FARM CONCRETE

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Modern Fireproof Farm Buildings, of Concrete.

FARM CONCRETE

BY

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INTRODUCTION

The importance of the correct use of concrete as a building material can scarcely be sufficiently emphasized, no matter into what particular type of structure the material enters. The cost of good concrete, in labor and materials, is practically no more than that of poor concrete. It is a fact, however, that a great amount of unsuccessful work in concrete results from the non-observance of simple fundamental rules. In the preparation of this manual on farm concrete, the writer has endeavored to treat this particular phase of the subject in a simple, non-technical, and at the same time, a reasonably comprehensive manner, so that a study of it will lead to a clear understanding of actual requirements for successful work.

A wealth of material relating to the agricultural uses of concrete has been evolved from various sources, but in the main it exists only in scattered and incoherent form, making its efficient use difficult. In this volume there is collected and correlated into concise and easily available form the essential principles and requirements underlying the successful use, for farm purposes, of this wonderfully flexible material, and special emphasis is laid upon the correct and efficient application of these principles to various types of farm structures. It is believed that by following conscientiously the practical requirements as outlined in this text, the most inexperienced layman will be enabled to produce concrete of such a quality that it will permanently endure.

While the treatment of the subject is purposely essentially practical in order that the most advantageous use of it may be made by the farmer and the student of agriculture, it is believed that many concrete contractors, particularly those whose work carries them into agricultural communities, will find something of value herein. It is unfortunately true that many contractors who make concrete their main business are woefully ignorant of the first principles of good construction.

The various phases of the subject are arranged in their natural sequence, beginning with a discussion of the materials from which concrete is made, and following with a description of its most important properties. The essential processes in making concrete are next considered, and finally, detailed directions are given for specific types of construction.

It is the writer's pleasure at this time to express his appreciation of the courtesy accorded him by the Universal and the Atlas Portland Cement Companies in permitting the use of material contained in their many admirable bulletins; some of this material has been modified and abstracted, so that it is difficult to give exact credit for it; permission for this, however, was given. The Portland Cement Association has been extremely courteous in offering suggestions and criticisms, and special thanks are due to Messrs. A. J. R. Curtis, R. D. Brewer, and H. Colin Campbell, of this association.

The following illustrations and drawings were gotten entirely or in part from the Portland Cement Association: 3, 7, 21, 22, 23, 29, 31, 32, 35, 36, 37, 39, 45, 49, 50, 62, 72, 80, 82, 83, 85. Figures 60 and 61 were adapted from the Atlas booklets. Other figures are credited as follows: 11, Chain Belt Co.; 38, Ross Studding Socket Co.; 53,

D. & A. Post Mold Co.; 47, 69, W. E. Dunn Mfg. Co.; 76, Elgin Silo Co.; frontispiece, 8, Polk-Genung-Polk Co.

The writer wishes also to acknowledge his indebtedness to his wife, Alma Heuman Ekblaw, for the assistance she has given in the preparation of the manuscript and in the work incidental to publication.

Though care has been taken to eliminate errors as far as possible, they will probably occur, and any corrections, as well as criticisms or suggestions, will be gladly received.

K. J. T. EKBLAW.

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CHAPTER I

CEMENT

History. — The broadest development of the cement industry, though it is thousands of years old, has occurred almost within the last century. It is known that the Egyptians 4000 years ago possessed the knowledge of making a cement which had the property of hardening in the presence of water. The ruins of ancient Babylon and Nineveh show definite traces of the use of some cementitious material which was employed in bonding together the huge blocks of their masonry structures. It is said that the Aztecs and Toltecs, the prehistoric peoples of America, employed a cement mortar so effective and durable that masonry joints are projecting where the adjacent stones have been worn away by thousands of years of weathering action. The Romans, in the construction of their sewers, aqueducts, buildings, and roads, employed hydraulic cements of such good quality that specimens possessing great strength and toughness are to be found to-day. One of the largest and best examples of ancient concrete construction which is extant is the dome of the Pantheon, erected at the beginning of the Christian era; this magnificent structure has withstood the test of nineteen centuries of destructive elements and does not exhibit a single crack.

Though the use of hydraulic cements was apparently so wide in earlier times, during the Middle Ages it fell, for some reason, into disrepute; the builders of this time seemed to prefer lime and silt mortars of no durability or permanence. Many of the beautiful European cathedrals were begun at this time and the inefficiency of this type of mortar is seen in the frequency of the repairs which were necessitated in these structures. Later there came in Italy and in Germany a half-hearted revival of the use of hydraulic cements. The Italians made use of volcanic slag in the preparation of a cement known as "puzzolana." The Germans made a similar product, giving it the name of "trass." Both of these products, though inferior to the modern article, were superior to the mortars which had been used for several centuries.

To John Smeaton, an English engineer, must be given the honor of the actual rediscovery of the method of manufacture of hydraulic cements from natural rock. Intrusted with the replacement of the famous Eddystone lighthouse upon a permanent foundation, his first effort was the determination of some material which would bind the foundation stones together and resist the disintegrating effect of the water. He found in 1756 that argillaceous limestones or those containing clays would produce a cement which exhibited the property of setting under water, thus rediscovering hydraulic cements and securing for himself lasting engineering fame.

The first manufacturer of hydraulic cement in anything like merchantable quantity was Joseph Parker, who in 1796 established a factory for the manufacture of what he called Roman cement, from concretionary or geodic nodules containing limestone and clay. A similar product was produced at Boulogne from practically the same material in 1802.

The manufacture of natural cements in the United States

Fig. 1. — The Appian Way — A Roman Concrete Road.

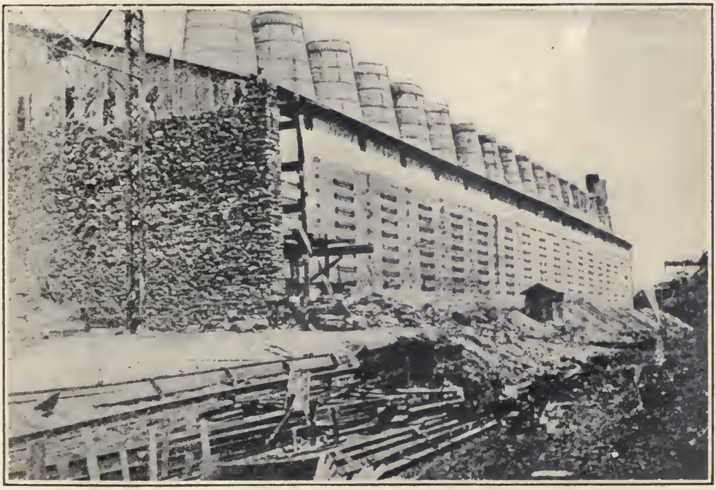


Fig. 2. — Old-fashioned Vertical Cement Kilns.

was begun by Canvass White, who, in 1818, established a factory near Fayetteville, New York. The use of cement was quite limited for many years, only 300,000 barrels being manufactured between 1818 and 1830, but reconstruction following the Civil War brought about a demand which resulted in a rapid increase in production. The climax in the natural cement industry was reached in 1899 when nearly 10,000,000 barrels were produced. Since then, due to the perfection of better methods for manufacturing artificial cement, the production of natural cements has been on a constant decline until now only a small percentage of all the cement used in the United States is natural cement.

Artificial cement was invented by an Englishman, Joseph Aspdin, in 1824, and the next year the first plant for the manufacture of this cement was established by him. He called his product "Portland Cement," from its close resemblance when hardened to the stone from the famous Portland quarries. For many years England led in the manufacture of Portland cement but was displaced by Germany and later by the United States, which has surpassed all other countries as a manufacturer and user of Portland cement.

The manufacture of artificial Portland cement was initiated in the United States by David O. Saylor of Coplay, Pennsylvania, in 1875. Though the development was slow at first on account of high production cost, it has been extremely rapid in the last twenty years, until at the present time the total annual production of the hundreds of cement factories in the United States approximates 90,000,000 barrels.

Cements. — Though there are many different kinds of cements used for many different purposes, in this discussion we shall have to do only with hydraulic cements; consequently, it will be understood that when the term "cement" is used hereafter, hydraulic cement is referred to.

Hydraulic cement may be defined according to Reid as a pulverized material composed principally of silica, alumina, and lime which, when mixed with water, undergoes a chemical change forming new compounds that develop the property of setting or crystallizing into a solid mass, even under water.

Cements are usually included under the following four general classes:

1. Hydraulic limes.
2. Natural cements.
3. Portland cements.
4. Puzzolana.

Hydraulic limes are made by roasting argillaceous or siliceous limestones, then slaking by the addition of water either completely or partially with no sensible change in volume.

Natural cements are manufactured by the calcining and subsequent pulverization of a natural argillaceous limestone without preliminary mixing and grinding. This type of cement was formerly called "Rosendale" cement from the fact that large quantities of it were manufactured at Rosendale, New York.

Portland cement, or artificial cement, is the artificial product made by mixing finely ground argillaceous and calcareous materials in proportions approximating three parts of carbonate of lime to one part of silica, alumina, and iron oxide, then calcining it and finely pulverizing the resulting clinker. The essential components of Portland cement are silica, alumina, and lime. In addition to these ingredients there are always found small quantities of iron, magnesia, alkalies, sulphuric and carbonic acids, and some water. Puzzolana cement, though properly including only cement manufactured from volcanic slag, is sometimes taken to include slag cement or cement manufactured from blast furnace slag.

It is interesting to note the difference in composition between natural cements, Portland cements, and puzzolana. A comparison of the principal constituents of these three cements is herewith given:

	Per Cent SiO_2	Per Cent AlO_2	Per Cent CaO
Natural cement	15–23	2–10	25–50
Artificial Portland cement .	22	6	63
Puzzolana	29	12	50

The variation which is noticeable in the constituency of the natural cement is due to the fact that the products from which the cement is made are taken as they occur in nature and an extreme degree of variation is certain to result. This is an undesirable feature since it is improbable that a natural cement which is uniform both in strength and color can be secured at all times from even the same factory. The composition of the artificial Portland cement is practically constant, and since the constituency can be quite definitely controlled the buyer is assured of a constantly uniform product; in fact, from the large cement companies cement can be secured which does not vary to any appreciable degree year after year.

Manufacture. — The manufacture of Portland cement in the early days of the industry was carried on in a vertical, continuous, mixed-feed type of kiln, Fig. 2. These

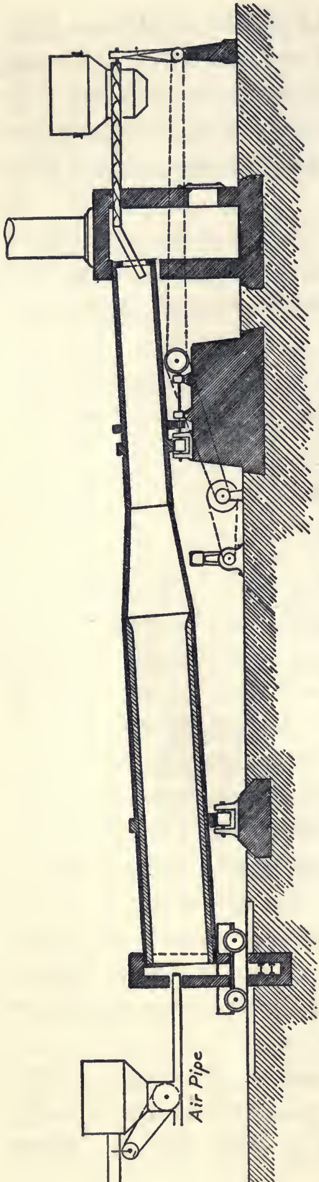


Fig. 3. — Cross-section of Modern Rotary Kiln.

were usually forty-five feet in height and sixteen feet in diameter, built of masonry and lined with fire brick. The cement rock and fuel, which was either anthracite or a good quality of bituminous coal, were spread in the kiln in alternate layers, about ten pounds of coal being required to burn one hundred pounds of rock. The temperature of burning varied with the character of the rock, but was usually less than 2500° F. The calcined rock was drawn off through the vent holes at the bottom and carried to the crushing machines and from there to the grinders.

In the manufacture of artificial Portland cement, horizontal rotary kilns are used almost exclusively. The rotary kilns, shown in Fig. 3, are long steel cylinders from five to eight feet in diameter and from 60 to 240 feet in length. These cylinders are set upon two sets of rollers with their axes inclined about one foot in twenty to the horizontal. They are rotated by means of gears. The mixed rock is introduced at the upper end of the cylinder, while the fuel, which is usually powdered coal but sometimes gas or oil, is injected at the lower end through a special burner. The rotation of the cylinder gradually works the material toward the lower end, a fusion temperature of 2600° F. or more being maintained in the lower twenty or twenty-five feet. The clinker is discharged at the lower end in greenish black balls, varying from one-quarter to one inch in diameter. These balls are then passed through buhr or ball mills and ground to the finest possible degree, since the finer the cement, the greater is its cementing quality. One type of Portland cement is made by intimately mixing granulated blast furnace slag of proper composition with a certain amount of slaked lime and then grinding to as fine a powder as possible. The composition of this cement can be made to accord almost exactly with that of any other Portland cement.

Storage. — Cement is almost universally sold by the barrel, though occasionally small users will buy a single bag or two. In early days it was put up in paper or cloth bags and in wooden barrels, but modern deliveries are made almost entirely in cloth bags or in bulk. The material is so heavy that it soon bursts the paper bags, thus occasioning a high loss. The wooden barrels were variable in size and were extremely heavy to handle so that their use was ultimately discontinued. The modern bag is made of heavy muslin or light duck and is quite durable so that it can be refilled several times if carefully handled. Custom has made the ninety-four pound (net) bag standard, and four bags constitute a barrel.

Since practically every cement manufacturer in the United States ships a large portion of his product in cloth bags, a considerable outlay of capital is invested in the bags themselves. It has been estimated that in the United States the bags containing a year's shipment of cement are worth in the vicinity of $30,000,000. When cement is sold, the price of the sacks is included in the price of the cement, but the cement company will repurchase such sacks as are in good, sound, serviceable condition when delivered to their mill. In order to keep the bags in this condition so that they will be accepted by the manufacturer, they should not be allowed to become wet or torn. Considerable loss of bags results from improper methods of shipping them. A recommended method is to pile the bags in bundles of fifty with two ropes or wires forty inches long beneath the pile and a longer rope or wire eight feet in length resting lengthwise across the top of the bags. The bags are rolled up around the long wire, the outside wires then brought around and the ends tied together, while the long wire is brought over the two ends of the bundle thus formed and tied securely, as shown in Fig. 4.

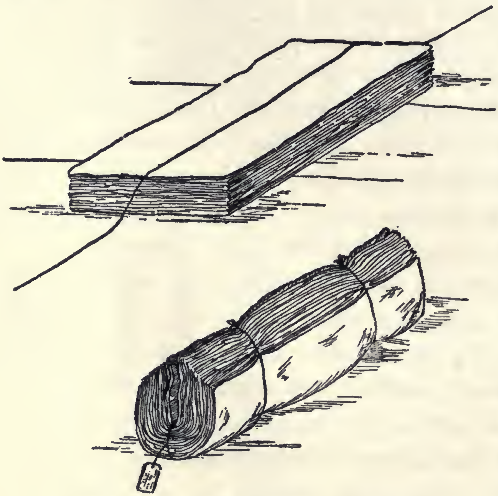


FIG. 4. — Packing Bags for Shipment.

Cement when in bags should be stored in a house that will effectually preserve it from dampness. The floor should be very well supported and strongly built, and should be raised off the ground to some extent so that dampness will not creep through it. A circulation of air under the floor will insure dryness. The building should be made sufficiently large so that there will be no difficulty

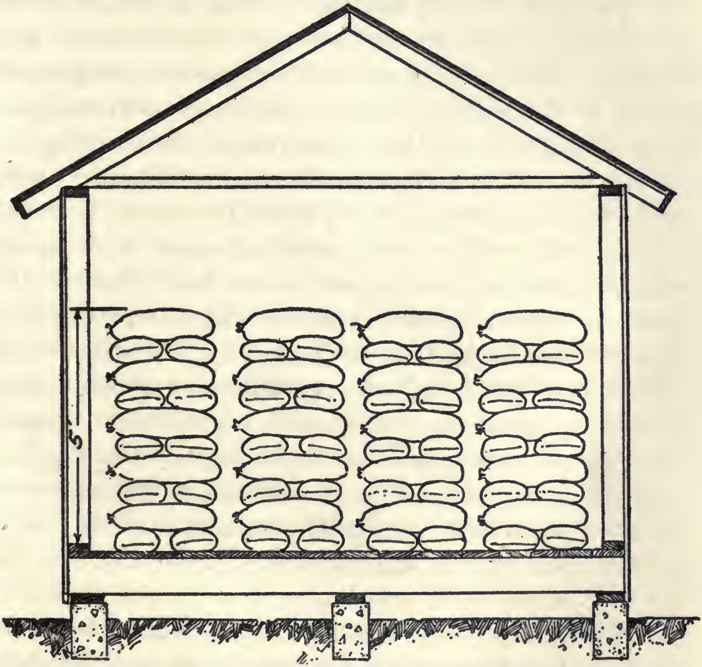


FIG. 5. — A Store-house for Bagged Cement.

in getting at any individual bag of cement. The common way of piling the cement bags is to lay them in tiers of two bags each, each successive pair of bags being laid at right angles to the preceding one. It must also be remembered that if no lifting device is to be used the piles of bags should not be over six feet high, since it is extremely difficult for a laborer to lift a bag of cement above his shoulders. The height of the tiers may be increased by using a small portable platform five or five and one-half feet high upon which a second man may stand and receive the bags handed to him by the first man. Another advantage of having the piles of bags separated by passages is the possibility of freer circulation of the air around them. The building itself should be made weather-proof and the walls, while air-tight, need not be especially strengthened because all the weight of the cement comes upon the floor. Fig. 5 gives an idea of the construction of the building.

When cement is sold and delivered in bulk as it quite commonly is to large users, it should be stored in a dry building with weather-proof walls. It must be borne in mind that the bins should not be too large because the cement is extremely heavy material and a large quantity might result in the bursting of the walls. The bulk method of handling cement is becoming quite popular among dealers since bulk cement is usually sold considerably cheaper than bagged cement and the dealer himself can bag the cement at a low cost. If one is desirous of getting a certain brand of cement, he should ascertain that the dealer has not put a cement manufactured by one company, in bags bearing another's brand.

Sampling and Testing. — Sampling and testing of cement is usually not done except on large contracts. There is no uniformity of the methods of sampling, some engineers testing every fifth barrel, some every tenth, and still others test every other barrel delivered. In very important work it may be desirable to test every barrel. For small jobs such as usually are found on the farm it is generally sufficient if a standard brand of cement be purchased from a reputable dealer. The large cement companies have so standardized their product and its manufacture that it is seldom if ever that any cement which could not be used for agricultural purposes is produced.

Properties. — The properties of cement with which we are chiefly concerned are those of strength and permanence. Other qualities such as color, specific gravity, activity, soundness, fineness, and constancy of composition are also important, but when we take cement on faith as we do when we purchase and use cement in small quantities, we need not pay particular attention to them.

Natural cement is extremely variable in strength at all times. This is due to the indefiniteness of its composition. However, the manufacture of natural cement has so decreased that its production at the present time is practically negligible and it would require considerable effort in most cases to obtain it. The artificial cement is somewhat variable in strength, depending upon the care used in its manufacture. Its strength also varies with its age. Concrete three months old may be several times as strong as that seven days old. Poorly manufactured cement sometimes will deteriorate so that while apparently possessing the requisite strength soon after mixing, it will lose this gradually and ultimately cause the concrete in which it is used to disintegrate.

The color of cement is usually not important. It is chiefly derived from its impurities such as oxides of iron or manganese rather than its essential ingredients. An underburned cement will usually exhibit a lighter color than will one which is well burned. Sabin states that gray or greenish gray is indicative of good cement. Specific gravity is important in accurate tests as a means of detecting adulteration, because good cement will have a specific gravity of about 3.1 and a variation of 0.2 or more from this will be a strong indication that some foreign material such as unburned stone, etc., has been added.

By activity is meant the time required for the initial set, or the first evidence of crystallization, and the final set, when the mass cannot be appreciably distorted without rupture. Setting is mainly a chemical process, while hardening is more a physical process. The initial set, according to standard specifications, shall not develop in less than 45 minutes, while the final set shall not develop in less than one hour nor more than ten hours.

The property of soundness includes resistance to shrinkage and expansion with the resultant cracking. Various methods for testing for soundness have been devised and an approximate method will be described later.

It is the aim of all cement manufacturers to grind their cement as fine as possible since fineness increases the strength. The standard specifications require that 78 per cent of the cement shall pass a No. 200 sieve, *i.e.*, a sieve having 200 meshes to the lineal inch.

Various methods are used in the determination of the strength of cement. It is usually mixed in certain proportions with what is called standard sand, standard sand being a natural silica sand obtained at Ottawa, Illinois, screened to pass a No. 20 sieve and be held on a No. 30. Test pieces are made from this mixture either in the form of small beams or briquettes and subjected to transverse or tension tests. The chemical analysis of cement is one with which we are not particularly concerned, since it is only in exceptional cases that tests for chemical composition are made.

CHAPTER II

CONCRETE

CONCRETE is a mixture of hydraulic cement with a quantity of inert materials which when mixed with water will harden to form an artificial stone. In this chapter will be discussed the various ingredients constituting concrete with the exception of cement which was discussed in the preceding chapter.

In order that the reader may follow the subsequent discussions more closely, it will be well to keep the following distinctions in mind:

Paste — a mixture of cement and water.

Mortar — a mixture of cement, sand, and water.

Concrete — a mixture of cement, sand, and pebbles, or broken stone; or in other words, a mixture of cement, a fine aggregate and a coarse aggregate.

Rubble concrete — a concrete using an aggregate of exceptionally large particles.

AGGREGATE

The term "aggregate" is applied to the inert materials which are used for the purpose of giving bulk to concrete. The aggregate may be of widely different materials such as sand, gravel, broken stone, brick, boulders, etc., and may be equally widely variable as to size, from the finest particles of sand to large boulders of "two-man" size, or even larger in special cases. The term "sand" is a very loose one and in order that subsequent discussions may be simplified, we shall make an arbitrary distinction so that under the term will be included only the aggregate passing through a sieve with meshes one-quarter of an inch square. When bank run gravel is so screened the particles held on the screen will be given the name "pebbles," while those passing through will be designated "sand." If crushed stone is used, the particles corresponding to the sand are called "screenings."

The aggregates most commonly used are *pebbles* and *rough stone.* A great many attempts to determine which is the better of these two have been made, but the general consensus of opinion seems to be that for most practical purposes one is practically as good as the other. Gravel makes an excellent aggregate and in many cases is much more easily accessible than broken stone, but in localities where gravel is not available the broken stone will of course be used. The greater portion of rural concrete construction is accomplished using gravel from local sources as the aggregate. Large boulders are used in large mass concrete construction such as heavy bridges, abutments, dams, and work of similar nature; it is seldom that work sufficiently massive for the employment of this type of aggregate is undertaken on the farm. However, small boulders up to six or eight inches in diameter can be successfully employed in the construction of foundations, care being taken that the boulders are perfectly clean and that when put in place are completely surrounded with a cement mortar.

Pebbles. — The precautions to be used in the selection of the type of aggregate will apply in the main with equal pertinence to sand or pebbles. Sand is really fine pebbles. In specifications the statement is usually made that the

FIG. 6.—What Actually Happens in Removing Gravel from Small Pits.

FIG. 7.—A Common Appearance of Small Gravel Pits.

sand be clean and sharp. The first requisite, that of cleanness, is extremely important, but it is not absolutely necessary that the sand be sharp in order to produce a strong durable concrete; what is more to the point is to have it well assorted as to size with only small percentage of fine sand. If it is necessary to use fine sand, the proportion of cement should be increased because fine sand used alone does not make as strong concrete as does coarser sand; in fact, nearly double as much cement will be necessary in order to bring the concrete up to the requisite standard strength. From this it is evident that in many cases it will be economical to screen the sand and recombine it with pebbles in such proportions as to reduce the fine sand content.

The chief objection to bank run gravel as ordinarily employed is the usual presence of a large amount of impurities; as bank run gravel is ordinarily obtained from local gravel banks and pits, it is impossible to prevent this. The banks or pits are usually covered with a stratum of soil or clay and this must be removed before the underlying gravel is available. The stripping process is never quite complete and as a result the upper layers of gravel are bound to contain more or less of the soil or clay which covered them. After the gravel is removed and a greater depth is reached, the gravel will be taken out from banks more or less vertical, and a quantity of the impurities from above, as illustrated in Fig. 6, will be continually slipping down to the bottom, there to be shoveled into the wagons. A surprising amount of deleterious material will thus be incorporated in ordinary gravel, the percentage sometimes running as high as twenty or twenty-five per cent.

When the impurities are of an organic nature such as vegetable loam, it has generally been found that the mortar or concrete is to a greater or less degree prevented from hardening and attaining its maximum strength. If the fine material is of ordinary argillaceous or silicious composition the bad effect is not so pronounced and is more mechanical in character, some engineers even going so far as to recommend the use of two or three per cent of clay in concrete, as giving it greater density without materially reducing its strength if at all. This point, however, is a debatable one, and we can err only on the side of safety if we make assurance that the aggregate is perfectly clean.

If the gravel contains an undue amount of impurities it can be easily detected by picking up a handful of the material and rubbing it between the palms of the hands, letting it dribble slowly away. The fingers and hands may be discolored and made to feel soapy or slippery. If such a condition exists, the material should be looked upon with suspicion for it probably contains sufficient impurities to prevent the successful manufacture of concrete from it.

The percentage of impurities can be determined with a fair degree of accuracy by the use of a graduated glass or cylinder of 100 cubic centimeter capacity. This should be filled half full of the material and shaken down well until it is thoroughly compacted. The interstices should be filled with water, the vessel shaken and refilled with aggregate. This procedure should be followed until the volume of the gravel and water is 100 c.c. Upon allowing the mixture to settle a distinct division line between the dirt and the clean sand and gravel will be formed which will indicate the amount of impurities. Material containing over 2 or 3 per cent of impurities should be washed. The washing of gravel may be accomplished by piling up small quantities of it as it is used and letting water from a hose run through it until the water runs clean.

Equally important with the necessity of using clean aggregate is that of having an aggregate with the correct variation in size of its particles. The old idea that strength and durability depend largely upon the cement is a mistaken one. Proper proportioning is necessary and the man who understands his aggregates will mix them in the proper proportions which have been shown to be the best by tests or actual experience, and is the one who will have the best results.

Ordinary bank run gravel generally contains a much greater quantity of fine aggregate than is desirable for good concrete work. The best aggregate contains just a

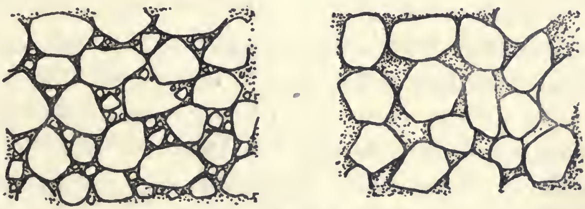


FIG. 8. — Variation in Size of Aggregate Means Less Cement.

sufficient number of smaller particles to fill the interstices between the largest ones, just enough still smaller to fill the voids still existing, and so on down until the finest particles are used. In this way a minimum amount of cement is used and since cement is the expensive part of concrete, it is an economical procedure to employ an aggregate with the proportions of the different sized particles as nearly ideal as possible. This is illustrated in Fig. 8.

There are certain principles relating to volumes of different materials and to their voids which may be of interest.

"1. If a mass of equal spheres are symmetrically piled, theoretically in the most compact manner, it can be shown mathematically that whatever the size of the spheres, the voids will be about 26 per cent, though in practical experience, it is difficult to get below 45 per cent voids.

2. In any aggregate the largest percentage of voids will occur with grains of uniform size and the smallest percentage of voids with a mixture of sizes so graduated that the voids of each size are filled with the largest particles that will enter them.

3. An aggregate consisting of a mixture of coarse particles and sand will contain a smaller percentage of voids than will sand alone.

4. An aggregate with rounded grains such as gravel contains a smaller percentage of voids than one with sharp grains such as broken stone, even though the particles in both may have passed through and been caught by the same screens.

5. The bulk of dry sand is increased by the addition of small amounts of water, the increase in volume being from five to eight per cent." [1]

In connection with these principles it will be seen that the ideal procedure is to separate the gravel into grades containing various sizes and then recombine these grades into such proportions as would be in accord with the principles above enumerated. While this may not be entirely practical still it may be followed to the extent of screening out the sand, and then adding sufficient sand to fill the voids that have been shown by tests to exist in the coarse aggregate. This is not expensive and it will be found to repay many fold in the production of better concrete, considering the time and labor required.

In practical work both of the exceedingly important preceding precautions are seldom taken; so many local concrete contractors with little or no knowledge of the fundamental principles underlying concrete construction simply assume that all that is necessary is to mix the materials and then put them in place. It is probably due to the non-observance of the foregoing principles that much

[1] Taylor and Thompson, "Plain and Reinforced Concrete."

concrete construction fails, the blame being laid upon the concrete itself as being of poor structural material, when in all fairness the entire blame should be laid upon the manufacturers of the concrete for their ignorance and carelessness in allowing such poor workmanship.

Broken Stone. — Broken stone is considered by some engineers superior to gravel for concrete. Its chief advantage lies in the fact that the surfaces of the angular fragments are not so smooth, thus assisting the formation of the bond between the cement and the stone. Most tests, however, seem to indicate that this quality is of no special advantage and it has usually been found that aggregates of rounded shape give better results than angular crushed quartz. Some investigators have found that the maximum strength is obtained by the use of a mixture of gravel and broken stone.

Most dealers handle broken stone of several sizes, such as screenings, $\frac{1}{2}''$, $\frac{3}{4}''$, $1\frac{1}{2}''$, etc., these figures representing the size of opening through which the stone particles have been passed. In consequence the stone is fairly uniform in size and as such is not the most desirable for concrete work. If broken stone must be used, it is well to buy a quantity of each of the several sizes and recombine them in such proportions as will reduce the voids.

For good concrete it is essential, of course, that the aggregate be hard and tough of itself. The following rocks are employed in the production of broken stone and they are listed with the hardest rock first:

1. Granite
2. Trap
3. Gravel
4. Marble
5. Limestone
6. Slag
7. Sandstone

A hard limestone is perhaps the commonest of the crushed stones. The particles of rocks should be free from dust and dirt and should not be used when even partly covered with clay because thereby the cement is prevented from obtaining a firm joint with the surface of the stone.

Miscellaneous Aggregate. — A number of other materials are used as concrete aggregate under special conditions, such as broken brick, cinders, etc.

Cinders are used to a considerable extent in the construction of concrete roofs and floors on account of their light weight. Cinder concrete weighs only about two-thirds as much as concrete manufactured from gravel or broken stone. The strength, however, is proportionately less and care must be exercised in its use. Only clean hard-burned cinders should be used because any others are likely to be subject to disintegration and are practically valueless for concrete work.

Water. — It is to be expected that every manufacturer of concrete understands the necessity of using clean water for mixing his concrete, but sometimes while the water is apparently pure, there are impurities in it that may ultimately cause the failure of the concrete. It has been found that certain alkalies have a deleterious effect upon concrete and no doubt strong acids will also affect it so that precautions should be taken to avoid the use of water containing either of these. More will be said later in regard to the action of alkalies.

In the construction of small dams, bridge abutments, etc., by those who have not had considerable experience in concrete construction, it very often happens that the water for tempering the concrete is taken from the stream itself with a result that a considerable quantity of sediment is stirred up at the bottom of the stream and put into the concrete. Numerous failures of concrete bridge abutments have occurred from this very cause.

Proportioning

In proportioning to obtain the best concrete, it is generally recognized that the maximum strength will accompany maximum density; or in other words, that the percentage of voids should be small as possible. It is evident that only approximately perfect concrete can be secured, even under the best conditions, because of practical considerations. Fuller[1] states:

"Perfect spheres of equal size piled in the most compact manner theoretically possible leave but 26 per cent voids. If the spaces in such a pile of equal-sized perfect spheres were filled with other perfect spheres of diameter just sufficient to touch the larger spheres, it would take spheres having relative diameters of 0.414 and 0.222 of the larger spheres, and the voids in the total included mass would be reduced to 20 per cent. Using in this same manner smaller and smaller perfect spheres, it is conceivable that the voids could be reduced to so low a per cent of the total mass and to a size so small as to be only in a capillary form, and thus prevent the passage of water. This is assuming that every particle is placed exactly in its assigned place, but it is inconceivable that such an arrangement should take place under practical conditions, and in fact numerous trials by the writer with large masses of equal-sized marbles have demonstrated that they cannot be poured or tamped into a vessel so as to give less then 44 per cent voids.

"If equal quantities of spheres of, say, three sizes are mixed together, the per cent of voids in the total mass immediately increases, becoming about 65 per cent, due probably to the smallest spheres getting between and forcing apart the largest. If, however, the containing vessel is continually shaken and the spheres stirred around, the smallest spheres will gradually all gravitate to the bottom and the largest to the top and the amount of voids in the total mass will again approach 44 per cent. If a large number of different sized

[1] Taylor and Thompson, "Plain and Reinforced Concrete."

spheres are used, employing an increasingly large number of the smaller sizes so that each larger size may be said to be wholly surrounded by the next smaller size, the voids remain the same, no matter what the shaking, and will in some cases reach as low as 27 per cent.

"With ordinary stones and sands the same law holds as with perfect spheres except that they do not compact as closely, and the percentage of voids under comparable conditions is larger, varying with the degree of roughness and other features of the stones and sands used for the experiments."

The proportions of materials entering into the manufacture of concrete will depend to a great extent upon the nature of the work. When strength is the prime requirement and must be obtained at a sacrifice of cost, a very rich mixture should be used. On the other hand, when strength is only a minor requisite and the concrete is placed so that full advantage is taken of its compressive strength, a weak mixture can be used for the sake of economy. From tests of strength it is known that the strongest concrete can be obtained if the quantity of mortar is just sufficient to fill the voids in the aggregate. If the mortar is not sufficient in quantity, the strength of the concrete will be materially diminished and unless the mortar possesses great strength in itself, a similar impairment of strength will result if an excess of mortar is used.

In view of these considerations, concrete should be considered not a mixture of cement, sand, and stone, but as an aggregate with a mortar filling the main office of binder. The important points in proportioning concrete are the strength of the mortar itself, the amount of voids in the aggregate, and the percentage of voids that is occupied by the mortar.

In many popular discussions of concrete, certain proportions of materials are given for different classes of work.

These so-called standard proportions have as a basis more accurate determinations and are in themselves merely an approximation of correct proportions. Their chief value lies in the fact that they serve as a simple guide to an inexperienced user of concrete. These proportions as given in Taylor and Thompson's "Concrete, Plain and Reinforced" are as follows:

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

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

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

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

As noted, the proportions are stated in three parts; for instance, a 1 : 2 : 4 mixture means that one part of cement, two parts of sand, and four parts of loose gravel or broken stone constitute the mixture. It is common practice to express concrete proportions with the quantity of cement as unity and the quantities of other materials as aliquots or multiples of this.

Actual proportioning is highly desirable, because it is only by mixing concrete in as nearly correct theoretical proportions as possible that we can obtain at the same time maximum strength and economy. A rough method of proportioning is as follows:

A vessel of known content is filled with the aggregate; water is then poured in until the joints are filled. The amount of water that is required to fill the joints should be an indication of the quantity of the voids.

This method in practice is of no great value unless it is carefully done and unless certain precautions are not lost sight of. The aggregate, if dry, will absorb a considerable quantity of moisture. It has been found that one cubic foot of dry sand will gain about 10 per cent in volume when dampened. When loose, dry, Portland cement is dampened it shrinks about 15 per cent in volume, acting differently from sand; thus it is seen that it is difficult to make anything more than an approximate determination of the voids in this way. However, it is entirely possible that even though the results be inaccurate, the proportions thus obtained are more nearly correct than those resulting from mere guess-work, and in most cases the small amount of effort required for the performance of the test will be sufficiently repaid. A simple and practical apparatus [1] for measuring voids in aggregate is shown in Fig. 8a. While the voidmeter shown is designed primarily for laboratory use, the idea can be applied wherever there is need for it. The apparatus consists of a section of 8″ cast iron pipe, with a cap at one end,

[1] This apparatus was built for Professor F. M. White, of the University of Wisconsin, who kindly furnished the accompanying illustration.

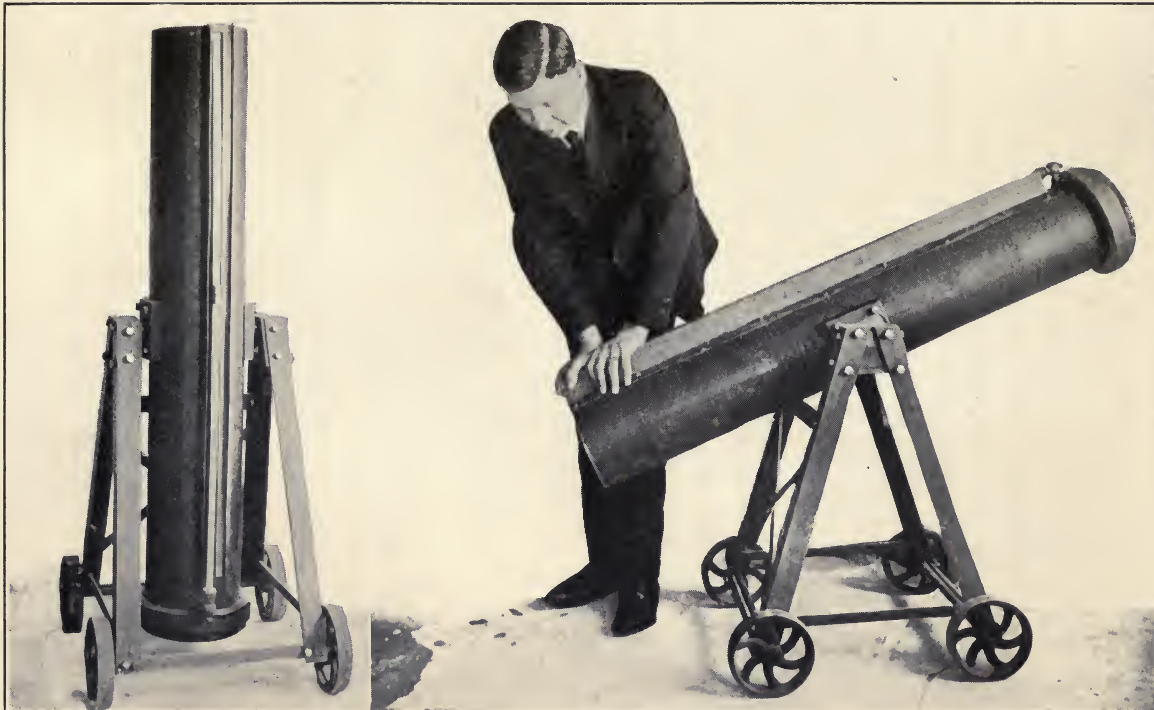


FIG. 8 *a*. — A Practical Laboratory Voidmeter.

and fitted with a gauge glass and gauge, graduated to read in hundredths of a cubic foot. For convenience it is fitted with trunnions and mounted on a rolling carriage, so that it can be easily moved about and emptied when desired. In using the voidmeter, a quantity of water is poured into the container and the gauge reading taken; then a cubic foot of aggregate is added, and the rise of the water in the glass noted. The difference between the two readings subtracted from one cubic foot gives the amount of voids in the aggregate, and coincidently, since the scale is graduated in hundredths, the per cent of voids.

Of course, in large structural contracts where an immense amount of concrete is used, exceedingly careful volumetric analyses of both sand and gravel are made, but such a procedure is impracticable on small jobs. The accompanying tables will be of assistance in a quick determination of the amount of materials needed.

QUANTITIES OF SAND AND GRAVEL OR STONE REQUIRED FOR A ONE-BAG BATCH OF MORTAR OR CONCRETE, AND VOLUME OF RESULTING COMPACTED MORTAR OR CONCRETE

MIXTURES			MATERIALS			VOLUME IN CU. FT.	
Cement	Sand	Gravel or Stone	Cement in Sacks	Gravel, Sand, or Stone Cu. Ft.	Gravel, Sand, or Stone Cu. Ft.	Mortar	Concrete
1	1.5	—	1	1.5	—	1.75	—
1	2.0	—	1	2.0	—	2.1	—
1	2.5	—	1	2.5	—	2.5	—
1	3.0	—	1	3.0	—	2.8	—
1	2.0	3	1	2.0	3	—	3.9
1	2.0	4	1	2.0	4	—	4.5
1	2.5	4	1	2.5	4	—	4.8
1	3.0	5	1	3.0	5	—	5.8

Quantities of Cement, Sand, and Gravel or Stone Required for One Cubic Yard of Compacted Mortar or Concrete

Mixtures			Quantities of Materials				
Cement	Sand	Gravel or Stone	Cement in Sacks	Sand		Stone or Gravel	
				Cu. Ft.	Cu. Yd.	Cu. Ft.	Cu. Yd.
1	1.5	—	13.5	23.2	0.86	—	—
1	2.0	—	12.8	23.6	0.95	—	—
1	2.3	—	11.0	27.5	1.02	—	—
1	3.0	—	9.6	28.8	1.07	—	—
1	2.0	3	7.0	14.0	0.52	21.0	0.78
1	2.0	4	6.0	12.0	0.44	24.0	0.89
1	2.5	4	5.6	14.0	0.52	22.4	0.84
1	3.0	5	4.6	13.8	0.51	23.0	0.85

Stone and gravel = 45% voids (average). 1 sack cement = 1 cu. ft. 4 sacks = 1 bbl. Based on Tables in "Concrete, Plain and Reinforced," by Taylor and Thompson.

Example:

To find the quantities of materials to build a concrete feeding floor 30 feet long and 27 feet wide, the floor to be 5 inches thick and the concrete composed throughout of a mixture of 1 part Portland cement, 2 parts clean, coarse sand, all of which will pass a $\frac{1}{4}$-inch mesh screen, and 3 parts of clean, hard, screened gravel or crushed stone. First, find the number of cubic yards of concrete in the floor; 30 feet by 27 feet by $\frac{5}{12}$ foot equals 337.5 cubic feet; divided by 27, the number of cubic feet in a cubic yard, gives 12.5 cubic yards. From the table it is found that using the proportions 1 : 2 : 3, the following quantities of materials are required for a cubic yard of concrete: 1.74 barrels of cement, 0.52 cubic yard of sand, 0.77 cubic yard of gravel or stone; multiplying these unit quantities by 12.5, the number of cubic yards in the floor, we find that the materials required for the construction of this feeding floor are approximately 21.75 barrels of cement, 6.5 cubic yards of sand, 9.75 cubic yards of stone or gravel.

A simple rule for the determination of the quantities of materials in a cubic yard of concrete is one devised by Fuller and is taken from Taylor and Thompson's "Concrete, Plain and Reinforced."

"Let c = number of parts of cement;
s = number of parts of sand;
g = number of parts of gravel or broken stone.

Then $\frac{11}{c+s+g} = P$ = number of barrels of Portland cement required for one cubic yard of concrete.

$P \times s \times \frac{3.8}{27}$ = number of cubic yards of sand required for one cubic yard of concrete.

$P \times g \times \frac{3.8}{27}$ = number of cubic yards of stone or gravel required for one cubic yard of concrete."

The following table is made up from Fuller's rule and represents fair averages of all classes of material. The first figure in each proportion represents the unit, or one barrel (4 bags) of packed Portland cement (weighing 376 pounds), the second figure, the number of barrels loose sand (3.8 cubic feet each) per barrel of cement, and the third figure, the number of barrels loose gravel or stone (of 3.8 cubic feet each) per barrel of cement:

MATERIALS FOR ONE CUBIC YARD OF CONCRETE

PROPORTIONS	CEMENT	SAND	GRAVEL OR STONE
	Barrels	Cubic Yards	Cubic Yards
1 : 2 : 4	1.57	0.44	0.88
1 : 2½ : 5	1.29	0.45	0.91
1 : 3 : 6	1.10	0.46	0.92
1 : 4 : 8	0.85	0.48	0.96

If the coarse material is broken stone screened to uniform size it will, as is stated above, contain less solid matter in a given volume than an average stone, and about 5 per cent must be added to the quantities of *all* the materials. If the coarse material contains a large variety of sizes so as to be quite dense, about 5 per cent may be deducted from all of the quantities.

Example: What materials will be required for six machine foundations, each 5 feet square at the bottom, 4 feet square at the top, and 8 feet high?

Answer: Each pier contains 163 cubic feet, and the six piers therefore contain $\frac{6 \times 163}{27} = 36.2$ cubic yards. If we select proportions $1 : 2\frac{1}{2} : 5$, we find, multiplying the total volume by the quantities given in the table, that there will be required, in round numbers, 47 barrels packed cement, $15\frac{1}{4}$ cubic yards loose sand, 33 cubic yards loose gravel.

As will be noted, this rule is made to apply primarily in the use of 3-part mixtures of cement, sand, and concrete. When cement and bank run gravel are used, the rule is not so successful nor accurate in its application. A rule known as the mortar rule is sometimes employed in the determination of the amount of materials in a mortar mixture. This rule expressed as a formula is as follows:

Let c = number of parts of cement;
s = number of parts of sand;
m = number of parts of mortar.
Then $m = (c + s)0.7$.

Mixing

The importance of thoroughly and carefully mixing the ingredients employed in the manufacture of concrete cannot be overestimated. An essential factor of successful concrete construction is the coating of every grain of sand with a film of neat cement and of every piece of coarse aggregate with mortar. There is a tendency to slight this part of the concrete work, but success can never be achieved thereby. The conscientious and understanding worker will never be guilty of carelessly mixing concrete.

Either hand mixing or machine mixing may be employed. Opinions vary as to the comparative merits of the two systems, but there is no doubt but what machine mixing is considerably the cheaper of the two and consequently in large contracts is mainly employed. In work of inconsiderable extent, hand mixing is probably the more advisable since cheap labor can be employed.

Hand Mixing. — The tools required in mixing concrete by hand are a mixing board and shovels with the addition

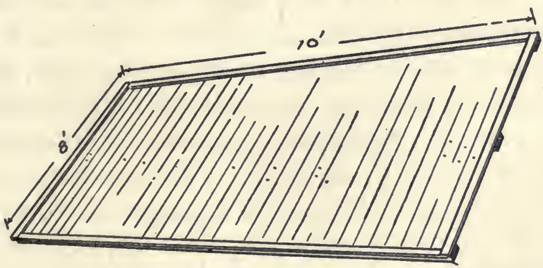


FIG. 9. — Mixing Board.

of wheelbarrows if the material has to be transported any considerable distance. The platform for a small gang in which only two men will be employed at mixing at the same time, should be 8 feet wide and 10 or 12 feet long. A simple one is made by nailing matched flooring 8 feet long upon flat 2-inch planks of the required length. A shallow rim of 1 × 4 stuff may be added if desired. The board should be 14 or 16 feet long if the number of men available for mixing is greater. Probably the best shovels are the ordinary square point, D-handled shovels. In addition to these implements, a couple of measuring boxes are decidedly advantageous in securing correct proportions. A convenient size box is made from 12-inch boards; the box being made 1 foot wide and 2 feet long, the sides extending past the ends of the box and shaped to form handles. No bottom is put in. Figs. 9 and 10 illustrate the construction of the mixing board and the measuring box.

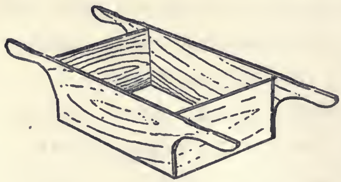


FIG. 10. — Measuring Box.

In proceeding with the mixing, assuming that a 1 : 2 : 4 mixture is to be used, the measuring box is set upon the mixing board and filled with sand. The box is then lifted up, leaving the sand in a clean pile. Upon this is spread one bag (1 cu. ft.) of cement, which is mixed dry, with the sand, until the resulting product is absolutely uniform in color. After the ingredients have been thoroughly mixed dry, water is added and the whole mixture is turned over several times again. The coarse aggregate is now measured out by the use of the measuring box, filling it twice, and is thoroughly mixed with the mortar. After the correct amount of water to produce the required consistency has once been obtained, this amount of water may be added all at one time when the dry mixture of sand and cement is wetted.

The degree of consistency or wetness which should be used is governed to some extent by the nature of the work. Dry mixtures are necessary for rapidity of molding in the case when expensive molds must be used a number of times. This, however, is done at a sacrifice of strength because up to a certain degree the wetter the mixture, the stronger and denser will be the resulting concrete. If the dry mixture must be used, much ramming is necessary, and this at times is difficult to do. It is expensive and on account of confined spaces is sometimes impossible.

An arbitrary classification of different degrees of consistencies may be made as follows:

1. *Dry.* — In this case just enough water is used to dampen thoroughly every particle of the mixture. A common criterion is its similarity in texture to ordinary damp soil; a quantity of it compressed in the hand will usually form a compact mass.

2. *Medium.* — A medium degree of consistency is one in which there will be a tendency toward a slight flow when the mixture is piled up. The gentle compression of a quantity of it will force out moisture.

3. *Wet.* — Wet concrete is similar in consistency to plaster that is ready to be applied or even more slushy. It is so wet that it will not hold its shape when piled, and can be poured from a shovel or bucket.

Wet concrete must be kept in the forms longer than the other mixtures on account of the greater length of time required for hardening, but in many cases this is fully repaid by the labor saved in ramming or tamping and by the greater strength developed. In foundation work and the like it is quite successful.

Machine Mixing. — The use of machinery on small jobs has come only recently. There are small mixers on the market now which can be obtained at a cost so low that any farmer who has considerable concrete work to do can not afford to be without one; in fact, the ingenious man can easily construct a very efficient one himself to be operated either by hand or small power. The chief advantage of the machine mixer is the saving in the actual labor of the mixing.

Machine mixers are of two classes: 1. Continuous mixers into which materials are fed constantly and from which the concrete is discharged in a steady stream. 2. Batch mixers, designed to receive at one charge all the materials in the proper quantities to make a certain quantity of concrete.

The selection of the mixer is often governed by local conditions; for instance, where labor is insufficient and where comparatively small quantities of concrete must be made at long intervals, the continuous mixers may prove most efficient. In general, however, the batch mixer on small jobs is the most advisable because the homogeneity of the product can be more definitely assured since the amount of materials can be accurately gauged and the time of mixing can be made as long as desired.

Placing

Of the four essential processes included in the manufacture of concrete, viz., selection of material, proportioning, mixing, and placing, the last is by no means the least important. There is no doubt but that the ignorant, inexperienced person can ruin even a very simple piece of concrete work by the non-observance of the few simple underlying principles concerning the proper placing of concrete.

It must be borne in mind that concrete, after mixing, undergoes a chemical transformation as well as a physical one. The chemical changes are known as "setting." In this setting there is formed a considerable amount of calcium hydroxide which exists in a crystalline form in the set cement. The formation of this crystalline substance usually begins within 45 minutes after application of water to the concrete materials and may not be completed even after the expiration of several hours. It is evident that if during this time the concrete is jarred or disturbed in any way the crystals that have already been formed will be broken apart and it is doubtful if they will later recombine with anything like their original density and strength. From this it is seen that concrete should be placed in its ultimate location within 45 minutes, and if the maximum strength of the concrete is to be attained it should not be disturbed for at least ten hours; indeed it should not be disturbed for a considerable time longer than this because in all probability the crystallization continues in a less degree for some time, and it is well known that concrete continually increases in strength with age, providing it is not subjected to heavy jars or strains.

The first and foremost precaution then to be observed in the placing of concrete is to complete it if possible within 45 minutes from the time of the application of the water. This may be inconvenient at times and even under certain circumstances impossible, but it constitutes a rule for guidance which will insure to a certain degree successful concrete.

The tools which will be used in the placing of concrete will depend to a very great extent upon the nature of the work undertaken. For work in which the mixing is done adjacent to the place where the concrete is to be located, shoveling is perhaps as expeditious a manner as can be devised. Care must be taken, however, that the concrete is not thrown with any great force or to any considerable distance, because the larger particles when handled in this way have a tendency to become separated from the smaller ones and a non-homogeneous mixture is likely to result. When the mixing is done at some distance from the location of the concrete work, one of three methods of transportation is commonly employed.

1. By means of *buckets* either carried by hand or by mechanical conveyors.

2. By means of *wheelbarrows*.

3. *Elevating* the concrete to the top of a tower and *distributing* it therefrom by means of flexible chutes.

On comparatively small jobs the wheelbarrow method is perhaps the most adequate one and is probably the most economical, though for special work, buckets may be found to be necessary as in the case of monolithic silo construction. The elevation and chuting of concrete is a method that is followed only in large construction work and usually is not practicable nor advisable in common concrete work.

There are three distinct methods of getting the concrete firmly placed in the forms so as to insure good results. These are brought about by the three arbitrary degrees of consistency which were mentioned previously.

1. *Pressing* or *tamping*. — This is done when a dry mixture is used to produce such non-reinforced products as blocks, brick, or ornamental work; in fact, it must be used wherever the consistency of the mixture is such that it will not of itself fill the corners of the forms. It is necessary that the tamping be done very thoroughly, otherwise many air bubbles will be retained in the concrete and a dense hard concrete cannot be formed. Unevenness of surface texture will also occur unless the tamping is regular and uniform.

2. *Agitation*. — In cement products requiring reinforcement, such as pipe, poles, slabs, etc., neither tamping nor

pressure will be advisable. A comparatively wet mixture must be employed in order that a firm bond be made between the concrete and the steel. Tamping a wet mixture will do considerable harm, for the larger particles will be forced to the bottom and the upper layers of the concrete will be unduly rich. Besides this, the reinforcement, which must be very carefully and accurately located, is likely to be displaced, which is a very serious occurrence indeed; consequently, in the manufacture of products requiring reinforcement, a wet or quaky mixture of concrete is forced into the corners of the mold and around or through the reinforcement by carefully but vigorously stirring the mixture and jarring the mold. This should not be done so strenuously as to cause a displacement of the reinforcing; a firm but gentle agitation will achieve better results than one too vigorous.

3. *Self-deposition.* — Reinforced concrete structures, including silos and all sorts of buildings, involve work on a scale which necessitates extra effort to save time and labor; therefore, a very wet mixture which can be easily poured is employed. The reinforcement has previously been located and the concrete, when poured into the forms will, on account of its fluidity, flow into all the corners, cracks, and crevices within the mold and around the reinforcing, thus rendering further tamping or agitation unnecessary. The only thing that should be done is to force back from the face of the forms the large pieces of aggregate in order that they may not occupy surface positions when the forms are removed.

A little ordinary care and intelligence at the time the concrete is being put in place will often assure a successful outcome of the work. The mixing and placing should be carried on rapidly and continually so that one deposition of concrete will not have hardened before the next application has been put in. This can usually be easily accomplished if the concrete is mixed in small batches and handled expeditiously.

Sometimes it is important to carry on a section of concrete work continuously to completion. Unless special precautions are taken later upon continuance of the work, lines of separation or cleavage between adjacent depositions of concrete are likely to be formed. However, if before beginning concreting anew the following precautions are observed, good joints can be secured: the surface at the joint should be cleaned and washed with a new cement paste of the consistency of cream; this should be followed immediately with a layer of concrete and then the depositing can be continued as before.

It is sometimes necessary to apply concrete to make a firm joint with some that has been placed a long time before. In this case the procedure is a little more difficult, but in principle is the same as that above outlined. The surface of the joints should be thoroughly cleaned with water, then gone over with dilute hydrochloric acid and wire brush and then again thoroughly flushed with water to remove every trace of the acid. The acid will have destroyed all trace of impurities on the surface of the concrete and a raw, fresh surface is exposed to which the new concrete should adhere as firmly as to new stone or gravel.

Making Concrete in Cold Weather

As a rule it is undesirable to lay concrete in freezing weather. At times, however, certain conditions make it not only desirable but necessary to carry on concrete construction work when weather conditions are not the best, and in such a case, if proper precautions are taken, the work may be conducted without serious injury to the concrete.

The main requisite for successful concreting in cold weather is a prevention of freezing of the water; the water is an element required in bringing about the hardening of the concrete, consequently it must be kept in a fluid condition and not allowed to become ice. It is generally admitted that low temperatures practically stop the hardening of concrete, and while there is some difference of opinion as to the ultimate effect of freezing on concrete, it is generally accepted that concrete which has had a chance to harden for forty-eight hours under favorable conditions will not be endangered. It is also believed that concrete that is frozen before it has begun to harden may not be injured permanently if upon thawing it is not again frozen until it has had an opportunity to harden sufficiently to withstand subsequent freezing. It is a recognized fact, however, that alternate freezing and thawing at comparatively short intervals will damage concrete and since this condition is one that occurs in actual practice, it is imperative that the concrete be mixed and placed in such a manner as to insure proper hardening during the first two or three days. The precautions necessary during freezing weather to insure satisfactory results with concrete depend to a large extent upon the class of construction. It is evident that large mass work such as heavy walls and abutments will possess a greater power of heat retention than will thin walls and floor slabs and will, consequently, require less careful protection.

There are two methods of concreting in cold weather which can be said to be successful:

1. The freezing point of a concrete mixture can be lowered.

2. The materials in which the concrete is made up can be heated and the work protected until it has had a chance to harden.

Perhaps the cheapest and simplest method of lowering the freezing point of concrete is to use ordinary salt or calcium chloride, the first being perhaps the better. This method is only effective for temperatures but little below freezing. A common rule for the use of salt requires 1 per cent by weight, of salt of the weight of water, for each degree Fahrenheit below freezing. A number of experimenters have determined that the maximum amount of salt which should be used is 10 per cent since any larger quantity apparently injuriously affects the strength of the cement. Consequently, some other procedure must be adopted when the temperature is 22° F. or less.

The most satisfactory results are obtained when the materials and mixing water are heated and the concrete work is given protection for at least forty-eight hours after having been placed. In large construction work, such as reinforced concrete buildings, the columns, floors, and walls can be protected by hanging on the outside of the structure a close covering of heavy canvas. Salamanders or charcoal furnaces are then located within the structure and the air within thus easily maintained at a temperature not below 40° F. On small jobs, if the materials are heated quite thoroughly it will probably not be necessary to maintain any artificial heat after the concrete has been placed, since if the work is properly protected the latent heat of the mixture will keep it sufficiently warm to enable the hardening process to be carried on to a satisfactory completion.

The material can be heated in various ways. Half cylinders of sheet steel set directly on the ground in the form of an arch make excellent heaters, fire being built underneath them and the sand and gravel piled above. Or, a flat sheet of heavy steel can be supported, with a fire underneath and the materials piled on top of it. Too high a temperature will injure the materials, sandstone and gravel being likely to soften or crack under such conditions. A temperature not exceeding 150° F. is ample and will generally prove completely satisfactory.

The mixing water should also be heated. The simplest way of course is to have a large kettle and heat the water in it. Metal tanks holding a considerable quantity of water are also very convenient. The water should not be heated to a temperature exceeding 150° F.

A certain amount of internal heat is developed within the concrete during its setting and early hardening. Heat introduced into concrete by the use of hot water and heated materials and maintained by proper protection is supplemented by internal heat, the latter being practically of no value under less favorable conditions. The temperature developed by concrete during the early hardening will increase from a temperature of about seventy to one hundred and ten in from thirty to forty hours under favorable conditions. Heated materials hasten the rise in temperature and also increase the maximum temperature attained; thus it is seen that the heating of the materials is not only valuable in itself, but even more valuable in making use of the internal heat developed by the concrete during setting and hardening.

Forms

The elasticity of concrete and the adaptability of this material to all shapes and sizes of construction have made the production of molds of the desired shape an extremely important consideration in all types of concrete construction work. The amateur concrete worker will soon find, often to his surprise, that the design, arrangement, and construction of his molds is as important and essential a matter as the making and placing of the concrete itself. The purpose of the molds is the inclosure and retention of the concrete until it has hardened sufficiently to enable it to retain its shape after the molds have been removed.

In small concrete production such as blocks, bricks, and special ornamental work, iron and steel molds can be successfully and economically used, because the same shape and size is repeated an indefinite number of times. Local conditions and particular needs demand individual designs and one of the chief merits of concrete as a construction material lies in the ease with which it may be adapted to such particular requirements of individual use. For large construction work, when it is necessary that means be provided for construction at or near the place where the concrete is to be used and from materials easily procured, molds may be made to fit the particular circumstances of the particular case. Molds of such a diversified character are commonly called *forms*.

Perhaps the best material to be employed in the construction of forms is spruce or fir, because of the uniformity in shrinkage and expansion of these woods. Contrary to the usual practice in building construction, ordinary air-dried lumber will keep its shape in forms better than lumber that is thoroughly dry. The reason for this is evident: very dry lumber will absorb considerable moisture from the concrete itself and the subsequent expansion which will naturally occur quickly after as a result of the rapid absorption of the moisture is likely to be irregular and thus cause a serious distortion of the forms. If dry lumber must be used for forms it should be thoroughly soaked with water.

The planning of the forms preliminary to the placing of the concrete should be done very carefully so that the construction work will be simplified. An excellent opportunity for the exercise of considerable ingenuity in the design of forms is afforded whenever concrete work of any complexity is undertaken, as for instance in the construction of steps, troughs, etc.

The forms should be made strong enough to hold the weight of concrete without bulging out of shape, for cracks are thus opened between the planks, and the water in the concrete, with some sand and cement, will leak out. This not only weakens the concrete, but causes hollows in the surface which detract from its appearance. Only for small pieces of work should one-inch lumber be used; two-inch stuff is much better and even this will require strong and careful bracing to keep it firmly in place. Originally only surfaced lumber was used for forms, dependence being placed upon it for giving a finished surface to the concrete. While surfaced lumber has some advantages such as being more easily handled and cleaned, it is entirely practicable to use ordinary rough lumber in many instances, since simple methods have been devised and put into practice for obtaining different kinds of surface effects.

Forms which lose their shape after having been used once can hardly be used a second time. If the forms are to be used a number of times they should be made up very carefully of good materials and it may be found advisable to put them together with screws. If nails are used for attaching different sections of the form to each other, they should not be driven home, but should be left with their heads projecting $\frac{1}{4}''$ so that they may be easily seized and withdrawn by means of a claw hammer.

Some judgment must be employed in the planning and use of forms, because neglect to consider the use to which they are to be put is likely to mean a waste of time and money. If the surface of the concrete is to be given a different treatment, the finish of the surface is of small moment while the alignment of the form is all important. On the other hand if a large tank or foundation wall is being built the fact that the forms are not exactly aligned will hardly be noticed, yet it may be that the surface produced by the forms will be left without any further treatment.

Metal forms are coming into very wide use for certain types of concrete construction, particularly for sidewalks, curb construction, silos, and for residences. The advantage of the use of metal is that it is permanent and durable, and when desired, a very smooth finish can be obtained. Metal forms are quite heavy and consequently the forms are usually made in small sections to facilitate the handling of them. Since metal forms are quite expensive, they are used only in such types of construction work as will permit of their use over and over again, and consequently are not practical where special shapes have to be produced.

Due to the adhesive nature of concrete, it will stick closely to the forms whether of metal or of wood unless the surface of the form next to the concrete is coated with a film of oil or soft soap. The forms should be coated with this just previous to the introduction of the concrete and should be protected so that a minimum amount of dust and dirt comes in contact with them. Linseed, black, or cylinder oil may be used for the lubrication of the coating of forms, but kerosene is inadvisable. Immediately after the removal of the forms from the work, any small particles of concrete adhering to them should be immediately scraped off. This can be done with little difficulty if done immediately and a scraper or brush is the only tool that is necessary. If the forms have been thoroughly greased the first time, in all probability it will not be found necessary to recoat them after each time of use. Careful observation of the form will indicate when the surface becomes dry and will require recoating.

Forms should be left in place for some time after the deposition of the concrete has been completed. The time required will vary with the type of construction work and with the consistency of the mixture. In retaining walls, abutments, and work of like character which is subjected to more or less of a strain, it may be necessary to keep the forms in place for three or four weeks. On the other hand it is common practice in the construction of silos to raise the forms for a filling after having been left in place around the previous filling for only twenty-four hours. In the manufacture of the dry process concrete blocks, the primary purpose of the form is to simply give shape to the block and it may be removed as soon as the tamping is completed. However, in the construction of good fence posts, a wet mixture is employed and it is not advisable to remove the forms for fifty to sixty hours.

The cost of the forms, aside from those used for ornamental work, is sometimes surprisingly large. Even in the simplest type of mass construction, the cost is seldom less than 5 per cent of the total cost of the work, and it may run up as high as 35, 40, or even 50 per cent in certain complex cases. This factor is one that is often lost sight of by the inexperienced concrete man and it is extremely important because it sometimes spells the difference between profit and loss.

Discussions of forms for specific types of concrete construction will be taken up later.

Cost Estimating

The cost of concrete depends more upon the character of construction and the conditions which govern it than upon the cost of the materials. The cost of the materials can be very readily estimated from the quantities of materials used, and since the quantities can be ascertained with a fair degree of accuracy, all that is necessary is to obtain the prices and calculate the cost of the materials. The expense of transportation of the materials can also be quite accurately determined when the weight per load is given and the cost of hauling is known. Labor in mixing and placing concrete can also be estimated from long experience under varied conditions. The most difficult items to estimate correctly are the cost of the forms and of the incidental expenses connected with the work. These are likely to vary largely with the local conditions. The following data are abstracted from Taylor and Thompson's "Concrete, Plain and Reinforced":

"In a very general way it may be said that concrete is laid in large masses such as abutments and thick walls, etc. Where the form cost is relatively low, the cost per cubic yard will likely range from four to seven dollars. The lower figure represents construction work under favorable conditions, using materials in large quantities; the higher figure being applicable to cases where inexpensive men are doing small jobs. Thin building walls may cost from ten to twenty dollars per cubic yard, depending upon the cost of the forms, the height of the walls, and the finish which is given to the surface."

Lewis and Chandler, in their "Handbook for Cement and Concrete Users," give the following:

"Where cement can be obtained at $1.50 per barrel, sand at 80 cents per cubic yard, and broken stone at $1.50 a yard delivered on the work; and where the cost of form timber does not exceed $25.00 per M; while the rate of wages for carpenters is $3.50, laborers $1.75 and teams $3.75 per ten-hour day, the cost of concreting, including interest and depreciation in the plant, but with no allowance for profits, will run as follows:

Heavy mass constructions, as large dams, reservoir walls, pavements, heavy foundations, abutments, rubble concrete, etc.	$3.50 to $6.00 per cu. yd.
Foundation footings and difficult mass construction	$6.00 to $8.00 per cu. yd.
Thin rough walls, sewers, and culverts	$8.00 to $10.00 per cu. yd.
Thin tooled or reinforced walls, heavy buildings and bridges, reinforced concrete retaining walls, etc. . . .	$10.00 to $15.00 per cu. yd.
Light reinforced-concrete buildings having thin walls, slabs, and columns, light reinforced concrete bridges, arches, etc.	$15.00 to $20.00 per cu. yd."

Since the prices of materials are rather definite, variation in cost of materials is more strongly influenced by their transportation from the market to the place where they are used than anything else. A team of good horses should haul over the average country road a load of ten barrels of cement or 4000 pounds, and should be able to travel twenty to twenty-five miles per day. The cost of sand will approximate thirty-five cents per cubic yard for loading with perhaps an additional twenty cents if screening is required. This must be added to the charge per cubic yard for the sand if the sand is purchased. The cost of hauling will approximate fifty cents per mile per yard. The same figure can be applied to gravel. A two-horse load of sand or gravel will vary from 1 to 2½ yards, a large wagon being required to haul the latter amount. An experienced gang of men can mix and place concrete at a cost varying from one dollar to a dollar and a quarter per cubic yard. With inexperienced workmen the cost will run up to probably twice this, but since experience in mixing and placing can be obtained quickly, the cost should be as quickly reduced. Machine mixing will generally reduce the cost to some extent.

For simple farm concrete construction work it is entirely possible to obtain the materials, and mix and place the concrete for a figure approximating thirty-five cents per cubic foot. The cost may, of course, run a little above or below this, but it is a good average figure. Floors and sidewalks will cost from ten to fifteen cents per square foot, depending upon the thickness, the labor cost being from four to six cents per square foot. In making small units such as fence posts, the labor cost will approximate five cents per unit if they are produced in any considerable quantity.

Waterproofing

It is well known that comparatively lean mixtures of cement, sand, and gravel or stone are for certain purposes abundantly strong, but the drawback to these lean mixtures is their porosity, which causes them to absorb water like a sponge. As a result, water will pass through them with no difficulty. For some purposes and in some situations it is exceedingly important that the concrete be at least practically waterproof.

In modern practice, both in technical and practical consideration of the general subject of protecting concrete structures against the percolating action of moisture, it is advisable to divide this study into two separate divisions, viz., *damp-proofing* and *waterproofing*. Damp-proofing should be clearly confined to the consideration of the methods and means of keeping water and dampness out of the superstructure of building or out of the structures through which the moisture may be said to pass through by capillary action. It deals mainly with exterior walls above the grade line. The application of correct damp-proofing methods insures exterior walls which are not affected by the general disintegrating action of water and interior walls which are free from the unsanitary, disagreeable, and discomforting effects of dampness.[1]

Waterproofing in its modern interpretation should directly apply to methods and means of treating subterranean construction and structures intended for the retention and storage of water under and against hydrostatic head. In accordance with this definition, waterproofing then applies directly to the treatment of foundation, cisterns, tanks, and similar structures.

Under the head of damp-proofing, we may include three methods which, while practically similar in their application and results, are different in their effect.

1. *Transparent coatings.* — These are transparent liquids which can be applied without changing the physical appearance and texture of the coated surface. They usually consist of a water-repellent compound which enters the pores to some distance and prevents the ingress of moisture. They should be applied only to surfaces that are absolutely dry in order to insure the proper depth and completeness of the deposition of the repellent base in the pores of the concrete. Since the coating is comparatively thin, it is not permanent and must be occasionally renewed, much as is necessary in the case of ordinary paints.

[1] For a fuller discussion, see booklet on waterproofing published by Truscon Laboratories, Detroit, from which part of the above material has been abstracted.

2. *Opaque decorative coatings.* — The opaque decorative coatings are similar to the preceding class, but contain an opaque base which, in addition to providing a water repellent, may also provide a different surface color.

3. *Special bituminous coatings.* — These form a continuous damp-proof coating for exposed walls and are usually of such a nature as to possess the ability of holding a coat of plaster applied directly to them. When used in this way they form an impervious layer between the concrete wall and plaster coat, thus quite effectually waterproofing the surface.

In the more correct consideration of real waterproofing there are two general systems of the application of the waterproofing material.

1. *The integral method.* — In this method some form of waterproofing compound which in itself is a water repellent is employed and mixed intimately with the concrete. It may be a powder to be added to the dry cement or a liquid or paste to be added directly to the water.

2. *Membranous coating method.* — There are three classes of these materials, viz., coal tar products, asphalt, and its derivatives, and special compositions. They are usually heated and applied by means of a brush in a layer of varying thickness upon the surface of the concrete, forming a waterproof film.

In practical waterproofing, there are four distinct methods all of which are quite effective and the selection of the method to be used will depend somewhat on the nature of the structure to be waterproofed. These methods are as follows:

1. *Ideal proportioning of the cement and aggregates.* —As can be easily seen by anyone who understands the theory of ideal proportioning, if ideal materials are used in ideal

proportions, there will be no voids and consequently no possibility of the passage of water through the concrete. While such a condition of ideality cannot be obtained in practice, careful workmanship will enable us to approach it to a surprising extent. Indeed many cement manufacturers

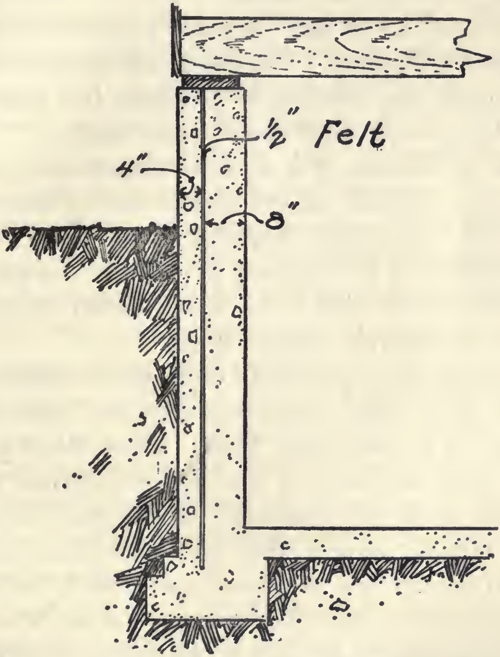


FIG. 12. — Old Method of Using Felt Waterproofing.

are advising the use of rich mixtures to reduce the void content and increase the waterproof quality of the concrete.

2. *Special surface treatment.* — Under this heading are included the materials which were previously listed under the head of membranous coatings. These can be used only where the preservation of attractive appearance is not essential such as in foundation walls, cisterns, etc.

3. *The production of a water-repellent mixture.* — This is identical with the integral method of waterproofing mentioned previously. Some engineers are opposed to the use of this method on the ground that it reduces the strength of the concrete to an alarming degree, but there is no doubt but what the method is effective when properly employed and can be used in many situations with entire satisfaction and safety. Practically all the materials used in this system are commercial products, but their composition is understood to be more or less similar.

4. *The application of a layer of waterproofing materials* such as felt, asphalt coated paper, etc. This is an old method and, while quite expensive, is very effective. One way of employing this method is to apply the material to the outside of the wall to be waterproofed, then place a thin layer of concrete outside of this.

Experiments and experience have shown that dry mixtures are much more permeable than wet ones since the pores are not so completely filled. From this it is evident that the impermeability of concrete will depend to a certain degree upon its consistency and it may be said that up to a certain degree, with other conditions favorable, the wetter the mixture, the more impervious is the concrete. For a great deal of concrete work where a moderate degree of water-tightness is all that is necessary, it may be entirely sufficient to use a wet, rich mixture, but where absolute water-tightness is an essential requirement, recourse must be had to some of the above noted methods. Sometimes, as for instance in the construction of concrete watering tanks or troughs, washing the interior surface with a neat mixture of cement and water before the concrete has thoroughly hardened will be sufficient to make the concrete practically waterproof under low heads.

The integral methods of waterproofing indicate that the perfect waterproofing is colloidal in nature. The process of setting and hardening of mortar and concrete is not alone a process of hydration and crystallization but is further supplemented by the formation of a colloidal substance which surrounds and protects the crystals of cement that bind the particles of sand and stone together. The partial degree of water-tightness which is characteristic of all cement mortar and concrete is due entirely to the presence of this colloidal substance. Its absence would result in the gradual softening, dissolution, and disintegration of the concrete when subjected to actual exposure. It is never formed in sufficient quantity, however, to entirely fill all the voids in the mass and for this reason it is necessary to resort to some material which will supplement and intensify the effect. There have been some attempts to manufacture a cement which will produce a waterproof concrete under ordinary conditions, but they have met with only ordinary success. The increase of the colloidal material comes with extremely fine grinding and cannot be practically accomplished without so increasing the expense of production that the average consumer cannot use the cement thus produced.

Oil-mixed Concrete. — Experimenters in the office of Public Roads, attempting to develop special road materials, accidentally discovered that when a heavy mineral residual oil was mixed with cement, it entirely disappeared in the mixture and did not separate from the other ingredients after the cement had become hard. The office immediately began tests to determine the physical properties of concrete and mortar containing various quantities of oil mixtures. The results of these tests demonstrated the value of oil-mixed concrete for damp-proofing and waterproofing.

The summarized conclusions are as follows: The admixture of oil is generally not detrimental to the tensile strength when the oil does not exceed 10 per cent of the weight of the cement used. The compressive strength suffers slightly with the addition of oil, although the decrease in strength is not serious unless oil in excess of 10 per cent is added. The time of setting is increased from 50 to 100 per cent but the subsequent increase in strength is nearly as rapid in the oil-mixed material as in the plain concrete.

It was found that the addition of oil was not efficacious in increasing the impermeability of concrete subjected to heavy water pressure, but for damp-proofing purposes every test showed that oil admixtures are almost perfectly non-absorbent of water. Oil appeared to be equal to any other substance used to prevent the absorption of water in mass concrete. In laboratory tests, oil-mixed concrete compared favorably with plain concrete in toughness and stiffness, and its elastic behavior within working stress limits is identical with that of plain concrete.

As would naturally be expected, the bond between smooth bar reinforcement and oil-mixed concrete is less than with plain concrete. When deformed bars or any kind of reinforcing not having a smooth surface is employed, there is no apparent decrease in the efficiency of the reinforcement. Some experiments were conducted to determine the effect of oil in retarding the action of alkali salts on cement and it was clearly demonstrated that the action is materially retarded by the addition of 5 to 10 per cent of oil. All of these experiments have given very encouraging results and it is claimed point to the use of oil-mixed mortars and concretes as a cheap and effective solution of the problem of waterproofing for a great many types of concrete construction.

The oil that is recommended to be used in this connection is a heavy crude oil containing no fatty or vegetable oils. The specific gravity should be not more than 0.945 at a temperature of 25° C. Any saponifiable oils will break down the strength of the cement; consequently, any oil which contains them should not be used, nor should there be any materials which will readily emulsify with alkali for if this occurs the strength will be seriously affected.

For most purposes where damp-proofing is required, 5 per cent of oil, based upon the weight of the cement in the mixture, is all that is necessary. A bag of cement weighs 94 pounds, and consequently for each bag of cement that is used, 4.7 pounds, or about 2½ quarts, of oil are required.

In mixing the following method is employed. The sand and cement are first mixed together until they appear to be of uniform color. Water is then added to the mixture and the mass is again mixed to a mortar of mushy consistency. The oil is then measured out and added to the mortar and the mixing continued until all the oil is thoroughly incorporated. Experience has shown that the best results require that the time of mixing should be double that when oil is not used. The coarse aggregate of stone or gravel which has been previously moistened is then combined with the oil-mixed mortar and the mass turned until all the materials are thoroughly mixed. Should only oil-mixed mortar be desired, no coarse aggregate is added.

Oil-mixed concrete will be found to be a very convenient method of waterproofing basement floors. The floor may be constructed in two layers, no oil being incorporated in the concrete forming the bottom layer. The top layer may be mixed in the proportions of 1 part of cement to 2 parts of sand and should contain 5 per cent of oil. This top coat, because of its non-absorbent character, will give perfect protection from underlying moisture and the floor itself will dry out very quickly after washing since practically none of the washing water will be absorbed. The addition of oil will not make the surface slippery and in appearance the floor will be very much the same as if no oil had been added.

Cellar walls and foundation walls of any kind can be very handily waterproofed by the use of oil-mixed concrete. Ten per cent of the oil will prove amply rich for most conditions.

It is sometimes very difficult to waterproof tanks and cisterns effectually. If oil-mixed concrete is used in their construction, it will be found to give excellent results not only in making them waterproof but in maintaining them in a water-tight condition. The oil may be mixed with the concrete forming the body of the structure in a proportion of 10 per cent of oil by weight. If a very smooth surface is desired, a cement wash containing 3 per cent of oil can be applied in several coats to the surface. About a pint of oil to a 10-quart bucket of cement will result in approximately the correct proportions for this paste. Care should be taken that the coating does not dry out too quickly by applying it to dry concrete or exposing it to the direct rays of the sun.

The main objection to concrete walls for residences can be overcome by the use of oil as a waterproofing mixture in the concrete. This applies to all of the various types of concrete used in residence walls whether in block, plaster, or monolithic form. In concrete blocks, 5 per cent of oil is a sufficient quantity to guard properly against absorption.

A public patent has been obtained by the inventor of this process, Mr. L. E. Page, and anyone is at liberty to use oil-mixed concrete without the payment of royalty.

Properties

Strength. — The strength of concrete is an extremely variable quantity, this being due to several causes among which the following are the most important:

1. The quality and amount of cement used.
2. The kind, size, and strength of the aggregate.
3. The degree of consistency or the amount of water used in gauging.
4. The correctness of proportioning.
5. Method and thoroughness of mixing.
6. Age.

Concrete is rarely used where the strain is that of tension since it is extremely weak in this particular regard. Even in reinforced structures where the tension of the member must be considered, the tensile strength of the concrete is usually neglected and only that of the reinforcing is taken into account.

Concrete possesses the greatest strength when used in compression and it is due to its great resistance to crushing that it has become such a popular building material. It is also quite strong in shear, though not nearly so strong in shear as in compression. When properly reinforced it makes an excellent material for the construction of beams and slabs which are in transverse strain.

The following table taken from Sabin's "Cement and Concrete," gives interesting comparisons as to the strength of concrete over varying conditions.

COMPARATIVE TENSILE, TRANSVERSE, AND COMPRESSIVE TESTS.
VARYING PROPORTIONS OF SAND

Mean Strength, Pounds per Sq. In., for Varying Richness of Mortar

Cement	Age of Specimens	Parts Sand to One of Cement by Weight											
		Neat Cement			1 Part Sand			2 Parts Sand			3 Parts Sand		
		Ten.	Tran.	Com.	Ten.	Tran.	Com.	Ten.	Tran.	Com.	Ten.	Tran.	Com.
P	7 das.	588	1115	3453	484	607	2672	294	407	1420	182	247	695
P	28 das.	698	1237	4617	630	915	3343	—	—	—	277	397	1088
P	3 mos.	733	1340	4447	705	1121	3250	491	764	1950	338	541	1245
P	1 yr.	—	—	—	738	1185	5825	—	—	—	379	582	1725
N	7 das.	136	237	940	90	145	505	64	78	340	—	—	—
N	28 das.	214	470	1834	—	—	—	128	212	730	110	103	412
N	3 mos.	285	515	2410	408	639	1813	319	465	1165	247	321	675
N	1 yr.	—	—	—	—	—	—	313	472	1227	—	—	—

Note: Cement P = Artificial.
Cement N = Natural.
Sand, crushed quartz, passing No. 20, retained on No. 30 sieve.

From this table it is seen first that artificial cement is much stronger than natural cement under the same conditions; second, that concrete increases rapidly in strength with age, this being true of all mixtures; and third, increasing the amount of aggregate decreases the strength of the resulting concrete.

In the next table, which is taken from the same source, are shown the figures resulting from the use of different amounts of water. The concrete decreases in tensile strength but increases in transverse or compressive strength with an increase in the amount of water used.

Comparative Tensile, Transverse, and Compressive Tests. Effect of Varying Consistency of Mortar

Water as Per Cent of Dry Ingredients	Mean Strength, Pounds per Square Inch		
	Ten.	Tran.	Comp.
9	516	837	1731
12	533	987	2173
15	467	850	2498
18	461	966	2823
21	430	1022	2487

Notes: Cement, Artificial; Sand, passing No. 10 sieve. Age of specimens, one year. Two parts sand to one of cement by weight.

It should be noted that in the first tests standard sand or sand passing a No. 20 and retained on a No. 30 sieve is used. This sand has been universally adopted for all mortar tests of cement and the results obtained will probably not be in accord with those which would be gotten if actual field specimens of concrete were used. However, since all conditions for the test were uniform, the results are directly comparable.

Under practical conditions, when it is necessary that concrete be used in tension, a working stress not less than from thirty to one hundred pounds, depending upon the age and richness of the mixture, should be employed. Tests have shown that the average tensile strength of a 1 : 2 : 4 mixture one month old will approximate 300 pounds, this increasing to perhaps 400 pounds or more at three months. Of course, these are maximum values and should not be considered as working stresses.

When unreinforced concrete beams are used the factor limiting the strength of the beams is the tensile strength of the concrete at the place of greatest strain, which in a symmetrical beam is at the point most remote from the center. This value is usually greater than the actual tensile strength of concrete as shown by tests; Sabin states that the ratio of transverse strength to the tensile strength varies from 1.25 to 1.91 for artificial cement. Concrete is seldom used in this manner unless it is reinforced and the reinforcing changes conditions entirely.

The shearing strength of concrete is important because in many reinforced beams the shearing strain is as great or greater than the tensile strain. Professor A. N. Talbot states that it is probable that the shearing strength of concrete is from 50 to 70 per cent of its compressive strength. Older writers gave as safe working values for concrete in shear 25 to 35 pounds per square inch. Modern practice increases these values somewhat and working values of 40 to 75 pounds are commonly allowed.

As stated before, the chief value of concrete lies in its exceptional strength in compression. The accompanying table from Taylor and Thompson's "Concrete, Plain and Reinforced" gives approximate values for the crushing strength of concrete under average working conditions. It must be remembered that these values are affected by so many conditions that the data can be given only as extremely rough approximation.

APPROXIMATE AVERAGE CRUSHING STRENGTH OF CONCRETE

Proportions by Volume	Medium Consistency		Wet Consistency			
	30 da. lb. per sq. in.	6 mo. lb. per sq. in.	30 da. lb. per sq. in.	6 mo. lb. per sq. in.	30 da. lb. per sq. in.	6 mo. lb. per sq. in.
1 : 1½ : 3	2800	3700	2600	4100	2300	3600
1 : 2 : 4	2500	3300	1900	3100	1700	2700
1 : 2½ : 5	2200	2900	1700	2700	1500	2400
1 : 3 : 6	1900	2600	1500	2400	1300	2100
1 : 4 : 8	1500	2100	1000	1600	900	1400

Other Properties of Concrete

Fire Resistance. — The concrete enthusiast is likely to make unduly extravagant claims as to the fireproof qualities of concrete. It must be remembered that "fireproof" is a relative term and that a material that will resist fire at a high temperature for an indefinite period is practically unknown. Under normal conditions the term "fireproof" is generally taken to cover those materials that will resist the flames and heat of an ordinary conflagration in such a manner that the structure will be safe and practically intact after moderate repairs. It certainly is true that with such a definition, concrete is fireproof, as has been shown by numerous tests both in laboratory and in field work. The rigorous building code of the city of New York requires that a structure to be considered fireproof shall withstand when fully loaded, a temperature of 1700° for four hours, then subjected to a stream of water discharged from a $1\frac{1}{8}$ inch nozzle under a pressure of sixty pounds for five minutes without failure. A number of systems of reinforced concrete have successfully withstood this test for beams, floor slabs, and columns. Other systems have failed, but in almost every case there have been other causes contributing to the failure.

One explanation that is given as a reason for concrete being fireproof is that Portland cement in hardening absorbs from 10 to 20 per cent of its weight in water, the water that is being absorbed being taken up in chemical combination. A temperature of at least 500° must be reached before dehydration begins and it is probable that all the moisture is not given off until a temperature of about 1000° is reached. This moisture during the dehydration of the concrete vaporizes and keeps the surrounding materials at a comparatively low temperature. After the dehydration has occurred, the concrete is greatly improved as a non-conductor of heat and thus acts to retard the dehydration of the adjacent concrete. Thus if the outer surface of a concrete column has been subjected to this process of dehydration, the concrete in the interior of the column will be much more able to resist the destructive effect of higher temperatures. Reid, in his treatise on concrete, writes as follows:

"Concrete itself is a poor conductor of heat, and the materials a fraction of an inch away may be practically insulated from the action of heat for a long time. Tests show that a thickness of from $\frac{3}{4}$ to 1 inch of stone concrete is sufficient to protect the metal in a floor slab; and for cinder concrete $\frac{1}{2}$ to $\frac{3}{4}$ inch is sufficient, while for beams and columns the thickness should be from $1\frac{1}{2}$ to 2 inches for a stone concrete, and from 1 to $1\frac{1}{2}$ inches for cinder concrete, depending upon the size of the member. Care must be taken in selecting the cinders for cinder concrete, for if any unburnt coal is present the fire resisting quality is greatly reduced. Limestone should be avoided and granite may chip under the action of heat."

Rust Resistance. — The question is sometimes brought up as to whether metal that is imbedded in concrete for the purpose of reinforcing is properly protected against corrosion and whether the concrete itself will not have a corrosive effect on the metal. A simple analysis of the situation will show that no fears need be felt. Corrosion of iron will occur only in the presence of air, moisture, and carbon dioxide; it will not occur in perfectly dry air nor in perfectly pure water. Under suitable conditions, however, the iron, water, and carbon dioxide or carbonic acid combine to form ferrous carbonate, the latter combining immediately with oxygen from the air to form ferric oxide, the carbonic acid being liberated to act on a fresh portion of the metal so that only a small quantity of carbon dioxide is necessary to cause a great deal of corrosion. However, if the carbonic acid is neutralized by some alkaline material, the action just described cannot occur and since concrete is strongly alkaline it thus furnishes almost perfect protection against rusting. The only precaution to be observed in this regard is to be certain that the metal is completely covered by the concrete, for when any corrosion of the metal does occur it is always at a point where voids exist in the concrete. Whenever the concrete is mixed wet so that the surface of the metal is coated with a thin layer of grout, no rust spots will appear. This is extremely important in the use of metal lath for stucco work; the lath can be prevented from rusting by giving it a thorough coating of grout such as can be obtained by dipping the lath in a mixture of cement and water.

Resistance to Acids and Alkalies. — Concrete when properly made is sufficiently resistant to weak acids to enable it to be used successfully. However, the action of strong acids is likely to be injurious to some extent. Alkalies do not seem to have special deleterious effect upon concrete providing the concrete is made dense and rich or waterproofed in some way so that the alkali solution cannot obtain ingress to the body of the concrete.

Resistance to Oil. — The question of the destruction of concrete by oil is one that has not yet been thoroughly settled. In some cases it appears that concrete has disintegrated where the sole cause seemed to be oil. In other places there are samples of concrete several years old which have been saturated with oil and which appear to be entirely unaffected. The Chicago, Milwaukee & St. Paul Railroad conducted a series of tests with different kinds of oils and their conclusions showed that the greatest disintegrating effect was caused by animal fat or extract of lard oil. Petroleum and boiled linseed oils have no disintegrating effect on concrete to any appreciable extent. As a result of the tests, however, the observations made were: first, that most oils penetrate concrete mortar and may possibly weaken it; second, that when the concrete is thoroughly set it is less liable to disintegrate from oil; and third, the better the quality of the concrete the less liability of disintegration. It is generally accepted as a fact that machine oils of a paraffin base which do not contain animal fats are not likely to have a deleterious effect on concrete. The United States Department of Agriculture advocates the use of crude mineral oil as a waterproofing, evidently finding that it does not have an appreciable disintegrating effect upon the concrete. Investigations of the Portland Cement Association indicate that well-made concrete is proof against action by oil.

Reinforced Concrete

The time of the first use of reinforced concrete is somewhat vague, though it is known that as early as 1855 beams made of a combination of concrete and iron were tested. In 1875 there was constructed in America a dwelling consisting entirely of concrete, the floors, roofs, and other parts that were subjected to heavy loading being reinforced with light iron beams and rods. In 1876 a French gardener by the name of Jean Monier conceived the idea of extending his practice of using wire netting as a nucleus about which he constructed pots for his flowers and shrubs. Gifted with unusual foresight, he saw that a great future lay before the one who could develop the idea so as to include all types of structures, and as a result, the famous Monier system of reinforced concrete, the forerunner of numerous modern systems, came into being.

Reinforced concrete is concrete in which steel or other material is imbedded to increase its strength. A full understanding of the principles underlying reinforced concrete has not yet come, but the general principles are understood sufficiently to enable the material to be used with assurance of permanent strength and durability. True, there have been failures of reinforced concrete, but the occasional failures that have occurred were the result of the neglect of essential principles; poor design, poor materials, wrong placing of the reinforcing, and too early loading of the unsupported concrete all contribute to failure. The design of reinforced concrete structures is extremely complicated and consequently no one but the technically trained and experienced engineer is qualified to undertake it. For very simple constructions, the layman may use prepared tables in which values in accordance with extra conservative design are given. When it is necessary to have a large and complex structure built, involving careful design, the logical procedure is for the owner to put it in the hands of an experienced concrete engineer and leave the details of the design to him. As with an architect, the concrete designer, from his wide experience, is able to more than pay for the cost of his services in the saving of material which he can accomplish, besides giving the assurance of correct design.

A consideration of the fundamental principles underlying simple reinforced concrete construction may be of interest. Let us take a simple beam symmetrical in cross section and supported at both ends, with a vertical load applied at the center of the beam. When the load is applied, the fibers in the lower part of the beam, as shown in Fig. 13, will have a tendency to be torn apart, or in other words, they will be in tension. The fibers in the upper part of the beam, on the other hand, will be in compression or will be resisting a force tending to crush them together. As will be observed, there will be a plane perpendicular to the force applied at which there will be neither tension

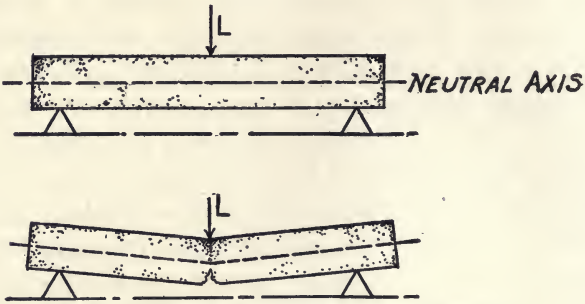


FIG. 13. — Result of Loading a Simple Beam.

nor compression. This plane is known as the neutral plane, and in a beam of symmetrical cross section the neutral plane cuts the beam in halves.

As has already been stated, concrete is weak in tension and strong in compression; consequently when a beam such as the one just described is made of concrete and so loaded, the lower part of the beam, being weak in tension, will be torn apart long before the fibers in the upper part are strained to the maximum. In order to make the lower part of the beam just as strong as the upper part, we must imbed some material in the beam which is especially high in tensile strength; and we must apply it as far as possible from the neutral plane since the farther from the neutral plane the greater is the strain and the greater will be the resistance to tension of any material there imbedded. For the purpose of thus strengthening the concrete, iron and steel of varying grades have been almost universally used. Steel is very strong in tension and it requires only a comparatively small amount of steel in the lower part of the beam to so add to the tensile strength that the values of the tensile and compressive strength on the opposite sides of the neutral plane are approximately equal.

The above is, in simple words, an explanation of the reason for reinforcing concrete. A number of practical considerations will of course enter into the proposition, complicating it to an almost unbelievable extent, but investigations of the last quarter century are fast bringing information to the hands of designers so that thoroughly safe reinforced concrete construction is now possible. The amount of steel required and the economical placing of it have been worked out rather carefully. Usually the amount of steel used is, in total area of cross section, not less than ½ per cent nor more than 1½ per cent of the total cross section area of the concrete beam or slab in which

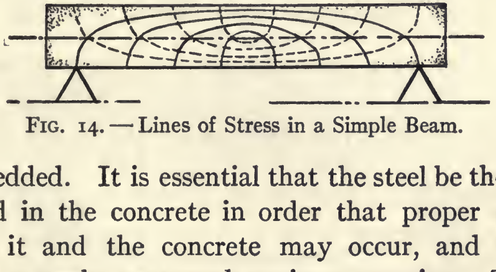


FIG. 14. — Lines of Stress in a Simple Beam.

it is imbedded. It is essential that the steel be thoroughly imbedded in the concrete in order that proper adhesion between it and the concrete may occur, and that the steel be properly protected against corrosion. The particles of the aggregate should not be so large as to interfere with the placing of the reinforcement.

In the simple beam discussed above, the reinforcing was placed as near as possible to the surface of the beam away from the place where the load is applied. The simplest way to place this reinforcement is to place it along the lower side of the beam. However, the lines of stress in a beam under a bending strain are as shown in Fig. 14; consequently in order to better resist the strain the reinforcing may be given a curved form, bringing the ends of the reinforcing up near the top of the beam as shown in Fig. 15.

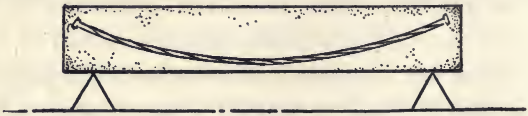


FIG. 15. — Curved Reinforcement in a Simple Beam.

When the beam is fixed at the ends as shown in Fig. 16, the lines of stress lie differently and there will be a certain amount of tension at the top of the beam which should be

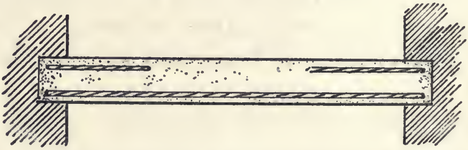


FIG. 16. — Reinforcing a Beam Fixed at Both Ends.

taken care of by some reinforcing located at the point where the tension occurs. Sometimes this upper reinforcing bar is made to extend throughout the length of the entire piece, giving a double reinforcing. This upper bar may be curved down so that it will extend along the lower part of the middle of the beam and rise to the upper part at the support, as in Fig. 17, giving the desired effect both at the center and the ends.

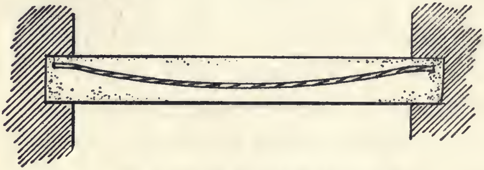


FIG. 17. — Single Bar Reinforcement.

There are many systems of reinforced concrete in use and all of them possess certain advantages and disadvantages. The decision as to which type to use should be arrived at only in consultation with a competent engineer.

Solution of Problems in Reinforced Concrete Design

While it is not considered to be within the scope of this book to include an elaborate discussion of the principles underlying the design of various types of reinforced concrete structures, the presentation of a few simple formulas and their explanation may be of value in enabling the design of simple beams, slabs, and columns to be accomplished safely and with little difficulty. In farm concrete work complicated structures are not common; in fact, the following examples will cover most cases that are likely to occur.

BEAMS

The essential steps in the design of beams carrying a uniformly distributed load may be enumerated as follows:[1]

1. Calculate the total load, W, upon the beam.

2. Estimate, as closely as possible, the weight of the beam itself, W'.

3. From the formula

$$bd^2 = \frac{l\,(W + W')}{8\,D}$$

calculate the dimensions of the beam.

4. Calculate the cross-sectional area, A, of the steel from the formula

$$A = pbd.$$

[1] This is an abstract of the method given in "Handbook for Cement and Concrete Users," by Lewis and Chandler.

The nomenclature is as follows:

b = breadth of beam in inches.
d = depth of beam in inches, to the plane of reinforcing.
l = length of span in inches.
p = percentage of steel in lower half.
D = an arbitrary value depending upon the value of p; for p = 0.007, $D = 74$, assuming a maximum compressive stress of 500 lb. per square inch for concrete and a tensile stress of 15,000 lb. per square inch in steel.

5. Locate the reinforcing according to the following:

The percentage of steel varies from 0.7 to 1 per cent in the lower part of the beam. Girders extending over three or more supports must have at least an additional 0.4 per cent of steel in the upper part over the supports, and this must extend in each direction a distance equal to $\frac{1}{4}$ the distance between supports.

When $\frac{W + W'}{bd}$ exceeds 60, include three or four stirrups, according to the rule given by E. L. Ransome, which locates them at distances from the end of the beam equal to $\frac{1}{2}d$, $\frac{3}{4}d$, $1\frac{1}{2}d$, and $2\frac{1}{2}d$, respectively. These stirrups are usually made of $\frac{1}{4}''$ or $\frac{3}{8}''$ rods.

6. Determine whether the bond is sufficiently great by the formula

$$\frac{4(W + W')}{7\,nd} \leqq 50,$$

n being the sum of the perimeters of the steel bars in inches.

7. Determine the actual weight of the beam, and revise the design if the difference between this and the estimated weight exceeds 10 per cent.

Experience and observation have led to the formulation of the following general rules which should be kept in mind in designing beams:

The breadth should be from $\frac{1}{2}$ to $\frac{3}{4}$ of the depth, the better to combine strength and economy, and should be not less than $\frac{1}{24}$ of the span.

The lateral spacing of the reinforcing bars should be not less than $1\frac{1}{2}$ times their diameter, and their diameter should not exceed $\frac{1}{200}$ of the span.

Example: Design a horizontal reinforced concrete beam to support safely a uniformly distributed load of 10,000 pounds over a span of 10 feet.

Solution: $W = 10,000$ lb., $p = 0.007$, $l = 10 \times 12 = 120$ in.
Assume W' to be 2500 lb.

Then $$bd^2 = \frac{120 \times 12,500}{8 \times 74} = 2534.$$

Choosing any reasonable value for b, as 12 in.

$$12\, d^2 = 2534$$
$$d^2 = 211.25$$
$$d = 14.5 \text{ in.}$$
$$A = 0.007 \times 12 \times 14.5 = 1.218 \text{ sq. in.}$$

Using 5 steel rods, the area of each is 0.244 sq. in. and if of circular section, the diameter is $\frac{9}{16}$ in., calculating to the 16th of an inch next larger than the actual diameter; if square rods be used, they will measure $\frac{1}{2}$ in. on each side. Since at least 2 in. of concrete should be placed below the reinforcing for protection and bond, the total depth of the beam is 16.5 in.

Now, considering that the weight of good rock concrete is about 150 lb. per cubic foot, the weight of the beam is approximately 2100 lb., or about 16 per cent less than the estimated weight. A recalculation of the problem will reduce the value of d by perhaps $\frac{1}{2}$ in.

Testing the strength of bond between the reinforcing and the concrete by the formula given, n in this case being 8.8 for circular rods,

$$\frac{4 \times 12,100}{7 \times 8.8 \times 14} = 56,$$

which would indicate that the square rods, with $n = 10$, would be safer to use, since they give a value of 49.5. From the fact that

$$\frac{12,100}{168} = 72,$$

it is indicated that stirrups are necessary.

SLABS

Practically the same principles used in beam design can be applied to slabs, considering that for the purposes of design the slab may be imagined as divided into narrow strips, each having a width equal to the spacing of the reinforcing rods, and a length equal to the span between girders. Rods used for reinforcing should be located, as previously instructed, in both the upper and lower halves of the slab; if some sort of metal fabric is used, it should be so laid as to approach the upper surface of the slab over supports, and to sag to near the bottom of the slab in the middle of the span.

The formulas used are as follows:

$$bd^2 = \frac{l\,(W + W')}{10 \times 74}$$
$$A = 0.007\, bd.$$

Their application is exactly the same as when used for beams, except that the 8 which occurs as a factor in the denominator of the first formula is replaced by 10.

Design of Reinforced Concrete Columns [1]

This consists in determining proper dimension for the post or column, and the steel required for its reinforce-

[1] From "Handbook for Cement and Concrete Users," by Lewis and Chandler, published for the Norman W. Henley Publishing Co., 132 Nassau St., New York City, price $2.50.

ment. The following order of computations should be observed:

(1) Compute the load, P, to be supported by the column.

(2) Estimate the weight, W', of the column itself.

(3) Determine the load per square inch of sectional area which the concrete can be designed to carry, also the ratio between the moduli of concrete and steel.

(4) Choose the percentage of vertical reinforcement. In general, this should be between 1 and 2½ per cent.

(5) If spiral wrappings are to be used, choose the sectional area and spacing of the bands.

(6) Compute the sectional area required for the column by the following formula, and check its weight.

$$A_e = \frac{P + W'}{C + pC(r - 1)}$$

$$A_s = pA_e$$

A_c = the sectional area of the column.
A_s = the sectional area of the vertical reinforcement.
A_e = the effective area of the column.
A_h = the effective area of the hooping.
P = the load to be supported.
W' = the estimated weight of the column itself.
C = the safe compressive stress for concrete.
p = the percentage of vertical steel reinforcement.
r = the ratio between the modulus of elasticity of steel and that of concrete in compression.

Where bands are used, the section of the column contained within the spirals may be designed to carry 50 per cent more stress than the column without bands, providing:

(a) The wrapping is circular in form.

(b) A thickness of two inches of concrete is placed outside the bands, for protection, but not considered as taking any part of the load.

(c) The bands are of sufficient size so that their sectional area A_h, divided by the pitch S, or distance between spirals, is not less than the diameter of the spiral D, divided by 500, or

$$\frac{A_h}{s} \text{ must not be less than } \frac{D}{500}.$$

The following practical rules should also be observed:

(7) The length of the column must not exceed more than twelve times its least lateral dimension.

(8) The vertical steel must be as straight as possible, and rest upon bed plates at the bottom. When the bars are spliced, the bars must not be lapped and wired, but the end of the upper bar must rest on the top of the lower one, and be held in place by sleeves made of pipe. The sleeves should be 24 diameters long, and the joints should also be stiffened by a half-inch bar about four times as long as the sleeve, which is set alongside of but not in contact with the reinforcement.

(9) In all large columns the steel should be protected by at least two inches of concrete, and in small columns by not less than one inch.

(10) The percentage of steel which can carry the entire load when stiffened by the concrete can be found by dividing the load to be supported in pounds by 16,000. In general this will run from 4 to 6 per cent.

(11) The load on the column must be symmetrically placed, so that the center of the load coincides with the column. If the load bears more on one side of the column than it does on the other, it is called an eccentric load, and it requires a larger column to carry an eccentric than it does to carry a symmetrical load. An eccentrically loaded column cannot be designed by the methods explained herein.

Example 1: Design a square reinforced concrete post, 10 feet long, which will support a load of 20 tons without spiral wrappings.

Solution: (1) $P = 20 \times 2000 = 40{,}000$ lb.

(2) Estimate W' at 1500 lb.

(3) A safe load for concrete in compression is 350 lb. per sq. in. and a safe value of the ratio, r, is 12.

(4) Employ 1.7 per cent of vertical reinforcement.

(5) $A_e = \dfrac{40{,}000 + 1500}{350 + 0.017 \times 350(12 - 1)} = \dfrac{41{,}500}{415.45} = 100$ sq. in.

or 10×10 in.

This column will weigh about

$\frac{10}{12} \times \frac{10}{12} \times 10 \times 144 = 1000$ lb., which is less than the assumed weight and therefore safe.

The area of the steel will be:

$$0.017 \times 10 \times 10 = 1.70 \text{ sq. in.}$$

If 4 square bars are used the area of each will be:

$$1.70 \div 4 = 0.43 \text{ sq. in.},$$

or 4-$\frac{11}{16}$ in. square bars are required.

(6) The least lateral dimension is 10 in.

$$10 \text{ in.} \times 12 = 10 \text{ ft.}$$

As the length of the post is 10 ft. or equal to the above value, the design is permissible.

Summarying the results of the design, we have:

External load, 20 T.

Weight of column, 1000 lb.

Dimensions, 10 in. $\times$ 10 in. $\times$ 10 ft.

Vertical reinforcement, 4-$\frac{11}{16}$ in. square bars.

Example 2: Design a circular reinforced concrete column with spiral wrappings 12 feet long which will support a load of 59 tons.

Solution: (1) $P = 59 \times 2000 = 118{,}000$ lb.

(2) Estimate W' at 4000 lb.

(3) Take C at 350 and r at 12.

(4) Take p at 1.5 per cent.

(5) For hooping, use $\frac{5}{16}$ in. round or oval steel bars having the same sectional area of 0.076 sq. in., and let the spirals be spaced apart or have a pitch of 2 in.

$$(6)\ A_e = \frac{118{,}000 + 4000}{350 + 0.015 \times 350\ (12 - 1)} = \frac{122{,}000}{611.63} = 200 \text{ sq. in.}$$

or diameter of spirals $\sqrt{\dfrac{200}{0.7854}} = 16$ in.

With 2 in. of concrete outside of the hooping, the diameter of the post will be $4 + 16 = 20$ in. and will weigh

$$0.7854 \times \tfrac{20}{12} \times \tfrac{20}{12} \times 12 \times 144 = 3770 \text{ lb.},$$

which is less than the estimated weight and is therefore safe. 1.5 per cent of steel is 3 sq. in., which is equivalent to 6-$\frac{3}{4}$ in. sq. rd.

From (5), $A_h = 0.076$ and $s = 2$ in., also from (6), $D = 16$ in., and since $\dfrac{A_h}{s}$ must not be less than $\dfrac{D}{500}$, $\dfrac{0.076}{2}$ must not be less than $\frac{16}{500}$; or since 0.038 is greater than 0.032 the hooping is in conformity with the condition.

(7) The least lateral dimension is 20 in.

$$20 \text{ in.} \times 12 = 20 \text{ ft.}$$

As this is greater than the length of the post, the design easily satisfies the condition as to the ratio of length to the least lateral dimension.

Summarizing the results of the design, we have for the circular column:

External load, 59 T.

Weight of column, 3770 lb.

Diameter of column, 20 in.

Diameter within hooping, 16 in.

Length of column, 12 ft.

Vertical reinforcement, 6-$\frac{3}{4}$ in. sq. rd.

Hooping, $\frac{5}{16}$ in. round or oval bars with spirals placed 2 in. apart.

CHAPTER III

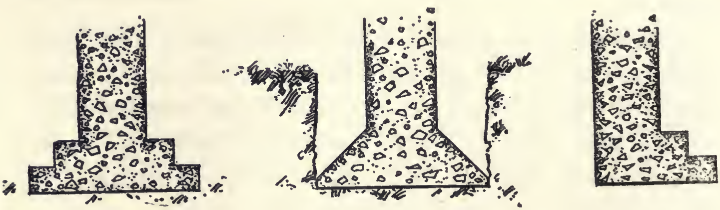
FOUNDATIONS AND WALLS

SINCE concrete possesses its maximum strength in compression it naturally follows that it is an excellent material to be used in the construction of foundations, and in this connection it finds a very wide and important field of usefulness. Other considerations which make concrete valuable for foundations are the simplicity and ease of form construction and the fact that no special attention need be given to the production of a smooth and attractive surface.

Bearing Powers of Soil. — In a discussion of foundations, perhaps the first thing that must be known is the bearing power of the soil or rock upon which the foundation is to be erected. This is a value which is extremely variable and no exact data can be given. It is to be assumed that in agricultural concrete construction not very much concrete will be placed upon solid rock; where it is placed upon rock the chances are that the structure will not be heavy enough to make any consideration of the strength of the rock necessary. The sustaining power of earths varies with their composition, their compactness and solidity, and the degree of moisture which they contain or are likely to receive. The following values are given by Mr. George B. Francis:

Material	Tons per Sq. Ft.
Solid rock	36
Hard pan	8
Gravel	5
Sand	4
Dry clay	3
Wet clay	2
Loam	1

Footings. — In soil whose bearing power is somewhat low and not sufficiently great to resist the load which would be likely to come upon it, it is of course necessary to adopt some means of so distributing the load that it comes upon a greater area. This is accomplished by spreading the lower part of piers or foundations into a "footing." Even where the soil is sufficiently compact to give adequate



a *b* *c*

Fig. 18. — Types of Simple Footings.

bearing, the construction of footings is desirable because it increases the material stability of the structure above. The footings must be made of sufficient size and strength so as to be able to resist not only the load which comes upon them but also the tendency to overturn, which might occur in the case of eccentric loading, or loading concentrated at some other point other than the center of the footing. In Fig. 18 are shown different types of footings; (a) illustrates a simple footing which is made by locating forms for the footings a greater distance apart than are the forms for the foundation wall itself; in (b) is illustrated a self-formed footing which is not to be especially recommended as far as strength is concerned; when the loading is eccentric some form of footing as shown at (c) must be put in.

Foundations

Laying out the Work. — In laying out the foundation for any building reference is usually made to some existing object such as a drive, another building, or a highway. The first line should be very carefully located and used as a base line for the location of the remaining ones. When the base line has been definitely established the ends of this line or the corners of the building are next to be located; it is probable that one of the corners will be located with reference to some other object as was the original base line. A stake should be driven at this point and the exact corner located by a nail driven into the stake. When the location of the first corner is thus confirmed, proceed to the location of the remaining corners. If the building is to be rectangular, care must be taken to see that all intersections of walls come at exactly 90°. The perpendicularity of the lines can be ascertained by various methods, of which the "3, 4, 5" method is perhaps as simple as any. This is illustrated in Fig. 19 and depends upon the well-known fact that when the legs of a right triangle are respectively 3 and 4, the hypotenuse will be 5. In applying this rule, lay out a distance of 4 feet along one line, a distance of 3 feet along the other; then if the lines are truly

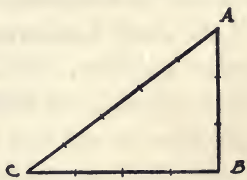


FIG. 19. — 3, 4, 5 Method of Squaring Corners.

perpendicular the distance between the extremities of the 3 and 4 foot lines will be exactly 5 feet.

When the four corners of the building have been located exactly, drive 3 stakes at each corner as indicated by the letters *a*, *b*, and *c* in Fig. 20, the stakes being driven several feet out from the proposed location of the building and firmly braced as shown.

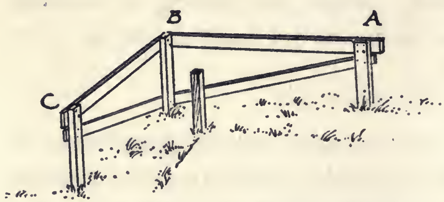


Fig. 20. — Location of Building Corner.

Stretch cords along the four sides of the rectangle thus laid out and where they cross the braces at the corner posts make a shallow saw mark. Thus at any time even when the original corner stakes have been removed, the exact corner of the building can be ascertained by stretching cords along the sides of the rectangle, the intersection of the cords indicating the location of a corner of the proposed building. This method is advantageous in the fact that it makes no difference whether the corner stakes are disturbed or not and work such as excavating can be carried on without destroying the location.

After having proceeded thus far the next step is to locate any construction lines that will be necessary; for example, let us assume that we are going to put in a 12-inch foundation wall; it will be necessary to have two lines 12 inches apart to define the wall itself and to indicate to the excavator where he shall dig or where the forms are to be located. Both these lines can be indicated by saw marks as previously described. It must be borne in mind, however, that these subsequent marks must be made so as to be easily distinguishable from the corner marks.

Excavation. — The removal of sufficient earth to provide a good base for the foundation and for perhaps part of the foundation wall itself is the next step. It is usually a practice to be recommended that the foundation be brought below the point reached by frost, but unless the building is of large size or unless it is located in a region of extreme cold, it will be unnecessary to excavate to a depth exceeding 3 feet, providing good bearing soil is found at that depth.

Very often foundations are ruined as a result of having been placed on unsuitable soil. If a heavy structure is to be placed upon the foundation it is essential that the foundation be extended sufficiently deep to reach solid, well-packed earth, for if this is not done the resistance to the weight will be variable at different points along the length of the foundation resulting in a possibility of rupturing the foundation. Even if this provision would result in making the foundation of uneven depth it would make no especial difference because concrete is such a plastic material that no difficulty attends the placing of it upon an uneven base. If the foundation were constructed out of stone or brick, an uneven base would be the cause of much trouble and annoyance.

In the construction of small buildings such as sheds, poultry houses, etc., where a heavy substantial foundation is not at all necessary, it is sometimes impossible to reach solid earth in the shallow excavation that is made for the foundation. The difficulty in this case can be easily overcome by reinforcing the foundation as it is laid with some bars of steel, making the foundation act as a beam.

Forms. — If the soil in which the excavation is made is sufficiently stiff so that it will stand in a practically vertical position when dug, it may not be necessary to erect special forms for the concrete but simply place the concrete into the trench which has been excavated to the proper depth. It is desirable when this method is practiced to dig the trenches as nearly as possible the exact dimensions required. In placing the concrete into an excavation of this kind, care should be taken that the edges of the trench are not broken in order that the wall be kept as smooth as possible and that dirt be prevented from falling into the concrete. A simple precaution which will prevent this to a great extent is to place some 2″ × 4″ pieces across the trench, and upon these lay 2″ × 12″ plank projected an inch or two over the edge of the trench.

Very often the nature of the soil prevents such a simple expedient in the way of forms as is described above. The walls of the excavation may not be self-supporting, and regularly erected forms must be provided for that portion of the foundation below the ground as well as for the portion above the ground if there be any. Two methods can be followed in building these forms; first, constructing units of convenient length flat on the ground, then erecting them into place; second, constructing the forms in the actual position in which they are to be used.

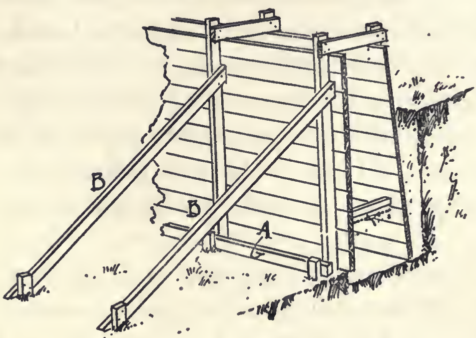


FIG. 21. — Foundation-wall Forms in Soft Earth.

The first method is desirable when the type of construction is extremely simple, and is advantageous in that the units can be taken down and re-erected a number of times without any serious damage to the lumber. Care must be taken in constructing forms of this type to make them absolutely flat so that when lifted they will not assume a warped position. In building forms in position a guide board should be placed in the position indicated at *A*, Fig. 21, so that when the inside form is erected the inner face of the form sheathing will be exactly coincident with the inner face of the foundation wall to be constructed. With this as a base, the erection of the forms proceeds as illustrated in the figure. 2 × 4's, or if the wall is unusually high,

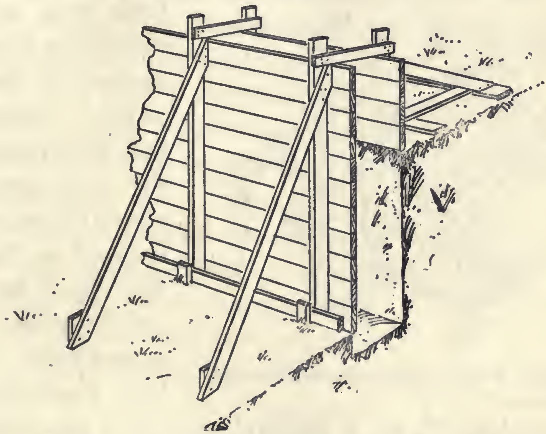


FIG. 22. — Foundation-wall Forms in Firm Soil.

2 × 6's, are fastened to this guide board at the bottom and a cross-piece consisting of the top piece of the sheathing is nailed on to keep the vertical 2 × 4's in their place at proper distances apart. The vertical 2 × 4's are then carefully plumbed and fastened securely in place by the braces *B* extending between the upper end of the 2 × 4's and stakes driven into the ground; the remainder of the sheathing is nailed on, keeping it straight at the bottom. After the next form wall has been erected, construction of the outer one

is comparatively simple, care being taken to keep the two the proper distance apart. If a small footing is desired it can be easily obtained by leaving out the bottom board of the sheathing on each side so as to permit the concrete to spread into the trench, which may be widened at this point.

If the soil is comparatively stiff, it may not be necessary to erect an outer form for the entire height of the foundation wall. By referring to Fig. 22, the method to be employed in this case is very easily understood; the inner form wall is constructed in a manner similar to that described previously and that portion of the wall extending above the ground is inclosed on the outside by a specially constructed and braced form. When the foundation is being constructed for a building such as a barn with no basement but with the foundation wall extending up a foot or two above the ground line, both the inside and outside wall forms are constructed in the same way, as shown in Fig. 23.

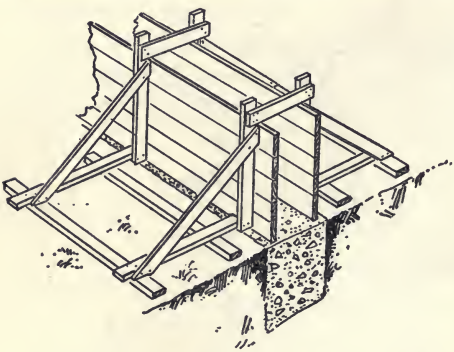


Fig. 23. — Simple Foundation-wall Forms.

It must be borne in mind that the forms are to be removed when the concrete has set, and that some provision must be made for their easy removal. When there is only a narrow space between the form and the earth wall this provision should be some means which will result in the least damage to the lumber. In order more firmly to hold the forms in place it will be well to wire the inside and outside sections together by running a wire through the sheathing and around the studs at intervals and after spacing blocks of proper length have been inserted between the forms twist the wire up tightly. When the forms are removed these wires can be easily cut with pliers and the wires left in the concrete wall. The spacing blocks are removed as the concrete progresses by knocking them loose and taking them away.

In buildings of large dimensions the cost of the lumber for forms is likely to be rather high, and to keep it reduced it may be found advisable to build the form in units with a length equal to the stock length of the sheathing boards; the foundation wall can then be constructed in sections. End blocks can be put in the forms of such a shape that succeeding sections of concrete wall can be made to interlock with the one that has just been built, as shown in Fig. 24. Unless a very large force of men is employed four to six such unit sections will be found sufficient to keep the men busy since the forms can be removed and used again when the concrete has hardened sufficiently.

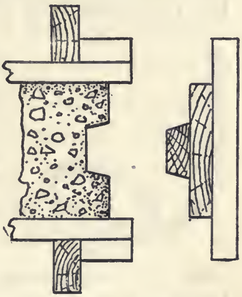


FIG. 24.—Method of Joining Wall Sections.

Mixture. — Since concrete has its maximum strength in compression and since practically the only strain to which the foundations are subjected is compression, a comparatively weak mixture can be used. It is essential of course that good clean materials should be employed and that they should be proportioned well. However, excellent foundations have been constructed of proportions of one part of cement to seven or eight or even ten of clean, well-graded pebbles. The necessity, which does not always exist, for a waterproof foundation renders advisable the use of a rich, well-proportioned mixture, or the employment of some commercial form of waterproofing.

In foundation work it is often possible to increase the size of aggregate up to several inches, which would not be possible in many other cases. The employment of small boulders from which all adhering dust and dirt has been removed is also possible and will result in cheapening the concrete to a considerable extent.

Residence Foundation Walls. — Concrete is beginning to be recognized as an excellent material to use in the construction of foundation walls for residences. The methods that have been previously described for the erection for the foundation wall forms can be utilized, care being taken, of course, that the top edge of the wall is kept perfectly level. A simple device which will aid in maintaining the level top surface is illustrated in Fig. 25. It consists of a rubber tube of 25 or 30 feet in length into each end of which has been inserted a glass tube. This can be extended along the line of the foundation and filled with water. The level of the water in the two glass tubes will, of course, coincide and can be used as a gauge on different parts of the foundation.

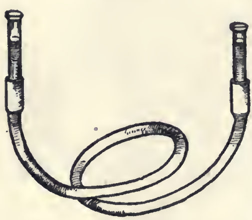


FIG. 25. — Simple Level Made of Hose and Glass Tubing.

Foundation walls for residences usually extend a sufficient depth into the ground to provide the walls for the basement, the footing of the walls being made below the floor level of the basement. Fig. 26 illustrates one way of obtaining a waterproof joint between the foundation wall and the basement floor. The inner angle between the footing and foundation wall is given a heavy coating of pitch or asphaltum and the concrete basement floor is laid up into this.

FIG. 26. — Waterproof Joint between Footing and Floor.

A variation of the ordinary foundation wall is shown in Fig. 27 in which the footing is extended and brought down in such a way as to form a basement shelf. This shelf will be found to be extremely convenient in a residence basement, especially when the basement floor is being scrubbed. The shelf should not be so high that lifting of objects up on to it will be difficult; $2\frac{1}{2}$ feet is usually ample. This arrangement of wall has another advantage in that while it gives a wall of ample strength, less excavating and less concrete is necessary to construct it.

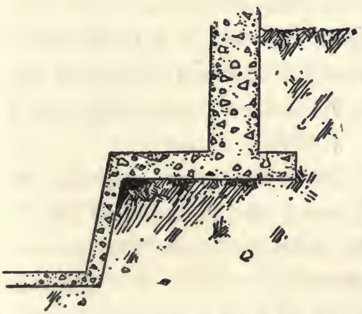


FIG. 27. — Basement Shelf Made by Extending Footing.

WALLS

There are several types of walls which can be utilized in the construction of farm buildings. In all of these must be observed the general requirements that the wall must be made sufficiently rigid to support the strains to which it is subjected, that it must be practically water-tight, and that under certain conditions, it must present an attractive appearance. The difference in the walls lies in their method of manufacture, and a decision as to the type to be employed can be arrived at only after consideration has been given to the nature of the construction into which the walls are to enter and to the material and equipment at hand.

The types of walls which can be most easily utilized for farm buildings are: monolithic, block, unit slab and column type, and plaster. Each of these types will be taken up and their construction described in detail.

Monolithic Walls. — In the construction of monolithic walls the same general procedure is followed as in the construction of monolithic foundations with the exception that, as requirements make it necessary, a certain amount of reinforcing is located in the concrete to resist transverse or bending stresses. It must be borne in mind that reinforced concrete used in an extensive way is a proposition to be handled by the experienced engineer and should not be attempted by the layman if he is desirous of obtaining a safe structure.

Perhaps the most difficult part of the construction of monolithic walls is the arrangement and erection of forms. This is done in much the same manner as the preparation of the forms for monolithic foundation walls. Exceptional care must be exercised because the superstructure wall is usually thinner than the foundation wall, and unless some special subsequent finishing is to be done, the surface of the concrete must be left in such a condition as not to be unsightly. The wall forms may be arranged in two ways; first, in units or sections; second, the erection of large portions of the forms in non-separable units so that when they are removed they must be completely dismantled. They may be either of wood or metal. The wood forms are perhaps the most practical when only a comparatively small amount of concrete work is to be done. In the hand of a contractor, forms of this kind would be practically useless; so he makes use of the more permanent forms which can be used over and over again with little harm resulting to them.

In the selection of lumber for the construction of forms it is advisable to use lumber that is not well-seasoned or that has been thoroughly soaked with water before being built into the forms. The purpose of this is to prevent the expansion which will follow the absorption of moisture were dry wood used in the forms. White pine, fir, spruce, in fact any type of cheap soft lumber serves very satisfactorily for the surfacing of the forms. For braces, struts, etc., it is better to use some stiff rigid lumber such as hard pine, or oak. While it is not necessary to specify absolutely clear lumber, it should be carefully selected to see that there are no unusual places nor cracks nor loose knots in the wood, because the hydrostatic pressure of the concrete is considerable and the additional pressure resulting from tamping and jarring might cause the forms to fail. The boards which form the surface of the forms should be surfaced on one side so that the concrete will be smooth, and on two edges so that form boards may fit up closely together. If a slight bevel is given to one edge of the board it may obviate bulging of the boards as the result of swelling in case lumber that is a little dry be employed in the forms; the expansion will quickly be taken up by the few fibers of the wood which are subjected to compression. This is illustrated in Fig. 28.

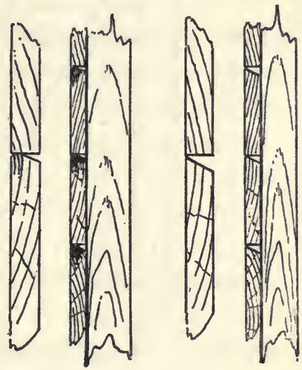


FIG. 28.—Beveled Edges on Form Boards to Prevent Warping.

For light work, 1-inch stuff will be sufficiently strong, provided the outside braces are located at sufficiently close intervals. If there is any danger that the walls will be thrown out of alignment as a result of bulging of the boards, 2-inch stuff should be used. This will require bracing on the outside at three or four foot intervals for a wall eight or ten feet high. The arrangement of the forms

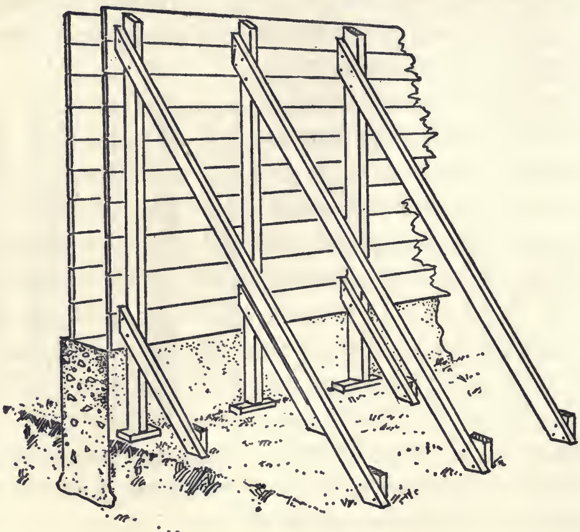


FIG. 29. — Forms for Low Wall.

is a matter that may call for considerable ingenuity, but a little experience in handling them will soon teach one the simple way of meeting the problem that arises. In Fig. 29 is shown an excellent way in which the forms for an ordinary wall can be erected.

Metal forms which are used in the construction of monolithic walls can be made at home using sections of No. 18 or 20 gauge galvanized metal or even heavier nailed upon a frame of 2 × 2 or 2 × 4 stuff. This, too, admits of the exercise of considerable mechanical ingenuity, and in fact all labor-saving commercial wall forms have been evolved from some simple beginning in the way of an idea which was found to facilitate operations. There are various companies manufacturing different kinds of metal forms which can be found in the advertising pages of almost any concrete periodical. The employment of commercial forms is advisable when the construction of walls of any extent is projected.

The location of window and door frames may be done at the time that the forms are put in place and the concrete poured directly around them. This makes a very close joint between the concrete and the frames. However, it is entirely possible to arrange the forms in such a fashion that openings of the proper size will be left for the window and door frames, which can be fitted in later. A small clearance should be provided in making the opening and this clearance space is to be filled in with a mixture of rather stiff cement mortar when the frames are finally set in place.

It is very often the case that the work is of such a magnitude that not all the concrete can be placed in one continuous operation. Under such conditions, joints must be made between the adjacent placings of concrete in such a manner as not to destroy the efficiency of the wall in any way. It may be possible, if the wall is not too high, to cast it in vertical sections of various lengths, for instance, as one side of a building. In order that the adjacent sections of the wall may be properly keyed one into the other, a sort of a tongue-and-groove joint can be made by employing the device shown in Fig. 30. If it is desired to make

Fig. 30.—Joining Wall Sections.

this joint waterproof the surface of the old concrete can be given a thick coating of asphaltum to which the new concrete will adhere. The same device can be used in joining walls to floors or roofs to walls without any special difficulty.

If for any reason it has been impossible to fill in one continuous operation a section of forms that has been erected, the surface of the old work should be left as rough as possible. When work is renewed, the old work should be thoroughly cleaned off, roughened with a pick, and thoroughly wetted down, previous to the application of a cement wash. Before the cement has had any opportunity to dry the new concrete should be applied, and if care has been taken, a successful union of the old and the new concrete will result.

Wall Reinforcement. — Ordinarily monolithic concrete walls in small buildings will not require any reinforcing, but provided good construction is practiced, a considerable saving in materials can be effected if a small amount of properly-placed reinforcing is employed. The reinforcing rods may be of almost any type, provided the cross-sectional area is sufficiently great. Since the purpose of the reinforcing is to increase the strength of the concrete, it is obviously bad practice to use anything but a good grade of steel.

The reinforcement of the walls in a large structure should be left to an experienced engineer; for small buildings the following will prove adequate. When the walls are less than 8 inches in thickness, single reinforcing consisting of $\frac{3}{8}$-inch rods spaced 24 inches apart center to center, both vertically and horizontally, is used. When the walls are 8 inches or more up to 10 inches, the same spacing may be used, but the size of the rods should be increased to $\frac{1}{2}$ inch. For walls up to 12 inches in thickness, a double reinforcing consisting of two systems of $\frac{3}{8}$-inch rods near the inside and the outside of the wall will be sufficient. At every intersection of the reinforcing tie wires should be located to unite the reinforcing into one large firm network. Where lapping is necessary the length of the lap should be 64 times the diameter of the rods in order to give firm bond on the ends of the reinforcing bars.

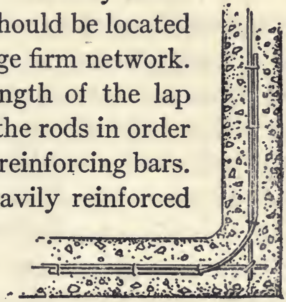


FIG. 31. — Reinforcing Corners of Walls.

Corners need to be especially heavily reinforced and some means similar to that employed in Fig. 31 should be employed. In a rectangular building the corners are quite liable to open up as a result of shrinkage cracks. Window and door openings also require special reinforcing as is illustrated in Fig. 32.

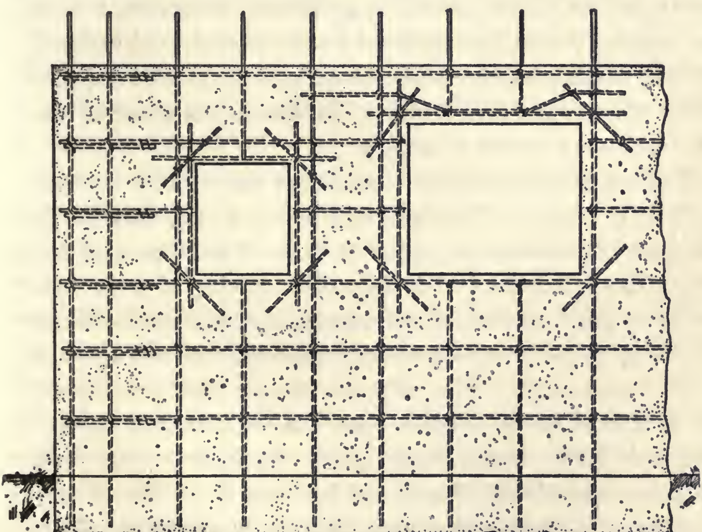


FIG. 32. — Where to Locate Wall Reinforcement.

Concrete Block Walls. — The construction of concrete blocks will be described in a subsequent chapter; they afford a very flexible and easily applicable material for the construction of walls for small buildings. The main advantage in the employment of concrete blocks lies in the fact that no forms are necessary and that the work can be carried on with considerable rapidity. The wall to a certain extent will possess the advantages and disadvantages which pertain to the blocks themselves.

Foundations can be constructed using concrete blocks in a manner similar to the construction of brick foundations. The footings for a concrete block foundation wall may be either monolithic or block construction; in case blocks are used for the construction of the footings it is well to spread a layer of cement mortar in the bottom of the trench to provide a good footing for the blocks themselves. The principal objection to the employment of concrete blocks in foundation walls is derived from the fact that it is difficult to make a concrete block waterproof, and consequently in basements and similar places the leakage of water through the wall may prove annoying.

Laying up the blocks into a wall is a matter which requires a little practice. The work will proceed very rapidly once the workmen have acquired a little dexterity, and there is no reason why they should not do a quality of work practically as good as that of an experienced mason. The precautions to be observed are to drench the blocks thoroughly with water so that they will not absorb moisture from the mortar and to be certain that the wall is kept properly aligned both horizontally and vertically. The joints between the blocks should not be over $\frac{1}{4}''$; this is amply sufficient. The corner blocks should of course be laid first and the wall continued toward the middle. If the wall is likely to be subjected to any considerable lateral pressure it is desirable that adequate reinforcing be located between the blocks in the mortar joints.

In the arrangement of the blocks the same plans can be followed as in the laying of stone masonry. Blocks of even height can be used to maintain the ashlar type of masonry or if different sizes of blocks are used, the wall can be laid up in broken ashlar. Since concrete blocks are made in almost every conceivable variety or size and type it follows that the variety in surfaces of concrete block walls will be equally variable.

Plastered Walls.—An extremely efficient and simple method of wall construction is that used in the type of wall called the plastered wall. In this, some form of continuous metal reinforcing, of which there are so many different types on the market, is plastered on one or both sides to form a comparatively thin wall of concrete and steel. Either single or double wall construction can be employed, and it is comparatively easy to construct a double wall with a dead air space that will act very efficiently as an insulator of both heat and cold.

A wall of this type will require a certain amount of framing; this framing can be accomplished either by setting up frames of wood or steel, or by reinforced concrete columns and beams. The latter is probably the best method, though perhaps not the cheapest. The method of construction of concrete columns and beams will be described later.

Metal reinforcement of the plastered wall should be applied to the frame so as to stretch it well over the entire area, because if this is not done the pressure which is necessary to apply the first coat probably will bend the reinforcement or metal lath, giving the wall an uneven surface.

Most commercial types of metallic reinforcement have some provision for stiffening so that the fault of bending is remedied to a great extent.

The cement mortar which is employed to give body to the wall is usually applied in three coats, none of which should be over $\frac{1}{2}$ inch thick. The first coat, which should contain approximately one pound of hair to a bag of cement, is made of 1 : 2 mixture of cement and sand and is applied with a rather firm pressure in order that the mortar may be forced into the interstices of the reinforcement and form a good key. The surface of the first coat should be brought down to a true plane, and before the mortar has hardened should be gone over with a pointed scratching tool to roughen the surface so that the succeeding coat will have a good base upon which to adhere. The second and third coats need contain no hair and each consecutive coat should be applied as soon as possible upon the preceding coat before hardening to any extent has occurred. The final coat may be applied so as to give any one of the special finishes which are described in the discussion of stucco.

Plasterers are prone to insist upon the use of lime in the first and sometimes in the succeeding coats, but this is not advisable on account of the danger of getting unslaked lime into the mixture. If lime must be used it should be mixed with a considerable quantity of water so as to form a liquid mass, then strained through a rather fine sieve, allowed to settle, and the surplus water drawn off. The resulting wet mass of lime is known as lime putty and if kept damp will keep indefinitely and not become hard. A small quantity of this lime putty can then be mixed with cement mortar, the advantage claimed for it being a smoother working under the trowel.

Extreme care should be exercised in maintaining the constancy of proportions both of the cement and the materials so that no appreciable difference in color will present itself in the finished wall. This applies, of course, only to the finishing coat. Cement plaster has a tendency to intensify even a very small difference in shade which may be caused by a slight inaccuracy in proportioning, and even with the greatest of care, large wall surfaces will sometimes show the location of every different batch of plaster that was applied. The various coats of plaster when applied should not be allowed to dry rapidly for if rapid drying occurs, shrinkage cracks are almost sure to develop, thus destroying the efficiency of the wall. The plaster should be properly protected from the sun and drying winds, by hanging a heavy canvas or burlap cloth in front of the wall and keeping it damp until the plaster becomes quite hard.

Column and Slab Walls. — This type of wall construction is a method that lends itself particularly well to the construction of small buildings. As the name implies the wall is made of columns supporting thin slabs of reinforced concrete. The columns for a single story building should not be less than 7 inches square and should be reinforced with a $\frac{3}{4}$-inch rod in each corner. The slabs which are approximately 2 inches thick are cast in special forms and should not be over 16 square feet in extent.

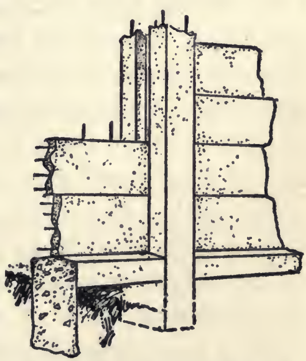


FIG. 33. — Construction of Column and Slab Wall.

Fig. 33 shows the principle of the construction. As seen in the illustration the columns are grooved to admit the slab. Corner columns will have this groove on two adjacent sides and since this weakens the inside corner somewhat it is advisable to make the corner columns at least eight inches square. A form for the construction of the column is shown in Fig. 34. The slab form consists of a frame of 2 × 4's firmly braced and laid upon any flat surface upon which the concrete can be poured. A piece of ordinary building paper forms an excellent bottom for the slab forms. The reinforcing of these consists of $\frac{1}{4}$-inch rods extending lengthwise through the slabs and spaced about 4 inches apart; the two outer ones being 1 inch from the edge of the slab.

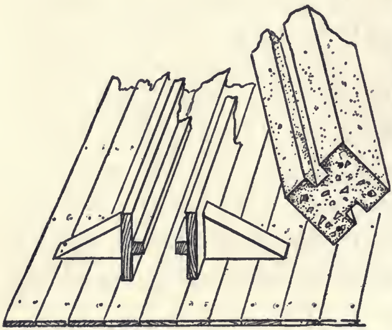


FIG. 34. — Forms for Casting Columns.

Cross rods of $\frac{1}{4}$-inch stock are located at intervals of 1 foot and firmly tied to the longitudinal rods. The horizontal edges of the slabs may be made so as to interlock, that is, making one edge convex and the other edge correspondingly concave so that when two blocks are placed together a sort of tongue-and-groove effect is obtained.

In erecting the columns and slabs the former are set upon a concrete curb at least 18 inches deep and as thick as the columns themselves. Sometimes two or more of the reinforcing rods of the column are left to extend three or four inches beyond the end, and when the column is set upon the curbing the reinforcing rods fit into holes drilled into the foundation wall. After the columns have been firmly located the slabs are carefully lifted and slipped into place with a convex edge upward. Some sort of small crane is desirable to use in this connection because the greatest strain comes upon the columns and slabs while they are being put in place. After the columns and slabs are all in place the cracks can be filled with a rich mortar, thus effectually sealing them.

Concrete Roofs

Roofs for small concrete buildings can be very handily made of concrete. Where the building is of rather large size the layman should not attempt its design, but leave this to one of more experience. In small buildings all that is necessary for constructing a simple roof is to set up a form nearly horizontal with sufficient supports below, and place the concrete directly upon this. The accompanying tables will indicate the thickness of the roof slabs and also the amount of reinforcing required to give them sufficient strength:

Thickness of Roof Slabs in Inches

Width in Feet between Center Lines of Walls	Length of Roof in Feet between Center Lines of Walls						
	4 ft.	6 ft.	8 ft.	10 ft.	12 ft.	14 ft.	16 ft.
4 ft. . .	2 in.	2 in.	2½ in.	2½ in.	2½ in.	2½ in.	2½ in.
6 ft. . .	—	2½ in.	2½ in.	2½ in.	3 in.	3 in.	3 in.
8 ft. . .	—	—	3 in.	3½ in.	3½ in.	3½ in.	4 in.
10 ft. . .	—	—	—	3½ in.	4 in.	4½ in.	4½ in.
12 ft. . .	—	—	—	—	4 in.	4½ in.	5 in.
14 ft. . .	—	—	—	—	—	5 in.	5½ in.
16 ft. . .	—	—	—	—	—	—	6 in.

Load = Weight of roof + 50 lb. per sq. ft.

There are certain concrete products which are adaptable to concrete roof construction. Among these are concrete tile and concrete shingles. Concrete tile are made in shapes and sizes similar to clay tiles and are used in much the same fashion. Their cost is approximately the same as that of clay tile and they may be colored in imitation of the clay tile. The concrete shingles are thin slabs of a rich mixture of concrete provided with perforations so that they can be attached to the sheathing. A number of different types are in use and seem to be giving a fair degree of satisfaction. Some types of shingles have mixed with the concrete a certain amount of asbestos, making them tougher than when made of plain concrete.

The advantage of the concrete roof lies in the fact that its cost is not excessive, it does not need to be replaced, and when properly made it is waterproof. In addition to this it is fireproof and when everything is considered it can be easily seen that this type of roof is an especially advantageous one to use.

Spacing of Reinforcing Rods in Inches

Width in Feet between Center Lines of Walls	Length of Roof in Feet between Center Lines of Walls: 4 ft.	6 ft.	8 ft.	10 ft.	12 ft.	14 ft.	16 ft.	Size Steel
4 ft.	12 in. 12 in.	9¼ in. 24 in.	8 in. 36 in.	8 in. 36 in.	8 in. 36 in.	8 in. 36 in.	8 in. 36 in.	¼ in. Round Rods.
6 ft.		6 in. 6 in.	4¾ in. 12 in.	4 in. 36 in.	4 in. 36 in.	4 in. 36 in.	4 in. 36 in.	
8 ft.			11 in. 11 in.	9½ in. 22 in.	9 in. 36 in.	7¾ in. 36 in.	7¼ in. 36 in.	⅜ in. Round Rods.
10 ft.				8¾ in. 8¾ in.	7¾ in. 16 in.	7 in. 27 in.	6½ in. 36 in.	
12 ft.					6½ in. 6½ in.	5¾ in. 12 in.	5¼ in. 16 in.	
14 ft.						5¼ in. 5¼ in.	4½ in. 8¾ in.	
16 ft.							4 in. 4 in.	

Load = Weight of roof + 50 pounds per square foot.

Note. — Upper figures are for cross reinforcement; lower figures for long reinforcement.

CHAPTER IV

PAVEMENTS, FLOORS, SIDEWALKS, STEPS

Pavements

Much has been said and written about the value and desirability of concrete as a material for the construction of pavements. Some of this has been extremely favorable, while some has been equally derogatory. Authentic records seem to show that when the proper precautions are exercised, as should always be done in any type of concrete construction, the numerous objections to concrete pavements are difficult to support. Since the use of concrete as a construction material is much newer than most of the materials used in pavement work, there is not a wealth of data at hand from which conclusions can be drawn; but in a number of cases where relative data are obtainable, the concrete pavement has completely and thoroughly justified itself.

The practice and experience of Wayne County in Michigan is one of the best examples of what can be accomplished by the use of concrete in the proper way. In this county the construction of concrete pavements began with the building of a few miles of sample roads; to-day the commissioners cannot build the roads fast enough to meet the demands of the people, so intensely popular has this type of pavement proved in that locality. The Wayne County commissioners attacked the proposition in a sane, business-like way and have learned a great deal by experience from

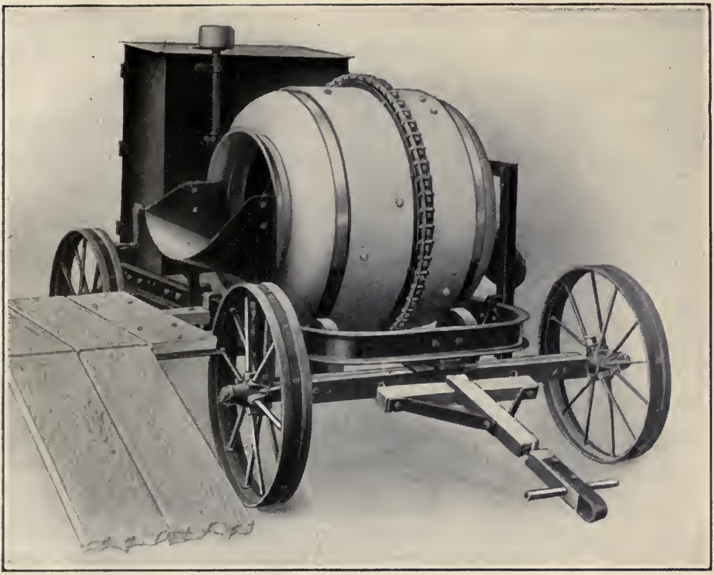


FIG. 11. — A Small Concrete Mixer.

FIG. 35. — A Stretch of Concrete Road in Wayne Co., Michigan.

which others may now reap the benefit. Throughout the United States are numerous examples of small strips of concrete pavements that were installed with the idea of subjecting them to difficult traffic conditions and almost invariably these installations have been very successful.

In order that a highway may serve with the best efficiency for the greatest length of time it should possess the following qualifications:

1. A firm unyielding base.
2. An elastic intermediate foundation.
3. Permanent wearing surface.

The history of highway construction shows that these principles have been understood as far back as the times of the Romans, when four course highway construction was the best practice. These four courses consisted first, of large stones laid in a lime mortar; next, a concrete of lime and broken stone well compacted; this was covered with another layer of loose concrete, upon which was placed the final wearing course of flat stones fitted to close joints, and laid in mortar. The total thickness of these four courses sometimes reached three feet and as an evidence of the thoroughness of the construction, there are found sections of the old Roman roadways in use to-day.

The advent of the automobile has put an entirely different aspect upon modern highway construction. The suction occasioned by the rapid passage of inflated pneumatic tires results in the gradual disintegration of road materials that are not dense and completely compacted. Macadam pavements which have for so many years been the standard highway construction were quickly destroyed by automobile traffic and a type had to be perfected to take their place; it seems that concrete is an excellent substitute.

The value of concrete as a paving material is due to several things. Properly made concrete is practically permanent and strongly resistant to even very heavy wear. Automobile traffic has practically no effect upon it. Since concrete can be laid almost perfectly smooth, the road surface will contain no projections or indentations which so often in other types of pavements produce an annoying vibration. A very slight cross-grade is sufficient to give good drainage to the surface of concrete pavement, therefore increasing the comfort of those riding upon it. The cost of concrete is not excessive and compares very favorably indeed with other types of paving materials; in fact, in most cases, assuming equal qualities, concrete is considerably cheaper not only in first cost but in maintenance. Last, but not least, must be mentioned another attribute of concrete in which an economical advantage results from the use of local materials and the employment of local labor, thus insuring that the greater part of the money appropriated for the construction of the pavement will be spent in the locality where it is raised.

Types of Concrete Pavements. — There are in reality only two essentially different types of concrete pavements, the *one course* and the *two course*. Of these two types there are several variations, the distinctions in each type being rather vague and consisting mainly of difference in material and in method of manipulation to get the desired results. In the one course pavement the entire pavement is constructed of the same rather rich mixture throughout and the entire layer is placed at once. The two course type provides for a thick bottom layer of a slightly leaner concrete than would be used in the one course type and on top of this is placed a second layer of very rich mixture of cement and fine crushed granite or other tough and durable aggregate.

The selection of the type of the pavement to be constructed will depend more upon local conditions than upon anything else. Both types of pavements give excellent results in practice, the single course type being somewhat cheaper than the two course type. If the proper aggregate is readily available a single course pavement is probably the best type to use, but in regions where the aggregate must be imported it will be just as well to construct a two course pavement using cheaper aggregate for the bottom course and making a thin layer of the more expensive aggregate for the top wearing course. The one course pavement, however, has proven remarkably successful and is usually preferable when conditions admit.

The inclusion of reinforcement in the pavement complicates construction methods somewhat. This reinforcing usually consists of some sort of woven wire cloth and its use necessitates the placing of the layers of concrete containing it in two operations. In this case the labor cost of the single course pavement is very likely to approximate closely that of the two course construction. The cost of concrete pavement, since it is influenced by so many outside factors, cannot be stated with any degree of accuracy. First class durable pavements have been constructed at a cost as low as one dollar per square yard, and from this minimum, a variation in price has been paid up to two dollars or perhaps a little higher in a few instances. It seems that $1.65 or $1.75 will cover the cost of ordinary good construction.

Foundation. — The first essential for good pavement construction is an adequate and substantial foundation. The surface should be made smooth, firm, and unyielding at every point and should be thoroughly compacted by using a heavy roller. If any fill is made in spots this should be especially firmly compacted since it is very difficult to get this fill brought up to the same degree of firmness as exists in the surrounding soil which has been compacted by traffic and weather conditions for years. Unless the foundation is made uniformly resistant, the strains to which the pavement will be subjected will not be distributed evenly, and unsightly and destructive cracks are almost certain to form. The foundation should be carefully inspected before any concrete is placed upon it and if the concrete materials are hauled upon the foundation after the first inspection, a second inspection must be given after the hauling has been completed.

Drainage. — The matter of drainage should be given special attention, because it is absolutely essential for the successful maintenance of the pavement that water be prevented from seeping in and standing beneath it. If the foundation becomes soaked it is likely to settle and cracking of the concrete will almost invariably result. Adequate drainage can usually be provided by well constructed tile drains or open ditches at the side of the road. The preparation of a sub-base is usually necessary, though occasionally some very firm soils are found upon which the concrete can be placed directly with a reasonable degree of safety. In most cases, however, it will be necessary to make a fill of from four to six inches of gravel or cinders and to compact it very thoroughly before the concrete is placed upon it. This acts as a sort of cushion for the layer of concrete besides giving excellent drainage for the small amount of water which might gain entrance beneath the concrete. This sub-base should be placed upon a crowned foundation and the sub-base itself given a slight crown. After the sub-base has been properly compacted, the placing of the concrete may be begun.

Proportions and Placing. — The mixture that is recommended to be used in the construction of a one course type of pavement is a 1:2:3 mixture of cement, fine aggregate, and coarse aggregate, no particles larger than those passing through a one-inch ring being permitted in the coarse aggregate. The only forms that will be necessary will be planks of the proper width placed along the sides of the proposed pavement. The width of the pavement will vary according to conditions and the crown will in turn depend upon the width. If the surface is properly finished, a crown of one-quarter inch per foot is usually sufficient. Occasionally, especially in the case of narrow pavements, the concrete is laid directly upon a flat subbase and the crown obtained by increasing the thickness of the concrete at the middle, thus giving the additional strength where it is needed.

The mixture is made rather wet so that it can be easily handled. Too wet a mixture, however, should be avoided as it injures the strength of the concrete. A consistency equal to that of mortar for plastering will be satisfactory. In placing concrete the work should continue until a section is completed and should not be stopped at any point between the expansion joints, for if this is done unsightly cracks are almost certain to appear where the work was stopped. The concrete, having been placed as evenly as possible in strips across the width of the pavement, is further smoothed out by the use of a striker board; and if the pavement is of a one course type, this operation will be followed by the tamping and finishing with a wood float. If the two course type is employed, the concrete is brought down to a reasonably smooth surface and slightly tamped so as to compact the bottom layer well before the wearing coat is placed. Care should be taken that the placing of the second coat occurs as soon as possible after the first layer has been deposited since it is essential that a firm bond be made between the two layers, and this cannot be accomplished if the cement in the first coat has become set; this will usually occur within forty-five minutes. The edges of the pavement should be beveled so there will be no sharp square corners that might be broken off by the action of traffic; this beveling must be done before the concrete has set in order to prevent any reduction in its strength or durability.

Expansion Joints. — A very necessary factor in the successful construction of concrete pavements is provision for expansion; improper expansion joints have been the cause of the ruin of many otherwise good concrete pavements. The expansion joints are usually located about 30 feet apart and are about 1 inch in width, being easily formed by the removal of a 1-inch board after the concrete has set; the space thus formed is subsequently filled with an asphalt filler. The edges of the concrete at the expansion joints are protected by means of angle irons or other specially prepared corner irons fastened into the concrete; were this not done the corners would gradually break off and a depression extending clear across the pavement would soon be in evidence. Sometimes the expansion joints are placed diagonally across the pavement at an angle of about 60° to the side of the paving. The angularity of these expansion joints is opposite in adjacent joints, *i.e.*, as the observer stands facing the side of the pavement, one joint will swing to the right, the next to the left. The advantage claimed for this arrangement of joints is that in case any excessive expansion of the concrete does occur, the blocks will slip past each other slightly. Another advantage is that two wheels of vehicles will not hit the expansion joint at the same time.

Thickness. — The ordinary thickness of the single course pavement varies from 5 to 7 inches, the latter figure, of course, giving the strongest pavement; 6 inches is perhaps sufficient for ordinary traffic. In the two course pavement the lower course may be made 5 or $5\frac{1}{2}$ inches thick and a second course sufficiently thick to bring the total up to 7 inches. The second coat in the two course pavement is finished much as sidewalk is finished except that only a wood float is used so that the surface will not be too smooth.

One objection to the concrete pavement is that it is noisy. This is more or less true, but the noise occasioned by traffic running over concrete pavement is less than that of a brick pavement. A construction by which practically all noise can be eliminated and by which the same results can be obtained as with an asphalt pavement is to coat the surface with a layer of pure asphalt an inch or two in thickness, or, as is more commonly done, to make the coating a mixture of asphalt and fine gravel or crushed granite. This particular surfacing is very elastic and sufficiently soft to reduce the noise of traffic to a minimum. It is quite durable and when mixed with the proper amount of gravel or granite will resist ordinary heavy wear. It has been found to be highly desirable in parks, etc., where very heavy traffic does not occur.

Floors

Concrete floors can be used to advantage in a number of places on the farm. They are especially valuable in the construction of dairy barns where sanitation is the keynote, but they can be used successfully on almost any building. Concrete feeding floors have thoroughly proven their worth in feeding operations, both in sanitation and in a saving of the feed. The main ideas to be borne in mind in the construction of concrete floors are that they should be made of a medium rich mixture; that they should be placed on a good foundation; and that they should be properly protected from heavy loading, direct sunlight, and hot winds for a week or two after they have been completed.

Foundation. — The first essential of a good concrete floor is a properly prepared foundation. In some firm soils it is possible to locate a thin concrete floor directly upon the soil without the construction of a sub-base. When this is done the soil must be scraped off to a level surface and thoroughly tamped or rolled with a heavy roller so that there will be no yielding spots under the floor. This practice is not to be recommended for the construction of heavy floors nor for any floors upon which even a moderately heavy load is likely to come. For ordinary floor construction it is much better to put in an adequate sub-base of gravel or cinders upon the soil and compact it very firmly; this not only gives a solid sub-base, but provides excellent drainage beneath the floor itself, which is a factor not to be overlooked. In preparing the sub-base it must be known whether the top surface of the floor is to be higher than the surrounding ground or whether it is to be level with it; in the latter case proper provision must be made to bring the floor to the required level by making the necessary excavation.

Most floors are constructed of two courses of concrete, a bottom course made of a three part mixture of cement, sand, and coarse aggregate and a surface coat made of cement and sand, usually of a rich mixture. The one

FIG. 36. — A Feed-lot Paved with Concrete.

FIG. 37. — No Feed is Lost on this Floor.

course floor, however, has been used very successfully in barns and for feeding floors. When the one course type of construction is employed the whole mixture is generally made richer than the bottom course of the two course floors.

Thickness. — The thickness of the floor will vary with the purpose for which it is to be used. In a small poultry house where no severe loads will ever come upon it, a floor three inches thick is amply sufficient for all needs. It is well to reinforce such a thin floor with wire netting, this being placed between the first and second coats, but not so as to prevent a good bond between them. In basements, milk houses, and buildings of such a character a four-inch floor is usually sufficient, the bottom course in this case being three inches thick. Barn floors are generally made thicker, the concrete under horse stalls being at least six inches thick and under cow stalls five inches thick, the bottom layer being five inches and four inches in thickness respectively. Feeding floors or any floor over which a loaded wagon is likely to be driven should be made at least 6 inches thick.

Construction. — Arrangements should be made so that floors of small extent can be finished in one continuous operation. Larger floors must be laid out in sections and the mixing so regulated that the second course can be applied before the first course has begun to set, for unless a firm bond exists between the two courses, the floor is likely to fail, due to the separation of the upper course from the lower, followed by the breaking into pieces of the upper course. Small floors need not be divided up into sections; large floors should be so divided, the sections varying in size from 3 × 3 feet to 10 × 10 feet, though sections 6 × 6 feet will usually be found to work more satisfactorily. The divisions between the sections should extend through the entire floor, with little or no connection between the adjacent sections. The purpose of these divisions is to provide opportunity for expansion and contraction and to prevent the formation of unsightly cracks across the surface of the floor itself. If the floor is greater than 25 feet in either direction, an expansion joint one inch wide should be provided and this filled with asphalt such as is done in the case of concrete pavements.

Various methods can be followed in the arrangement of the forms which are necessary in floor construction; one of these is illustrated in Fig. 40. Dimensions of the floor having been ascertained the size of the sections is calculated. The sections should be uniform in size. 2 × 4's, or

FIG. 40. — Placing Concrete in Alternate Blocks.

2 × 6's, as the case may be, are then set in place, firmly held by stout pegs on the outside. The nails are driven through the pegs into the form boards, but not through the latter; the head should project so that the nail can be easily withdrawn in order not to disturb the form itself. The forms are then placed so that sections *A*, *C*, and *E* are first filled and finished; then, when the concrete has hardened sufficiently so that the form boards can be removed without danger to the concrete, the cross-pieces between sections *A* and *B*, and between *B* and *C*, etc., are removed and sections *B* and *D* are then filled and finished. This method results in the slabs having a distinct line of demarcation between them and the adjacent ones. Another method is to cut through the mixture with

FIG. 38. — Iron Studding Sockets Set in a Concrete Crib Floor.

FIG. 39. — The Use of Concrete in a Sanitary Dairy Barn.

a trowel at the section lines, care being taken that the cut through the second coat corresponds to the cut in the bottom course below. This method is not likely to be entirely satisfactory since the division is not distinct and since it is likely to fill up with concrete and be practically as strong as the remainder of the section so that when cracks do occur they are as likely to occur any place in the section as at the division line. Sometimes metal strips are placed between the blocks and withdrawn before the concrete has set; this method is very satisfactory.

Mixture. — The mixture that is usually used in making concrete floors is about a 1 : 2½ : 4 mixture, though variations from this will quite often be found. The reason that a rather rich mixture is used is that the floor is likely to be subjected to uneven loadings and some degree of strength is necessary. The consistency of the mixture should be such that it will show moisture on the surface with very little pressure. When the batch of concrete is placed it should be very quickly smoothed out and tamped, and if a second coat is to be applied it should have been made ready so that it can be placed before the first coat has had a chance to harden. In this way only can a good bond be formed. If only a one course floor is being constructed the tamping should be very carefully done until the surface is smooth and even. This should be followed immediately by the wood float, to bring the surface to the required degree of smoothness. Too much tamping or too much working of the cement near the surface is injurious. Excessive tamping will bring so much cement to the top that there will be a layer which is practically a mixture of cement and water, and this in drying is extremely likely to form cracks on the surface. In going over the surface with the float or trowel, no more smoothing should be done than is absolutely necessary to get the required results.

Feeding Floors. — In the construction of feeding floors the same procedure should be followed as has been heretofore described. The only distinctive feature of the feeding floor is a low curb around the edge; the purpose of this curb is to outline the floor and to prevent stock from spreading the feed into the surrounding soil. The curb need not be over three or four inches high. Feeding floors should be made with a slope toward one corner and the curb omitted at this point; this is to admit of the free flushing of the floor with water when cleaning is done. The slope of the floor should be not less than one inch in ten feet, which will not be great enough to be very perceptible but will admit a rapid flow of water.

The thickness of feeding floors will depend on the purpose for which they are to be used. If swine only are to be allowed to run upon the floor and no wagons or other loads are to be applied a four-inch thickness will be sufficient. A six-inch floor will be necessary when cattle use the floor or when any portion of it will be driven over by loaded wagons. Feeding floors are usually made in a single course and are tamped just sufficiently to obtain a uniform surface. It is better to leave the surface somewhat rough since in most instances feeding floors are out of doors and a smooth floor would be dangerous in winter time when the formation of ice is to be expected.

Sidewalks

The apparent ease with which concrete sidewalks may be constructed has led many people with little experience to undertake making them, with a result that perhaps there has been as high a percentage of failures in this particular work as in any phase of concrete construction. The concrete sidewalk is a type of concrete construction which is subjected to more than ordinarily hard usage; in consequence of this considerable care should be employed in the construction methods in order to insure a successful outcome. The underlying principles of selection of materials, mixing, and placing apply with great pertinence to sidewalk construction and should never be in the least degree slighted.

Concrete is perhaps the most suitable material yet employed in the construction of sidewalks. When properly utilized it fulfills to a surprising degree every requirement of a perfect sidewalk. Smoothness, solidity, durability, both in resisting wear and destructive action of the elements, are all qualities of good concrete. Often, however, through lack of knowledge of the material and inexperience in handling it, many walks are built which sooner or later become more or less defective and the concrete as a construction material has to bear the brunt of the blame.

The fundamental requirements of good concrete sidewalks may be enumerated as follows:

1. Good drainage is essential, as emphasized in the discussion of floors and pavements; in fact the concrete sidewalk is in reality a long strip of concrete floor which is subjected to perhaps a little harder usage than is the floor itself.

2. Good durable materials are necessary because the walk is subjected to hard wear and the aggregate that is used in the concrete must present a hard wearing surface.

3. Good workmanship, which includes proper proportioning of materials, sufficient mixing, rapid placing, and the prevention of too rapid drying, must be insisted upon.

Foundation. — A concrete sidewalk, though a broad-based structure in itself, requires a good foundation on account of the fact that it is almost always in a very exposed location and because of the heavy weights that are likely to come upon it. In open, well-drained, solid soils it may not be necessary to put in a foundation or sub-base, but this condition is rare. It will almost always be advisable to put in some sort of sub-base consisting of cinders or gravel well tamped, and varying in thickness from four to eight or ten inches, depending upon the nature of the soil. Excavation for this sub-base is usually necessary, though special circumstances may arise when the walk is to be located on a fill; in such a case the top surface of the fill can be made of the sub-base materials and will act as a foundation for the walk. If the location of the walk is not a well-drained one, it may be advisable to put in a string of drain tile.

Forms. — After the sub-base has been prepared, the next thing in order of procedure is the preparation of the forms to receive the concrete. Most sidewalks are made four inches thick and are usually of two course construction, similar to that described under the head of "Floors." If a portion of the sidewalk is to constitute a crossing for loaded wagons it will be well to make this portion of the walk at least six inches thick. The material commonly used for forms for a four-inch walk is 2 × 4 stuff which is laid on edge along the sides of the proposed location for the walk. Wooden pins are driven in along the outside of the 2 × 4's, the top of the pins being below the upper edge of the plank. To hold the forms in place, nails are driven in from the outside through the peg, into the plank but not through it. If 10d nails are used a sufficient length of the head and of the nail will project outside the peg to admit of easy pulling of the nail, thus releasing the peg from the 2 × 4 and facilitating its removal. The pegs should be located at intervals not to exceed three feet. Care must be taken to see that the inner surface of the 2 × 4's forms a perfectly straight line, for any inaccuracy in the edge of the walk resulting from a careless placing of the forms will be very evident in the completed walk. For use in extensive work, excellent special forms are obtainable; such forms are widely used in commercial work.

If a narrow walk is being constructed, one that is not more than four feet wide, the surface drainage can be accomplished very easily by making one line of 2 × 4's lower than the other, thus giving the walk a slope toward one side. A slope of $\frac{1}{16}$ inch to the foot in such a case is ample. If a walk wider than four feet is being made it will present a handsome appearance if it be crowned in the middle. A crown of $\frac{1}{16}$ inch per foot of width will be so low as to be imperceptible to any one using the walk, yet it will give ample opportunity for the removal of water.

Mixture. — Since the concrete sidewalk is subjected to considerable strains at times it should be made of a mixture sufficiently strong to resist them. The ordinary mixture that is used in the bottom course which is the part of the walk that mainly sustains the load is 1 : 2 : 4. For light walks around residences, a 1 : $2\frac{1}{2}$: 5 mixture is sometimes used with success, but for the sake of durability it is better to be safe and use the richer mixture. The finish coat is a 1 : $1\frac{1}{2}$ or a 1 : 2 mixture of cement and hard sand. The thickness of the bottom layer is a little more than three inches, the surface coat being applied in a layer of sufficient thickness to bring the total thickness of the walk up to four inches.

Mixing and Placing. — In the construction of walks it is necessary to work with considerable rapidity in the placing of the two coats in order that an opportunity for their union be afforded before either one has had an opportunity to set. Otherwise, the top coat will later crack and separate from the bottom one rendering the walk very unsightly in appearance and very difficult to repair.

The material for the bottom layer having been very thoroughly mixed, it is then shoveled on to the foundation between the forms, spread out and struck off with a striker board similar to one of the types shown in Fig. 41. The

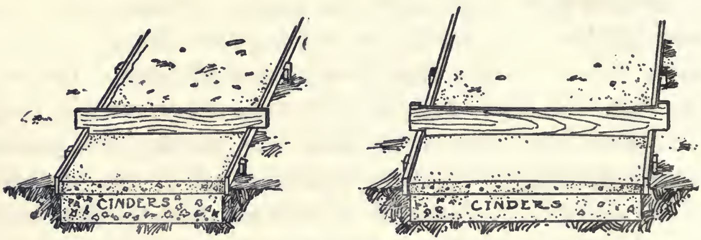


FIG. 41. — Striker Boards for Sidewalks.

selection of the type depends upon whether the sidewalk is to have a flat surface or a crowned surface. The striker board is drawn along the forms, evening out the concrete to the proper thickness, after which the concrete is tamped firmly into place. Too much tamping will drive the aggregate to the bottom and bring an undue amount of moisture to the top; this may cause difficulty later by seeping up through the finish coat and making it so wet that it will be difficult to finish properly. Just enough tamping should be done to get the concrete in place. When the first layer has been put in place the second layer, which should have been prepared in the meantime, is spread upon it and evened out by means of trowels and then smoothed off with the back edge of the striker board which should be made long enough to extend several inches on either side past the sidewalk forms. The striker board is drawn along the forms with a cutting motion which assists in filling up small holes that might occur. A wood float follows the striker board and improves upon its work somewhat. The final finish is usually put on by means of a steel plasterer's trowel.

The consistency of the mixture is of considerable importance. The concrete in the lower part of the walk should be mixed to a medium consistency, while the mortar put on for a finishing coat is drier than that which would be used in plastering. The reason for this is that the finishing process will bring a certain amount of moisture to the surface so that there is more danger of getting too much moisture than there is of getting enough. Too wet a finish mixture will sometimes result in the formation of hair cracks on the surface of the walk.

Finishing. — A little experience is necessary for successful and rapid finishing. The amateur in endeavoring to get a smooth surface will mull over the surface to such an extent as to bring a thin coating of neat cement mixture to the surface. This in drying will check and crack and is not likely to prove as durable a surface as a mixture of cement and sand itself. The finish produced by the steel trowel in the hands of an experienced workman is not too smooth for average use. The surface will have a fine granular finish, depending in texture upon the amount and kind of sand used in the mixture. If a rougher finish is desired, the wood float can be used instead of the steel trowel, though it will usually not be found necessary except in occasional instances to do this.

Curing. — No matter how carefully the work of mixing and placing has been carried on, unless great care is taken failure will result on account of improper curing of the concrete. In most instances, a concrete sidewalk is laid in an exposed position where it is likely to be subjected to the direct rays of the sun in the summer time or low temperature in the winter time. In the first instance, the evaporation of water from the concrete will be so rapid that shrinkage cracks and checks will form; in the second, the concrete may be ruined by the freezing of the moisture before the cement has had an opportunity to get its final set.

If it is necessary to make concrete sidewalks in the winter time, the best way to proceed is to follow the directions previously given for concreting in cold weather; that is, by heating the materials from which the concrete is made. This will probably enable the cement to get its initial set before the temperature is very much reduced, and if the walk is covered with heavy canvas or strips of burlap which are laid so as not to come in contact with the surface of the walk itself, enough heat will be retained to keep the moisture from freezing for ten or twelve hours, when the final set should have occurred. Protection for a longer time than this is advisable and if possible the canvas or burlap should be left in place for several days. If artificial heat or steam can be introduced beneath the covering, it will be additional insurance of a successful outcome. The practice is sometimes followed of covering the concrete with manure after the finish coat has hardened sufficiently to prevent the formation of dents under ordinary pressure, but while the method is efficient as a means of heat retention, it sometimes causes discoloration of the concrete which is impossible to remove; the discoloration is due to the absorption of materials from the manure itself. If any other method of protection from cold is available, it should, by all means, be taken advantage of in preference to the application of manure.

In summer time, the protection of the sidewalk is an easier matter since it is necessary only to prevent the sun's rays from striking the walk and to keep the surface of the concrete moist. This can be very easily done by erecting a loose framework over the walk upon which is spread canvas, burlap, old boards, or anything else that will exclude the sun's rays. These should be left in position for several days or until the concrete has had a chance to harden thoroughly. In the meantime, the walk should be sprinkled occasionally, often enough to keep the surface damp, which will reduce the time of drying and the tendency to form cracks as the result of excessive shrinkage. It also means a harder and more durable wearing surface.

Sometimes the surface of the concrete wears off very roughly. This may be due to various causes, one of which is too rapid drying. Even if no perceptible cracks have appeared, the surface of the concrete does not possess the strength which it ordinarily would had it been properly protected. It has been found in the construction of floors in warehouses, factories, etc., that if the floor is covered with a thin layer of sawdust and kept constantly damp that the concrete will harden into a very dense and almost dustless material, much more wear-resistant than a floor allowed to harden without adequate protection.

Expansion Joints. — Many builders of concrete sidewalks either are not aware of the fact that concrete expands and contracts or if they do know it, they do not take this factor into consideration. Experience has shown that it is necessary to provide a one-inch expansion joint at intervals not to exceed fifty feet. This thickness may be distributed in several joints if it is desired, making a $\frac{1}{4}$-inch joint at intervals of ten or fifteen feet. The advantage of the latter arrangement is the elimination of the wide joint which for various reasons may be found to be objectionable. In case a long stretch of walk is constructed without proper provision made for expansion, there is very great likelihood of the occurrence of "buckling" or the bulging up of two or more of the blocks. Sometimes, instead of "buckling," the blocks will crush or crack badly. Under any circumstances, the occurrence is a bad one since it means the construction of a new section of walk and it will be found very difficult to match the remainder of the walk in color and appearance.

The material which is used to fill the joint may be either sand or some asphaltum product, the latter being preferred since it is more likely to stay in place once it has been put there. Sand is likely to become packed so hard in dry weather, at the time when it is most needed, that it will not compress, and as a result, is of no value in permitting expansion of the concrete.

Special Sidewalk Tools. — Certain tools are used in sidewalk construction that are not used in any other type of concrete construction, except floors. Among these are the groover, edger, finishing trowel, float, and roller. These are illustrated in Fig. 42. The purpose of the groover is to provide a rounded edge at the intersection of the adjacent blocks in the floor or sidewalk. The edger fulfills the same purpose along the outside edges of the sidewalk or the floor. The finishing trowel and float are used to put the desired finish upon the surface of the concrete, while the roller, made in a variety of designs, is employed to put in the surface of the concrete various corrugations and indentations to make it safer for traffic. Instances of where the roller is used are in grooving driveways, concrete crossings, steps, etc.

Failures of Sidewalks and their Causes. — It must not be supposed that because several different types of failures are here described that they will occur in the work of every sidewalk builder. In almost every instance, they are the

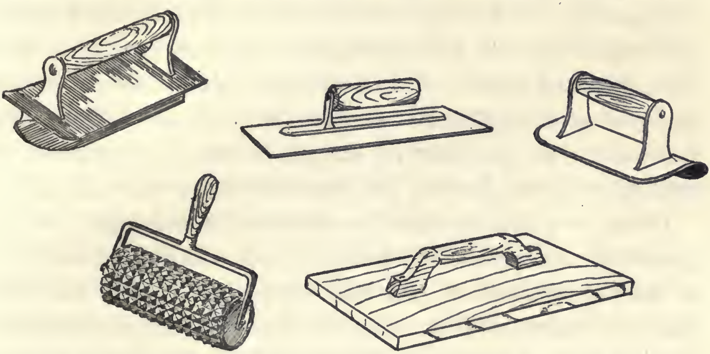


FIG. 42. — Special Tools Used in Floor and Sidewalk Construction.

direct result of poor workmanship, and anyone with ordinary ability and common sense can easily so conduct his work as to insure to a reasonable degree the impossibility of any failures.

Probably the greatest number of failures result from the use of improper materials or from improper mixing and placing. It may be that considerable emphasis is placed upon these points, not only at this time, but on other pages in this text; the fact remains, however, that it is only by such repeated emphasis that the lesson be thoroughly taught unless experience, a more expensive teacher, is employed. The sidewalk is subjected to rather hard usage and the materials must be clean and well proportioned and the mixing and placing done under strict care and supervision if the finished product is to possess sufficient strength to resist the heavy strains to which it will be subjected.

Occasionally a walk will be found that has cracks extending in every direction with hollows and hills throughout the entire surface. This is almost surely an indication that a proper foundation for the walk has not been provided. The practice of laying concrete walks directly upon loose soil, especially soil not thoroughly drained, cannot be too strongly condemned. The foundation should be an essential part of sidewalk construction, and not only should the foundation or sub-base be included, but it should be as carefully put in place as the concrete of the sidewalk itself.

When two adjacent blocks are found heaved up at their junction, or crushed or broken, it is an indication that sufficient opportunity for the expansion of the concrete has not been provided. As stated previously, the appearance of such a walk is decidedly bad, besides being inconvenient to use. The remedy for this difficulty is the insertion of an expansion joint described in a preceding discussion.

Sometimes sidewalks must be located near trees. In a case of this kind, consideration must be taken into account of the future growth of the tree, and provision must be made for the enlargement of the trunk and for the growth of the roots beneath the sidewalk. The best plan is to avoid going anywhere near the tree, keeping at a distance of several feet, if possible, from the trunk. If close proximity is necessary, however, deep grooves extending clear through the concrete should be made so that heaving or displacing of the concrete caused by the growth of the tree will result in the loss of only a small section of the concrete.

Every one has noticed concrete walks which apparently have separated into two layers, the top layer cracking off in large sections and separating entirely from the bottom layer. The cause of this is that the bottom layer of concrete was allowed to harden before the finish coat was applied. A firm bond between the two layers in the sidewalk is absolutely necessary, and where it is not obtained, the separation of the layers is certain to occur. The upper layer, separated from the lower one, is not sufficiently strong to resist traffic and will soon crack, and the walk will be ruined. It is difficult to repair a walk when this unfortunate circumstance has occurred. The best procedure is to tear up the old walk and replace it with one entirely new, properly made.

Small hair cracks on the surface of the sidewalk, which in all probability are soon followed by the destruction of the surface coating on the concrete, are the result of either too rapid drying or of too much troweling. The latter cause is much the more common, especially in walks constructed by the inexperienced workman. In his endeavor to produce a smooth surface, he will pass the trowel repeatedly over the same area with more or less pressure applied. As a result, the aggregate will be pushed down and a mixture of cement and water will come to the surface. This, in drying, is almost sure to check, with the resulting destruction of the surface of the walk. As far as utility is concerned, the walk may be as satisfactory as ever, but its appearance will be very badly spoiled. Just enough troweling should be done to bring the surface of the walk to a reasonable degree of smoothness. Practice is the one thing which will enable one to do the finishing with any degree of rapidity or success.

If the surface of the concrete is permitted to freeze slightly before the set of the cement has occurred, a granular or pitted appearance of the surface is likely to occur. This is due to the fact that particles of the cement have not set properly and become points of weakness. When the walk becomes slightly worn, these weak spots show up very rapidly and give the walk a very bad appearance.

As a final precaution to builders of concrete sidewalks, let emphasis be laid upon the fact that most walks are not made wide enough. For walks around residences, and especially around farm residences, where there is plenty of room and no reason for cramping, a walk three feet is none too wide. A front walk, or one used a great deal, should be a foot wider, and sidewalks along streets and in public places should never be less than five feet wide, being made as much wider than this as traffic conditions will demand. The extra width can be added at practically the only expense of the cost of the additional materials, and it will be found that in the additional strength, durability, and convenience, the extra expenditure has been fully repaid.

Steps and Stairs

The construction of steps and stairs is one of the most difficult problems with which the amateur concrete worker will have to contend. Not only is the preparation of the forms rather difficult, but the concrete itself, after the forms have been put in place, must be placed very carefully in order to get good results. There are numerous ways of arriving at the same end, and the person in charge of the work must use his ingenuity in the use of the materials at hand and adopt the method best suited to his requirements. In the following discussion, the fundamental principles will be given and they can be applied to suit various circumstances.

Design. — Stairs, to be convenient, should fulfill certain requirements. The "rise" or vertical distance between the horizontal portion of two adjacent steps should not be over 8 inches nor less than 6 inches. Limits of $6\frac{1}{2}$ and $7\frac{1}{2}$ are better. The width of the "tread" or the horizontal distance between two adjacent risers should not be less than 9 inches and need not be more than 10 inches. An old rule for determining the width of the tread is to make the tread as wide as the distance required to bring the sum of the riser and tread to 17 inches. Winding steps should be avoided, if possible, for they are likely to be the source of danger besides being difficult to construct. It is better to take a little additional room and make a short flight of steps after turning a square corner, leaving a landing, which should be in length and width the same as the length of the step itself. A "nosing" or projection of the tread over the riser sometimes adds to the width of the tread and to the appearance of the steps as well. It can be incorporated in concrete steps with no great difficulty.

Construction. — The simplest type of stairs consists of a block of concrete in which the steps are molded at one side. The construction of such a flight is shown in Fig. 43. The forms can be made either of 1- or 2-inch stuff, preferably the latter, though if the 1-inch stuff is used, the bracing must be sufficiently strong to prevent bulging, since a considerable quantity of concrete is included in the block. The boards forming the side forms should be extended beyond the rise-boards for a distance of 5 to 6 inches. Cleats can then be nailed on with the nails driven only partly in. The rise-boards will rest against the cleats and when the cleats are removed the rise-boards can be very easily taken out.

The concrete should be placed in position very carefully. Too much tamping must not be given it, or else the concrete will run over the treads of the lower steps. It is also necessary to have a mixture that is not too wet or else the same thing will occur. The treads should be troweled as soon as the concrete has hardened sufficiently

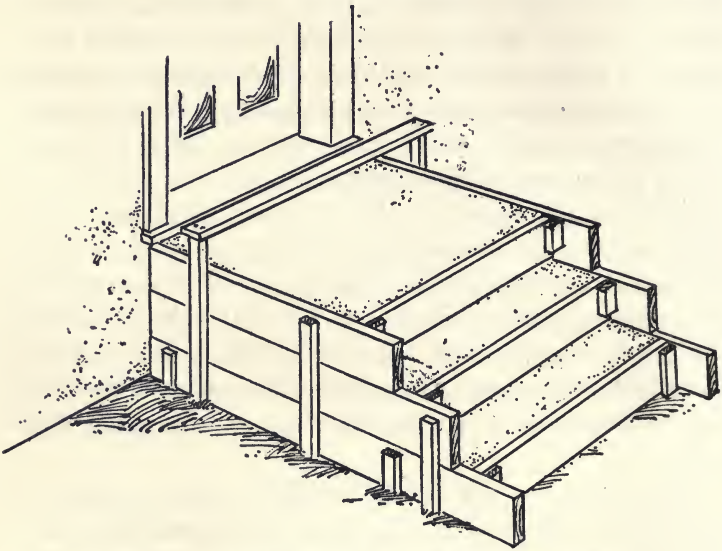


FIG. 43. — Arrangement of Forms for Simple Steps.

and the rise-boards can be removed so that the risers can be troweled while the concrete is still green.

If the steps are to be located in a place such as from one level to another on a terrace or in a cellar area-way, the back form for the flight may be the earth itself which has been cut down until it slants in the general direction in which the flight is to run. This will save a considerable amount of cement and when properly done is entirely satisfactory. Fig. 44 illustrates how this is done.

In Fig. 44 is also shown the method of forming a "nosing" on concrete steps. This illustration shows the nosing being made with the finish coat but it is entirely possible to obtain the same results with a single mixture of concrete by using similar rise-boards. Care must be taken, however, when making nosings on steps not to remove the rise-boards too soon because it will be found that this projection of concrete is very easily broken off. The loose facing board shown in the illustration can be removed as soon as the concrete has hardened sufficiently so that

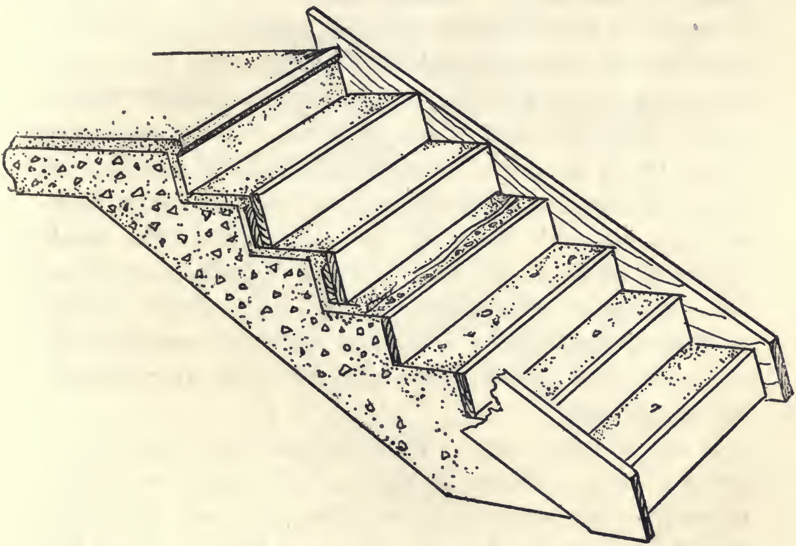


Fig. 44. — Stair-forms, Showing Method of Forming Nosing.

it will not flow. The finish coat is then applied and worked in with a trowel. It is necessary to apply the finish coat as soon as possible after the main body of the concrete has been laid to enable the two mixtures of concrete to form a firm bond.

It is sometimes necessary to construct a flight of stairs with side walls which may be just a few inches high as in the case of an exterior flight of stairs or which may be several feet high as in a basement entrance. The steps may be constructed first and the side walls afterward or vice versa. Building the steps first makes the construction of the side wall a little more difficult but it greatly simplifies the making of the steps themselves. When the side walls are constructed first, a somewhat complicated form, which must be very carefully and exactly made and firmly braced, is necessary. Construction of the side walls first is usually a more suitable method, however, for then the steps have to bear only their own weight, while if the steps were constructed first they would have to bear the weight of the side walls, and unless they are heavily reinforced would be in danger of being broken. It is possible, by means of complicated forms, to construct the entire flight of steps and side walls in one solid block. For small flights of stairs, it will not be too difficult a proposition for a workman with a little ability. The object of this method of construction is obvious since the concrete is in one solid piece and the steps and side walls are mutually self-supporting.

If the side walls are to be constructed first, simple wall forms of a type shown in Fig. 22 will answer very satisfactorily. The excavation for the steps and side walls should be made at the same time and the trench for the side walls should be at least 6 inches deeper than the excavation for the steps, which should provide a minimum of 4 inches of concrete under the steps. In order to prevent a tendency of the steps to slide downward, a horizontal bed should be provided for the whole of the top step.

When the forms are put in place they should be very rigidly braced one against the other at the top and the bottom. It is desirable that the forms for both side walls be built at the same time since they can be braced firmly against each other in this arrangement, but it means that twice as much form lumber is used as would be necessary. It is possible, under some circumstances, to cast first one side wall and then the other if a saving of form lumber is absolutely necessary. The thickness of the side wall need be not more than 6 inches if no load is to come upon

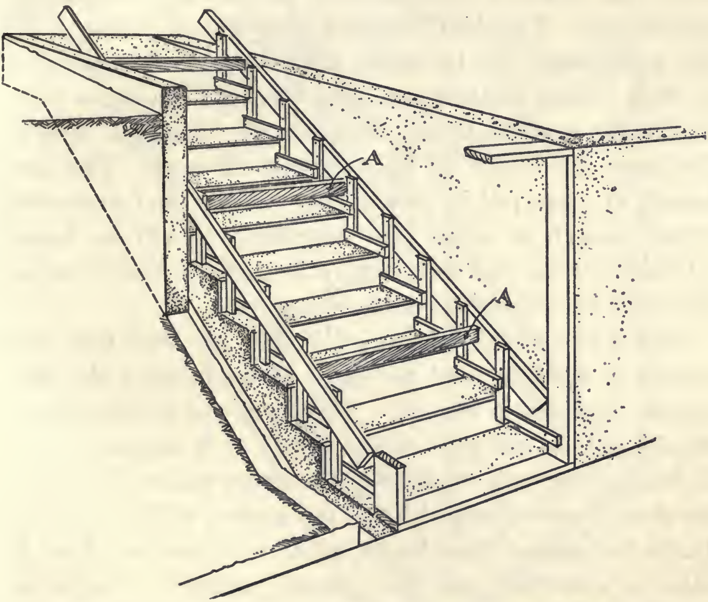


FIG. 45. — Forms of Stairs Made Subsequent to Side Walls.

them. If they are to act to some extent as a foundation wall at the same time, it will be necessary to provide some sort of footing beneath them and to make them 8 inches thick.

Fig. 45 illustrates the best method of constructing the form for the steps after the side walls have been constructed. 2 × 6 stringers are extended up and down along the inside of the side walls and to this are nailed 2 × 4 strips vertically to hold the rise-boards. The vertical 2 × 4's are braced by horizontal pieces of 2 × 4 as shown in the illustration. It is possible to fasten the rise-boards in place by means of nails partly driven in from the outside of the form. This will render the removal of the forms when the concrete has hardened a comparatively simple proposition. The two stringers carrying the braces for the rise-boards can be made separately, then suspended in their proper position and held there by the strips "A" which are wedged tightly between the stringers so that the latter are forced up tight against the wall. The rise-boards are then put in their proper position and supported firmly enough to retain the concrete. It will be found advisable to use two inch lumber for the rise-boards unless the steps are more than ordinarily narrow.

Forms required for the steps, if they are built first, will consist of stringers and the cross pieces forming the rise-boards as shown in Fig. 46. The lower end of the stringer should rest on the floor of the trench or if necessary may be blocked up from the floor. The upper end of the stringers should come flush with the top surface of the top step. In the building of these forms, which may be done either in place or assembled and then placed, stringers of sufficient length should be selected; 2 × 10 or 2 × 12 planks usually will be wide enough. The location of the treads and risers can be laid out on the stringers after the rise and run of the steps has been determined. This determination is made as follows: Divide the vertical height in inches of the entire flight of steps by 7 inches which is an average height for a riser. The quotient giving the number of steps will usually contain a fraction and since we wish to have all our steps of the same height, we will again divide the vertical height by the next highest whole number above the first quotient. The result of our second division will give us the rise, in inches and fraction of an inch, of our steps. The same method can be employed in determining the

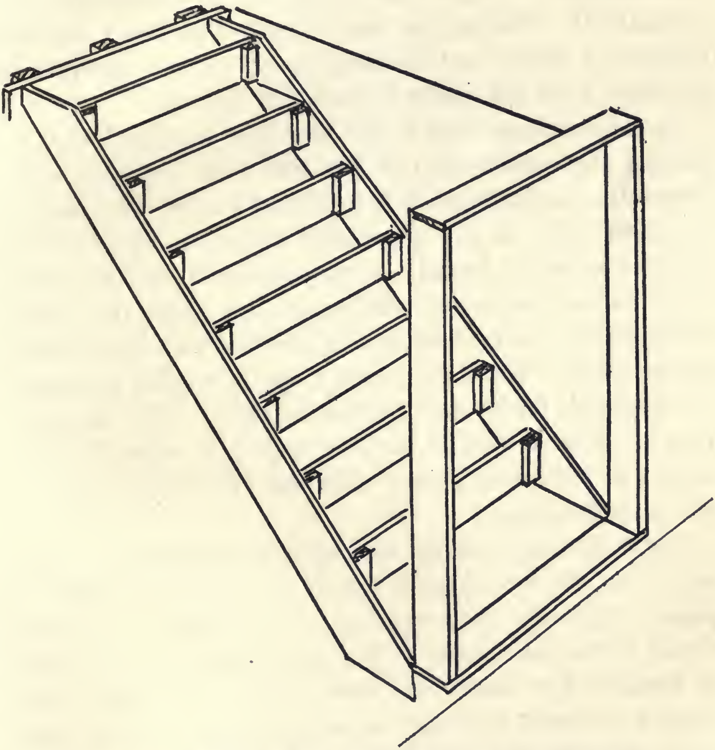


FIG. 46. — Forms of Steps Made Previous to Side Walls.

tread, if the flight is to be located within some specified horizontal distance. However, where ample space is available, the width of the tread can be chosen and the total horizontal length of the flight can be found by multiplying the number of risers by the chosen width of tread. Provision must be made for a landing at the bottom of the flight, of course.

For example, if a flight of steps is to be built from a ground level that is 5 feet above the basement floor, reduce this distance to inches and divide by 7. 60 divided by 7 equals $8\frac{4}{7}$. Taking the next highest number, 9, for the number of steps, and dividing 60 by it, the quotient is $6\frac{2}{3}$ which gives the height in inches of each riser.

In constructing steps in the way just described, that is, leaving the construction of the side walls until the steps themselves are finished, it is necessary to give the concrete an opportunity to dry thoroughly before the construction of the side wall is begun. It may also be found necessary to run some horizontal reinforcing bars along the length of the steps to prevent the load of the side walls from breaking the steps. When the concrete has thoroughly hardened, the side-wall forms may be put in place. The construction of these is similar to that employed when the side walls are built first except that the inner form must be cut to fit the steps.

When the steps and the side walls are constructed as one solid unit, the best plan to follow is to build the forms in place. The outer side-wall form is built first and braced firmly to the soil outside. The step forms are next placed in position and finally the inner forms of the side walls. It may be found necessary to suspend part of these forms from the outer side-wall forms. The filling in of the concrete must be done with great care and the steps and side walls must be filled uniformly, beginning at the bottom. There will be a tendency of the concrete to rise at the treads because of the comparatively large quantity of concrete which is pressing down upon the bottom. For this reason, a somewhat dry mixture will have to be employed and consequently it may be found necessary to remove the forms early so that the surface of the concrete may be given a smoother finish than can be obtained ordinarily by the use of a dry mixture.

CHAPTER V

CONCRETE BUILDING BLOCKS

One of the forms in which concrete can be used to decided advantage under many circumstances is that of blocks. When properly made and used they form an excellent material for the exterior walls of buildings. They can usually be made cheaper than brick or stone and while more expensive than wood are much more durable and possess the additional merit of being fireproof.

Among the advantages claimed for the concrete block may be listed the following:

1. *Cheapness.* — As compared with other forms of fireproof building material.

2. *Flexibility.* — It is possible to make concrete blocks in almost every conceivable size and shape.

3. *Good insulation.* — If properly constructed, a hollow concrete wall tends to prevent sudden temperature changes in the room.

4. *Low labor cost.* — Since concrete blocks are larger than brick, they can be laid up more rapidly and with less mortar than brick.

5. *Convenience for wiring and piping.* — The openings in hollow concrete blocks afford an excellent opportunity for running pipes and wires.

6. *Strength.* — It is claimed that properly constructed walls of concrete blocks are stronger than walls of equal size made of brick or stone.

FIG. 47. — A Small Concrete Block Machine.

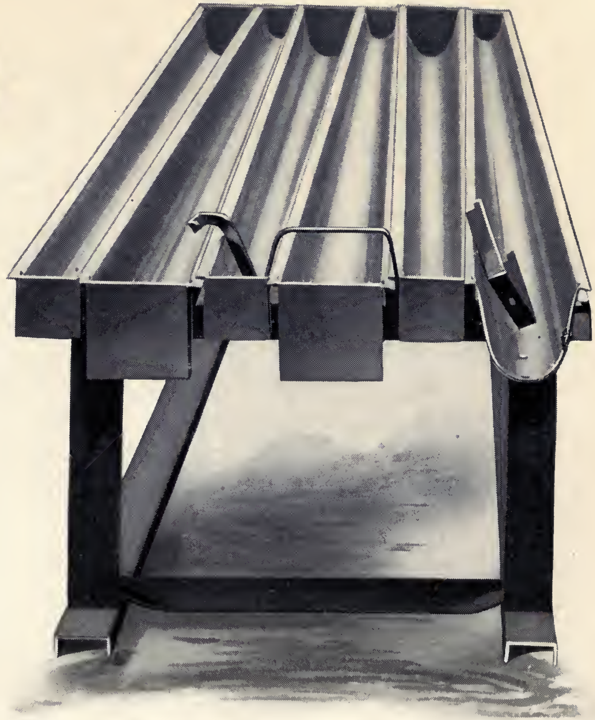


FIG. 53. — Commercial Post Mold Made Entirely of Metal.

7. They afford a means of producing an excellent imitation of cut stone at a low cost.

Materials. — A careful consideration of the material that goes into the concrete blocks is an essential requirement of their successful manufacture. The average block is a comparatively small piece of concrete and must be constructed and handled much more carefully than a heavy block or a piece of mass concrete. Very often the walls are quite thin and this necessitates the use of rather fine aggregate; also, since the concrete block is very often subjected to considerable strain it will have to be made of a rather rich mixture, and in fact, under certain conditions it may be necessary to reinforce them in order to give them sufficient strength to withstand the strain which may come upon them.

In the construction of *solid* concrete blocks, it is entirely permissible to use aggregate of a comparatively large size, as for example, small boulders 2 or 2½ inches in diameter, provided, of course, that there is a sufficient amount of finer aggregate used in the proportioning to insure a complete filling of the voids with the employment of a minimum amount of cement. In the usual *hollow* block, however, the thickness of the wall seldom exceeds 1½ inches. From this it is readily seen that aggregate larger than ¾ inch in diameter would be likely to prove awkward and in fact many regulations require that for blocks of this kind the maximum size of the aggregate be not over ½ inch. It goes without saying that the materials must be clean and well assorted as to size.

When concrete blocks are used for the exterior walls of buildings it is important that they be constructed in such a manner as to prevent the ingress of moisture. This will necessitate the use of a rich, dense mixture which will make the concrete in itself practically impermeable, or the admixture of some commercial waterproofing compound, or the application of some waterproofing material to the outer surface of the block.

All exterior walls, and those interior walls which are subjected to any considerable strain, must be made of blocks containing a sufficiently rich mixture to withstand the loading. Partition walls or other walls which do not support any load may be made of blocks of a leaner mixture. In fact, it is possible to construct concrete blocks using cinders as an aggregate. Blocks made in this way have no great strength but they do possess lightness and this feature is sometimes worthy of consideration.

The great majority of blocks are made using gravel or broken stone as an aggregate. Either material will work satisfactorily provided precautions to be observed in their selection as previously stated are strictly adhered to. Special materials such as colored granites, carefully selected and screened sand, and certain coloring matters, are sometimes included in concrete blocks made for special purposes.

Proportions. — As stated previously, when a concrete block is subjected to considerable strain, it must be made of such a mixture as will resist this strain. This necessitates the use of a rich mixture and proper proportioning. In the early development of the concrete block industry, the high profits which apparently could be gathered in without very arduous preparation enticed a number of very careless workmen to enter the business. The industry suffered a great deal from the careless work and misrepresentations of these men. It is only recently, when the work has been placed upon a sound engineering basis, that the properly constructed concrete block is coming into its own. These early manufacturers in their scramble to obtain the highest profits possible also lowered the quality of the work to an astonishing degree. Blocks were made of mixtures as low as 1 : 10 or 1 : 12 and scarcely enough cement was used in their construction to hold the particles of aggregate together. As a result, popular prejudice has arisen against the use of concrete blocks in many localities and to some extent objections are entirely justified. However, the concrete block when properly made is proving satisfactory and is being used more and more widely for a greater variety of purposes.

According to common custom, as in other types of concrete construction, the proportion of materials is fixed arbitrarily. When sand is employed for the aggregate, the mixture may vary from 1 : 3 to 1 : 6, depending upon the quality of the block desired. When a three part mixture is used the proportions of 1 : 2 : 4 and 1 : 3 : 5 are perhaps the most common, though occasionally a much weaker mixture is employed. It is highly desirable that the proportions be made as nearly ideal as possible in order that a maximum of strength and density be obtained, where the quality of the block is to be kept at a high standard.

The building regulations of most cities require that the leanest mixture be composed of 1 part of cement to 5 parts of aggregate. This, under most circumstances, is a little too lean to be advisable and a mixture of 1 part of cement to 4 parts of aggregate is much more to be recommended. This is on the assumption that the block is to withstand ordinary strains.

For special purposes, such as for ornamental concrete blocks, for lawn furniture, etc., a mixture of sand and cement is used. This mixture should not be leaner than 1 : 3 and necessitates the employment of a good grade of aggregate.

Curing. — The process of curing the concrete after the block has been made is perhaps the most important one in the manufacture of concrete blocks. Since the final set of cement may not occur for 10 hours, the concrete after having been placed in the mold should not be disturbed during this time and in fact much better blocks will result if they can remain two or three times as great a time as this. They should be stored in some place where they can be kept under cover and protected from the sun, wind, and frost until thoroughly cured. After having become sufficiently hard so that water will not wash the surface, the blocks should be carefully sprinkled and from this time on should be kept moist by sprinkling two or three times a day for two weeks. It is absolutely necessary for the complete setting of cement that a sufficiency of moisture be provided and blocks should never be allowed to dry on the surface until the center has thoroughly cured. Care should be taken to pile the blocks in such a manner that they will receive moisture equally on all sides, and it may be found desirable to repile the blocks every two or three days, turning them up side down in the process. If this is not practicable, it may be possible to store them on a moist sand floor, keeping the floor, as well as the blocks, sprinkled for the proper length of time.

It is desirable that the appearance and texture of the blocks be as nearly uniform as possible. Any deviation in curing methods may cause a slight difference of appearance in blocks which, while almost imperceptible in the block itself, will show up distinctly when the blocks are placed in a wall. If the blocks are properly protected and are supplied with an abundance of moisture, this variation is not likely to occur, providing other influencing factors have been properly attended to.

In large establishments, where the manufacture of concrete blocks is carried on as a business, steam curing is practiced to a great extent, and, it is claimed, with great success, for 48 hours curing will apparently harden the block sufficiently for it to be placed in a wall. This method of curing is, of course, impracticable for the small manufacturer or for the man who makes a few blocks for his own use.

The violation of any of the rules for curing concrete blocks means that a defective block is likely to be produced. A concrete wall is like a chain in that its strength is as great as that of its weakest component unit. Instances are on record where an entire wall has failed as a result of the failure of one or several of the blocks. The casual manufacturer of concrete blocks, thinking that he has a small job on hand, is likely to neglect it with the result that his product will be inferior.

Types of Blocks. — There are three general methods of making concrete blocks, which depend upon the consistency of the mixture and the method by which the mortar or concrete is to be compacted. These methods are by tamping, by pressing, and by molding. The first method generally requires a mixture of comparatively dry consistency. The mixture is put into the mold, firmly tamped, and then removed. The tamping may be done by hand or machine, the latter usually resulting in more uniform compaction. The method of compaction by pressure employs the use of a mixture somewhat more moist than that used in the tamped blocks on account of the method of applying the pressure. Pressed blocks when properly made are an excellent product and can be used generally as a substitute for stone. The molded blocks are made of a fairly wet mixture and are usually left in the mold for several hours or until the concrete has hardened sufficiently to allow the removal of the forms without subsequent falling of the inclosed material. The wetness of the mixture is depended upon to permit the concrete to run into all the corners of the mold, thus producing smooth even surfaces. On account of the greater cost of forms in this system of making concrete blocks, the price of the molded blocks is usually greater than that of either of the other two types. This results in their being used mainly for ornamental purposes.

In any one of the three methods of manufacturing blocks enumerated above, the block may be molded upright or face down. The advantages claimed for the latter arrangement are that a face mixture may be readily used and thoroughly incorporated and that the concrete is tamped in layers parallel to the face of the block thus making it more waterproof. A board may be placed in the mold in the position of the facing coat and when the block is filled the board is gradually removed, being replaced by the facing mixture; or, as can be very easily done in the face-down machine, the facing mixture is first filled in, then tamped well, and the remainder of the block which is usually of a coarser, leaner mixture is placed on top and tamped. The second method is to be recommended since it assures a firm union between the two adjacent mixtures, which is not so likely to be the case in the first described method.

Concrete blocks are made in almost every conceivable shape and size for every different purpose. There are almost as many different varieties of machines for making the blocks as there are varieties of blocks themselves. The rapid growth of the concrete block industry brought about a coincident rapid development in block machines and many ingenious arrangements were devised for making a number of different shapes and sizes upon the same machine, the variation occurring in the mold of the block itself, since the remaining parts of the machines could be utilized as they were.

Blocks may be made either solid or hollow. The first type is, of course, the stronger on account of containing more material and because full advantage is taken of the compressive strength of the concrete. Practically the only strain which will come upon a concrete block is that of compression. When the block is made so long or is placed in such a position as to be subjected to a transverse strain as in the case of a sill or lintel it may be more properly considered a beam and consequently should be designed as such. In some types of machines the construction of the solid block is somewhat simpler than that of the hollow block since the construction of the latter necessitates the use of cores, the insertion and removal of which requiring in most instances some special arrangement in the machine. The advantages claimed for the hollow block are:

1. The insulation from heat and cold, accomplished by the air space.

2. Sufficient strength combined with lightness.

3. Reduction in cost of manufacture on account of the saving in material.

4. Reduction in cost of erection because the blocks are lighter, more easily handled, and a saving in the amount of mortar used can be made.

Probably 95 per cent of all blocks made are of the type in which an air space is provided in some way or other. Practically the only place in which solid blocks would be used in farm concrete construction is in the erection of small piers for buildings where heavy compressive loads are likely to be applied.

As to external shape, there is a wide variety from rectangular to circular and irregularly shaped blocks. The rectangular blocks are used in foundation walls, exterior and interior walls of buildings, built up columns, etc. The blocks which are segments of a circle, are used in the construction of tanks and silos. The radius of curvature of these blocks should be correctly measured. Irregularly shaped blocks are sometimes used the way they are made or in combination to form rectangular units. Fig. 48 illustrates a sample of each of these types of blocks.

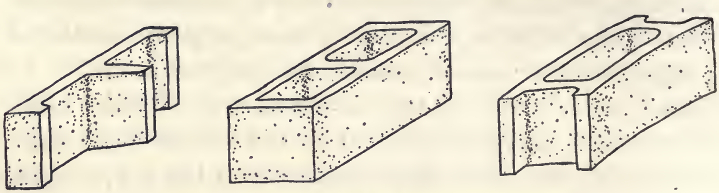


FIG. 48.—Various Shapes of Concrete Blocks.

Other special shaped blocks are also made. A flat rectangular block with a hole in the middle is made for a chimney block, the hole being made to fit the size of the flue. The advantage claimed for this particular block is that it is in one solid piece and will aid in holding the chimney bricks in place. It is much cheaper than a similar stone block which has to be cut out. Concrete blocks are used for the coping of brick parapets. They can be made in any length desired; however, if care is not taken in handling them, there is danger of cracking, if the blocks are made too long. Concrete bricks are obtainable; that is, blocks whose dimensions approximate those of ordinary clay brick. Special machines have been made for the molding of these blocks and in some localities, where clay for the manufacture of brick is not available and the cost of shipping bricks in would be too high, it may be entirely possible to find materials for the construction of concrete

FIG. 49. — A Concrete Block Farmhouse.

FIG. 50. — A Small Concrete Block Barn.

brick under such circumstances as would make their production an economical proposition. For this same reason, concrete blocks in certain localities have become a popular construction material.

Method of Laying. — Concrete blocks should be laid up with as thin a mortar joint as possible. The joint should be completely filled with the mortar which, of course, should be a cement mortar of 1 to 2 or 1 to 2½ mixture. The air space in the wall which is formed by the blocks should be entirely inclosed if it is to be of any advantage, for an air space in which a circulation of air is permitted is of not much more value than if it were filled up solid. Enough blocks should be on hand so that construction can proceed without interruption. This will necessitate a careful consideration of the work in hand so that all special end blocks, sills, etc., will be prepared in advance. If all the blocks are made in advance, there is greater likelihood that they will be made uniform, resulting in a uniform appearance of the wall.

A footing for a foundation wall of concrete blocks is just as necessary as for any other kind of material. The footing can be constructed of the blocks themselves in much the same way as an ordinary brick footing is made by simply widening the wall at the lower part. Where well-made blocks are employed, plastering may be done directly upon the inside face of the blocks. This practice, however, may not be advisable if the blocks are at all porous because the transmission of moisture through the blocks will be sufficient to cause dampness of the interior wall and may result in the falling off of the plaster. It is better to use furring strips and apply lath and plaster in the ordinary way. As it is impossible to drive nails into concrete, some means must be provided for fastening these furring strips as well as door and window trim, baseboards, etc. Various types of metal plugs have been devised which can be laid in the mortar joint and into which a nail may be driven or a flat wooden plug can be laid between the blocks and used as a nailing ground. The construction details of residences and other buildings of concrete blocks are very similar to those of brick construction.

Building Regulations. — In most cities, rather stringent building regulations regarding construction methods employed in the use of concrete blocks have been passed. Two reasons aside from the natural desire to get safe construction are responsible for this. First, the regulations were in many instances prepared by authorities somewhat inimical to concrete construction. Second, so many very poor blocks were made in the beginning of the concrete block industry that some means of restricting the manufacture of blocks to good ones had to be devised.

The thickness of walls usually employed for block construction is as follows:

One story buildings, 8 inch walls.

Two story buildings, 10 inch walls.

For three and four story buildings, 10 to 12 and 15 inch walls, the thickness increasing, of course, from the top downward. It is doubtful if the use of concrete blocks is advisable on very high buildings.

As in brick masonry construction, it will be necessary to put in an occasional course of headers or blocks extending across the wall. This practice is not followed where the wall is not over 25 or 30 feet high, but where higher walls are constructed, every fifth or sixth course should be a course of headers. In many cities, the manufacturers of concrete blocks are not permitted to sell or use their product until it has been tested and approved by the building inspectors. The blocks are made under certain specifications regarding the materials, and the tests to which the blocks are subjected are similar to the test for brick, stone, and general concreting. These include tests for compressive and transverse strength, for absorption, and for fire resistance. In small municipalities or in rural districts, such testing and inspection, of course, will not be done and it will remain for the consumer to ascertain that the product he is using is of standard grade.

CHAPTER VI

CONCRETE FENCE POSTS

One of the big expense bills that the American farmer pays annually is that for fence posts. It is estimated that in the United States there are 5,000,000,000 fence posts. Observations and investigations serve to indicate that the average life of a wood fence post is about five years. Posts made from certain kinds of timber, for instance, such as cedar, mulberry, locust, and osage orange are, of course, much more durable. This timber, however, is comparatively scarce and expensive or its use is confined to restricted localities. Many varieties of wood, when made into posts and set into the ground, do not endure for more than two or three years. While there are no doubt instances of lines of fence posts having stood in good shape for 20 or 25 years or even longer periods of time, it is perfectly reasonable to believe that the figure given above for the average life of a post is fair. On this assumption, it is seen that the number of posts that require replacement every year is in the neighborhood of 1,000,000,000. At an average cost of 15 cents this would mean an annual replacement cost of $150,000,000, a very heavy toll indeed for the maintenance of fences. If any material can be found which will reduce this heavy expenditure it would certainly seem to be worthy of the most earnest consideration by the consumer. One of the best indications of what a serious economic consideration the matter of fence posts is, is the attitude of the railroads of the United States towards this proposition. All of them together have thousands of miles of fence to erect and maintain and they are continually spending immense sums for this item alone. It is significant to note that a number of the largest railway systems in the country have adopted concrete fence posts to reduce this great expense item.

Let us assume, for the purpose of comparison, that a line of fence containing 100 posts is to be erected. A reasonably good grade of cedar posts will cost approximately 25 cents apiece and a liberal estimate of the length of life of such a post is 15 years. In a period of 150 years the posts in this line of fence would have been replaced ten times and estimating that the cost of the posts remains the same, this would mean an expenditure of $250 for posts alone for replacement. If, in the place of wood posts, concrete posts had been used, the original cost would have been approximately the same, for good concrete fence posts can be made at this cost. Experience has shown that under average conditions the amount of loss of well-made posts in a line of fence does not exceed 2 per cent, or in other words, in the line of fence of 100 posts, we should have had to replace them three times during a period of 150 years, the replacement being made every 50 years. This means an expenditure of only $50 for posts for replacement. No consideration has been made of the labor involved in resetting the posts or in the taking down and erection of the fence each time the posts have been reset.

The concrete fence post is a cement product that has suffered severely from a number of causes. Ignorance of construction methods and carelessness in handling have been responsible for a great deal of the blame which has been unjustly laid upon the post itself. It has been thoroughly demonstrated, however, that the properly made concrete fence post is an entirely satisfactory piece of concrete for the purpose for which it is to be used. In this connection the conclusion of the report of the Committee on Signs and Fences of the American Railway Engineering Association is significant; the Committee had gone into the subject of fence posts very exhaustively and the conclusions at which it arrived closed with the statement that "concrete posts are practical, economical, and a suitable substitute for wood."

Forms. — Forms for the manufacture of concrete fence posts may be made either of wood or of metal. When

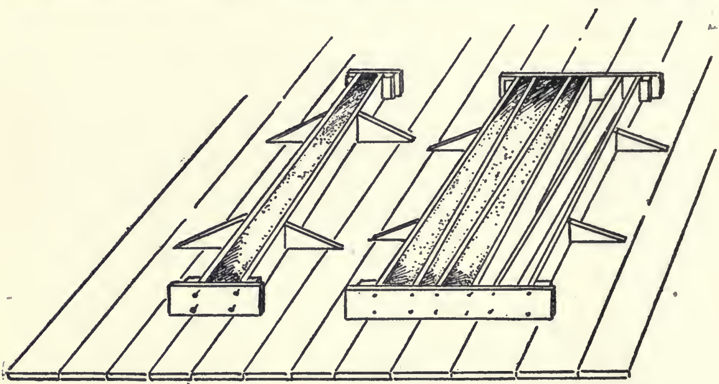


FIG. 52. — Home-made Wooden Post Molds.

fence posts are constructed in small quantities for occasional use, it may be entirely advisable to use wooden forms. They possess certain disadvantages, however, in that they are somewhat awkward to use, slow to handle, and permit escape of considerable moisture, thereby losing also some of the cement. Fig. 52 illustrates one type of home-made forms. It is for the manufacture of a post 5 inches square at the bottom and 3 by 5 at the top and may be constructed in such a way that 4, 6, or even 10 posts can be made at the same time.

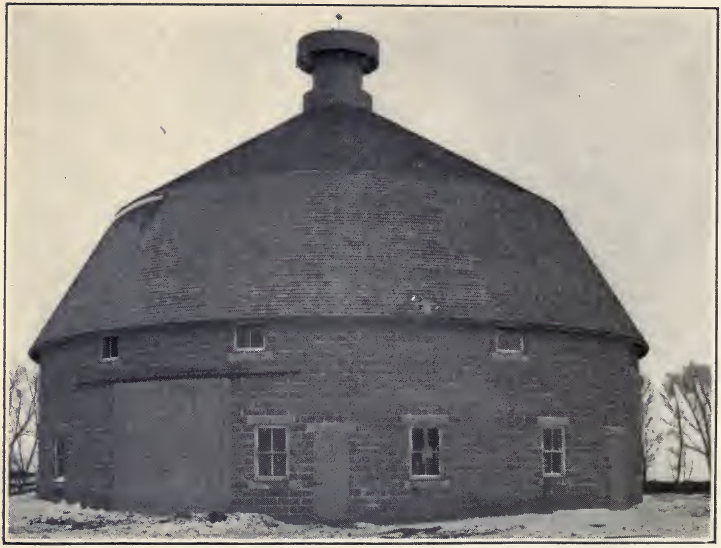


FIG. 51. — A Circular Barn Built of Concrete Blocks.

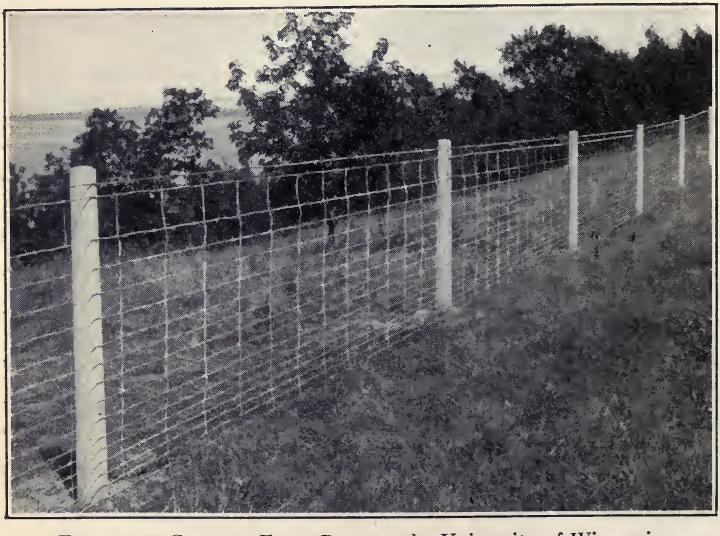


FIG. 54. — Concrete Fence Posts at the University of Wisconsin.

The form itself consists first of a flat platform or pallet; upon this is located the side boards of the forms. These may consist of 1-inch stuff surfaced on four sides. The two outside boards must be firmly braced by triangular blocks as shown in order to prevent bulging, because the placing of a quantity of concrete into the form and the consequent tamping will result in considerable lateral pressure. The end boards are made of the same material as the side boards. Nails are driven part way in the end boards and into the ends of the side boards; in this way, the side boards of the form can be properly located and held in place, and when the posts are ready for removal the nails can be easily withdrawn and the form dismantled. One serious objection to the use of wood forms is that they are likely to be expensive on account of the entire form having to lie idle while the concrete is setting and hardening.

In Fig. 53 is shown one form of a metal mold which has a number of good points; metal molds are generally to be recommended. There are a number of good commercial forms on the market and their cost is not excessive. Their use is almost imperative when a quantity of posts are to be made, and when the cost is to be kept down, for the use of well designed and well constructed forms will greatly reduce the labor cost. Metal forms are usually so constructed that the leakage of moisture and cement is practically negligible, and smoother surfaces are likely to result from their use than from wooden molds. Several of the commercial forms are especially designed to give exceptionally good agitation and tamping to the concrete resulting in a dense mixture and the elimination of air bubbles. The metal molds are very well made and with the employment of a reasonable degree of care in handling to prevent rusting and deformation, they are practically permanent.

Metal molds are made to produce posts in a variety of shapes, — triangular, square, rectangular, circular, or irregular. They are also made to be used in various ways, some molds being filled from the top when placed on end, others from the side. The majority of users, however, are coming to favor the simplest type of post which is rectangular in cross section and which is made by filling the form from the side. The post of triangular or irregular cross section is not equally resistant to strains coming from all

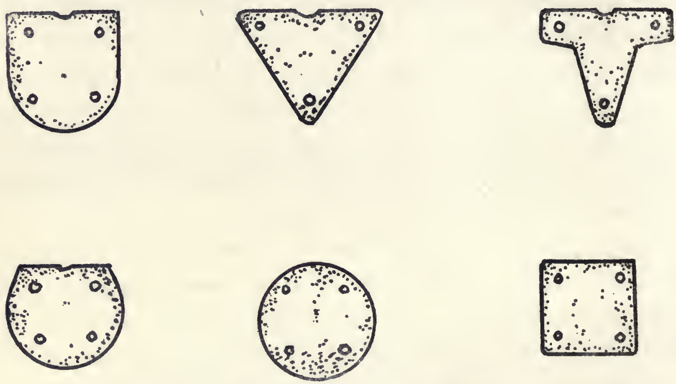


FIG. 55. — Cross Sections of Different Shapes of Posts.

directions. The average line post is likely to be strained from both sides of a fence and consequently should be able to resist the strains equally well from either direction. For this reason, a post of simple symmetrical cross section is generally to be recommended.

The average line post used in ordinary fences will be 7 feet in length. In cross section, it should be at least 5 inches square at the bottom and not less than 3 inches square at the top. It would be better if the top dimensions be 3 by 5 inches and that when the post is set the long dimension be perpendicular to the line of the fence, thus giving additional strength when the loads come from either side of the fence. Of course, for special purposes posts of different sizes can be used. Small posts to indicate boundaries only need not be so heavy while end posts will have to be much heavier and stronger. Sometimes, too, it is desirable to make the posts longer than 7 feet when a high fence must be made.

Materials. — A concrete fence post is a cement product whose chief quality is strength and durability. Low cost, of course, is desirable, but the two first mentioned qualities are the predominant ones. The materials which enter into the construction of the concrete fence post are of great importance in maintaining these characteristics of the post to the highest degree and great care should be used in their selection. It is much better to add slightly to the cost of the post and insure strength and durability than to practice false economy by using poor materials which will result in a weak post.

The discussion which has been previously given regarding the selection of the cement applies with great pertinence especially to fence posts. The cement, of course, must be good, because nothing will so weaken a post as to have cement that does not properly set.

Since the concrete post is a rather small unit, the aggregate entering into its construction must be rather fine. Posts have been made with a mixture of cement and sand alone; the best practice does not approve of this and the general procedure is to employ a three part mixture of properly proportioned materials. Either gravel or broken stone can be used for the aggregate, but it is essential that it consist of a variety of sizes, the maximum dimensions of any particle of aggregate being $\frac{1}{2}$ inch; one of the main reasons for this is the fact that larger particles are likely to interfere with the placing of the reinforcement.

If broken stone is used as an aggregate for the concrete fence post it should be assorted as to size and should contain no dust or impurities. Great care must be used in tamping broken stone for the sharp edges and rough surfaces have a tendency to form bridging combinations leaving unnecessarily large voids which are difficult to fill and, when not filled, reduce the strength of the concrete. Sometimes for ornamental effect, white crushed stone and white cement are combined to produce a post that is like white marble in appearance.

So many failures of concrete fence posts come from the very fact that the makers of them dug the aggregate out of a local gravel pit and with the gravel collected a high percentage of impurities. From a previous discussion, the bad effect of impurities in concrete put into posts will be fully realized. If gravel is used as an aggregate for fence posts extra precaution must be taken to ascertain that it is perfectly clean. The directions which have been given previously for the screening and reproportioning of gravel should be followed assiduously, for it is only by constant vigilance that the maximum strength of the concrete fence post may be obtained.

Mixing and Placing. — A small concrete mixer will be found to be a very desirable addition to the concrete post factory. Hand mixing may, of course, be employed and for small quantities of posts may be found perfectly satisfactory. Very thorough mixing, however, is essential in order to get the greatest strength of the concrete and hand mixing is more likely to be cut short than extended. With a small mixer operated by an engine there is no tendency to do this; on the contrary, the user will be found perfectly willing to run the engine the additional half minute which will result in the thorough mixing of the materials.

Commercial forms are usually made with gang molds of 6, 8, or 10 separate molds in the gang. The batch of concrete to be mixed should be so proportioned that the resulting product will be just sufficient to fill the molds; a trial or two will indicate the exact amount of materials to be employed with no waste. The placing of the concrete should be done just as rapidly as possible after the mixing has been finished. It is imperative that the concrete be placed in the forms and the tamping finished before the initial set of the concrete has occurred. This will mean the mixing of the concrete and the placing of it in less than 45 minutes. Two men with proper equipment can do the work in less than this time and in fact, it should be possible, if sufficient molds are at hand, for two men to mix and place sufficient concrete to make 25 posts in one hour.

After the concrete has been placed in the molds, it should not be disturbed except to remove the individual molds from the frame for at least 10 hours or until the final set has occurred. Upon the removal of the individual molds, they can be laid in a place where they will be undisturbed until the posts can be taken out of the molds which under ordinary conditions will be in 50 or 60 hours. It may seem that this is an unreasonably long time before the removal of the molds, but it must be remembered that every precaution is being taken to maintain the greatest strength possible in the posts themselves and this is but one of the precautions.

Before the concrete is placed, the interior surface of the forms should be coated with some material to prevent adhesion of the concrete to the walls of the forms. This may be some sort of grease or oil applied in a thin coat. Common machine oil is good but somewhat expensive; crude oil serves just as well or a mixture of tallow and cheap oil. A thin coat of this is applied to the interior surface of the molds; too much oil should not be applied as it is likely to retard the setting of the cement besides resulting in a possibility of discoloration which may or may not be considered a fault.

After the posts have been removed from the molds, the molds should be thoroughly cleaned out by means of a wire brush and a fresh coat of oil applied before the next filling of concrete is made. Since the concrete post must be made as strong as possible, it follows that a wet mixture must be employed. Some molds are made with the intention of using a dry mixture but the dry mixed concrete post has not proved a success. The mixture which will result in the best post is one almost slushy in its consistency, about the same as that of ordinary plastering mortar. This will fill all corners of the mold well and will require little tamping, a gentle agitation being sufficient to drive out the air bubbles and to make a dense concrete. The use of the wet mixture necessitates leaving the concrete in the forms for a considerable length of time since naturally the wet concrete will require a longer time to harden than will dry concrete.

In placing the concrete, enough material is spread in the bottom of the mold to make a layer a little more than ½ inch in thickness. This is smoothed out and upon it is laid the reinforcing. In a rectangular post, two reinforcing units are laid in the concrete at this time about ½ inch from the edge of the concrete. They should be pressed into the concrete slightly so as to retain their position. Following this, more concrete is poured into the mold and smoothed out until the mold is filled within ½ of an inch or so from the top. At this point, more reinforcing units are included and placed in the same manner as the previous ones. The mold is then filled with concrete and smoothed down. It is imperative that the placing of the reinforcing units be very carefully done because improperly located reinforcement reduces the strength of the post.

Reinforcement. — Lacking of adequate and properly designed reinforcement has been the cause of many failures of concrete fence posts. Posts made with little or no reinforcement and without regard to principles of scientific design have not been satisfactory. When, however, the materials used have been of the right kind and properly handled, very satisfactory results have been obtained. A number of different types of steel reinforcement have been proposed and tried including smooth fence wire, barbed wire, smooth and deformed round or square rods, twisted wire, flat bands, iron pipe, specially constructed trusses of rods and wire, and even hard wood rods.

Certain fundamental principles relating to the reinforcement of concrete must be understood before the post can be successfully reinforced. In a previous discussion on reinforced concrete these fundamental principles were expounded. Summarized, they are as follows:

The reinforcing must possess sufficient tensile strength to equalize the compressive strength of the concrete, and to obtain the greatest economy reinforcing must be placed as far as practicable from the plane of neutral strain. The material of which the reinforcing is made must also possess a surface sufficiently rough to enable the concrete to obtain a firm bond upon it so that failure by slippage will not occur before the compressive strength of the concrete has been fully developed. When placed near the center of the post the reinforcement is of little use because it occupies in effect the same position as the neutral plane and practically the only effect it gives is to add its own strength and stiffness to that of the post; to be most effective, it must be placed within half an inch of the surface. This brings it far away from the neutral plane and yet leaves enough concrete covering it to prevent destruction by rust.

Several specially constructed reinforcing systems have been made for fence posts but almost without exception these are rather expensive and do not add enough to the strength of the post to pay for their extra cost. The average user will generally employ a simple type of reinforcing and will obtain results which are entirely satisfactory and commensurate with the expense incurred.

The simplest satisfactory reinforcement consists of smooth steel rods. It is doubtful whether sizes any smaller than No. 5 rods, which are 0.205 of an inch in diameter, should be used. If they are smooth or almost polished, it would be well to treat them with a weak solution of hydrochloric acid or some other rust-inducing solution to roughen the surface so that a better bond may be obtained. $\frac{9}{16}$ or $\frac{1}{4}$ inch square rods have also been found to be very satisfactory though a little more expensive than No. 5 round rods. The latter can be purchased at a low price from the mills, the seconds or rejected ones being taken. These serve the purpose just as well as the first-class stock, the only difference usually being some slight irregularity in shape of cross section. Another form of reinforcement which has been used extensively and which apparently has given good results, is twisted wire, a cable of two twisted wires being placed in each corner of the post. Wires smaller than No. 10 should not be used. If smaller wire be used, there will be a likelihood that failure or rupture of the wire will occur, showing that the full compressive strength of the concrete has not been developed.

The use of barbed wire, either new or old, for reinforcing is not to be recommended. The main reason for this is that the wire is more or less kinked and bent and it is extremely difficult to get it stretched out into a straight and stiff rod. The reinforcement should be in such a form that when the strain is transmitted to it through the concrete, it will immediately take up this strain throughout its entire length and this cannot be done when kinks or bends are present. Barbed wire is also very difficult to handle on account of the sharp points and its cost is usually as great as that of plain wire which gives much better results.

The preparation of the reinforcing rods consisting of the two twisted strands of wire is a comparatively simple

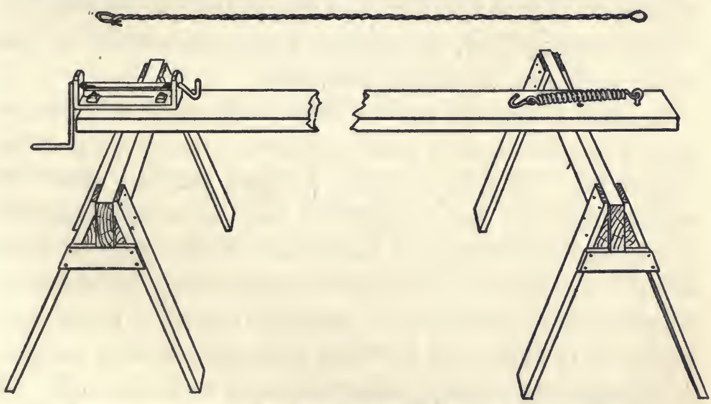


Fig. 56. — Device for Making Twisted Wire Reinforcement. (Courtesy of A. Tornquist.)

matter. One arrangement is to pass a long piece of wire around a tree, post, or other solid object, bring the ends back and twist them securely around opposite spokes of a heavy wagon wheel. If the axle of the wagon then be raised slightly the wheel can be spun around and the wire will be twisted quickly. In twisting the wire in this way there will be a tendency, of course, to shorten and provision must be made for this so that the tension may be kept upon the wire. A twisted cable may be made in this way 100 or 200 feet long and after having been made can be cut up into suitable lengths with hammer and chisel or with pliers. The ordinary line post will require a reinforcing rod approximately 6½ feet long. Another device whereby the twisted wire reinforcement can be very easily made is shown in Fig. 56. This consists of a crank mounted at one end of a plank or bench and a hook attached to the spring at the other end of the plank. A length of wire sufficient to make a single reinforcement is cut off, bent around the hook on the spring, and the ends fastened around the crank rod. By turning the crank the wire in a few seconds is twisted into a firm, straight bar, the tension being maintained by the heavy spring at the end of the plank.

In some cases, the ends of reinforcing rods or wires are looped or bent back in order to prevent the slipping of the reinforcing. Results of tests do not indicate that this means increases the strength to any appreciable degree. While some investigators state that smooth rods or wires will slip in concrete when used as reinforcing, it is doubtful whether this conclusion is entirely correct. Most tests certify to the fact that the bond between steel and concrete is considerably stronger than necessary to develop the full tensile strength of the steel when the reinforcing is as small as it is in the fence post. It is evident that with the small reinforcing rods used the ratio between the surface exposed and the cross section area of the steel is comparatively high. The consistency of the mixture will have some effect upon this particular point, for when concrete is mixed dry there is less contact between the concrete and the steel, but with a wet mixture good contact should be made throughout the entire length of the reinforcing.

In most instances the concrete fence post will break at the ground as the result of a thrust from above. It may be found advisable to include in the post some additional reinforcing which extends 10 or 12 inches above and below this point. If such reinforcing is located in this way, the ends should be bent because it is doubtful whether such a short piece of metal would not slip in the concrete.

The large end posts and brace posts require special arrangements for their reinforcing. Gate posts and end posts are very often subjected to extremely heavy loads and their reinforcing should consist of $\frac{3}{8}$ or $\frac{1}{2}$ inch or even larger bars properly located. For instance, an average 42-inch woven wire fence should have put upon it a tension of four or five thousand pounds for its best maintenance, and the end posts will have to bear practically this entire strain; and consequently, will require proportionately heavy reinforcing.

Curing. — Proper curing of fence posts is essential to the development of their full strength. As previously stated, the posts will remain in the individual molds for 50 or 60 hours. During this time, they should be sprinkled two or three times a day in order to retard the hardening of the exterior. When they are removed from the mold, they should be handled with extreme care so that no cracks, however fine, might develop, and if possible, should be laid on a bed of damp sand and sprinkled as before for several days. By the end of a week after molding they should be strong enough to stand careful handling and can then be stood up on end, in a slightly leaning position, against some support.

From this time on, the posts should be stored in some location which is protected from the wind, sun, and frost; a corner of a protected shed makes an excellent place. If no such place is available a temporary shed consisting of canvas on a solid frame will suffice, providing the temperature within this inclosure does not get too low. After the posts have been set on end in this location the sprinkling should still continue for two or three weeks more. The purpose of the constant application of water is to insure the uniform hardening of the posts and the prevention of shrinkage cracks which would ruin the posts. Posts should not be used for at least 60 days after having been made and it would be better if three months elapsed between the time of their manufacture and the time of their setting. From this, it is evident that the manufacture of the posts should not be left until the time when the posts are needed. Instead, the making of them should be a "rainy day" job; a few posts can thus be made at intervals and it is surprising to see how fast they accumulate if full advantage is taken of every opportunity to make them.

At the end of from 60 to 90 days the posts will have hardened sufficiently to withstand rather severe handling. This does not mean that the posts should be carelessly handled, for dropping them upon a rough surface or dropping one upon the other will result in breaking since concrete is a brittle material and possesses little elasticity. In hauling them to the place where they are to be set, they should be laid in the bottom of a wagon, preferably upon a thin bed of straw. They should not be piled one on top of each other if it is possible to avoid it. The weight of the concrete fence post will vary from 60 to 100 pounds which is not too much for one man to handle if care is employed. The posts should be set to a depth of at least $2\frac{1}{2}$ feet and the earth firmly tamped in around them. Some objections have been raised to concrete fence posts on the ground that the frost would raise them out of the ground. Their own weight would tend to prevent this and the fact that they are larger at the bottom than at the top will be an additional cause of prevention of raising. It will be found in actual practice that the concrete fence post will stand as firmly and as solidly, if not more so, than almost any other type of post.

Fasteners. — The subject of fasteners is one that has given the manufacturer a great deal of trouble. For many years, hundreds of special devices for this purpose were tried out but it has been found that nothing is so satisfactory as a simple tie wire wrapped around the post and firmly twisted on to the line wire of the fence as shown in Fig. 57. The wire used for this fastener can be as light as No. 12, and a fastener may be located at every wire in a woven wire fence or at every second or third wire, depending upon the degree of security desired. This fastener is cheap, very easy to use, does not affect the strength of the post in any way, admits of the easy removal of the fence by simply snipping the fasteners with pliers, and taking everything into consideration, it is as worthy of recommendation as any that has ever been devised.

FIG. 57. — Attachment of Wire to Post.

End and Gate Posts. — A properly designed and built end post will add very much to the life of any kind of fence. It would seem that it would not be consistent to construct a fence using concrete line posts unless especially strong and durable posts were erected at the ends to take the tension load of the fence. As previously stated, this is likely to be several thousand pounds, though as a matter of fact the farmer who will put such a load upon his fence is the exception rather than the rule.

End posts and gate posts are very often made much too light. To sustain the fence properly they should be at least 14 inches square at the ground line, tapering up to 10 inches square at the top. The reinforcing should be ample and it will be found advisable, since such posts are not very numerous, to put some additional expense into them to be certain that they will be strong enough.

Fig. 58 shows one type of end post which has been successfully employed to resist the strain of a tightly stretched

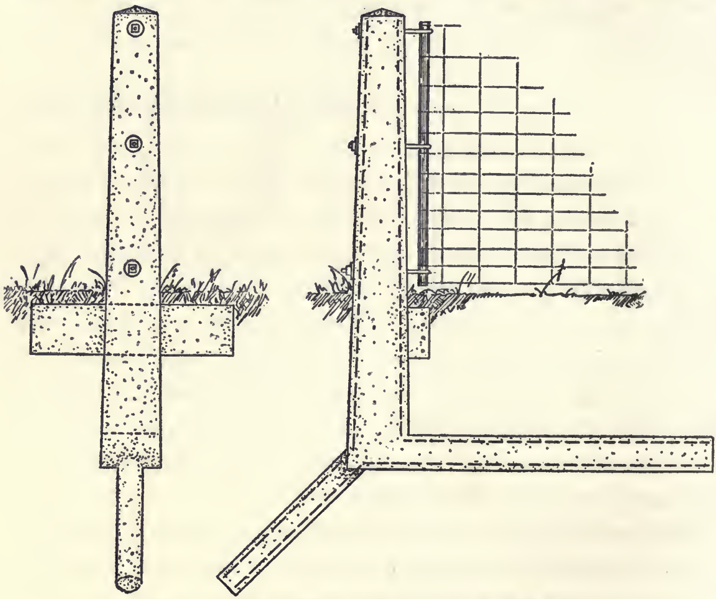


Fig. 58. — An Unusually Strong End Post.

wire fence. The method of construction is evident from the study of the illustration. A trench is dug extending from the end of the fence along the line of the fence itself. This trench may be 5 or 6 feet long and about a foot wide. Short trenches are dug near the surface of the ground, perpendicular to this longer trench. From the point of the base of the post a hole is bored backward and downward with a post auger for a distance of several feet. These holes are filled with a slushy concrete as are the trenches, the concrete being at least 8 inches deep. The form for the post itself which has been previously prepared of 2-inch lumber and greased on the inside is now supported in position above the concrete in the trench and is filled with a rather wet concrete. As the concrete is put in the holes, trenches, and form, the reinforcing rods are inserted. These consist of $\frac{1}{2}$-inch square twisted or corrugated steel bars reaching around all the corners as shown in the illustration. Holes are provided in the post by inserting greased cores of $\frac{5}{8}$-inch steel extending through the form. They are inserted before the concrete is put in and as soon as the concrete has hardened are driven out. The method of attaching the fence is shown in the illustration. If the post is a corner post, and must sustain the tension of the fence from two directions, the construction is similar except that two trenches are extended, one in the direction of each line of fence, and two diagonal holes are bored extending back from the location of the post itself.

Strength. — In the following table are shown the results of some tests of concrete fence posts which were made by Professor J. J. Richey of the University of Illinois in 1910.

These tests are on posts of various mixtures, sizes, and reinforcements. It is seen that there is a great deal of variation in the average strength of the post, which is to be expected. In these tests it was intended that the steel be placed 1 inch from the surface though measurements made after the posts had been broken showed that the distance varied from $\frac{8}{10}$ of an inch to $1\frac{3}{10}$ inches. The aggregate consisted of sand and gravel fairly well graded in size.

Tests of Concrete Fence Posts
(Age of Posts 90 Days)

No. of Posts Tested	Reinforcement	End Dimensions in Inches		Ratio of Cement to Aggregate	Average Load at First Visible Crack	Average Breaking Load	Remarks
		Base	Top				
2	8 No. 12 wires	6 × 5	4 × 4	1 : 7½	445	620	
2	8 No. 12 wires	6 × 5	4 × 4	1 : 6	690	710	
2	8 No. 12 wires	5 × 5	3½ × 3½	1 : 6	515	570	
2	12 No. 12 wires	5 × 5	4 × 4	1 : 6	810	1035	
2	12 No. 12 wires	5 × 5	3½ × 3½	1 : 6	435	640	
2	4 No. 8 wires	6 × 6	4 × 4	1 : 7½	445	645	Wires broke. 70% failed by breaking reinforcement. 30% failed by crushing.
2	4 No. 8 wires	6 × 6	4 × 4	1 : 6	560	725	
4	4 No. 8 wires	6 × 5	4 × 4	1 : 7½	485	625	
8	4 No. 8 wires	6 × 5	4 × 4	1 : 6	580	820	
2	4 No. 8 wires	5 × 5	3½ × 3½	1 : 6	470	820	
2	4 $\frac{3}{16}''$ rods	6 × 5	4 × 4	1 : 7½	850	850	Failure in every case by crushing.
2	4 $\frac{3}{16}''$ rods	6 × 5	4 × 4	1 : 6	695	800	
2	4 $\frac{3}{16}''$ rods	5 × 5	3½ × 3½	1 : 7½	365	585	
2	4 $\frac{3}{16}''$ rods	5 × 5	3½ × 3½	1 : 6	565	640	
2	4 ¼″ rods	6 × 5	4 × 4	1 : 7½	875	1275	
2	4 ¼″ rods	6 × 5	4 × 4	1 : 6	1360	1390	
2	4 ¼″ rods	5 × 5	3½ × 3½	1 : 7½	1020	1020	
2	4 ¼″ rods	5 × 5	3½ × 3½	1 : 6	870	960	
	Posts of Triangular Cross Section						
1	3 No. 8 wires	7	4	1 : 6	200	400	Tested 1 edge down.
1	3 No. 8 wires	7	4	1 : 6	380	640	Tested 1 edge up.
1	6 barbed wires	7	4	1 : 6	100	320	Tested 1 edge down.
1	6 barbed wires	7	4	1 : 6	450	860	Tested 1 edge up.

Note: — Posts were supported horizontally as simple beams, with the supports 6 feet apart. Load applied 2 feet from support near base.

The maximum size of the gravel was ¾ inch though Professor Richey states that in his opinion the maximum size should be ½ inch in order that the reinforcement may be conveniently placed at a distance of ¾ of an inch from the surface.

Cost. — To estimate the probable cost of a concrete fence post let an analysis be made of the cost of the materials and labor. In small quantities cement will cost $1.60 per barrel. Excellent aggregate can be obtained at a cost not to exceed $1.50 per cubic yard. The cost of the reinforcement should not exceed 8 cents per post. Two men with proper equipment can make at least 100 posts per day. The number of line posts of average size that can be made from a barrel of cement will vary, depending upon the mixture, but using a proportion of 1 part of cement to 2½ parts of small aggregate to 3 parts of coarse aggregate, which is a good rich mixture, a minimum of 20 posts can be made. The total cost of materials for 20 posts will then be as follows:

1 barrel of cement	$1.60
1 cubic yard of aggregate	1.50
Reinforcing 20 posts at 8¢	1.60
Total	$4.70

This is approximately 24 cents per post for materials and the labor at a liberal estimate will bring it up to 30 cents. This is no more than good wood posts will cost in localities where lumber is scarce.

To reduce the cost, bagged cement can be bought in large quantities at a reduction of 15 cents to 20 cents per barrel and bulk cement at an even greater reduction. Under favorable conditions, good gravel can be secured for 50 cents a cubic yard. By buying reinforcing in quantities, the cost of this time can be reduced to 6 cents per post. If common labor is used, two men at \$1.75 each per day will bring the labor item to 3½ cts. These revised figures will show the minimum cost of 20 posts to be then as follows:

Cement, 1 barrel	\$1.40
Aggregate, 1 cubic yd.	.50
Reinforcing, 20 posts at 6¢	1.20
Labor, 20 posts at 3½¢	.70
	\$3.80

Cost of 1 post, 19¢

This reduction in cost has been accomplished without weakening the mixture.

CHAPTER VII

TANKS, TROUGHS, AND CISTERNS

Tanks. — The progressive farmer considers that the health of his live stock is second in importance only to that of his family. He knows that the only way in which he can maintain the health of his live stock is to promote, as far as possible, sanitary conditions surrounding them and to provide for them sanitary equipment. Concrete, being the most practical sanitary building material, comes into its own in this connection and becomes a great factor in promoting and preserving health. A very common source of infection for the various diseases to which the farm animals are subject are tanks and watering troughs from which they are compelled to drink; in so many instances, the reservoir containing the water supply consists of an old, rotten, slimy, covered wooden tank which, especially in warm weather, affords a splendid breeding place for germs. Concrete tanks, if properly built, are superior in most respects to any other kind of tank. Concrete is smooth, impervious, easily cleaned, permanent, produces no slivers to stick into the gums and lips of the animals, and never becomes "sour." There is no rotting and no infestation with disease germs. Should occasion demand it, tanks and troughs when made of concrete can be disinfected very easily and thoroughly.

There are a few special precautions in the construction of concrete tanks that must not be overlooked. In the first place, the foundation and walls must be made sufficiently strong to be durable; a farm stock tank is subjected to very hard usage and even concrete, as hard as it is, will succumb unless precautions are taken to make the strength sufficiently great to resist it. It is possible to make the walls of solid concrete without reinforcing but as a general rule this is an undesirable procedure, for more than twice as much concrete must be used as in reinforced walls, and even then the same degree of strength cannot be obtained. In the second place, the concrete from which the tank is made should be placed continuously so there will be no line of demarcation between the placings of concrete, as might occur were the foundation made one day and the walls made the next. This necessitates that complete preparation for the making of the tank be finished before the mixing of the concrete is begun; all materials should be on hand and sufficient help should be available so that the mixing and placing can proceed with the greatest rapidity. Finally, the concrete from which the tank is made should be of such a quality that it be waterproof; this can be accomplished by making a rich dense mixture of the proper proportions, or perhaps including some form of commercial waterproofing in addition to coating the inside of the walls with a cement paste.

In tanks of any great size, reinforcing will, of course, be necessary. The size of the reinforcing will depend upon the size of the tank, but usually $\frac{3}{8}$-inch rods running both lengthwise and crosswise and placed 6 inches apart will prove sufficient; at every intersection of the rods, they should be fastened together by soft fine wires. The concrete must be mixed so wet that it will flow over and around the metal reinforcing and against the forms. The materials for the concrete must be very carefully proportioned and no aggregate larger than that which will pass through a $\frac{1}{2}$-

inch screen should be employed. It must be remembered that a concrete tank when once in place is usually there to stay and the location of it should consequently be chosen with care.

Construction of a Square Tank. — The first thing to be done in the construction of a tank will be to excavate for the foundation; the depth of the excavation will depend upon the contour of the land and somewhat upon the size of the tank. In ordinary cases, an excavation of about 12 inches will be sufficient. This will admit of a fill of 6 inches of cinders or screened gravel which should be very carefully tamped in place. Upon this sub-base is laid the foundation of the tank; this should consist of about 6 inches of concrete of a somewhat leaner mixture than that used in the construction of the tank itself. With good materials, a mixture of 1 : 3 : 6 will probably be satisfactory. If desired, the sub-base and foundation of the tank may be made to extend several feet outside the exterior wall of the tank. This will prevent the formation of mud holes which would otherwise be extremely likely to occur, besides making a more substantial and better appearing job.

When the foundation has been laid, the wall forms which have been previously prepared should be put in place. Fig. 59 illustrates the construction of the forms for a rectangular tank. The boards that are used in the forms themselves consist of 1 × 6 surfaced boards very firmly braced by means of 2 × 4's. It is well to build the outside forms in four sections and have them carefully marked so that they can be erected rapidly and with no waste of time or labor. In the illustration it is seen that in the exterior form, the boards of uneven length can be used without sawing more than one end; thus there will be no waste of lumber. The interior forms are made of the same material as the exterior forms and very thoroughly braced so that no bulging will occur. Braces running across in one direction are shown but if the tank is 4 feet wide or more it will be found advisable to extend braces in the other direction in order to prevent bulging at the ends. The interior form is made with a taper toward the bottom so that the thickness of the wall at the bottom is about 8 inches and that at the top is but 5 inches. This taper serves two purposes;

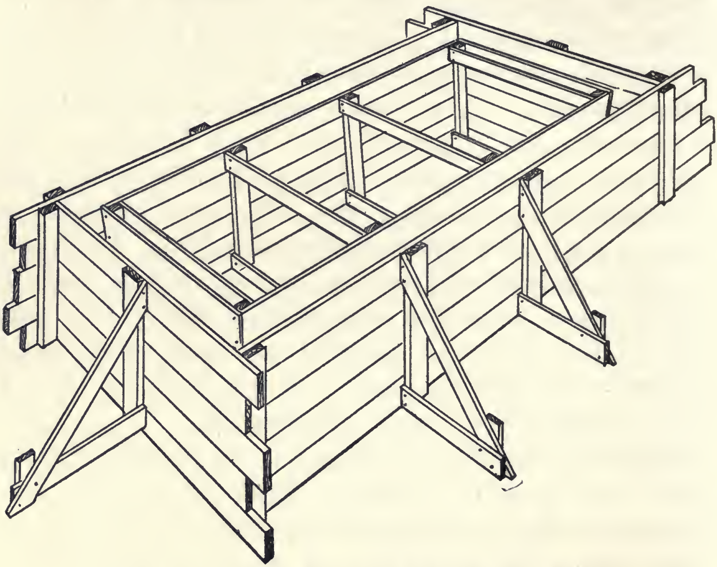


Fig. 59. — Wall Forms for a Rectangular Tank.

first, it admits of the easy removal of the interior form and second, it forms a battered wall on the tank which prevents a direct lateral strain should freezing occur in the tank. The thrust of the ice will be deflected and the ice, instead of breaking down the walls, will be forced upward. The total depth of the interior forms should be about 6 inches less than that of the exterior forms. Of course, the surface of the exterior forms with which the concrete comes in contact should be well greased so that there will be no adhesion of the concrete to the boards. Since the inner wall is to receive a coating of cement wash, it is better not to grease it; any pitting caused by the removal of the inner form can be filled up with a rich mortar, before the wash is applied.

The outer form is put in place and firmly braced. A 2½ inch layer of a rich mixture of concrete is then spread out on the foundation; immediately following this, the reinforcing, of whatever type is used, is spread over the concrete, bending the ends up so that they will project to within 1 inch of the top of the form at the side and the ends. When the reinforcing has been placed, another 2½ inch layer of concrete is placed upon the bottom and the whole mass is then lightly but evenly tamped to bring the mortar to the surface and to smooth it off evenly. The inner form which has been previously prepared is then set in place, taking care to keep it at equal distances on all sides from the exterior form and being certain that its top is level with the top of the exterior form. The filling of the concrete between the inner and outer form then proceeds, placing horizontal reinforcing at 6 inch intervals around the tank until the forms are filled. A few additional reinforcing rods should be bent at right angles and placed in the corners so as to give additional strength at this point where it will be found to be necessary. Under some circumstances, some sort of a woven wire fabric can be used instead of the rod reinforcement. This must be laid so that it may run up in the side walls quite close to the top.

If the work has been carefully done and properly managed, the filling in of the concrete for the tank itself will be the last thing that is done in the evening. During the night, the concrete will have an opportunity to set and to harden somewhat, probably enough so that the interior form can be removed carefully the next day. In large tanks, however, it may not be possible to do this until two days have elapsed. It is difficult to state just what length of time will be required for sufficient hardening of the concrete to permit the safe removal of the forms because so much depends upon the weather, the temperature, and the wetness of the mixture. However, the forms should be removed as soon as possible and both the interior and the exterior surfaces should be gone over with a wash of a cement paste in order to fill in existing pores and to give it a good appearance. It may be found advisable to coat the interior of the tank several times at five or six hour intervals in order to get a perfectly smooth surface. The tank should be protected, of course, from the direct rays of the sun or from hot winds and should be sprinkled every day to insure an even hardening of the concrete. After a week has elapsed, the concrete should be hardened sufficiently to permit of filling with water when, of course, the hardening will continue under the best conditions.

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

Circular Tanks. — The construction of a circular tank is in the main the same as that of rectangular tanks. The same general directions for the construction of the foundation, floor, and walls will obtain and an equal amount of reinforcing will be necessary to gain sufficient strength. No special advantage accrues from building a stock tank in this shape except that any lateral pressure from the inside will be evenly distributed on every portion of the wall. The construction of the forms is a little more difficult with the

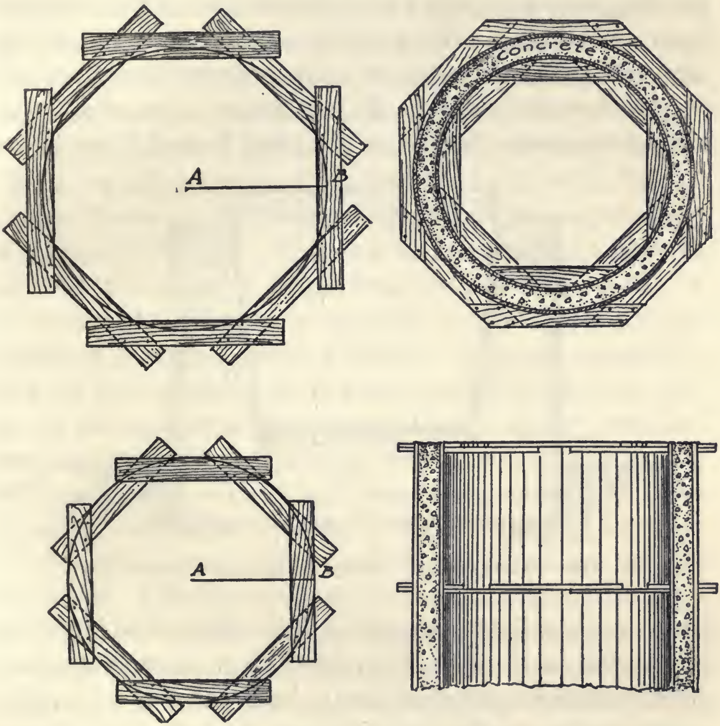


FIG. 60. — Forms for a Circular Tank.

circular tank than with the rectangular tank, and especially so, if the inner surface of the tank wall is to slope out from the bottom upward.

Fig. 60 illustrates the method of constructing forms for a circular tank. Two sets of forms are needed; one for the inside and one for the outside. Both the inner and outer forms are made practically the same except that the radius of the outer form is of necessity greater than that of the inner form because of the thickness of the wall between the two forms. The illustration shows the method of constructing the forms for a wall in which both the inner and outer faces are vertical. When the inner face is to be sloping the vertical boards nailed on to the circular form must be tapered toward one end. It is possible to use sheet iron instead of circular boards on the outer form if a few cross

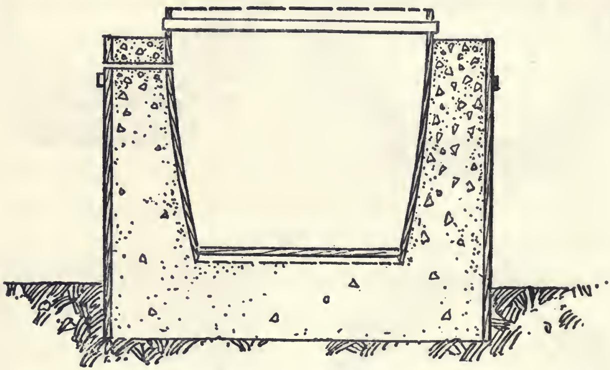


FIG. 61. — Arrangement of Forms for a Small Circular Tank.

braces are put in to prevent denting. Sheet iron is not so practicable for the inner form since the pressure of the concrete would cause the sheet iron to bulge inward spoiling the good appearance of the inner face of the wall. Sometimes silo forms are used in the construction of circular stock tanks, the forms being set up and filled to the required depth.

A simple form for the construction of a small and attractive circular watering trough is shown in Fig. 61. The construction of the trough is as follows: an old wagon or buggy tire is laid on the ground and a line marked on the inside of the tire. Excavation to a depth of 12 inches is made inside of the tire, care being taken to keep the earth wall as straight as possible. The excavation is filled to a depth of 6 inches with cinders or screened gravel thoroughly tamped. Three stakes each 3 feet long and 1 × 2 inches in cross section are placed endwise on the inside of the tire. The tire is then raised two feet above the ground and a nail is driven in each of the three stakes under the tire to support it at this height. A circular form is then completed within the tire by filling the space between the stakes with slats or narrow boards, a nail being placed in each board to hold it in place at the top. All that is necessary to hold them in place at the bottom is a little sand tamped at the foot. A layer of a rich mixture of concrete is laid on top of the cinders to a depth of about 4 inches. U-shaped reinforcing rods are then placed so as to extend across the bottom and up on the sides, the bars being about 2 inches from the surface of the slats. The inner form consists of half of a well-made barrel with all but the top hoop removed. The staves are held at the middle by light wooden crosspieces or by other means. This inner form should not be put in place until the thickness of the bottom has been brought up to about 6 inches by filling in with concrete; then with the inner form in place the placing of the concrete for the walls may be completed. The barrel, on account of its taper, can be easily removed. Of course, the surface of the forms should be well oiled before the concrete is placed or otherwise there may be difficulty in removing them. Care must be taken to see that the diameter of the barrel and of the tire are such as to correspond reasonably well in order that the thickness of the wall at the top may not be less than 4 inches.

Small Troughs. — Small troughs made of concrete are a very convenient type of trough to use for poultry and swine. On account of their weight, they are not easily disturbed; they never rot, and can be very easily cleaned. They can be made in any length desired from a small rectangular trough to one several feet long.

In Fig. 63 are shown the cross sections of several types of small troughs. The outer form can be made by building a bottomless box as long as desired about 14 inches broad and 10 inches deep. The inner form can be made as shown in the sketches. The forms are laid on a piece of roofing or building paper before being filled with concrete; the troughs,

Fig. 63. — Small Trough Shapes.

as will be noticed, are molded in an inverted position. Care should be taken to see that the forms are well oiled before any concrete is placed. The concrete should be of a rich mixture with no large particles of aggregate and it should be well tamped but not so thoroughly as to force all the large particles of the aggregate to the bottom. Usually, with the proper mixture, the interior surface of the troughs will be so smooth that painting with a cement wash will not be necessary but should it be found that the inner walls are unusually rough, it may be desirable to give them a coating of cement and water mixed to a consistency of cream. Under some circumstances, and especially if the forms are made longer than ordinary, it is advisable to include a few reinforcing bars to give additional strength. The forms should not be removed until the concrete has had an oppor-

FIG. 62. — A Durable Concrete Stock Tank.

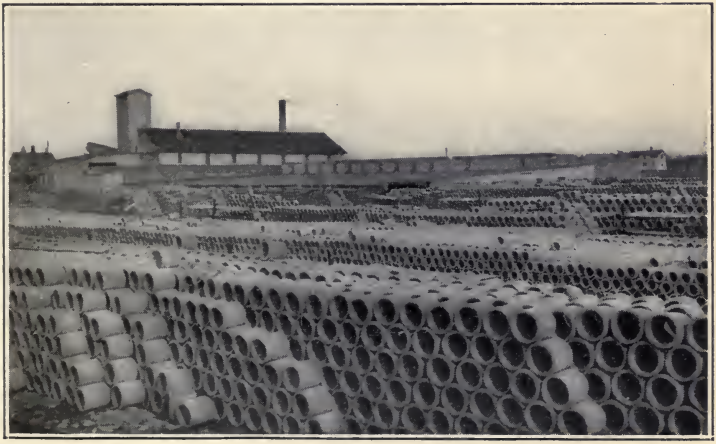


FIG. 70. — View of a Concrete Tile Factory in Iowa.

tunity to harden well; this will usually not be for three or four days, since a wet mixture is used.

Cisterns. — Probably no material is so satisfactory for the construction of cisterns as is concrete when properly made. This material has been used for this purpose a great many years, and with varying degrees of success, for in many instances, poor concrete was used with an unsatisfactory cistern resulting. Underground cisterns are useless if they leak; in dry weather, they become empty and at other times the ground water seeps in and makes the soft water as hard as that of the well. Concrete cisterns properly made do not leak since they are made in one solid piece and no trouble is experienced from the hardening of the water.

In locating a cistern, a site should be selected convenient to the principal downspout and to the kitchen or laundry. Allowance should be made for walls not less than 6 inches in thickness in laying out the plans. In fact, if a cistern of considerable size is to be constructed, the walls should be 8 inches thick. If the ground in which the pit is dug is sufficiently firm to stand alone no outside form will be needed, provided care is taken to make the excavation very exactly. If the ground is loose so that it will not stand alone, the excavation should be made large enough to include an outside form built in a manner similar to the inside one.

The inside form is made by nailing 1-inch boards on to 2 × 4 studding so that siding will be toward the earth walls. If an outer form is necessary, it is made with the boards away from the earth wall. A 6-inch layer of rich concrete is placed on the bottom of the pit and immediately the wall forms are set on all sides. In building the cistern, care should be taken not to get any dirt into the concrete because it is liable to make a porous and leaky wall. After the walls have been brought up to the level of the ground, a board 5 inches high is set on edge around the outside of the cistern to act as a form for the platform or cover of the cistern. A wood floor is then laid on top of the inside form leaving the top of the concrete wall exposed. This con-

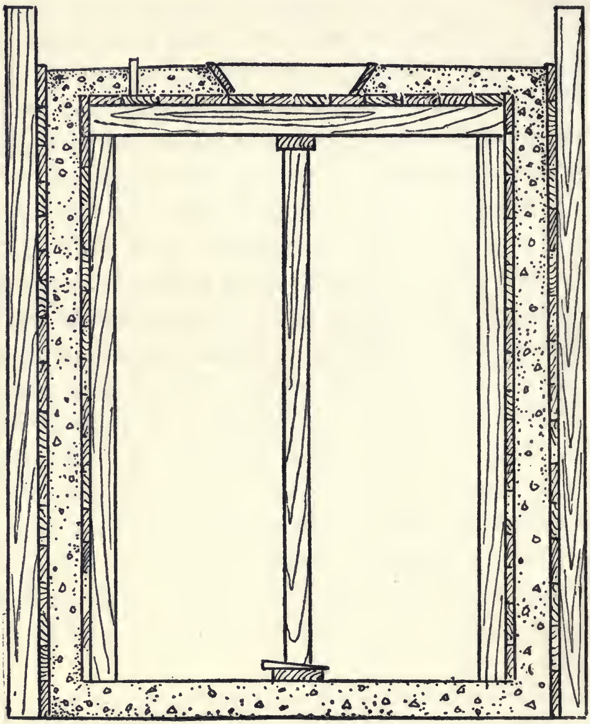


FIG. 64. — Cistern Forms.

struction is shown in Fig. 64 which also shows the forms for the manhole that must be provided at the same time. With these forms in place, the construction of the platform will proceed, a $1\frac{1}{2}$-inch layer of rich concrete being laid upon the floor. Sections of heavy woven wire fencing are then laid upon the concrete, the ends of the wire being allowed to extend within an inch of the outside lines of the platform. The remainder of the concrete is then placed, bringing a total thickness of the concrete up to 5 inches. The placing of the concrete should be done very rapidly and not stopped for any reason until the cistern cover is completed. The upper surface of the cover should be finished with a wooden float, and troweled, if desired. Fig. 65 shows the construction of the manhole forms. The manhole form itself is filled with concrete while it is still in place. This forms a cover of the same size and shape as the opening which is left in the cistern cover.

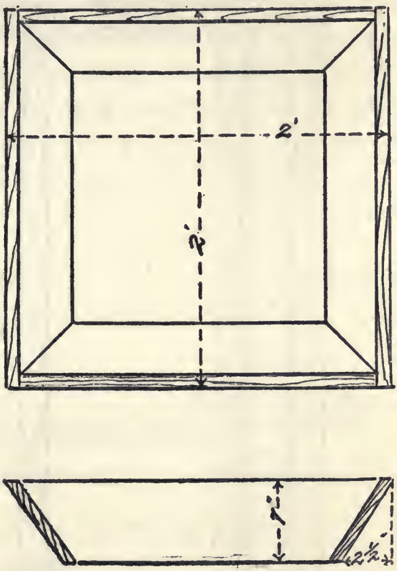


FIG. 65.—Manhole Forms.

At the end of ten days or two weeks the concrete should have hardened sufficiently to stand considerable weight. The manhole cover can then be lifted out by means of a ring which was placed in the concrete at the time of making. A hole is cut in the wooden floor, through which ingress into the cistern can be made, and the interior forms are then removed, being passed up through the manhole piece by piece.

The type of platform that has just been described may not be desirable under all circumstances. It is entirely possible that an arch or conical cover may be more practicable than the flat cover. In Fig. 66 is shown the method of construction for a cover of this kind. The horizontal floor is put in the same way as described above, and is covered with sand, which is heaped up in a hemispherical shape. At the top of the heap of sand of circular form, 5 inches in

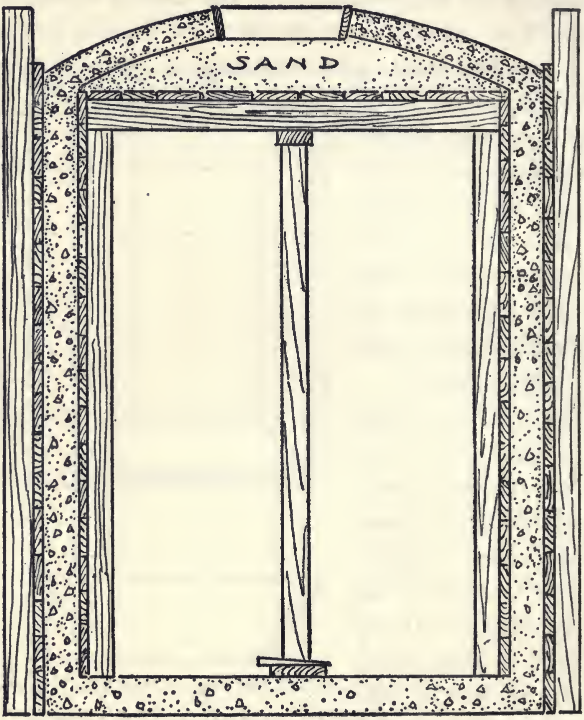


Fig. 66. — Construction of Arched Cistern Cover.

height is put in place to form the manhole. Reinforcing rods extend radially from the edge of the manhole to the outer edge of the cover with some additional reinforcing in the way of horizontal rings extending around the manhole at intervals of 6 inches. The forms may be built in such a way that the top of the manhole is just flush with the ground. An iron manhole cover may be put in or the forms for a concrete one described in the previous discussion can be utilized. The floor upon which the sand for the cover form is piled should be very firmly supported because of the great weight of the sand itself and of the concrete which is spread on top of it.

Hog Wallows. — A wallow is as necessary for a hog as a bath tub is for a human being. A clean bath benefits the health of the hog, especially if the wallow is filled with some dipping solution. The hog is a rather clean animal when he is given opportunity for being so, and he is sure to take advantage of every opportunity afforded. A concrete wallow can be constructed at comparatively little expense, can be easily kept clean, and will prove to be a source of great comfort for the hogs on hot summer days.

The wallow should be located in a place convenient to the water supply; a level, well-drained spot is desirable, one in

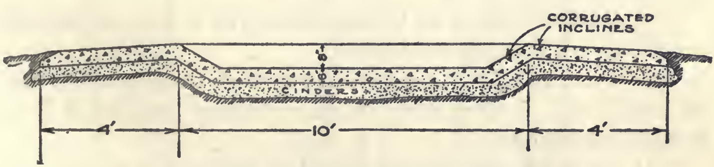


FIG. 67. — Cross Section of Concrete Hog Wallow.

which mud will not be washed into it. The size will depend upon the number of hogs to be accommodated, though one that is 10 feet square is usually amply large. Excavation should be made to a depth of about 2 feet and a 10-inch subbase of cinders or screen gravel should be firmly tamped into the excavation. Upon this is placed a rich mixture of concrete in a 6-inch layer, the sides sloping up to the outside as shown in Fig. 67. The walls are extended flat on the ground for a distance of about 4 feet around the tank. This approach should be grooved so that the hogs will not slip in approaching the wallow. The concrete should be allowed to cure thoroughly before the hogs are allowed in it, which will usually take about 2 weeks.

Dipping Vats and Tanks. — The progressive hog raiser will certainly be the possessor of a dipping vat. It is extremely valuable as a means of preventing disease and in fact, in some parts of the country, cattle are not allowed to be shipped unless they have been dipped in some disinfecting solution. In Farmers' Bulletin No. 481 published by the United States Department of Agriculture, the following discussion of dipping vats is given:

"Since the vat, of necessity, must be sunk in the ground, a water-tight vat of some permanent material is needed. On account of its lasting qualities concrete has been found to be an excellent material for dipping vats.

"There are five important points to be considered in the building of a dipping vat:

"(1) A blind chute — an inclined chute with a turn, so that the animal can not see where he is going.

"(2) An entering slide, steep enough to shoot the animal in, without a full drop. A direct drop, the entire depth of the tank, is liable to injure the animal.

"(3) The vat must be narrow enough to prevent the animal turning around, long enough to keep him in from one to two minutes, and deep enough not only to force him to swim, but also to make him disappear entirely when he takes the plunge.

"(4) The slope at the leaving end must be gentle and its surface roughened or cleated, so that the animal may easily climb out to the dripping pens.

"(5) As the liquid dip is the most expensive part of the operation, there should be provided two dripping pens draining into a settling tank or trough.

"In locating the dipping vat, select a well-drained site handy to a water supply and convenient for a chute leading from a small, well-

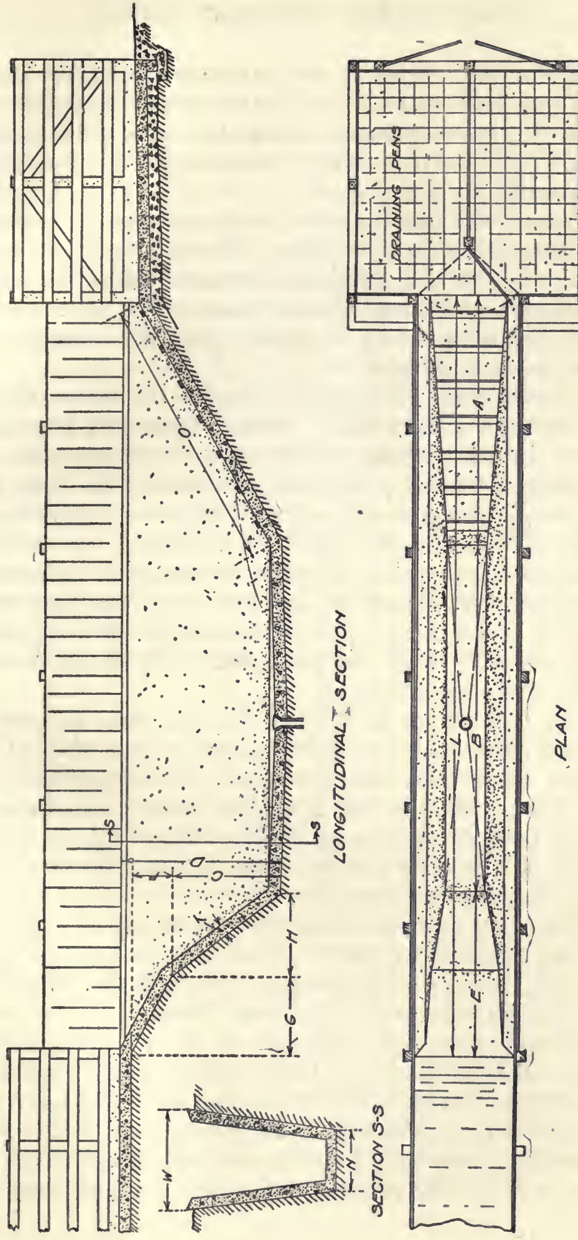


FIG. 68. — Concrete Dipping Vat.

fenced lot or corral. (Consider also the means to be used in heating the dip in case this is required.) At the narrow end of the chute and in line with it, lay out the dipping vat with the entering slide abutting the chute. Often the chute is built on a curve, so that the animals can not see what is ahead of them.

"One shape, with modifications as to size, is common to dipping vats for horses, cattle, sheep, and hogs. The vat is merely a box with sloping ends to make easy the animal's entering and leaving. From the accompanying table and the plan shown in Fig. 68, choose the proper dimensions according to whether the tank is intended for horses, cattle, sheep, or hogs.

"The lengths given will keep the animal in the vat one minute, which is usually a sufficient time. Where a longer treatment is desired, most ranchmen, instead of building vats of greater length, provide a drop gate working in a groove and controlled by a rope over a pulley, by means of which the animal is kept in the vat as long as necessary. Likewise, rather than build a separate vat for sheep and hogs, stockmen insert a temporary division fence, running the full length and depth of the cattle and horse vat. This fence should be solid and so spaced as to prevent hogs and sheep from turning around in the vat. In this way, a single dipping vat may be used for horses, cattle, sheep, and hogs.

"Dip the deep part of the hole first, and then slope the earth for the slide and climb. Lay the outlet drain pipe so that the top of the elbow bend will be even with the surface of the finished concrete bottom. Tamp back the dirt thoroughly about the drain before placing the concrete. If a pump or steam siphon is to be used to remove the dip, slope the earthen bottom to a sump hole in which the pump or siphon pipe can be set.

"The side walls only will require forms. If the banks stand firm, inside forms alone will be needed. Otherwise, cut away the banks so long as they crumble, and build an outside form similar to the inner form, but enough larger to provide for the thickness of wall required. Make the inside form of 1-inch boards on 2 × 4 uprights. Use a rich mixture and lay the floor and slopes directly on the solid earth. The concrete for the sloping ends should be mixed fairly dry so that it will tamp well and stay in position without the use of forms. With the bottom and slopes built, lower the side-wall forms into the pit. Take care not to jar the concrete already placed. Space the forms properly and cross-brace them firmly upon each other. Fill the wall space with concrete mixed mushy wet.

"In placing this concrete, be sure that it strikes the wood form instead of the earthen side, as concrete mixed with earth makes a weak, leaky wall. Carry the walls 6 inches above the surrounding ground to prevent floor water from running into the vat. Have everything at hand and work rapidly, so that the whole vat may be finished at one time and without stopping.

"The entrance slope should be smooth to slide the animals into the vat without skinning them up. Finish this surface with a wooden float and steel trowel. Some ranchmen prefer to cover the entire slide with a polished steel plate, the edges of which are sunk into the concrete when the slide is built. If preferred, bolts may be set in the green concrete slide, clear of the animal's path, to which the steel plates are later bolted. To aid the animals in climbing out, imbed in the concrete the turned-up ends of iron cleats bent at right angles similar to a capital U. Old wagon tires cut in lengths no greater than 20 inches and turned up 4 inches at each end will do. To better the footing, leave 1-inch clearance between the flat surface of the cleats and the concrete. Space the cleats 18 to 20 inches for horses and cattle and 10 to 12 inches for sheep and hogs.

Draining Pens

"At the leaving end of the vat, lay out the two dripping pens with their division fence on a line with the center line of the vat, so that the gate at the dipping vat, hung to this fence, may close either pen, when it is full, and allow the animals from the vat to pass into the empty pen. Use concrete posts for the fences, as they will require no replacing. Excavate for the drainage foundation, set the posts, and build a 6-inch concrete floor according to the previous directions. Slope the floors one-fourth inch to each foot in length or width, so that the dip running off the animals will be saved and drained back to the vat. Corrugate or groove the floor to the depth of one-half inch every 8 inches, in one direction. During the construction of the floor, mold around the outside a concrete curb, 6 inches above the floor and 4 inches wide. Where the dip from the floor empties into the vat, place a removable wire screen or strainer to keep the droppings and wool tags out of the vat. The wall forms may be removed after one week, but the vat should not be used until it is 3 weeks old.

"Fig. 68 shows a plan for draining the dip from the draining pens back to the vat which is much more convenient than strainers, and permits the floors of the drain pens to be made with very slight fall, thus preventing the animals from crowding to the rear of the drain pens after being dipped.

"A shallow trough, about 8 or 10 inches deep and 8 inches wide, is made from the side of the incline from the vat along the edge of the drain pen, or in the case of a double pen, on both sides of the incline. At any convenient point, insert a 2-inch iron pipe into the trough, 2 inches below the top of the trough, and run the pipe into the vat. The dip drained from the animals will run to the trough, the solid matter washed into the trough will settle to the bottom and the liquid will drain through the pipe back into the vat. As solid matter accumulates it is shoveled out of the trough. By making a hole in the far end of the trough and inserting a plug, rain water can be drained away from the vat when it is not in use.

Dimensions of Ground Pits for Dipping Vats

"The dimensions of ground pits for dipping vats are shown in the following table, the letters at the heads of each column corresponding to those shown in Fig. 68.

Kind	W		N		D		L		E		B		A	
	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.
Horses	5	10	3	4	8	8	55	0	7	6	31	0	16	6
Cattle	5	4	3	4	7	8	51	0	6	8	31	0	13	4
Sheep	3	4	2	4	5	8	46	0	5	0	31	0	10	0
Hogs	3	4	2	4	5	8	36	0	5	0	21	0	10	0

	G		F		H		C		O		T	
	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.
Horses	3	9	2	2	3	9	3	9	18	7	0	8
Cattle	3	9	1	11	3	4	3	4	15	4	0	8
Sheep	2	6	1	5	2	6	2	6	11	6	0	8
Hogs	2	6	1	5	2	6	2	6	11	6	0	8

Care of Concrete Dipping Vats

"Concrete dipping vats need no care other than covering them up or so inclosing them that persons and animals can not accidentally fall into them. Concrete is not injured by moisture. A concrete dipping vat, built of good materials and properly constructed, will always be ready for use and lasts forever."

CHAPTER VIII

DRAIN TILE, CULVERT PIPE, CULVERTS, AND BRIDGES

Drain Tile and Culvert Pipe. — A great deal of land throughout the United States must be drained in order to attain its highest productivity. The method of draining the land was a question for many years but the use of drain pipes or tile, as they are commonly called, has become almost universal. About the only materials which are used in the manufacture of these tile are clay and concrete, the latter material coming into use at a much later date than the clay. In some parts of the country, especially in the central western and western states, the cost of clay tile in the early days of drainage was unduly high because of the lack of proper clays from which to make the tile and also on account of the high shipping rates when they were imported. As a result, the manufacture of concrete tile assumed almost the magnitude and importance of an industry. Millions of feet of concrete drain tile were made and laid under various conditions, and naturally, since the demand increased very rapidly, the growth of the concrete tile industry was very similar to that of the concrete block industry. A great many manufacturers took advantage of the heavy demand, went into the business with inadequate equipment, and as a result, turned out a poor, unsatisfactory product which resulted in much adverse criticism being directed towards it.

There are many forms of concrete tile machines on the

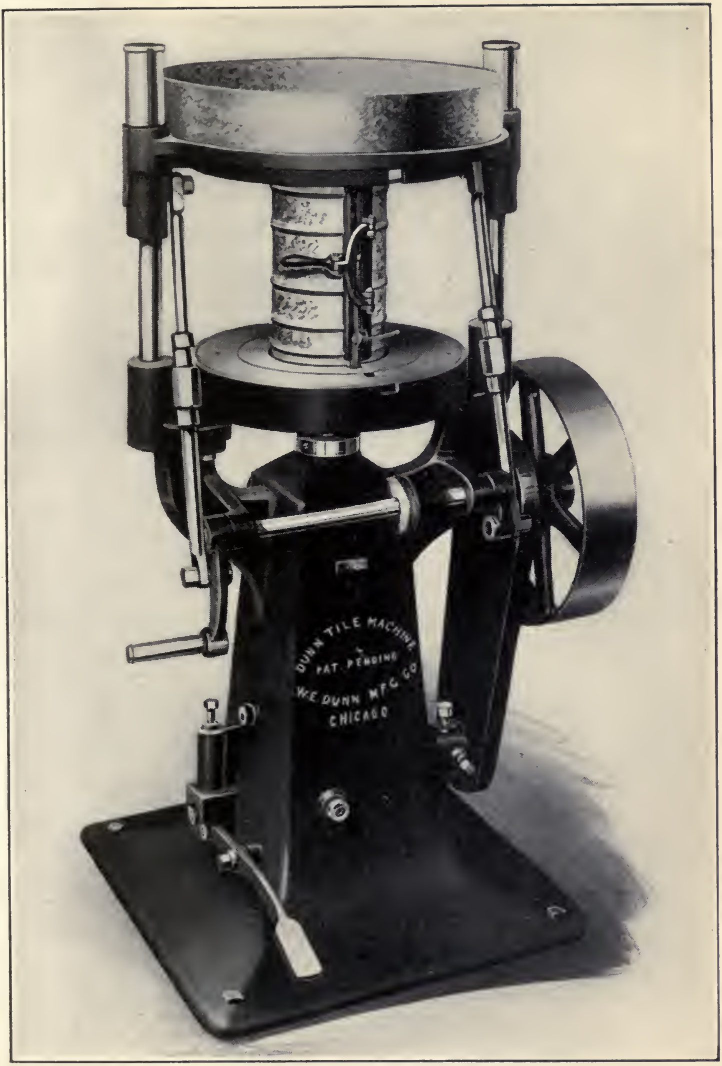


FIG. 69. — A Small Concrete Tile Machine.

market, from a small hand machine making but a single tile at a time to large machines entirely mechanically operated manufacturing a number of tile simultaneously. From the nature of the size and shape of the tile, and the thickness of their walls, it is evident that great care is necessary in the handling of them and that to make the product profitable it is almost necessary to use a mixture somewhat dry in its consistency; a wet mixture of concrete could not be removed from the forms rapidly enough. Most machines, as has been stated, use a dry mixture and are equipped with various size forms so that different size tile can be made. Even with the dry mixture the tile, if properly cured and carefully handled, are strong enough to resist ordinary usage and many thousands of such tile are probably still doing satisfactory duty after many years of service.

However, the properly constructed concrete tile is one that is made with a rather wet mixture and properly cured in order to obtain as great a strength as possible. Lean mixtures result in a weak concrete and consequently are objectionable in the manufacture of concrete tile. Richer mixtures are being used by present day manufacturers and very careful attention is given to curing; consequently, the concrete tile of to-day are equal or superior to those made of almost any other material.

Two tests for the quality of concrete tile are the "ring" and absorption tests. It is impossible to make a weak, porous concrete tile give a clear metallic ring when struck with a hammer or piece of metal; consequently this test is quite satisfactory. The absorption test consists in weighing the cured tile before and after placing in water for 24 hours. The per cent of absorption should not exceed 8 per cent of the original weight of the tile.

Concrete tile are made in a great variety of lengths and diameters to suit different requirements. No concrete tile should be made more than 30 inches in length or diameter without being reinforced and all large tile should have a wall thickness of at least $\frac{1}{12}$ of the diameter. The minimum thickness of wall of small tile should be $\frac{1}{2}$ inch. The construction of large concrete culvert tile may not come within the province of the farmer manufacturer of concrete; such tile are usually made in factories especially equipped for the purpose and where a thorough understanding of the construction including the reinforcing is had.

At various times there has arisen considerable objection to the use of concrete drain tile. These objections have been undoubtedly, to a certain extent, originated by manufacturers of drain tile of other materials. It is true that there have been failures of concrete drain tile, but in almost every instance when such failure has been investigated, it has been found to be due to the use of poor materials, a lean mixture, or the employment of poor workmanship.

In some localities, particularly in the West, it has been claimed that the action of the alkaline soils in which the drain tile has been laid has been so destructive to the cement as to cause the complete disintegration of the tile itself. A very exhaustive discussion of this action is given in Bulletin No. 81 of the Montana Experiment Station. This station collected data showing that it was evident that the alkali in soil was in some way connected with the destruction of concrete. Very careful observations and tests were made and certain definite results were achieved.

"Alkali, in the popular sense, is a term used to designate the soluble salts that accumulate in regions of little rain fall. They are made by the disintegration of rocks and consequently are present in all soils when they are formed, but they are leached out and removed in the drainage water when there is sufficient rain fall and drainage. Where alkali-laden waters collect and evaporate, as in the ocean or in soils which receive such drain waters and allow them to evaporate, there will be an accumulation of alkali; they may amount to only a few pounds per acre or great salt deposits inches or feet in thickness. The alkali salts which are present in greatest amounts in western soils are the sulphates, carbonates, and chlorides or sodium, magnesium, and calcium. The 'white alkali' is mostly sodium sulphate while 'black alkali' is largely sodium carbonate. The former is the most abundant."

The conclusions at which these investigators arrived is interesting. They found

"that the chemical reaction of alkali that is destructive to concrete is the double decomposition between the various alkali salts and calcium hydroxide which is a necessary constituent and probably the binding one of all set cement. As a result of reactions between these salts and the calcium hydroxide new compounds relatively insoluble are formed in the body of the cement structure and these new compounds have greater weight and require greater space than the calcium hydroxide replaced. *This increase of space occupied disrupts the cement, causing it to bulge, crack, and crumble.* A certain *weakening,* not a disruption, of the cement is due to the loss of a portion of the binding material, crystallized calcium hydroxide, which is merely dissolved and removed in solution. In order for a destructive action to become marked, the alkali solutions must percolate through the concrete or at least must penetrate far beyond the surface. Consequently, any measures that hinder the penetration of the alkali solutions into the interior of the concrete will delay the destructive action. Of course, when cracks are started by the expansive action due to alkali salts, intermittent wetting and drying or freezing and thawing will hasten the destruction of the concrete by extending the crack already started."

From this it is seen that it is entirely possible to manufacture a concrete drain tile which will be resistant to the action of alkali salts. All that is necessary is to make the concrete waterproof, which may be done by making it of a rich mixture or by using some form of effective commercial waterproofing. In fact, it has been found that the chemical action described above aids in the waterproofing if the concrete is of a rich mixture. The formation of new compounds displacing the calcium hydroxide will occur to a depth of a fraction of an inch on the surface of the concrete but not to such an extent as to result in the formation of cracks. Instead, these new compounds will assist in filling up what pore spaces exist, thus effectually sealing them and preventing further ingress of alkali solutions.

The subject of the disintegration of drain tile as the result of alkali has been investigated by a number of authorities and the findings are almost unanimous that properly constructed concrete drain tile are durable and economical.

Culverts. — Very often the farmer will be called upon to provide a simple and satisfactory crossing for small-stream water courses and ditches which are found on almost every farm. Many of these ditches are spanned by carelessly built wooden or other temporary culverts requiring constant attention and which frequently are in a condition to invite accident. The continual annoyance and expense of repairs which these temporary structures occasion can easily be avoided by the building of concrete culverts. Concrete is a material which adapts itself very well indeed to the construction of small culverts and bridges. It is durable and economical and the initial cost is not great. The accompanying table prepared by Mr. A. R. Hirst, Acting State Engineer of Wisconsin, gives the estimated cost of maintaining the most common kinds of culverts over a period of 100 years.

Kind	Shape	Size	Cost	Cost for 100 Yrs.
Wooden Box . .	Rectangular	15″ square	$16.80	$252.00
Concrete Box . .	Rectangular	15″ square	40.00	40.00
Cast Iron . . .	Semi-Circle	16″ diameter	57.90	97.80
Cast Iron . . .	Sector	18″ diameter	65.25	112.50
Cast Iron . . .	Circle	18″ diameter	92.40	168.80
Vitrified Tile . .	Circle	18″ diameter	42.00	42.00
Corrugated Steel .	Circle	18″ diameter	50.40	198.00
Circular Concrete	Circle	18″ diameter	35.00	35.00

Culverts should be made large enough to carry the largest amount of water which is likely to flow through them. As far as possible, they should be placed in the direction of the flow of the water in order to prevent clogging which may result in wash-outs and consequent repairs. The length of the culvert will depend upon the amount of traffic over it and upon the depth of the fill on top of the culvert. If the fill is unusually heavy, the culvert must be of sufficient length to accommodate the slope of the fill.

The concrete culvert may be built either in arch form or as a simple, reinforced, flat-top, concrete box. This type is simpler than the arch culvert since it requires much less head room and therefore less excavation, besides simpler form work and lower construction costs. It is a favorite type in a flat country and under shallow fills.

The forms for this type of culvert are very simple and no detailed specifications are necessary. The face of the forms should be made of 2 × 6 lumber dressed on one side and 2 edges held by supports at intervals of 3 feet of 2 × 4 lumber. Culverts may be built with or without a floor according to the stability of the soil and local conditions. Usually a concrete floor is an advantage since it gives a smooth waterway which increases the capacity of the

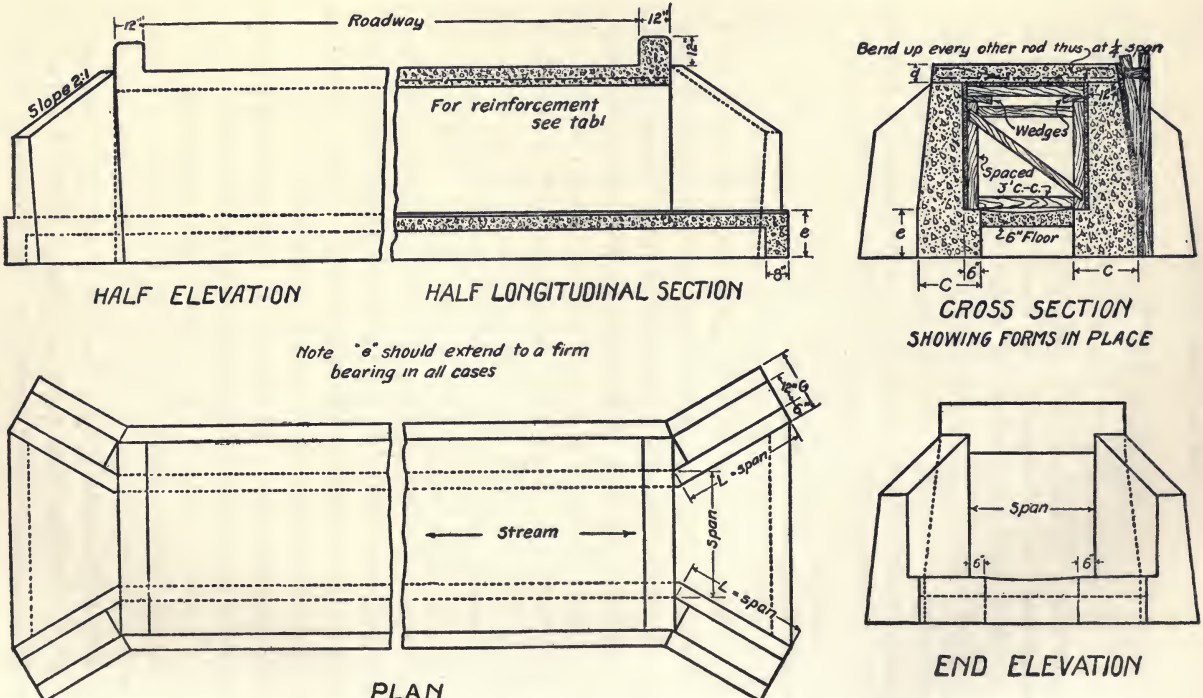


FIG. 71.—Reinforced Box Culvert.

culvert, and prevents clogging of the waterway and eroding of the stream bed with a consequent undermining of the foundation. Fig. 71 shows a typical design of a reinforced box culvert from 3 to 10 feet in span and gives a general idea of its construction. For spans less than 3 feet the construction can be somewhat simpler and the reinforcing omitted.

When the area of the waterway required is small, that is, under 36 inches in diameter, it is usually more economical to build a concrete pipe culvert. No culvert of this type should be constructed having an opening smaller than 15 inches. They should be provided with end walls at both ends to protect them, the end walls extending upward to a height at least as great as the height of the fill.

Bridges. — While the construction of concrete bridges usually does not come within the scope of the farmer, yet it is something in which he is more or less directly interested. The advantage of concrete in durability, the elimination of maintenance cost and its economy in first cost, make this an especially desirable material in bridge construction. Bridges stand in intimate relation to the improvement of the public highways but the economy of building these structures of durable and permanent materials and according to intelligent economic design has not generally been recognized.

The administration of road improvements in the United States is mainly placed in the hands of local officials. The bridge improvements of many of these communities are mainly the construction and repair of culverts and small span bridges.

Local officials should be interested in securing proper, intelligent, and economic design for all bridges and culverts especially where the span is greater than 20 feet. Many states maintain an engineer who will give free engineering advice to local officials requesting his services and most states have state highway commissions which should always be consulted by communities contemplating extensive bridge improvements. Concrete, in the hands of competent engineers, is properly fitted for bridge construction. Aside from the advantages which have been previously enumerated, the materials can be purchased in the vicinity and so permit the greater part of the cost of the construction to be spent at home. The same is true of the labor; no great amount of skilled labor is employed. As a result, local labor can be utilized, thus furthering the local distribution of expenditures and returning a greater proportion of the cost to the community.

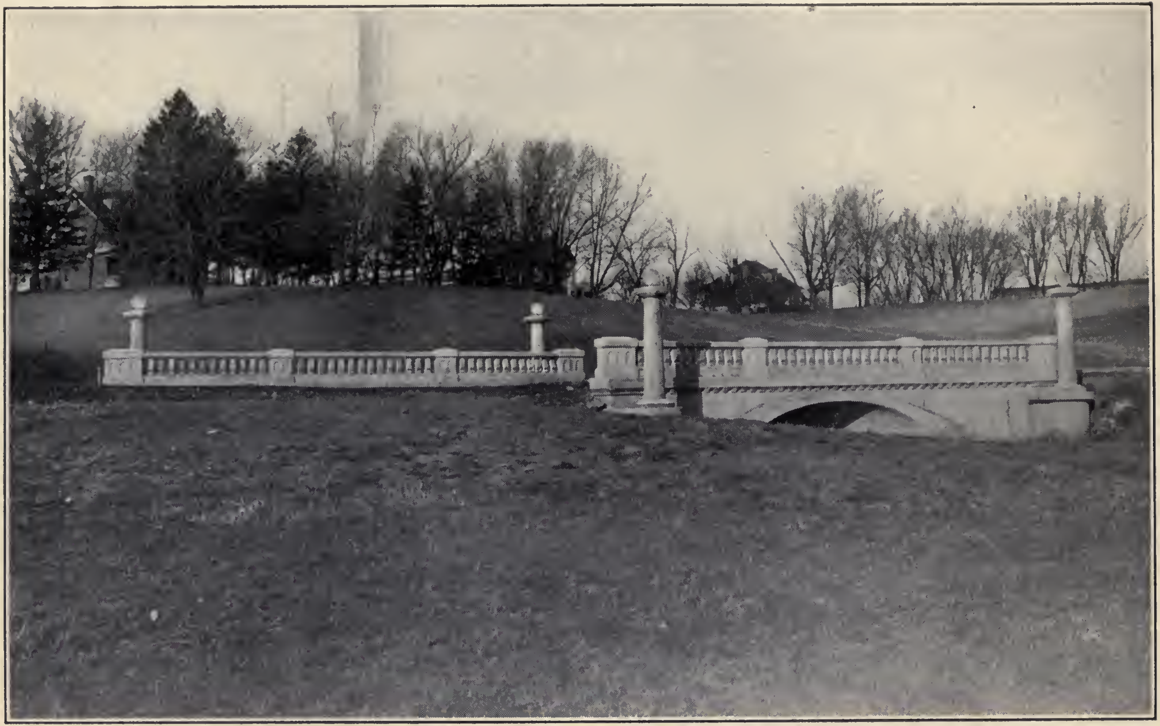


Fig. 72. — A Beautiful Concrete Bridge.

CHAPTER IX

CONCRETE SILOS

It is admitted by those who have made a careful study of the subject from an impartial standpoint that silage can be kept in good condition in a silo of any material be it concrete, stone, tile, or wood, if the material selected be properly used. The length of time for which the silo will continue to fulfill in a satisfactory manner the service required of it depends, however, upon the selection of the material best able to combat the action of the elements, withstand the heavy strains due to the pressure of the silage, and furnish a reserve for such extraordinary conditions as fire and cyclones.

One of the first essentials of any silo is that it be air-tight. It must, therefore, be of such material as will not warp or shrink, thus causing cracks; as much as possible it must be of one solid material so that changing temperature and weather conditions will not tend to tear it apart and cause openings. It must be of such hard substance that rats and other vermin cannot gnaw into it. The material should be such that it will not corrode or decay when exposed to the air and should require a minimum of care in order to reduce the maintenance cost.

It is also essential that it be durable, for since it is a fact that most farmers owning silos keep them filled more or less the year around, it becomes very difficult, aside from the expense incurred, to replace any defective parts. The greater the durability of the silo the better investment it is and a silo is a structure in which there is invested enough money to make it imperative that returns be made for a considerable length of time.

Another essential of the silo is that it be fireproof. The average farm building is constructed of highly inflammable materials and the silo is, as a rule, for convenience located in close proximity to such a building. In the majority of instances when fire occurs in a building of this kind, its total destruction results and should the silo be connected with it, its destruction would mean the loss of both shelter and food for the stock, which might necessitate their sale at a loss. The combined loss of food and stock would be far in excess of the slight additional amount which would have built a fireproof silo. Under some conditions, especially in the western states, it is highly desirable that the silo be wind or tornado proof. Many farmers are thoroughly aware of this lack in many silos and know to their sorrow the dire results that sometimes occur when certain types of silos are struck by wind storms.

In view of these facts, it would seem that the concrete silo as a distinct type of silo is more than ordinarily good. Whether it be monolithic, stone, block, or plaster, the concrete silo is in effect one solid mass having a uniform temperature, expansion, and contraction. Rats and other rodents, woodpeckers, and all wood-boring insects have no effect upon the silo built of concrete. The concrete silo not only protects its contents against loss but protects itself as well, always maintaining a maximum efficiency. It does not burn like wood nor will it crack and break up like inferior vitrified brick and tile when subjected to the test of fire. The additional fact that concrete is a slow conductor of heat preserves the silage from injury through the fire.

Not only does the material from which a concrete silo is made make it fireproof and air-tight, but the very nature of the structure itself is permanent. It is proof against tornadoes, floods, and all other such unusual yet occasional tests, and it even cannot be seriously damaged by lightning. In erecting a silo it is important to remember that while it may be expected to repay its cost in a comparatively short time, its period of usefulness and consequent profit are indefinite and will be limited only by the durability of the silo itself. Consequently, no builder of a silo should feel at all disgruntled if it is found necessary to add a small fraction to the original cost of the silo to make it a permanent one if this additional expenditure be multiplied many times in later profits. The objection has been made to concrete as a silo material that it is porous, the porosity permitting the absorption of the silage juices which in turn cause the silage to become so dry as to spoil around the walls of the silo. As a matter of fact, there is no danger of juice absorption if the concrete from which the silo is built is properly made, because such concrete is in itself dense and impervious. Even were there moisture absorption in a concrete silo the quantity of moisture thus abstracted from the silage would be so small in amount as to be practically negligible.

Another argument advanced against the concrete silo and one which has unfortunately, through the agency of promoters of other types of silos, been broadcast, is that the acid in the silo eats into and disintegrates the concrete, forming a compound with the various elements in concrete which renders the silage unfit for food. It is a fact that there is a small amount of acid in silage; if, however, this acid were present in such quantities as to have any perceptible effect on the concrete walls of a silo, it could not be the beneficial food that it is for cattle. The percentage of acid in silage is extremely low and only in porous concrete can the juice enter to any appreciable extent. Consequently, when the silo is built of properly made concrete the action of the acid in the silage juices is barely, if at all, apparent.

The question of freezing which is one very often brought up in connection with the concrete silo, is not a really legitimate one. As a matter of fact, silage will freeze in almost any kind of silo if it is built in a cold region. Frozen silage should not be fed to stock, but if thawed out and fed immediately there is abundant evidence to prove that no bad effects whatever will be experienced. Concrete is a poor conductor of heat; consequently in a short sharp frost, the frost will not reach the ensilage. In case of a heavy and continued frost, the walls of the concrete silo will absorb and retain the cold for a long time, thus preventing rapid thawing. The action of this is to maintain the silage at an even temperature. The experience of thousands of concrete silo owners is to the effect that if the concrete is made right the silage put into the silos will be of as perfect a quality as in any other type of silo.

Concrete silos are made in several different types; these may be included in the following classification: *block*, *stave*, *plaster*, and *monolithic*. All advantages and disadvantages pertaining to one type of concrete silo are not necessarily possessed by the other kinds, but the general qualifications of the concrete silo can be applied to all types. They will require practically the same foundation and can be equipped with the same kind of roof and chute. There are enough owners of each one of the different kinds reporting upon them to furnish ample evidence that all kinds are satisfactory.

Foundation. — The location of the silo depends upon a number of things and more particularly upon the local arrangement of the farmstead. In the case of the silo supplying two barns it is well to have it located at one end of the passageway between these barns. In cases where there is a large herd to supply, it is economical to have some small cart or carrier running on wheels to convey the silage to the feed boxes. If possible, the silo should be located on the south side of the barn to be protected as much as possible from the cold. In a round barn, the natural location for it will, of course, be in the center of the barn, which

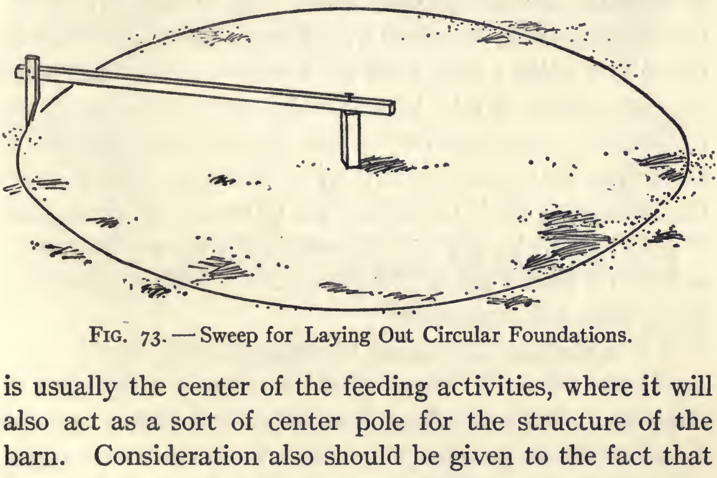


FIG. 73. — Sweep for Laying Out Circular Foundations.

is usually the center of the feeding activities, where it will also act as a sort of center pole for the structure of the barn. Consideration also should be given to the fact that it must be easy of access at time of filling, proper provision being made for the engine and cutter and for the loads of fodder, so that there will be a minimum interference with the regular farm work while the process of filling is proceeding.

When the location has been decided upon, the construction of the foundation may begin. The excavation can be laid out very conveniently with the employment of a simple sweep, such as is shown in Fig. 73, which consists of a heavy stake driven in the center of the spot selected for the silo and upon which is pivoted a long arm bearing a chisel-shaped stake with which to mark the circumference as the arm is swung about the center.

The excavation should be carried to a depth not to exceed 5 feet below the ground line. In this way, the height above the ground is reduced, considerably decreasing the amount of scaffolding necessary and reducing the amount of work required in the hoisting of materials. In addition, the foundation is brought below the frost line. Any greater depth than that mentioned is objectionable in that it adds to the labor of removing the silage. All of the earth within the circumference described by the sweep should be removed down to a point 1 foot from the bottom; below this point the excavation should be made the shape and size of the foundation, 2 feet wide by 1 foot deep, so placed that the outer edge will come directly up to the edge of the excavation, assuming that the sides of the latter are perpendicular. If a floor is to be put in, the excavation should be carried down to 4 inches below the top level of the floor, providing for a floor 4 inches thick.

It is sometimes advisable to dispense with the silo floor, especially when the silage would rest upon a dry clay or non-porous soil and where the foundation is deep enough to prevent undermining by rodents. As a general procedure, however, a floor is a good thing because it is not very expensive and it will mean that the floor of the silo can be easily cleaned and there will be no mixing of earth with the silage; a 4-inch thickness is amply sufficient because the weight of the silage, though very great, is uniformly distributed. The floor itself should be made separate from the foundation.

When the excavation has been completed, the placing of the concrete for the foundation may begin. Since the concrete is entirely in compression, a medium lean mixture will be entirely permissible. Usually the concrete may be placed in the excavation with no forms whatever, but in some kinds of loose soil light boards held in position by stakes may be necessary. The top of the concrete must be leveled off with the top of a straight-edged board and spirit level in order that the superstructure which follows may be vertical and present an even weight on every portion of the foundation. Twenty-four hours is the time

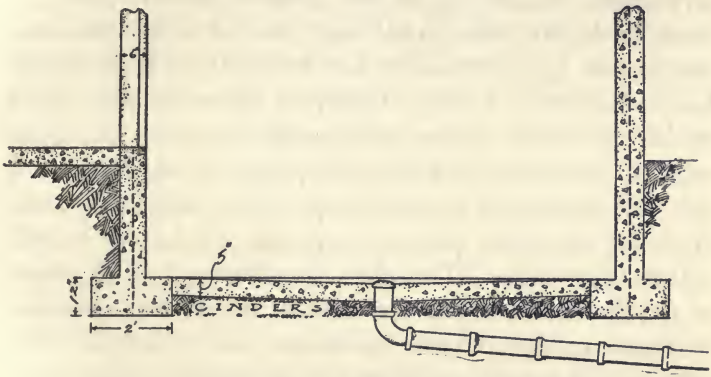


FIG. 74. — Construction of Silo Floor and Foundation.

usually required for sufficient hardening of the foundation to permit of the procedure of the building of the walls. If the silo is to be built to a great height, as is being done in recent years, it may be necessary to make the foundation heavier and wider in order to provide plenty of footing to bear the exceedingly heavy superstructure. Fig. 74 illustrates the details of the construction of the silo foundation and floor.

Block Silos

Concrete silos constructed of hollow blocks are popular in all of the northern states and more especially so where the winters are very cold, because of the security against freezing provided by the hollow wall. Next to the monolithic type, the concrete block silo is the style of concrete silo most common at present. The cost of this silo is often more than for one of monolithic construction. The best concrete block silos are those erected by contractors who have made a specialty of this class of work. There are good block silos which have been erected with homemade blocks and by home labor, but where there is a reliable block contractor in the vicinity it generally pays in a saving of time as well as in materials and numerous other ways to have the work done by people of experience. A concrete block silo is constructed with comparative ease since no forms are necessary and the blocks are usually rather large units. The main disadvantage of this type of silo lies in the difficulty of making blocks that are dense and impermeable. As a consequence, many concrete block silos are not entirely satisfactory. If the interior face of the block is made waterproof, this objection can be overcome without any great difficulty. There is also a little danger of an opening forming between a block and its adjacent mortar joint due to the shrinkage of the cement mortar in which the block is laid.

Concrete blocks can be made in the winter, when there is no press of other farm work, and the blocks are allowed to cure thoroughly before use. They can also be transported to places where it might be difficult to transport the forms used in monolithic construction. The air space of the hollow block silo is an advantage in protecting the silage from freezing. The blocks may be either flat faced, bevel edged, or faced in imitation of stone. As a rule, the flat-faced block will give the better looking silo.

It is true that the concrete ends of the hollow blocks convey the cold from the outer to the inner surface of the block, but not to the extent it would if the block were solid. There are now on the market block machines which construct blocks in which the only connection between the outer and inner surface is the reinforcing used.

Although, as said before, the blocks can be constructed by the owner of the silo in the winter, the same saving of time will be effected and probably superior blocks procured if he obtains them from some reliable block contractor whose experience has taught him how to obtain the best results in block making. The owner, however, should always examine the blocks before they are used in the silo, rejecting all that are damaged or of an inferior quality. A crack of any size or broken or crumbly edges are sufficient reason for the rejecting of a block. Blocks which absorb moisture too rapidly should also be rejected. Warped and distorted blocks, though they might give good service, are unsightly and are also likely to cause an uneven surface on the interior of the silo which will prevent the even settling of the silage.

The laying of the foundation has already been described. In the mortar between the foundation and the first layer of blocks should be placed the first hoop of horizontal reinforcing. A sweep from the center of the silo should be used with a guide board to insure maintaining a true circle on the interior of the silo. In laying the blocks the two on each side of the doorway should be laid first, the balance following the course of the sweep around the circle.

It is essential that sufficient reinforcing be used horizontally between the blocks, particularly at the base of the silo, where the walls must stand tremendous pressure. When obtainable, it is best to use blocks in which the reinforcing rests in a groove on the upper surface of the block, thus giving it a firmer hold in the wall. Instead of overlapping as in the case of the monolithic silo, the reinforcing

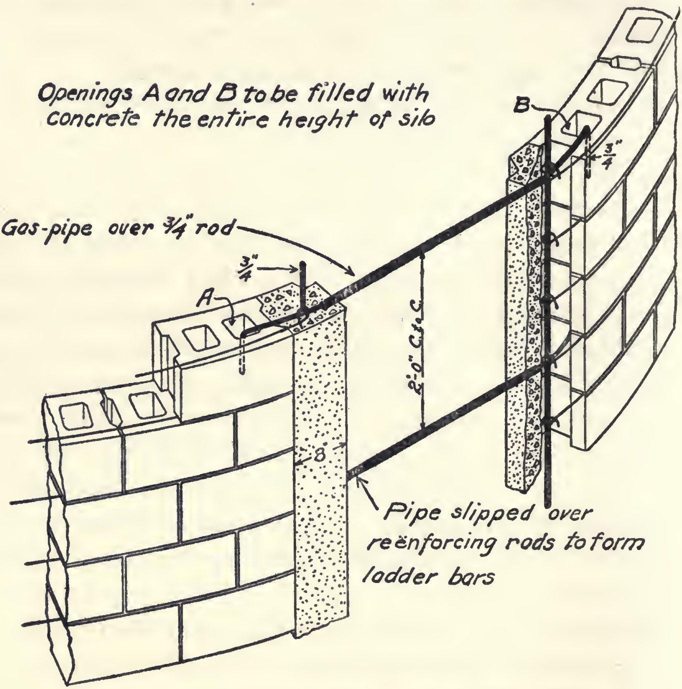


FIG. 75. — Continuous Door Opening for Block Silo.

rods must either anchor around a block or have their ends hooked into each other. Vertical reinforcing is not common in block silos, though there are some firms having block forms which provide for such reinforcing, this giving added strength to the silo.

Horizontal Reinforcement for Block Silos, showing Size of Wire or Round Rods to be used between Each 8-inch Course of Blocks

Feet from Top of Silo	Diameter of Silo							
	8 Feet	10 Feet	12 Feet	14 Feet	16 Feet	18 Feet	20 Feet	22 Feet
0– 4	No. 6	No. 6	No. 6	$\frac{1}{4}$ inch	$\frac{1}{4}$ inch	$\frac{1}{4}$ inch	$\frac{1}{4}$ inch	$\frac{1}{4}$ inch
4– 8	No. 6	No. 6	No. 6	$\frac{1}{4}$ inch	$\frac{1}{4}$ inch	$\frac{1}{4}$ inch	$\frac{1}{4}$ inch	$\frac{1}{4}$ inch
8–12	No. 6	No. 6	$\frac{1}{4}$ inch	$\frac{1}{4}$ inch	$\frac{1}{4}$ inch	$\frac{1}{4}$ inch	$\frac{3}{8}$ inch	$\frac{3}{8}$ inch
12–16	No. 6	$\frac{1}{4}$ inch	$\frac{1}{4}$ inch	$\frac{3}{8}$ inch	$\frac{3}{8}$ inch	$\frac{3}{8}$ inch	$\frac{3}{8}$ inch	$\frac{3}{8}$ inch
16–20	$\frac{1}{4}$ inch	$\frac{1}{4}$ inch	$\frac{3}{8}$ inch	$\frac{3}{8}$ inch	$\frac{3}{8}$ inch	$\frac{3}{8}$ inch	$\frac{3}{8}$ inch	$\frac{3}{8}$ inch
20–24	$\frac{1}{4}$ inch	$\frac{3}{8}$ inch	$\frac{3}{8}$ inch	$\frac{3}{8}$ inch	$\frac{3}{8}$ inch	$\frac{3}{8}$ inch	$\frac{3}{8}$ inch	$\frac{3}{8}$ inch
24–28	$\frac{3}{8}$ inch	$\frac{3}{8}$ inch	$\frac{3}{8}$ inch	$\frac{3}{8}$ inch	$\frac{3}{8}$ inch	$\frac{1}{2}$ inch	$\frac{1}{2}$ inch	$\frac{1}{2}$ inch
28–32	$\frac{3}{8}$ inch	$\frac{3}{8}$ inch	$\frac{3}{8}$ inch	$\frac{3}{8}$ inch	$\frac{1}{2}$ inch	$\frac{1}{2}$ inch	$\frac{1}{2}$ inch	$\frac{1}{2}$ inch
32–36	$\frac{3}{8}$ inch	$\frac{3}{8}$ inch	$\frac{3}{8}$ inch	$\frac{1}{2}$ inch	$\frac{1}{2}$ inch	$\frac{1}{2}$ inch	$\frac{1}{2}$ inch	$\frac{1}{2}$ inch
36–40	$\frac{3}{8}$ inch	$\frac{3}{8}$ inch	$\frac{3}{8}$ inch	$\frac{1}{2}$ inch	$\frac{1}{2}$ inch	$\frac{1}{2}$ inch	$\frac{1}{2}$ inch	$\frac{5}{8}$ inch
40–44	$\frac{3}{8}$ inch	$\frac{3}{8}$ inch	$\frac{1}{2}$ inch	$\frac{1}{2}$ inch	$\frac{1}{2}$ inch	$\frac{1}{2}$ inch	$\frac{5}{8}$ inch	$\frac{5}{8}$ inch
44–48	$\frac{3}{8}$ inch	$\frac{3}{8}$ inch	$\frac{1}{2}$ inch	$\frac{1}{2}$ inch	$\frac{1}{2}$ inch	$\frac{5}{8}$ inch	$\frac{5}{8}$ inch	$\frac{5}{8}$ inch
48–52	$\frac{3}{8}$ inch	$\frac{1}{2}$ inch	$\frac{1}{2}$ inch	$\frac{1}{2}$ inch	$\frac{1}{2}$ inch	$\frac{5}{8}$ inch	$\frac{5}{8}$ inch	$\frac{5}{8}$ inch
52–56	$\frac{3}{8}$ inch	$\frac{1}{2}$ inch	$\frac{1}{2}$ inch	$\frac{1}{2}$ inch	$\frac{5}{8}$ inch	$\frac{5}{8}$ inch	$\frac{5}{8}$ inch	$\frac{5}{8}$ inch
56–60	$\frac{3}{8}$ inch	$\frac{1}{2}$ inch	$\frac{1}{2}$ inch	$\frac{1}{2}$ inch	$\frac{5}{8}$ inch	$\frac{5}{8}$ inch	$\frac{5}{8}$ inch	$\frac{5}{8}$ inch

Before being placed in position, all blocks should be thoroughly soaked to prevent the absorption of moisture from the mortar. The mortar should consist of a 1:2 mix of cement and clean sand, to which may be added not more than 10 per cent of hydrated lime if the mason wishes to make it work more easily under the trowel.

The continuous doorway is used practically without exception for block silos. To the vertical rods of the doorway are securely tied the horizontal rods of the silo. These same vertical rods also sustain the cross-rods of the doorway.

The accompanying table gives the amount of horizontal reinforcing necessary for block silos. Fig. 75 illustrates the method of constructing a continuous door opening for a concrete block silo, the vertical rods in the door jamb acting as anchors for a horizontal reinforcing of the silo. It is entirely possible that individual doors can be used by leaving out some of the blocks in certain tiers, care being taken to increase the reinforcing in the space between the doors so that the total amount of reinforcing is not decreased.

Stave Silos

The concrete stave silo was originated in order to provide a silo which would have all the advantages of concrete silos and yet be as simple in construction as the ordinary wood stave silo. In its development, however, certain inherent disadvantages came to light, but as time progressed they have been to a great extent eliminated. The objection of porosity which applies to the concrete block silo applies with equal pertinence to the concrete stave silo in the majority of instances. Most staves are manufactured under patents and in order to reduce the cost of manufacture the making of the staves must proceed with as great rapidity as possible. Consequently, it is the usual thing to find that the staves are made of a dry mixture and are therefore porous. Another fundamental weakness of this class of silo is the constant exposure of the reinforcing steel to the action of the weather since in practically all concrete stave silos the reinforcing is not imbedded in the silo itself but is in the shape of hoops which band it just as do the hoops of a wooden stave silo; consequently it is not so permanent as one in which the reinforcing is covered and so protected.

The main advantage of the concrete stave silo lies in the fact that it can be constructed without the use of forms, the process of erection being in most respects similar to that of erecting a wood stave silo. It is also possible to discontinue the work at any time without any detrimental effects being consequent. Since the walls are usually not more than 2½ or 3 inches thick a considerable saving in concrete is accomplished.

The construction of this type of silo is a comparatively simple proposition. The foundation is prepared just exactly the same as for any other type of silo. The staves are set upon the foundation, then hoops are put around and tightened up and all joints are either covered with a cement paste or, in some certain cases, poured concrete is used to make the junction between the staves. It is in the construction methods that most of the disadvantages of the concrete stave silo occur for it is difficult to make every joint between the staves a perfect one and it is also difficult to have the tension of the hoops absolutely uniform. If the tension in the hoops is not uniform, the lateral pressure against the staves when the silo is filled will meet unequal resistance and transverse cracks are likely to occur in the staves.

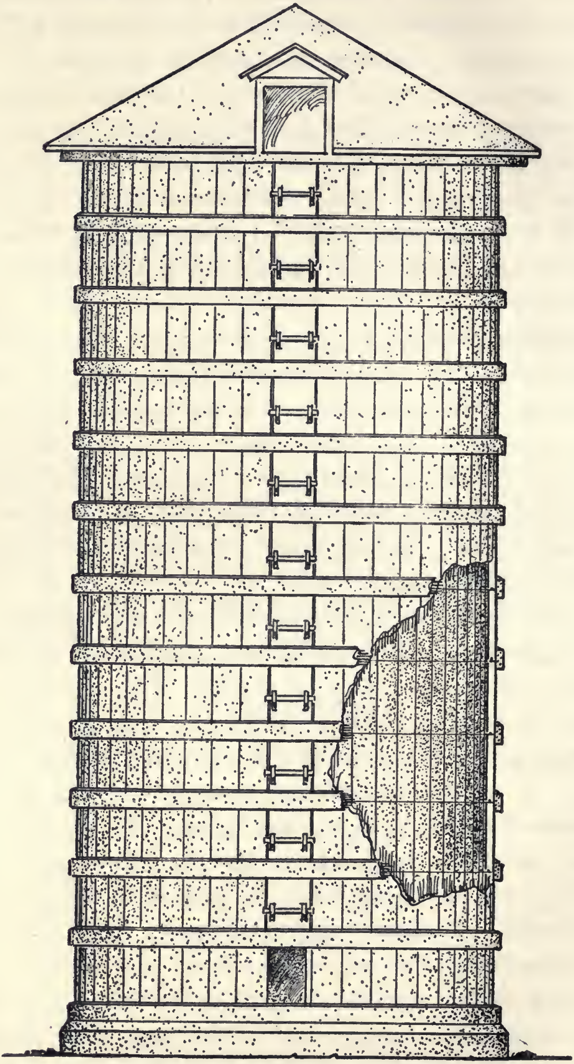


FIG. 76. — An Efficient Stave Silo.

There are many types of concrete stave silos on the market all giving satisfaction to a greater or less degree. In Fig. 76 is shown a sketch of one form of concrete stave silo in which most of the objections to this general class are eliminated. In this particular silo the staves are made of wet mixture, the concrete being cast flat in the molds. The concrete itself is thoroughly waterproofed and the staves are reinforced longitudinally by means of steel rods, the number of rods depending upon the location of the stave in the wall of the silo. The edges of the staves are all grooved so that when the staves are set up edge to edge an open space is formed between each pair of staves into which a cement mortar is poured. A very unique feature is the arrangement of the reinforcement; this is placed outside of the silo at the junction of the tiers of staves and is firmly imbedded in sufficient concrete to give it thorough protection. The concrete in the reinforcing bands is a slushy concrete that is poured into forms which are kept in position by supports extending from the next lower band. The joints should be practically perfect and there are no exposed reinforcing hoops. A considerable saving is effected in the amount of material used since the thickness of the staves is but $2\frac{1}{2}$ inches.

The Plastered Silo

The silo made with the use of concrete in the form of plaster is perhaps the least used of any of the various types of concrete silos. The chief objection to this particular type of silo is that experience has shown the cost to be, under most circumstances, unduly high, though undoubtedly, under favorable conditions, the cost can be so reduced as to make competition with other types of silos permissible.

The main advantages of the plastered silo are: first, it provides its own forms and shape; second, it furnishes its own reinforcing; third, this reinforcing is distributed evenly throughout the entire structure; fourth, it permits a very rapid method of construction; and fifth, it requires only a couple of men to erect the frame and but one to do the plastering. Practically the same scaffolding for the plastered silo is required as would be required for the block silo. The same foundation is used with the exception that properly spaced pins must be set in the foundation to which may be attached the metal lath.

The plastered silo is a modification or a development of the Gurler silo. The original Gurler silo consisted of wood studs set upon a foundation, the interior wall being covered with resawed sheathing, a special lath, and a layer of cement plaster, and the exterior covered with vertical boards, or horizontal, if desired. The modern plastered silo may contain either wood or metal studs, the latter being preferable though somewhat more expensive. Small I-beams can be used for this purpose. In place of the resawed siding used to stiffen the walls in the Gurler silo, flat metal bands may be used and riveted to the studs or as is very often the case, metal lath is used of a type which will give sufficient rigidity in itself. In such a case the metal lath is usually applied both on the interior and exterior of the studs and plastering is done on both sides so that the result is in effect a double-walled silo possessing a real dead air space which can not fail to have some value in the prevention of freezing.

The metal lath that is used in a silo of this type should be chosen to make sure of its durability. There are types of lath on the market which when placed in concrete soon change into a mass of rust. It is essential that the lath should be protected against corrosion; consequently, the plaster should be applied in a thick enough coat to form a heavy key so that all parts of the lath are covered.

The preparation of the plaster is very important. Several coats should be applied, the first coat being well scratched before the application of the succeeding ones. The composition is usually 1 part of cement to $2\frac{1}{2}$ parts of sand; sometimes the addition of 10 per cent of hydrated lime will make the plaster work more smoothly under the trowel and will keep it from drying too rapidly. All of the coats except the finishing coat should contain a small quantity of hair in order to prevent to as great an extent as possible the formation of cracks and to unite the stucco into one solid mass. It is common to apply three coats on the inside and two coats on the outside. The inside finish coat should, of course, be brought down very smooth in order to facilitate the even settling of the silage. The finish coat on the outside may be made in any one of the various ways in which the finish coat of stucco may be applied so as to obtain any desired surface effect.

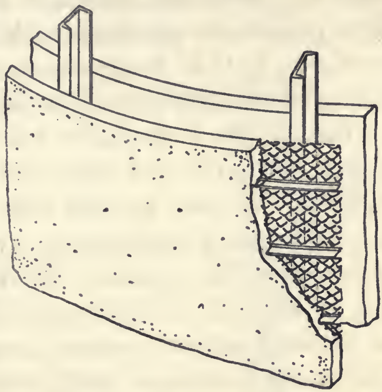


FIG. 77. — The Use of Metal in a Plastered Silo.

Fig. 77 illustrates the details of the construction of the walls of a plastered silo. When the materials are properly handled and when too rapid curing is prevented, there is no reason why a successful silo of this type cannot be made rather easily.

Pit Silos

The modern pit silo is a sort of reversion to earlier types. It is in use in the central West and other isolated instances where a sufficiently well-drained site is available. Almost perfect drainage of the site is absolutely necessary for the successful operation of a silo of this kind for, if the soil be at all moist and if there be a tendency for the accumulation of soil moisture, the pit, instead of being a silo, will be a cistern. When the conditions are advantageous, however, it is possible to construct a pit silo at an exceedingly low cost; in fact, in some instances, the cost of a moderate size of pit silo has been as low as $30.

The pit silo is in reality a form of the plastered silo in which the earth wall takes the place of the lath and its supports. It may be built entirely below the ground or it may be made a combination of pit and above-ground construction. The greatest difficulty attendant upon the use of a pit silo is in the removal of the silage itself; this is to some extent counterbalanced by the elimination of the blower or elevator which is necessary for conducting the silage into an ordinary silo, and the power required to perform this operation. All that is necessary with the pit silo is to cut the material into the proper-sized pieces and let them fall into the pit. It is possible to arrange an adaptation of the ordinary hay hoist for the pit silo, the silage being loaded into buckets, raised to the top of the silo, and then conducted away on a carrier to the place where it is fed.

The danger of asphyxiation from carbonic acid gas which is formed during the process of silage fermentation is particularly great with the pit silo. This poisonous gas is given off in considerable quantity and since it is heavier than air will occupy a position next to the silage itself. It is usually given off to an appreciable extent only during the first two or three weeks immediately subsequent to the filling of the silo. With the ordinary silo above ground, the presence of the door openings permits the easy escape of this gas but in the pit silo it is imprisoned and there is no means of readily eliminating it; consequently, great care should be exercised in entering a pit silo, particularly just after the silage has been put into it.

In constructing a pit silo as illustrated in Fig. 78, the first step is to lay out a circle much the same as for the

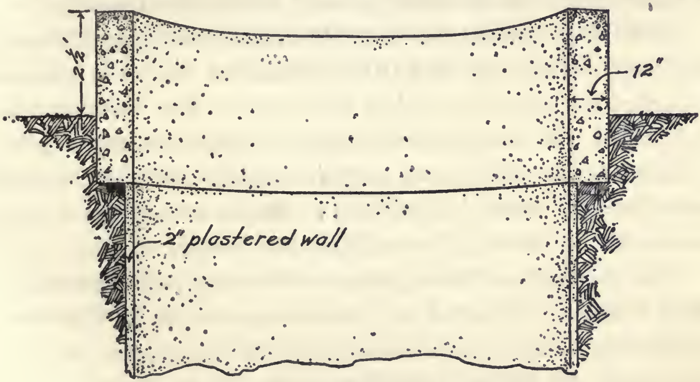


FIG. 78. — Construction of Pit Silo.

foundation of the ordinary silo. A trench is dug 1 foot deep and 1 foot wide, which is filled with concrete to the level of the ground, or preferably higher, for if it be brought up to a point 2½ or 3 feet above the surface of the ground, it will serve as a protecting medium, preventing danger of falling into the pit. When this concrete ring has hardened, excavation of the interior is begun and continued to a depth of perhaps 5 feet. Since a silo of this kind is practical only in dry regions, the chances are that the soil will be sufficiently firm to obviate the necessity of any shoring or bracing. A mixture of cement and sand in the proportions of 1 : 2½ is then applied to the earth wall in two or three coats or until the thickness of the concrete is 2 or 2½ inches. When this plaster has hardened somewhat, excavation is begun again and another 5-foot layer of earth is removed from the interior and the walls plastered as before. This process is continued until the desired depth of the pit is reached. Usually 20 to 25 feet is all that is required, though under exceptional circumstances a depth of 30 feet may be permissible. To go deeper than this greatly increases the danger of the admission of ground water into the silo.

Some sort of a floor is usually desirable, though if a hard firm clay be encountered at the bottom of the pit it may be puddled by mixing it with a little water, then tamped and smoothed off; when hard it will be found to serve quite satisfactorily. Of course, a roof is highly desirable to keep out the rain water; otherwise it would be difficult to remove the water which would fall into the pit.

The description that is given above is that of the method that is usually followed in the building of silos of this kind. The lateral pressure of the earth is usually not great enough to cause any danger of collapse, but where it is thought that there is any danger of such occurrences being possible, it is well to apply a reinforcement of heavy chicken netting in between the first and second coats of the plaster. This can be held in place by pins driven through the first coat into the surrounding earth until the second coat can be applied.

Monolithic Silos

In the monolithic type of concrete silo, we have what is perhaps the simplest and best known of all the various types. The word "monolithic" is derived from two Greek roots, meaning "one," and "stone"; consequently the literal meaning "single stone" gives in itself a description of what this type of silo actually is; namely, one single massive stone, annular in shape.

One advantage of the monolithic concrete silo is that the expense of construction is usually less than for any other type, since skilled mason labor is not required in its construction and since the work can be done on the spot with maximum rapidity. Since it is of mass construction the full strength of the concrete is utilized and the best opportunity is given for the placing of the reinforcing, both vertical and horizontal. It is perhaps more durable than any other type and it is perfectly reasonable to believe that nothing short of a violent earthquake will ever cause its destruction.

On the other hand, among the disadvantages may be enumerated the necessity of using forms, though the development of the modern types of commercial forms has rendered this objection almost negligible. The work of the construction of the monolithic type of silo should be, for best results, continuous and cannot be postponed so readily at any stage as can the work on the other types of silos. It is necessary that all the work in connection with the construction of a monolithic concrete silo be done at one time though this may or may not be a disadvantage, depending upon the circumstances.

Forms. — It is necessary in the construction of monolithic silos to have some sort of forms both for the interior and exterior face of the walls. These forms may be either homemade or purchased from some silo construction company. There are arguments in favor of each of these ways, though it is generally to be recommended that the commercial forms be used, especially if they can be used in the construction of a number of silos so that the form cost may be distributed and thus reduced. Homemade forms are usually constructed in such a way as not to be very durable. Even with good care, they are not likely to last through the construction of more than ten or a dozen silos, while the commercial forms, being very carefully developed in design and construction, will with proper care last almost indefinitely, since they are largely made of metal. Though the commercial forms are usually much more expensive than homemade forms, the form cost per silo is usually less with the former on account of their greater durability than homemade ones.

While it is generally not advisable to recommend the manufacture or use of homemade forms, the fact remains that many successful silos have been built with the use of them. One type of such forms has been widely used in Wisconsin and neighboring states with a considerable degree of satisfaction. The construction of these forms is a comparatively simple matter and the cost is reasonable, being $60 or $75 for a complete set. They usually have been durable enough to work satisfactorily on a dozen or more silos so that the cost per silo was not excessive.

The inner forms consist of a number of segments or ribs made of 2 × 12 plank which are fastened together at their junction by cleats of 2 × 6 stuff, over which thin galvanized sheet iron is placed. The outer form is made of heavy galvanized sheet iron with strips of heavy band iron riveted on each side of the joints, the ends near the joints turned out at right angles and provided with holes to receive the tightening bolts. Fig. 80 shows the plan of the homemade wall form and the details of the outside form. The position of the doubled 2 × 4 uprights upon which the form is raised is also shown. In using these forms, it is

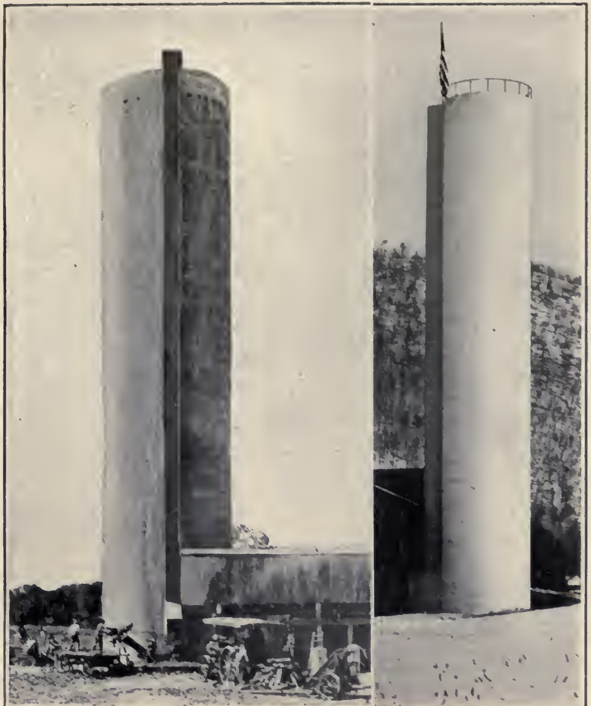


FIG. 79. — The Two Highest Silos in the World — 115 and 108 Feet High.

FIG. 81. — A Modern Metal Form for Monolithic Silo Construction.

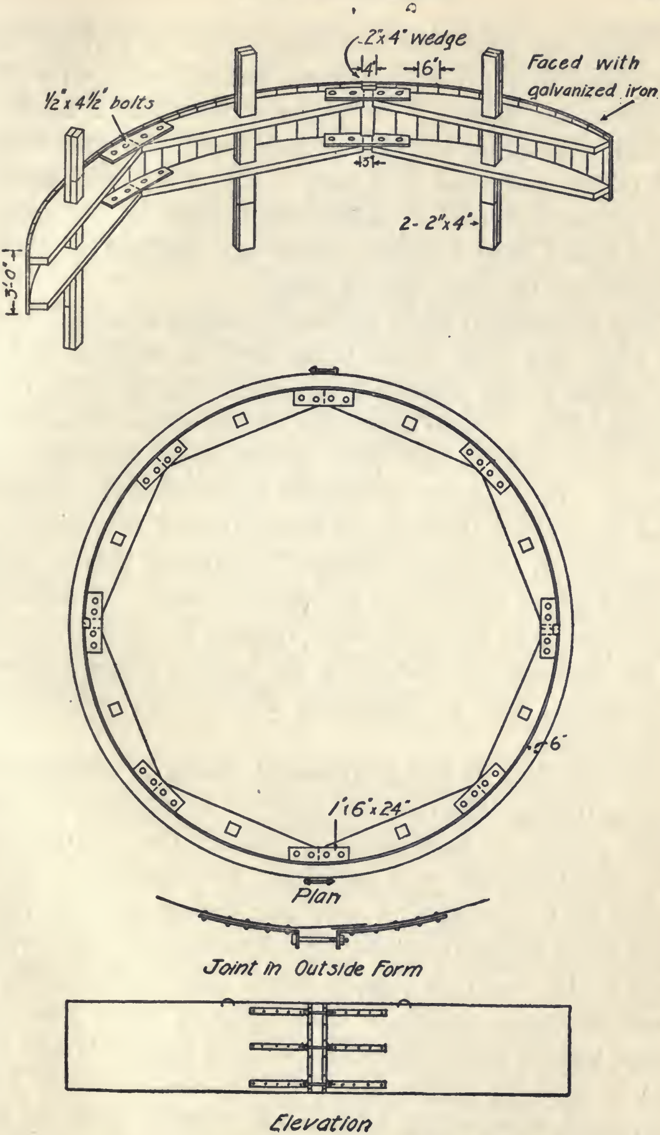


FIG. 80. — Homemade Forms for Monolithic Silos.

absolutely essential that the uprights be set carefully so that they will be absolutely plumb and will not bind when the forms are raised. The raising of the forms is accomplished by loosening the various segments of the inner form and raising them one at a time. The outer form, which may be made in several pieces, has attached on the upper edges heavy wire handles; ropes are fastened in these handles and the form is then raised.

Most commercial forms are made entirely of metal, both the inner and outer forms being made in sections which are braced at the edges and across the face by strap iron or angle iron. These forms are usually made in sections three feet high, though with certain types this may be greater. The majority of commercial forms have a central mast upon which the forms are raised, though one particular type has an especially designed combined derrick and scaffold which rests upon the concrete wall. Details for the operation of the commercial systems of forms are given in the literature published by the various manufacturing companies. Fig. 81 illustrates one of the commercial form systems.

The question of using homemade forms or commercial ones naturally brings up the point as to whether the silo itself should be homemade or whether the construction of it should be left to a competent silo contractor. It is a fact that a number of very fine homemade silos have been made which are giving perfect satisfaction, but when such is the case it is usually found that the builder is a good mechanic, skilled in other lines of work, who can adapt himself to the particular work in hand. Where the silo is built by inexperienced hands, unsatisfactory jobs very often result which bring much discredit upon the silo itself. It is usually very desirable indeed to let an experienced silo contractor undertake the task of building the silo. He is equipped with the best in the way of forms, hoists, and mixers, has built enough silos so that he can handle his forms with facility and can usually guarantee that a successful job will be the outcome. Most silo contractors guarantee the quality of their work. In fact, the writer knows of one contractor who guarantees his silos absolutely, even going so far as to offer the return of the cost of the silo to the owner if the walls are an inch out of plumb. Then too, a silo contractor can usually, since he has experienced workmen, put up the silo in a shorter time than can the inexperienced men. As a result, it is cheaper to employ the contractor even if one knows that his charges include his profit.

Reinforcement. — Two types of reinforcement are in general use in monolithic concrete silos; namely, the triangular mesh reinforcing and the simple rod reinforcing. The triangular mesh reinforcing is a type of woven wire reinforcing that has been developed especially to meet the needs of the purpose for which it is used. The wires in this reinforcing extend horizontally, vertically, and diagonally so that all the internal strains and stresses to which the concrete is likely to be subjected can be taken care of in the most economical manner. The horizontal wires are, of course, the heaviest. The placing of this reinforcement is a comparatively simple matter since it comes in rolls of a width usually 2 inches greater than the height of the course of concrete that will be placed in one day. The extra two inches in the width is for the purpose of lapping the reinforcing in adjacent courses. If this woven reinforcing is not used, rod reinforcing will be used, and this consists of various sizes, depending upon their location in the wall of the silo; the number of rods and their size will naturally be greater at the bottom of the silo than at the top of the wall. If rod reinforcement is used, care must be taken to see that it is clean and free from dirt and grease and that when a single length of rod is not sufficient to reach over the space required it should be lapped over the next rod a distance of 64 times its diameter.

Height. — Monolithic silos permit of greater height in their construction than any other type since all that is necessary is to put in sufficient reinforcing and make provision for the raising of the forms to the required height. In days gone by, before the era of this type of silo, it was generally assumed that the best ratio of dimensions was a height from two to two and one-half times the diameter. With the advent of better forms and better understood construction methods, it developed that the relative dimensions could be changed to advantage and it is now common to build monolithic concrete silos in which the height is four or five times the diameter.

There is no question but that high silos make and preserve silage better than those where the ratio of height to diameter is low; also that tall silos have a relatively greater capacity owing to the extreme compaction resulting from the weight of the pile of silage. It is this feature undoubtedly that has led many builders to build extraordinarily high silos, but there is some question as to the entire advisability of this procedure.

One of the disadvantages of an extremely high silo is the height to which the silage must be lifted; where the height is more than 75 or 80 feet this is a very serious problem, though companies manufacturing silage cutters and blowers have usually been able to solve it without great difficulty. Then too, there is a point in the height of the silo beyond which the contractor's outfit, organization, and construction methods begin to fall off in efficiency; that is, it may be more profitable for him to take his forms down and start a new additional silo rather than to cause a decrease in his profits, not to speak of the likelihood of loss which might actually result by building beyond a certain maximum height. Construction difficulties are proportionately greater at unusual heights and the risks taken both to equipment and to men are proportionately greater.

It is not only to the contractor that this applies for the owner of the silo may find that the same points may be applied in a somewhat different way to his own case, in the labor of removing the silage, greater cost for the additional reinforcing necessary, etc. The foundation will have to be constructed with unduly heavy footings and care must be exercised to see that the soil is of such condition as to bear the immense weight which will come upon it. Under certain seasonal conditions, the silage will contain a very high percentage of water. This may collect in the bottom of the silo to such an extent as to strain the concrete in a way similar to hydrostatic pressure and this, of course, is in excess of the strain for which concrete is designed. On the whole, it is an open question whether the construction of extremely high silos is altogether desirable, though where more than ordinary height is necessary, monolithic concrete is the most successful solution of the proposition.

Foundation. — The foundation of a monolithic concrete silo is constructed as an ordinary silo foundation with the exception of the insertion of vertical reinforcing rods into the foundation wall. These are left to project up into the wall itself, thus forming between the foundation and the wall an extremely good union. The interior form for the construction of the silo wall can very well be the interior for the construction of the foundation. With most commercial forms the forms themselves are supported and rest upon a central mast and it is necessary for good construction to have this mast very firmly and solidly planted and guyed into a perfectly vertical position.

Walls. — The walls of monolithic silos are almost universally constructed 6 inches thick, the same thickness being employed from the bottom to the top of the wall, any necessary change in resistance to strain being accomplished by changing the amount of reinforcing to be imbedded in the wall. When the foundation wall has been finished, the inner and outer wall forms are placed in position. These forms are usually 3 to 6 feet in height and the amount of concrete that will be placed in one day will be a layer 3 to 6 feet in depth. The reinforcing rods which have been previously placed in the foundation wall will extend up vertically between the two sets of forms and the concrete should be placed around them.

The mixture that is used in monolithic walls is a medium mixture of perhaps a 1:2:4 proportion, though where screened pebbles are used a determination should be made of the proper proportions to be used as they will generally vary somewhat from the arbitrary proportion just given. The mixture should be mixed to a rather wet consistency since a great deal of tamping will not be possible and the concrete should flow around the reinforcing and up against the forms. A little tamping may be desirable and if the aggregate is somewhat large, spading may be practiced with advantage; that is, inserting a flat spade near the form and bending it inwards pushing the large particles of the aggregate away from the wall and permitting the inflow of the finer material, thus resulting in a denser mixture at the surface where its presence is desirable.

Amount of Materials Necessary for a Silo Wall 1 Foot in Height and 6 Inches Thick Made of a 1 : 2 : 4 Mixture

Dia. in Ft.	Bbls. Cement	Cu. Yds. Sand	Cu. Yds. Gravel
8	.78	.23	.46
10	.96	.30	.60
12	1.14	.36	.72
14	1.32	.42	.84
16	1.50	.47	.94
18	1.68	.53	1.06
20	1.87	.59	1.18

After the forms have been once filled, the concrete is left in them to harden overnight; usually 24 hours is sufficient to permit of the raising of the forms. They are then loosened at the connections and then raised almost their full height, the concrete being made to serve as a bottom for the next layer. As the concrete is exposed any unsightly holes or cavities that have occurred should be filled with a cement mortar.

Immediately before the concrete is placed for each succeeding course, the surface of the concrete that has been previously laid should be thoroughly cleaned off, moistened, and coated with a cement wash of about the consistency of cream. This precaution is necessary to secure a good bond between the courses and should be carefully observed in every case as the pressure of the silage is apt to force moisture through any seam which might occur because of imperfect bond. Concreting should not be discontinued with a course partially completed but if this is unavoidable the concrete surface should be left as nearly vertical as possible.

The form for the exterior face of the wall should be coated with some form of oil or grease to prevent its adhesion to the concrete. This, to be effective, should be renewed at each raising of the forms. No grease should be used on the inside form because the interior face of the wall is to receive a brush coat of cement wash and for the successful union of the wash and the wall, no impurities must be present. Small particles of cement will adhere to the inside form each time it is raised, though with care in handling the forms the amount of cement thus adhering will be very small indeed. Before the forms are used again, all such adhering cement should be very carefully removed by means of a broom or wooden trowel; if it is not removed, difficulty in raising the interior form will result and the forms themselves will be injured.

The forms are usually quite heavy; consequently they should not be raised unless sufficient help is at hand to insure their being moved undamaged. An experienced contractor usually has sufficient men on the job to accomplish this and by long experience they have learned to handle the forms with a minimum of effort and of danger to themselves and the forms.

As the forms are moved and raised upward each day, there will be a tendency for too rapid drying of the concrete in the courses that have been laid earlier, thus giving an opportunity for the formation of shrinkage cracks. A good builder will usually give both the interior and exterior walls of the concrete a soaking with water each day. This will help materially in accomplishing a uniform development of the inherent strength of the concrete.

For the purpose of making the exterior wall of the silo more handsome in appearance, it is usually gone over with a coating of cement wash. This may be done as fast as the forms are raised or it may be done after the whole silo is finished, the latter being perhaps the most satisfactory plan. The oil or grease from the forms may interfere with this to some extent, but if the cement wash is not applied until the silo is finished, the oil will usually have evaporated and no great trouble will be experienced from this source. The wash should be made of cement and water and applied thickly with a whitewash brush. It will help to make the concrete denser at the exterior and consequently more waterproof and will also greatly improve the appearance.

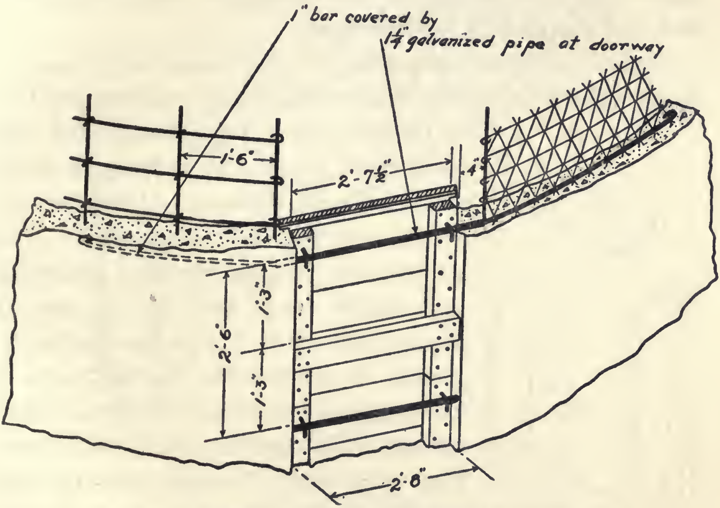


FIG. 82. — Monolithic Silo Wall and Reinforcement.

Care must be taken to locate the reinforcement accurately. If the woven reinforcement is used, it must be placed near the outside wall in order to get the greatest advantage from it. Usually, a distance of 2 inches from the exterior of the wall is satisfactory since it insures adequate protection of the metal. Horizontal and vertical reinforcing must be put in with strict regard to its location.

This must be very carefully worked out before the silo is built and whenever the reinforcing should be put in it must be put in at that place. Carelessness in this respect is responsible for silo failures which might otherwise have been avoided. The horizontal reinforcing may be laid directly upon the concrete when a layer of sufficient thickness has been placed or it may be bound to the vertical reinforcing rods by light tie wires.

Fig. 82 illustrates details of the construction of walls of monolithic silos with both the triangular mesh reinforcing and the simple rod reinforcement.

Doors. — Either individual or continuous doors can be employed with the monolithic silos though modern practice is inclined very strongly toward the continuous type. If individual doors are to be used, a doorway form such as is shown in Fig. 83 is employed. It is set into the concrete between the inside and outside forms and the concrete is poured around it. The two-inch strip around the edge of the doorway form is set toward the inside and forms a rabbet against which the door may be placed. The reinforcing through the concrete between the doors must be heavy enough to take all the strain that will come upon this section of the concrete; that is, the cross-sectional area of the steel between the doors must be as great as the total cross-sectional area of all the steel in the silo wall between similar points on adjacent doors. When this precaution is taken, there will be no danger of cracking between the doors and the strength of the silo wall will be unimpaired.

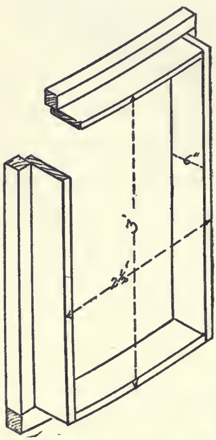


FIG. 83. — Individual Doorway Form.

When continuous doorways are to be used, a partition block consisting of a 2″ × 6″ plank with a 2″ × 2″ strip on one side may be set in between the forms. This is shown in Fig. 84. Holes can be bored through this plank, and the plank sawed across the holes into sections to admit of the passage of the necessary reinforcing rods. Instead of

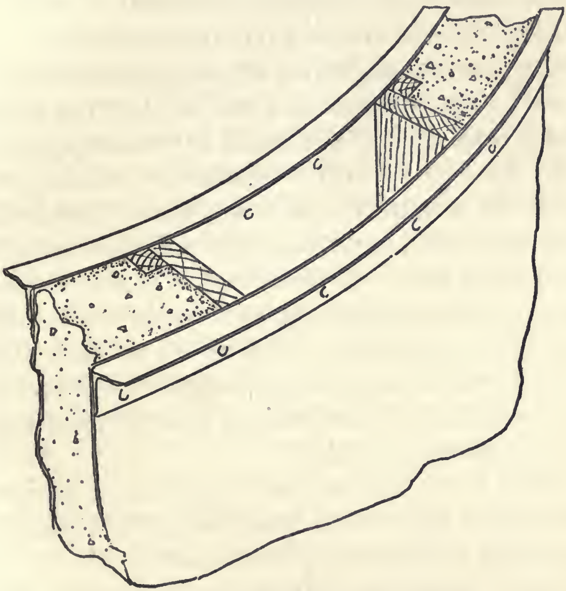


FIG. 84. — Form for Continuous Doorway.

having every reinforcing rod pass across the doorway, it will be necessary to hook the ends of the horizontal reinforcing around a heavy, vertical reinforcing bar near the edge of the doorway. At intervals of 30 inches or so heavy reinforcing rods covered by galvanized iron pipe are passed across the doorway and extended in to the wall for a distance of two or three feet, there to be hooked around the reinforcing. The pipes should be long enough to extend several inches into the concrete on either side. With the cross bars on the cleats of the doors, they will form the steps of the ladder which is used for mounting the silo. The details of this construction are shown in Fig. 82.

Roofs

With a concrete silo, it would be natural to assume that the most desirable form of roof is the concrete roof. Various ways have been developed for the construction of the concrete roof so that the cost of a roof of this type is usually no greater than the cost of a metal or wood roof, and when properly handled perfectly satisfactory results can be obtained. In making the silo roof, a trap door should be provided into which the blower pipe may be inserted when the silo is being filled. A better way is to put this opening in the front of a small gable since it makes better construction and better appearance. Two gables are more desirable than one, for the opening in the second one will provide a means of ventilation when the silo is being filled near the top and all the doors are in.

The pitch of the silo roof may vary from a quarter to a half, the advantage of the latter being the possibility of filling the silo above the top of the wall so that it will be more nearly full after settling has occurred. The disadvantage of a flat roof is that the silo can not be filled so full nor is the workman given room for work during filling. Such a roof, of course, will not shed snow or rain like a steeper roof.

There are many commercial roof forms on the market and their use is generally to be recommended. It is also possible to build up a wood or steel framework and fasten metal lath upon it, then apply a waterproof cement plaster to a total thickness of about 3 inches upon this lath, making a construction very similar to that employed for the plastered silo.

If no commercial forms are available and it is desired to use a cast type of construction in the construction of the roof, a method shown in Fig. 85 may be employed. The inner form is raised a little bit higher than the outer form and is used to support the framework of the form for the roof. Upon the outer form is supported a form for the cornice which may project anywhere from 4 to 8 inches, depending upon the desires of the builder. The vertical reinforcing rods should extend up through the silo wall for a distance of two or three feet and when the wood form for the roof has been put in place, these rods should be bent down so as to lie within 1 inch of the boards. A rich mixture of concrete is then spread upon the boards to a depth of not less than 4 inches. Reinforcing rods extending radially from the peak of the roof into the cornice must be put in place; $\frac{1}{4}$-inch rods will be large enough for silos of small diameter while $\frac{3}{8}$-inch rods are better for larger diameters; they should extend into the cornice at intervals of 12 inches. The horizontal reinforcing is laid in a circular position around the roof, the spacing at the apex being 12 inches and being gradually decreased to 6 inches at the outer circumference. At every junction of the radial and circular reinforcing, the rods should be securely tied together with light wire. The forms for the roof should be left in place as long as possible and special precautions taken to protect the concrete from snow, strong wind, and freezing until it is thoroughly hardened.

A monolithic roof can be very easily located upon the top of a concrete block silo. The framing for the forms can be supported upon the interior of the blocks themselves which can be set out so as to leave a little projecting edge

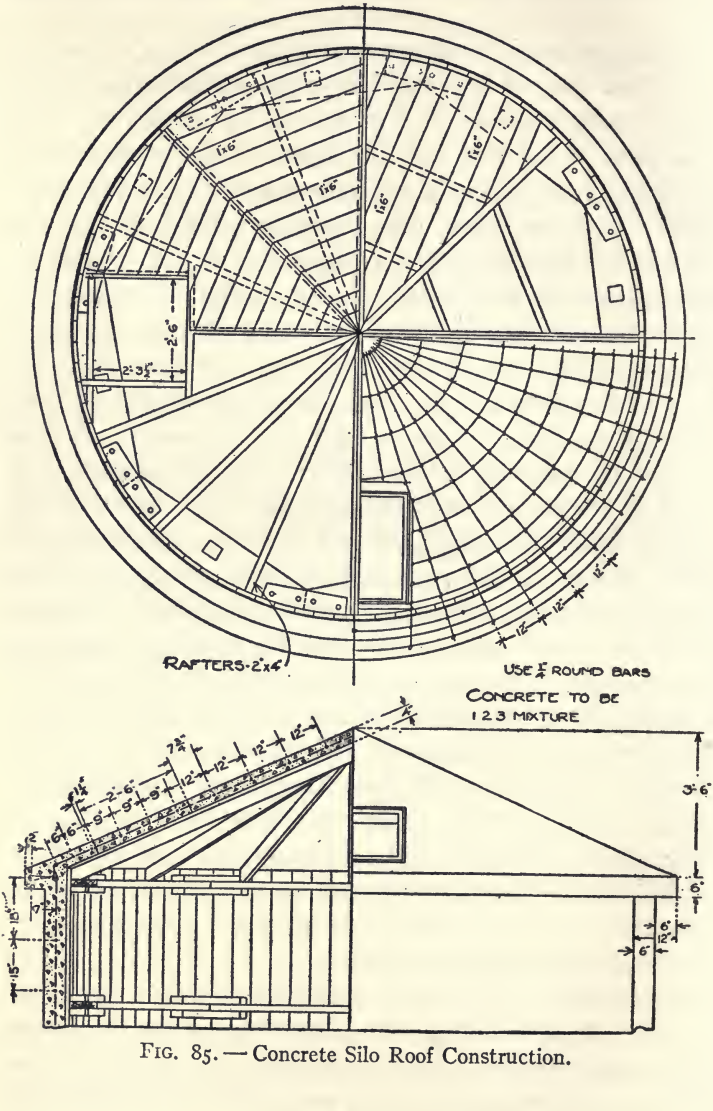


FIG. 85. — Concrete Silo Roof Construction.

for the support of the framing pieces. Some sort of a cornice form will have to be provided but this can be very easily attached to the exterior of the blocks. The method of construction and reinforcing will otherwise be practically the same as for monolithic silos.

Chutes

Almost all monolithic silos that are constructed at the present time are being constructed in such a way as to have the chute built integral with the walls of the silo, this being accomplished by having specially prepared chute forms attached to the regular wall forms. The thickness of the chute wall is usually 4 inches in such a case and the reinforcing consists of $\frac{1}{4}$-inch bars at frequent intervals. These bars are brought up into the space between the wall forms and are anchored to the reinforcing of the body of the silo wall. Such chutes are entirely satisfactory and their use is to be recommended.

With concrete block silos, thin blocks can be used in the construction of the chute. It is necessary to build up from the ground at least two of the walls, in order to provide support for the blocks from which the chute is built. Since there is no great weight or strain to which the blocks in the chute are subjected, there is no need for an especially strong block.

As with concrete roofs for concrete silos, so with concrete chutes, — their use is the most logical. They are simply a permanent addition to an already permanent structure and their cost is generally no greater than that of wood or metal construction. A desirable feature of any type of chute is an occasional window whereby light is admitted to an interior which otherwise may be dark.

Water Tanks

The top of a monolithic silo is a convenient place for the farm water supply tank and many builders are taking advantage of this location for a source of water supply under pressure. In monolithic silos it is very easy indeed to put in a floor when a certain height has been reached, then to continue the construction of the walls until the desired depth of the tank has been obtained. With a silo 12 feet in diameter, a tank 5 feet deep will hold approximately 135 barrels; with diameters of 14 and 16 feet, the corresponding capacities will be 185 and 240 barrels respectively. The usual depth does not exceed 10 feet, though deeper tanks have been built.

It must be remembered that with a tank of this size on the top of the silo, the concrete is subjected to tremendous additional strain and additional reinforcing should be placed in the wall. If a continuous doorway is used, this must be bridged by a strong bridge of concrete across the top before the concrete floor is laid.

As soon as the wall has been brought up to the level of the tank floor, the outer form should be raised 1 foot and the inner form lowered 1 foot. A heavily braced platform which will support the concrete floor should then be erected upon the inner form. Two-inch planks are necessary in the construction of the form for the floor and these should be supported on 2 × 10 inch girders very strongly braced. The greatest caution must be exercised in putting up this form in such a way that it will carry the load without danger of collapse.

The entire floor must be concreted at one operation in order to make a satisfactory job. The necessary materials must be on hand and provision made for mixing large batches and for rapid elevation. A rich mixture of concrete is used, for it is necessary that the floor be practically waterproof. The floor must also be very strongly reinforced, the rods, consisting of $\frac{3}{8}$- or $\frac{1}{2}$-inch stuff, being placed from 4 to 8 inches apart. The spacing at the center should be rather close and widened as the edge of the floor is reached. The reinforcing should extend in two directions and up into the wall for a distance of at least 2 feet, being joined to the horizontal wall reinforcing. In a silo 12 feet in diameter, the floor should be not less than 8 inches thick, while in 14- or 16-foot silos, the thickness should be 10 inches. After the floor has been finished, the forms for the walls may be again erected above the floor and the walls of the tank completed.

One difficulty attendant upon the construction of water tanks in this location is that of providing an inlet and outlet. Of course, a force pump of sufficient capacity to raise the water to the desired height must be supplied. In wintertime there is danger of both the inlet and the outlet pipes freezing, and for this reason it is necessary to protect them very thoroughly. Some builders place them within the silo, but this is unsatisfactory for several reasons. The better practice, and one that is usually followed, is to make the chute a little larger than usual and to set off one corner of it for the water pipes. These are then very carefully packed with some insulating material.

In large supply tanks where the water is continually agitated the water seldom freezes sufficiently to damage the tank. However, it is safer to build the tank with a slight batter all around; that is, making the inside diameter greater at the top than at the bottom. This batter should be about 1 inch for every foot in height. When the ice does form, in expanding it will rise upward and a direct lateral pressure which might otherwise be communicated to the walls and possibly injure them is transmitted into a harmless upward thrust.

As an additional precaution against freezing and to protect the water from pollution it is almost necessary to put a roof over the tank. This can be constructed as previously described for the silo itself.

CHAPTER X

CONCRETE SURFACES AND STUCCO

In order to take the fullest advantage of concrete as a building material, it is at times necessary to subject the surface to certain treatments that will result in the presentation of the most pleasing appearance. No matter how suitable a material may be in other respects, unless it does present a pleasing appearance on the exposed surfaces, its field of usefulness as a building material is limited. To the general mind, the ordinary untreated concrete surface is objectionable on account of its comparatively lifeless appearance which is due more or less to its dull color. Under many circumstances this would not be an objection, but in the construction of residences and other buildings where an artistic keynote must be struck, the untreated concrete surface may be found to be unsatisfactory. This fault of concrete was early recognized and the development of the methods for the proper finishing of concrete surfaces so as to bring out the most pleasing and artistic effects has been in recent years rather rapid. There is no question but what properly treated concrete can be made to present more varieties of pleasing and attractive surfaces than almost any other building material.

Variation in Texture. — Almost any statement that can be made regarding stone as a building material will apply with equal pertinence to concrete, because when it is so desired concrete can be made by the use of proper mixtures and aggregate in almost perfect imitation of common building stones. It is possible to treat the concrete as an artificial stone and finish its surface in the same manner that stone surfaces are finished. When it is proposed to use this method of rendering the concrete more attractive, it will be found advisable to use a comparatively fine aggregate in order that the uniformity of the texture may be more easily maintained; almost every one has seen statuary not only cast in molds but carved from blocks of solid concrete. It will also be necessary to use a comparatively rich mixture so that the concrete will be as dense and hard as possible. The various stone-working tools that are used by the stone mason will be used in the same way in the preparation of corresponding finishes in the concrete. It may be possible to get a satisfactory surface by using extreme care in the arrangement of the forms without any subsequent tooling but this is quite doubtful because concrete is an extremely plastic substance and the slightest imperfections and irregularities in form surfaces are faithfully reproduced in the concrete; consequently unsightly surfaces may be the result instead of attractive ones.

Exposure of Aggregate. — Mixtures of concrete can be made using an aggregate which exhibits the greatest difference in color, shape, and texture, but unless they are so treated as to expose and emphasize the inherent qualities of the aggregate, the surfaces resulting from the different aggregates may be exactly similar in superficial appearance. This is due to the fact that the particles of cement coat every portion of the concrete and while there may be some resulting variation in texture, still the surfaces will possess the same somber, grayish color. It is quite difficult to distinguish an unfinished concrete surface in which ordinary bank run gravel is used as an aggregate from one in which crushed red granite, for example, is used; but the same surfaces if subjected to any one or a number of different methods of surface treatment will present a marked and pleasing contrast in appearance.

There are various ways in which this film of cement may be removed from the surface of the aggregate and leave it exposed. Among these are brushing by means of a stiff brush of fiber or wire; washing the concrete before it is hardened so as to remove the particles of green cement; applying dilute hydrochloric acid, subsequently giving it a thorough rinsing; or using the sand blast after the concrete has hardened sufficiently to withstand its destructive action. The first thing in the preparation of a surface by this method is to make and finish a small sample surface in order that an exact idea may be had of what the completed product will resemble. The color and texture of the finished surface depends upon the color and size of the aggregates used, and the obtaining of an attractive surface is dependent upon the proper selection, grading, proportioning, mixing, and placing of the materials as well as the finishing of the surface; therefore it is imperative that care be taken in every operation from the very first. After certain proportions have been decided upon, these particular aggregates which make up the mixture should be used exclusively with absolutely no variation from the set formula. It will be found profitable to measure not only the amount of cement and aggregate but the amount of water which produces the desired consistency, for a variation in the amount of water is likely to produce a variation in the appearance of the finished surface.

A variation in the kind, size, and proportion of the aggregate will enable one to produce almost any surface finish desired. The possibilities are limited only by the number of different aggregates available and their possible combinations. Combinations of colored marbles or granites can be used with surprisingly attractive results. Even ordinary sand or gravel which is carefully graded as to size and to which may be added small quantities of special, fine aggregates will furnish very bright and attractive finishes.

Where brushing is the method to be used in the removal of the film of mortar it is necessary that the forms be removed as quickly as possible so that the brushing can be done while the surface is still green. The time elapsing before the removal of the forms will depend to a great extent upon the consistency of the mixture and upon weather conditions. In hot, dry weather it will usually be found necessary to remove the forms about 24 hours after the concrete has been placed, while cool damp weather may require several days for the concrete to obtain the necessary hardness and strength to support itself and to resist the tendency of the brushing to remove the aggregate. Special care must be taken to avoid the latter contingency, for, should particles of the aggregate be torn loose, the surface resulting will be pitted and irregular. On the other hand, it must be remembered that the longer the concrete stands before being brushed, the more difficult will it be to remove the mortar film. The brush used in this work may be an ordinary short-bristled wire brush in which the bristles are not too closely placed. Stiff fiber brushes may be used when the concrete is not too hard. By keeping the concrete thoroughly wet, the work may be greatly facilitated.

On work of fine texture, it is possible that the brushing necessary to remove the mortar film may be so vigorous as to remove a high percentage of the particles of the aggregate. Under circumstances such as these, the application of a 25 per cent solution of hydrochloric acid may be found to be more effective. Even in the ordinary brushed surface, the appearance of the work can sometimes be improved by applying the dilute acid. Extreme care must be exercised in the use of the acid solution to prevent its action being too long continued and every trace of the acid should be removed by an abundant application of water after the softened surface has been gone over with the brush. The adhesion of a small quantity of the acid, no matter how dilute, is likely to cause a mottled, dirty appearance. The acid, when properly used, will add in making the appearance of the surface uniform, particularly if it is a large one and has been brushed in spots or at different times. The hydrochloric acid is likely to discolor concrete in which white cement or white aggregates are used. In such a case, a sulphuric acid solution of the same degree of dilution can be used, taking extreme precaution to be absolutely certain that all traces of the acid are removed when the work is finished.

Sand blasting a surface of concrete to produce a different texture is not a method that is likely to be employed to any great extent except on large structures. In this method, a fine sand is blown under high pressure against the surface to be treated. This will cut out the softer particles of the surface leaving hard ones as elevations. It follows that it will be necessary to use an extremely hard aggregate where sand blasting is resorted to or otherwise the aggregate itself might be removed and undesirable results obtained.

Another method whereby the colors of the aggregate may be exposed is to remove the forms when the concrete has set somewhat and rub the surface with a brick of carborundum or soft stone. The abrasive action removes the cement film covering the outer aggregate and also cuts into the aggregate itself. Sometimes, in connection with the rubbing, a thin grout composed of cement and sand should be applied to the surface, rubbed in, and after a few hours of hardening, washed down with clean water. It is not supposed that the grout should remain as a film on the surface. Where care has been taken to keep the surface of the wall uniform and where the form marks are not too deep, this method is a very suitable and economical method of finishing.

Breaking Up of Surface. — There is no doubt but that a broad expanse of natural concrete surface is monotonous in appearance; there are no opportunities for contrast and as a result the surface appears dead in tone. This objection can, to some extent, be obviated by breaking up the surface of the concrete by means of pilasters and panels either alone or in combination. If small aggregates are used, a great variation in treatment may be obtained by the use of special moldings and ornamental designs. This will so relieve the surface as to render attractive what might otherwise have been extremely unattractive. Very often the simple design of breaking the surface up by means of joints in imitation of the joints in stone masonry may be found attractive, the joints being simply indentations in the surface produced by small triangular or rectangular strips of boards nailed to the forms. This device will be found useful in work that is impossible to carry on continuously. The junction of two different days' work may be made at the occurrence of one of these joints and the slight variation in surface appearance which would be extremely likely to occur can be thus almost perfectly eliminated.

A similar effect of contrast can be obtained by an adaptation of the old English half timbering in which strips of wood are set in the forms and the concrete poured around them, the wood being exposed when the forms are removed. Of course, this procedure is open to objection because wood is a perishable material and it is likely to decay, leaving unsightly recesses. This objection is valid, but it is possible to so design the timbering as to make it replaceable.

Coloring. — The use of coloring matters for obtaining a variation in the surface appearance of concrete is a matter that has not in the past received the fullest attention that it deserves. There are two reasons for this; namely, ignorance on the part of the builder, and the fact that pigments cheap enough to be used economically in this work were not sufficiently durable. Surfaces which presented an attractive appearance at the time of their making soon became shabby and faded and as a result have not become very popular. A much more satisfactory method of obtaining a colored surface of concrete is to use aggregates of the desired color. Such a surface may be considered as permanent, for when properly produced it will not deteriorate, fade, scale, or require renewing.

In mixing coloring pigments with the concrete, they may be applied to the entire body of the concrete or as surface colorings. It is also possible to use what might be termed a combination of these two methods; that is, to apply a comparatively thin facing coat to which the coloring matter has been added, leaving the main body of the concrete of the ordinary mixture. Some pigments can be used more satisfactorily in dry form; others as a paste. However, in general, the most satisfactory results seem to be obtained when the coloring matter is first mixed very thoroughly with the dry cement and this mixture mixed dry with the aggregate before any water is added. Of course, if liquid or paste colorings are used, it will be necessary to add the pigments to the mixing water.

Most of the ordinary pigments that can be used in concrete are acted upon injuriously by the constituents of the cement. Vegetable colors are more injurious than mineral ones; consequently, for the best results only the latter should be used. It has been found that the strength of the mixture is impaired by a too liberal use of pigments, the latter acting as impurities; consequently, great care should be used in the selection of the pigments to obtain the desired shade by the use of a small amount of an enduring pigment rather than by the use of a large quantity of a cheap injurious one.

One of the most important questions and one that is bound to arise whenever the use of coloring matter in cement is contemplated, is that of permanence. Blacks are safe colors, as a rule, although it is better to avoid experiments with cheap blacks. The carbon blacks are preferable to lampblacks, because they do not have the same tendency to float to the top during mixing. There are fewer grades of carbon blacks, and there is, therefore, less likelihood of getting a worthless color. Ultramarine blue, if of good quality, will hold its color for a number of years, and generally possesses the virtue of fading out evenly, when it does finally lose its color. It cannot be classed as a permanent color, as is black, brown, or ochre.

In surface coloring the coloring material is applied in much the manner in which ordinary paint is applied to wood or metal surfaces. While the immediate results are satisfactory, the finish is not durable since the surface is likely to weather badly and be less durable than ordinary paint. If such a means of coloring is to be utilized, it is well to get the materials from well-established, reliable companies and to use applications which have been prepared for this particular purpose.

TABLE OF COLORS TO BE USED IN PORTLAND CEMENT

COLOR DESIRED	COMMERCIAL NAMES OF COLORS FOR USE IN CEMENT	APPROXIMATE PRICES PER LB. IN 100 LB. LOTS FOR HIGH GRADE COLORS	LBS. OF COLOR REQUIRED FOR EACH BAG OF CEMENT TO SECURE	
			Light Shade	Medium Shade
Grays, blue-black and black . .	Germantown lampblack	10 cts.	½	1
	Carbon black	8 cts.	½	1
	Black oxide of manganese	6 cts.	1	2
Blue shade . .	Ultramarine blue	18 cts.	5	10
Brownish red to dull brick red .	Red oxide or iron	3 cts.	5	10
Bright red to vermilion . . .	Mineral turkey red	15 cts.	5	10
Red sandstone to purplish red .	Indian red	10 cts.	5	10
Brown to reddish brown . . .	Metallic brown (oxide)	4 cts.	5	10
Buff, colonial tint, and yellow . .	Yellow ochre	6 cts.	5	10
Green shade . .	Chromium oxide	26 cts.	5	10

(Portland Cement Association)

STUCCO

Stucco has been used to a greater or less extent in building construction for ages. Greeks and Romans were experts in its application and some of the finest examples of inlaid tile work to-day are in stucco surfaces. In this country, the use of stucco dates back to some of our earliest structures. Many of the adobe houses of Mexico and the southwestern part of the United States are finished with a sort of stucco made of puddled mud plaster. The old mission houses of this region have stucco exteriors. In European countries, stucco or plastered houses are more common than frame, probably because lumber is comparatively scarce and because the appreciation of the beauty of plastered surfaces is greater than here.

The successful use of stucco has been mainly in warm, dry climates for in the past only mud plasters have been used. In damp climates or in climates where the weather extremes are unusually great, such material could not endure. The use of cement, however, has changed this and the architectural beauty which can be developed in the use of stucco can be enjoyed anywhere.

Modern cement stucco can be used for a variety of purposes, not only to provide wall covering for new buildings, but to renovate old frame, brick, and stone buildings. It is used in almost every kind of construction from garden walls and gate posts to large factories. It is particularly advantageous in the construction of small buildings for farm use since in combination with lath it makes a very easily handled building material.

Preparation. — Since stucco is applied in comparatively thin layers, it follows that quantities which cannot be applied before the cement has begun to set should not be mixed. The amount that is mixed will depend to a certain extent upon the character of the work in hand. Under most circumstances, the following procedure is usually desirable: hydrated lime or lime slaked by a mechanical process by which the moisture is driven off, is mixed with water to a medium consistency. A certain amount of sand is mixed with the lime putty, the proportions being

1 part of lime putty to 9 parts of sand. When the work is to proceed, the certain amount of the putty-sand mixture is taken, an equal volume of cement, and then sand equal in color to 1 or $1\frac{1}{2}$ times the cement. These ingredients are thoroughly mixed; the resulting product will contain $\frac{1}{10}$ as much lime as it does cement, while the approximate proportion of cement to sand will be 1 : 2. The purpose of the hydrated lime is to make the mixture work more easily under the trowel.

It is usual to apply a small quantity of clean hair in all but the finish coat. The amount of hair that should be used will be about 1 pound of hair to each bag of cement, the hair being added during the process of wet mixing. More mortar than can be used within one hour should not be mixed and any mortar which has begun to stiffen or take its initial set should not be used.

Application. — Stucco can be applied either to wood, brick, or stone surfaces, providing they have been previously properly prepared. In Fig. 86 is shown the method of applying stucco on frame buildings, three variations being shown. The application of stucco to a wall which has no sheathing is not generally to be recommended, since the building is not rigid enough to prevent the cracking of the stucco when racked by the wind. On brick walls, the joints are cleanly raked out to a depth of $\frac{1}{2}$ inch, thus furnishing a key for the stucco. The same general procedure is followed on old stone walls, though it is possible to attach furring strips and to apply lath upon which the stucco can be placed in the ordinary way.

Either wood or metal lath can be employed, there being strong proponents for each material. The objection to the use of wood lath is that the absorption of moisture from the stucco may result in its weakening; the wood will swell, which may cause the stucco to crack. Metal lath, on the other hand, while not open to this objection, is usually not very durable. If metal lath is used, it should be either galvanized after it has been cut or should

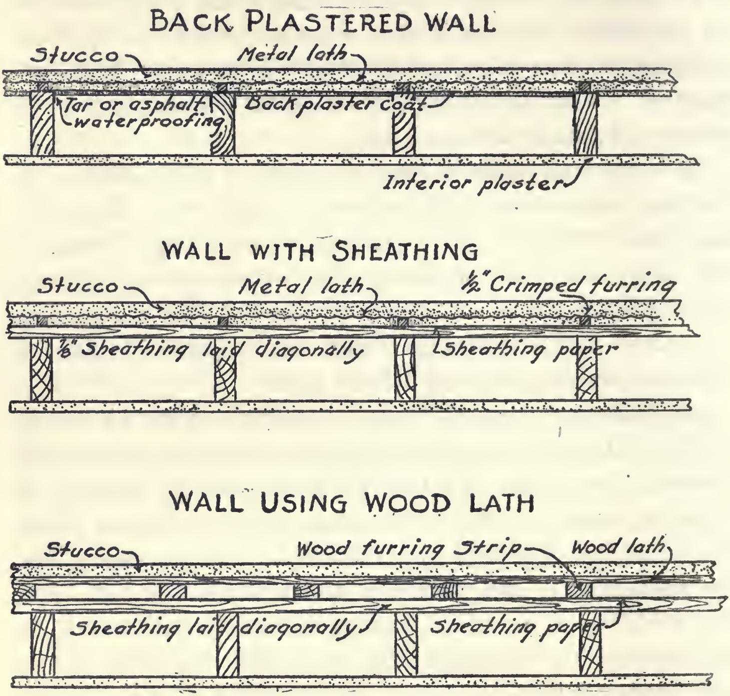


Fig. 86. — Application of Stucco to Frame Buildings.

be given a heavy coat of some bituminous paint to which the stucco will adhere.

The first coat should be of such a thickness as will cover the lath and fill the meshes; as soon as it has hardened a little, it should be scratched at right angles and at 45° to the horizontal by means of some kind of coarse multi-pointed tool. The purpose of the scratching is not to cut sharp lines in the plaster but rather to form grooves with ridges on the sides, this making a rough surface to receive the next coat.

The second coat, and in fact all subsequent coats, should be applied as soon as possible after the preceding one has hardened sufficiently to resist disruption. This will depend, of course, upon weather conditions; ordinarily it will be possible to apply the various coats at 3- or 4-hour intervals. Immediately before applying any coat, the preceding coat should be thoroughly drenched with water and then treated with a cement wash.

In plastering buildings the work should be so planned that if possible an entire wall of the structure can be covered with plaster in one day. In this way, the uniformity of the work can be more easily maintained. Stucco is a material in which any variation in materials, proportions, or consistency is inadvisable; consequently, extreme care should be taken to make all batches exactly alike. The application of the stucco should be begun at the top of the wall and carried downward continuously without allowing the stucco to dry at the raw lower edge. If the wall is so wide as to make it impossible to work the full width at one time, the break should be made, if possible, at some natural division, such as a door or window. In hot weather, the plastering should be protected from sun or drying winds by hanging cloth 6 inches or so away from the wall and keeping it damp until the plaster is well hardened when further dampening can be done by spraying with a hose.

Finishing. — Some of the various finishes which have been described previously for concrete walls can be applied to stucco walls. However, on account of the method of construction of stucco walls it is possible to use other finishes which may be more desirable. Among these are the following:

Smoothing. — This finish can be secured by troweling the finish coat to a smooth surface of even texture.

Brushing. — This surface is secured by rubbing vigorously with a wire brush after the smooth surface has hardened somewhat.

Rough Cast. — By using plasterer's trowels covered with burlap a rough finish coat may be obtained. The irregularity of the surface may be varied by using coarse grain sand.

Slap Dash. — This finish is one that requires expert ability in order to get it done well. A flat paddle is used to apply the layer and it is not spread but rather thrown on with a sweeping motion.

Pebble Dash. — The finish coat is applied rather wet and then clean pebbles from $\frac{1}{2}$ to $\frac{1}{4}$ of an inch in diameter are dashed against the wall at right angles to it. Not all the pebbles will adhere but the process should be continued until the surface has a certain regularity in its appearance.

Fig. 87. — A Handsome Residence of Poured Concrete.

Fig. 88. — A Monolithic Concrete House, Showing Variety in Treatment and Expression.

CHAPTER XI

CONCRETE IN RESIDENCES

Concrete, in its various forms, offers an excellent opportunity for the widest variety in expression in residence construction. Whether in the form of plaster, of blocks, of larger cast units, or solid monolithic construction, it is an exceedingly desirable building material, for it is economical, fireproof, adaptable, permanent, and with all the numerous variations in surface treatment that have been devised, it can be made extremely attractive. The prospective builder who realizes the advantages of permanent building construction will find in concrete a material that can be molded to suit almost every requirement.

The concrete house is rather elusive of definition, in consequence of the wide variety of construction methods. It is not *one kind* of house. Concrete is a universal material, and its variety of applications does not lag in realization through any inherent sameness in the material itself, either structurally or architecturally. The applications merely wait upon the desires of the owner and the skill of the architect and engineer to work them out.

Construction Methods

Plaster. — Everyone is familiar with the dwelling in which the exterior wall coating consists of a cement plaster or stucco. The particulars of the mixing and application of stucco have been given in a previous discussion. The best way to obtain beauty and durability in stucco, as in any concrete work, is to obtain the coöperation of practical minds, conversant with the physical properties of these materials, and of imaginative minds capable of picturing artistic possibilities, and willing to translate them into actualities. In cases where stucco has not achieved the success it deserves, the cause has usually been either the reluctance of architects to consider new materials that require special treatment, or the obstinate adherence of the average workman to his own notions and his insistence that the architect's specifications are of small importance, or both. The fact remains, however, that when conditions are favorable, stucco is successful.

A distinct advantage of stucco over other types of concrete construction is its flexibility in application. It can be applied any place a board can be used, and in many places that can be covered with wood only with difficulty, it can be applied with ease.

Concrete Blocks. — Blocks were used in these first residences in which the walls were constructed entirely of concrete. The ease with which the various sizes of blocks could be produced and placed, made them a very convenient type of building material, and numerous residences throughout the country bear evidence to its popularity. The fact that many blocks were molded in which no attempt was made to eliminate porosity and to combine strength and water-tightness served to decrease their value in the minds of many people who had experience with cold, damp, and crumbly walls. As a better understanding between producer and consumer came about, however, and better machines and construction methods were developed, more satisfactory blocks were produced, and probably more blocks are now being utilized than ever before.

Concrete blocks can be used advantageously in foundations and both exterior walls and interior partition walls; specially designed blocks can be used in combination with other materials in floor construction. They can be made of any desired size or shape, either solid or with hollow spaces. Where blocks are used for foundation walls, and appearance is not an influencing factor, no attempt need be made to provide an attractive surface. For exterior wall construction, however, the opposite is the case and considerable attention must be given to this point.

Cast Units. — The process of casting integral portions of the elements of a residence as single units is a comparatively new departure, but developments that have already been achieved seem to indicate that the future of this method of construction gives great promise. The idea is to take certain portions of the building, such as sections of the wall, window frames, floors, steps, etc., cast them separately in exterior forms, then set them in place by the use of cranes and hoists, making the joints tight by means of rich cement mortar. The main objection to the employment of this method is the weight of the various units that are cast. In factory construction or in the construction of any large building, this limitation would not hold because practically all problems that would arise in the handling of large pieces have already been solved by the engineers who have had to handle large steel structural members.

The entire process of manufacture, transportation, and erection involves only three necessary handlings of the units. After being poured from the mixer into the steel molds and partially hardened, the sections are lifted out upon false bottoms and finished while still green. As soon as they are hardened, they are lifted off of the false bottoms and placed on cars or trucks to be handled for the third time when they are picked up and set in their proper places in the building with an erecting crane. The actual time during which labor is put upon these sections, it is claimed, amounts to less than 5 hours. The minimum time for seasoning during which no labor is put upon them will vary from three days to one week, depending upon weather conditions and other factors.

It is doubtful whether a system of this kind can be used with any great degree of success on isolated structures. It is probably necessary for a contractor or engineer to possess a set of forms for the making of the various individual units in order that a number of structures might be completed and the form cost distributed between them. It might be possible to adapt the process to the construction of a series of small farm buildings other than residences in which case the molds would probably be less elaborate and the number of units cast likely to be greater.

All sorts of combinations and devices can be utilized in the unit cast form of construction, depending upon the requirements of the building to be constructed and the ingenuity of the builder. It is possible to finish both the exterior and the interior of the wall section, for the system contemplates the omission of lath, plaster, and the interior trim, variation in surface being secured by molding the sections in such a way as to form panels and self-contained moldings.

Monolithic Construction. — The monolithic method of wall construction is one which has engaged the attention of numerous competent engineers and is yet proving to be a splendid field for development. In this construction, the foundation, walls, and even the floors, roofs, and staircases are constructed of solid concrete in practically integral form, being reinforced, where needed, by the proper forms of steel. Numerous types of forms have been devised for construction along this line, some of them meeting with more than ordinary success. In practically every locality are to be found examples of residence construction in which the application is made of monolithic principles. The success has been quite uniform; practically every unsatisfactory job can be traced back to some fault in materials or workmanship.

In order to secure the greatest and best results from monolithic residence construction, it is desirable that a competent concrete engineer be employed in conjunction with the architect; the two working together will help each other in the combination of practical ideas with æsthetic opportunities. Many men will assume that their knowledge of concrete is sufficient to undertake the construction of an apparently simple project such as the construction of a house. However, there are many details entering into the idea which require very careful working out in order to achieve the most significant results and it is doubtful whether the amateur concrete contractor is able to handle a job of this kind with the assurance of a successful outcome. With proper guidance, however, in the way of sensible plans and efficient supervision, no fears need be felt on this score.

Monolithic walls may be either single or double in their construction, practice and experience favoring the latter to a considerable extent. The single wall is likely to be somewhat damp; but if a rich mixture is used, this possibility is obviated to a great degree. It is cheaper to construct, however, the saving lying principally in the use of only a single set of forms. With the double forms and the construction of the double wall, an air space of at least 2 inches is provided between the inside and the outside walls of concrete, the claim being made that this air space will aid in the retention of heat in the wintertime and the exclusion of it in the summertime. In the double wall construction the two walls are fastened together by means of metal wall-ties. The double concrete wall will necessarily be somewhat greater in cost but the advantages gained are usually sufficient to recompense the builder for going to a little extra expense in obtaining the desired result.

The trouble with most mixtures that are used in the construction of monolithic residence walls is that they are too lean. As a result, the concrete is more or less porous, and the continued damp weather, which is likely at any time to occur, will cause trouble.

There are two distinctly different types of forms that are used in monolithic construction; one of these is small and only a small portion of a wall is constructed at one time. It is presumed that a dry mixture be used which will permit of the rapid removal of the form to be used for the next filling. Several such forms may be used on a building which will require rapid work. Of course, with a dry mixture, the resulting concrete will naturally not have its maximum strength, but nevertheless, experience has shown that for residences the walls are sufficiently strong to sustain the loads which are placed upon them. The second type of forms consists of large sections which are erected and a rather wet mixture poured into them. The cost of the latter type of forms is greater than that of the former, but generally a denser concrete is used; consequently, the structure is more waterproof and satisfactory in every way.

Reinforcing will, of course, be necessary if the walls are continued to any height. A great deal of reinforcing is not used, the main purpose being to bind together all the various portions of the concrete and to prevent as far as possible the formation of cracks. A single $\frac{1}{4}$-inch rod every 10 or 12 inches is usually considered sufficient in an ordinary wall. Double walls should be tied together with at least one tie for every square foot of wall. It is well to consult an engineer before construction of such a building is undertaken in order to make certain that the strength of the structure will be up to the necessary standard.

Many methods have been devised to put in concrete floors in residences. The things that must be kept in mind are cheapness, strength, weight, and ease of construction. This will require simplicity both in design and in construction. Certain types of building blocks are used for this purpose with some degree of success, being supported at intervals by I-beams or channels. The use of monolithic construction is also rather favored. It is possible to construct light, solid floors, provided sufficient reinforcing is included. A few residences have been built in which the floors have been specially finished concrete, but in most instances, owners will object to this material as a floor surface, probably because they have not become accustomed to it. In such cases, a wood floor may be laid directly upon the concrete or upon furring strips. A floor of this kind is practically soundproof.

Many buildings that are otherwise fireproof have their efficiency greatly reduced by the construction of a roof and roof supports of material that are not fireproof. It would seem logical in the construction of concrete residences to make the entire structure of concrete. This idea can be extended to include the roof, several types being available. The supports can be made of concrete units cast separately or in place and the roof covering itself can be made of waterproofed concrete. If this is not considered a practical plan, concrete tile made to resemble clay tile in thickness, shape, and coloring are available, or concrete shingles which are sometimes made with an aggregate consisting partially of asbestos can be utilized.

While it may be somewhat irrational to believe that all houses of the future will be constructed of concrete, it still remains a very pertinent fact that tremendous advances in residence construction of concrete have been made in recent years. It is reasonable to assume that when full appreciation is had of the advantages of permanent construction in residences that concrete will become more favorably prominent on account of the opportunities for individual and artistic expression.

CHAPTER XII

APPROXIMATE CEMENT TESTS

UNDER ordinary conditions, the average farmer will not find it necessary to subject the cement he uses to any special tests. As was stated previously, if he purchases a well-advertised brand of cement of a reliable and responsible dealer, the insurance of his getting a good quality of cement is practically certain. In a great deal of the concrete that is made on the farm, the material is subjected to compressive strains only and is not so likely to fail as when it is subjected to tensile or transverse strains. However, it is sometimes desirable to have at hand means by which it is possible to obtain information as to the quality of cement with little or no apparatus and without much experience in testing. Such tests as will hereafter be described are useful even to the expert when examining material in a locality far removed from laboratories and apparatus, and may enable the user of small amounts of cement to determine definitely that the cement which enters the work is of the best quality.

The American Society for Testing Materials has evolved a very careful set of test specifications to which all standard cements must conform. (See Appendix.) These tests are much more elaborate than can be undertaken except in an especially equipped laboratory, and unless the person doing the testing has had considerable experience the results are likely to be extremely variable and to have little value. By means of certain approximate tests, it is possible to obtain a fair idea as to the quality of the cement, but on account of an inferior degree of accuracy, they should be regarded more as comparative tests than as exact ones and the interpretation of the results should be made very liberally. Material that is absolutely unfit to be used in responsible concrete work may always be discovered by the use of these tests. The tests which can be undertaken in this connection are those of *fineness, time of setting, soundness, purity, and strength.*

Fineness

The performance of this test is practically the same under any conditions whether it be made an approximate test or an exact one. The importance of the test is based upon the fact that the more finely a cement is ground the greater will be its cementing quality. In fact, it is quite generally conceded that it is only the extremely fine cement dust that acts as a cement, while the coarser particles, though they may possess certain cementing qualities, act to a greater extent as a fine aggregate.

The apparatus that is necessary for the performance of the test for fineness consists of scales, a fine sieve 8 inches in diameter, a bottom pan, and a cover. These are made so as to fit tightly together. The sieve that is used is the No. 200, this number corresponding approximately to the number of meshes per lineal inch; a No. 200 sieve will have approximately 40,000 to the square inch. The wire forming the material from which the sieves are made should be very fine and uniform in cross section. The weaving should also be very carefully done so that the meshes will be uniform in size. Ordinarily, the space between the wires will be 2½ or 3 times the diameter of the wire. Care must be taken not to displace any of the wires in the screen, for the uniformity of the meshes is thereby destroyed; the sieve must also be kept perfectly dry, and no damp materials should be placed in it.

The method of performing the test is as follows: Seven ounces of cement are weighed out on a good fine scale. The cement is placed in the sieve and covered; then it is shaken by a rapid lateral shifting movement of the sieve from one hand to the other for 12 or 15 minutes. The operation may be accelerated somewhat by placing two or three small coins in the sieve. When the sifting is complete, the residue on the sieve is weighed. The standard practice in cement specification limits the residue retained on the No. 200 sieve to 22 per cent of the total weight of the cement; consequently, in an approximate test, with 7 ounces of cement, if the weight of the residue on the No. 200 sieve is 1.5 ounces or less the cement may be considered as fulfilling the requirements for fineness.

Time of Setting

While the two actions of setting and hardening which have been previously discussed are more or less independent, there being no fixed relation between them, two stages in the setting can be readily recognized and used as a means of comparing certain physical qualities of different kinds of cement. For certain kinds of work, a quick setting cement is needed; for other kinds, the use of a slow setting cement is more desirable. From this standpoint it is readily seen that a method whereby such a comparison can be made with some degree of accuracy will undoubtedly possess certain value. In actual construction work, it is imperative, if the maximum strength of the cement is to be attained, that the set should not have begun before the concrete has been placed. Any disturbance of concrete or mortar after setting has begun tends to break up the crystals already formed, thus reducing the strength and rendering the concrete more susceptible to disintegration. Certain chemical constituents of various cements affect their time of setting as do also age, fineness, and other exterior conditions which are very difficult to control.

In making exact tests for the time of setting of cement, the use of either the Vicat or the Gillmore needles is general. The action of both of these needles is based upon the variable resistance which they will meet in penetrating cement in various stages of setting. They are rather difficult of manipulation, however, and are not practical for the amateur workman. The approximate test subsequently described will probably be more satisfactory and even more accurate for a person unaccustomed to cement testing than to make a test with such apparatus as the Vicat or Gillmore needles which are easily mishandled so as to give unreliable results.

The first thing that must be learned in making a test for the time of setting is what is meant by normal consistency. It is well known that the amount of water used in mixing exerts some influence on the time of setting; consequently, it follows that the mixture must be made with some definite percentage of moisture so that the plasticity or the consistency of the paste may always be uniform. The method of obtaining the normal consistency or the degree of plasticity which should be possessed by all cement pastes subjected to the time of setting test is as follows: A pound of cement is weighed out and mixed with approximately $3\frac{1}{4}$ ounces of water; the cement is placed on a glass or marble plate, formed into a crater, and the water poured in the center. The water and cement are mixed with a trowel until the water is taken up, when the whole mass is kneaded vigorously for a minute and a half. With this mixing, the cement should be nearly of such a consistency that a ball of the paste about 2 inches in diameter made by rolling in the hands will not, when dropped from a height of 2 feet, flatten to more than one-half of its diameter, nor crack to any appreciable extent. If the consistency of the paste is too wet or too dry the process should be repeated, using more or less water until the proper degree is obtained.

When the normal consistency has been obtained the cement should be molded rapidly into small cakes about $2\frac{1}{2}$ or 3 inches in diameter and $\frac{3}{4}$ of an inch in depth; a baking powder can cover makes an excellent mold. The surface should be carefully smoothed off.

In concrete of standard specifications, the initial set should not develop in less than 45 minutes; consequently, at the expiration of 45 minutes, the time being taken from the moment the water is added to the cement, the cake should be examined. If the surface appears and feels wet, and if a slight working of the cake will not crack it, the requirement is fulfilled; however, if the surface appears dry and ashy and if cracks develop upon working, it is an indication that the initial set has occurred and the cement has not fulfilled the requirements.

If the cement does pass the requirements for the initial set, the cake should be set away in a protected place and examined at the end of 10 hours. Standard specifications require that the final set, or hard set, should have occurred within this time. If the paste has become sufficiently hard so that it resists a firm pressure of the thumb nail or a dull pencil point, it has met the required specifications. If it is not hard, however, but is still soft, the material has failed in hard set. It may be that the final set will occur at a subsequent time and that if the cement be used it will work out successfully provided sufficient time is given for setting. This may be a factor, however, which will interfere seriously with the progress of construction work.

Soundness

W. P. Taylor defines soundness of cement as "that property which resists any force tending to cause disintegration or lack of permanency in the structure." Since, if such disintegration occurs, it is usually accompanied by a change of volume, tests for soundness are sometimes termed tests for "constancy of volume." The test for soundness is unquestionably one of the most important for although a sample may pass all other tests with ease, if it is unsound and will eventually disintegrate on the work, it is evidently worse than worthless for constructive purposes.

There are various causes which result in unsoundness of cement. One of the most important of these is the presence of an excess of lime which may result from incorrect proportioning, insufficient grinding, underburning, or lack of seasoning. It is stated that an excess of magnesium or alkalies and the presence of certain sulphides are also reasons for disintegration. Soundness is affected by age; quite often a cement that when fresh will fail in the soundness test, if given two or three weeks of age, will pass the test with ease.

The test for soundness is one that can be performed by any one under almost any conditions with an assurance that reasonably accurate results will be obtained. The procedure for the performance of these tests is practically the same the world over and is the same whether an exact determination of the quality of the cement is being made or whether merely approximate tests are being undertaken. Little equipment is necessary and all that is necessary on the part of the operator is reasonable care. Though there have been devised certain rather complicated tests for the measurement of any change in volume under various conditions, those known as "normal" or "pat" tests are the most common and the simplest. These tests consist of making pats of cement on glass plates and subjecting them to various temperature and moisture conditions and scrutinizing them at frequent intervals to observe any of the phenomena that accompany unsoundness.

A small quantity of cement is mixed with water to normal consistency as previously described. A portion of the paste is transferred to a glass plate about 4 inches square; the paste is spread out on the glass and then flattened out by means of a small trowel until it forms a disk about 3 inches in diameter, $\frac{1}{2}$ inch thick at the middle, and tapering to a thin edge at the circumference. This shape can very readily be made by stroking the cement with the trowel from the outside toward the center, going around the circumference with consecutive strokes so as to keep the cement piled up in the center; otherwise the tendency will be to flatten out the pat so the central thickness will not be sufficiently great.

Three such pats should be made and kept in moist air for a period of 24 hours to afford an opportunity for even and regular setting of the cement. One pat is then kept in air at normal temperature but away from any undue influence, such as the direct rays of the sun or drying winds. Another pat is kept in water maintained as near as possible at 70° F. The third pat is exposed in any convenient way in an atmosphere of steam above boiling water, in a loosely closed vessel, for a period of 5 hours.

To pass the requirements for soundness satisfactorily, the pats shall remain firm and hard and show no signs of destruction, checking, cracking, or disintegrating. The pats in air and in water should be examined at intervals for at least 28 days. When the pats are examined it should be ascertained, (1) whether they have left the glass, (2) if they have left the glass, whether they are straight or curled, (3) whether any cracks have developed, (4) whether any blotches have appeared, and (5) whether the glass itself is cracked.

The pat that has successfully withstood the tests will present an appearance not to any great degree widely different from when it was first made. Sometimes a fine crack or two may appear in the center of the pat, but these are usually due to an inaccurate determination of normal consistency or lack of care in storing the pats the first 24 hours after having been made; consequently, they do not indicate dangerous qualities of the material. If circular cracks appear near the edge of the pat, it is an indication that the cement contains an undesirable proportion of expansive elements. If the edges of the pat have curled up from the glass, it may be taken as a different manifestation of the action of expansive elements. Sometimes the entire pat will separate from the glass plate. If the lower surface is perfectly straight it merely indicates that there is lack of adhesion and does not indicate any unsoundness. Even a slight convex curvature of the bottom should not be a cause for suspicion unless it occurs to a marked degree. A concave curvature of the bottom rarely occurs in water but in air is often indicative of dangerous properties. The presence of blotches or discolorations on any of the pats is usually indicative of either underburning or adulteration. The degree of blotching or discoloration shows the extent of the defect. The probability of disintegration of the cement is shown by the formation of radial cracks in the pats. These cracks may be only few in number and slight in extent, but as time goes on are extremely likely to multiply. Sometimes the entire surface of the pat will be covered with small checks and cracks, a certain indication that the cement is not fit for use.

Purity

It is questionable whether the test for purity is a practical one under present conditions of manufacturing cement. The purpose of the test for purity is to ascertain whether or not the cement contains any materials which will be detrimental to its physical properties as a cement. Practically all manufacturers of cement are equipped to manufacture standard cements and in most instances it will be more expensive to adulterate the cement than to manufacture the standard cement itself; consequently, it is seldom that modern cements do not come up to requirements in regard to purity. A description of a simple method of performing a test for purity is appended herewith, merely for the sake of interest.

The materials needed for the test will consist of a clean glass bowl or tumbler, a glass stirring rod, a small quantity of dilute hydrochloric acid (1 : 1), and a small quantity of acetate of lead. A small quantity of cement, about as much as can be lifted on a ten cent piece, is placed in a glass vessel. About a teaspoonful of dilute hydrochloric acid is slowly poured on the cement which is stirred at the same time. If the cement is pure, it will effervesce violently for a second or two and leave a residue of reddish yellow jelly. Upon the addition of an ounce or two of water this jelly will go into solution with the exception of a few flakes of silica. A further examination of the residue can be made by adding more water. If a gritty residue remains, it will indicate the presence of cinders, sand, slag, or similar materials. As has been previously mentioned, it may be that these are not adulterants. The presence of slag may be detected by the odor of hydrogen sulphide on the addition of the acid or by holding a strip of soft paper moistened in lead acetate over the vessel while the effervescence occurs; if slag is present, it will turn the paper black or blackish brown.

Strength

The determination of the strength of cements cannot be made by the inexperienced person with any degree of success or accuracy. There is room for so many faults in the conduct of the determination that the results are apt to be very far from true. The personality of the operator in the mixing, molding, and breaking of the specimens is likely to enter to a great extent. However, it is possible, even by the inexperienced operator, to get results that will have some value when used as a basis for comparison.

Cement is tested in various ways, in compression, tension, shearing, etc. The performance of a test for the tensile strength of cement requires the use of a tension machine which is usually not possessed by the amateur. It is also one of the most difficult tests to perform. The compressive test gives more uniform results since concrete is high in compression. Machines for testing cement to destruction in compression are usually expensive and not available. Simple comparative tests of the strength of concrete can be made with the use of a cross-breaking machine and the results translated into other terms by means of standards that have been otherwise established. The specimens for the test consist of rectangular prisms of which a desirable size is 1″ × 1″ in cross section and 6 or 12 inches long, preferably the latter. Better results are obtained when the cement is tested in a mortar than when it is made into a neat mixture. The sand that is used in making the mortar should be what is known as standard sand; in regular practice, standard sand is an Ottawa silica sand which will pass through a sieve having 20 meshes to the lineal inch, but is held on the sieve having 30 meshes to the lineal inch. The standard mixture to be used is a 1 : 3 mixture of cement and sand of normal consistency.

Any kind of mold that can be made so as to produce specimens exactly 1 inch in cross section can be utilized for the purpose. Some 1-inch strips of iron mounted on end blocks of wood and laid on a flat glass plate can be made to serve admirably. The molds should be well oiled before use. The mortar which has been made up is placed in the molds and the latter by means of a trowel are filled and smoothed over so that the top surface of the mortar is flush with the top of the mold. At the expiration of 24 hours, the specimens are carefully removed from the mold and placed under a moist cloth or in any place where a moist atmosphere may be had and allowed to cure for a certain definite period. Tests are usually made at the end of 7 and 28 days, or 3 months and 6 months, etc.

A simple testing machine can be made by mounting knife edges upon supports 10 inches apart. From the center of the specimen is suspended a vessel into which small shot are gradually poured until the specimen breaks. The combined weight of the shot and the containing vessel will be the weight required to rupture the specimen.

The results of transverse tests are customarily expressed by the formula

$$\frac{3\,wl}{2\,bh^2}$$

in which w = center load, l the span in inches, b and h the width and depth respectively of the specimen. When the specimens tested are 1 inch square in cross section, the formula becomes $\frac{3}{2}wl$. Experience has shown that the results obtained from this formula are under average conditions about $1\frac{1}{2}$ times the tensile value; consequently, with a 10-inch span the center load will be just $\frac{1}{10}$ of what we can reasonably expect the tensile strength to be as indicated in a test for tension. At least three specimens should be made up of each sample and the average taken of the three specimens. Any wide variation from an average result should be discarded as doubtful, being in all probability caused by some inaccuracy in preparation. It is stated by good authority that the results obtained by this simple method of testing will not be more than 5 or 6 per cent in error and it is doubtful whether any approximate tests will exhibit an equal degree of accuracy.

APPENDIX

AUTHORIZED PUBLICATION OF THE STANDARD SPECIFICATIONS AND TESTS FOR PORTLAND CEMENT[1]

These specifications are the result of several years' work of a special committee representing a United States Government Departmental Committee, the Board of Direction of the American Society of Civil Engineers, and Committee C-1 on Cement of the American Society for Testing Materials in coöperation with Committee C-1.

Serial Designation: C 9–17

The specifications and tests for this material are issued under the fixed designation C 9; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ADOPTED, 1904; REVISED, 1908, 1909, 1916

AMERICAN SOCIETY FOR TESTING MATERIALS

PHILADELPHIA, PA., U. S. A.

AFFILIATED WITH THE

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS

SPECIFICATIONS

1. Portland cement is the product obtained by finely pulverizing clinker produced by calcining to incipient fusion, an intimate and properly proportioned mixture of argillaceous and calcareous materials, with no additions subsequent to calcination excepting water and calcined or uncalcined gypsum.

[1] These specifications and tests were adopted by letter ballot of the Society on September 1, 1916, with the understanding that they will not become effective till January 1, 1917.

I. CHEMICAL PROPERTIES

2. The following limits shall not be exceeded:

Loss on ignition, per cent	4.00
Insoluble residue, per cent	0.85
Sulphuric anhydride (SO_3), per cent	2.00
Magnesia (MgO), per cent	5.00

II. PHYSICAL PROPERTIES

3. The specific gravity of cement shall be not less than 3.10 (3.07 for white Portland cement). Should the test of cement as received fall below this requirement a second test may be made upon an ignited sample. The specific gravity test will not be made unless specifically ordered.

4. The residue on a standard No. 200 sieve shall not exceed 22 per cent by weight.

5. A pat of neat cement shall remain firm and hard, and show no signs of distortion, cracking, checking, or disintegration in the steam test for soundness.

6. The cement shall not develop initial set in less than 45 minutes when the Vicat needle is used or 60 minutes when the Gillmore needle is used. Final set shall be attained within 10 hours.

7. The average tensile strength in pounds per square inch of not less than three standard mortar briquettes (see Section 51), composed of one part cement and three parts standard sand, by weight, shall be equal to or higher than the following:

Age at Test, Days	Storage of Briquettes	Tensile Strength, Lb. per Sq. In.
7	1 day in moist air, 6 days in water	200
28	1 day in moist air, 27 days in water	300

8. The average tensile strength of standard mortar at 28 days shall be higher than the strength at 7 days.

III. PACKAGES, MARKING AND STORAGE

9. The cement shall be delivered in suitable bags or barrels with the brand and name of the manufacturer plainly marked thereon, unless shipped in bulk. A bag shall contain 94 lb. net. A barrel shall contain 376 lb. net.

10. The cement shall be stored in such a manner as to permit easy access for proper inspection and identification of each shipment, and in a suitable weather-tight building which will protect the cement from dampness.

IV. INSPECTION

11. Every facility shall be provided the purchaser for careful sampling and inspection at either the mill or at the site of the work, as may be specified by the purchaser. At least 10 days from the time of sampling shall be allowed for the completion of the 7-day test, and at least 31 days shall be allowed for the completion of the 28-day test. The cement shall be tested in accordance with the methods hereinafter prescribed. The 28-day test shall be waived only when specifically so ordered.

V. REJECTION

12. The cement may be rejected if it fails to meet any of the requirements of these specifications.

13. Cement shall not be rejected on account of failure to meet the fineness requirement if upon retest after drying at 100° C. for one hour it meets this requirement.

14. Cement failing to meet the test for soundness in steam may be accepted if it passes a retest using a new sample at any time within 28 days thereafter.

15. Packages varying more than 5 per cent from the specified weight may be rejected; and if the average weight of packages in any shipment, as shown by weighing 50 packages taken at random, is less than that specified, the entire shipment may be rejected.

TESTS

VI. SAMPLING

16. Tests may be made on individual or composite samples as may be ordered. Each test sample should weigh at least 8 lb.

17. (*a*) *Individual Sample.* — If sampled in cars one test sample shall be taken from each 50 bbl. or fraction thereof. If sampled in bins one sample shall be taken from each 100 bbl.

(*b*) *Composite Sample.* — If sampled in cars one sample shall be taken from one sack in each 40 sacks (or 1 bbl. in each 10 bbl.) and combined to form one test sample. If sampled in bins or warehouses one test sample shall represent not more than 200 bbl.

18. Cement may be sampled at the mill by any of the following methods that may be practicable, as ordered:

(*a*) *From the Conveyor Delivering to the Bin.* — At least 8 lb. of cement shall be taken from approximately each 100 bbl. passing over the conveyor.

(*b*) *From Filled Bins by Means of Proper Sampling Tubes.* — Tubes inserted vertically may be used for sampling cement to a maximum depth of 10 ft. Tubes inserted horizontally may be used where the construction of the bin permits. Samples shall be taken from points well distributed over the face of the bin.

(*c*) *From Filled Bins at Points of Discharge.* — Sufficient cement shall be drawn from the discharge openings to obtain samples representative of the cement contained in the bin, as determined by the appearance at the discharge openings of indicators placed on the surface of the cement directly above these openings before drawing of the cement is started.

19. Samples preferably shall be shipped and stored in air-tight containers. Samples shall be passed through a sieve having 20 meshes per linear inch in order to thoroughly mix the sample, break up lumps, and remove foreign materials.

VII. CHEMICAL ANALYSIS

Loss on Ignition

20. One gram of cement shall be heated in a weighed covered platinum crucible, of 20 to 25 cc. capacity, as follows, using either method (*a*) or (*b*) as ordered:

(*a*) The crucible shall be placed in a hole in an asbestos board, clamped horizontally so that about three-fifths of the crucible projects below, and blasted at a full red heat for 15 minutes with an inclined flame; the loss in weight shall be checked by a second blasting for 5 minutes. Care shall be taken to wipe off particles of asbestos that may adhere to the crucible when withdrawn from the hole in the board. Greater neatness and shortening of the time of heating are secured by making a hole to fit the crucible in a circular disk of sheet platinum and placing this disk over a somewhat larger hole in an asbestos board.

(*b*) The crucible shall be placed in a muffle at any temperature between 900 and 1000° C. for 15 minutes and the loss in weight shall be checked by a second heating for 5 minutes.

21. A permissible variation of 0.25 will be allowed, and

all results in excess of the specified limit but within this permissible variation shall be reported as 4 per cent.

Insoluble Residue

22. To a 1-g. sample of cement shall be added 10 cc. of water and 5 cc. of concentrated hydrochloric acid; the liquid shall be warmed until effervescence ceases. The solution shall be diluted to 50 cc. and digested on a steam bath or hot plate until it is evident that decomposition of the cement is complete. The residue shall be filtered, washed with cold water, and the filter paper and contents digested in about 30 cc. of a 5 per cent solution of sodium carbonate, the liquid being held at a temperature just short of boiling for 15 minutes. The remaining residue shall be filtered, washed with cold water, then with a few drops of hot hydrochloric acid, 1 : 9, and finally with hot water, and then ignited at a red heat and weighed as the insoluble residue.

23. A permissible variation of 0.15 will be allowed, and all results in excess of the specified limit but within this permissible variation shall be reported as 0.85 per cent.

Sulphuric Anhydride

24. One gram of the cement shall be dissolved in 5 cc. of concentrated hydrochloric acid diluted with 5 cc. of water, with gentle warming; when solution is complete 40 cc. of water shall be added, the solution filtered, and the residue washed thoroughly with water. The solution shall be diluted to 250 cc., heated to boiling, and 10 cc. of a hot 10 per cent solution of barium chloride shall be added slowly, drop by drop, from a pipette and the boiling continued until the precipitate is well formed. The solution

shall be digested on the steam bath until the precipitate has settled. The precipitate shall be filtered, washed, and the paper and contents placed in a weighed platinum crucible and the paper slowly charred and consumed without flaming. The barium sulphate shall then be ignited and weighed. The weight obtained multiplied by 34.3 gives the percentage of sulphuric anhydride. The acid filtrate obtained in the determination of the insoluble residue may be used for the estimation of sulphuric anhydride instead of using a separate sample.

25. A permissible variation of 0.10 will be allowed, and all results in excess of the specified limit but within this permissible variation shall be reported as 2.00 per cent.

Magnesia

26. To 0.5 g. of the cement in an evaporating dish shall be added 10 cc. of water to prevent lumping and then 10 cc. of concentrated hydrochloric acid. The liquid shall be gently heated and agitated until attack is complete. The solution shall then be evaporated to complete dryness on a steam or water bath. To hasten dehydration the residue may be heated to 150 or even 200° C. for one-half to one hour. The residue shall be treated with 10 cc. of concentrated hydrochloric acid diluted with an equal amount of water. The dish shall be covered and the solution digested for ten minutes on a steam bath or water bath. The diluted solution shall be filtered and the separated silica washed thoroughly with water.[1] Five cubic centimeters of concentrated hydrochloric acid and sufficient bromine water to precipitate any manganese which may be present, shall be added to the filtrate (about 250 cc.). This

[1] Since this procedure does not involve the determination of silica, a second evaporation is unnecessary.

shall be made alkaline with ammonium hydroxide, boiled until there is but a faint odor of ammonia, and the precipitated iron and aluminum hydroxides, after settling, shall be washed with hot water, once by decantation and slightly on the filter. Setting aside the filtrate, the precipitate shall be transferred by a jet of hot water to the precipitating vessel and dissolved in 10 cc. of hot hydrochloric acid. The paper shall be extracted with acid, the solution and washings being added to the main solution. The aluminum and iron shall then be reprecipitated at boiling heat by ammonium hydroxide and bromine water in a volume of about 100 cc., and the second precipitate shall be collected and washed on the filter used in the first instance if this is still intact. To the combined filtrates from the hydroxides of iron and aluminum, reduced in volume if need be, 1 cc. of ammonium hydroxide shall be added, the solution brought to boiling, 25 cc. of a saturated solution of boiling ammonium oxalate added, and the boiling continued until the precipitated calcium oxalate has assumed a well-defined granular form. The precipitate after one hour shall be filtered and washed, then with the filter shall be placed wet in a platinum crucible, and the paper burned off over a small flame of a Bunsen burner; after ignition it shall be redissolved in hydrochloric acid and the solution diluted to 100 cc. Ammonia shall be added in slight excess, and the liquid boiled. The lime shall then be reprecipitated by ammonium oxalate, allowed to stand until settled, filtered, and washed. The combined filtrates from the calcium precipitates shall be acidified with hydrochloric acid, concentrated on the steam bath to about 150 cc., and made slightly alkaline with ammonium hydroxide, boiled and filtered (to remove a little aluminum and iron and perhaps calcium). When cool, 10 cc. of saturated solution of sodium-ammonium-hydrogen phosphate shall be added with constant stirring. When the crystalline ammonium-magnesium orthophosphate has formed, ammonia shall be added in moderate excess. The solution shall be set aside for several hours in a cool place, filtered, and washed with water containing 2.5 per cent of NH_3. The precipitate shall be dissolved in a small quantity of hot hydrochloric acid, the solution diluted to about 100 cc., 1 cc. of a saturated solution of sodium-ammonium-hydrogen phosphate added, and ammonia drop by drop, with constant stirring, until the precipitate is again formed as described and the ammonia is in moderate excess. The precipitate shall then be allowed to stand about two hours, filtered, and washed as before. The paper and contents shall be placed in a weighed platinum crucible, the paper slowly charred, and the resulting carbon carefully burned off. The precipitate shall then be ignited to constant weight over a Meker burner, or a blast not strong enough to soften or melt the pyrophosphate. The weight of magnesium pyrophosphate obtained multiplied by 72.5 gives the percentage of magnesia. The precipitate so obtained always contains some calcium and usually small quantities of iron, aluminum, and manganese as phosphates.

27. A permissible variation of 0.4 will be allowed, and all results in excess of the specified limit but within this permissible variation shall be reported as 5.00 per cent.

VIII. DETERMINATION OF SPECIFIC GRAVITY

28. The determination of specific gravity shall be made with a standardized Le Chatelier apparatus which conforms to the requirements illustrated in Fig. 1. This apparatus is standardized by the United States Bureau of Standards. Kerosene free from water, or benzine not

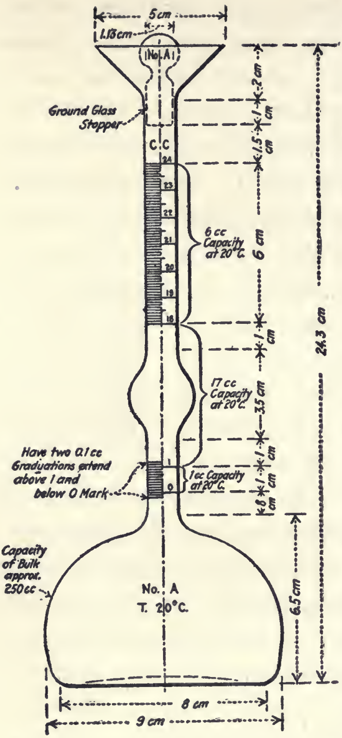


FIG. 1. — Le Chatelier Apparatus.

lighter than 62° Baumé, shall be used in making this determination.

29. The flask shall be filled with either of these liquids to a point on the stem between zero and one cubic centimeter, and 64 g. of cement, of the same temperature as the liquid, shall be slowly introduced, taking care that the cement does not adhere to the inside of the flask above the liquid and to free the cement from air by rolling the flask in an inclined position. After all the cement is introduced, the level of the liquid will rise to some division of the graduated neck; the difference between readings is the volume displaced by 64 g. of the cement.

The specific gravity shall then be obtained from the formula

$$\text{Specific gravity} = \frac{\text{Weight of cement (g.)}}{\text{Displaced volume (cc.)}}$$

30. The flask, during the operation, shall be kept immersed in water, in order to avoid variations in the temperature of the liquid in the flask, which shall not exceed 0°.5 C. The results of repeated tests should agree within 0.01.

31. The determination of specific gravity shall be made

on the cement as received; if it falls below 3.10, a second determination shall be made after igniting the sample as described in Section 20.

IX. DETERMINATION OF FINENESS

32. Wire cloth for standard sieves for cement shall be woven (not twilled) from brass, bronze, or other suitable wire, and mounted without distortion on frames not less than $1\frac{1}{2}$ in. below the top of the frame. The sieve frames shall be circular, approximately 8 in. in diameter, and may be provided with a pan and cover.

33. A standard No. 200 sieve is one having nominally a 0.0029-in. opening and 200 wires per inch standardized by the U. S. Bureau of Standards, and conforming to the following requirements:

The No. 200 sieve should have 200 wires per inch, and the number of wires in any whole inch shall not be outside the limits of 192 to 208. No opening between adjacent parallel wires shall be more than 0.0050 in. in width. The diameter of the wire should be 0.0021 in. and the average diameter shall not be outside the limits 0.0019 to 0.0023 in. The value of the sieve as determined by sieving tests made in conformity with the standard specification for these tests on a standardized cement which gives a residue of 25 to 20 per cent on the No. 200 sieve, or on other similarly graded material, shall not show a variation of more than 1.5 per cent above or below the standards maintained at the Bureau of Standards.

34. The test shall be made with 50 g. of cement. The sieve shall be thoroughly clean and dry. The cement shall be placed on the No. 200 sieve, with pan and cover attached, if desired, and shall be held in one hand in a slightly inclined position so that the sample will be well distributed over the

sieve, at the same time gently striking the side about 150 times per minute against the palm of the other hand on the up stroke. The sieve shall be turned every 25 strokes about one-sixth of a revolution in the same direction. The operation shall continue until not more than 0.05 g. passes through in one minute of continuous sieving. The fineness shall be determined from the weight of the residue on the sieve expressed as a percentage of the weight of the original sample.

35. Mechanical sieving devices may be used, but the cement shall not be rejected if it meets the fineness requirement when tested by the hand method described in Section 34.

36. A permissible variation of 1 will be allowed, and all results in excess of the specified limit but within this permissible variation shall be reported as 22 per cent.

X. MIXING CEMENT PASTES AND MORTARS

37. The quantity of dry material to be mixed at one time shall not exceed 1000 g. nor be less than 500 g. The proportions of cement or cement and sand shall be stated by weight in grams of the dry materials; the quantity of water shall be expressed in cubic centimeters (1 cc. of water = 1 g.). The dry materials shall be weighed, placed upon a non-absorbent surface, thoroughly mixed dry if sand is used, and a crater formed in the center, into which the proper percentage of clean water shall be poured; the material on the outer edge shall be turned into the crater by the aid of a trowel. After an interval of $\frac{1}{3}$ minute for the absorption of the water the operation shall be completed by continuous, vigorous mixing, squeezing, and kneading with the hands for at least one minute.[1] During the operation of mixing, the hands should be protected by rubber gloves.

[1] In order to secure uniformity in the results of tests for the time of setting and tensile strength the manner of mixing above described should be care-

38. The temperature of the room and the mixing water shall be maintained as nearly as practicable at 21° C. (70° F.).

XI. NORMAL CONSISTENCY

39. The Vicat apparatus consists of a frame *A* (Fig. 2) bearing a movable rod *B*, weighing 300 g., one end *C* being 1 cm. in diameter for a distance of 6 cm., the other having a

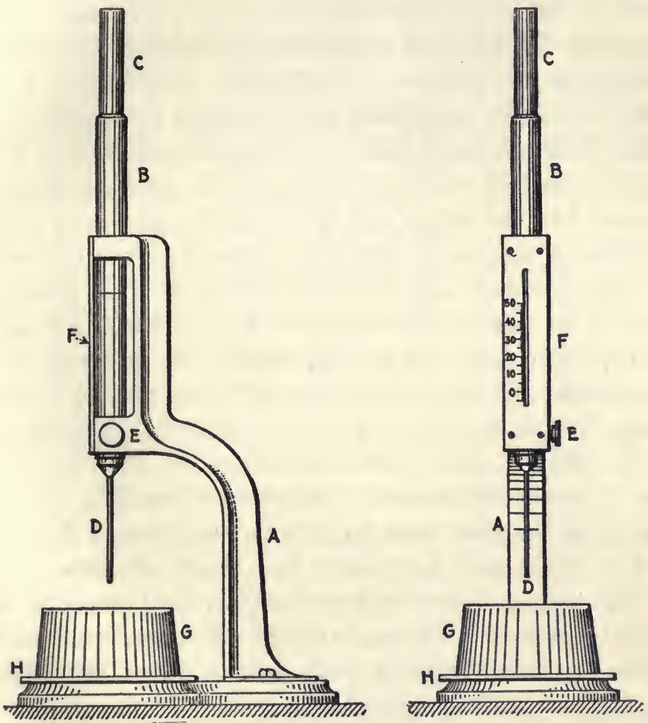


FIG. 2. — Vicat Apparatus.

fully followed. At least one minute is necessary to obtain the desired plasticity which is not appreciably affected by continuing the mixing for several minutes. The exact time necessary is dependent upon the personal equation of the operator. The error in mixing should be on the side of over-mixing.

removable needle *D*, 1 mm. in diameter, 6 cm. long. The rod is reversible, and can be held in any desired position by a screw *E*, and has midway between the ends a mark *F* which moves under a scale (graduated to millimeters) attached to the frame *A*. The paste is held in a conical, hard-rubber ring *G*, 7 cm. in diameter at the base, 4 cm. high, resting on a glass plate *H* about 10 cm. square.

40. In making the determination, 500 g. of cement, with a measured quantity of water, shall be kneaded into a paste, as described in Section 37, and quickly formed into a ball with the hands, completing the operation by tossing it six times from one hand to the other, maintained about 6 in. apart; the ball resting in the palm of one hand shall be pressed into the larger end of the rubber ring held in the other hand, completely filling the ring with paste; the excess at the larger end shall then be removed by a single movement of the palm of the hand; the ring shall then be placed on its larger end on a glass plate and the excess paste at the smaller end sliced off at the top of the ring by a single oblique stroke of a trowel held at a slight angle with the top of the ring. During these operations care shall be taken not to compress the paste. The paste confined in the ring, resting on the plate, shall be placed under the rod, the larger end of which shall be brought in contact with the surface of the paste; the scale shall be then read, and the rod quickly released. The paste shall be of normal consistency when the rod settles to a point 10 mm. below the original surface in ½ minute after being released The apparatus shall be free from all vibrations during the test. Trial pastes shall be made with varying percentages of water until the normal consistency is obtained. The amount of water required shall be expressed in percentage by weight of the dry cement.

41. The consistency of standard mortar shall depend on the amount of water required to produce a paste of normal consistency from the same sample of cement. Having determined the normal consistency of the sample, the consistency of standard mortar made from the same sample shall be as indicated in Table I, the values being in percentage of the combined dry weights of the cement and standard sand.

TABLE I. — PERCENTAGE OF WATER FOR STANDARD MORTARS

Percentage of Water for Neat Cement Paste of Normal Consistency	Percentage of Water for One Cement, Three Standard Ottawa Sand	Percentage of Water for Neat Cement Paste of Normal Consistency	Percentage of Water for One Cement, Three Standard Ottawa Sand
15	9.0	23	10.3
16	9.2	24	10.5
17	9.3	25	10.7
18	9.5	26	10.8
19	9.7	27	11.0
20	9.8	28	11.2
21	10.0	29	11.3
22	10.2	30	11.5

XII. DETERMINATION OF SOUNDNESS[1]

42. A steam apparatus, which can be maintained at a temperature between 98 and 100° C., or one similar to that shown in Fig. 3, is recommended. The capacity of this apparatus may be increased by using a rack for holding the pats in a vertical or inclined position.

[1] Unsoundness is usually manifested by change in volume which causes distortion, cracking, checking, or disintegration.

Pats improperly made or exposed to drying may develop what are known as shrinkage cracks within the first 24 hours and are not an indication of unsoundness. These conditions are illustrated in Fig. 4.

The failure of the pats to remain on the glass or the cracking of the glass to which the pats are attached does not necessarily indicate unsoundness.

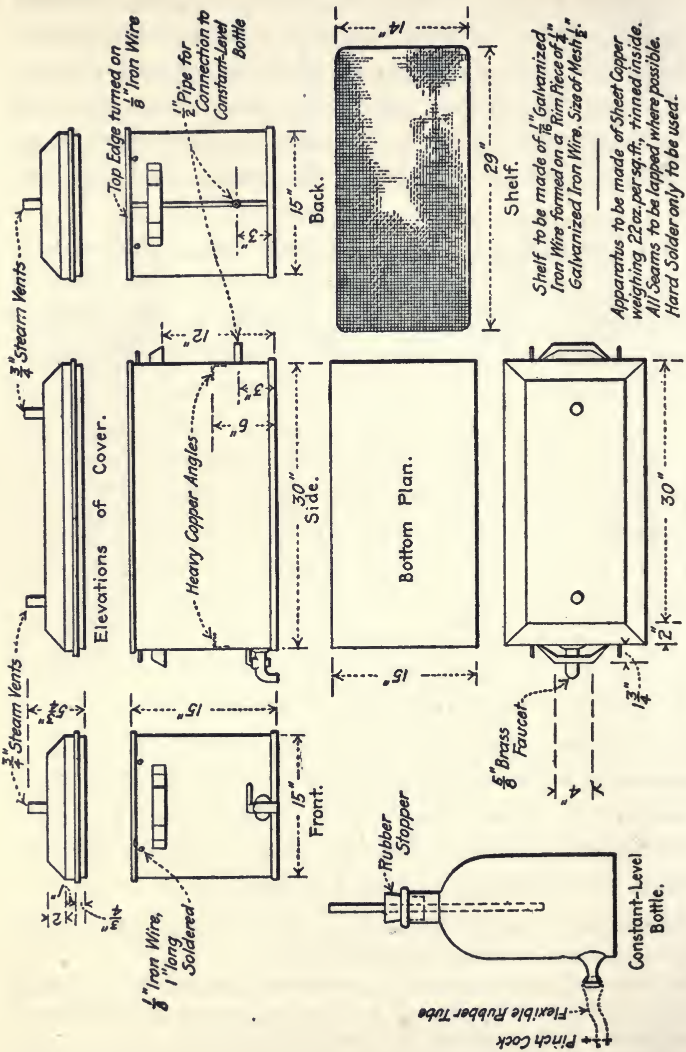


FIG. 3. — Apparatus for Making Soundness Test of Cement.

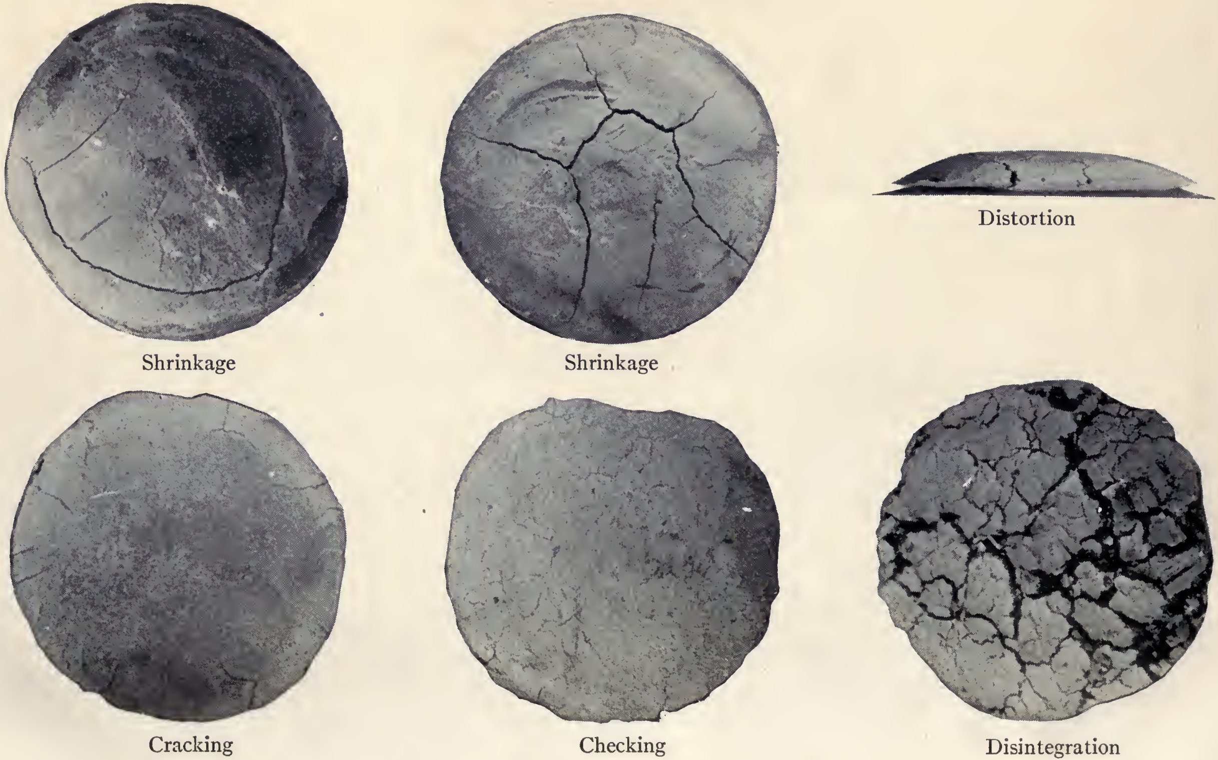


FIG. 4. — Typical Failures in Soundness Test.

43. A pat from cement paste of normal consistency about 3 in. in diameter, ½ in. thick at the center, and tapering to a thin edge, shall be made on clean glass plates about 4 in. square, and stored in moist air for 24 hours. In molding the pat, the cement paste shall first be flattened on the glass and the pat then formed by drawing the trowel from the outer edge toward the center.

44. The pat shall then be placed in an atmosphere of steam at a temperature between 98 and 100° C. upon a suitable support 1 in. above boiling water for 5 hours.

45. Should the pat leave the plate, distortion may be detected best with a straight edge applied to the surface which was in contact with the plate.

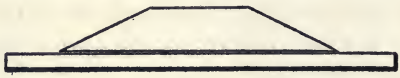
XIII. DETERMINATION OF TIME OF SETTING

46. The following are alternate methods either of which may be used as ordered:

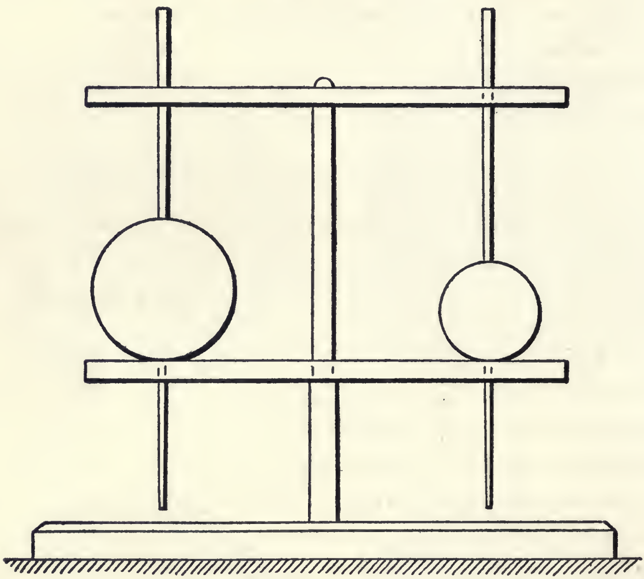
47. The time of setting shall be determined with the Vicat apparatus described in Section 39. (See Fig. 2.)

48. A paste of normal consistency shall be molded in the hard-rubber ring *G* as described in Section 40, and placed under the rod *B*, the smaller end of which shall then be carefully brought in contact with the surface of the paste, and the rod quickly released. The initial set shall be said to have occurred when the needle ceases to pass a point 5 mm. above the glass plate in ½ minute after being released; and the final set, when the needle does not sink visibly into the paste. The test pieces shall be kept in moist air during the test. This may be accomplished by placing them on a rack over water contained in a pan and covered by a damp cloth, kept from contact with them by means of a wire screen; or they may be stored in a moist closet. Care shall be taken to keep the needle clean, as the collection of cement

on the sides of the needle retards the penetration, while cement on the point may increase the penetration. The time of setting is affected not only by the percentage and temperature of the water used and the amount of kneading



(*a*) Pat with Top Surface Flattened for Determining Time of Setting by Gillmore Method.



(*b*) Gillmore Needles.

FIG. 5.

the paste receives, but by the temperature and humidity of the air, and its determination is therefore only approximate.

49. The time of setting shall be determined by the Gillmore needles. The Gillmore needles should preferably be mounted as shown in Fig. 5 (*b*).

50. The time of setting shall be determined as follows: A pat of neat cement paste about 3 in. in diameter and $\frac{1}{2}$ in. in thickness with a flat top (Fig. 5 (*a*)), mixed to a normal consistency, shall be kept in moist air at a temperature maintained as nearly as practicable at 21° C. (70° F.). The cement shall be considered to have acquired its initial set when the pat will bear, without appreciable indentation, the Gillmore needle $\frac{1}{12}$ in. in diameter, loaded to weigh $\frac{1}{4}$ lb. The final set has been acquired when the pat will bear without appreciable indentation, the Gillmore needle $\frac{1}{24}$ in. in diameter, loaded to weigh 1 lb. In making the test, the needles shall be held in a vertical position, and applied lightly to the surface of the pat.

XIV. TENSION TESTS

51. The form of test piece shown in Fig. 6 shall be used. The molds shall be made of non-corroding metal and have sufficient material in the sides to prevent spreading during molding. Gang molds when used shall be of the type shown in Fig. 7. Molds shall be wiped with an oily cloth before using.

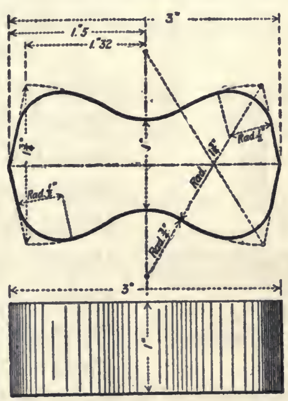


FIG. 6. — Details for Briquette.

52. The sand to be used shall be natural sand from Ottawa, Ill., screened to pass a No. 20 sieve and retained on a No. 30 sieve. This sand may be obtained from the Ottawa Silica Co., at a cost of two cents per pound, f. o. b. cars, Ottawa, Ill.

53. This sand having passed the No. 20 sieve, shall be considered standard when not more than 5 g. pass the No.

30 sieve after one minute continuous sieving of a 500-g. sample.

54. The sieves shall conform to the following specifications:

The No. 20 sieve shall have between 19.5 and 20.5 wires per whole inch of the warp wires and between 19 and 21 wires per whole inch of the shoot wires. The diameter of the wire should be 0.0165 in. and the average diameter shall not be outside the limits of 0.0160 and 0.0170 in.

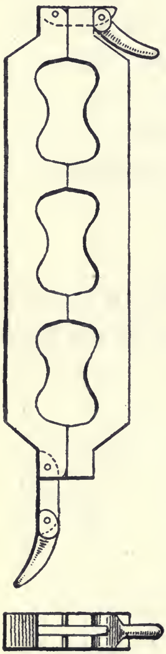


FIG. 7. — Gang Mold.

The No. 30 sieve shall have between 29.5 and 30.5 wires per whole inch of the warp wires and between 28.5 and 31.5 wires per whole inch of the shoot wires. The diameter of the wire should be 0.0110 in. and the average diameter shall not be outside the limits 0.0105 to 0.0115 in.

55. Immediately after mixing, the standard mortar shall be placed in the molds, pressed in firmly with the thumbs and smoothed off with a trowel without ramming. Additional mortar shall be heaped above the mold and smoothed off with a trowel; the trowel shall be drawn over the mold in such a manner as to exert a moderate pressure on the material. The mold shall then be turned over and the operation of heaping, thumbing, and smoothing off repeated.

56. Tests shall be made with any standard machine. The briquettes shall be tested as soon as they are removed from the water. The bearing surfaces of the clips and briquettes shall be free from grains of sand or dirt. The bri-

quettes shall be carefully centered and the load applied continuously at the rate of 600 lb. per minute.

57. Testing machines should be frequently calibrated in order to determine their accuracy.

58. Briquettes that are manifestly faulty, or which give strengths differing more than 15 per cent from the average value of all test pieces made from the same sample and broken at the same period, shall not be considered in determining the tensile strength.

XV. STORAGE OF TEST PIECES

59. The moist closet may consist of a soapstone, slate, or concrete box, or a wooden box lined with metal. If a wooden box is used, the interior should be covered with felt or broad wicking kept wet. The bottom of the moist closet should be covered with water. The interior of the closet should be provided with non-absorbent shelves on which to place the test pieces, the shelves being so arranged that they may be withdrawn readily.

60. Unless otherwise specified all test pieces, immediately after molding, shall be placed in the moist closet for from 20 to 24 hours.

61. The briquettes shall be kept in molds on glass plates in the moist closet for at least 20 hours. After 24 hours in moist air the briquettes shall be immersed in clean water in storage tanks of non-corroding material.

62. The air and water shall be maintained as nearly as practicable at a temperature of 21° C. (70° F.).

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FARM STRUCTURES

By K. J. T. EKBLAW, M.S.

Associate in Agricultural Engineering, University of Illinois; Associate Member of American Society of Agricultural Engineers

Illustrated, cloth, crown 8vo, 347 pages, $1.75

In the preparation of this book it has been purposed to provide a treatise concerning farm structures which will appeal not only to the teacher who desires to present the subject to his students in a straightforward and practical way, but to the progressive farmer who recognizes the advantages of good farm buildings. The popular literature on this subject consists mainly of compilations of plans accompanied by criticisms of more or less value, or of discussions of farmsteads too expensive or impractical to be applied to present ordinary conditions. The elimination of these faults has been among the objects of the author in the writing of this text.

The development of the subject is manifestly the most logical, beginning with a description of building materials, followed by a discussion of the basic methods employed in simple building construction, then presenting typical plans of various farm buildings in which the principles of construction and arrangement have been applied. Descriptions of the more essential requirements in the way of equipment and farm-life conveniences are appended. The illustrations have been prepared with the object of making them truly illustrative and of aid in the understanding of the subject matter which they accompany. Comparatively few building plans are included, since most building problems possess so many local requirements that a general solution is impossible; however, the plans presented are typical, and are so suggestive in presenting fundamental principles that a study of them will aid in the solution of any particular individual problem.

It is not intended that the study of this text will produce an architect; but it is hoped that it will provide the student with a sufficient knowledge of building operations to enable him, with some knowledge of carpentry, to erect his own minor structures and to differentiate between good and bad construction in larger ones.

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