REINFORCED CONCRETE
IN
FACTORY CONSTRUCTION

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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 presents at the close of the book 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,
November 1, 1907. Newton Highlands, Mass.

CONTENTS.

CHAPTER I.

Factory Construction.

CHAPTER II.

Design and Construction.

CHAPTER III.

CONCRETE AGGREGATES.

CHAPTER IV.

PACIFIC COAST BORAX REFINERY.

CHAPTER V.

KETTERLINUS BUILDING.

CHAPTER VI.

LYNN STORAGE WAREHOUSE.

CHAPTER VII.

BULLOCK ELECTRIC MACHINE SHOP.

CHAPTER VIII.

WHOLESALE MERCHANTS' WAREHOUSE.

CHAPTER IX.

BUSH MODEL FACTORY.

CHAPTER X.

PACKARD MOTOR CAR FACTORY.

CHAPTER XI.

TEXTILE MACHINE WORKS.

CHAPTER XII.

FORBES COLD STORAGE WAREHOUSE.

CHAPTER XIII.

BLACKSMITH AND BOILER SHOP OF THE ATLAS PORTLAND CEMENT CO. PAGE

CHAPTER XIV.

DETAILS OF CONSTRUCTION.

MISCELLANEOUS BUILDINGS.

LETTERS.

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, of 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 non-conductor 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 sceptical 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 the 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 to 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, penstocks 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 Bldgs. 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 Bldg	35c.	75c.	50c.	100c.	100c.	150c.	25c.

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

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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.

the mixer so regularly that the amount of dust (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 around and

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* See footnote page 25.

† For specifications for high carbon steel, see Taylor & Thompson's "Concrete, Plain and Reinforced," page 38.

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 has attained sufficient

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* See footnote page 25.

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 buttesses 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 waterproofing 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 between 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

$$M = \tfrac{1}{8}\,WL \qquad (1)$$

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.

CONCERTE.—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 ¼-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. René 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,

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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.

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 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—

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* Seventh Report of Boston Transit Commission, 1901, page 39.

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 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 denest 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 the 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.
G_c = specific gravity of cement.
G_s = specific gravity of sand.

Then

$$P=K\left(\frac{G_s}{G_c}\right)^2\left(\frac{C}{G_sQ-S}\right)^2$$

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.

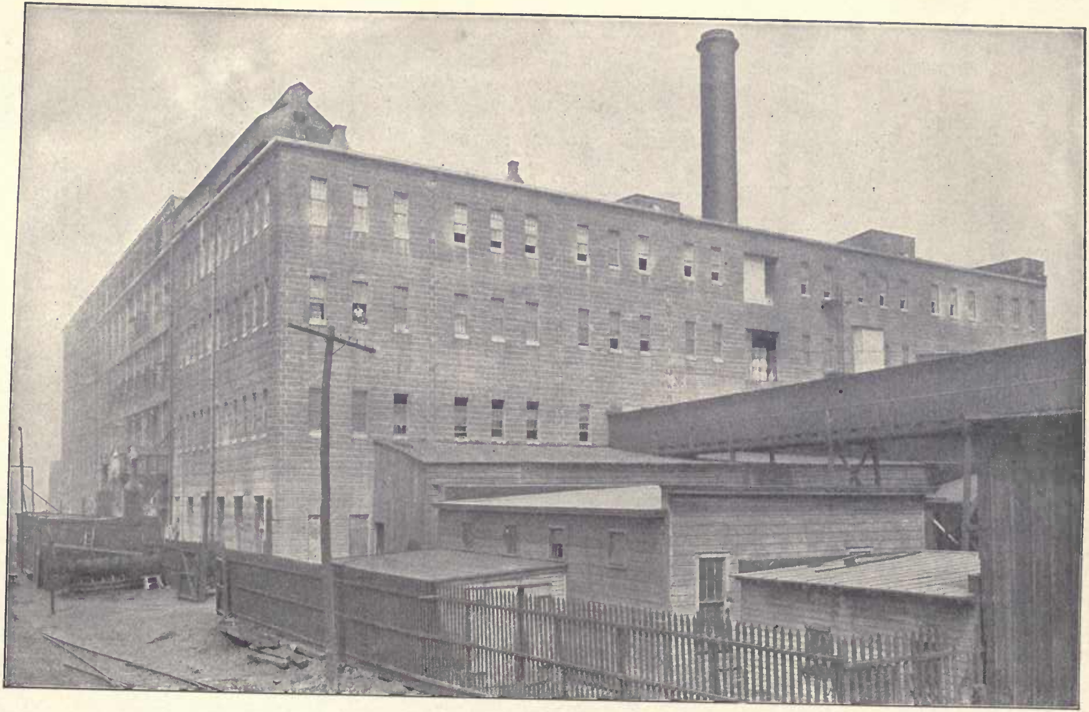

Fig. 1.—Pacific Coast Borax Refinery. (*See p. 47.*)

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 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

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* Illustrated on page 210.

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

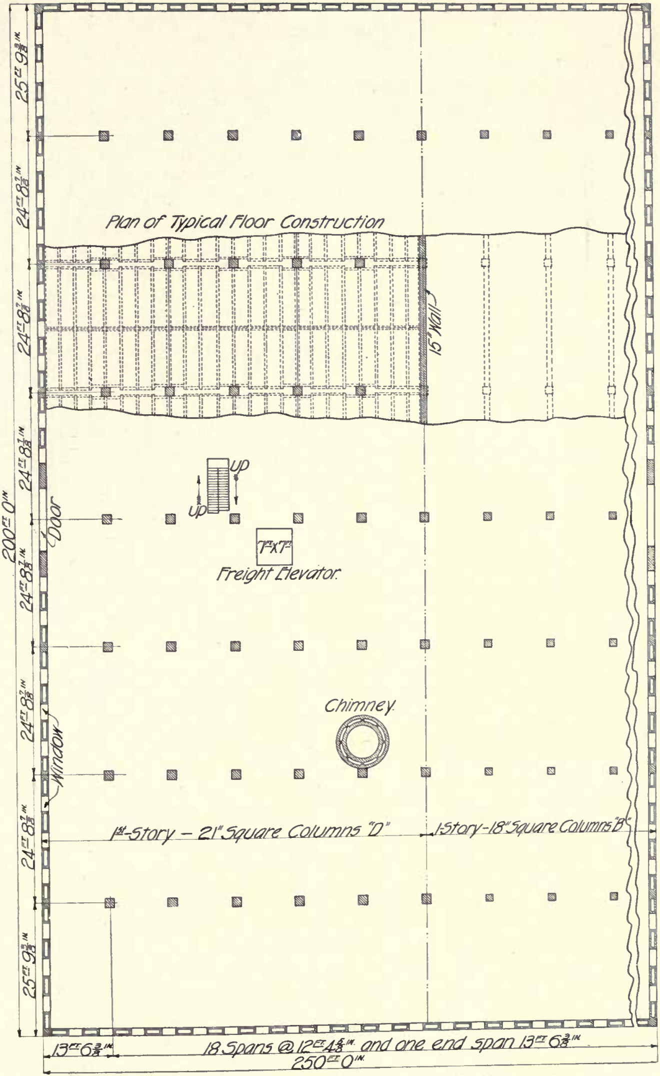


Fig. 2.—Plan of First Story of Pacific Coast Borax Refinery. (*See p.* 48.)

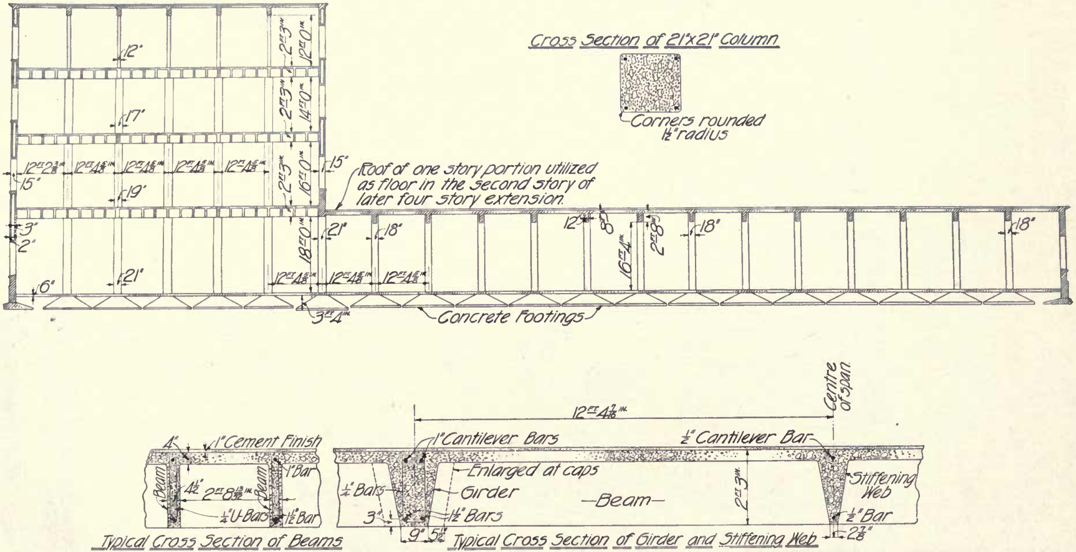


Fig. 3.—Cross Section of Pacific Coast Borax Refinery. (See p. 48.)

stated above, it is not now customary to insert contraction joints 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.

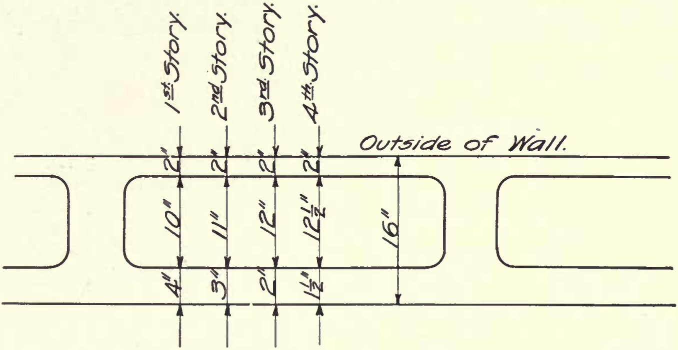


Fig. 4.—Typical Horizontal Section of Wall. (*See p.* 51.)

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.

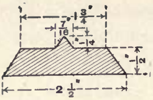
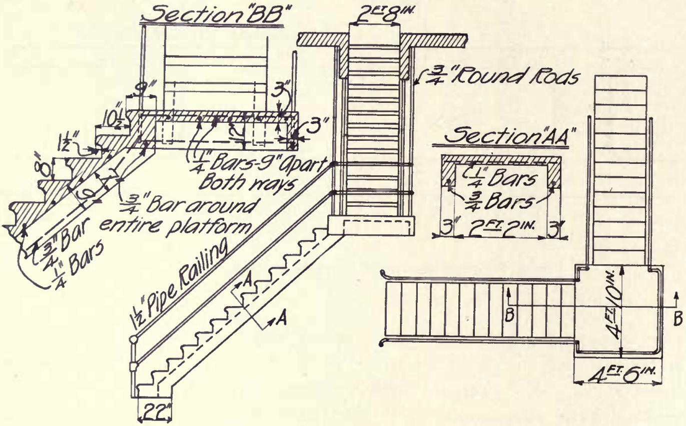


Fig. 5.—Molding for Wall Joints.* (*See p.* 52.)

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.



No. 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 particles

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* Reproduced by permission from Taylor & Thompson's "Concrete, Plain and Reinforced."

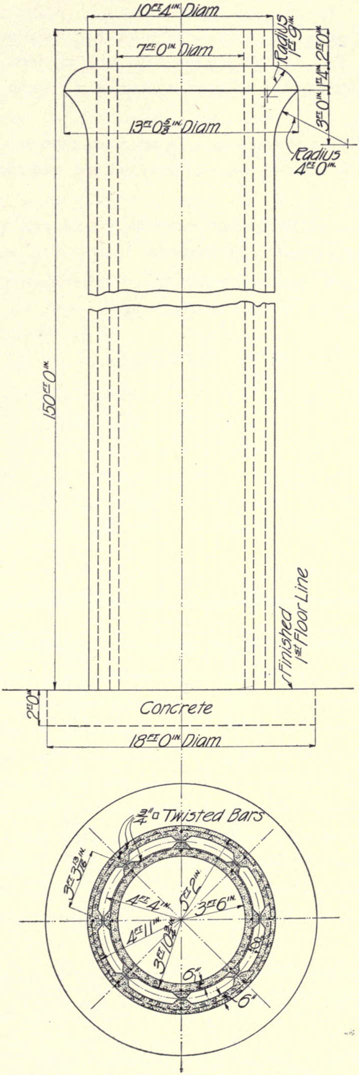


Fig. 7.—Plan and Elevation of Chimney. (*See p.* 52.)

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.

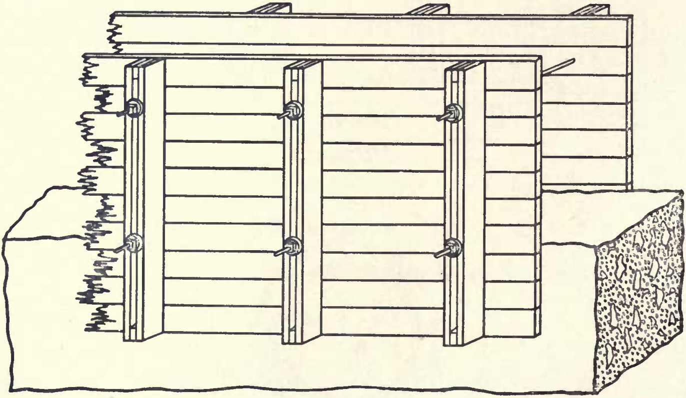


Fig. 8.—Type of Wall Molds. (*See p.* 55.)

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 2200° 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.

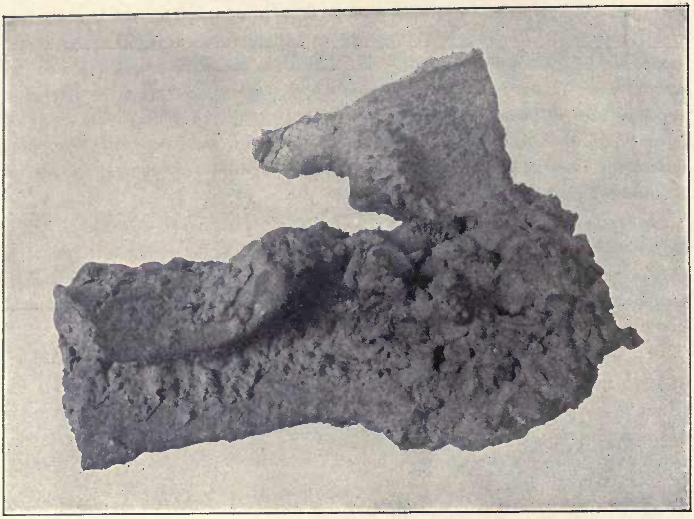


Fig. 9.—Photograph of Cast Iron Melted by the Fire. (*See p.* 55.)

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 two 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 ¼ 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 of

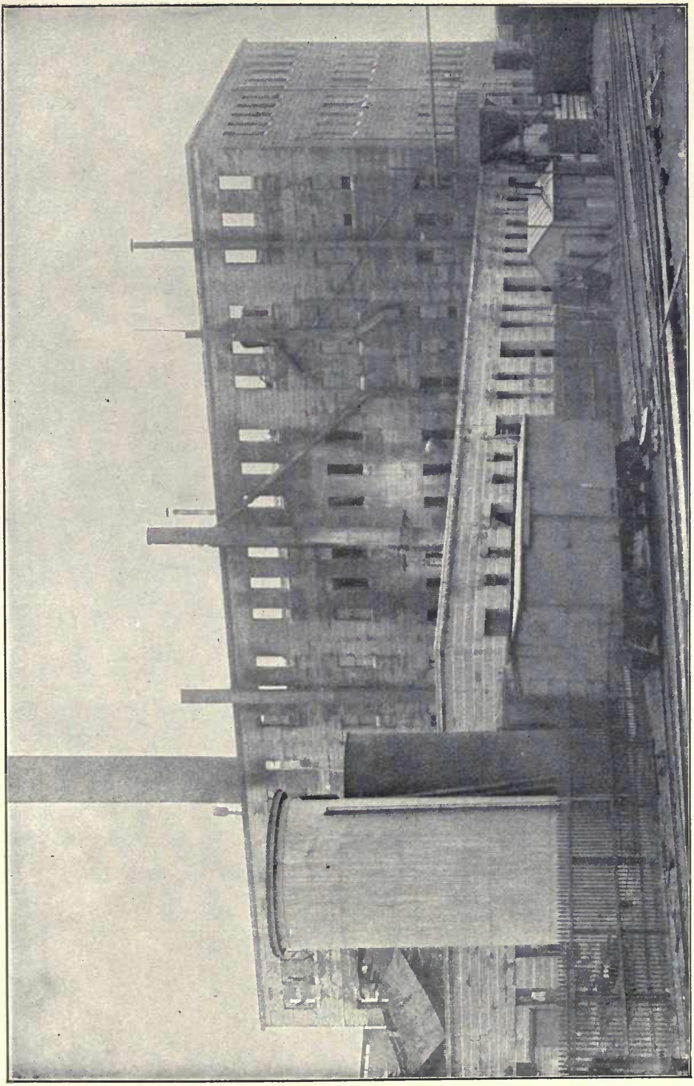


Fig. 10.—View of Refinery After the Fire. (*See p.* 56.)

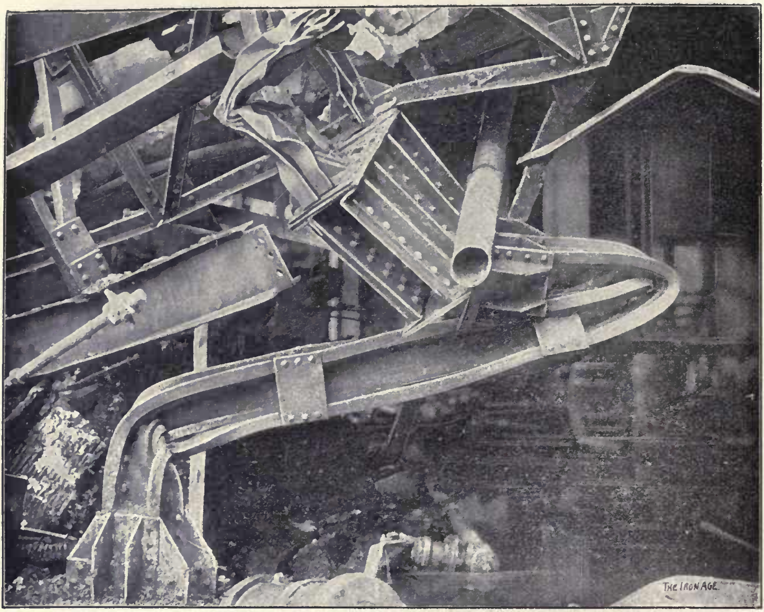


Fig. 11.—Effect of Fire Upon Steel Tank House. (*See p.* 58.)

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.

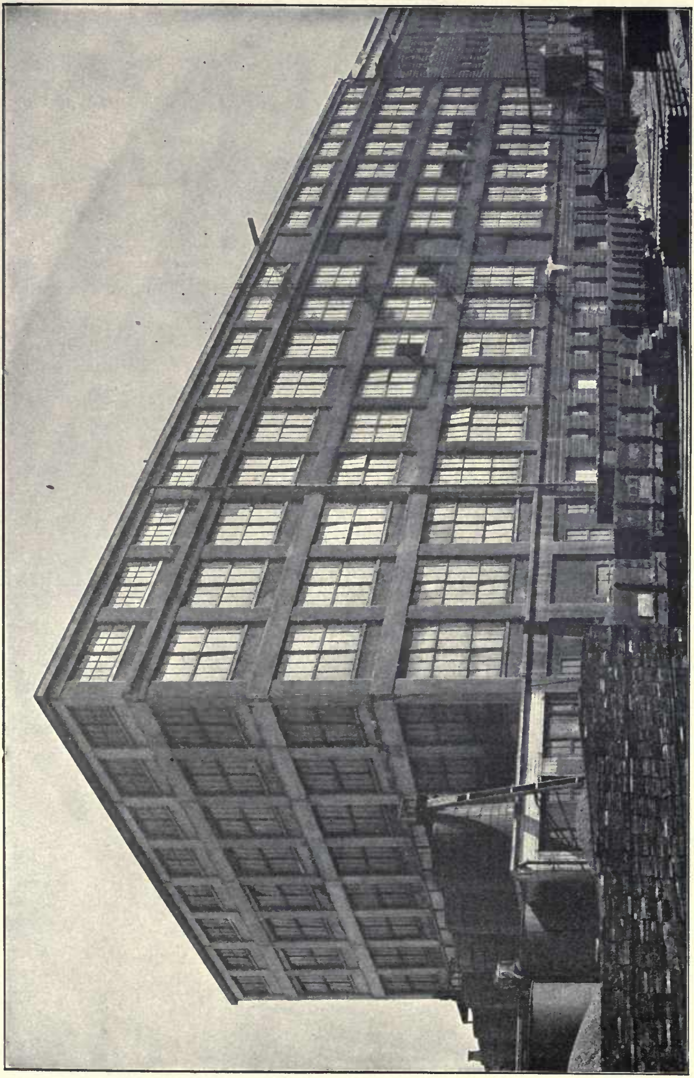
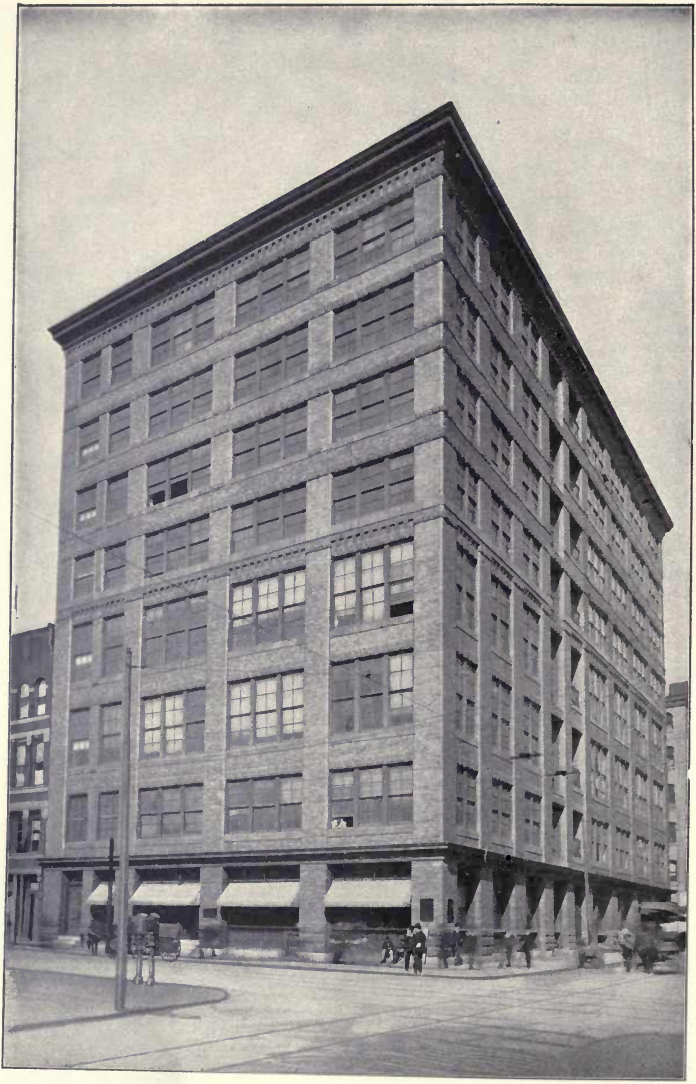


Fig. 12.—View of Refinery, Including New and Old Structures. (*See p.* 58.)



No. 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.

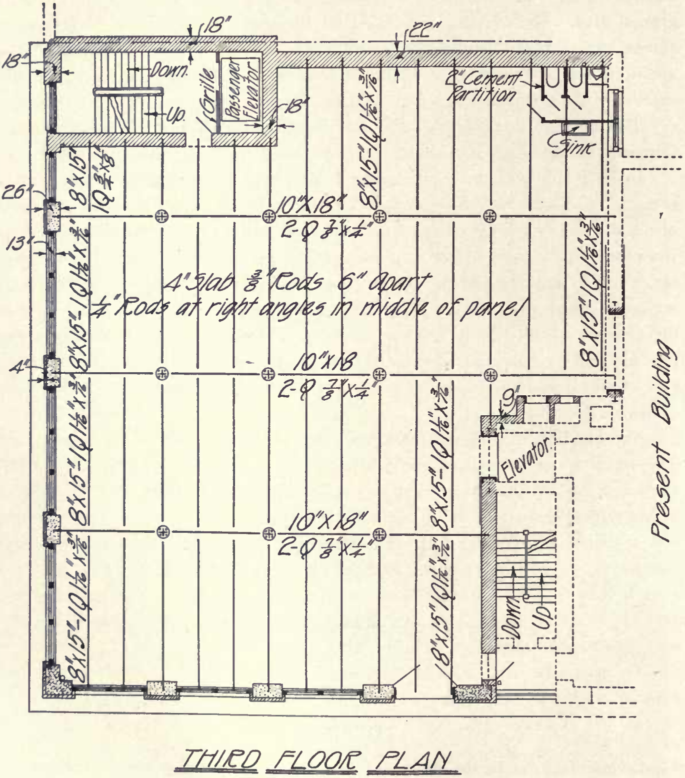


Fig. 15.—Typical Floor and Roof Plans of the Ketterlinus Building. (*See p. 62.*)

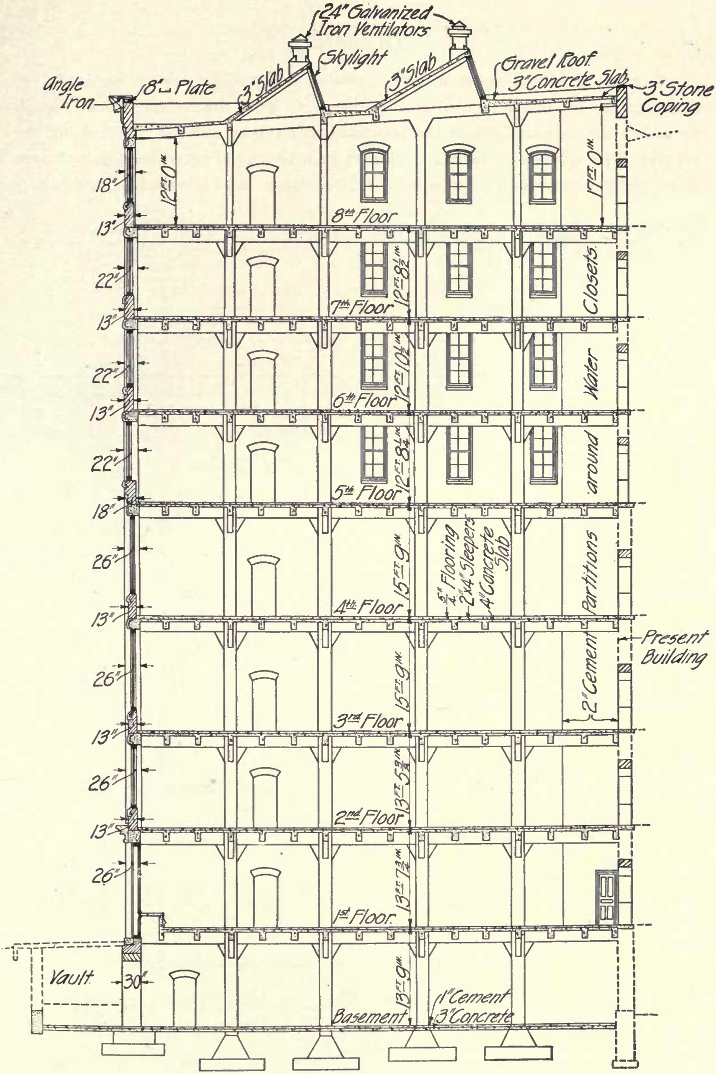


Fig. 16.—Cross-Section of Ketterlinus Building. (*See p. 62.*)

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 premium, and where

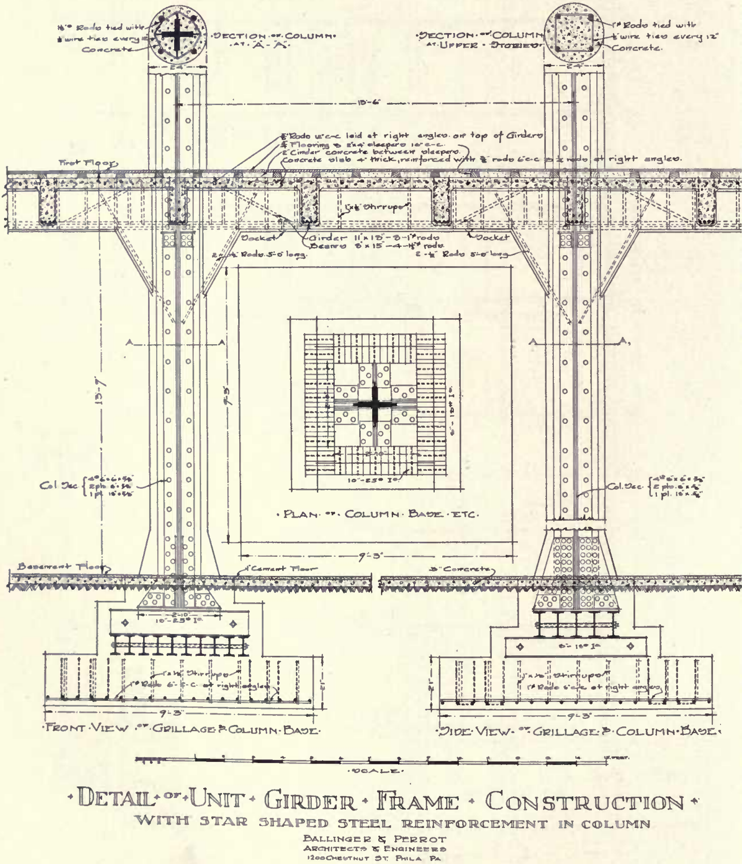


Fig. 17.—Details of Columns and Girders. (*See p.* 65.)

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 ⅛ 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 ⅝ 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 ⅝ inch all riveted together. The four round rods, which complete the so-called "Star" reinforcement are 1⅛ 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 ½-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 construction by the Philadelphia building laws. The details of the design and reinforcement are illustrated in Fig. 18.

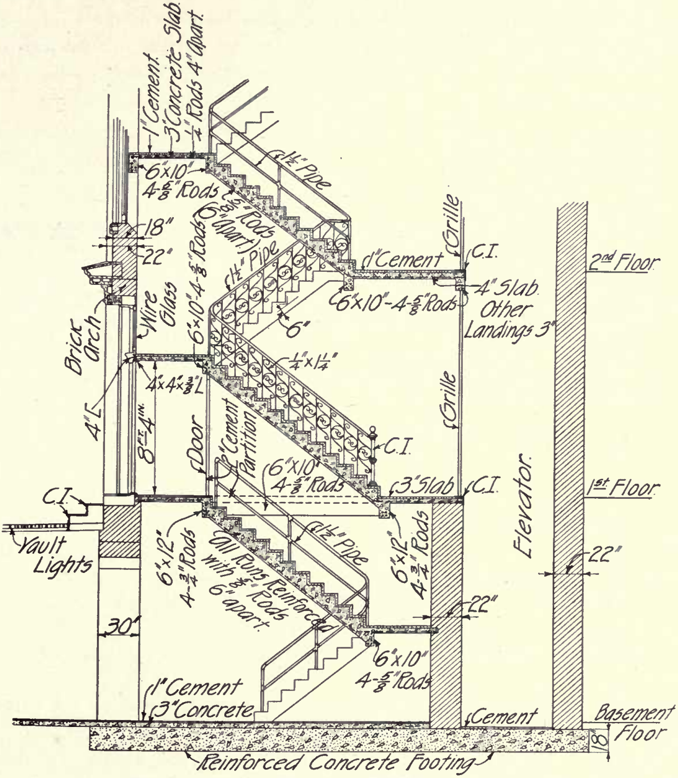


Fig. 18.—Stairs in Ketterlinus Building. (*See p. 67.*)

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.

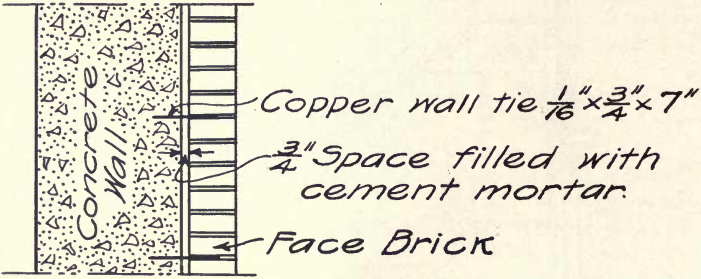


Fig. 19.—Brick Wall Ties. (*See p.* 68.)

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.

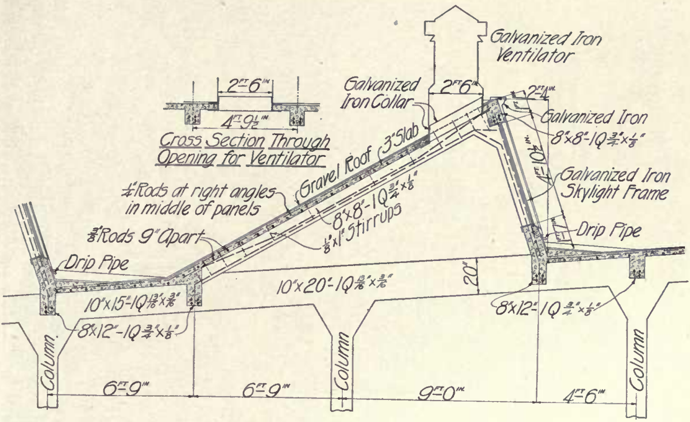


Fig. 20.—Cross-Section Detail of Saw-Tooth Roof. (*See p.* 68.)

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.

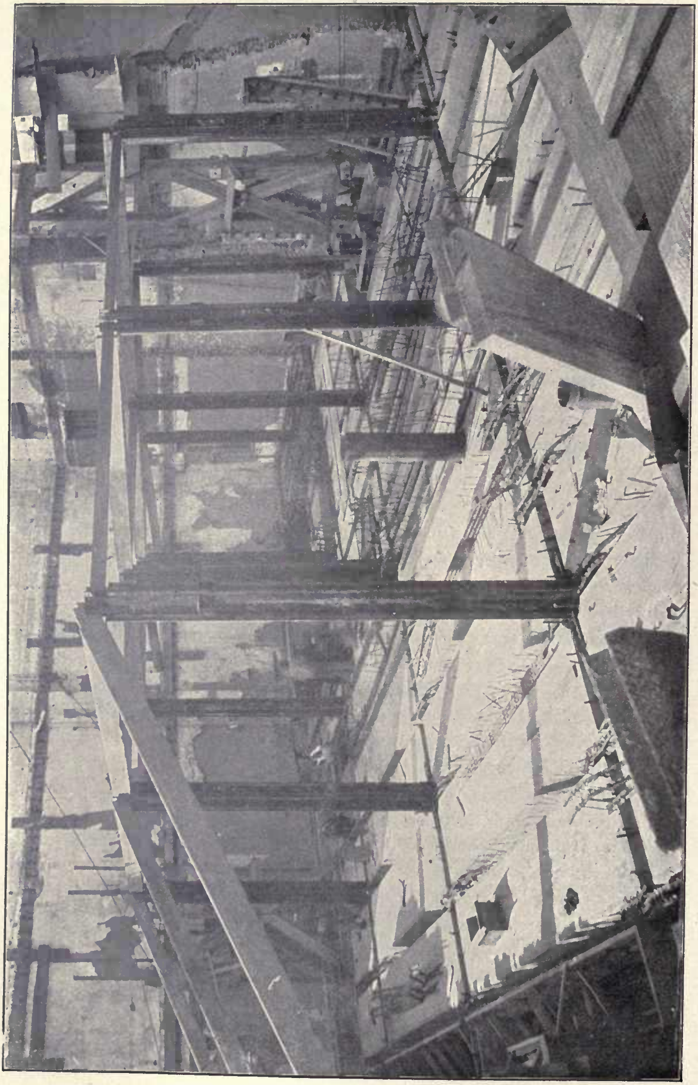


Fig. 21.—Placing the Reinforcement in the Ketterlinus Building. (*See p. 69.*)

Fig. 22.—Exterior of the Ketterlinus Building During Construction. (*See p.* 69.)

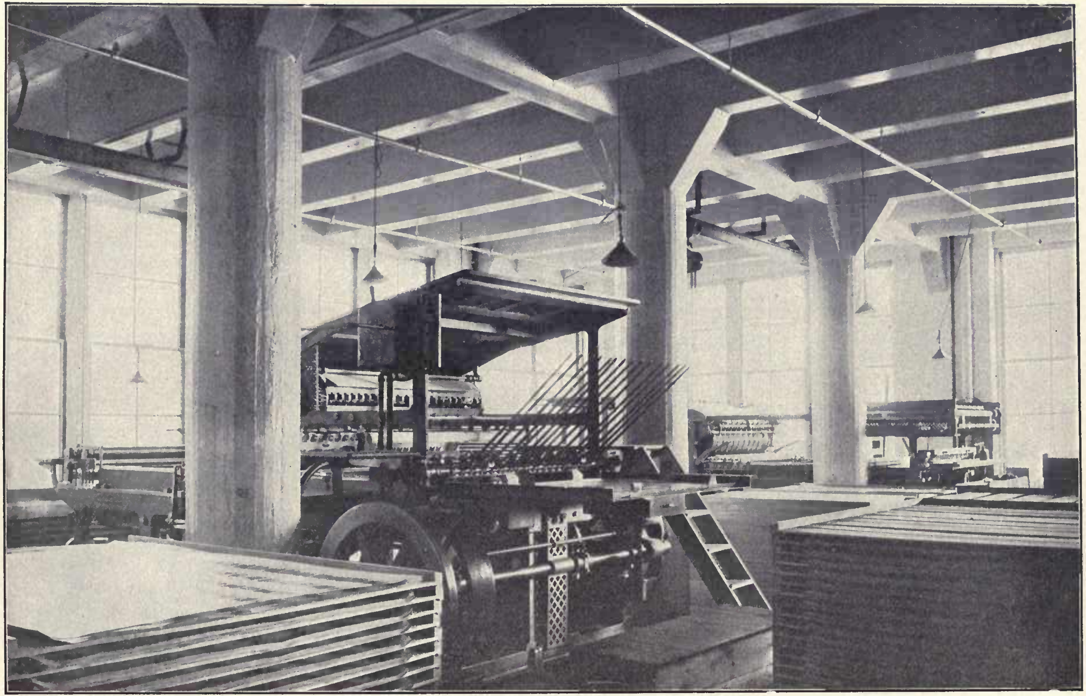


Fig. 23.—Interior of Ketterlinus Building, Showing 20-Ton Lithographic Press. (*See p.* 69.)

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.

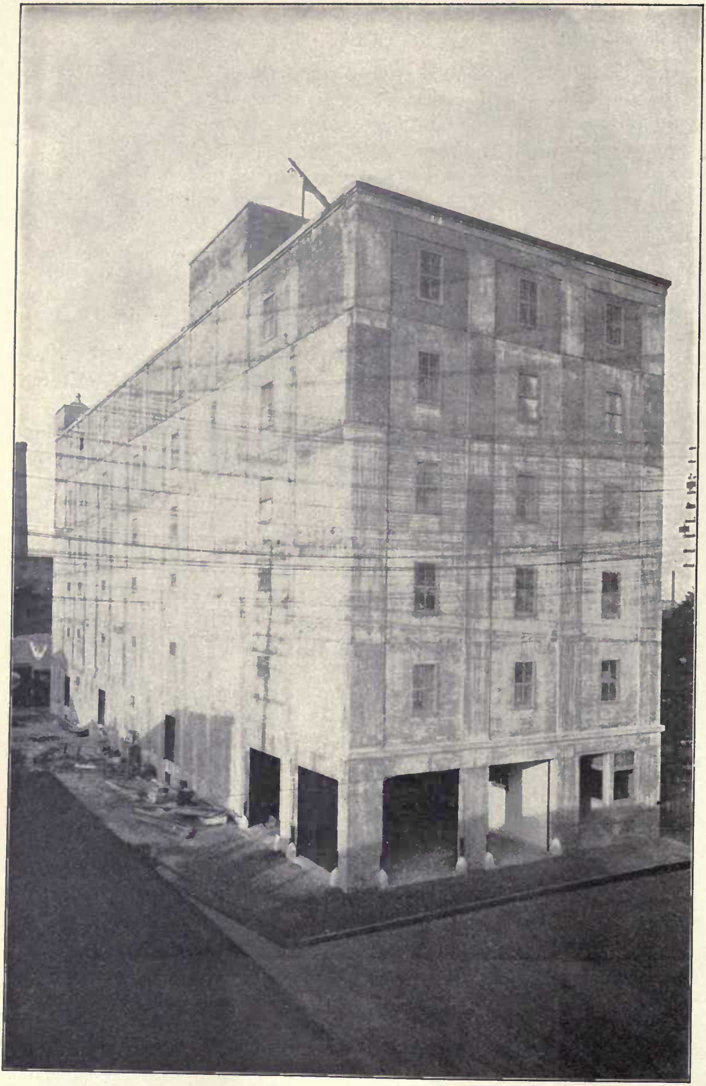


Fig. 24.—Lynn Storage Warehouse. (*See p.* 75.)

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 22 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 width from center to center of beam

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* See illustration, Fig. 108, page 182.

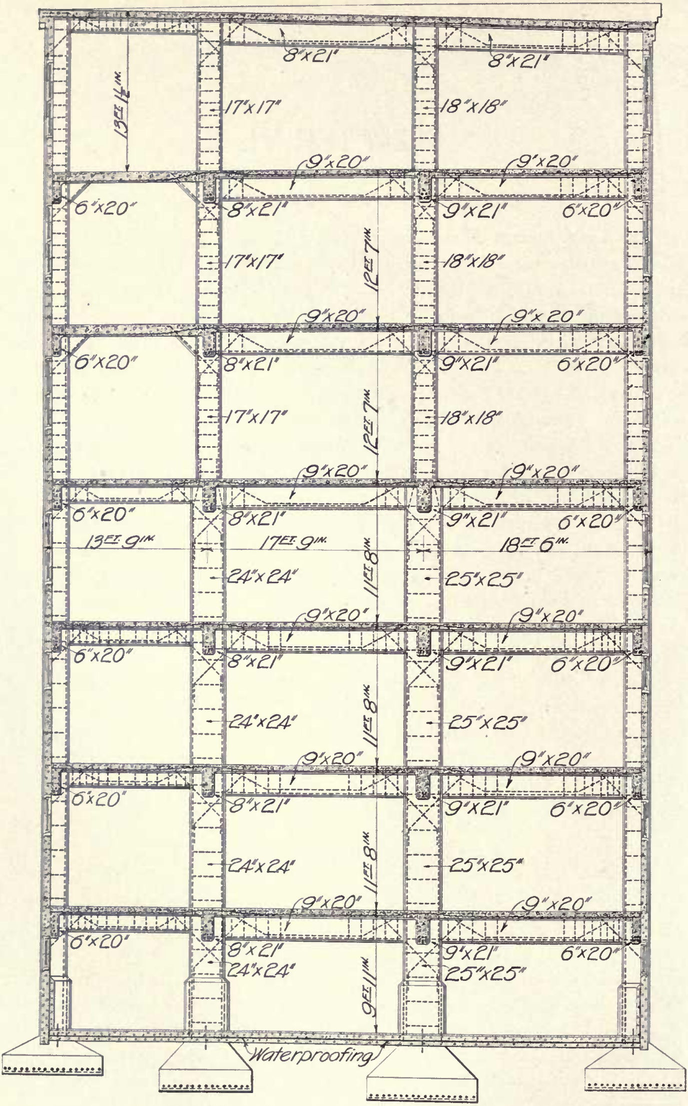


Fig. 25.—Cross-Section Through Lynn Storage Warehouse. (*See p. 75.*)

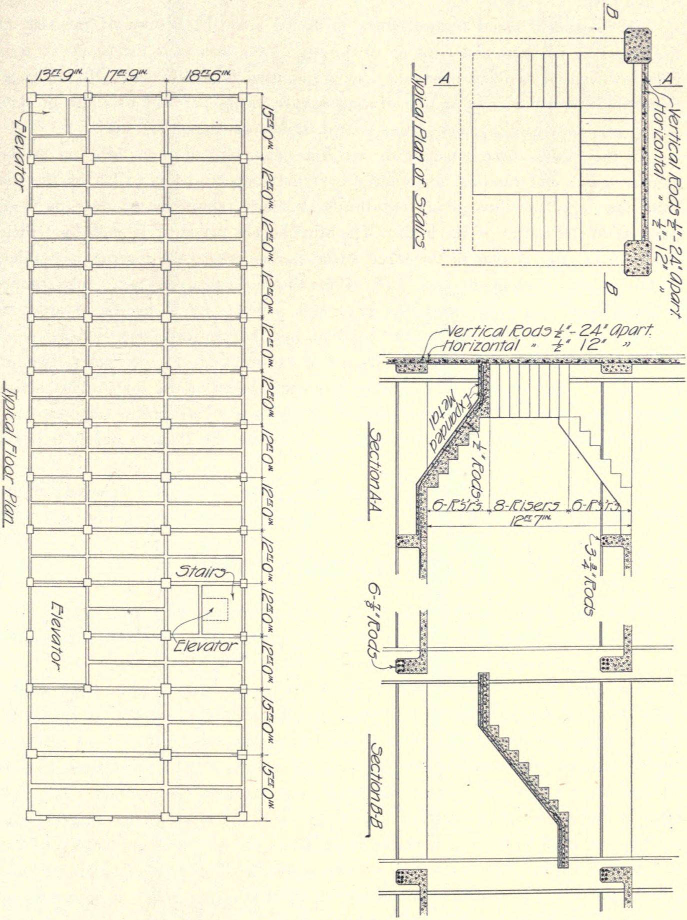


Fig. 26.—Typical Plan and Typical Stair Details of Lynn Storage Warehouse. (*See p.* 75.)

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.

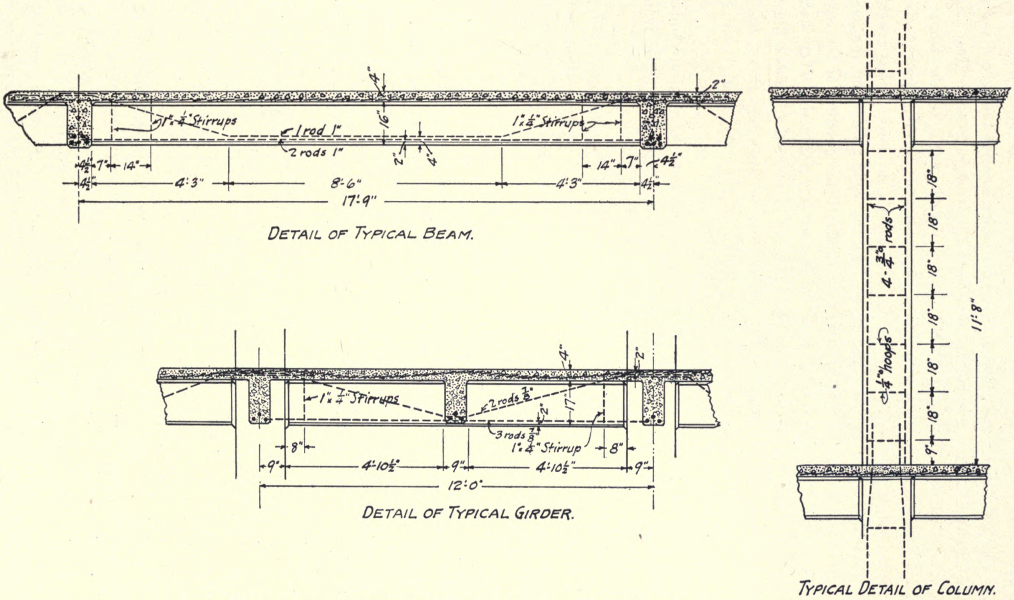
Instead of the more usual practice of forming the wall girders as a part of the wall, they are built independently of the wall slab, as indicated in Fig. 25.

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 that the



DETAIL OF TYPICAL BEAM.

DETAIL OF TYPICAL GIRDER.

TYPICAL DETAIL OF COLUMN.

Fig. 27.—Details of Typical Beam, Girder and Column. (See p. 75.)

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 ¼ inch to 1¼ 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 of 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 ¼-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.

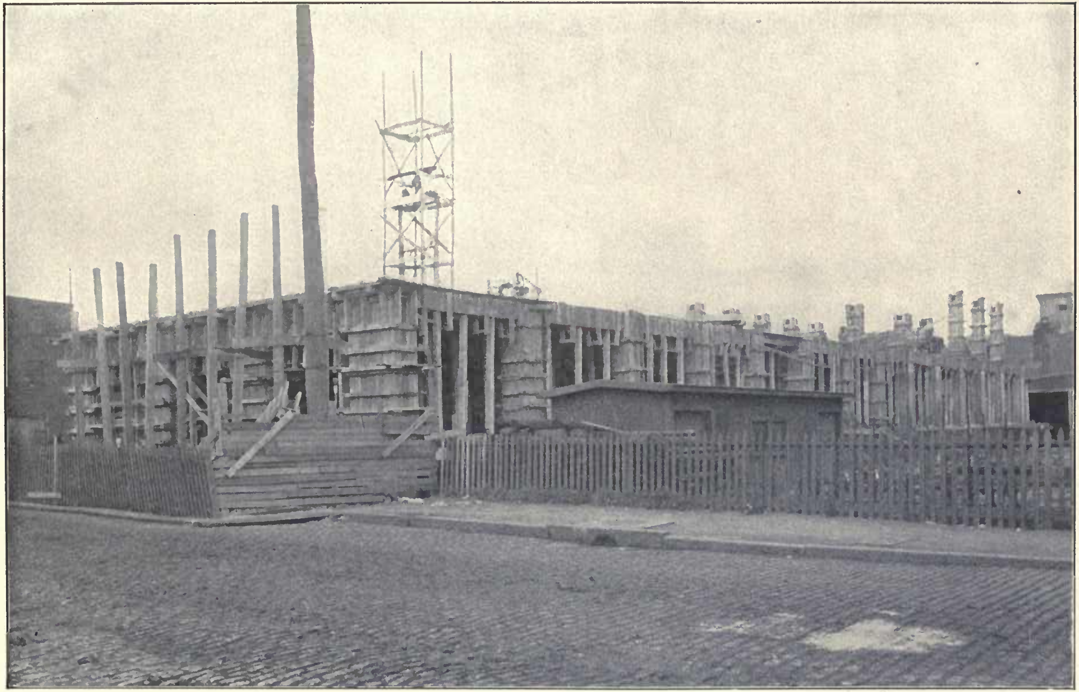


Fig. 28.—Lynn Storage Warehouse at Second Floor Level. (*See p.* 82.)

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.

The concrete was mixed on the ground in a rotary mixer (see Fig. 30), and a

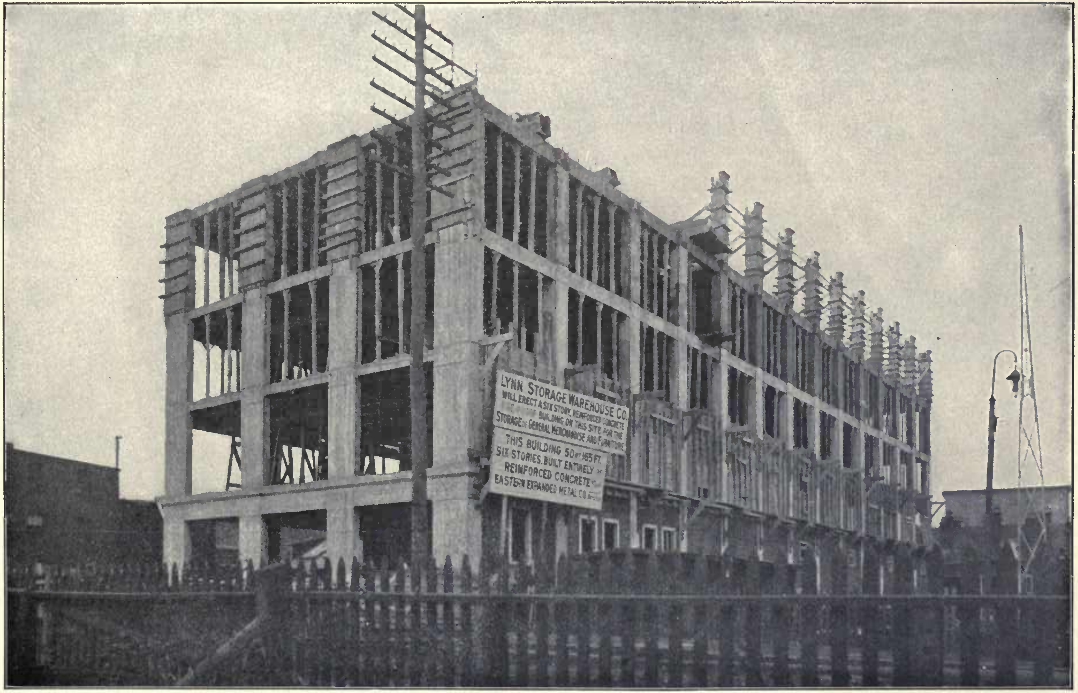


Fig. 29.—Lynn Storage Warehouse at Fifth Floor Level. (*See p.* 82.)

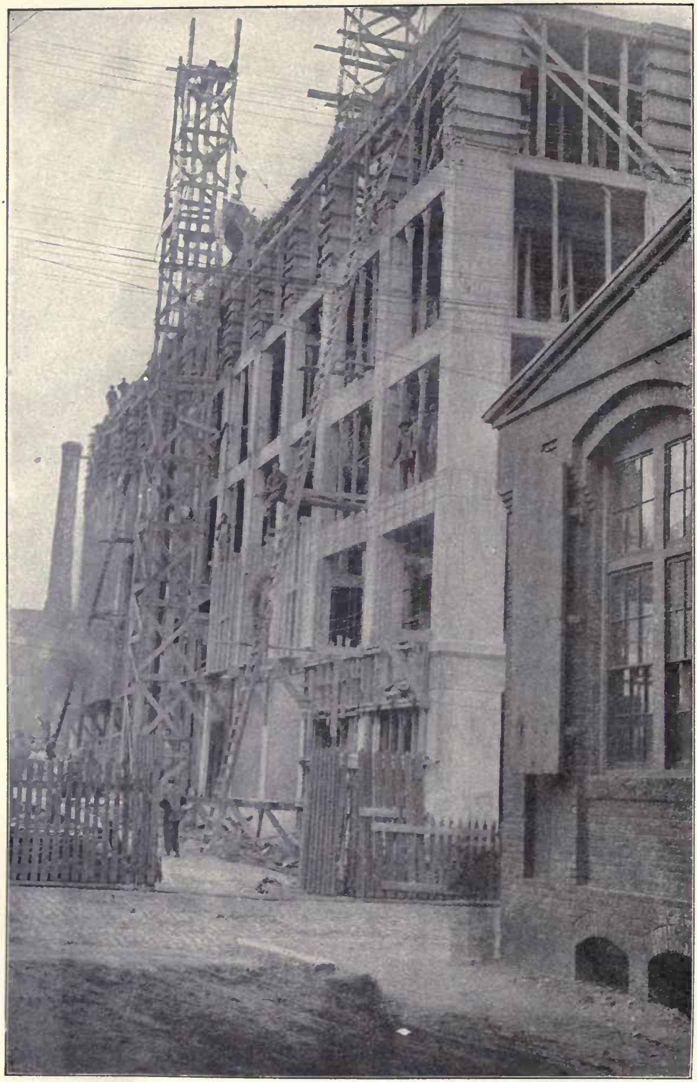


Fig. 30.—Lynn Storage Warehouse at Sixth Floor Level. (*See p. 82.*)

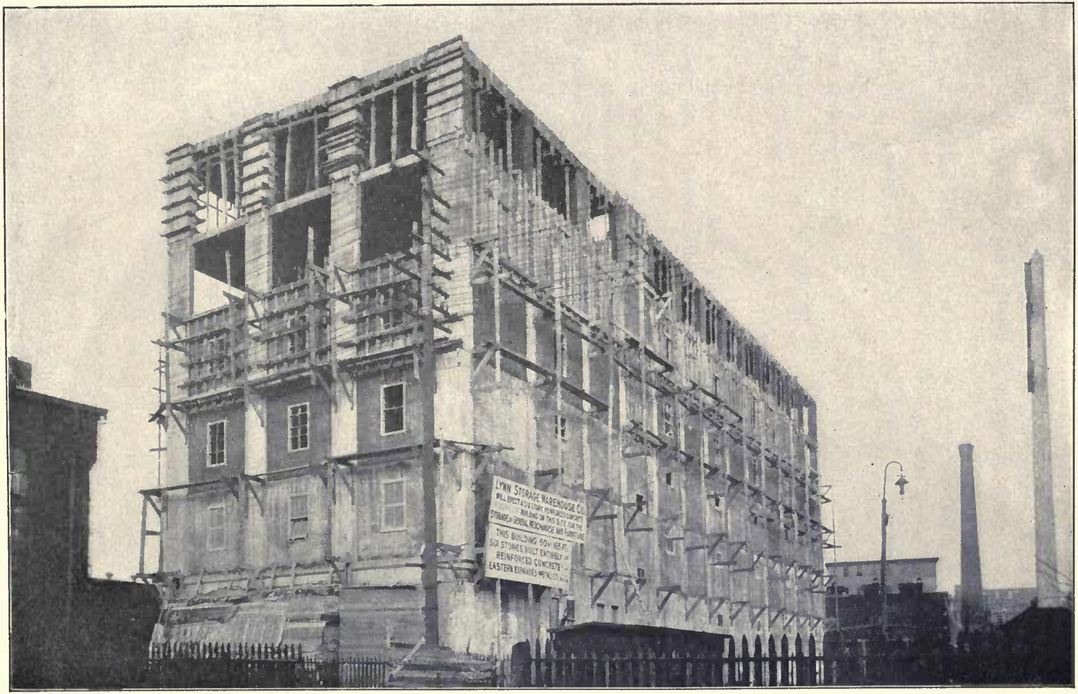


Fig. 31.—Lynn Storage Warehouse with Roof in Place. (*See p.* 82.)

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.

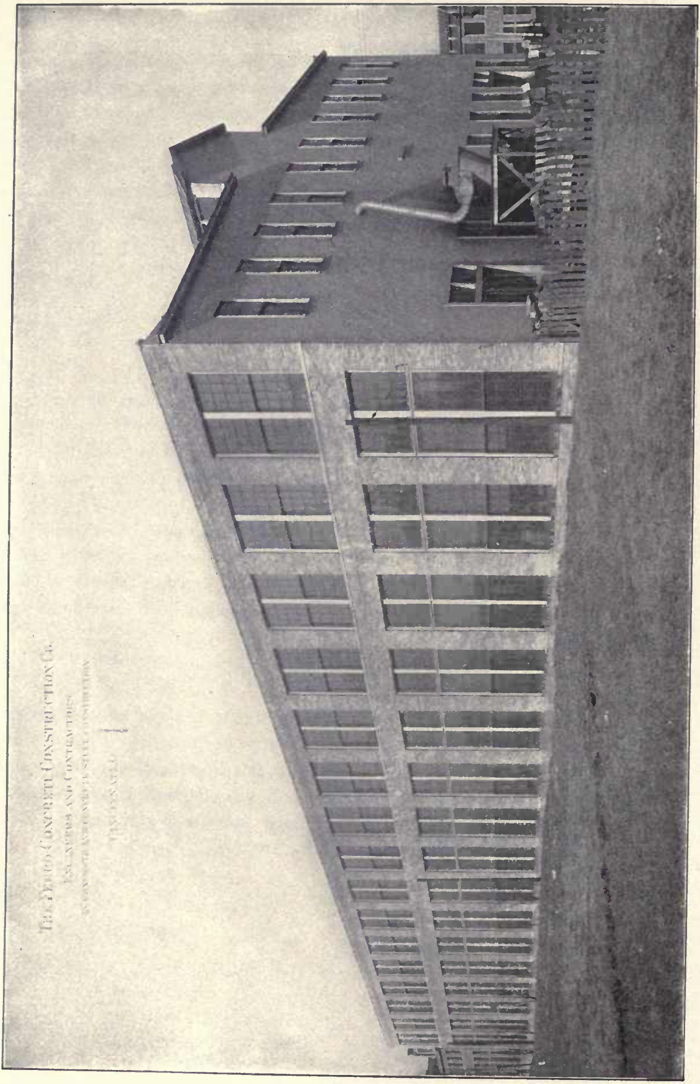


Fig. 32.—**Bullock Electric Machine Shop.** (*See p.* 89.)

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, lengthwise of the

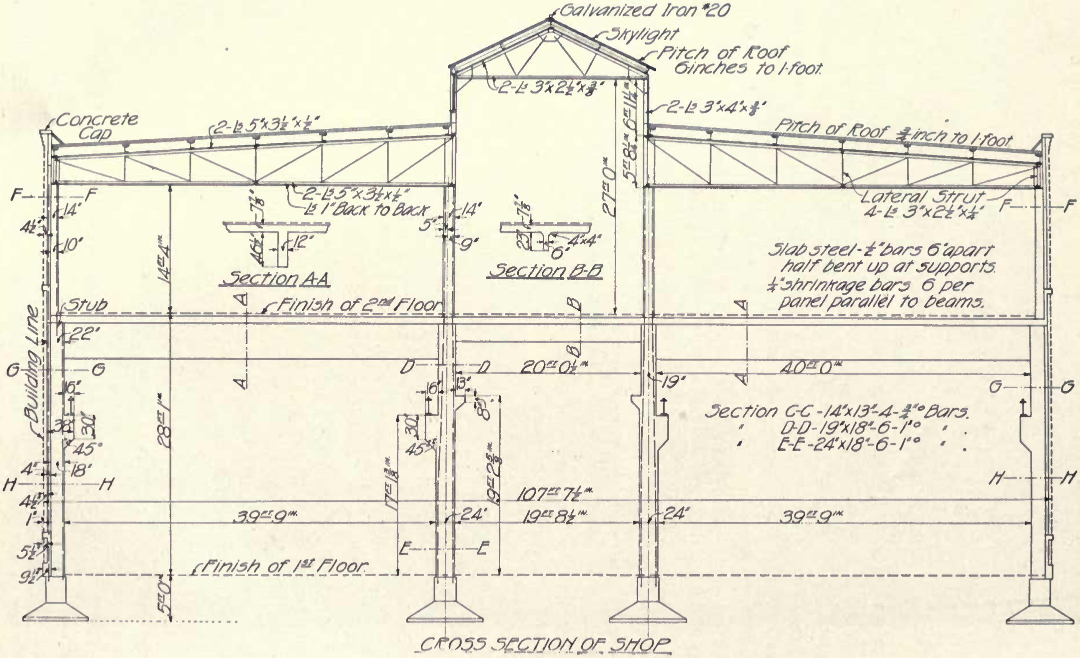


Fig. 33.—Cross-Section of the Bullock Machine Shop. (See p. 89.)

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.

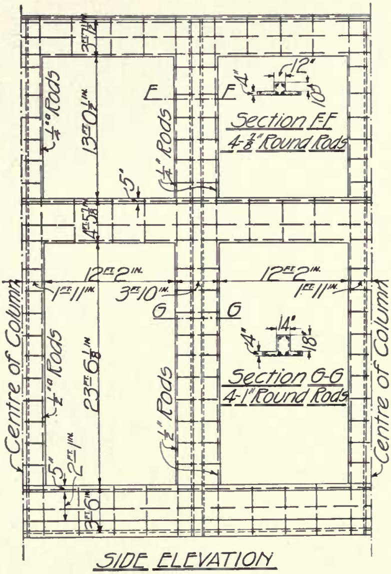


Fig. 34.—Side Elevation of the Bullock Machine Shop. (*See p.* 89.)

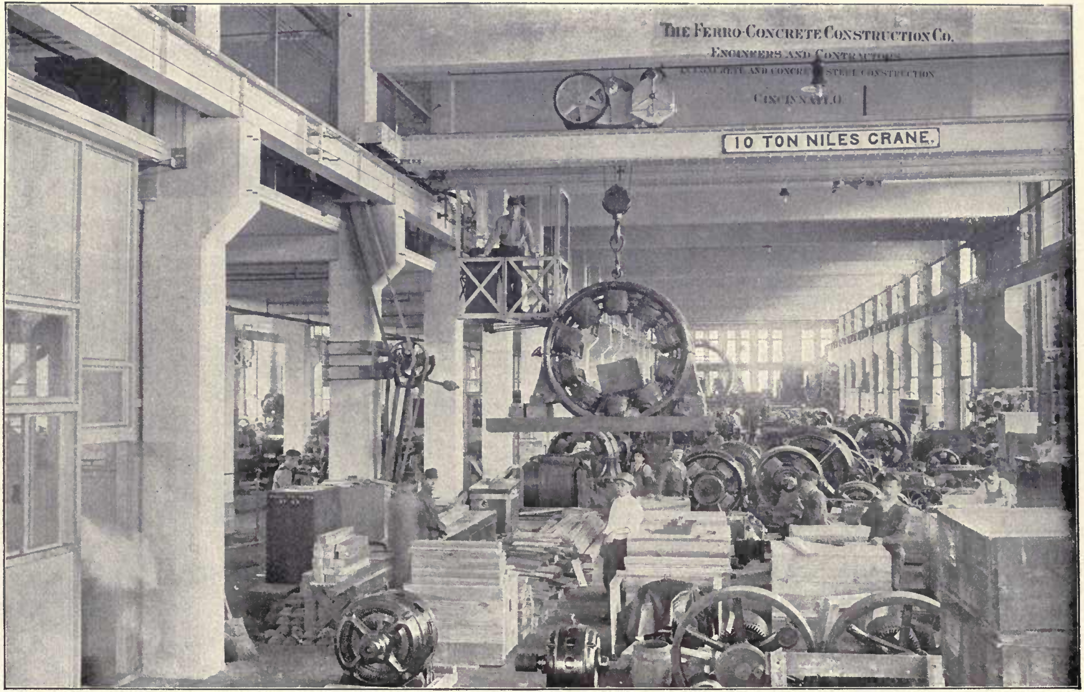


Fig. 35.—Bullock Electric Company Machine Shop in Operation. (*See p.* 89.)

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.

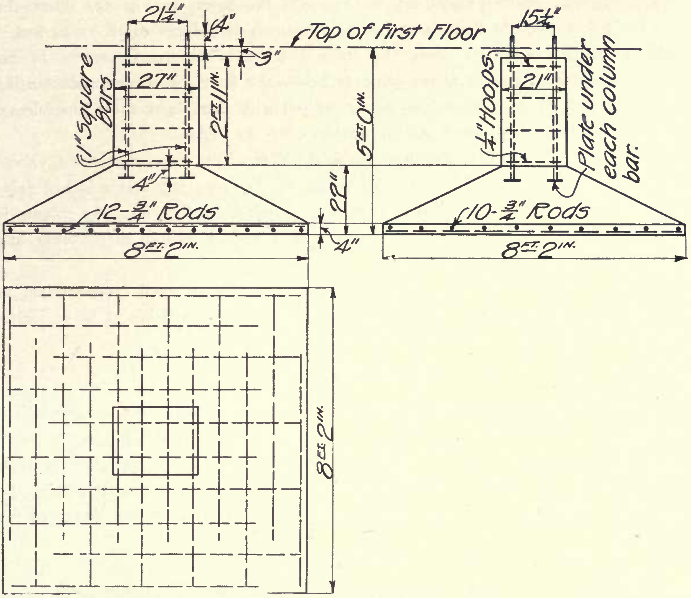


Fig. 36.—Reinforced Footings for Interior Columns. (*See p. 93.*)

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 ¼-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 ½-inch rods in each layer. Below the first floor the column is 20 inches by 26 inches, reinforced simply with a ⅜-inch rod in each corner and four ¼-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 54½ 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 ½-inch and ten ¼-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 troweled on the top

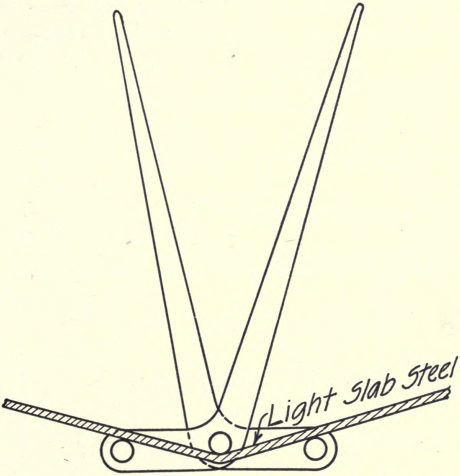


Fig. 37.—Tongs for Bending Light Steel Bars. (*See p.* 96.)

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.

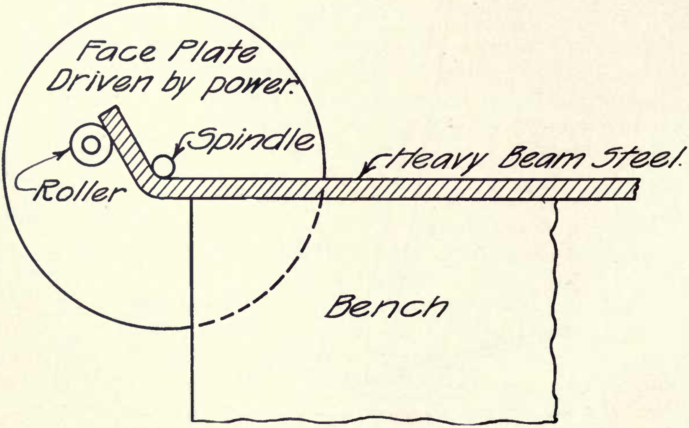


Fig. 38.—Power Bender for Large Steel Bars. (*See p.* 98.)

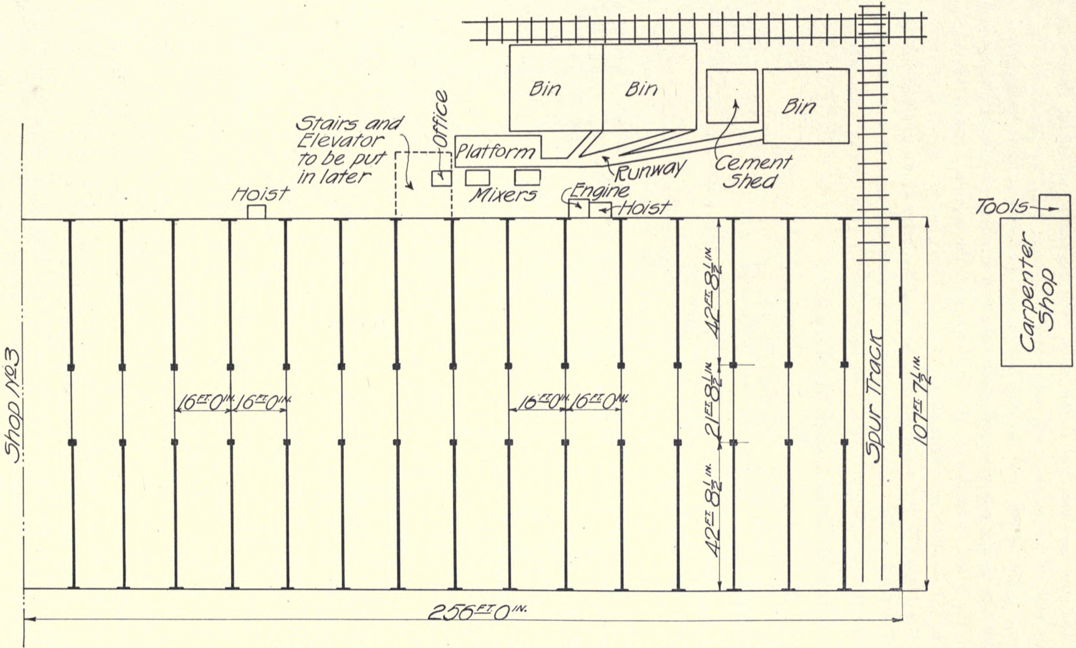


Fig. 39.—Plan of Machine Shop, with Construction Plant. (*See p.* 96.)

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.

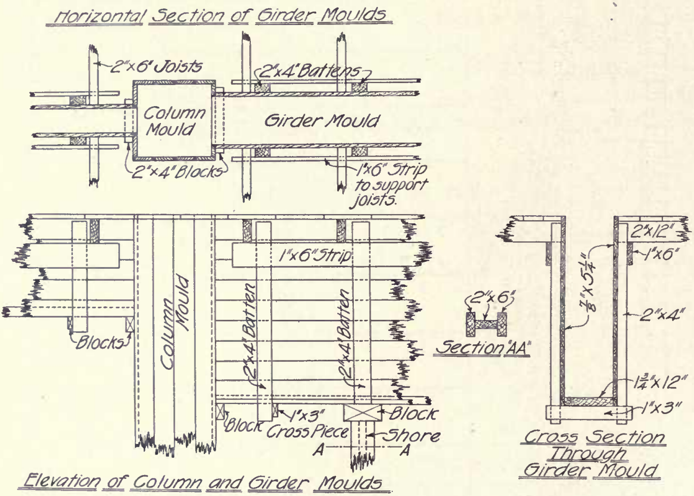


Fig. 40.—Sectional Plan and Elevation of Girder Molds. (*See p.* 100.)

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.

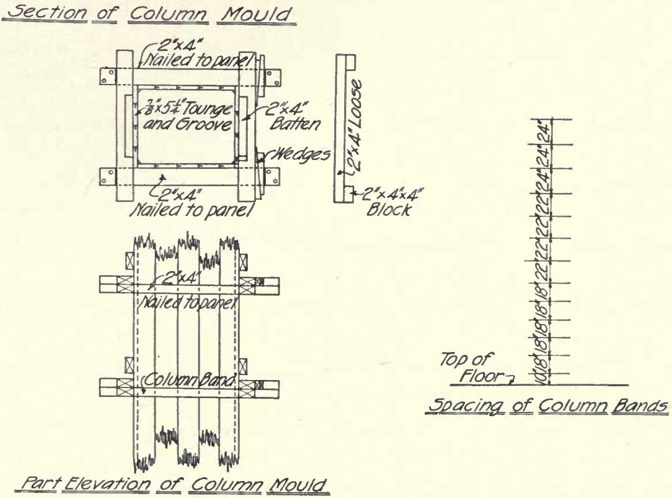


Fig. 41.—Details of Column Molds. (*See p.* 100.)

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.

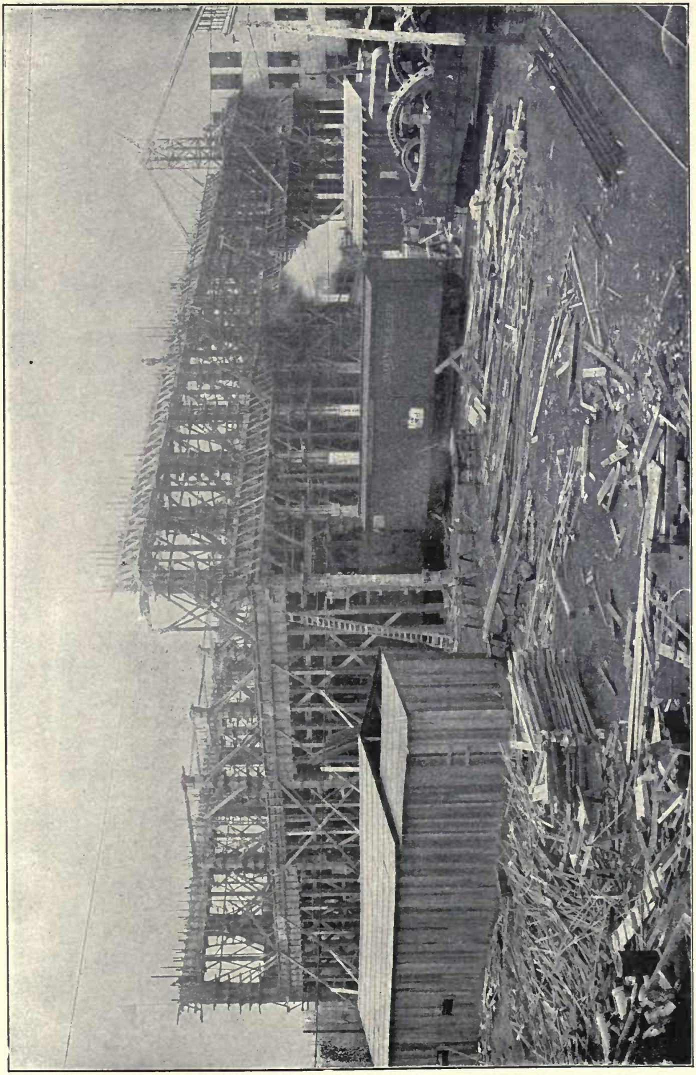


Fig. 42.—Photograph Showing Form Construction. (*See p.* 100.)

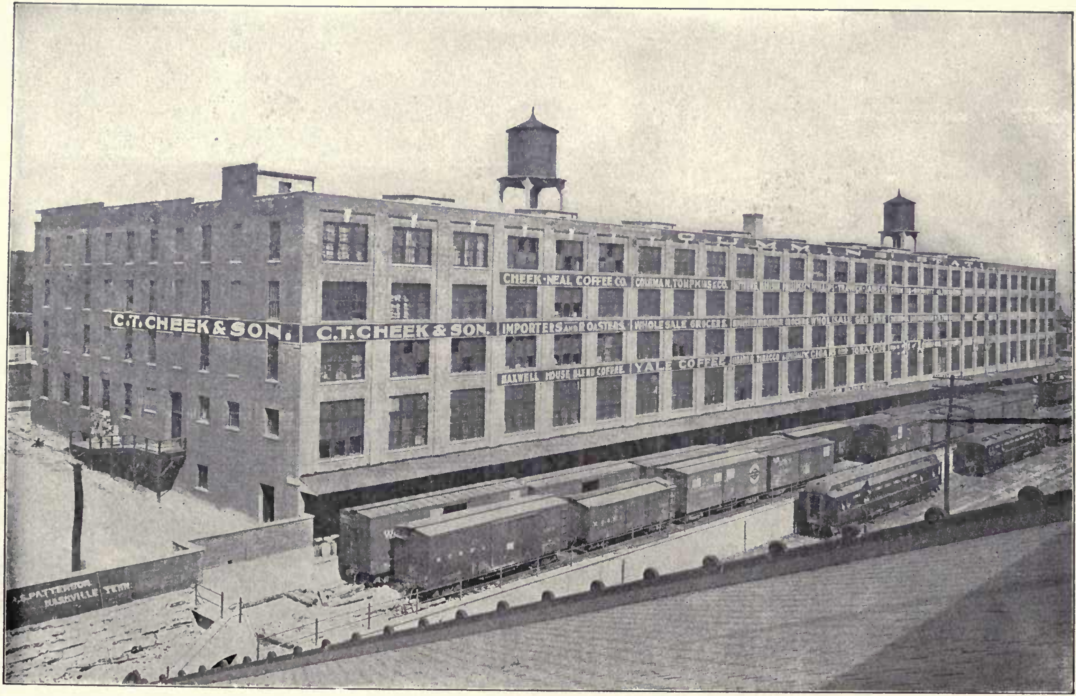


Fig. 43.—Wholesale Merchants' Warehouse, Nashville. (*See p.* 103.)

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 apart in one direction and 16 feet 7½ inches in the other. In general, the beams run lengthwise of the

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* See Fig. 103, page 179.

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 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.

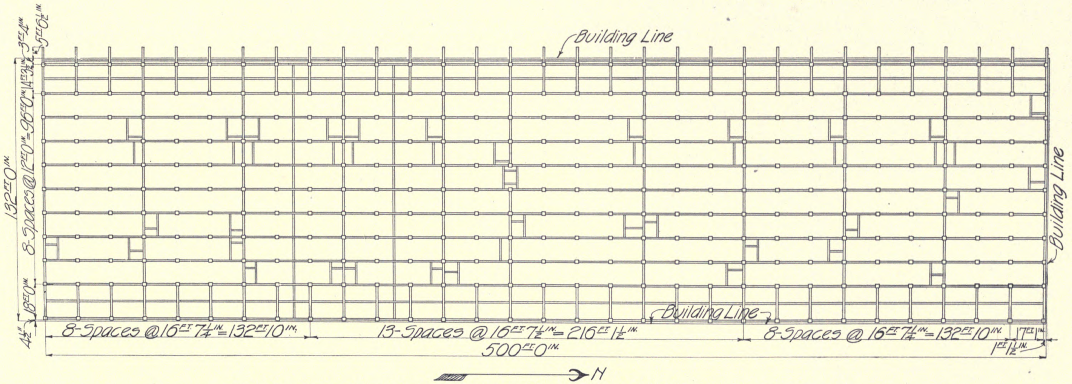


Fig. 44.—Typical Floor Plan of Wholesale Merchants' Warehouse. (*See p.* 103.)

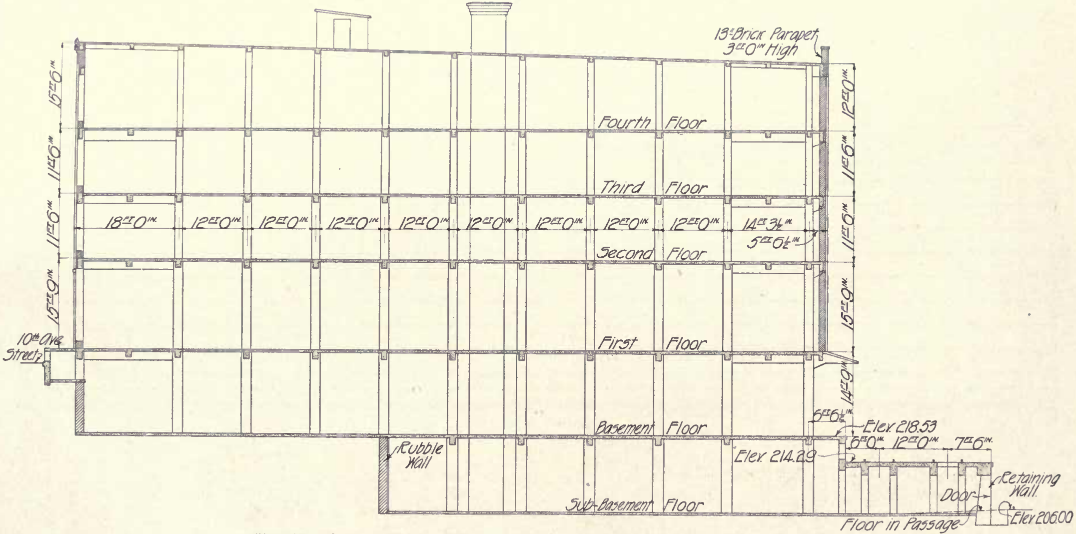


Fig. 45.—Cross-Section of Wholesale Merchants' Warehouse. (*See p.* 104.)

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 somewhat 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.

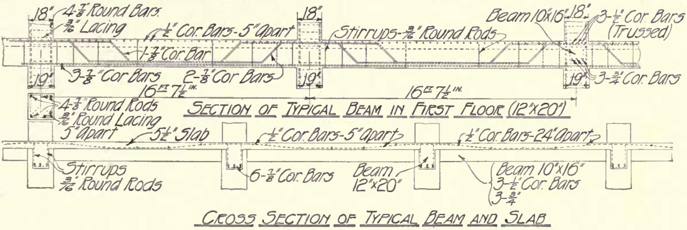


Fig. 46.—Details of Reinforcement of Typical Beam and Slab. (*See p.* 104.)

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 window 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.

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.

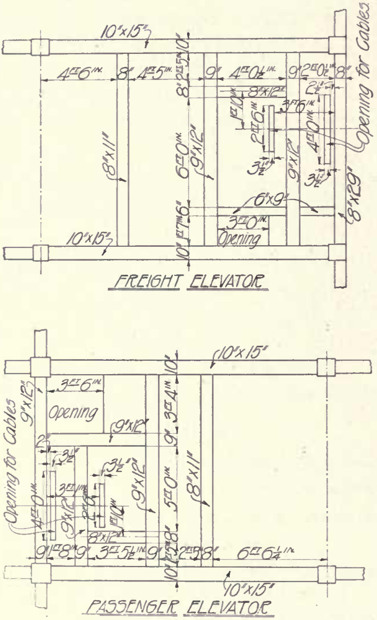


Fig. 47.—Detail of Framing at Elevator. (*See p.* 108.)

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 specially 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.

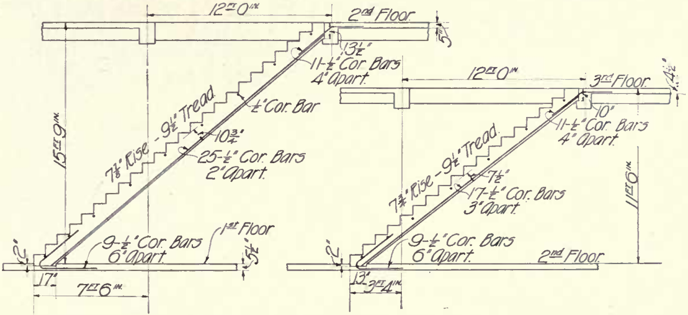


Fig. 48.—Details of Stairs. (*See p.* 109.)

Two railroad tracks are carried by the trestle and most of the surface is floored over, the slabs being sloped to drains.

CONSTRUCTION.

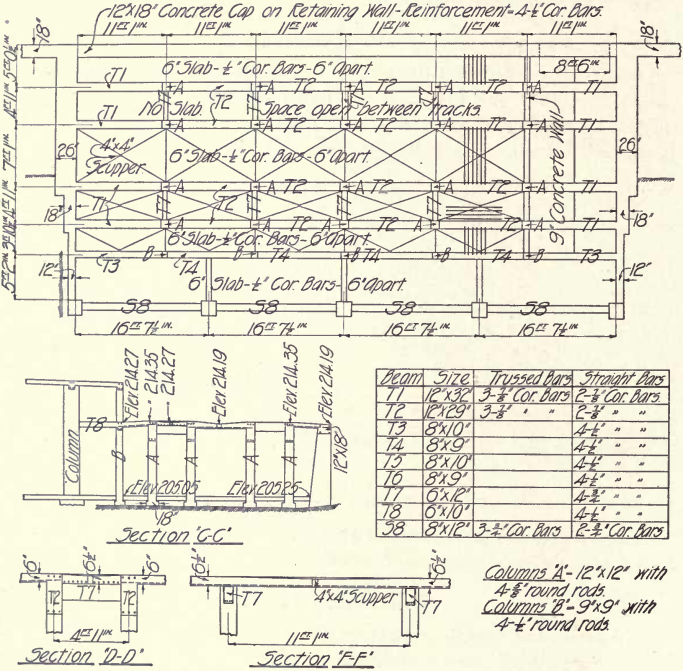
The warehouse was about eight months in building, and during this period 11,830 cubic yards of concrete were placed; of this 8,398 cubic yards were reinforced and 3,432 cubic yards plain. The latter figures included the blocks. The mortar finish for the floors measured in addition 510 cubic yards.

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.

The concrete was supplied to the different parts of the building by a cableway which is clearly seen in Fig. 50.



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 cable was supported by the two towers located at each end of the 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

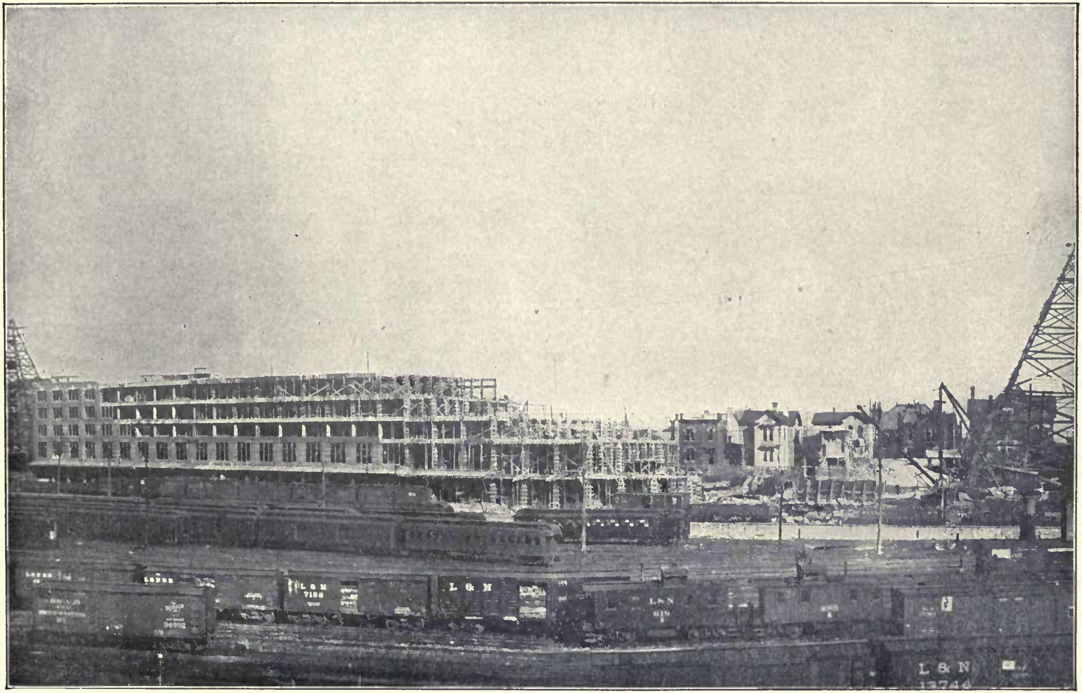


Fig. 50.—Rear View of Wholesale Merchants' Warehouse During Construction. (*See p.* 110.)

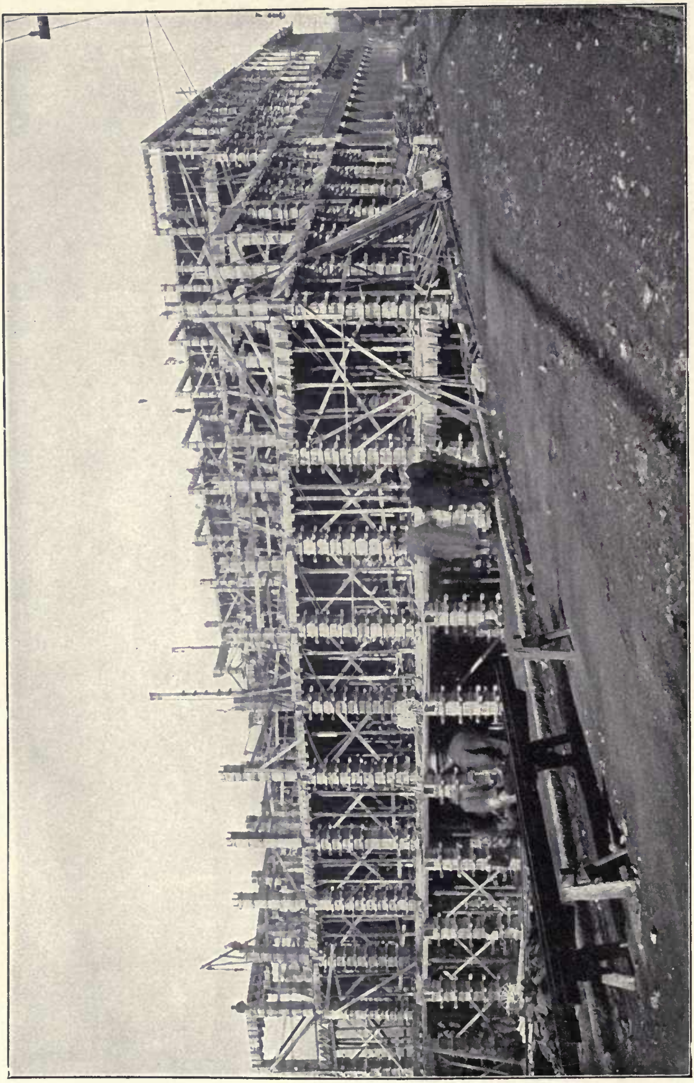


Fig. 51.—End View of Wholesale Merchants' Warehouse Under Construction. (*See p.* 110.)

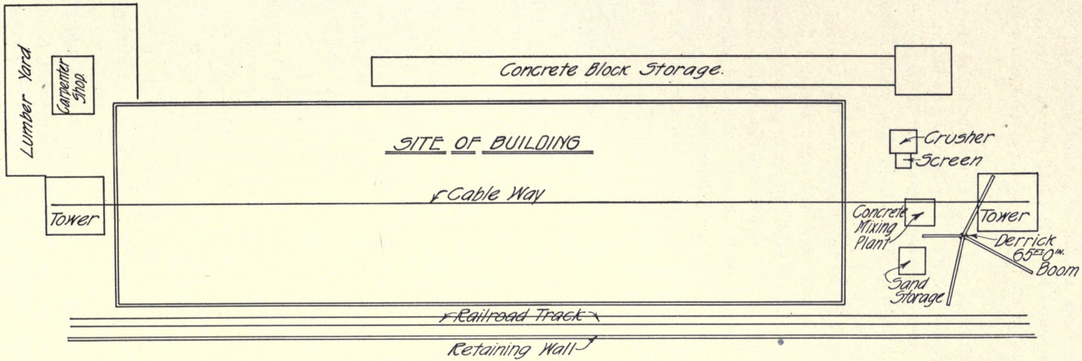


Fig. 52.—Plan of Construction Plant. (*See p.* 110.)

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.

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.

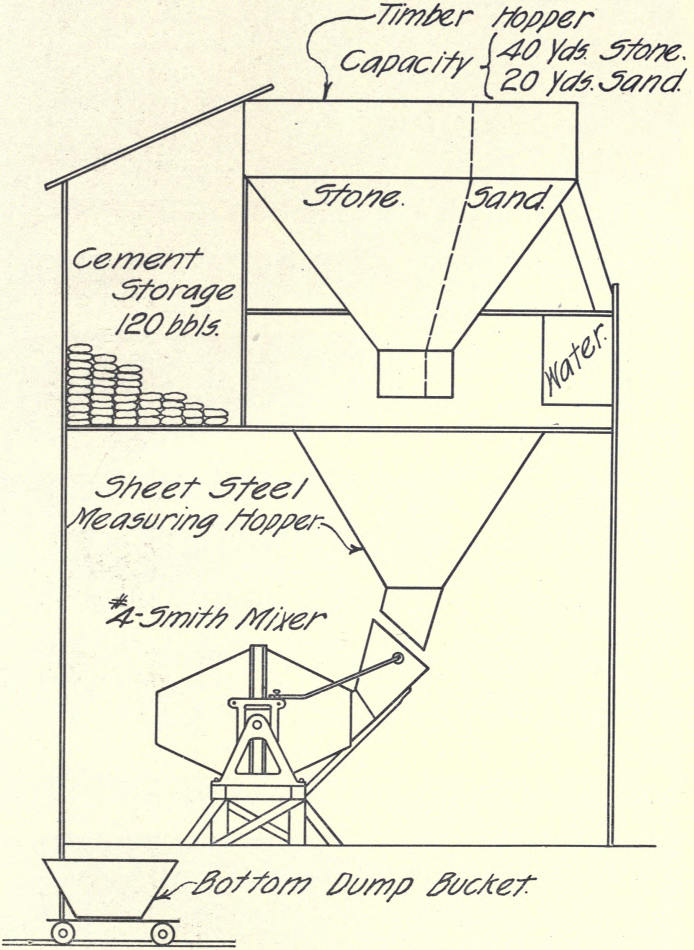


Fig. 53.—Mixing Plant. (*See p.* 114.)

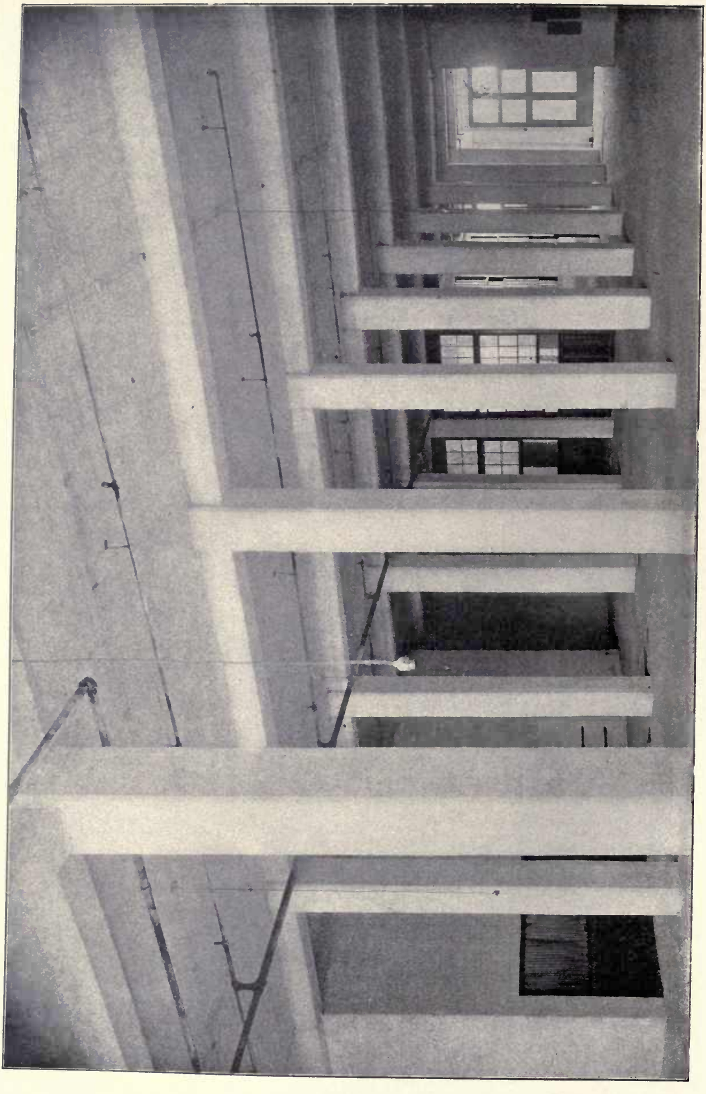


Fig. 54.—Interior of Wholesale Merchants' Warehouse. (*See p.* 117.)

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.

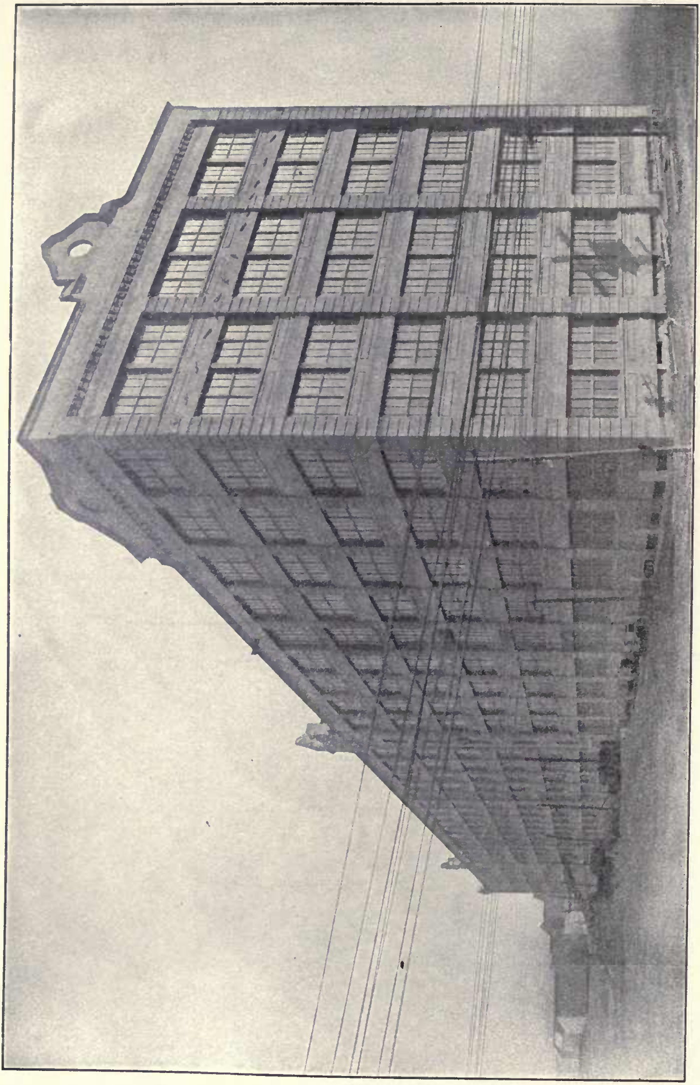


Fig. 55.—Bush Model Factory No. 2. (*See p.* 119.)

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, from 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.

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

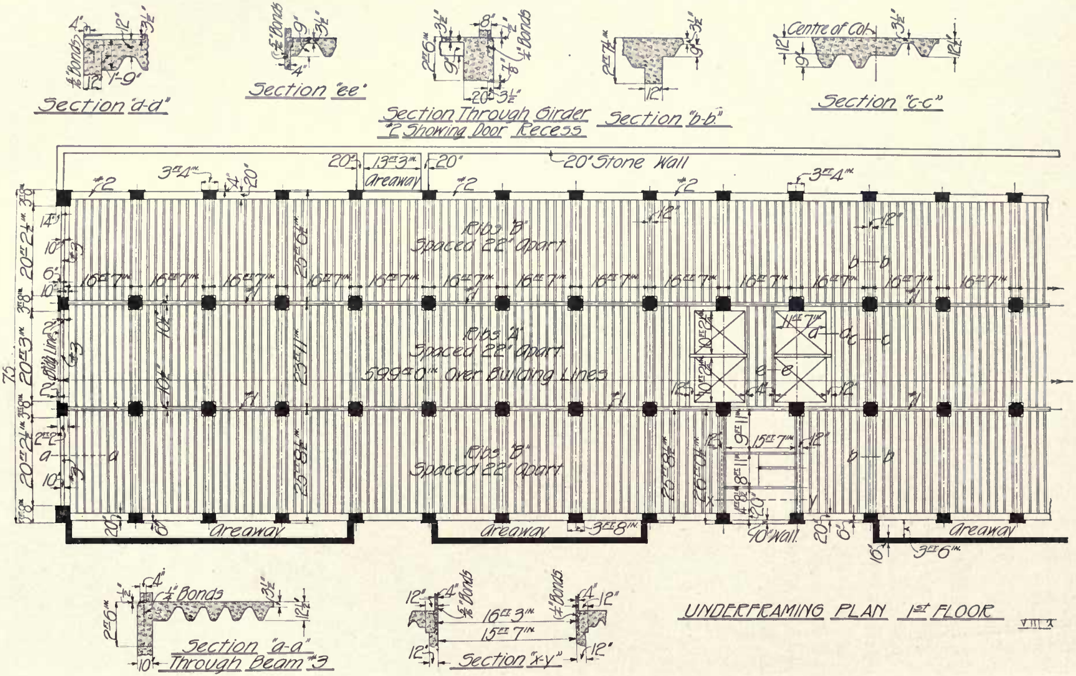


Fig. 56.—General Floor Plan of Bush Factory No. 2. (*See p.* 119.)

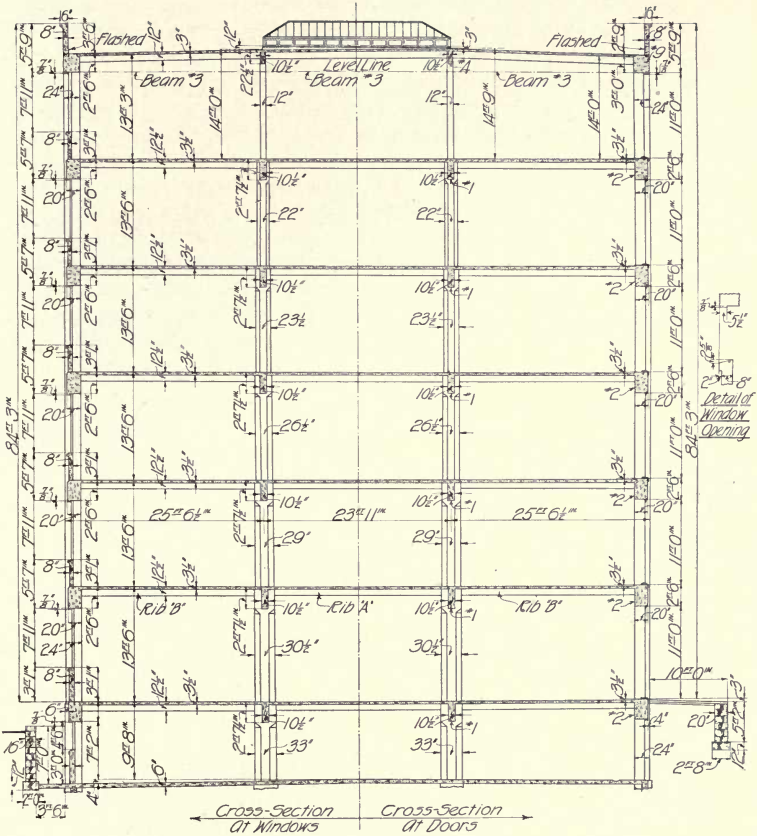


Fig. 57.—Sectional Elevation of Bush Factory No. 2. (*See p.* 119.)

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 rodding 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 performed

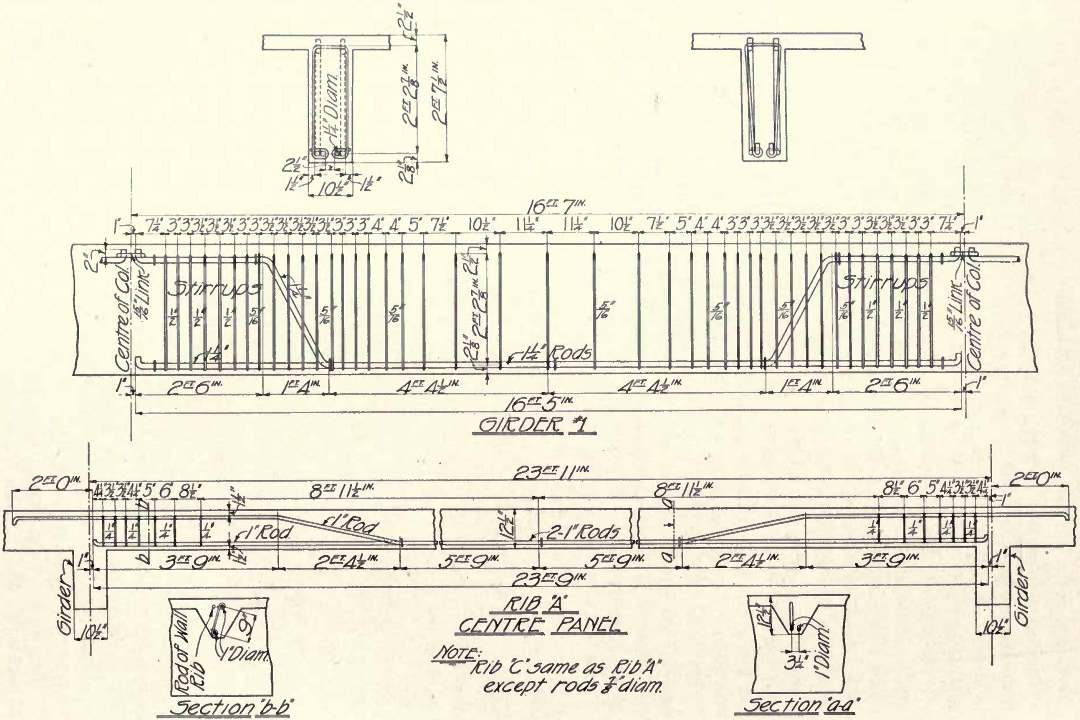


Fig. 58.—Details of Floor Design. (See p. 123.)

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, 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

Fig. 59.—View of Interior of Bush Model Factory No. 2. *(See p. 123.)*

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.

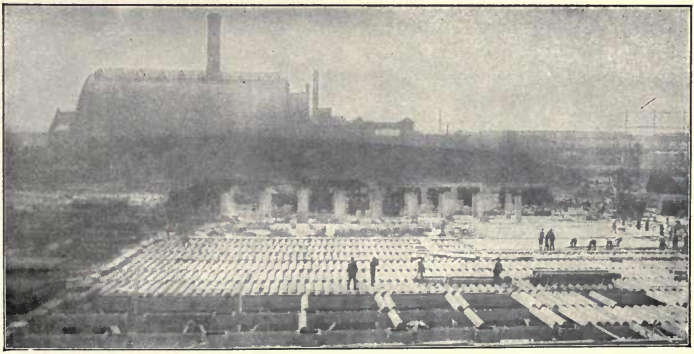


Fig. 61.—View Illustrating Form Construction for Bush Terminal Factory. (*See p. 127.*)

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.

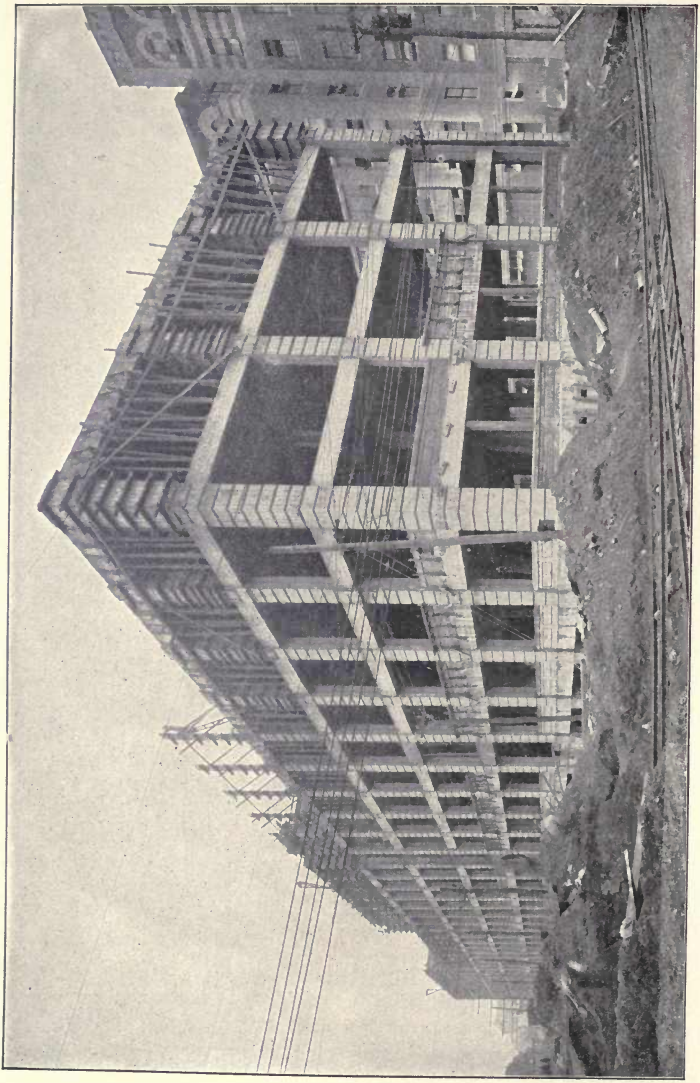


Fig. 60.—Bush Terminal Factory No. 2 Under Construction. (*See p. 127.*)

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.

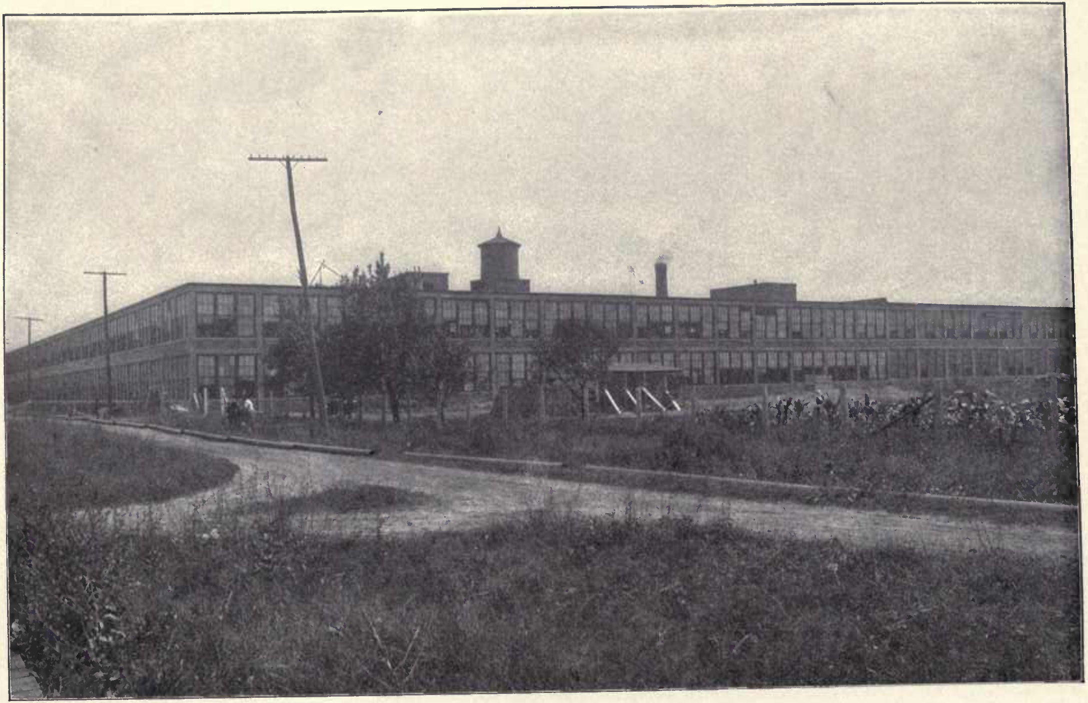


Fig. 62.—Packard Motor Car Factory. (*See p.* 131.)

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

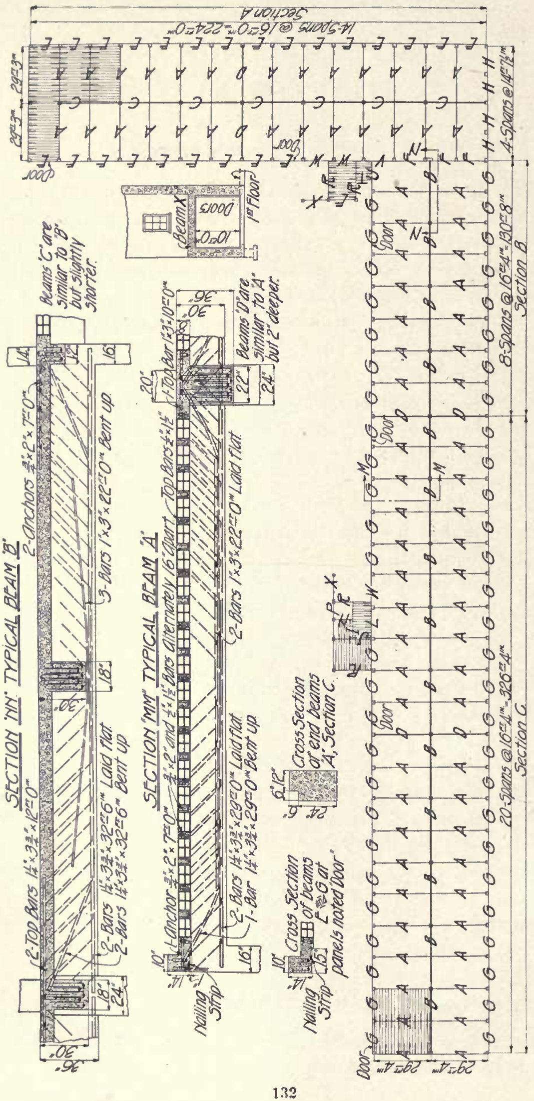


Fig. 63.—Floor Plan and Beam Details in Packard Factory. (*See p. 131.*)

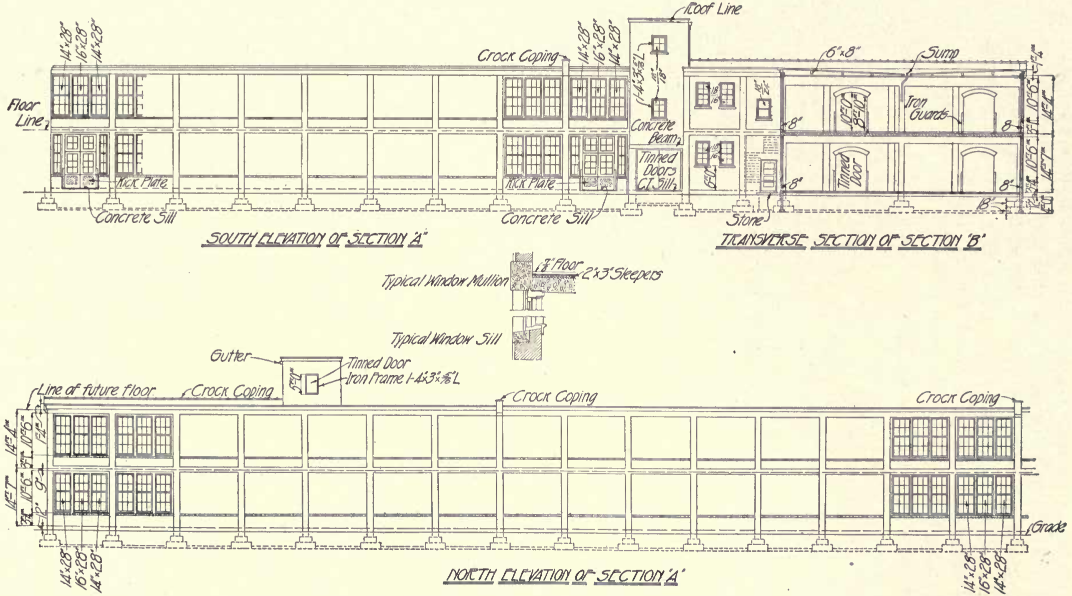


Fig. 64.—Longitudinal Elevations and Sections of Packard Factory. (See p. 131.)

hard to receive the concrete. On top of this porous layer, a 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.

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* See Illustration, Fig. 107, page 183.

† Figured by the parabolic formula, or nearly 600 pounds by the straight-line formula.

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 object 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.

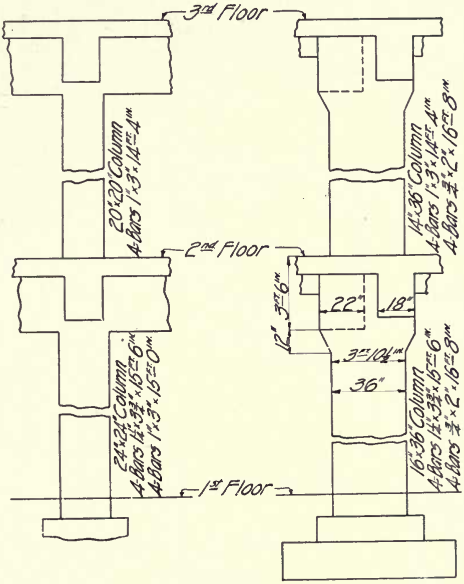

Fig. 65.—Typical Interior Columns in Packard Factory. (*See p.* 136.)

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.

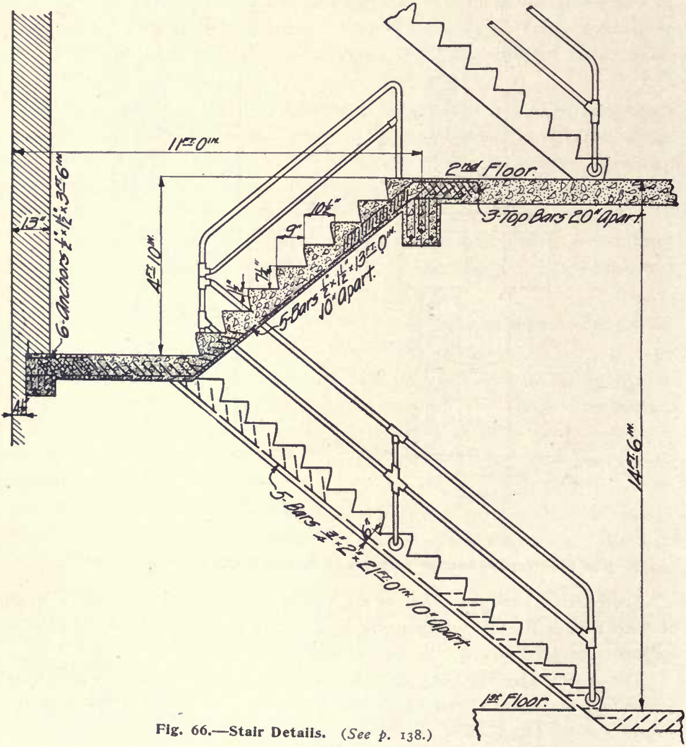

Fig. 66.—Stair Details. (*See p.* 138.)

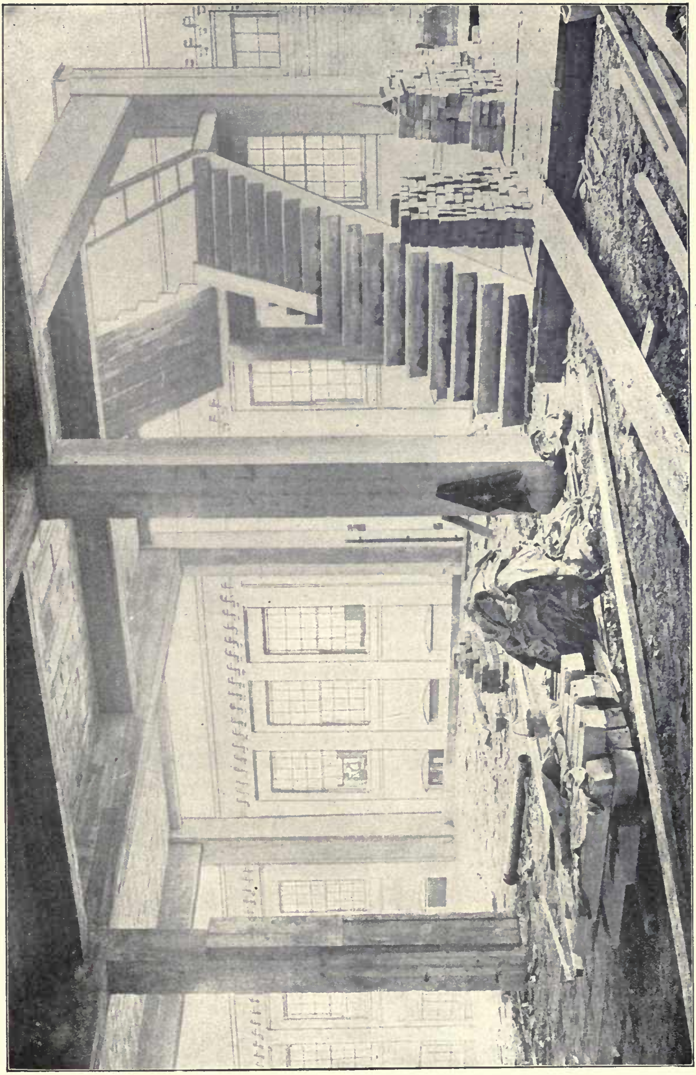

Fig. 67.—View of Stairs. *(See p. 138.)*

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).

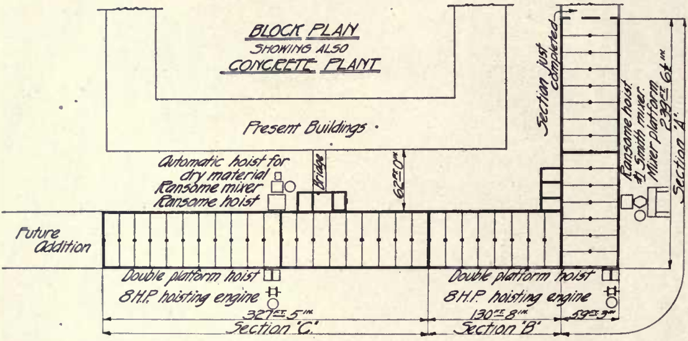

Fig. 68.—Plan of Construction Plant. (*See p.* 138.)

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 proportion 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

Fig. 69.—Concrete and Tile Floor under construction. (*See p.* 138.)

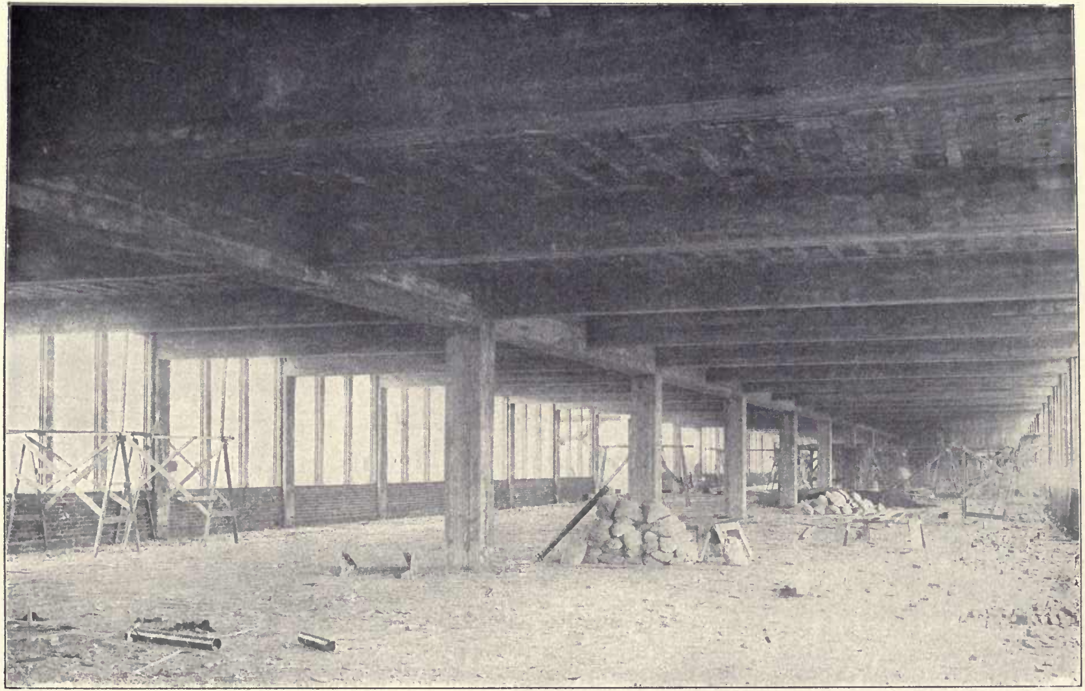

Fig. 70.—Interior View of Packard Factory under construction. (*See p.* 138.)

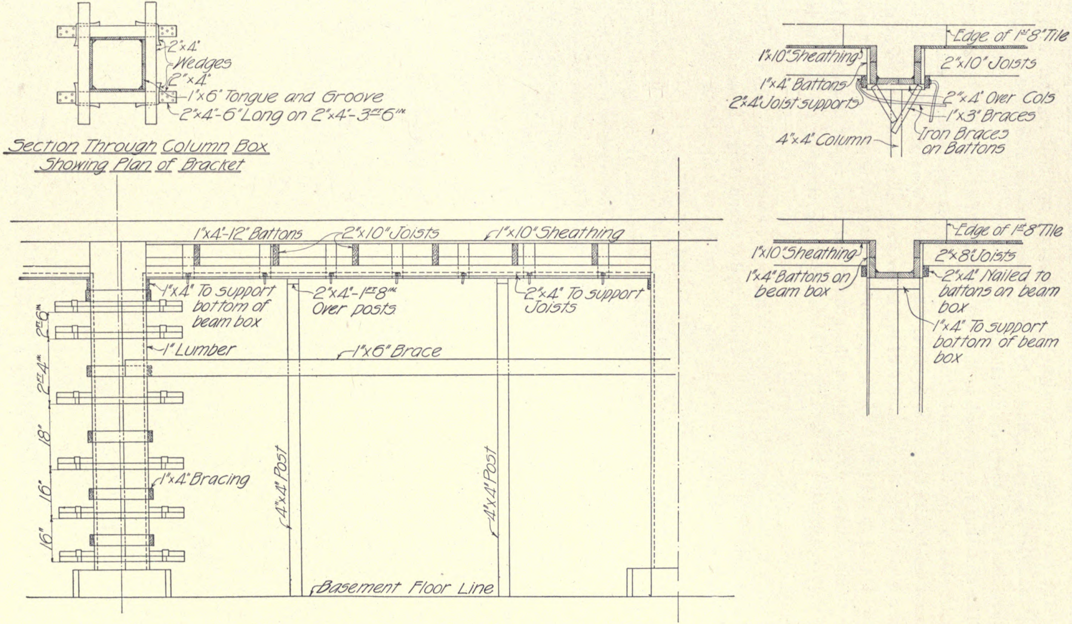

Fig. 71.—Detail of Form Construction. (*See p.* 138.)

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.

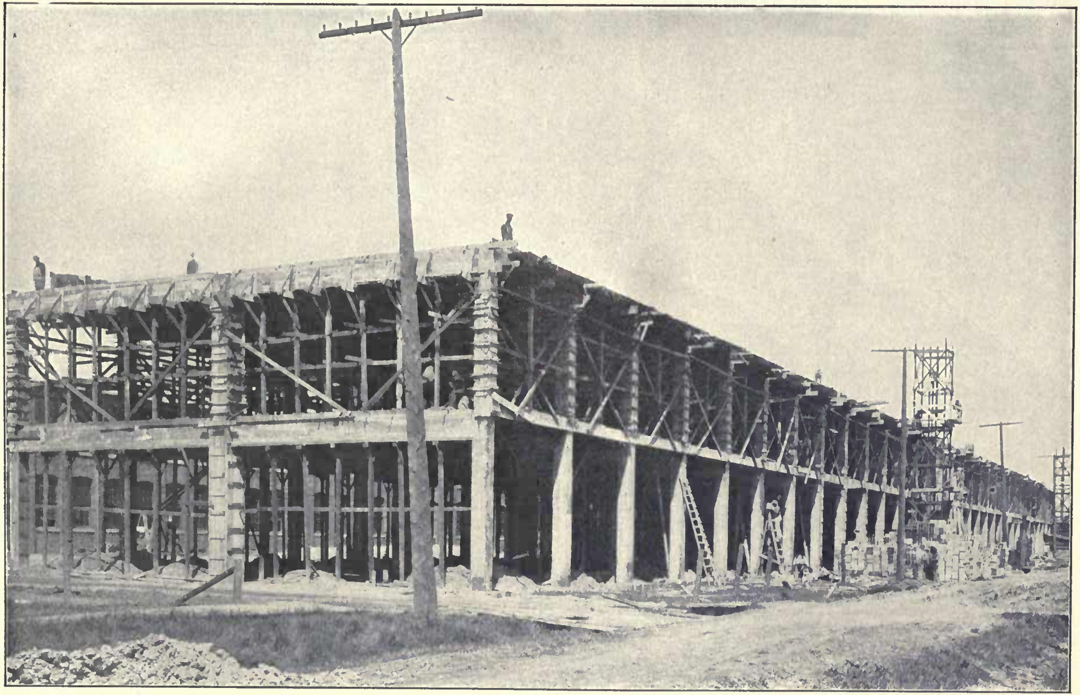

Fig. 72.—Exterior View of Packard Factory Under Construction, Showing Second Floor Centering in Place. (*See p.* 142.)

Fig. 73.—Exterior View of Packard Factory Nearly Completed. (*See p.* 142.)

Fig. 74.—Interior View of Packard Factory Completed. (*See p.* 138.)

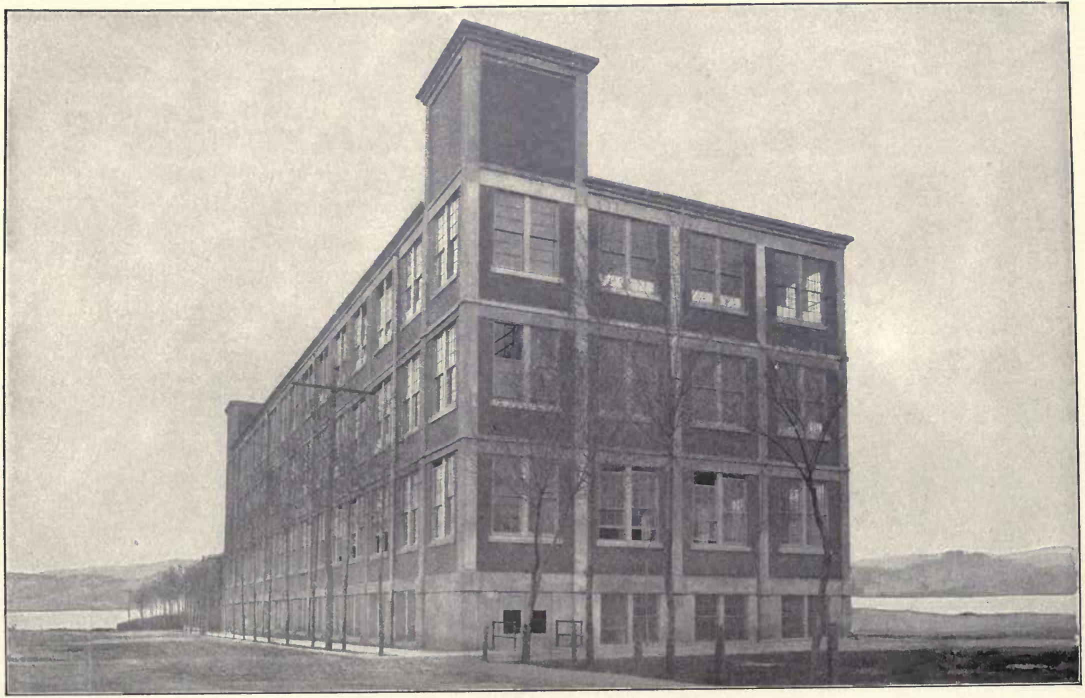

Fig. 75.—Textile Machine Works. (*See p.* 147.)

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 dressed white pine were built around them. The concrete of the column was then poured in the

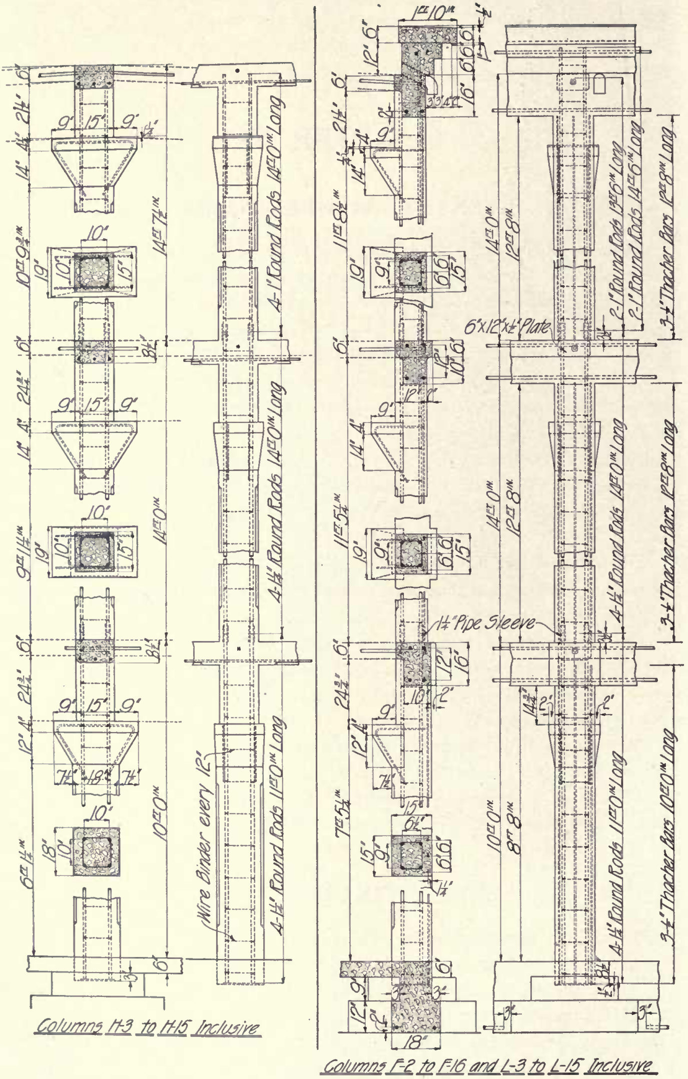

Fig. 76.—Details of Columns in Textile Machine Shop (See Fig. 78). (*See p.* 147.)

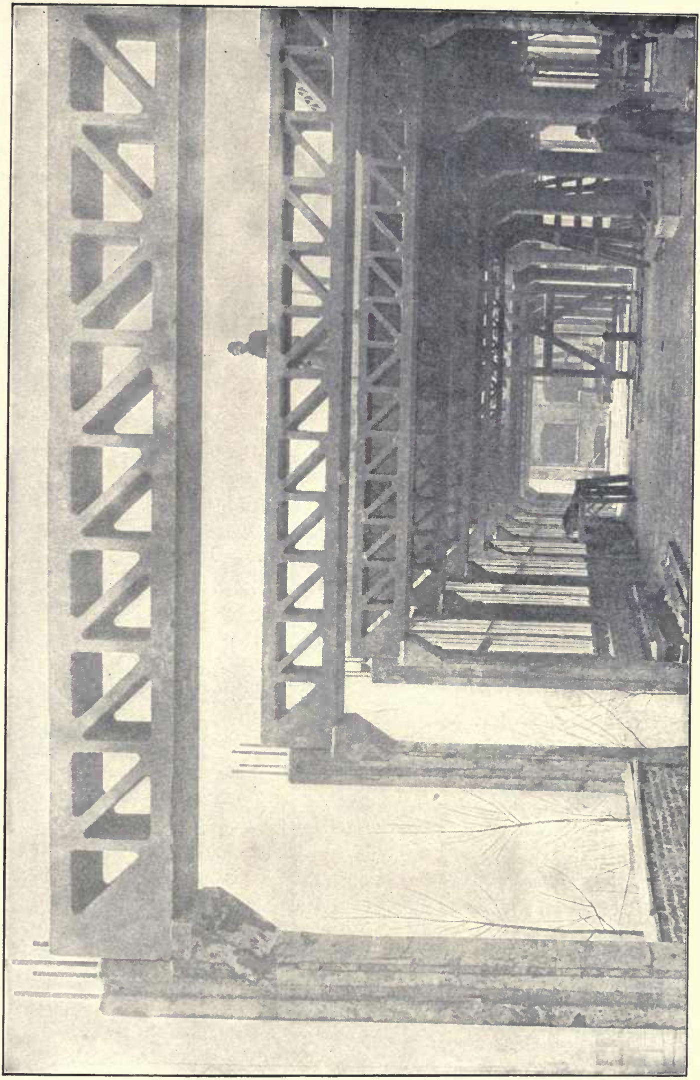

Fig. 77.—View of Visintini Columns and Girders in Textile Machine Shop. *(See p. 151.)*

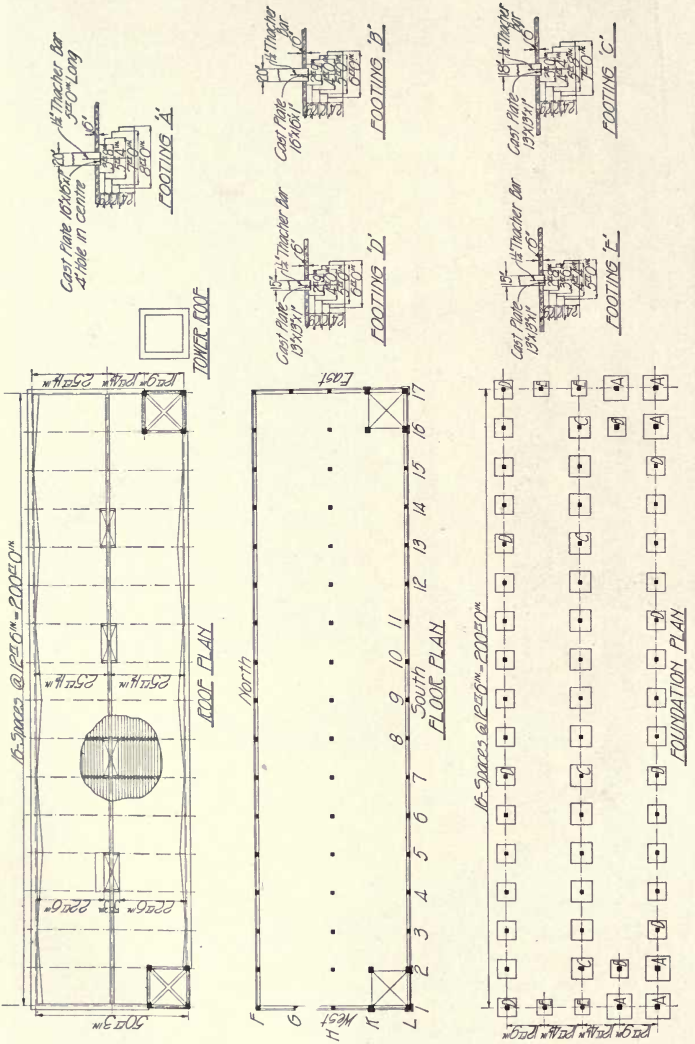

Fig. 78.—General Plans of Textile Machine Shop.

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 of 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 designed and

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* See illustration, Fig. 102, page 179.

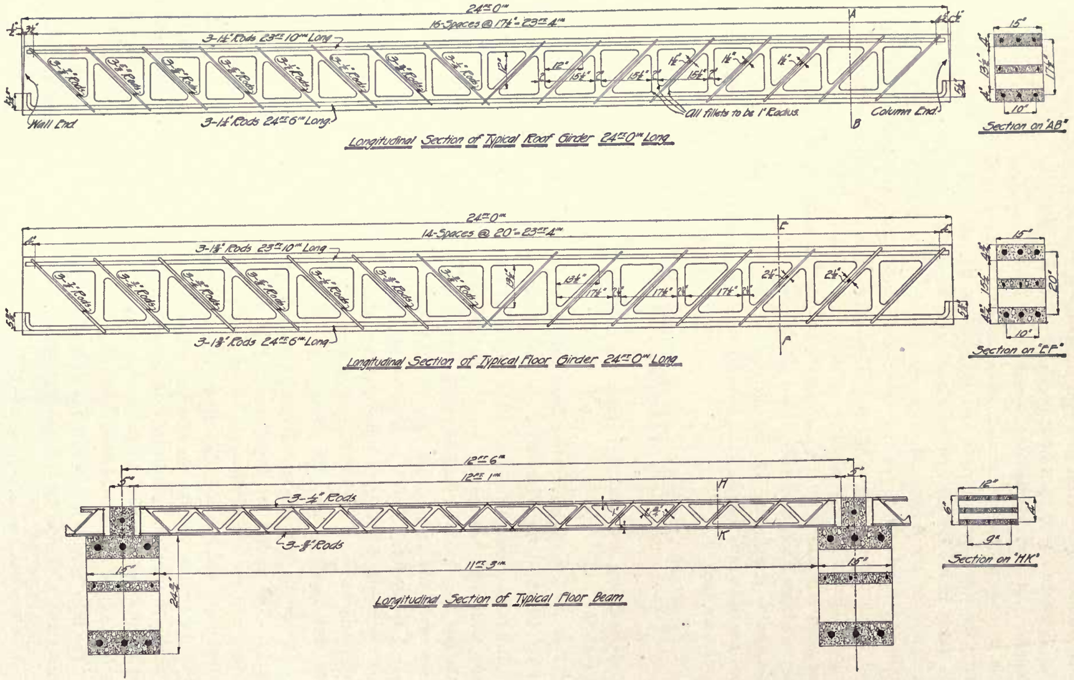

Fig. 79.—Details of Visintini Girders and Floor Beams. (*See p.* 151.)

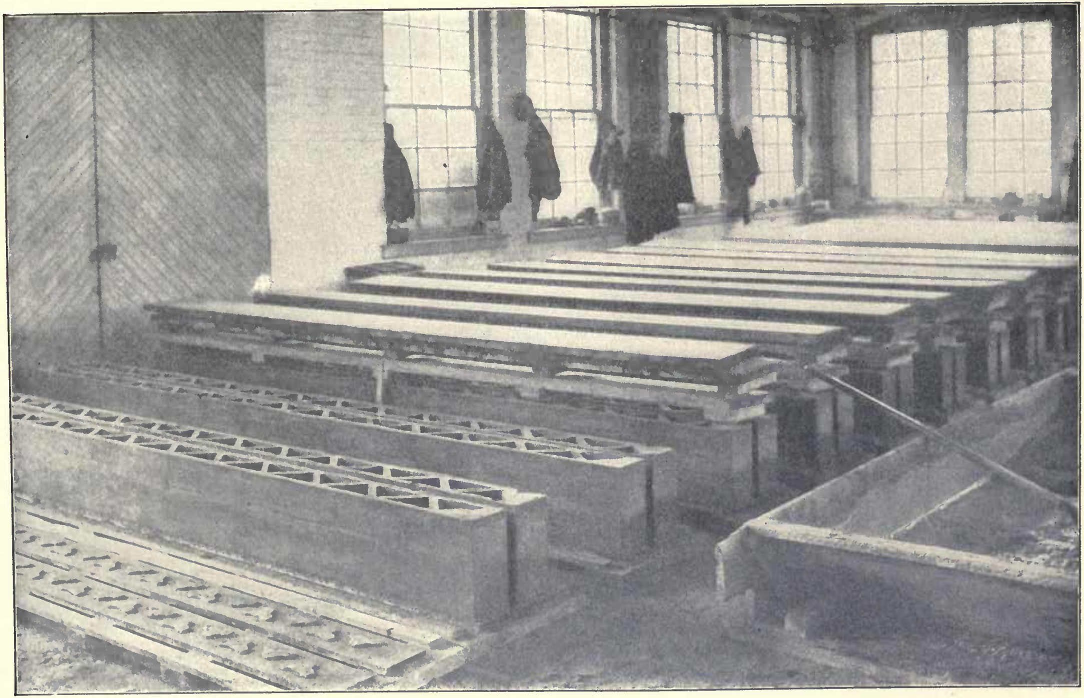

Fig. 80.—Molding of Visintini Girders. (*See p.* 155.)

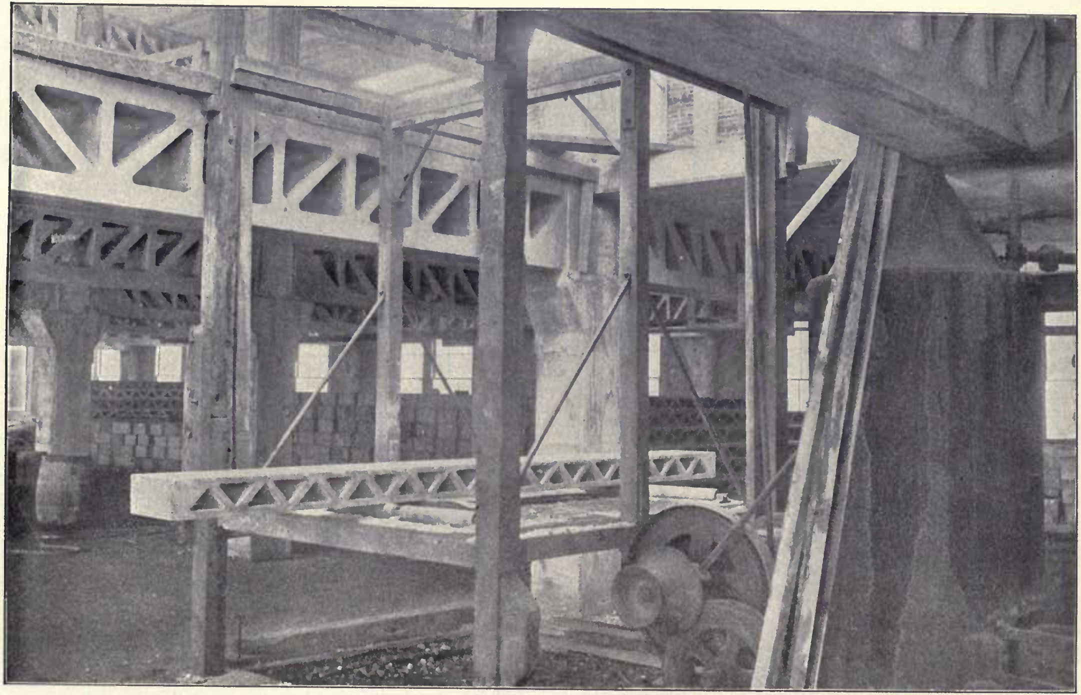

Fig. 81.—Interior View of Textile Machine Shop under construction. *(See p. 155.)*

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 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.

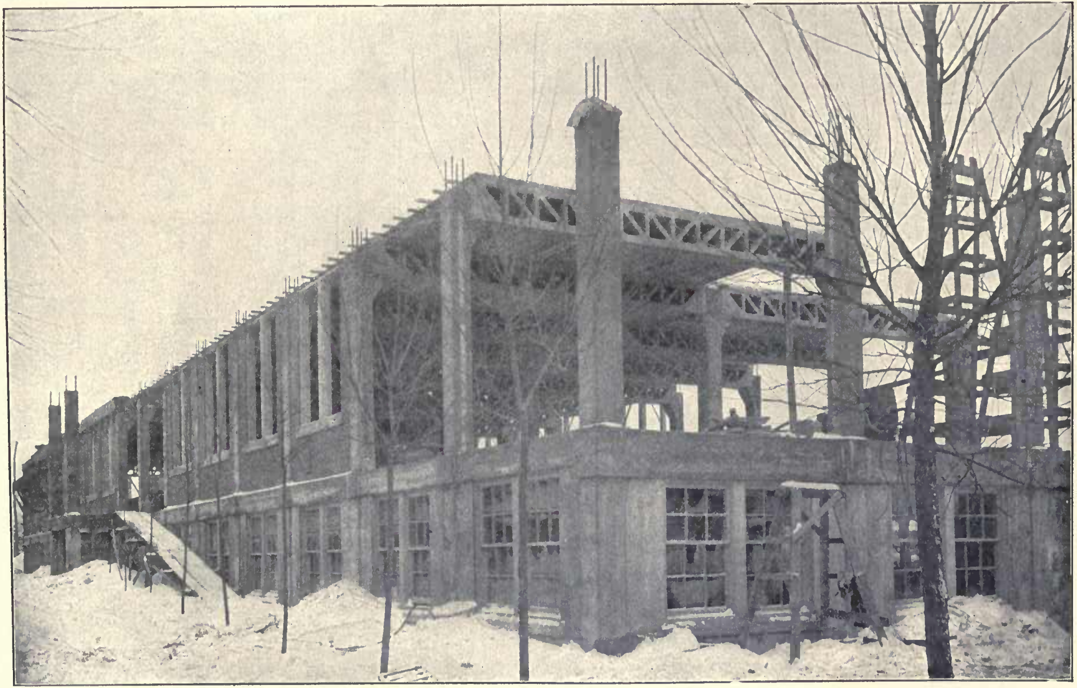

Fig. 82.—Textile Machine Shop under construction. (*See p.* 155.)

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 scrubbing, 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 specially 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.

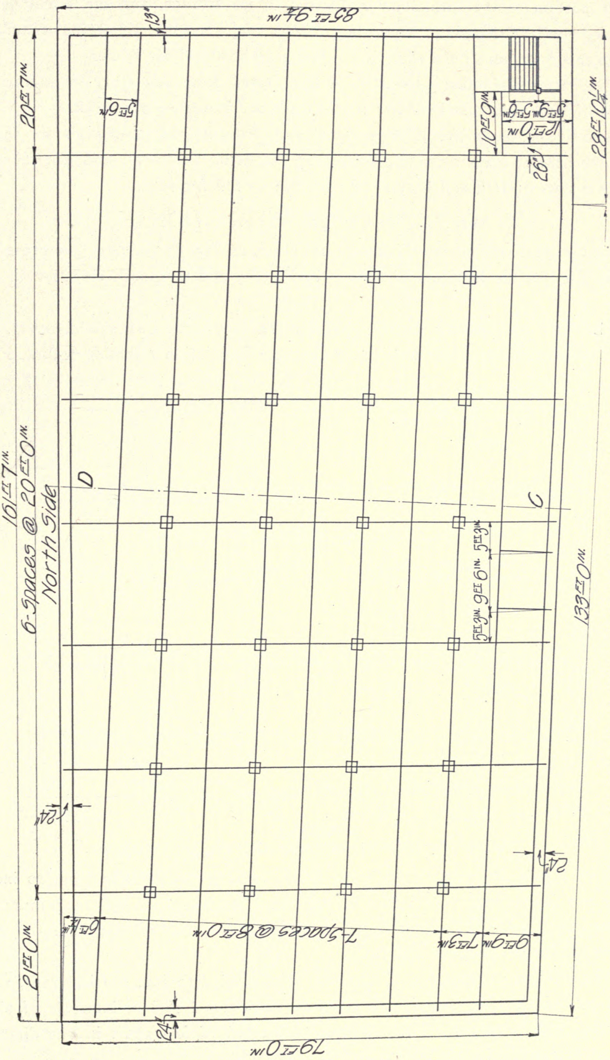

Fig. 83.—General Plan of Forbes Cold Storage Warehouse. (*See p.* 160.)

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. 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.

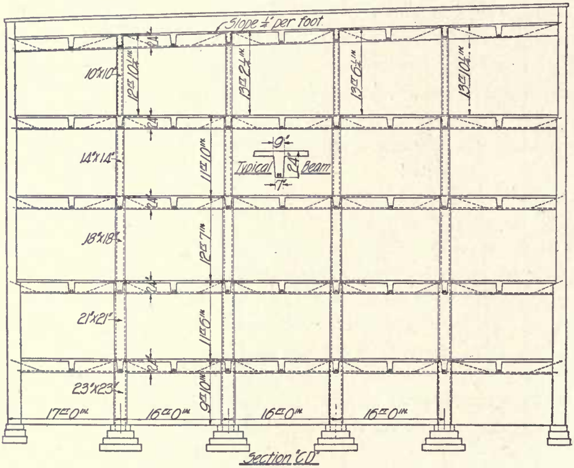

Fig. 84.—Cross-Section of Forbes Cold Storage Warehouse.

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 about 12 inches with wire ties. The columns are located 16 feet apart in one direction and 20 feet apart in the other.

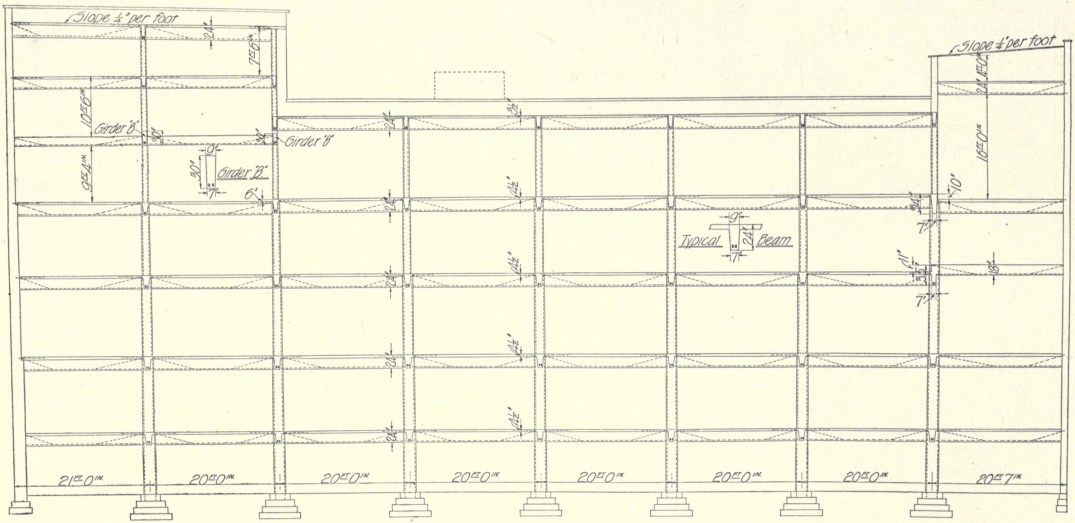

Fig. 85.—Longitudinal Section of Forbes Cold Storage Warehouse. (*See p.* 160.)

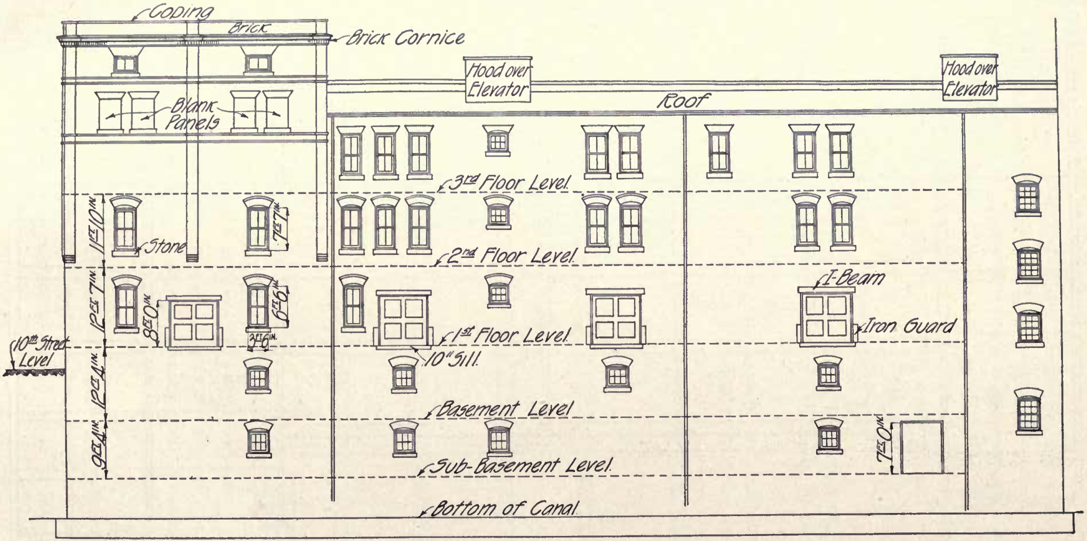

Fig. 86.—South Elevation of Forbes Cold Storage Warehouse. (*See p.* 160.)

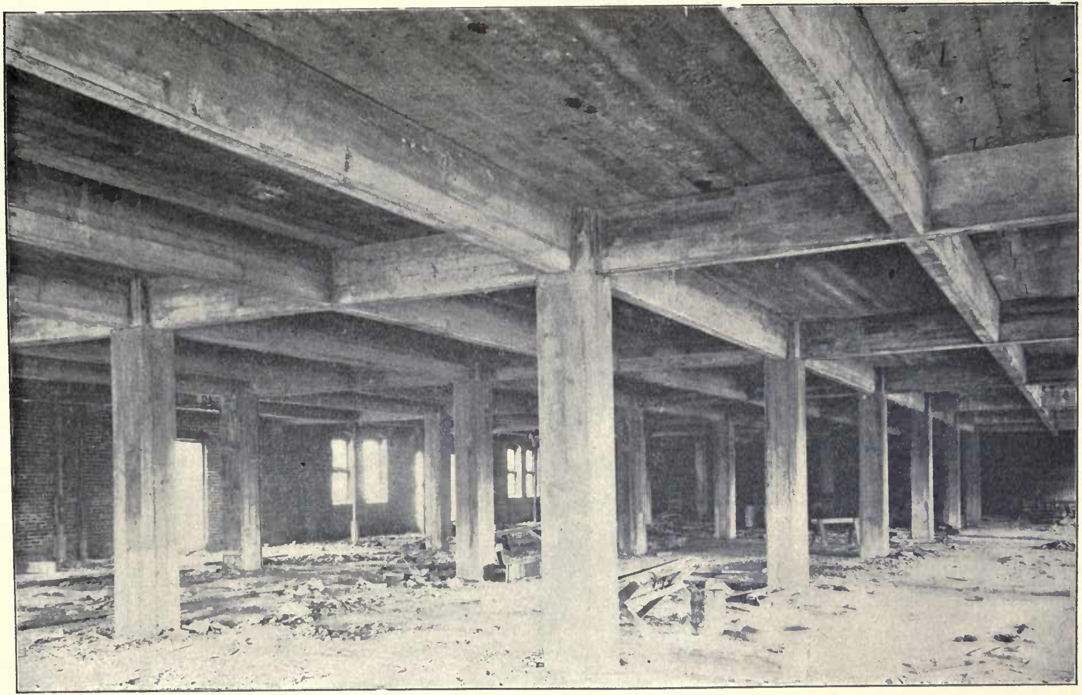

Fig. 87.—Interior View of Forbes Cold Storage Warehouse. (*See p.* 165.)

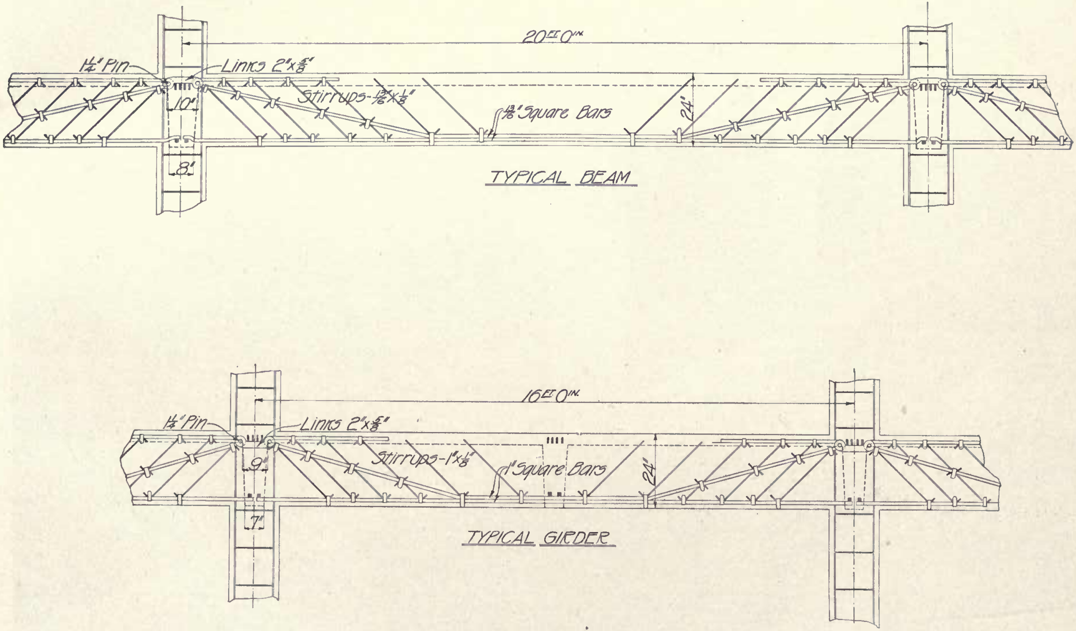

Fig. 88.—Details of Typical Pin-Connected Beam and Girder Reinforcement. (*See p.* 165.)

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.

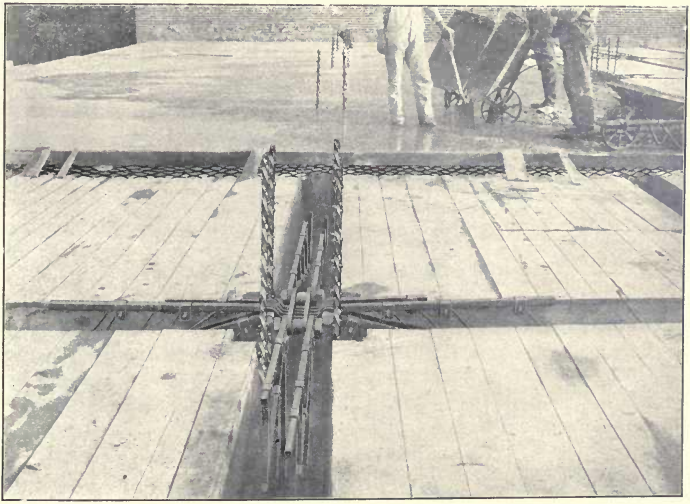

Fig. 89.—Placing of Pin-Connected Girder Frames. *(See p. 167.)*

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.

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

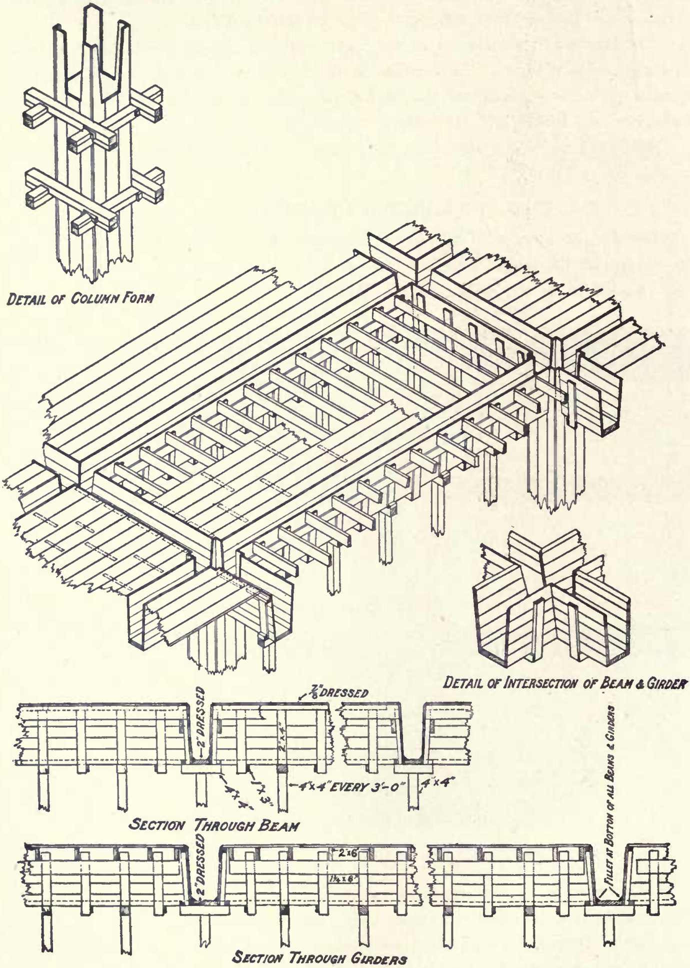

Fig. 90.—Details of Form Construction. (*See p.* 167.)

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.

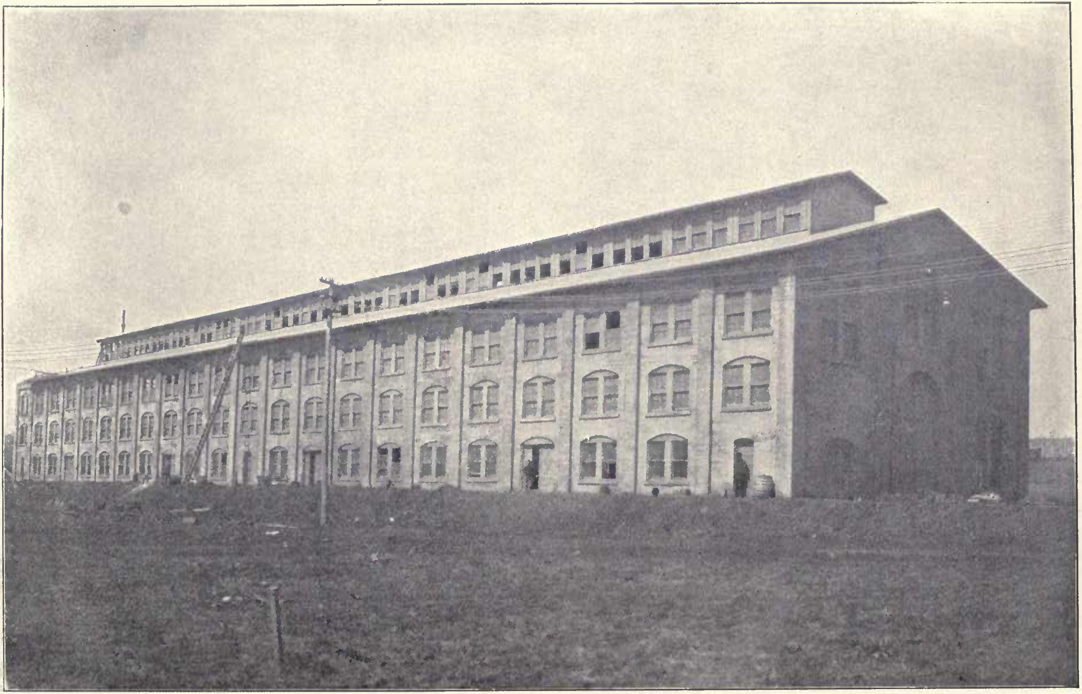

Fig. 91.—Blacksmith and Boiler Shop of the Atlas Portland Cement Company. (*See p.* 169.)

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 were first run up to the full height of the building, as illustrated in the photograph,

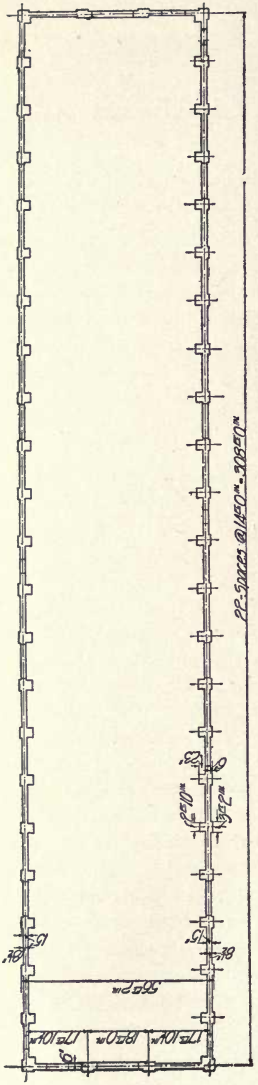

Fig. 92.—Plan of Blacksmith and Boiler Shop of the Atlas Portland Cement Company. (*See p.* 169.)

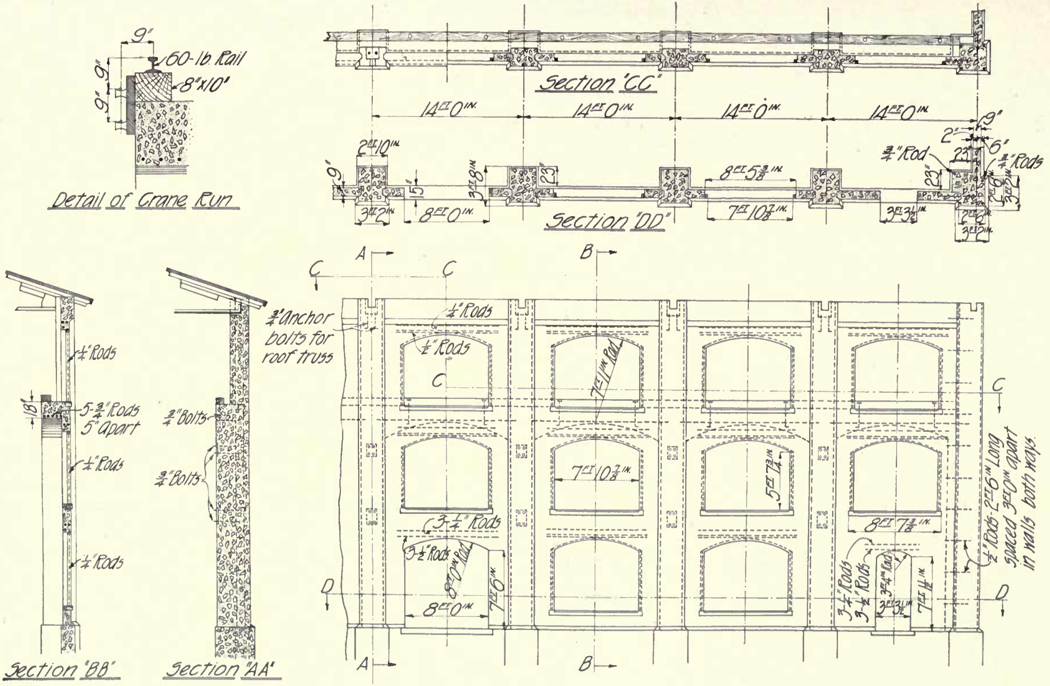

Fig. 93.—South Wall of Blacksmith and Boiler Shop of the Atlas Portland Cement Company. (*See p.* 169.)

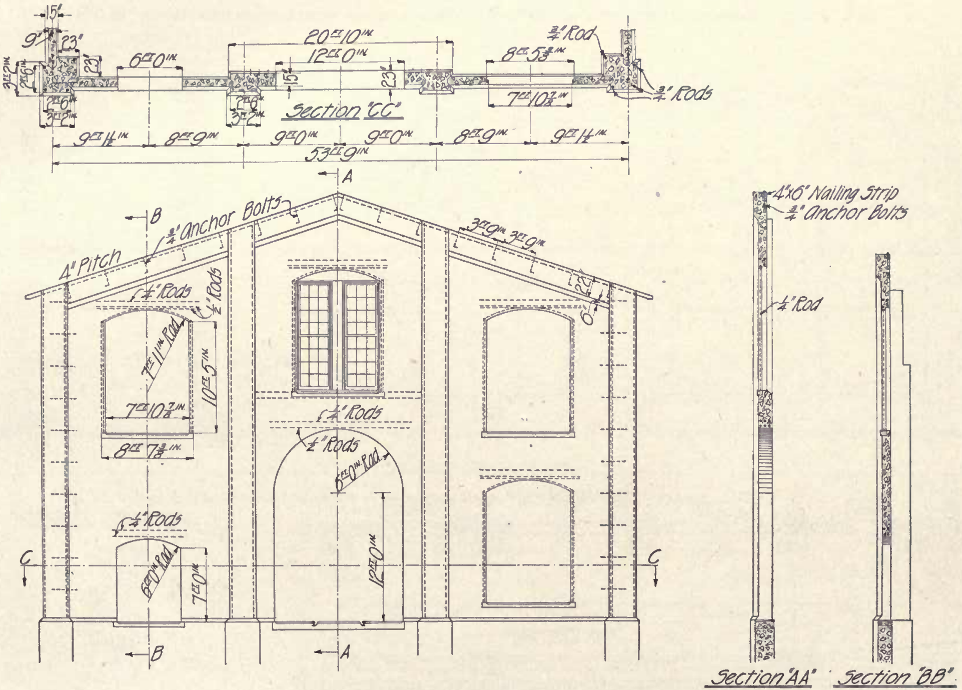

Fig. 94.—East Wall of Blacksmith and Boiler Shop of the Atlas Portland Cement Company. (*See p.* 169.)

Fig. 96.* Then the panel forms were placed, as in Fig. 97, and the concrete poured between them.

The widow 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.

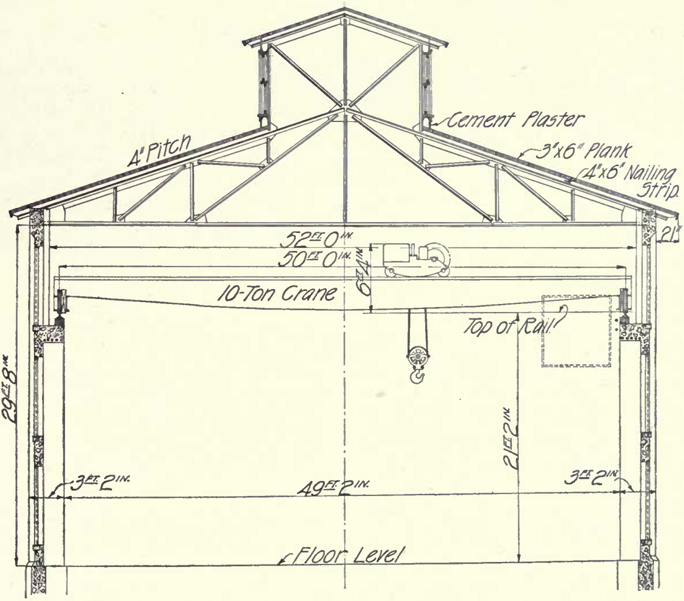

Fig. 95.—Cross Section of Blacksmith and Boiler Shop of the Atlas Portland Cement Company. (*See p.* 169.)

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 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

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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.

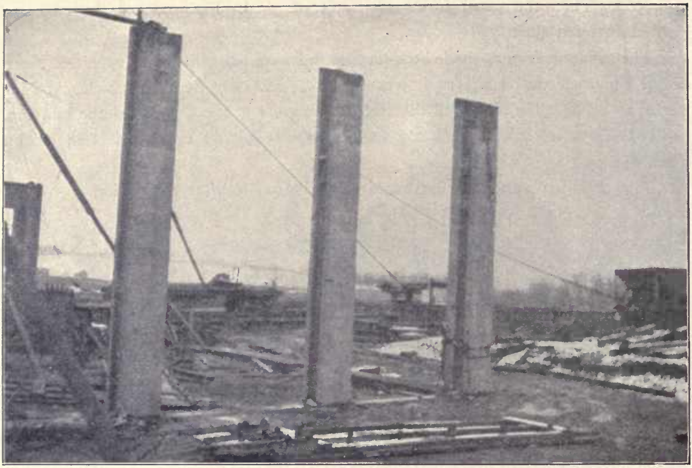


Fig. 96.—Wall Piers for an Atlas Portland Cement Company Building. (*See p.* 173.)

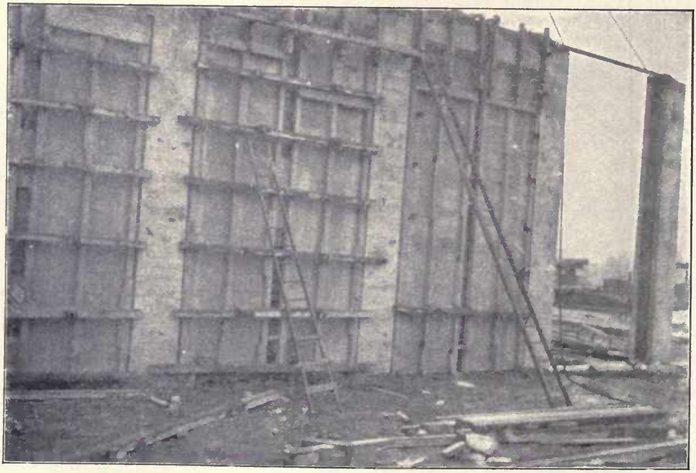


Fig. 97.—Panel Wall Forms for an Atlas Portland Cement Company Building. (*See p.* 173.)

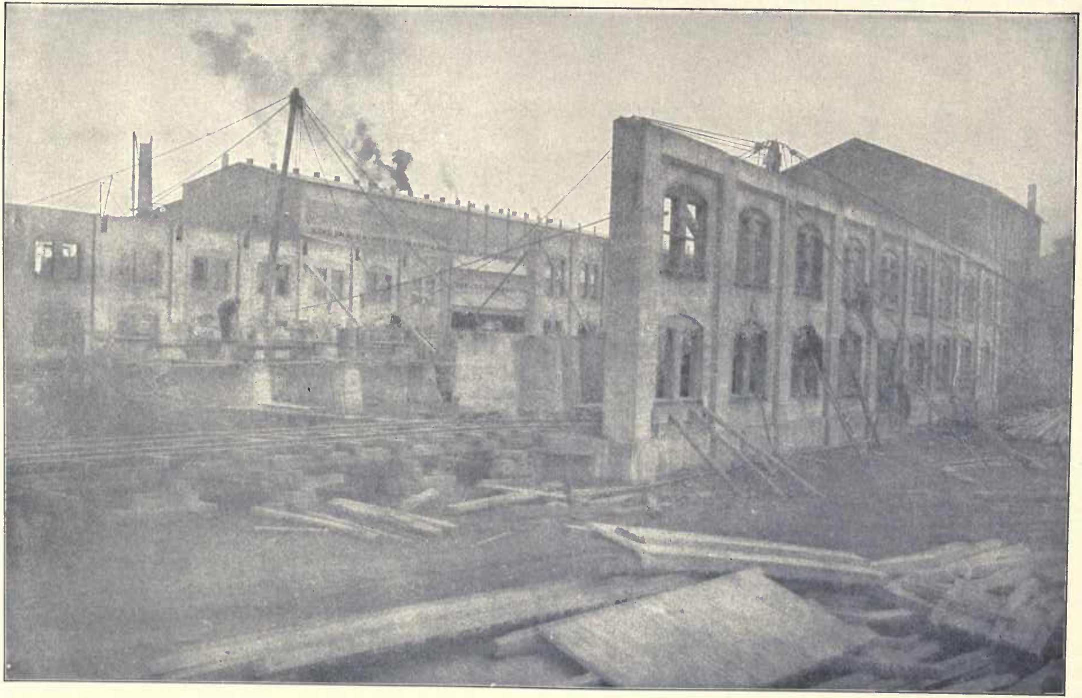


Fig. 98.—Side Wall of an Atlas Portland Cement Company Building. (*See p.* 173.)

$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.

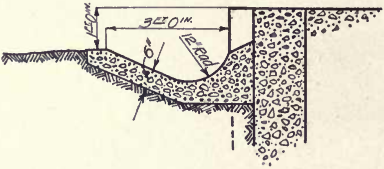


Fig. 99.—Drainage Gutter. (*See p.* 176.)

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.

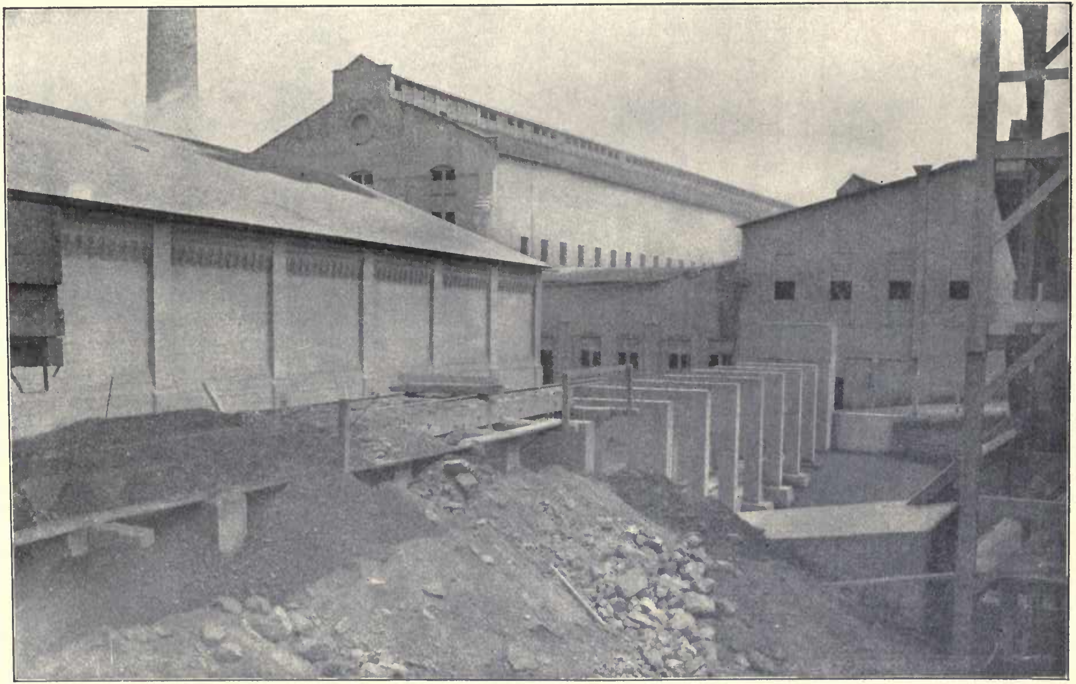


Fig. 100.—Coal Trestle. (*See p.* 176.)

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.

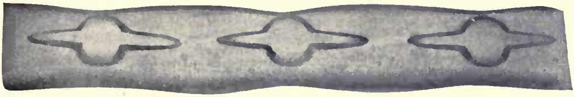


Fig. 102.—Thacher Bulb Bar. (*See p.* 179.)

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:

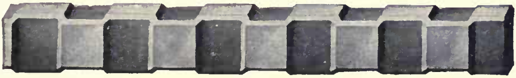


Fig. 103.—Johnson or Corrugated Bar. (*See p.* 179.)

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	¼ in.	⅜ in.	½ in.	⅝ in.	¾ in.	⅞ in.	1 in.	1¼ 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

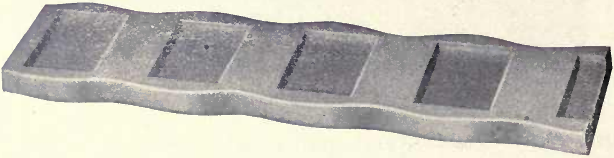
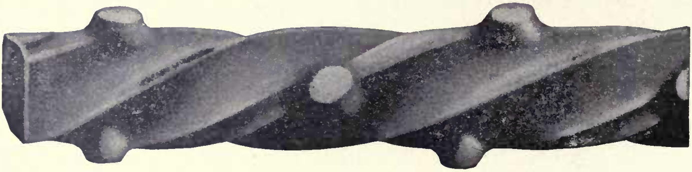


Fig. 104.—Universal Bar. (*See p.* 179.)

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	Ex. 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 "

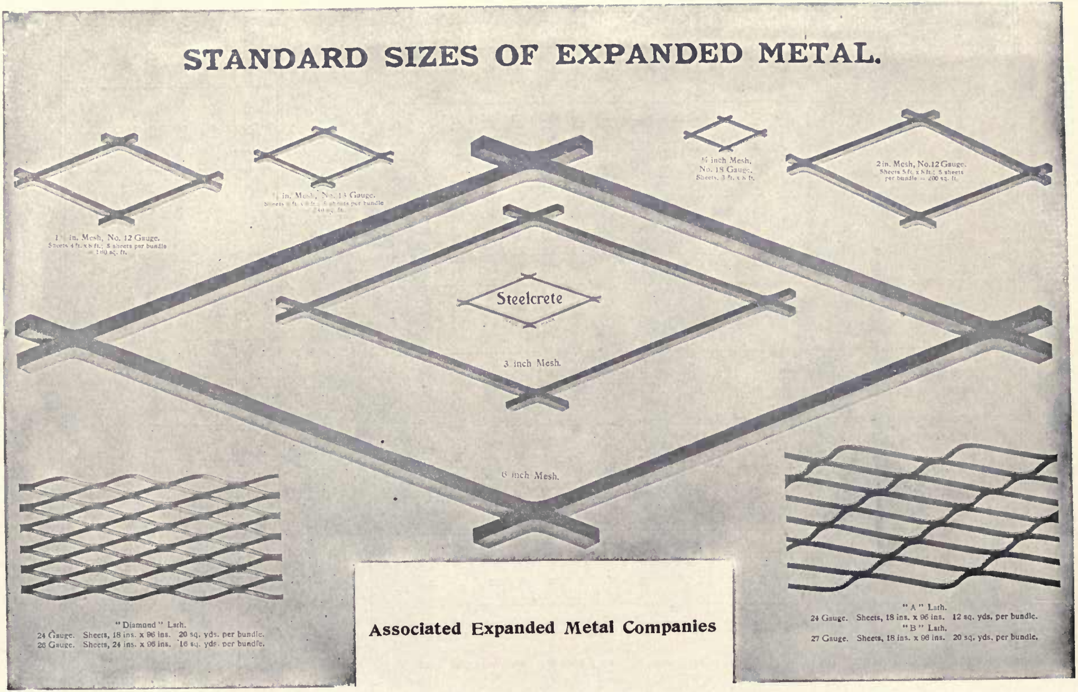


Fig. 108.—Expanded Metal of Standard Mesh. *(See p. 181.)*

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.

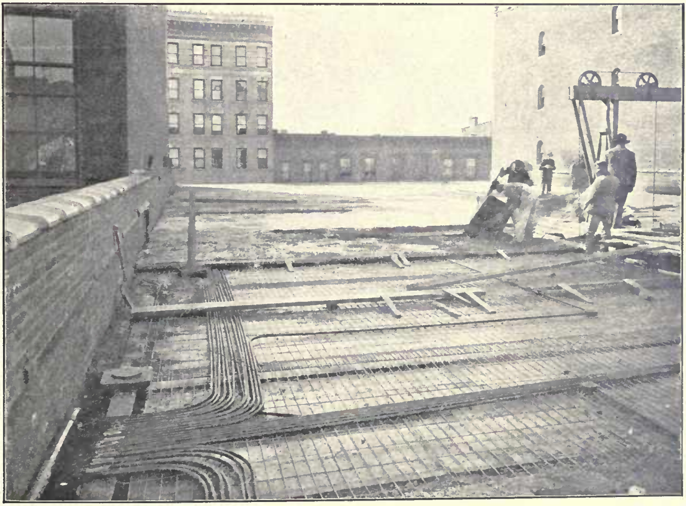
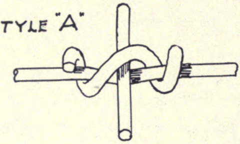


Fig. 109.—Laying Clinton Welded Wire in Decauville Garage, New York. (*See p.* 183.)

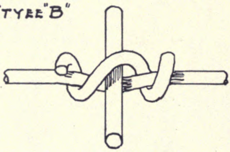
CLINTON WELDED WIRE.—Clinton welded wire fabric, made by the Clinton Wire Cloth Company, is manufactured in different sizes of mesh and different gages of wire. As commonly made, the longitudinal strands are of larger diameter and closer spacing than the cross strands, the latter being chiefly to prevent construction cracks in the concrete. The wires are electrically welded at every intersection.

STYLE "A"



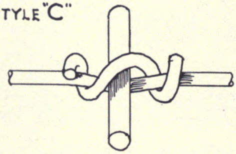
LONG WIRES #10 GUAGE ON 4" CENTERS
CROSS WIRES #9 GUAGE ON 6" CENTERS

STYEE "B"



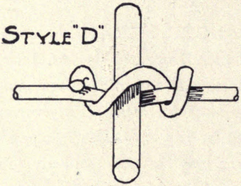
LONG WIRES #8 GUAGE ON 4" CENTERS
CROSS WIRES #10 GUAGE ON 6" CENTERS

STYLE "C"



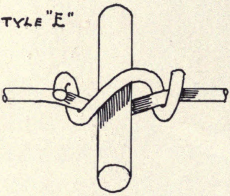
LONG WIRES #6 GUAGE ON 4" CENTERS
CROSS WIRES #10 GUAGE ON 6" CENTERS

STYLE "D"



LONG WIRES #4 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

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.

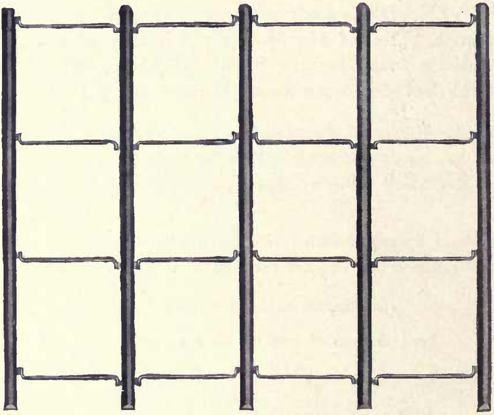


Fig. 110a.—Rib Metal. (*See p.* 185.)

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.

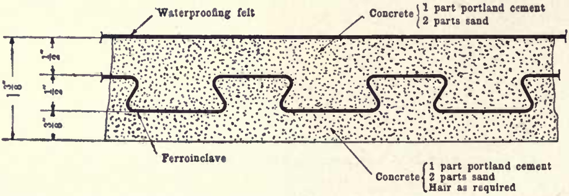


Fig. 111.—Section of Ferroinclave Roof. (*See p.* 185.)

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 shown in the sketches below of "Arrangement of Steel." The "Supporting Chairs," placed at the point of the

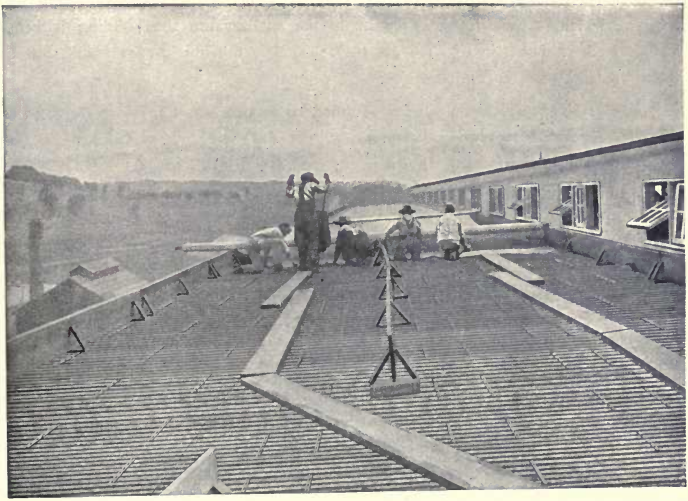


Fig. 112.—Placing of Ferroinclave Roof. (*See p.* 185.)

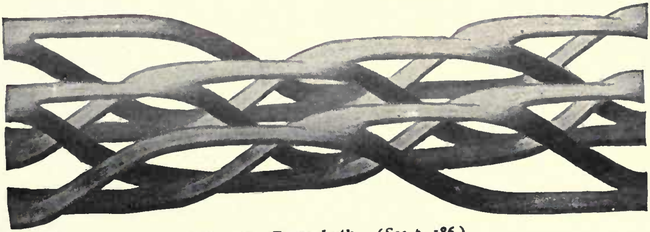


Fig. 113.—Truss Lath. (*See p.* 186.)

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).

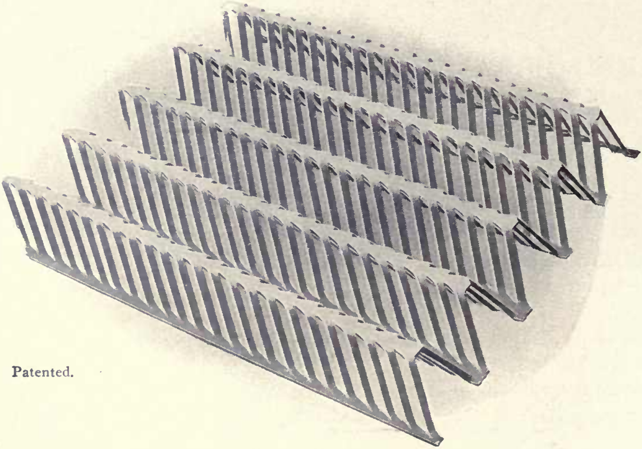


Fig. 114.—Trussit. (*See p.* 186.)

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 porus concrete of high fire resisting quality.

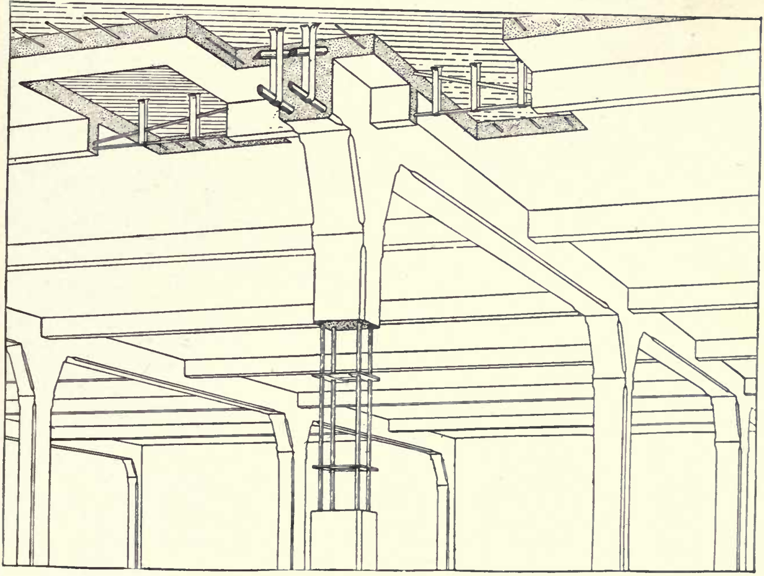


Fig. 115.—Hennebique System. (*See p.* 186.)

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.

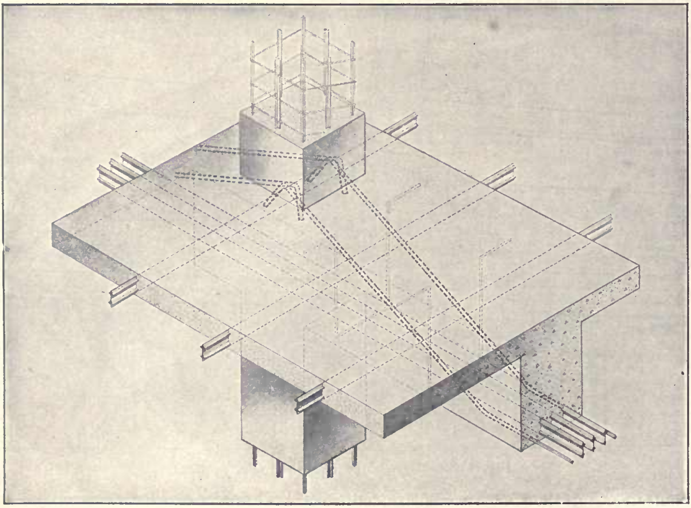


Fig. 116.—Columbian System. (*See p.* 186.)

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.

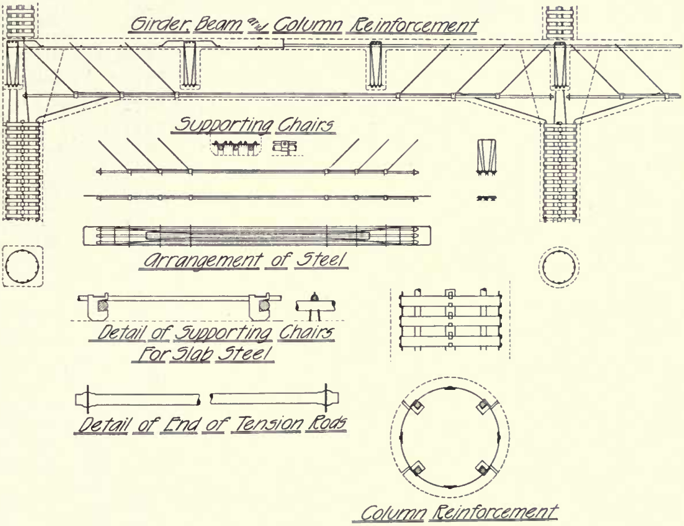


Fig. 117.—Details of Cummings System. *(See p. 187.)*

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, 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

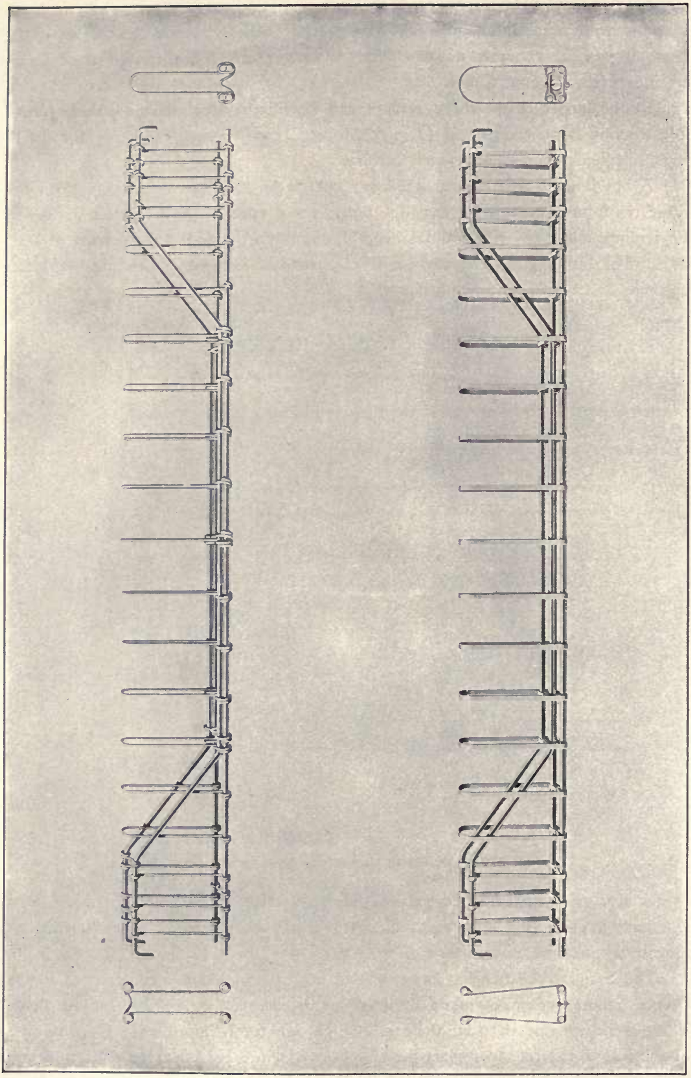


Fig. 118.—Unit Girder Frame System. *(See p. 188.)*

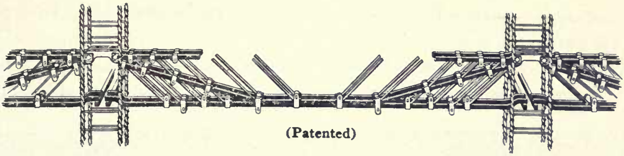


Fig. 119.—Pin-Connected Girder Frame. (*See p.* 188.)

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.

A nailing piece is inbedded 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.

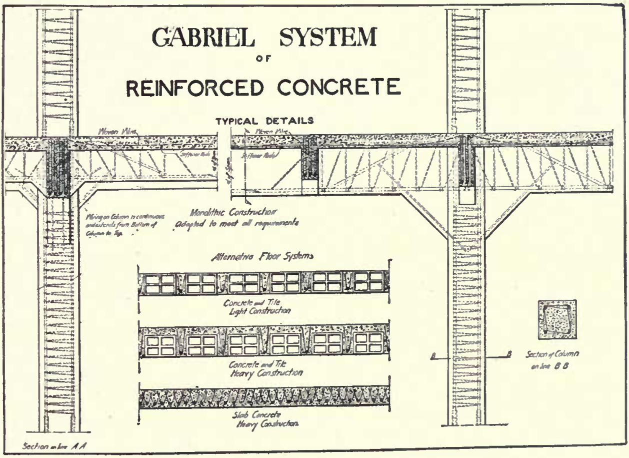


Fig. 120.—Gabriel System. (*See p.* 188.)

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.

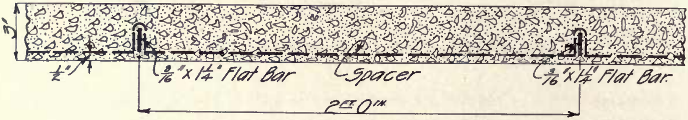


Fig. 121.—Roebling System. (*See p.* 188.)

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.

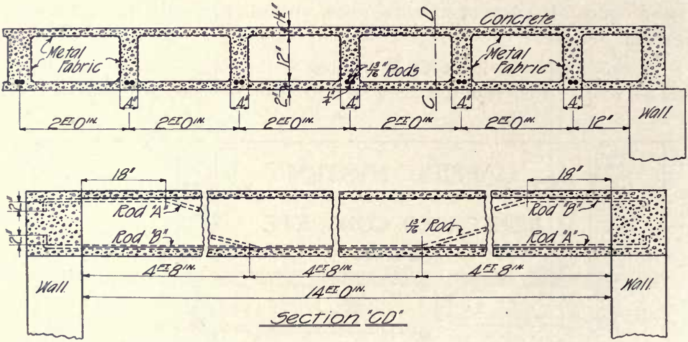


Fig. 122.—Merrick Floor System. (*See p.* 189.)

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).

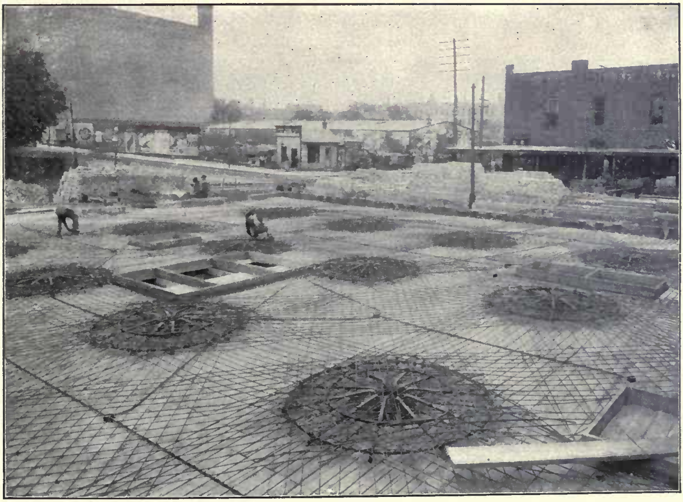


Fig. 123.—Mushroom System. (*See p.* 190.)

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).

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.

Fig. 124.—Interior of Bovey Building, Built by the Mushroom System. (*See p.* 190.)

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).

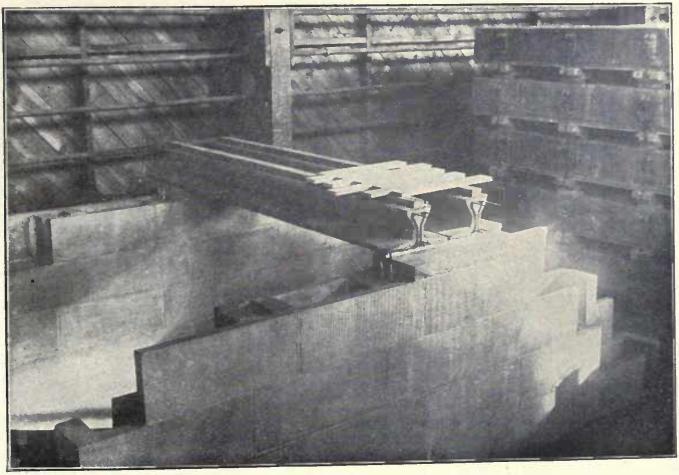


Fig. 124a.—Standard Floor Joists resting on Concrete Block Walls. (*See p.* 193.)

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.

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

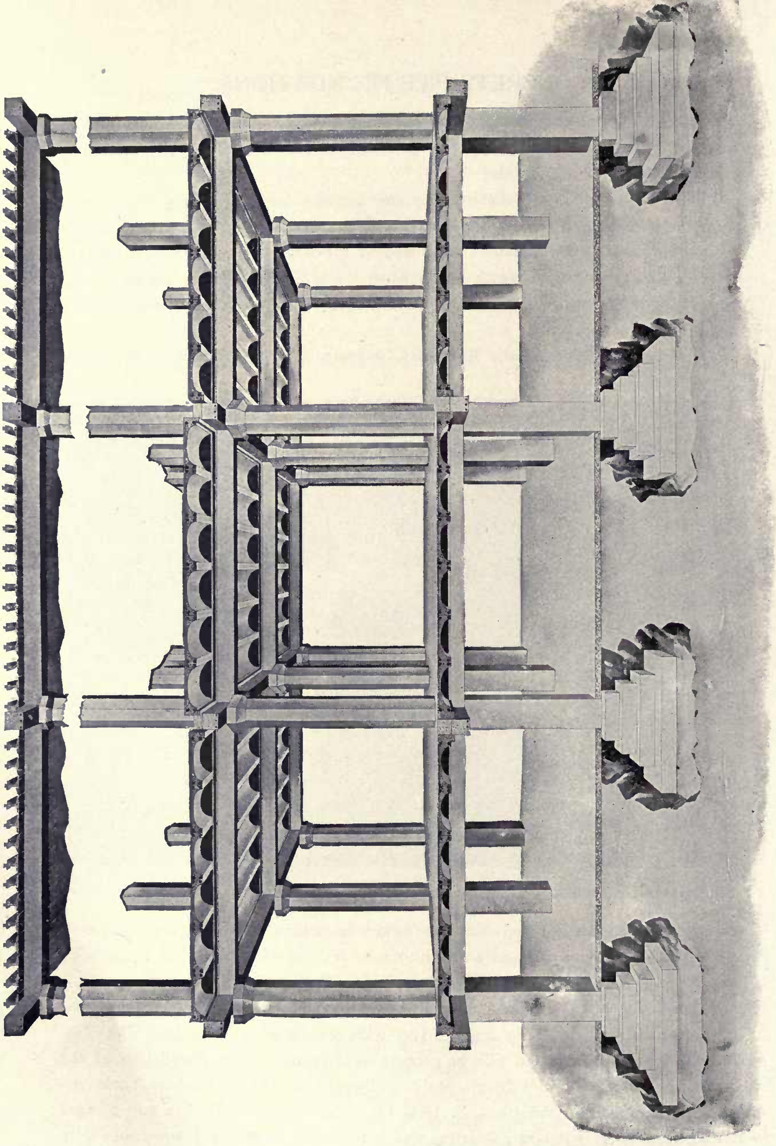
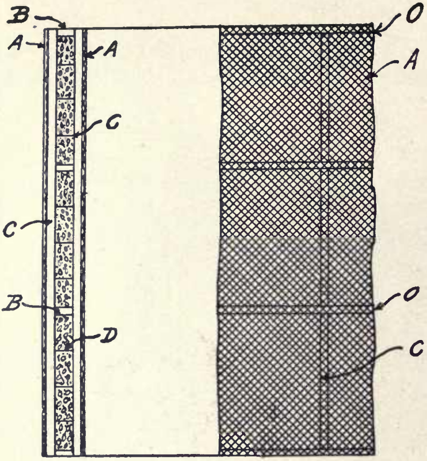


Fig. 124b.—Three Styles of Standard Floor Construction. (*See p.* 194.)

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.

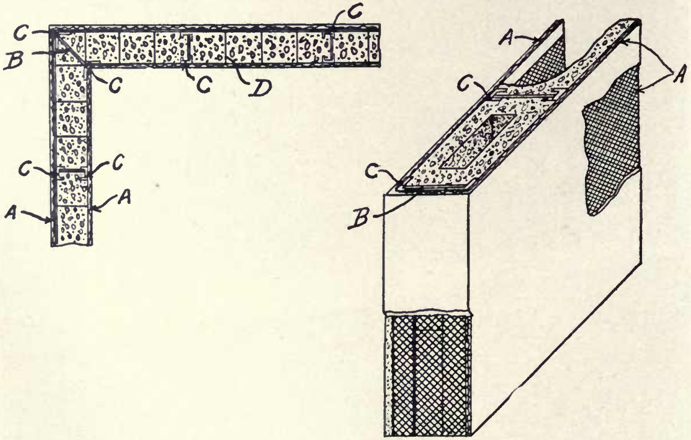


Fig. 126.—Lea's Concrete Metal Wall Construction. (*See p.* 195.)

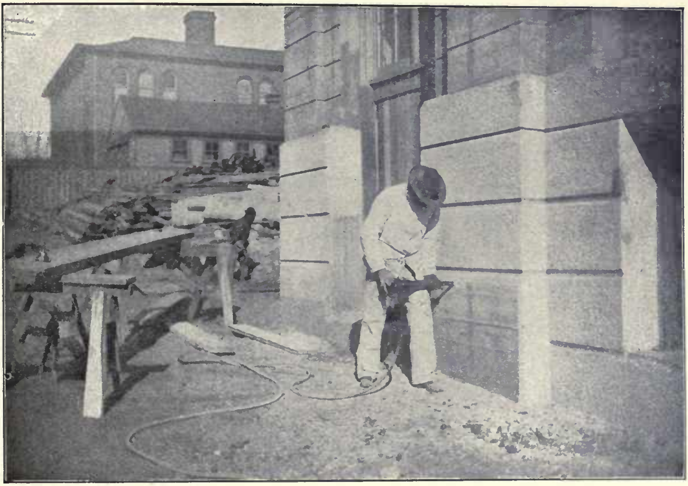


Fig. 127.—Tooling the Surface of Friedenwald Building Walls. (*See p.* 196.)

Fig. 128.—Photograph of Tooled Surface. (*See p.* 196.)

Fig. 129.—Photograph of Spatter Dash Finish of Lynn Storage Warehouse. (*See p.* 196.)

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.

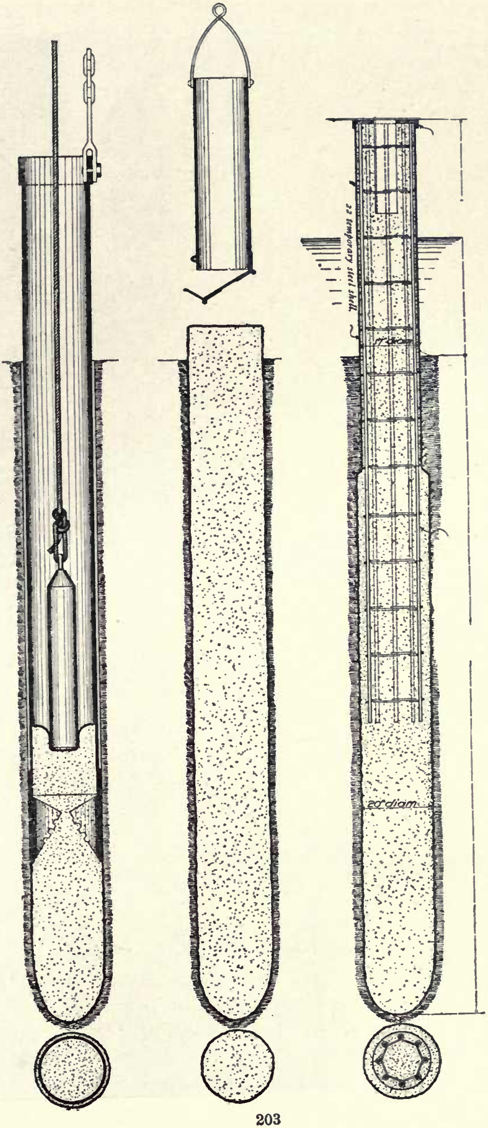


Fig. 130.—Simplex Piles. (*See p.* 197.)

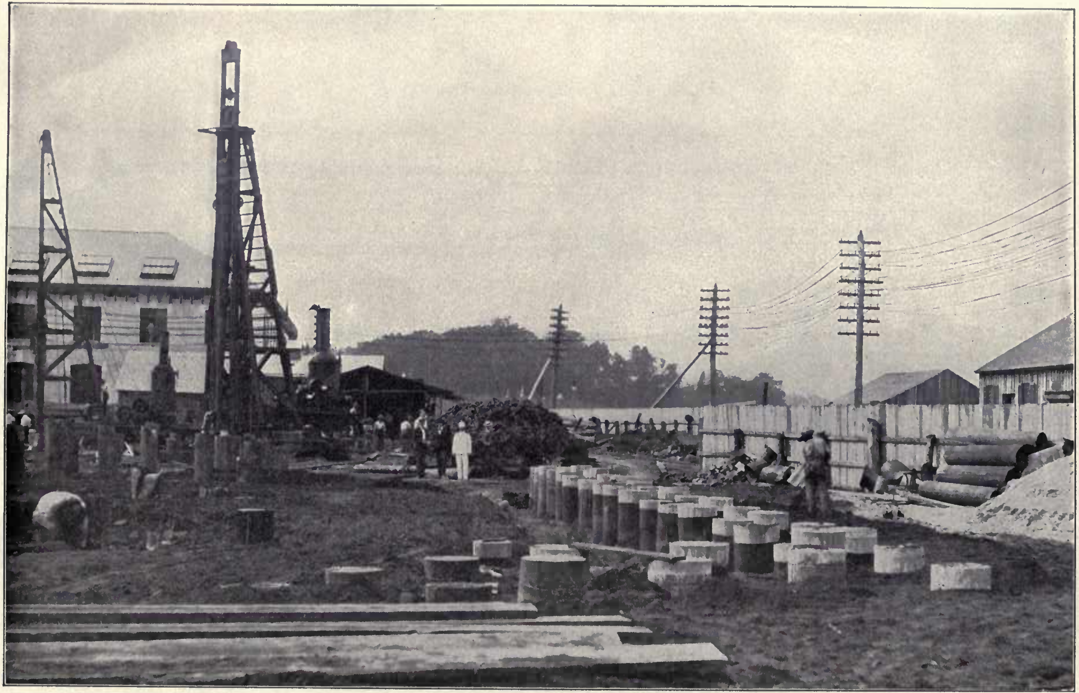


Fig. 131.—Raymond Pile. *(See p. 197.)*

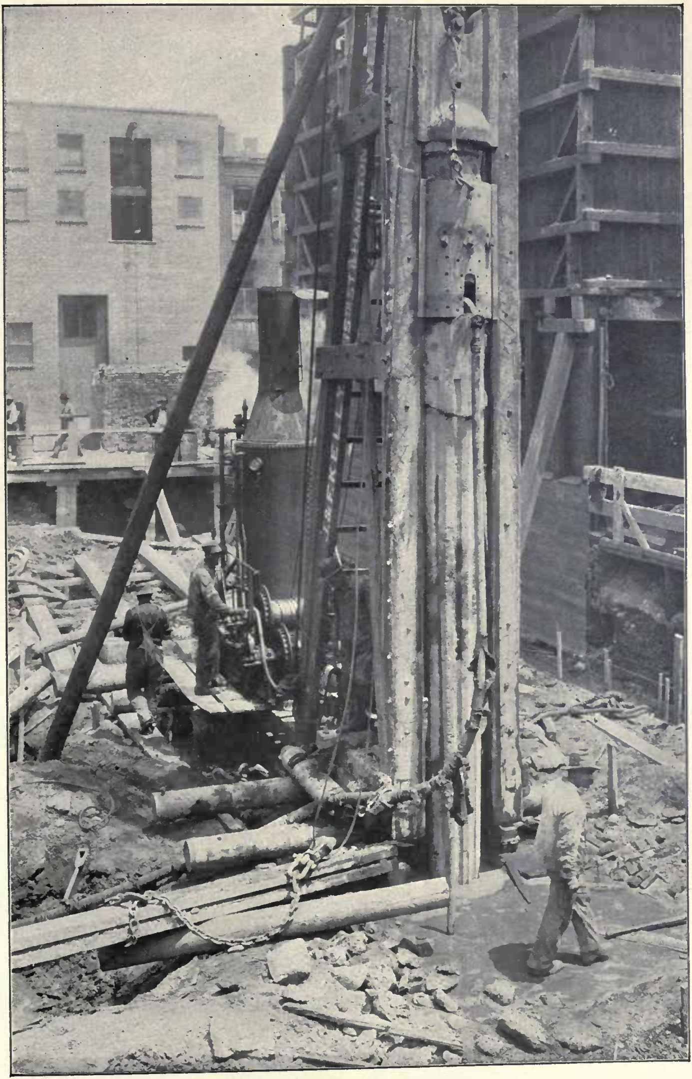


Fig. 132.—Gilbreth Corrugated Pile. (*See p.* 197.)

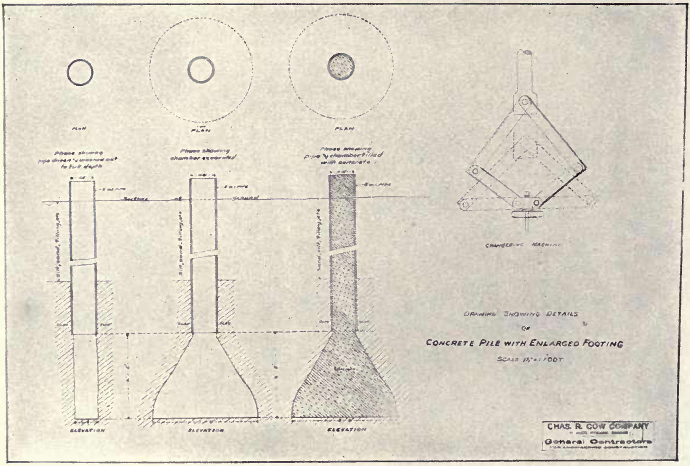


Fig. 133.—Gow Pile. (*See p.* 197.)

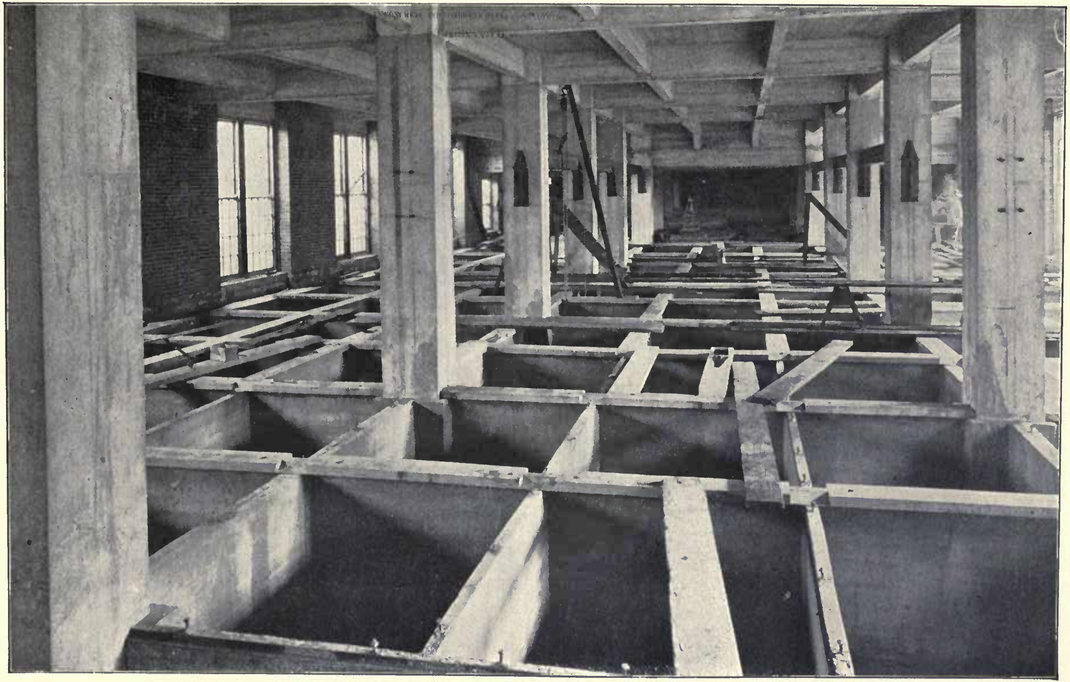
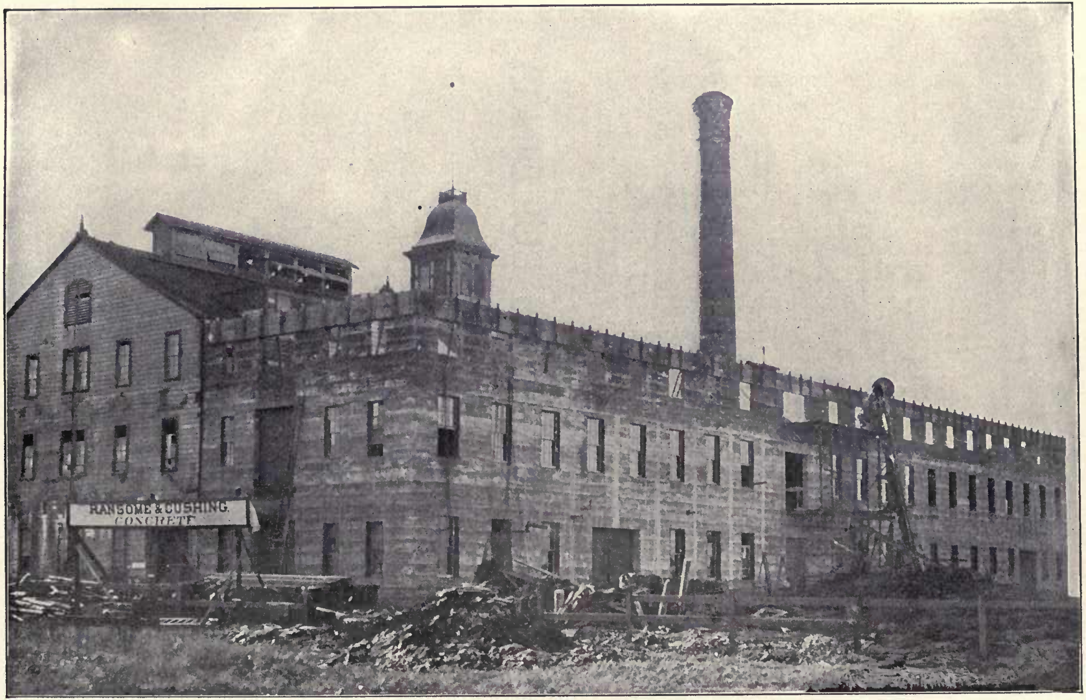


Fig. 134.—Concrete Tanks in American Oak Leather Company Factory. (*See p. 202.*)

MISCELLANEOUS BUILDINGS.



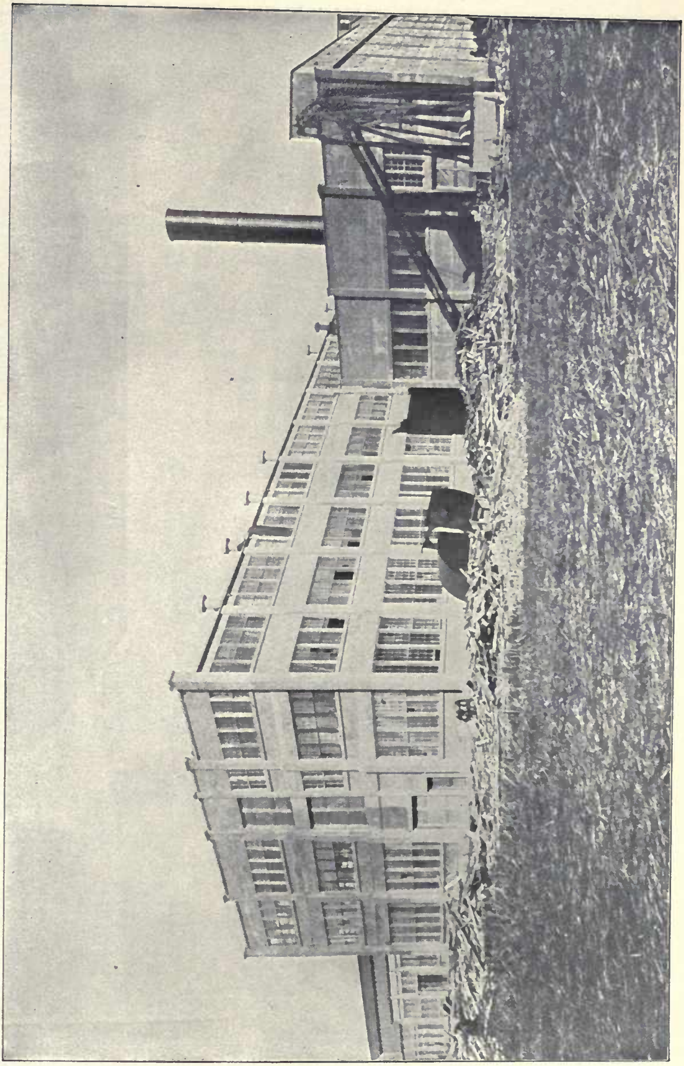
FACTORY AT ALAMEDA, CALIFORNIA.

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.

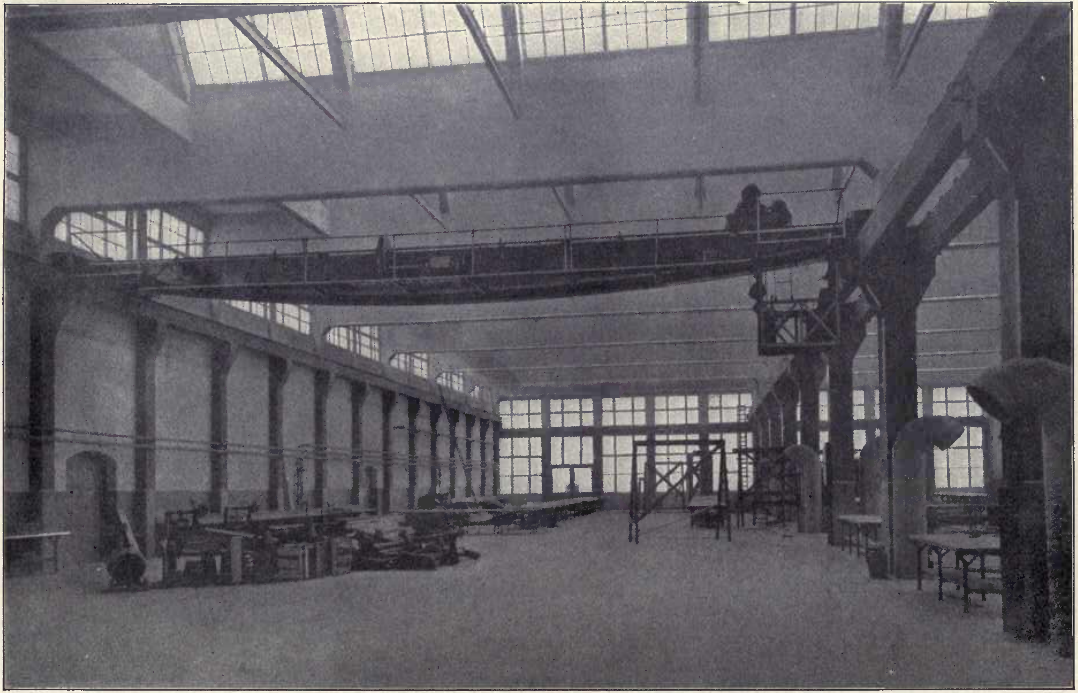
KUEFFEL & ESSER COMPANY FACTORY, HOBOKEN, N. J.
Louis Meyster & Son, Architects; Turner Construction Co., Builders.

MACHINE SHOP OF TRADERS' PAPER BOARD CO., BOGOTA, N. J.

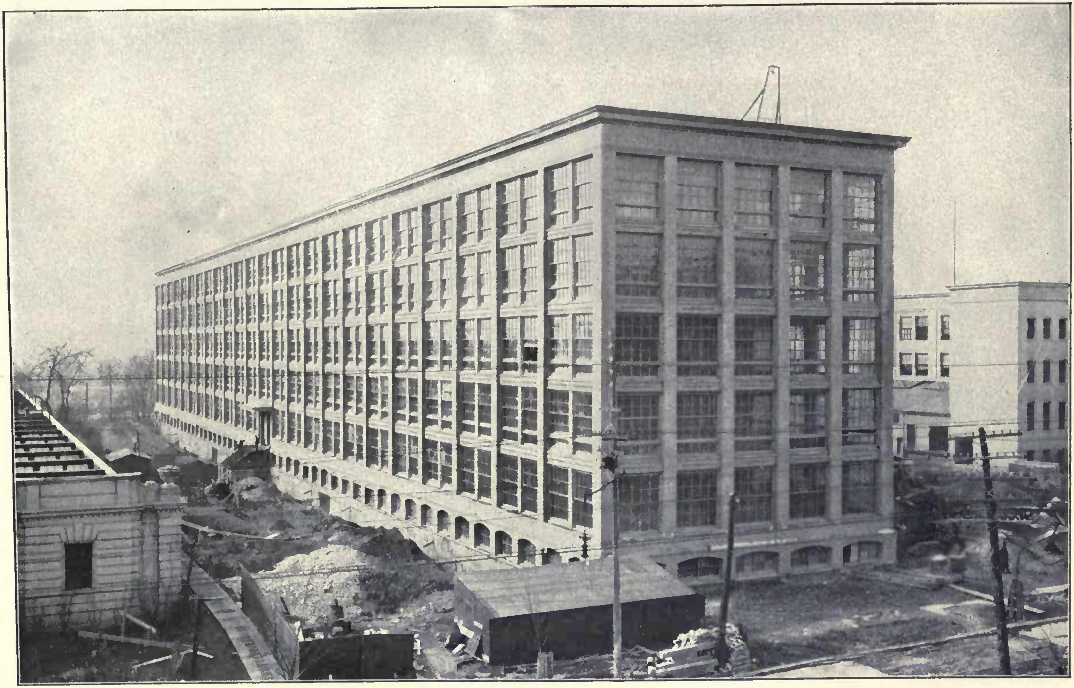
(See opposite page.)



TRADERS' PAPER BOARD CO., BOGOTA, N. J.
Curtin Ruggles Co., Engineers and Builders.

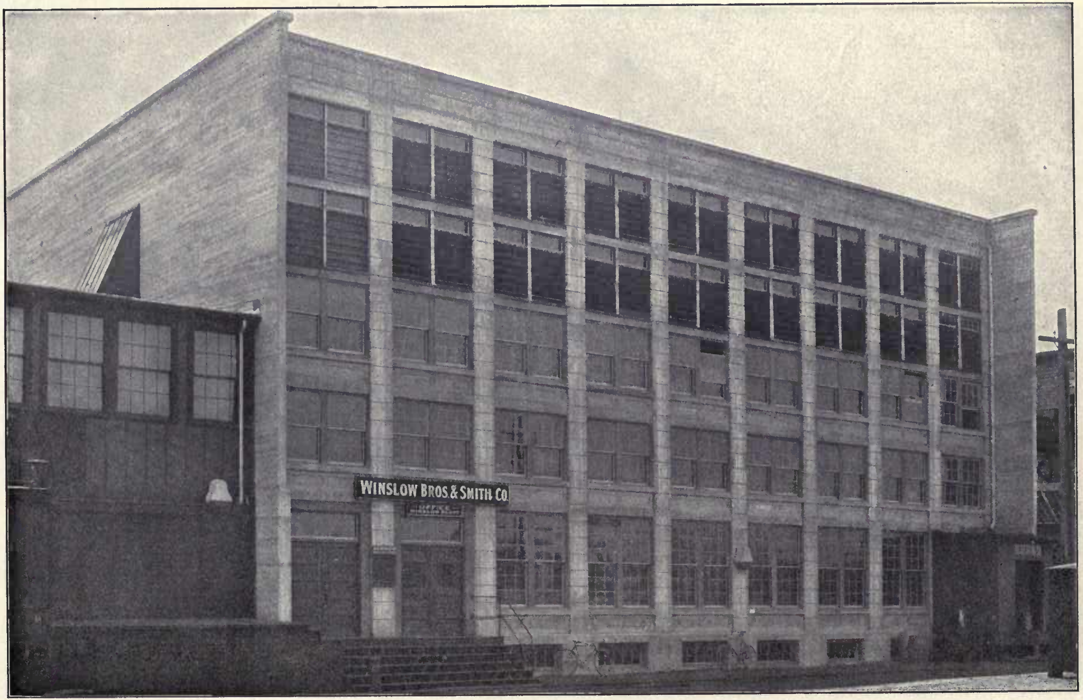


ASSEMBLY ROOM OF THE GEO. N. PIERCE AUTOMOBILE PLANT, BUFFALO, N. Y.
Room 122 ft. by 401 ft., with 61 ft. clear spans. Lockwood, Greene & Co., and Albert Kahn, Architects; Trussed Concrete Steel Co., Builders.

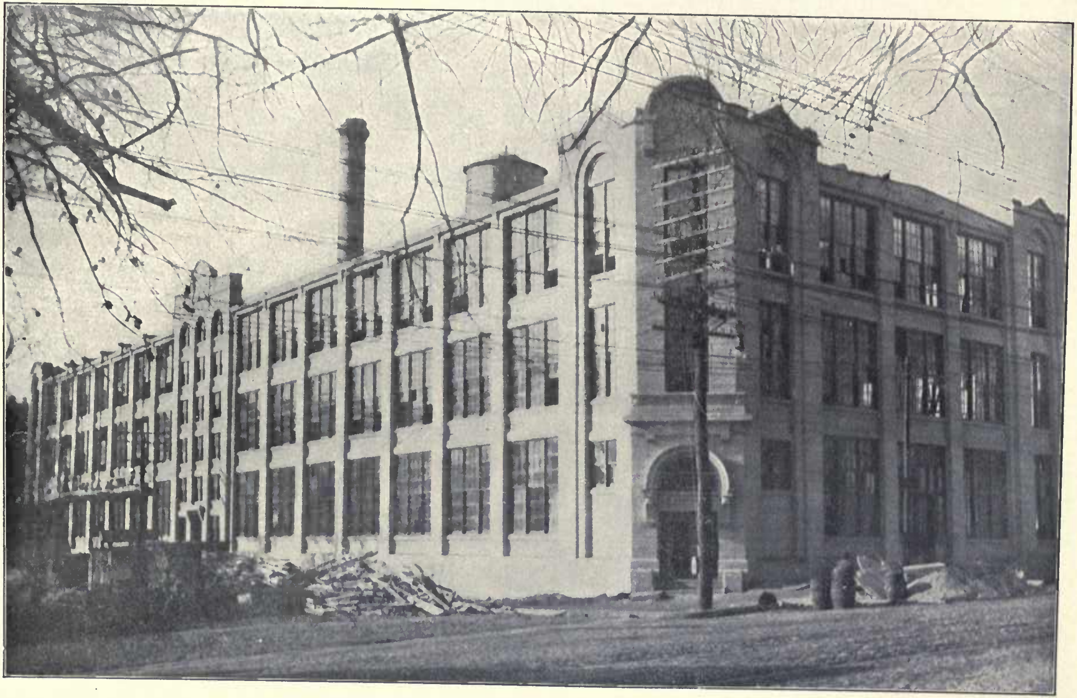


CARPENTRY SHOP, NATIONAL CASH REGISTER CO., DAYTON, OHIO.

The General Fireproofing Co. Designers of reinforcement; Expanded Metal Fireproofing Co., Contractors.

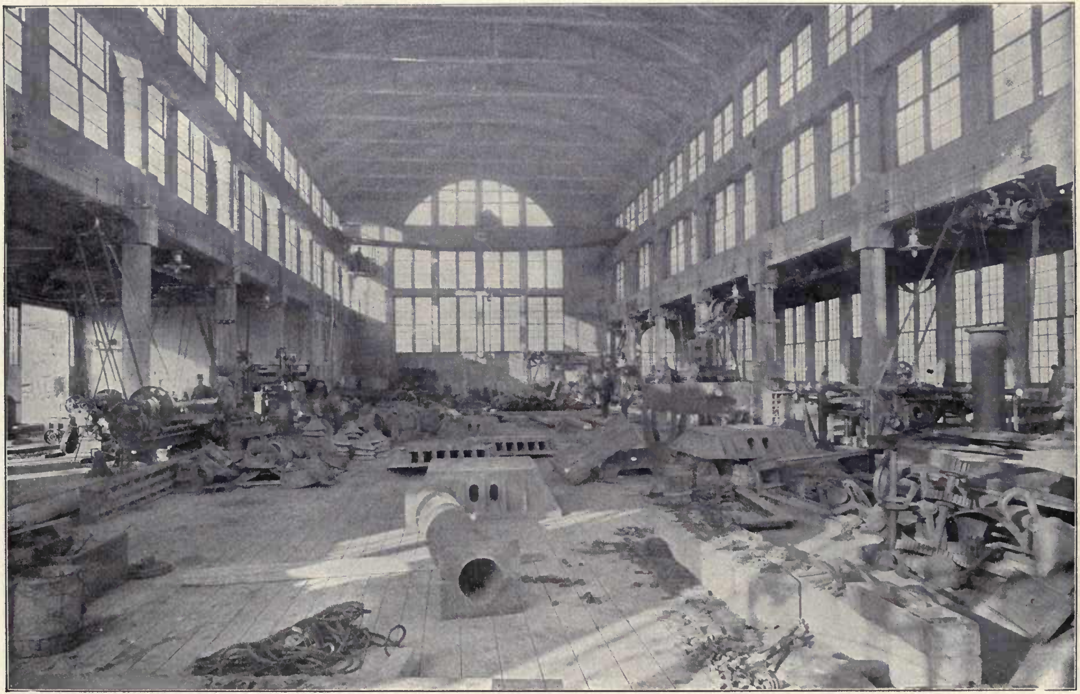


TANNERY OF WINSLOW BROS. & SMITH CO., NORWOOD, MASS.
Dimensions 87 ft. by 87 ft. Aberthaw Construction Co., Engineers.

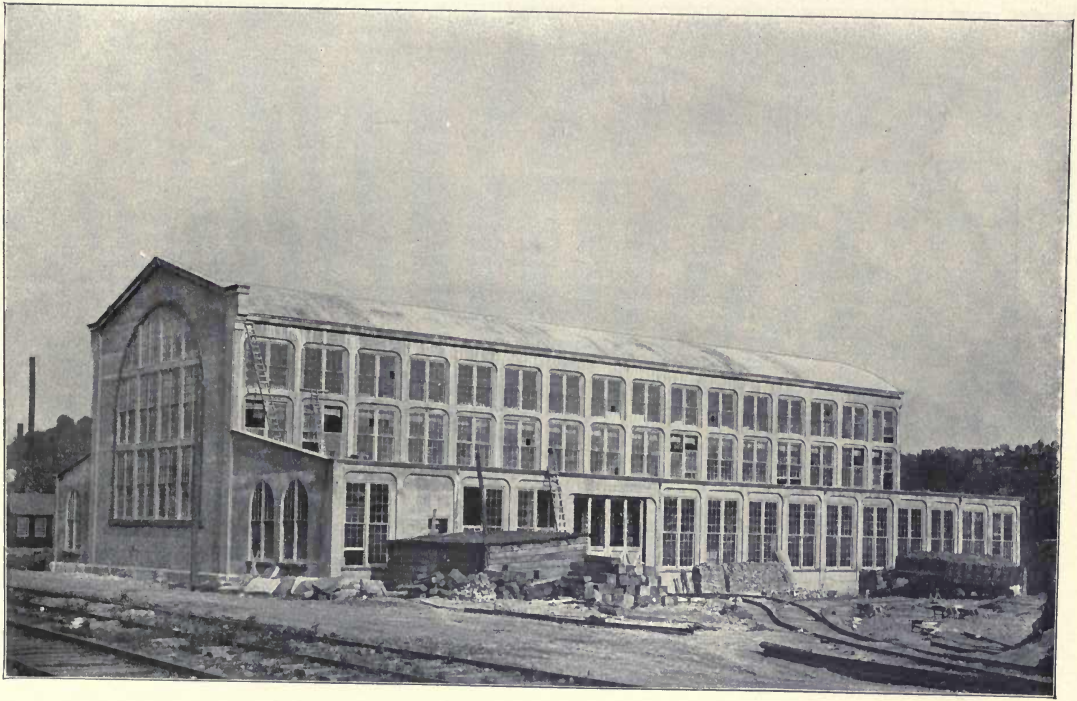


THE LORD BALTIMORE PRESS, BALTIMORE, MD.

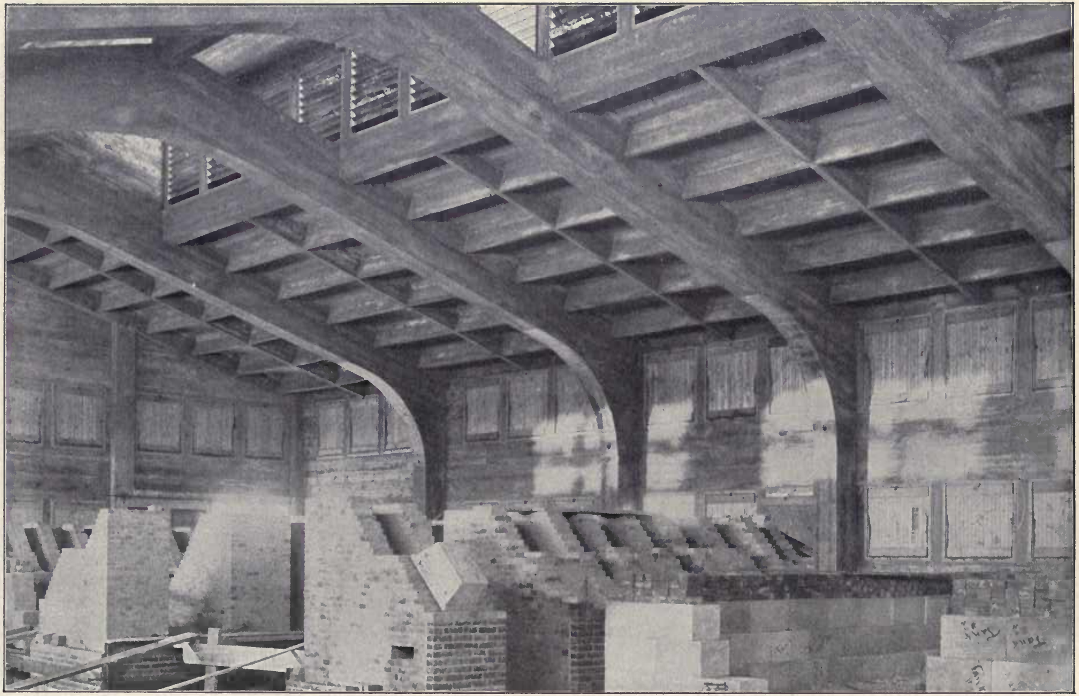
Dimensions 280 ft. by 80 ft. Ballinger & Perrot, Engineers; George A. Fuller Co., Builders.



INTERIOR OF MACHINE SHOP, TAYLOR-WILSON MANUFACTURING CO., McKEES ROCKS, PENN.
(See opposite page.)

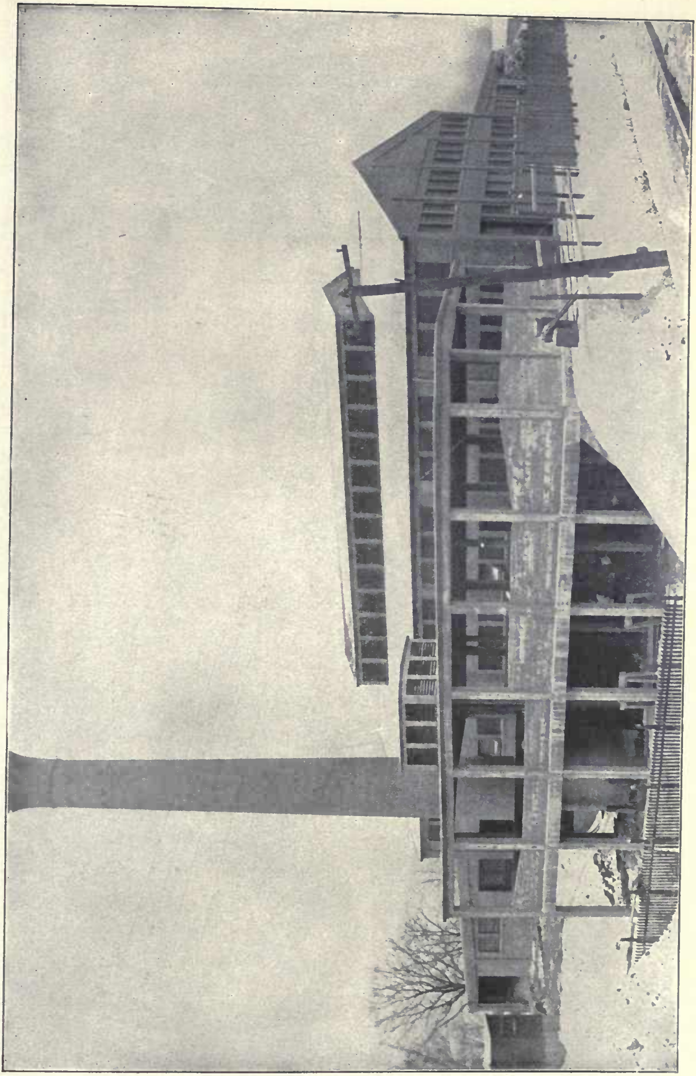


MACHINE SHOP, TAYLOR-WILSON MANUFACTURING CO., McKEES ROCKS, PENN.
Robert A. Cummings, Engineer and Builder.

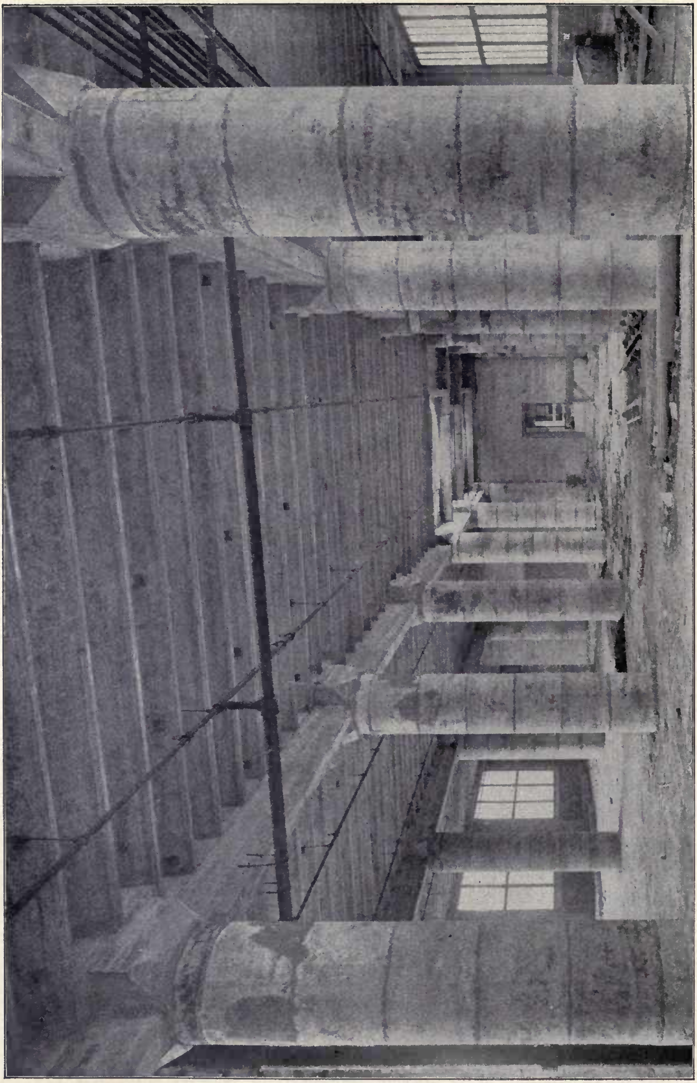


INTERIOR OF NORTHWESTERN OHIO BOTTLE CO.

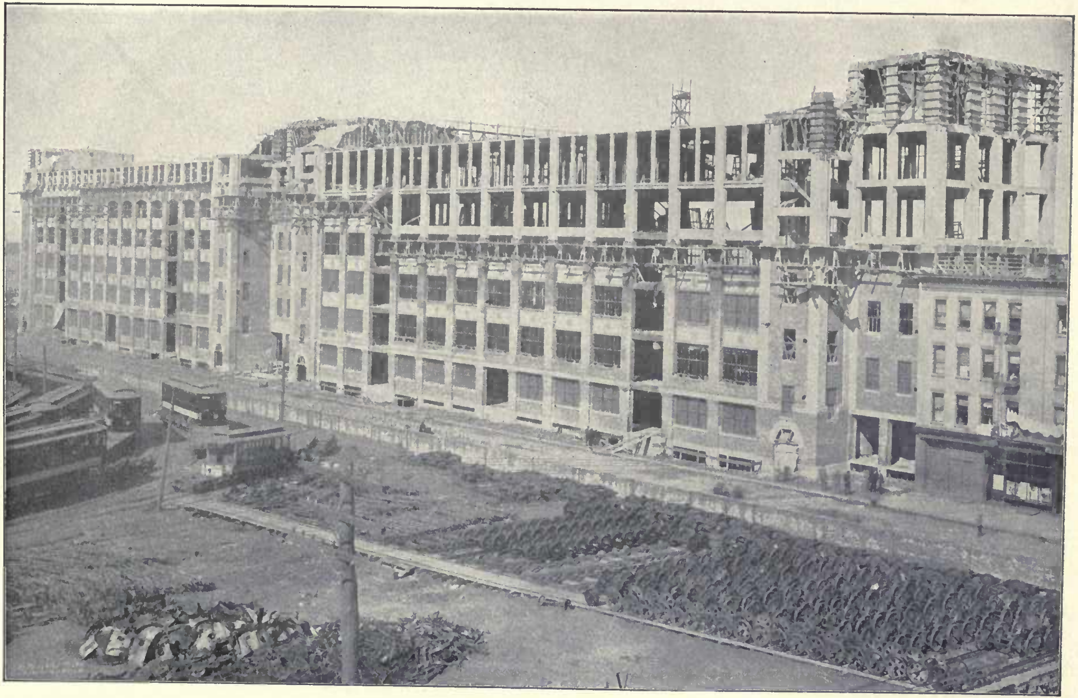
(See opposite page.)



THE NORTHWESTERN OHIO BOTTLE CO.
Harry W. Wachter, Architect; Henry J. Spieker, Builder.

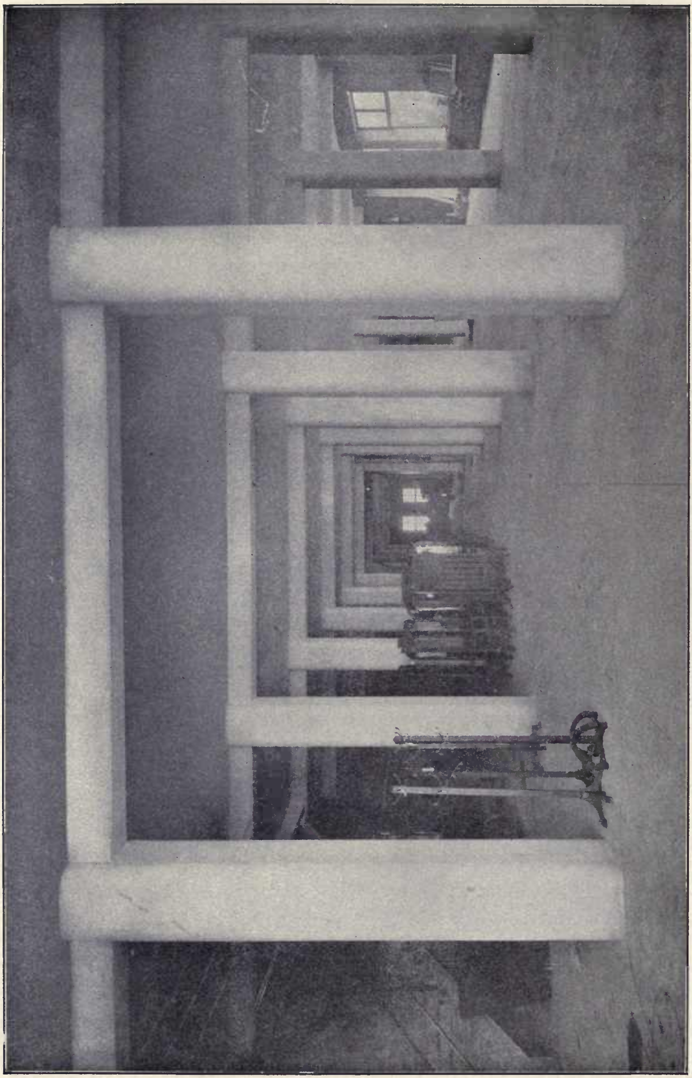


INTERIOR BUSH MODEL FACTORY NO. 1, BROOKLYN, N. Y.
(See opposite page.)



BUSH MODEL FACTORY NO. 1, BROOKLYN, N. Y.

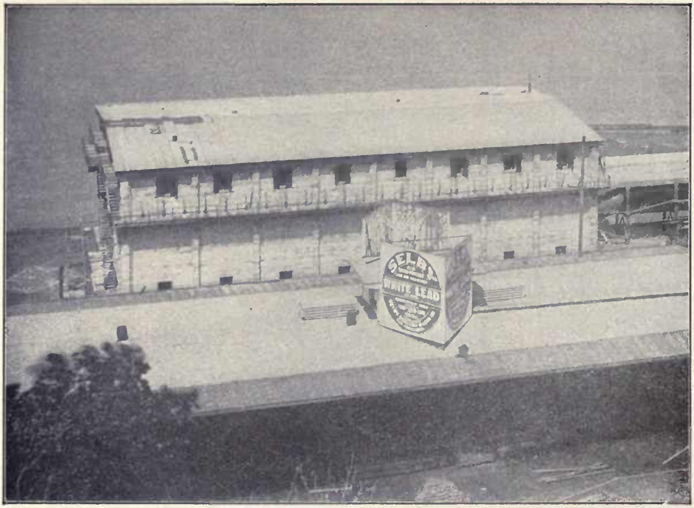
Dimensions 75 ft. by 600 ft. E. P. Goodrich, Chief Engineer; William Higginson, Architect; Turner Construction Co., Builders; R. F. Tucker, Consulting Engineer.



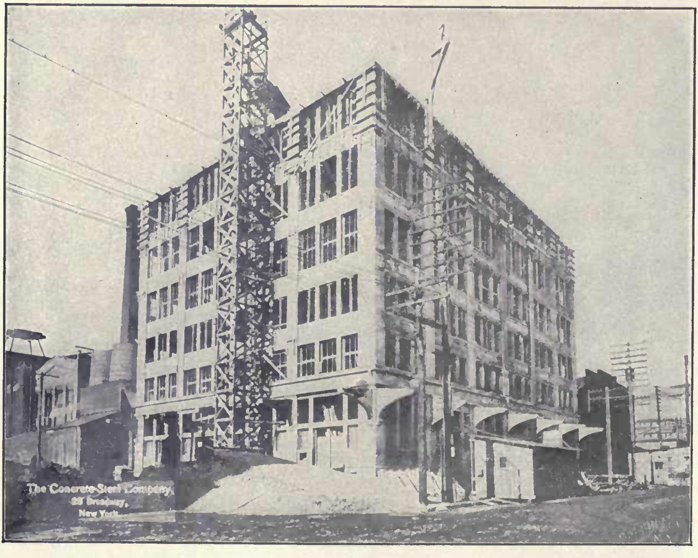
INTERIOR OF MANUFACTURERS' FURNITURE EXCHANGE BUILDING, CHICAGO, ILL.

(*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.

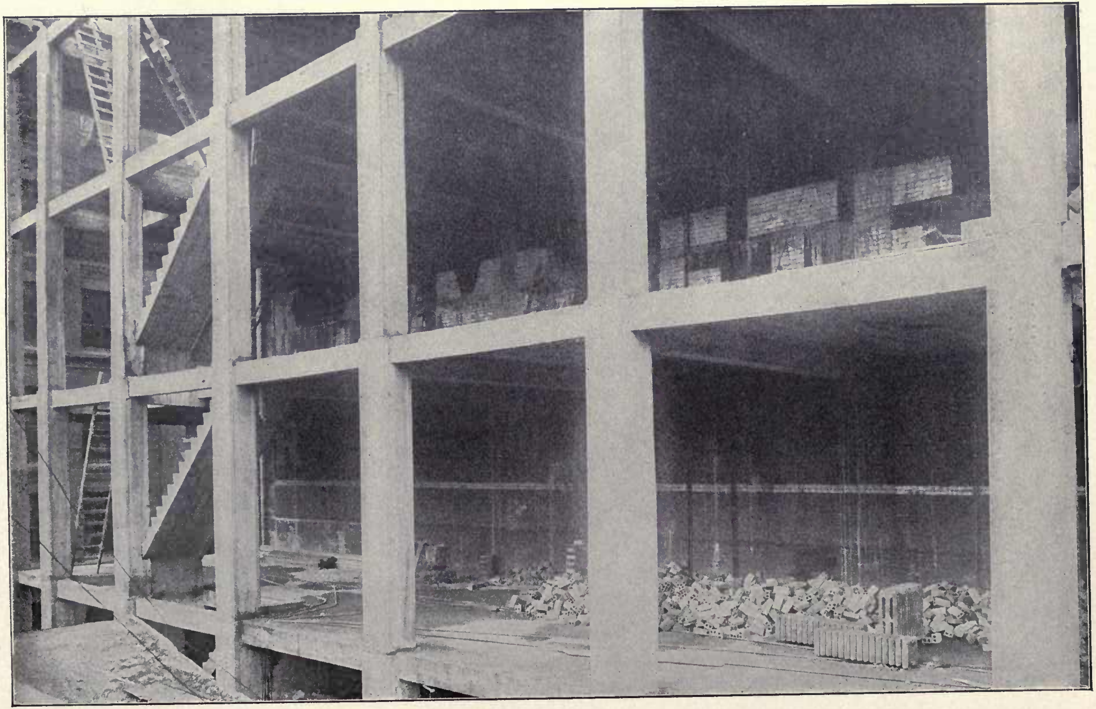


SELBY LEAD SMELTING PLANT, SELBY, CALIFORNIA.
Lindgren-Hicks Co., Builders; John B. Leonard, Consulting Engineer.



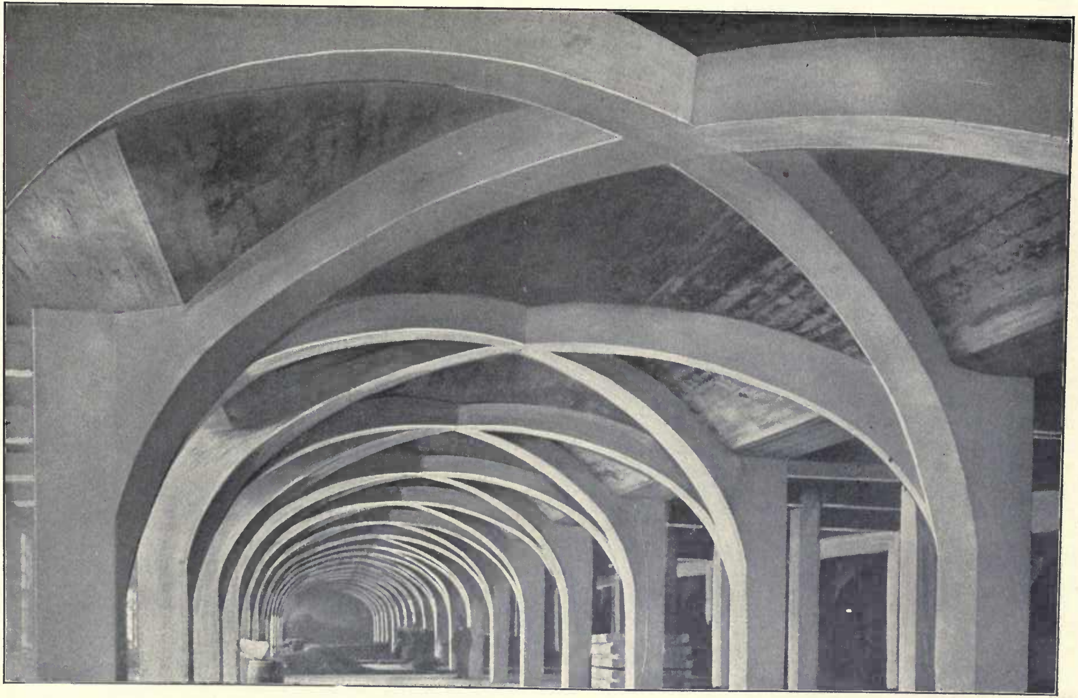
COLGATE SOAP FACTORY, JERSEY CITY, N. J.
Dimensions 85 ft. by 104 ft. William P. Field, Chief Engineer;
The Concrete-Steel Co., Builders.

SOAP WAREHOUSE OF KIRKMAN & SON, BROOKLYN, N. Y.
Expanded Metal Engineering Co., Engineers.

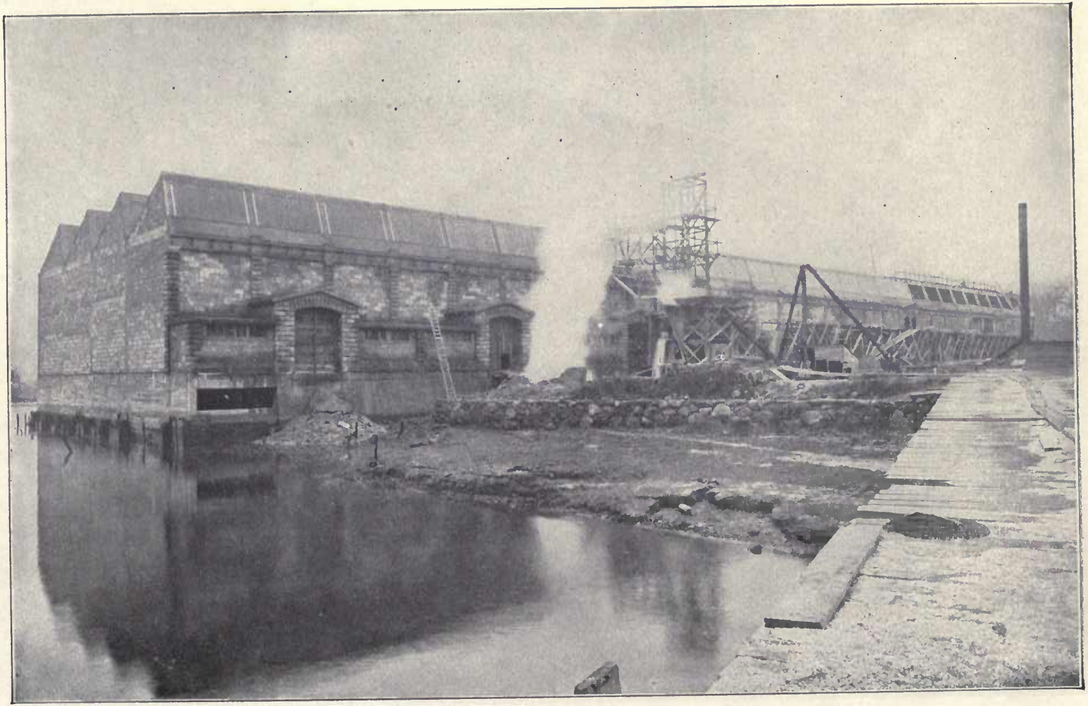


BENNETT BUILDING, PITTSBURGH, PENN.

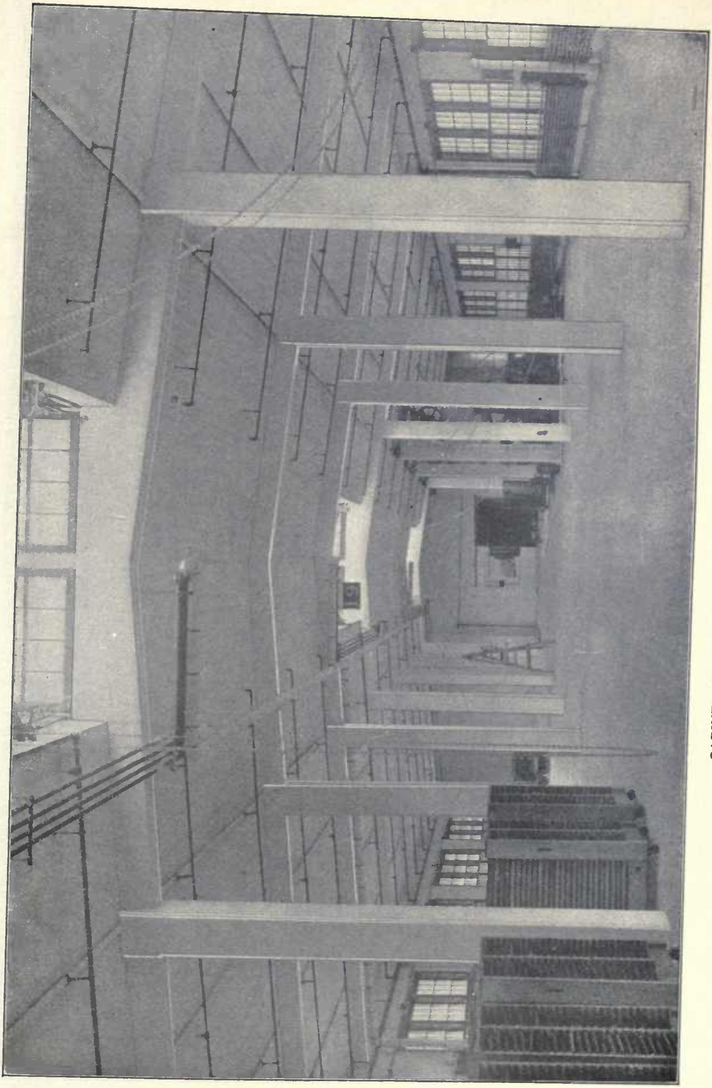
Dimensions 20 ft. by 100 ft. James T. Steen, Architect; Nicola Building Co., General Contractors; Columbian Reinforced Concrete Co., Reinforced Concrete Contractors.



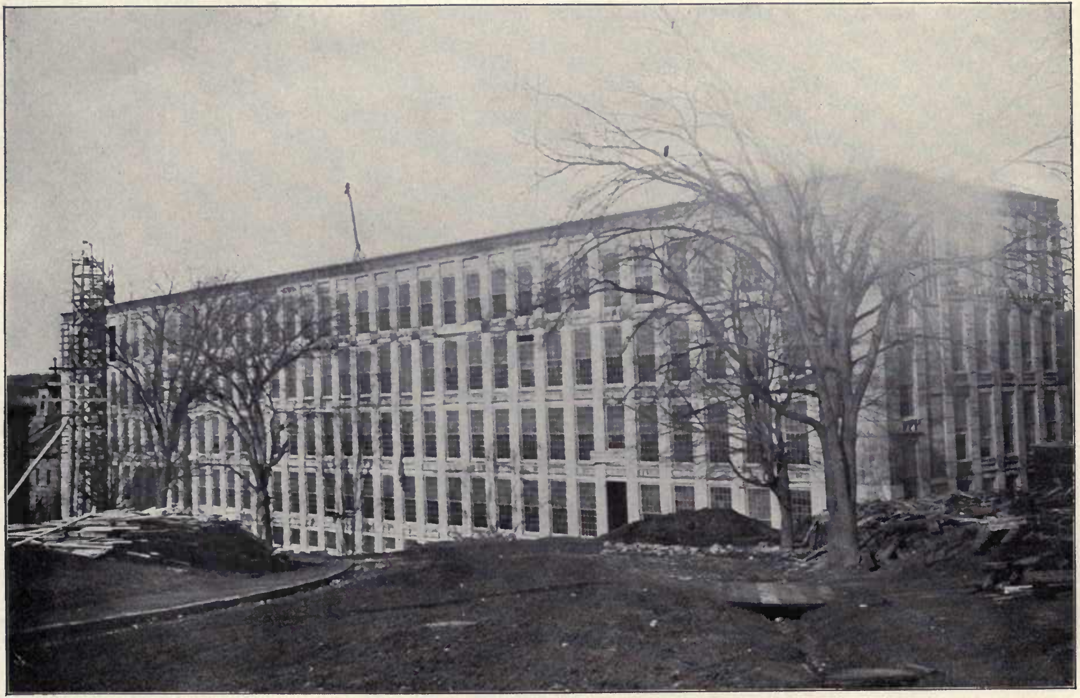
ARCHES SUPPORTING DYE HOUSE FLOOR, BOTANY WORSTED MILLS, PASSAIC, N. J.
Length of Building 925 feet. Charles J. Heuser, Architect; John F. Ferguson Co., Builders.



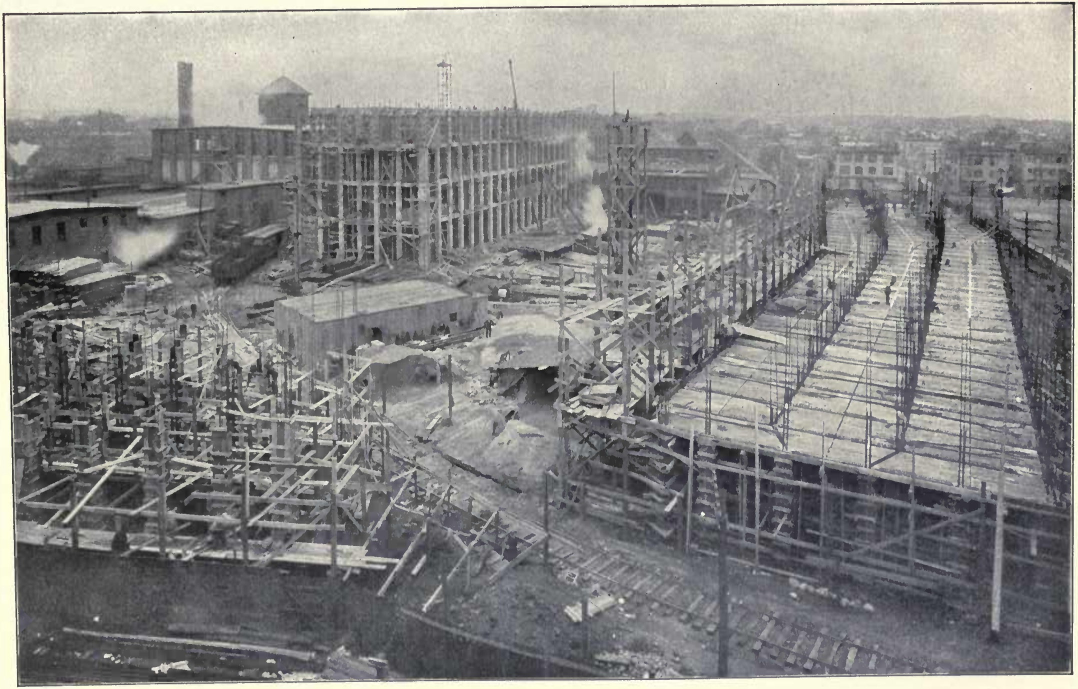
STOLLWERK BROS. CHOCOLATE MFG. CO., STAMFORD, CONN.
Ten Buildings 55,000 Square Feet Area. Ernest Flagg, Architect; Tucker & Vinton, Reinforced Concrete Contractors.



CABINET BUILDING OF CANADIAN SINGER MFG. CO.

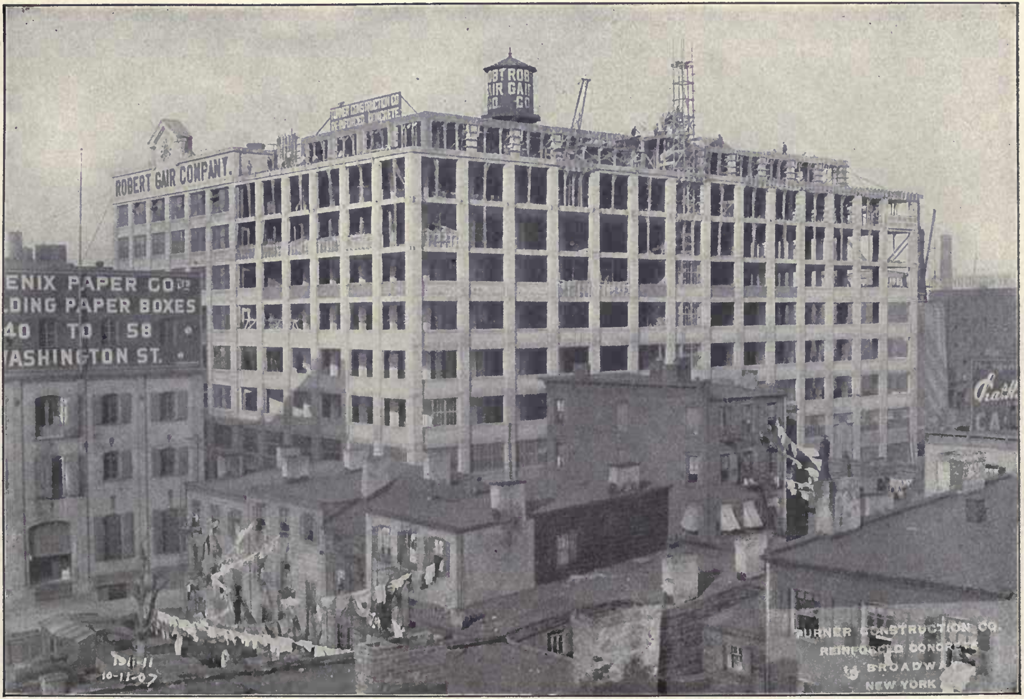


MAIN BUILDING MINTERBURN MILLS COMPANY, ROCKVILLE, CONN.
Dimensions 58 ft. by 294 ft. C. R. Makepeace & Co., Engineers; Frank B. Gilbreth, Builder.



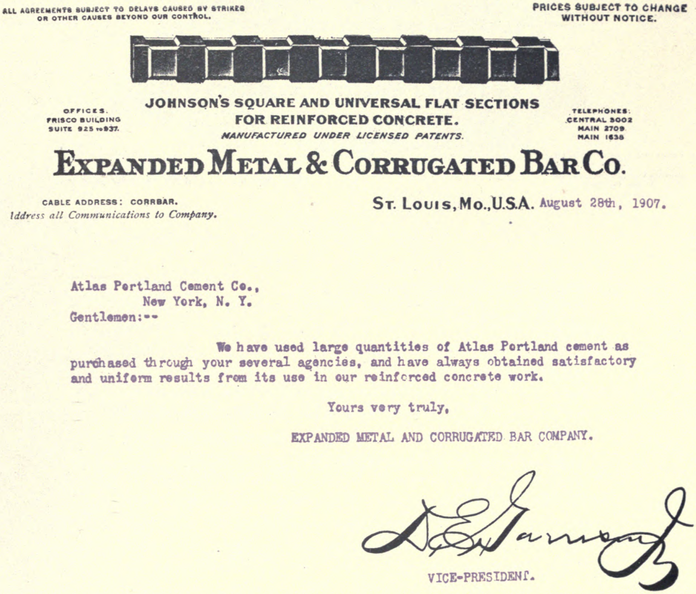
FACTORY AND WAREHOUSES OF THE BOSTON WOVEN HOSE AND RUBBER CO., CAMBRIDGE, MASS.

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.

JOHNSON'S SQUARE AND UNIVERSAL FLAT SECTIONS
FOR REINFORCED CONCRETE.
MANUFACTURED UNDER LICENSED PATENTS.

OFFICES.
FRISCO BUILDING
SUITE 925 to 937.

TELEPHONES:
CENTRAL 3002
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.

D. E. Garrison Jr.

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

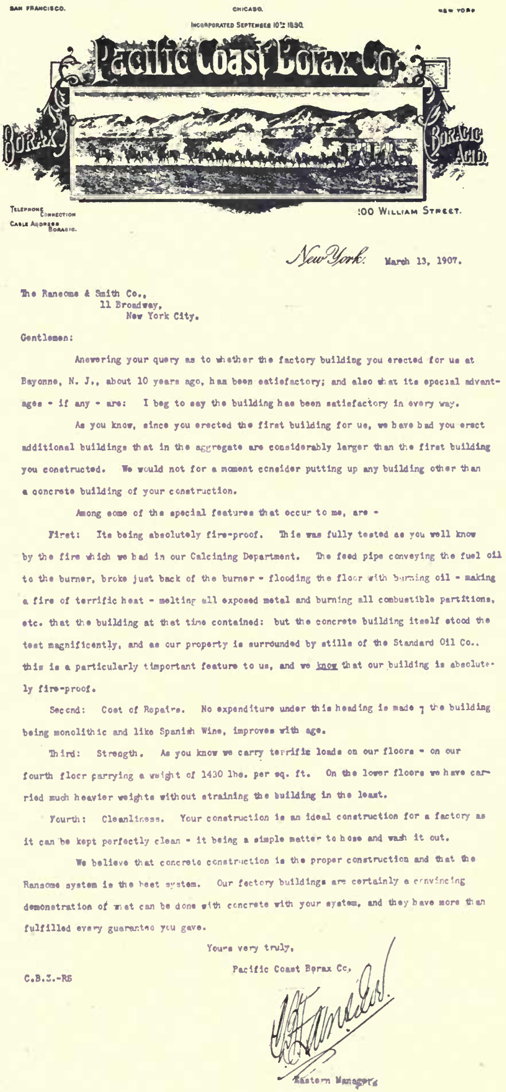
New York, Sept. 3, 1907.

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 timportant feature to us, and we _know_ 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 Managers

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

Aug. 27, 1907.

Atlas Portland Cement Company,
30 Broad St., New York, N. Y.

Gentlemen:-

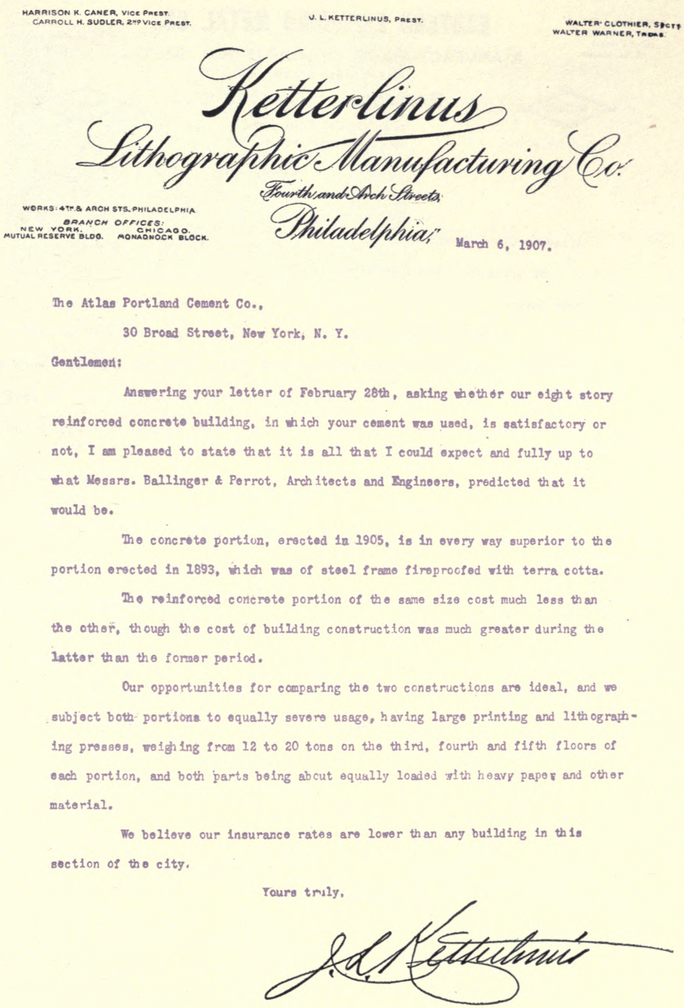
In reply to your favor of the 24th inst., asking us to write you stating what success we have had with Atlas Portland Cement, would say that this cement has been used in considerable of our work, the most notable instance being that of the eight-story Ketterlimus Printing House at Fourth and Arch Street, 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, SECTY.
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.

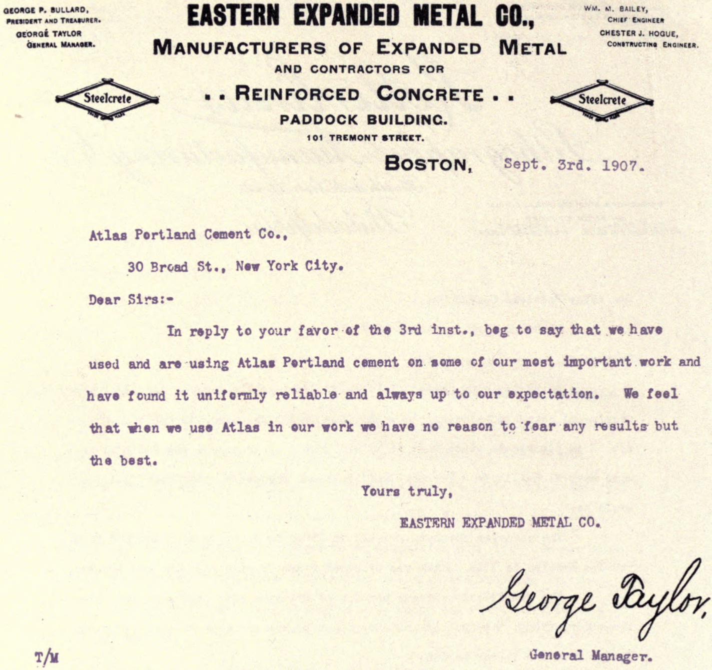
The reinforced concrete portion of the same size cost much less than the other, though the cost of building construction was much greater during the latter than the former period.

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
Steelcrete **. . REINFORCED CONCRETE . .** Steelcrete
PADDOCK BUILDING.
101 TREMONT STREET.

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,
General Manager.

T/M

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.

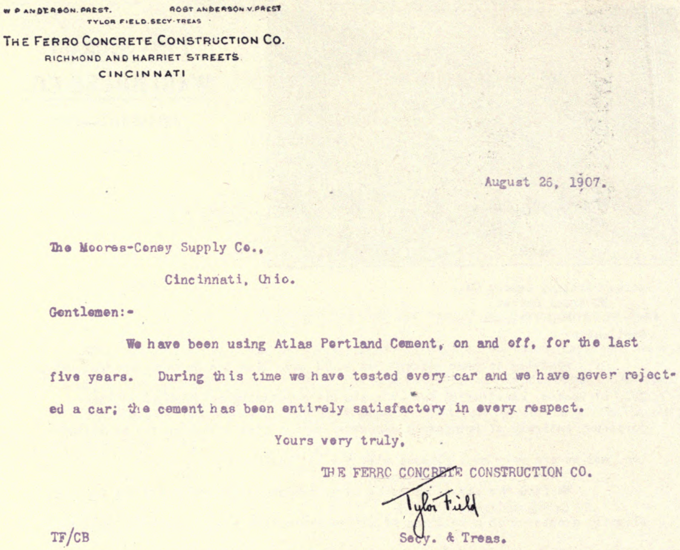
Yours very truly,

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.

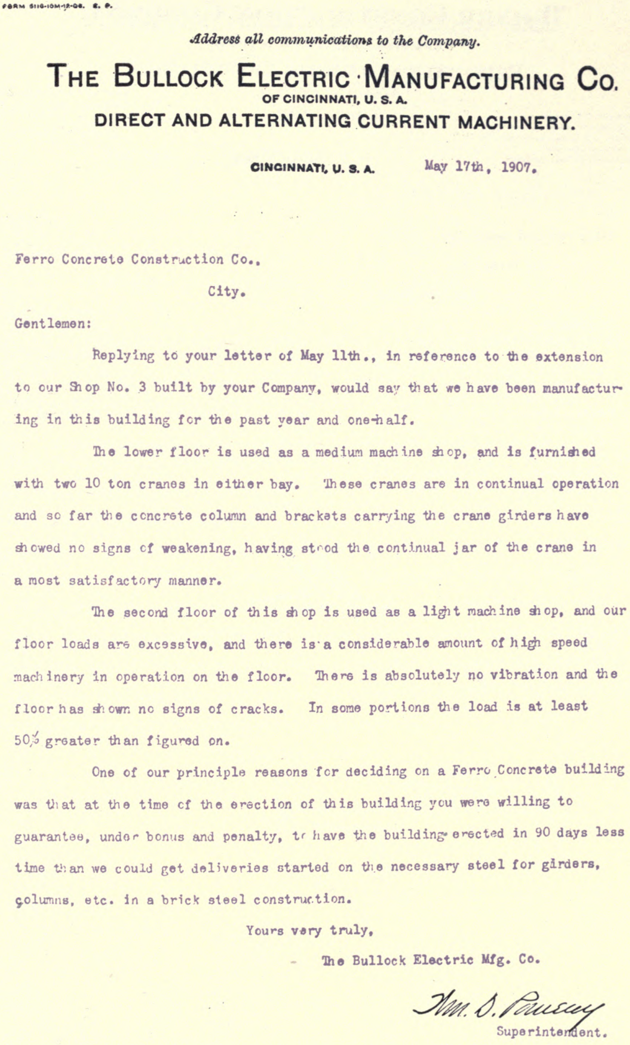
The Moores-Coney Supply Co.,
Cincinnati, Ohio.

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 5116-10M-12-06. E. 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 of 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.

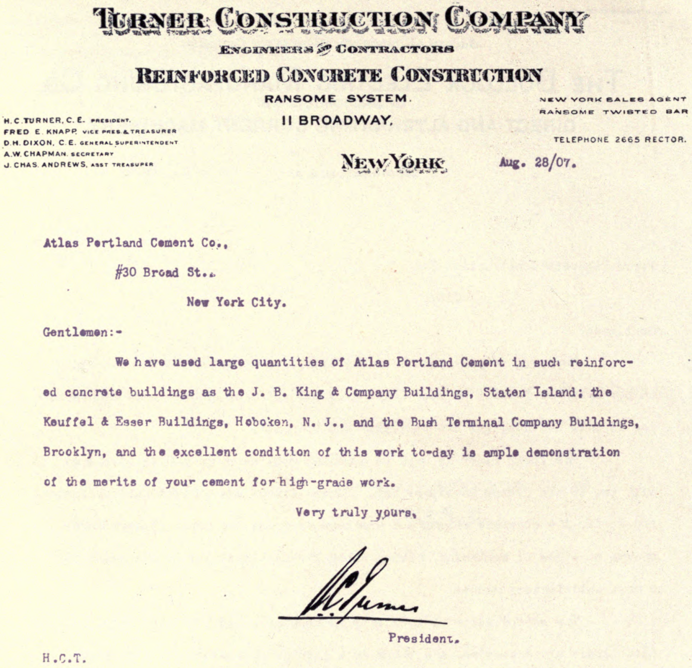
The second floor of this shop is used as a light machine shop, and our floor loads are excessive, and there is a considerable amount of high speed machinery in operation on the floor. There is absolutely no vibration and the floor has shown no signs of cracks. In some portions the load is at least 50% 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. Pauley
Superintendent.



TURNER CONSTRUCTION COMPANY

ENGINEERS & CONTRACTORS

REINFORCED CONCRETE CONSTRUCTION

RANSOME SYSTEM.

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

11 BROADWAY,

TELEPHONE 2665 RECTOR.

NEW YORK

Aug. 28/07.

Atlas Portland Cement Co.,
#30 Broad St.,
New York City.

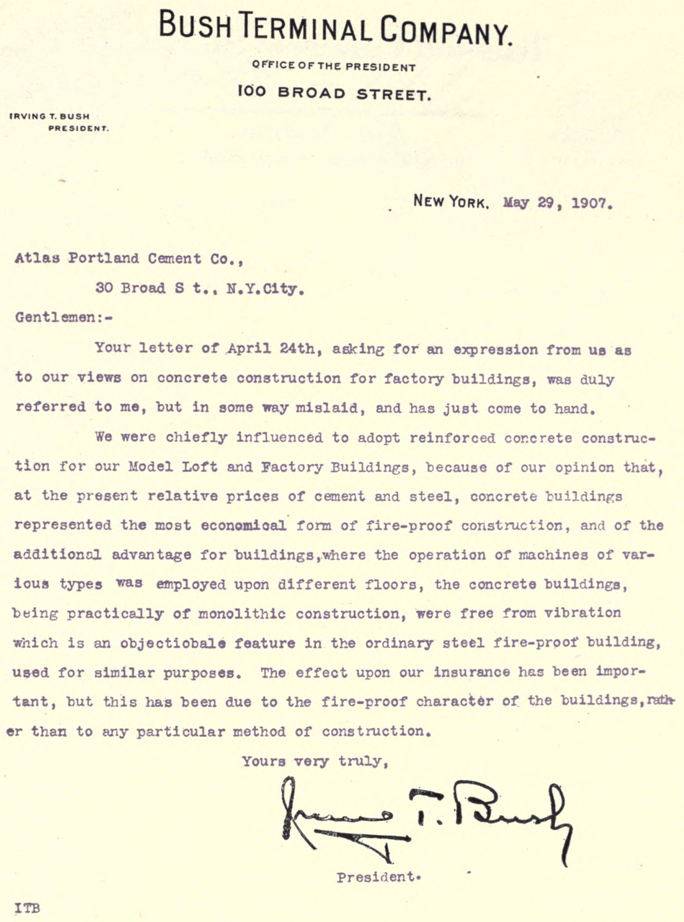
Gentlemen:-

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,

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.

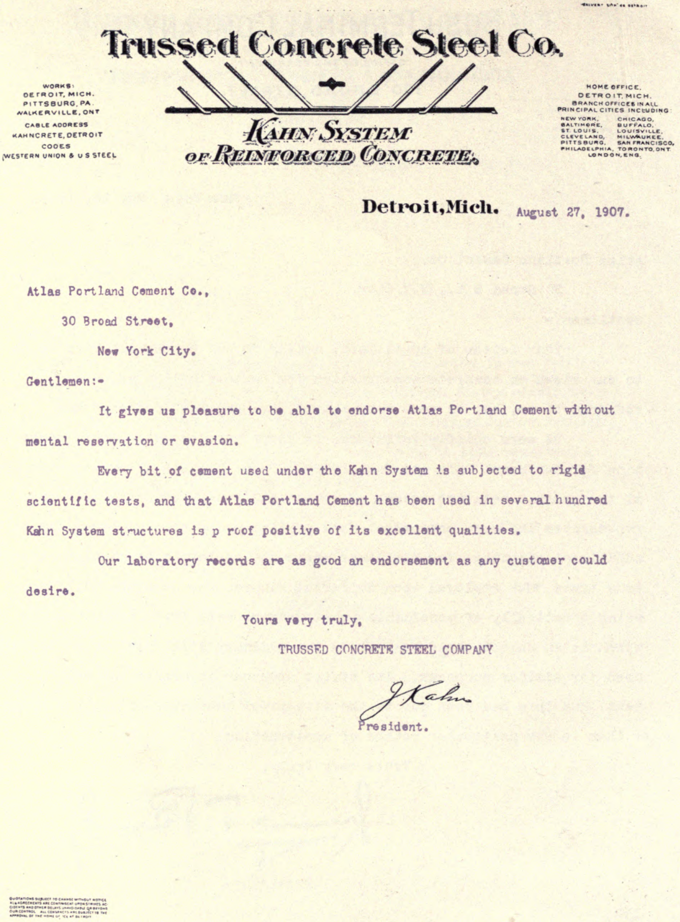
We were chiefly influenced to adopt reinforced concrete construction for our Model Loft and Factory Buildings, because of our opinion that, at the present relative prices of cement and steel, concrete buildings represented the most economical form of fire-proof construction, and of the additional advantage 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. August 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.

QUOTATIONS SUBJECT TO CHANGE WITHOUT NOTICE. ALL AGREEMENTS ARE CONTINGENT UPON STRIKES, ACCIDENTS AND OTHER DELAYS UNAVOIDABLE OR BEYOND OUR CONTROL. ALL CONTRACTS ARE SUBJECT TO THE APPROVAL OF THE HOME OFFICE AT DETROIT

Packard
MOTOR CAR COMPANY
ADDRESS ALL COMMUNICATIONS TO THE 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

WILLIAM 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. 1886.

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. 5, 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.

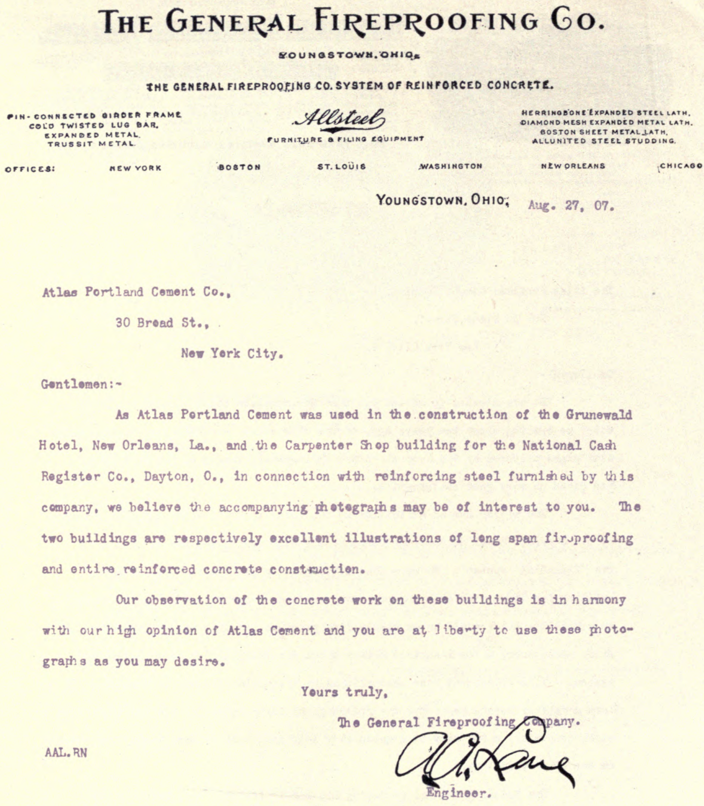
The building was put up during the winter of 1904, and, except a few days of extremely bad weather, the operations were continued uninterrupted even when the thermometer was down to almost zero. We had all the work done by day work or sub-contract, and we are satisfied that we have a first class job 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,

NER)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.

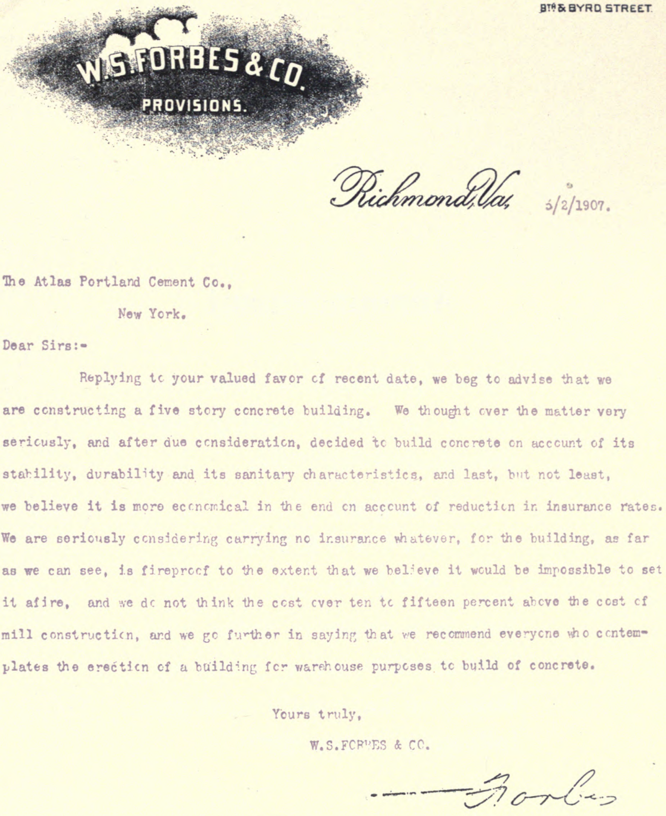
Yours truly,

The General Fireproofing Company.

AAL.RN

A. A. Lane

Engineer.



W.S. FORBES & CO.
PROVISIONS.

8TH & BYRD STREET.

Richmond, Va., 5/2/1907.

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: ☞