which consists of Kahn trussed bars*, is very clearly seen in section NN in the figure. The girder selected, as shown on the plan below it, is taken at the intersection of the two wings of the building, and the column at the right is therefore narrower than the left-hand support, the latter illustrating the typical columns in the building.

The floor system, as already mentioned, is designed for a load of 100 pounds per square foot in addition to the weight of the concrete and steel. The design is figured so that this loading will not produce a tension in the steel exceeding 16,000 pounds per square inch, and will keep the compression in the concrete everywhere within the limit of 500 pounds per square inch.† The proportions of the concrete are one part Atlas Portland cement, 2 parts sand, 4 parts broken limestone, the exact measurements being one barrel (4 bags) cement to 7.56 cubic feet sand to 15.10 cubic feet stone.

The shear or diagonal tension is provided for by bending some of the tension rods and also by the bent-up portion of the individual bars.

The beams, of which a typical section, MM, is also shown in Fig. 63, are 27 feet 1 inch net span between girder and wall column. The general construction is similar to the girder shown above it and labeled beam "B" except that fewer bars are bent up because the shear is less. The section of the typical beams is 30 inches deep and 18 inches in width.

A somewhat peculiar slab section is shown in the upper portion of section MM. This is made up of sections of tile and concrete placed alternately. The floor slab is 14 feet 6 inches net span between beams, and consists essentially of a series of concrete beams 8 inches deep by 4 inches in width spaced 16 inches apart on centers and reinforced with Kahn trussed bars. These little beams run directly into the upper surface of the regular beams, labeled "A" on the plan, and are supported by them.

Between these little beams hollow tile is laid, the method of construction being to first place the tile upon the level panel form, then set the reinforcing metal in position between the rows of tile, and pour the concrete. The ob-

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* See Illustration, Fig. 107, page 183.

† Figured by the parabolic formula, or nearly 600 pounds by the straight-line formula.

ject of the insertion of tile is to lighten the floor slab, and thus reduce the weight upon the beams and girders by occupying space which must otherwise be solid concrete. It also permits very simple form construction, consisting chiefly of a large plain surface readily built and removed.

After hardening, the under surfaces of the floors are plastered with 2 inches of Portland cement mortar to hide the tile and form the ceiling. On top of the floor slab, a 2-inch wearing surface of cement mortar finish is also laid to make the finished floor.

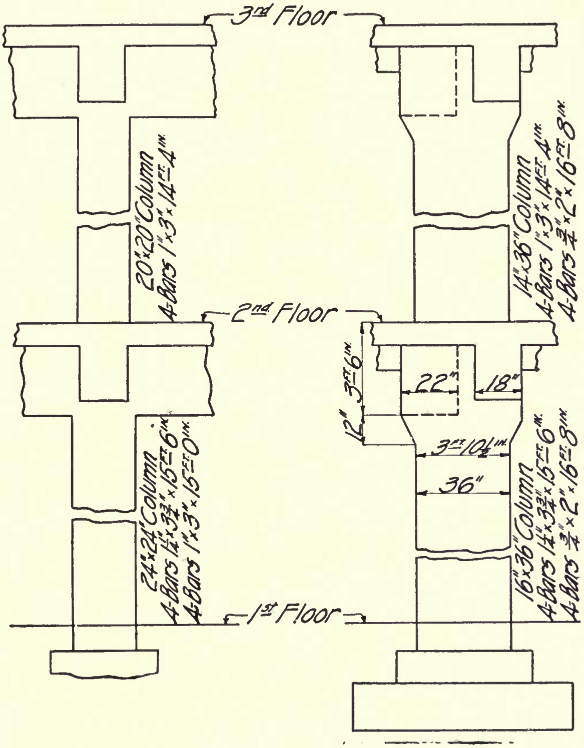


Fig. 65.—Typical Interior Columns in Packard Factory. (*See p. 136.*)

The beams around the elevators are especially constructed to sustain a weight of 8,000 pounds live or superimposed load, plus 8,000 pounds from the counterweights, plus 4,000 pounds, the weight of the elevators loaded.

The original specifications called for a roofing designed to carry 40 pounds per square foot, but it was afterwards decided to build this as a floor of the same construction as the second floor, so that another story could be added when required. On top of the level surface thus formed, a layer of cinders was spread and shaped so as to pitch to sumps; a 1-inch layer of mortar was laid on the cinders, and upon this tar and gravel roofing.

## COLUMNS.

The interior columns are in general 24 inches square and designed for a safe loading which produces a compressive stress in them not exceeding 450 pounds per square inch. The concrete was made in proportions one part Portland cement to 1½ parts sand to 2 parts stone, and reinforced with Kahn trussed bars, as indicated in Fig. 65 (p. 135).

The wall columns are similar in design, but smaller in section and spaced 16 feet 4 inches apart on centers, so that all the cross beams run directly into them. A longitudinal beam at each floor line connects these wall columns and also supports the brickwork, which is built up to the level of the window sills.

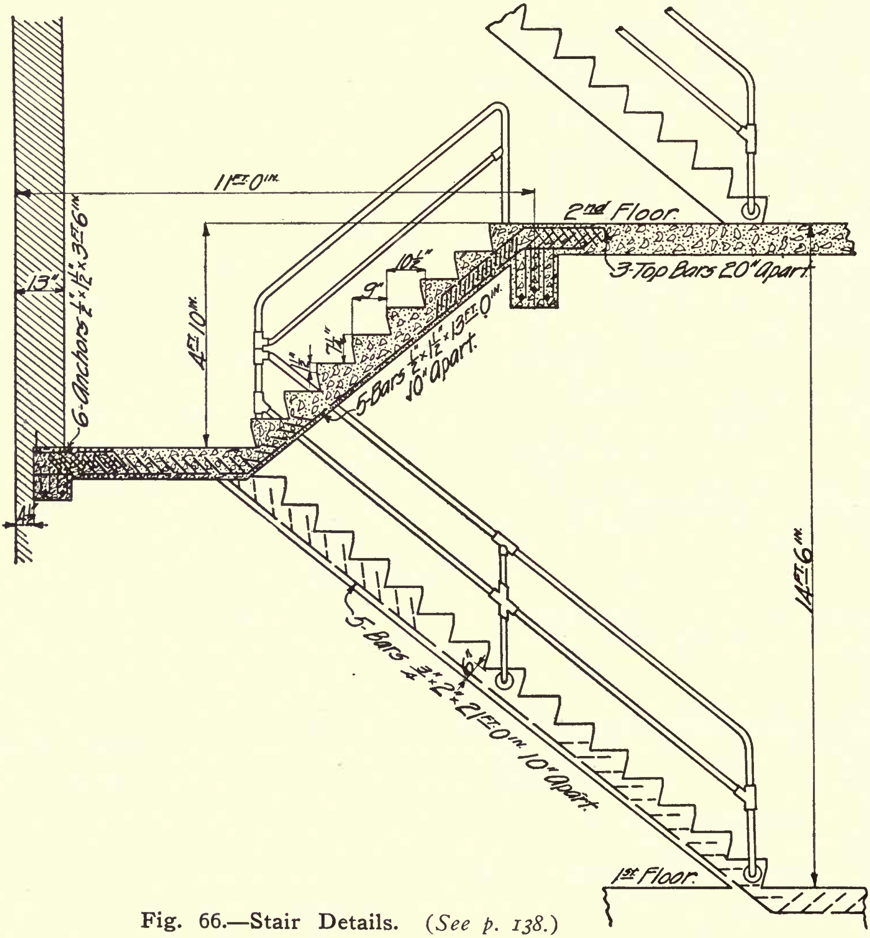


Fig. 66.—Stair Details. (*See p. 138.*)

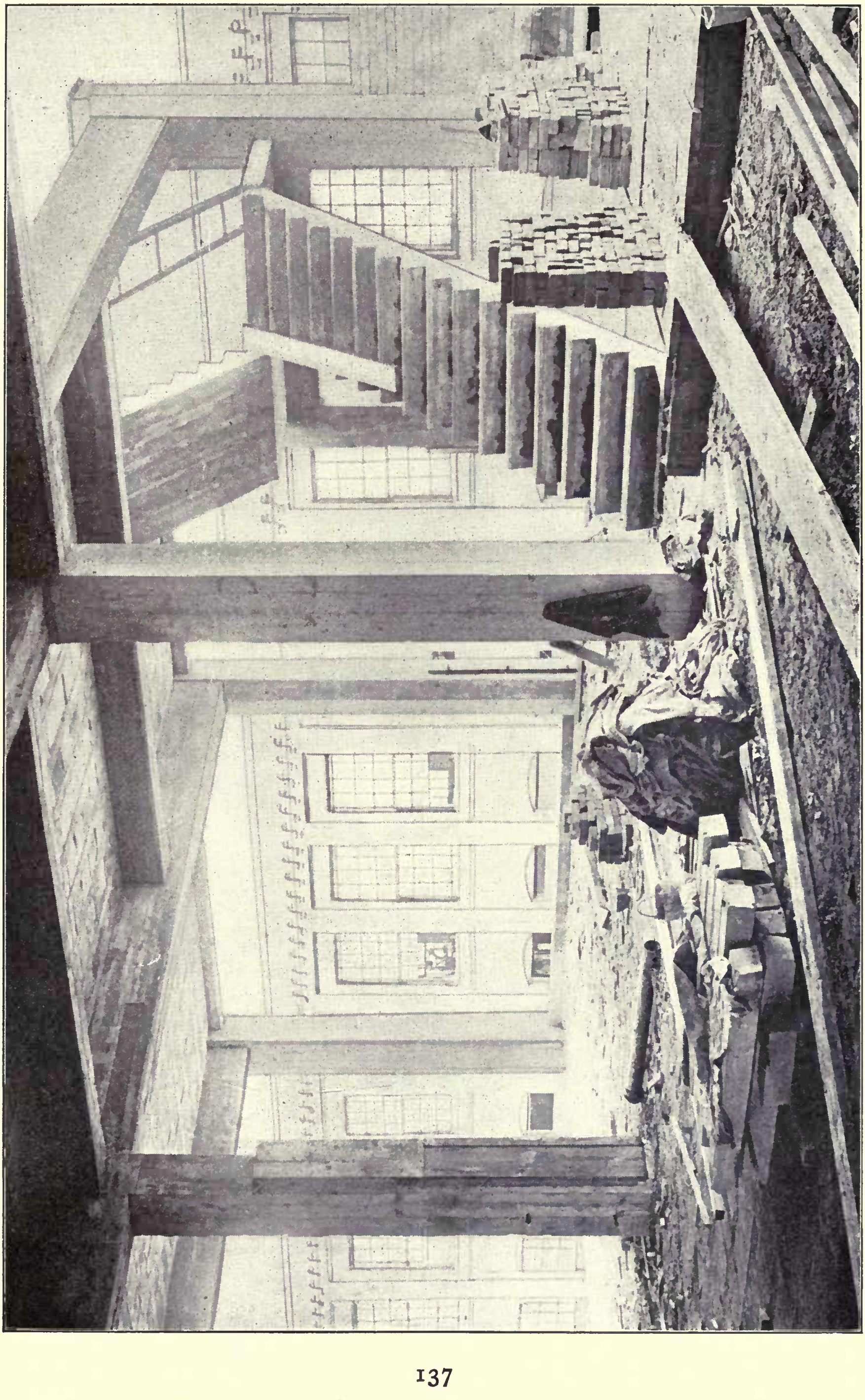


Fig. 67.—View of Stairs. *(See p. 138.)*

## STAIRS.

The stair details may be seen in Fig. 66 (p. 136). They consist in general of a slab reinforced with Kahn trussed bars and surface, with a 1-inch tread of cement mortar.

A photograph of the stairs, Fig. 67 (p. 137), taken soon after the concrete was laid, very clearly illustrates their arrangement and design.

## CONSTRUCTION.

The factory was sixteen weeks in building, and in its construction 2,100 cubic yards of concrete were laid and 225 tons of steel placed.

The arrangement of the plant is clearly shown in Fig. 68. Two mixing plants were located as shown, one with a Ransome mixer fed by an automatic hoist, and one with a Smith mixer. Each of the mixers dumped into a bucket hoist, which elevated the concrete to a bin on the fourth floor, where it was placed by wheelbarrows. The work of construction is shown in the photograph in Fig. 69. One of the concrete hoists is seen on the left, and one of the double platform hoists which elevate the tile and steel is on the right. The upper surface of the floor slabs, with the alternating concrete and tile, and the top surface of the girders and beams are also distinctly visible in the foreground. The underside of the floor, with the alternate tile and concrete surface, is illustrated in Fig. 70, and the interior of the finished buildings is presented in Fig. 74 (p. 145).

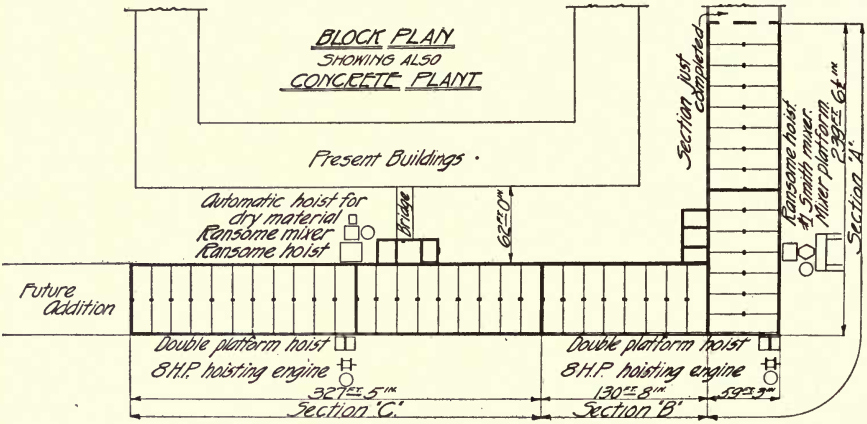


Fig. 68.—Plan of Construction Plant. (*See p. 138.*)

## FORMS.

For the forms, 1¾-inch lumber was used, except that for the floor panels No. 1 Norway pine, dressed four sides, was employed. The cost of lumber averaged $27 per thousand, but there was a large salvage, that is, a large pro-

Fig. 69.—Concrete and Tile Floor Under Construction. (*See p. 138.*)

Fig. 70.—Interior View of Packard Factory Under Construction. (*See p. 138.*)

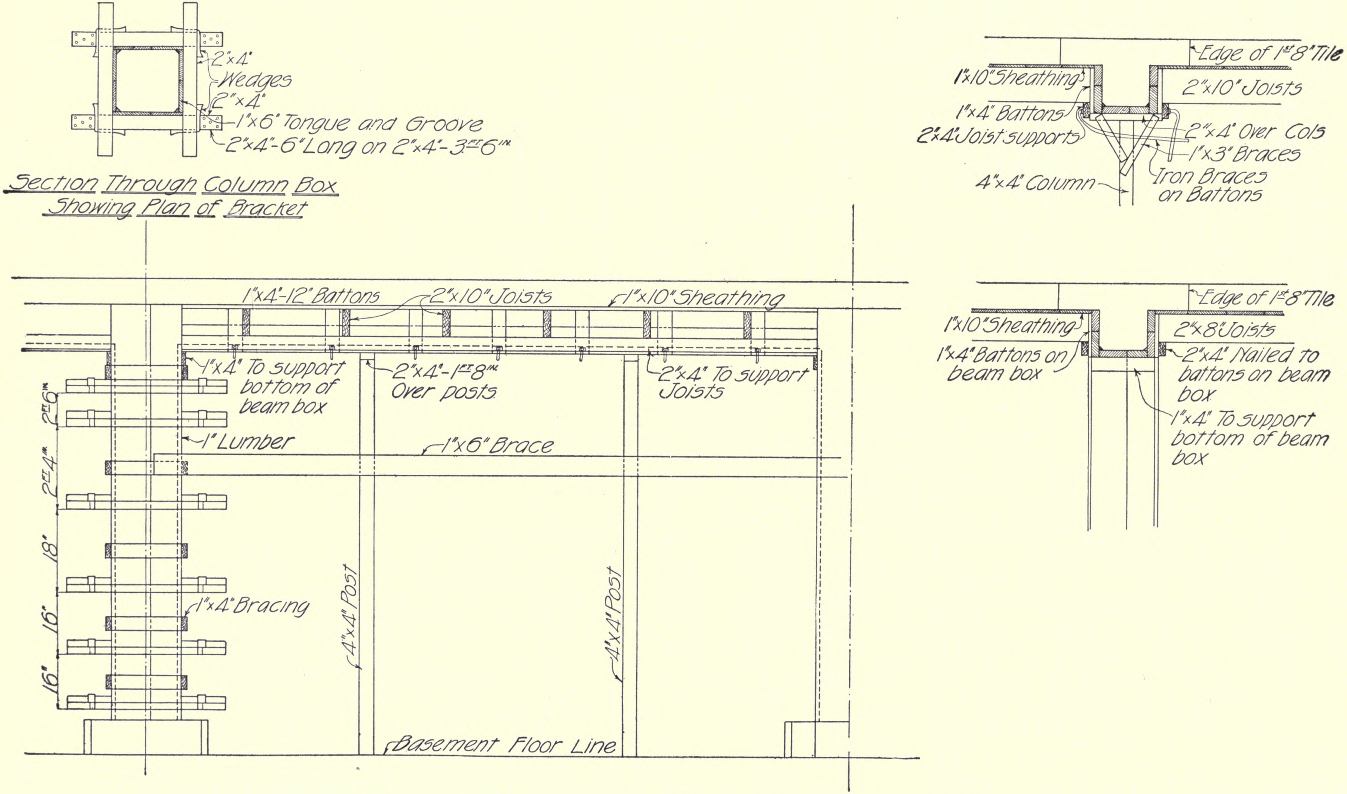


Fig. 71.—Detail of Form Construction. (*See p. 138.*)

portion of the lumber was suitable for use on another job, because of the wide floor slabs and large beams and girders, which cut up the stock less than usual.

Typical form details are drawn in Fig. 71 (p. 141). The clamps or brackets of the column forms are driven up with wedges so as to make tight and prevent twisting. The beam molds on the right of the diagram are held together with iron clamps or braces placed against 2 by 4 inch battens, which also serve as supports for the joists which carry the sheathing.

The centering was erected so that the column forms could be removed first, then the sides of the beam molds, and next the floor forms, leaving the bottom of the beam molds with the shores in place. These shores were generally left in three or four weeks, while the remainder of the forms were taken down in two or three weeks. Owing to the length of the span and the heavy weight of the beam molds, the bottoms of these were built on the ground and then raised to place, and the sides were constructed in position. This avoided the elevating of the completed mold.

Fig. 72 shows the exterior of the building under construction, with the column and beam forms and the struts still in place in the second story. Some of the first floor shores also remain to support the principal beams and girders. The illustration also shows the platform hoist for raising the tile.

The photograph in Fig. 73 was taken a little later, and shows the structural portion of the building practically completed but with some of the shores and part of the centering still in place on the upper floor. The window frames are set along one side of the first story and the brickwork laid there. In the background can be seen the stair and elevator well and just in front of it the concrete hoist.

The exterior view of the completed factory is shown in the photograph, Fig. 62, page 130.

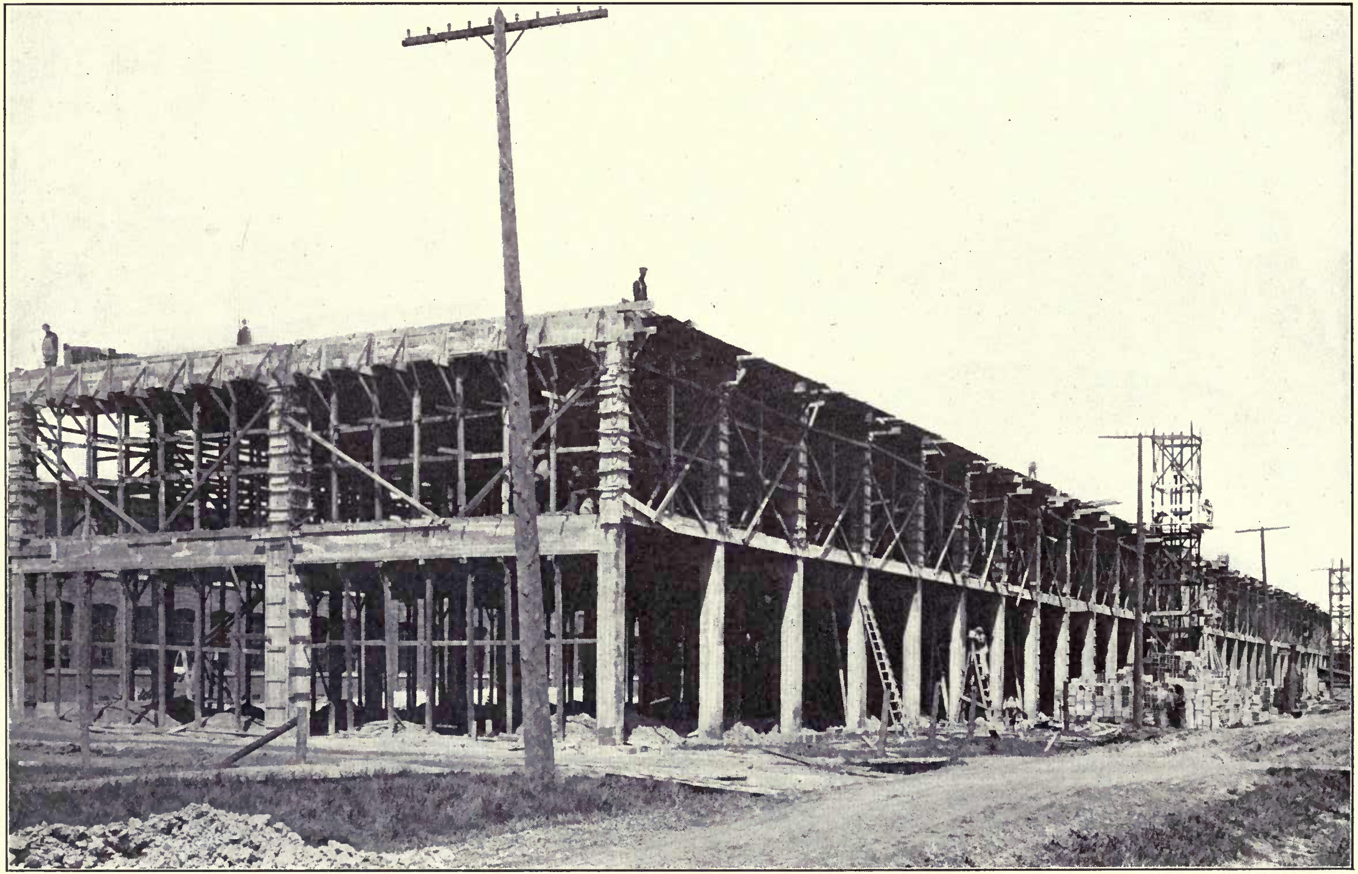


Fig. 72.—Exterior View of Packard Factory Under Construction, Showing Second Floor Centering in Place. (*See p. 142.*)

Fig. 73.—Exterior View of Packard Factory Nearly Completed. (*See p. 142.*)

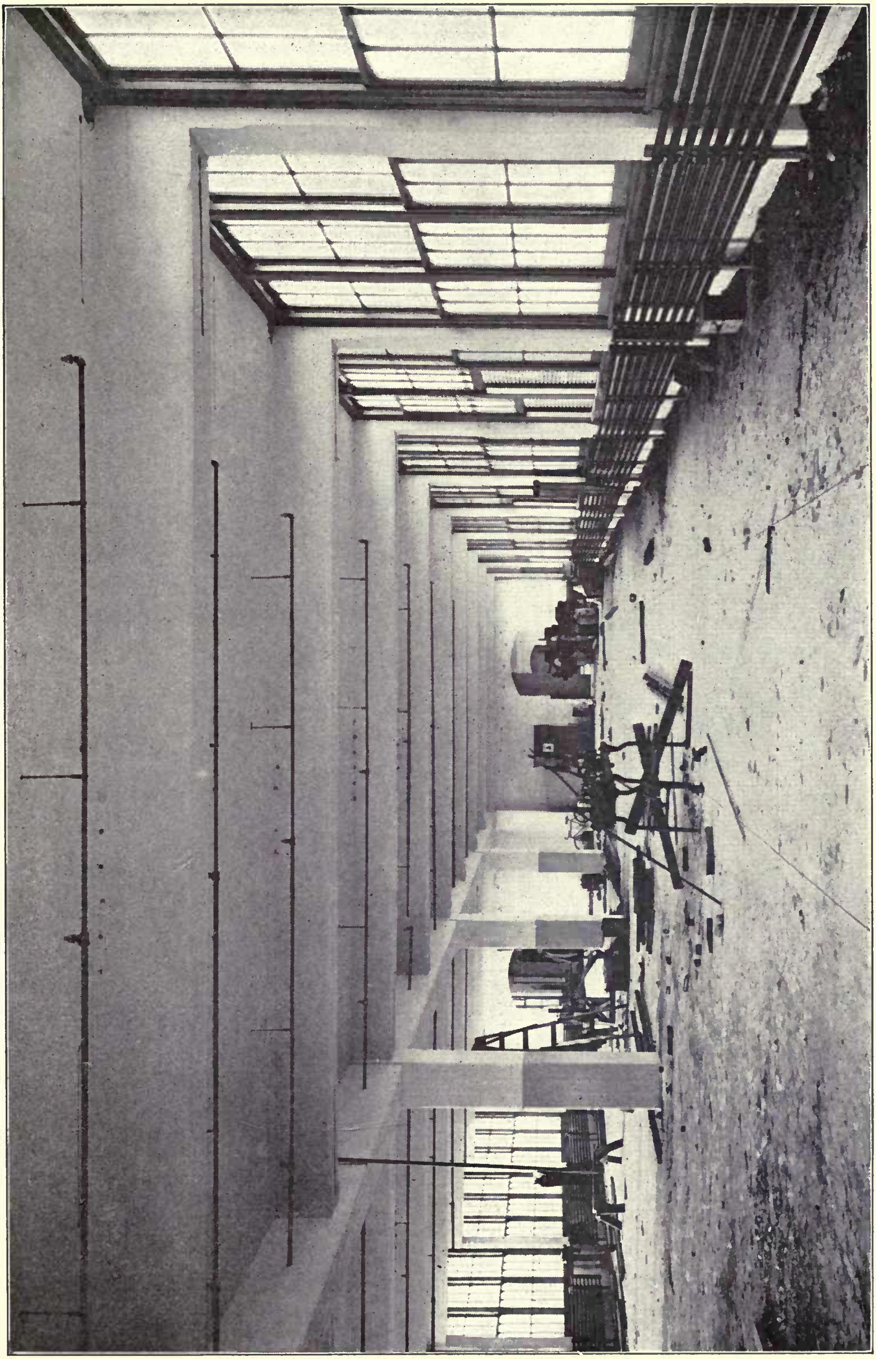


Fig. 74.—Interior View of Packard Factory Completed. (*See p. 138.*)

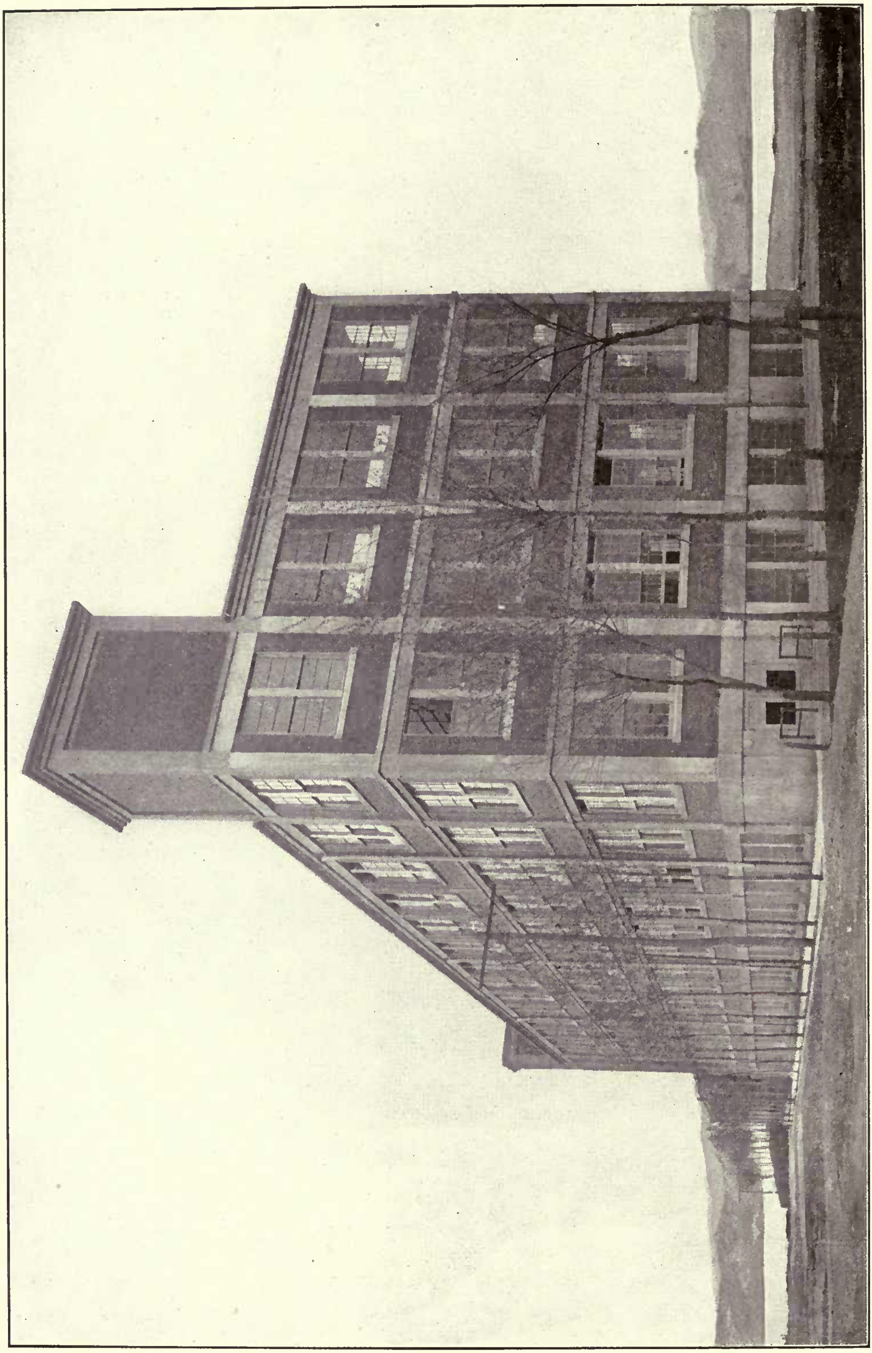


Fig. 75.—Textile Machine Works. *(See p. 147.)*

# CHAPTER XI.

## TEXTILE MACHINE WORKS.

An unusual type of factory building was erected at Reading, Penn., by the Textile Machine Works during the winter of 1904-5 for the manufacture of machinery for cotton and woolen mills. Comparatively light, but high speed, machine tools were installed, such as lathes, planers and drills.

The feature of most interest in the design is the floor system. The columns were built in place in the usual way by pouring concrete into wooden molds, but, instead of building wooden forms in place for the floor system and pouring the concrete into them, all the members were molded separately and placed after hardening. The design of the beams and girders also was decidedly unusual, for to reduce their weight and the quantity of concrete in them, the Visintini system was adopted, in which the members are of open or lattice work, formed as actual trusses.

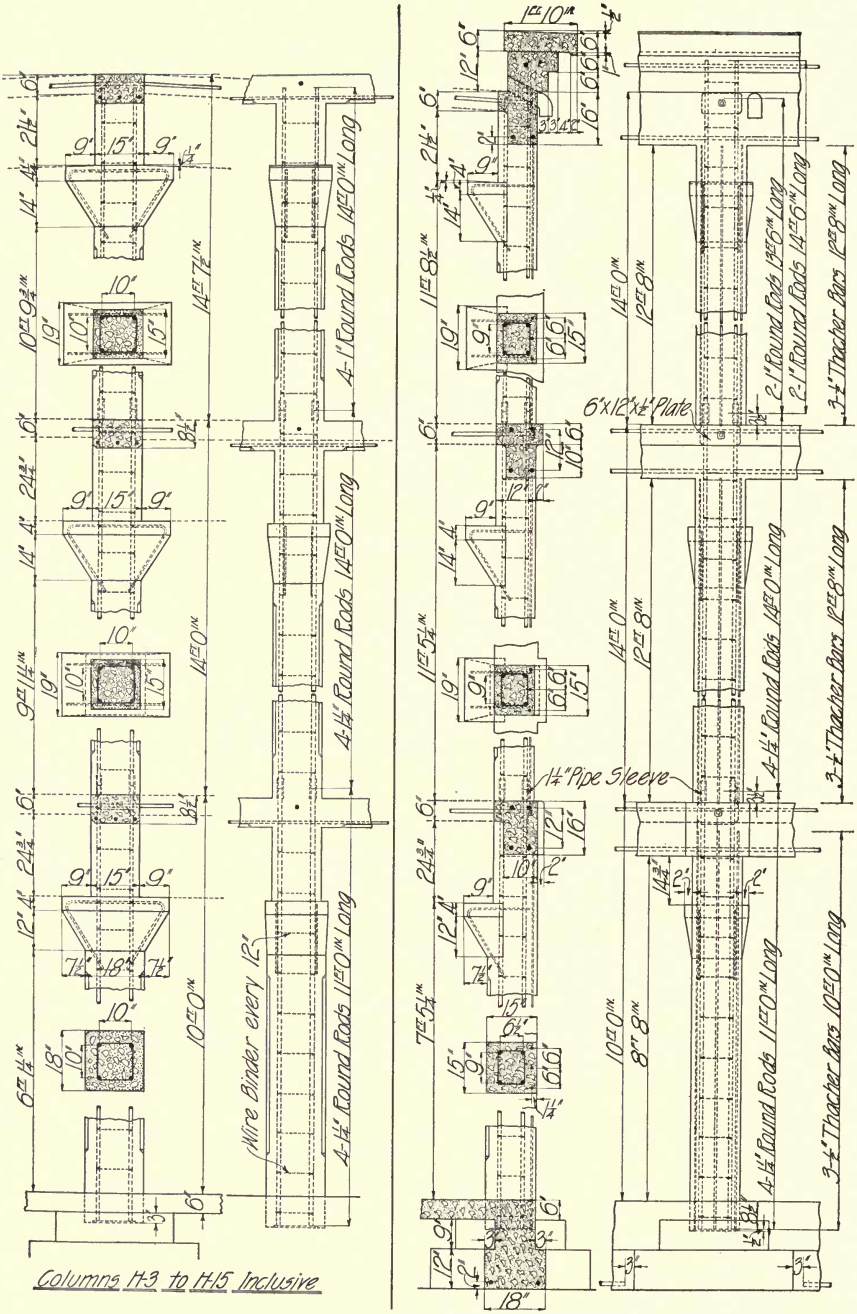
The Visintini system was invented by Franz Visintini, an architect of Zurich, Switzerland. Although applied in a number of cases in Europe, this building was its first introduction into the United States.

The Concrete-Steel Engineering Company, of New York, who controls the American patents, designed the building and also acted as consulting engineers during erection. Day labor was employed in the Construction, the men being directly upon the pay roll of the Textile Machine Works.

The building, which is shown complete in Fig. 75, is 50 feet wide by 200 feet long and four stories high. Wall columns are spaced 12½ feet apart, and a center line of columns on the same spacing extends through the center of the building. The principal girders, 24 feet long, run across the building, connecting the wall and center columns.

## COLUMNS.

The column footings are not reinforced but are stepped as shown in Fig. 76, and laid in proportions 1:3:6. To assist in transmitting the pressure of the columns, which are of richer proportions, 1:2:4, and also to afford a bearing for the column rods, a ½-inch plate was set 3 inches below the top of the footing. After laying the footings, the column reinforcement was placed with the longitudinal rods butting directly upon the plate, as shown, and forms of



Columns H-3 to H-15 Inclusive

Columns F-2 to F-16 and L-3 to L-15 Inclusive

Fig. 76.—Details of Columns in Textile Machine Shop (See Fig. 78). (*See p.* 147.)

Fig. 77.—View of Visintini Columns and Girders in Textile Machine Shop. (*See p. 151.*)

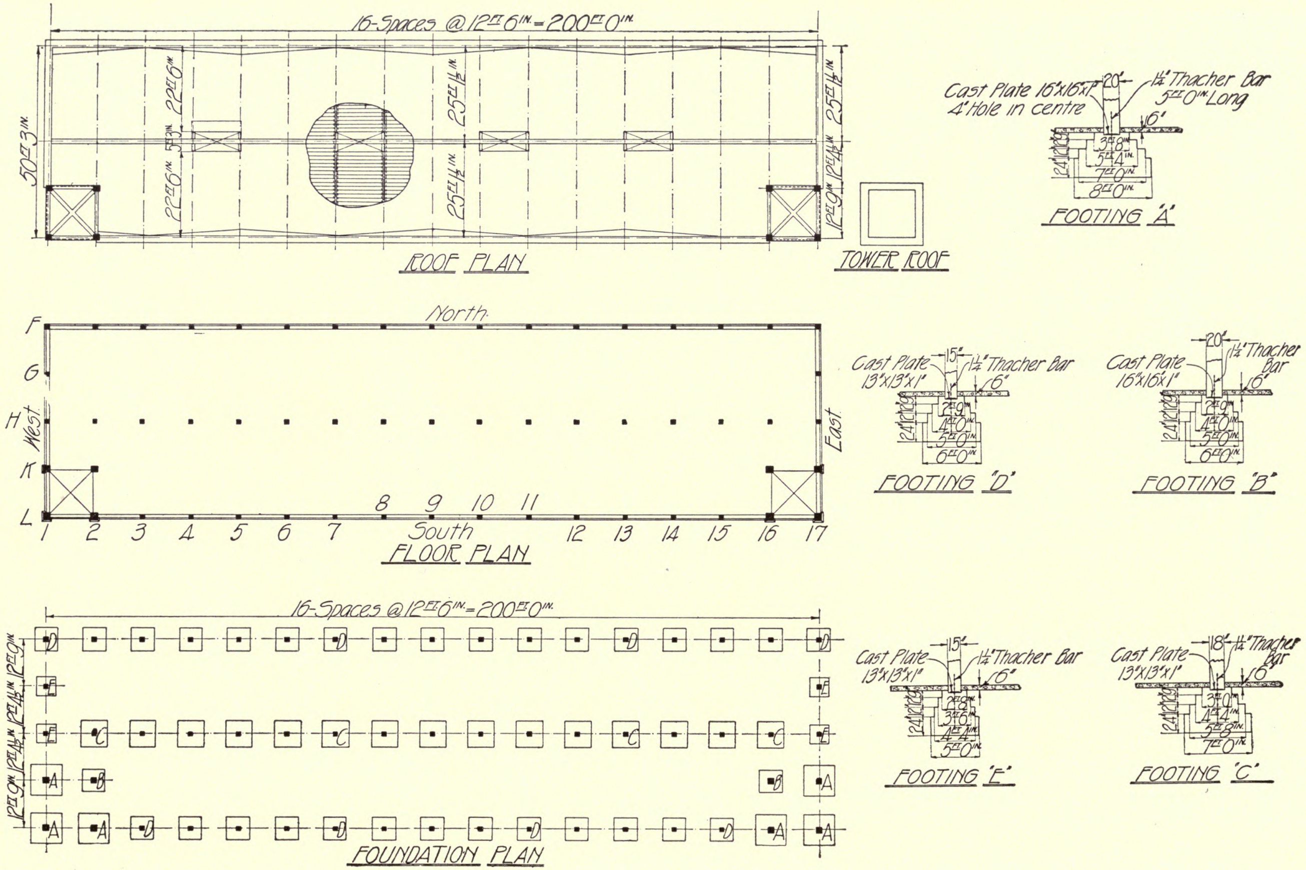


Fig. 78.—General Plans of Textile Machine Shop.

dressed white pine were built around them. The concrete of the column was then poured in the usual manner. The details of a typical interior and exterior column are shown in Fig. 76, and in Fig. 77 (p. 149) the columns are illustrated as they appeared with the shoulders for receiving the girders and with the rods projecting upwards so as to join on the columns in the next story above. The center columns in the lower story are 18x18 inches square and 15x15 inches for those above. Wall columns are 15x15 inches on the first floor and 12x15 inches above. The principal reinforcement in the columns through the middle of the building consists of four 1¼-inch vertical rods in the two lower stories, and four 1-inch rods in the third and fourth stories. Three half-inch Thacher rods* are also inserted in the exterior columns. Occasional loops of small rods hold the heavier rods in place, and assist in resisting shear. The ends of the principal rods are planed smooth and they are butted and connected with a 6-inch length of pipe sleeve, so that perfect compression is assured. The outside rows of columns are similar except that the rods are differently spaced. The pressure on the concrete is limited to 350 pounds per square inch.

## FLOOR SYSTEM.

Foundation, floor and roof plans, and sketches of column footings are drawn in Fig. 78.

Running across the building from column to column and 12½ feet apart on centers are the large Visintini lattice girders 24 feet long.

In ordinary design these would be connected by floor beams spaced 6 or 8 feet apart, with slabs between the beams. The Visintini system, however, permits the slabs and floor beams to be laid as one; that is, after placing the girders the floor beams were laid from girder to girder but close together so as to form a floor slab themselves. For a wearing surface, a maple floor was laid upon 2 by 4-inch stringers, which were bolted together at the ends so as to tie the floor together lengthwise of the building as well as to form nailing strips. Cinder concrete was placed between the strips.

The details of a typical floor girder, roof girder and floor beam are shown in Fig. 79. The girders are shaped like a Pratt truss, a common type used in steel bridges, and the computations of stresses were made as in bridge design. The bottom chord consists of a slab of concrete reinforced with 3 round rods to take all of the tension, and the top chord in compression, is similarly reinforced. The vertical web members, which are in compression, are of plain concrete, while the diagonals are each reinforced for tension with rods, whose ends are attached to the rods of the top and bottom chords.

The floor beams are only 6 inches thick and 12 feet 5 inches long, and these, as stated above, also form the slab, being placed close together. They are

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* See illustration, Fig. 102, page 179.

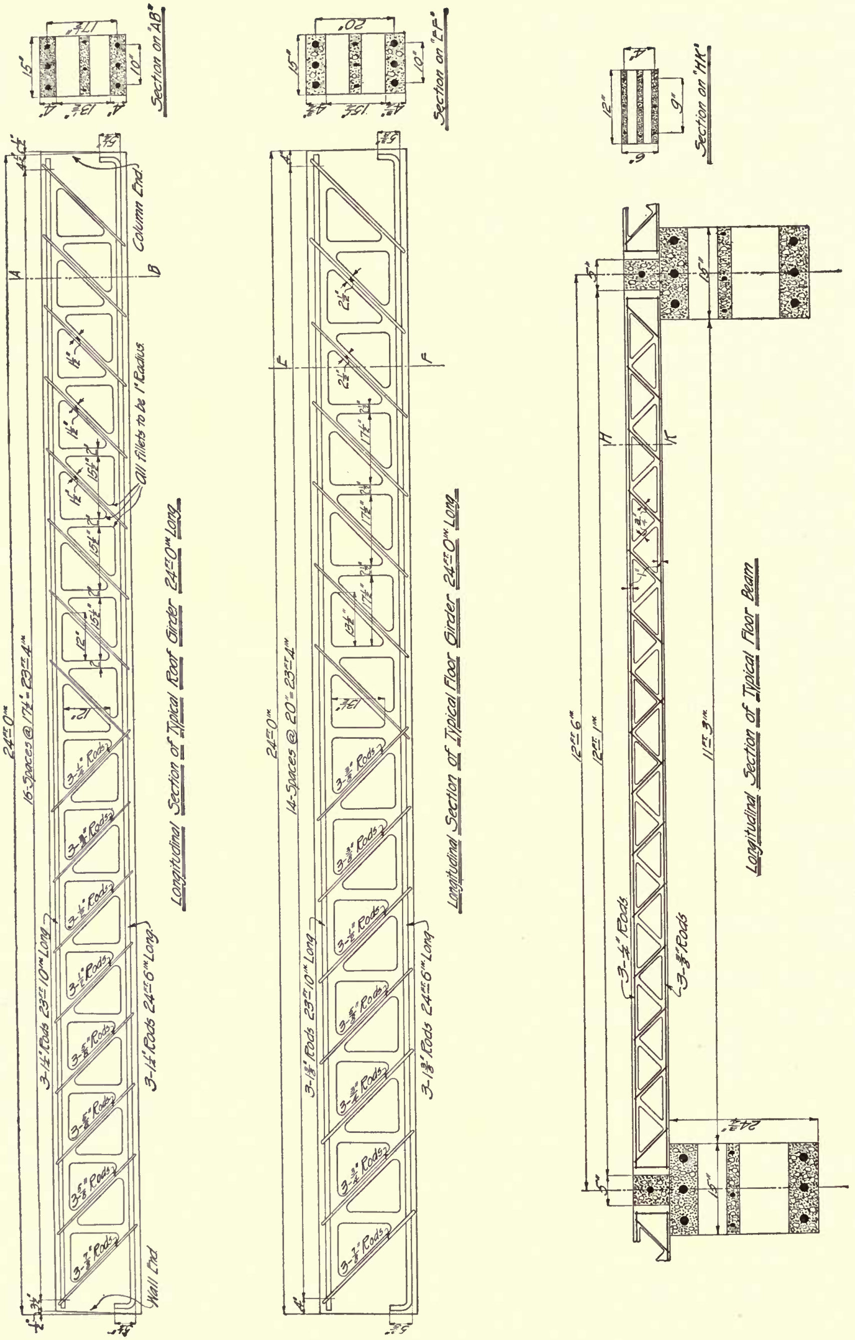

Fig. 79.—Details of Visintini Girders and Floor Beams. *(See p. 151.)*

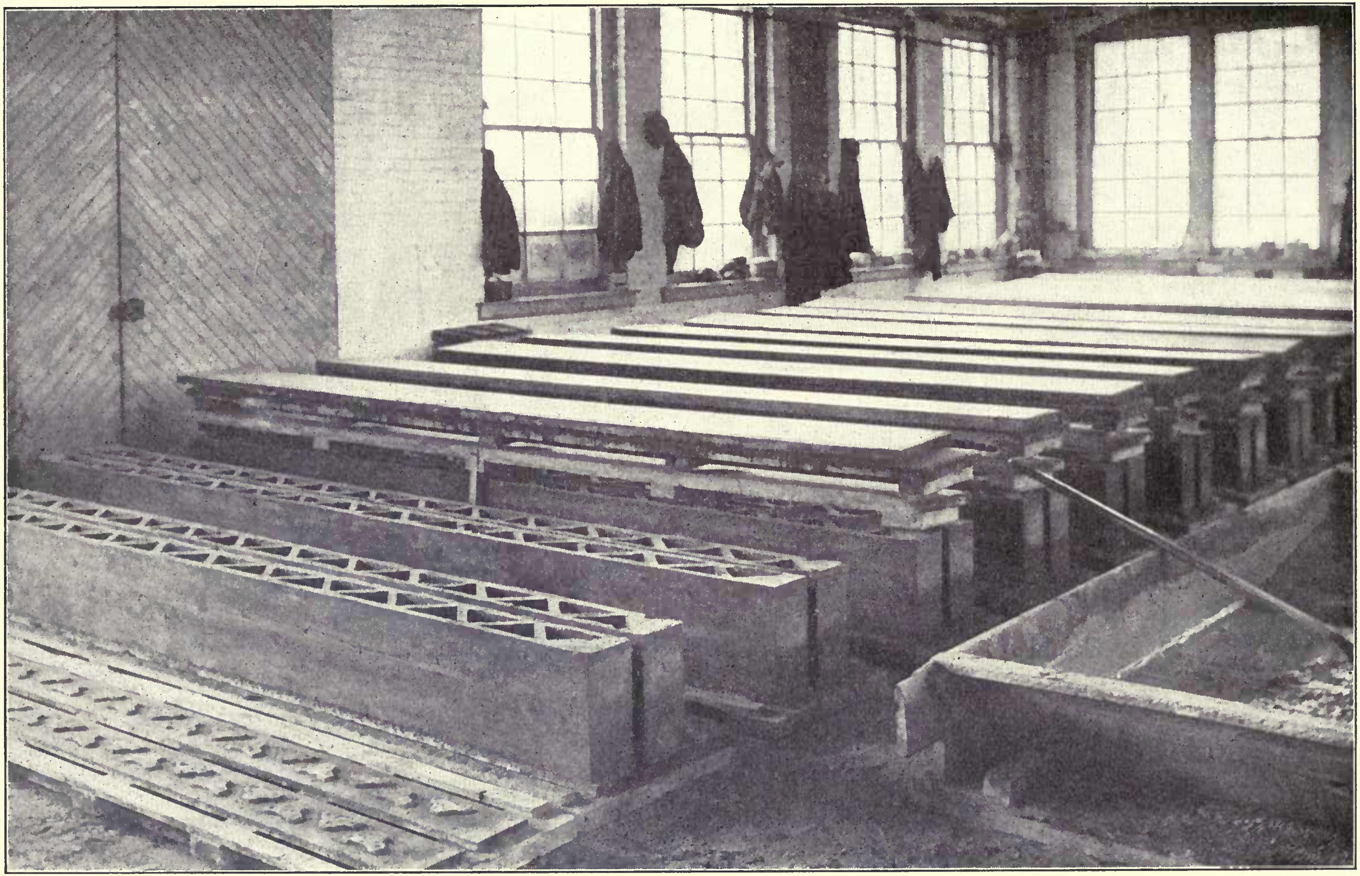

Fig. 80.—Molding of Visintini Girders. (*See p. 155.*)

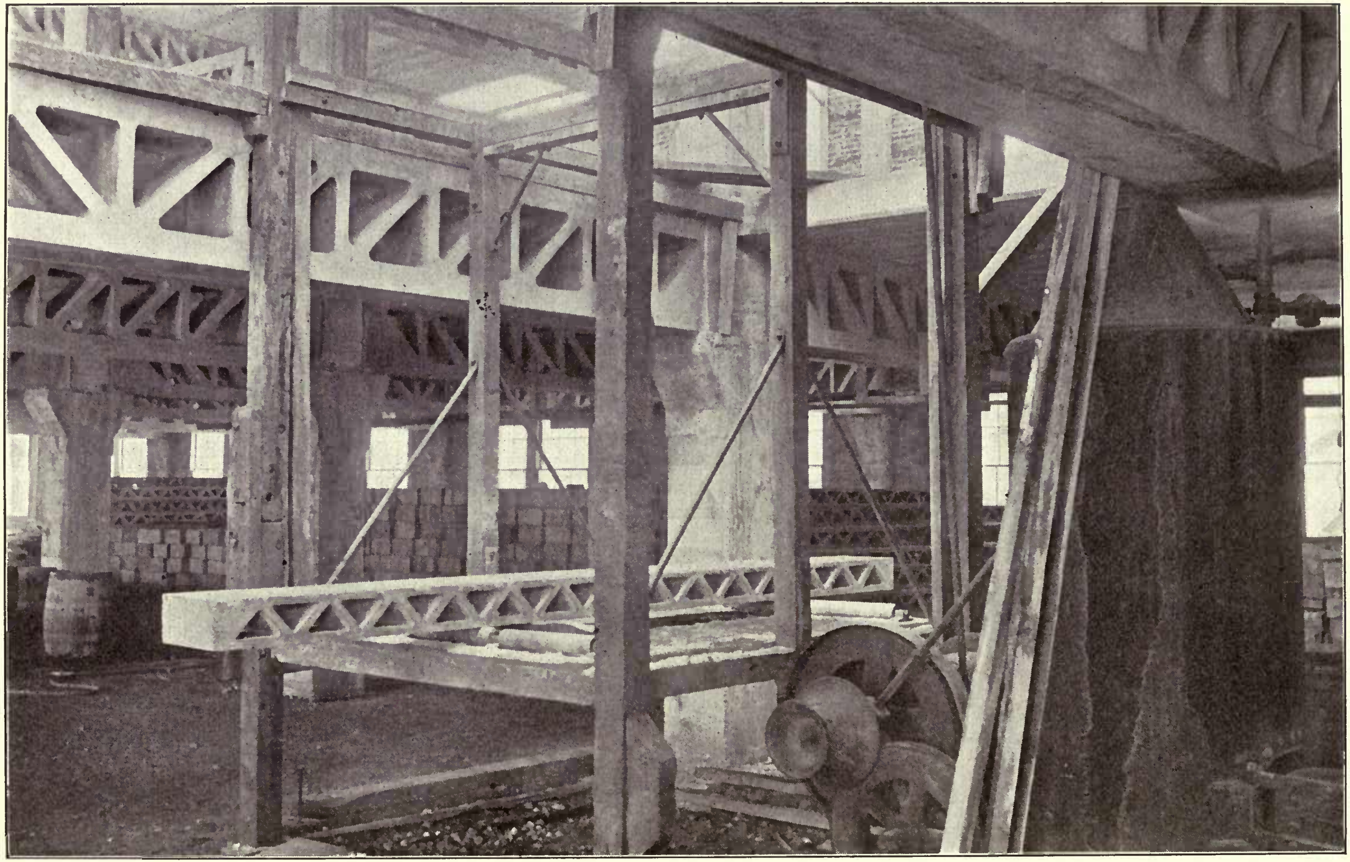

Fig. 81.—Interior View of Textile Machine Shop Under Construction. (*See p. 155.*)

designed and computed like a Warren truss with all of the web members inclined at 45°, half of them in tension and half in compression.

One of the chief advantages of this type of construction already noted, is in the method of molding the beams and girders so as to reduce the cost of forms. In this case the work was greatly facilitated because the building was erected in winter. The beams, of which there are about 2,900, were molded on the ground in an adjacent building, as shown in Fig. 80 (p. 153). At the left of the photograph is the bottom board of the forms, to which are screwed triangular cast iron plates. These locate the triangular cores which were set upon them. Two boards formed the sides of the mold, and when these were set and clamped, the reinforcement previously bent to shape and formed into three trusses, was carefully placed. The soft concrete was then poured in and lightly tamped. The proportions for the beam concrete, based on cement loosely measured, were one part Portland cement to one part sand to three parts stone screenings. The floor beams weigh only 480 pounds each.

The cores, which were oiled before placing, were pulled a few hours after pouring, and the side and bottom forms were left on for two days, when the beams were hard enough to move. After setting about 10 to 30 days longer, as needed, they were carried to the building and raised to place. They were run on to the first floor of the building, and then raised through an open bay to the floor where they were required by a platform elevator. A view of the girders in place and of a floor beam on the elevator is shown in Fig. 81.

Two of the floor beams were tested to destruction and broke under a load of pig iron weighing 342 pounds per square foot. The building is designed for a safe working load of 75 pounds per square foot.

The girders weigh about three tons each, and were molded upon the floor immediately underneath their final position, so that they required only to be hoisted into place, a distance of 14 feet, which was done by means of a special derrick and two strong hoists.

The proportions were one part Portland cement (measured loosely), 1½ parts sand, and 3½ parts broken trap rock passing a 1⅜-inch ring.

To tie the columns together across the building, the floor beams were placed with a 5-inch opening between their ends, and this space filled with concrete in which was imbedded a rod, as shown just above the cross-section of the girder in the lower portion of Fig. 79. The method of placing the floor beams is illustrated in Fig. 77. They are laid on top of the girders and are so thin that they appear in the photograph like planks, but careful inspection of the beams at the right of the photograph, which have just been placed, will show their lattice formation.

Another view of the building under construction is shown in Fig. 82 (p. 157).

## COST.

The total cost of the building was about $40,000, divided as follows:

| | |
|---|---|
| Concrete materials | $5,961.66 |
| Iron and steel | 6,277.46 |
| 93,000 feet B. M. lumber | 2,514.61 |
| Excavating | 388.23 |
| Foundry work (casting for cores) | 642.20 |
| Machine shop work (making all forms) | 3,295.21 |
| Carpenter work | 4,971.83 |
| Labor molding and pouring concrete | 7,919.27 |
| Labor placing concrete beams | 586.35 |
| Labor (outside of concrete work proper) | 2,422.25 |
| Brick walls, wooden floors and trim | 4,000.00 |
| Total | $38,979.07 |

This sum does not include the cost of engineering nor of general expense.

About 178 tons of steel were used in the reinforcing and the cost of bending and placing it was about ½ cent per pound; 3,590 barrels of Atlas Portland cement were used, 1,400 tons of stone and 1,495 tons of sand.

The total cost of the completed building including the finish was 7.7 cents per cubic foot.

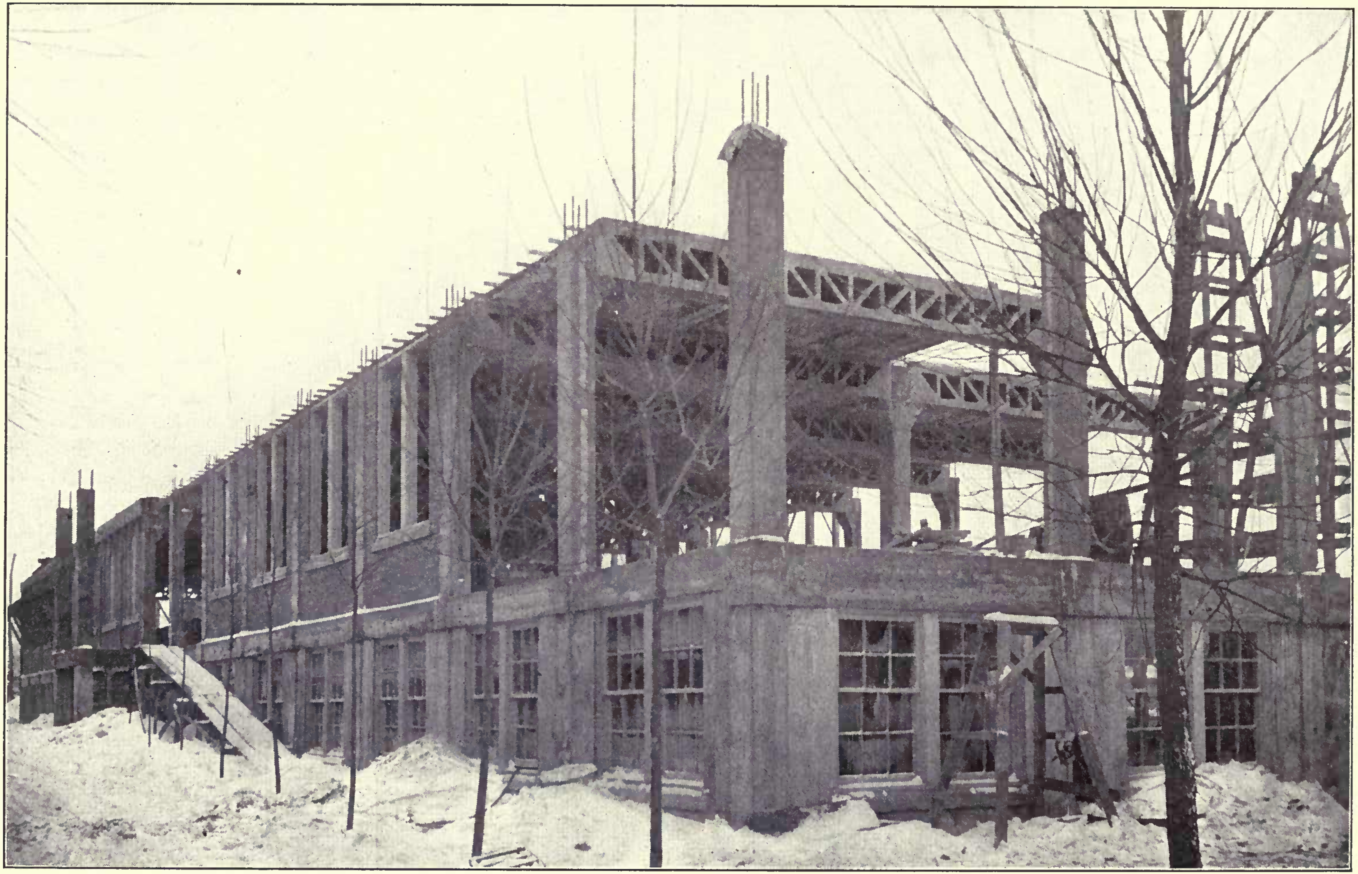

Fig. 82.—Textile Machine Shop Under Construction. (*See p.* 155.)

# CHAPTER XII.

## FORBES COLD STORAGE WAREHOUSE.

Reinforced concrete is admirably adapted to the construction of cold storage warehouses because of the advantages from a sanitary standpoint. A monolithic floor construction, free from structural joints and seams, fireproof, waterproof, and practically vermin proof, is unquestionably an ideal floor construction for this type of building. These advantages, together with the small cost of maintenance and favorable insurance rates, led to its selection by Mr. W. S. Forbes as the structural material for the cold storage warehouse and abattoir at Richmond, Va.

The bids for the construction indicated that it would cost about 10 per cent. more to build of reinforced concrete with brick walls than to carry out the design in wood, but the owner was convinced that the more serviceable and satisfactory results attained with the concrete outweighed the slight increase in cost. As a result, this building is one of the most thoroughly equipped cold storage plants and slaughter houses in the country.

The plant was erected by Mr. Walter P. Veitch, general contractor, from plans of Messrs. Wilder and Davis, of Chicago, packing house experts. The reinforced concrete work and structural features of the building were designed by the General Fireproofing Company, of Youngstown, O., who supplied the steel reinforcement for the building and superintended its installation. The structure is 160 feet 7 inches long, 85 feet 9¼ inches wide at one end, diminishing to a width of 79 feet at the other end. A part of the building is six stories high with a basement in addition, the remaining portion having four stories and basement.

The two lower stories are utilized for cold storage purposes, and are insulated from the outside and from the floors above by 10 inches of cork insulation on top of the concrete floor.

The two lower floors are finished with 1-inch granolithic. This enables the floors to be kept clean and sanitary by flushing with the hose and srubbing, gutters leading to drains being provided to collect the drip or scraps, and the refuse from the meats and their by-products.

The third story is the shipping floor, and its ceiling is completely equipped with a system of trolleys hanging from especially designed hangers suspended from the concrete beams.

The fourth floor is used as an office and general salesroom, and this floor is so insulated from above and below as to maintain a uniform temperature.

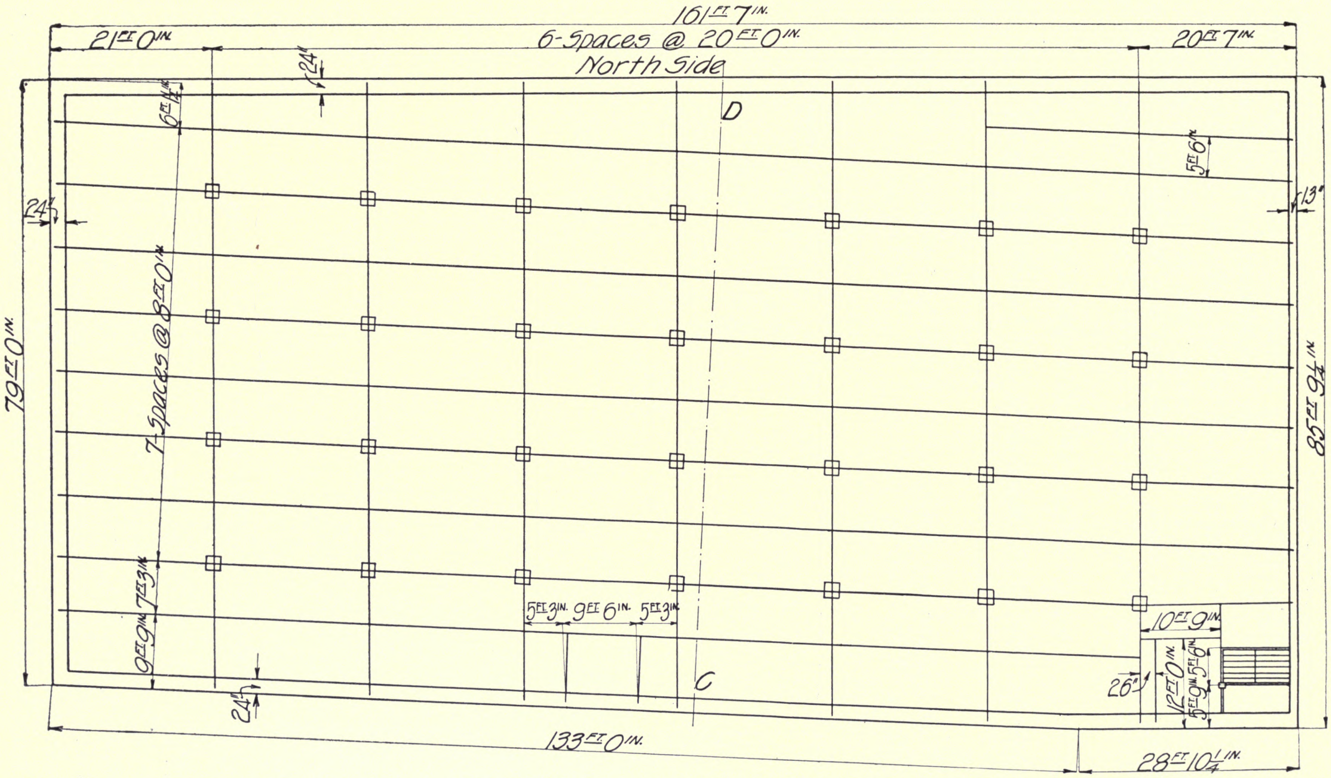

Fig. 83.—General Plan of Forbes Cold Storage Warehouse. (*See p.* 160.)

A portion of the fifth floor is devoted to ice storage, and the remainder is occupied by the hanging room, hog cooler department, and brine chambers. Above this floor, under the roof, is a thoroughly insulated air space.

The meats and other products are transferred from one story to another by means of large elevators in shafts whose walls are insulated with cork.

The live loads on the different floors vary from 250 to 400 pounds per square foot, the heavier loads occurring mostly on the fifth, where salt and general merchandise tubs of lard and barrels of pork are stored for sale.

## DETAILS OF CONSTRUCTION.

The general plan of the warehouse is shown in Fig. 83 (p. 159), the cross section in Fig. 84, the longitudinal section in Fig. 85, and the south elevation in Fig. 86.

The first and second stories, that is, the basement and sub-basement, are below grade, and surrounded by heavy concrete foundation retaining walls.

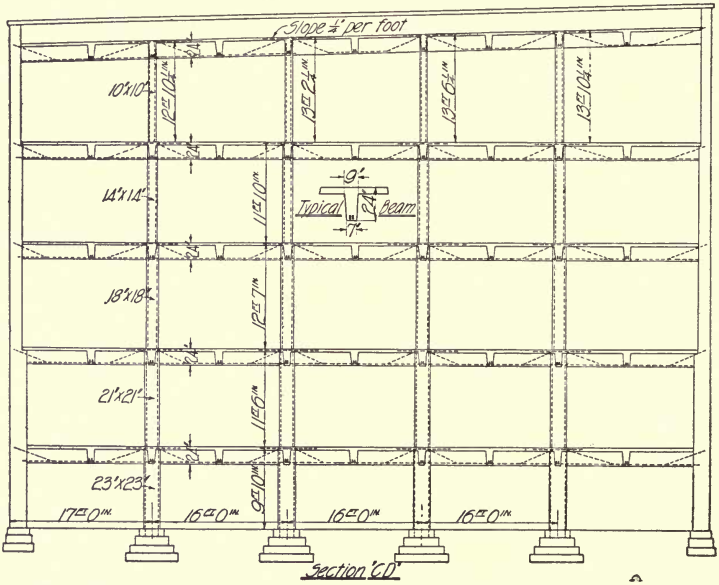

Fig. 84.—Cross-Section of Forbes Cold Storage Warehouse.

From the street grade the exterior walls are brick, varying in thickness from 20 inches above the foundation to 13 inches at the top. Bearing walls, although more expensive, were selected in preference to skeleton construction with curtain walls to provide more complete insulation.

The interior columns are of concrete, reinforced with four vertical rods, varying from 1 inch to ¾ inch in the different stories, and tied at intervals of

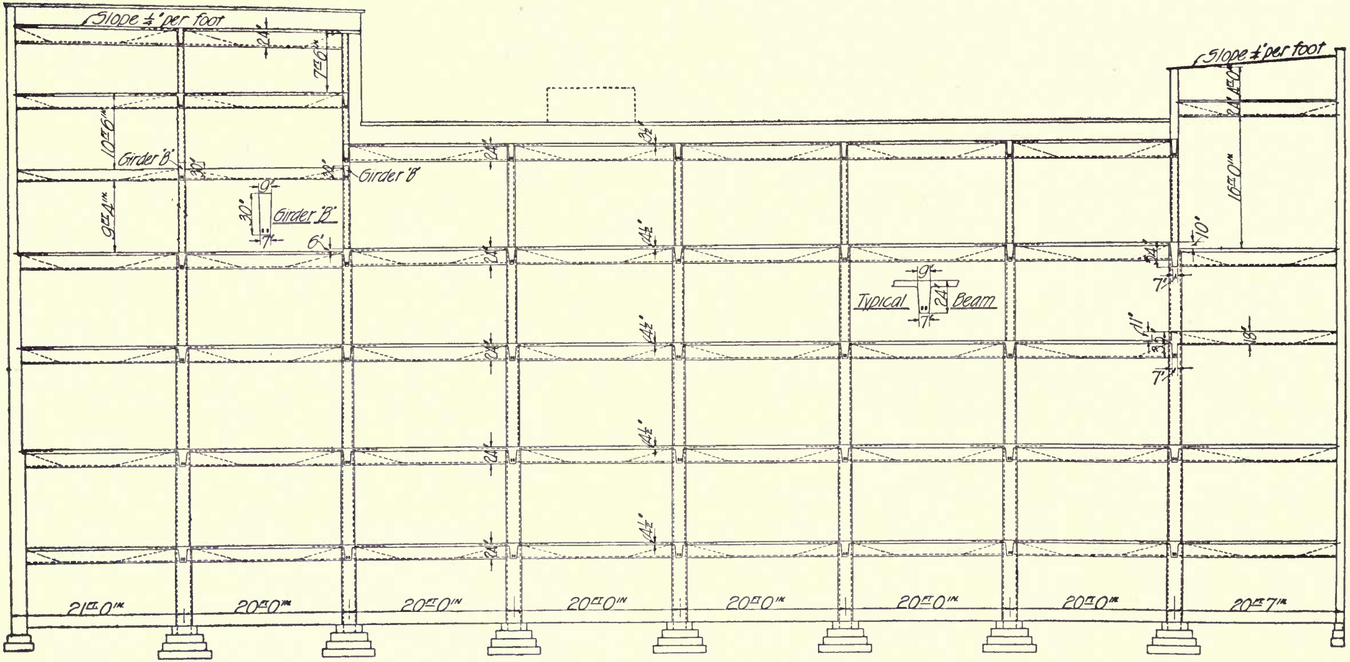

Fig. 85.—Longitudinal Section of Forbes Cold Storage Warehouse. (*See p. 160.*)

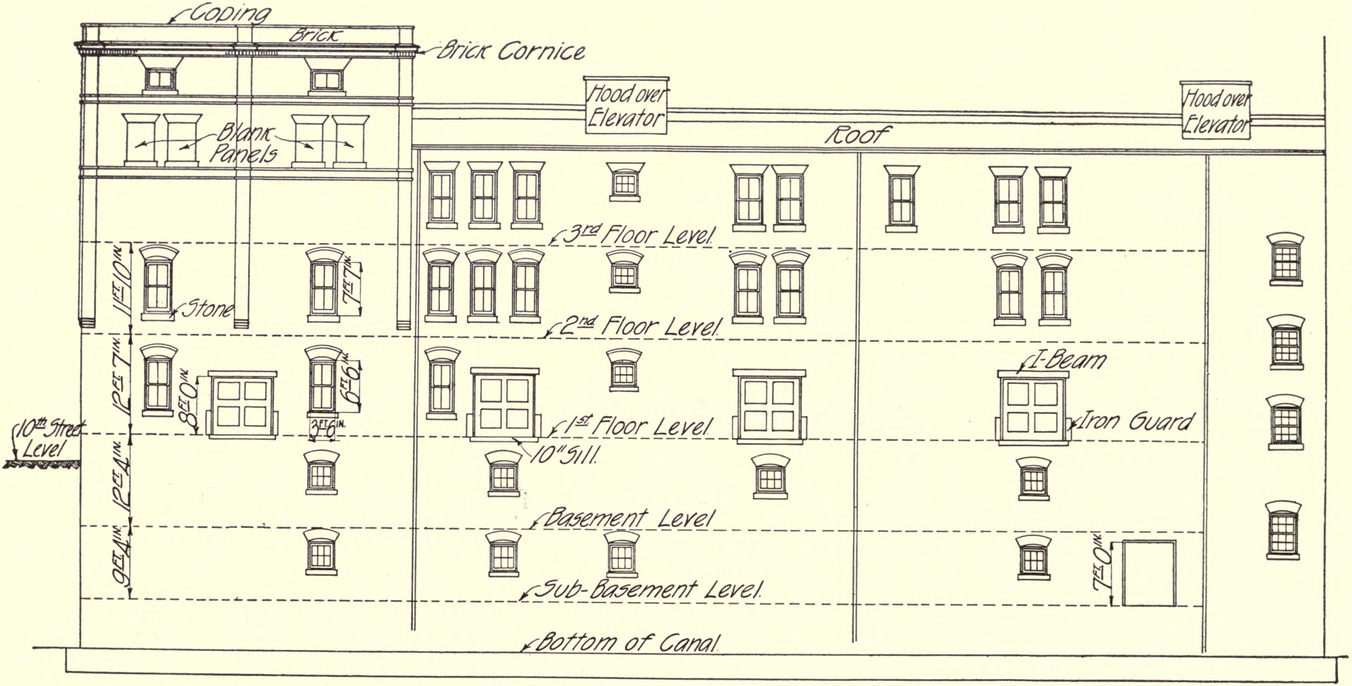

Fig. 86.—South Elevation of Forbes Cold Storage Warehouse. (*See p. 160.*)

Fig. 87.—Interior View of Forbes Cold Storage Warehouse. (*See p. 165.*)

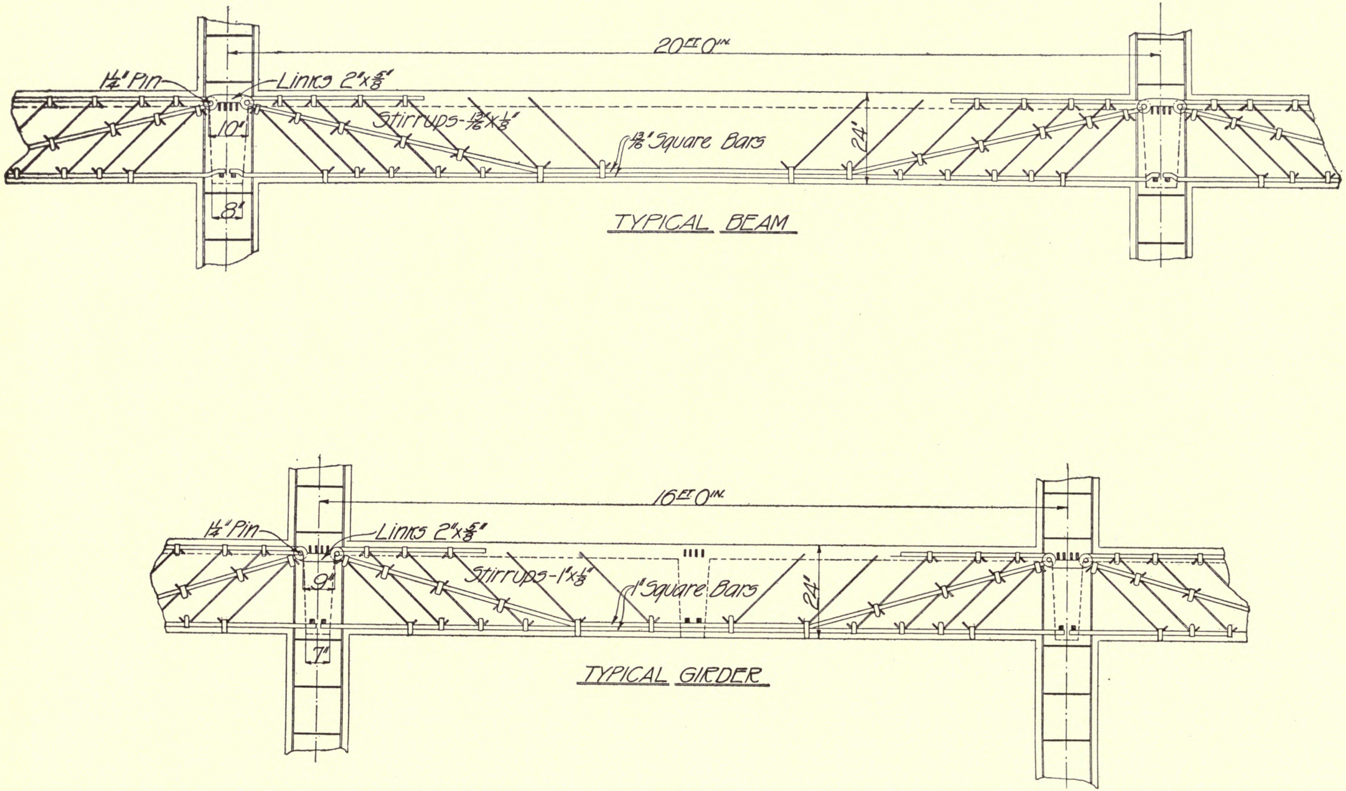

Fig. 88.—Details of Typical Pin-Connected Beam and Girder Reinforcement. (*See p. 165.*)

about 12 inches with wire ties. The columns are located 16 feet apart in one direction and 20 feet apart in the other.

The girders run across the building on the 16-foot span, with beams at right angles to them spanning from column to column, and also through the central points of the girders, thus making the bays 20 feet by 8 feet.

The beams and girders are of the same depth throughout the building, namely 24 inches, with a view to facilitating the installation and operation of the trolley systems. The floor slabs and the roof slabs, which are reinforced with expanded metal, are 4½ inches and 3½ inches respectively.

An interior view of one of the floors after completing the concreting is given in Fig. 87 (p. 163).

## GIRDER FRAMES.

The details of the reinforcement in the beams and girders are shown in Fig. 88 (p. 164), with the typical sizes of steel for a floor carrying 250 pounds per square foot in addition to the weight of the concrete.

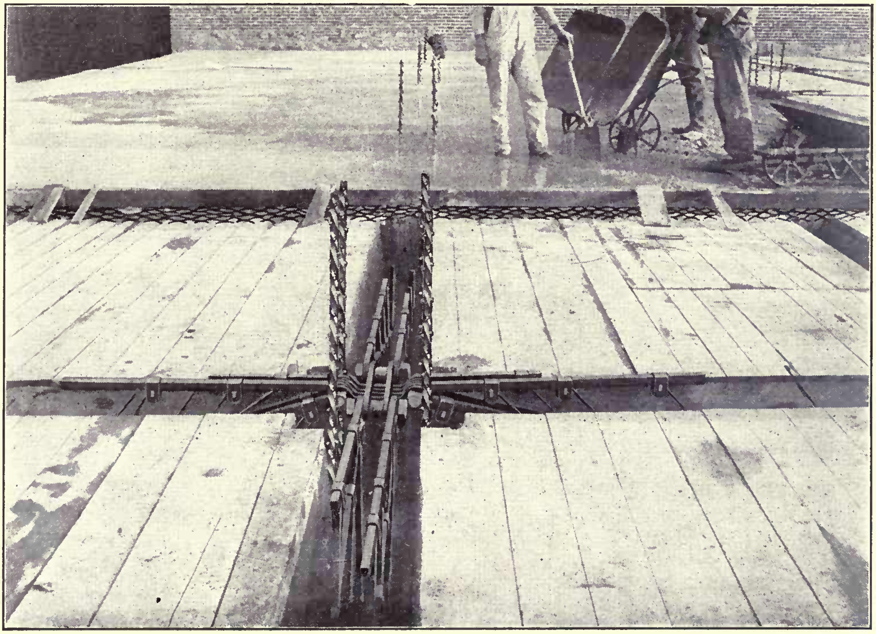

Fig. 89.—Placing of Pin-Connected Girder Frames. (*See p. 167.*)

Each frame is a complete truss of the pin-connected girder system, two or more frames constituting the reinforcement for each beam and girder. At intersections the frames are connected by steel links and bolts, thus providing continuous ties across the building in both directions.

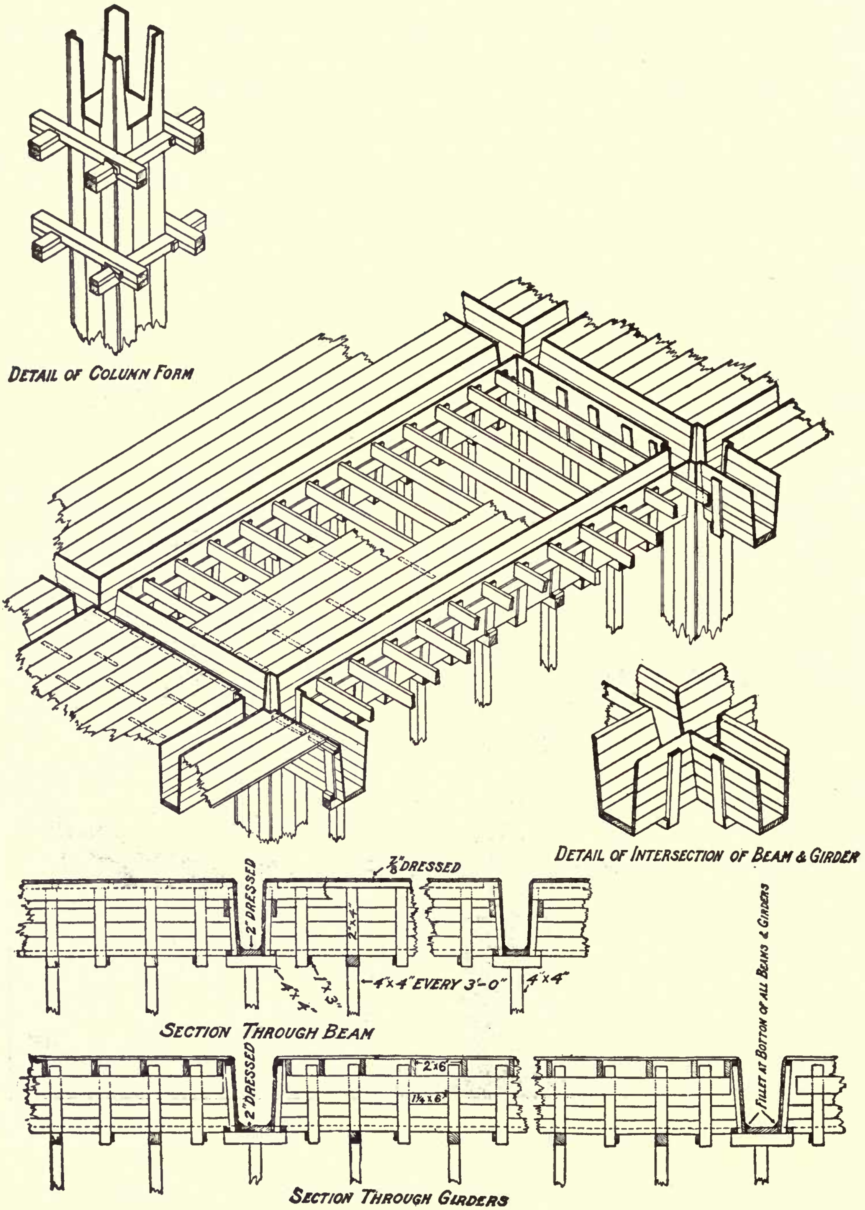

Fig. 90.—Details of Form Construction. (*See p. 167.*)

The frames were designed for the special floor loads and fabricated in the shop of the General Fireproofing Company at Youngstown, Ohio, then shipped to the building ready for installation in the forms. The tension and shear members are held rigidly in place by steel collars and pneumatically driven steel wedges, so that the displacing of the reinforcement by careless workmanship is impossible. The placing of the reinforcement is illustrated in Fig. 89 (p. 165).

## FORMS.

Isometric views of sections of the forms are illustrated in Fig. 90. The form lumber was Virginia pine, planed three sides, or else tongue-and-grooved, and cost $20 per thousand. The form construction was simplified by the uniform depth of the beams and girders, each of them being 24 inches deep, measured from top of the slab. The forms were left in place from two to three weeks, being used on the average three times.

## CONSTRUCTION PLANT

The construction plant consisted of a Smith mixer with elevator for hoisting the concrete in wheelbarrows, from which it was dumped into place. The plant cost approximately $2,000, and was operated by a gang of about twenty men, in addition to the carpenters and steel men.

## MATERIALS AND COST.

The bid for the concrete work was $27,000, and for the completed structure about $64,000. Some 2,050 cubic yards of reinforced concrete were laid in the building, besides 1,900 cubic yards of plain concrete in the foundations and foundation walls.

Six months were occupied in the erection, the average progress above the basement being about fourteen days per story. The quantity of steel used was 115 tons, and its cost made into trusses and delivered at the building was approximately 3 cents per pound. The placing was said to cost only $1.50 per ton.

The concrete was mixed in proportions of one part Atlas Portland cement, two parts sand and four parts stone, the labor of mixing and placing, exclusive of the forms and steel work, being about $1.50 per cubic yard.

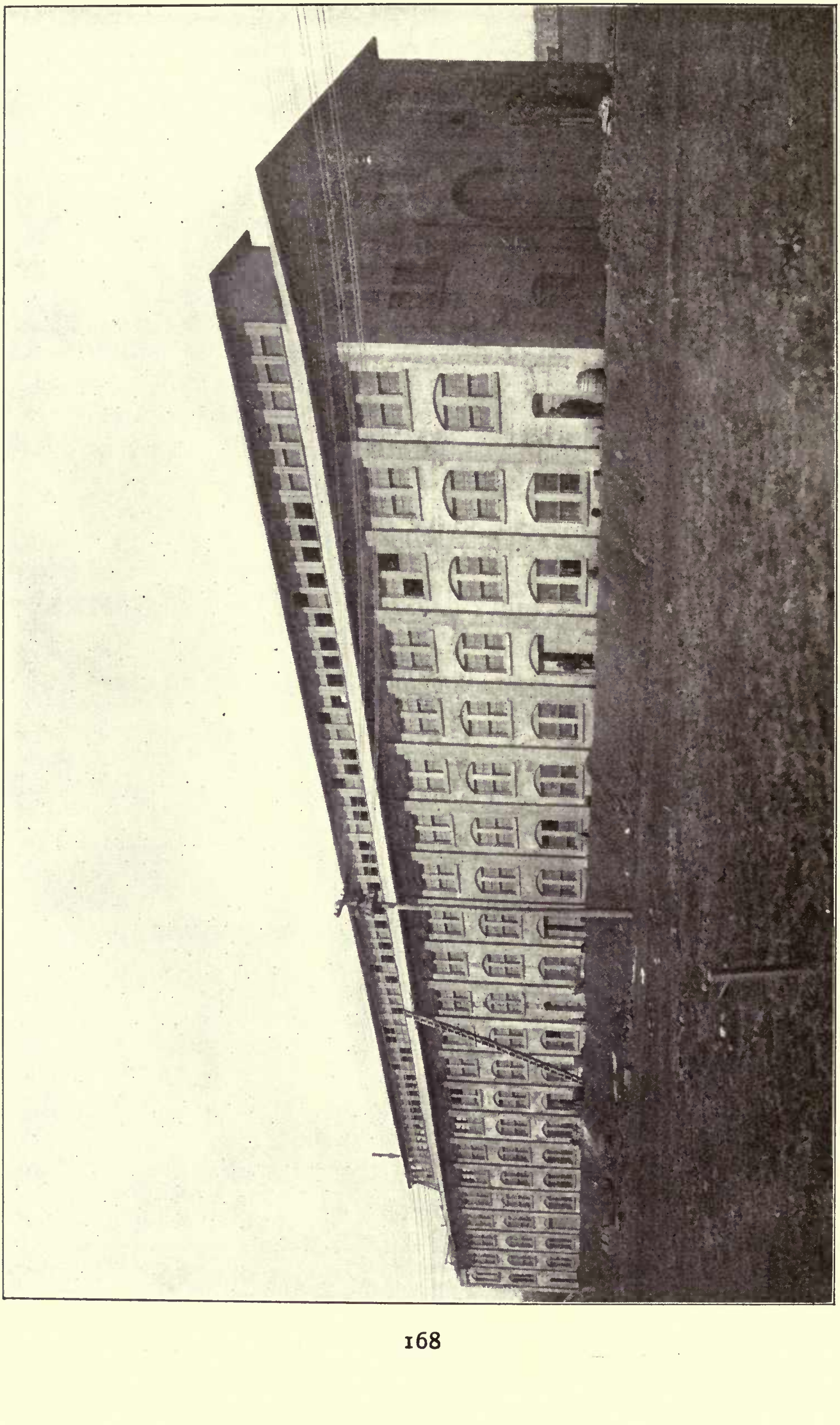

Fig. 91.—Blacksmith and Boiler Shop of the Atlas Portland Cement Company. (*See p. 169.*)

# CHAPTER XIII.

## BLACKSMITH AND BOILER SHOP OF THE ATLAS PORTLAND CEMENT COMPANY.

At the plant of the Atlas Portland Cement Company, in Northampton, Pa., concrete is used extensively in construction, not only in foundations and for the cement storehouses, but also for the floors and walls of the newer buildings.

In 1906 a new blacksmith and boiler shop was built with a 10-ton crane extending from wall to wall and running upon reinforced concrete arched beams. The building was designed by the company's engineer and built by day labor. It is shown complete on the opposite page.

### DESIGN.

The shop is 309 feet 9 inches long, 55 feet 6 inches wide and 31 feet 2 inches high to the bottom of the roof trusses, this height being necessary for the traveling of the crane.

The plan of the shop is shown in Fig. 92, and the elevations and sections in Figs. 93, 94, 95.

The walls consist of piers 14 feet on centers, with wall panels and windows between them. These piers are made of heavy section (see Fig. 93) to support the crane, and for this purpose they project into the building 23 inches as far up as the crane runway, and at the top are connected with arches which are laid at the same time and form a part of the wall. The arches are reinforced with five ¾-inch rods spaced 5 inches apart. The crane run is shown in section BB, Fig. 93, and also on a large scale in the detail above it. An 8-inch by 10-inch yellow pine timber is bolted directly to the concrete beam, and upon this rests the track. The walls between the piers, which are dovetailed into them, as shown, are 9 inches thick. This is somewhat excessive, but the extra quantity of concrete may be justified by the low cost of materials and the lean proportions of the concrete, which are 1 part cement to 4 parts sand to 5 parts gravel. There is no reinforcement in the wall panels except directly above the windows.

Fig. 95 (p. 173) shows a cross-section of the shop with its steel roof trusses and an outline of the crane.

### CONSTRUCTION

Somewhat unusual methods of construction were employed. The piers

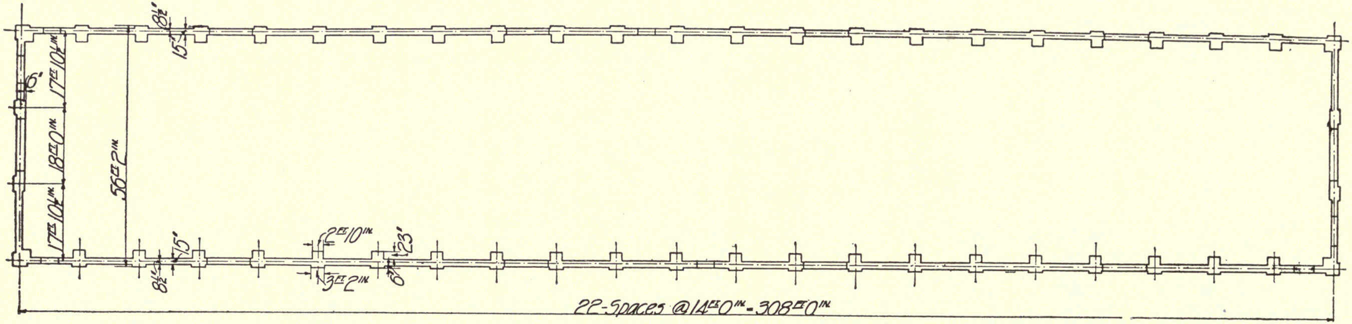

Fig. 92.—Plan of Blacksmith and Boiler Shop of the Atlas Portland Cement Company. (*See p. 169.*)

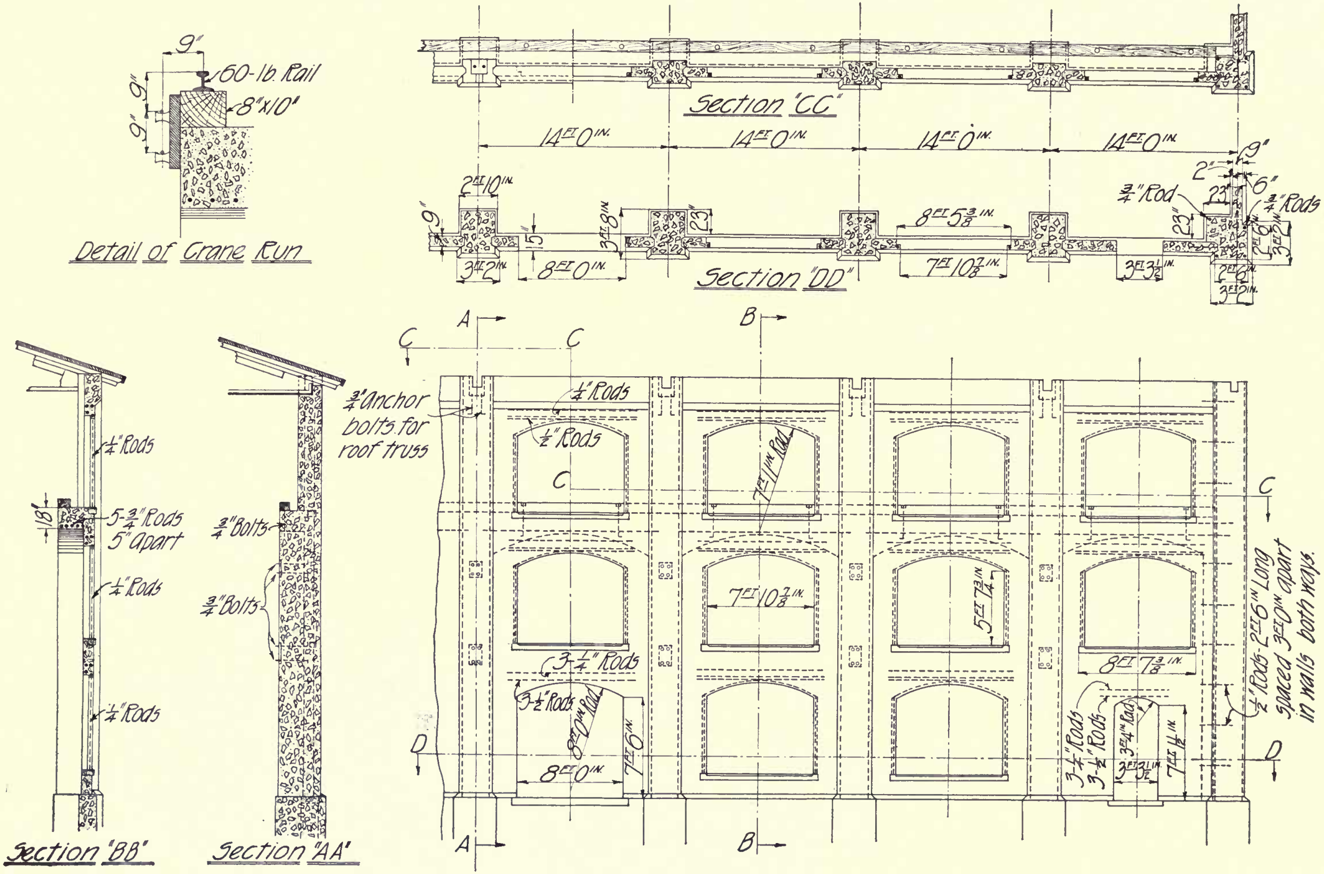

Fig. 93.—South Wall of Blacksmith and Boiler Shop of the Atlas Portland Cement Company. (*See p. 169.*)

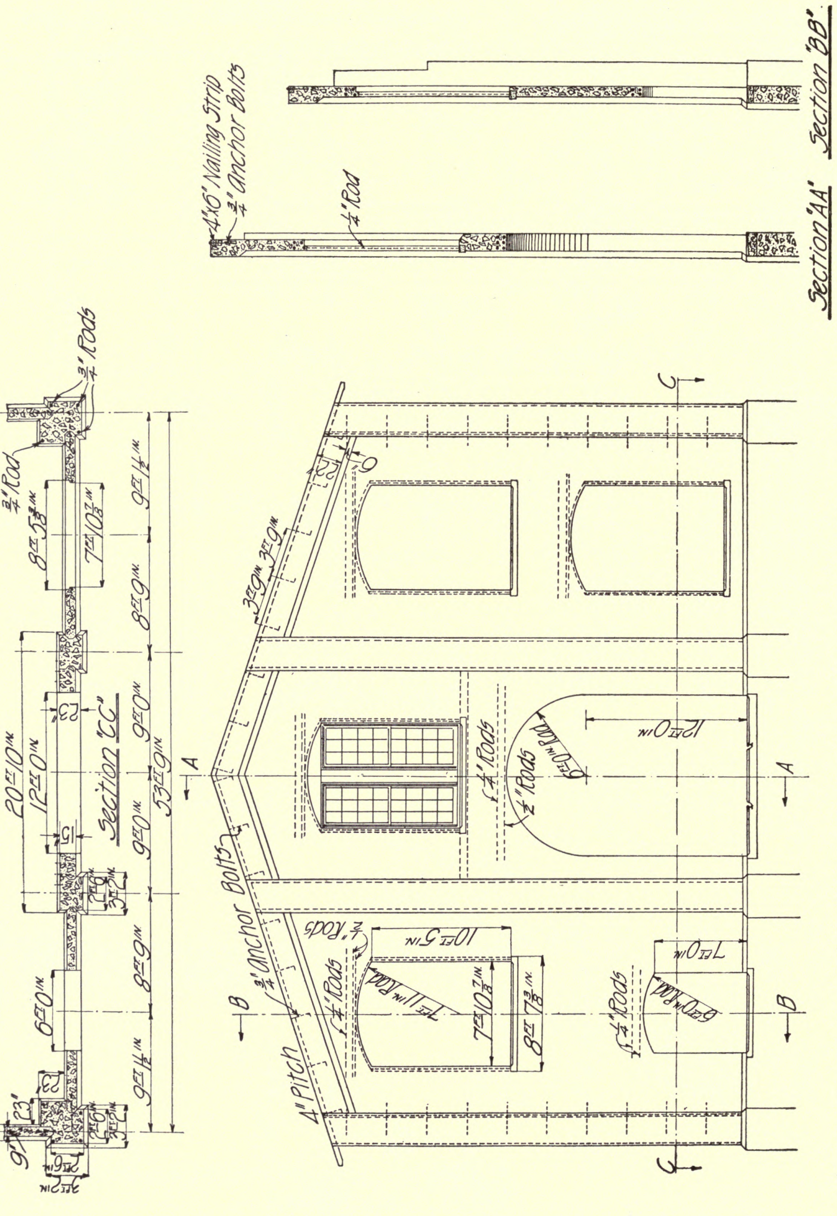

Fig. 94.—East Wall of Blacksmith and Boiler Shop of the Atlas Portland Cement Company. (See p. 169.)

were first run up to the full height of the building, as illustrated in the photograph, Fig. 96.* Then the panel forms were placed, as in Fig. 97, and the concrete poured between them.

The window frames had been set in advance, so that the openings were formed in each wall panel as it was poured. The only tie rods which were inserted to connect the piers and the wall panels were at the corners of the building, where ½-inch horizontal rods 2½ feet long were placed every 3 feet in height. (See Fig. 93.)

Fig. 98 is a photograph illustrating the side walls after completion.

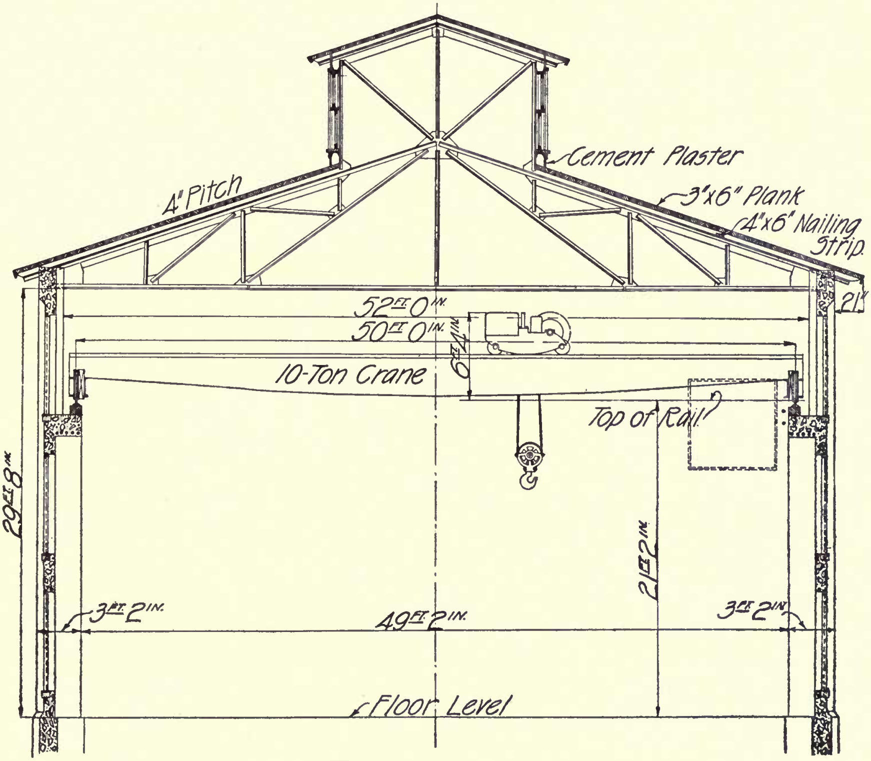

Fig. 95.—Cross-Section of Blacksmith and Boiler Shop of the Atlas Portland Cement Company. (*See p. 169.*)

Above the foundations of the shop, 792 cubic yards of concrete were required, with only 5,570 pounds of steel. In the foundation 460 cubic yards were laid in addition. The concrete was mixed by hand, and the usual gang consisted of 2 foremen, 17 men mixing, 4 men hoisting, 4 men placing, and 6

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* This photograph and the two which follow it are from a different building of the Atlas plant, but the method of construction is the same.

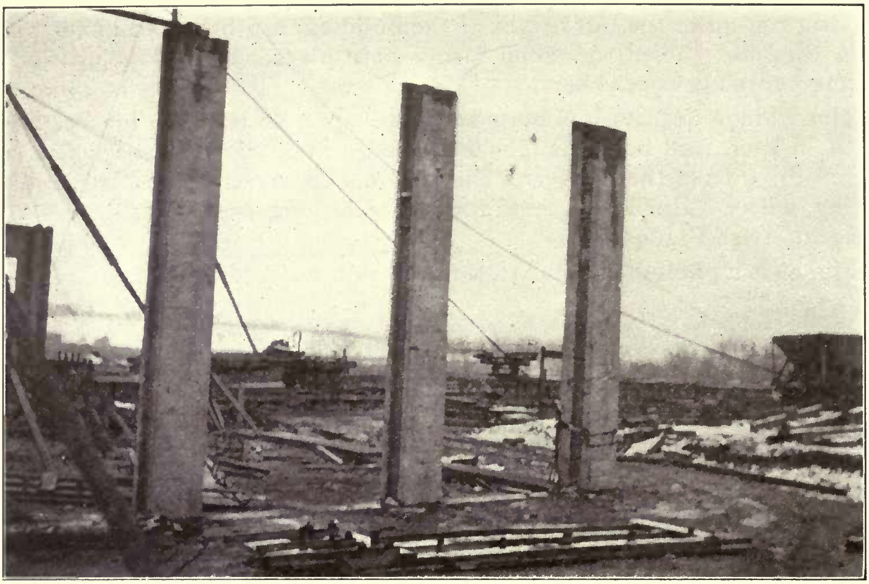


Fig. 96.—Wall Piers for an Atlas Portland Cement Company Building. (*See p. 173.*)

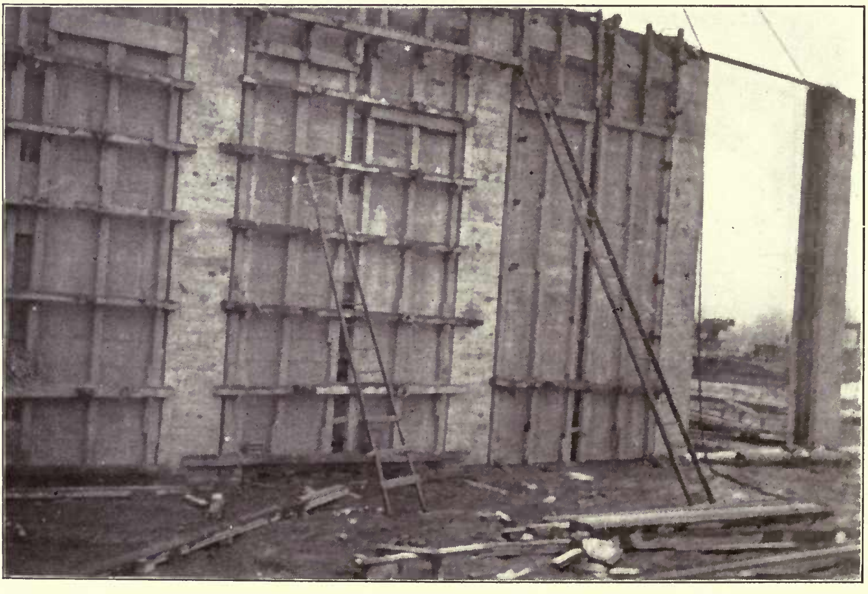


Fig. 97.—Panel Wall Forms for an Atlas Portland Cement Company Building. (*See p. 173.*)

Fig. 98.—Side Wall of an Atlas Portland Cement Company Building. (*See p. 173.*)

carpenters. The wages for the laborers ranged from $1.20 to $1.50 per day, with a $2 rate for the carpenters. The total cost of the concrete in the foundations and walls was $29,328, which is equivalent to only $4.93 per cubic yard of concrete, an exceptionally low price. The cheapness of labor partially accounts for the low cost. Ordinarily, in building construction with thinner walls and higher material and labor costs, the unit price per cubic yard will be greatly in excess of this figure.

The forms, of hemlock lumber, costing $25 per thousand, were dressed only on the side next to the concrete. About 19,000 feet of lumber was used at a cost of $485, the labor on forms being about $5,500. Although the forms were used ten times, the Engineer estimates the salvage for another similar job to be about 60 per cent., as the lumber was but slightly injured.

On the surface of the ground next to the building, a concrete gutter is laid to carry off the surface water and the roof drainage. A detail section is given in Fig. 99.

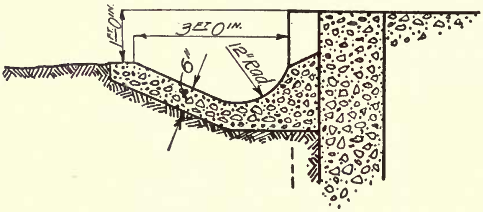


Fig. 99.—Drainage Gutter. (*See p. 176.*)

## COAL TRESTLE.

The coal trestle, which is shown in the photograph, Fig. 100, is supported upon bents of reinforced concrete 13 feet apart, resting upon heavy concrete foundations. The piers of each bent are 20 inches square and capped by a reinforced concrete girder with an arched bottom surface. Supporting the track are pairs of channel irons bolted to the concrete girders. At intervals in the trestle, diagonal tie rods with turnbuckles are placed in two adjacent bays, the rods extending from the top of one bent to the bottom of the next, so as to guard against danger from longitudinal expansion and contraction of the stringers as well as any longitudinal thrust due to the movement of the trains.

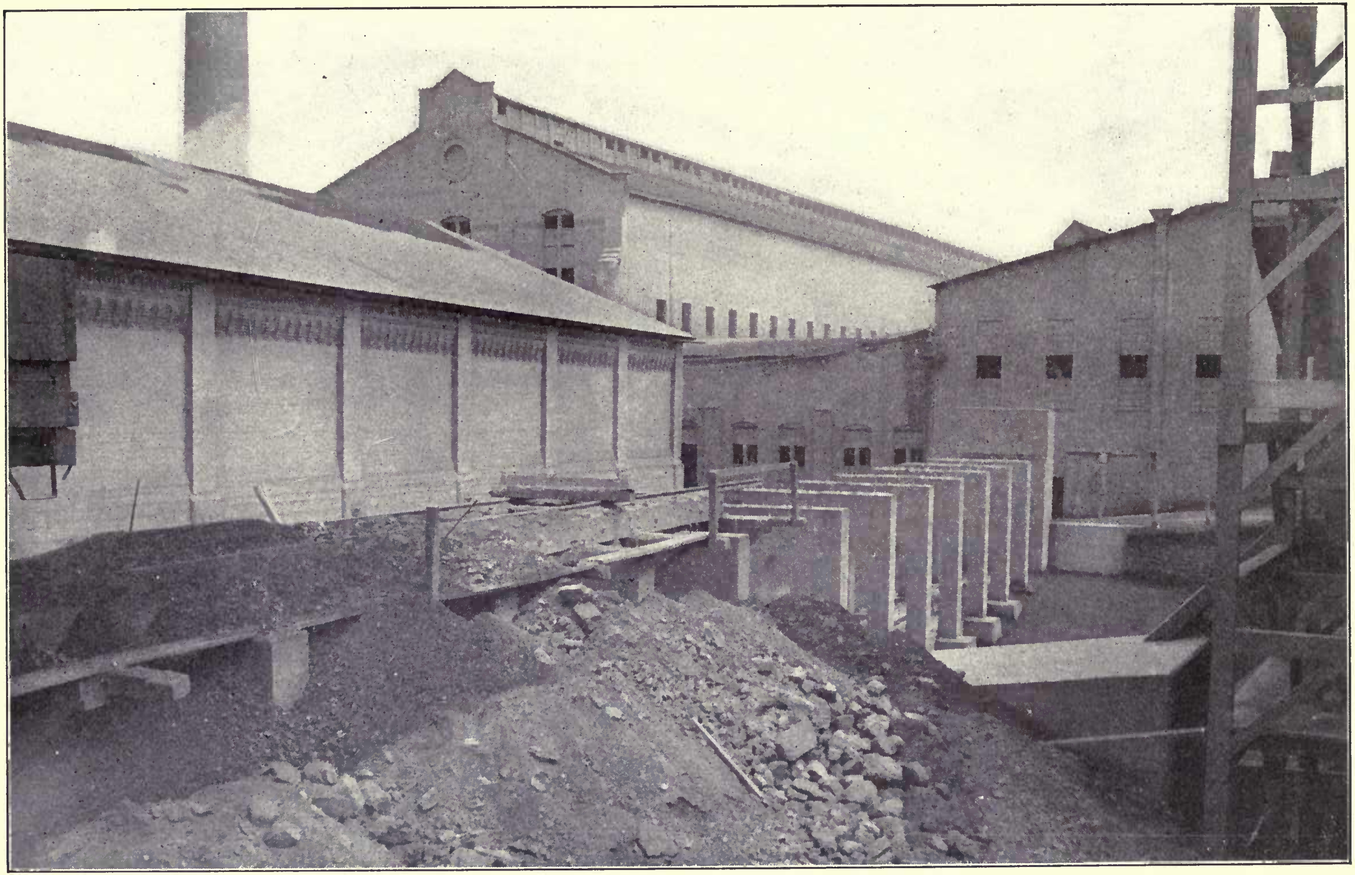


Fig. 100.—Coal Trestle. *(See p. 176.)*

# CHAPTER XIV.

## DETAILS OF CONSTRUCTION.

To provide better adhesion or bond between the steel and concrete than is given by round or square rods, many types of deformed bars have been invented, and those most commonly used in the United States are illustrated in the pages which follow. Views are also shown of a number of systems of assembling the steel or arranging the reinforcement for application to special conditions.

In addition to this digest of systems of reinforcement, a number of photographs are presented of details of construction most commonly met with in reinforced concrete buildings. In this connection are shown photographs of concrete block walls, surface finish for concrete walls, concrete piles, and concrete tanks.

## SYSTEMS OF REINFORCEMENT.

RANSOME TWISTED BARS.—One of the oldest types of reinforcing steel is the square twisted bar illustrated in Fig. 101, invented by Mr. E. L. Ransome, of the Ransome & Smith Co., and used as long ago as 1894.

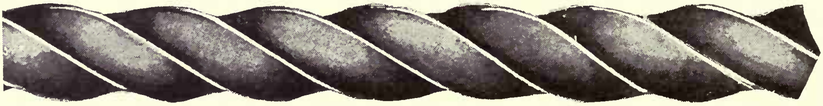


Fig. 101.—Ransome Twisted Bar. (*See p. 161.*)

Twisted bars may be purchased ready to use, or on a large job may be twisted on the work. The number of twists per linear foot depends upon the diameter; thus, for ¼-inch bars there may be five twists per foot and for 1-inch bars one twist per foot.

In computing cross-section area of steel in reinforced concrete, the twisted bars are figured as square bars of the dimension before twisting. Twisted bars are employed in the Pacific Coast Borax Refinery and the Bullock Electric Company shop, described in Chapters IV and VII.

**THACHER BAR.**—The Thacher bar, Fig. 102, was designed and patented by Mr. Edwin Thacher, of the Concrete Steel Engineering Company. Round bars are rerolled to the shape indicated. Thacher bars are used in parts of the Textile building, Chapter XI.

Fig. 102.—Thacher Bulb Bar. (*See p. 179.*)

**JOHNSON CORRUGATED BAR.**—The corrugated, or Johnson bar, Fig. 103, is the invention of Mr. A. L. Johnson, of the Expanded Metal and Corrugated Bar Company. It is a form of square bar with alternate elevations and depressions to grip the concrete. The normal size and net sections are given in the following table:

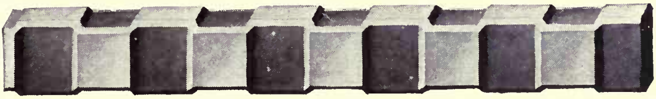


Fig. 103.—Johnson or Corrugated Bar. (*See p. 179.*)

Areas and Weights of Johnson Bars (New Style).

| Nominal diameter, inches. | Area, square inches. | Weight per linear foot. |
|---|---|---|
| ¼ | 0.06 | 0.24 |
| 1-3 | 0.11 | 0.38 |
| ½ | 0.25 | 0.85 |
| ⅝ | 0.39 | 1.33 |
| ¾ | 0.56 | 1.91 |
| ⅞ | 0.77 | 2.60 |
| 1 | 1.00 | 3.40 |
| 1¼ | 1.56 | 5.31 |

The Johnson bar is used in the Wholesale Merchants' Warehouse, Nashville, Tenn., described in Chapter VIII.

**UNIVERSAL BAR.**—A type of bar somewhat similar to the Johnson bar is shown in Fig. 104. This is manufactured by the Rogers Shear Company and the sale controlled by the Expanded Metal and Corrugated Bar Company.

**DIAMOND BAR.**—The Diamond bar, Fig. 105, is one of the most recent types of rolled bar and the invention of Mr. William Mueser, of the Concrete Steel Engineering Company. The sizes correspond to those of square bars as shown in the following table:

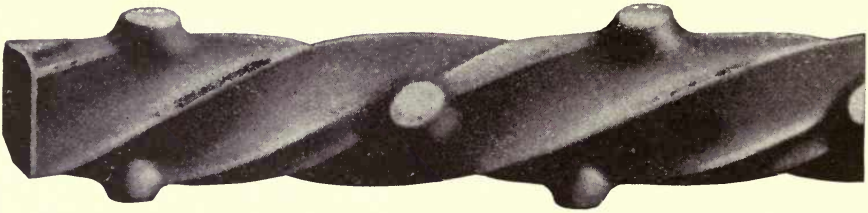
Areas and Weights of Diamond Bars.

| Size | 1/4 in. | 3/8 in. | 1/2 in. | 5/8 in. | 3/4 in. | 7/8 in. | 1 in. | 1 1/4 in. |
|---|---|---|---|---|---|---|---|---|
| Area in square inches | .0625 | .1406 | .25 | .39 | .56 | .76 | 1.00 | 1.56 |
| Weight per foot | .213 | .478 | .85 | 1.33 | 1.91 | 2.60 | 3.40 | 5.31 |

Fig. 104.—Universal Bar. (*See p. 179.*)

Fig. 105.—Diamond Bar. (*See p. 179.*)

COLD TWISTED LUG BAR.—A modification of the twisted bar is the twisted lug bar, Fig. 106, made by the General Fireproofing Company. This bar is used in the columns of the Forbes Building, described in Chapter XII.



(Patented)

Fig. 106.—Twisted Lug Bar. (*See p. 180.*)

KAHN TRUSSED BAR.—The Kahn trussed bar, Fig. 107 (p. 183), invented by Mr. Julius Kahn, of the Trussed Concrete Steel Company, is rolled with flanges, which are bent up, as shown in the figure, to resist the shear in the beam. The Kahn bar is employed in the Packard Building, described in Chapter X.

CUP BAR.—The cup bar, another product of the Trussed Concrete Steel Company, is rolled with four longitudinal ribs connected at frequent intervals by cross ribs so as to form cup depressions between them designed to grip the concrete.

Areas of cross-section of cup bars are made to correspond to square bars of the same nominal size.

# EXPANDED METAL MESHES.

| Designation | | | Section in Sq. Inches Per Foot of Width | Weight Per Square Foot in Pounds | Size of Standard Sheets | Number of Sheets in a Bundle | Number of Sq. Feet in Bundle of 8′0″ Length |
|---|---|---|---|---|---|---|---|
| Mesh | Gage (Stubs) | Strand Standard or Extra | | | | | |
| ½ in. | No. 18 | Standard | .209 | .74 | 4 ft. or 5 ft. x 8 ft. | 5 | |
| ¾ in. | " 13 | " | .225 | .80 | 6 ft. x 8 ft. or 12 ft. | 5 | 240 |
| 1½ in. | " 12 | " | .207 | .70 | 4 ft. x 8 ft. or 12 ft. | 5 | 160 |
| 2 in. | " 12 | " | .166 | .56 | 5 ft. x 8 ft. or 12 ft. | 5 | 200 |
| 3 in. | " 16 | " | .083 | .28 | 6 ft. x 8 ft. or 12 ft. | 10 | 480 |
| 3 in. | " 10 | Light | .148 | .50 | 6 ft. x 8 ft. or 12 ft. | 5 | 240 |
| 3 in. | " 10 | Standard | .178 | .60 | 6 ft. x 8 ft. or 12 ft. | 5 | 240 |
| 3 in. | " 10 | Heavy | .267 | .90 | 4 ft. x 8 ft. or 12 ft. | 5 | 160 |
| 3 in. | " 10 | Extra Heavy | .356 | 1.20 | 6 ft. x 8 ft. or 12 ft. | 3 | 144 |
| 3 in. | " 6 | Standard | .400 | 1.38 | 5 ft. x 8 ft. or 12 ft. | 3 | 120 |
| 3 in. | " 6 | Heavy | .600 | 2.07 | 5 ft. x 8 ft. or 12 ft. | 3 | 120 |
| 4 in. | " 16 | Old Style | .093 | .42 | 4½ ft. x 8 ft. or 9 ft. | 6 | 216 |
| 6 in. | " 4 | Standard | .245 | .84 | 5 ft. x 8 ft. or 12 ft. | 5 | 200 |
| 6 in. | " 4 | Heavy | .368 | 1.26 | 5 ft. x 8 ft. or 12 ft. | 3 | 120 |

# LATHING.

| Designation | Gage U. S. Standard | Size of Sheets | Sheets in a Bundle | Sq. Yards in a Bundle | Weight Per Sq. Yard |
|---|---|---|---|---|---|
| A | 24 | 18 x 96 | 9 | 12 | 4⅛ lbs. |
| B | 27 | 18 x 96 | 9 | 12 | 3 " |
| Special B | 27 | 20¼ x 96 | 9 | 13½ | 2½ " |
| Diamond No. 24 | 24 | 22½ x 96 | 9 | 15 | 3 " |
| Diamond No. 26 | 26 | 24 x 96 | 9 | 16 | 2⅔ " |

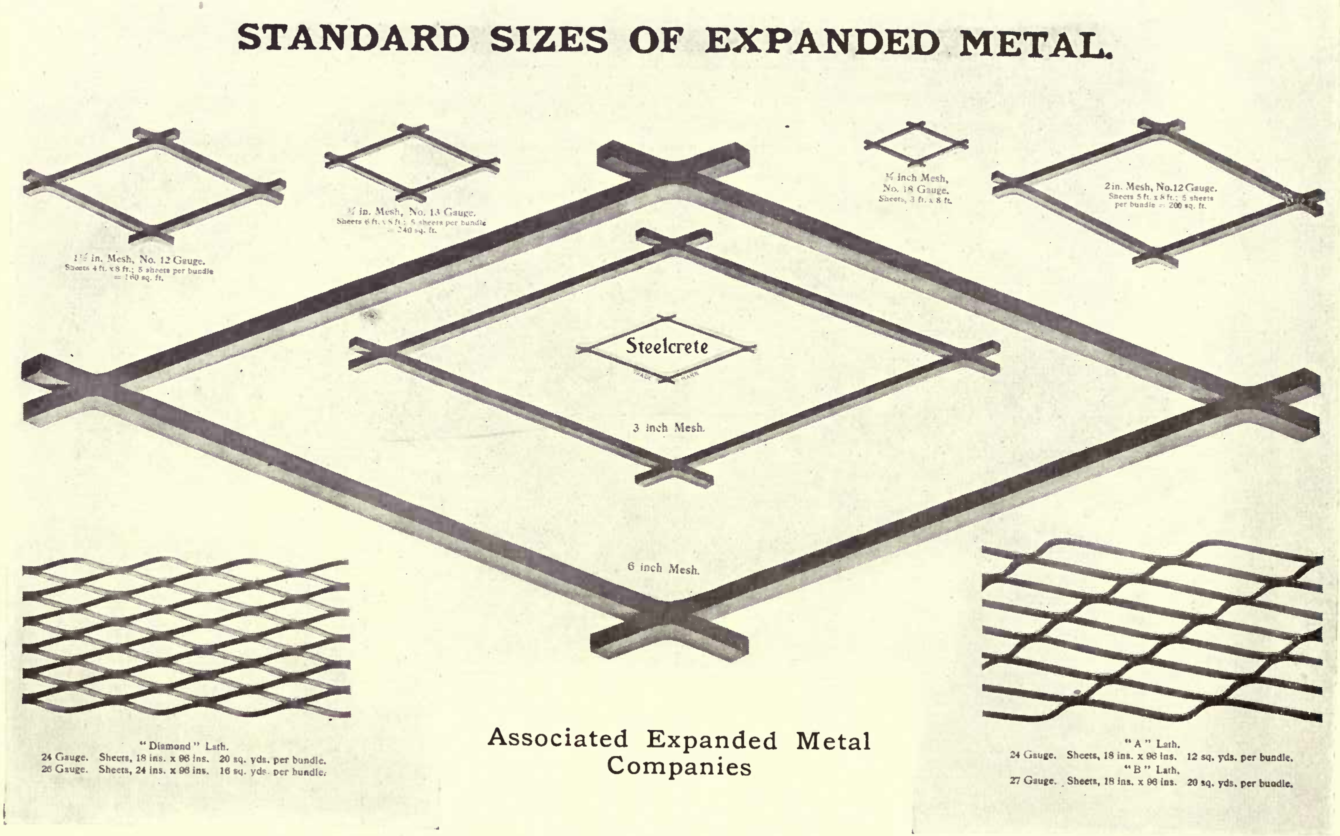


Fig. 108.—Expanded Metal of Standard Mesh. (*See p. 181.*)

Fig. 107.—Kahn Trussed Bar. (*See p. 180.*)

EXPANDED METAL.—One of the oldest forms of sheet reinforcement is expanded metal invented by Mr. John T. Golding.

Sheet steel is slit in a special machine and then pulled out or expanded so as to form a diamond mesh. For convenient reference, the standard sizes and gages as adopted by the Associated Expanded Metal Companies are shown in the illustration, Fig. 108 (p. 182), and are tabulated on page 181.

Expanded metal for slab reinforcement is employed in the Lynn storage warehouse, Chapter VI, and the Forbes cold storage warehouse, Chapter XII.

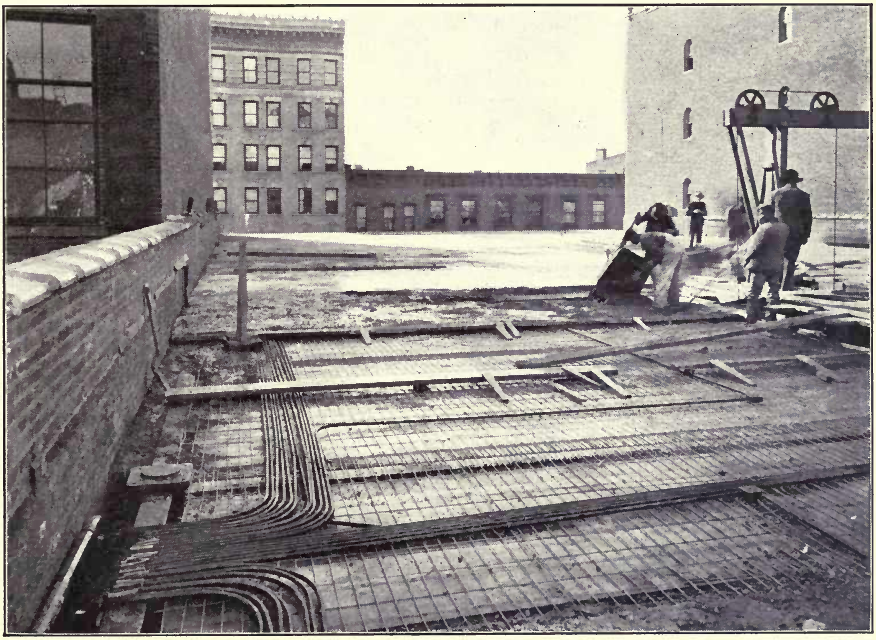
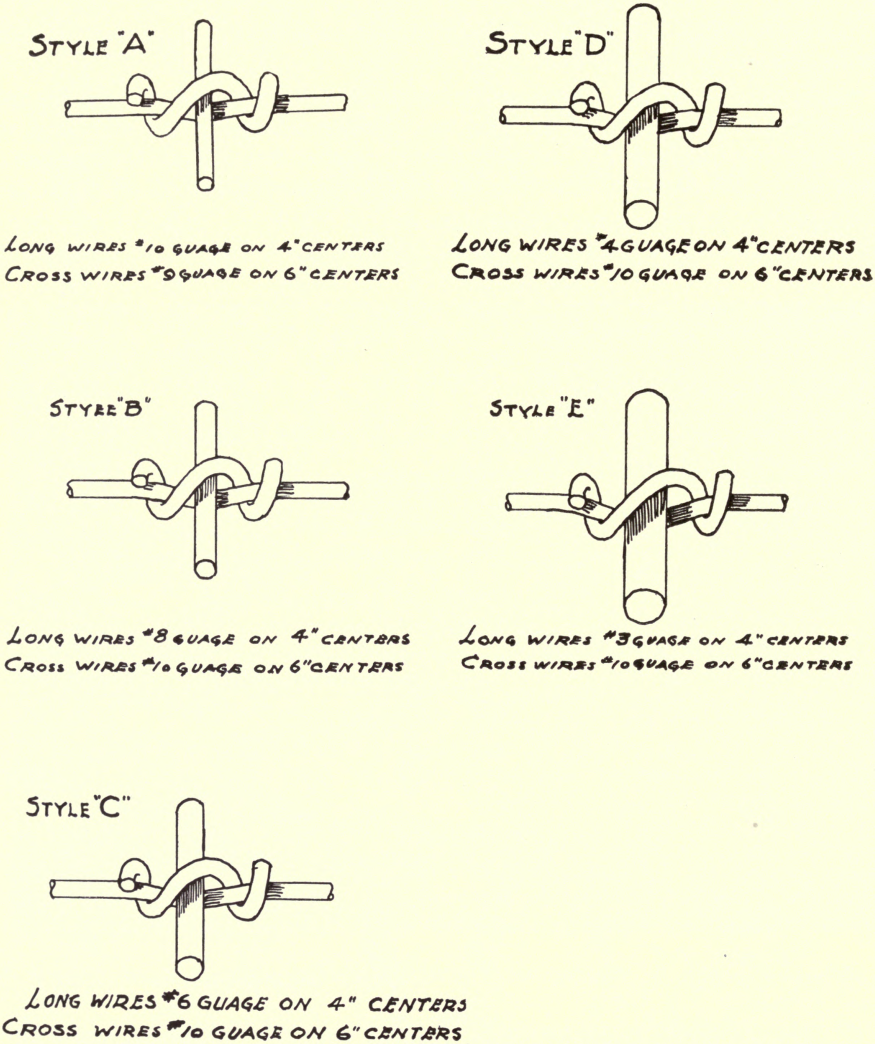


Fig. 109.—Laying Clinton Welded Wire in Decauville Garage, New York. (*See p. 183.*)

CLINTON WELDED WIRE.—Clinton welded wire fabric, made by the Clinton Wire Cloth Company, is manufactured in different sizes of mesh and different gages of wire. As commonly made, the longitudinal strands are of larger diameter and closer spacing than the cross strands, the latter being chiefly to prevent construction cracks in the concrete. The wires are electrically welded at every intersection.



STYLE "A"

LONG WIRES #10 GUAGE ON 4" CENTERS
CROSS WIRES #9 GUAGE ON 6" CENTERS

STYLE "D"

LONG WIRES #4 GUAGE ON 4" CENTERS
CROSS WIRES #10 GUAGE ON 6" CENTERS

STYLE "B"

LONG WIRES #8 GUAGE ON 4" CENTERS
CROSS WIRES #10 GUAGE ON 6" CENTERS

STYLE "E"

LONG WIRES #3 GUAGE ON 4" CENTERS
CROSS WIRES #10 GUAGE ON 6" CENTERS

STYLE "C"

LONG WIRES #6 GUAGE ON 4" CENTERS
CROSS WIRES #10 GUAGE ON 6" CENTERS

Fig. 110.—Lock Woven Fabric of Standard Gage. (*See p. 185.*)

The fabric is furnished in diameters of wire ranging from 1-10 inch to 3-10 inch, and with spacing between the strands from 2 inches up to 20 inches.

The laying of the fabric in the Decauville garage, New York, is illustrated in Fig. 109 (p. 183).

LOCK WOVEN WIRE.—Lock woven wire is made by W. N. Wight & Co. It is similar to the welded wire fabric, except that instead of electric welding the intersections are bound together by winding them with soft wire. The various gages and sizes of mesh are illustrated full size in Fig. 110.

RIB METAL.—Rib metal, illustrated in Fig. 110a, and made by the Trussed Concrete Steel Co., consists of straight bars for main tension members connected by light metal ties which serve as spacers, and also are useful for cross reinforcement.

The strength of the metal varies with the spacing of the ribs so as to provide various areas of cross-section of steel per foot of width, as shown in the table.

RIB METAL AREAS AND SECTIONS.

Area section of one rib = 0.9 square inch.

| Size No. | Width of Standard Sheet | Square Feet per Lineal Foot of Standard Sheet | Area per Foot of Width |
|---|---|---|---|
| 2 | 16 in. | 1.33 | .54 sq. in. |
| 3 | 24 " | 2.00 | .36 " |
| 4 | 32 " | 2.67 | .27 " |
| 5 | 40 " | 3.33 | .216 " |
| 6 | 48 " | 4.00 | .18 " |
| 7 | 56 " | 4.67 | .154 " |
| 8 | 64 " | 5 33 | .135 " |

Standard Lengths—8, 10, 12, 14 and 16 feet.

FERROINCLAVE.—Ferroinclave, invented by Mr. Alexander E. Brown, of the Brown Hoisting Machinery Company, is sheet metal bent as in Fig. 111, and spread over or plastered with mortar to form a sheet 1⅜ inches thick. An illustration of the placing of ferroinclave is photographed in Fig. 112 (p. 187).

**TRUSS METAL LATH.**—A form of slit metal is made by the Truss Metal Lath Company, with the strands bent to receive plaster, as shown in Fig. 113.

Truss lath comes in sheets ranging from 24 to 30 inches wide and 68 to 112 inches long, and in three gages.

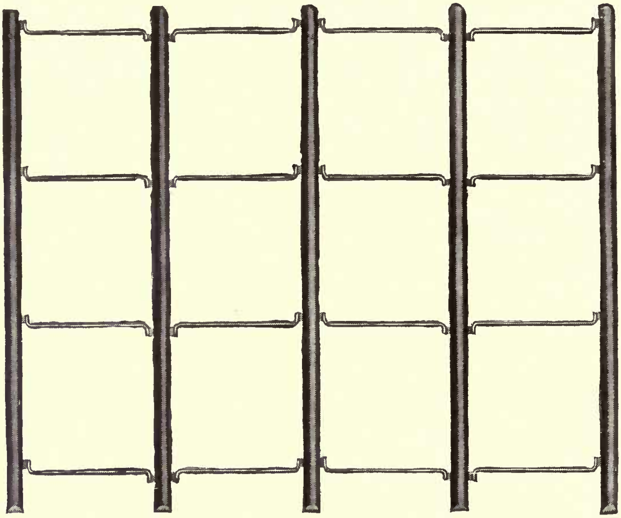


Fig. 110a.—Rib Metal. (*See p. 185.*)

**TRUSSIT.**—Trussit is formed by expanded metal or herringbone lath bent to V-shape section, as shown in Fig. 114. It is manufactured by the General Fireproofing Company.

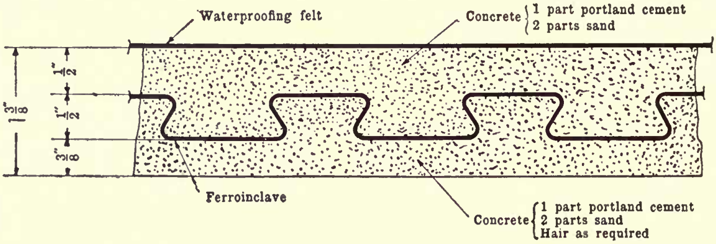


Fig. 111.—Section of Ferroinclave Roof. (*See p. 185.*)

**HENNEBIQUE SYSTEM.**—One of the pioneers in concrete construction in Europe is Mr. Hennebique, in France, and the system which still bears his name is shown in Fig. 115.

**COLUMBIAN SYSTEM.**—The special forms of Columbian bars and methods of placing them are illustrated in Fig. 116 (p. 190).

CUMMINGS SYSTEM.—A number of reinforcement details have been invented by Mr. Robert A. Cummings, as illustrated in Fig. 117 (p. 191).

In the illustration at the top of the diagram is shown the Cummings method of forming the bent-up bars and attaching them to the tension bars. In general the plan is to provide tension bars with ends specially anchored, while securely attached to them are small rods horizontal in the middle of the beam or girder, but bent up, as indicated, to pass across the top of the beam and form inclined inverted U bars or stirrups. The idea is more clearly

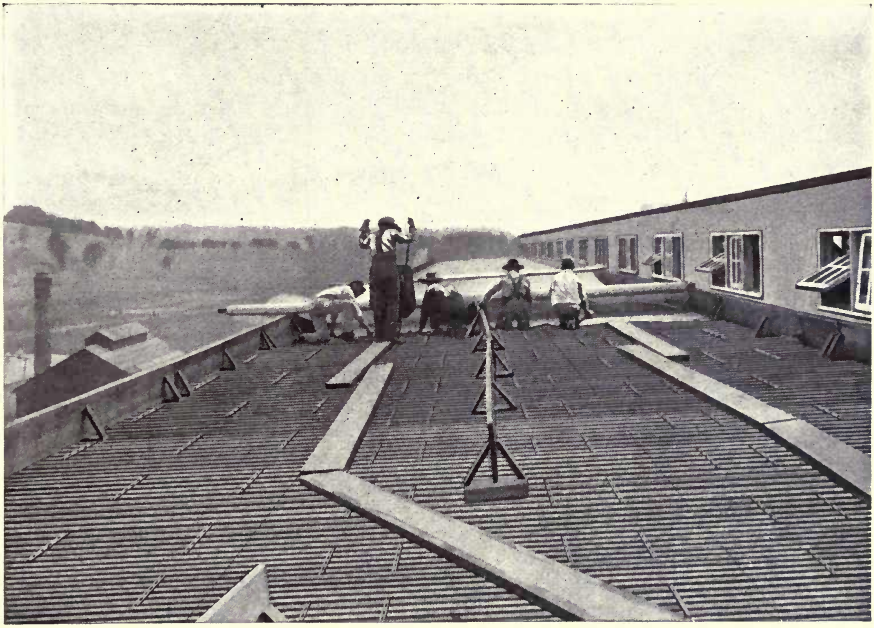


Fig. 112.—Placing of Ferroinclave Roof. (*See p. 185.*)

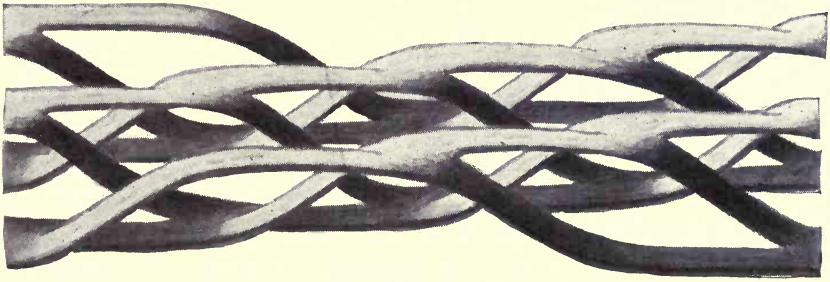


Fig. 113.—Truss Lath. (*See p. 186.*)

shown in the sketches below of "Arrangement of Steel." The "Supporting Chairs," placed at the point of the bending up of the rods, are also drawn. For the slab steel another type of supporting chair is employed, as illustrated in the detail sketch.

The Cummings hooped column is also shown in the upper sketch, and the details of the column reinforcement below. Each hoop is securely attached to the upright rods.

UNIT GIRDER FRAME SYSTEM.—A type of reinforcement for beams and girders, which is built in the shop or in the yard where the building is being constructed, is shown in Fig. 118 (p. 192). This is the unit girder frame, manufactured by Tucker & Vinton.

PIN-CONNECTED SYSTEM.—A modern form of unit reinforcement, made by the General Fireproofing Company, where the bars are made into a truss before placing in the form, is shown in Fig. 119 (p. 193).

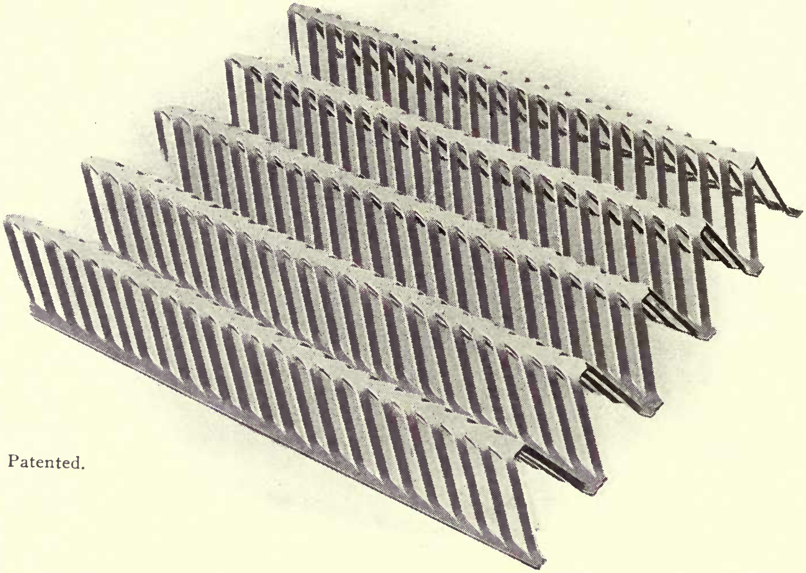


Fig. 114.—Trussit. *(See p. 186.)*

GABRIEL SYSTEM.—Details of the Gabriel system, as laid by the Gabriel Reinforcement Company, are shown in Fig. 120 (p. 193).

ROEBLING SYSTEM.—The Roebling system is employed in connection with a structural steel frame of I-beam or girder construction.

For all flat construction of floors, the reinforcing system used consists of flat bars placed upon edge, secured at the ends to the steel beams and bridged with bar separators. The object of the edgewise position of the bars is the increased protection thus secured to the reinforcing steel. With this type of floor the structural steel frame is generally completely encased with concrete.

For light roof construction where the steel work need not be protected, a continuous slab is built over the beams, reinforced with flat steel bars, 3-16 by 1¼ inches, placed edgewise and held in position by spacers, as shown in Fig 121 (p. 194).

For floor construction the Roebling Company also uses segmental arches of cinder concrete laid upon permanent stiffened wire lath centering, or upon wood centering which is carried on steel tees and supported by the steel I-beams of the floor system, which are generally placed about 7 feet on centers. In this system the material is placed upon the centering without puddling or tamping, in order to obtain a light porous concrete of high fire resisting quality.

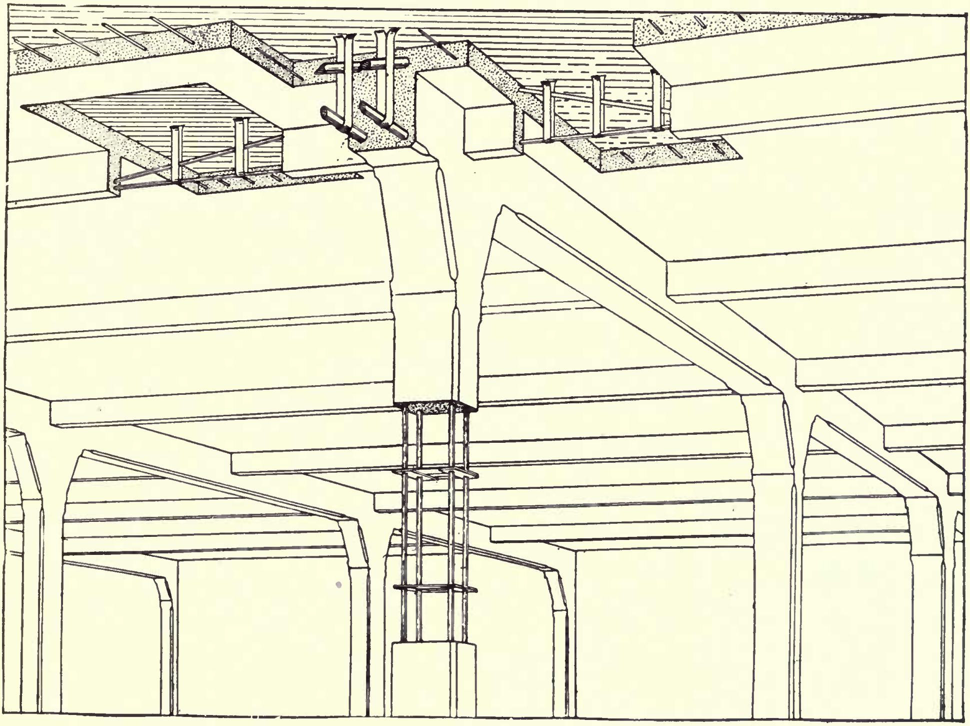


Fig. 115.—Hennebique System. (*See p. 186.*)

MERRICK SYSTEM.—To lighten the weight of the concrete slab Mr. Ernest Merrick has designed a hollow floor construction, as illustrated in Fig. 122 (p. 194). Directly upon the forms a 2-inch layer of concrete is placed, and before this has set, oblong boxes of metal fabric of small mesh are laid horizontally, with the reinforcing rods in the spaces between them, and the concrete is filled in between the boxes and around the reinforcing rods and covered over the top to form the floor.

MUSHROOM SYSTEM.—The mushroom system of flat slab construction is the invention of Mr. C. A. P. Turner. The rods run between the columns both transversely and diagonally, as in Fig. 123 (p. 195).

The interior of a building laid by this system and showing the large column capping which is incident to it is illustrated in Fig. 124 (p. 196).

## FACTORY MOLDED CONCRETE.

To eliminate the cost of forms and at the same time to utilize to best advantage the strength of the concrete, the plan has been adopted of molding in a shop the various members for a concrete house or factory, and transporting them to the site of the building for erection. A modification of this plan is followed in the Textile machine shop, described in Chapter XI, where the columns were built in place, but the girders and floor beams were cast separately by the Visintini System and raised to place.

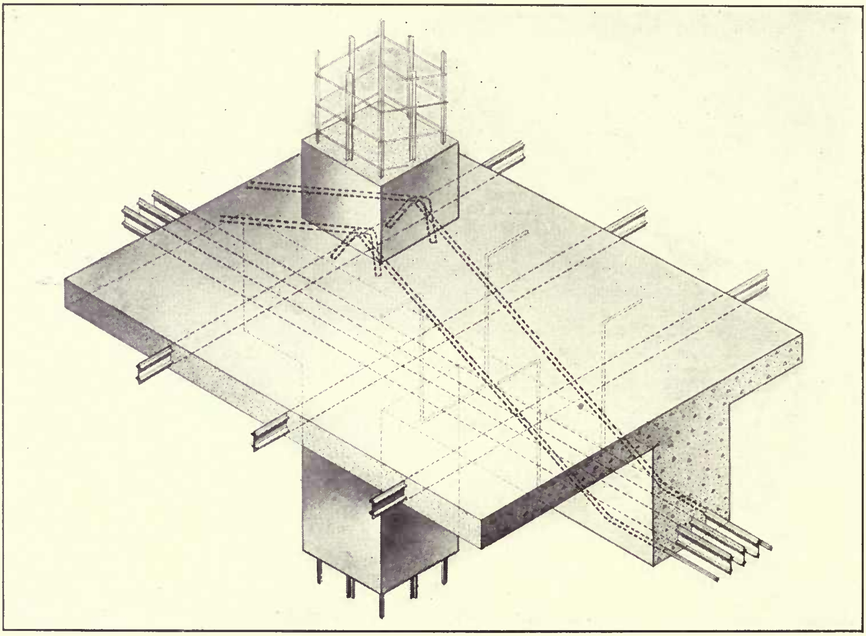


Fig. 116.—Columbian System. (*See p. 186.*)

Concrete members made in a factory are subject to the expense of transportation to the site of the building and to the erection cost, but over against this is not only the saving in form construction, but also the economy of manufacturing the concrete in a stationary plant where machinery can be utilized; the use of light sections with a minimum quantity of material; and the advantage of an initial seasoning of the concrete which eliminates danger of too early removal of forms by inexperienced contractors.

In the larger cities where a plant can supply the local demand, this type of construction is an economical form of fireproof construction, especially for dwellings, apartment houses and small factories.

A building of separately-molded members lacks the extreme rigidity of monolithic reinforced concrete construction unless the connections can be made positively unyielding, but even with ordinary care it should be possible to construct at least as stiff a building as ordinary mill construction with its brick walls, timber columns and beams, and plank floors.

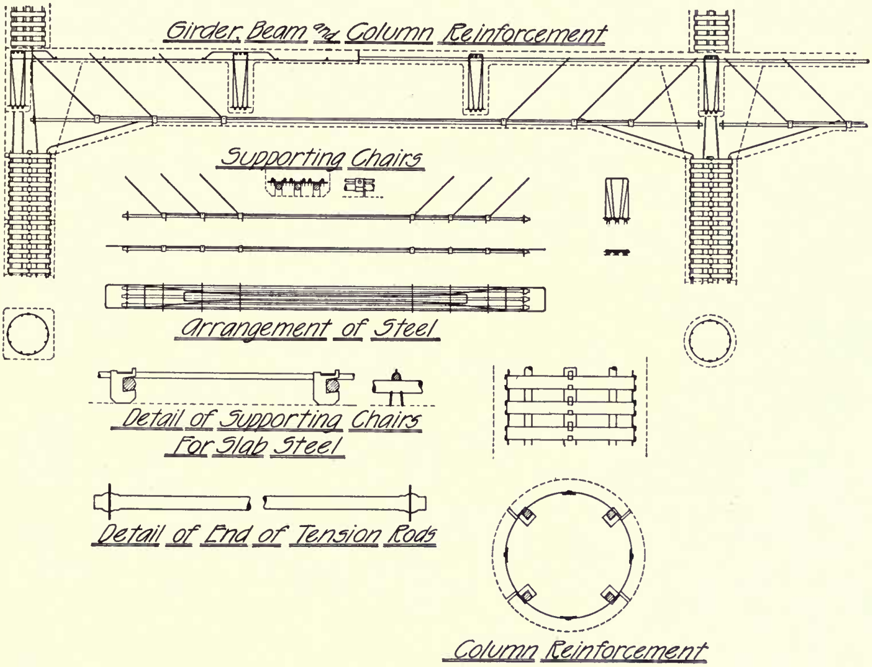


Fig. 117.—Details of Cummings System. (*See p. 187.*)

In Europe the Siegwart system of floor construction has been developed quite extensively, using for floor slabs a series of adjacent hollow beams formed by the use of collapsible cores.

The Standard system has been devised and is now being manufactured in the United States by the Standard Building Construction Co., of Pittsburgh,

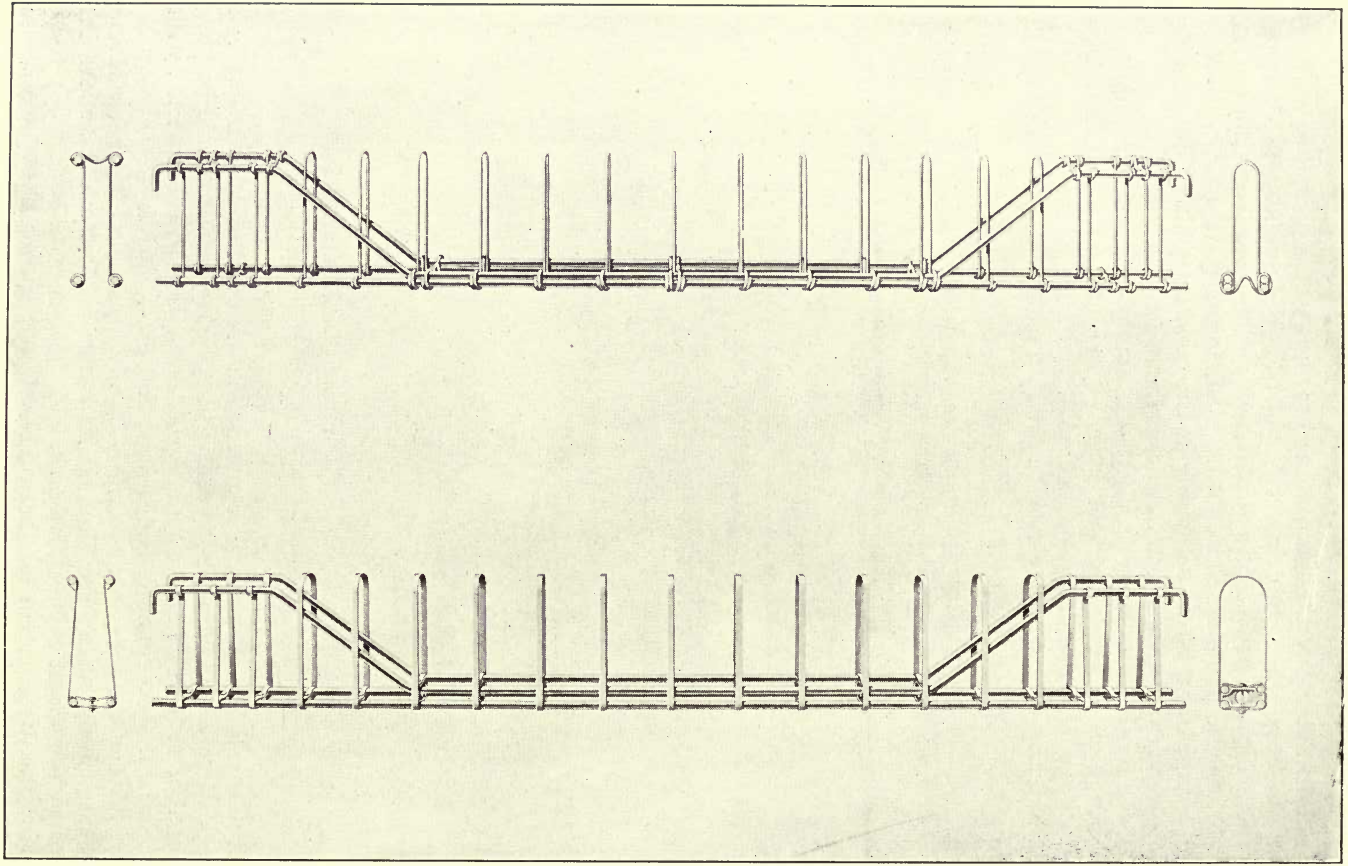


Fig. 118.—Unit Girder Frame System. (*See p. 188.*)

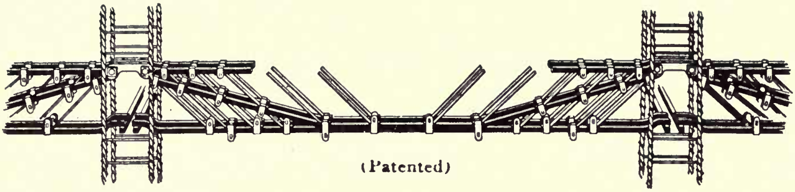


Fig. 119—Pin-Connected Girder Frame. (*See p. 188.*)

Penn. The general scheme is to build floors of light weight I-shaped or T-shaped joists of reinforced concrete to replace wood joists or reinforced concrete slabs, and rest the ends of the joists upon walls made of vertical interlocking concrete studding or concrete blocks. Columns are formed in the wall in light construction by filling the hollows between the vertical studs, or blocks, with concrete reinforced with steel rods. For heavy buildings the floor joists may rest upon monolithic reinforced concrete girders and columns, or upon structural steel girders and columns fireproofed in the factory with concrete.

Fig. 124a (p. 197), illustrates a floor joist resting upon 2-piece hollow block walls. The standard joist section shown is 16 inches wide by 8½ inches deep, with horizontal reinforcement for tension, and webbing of metal mesh which can be seen in the photograph, to provide for shear and the stresses which are liable in transportation. Members of other dimensions are made to suit the span and loading required.

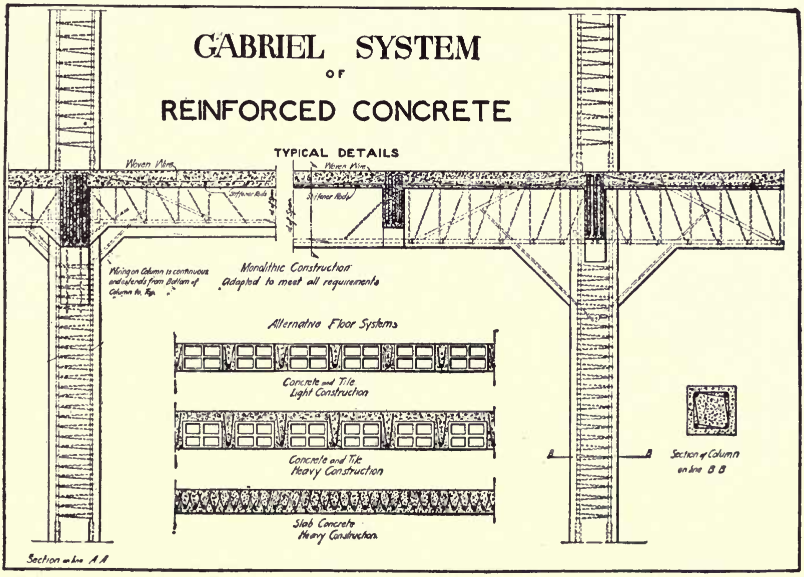


Fig. 120.—Gabriel System. (*See p. 188.*)

A nailing piece is imbedded in the top of the joist, as shown for laying wooden floors. If the floor is to have concrete finish, the joists are made I-shaped. The ceilings are plastered upon the lower flanges, the concrete being left rough for the purpose.

Three styles of Standard floor construction are illustrated in Fig. 124b (p. 198). The top floor is laid with joists just described, the two middle floors of separately molded arches, and the bottom floor of cast slabs with reinforced ribs molded on the bottom surface. The thin slabs are also well adapted for roof construction.

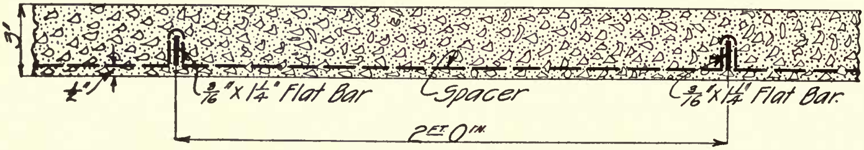


Fig. 121.—Roebling System. (*See p. 188*)

An important feature of the Standard system is the method of connecting the individual members. The reinforcement is allowed to project, and is mechanically connected after placing. The connection is finally imbedded in fresh concrete so as to give strength and rigidity.

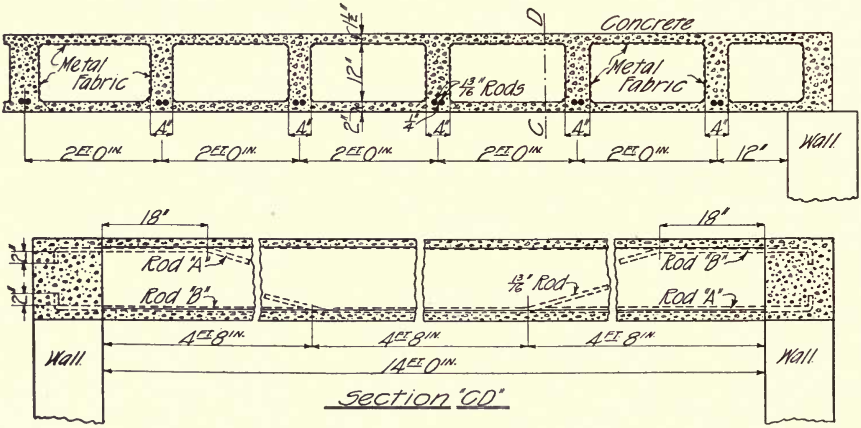


Fig. 122.—Merrick Floor System. (*See p. 189.*)

## CONCRETE BLOCK WALLS.

Frequently concrete blocks are cheaper for factory walls than solid concrete, because no forms are required. However, if used in combination with reinforced concrete interior construction or with steel beams, they must be securely connected to them with ties, and the compressive strength of the blocks carefully figured to see that there is sufficient area of concrete to carry the weight.

In the warehouse at Nashville, Chapter VIII, concrete blocks are utilized for partitions.

An example of a concrete block exterior with a reinforced concrete interior construction is shown in Fig. 125 (p. 199). This illustrates the Salem Laundry Building, Salem, Mass., of which Ballinger and Perrot were architects, and Simpson Brothers Corporation, builders. This has a reinforced concrete floor system and interior columns of solid concrete. The exterior columns are hollow blocks with reinforcing rods running through the openings in them and surrounded by mortar of the same proportions as the blocks themselves so as to form solid piers.

## CONCRETE METAL WALLS.

A type of wall in which the molds also form the permanent reinforcement has been designed and patent applied for by Mr. S. H. Lea. Two walls of metal lathing are erected and plastered and the concrete poured between them, as shown in Fig. 126 (p. 200).

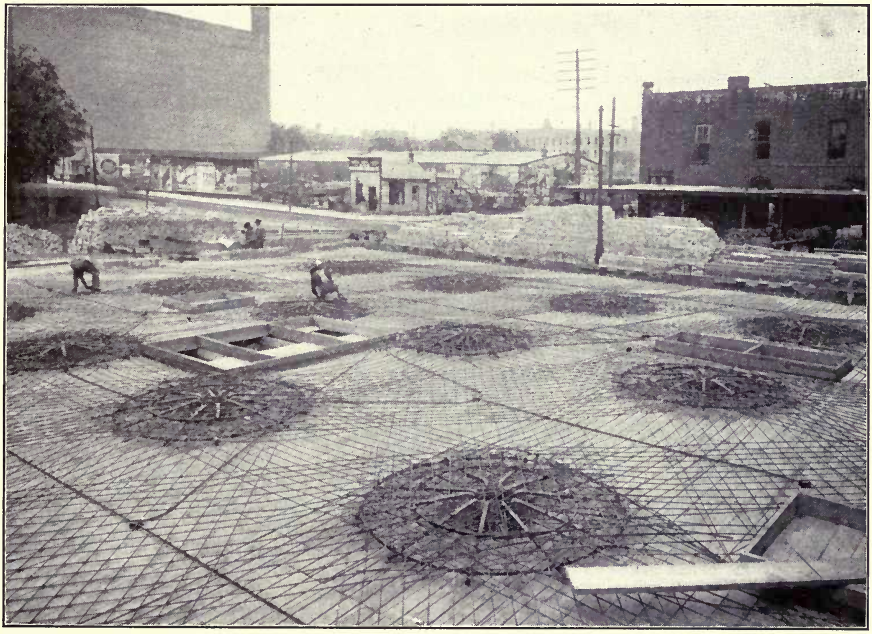


Fig. 123.—Mushroom System. (*See p. 190.*)

## SURFACE FINISH.

One of the most perplexing features of reinforced concrete construction is to obtain a pleasing exterior finish. In factory construction the appearance of the building is usually of less consequence than in the case of dwellings, and yet the effect must not be distasteful to the eye.

Plastering on solid concrete or on concrete blocks is unsatisfactory in climates where the temperature in the winter months falls below freezing. A very thin skin of cement may be plastered on by a skilled mechanic, but this is apt to appear streaked and prove unsatisfactory over a large surface. If the surface is broken by moldings or joints this plan can be used with fair results.

An excellent finish, although a somewhat expensive one, is obtained by removing the surface skin of cement which forms against the molds by dressing it with a pointed hammer of a pneumatic tool. This method is illustrated in Fig. 127 (p. 201), and a photograph of the same wall, taken at close range, is shown in Fig. 128 (p. 201).

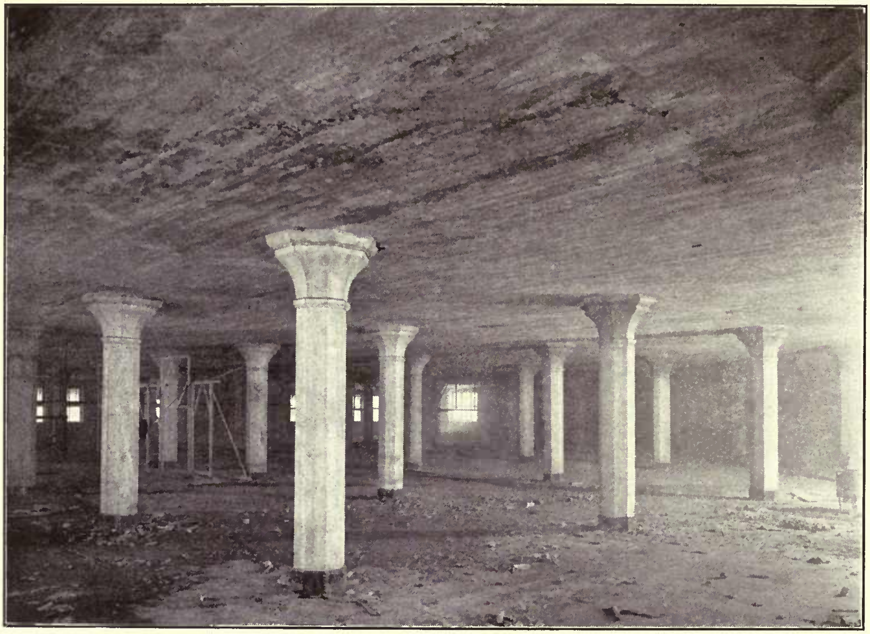


Fig. 124.—Interior of Bovey Building, Built by the Mushroom System. (*See p. 190.*)

Another style of finish is obtained by removing the wall forms within twenty-four hours and immediately washing the surface. To do this satisfactorily the concrete cannot be laid very wet, or the water will run down over the completed surface. A similar effect is obtained with acid treatment.

Another type of finish, which tests of several years in New England has shown to be satisfactory if properly applied, is the slap-dash, illustrated in Fig. 129 (p. 202), which is a view of the wall of the Lynn storage warehouse, built by the Eastern Expanded Metal Company, and described in Chapter VI. The wall is first plastered with cement mortar, and after drying the slap-dash is thrown on.

## CONCRETE PILE FOUNDATIONS.

In certain cases concrete piles are an economical substitute for wood piles or deep pier foundations. Four types of patented reinforced concrete piles are illustrated in the following figures:

The Simplex pile, manufactured by the Simplex Concrete Piling Co., is constructed by driving a hollow shell with a point to the full depth and gradually raising the shell as the concrete is placed in the hole thus made. The process, using an "alligator point" which opens when the shell is pulled, is shown in Fig. 130 (p. 203). Sometimes a solid point made of concrete is used, which is left in the ground.

The Raymond pile, of the Raymond Concrete Pile Co., is formed by placing concrete in a thin steel tube. The tube is driven with a collapsible core within it, and the core is then collapsed and withdrawn, leaving the outer shell to be filled with concrete. The driving of Raymond piles is illustrated in Fig. 131 (p. 204).

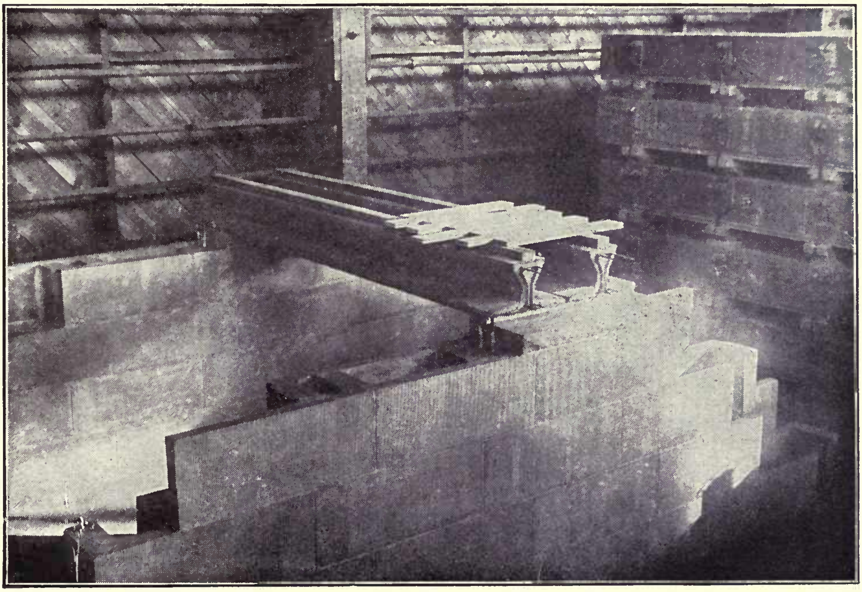


Fig. 124a.—Standard Floor Joists Resting on Concrete Block Walls. (*See p. 193.*)

The corrugated pile, patented by Frank B. Gilbreth, Fig. 132 (p. 205), is cast on the ground and driven by a pile-driver with the aid of a water jet. The illustration shows a corrugated pile in process of driving for the foundation of the warehouse for Mr. John Williams, at West Twenty-seventh street, New York city.

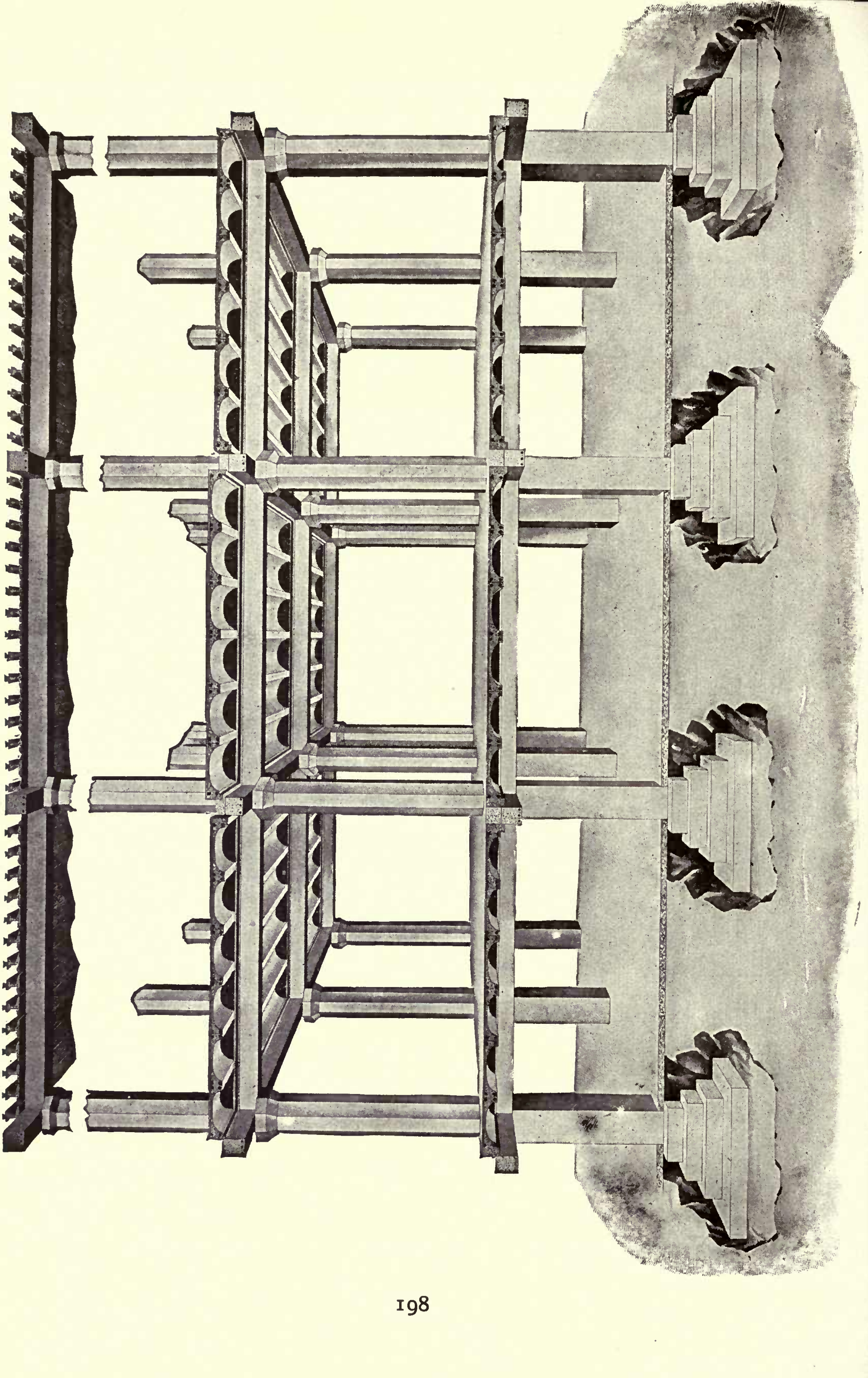
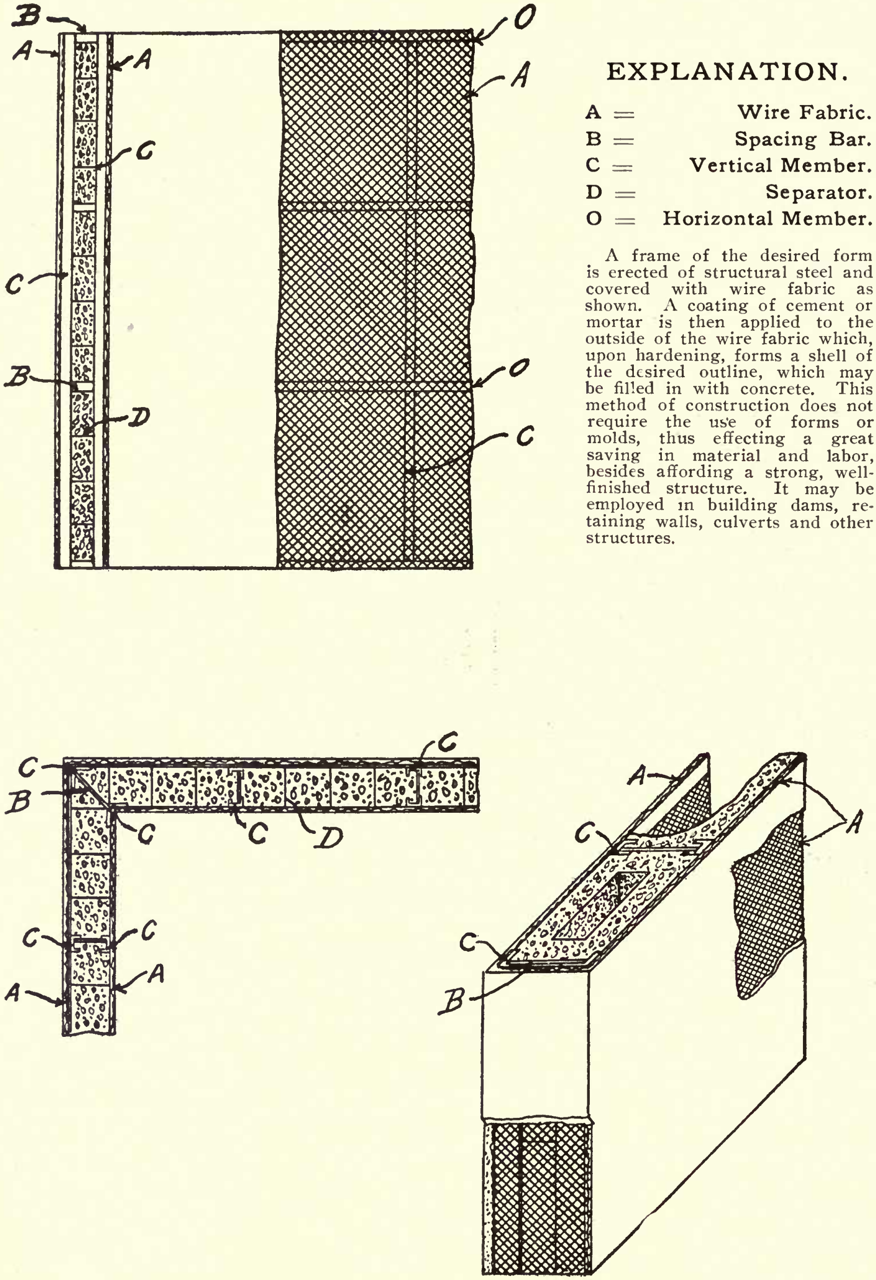


Fig. 124b.—Three Styles of Standard Floor Construction. (*See p. 194.*)

Fig. 125.—Concrete Block Walls, Salem Laundry. (*See p. 195.*)



## EXPLANATION.

A = Wire Fabric.
B = Spacing Bar.
C = Vertical Member.
D = Separator.
O = Horizontal Member.

A frame of the desired form is erected of structural steel and covered with wire fabric as shown. A coating of cement or mortar is then applied to the outside of the wire fabric which, upon hardening, forms a shell of the desired outline, which may be filled in with concrete. This method of construction does not require the use of forms or molds, thus effecting a great saving in material and labor, besides affording a strong, well-finished structure. It may be employed in building dams, retaining walls, culverts and other structures.

Fig. 126.—Lea's Concrete Metal Wall Construction. (*See p. 195.*)

Fig. 127.—Tooling the Surface of Friedenwald Building Walls. (*See p. 196.*)

Fig. 128.—Photograph of Tooled Surface. (*See p. 196.*)

Fig. 129.—Photograph of Spatter Dash Finish of Lynn Storage Warehouse. (*See p. 196.*)

The Gow pile, of the Chas. R. Gow Co., Fig. 133 (p. 206), has an enlarged footing so as to give it larger bearing, and is formed by washing down a tube with a water jet to a firm strata, and then enlarging the bottom of the excavation by an expanding arrangement to form the base of the pile. The apparatus is withdrawn and the space filled with concrete.

DRIVEN PILES.—In many cases where too many boulders are not liable to be encountered, piles of rectangular or round shape are built horizontally upon the ground, reinforced with steel rods, and, after setting for at least a month, are driven with a pile driver. A special form of cap is required to break the force of the ram on the head of the pile. The corrugated pile (Fig. 132) is a special type of driven pile.

## TANKS.

Reinforced concrete is being used to a large extent for tanks to contain liquids. They require careful design to see that there is sufficient steel to resist the pressure, and also very careful proportioning and placing of the concrete.

A system of square tanks or vats in the basement of the American Oak Leather Company, Cincinnati, is illustrated in Fig. 134. These are 6 feet by 8 feet and 6 feet deep, with reinforced walls 4 inches thick. They were built in groups of six by the Ferro-Concrete Construction Company with specially prepared aggregates. These vats, after over a year's service, have given entire satisfaction and show no signs of leakage.

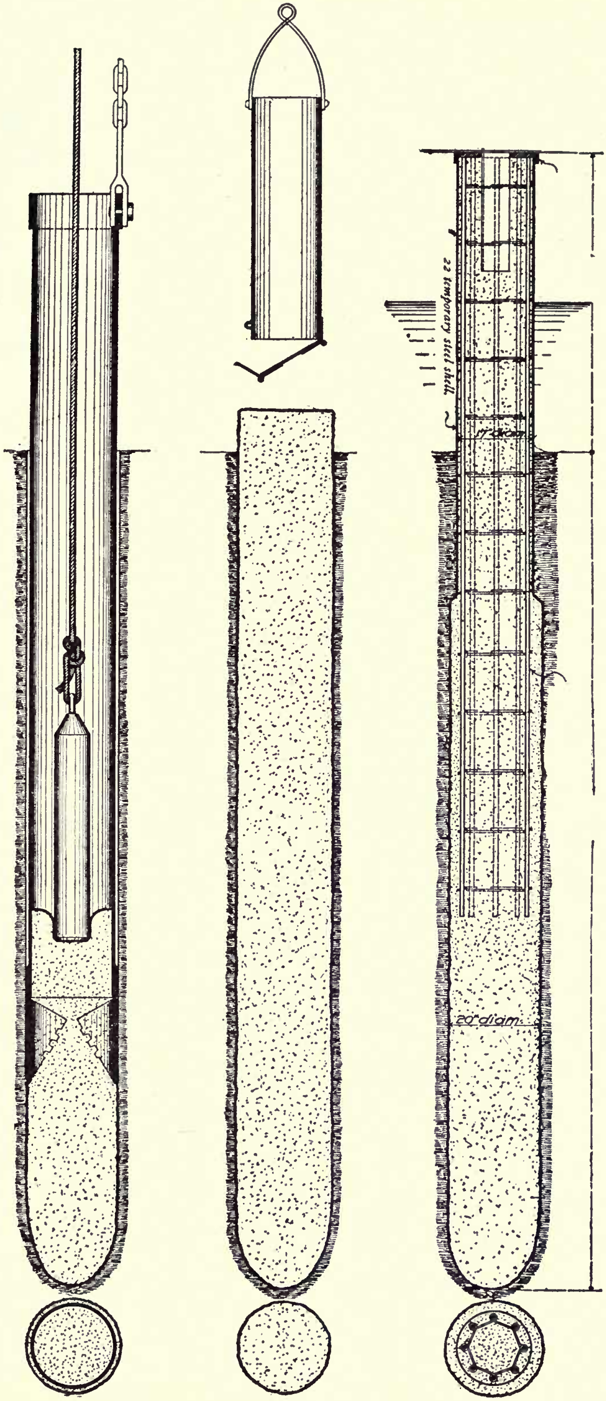


Fig. 130.—Simplex Piles. (*See p.* 197.)

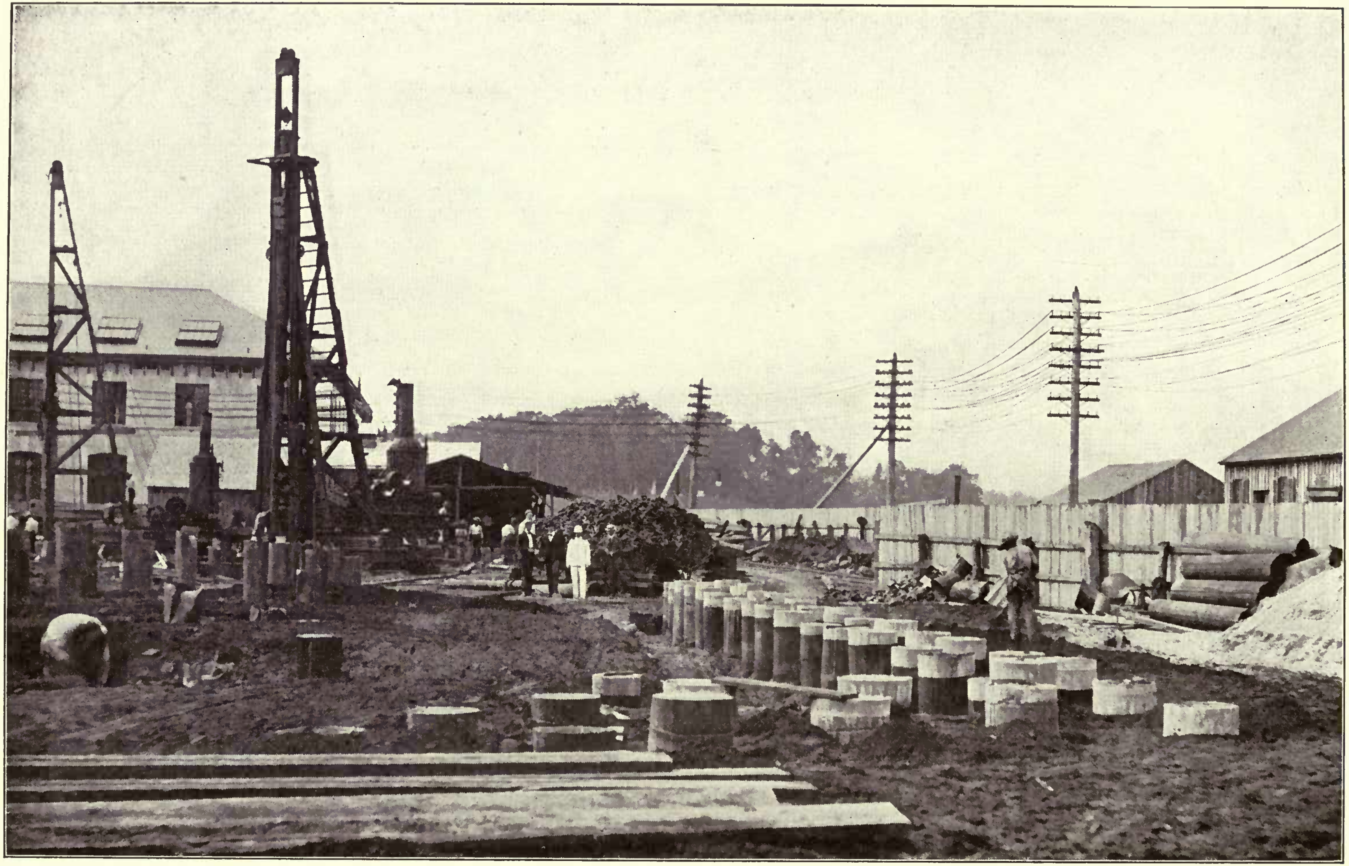


Fig. 131.—Raymond Pile. (*See p. 197.*)

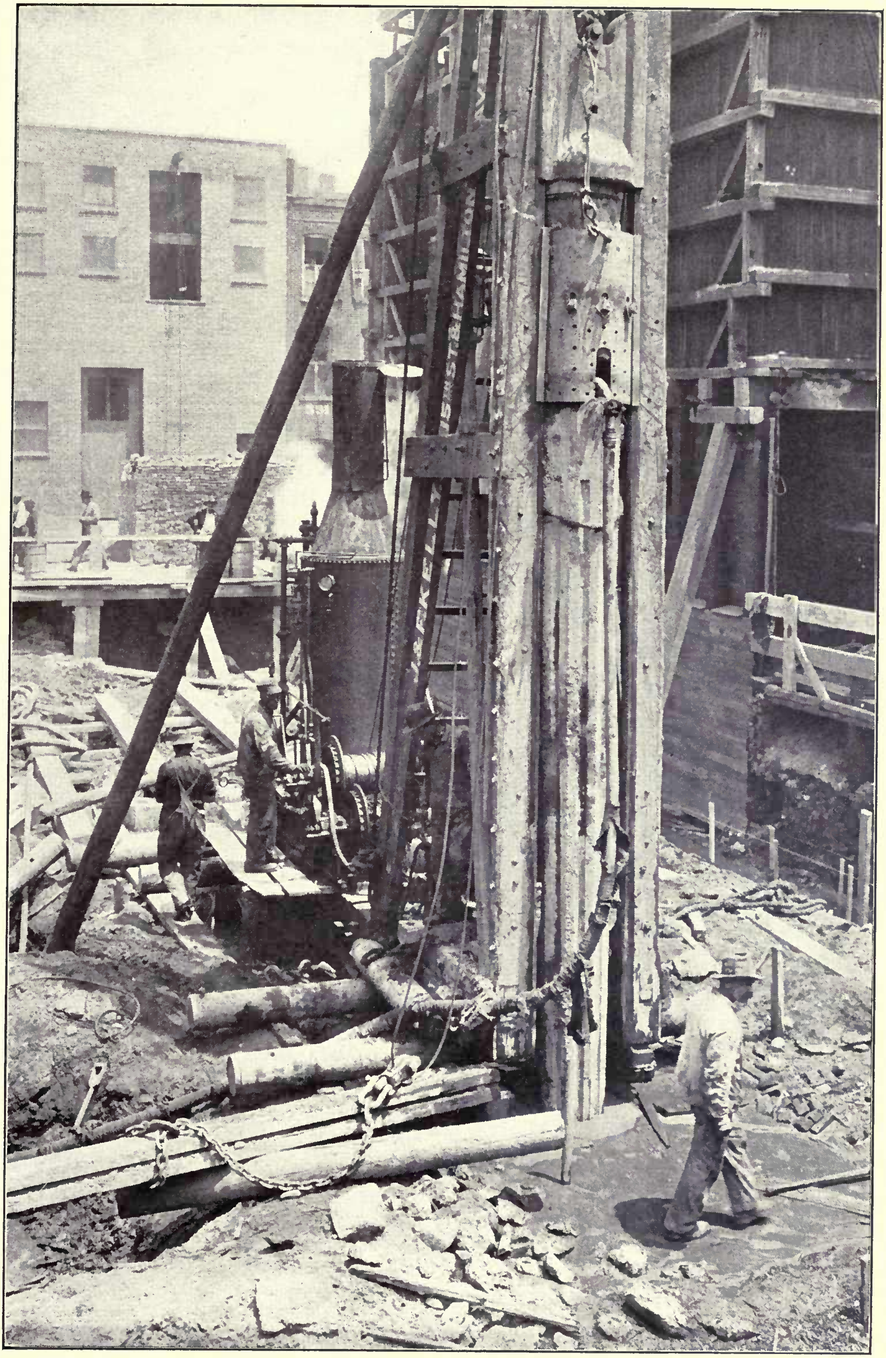


Fig. 132.—Gilbreth Corrugated Pile. (*See p. 197.*)

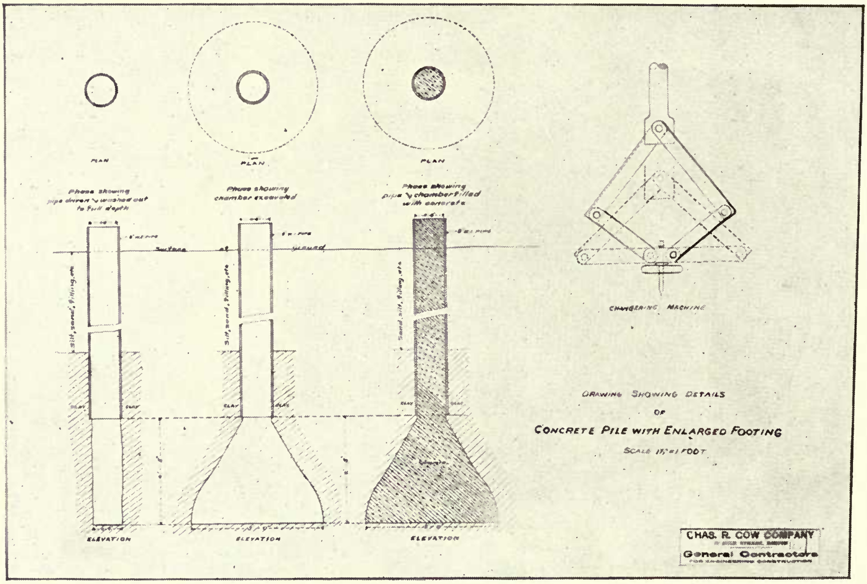
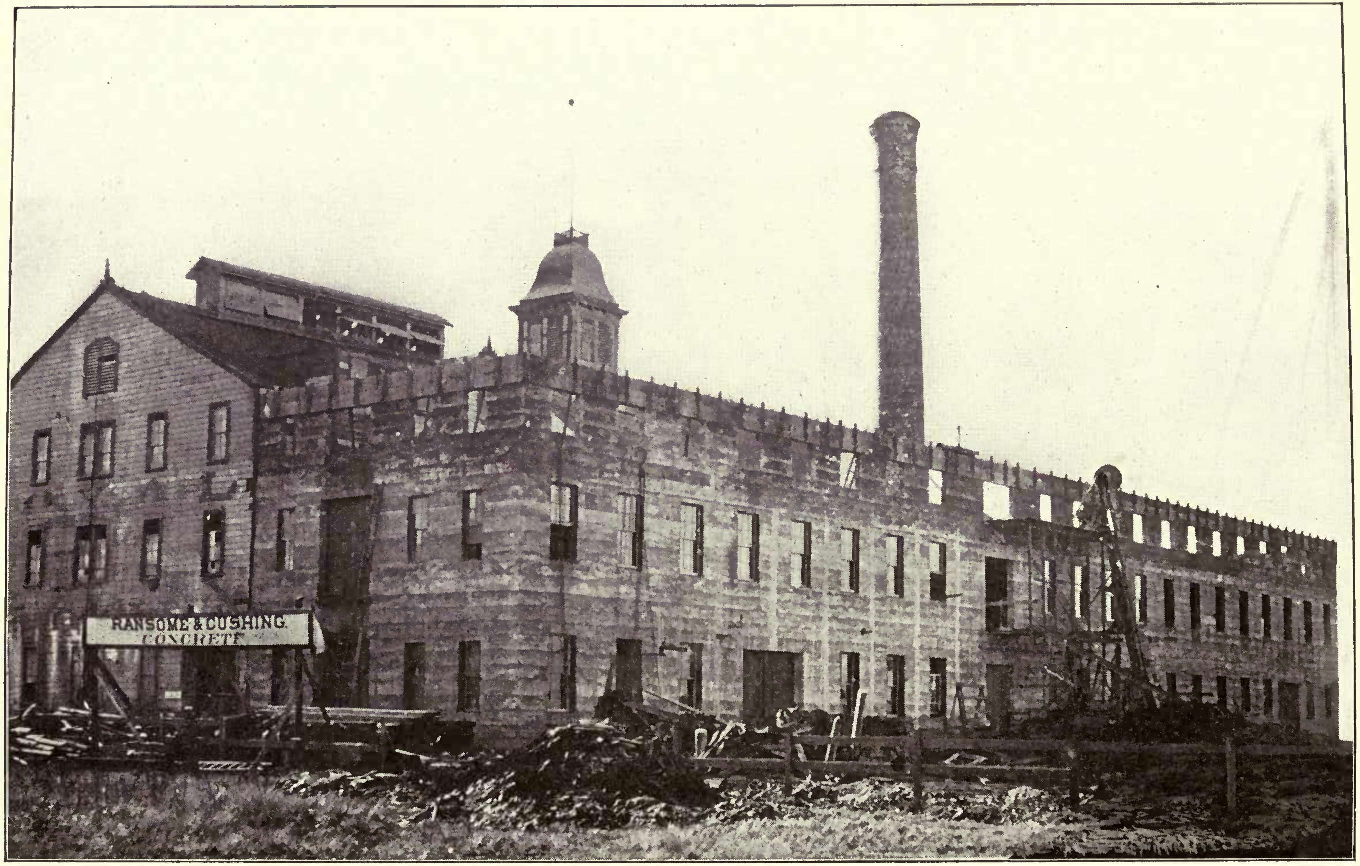


Fig. 133.—Gow Pile. (*See p. 197.*)

Fig. 134.—Concrete Tanks in American Oak Leather Company Factory. (*See p. 202.*)

# MISCELLANEOUS BUILDINGS.

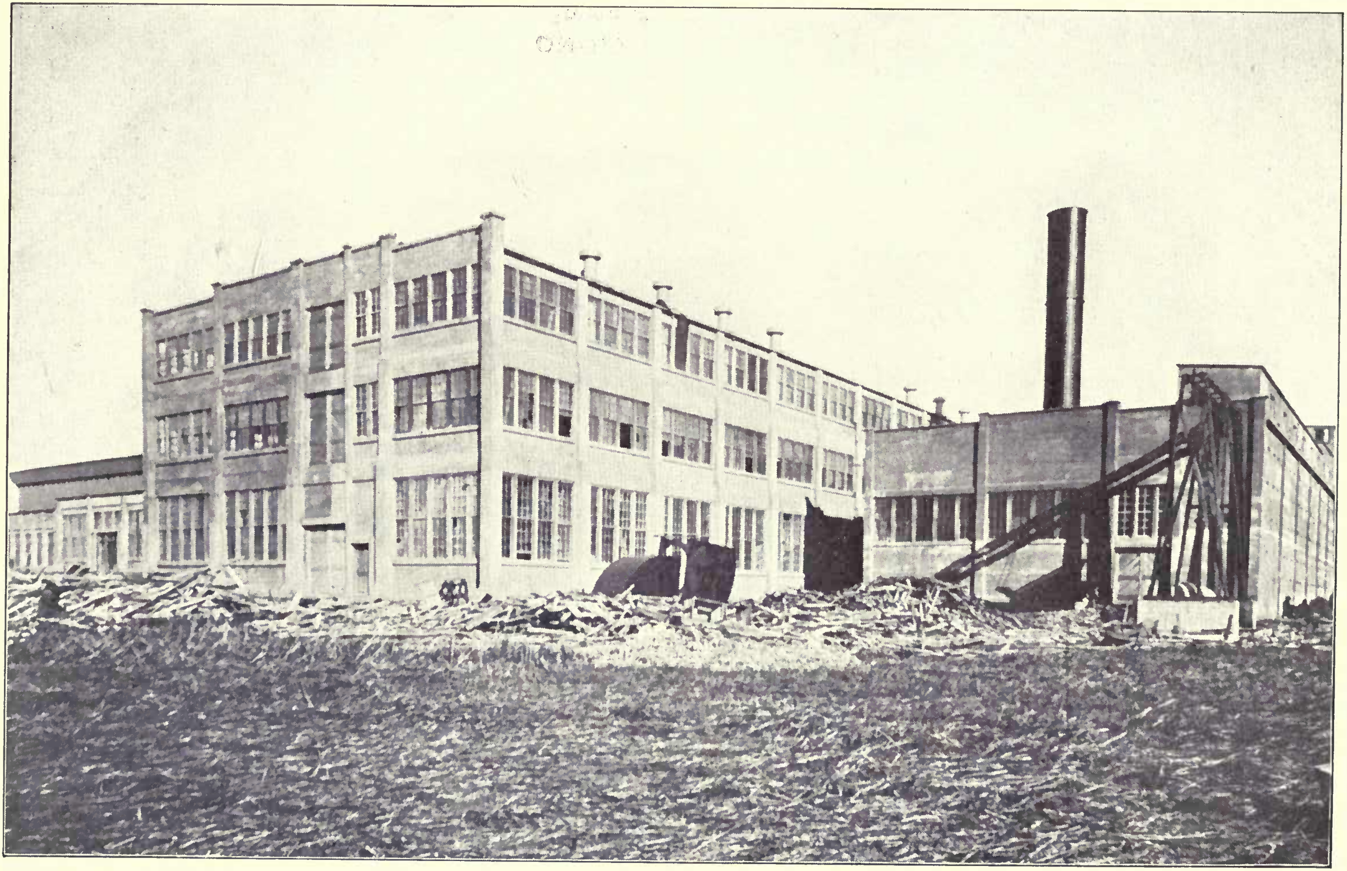


FACTORY AT ALAMEDA, CALIFORNIA.

Probably the first reinforced concrete factory erected. Dimensions 180 ft. by 40 ft. Floor spans 20 ft. and built to sustain a load of 300 pounds per square foot. Ransome & Cushing, Engineers and Builders.

KUEFFEL & ESSER COMPANY FACTORY, HOBOKEN, N. J.
Louis Meyster & Son, Architects; Turner Construction Co., Builders.

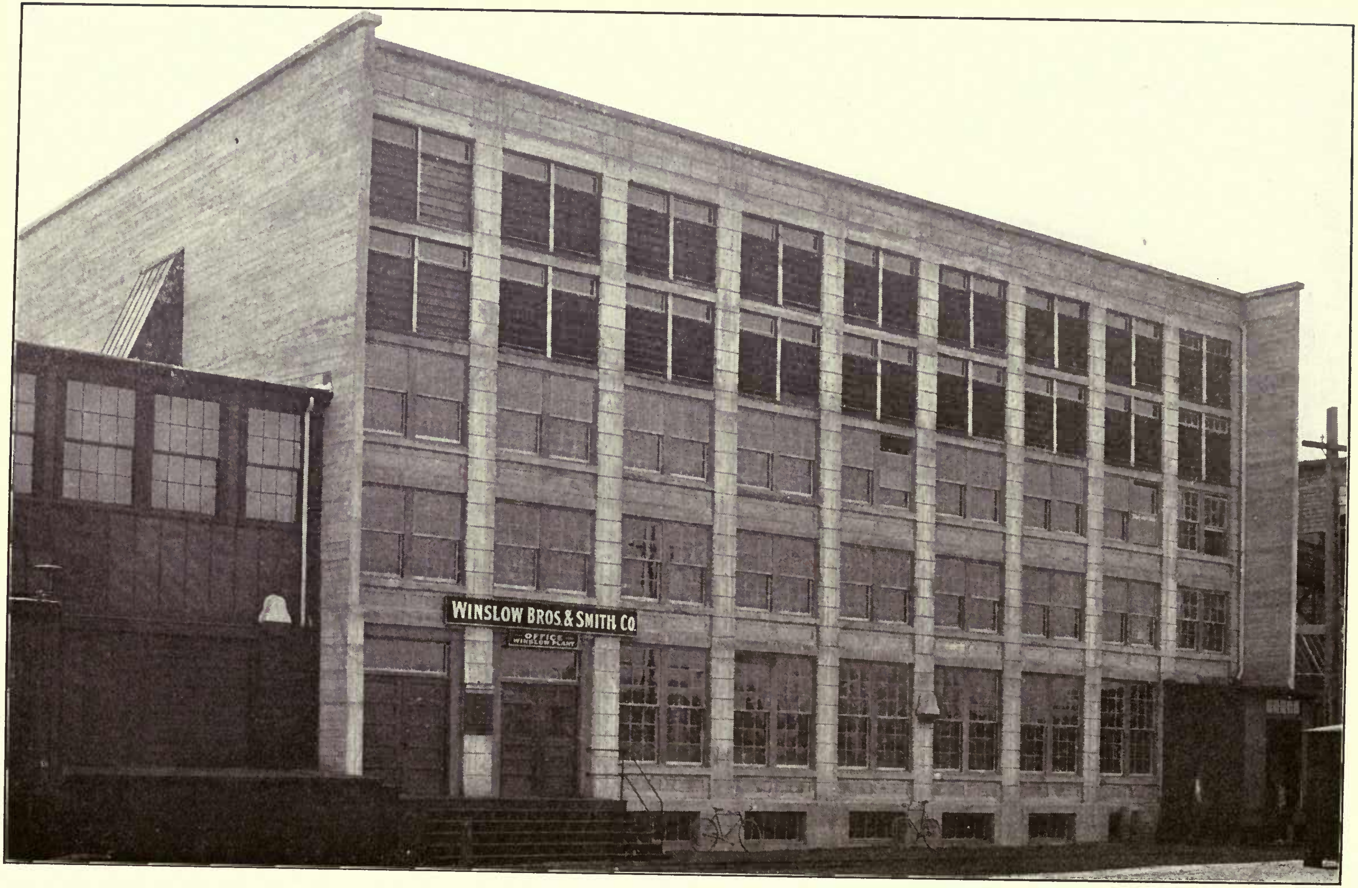
MACHINE SHOP OF TRADERS' PAPER BOARD CO., BOGOTA, N. J.
(*See opposite page.*)



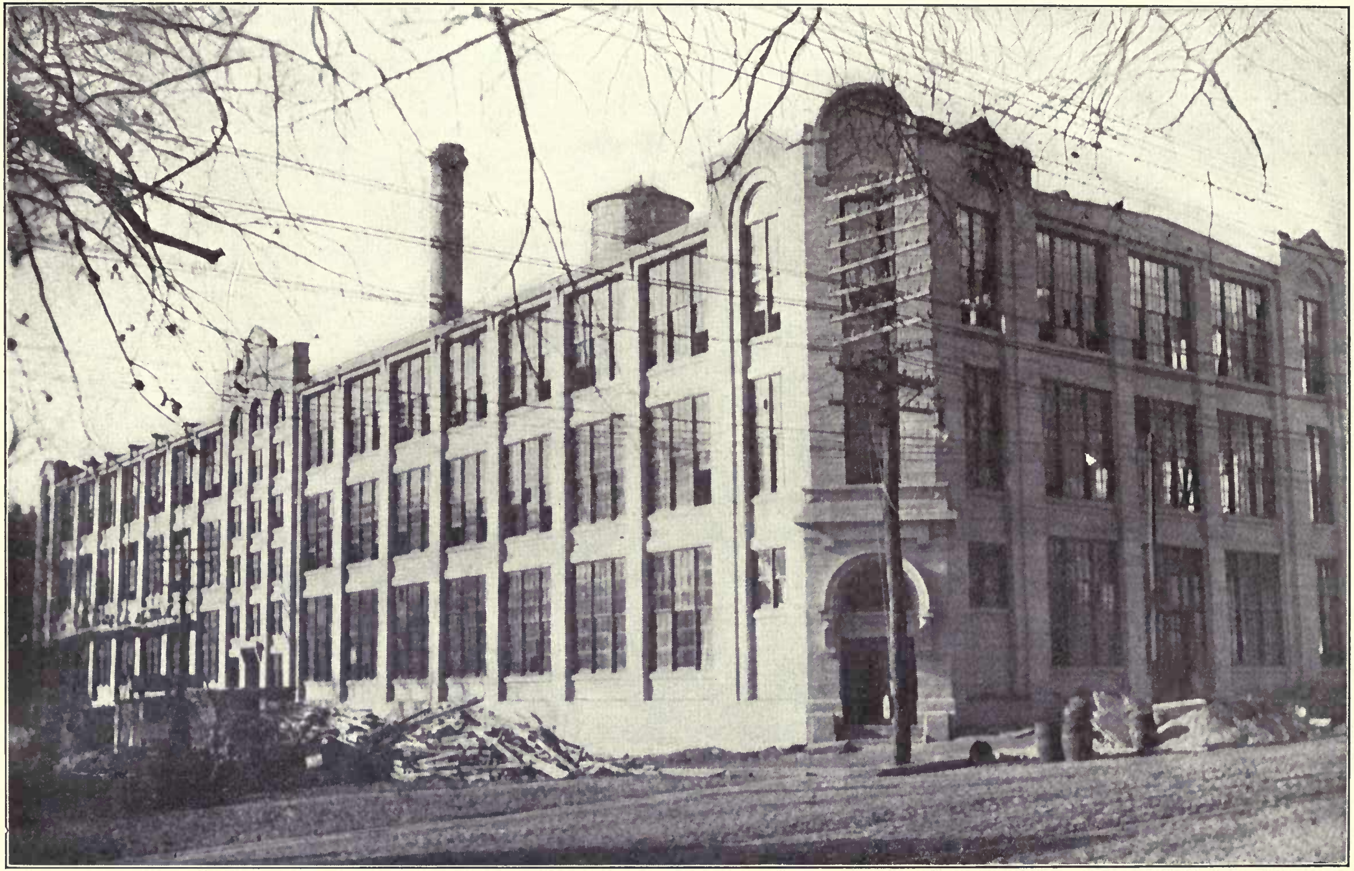
TRADERS' PAPER BOARD CO., BOGOTA, N. J.
Curtin Ruggles Co., Engineers and Builders.

ASSEMBLY ROOM OF THE GEO. N. PIERCE AUTOMOBILE PLANT, BUFFALO, N. Y.
Room 122 ft. by 401 ft., with 61 ft. clear spans. Lockwood, Greene & Co., and Albert Kahn, Architects; Trussed Concrete Steel Co., Builders.

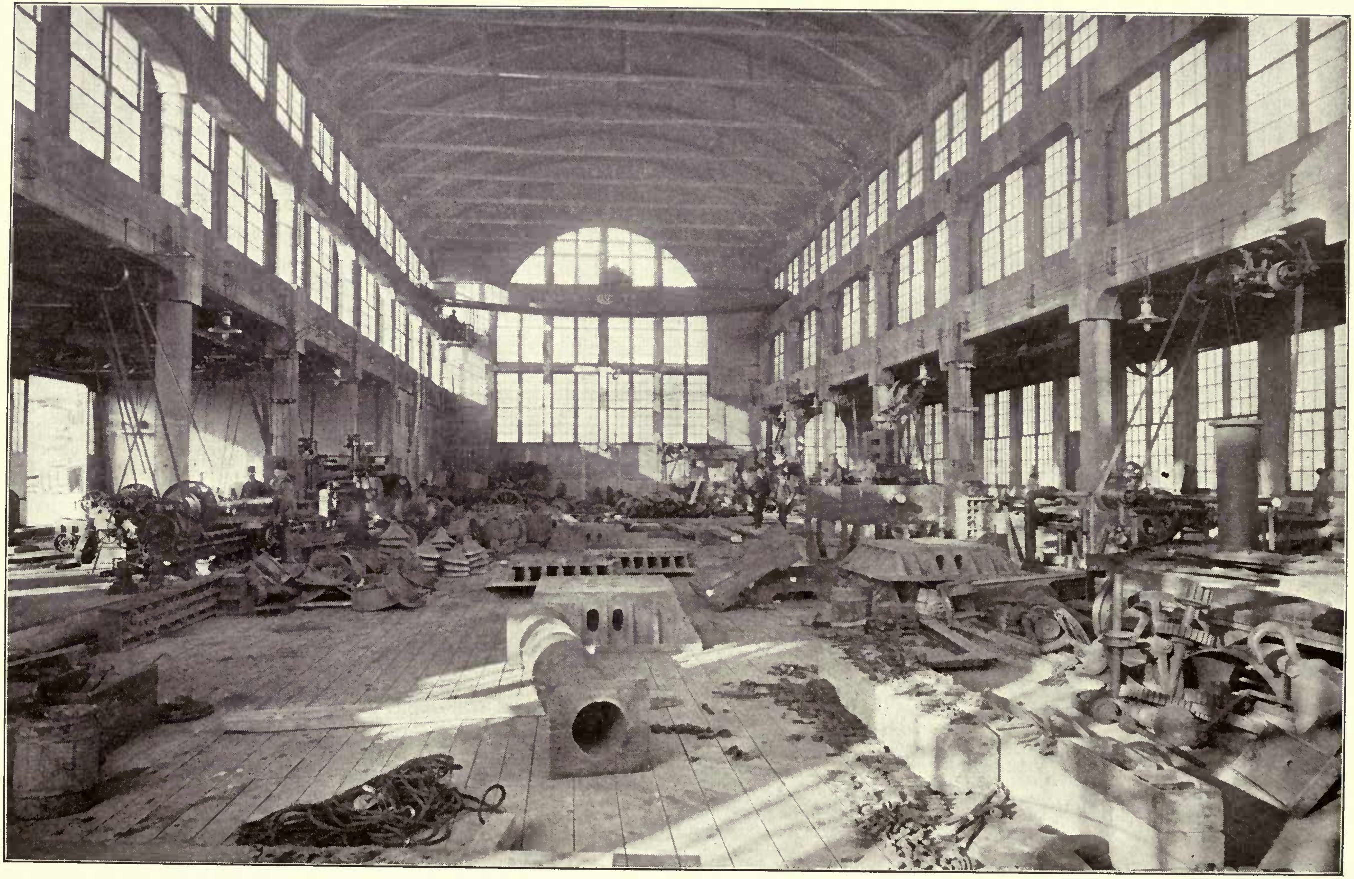
CARPENTRY SHOP, NATIONAL CASH REGISTER CO., DAYTON, OHIO.
The General Fireproofing Co. Designers of reinforcement; Expanded Metal Fireproofing Co., Contractors.



TANNERY OF WINSLOW BROS. & SMITH CO., NORWOOD, MASS.
Dimensions 87 ft. by 87 ft. Aberthaw Construction Co., Engineers.

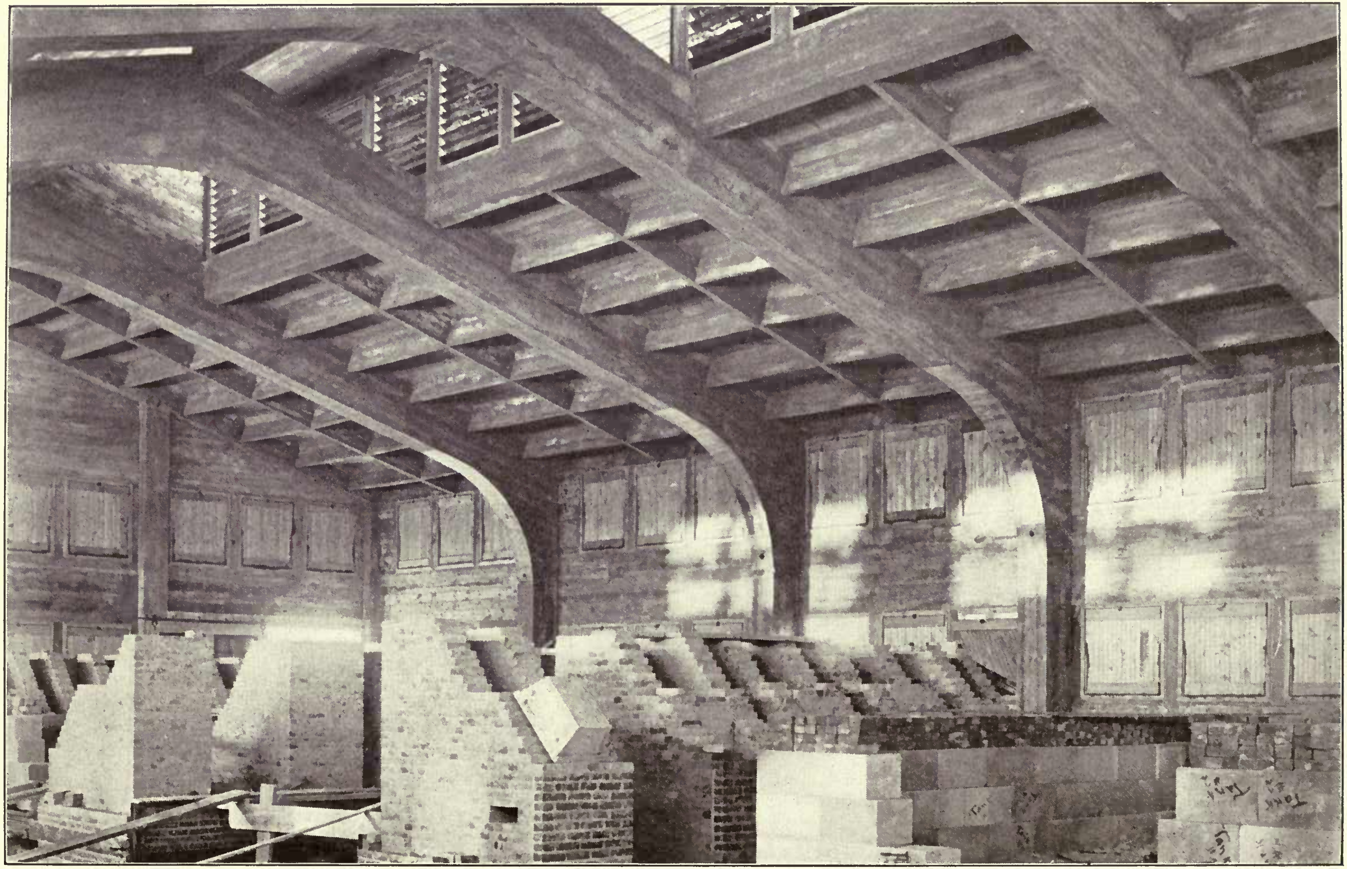


THE LORD BALTIMORE PRESS, BALTIMORE, MD.
Dimensions 280 ft. by 80 ft. Ballinger & Perrot, Engineers; George A. Fuller Co., Builders.

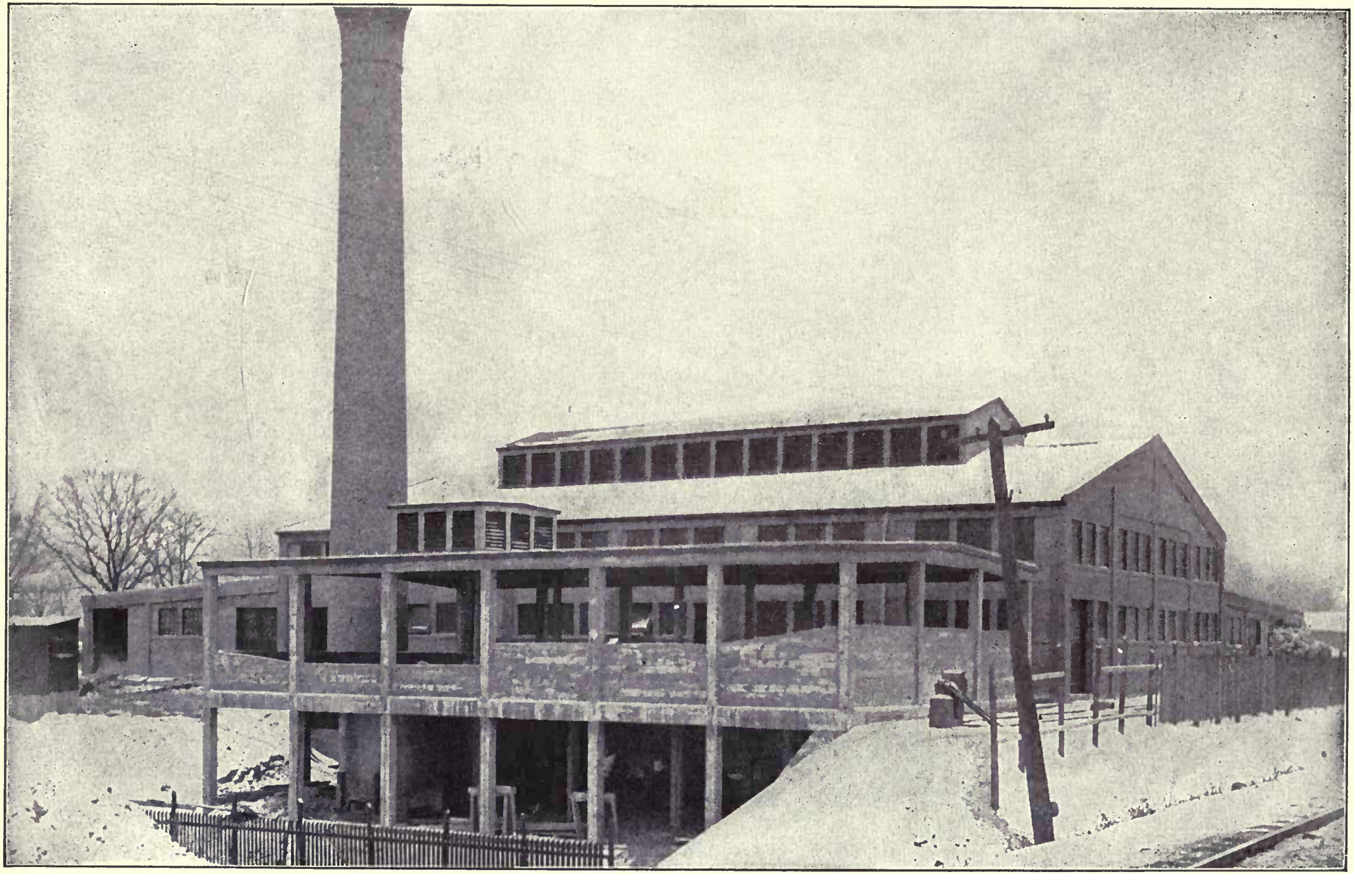


INTERIOR OF MACHINE SHOP, TAYLOR-WILSON MANUFACTURING CO., McKEES ROCKS, PENN.
(*See opposite page.*)

MACHINE SHOP, TAYLOR-WILSON MANUFACTURING CO., McKEES ROCKS, PENN.
Robert A. Cummings, Engineer and Builder.



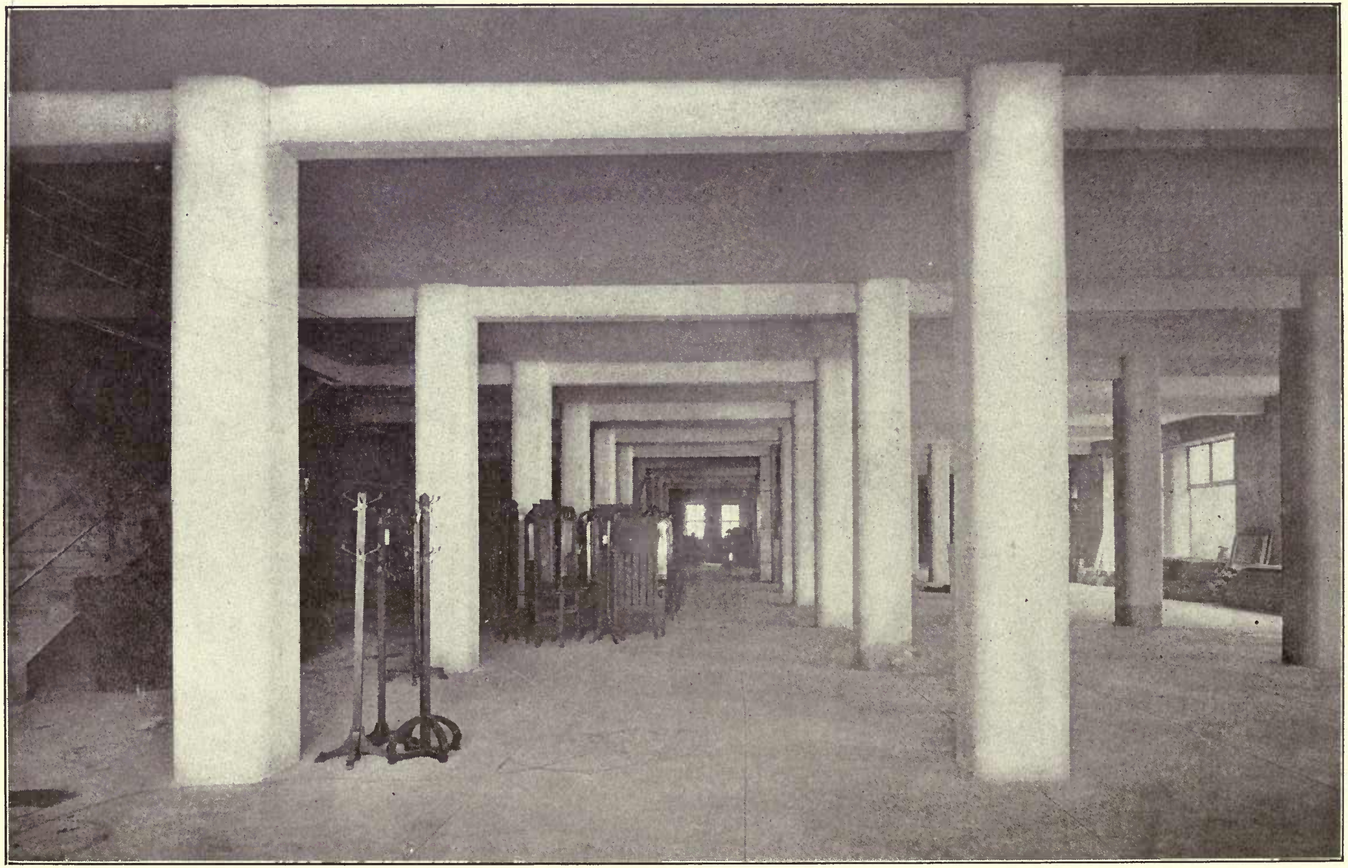
INTERIOR OF NORTHWESTERN OHIO BOTTLE CO.
*(See opposite page.)*



THE NORTHWESTERN OHIO BOTTLE CO.
Harry W. Wachter, Architect; Henry J. Spieker, Builder.

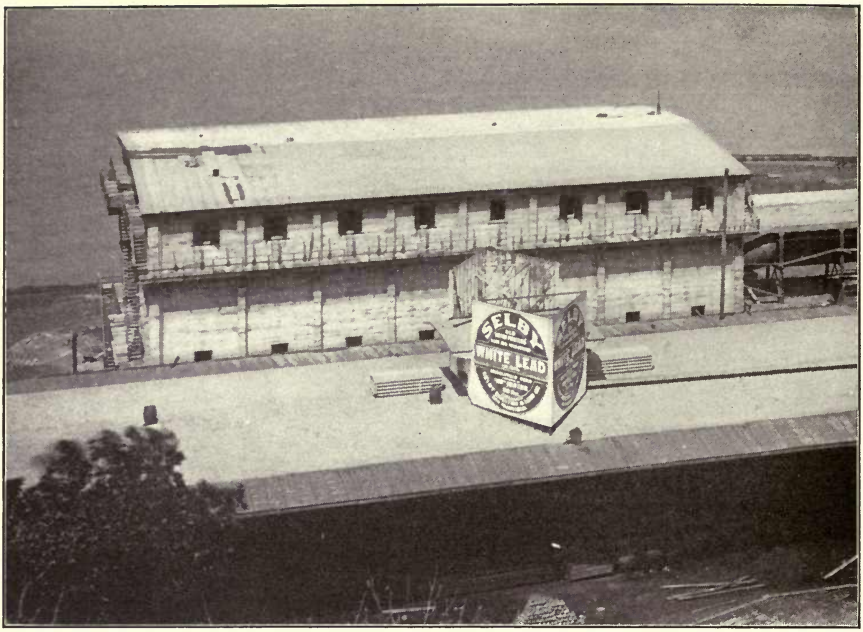
INTERIOR BUSH MODEL FACTORY NO. I, BROOKLYN, N. Y.
(*See opposite page.*)

BUSH MODEL FACTORY NO. 1, BROOKLYN, N. Y.
Dimensions 75 ft. by 600 ft. E. P. Goodrich, Chief Engineer; William Higginson, Architect; Turner Construction Co., Builders; R. F. Tucker, Consulting Engineer.



INTERIOR OF MANUFACTURERS' FURNITURE EXCHANGE BUILDING, CHICAGO, ILL.
(*See opposite page.*)

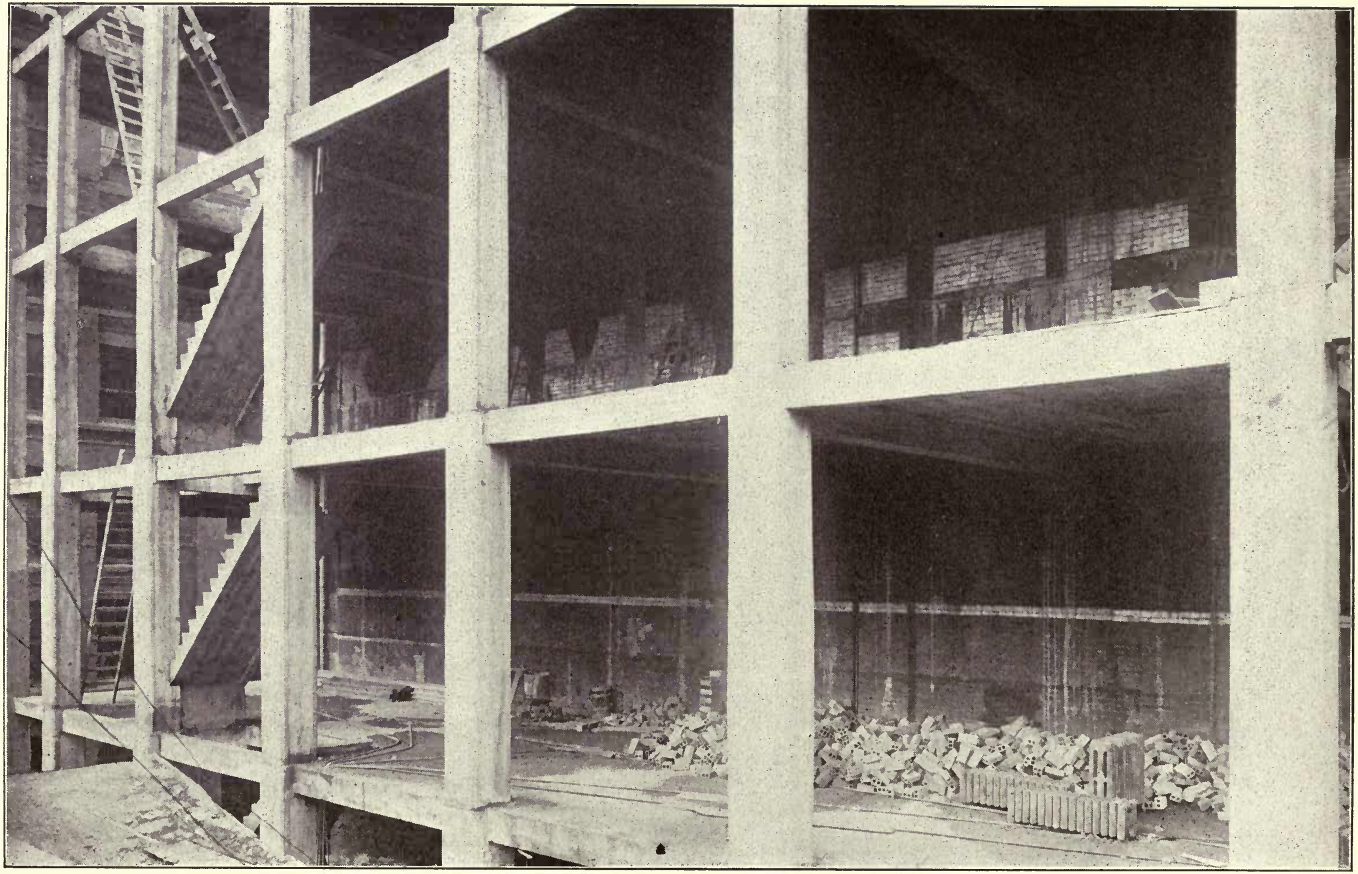
MANUFACTURERS' FURNITURE EXCHANGE BUILDING, CHICAGO, ILL.
Dimensions 70 ft. by 170 ft. Wm. Ernest Walker, Architect; Mortimer & Tapper, Builders; Condron & Sinks, Consulting Engineers.



SELBY LEAD SMELTING PLANT, SELBY, CALIFORNIA.
Lindgren-Hicks Co., Builders; John B. Leonard, Consulting Engineer.

COLGATE SOAP FACTORY, JERSEY CITY, N. J.
Dimensions 85 ft. by 104 ft. William P. Field, Chief Engineer; The Concrete-Steel Co., Builders.

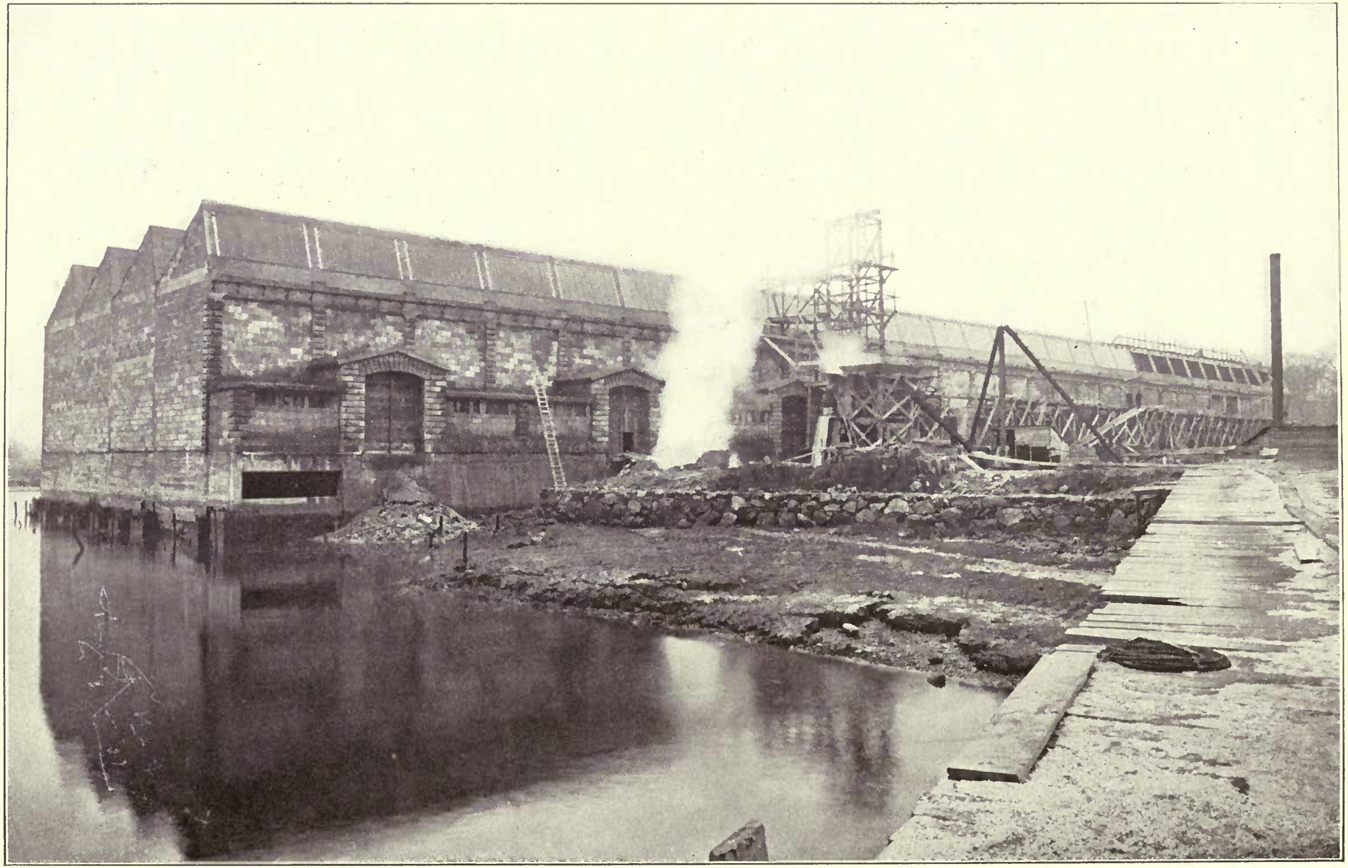
SOAP WAREHOUSE OF KIRKMAN & SON, BROOKLYN, N. Y.
Expanded Metal Engineering Co., Engineers.



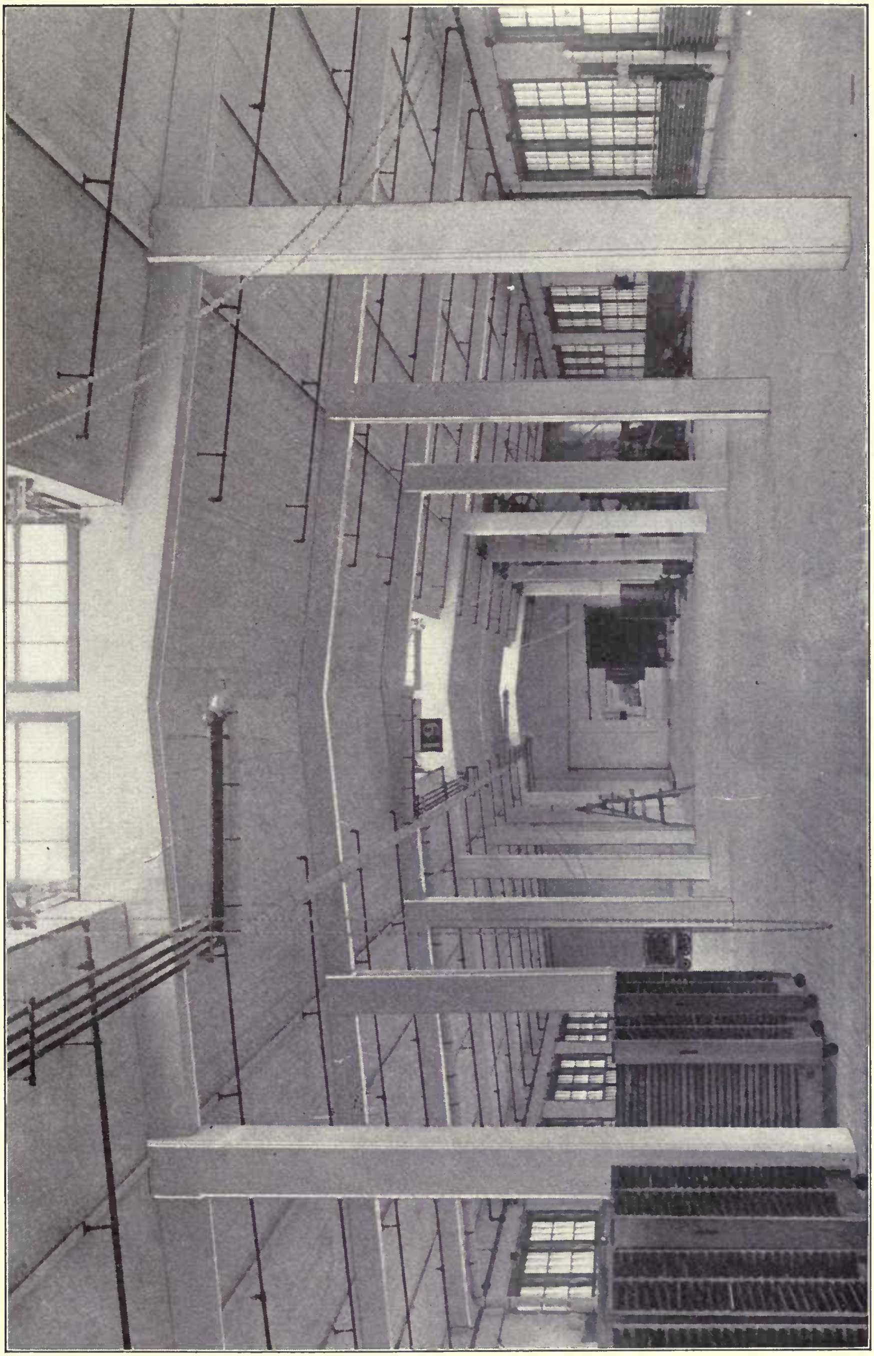
BENNETT BUILDING, PITTSBURGH, PENNA.

Dimensions 20 ft. by 100 ft. James T. Steen, Architect; Nicola Building Co., General Contractors; Columbian Reinforced Concrete Co., Reinforced Concrete Contractors.

ARCHES SUPPORTING DYE HOUSE FLOOR, BOTANY WORSTED MILLS, PASSAIC, N. J.
Length of Building 925 feet. Charles J. Heuser, Architect; John F. Ferguson Co., Builders.

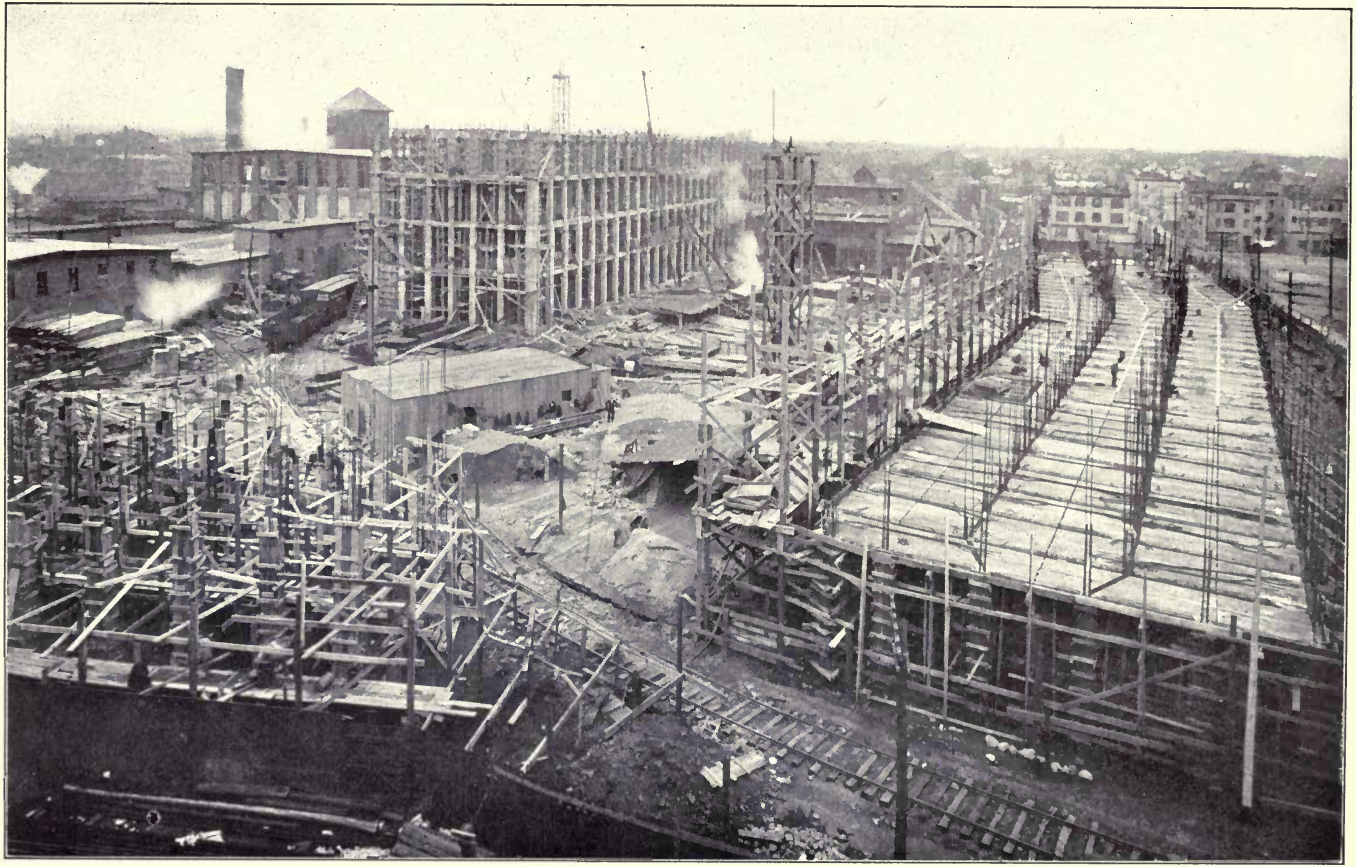


STOLLWERK BROS. CHOCOLATE MFG. CO., STAMFORD, CONN.
Ten Buildings 55,000 Square Feet Area. Ernest Flagg, Architect; Tucker & Vinton, Reinforced Concrete Contractors.



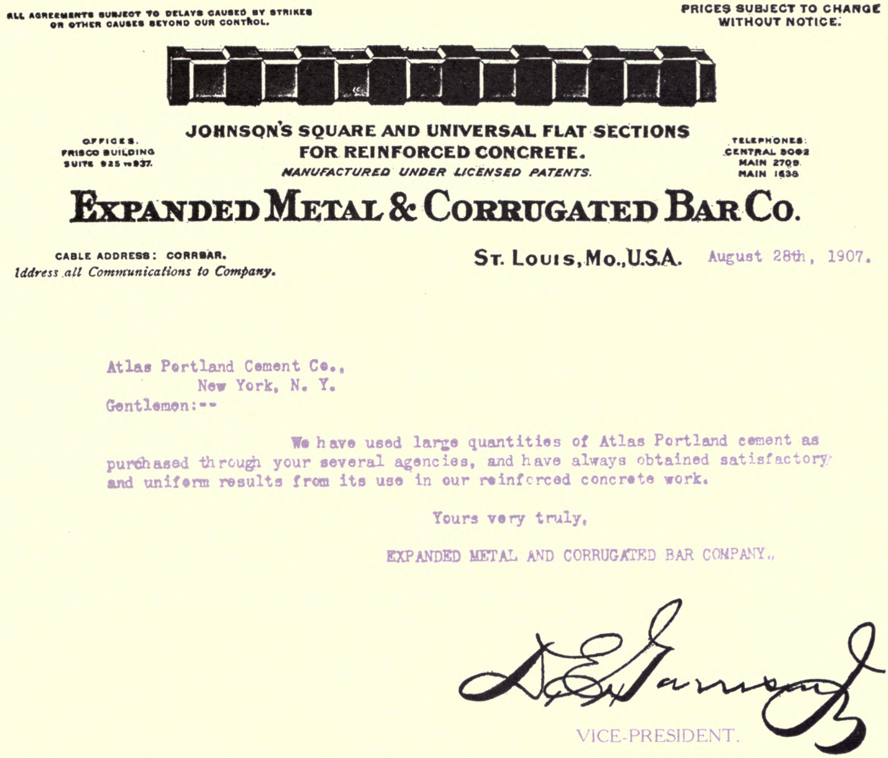
CABINET BUILDING OF CANADIAN SINGER MFG. CO.

MAIN BUILDING MINTERBURN MILLS COMPANY, ROCKVILLE, CONN.
Dimensions 58 ft. by 294 ft. C. R. Makepeace & Co., Engineers; Frank B. Gilbreth, Builder.



FACTORY AND WAREHOUSES OF THE BOSTON WOVEN HOSE AND RUBBER CO., CAMBRIDGE, MASS.
Combined length 817 ft. John O. DeWolf, Architect and Engineer; Benjamin Fox, Builder; Edward A. Tucker, Concrete Engineer; Sanford E. Thompson, Consulting Engineer.

ROBERT GAIR BUILDING, BROOKLYN, N. Y.
Area each floor, 41,700 square feet. Nine stories high and basement. William Higginson, Architect; Turner Construction Co., Contractors.



ALL AGREEMENTS SUBJECT TO DELAYS CAUSED BY STRIKES
OR OTHER CAUSES BEYOND OUR CONTROL.

PRICES SUBJECT TO CHANGE
WITHOUT NOTICE.

OFFICES.
FRISCO BUILDING
SUITE 925 TO 937.

JOHNSON'S SQUARE AND UNIVERSAL FLAT SECTIONS
FOR REINFORCED CONCRETE.
*MANUFACTURED UNDER LICENSED PATENTS.*

TELEPHONES:
CENTRAL 8092
MAIN 2709.
MAIN 1638

**EXPANDED METAL & CORRUGATED BAR CO.**

CABLE ADDRESS: CORRBAR.
*Address all Communications to Company.*

ST. LOUIS, MO., U.S.A. August 28th, 1907.

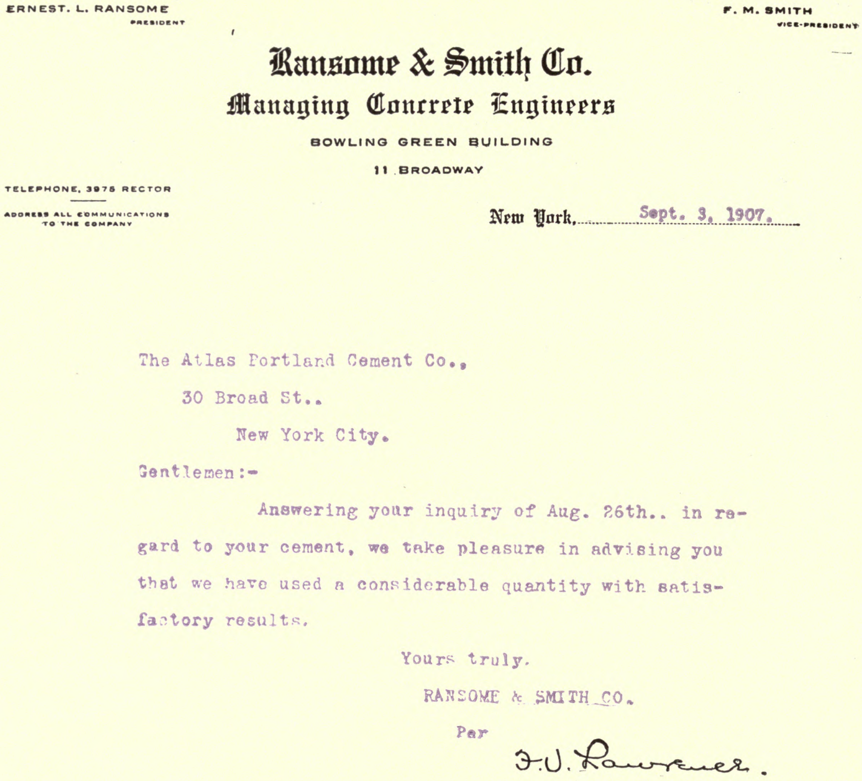
Atlas Portland Cement Co.,
New York, N. Y.
Gentlemen:--

We have used large quantities of Atlas Portland cement as purchased through your several agencies, and have always obtained satisfactory and uniform results from its use in our reinforced concrete work.

Yours very truly,

EXPANDED METAL AND CORRUGATED BAR COMPANY.,

VICE-PRESIDENT.



ERNEST. L. RANSOME
PRESIDENT

F. M. SMITH
VICE-PRESIDENT

**Ransome & Smith Co.**
**Managing Concrete Engineers**
BOWLING GREEN BUILDING
11 BROADWAY

TELEPHONE, 3975 RECTOR

ADDRESS ALL COMMUNICATIONS
TO THE COMPANY

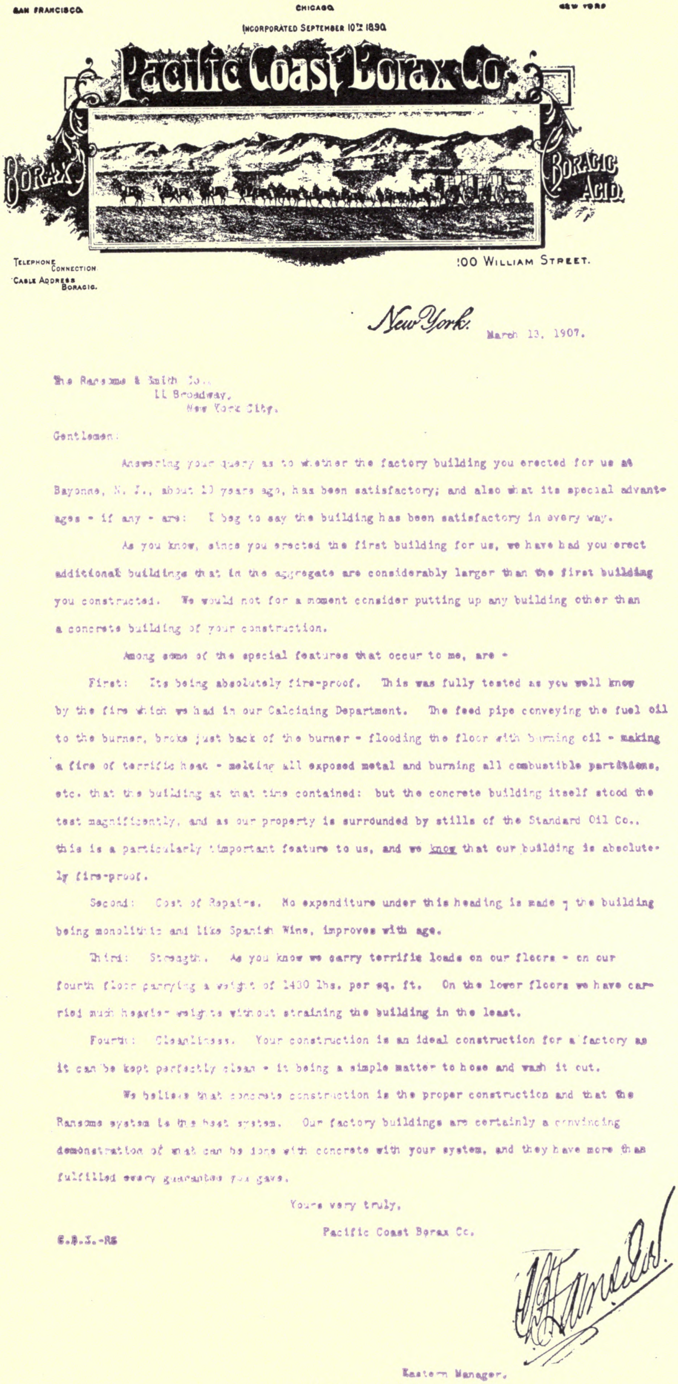
New York, Sept. 3, 1907.

The Atlas Portland Cement Co.,
30 Broad St.,
New York City.

Gentlemen:-

Answering your inquiry of Aug. 26th., in regard to your cement, we take pleasure in advising you that we have used a considerable quantity with satisfactory results.

Yours truly,
RANSOME & SMITH CO.
Per
F.J. Lawrence.



SAN FRANCISCO. CHICAGO. NEW YORK.
INCORPORATED SEPTEMBER 10th 1890.
Pacific Coast Borax Co.
BORAX BORACIC ACID
TELEPHONE CONNECTION
CABLE ADDRESS BORACIC.
100 WILLIAM STREET.

New York. March 13, 1907.

The Ransome & Smith Co.,
11 Broadway,
New York City.

Gentlemen:

Answering your query as to whether the factory building you erected for us at Bayonne, N. J., about 10 years ago, has been satisfactory; and also what its special advantages - if any - are: I beg to say the building has been satisfactory in every way.

As you know, since you erected the first building for us, we have had you erect additional buildings that in the aggregate are considerably larger than the first building you constructed. We would not for a moment consider putting up any building other than a concrete building of your construction.

Among some of the special features that occur to me, are -

First: Its being absolutely fire-proof. This was fully tested as you well know by the fire which we had in our Calcining Department. The feed pipe conveying the fuel oil to the burner, broke just back of the burner - flooding the floor with burning oil - making a fire of terrific heat - melting all exposed metal and burning all combustible partitions, etc. that the building at that time contained: but the concrete building itself stood the test magnificently, and as our property is surrounded by stills of the Standard Oil Co., this is a particularly important feature to us, and we <u>know</u> that our building is absolutely fire-proof.

Second: Cost of Repairs. No expenditure under this heading is made ; the building being monolithic and like Spanish Wine, improves with age.

Third: Strength. As you know we carry terrific loads on our floors - on our fourth floor carrying a weight of 1430 lbs. per sq. ft. On the lower floors we have carried much heavier weights without straining the building in the least.

Fourth: Cleanliness. Your construction is an ideal construction for a factory as it can be kept perfectly clean - it being a simple matter to hose and wash it out.

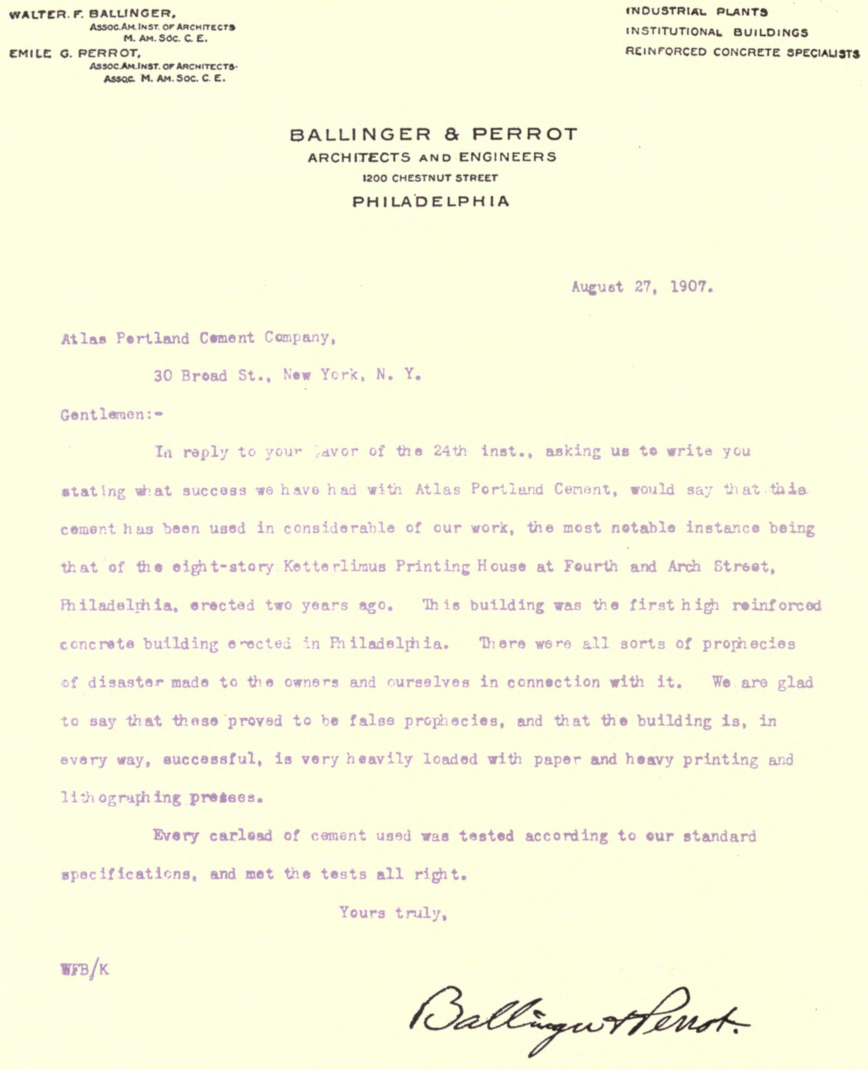
We believe that concrete construction is the proper construction and that the Ransome system is the best system. Our factory buildings are certainly a convincing demonstration of what can be done with concrete with your system, and they have more than fulfilled every guarantee you gave.

Yours very truly,

Pacific Coast Borax Co.

C.B.Z.-RS

Eastern Manager.



**WALTER F. BALLINGER,**
ASSOC. AM. INST. OF ARCHITECTS
M. AM. SOC. C. E.
**EMILE G. PERROT,**
ASSOC. AM. INST. OF ARCHITECTS
ASSOC. M. AM. SOC. C. E.

INDUSTRIAL PLANTS
INSTITUTIONAL BUILDINGS
REINFORCED CONCRETE SPECIALISTS

BALLINGER & PERROT
ARCHITECTS AND ENGINEERS
1200 CHESTNUT STREET
PHILADELPHIA

August 27, 1907.

Atlas Portland Cement Company,

30 Broad St., New York, N. Y.

Gentlemen:-

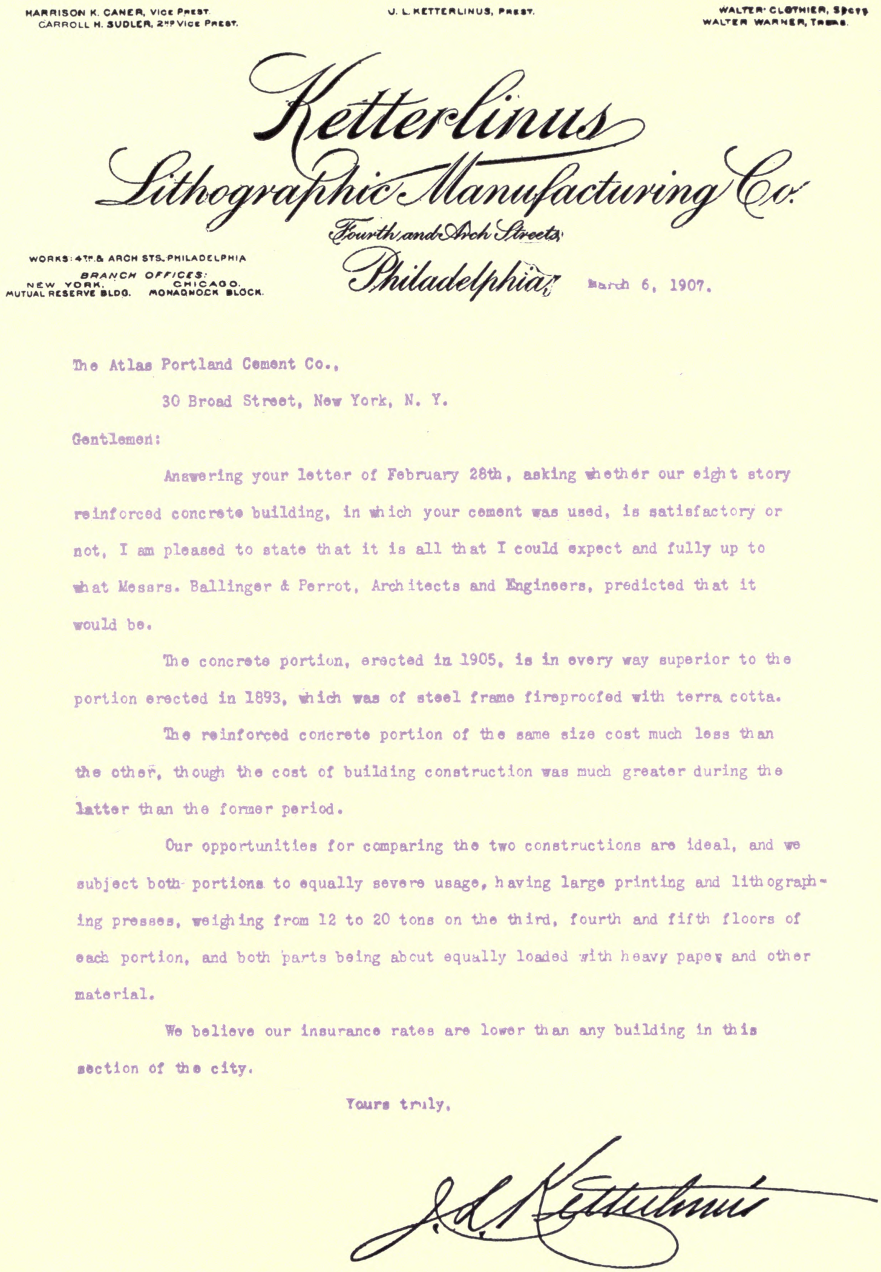
In reply to your favor of the 24th inst., asking us to write you stating what success we have had with Atlas Portland Cement, would say that this cement has been used in considerable of our work, the most notable instance being that of the eight-story Ketterlimus Printing House at Fourth and Arch Street, Philadelphia, erected two years ago. This building was the first high reinforced concrete building erected in Philadelphia. There were all sorts of prophecies of disaster made to the owners and ourselves in connection with it. We are glad to say that these proved to be false prophecies, and that the building is, in every way, successful, is very heavily loaded with paper and heavy printing and lithographing presses.

Every carload of cement used was tested according to our standard specifications, and met the tests all right.

Yours truly,

WFB/K

Ballinger & Perrot.



HARRISON K. CANER, VICE PREST.
CARROLL H. SUDLER, 2ND VICE PREST.
J. L. KETTERLINUS, PREST.
WALTER CLOTHIER, SEC'Y
WALTER WARNER, TREAS.

Ketterlinus
Lithographic Manufacturing Co.
Fourth and Arch Streets,
Philadelphia

WORKS: 4TH & ARCH STS. PHILADELPHIA
BRANCH OFFICES:
NEW YORK, MUTUAL RESERVE BLDG.
CHICAGO, MONADNOCK BLOCK.

March 6, 1907.

The Atlas Portland Cement Co.,
30 Broad Street, New York, N. Y.

Gentlemen:

Answering your letter of February 28th, asking whether our eight story reinforced concrete building, in which your cement was used, is satisfactory or not, I am pleased to state that it is all that I could expect and fully up to what Messrs. Ballinger & Perrot, Architects and Engineers, predicted that it would be.

The concrete portion, erected in 1905, is in every way superior to the portion erected in 1893, which was of steel frame fireproofed with terra cotta.

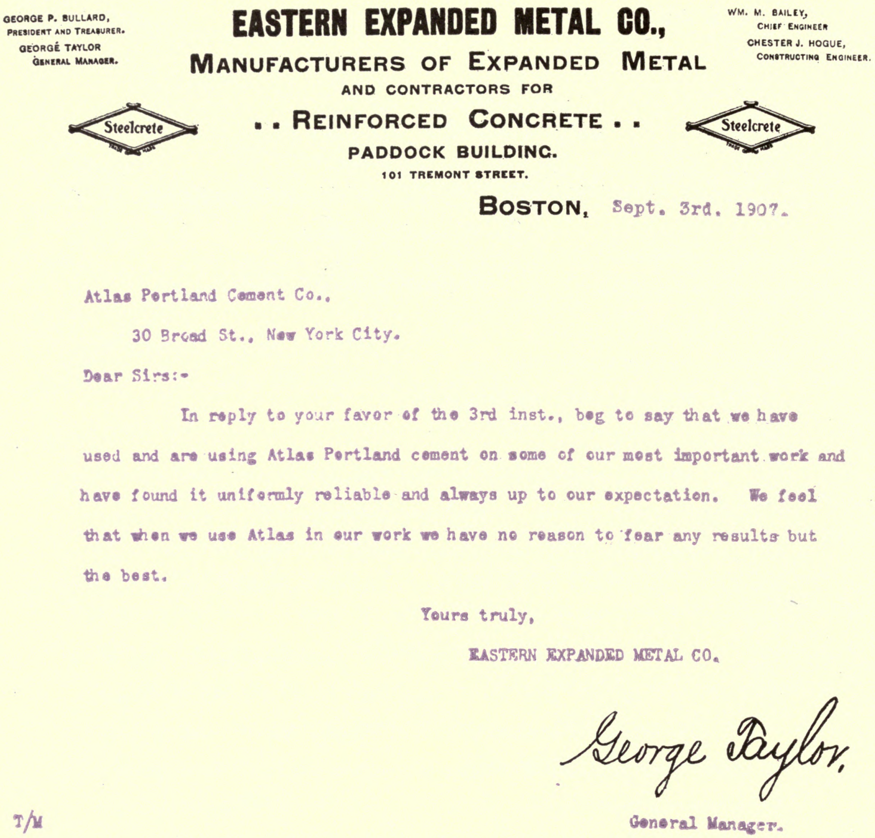
The reinforced concrete portion of the same size cost much less than the other, though the cost of building construction was much greater during the latter than the former period.

Our opportunities for comparing the two constructions are ideal, and we subject both portions to equally severe usage, having large printing and lithographing presses, weighing from 12 to 20 tons on the third, fourth and fifth floors of each portion, and both parts being about equally loaded with heavy paper and other material.

We believe our insurance rates are lower than any building in this section of the city.

Yours truly,

J. L. Ketterlinus



GEORGE P. BULLARD,
PRESIDENT AND TREASURER.
GEORGE TAYLOR
GENERAL MANAGER.

**EASTERN EXPANDED METAL CO.,**
**MANUFACTURERS OF EXPANDED METAL**
AND CONTRACTORS FOR
. . REINFORCED CONCRETE . .
PADDOCK BUILDING.
101 TREMONT STREET.

Steelcrete

WM. M. BAILEY,
CHIEF ENGINEER
CHESTER J. HOGUE,
CONSTRUCTING ENGINEER.

BOSTON, Sept. 3rd. 1907.

Atlas Portland Cement Co.,
30 Broad St., New York City.

Dear Sirs:-

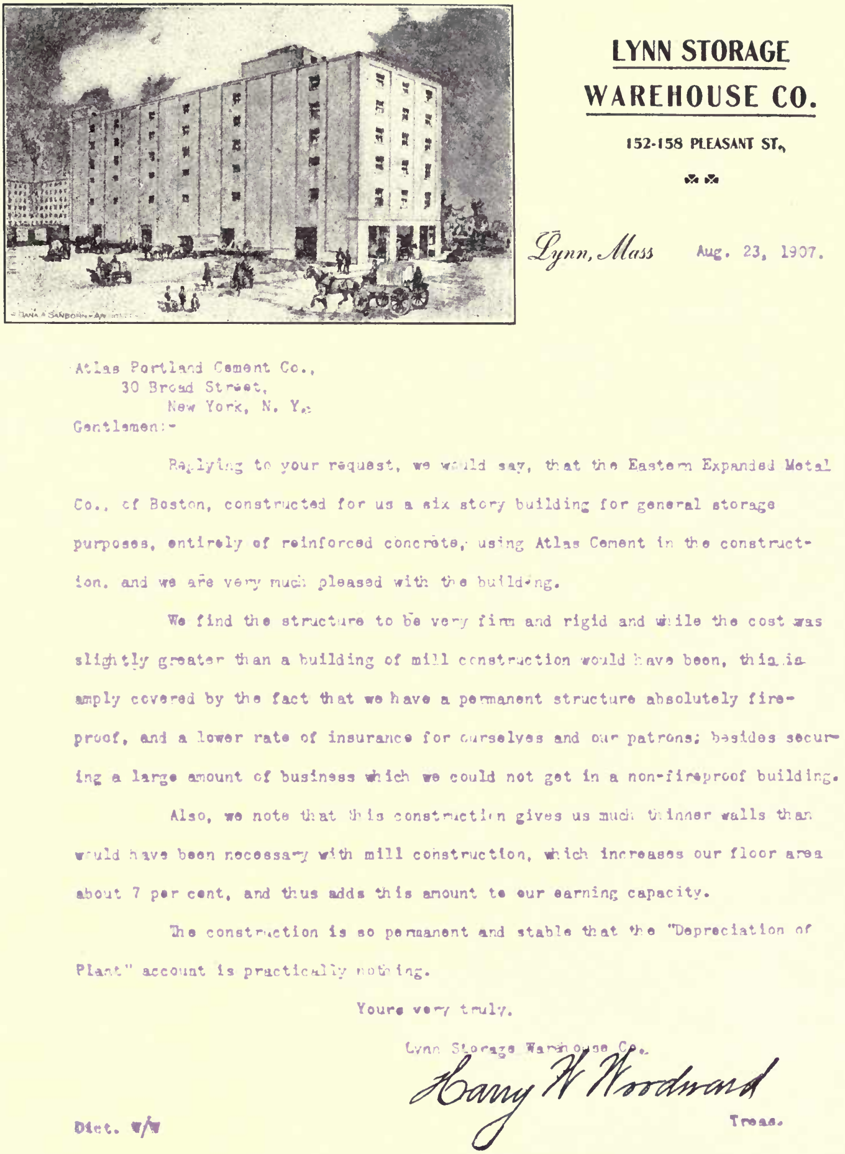
In reply to your favor of the 3rd inst., beg to say that we have used and are using Atlas Portland cement on some of our most important work and have found it uniformly reliable and always up to our expectation. We feel that when we use Atlas in our work we have no reason to fear any results but the best.

Yours truly,
EASTERN EXPANDED METAL CO.

George Taylor

T/M

General Manager.



LYNN STORAGE
WAREHOUSE CO.

152-158 PLEASANT ST.,

*Lynn, Mass* Aug. 23, 1907.

Atlas Portland Cement Co.,
30 Broad Street,
New York, N. Y.

Gentlemen:-

Replying to your request, we would say, that the Eastern Expanded Metal Co., of Boston, constructed for us a six story building for general storage purposes, entirely of reinforced concrete, using Atlas Cement in the construction, and we are very much pleased with the building.

We find the structure to be very firm and rigid and while the cost was slightly greater than a building of mill construction would have been, this is amply covered by the fact that we have a permanent structure absolutely fireproof, and a lower rate of insurance for ourselves and our patrons; besides securing a large amount of business which we could not get in a non-fireproof building.

Also, we note that this construction gives us much thinner walls than would have been necessary with mill construction, which increases our floor area about 7 per cent, and thus adds this amount to our earning capacity.

The construction is so permanent and stable that the "Depreciation of Plant" account is practically nothing.

Yours very truly.

Lynn Storage Warehouse Co.
Harry W Woodward
Treas.

Dict. W/W

W. P. ANDERSON, PREST. ROBT ANDERSON, V. PREST
TYLOR FIELD, SECY-TREAS
THE FERRO CONCRETE CONSTRUCTION CO.
RICHMOND AND HARRIET STREETS.
CINCINNATI

August 26, 1907.

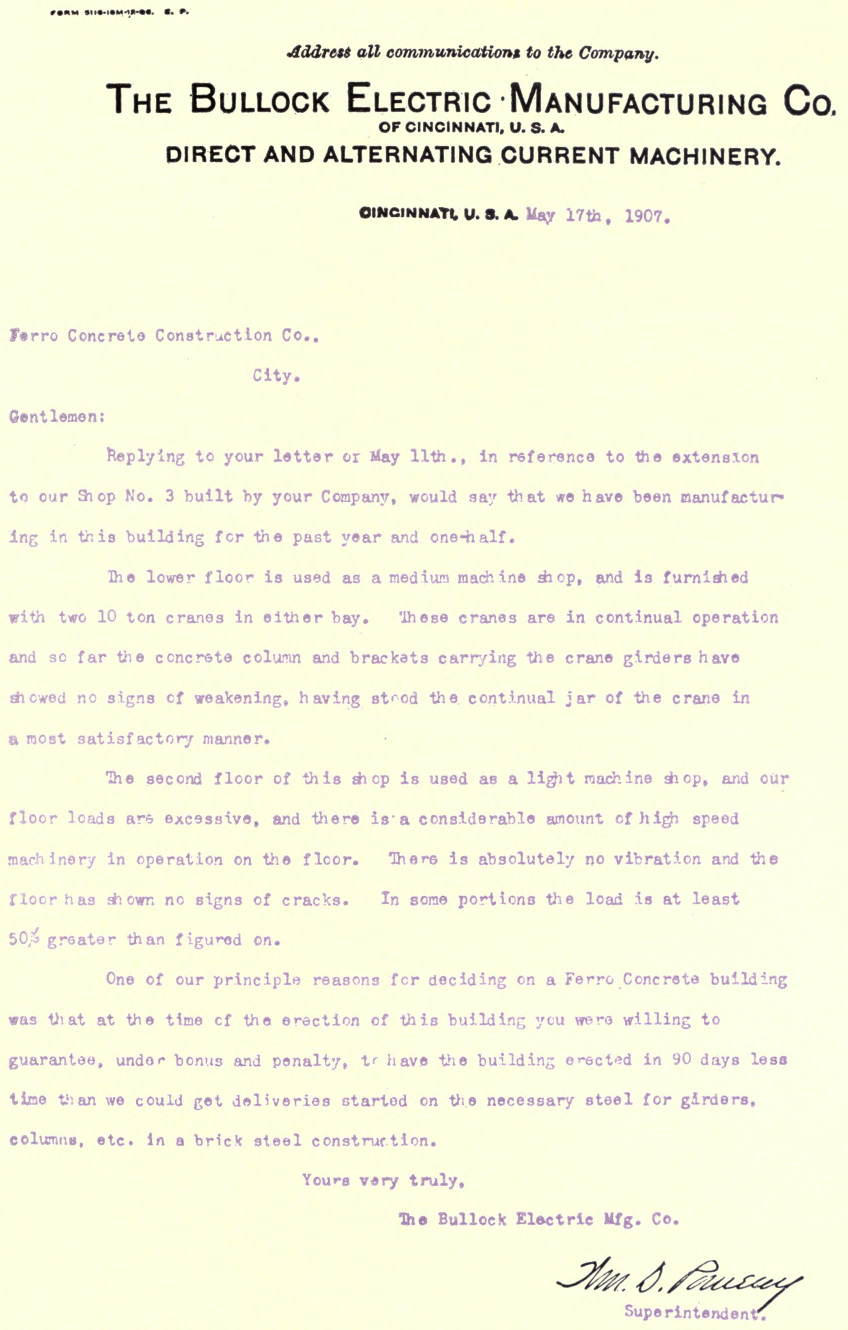
The Moores-Coney Supply Co.,
Cincinnati, Ohio.

Gentlemen:-

We have been using Atlas Portland Cement, on and off, for the last five years. During this time we have tested every car and we have never rejected a car; the cement has been entirely satisfactory in every respect.

Yours very truly,
THE FERRO CONCRETE CONSTRUCTION CO.
Tylor Field
Secy. & Treas.

TF/CB



FORM 3116-10M-12-06. S. P.

*Address all communications to the Company.*

**THE BULLOCK ELECTRIC MANUFACTURING CO.**
**OF CINCINNATI, U. S. A.**
**DIRECT AND ALTERNATING CURRENT MACHINERY.**

CINCINNATI, U. S. A. May 17th, 1907.

Ferro Concrete Construction Co.,
City.

Gentlemen:

Replying to your letter or May 11th., in reference to the extension to our Shop No. 3 built by your Company, would say that we have been manufacturing in this building for the past year and one-half.

The lower floor is used as a medium machine shop, and is furnished with two 10 ton cranes in either bay. These cranes are in continual operation and so far the concrete column and brackets carrying the crane girders have showed no signs of weakening, having stood the continual jar of the crane in a most satisfactory manner.

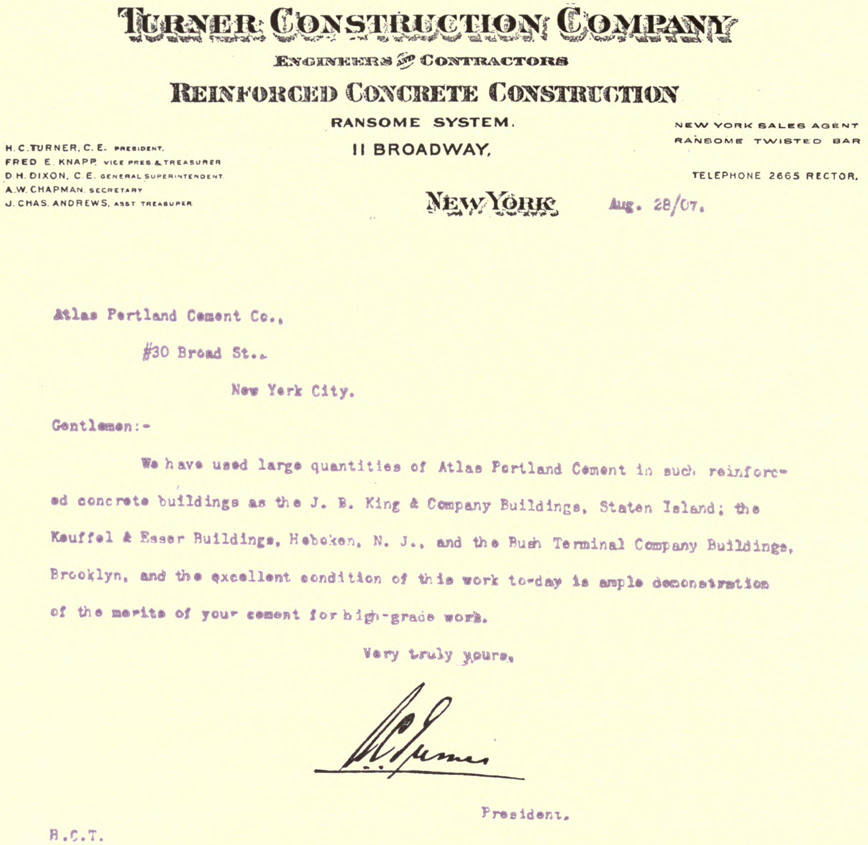
The second floor of this shop is used as a light machine shop, and our floor loads are excessive, and there is a considerable amount of high speed machinery in operation on the floor. There is absolutely no vibration and the floor has shown no signs of cracks. In some portions the load is at least 50% greater than figured on.

One of our principle reasons for deciding on a Ferro Concrete building was that at the time of the erection of this building you were willing to guarantee, under bonus and penalty, to have the building erected in 90 days less time than we could get deliveries started on the necessary steel for girders, columns, etc. in a brick steel construction.

Yours very truly,

The Bullock Electric Mfg. Co.

Wm. S. Pausey
Superintendent.



**TURNER CONSTRUCTION COMPANY**
ENGINEERS & CONTRACTORS
**REINFORCED CONCRETE CONSTRUCTION**
RANSOME SYSTEM.
11 BROADWAY,
NEW YORK SALES AGENT
RANSOME TWISTED BAR
H. C. TURNER, C. E. PRESIDENT.
FRED E. KNAPP, VICE PRES. & TREASURER
D. H. DIXON, C. E. GENERAL SUPERINTENDENT
A. W. CHAPMAN, SECRETARY
J. CHAS. ANDREWS, ASST TREASURER
TELEPHONE 2665 RECTOR.

NEW YORK Aug. 28/07.

Atlas Portland Cement Co.,
#30 Broad St.,
New York City.

Gentlemen:-

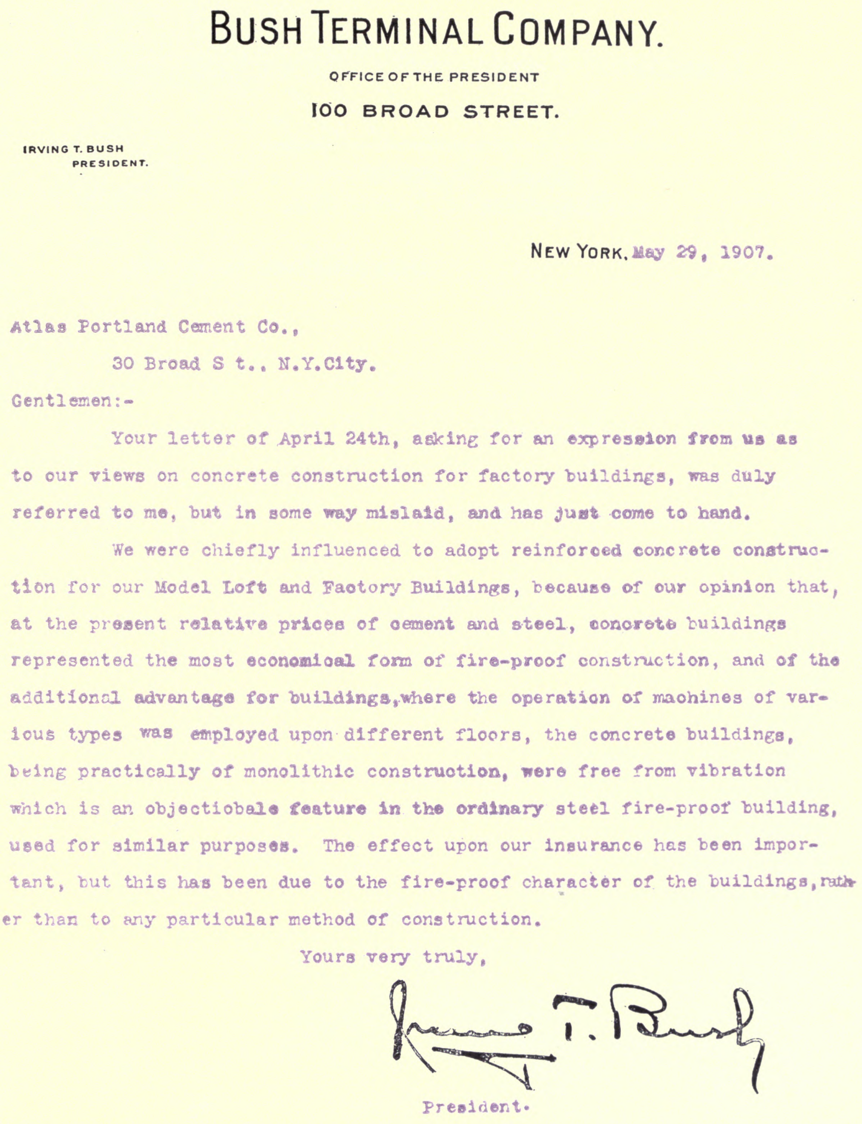
We have used large quantities of Atlas Portland Cement in such reinforced concrete buildings as the J. B. King & Company Buildings, Staten Island; the Keuffel & Esser Buildings, Hoboken, N. J., and the Bush Terminal Company Buildings, Brooklyn, and the excellent condition of this work to-day is ample demonstration of the merits of your cement for high-grade work.

Very truly yours,

H C Turner

President.

H.C.T.



BUSH TERMINAL COMPANY.

OFFICE OF THE PRESIDENT

100 BROAD STREET.

IRVING T. BUSH
PRESIDENT.

NEW YORK, May 29, 1907.

Atlas Portland Cement Co.,
30 Broad St., N.Y.City.

Gentlemen:-

Your letter of April 24th, asking for an expression from us as to our views on concrete construction for factory buildings, was duly referred to me, but in some way mislaid, and has just come to hand.

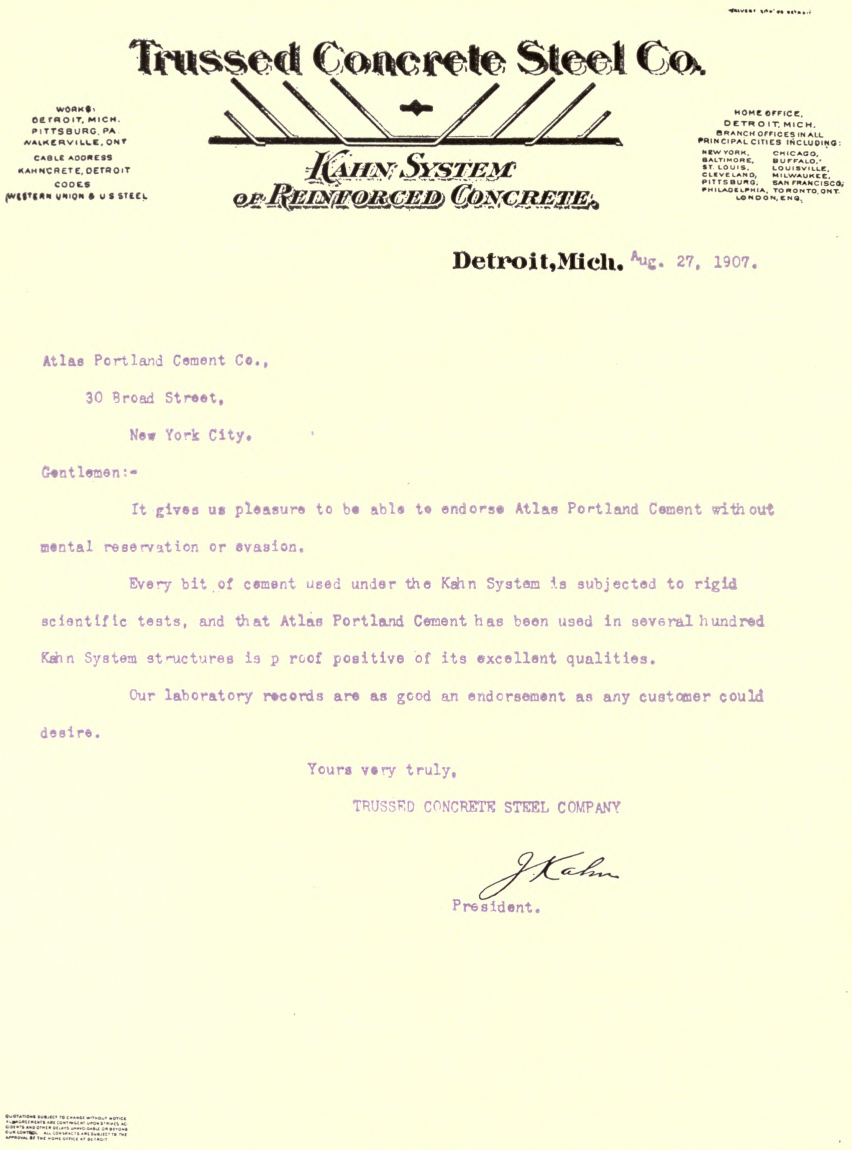
We were chiefly influenced to adopt reinforced concrete construction for our Model Loft and Factory Buildings, because of our opinion that, at the present relative prices of cement and steel, concrete buildings represented the most economical form of fire-proof construction, and of the additional advantage for buildings, where the operation of machines of various types was employed upon different floors, the concrete buildings, being practically of monolithic construction, were free from vibration which is an objectiobale feature in the ordinary steel fire-proof building, used for similar purposes. The effect upon our insurance has been important, but this has been due to the fire-proof character of the buildings, rather than to any particular method of construction.

Yours very truly,

Irving T. Bush

President.

ITB



**Trussed Concrete Steel Co.**

KAHN SYSTEM OF REINFORCED CONCRETE.

WORKS:
DETROIT, MICH.
PITTSBURG, PA.
WALKERVILLE, ONT.
CABLE ADDRESS
KAHNCRETE, DETROIT
CODES
WESTERN UNION & U S STEEL

HOME OFFICE,
DETROIT, MICH.
BRANCH OFFICES IN ALL
PRINCIPAL CITIES INCLUDING:
NEW YORK, CHICAGO,
BALTIMORE, BUFFALO,
ST. LOUIS, LOUISVILLE,
CLEVELAND, MILWAUKEE,
PITTSBURG, SAN FRANCISCO,
PHILADELPHIA, TORONTO, ONT.
LONDON, ENG.

Detroit, Mich. Aug. 27, 1907.

Atlas Portland Cement Co.,
30 Broad Street,
New York City.

Gentlemen:-

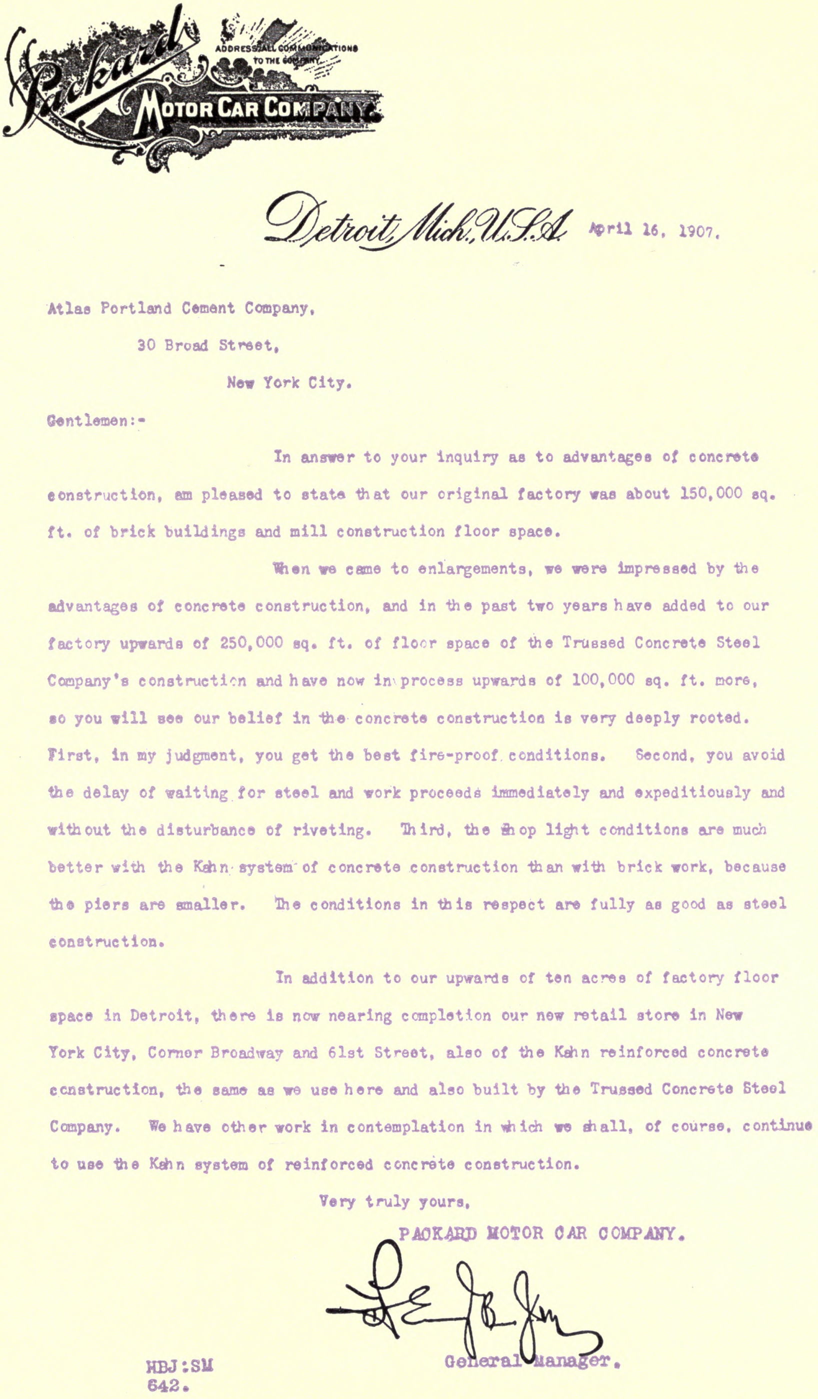
It gives us pleasure to be able to endorse Atlas Portland Cement without mental reservation or evasion.

Every bit of cement used under the Kahn System is subjected to rigid scientific tests, and that Atlas Portland Cement has been used in several hundred Kahn System structures is proof positive of its excellent qualities.

Our laboratory records are as good an endorsement as any customer could desire.

Yours very truly,
TRUSSED CONCRETE STEEL COMPANY

J. Kahn
President.



Packard
ADDRESS ALL COMMUNICATIONS TO THE COMPANY.
MOTOR CAR COMPANY.

Detroit, Mich., U.S.A. April 16, 1907.

Atlas Portland Cement Company,
30 Broad Street,
New York City.

Gentlemen:-

In answer to your inquiry as to advantages of concrete construction, am pleased to state that our original factory was about 150,000 sq. ft. of brick buildings and mill construction floor space.

When we came to enlargements, we were impressed by the advantages of concrete construction, and in the past two years have added to our factory upwards of 250,000 sq. ft. of floor space of the Trussed Concrete Steel Company's construction and have now in process upwards of 100,000 sq. ft. more, so you will see our belief in the concrete construction is very deeply rooted. First, in my judgment, you get the best fire-proof conditions. Second, you avoid the delay of waiting for steel and work proceeds immediately and expeditiously and without the disturbance of riveting. Third, the shop light conditions are much better with the Kahn system of concrete construction than with brick work, because the piers are smaller. The conditions in this respect are fully as good as steel construction.

In addition to our upwards of ten acres of factory floor space in Detroit, there is now nearing completion our new retail store in New York City, Corner Broadway and 61st Street, also of the Kahn reinforced concrete construction, the same as we use here and also built by the Trussed Concrete Steel Company. We have other work in contemplation in which we shall, of course, continue to use the Kahn system of reinforced concrete construction.

Very truly yours,
PACKARD MOTOR CAR COMPANY.

General Manager.

HBJ:SM
642.

ADDRESS ALL COMMUNICATIONS TO THE COMPANY

VILLIAM MUESER,
M. AM. SOC. C. E.

EDWIN THACHER,
M. AM. SOC. C. E.

CONCRETE-STEEL ENGINEERING COMPANY,
SUCCESSORS TO MELAN ARCH CONSTRUCTION COMPANY
CONSULTING ENGINEERS.

CONCRETE-STEEL
BRIDGES
VIADUCTS,
SUBWAYS,
GIRDERS, SEWERS,
FLOORS, ROOFS,
DOCKS,
AND
ALL KINDS OF
CONCRETE-STEEL
CONSTRUCTION.

THACHER AND
DIAMOND BARS
FOR
RE-ENFORCING
CONCRETE.

FOUNDATIONS.

75 ft Span Melan Arch Bridge for F.W. Vanderbilt
Hyde Park on the Hudson

OWNERS OF
MELAN, THACHER,
VON EMPERGER,
MUESER
AND
OTHER PATENTS.

PLANS, SPECIFICATIONS
AND
ESTIMATES FURNISHED

GENERAL OFFICES:
PARK ROW
BUILDING,
NEW YORK.

TELEPHONE, 2302 CORTLANDT.
CABLE ADDRESS, NALEMARCH.

NEW YORK Aug. 28th 1907.

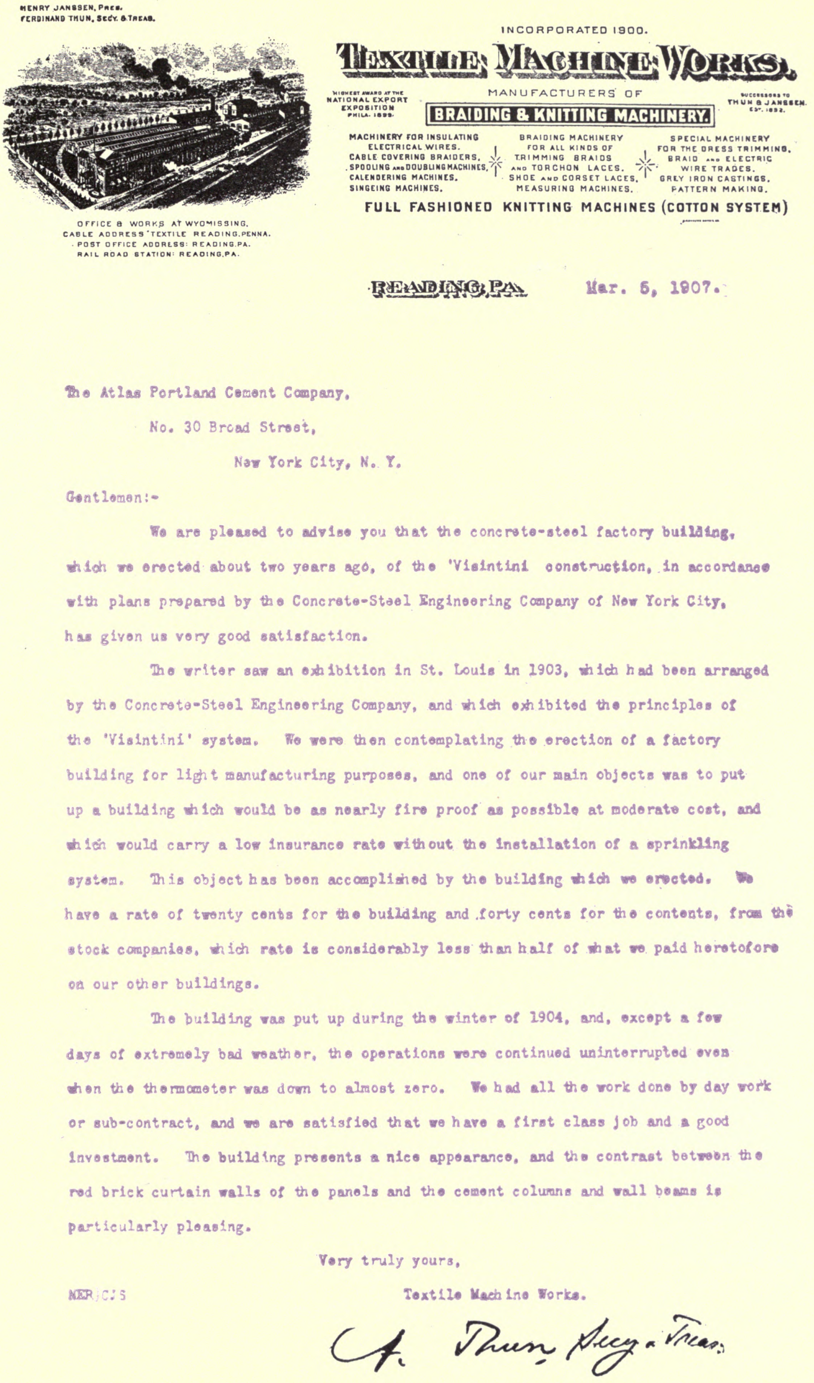
The Atlas Portland Cement Company,
Department of Publicity,
30 Broad Street,
New York City.

Gentlemen:-

Your cement has been used in large quantities in our concrete-steel arch bridges, built in different sections of the country and has always given complete satisfaction. We consider it a first class cement in every way.

Very truly yours,

CONCRETE-STEEL ENGINEERING COMPANY
by
Edwin Thacher



HENRY JANSSEN, PRES.
FERDINAND THUN, SECY. & TREAS.

OFFICE & WORKS AT WYOMISSING.
CABLE ADDRESS "TEXTILE" READING, PENNA.
POST OFFICE ADDRESS: READING, PA.
RAIL ROAD STATION: READING, PA.

INCORPORATED 1900.

TEXTILE MACHINE WORKS.

HIGHEST AWARD AT THE NATIONAL EXPORT EXPOSITION PHILA. 1899.

MANUFACTURERS OF

**BRAIDING & KNITTING MACHINERY.**

SUCCESSORS TO THUN & JANSSEN. EST. 1892.

MACHINERY FOR INSULATING ELECTRICAL WIRES.
CABLE COVERING BRAIDERS.
SPOOLING AND DOUBLING MACHINES.
CALENDERING MACHINES.
SINGEING MACHINES.

BRAIDING MACHINERY FOR ALL KINDS OF TRIMMING BRAIDS AND TORCHON LACES.
SHOE AND CORSET LACES.
MEASURING MACHINES.

SPECIAL MACHINERY FOR THE DRESS TRIMMING, BRAID AND ELECTRIC WIRE TRADES.
GREY IRON CASTINGS.
PATTERN MAKING.

FULL FASHIONED KNITTING MACHINES (COTTON SYSTEM)

READING, PA. Mar. 6, 1907.

The Atlas Portland Cement Company,
No. 30 Broad Street,
New York City, N. Y.

Gentlemen:-

We are pleased to advise you that the concrete-steel factory building, which we erected about two years ago, of the 'Visintini construction, in accordance with plans prepared by the Concrete-Steel Engineering Company of New York City, has given us very good satisfaction.

The writer saw an exhibition in St. Louis in 1903, which had been arranged by the Concrete-Steel Engineering Company, and which exhibited the principles of the 'Visintini' system. We were then contemplating the erection of a factory building for light manufacturing purposes, and one of our main objects was to put up a building which would be as nearly fire proof as possible at moderate cost, and which would carry a low insurance rate without the installation of a sprinkling system. This object has been accomplished by the building which we erected. We have a rate of twenty cents for the building and forty cents for the contents, from the stock companies, which rate is considerably less than half of what we paid heretofore on our other buildings.

The building was put up during the winter of 1904, and, except a few days of extremely bad weather, the operations were continued uninterrupted even when the thermometer was down to almost zero. We had all the work done by day work or sub-contract, and we are satisfied that we have a first class job and a good investment. The building presents a nice appearance, and the contrast between the red brick curtain walls of the panels and the cement columns and wall beams is particularly pleasing.

Very truly yours,

MER;CJS

Textile Machine Works.

F. Thun, Secy. & Treas.

THE GENERAL FIREPROOFING CO.

YOUNGSTOWN, OHIO.

THE GENERAL FIREPROOFING CO. SYSTEM OF REINFORCED CONCRETE.

PIN-CONNECTED GIRDER FRAME
COLD TWISTED LUG BAR.
EXPANDED METAL.
TRUSSIT METAL.

Allsteel
FURNITURE & FILING EQUIPMENT

HERRINGBONE EXPANDED STEEL LATH.
DIAMOND MESH EXPANDED METAL LATH.
BOSTON SHEET METAL LATH.
ALLUNITED STEEL STUDDING.

OFFICES: NEW YORK BOSTON ST. LOUIS WASHINGTON NEW ORLEANS CHICAGO

YOUNGSTOWN, OHIO, Aug. 27, 07.

Atlas Portland Cement Co.,
30 Broad St.,
New York City.

Gentlemen:-

As Atlas Portland Cement was used in the construction of the Grunewald Hotel, New Orleans, La., and the Carpenter Shop building for the National Cash Register Co., Dayton, O., in connection with reinforcing steel furnished by this company, we believe the accompanying photographs may be of interest to you. The two buildings are respectively excellent illustrations of long span fireproofing and entire reinforced concrete construction.

Our observation of the concrete work on these buildings is in harmony with our high opinion of Atlas Cement and you are at liberty to use these photographs as you may desire.

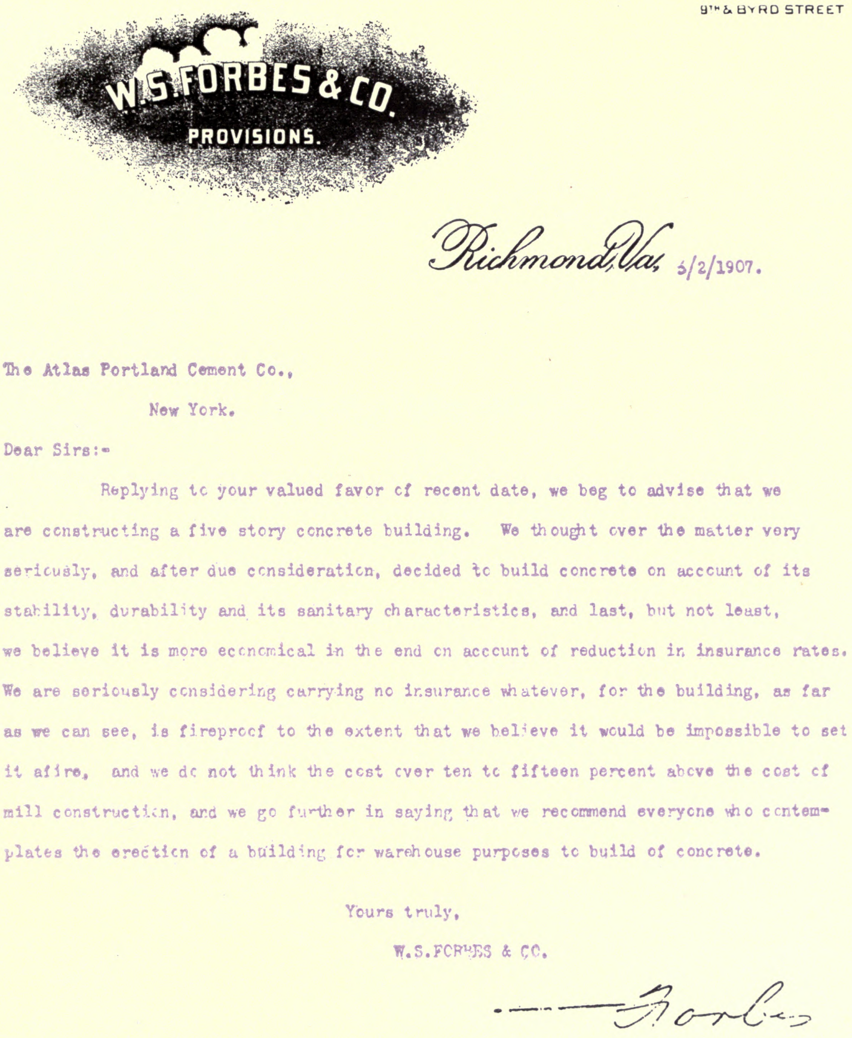
Yours truly,

The General Fireproofing Company.

A. A. Lane

Engineer.

AAL.RN



9TH & BYRD STREET

W. S. FORBES & CO.
PROVISIONS.

Richmond, Va, 6/2/1907.

The Atlas Portland Cement Co.,
New York.

Dear Sirs:-

Replying to your valued favor of recent date, we beg to advise that we are constructing a five story concrete building. We thought over the matter very seriously, and after due consideration, decided to build concrete on account of its stability, durability and its sanitary characteristics, and last, but not least, we believe it is more economical in the end on account of reduction in insurance rates. We are seriously considering carrying no insurance whatever, for the building, as far as we can see, is fireproof to the extent that we believe it would be impossible to set it afire, and we do not think the cost over ten to fifteen percent above the cost of mill construction, and we go further in saying that we recommend everyone who contemplates the erection of a building for warehouse purposes to build of concrete.

Yours truly,
W.S.FORBES & CO.

Forbes

# Announcement

For the benefit of those who desire to make lasting improvements about the

**FARM,**
**FACTORY or**
**HOME,**

and as a guide to those who contemplate new constructions, we have published the following books: ☞