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CEMENT MORTAR AND CONCRETE:

PREPARATION AND USE FOR FARM PURPOSES.

BY

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Office of Public Roads,
Washington, D. C., October 14, 1905.

Sir: I have the honor to transmit herewith the manuscript of a paper by Mr. Philip L. Wormeley, jr., which gives elementary directions for the preparation and use of cement mortar and concrete. The paper is designed to give information to those unfamiliar with the subject, and I believe will be particularly useful to farmers. I respectfully recommend that it be published as a Farmers' Bulletin.

Respectfully,

Logan Waller Page,
Director.

Hon. James Wilson,
Secretary of Agriculture.

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CEMENT MORTAR AND CONCRETE: PREPARATION AND USE FOR FARM PURPOSES.

INTRODUCTION.

The many letters received and referred to the Office of Public Roads with reference to the use of cement and the adaptability of concrete for various farm purposes have made it seem advisable to issue a short bulletin on the subject, in which a proper method of mixing concrete is described, together with a few of the many uses for which concrete is well adapted. No attempt has been made to give a technical discussion of the subject, the sole object being to treat in an elementary way those points in concrete construction which are of particular interest to the farmer.

In the appendix will be found the results of tests made to determine the strength of reinforced concrete fence posts, together with tests showing the effect of retempering Portland cement mortar, and a diagram (fig. 14) illustrating the variation in strength of cement mortar produced by different proportions of clay in the sand.

CEMENT.

The term " hydraulic cement " is applied to one of the most useful materials of engineering construction and one which in recent years has become widely extended in its field of application. Hydraulic cement possesses the property of hardening, or setting, under water, in which respect it differs from lime, which does not harden except in the presence of air. Thus it is evident that in all places where air is excluded, such as foundations, thick walls, etc., cement mortar should be used instead of lime.

Only two classes of cement will be discussed here—Portland and natural. The difference between these is due partly to the method of manufacture and partly to the condition and relative proportions of the materials employed, which are, generally speaking, limestone and clay. In the manufacture of Portland cement the separate materials are mixed in such proportions as have been found by experience to give the best results. The mixing is done by grinding the materials together in mills, after which the mixture is burned at a very high temperature in kilns, and the resulting clinker ground to an impalpable powder is known as Portland cement. In the case of natural cement the materials used have been already mixed by nature in approximately the correct proportions, being found in the form of a rock which is generally classed as a clay limestone, or a limey deposit technically called calcareous clay. This material is burned at a much lower temperature than Portland cement. When the manufacturer has each ingredient absolutely under control and can adjust the proportions to suit all conditions, it is reasonable to expect that a better and more uniform product will result than when the materials are found already mixed. Portland cement is far more extensively employed than natural cement on account of its superior strength, although the latter is frequently used in cases where great strength is of little importance. The superior strength and durability of cement as compared with lime, together with the low price at which it may now be procured, have caused the former to replace the latter in engineering construction to a great extent.

STORING CEMENT.

In storing cement care must be exercised to insure its being kept dry. When no house or shed is available for the purpose, a rough platform may be erected clear of the ground, on which the cement may be placed and so covered as to exclude water. When properly protected, it often improves with age. Cement is shipped in barrels or bags, the size and weight of which usually are as follows:

Bulk and weight of cement in ordinary barrels and bags.

Kind of cement.	Per barrel.		Per bag.	
	Quantity.	Weight (net).	Quantity.	Weight (net).
	Cu. ft.	*Pounds.*	*Cu. ft.*	*Pounds.*
Portland	$3\frac{1}{2}$	380	$\frac{7}{8}$	95
Natural [a]	$3\frac{1}{2}$	300	$\frac{7}{8}$	75

[a] Western natural cement usually weighs about 265 pounds per barrel net.

CEMENT MORTAR.

Cement mortar is an intimate mixture of cement and sand mixed with sufficient water to produce a plastic mass. The amount of water will vary according to the proportion and condition of the sand, and had best be determined independently in each case. Sand is used both for the sake of economy and to avoid cracks due to shrinkage of cement in setting. Where great strength is required, there should be at least sufficient cement to fill the voids or air spaces in the sand, and a slight excess is preferable in order to compensate for any uneven distribution in the mixing. Common proportions for Portland cement mortar are 3 parts sand to 1 of cement, and for natural cement mortar, 2 parts sand to 1 of cement. Unless otherwise stated, materials for mortar or concrete are considered to be proportioned by volume, the cement being lightly shaken in the measure used.

A " lean " mortar is one having only a small proportion of cement, while a " rich " mixture is one with a large proportion of cement. " Neat " cement is pure cement, or that with no admixture of sand. The term " aggregate " is used to designate the coarse materials entering into concrete—usually gravel or crushed rock. The proportion in which the three elements enter into the mixture is usually expressed by three figures separated by dashes—as, for instance, 1–3–5—meaning 1 part cement, 3 parts sand, and 5 parts aggregate.

In the great majority of cases cement mortar is subjected only to compression, and for this reason it would seem natural, in testing it, to determine its compressive strength. The tensile strength of cement mortar, however, is usually determined, and from this its resistance to compression may be assumed to be from eight to twelve times greater. A direct determination of the compressive strength is a less simple operation, for which reason the tensile test is in most cases accepted as indicating the strength of the cement.

MIXING.

In mixing cement mortar it is best to use a platform of convenient size or a shallow box. First, deposit the requisite amount of sand in a uniform layer, and on top of this spread the cement. These should be mixed dry with shovels or hoes, until the whole mass exhibits a uniform color. Next, form a crater of the dry mixture, and into this pour nearly the entire quantity of water required for the batch. Work the dry material from the outside toward the center, until all the water is taken up, then turn rapidly with shovels, adding water at the same time by sprinkling until the desired consistency is attained. It is frequently specified that the mortar shall be turned a certain number of times, but a better practice for securing a uniform mixture is to watch the operation and judge by the eye when the mixing has been carried far enough. In brick masonry the mistake is frequently made of mixing the mortar very wet and relying upon the bricks to absorb the excess of water. It is better, however, to wet the bricks thoroughly and use a stiff mortar.

GROUT.

The term " grout " is applied to mortar mixed with an excess of water, which gives it about the consistency of cream. This material is often used to fill the voids in stone masonry, and in brick work the inner portions of walls are frequently laid dry and grouted. The practice in either case is to be condemned, except where the conditions are unusual, as cement used in this way will never develop its full strength.

LIME AND CEMENT MORTAR.

L. C. Sabin [a] finds that in a Portland cement mortar containing three parts sand to one of cement, 10 per cent of the cement may be replaced by lime in the form of paste without diminishing the strength of the mortar, and at the same time rendering it more plastic. In the case of natural cement mortar, lime may be added to the extent of 20 to 25 per cent of the cement with good results. The increased plasticity due to the addition of lime much facilitates the operation of laying bricks, and has caused lime and cement mortar to become largely used.

CEMENT MORTAR FOR PLASTERING.

In plastering with cement, a few precautions must be observed to insure good and permanent results. The surface to receive the plaster should be rough, perfectly clean, and well saturated with water. A mortar very rich in cement is rather a drawback than otherwise on account of shrinkage cracks, which frequently appear. The mortar, consisting of two or three parts sand to one of cement, should be mixed with as little water as possible and well worked to produce plasticity. It is essential that the plaster be kept moist until it has thoroughly hardened.

MATERIALS FOR MAKING CONCRETE.

SAND.

In securing sand for mixing mortar or concrete, if it is possible to select from several varieties, that sand should be chosen which is composed of sharp, angular grains, varying in size from coarse to fine. Such sand is, however, not always obtainable, nor is it essential for good work. Any coarse-grained sand which is fairly clean will answer the purpose. If gravel, sticks, or leaves be present they should be removed by screening. The voids in sand vary from 30 to 40 per cent, according to the variation in size of grains. A sand with different-sized grains is to be preferred, because less cement is required to fill the voids. By mixing coarse and fine sand it is possible to reduce the voids considerably.

It is customary to use the terms "river sand," "sea sand," or "pit sand," according to the source of supply. River sand as a rule has rounded grains, but unless it contains an excess of clay or other im-

[a] Sabin, L. C., Cement and Concrete, 1905.

purities, it is suitable for general purposes. When river sand is of a light color and fine-grained it answers well for plastering.

Sea sand may contain the salts found in the ocean. The tendency of these salts to attract moisture makes it advisable to wash sea sand before using it for plastering or other work which is to be kept perfectly dry.

Pit sand for the most part will be found to have sharp, angular grains, which make it excellent for mortar or concrete work. Where clay occurs in pockets it is necessary either to remove it, or else see that it is thoroughly mixed with the sand. The presence of clay in excess frequently makes it necessary to wash pit sand before it is suitable for use.

The results of tests made in this laboratory would indicate that the presence of clay, even in considerable amounts, is a decided benefit to "lean" mortars, whereas it does not appreciably affect the strength of a rich mixture.[a]

GRAVEL.

It is important that gravel for use in concrete should be clean, in order that the cement may properly adhere to it, and form a strong and compact mass. As with sand, it is well to have the pieces vary in size, thereby reducing the voids to be filled with mortar. The voids in general range from 35 to 40 per cent.

CRUSHED STONE.

The best stone for concrete work consists of angular pieces, varying in size and having a clean, rough surface. Some form of strong and durable rock is to be preferred, such as limestone, trap, or granite. The total output of the crusher should be used below a maximum size, depending upon the nature of the work in hand. All material under one-eighth inch will act as so much sand and should be considered as such in proportioning the mixture. (See p. 10.) Precautions must be taken to insure a uniform distribution of the smaller pieces of stone, otherwise the concrete will have an excess of fine material in some parts and a deficiency in others.

Less than 8 per cent of clay will probably not seriously impair the strength of the concrete, provided the stones are not coated with it, and may even prove a benefit in the case of lean mixtures. The voids in crushed stone depend upon the shape and variation in size of pieces, rarely falling below 40 per cent, unless much fine material is present, and in some cases reaching 50 per cent. A mixture of stone and gravel in equal parts makes an excellent aggregate for concrete.

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[a] See Appendix, p. 32.

STONE VERSUS GRAVEL.

It would appear from tests that crushed stone makes a somewhat stronger concrete than gravel, but the latter is very extensively used with uniformly good results. This superiority of stone over gravel for concrete work is attributed to the fact that the angular pieces of stone interlock more thoroughly than do the rounded pebbles, and offer a rougher surface to the cement. A point in favor of gravel concrete is that it requires less tamping to produce a compact mass than in the case of crushed stone. Then, too, the proportion of voids in stone being usually greater than in gravel, a proportionately greater amount of mortar is required to fill the voids, which means a slight increase in the cost of concrete.

CINDERS.

Cinder concrete is frequently used in connection with expanded metal and other forms of reinforcement for floor construction, and for this purpose it is well adapted on account of its light weight. Its porosity makes it a poor conductor of heat and permits the driving of nails. Only hard and thoroughly burned cinders should be used, and the concrete must be mixed quite soft so as to require but little tamping and to avoid crushing the cinders. Cinder concrete is much weaker, both in tension and compression, than stone or gravel concrete, and for this reason admits only of light reinforcement.

CONCRETE.

GENERAL DISCUSSION.

Cement concrete is the product resulting from an intimate mixture of cement mortar with an aggregate of crushed stone, gravel, or similar material. The aggregate is crushed or screened to the proper size as determined from the character of the work. In foundation work, stone or gravel 3 inches in size may be used to advantage, whereas in the case of molded articles of small sectional area, such as fence posts, hollow building blocks, etc., it is best to use only such material as will pass a one-half inch screen. An ideal concrete, from the standpoint of strength and economy, would be that in which all voids in the aggregate were completely filled with sand, and all voids in the sand completely filled with cement, without any excess. Under these conditions there would be a thoroughly compact mass and no waste of materials.

It is a simple matter to determine the voids in sand and also in the aggregate, but in mixing concrete the proportions vary a great deal, depending in each case upon the nature of the work and the strength desired. For example, in the construction of beams and floor panels, where maximum strength with minimum weight is desired, a rich concrete is used, whereas in massive foundation work, in which bulk or weight is the controlling factor, economy would point to a lean mixture. When good stone or gravel is used, the strength of the concrete depends upon the strength of the mortar employed in the mixing and the proportion of mortar to aggregate. For a given mortar the concrete will be strongest when only enough mortar is used to fill the voids in the aggregate, less strength being obtained by using either a greater or less proportion. In practice it is usual to add a slight excess of mortar over that required to fill the voids in the aggregate.

It is more accurate to measure cement by weight, unless the unit employed be the barrel or sack, because when taken from the original package and measured in bulk there is a chance of error due to the amount of shaking the cement receives. As it is less convenient, however, to weigh the cement it is more common to measure it by volume, but for the reason stated this should be done with care.

PROPORTIONING MATERIALS.

For an accurate determination of the best and most economical proportions where maximum strength is required, it is well to proceed in the following way: First, proportion the cement and sand so that the cement paste will be 10 per cent in excess of the voids in sand; next, determine the voids in the aggregate and allow sufficient mortar to fill all voids, with an excess of 10 per cent.

To determine roughly the voids in gravel or crushed stone, prepare a water-tight box of convenient size and fill with the material to be tested; shake well and smooth off even with the top. Into this pour water until it rises flush with the surface. The volume of water added, divided by the volume of the box, measured in the same units, represents the proportion of voids. The proportion of voids in sand may be more accurately determined by subtracting the weight of a cubic foot of packed sand from 165, the weight of a cubic foot of quartz, and dividing the difference by 165.[a]

[a] The following will serve as an example of proportioning materials: Assume voids in packed sand to measure 38 per cent and voids in packed stone to measure 48 per cent. Cement paste required per cubic foot of sand $=0.38+\frac{1}{10}\times0.38=0.42$ cubic foot, approximately. By trial 1 cubic foot of loose cement, lightly shaken, makes 0.85 cubic foot of cement paste, and requires $\frac{0.85}{0.42}$, or 2 cubic feet of sand, approximately, producing an amount of mortar equal to $0.85+2(1-0.38)=2.09$ cubic feet. Mortar required per cubic foot of stone $=0.48+\frac{1}{10}\times0.48=0.528$ cubic foot. Therefore 2.09 cubic feet mortar will require $\frac{2.09}{0.528}=4$ cubic feet of stone, approximately. The proportions are therefore 1 part cement, 2 parts sand, 4 parts stone. Although such a determination is usually considered unnecessary in practical work, it may be of sufficient interest to justify giving it.

For general use the following mixtures are recommended.

1 cement, 2 sand, 4 aggregate, for very strong and impervious work.
1 cement, $2\frac{1}{2}$ sand, 5 aggregate, for ordinary work requiring moderate strength.
1 cement, 3 sand, 6 aggregate, for work where strength is of minor importance

AGGREGATE CONTAINING FINE MATERIAL.

In the case of gravel containing sand, or crushed stone from which the small particles have not been removed by screening, the amount of such sand or fine stone should be determined and due allowance made for it in proportioning the mortar.

When mixing an aggregate containing small particles with mortar, the same conditions obtain as if these particles had been screened from the aggregate and added to the sand used in making the mortar, and in reality we have a mortar containing a larger proportion of sand than was present before the aggregate was incorporated. It is evident, then, that in such cases the quality or richness of the mortar should depend upon the proportion of fine material in the aggregate.

For example, suppose that 1 cubic foot of gravel contains 0.1 cubic foot of sand, and that the voids in gravel with sand screened out measure 40 per cent. For general purposes this would suggest a 1–2–5 mixture, but since each cubic foot contains 0.1 cubic foot sand, 5 cubic feet of gravel will contain 0.5 cubic foot sand, and the proportions should be changed to 1 part cement, $1\frac{1}{2}$ parts sand, 5 parts gravel.

MECHANICAL MIXERS.

It has been demonstrated that concrete can be mixed by machinery as well, if not better, than by hand. Moreover, if large quantities of concrete are required, a mechanical mixer introduces marked economy in the cost of construction. None of the various forms of mechanical mixers will be described here, since concrete in small quantities, as would be used on the farm, is more economically mixed by hand.

MIXING BY HAND.

In mixing concrete by hand a platform is constructed as near the work as is practicable, the sand and aggregate being dumped in piles at the side. If the work is to be continuous, this platform should be of sufficient size to accommodate two batches, so that one batch can be mixed as the other is being deposited. The cement must be kept under cover and well protected from moisture. A convenient way of measuring the materials is by means of bottomless boxes or frames made to hold the exact quantities needed for a batch.

A very common and satisfactory method of mixing concrete is as follows: First measure the sand and cement required for a batch and mix these into mortar as described on page 5. Spread out this mortar in a thin layer and on top of it spread the aggregate, which has been previously measured and well wetted. The mixing is done by turning with shovels three or more times, as may be found necessary to produce a thoroughly uniform mixture, water being added if necessary to give the proper consistency. The mixers, two or four in number, according to the size of the batch, face each other and shovel to right and left, forming two piles, after which the material is turned back into a pile at the center. By giving the shovel a slight twist, the material is scattered in leaving it and the efficiency of the mixing is much increased.

CONSISTENCY OF CONCRETE.

A dry mixture, from which water can be brought to the surface only by vigorous tamping, is probably the strongest, but for the sake of economy, and to insure a dense concrete well filling the molds, a moderately soft mixture is recommended for ordinary purposes. Where the pieces to be molded are thin, and where small reinforcing metal rods are placed close together or near the surface, a rather wet mixture may be necessary to insure the molds being well filled.

USE OF QUICK-SETTING CEMENT.

In the manufacture of such articles as pipe, fence posts, and hollow blocks, a rather large proportion of quick-setting cement is sometimes used, the object being to reduce the weight and consequent freight charges by means of a strong mixture, as well as to make the concrete impervious to water. The use of a quick-setting cement permits the molds to be removed sooner than would be possible with a slow-setting cement, thus reducing the number of molds necessary for a given output. Quick-setting cements are not recommended for such purposes, however, as they are usually inferior to those which set slowly.

COLORING CEMENT WORK.

In coloring cement work the best results are obtained by the use of mineral pigments. The coloring matter, in proportions depending upon the desired shade, should be thoroughly mixed with the dry cement before making the mortar. By preparing small specimens of the mortar and noting the color after drying, the proper proportions may be determined.

For gray or black, use lampblack.
For yellow or buff, use yellow ocher.
For brown, use umber.
For red, use venetian red.
For blue, use ultramarine.

DEPOSITING CONCRETE.

Concrete should be deposited in layers of from 4 to 8 inches and thoroughly tamped before it begins to harden. The tamping required will depend upon the consistency of the mixture. If mixed very dry it must be vigorously rammed to produce a dense mass, but as the proportion of water increases less tamping will be found necessary. Concrete should not be dumped in place from a height of more than 4 feet, unless it is again mixed at the bottom. A wooden incline may be used for greater heights. Rammers for ordinary concrete work should weigh from 20 to 30 pounds and have a face not exceeding 6 inches square. A smaller face than this is often desirable, but a larger one will be less effective in consolidating the mass. In cramped situations special forms must be employed to suit the particular conditions. When a thickness of more than one layer is required, as in foundation work, two or more layers may be worked at the same time, each layer slightly in advance of the one next above it and all being allowed to set together. At the end of a day there is usually left a layer partially completed which must be finished the next day. This layer should not be beveled off, but the last batch of concrete should be tamped behind a vertical board forming a step.

To avoid introducing a plane of weakness where fresh concrete is deposited upon that which has already set, certain precautions have to be observed. The surface of the old work should be clean and wet before fresh material is put on, a thin coating of neat cement grout being sometimes employed to insure a good bond. The surface of concrete to receive an additional layer must not be finished off smoothly, but should offer a rough surface to bond with the next layer. This may be done by roughing the surface while soft with pick or shovel, or the concrete may be so rammed as to present a rough and uneven surface. Wooden blocks or scantling are sometimes embedded several inches in the work and removed before the concrete hardens, thus forming holes or grooves to be filled by the next layer.

RETEMPERING.

As stated before, it is important that concrete be tamped in place before it begins to harden, and for this reason it is proper to mix only so much at a time as is required for immediate use. The retempering of concrete which has begun to set is a point over which there is much controversy. From tests made in this laboratory [a] it would appear that such concrete suffers but little loss of strength if thoroughly mixed with sufficient water to restore normal consistency.

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[a] See Appendix, p. 31.

The time required for concrete to set depends upon the character of the cement, upon the amount and temperature of the water used in mixing, and upon the temperature of the air. Concrete mixed dry sets more quickly than if mixed wet, and the time required for setting decreases as the temperature of the water rises. Warm air also hastens the setting.

CONCRETE EXPOSED TO SEA-WATER.

Portland cement concrete is well adapted for work exposed to sea-water, but when used for this purpose it should be mixed with fresh water. The concrete must be practically impervious, at least on the surface, and to accomplish this the materials should be carefully proportioned and thoroughly mixed. It is also of great importance that the concrete be well compacted by tamping, particularly on exposed surfaces.

CONCRETE WORK IN FREEZING WEATHER.

Although it is advisable under ordinary circumstances to discontinue cement work in freezing weather, Portland cement may be used without serious difficulty by taking a few simple precautions. As little water as possible should be used in mixing, to hasten the setting of the cement. To prevent freezing, hot water is frequently used in mixing mortar or concrete, and with the same object in view salt is added in amounts depending upon the degree of cold. A common practice is to add 1 pound of salt to 18 gallons of water, with the addition of 1 ounce of salt for each degree below 32° F. Either of the above methods will give good results, but it should be remembered that the addition of salt often produces efflorescence. It seems to be a fairly well-established fact that concrete deposited in freezing weather will ultimately develop full strength, showing no injury due to the low temperature.

RUBBLE CONCRETE.

In massive concrete work considerable economy may often be introduced by the use of large stones in the body of the work, but only in heavy foundations, retaining walls, and similar structures should this form of construction be permitted. In placing these large stones in the work the greatest care must be exercised to insure each being well bedded, and the concrete must be thoroughly tamped around them. Each stone should be at least 4 inches from its neighbor and an equal distance from the face of the work.

TO FACE CONCRETE.

A coating of mortar one-half to 1 inch in thickness is frequently placed next the form to prevent the stone or gravel from showing and to give a smooth and impervious surface. If in preparing this mortar finely crushed stone is used instead of sand, the work will more nearly resemble natural stone. A common method employed in facing concrete is to provide a piece of thin sheet metal of convenient length and about 8 or 10 inches wide. To this pieces of angle iron are riveted, so that when placed next to the mold a narrow space is formed in which the cement mortar is placed after the concrete has been deposited behind it (fig. 1). The metal plate is then withdrawn and the concrete well tamped. The concrete and facing mortar must be put in at the same time so that they will set together. If the concrete is fairly rich. a smooth surface can usually be produced without

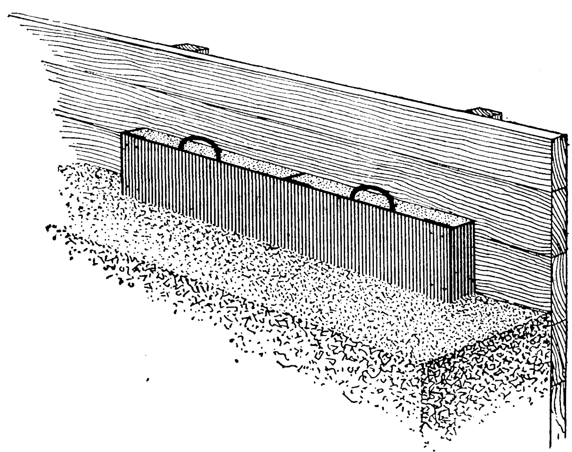


FIG. 1.—Sheet-metal plate used in facing concrete.

a facing of mortar by working a spade up and down between the concrete and inner face of the mold, thus forcing the larger pieces of the aggregate back from the surface.

WOOD FOR FORMS.

Lumber used in making forms for concrete should be dressed on one side and both edges. The expansion and distortion of the wood due to the absorption of water from the concrete frequently make it difficult to produce an even surface on the work, and unless the forms are accurately fitted together more or less water will find its way out through the cracks, carrying some of the cement with it. A method sometimes adopted to minimize the effect of expansion is to bevel one edge of each board, allowing this edge to crush against the square edge of the adjacent board when expansion takes place. In the case of a wooden core or inside mold, expansion must always be taken into consideration, for if neglected it may cause cracks or complete rupture of the concrete. Sharp edges in concrete are easily chipped and should be avoided by placing triangular strips in the corners of molds. To prevent cement from sticking to the forms they may be given a coating of soft soap or be lined with paper. This greatly facilitates their removal and enables them to be used again with but little scraping. A wire brush answers best for cleaning the forms.

CONCRETE SIDEWALKS.

A useful and comparatively simple application of concrete is in the construction of sidewalks, for which purpose it has been used with marked success for a number of years.

EXCAVATION AND PREPARATION OF SUBGRADE.

The ground is excavated to subgrade and well consolidated by ramming to prepare it for the subfoundation of stone, gravel, or cinders. The depth of excavation will depend upon the climate and nature of the ground, being deeper in localities where heavy frosts occur or where the ground is soft than in climates where there are no frosts. In the former case the excavation should be carried to a depth of 12 inches, whereas in the latter from 4 to 6 inches will be sufficient. No roots of trees should be left above subgrade.

THE SUBFOUNDATION.

The subfoundation consists of a layer of loose material, such as broken stone, gravel, or cinders, spread over the subgrade and well tamped to secure a firm base for the main foundation of concrete which is placed on top. It is most important that the subfoundation be well drained to prevent the accumulation of water, which, upon freezing, would lift and crack the walk. For this purpose it is well to provide drain tile at suitable points to carry off any water which may collect under the concrete. An average thickness for subfoundation is 4 to 6 inches, although in warm climates, if the ground is firm and well drained, the subfoundation may be only 2 to 3 inches thick or omitted altogether.

THE FOUNDATION.

The foundation consists of a layer of concrete deposited on the subfoundation and carrying a surface layer or wearing coat of cement mortar. If the ground is firm and the subfoundation well rammed in place and properly drained, great strength will not be required of the concrete, which may, in such cases, be mixed in about the proportions 1–3–6, and a depth of only 3 to 4 inches will be required. Portland cement should be used and stone or gravel under 1 inch in size, the concrete being mixed of medium consistency, so that moisture will show on the surface without excessive tamping.

THE TOP DRESSING OR WEARING SURFACE.

To give a neat appearance to the finished walk, a top dressing of cement mortar is spread over the concrete, well worked in, and brought to a perfectly smooth surface with straightedge and float. This mortar should be mixed in the proportion 1 part cement to 2 parts sand, sharp coarse sand or screenings below one-fourth inch of some hard, tough rock being used. The practice of making the concrete of natural cement and the wearing surface of Portland is not to be commended, owing to a tendency for the two to separate.

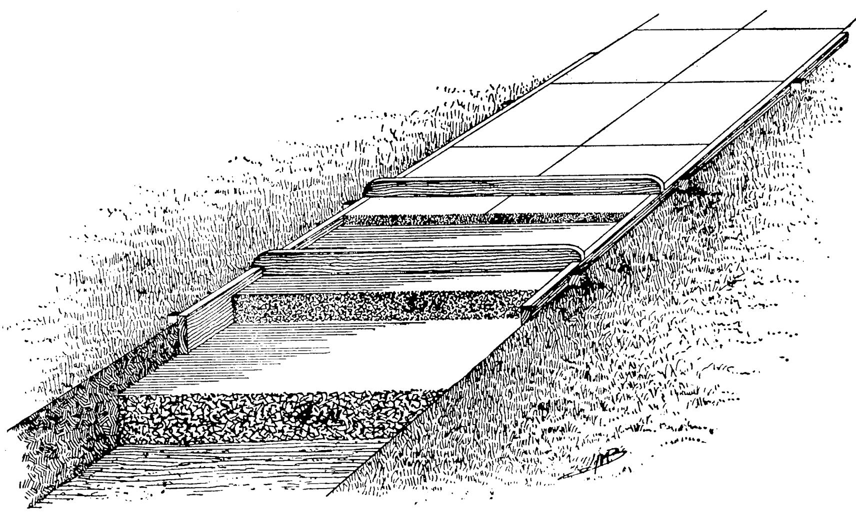


FIG. 2.—Details of concrete walk construction.

DETAILS OF CONSTRUCTION.

A cord stretched between stakes will serve as a guide in excavating, after which the bottom of the trench is well consolidated by ramming, any loose material below subgrade being replaced by sand or gravel. The material to form the subgrade is then spread over the bottom of the trench to the desired thickness and thoroughly compacted. Next, stakes are driven along the sides of the walk, spaced 4 to 6 feet apart, and their tops made even with the finished surface of the walk, which should have a transverse slope of one-fourth inch to the foot for drainage. Wooden strips at least 1½ inches thick and of suitable depth are nailed to these stakes to serve as a mold for the concrete. By carefully adjusting these strips to the exact height of the stakes they may be used as guides for the straightedge in leveling off the concrete and wearing surface. The subfoundation is well sprinkled to receive the concrete, which is deposited in the usual manner, well tamped behind a board set vertically across the trench, and leveled off with a straightedge as shown in fig. 2, leaving one-half to 1 inch for the wearing surface. Three-eighths inch sand joints are provided at intervals of 6 to 8 feet to prevent expansion cracks, or, in case of settlement, to confine the cracks to these joints. This is done either by depositing the concrete in sections, or by dividing it into such sections with a spade when soft and filling the joints with sand. The location of each joint is marked on the wooden frame for future reference.

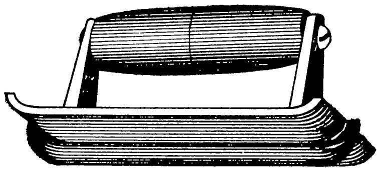


FIG. 3.—Jointer used in dividing walk into sections.

Care must be exercised to prevent sand or any other material from being dropped on the concrete, and thus preventing a proper union with the wearing surface. No section should be left partially completed to be finished with the next batch or left until the following day. Any concrete left after the completion of a section should be mixed with the next batch.

It is of the utmost importance to follow up closely the concrete work with the top dressing in order that the two may set together. This top dressing should be worked well over the concrete with a trowel, and leveled with a straightedge (fig. 2) to secure an even surface. Upon the thoroughness of this operation often depends the success or failure of the walk, since a good bond between the wearing surface and concrete base is absolutely essential. The mortar should be mixed rather stiff. As soon as the film of water begins to leave the surface, a wooden float is used, followed up by a plasterer's trowel, the operation being similar to that of plastering a wall. The floating, though necessary to give a smooth surface, will, if continued too long, bring a thin layer of neat cement to the surface and probably cause the walk to crack.

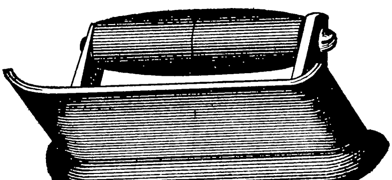


FIG. 4.—Tool used in rounding edges.

The surface is now divided into sections by cutting entirely through, exactly over the joints in the concrete. This is done with a trowel guided by a straightedge, after which the edges are rounded off with a special tool called a jointer, having a thin shallow tongue (fig. 3). These sections may be subdivided in any manner desired for the sake of appearance.

A special tool called an edger (fig. 4) is run around the outside of the walk next to the mold, giving it a neat rounded edge. A toothed roller (fig. 5) having small projections on its face is frequently used to produce slight indentations on the surface, adding somewhat to the appearance of the walk. The completed work must be protected from the sun and kept moist by sprinkling for several days. In freezing weather the same precautions should be taken as in other classes of concrete work.

CONCRETE BASEMENT FLOORS.

Basement floors in dwelling houses as a rule require only a moderate degree of strength, although in cases of very wet basements, where water pressure from beneath has to be resisted, greater strength is required than would otherwise be necessary. The subfoundation should be well drained, sometimes requiring the use of tile for carrying off the water. The rules given for constructing concrete sidewalks apply equally well to basement floors. The thickness of the concrete foundation is usually from 3 to 5 inches, according to strength desired, and for average work a 1–3–6 mixture is sufficiently rich. Expansion joints are frequently omitted, since the temperature variation is less than in outside work, but since this omission not infrequently gives rise to unsightly cracks, their use is recommended in all cases. It will usually be sufficient to divide a room of moderate size into four equal sections, separated by one-half inch sand joints. The floor should be given a slight slope toward the center or one corner, with provision at the lowest point for carrying off any water that may accumulate.

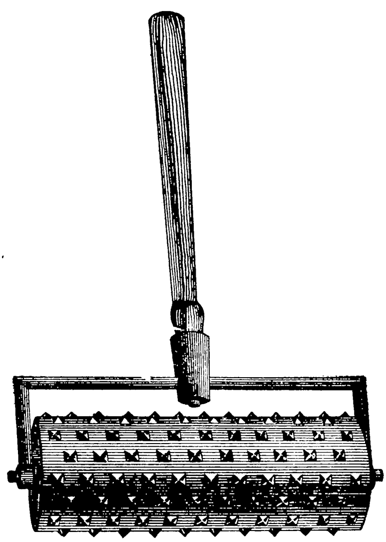


FIG. 5.—Roller used in finishing surface.

CONCRETE STABLE FLOORS AND DRIVEWAYS.

Concrete stable floors and driveways are constructed in the same general way as basement floors and sidewalks, but with a thicker foundation, on account of the greater strength required. The foundation may well be 6 inches thick, with a 1-inch wearing surface. An objection sometimes raised against concrete driveways is that they become slippery when wet; but this fault is in a great measure overcome by dividing the wearing surface into small squares about 4 inches on the side, by means of triangular grooves three-eighths of an inch deep. This gives a very neat appearance and furnishes a good foothold for horses.

CONCRETE STEPS.

Concrete may be advantageously used in the construction of steps, particularly in damp places, such as areaways and cellars of houses; and in the open, where the ground is terraced, concrete steps and walks can be made exceedingly attractive. Where the ground is firm it may be cut away as nearly as possible in the form of steps, with each step left 2 or 3 inches below its finished level. The steps are formed, beginning at the top, by depositing the concrete behind vertical boards so placed as to give the necessary thickness to the risers and projecting high enough to serve as a guide in leveling off the tread. Such steps may be reinforced where greater strength is desired or where there is danger of cracking, due to settlement of the ground.

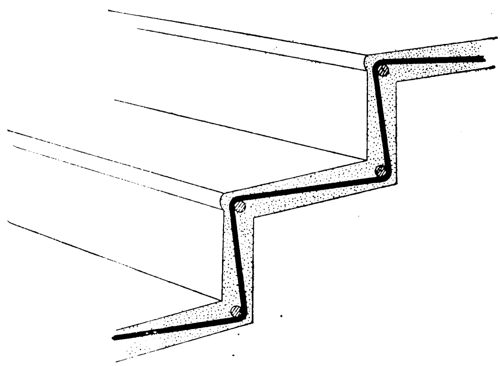


FIG. 6.—Reinforced concrete steps.

Where the nature of the ground will not admit of its being cut away in the form of steps, the risers are molded between two vertical forms. The front one may be a smooth board, but the other should be a piece of thin sheet metal, which is more easily removed after the earth has been tamped in behind it. A simple method of reinforcing steps is to place a half-inch steel rod in each corner, and thread these with quarter-inch rods bent to the shape of the steps, as shown in fig. 6, the latter being placed about 2 feet apart. For this class of work a rich Portland cement concrete is recommended, with the use of stone or gravel under one-half inch in size. Steps may be given a half-inch wearing surface of cement mortar mixed in the proportion 1 part cement to 2 parts sand. This system, as well as many others, is well adapted for stairways in houses.

REINFORCED CONCRETE FENCE POSTS.

COMPARISON OF DIFFERENT POST MATERIALS.

There is a constantly increasing demand for some form of fence post which is not subject to decay. The life of wooden posts is very limited, and the scarcity of suitable timber in many localities has made it imperative to find a substitute. A fence post, to prove thoroughly satisfactory, must fulfill three conditions: (1) It must be obtainable at a reasonable cost; (2) it must possess sufficient strength to meet the demands of general farm use; (3) it must not be subject to decay and must be able to withstand successfully the effects of water, frost, and fire. Although iron posts of various designs are frequently used for ornamental purposes, their adoption for general farm use is prohibited by their excessive cost. Then, too, iron posts exposed to the weather are subject to corrosion, to prevent which necessitates repainting from time to time, and this item will entail considerable expense in cases where a large number of posts are to be used.

At the present time the material which seems most nearly to meet these requirements is reinforced concrete. The idea of constructing fence posts of concrete reinforced with iron or steel is by no means a new one, but on the contrary such posts have been experimented with for years, and a great number of patents have been issued covering many of the possible forms of reinforcement. It is frequently stated that a reinforced concrete post can be made and put in the ground for the same price as a wooden post. Of course this will depend in any locality upon the relative value of wood and the various materials which go to make up the concrete post, but in the great majority of cases, wood will prove the cheaper material in regard to first cost. On the other hand, a concrete post will last indefinitely, its strength increasing with age, whereas the wooden post must be replaced at short intervals, probably making it more expensive in the long run.

In regard to strength, it must be borne in mind that it is not practicable to make concrete fence posts as strong as wooden posts of the same size; but since wooden posts, as a rule, are many times stronger than is necessary, this difference in strength should not condemn the use of reinforced concrete for this purpose. Moreover, strength in many cases is of little importance, the fence being used only as a dividing line, and in such cases small concrete posts provide ample strength and present a very uniform and neat appearance. In any case, to enable concrete posts to withstand the loads they are called upon to carry, sufficient strength may be secured by means of reinforcement, and where great strength is required this may be obtained by using a larger post with a greater proportion of metal and well braced, as is usual in such cases. In point of durability, concrete is unsurpassed by any material of construction. It offers a perfect protection to the metal reinforcement and is not itself affected by exposure, so that a post constructed of concrete reinforced with steel will last indefinitely and require no attention in the way of repairs.

REINFORCEMENT.

No form of wooden reinforcement, either on the surface or within the post, can be recommended. If on the surface, the wood will soon decay, and if a wooden core is used it will in all probability swell by the absorption of moisture and crack the post. The use of galvanized wire is sometimes advocated, but if the post is properly constructed and a good concrete used, this precaution against rust will be unnecessary, since it has been fully demonstrated by repeated tests that concrete protects steel perfectly against rust. If plain, smooth wire or rods are used for reinforcement they should be bent over at the ends or looped to prevent slipping in the concrete. Twisted fence wire may usually be obtained at a reasonable cost and is very well suited for this purpose. Barbed wire has been proposed and is sometimes used, although the barbs make it extremely difficult to handle. For the sake of economy the smallest amount of metal consistent with the desired strength must be used, and this requirement makes it necessary to place the reinforcement near the surface, where its strength is utilized to greatest advantage, with only enough concrete on the outside to form a protective covering. A reinforcing member in each corner of the post is probably the most efficient arrangement.

CONCRETE FOR FENCE POSTS.

The concrete should be mixed with Portland cement in about the proportion 1–2½–5, broken stone or gravel under one-half inch being used. In cases where the aggregate contains pieces smaller than one-fourth inch, less sand may be used, and in some cases it may be omitted altogether. A mixture of medium consistency is recommended on the ground that it fills the molds better, and with less tamping than if mixed quite dry.

MOLDS FOR FENCE POSTS.

Economy points to the use of a tapering post, which, fortunately, offers no difficulties in the way of molding. All things considered wooden molds will be found most suitable. They can be easily and quickly made in any desired size and form. Posts may be molded either in a vertical or horizontal position, the latter being the simpler and better method. If molded vertically a wet mixture is necessary, requiring a longer time to set, with the consequent delay in removing the molds. Fig. 7 shows a simple mold, which has been used with satisfactory results in this laboratory. This mold has a capacity of four posts, but larger molds could easily be made on the same principle. It consists of two end pieces (*a*) carrying lugs (*b*) between which are inserted strips (*c*). The several parts are held together with hooks and eyes, as shown in fig. 7. To prevent any bulging of the side strips they are braced, as illustrated. Dressed lumber at least 1 inch thick, and preferably $1\frac{1}{2}$ inches, should be used. In fig. 7 the post measures 6 by 6 inches at the bottom, 6 by 3 inches at the top, and 7 feet in length; having two parallel sides.

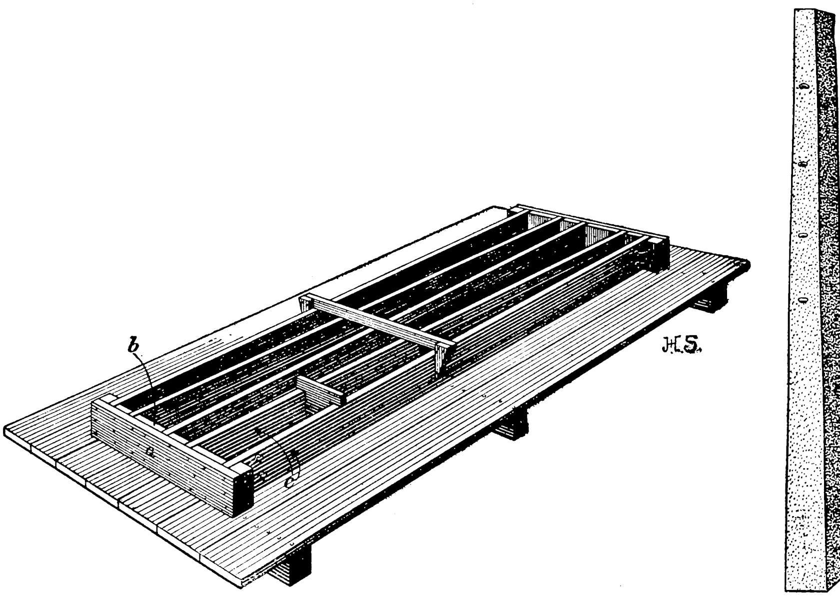


Fig. 7.—Wooden mold for making fence posts with two tapering sides.

If it is desired to have the posts square at both ends the mold must be arranged as in fig. 8. This latter form of post is not as strong as the former, but requires less concrete in its construction. Great care in tamping is necessary to insure the corners of the mold being well filled, and if this detail is not carefully watched, the metal, being exposed in places, will be subject to rust.

ATTACHING FENCE WIRES TO POSTS.

Various devices have been suggested for attaching fence wires to the posts, the object of each being to secure a simple and permanent fastener or one admitting of easy renewal at any time. Probably nothing will answer the purpose better than a long staple or bent wire well embedded in the concrete, being twisted or bent at the end to prevent extraction. Galvanized metal must be used for fasteners since they are not protected by the concrete. A piece of small flexi-

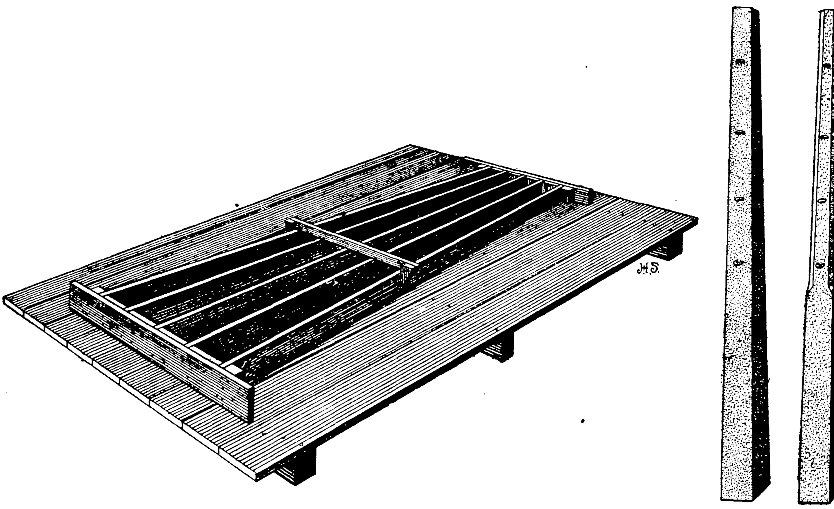


FIG. 8.—Wooden mold for making fence posts with four tapering sides.

ble wire, about 2 inches in length, threading the staple and twisted several times with a pair of pliers, holds the line wire in position (fig. 9).

MOLDING AND CURING POSTS.

For the proper method of mixing concrete see page 10. It is recommended that only so much concrete be mixed at one time as can be used before it begins to harden; but if an unavoidable delay prevents the posts being molded until after the concrete has begun to set, it is thought that a thorough regaging with sufficient water to restore normal consistency will prevent any appreciable loss of strength, though the concrete may have been standing one or two hours. In using a mold similar to those illustrated in figs. 7 and 8, it is necessary to provide a perfectly smooth and even platform of a size depending upon the number of posts to be molded. A cement floor if accessible may be used to advantage. The molds when in place are given a thin coating of soft soap, the platform or cement

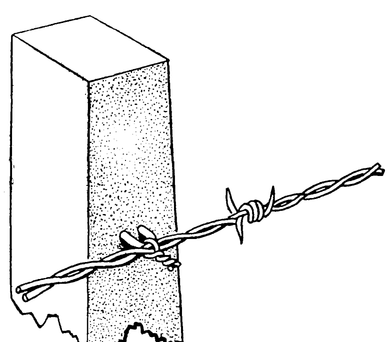


FIG. 9.—Detail showing method of attaching wire to post.

floor serving as bottom of mold being treated in the same way. About $1\frac{1}{2}$ inches of concrete is spread evenly over the bottom and carefully tamped, so as to reduce it to a thickness of about 1 inch. A piece of board cut as in fig. 7 will be found useful in leveling off the concrete to the desired thickness before tamping. On top of this layer two reinforcing members are placed about 1 inch from the sides of the mold. The molds are then filled and tamped in thin layers to the level of the other two reinforcing members, the fasteners for fence wires being inserted during the operation. These reinforcing members are adjusted as were the first two, and the remaining 1 inch of concrete tamped and leveled off, thus completing the post so far as molding is concerned. To avoid sharp edges which are easily chipped triangular strips may be placed in the bottom of mold along the sides, and when the molds have been filled and tamped, similar strips may be inserted on top. The top edges may be beveled with a trowel or by running an edging tool having a triangular projection on its bottom along the edges. Such a tool is shown in fig. 10 and can easily be made of wood or metal. It is not necessary to carry the bevel below the ground line.

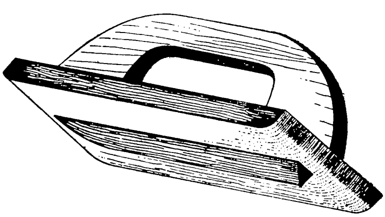


FIG. 10.—Tool used for beveling edges of posts.

The ends and sides of the mold may be removed after twenty-four hours, but the posts should not be handled for at least one week, during which time they must be well sprinkled several times daily and protected from sun and wind. The intermediate strips may be carefully withdrawn at the end of two or three days, but it is better to leave them in place until the posts are moved. Although a post may be hard and apparently strong when one week old, it will not attain its full strength in that length of time and must be handled with the utmost care to prevent injury. Carelessness in handling green posts frequently results in the formation of fine cracks, which, though unnoticed at the time, give evidence of their presence later in the failure of the post.

Posts should be allowed to cure for at least sixty days before being placed in the ground, and for this purpose it is recommended that when moved from the molding platform they be placed upon a smooth bed of moist sand and protected from the sun until thoroughly cured. During this period they should receive a thorough drenching at least once a day.

The life of the molds will depend upon the care with which they are handled. A coating of mineral oil or shellac may be used instead of soap to prevent the cement from sticking to the forms. As soon as the molds are removed they should be cleaned with a wire brush before being used again.

The cost of reinforced concrete fence posts depends in each case upon the cost of labor and materials, and must necessarily vary in different localities. An estimate in any particular case can be made as follows: One cubic yard of concrete will make 20 posts measuring 6 inches by 6 inches at bottom, 6 inches by 3 inches at top, and 7 feet long, and if mixed in the proportions 1–2½–5, requires approximately—

1.16 barrels of cement, at $2	$2.32
0.44 cubic yard of sand, at 75 cents	.33
0.88 cubic yard of gravel, at 75 cents	.66
Materials for 1 cubic yard concrete	3.31
Concrete for one post	.17
28 feet of 0.16-inch steel wire, at 3 cents per pound	.06
Total cost of concrete and metal for one post	.23

To this must be added the cost of mixing concrete, molding and handling posts, and the cost of molds, an addition which should not in any case exceed 7 cents, making a total of 30 cents per post.

CONCRETE BUILDING BLOCKS.

Concrete building blocks, or cement blocks, as they are frequently called, are more extensively used now than ever before. These blocks are molded hollow primarily to reduce their cost, but this hollow construction serves other useful purposes at the same time. The fundamental principles governing ordinary concrete work, so far as proportioning and mixing materials is concerned, apply equally well to the manufacture of building blocks, and it should be borne in mind that strength and durability can not be attained by the use of any machine unless the cement, sand, and aggregate are of good quality, properly proportioned, and well mixed. The aggregate for blocks of ordinary size should be crushed stone or gravel not larger than one-half inch. One of the chief causes of complaint against the concrete building block is its porosity, but this defect is in a great measure due to the fact that in an endeavor to economize, too little cement is frequently used. It is not unusual to give the blocks a facing of cement mortar consisting of about 2 parts sand to 1 of cement, while the body of the block is composed of a concrete of sufficient strength, though not impervious. This outside layer of mortar adds practically nothing to the strength of the block, and is used simply to give a uniform surface and to render the face of the wall more nearly impervious to water.

It would not be practicable as a rule to attempt the manufacture of concrete blocks without one of the many forms of molding machines designed for the purpose, nor would it be economical to purchase such a machine unless a sufficient number of blocks were required to justify such an outlay. Blocks in almost any desired shape and size, with either plain or ornamental faces, may be obtained on the market, and in the great majority of cases it is best to buy them from some reliable firm. Among the advantages claimed for hollow concrete block construction may be mentioned the following:

(1) Hollow block construction introduces a saving of material over brick or stone masonry.

(2) The cost of laying concrete blocks is less than for brickwork. This is due to the fact that the blocks, being larger, require a much smaller number of joints and less mortar, and, being hollow, are of less weight than solid brickwork.

(3) A wall constructed of good concrete blocks is as strong or stronger than a brick wall of equal thickness.

(4) Concrete blocks, being easily molded to any desired form, will prove to be a far more economical building material than stone, which has to be dressed to shape.

(5) Experience has proved concrete to be a most excellent fire-resisting material.

(6) Concrete blocks, being hollow, tend to prevent sudden changes of temperature within a house, making it cool in summer and easily heated in winter.

(7) The hollow spaces provide an easy means for running pipes and electric wires. These spaces may also be used wholly or in part for heating and ventilating flues.

APPENDIX.

TESTS OF CONCRETE FENCE POSTS.

In the summer of 1904 a number of reinforced concrete fence posts were made for experimental purposes, with a view to determining their adaptability for general use. These posts were made both with and without reinforcement, and tested at the age of 90 days. The reinforcement, ranging from 0.27 per cent to 1.13 per cent, consisted of four round steel rods, one in each corner of post about 1 inch from the surface, the posts having a uniform cross-section of 6 by 6 inches. The posts were molded in a horizontal position, as this was found by trial to be more satisfactory than molding them vertically.

The concrete was mixed moderately soft, crushed stone between 1 inch and one-fourth inch and gravel under three-fourths inch being used as aggregate. River sand, fairly clean and sharp, was employed with Portland cement. The posts were tested as beams supported at both ends and loaded at the center, with spans varying from 4 feet to 5 feet 6 inches. An attempt was made to prevent slipping by providing the reinforcing rods with collars and set screws at the ends, but in every case, with but two exceptions, the rods slipped under a comparatively light load, thus showing the necessity for some form of mechanical bond. As would be expected, those posts which were not reinforced possessed very little strength.

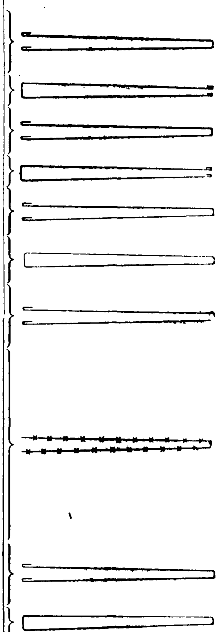
A series of tests were made with sheet-iron reinforcement, in the form of round and square pipes, embedded in the posts, but these posts, though developing considerable strength, proved less economical than those reinforced with plain rods, and at the same time were less simple in construction. The results of these tests, as recorded in Table I, do not properly represent the strength of similar posts in which some form of mechanical bond is provided to develop the full strength of the reinforcement.

TABLE 1.—*Showing results of preliminary tests of reinforced concrete fence posts.*

No.	Kind of reinforcement.	Per cent of reinforcement.	Mixture.	Material.	Span.	Load at first crack.	Maximum load.	Equivalent load on 4-foot cantilever at first crack.	Equivalent maximum load on 4-foot cantilever.
					Ft. in.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
1	No reinforcement.		1-3-5	Stone	4 0	1,435	1,435	359	359
2	do		1-3-5	do	4 0	670	670	168	168
20	do		1-3-7	Gravel	4 6	700	700	196	196
25	do		1-3-5	do	4 6	320	320	90	90
26	do		1-2-5	do	4 0	1,100	1,100	275	275
30	do		1-2-5	do	4 0	1,000	1,000	250	250
4	Plain steel rods	0.27	1-3-5	Stone	4 0	1,580	1,850	395	463
17	do	.27	1-3-5	do	4 0	1,135	1,945	284	486
21	do	.27	1-3-5	do	4 6	920	1,690	258	473
24	do	.27	1-3-5	do	4 6	940	1,660	263	465
28	do	.27	1-3-5	do	4 6	800	1,720	224	482
35	do	.27	1-2-5	Gravel	4 0	1,100	1,550	275	388
36	do	.27	1-2-5	do	4 6	900	1,460	252	409
39	do	.27	1-2-5	do	4 0	1,340	1,640	335	410
40	do	.27	1-2-5	do	5 6	760	1,120	258	381
42	do	.27	1-2-5	do	4 6	1,100	1,290	308	361
44	do	.27	1-2-5	do	5 6	....	1,080	....	367
3	do	.52	1-3-5	Stone	4 0	1,800	2,530	450	633
7	do	.52	1-3-5	do	4 6	1,600	2,155	448	603
13	do	.52	1-3-5	do	4 0	1,640	2,500	410	625
15	do	.52	1-3-5	do	4 0	1,960	2,400	490	600
27	do	.52	1-3-5	do	4 0	1,680	2,220	420	555
45	do	.52	1-2-5	Gravel	5 6	920	1,800	313	612
46	do	.52	1-2-5	do	4 0	900	2,740	225	685
47	do	.52	1-2-5	do	4 6	1,000	2,450	280	686
50	do	.52	1-2-5	do	4 0	1,200	3,125	300	781
5	do	.81	1-3-5	Stone	4 0	2,640	4,800	660	1,200
10	do	.81	1-3-5	do	4 0	1,480	4,100	370	1,025
12	do	.81	1-3-5	do	4 6	1,860	4,100	521	1,148
14	do	.81	1-3-5	do	4 6	1,800	3,915	504	1,096
19	do	.81	1-3-5	do	4 0	1,800	4,160	450	1,040
22	do	.81	1-3-5	do	4 6	1,900	2,900	532	812
34	do	.81	1-2-5	Gravel	4 6	1,750	4,100	490	1,148
37	do	.81	1-2-5	do	4 0	1,500	3,545	375	886
43	do	.81	1-2-5	do	4 0	1,700	4,200	425	1,050
48	do	.81	1-2-5	do	4 6	1,240	3,575	347	1,001
6	do	.95	1-3-5	Stone	4 0	1,980	5,150	495	1,288
11	do	.95	1-3-5	do	4 6	2,380	4,300	666	1,204
18	do	.95	1-3-5	do	4 6	1,800	4,240	504	1,187
49	do	.95	1-2-5	Gravel	5 6	900	2,600	306	884
51	do	.95	1-2-5	do	4 6	1,380	3,160	386	885
52	do	.95	1-2-5	do	4 6	1,200	3,345	336	937
53	do	.95	1-2-5	do	4 0	1,340	3,840	335	960
54	do	.95	1-2-5	do	5 6	980	2,600	333	884
8	do	1.13	1-3-5	Stone	4 6	2,220	3,820	622	1,070
9	do	1.13	1-3-5	do	4 0	2,560	5,080	640	1,270
16	do	1.13	1-3-5	do	4 6	2,000	3,100	560	868
23	do	1.13	1-3-5	do	4 0	1,800	4,900	450	1,225
29	do	1.13	1-3-5	do	4 0	2,400	4,460	600	1,115
32	do	1.13	1-2-5	Gravel	4 6	1,500	2,900	420	812
33	do	1.13	1-2-5	do	4 0	1,400	2,320	350	580
38	do	1.13	1-2-5	do	4 6	1,500	3,270	420	916
41	do	1.13	1-2-5	do	4 6	1,250	4,300	350	1,204
55	Pipe 5 inches diameter, $\frac{1}{40}$-inch thick.	1.10	1-2-5	do	4 6	1,800	4,000	504	1,120
56	do	1.10	1-2-5	do	4 6	1,720	4,000	482	1,120
57	do	1.10	1-2-5	do	4 6	....	4,660	....	1,305
58	□ 5 by 5 inches, $\frac{1}{40}$-inch thick.	1.39	1-2-5	do	4 6	2,400	6,320	672	1,770
59	do	1.39	1-2-5	do	4 6	2,100	5,880	588	1,646
60	do	1.39	1-2-5	do	4 6	2,200	6,040	616	1,691
61	× 5 by 5 inches, $\frac{1}{40}$-inch thick.	.98	1-2-5	Stone	4 6	1,100	2,450	308	686
62	do	.98	1-3-5	do	4 6	860	2,660	241	745
63	do	.98	1-3-5	do	4 6	1,800	2,400	504	672

In order to obtain more data on the subject, this investigation has been supplemented by a second series of tests, the results of which form the subject-matter for the sections on concrete fence posts and are expressed numerically in Table II.

TABLE II.—*Showing the strength of reinforced concrete fence posts.*

No.	Kind of reinforcement.	Total sectional area of reinforcement.	Load at first crack.	Maximum load.	Equivalent load on 4-foot cantilever at first crack.	Equivalent maximum load on 4-foot cantilever.	Form of reinforcement.
		Sq. in.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	
1	Drawn steel rods	0.08	800	1,120	218	306	
2	do	.08	820	1,145	224	313	
3	do	.08	640	1,080	175	295	
4	do	.08	795	1,040	217	284	
37	do	.08	940	1,170	257	319	
38	do	.08	740	1,075	202	293	
9	do	.19	1,140	1,280	311	349	
10	do	.19	1,170	1,885	319	515	
11	do	.19	1,020	1,950	278	532	
39	do	.19	760	1,945	207	531	
40	do	.19	820	1,925	224	526	
13	Twisted fence wire	.06	825	935	225	255	
15	do	.06	755	905	206	247	
16	do	.06	800	940	218	257	
17	do	.06	815	935	222	255	
18	do	.06	770	980	210	268	
19	do	.06	780	975	213	266	
21	do	.13	1,550	1,920	423	524	
22	do	.13	1,275	1,670	348	456	
23	do	.13	1,200	1,830	328	500	
24	do	.13	1,500	1,955	410	534	
25	Barbed wire	.06	980	980	268	268	
26	do	.06	820	820	224	224	
27	do	.06	590	740	161	202	
28	do	.06	745	745	203	203	
29	do	.06	590	590	161	161	
30	do	.06	550	640	150	175	
31	do	.06	560	635	153	173	
32	do	.06	480	530	131	145	
33	do	.13	680	1,040	186	284	
34	do	.13	840	1,010	229	276	
35	do	.13	1,280	1,515	349	414	
36	do	.13	800	1,375	218	375	
6	Drawn steel rods	.08	Tested by impact				
7	do	.19	do				
8	do	.19	do				
14	Twisted fence wire	.06	do				
20	do	.06	do				

In these tests it was decided to make the posts tapering in order to economize material and reduce their weight. For the concrete, Portland cement, river sand, and gravel were used in the proportion 1–2½–5, measured by volume, the gravel being screened below one-half inch. Sufficient water was used in mixing to produce a plastic mass, requiring only a moderate degree of tamping to bring water to the surface. The posts were molded, as described on page 23, kept under wet burlap for four weeks, and tested at the end of sixty days. The reinforcing members were placed in the corners of the posts about 1 inch from the surface, being looped and bent, as indicated in Table II. These posts were not designed with a view to developing the ultimate compressive strength of the concrete, but where greater strength is necessary it may be obtained at small expense by increasing the percentage of reinforcement. It is important that a fairly rich concrete should be used in all cases to enable the posts to stand exposure and to prevent chipping.

In these tests, as in those previously described, the object was to determine what transverse load, applied at a point 4 feet above the ground line, would be sufficient to crack the post, as well as the maximum load which could be sustained. Accordingly the posts were supported and loaded, as illustrated in figure 11, from which it is evident that the reaction at R represents the equivalent transverse load at the end of a 4-foot cantilever, corresponding to the applied load W at A, which is supposed to be the ground line, near which point failure occurred in every case except post No. 9, which sheared along the neutral axis.

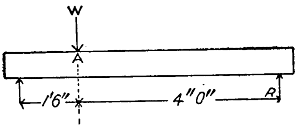


FIG. 11.—Method of testing posts under static loads.

All of these posts measured 6 by 6 inches at the bottom and 6 by 3 inches at the top, except Nos. 29, 30, 31, 32, 33, and 34, which were 6 by 6 inches at the bottom and 3 by 3 inches at the top. It will be noticed that the saving in concrete introduced in the construction of these posts is accompanied by a marked decrease in strength as compared with the other posts similarly reinforced. It would also appear that the twisted wire has a slight advantage over the barbed wire as a reinforcing material, particularly when two wires are used in each corner of the post.

As stated on page 20, it is impracticable to make a reinforced concrete fence post as strong as a wooden post of the same size, and this is more especially true if the post has to withstand the force of a sudden blow or impact. In order to study the behavior of these posts under impact, a number of them were braced, as illustrated in figure 12, and subjected to the blows of a 50-pound bag of gravel, suspended from above by a 9-foot rope. The first blow was delivered by deflecting the bag so as to give it a vertical drop of 1 foot, and for each successive blow the drop was increased 1 foot. None of the posts showed any sign of failure under the first blow. Posts Nos. 14 and 20 cracked under the second blow, and failed under the third. Post No. 6 cracked under the second blow, which crack opened under the third blow, causing a momentary deflection of 5 inches. Posts Nos. 7 and 8 each developed

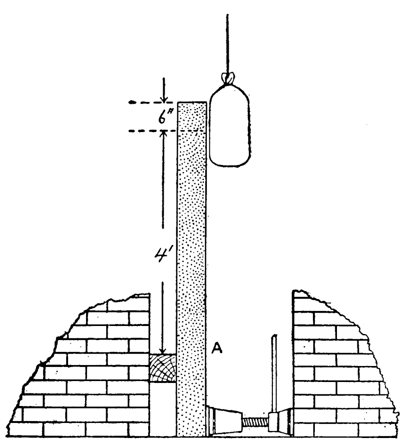


FIG. 12.—First method of testing posts by impact.

a crack under the second blow, but showed no further signs of weakness after the fifth blow, other than a slight opening of the initial crack. In each case the only crack developed was at point *A*. Posts 6, 7, and 8, which cracked but did not fail under the impact test, were further tested, as indicated in figure 13, by raising the small end and allowing them to drop from successive heights at 1, 2, 3, and 4 feet. Under this test a number of cracks developed, but in no case did the reinforcement fail.

Although it might appear from these results that posts as here described have hardly enough strength to recommend them for general use, it should be remembered that in many cases fence posts are not subjected to impact, and it may prove more economical to replace from time to time those which fail in this way than to use wooden posts, which, being subject to decay, must all be replaced sooner or later.

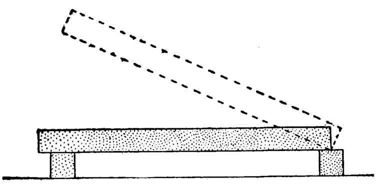


FIG. 13.—Second method of testing posts by impact.

RETEMPERING.

Table III illustrates the effect of retempering Portland cement mortar. The mortars used consisted of Portland cement and crushed quartzite between one and two millimeters in size, mixed in different proportions. In each case, after the initial or final set had taken place, sufficient water was added in retempering to restore normal consistency. The briquettes were tested at the age of four months.

TABLE III.—*Effect of retempering on cement mortars.*

Treatment of mortar.	Tensile strength, in pounds per square inch. Neat cement.[a]	1 part cement, 1 part sand.[b]	1 part cement, 2 parts sand.[c]	1 part cement, 3 parts sand.[d]
Mortar made up into briquettes immediately after mixing.	651 650 673 634 679	624 701 624 581 610	527 493 529 480 492	417 385 421 403 409
Average	657	628	504	407
Mortar allowed to take initial set, then broken up and made into briquettes.	671 593 644 633 724	692 670 654 676 700	589 554 559 534 532	326 349 330 358 267
Average	653	678	554	326
Mortar allowed to take final set, then broken up and made into briquettes.	455 522 525 558 642	527 569 587 566 568	492 491 497 486 531	364 380 361 315 345
Average	540	563	499	353

[a] Initial set, 1 hour 42 minutes; final set, 7 hours 15 minutes.
[b] Initial set, 1 hour 30 minutes; final set, 7 hours 15 minutes.
[c] Initial set, 2 hours; final set, 7 hours.
[d] Initial set, 2 hours 20 minutes; final set, 7 hours.

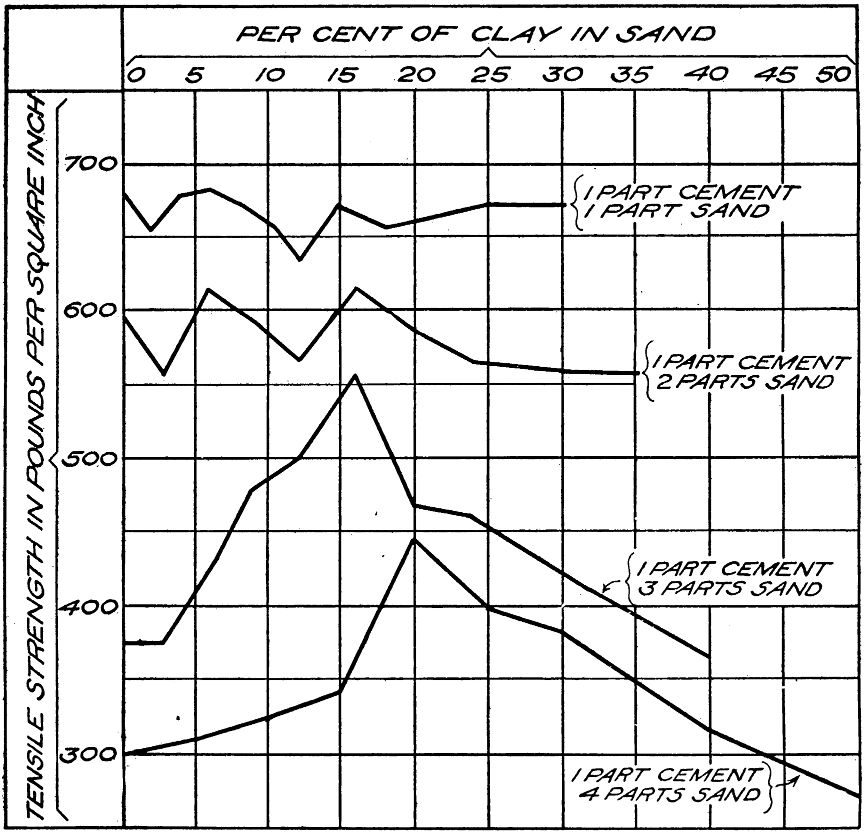


FIG. 14.—Diagram showing the effect of clay on cement mortars.

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