The

Cement Worker's

Hand-Book.

A Practical Treatise on Cement and its use in Construction.

Compiled to Meet the Requirements of the Lay Workman,

By

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NOTICE

The author feels indebted to S. B. Newberry, E. M., Ph. D.; Adolph Cluss, F. A. I. A., and others for much valuable information.

Also to "Portland Cement und seine Anwendungen im Bruwasen," and "Das Kleine Cement Buch." The two books that represent the latest and best thoughts on this subject in Germany, and perhaps in the world.

PREFACE

The present generation has witnessed a marvelous growth in the uses of hydraulic cements. And had the workmen in its manipulation kept in step with the constant and rapid evolution in its manufacture it would have still more completely revolutionized building and the materials used in general construction.

In 1882 only 185,000 bbls. of Portland Cement were used in the U. S.; in 1902, one decade later, 17,230,000 bbls. were used. Today in one district of the U. S. covering 100 square miles alone, there are 20 mills with an output per year of 11,00C,000 bbls. of Portland Cement.

The chemical and physical makeup, and consequently the nature of cement was often misjudged by the workman, resulting in work the most crude and unsatisfactory. Notwithstanding this condition of things, its generally recognized desirability, the multiplication of its uses and its demonstrated durability, have won for it the favor of the best engineers and architects of the day. Its rapidly increasing use has surpassed the predictions of its best friends. "Cement and steel are to be the building materials of the future."—Thos. A. Edison.

Before the American Institute of Architects Adolf Cluss stated, "That in the building trade cement must be reckoned with as one of the foremost components." For the reasons stated a more practical knowledge of its nature, and the workmanship in its application is greatly to be desired.

For twenty years (as a mason) I have had a varied experience in the uses of cement, and must say, as perhaps would many an honest fellow-workman, that I have constantly felt hampered by the want of more practical knowledge in this line. Though careful that I might add to my scant knowledge by experience and observation, yet no doubt there were defects that with the same materials, but by more skillful handling could have been averted. The amateur workman in cement always flies to the conclusion that what he lacks in experience he can readily make up by extra quantities of cement. Yet what is further from the truth? Even dangerous and expensive.

During this time, by constant effort, I was enabled to find but few books and a few articles in trade journals upon this, to me, important subject. These were written for engineers and architects, and consisted in trade words and technical terms which though clear to them, yet to the average workman they were obscure and meaningless, placing their application just a little above their comprehension or use. It has always been my contention that the workman who labors with his back to the sun should not be a mere machine in the hands of the engineer, but that for the best results in his craft, and for the intelligent consummation of the plans of an engineer or architect, he must be an intelligent force, knowing the fundamental principles, the causes and effects, that preserve his craft from the unskilled laborer.

Surely no calling presents a more exacting bid for skill, and in no calling can the want of it produce greater harm or ruin. Hence this little treatise, written for the humblest workman by a fellow-workman. We have not written because we felt most competent to do so, but because we have so keenly felt its need.

We aim to make this little book so simple, so clear, and fundamental, that the farmer and others not familiar with cement may do much of their own work, confident of success, while the more difficult work in this line must of necessity go to the regular cement worker, or mason.

Should you, after careful examination, decide that your theory and practice in handling cement cannot be enhanced by our humble efforts, no offense! On this very threshold we bid you "God speed," and may the stability and grandeur of your work be a worthy incentive to many a less fortunate workman.

But it is to you, my dear brother, who wishes to know more in this craft, that I dedicate this little volume.

W. H. BAKER,
Wadsworth, Ohio.

A. D., 1905.

After three editions of the first print had been exhausted, and the continued demand for the book having increased so much beyond the author's anticipations, it was thought advisable to revise the first copyright by a few changes and the addition of some matter not contained in the first. The brevity and simple directness which characterized the first print and which was so frequently commented on in reviews of note, has not been lost sight of.

It has also been the object of the author that the price of the book, which though not over one-fourth the price of similar books might not be increased, thus keeping it within the reach of the laborer for whom it is written.

April, 1906 W. H. BAKER.

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PART I.

INTRODUCTORY

COMMERCIAL HYDRAULIC CEMENTS

Historical

Hydraulic cements antedate the Christian era. Mortars play an important part in unraveling the mysteries of pre-historic civilization. Of ancient Niniva and Mantinea, though in their time magnificent and powerful, now little is known. Their structures of sand, dried clay and loam mortar have long since crumbled to dust.

The contemporaneous Roman buildings were built of hard burned bricks or stone bedded in either Bitumen or Asphalt pitch. Recent excavations show that these mortars show no trace of disintegration. The Pantheon at Rome, built with two masonry faces filled with Puzzolan concrete, show no unequal settling or shrinkage and but for external causes remain intact.

The phenomenal strength and durability of these Roman edifices today reap well deserved tribute and admiration.

Approaching the "Middle Ages," we find that the use of hydraulic mortars had given way to fat lime and silt mortars. The secret of these was even confined to centers of superior workmanship, such as the sites of renowned cathedrals. This was clearly a retrograde movement, as some of these costly structures were kept erect only by constant and expensive nursing. The mortar used in their construction became an inert powder devoid of strength and hardness.

About 1757 Smeaton in the erection of the Eddystone lighthouse tower on a reef near the English coast, by necessity was obliged if possible to find a hydraulic cement that would resist the action of the turbulent surf of the coast.

By extensive experiments he found that the limestone from Aberthaw which contained larger traces of clay than the others used in the test, showed greater cementing properties in water. This test was very important as establishing a chemical analysis favorable to clay (silica and alumina) with lime.

In the year 1796, Parker, an Englishman, burned the chalky clay lumps on the coast of England, and from it introduced a superior cement called Roman cement (because it resembled Puzzolan in color). This for a time was largely used. Following this came such men as Apsdin, the English mason, Pasly and many others.

In England, Germany, France and Belgium factories multiplied, and each successive factory may be claimed as a triumph towards better results. With the more recent methods of calcination and grinding the evolution has been rapid. Physical, chemical and mechanical investigations have been carried on from which important tests have been collated.

COMPOSITION

According to Dr. Michhaelis, a noted cement expert, the chemical analysis of good cement when burned is as follows: 62½ to 67 per cent lime, and 33½ per cent of silicates. This allows 4 per cent for accessories.

The basic elements are lime and clay.

An analysis of one of the foremost Portland cements of the U. S. shows the following elements:

Silca	20.64 per cent
Alumina	6.93 per cent
Oxide of Iron	5.41 per cent
Lime	62.79 per cent
Accessories	4.23 per cent

The most important process in the manufacture of cement is the vitrification process (differing with the various mills). The constituents having been pulverized are mixed into a homogeneous paste, balled, dried and burned by exposure to a quick white heat equal to the melting point of wrought iron, when the mass approaches the point of vitrification the heat is now withdrawn and the mass requires rapid cooling.

During this process chemical transformation by complicated reactions have taken place.

After cooling these vitrified clinkers they are ground into a dense drossy steel hard powder, most of which must pass through a silk sieve of 10,000 meshes to the square inch.

Portland cement owes its high reputation largely to these physical changes. Globulated textures make contact by points, laminated textures by sides or surface. In the U. S. great strides in the production of a superior Portland cement have resulted in a great reduction of prices (formerly paid importer and compared with which in many cases it is superior) bringing it into an extensive and wide range of uses.

PROPERTIES

By nature, natural or common cements are light or dark gray, varying according to the character of the stone from which they are made. Portland cements are bluish or greenish gray. Very fine ground cements, other things being equal, are superior to coarser varieties, carrying more sand. Cements have great specific gravity. Portland cements are heaviest, weighing 380 lbs. net per barrel of from 3½ to 4 cubic feet; 4 sacks of 95 lbs. each constitute one barrel. One barrel of natural (or common) cement weighs 300 lbs. per barrel of about 4 cubic feet; also 3 sacks of 100 lbs. each constitute one barrel.

Portland cements, especially if properly stored, can be carried from one season to another without loss in quality. Some makes have shown improvement. Long-stored cements become slightly slower setting but ultimately acquire full hardness and strength, but when cement is stored where it draws dampness sufficient to harden, it is damaged and in some cases worthless.

The amount of water required to work Natural and Portland cements plastic, varies with fineness, age and temperature, but is approximately as follows: Neat (cement only) Portland about 28 per cent; neat Natural about 32 per cent; one part cement and one part sand, 15 to 18 per cent; one part cement and two parts sand, 12 to 13 per cent of total weight of cement and sand.

CLASSIFICATION

Cements as manufactured today admit of being classified into two general classes, namely, Natural or Common, and Portland. For our purpose in this little treatise we will include Natural and Artificial Portland under the one head of Portland.

Natural Cement, in many places better known as common cement, is produced from calcareous (lime) stone, as found in nature. It is burned at a low temperature and is afterwards ground to a fine powder. It is less uniform in composition and consequently less reliable than are Portland cements. They usually show great hydraulic activity (quick setting); they carry less sand and require more water to hydrate than do Portland cements, work very plastic and smooth, and frequently show great adhesive power.

Portland Cement, so named because resembling in color the Portland rocks of England.

Natural Portland is manufactured in those rare cases where limestone is found which contains combinations of lime, silica, alumina in the chemical proportion found necessary in producing Artificial Portland, from which it does not differ in mechanical treatment. Natural Portland is still manufactured in England and the European Continent.

Artificial Portland—This is the cement in most common use, and which we refer to in this book in all our directions unless the natural or common is especially spoken of. This cement is considered the highest grade cement, being entirely in the hands of the operator its composition can be controlled to a per cent. In this country as elsewhere it has been found that there are many places where limestone and clay abound, from which the elements of a good artificial Portland can easily be obtained. Consequently the recent cheapening of this best quality of cement in this country. This cement is manufactured to be either slow or quick setting as desired for special uses. After many years' use of Portland cement, tests show no disintegration where they have been properly used; they carry large portions of sand, require less water to hydrate, are best for all kinds of work, mortar or concrete; submerged or in air react all climatic conditions and it now seems imminent that in the near future it will drive the natural or common cements entirely from the market.

PART II.

MORTARS

In the preceding chapter we spoke of the cement of commerce or cement shipped to points for use in bulk, barrels and sacks. In this chapter we shall speak of cement as incorporated in sand and water mixed into a plastic form and used in joining or bonding brick, stone and other constructing materials, for plastering walls, etc., and is also used to form the matrix for concrete, etc., but of this we shall speak more fully under concrete.

Composition.

The components of mortar are cement, sand and water, varying in proportion to suit the character of the work for which they are intended. Much will depend on the character of the sand used. Indeed so important is this that it is impossible to give reliable and at the same time economic proportions for a mortar that would be invariable when the character of the sand varies with every location, and sometimes with every job; so right at this point allow us to specify what we would require in sand. It must be clean, contain no clay, loam or soil deposits; if these are found the sand must be thoroughly washed before used. It must contain no soft, friable or chalky particles; such sand should be entirely discarded. For economy it should be irregular in shape and size.

"A chain is no stronger than its weakest link," neither can cement work be any stronger than its weakest component part. The best cement can form no adhesion to soft, yielding surfaces.

Then from this we conclude that sand must be clean, hard and irregular shaped (sharp), and variable in size. Clean that the cement in crystalizing may form contact or adhesion to surface. Irregular in shape that they may pack more closely and give strength by interlacing and cohesion to mass. Variable in size that the voids or spaces between the larger grains may be filled by the smaller ones, and their voids again by the cement, thus making a dense and compact mass. By breaking a piece of thoroughly hardened cement mortar and carefully examining the same on the broken edge with a magnifying glass the process of crystalization and the binding of particle to particle can clearly be seen.

It must be noted, too, that for proper cohesion the entire surface of each particle incorporated must be entirely coated over with cement, with so much in addition that the voids may all be filled; any more cement added would clearly be a waste, and, not only waste but harm, since excessive doses of cement have shown by many tests to weaken, ultimately causing rupture of cohesion in final crystalization, and yet what is more common for the inexperienced workman, than to "make sure," by extra doses of cement. From this the workman will remember that if the sand is quite fine and uniform that more cement must be used than when coarse. The water used in mixing mortar should be clean and free from mineral deposits. In preparing a few formulas in which we have reference to Portland cement only, the proportion could be changed for natural cement, where this can be used, by taking only two-thirds as much sand as given for the Portland.

Formula No. 1.—Cement, 1 part; sand, 1 to 2 parts. This composition forms the very best mortar and would be used only where extraordinary strength is required or great resistance to wearing or impermeability to water.

Formula No. 2.—Cement, 1 part; sand, 3 to 4 parts. This last composition forms a very ordinary mortar used in plastering, for bonding or brick in building, for foundations and cast work. The variation allowed in the sand in each formula will admit of slight adjustment to meet requirements. However, that we may not be misunderstood in formula No. 1 with good, rough sand 2 parts sand to 1 part cement is equal to, and usually better, than a mortar made from one part sand to 1 part cement.

Mixing and Handling Mortar.

Procure box of suitable size for the work at hand —stiled mortar box. The boards should be surfaced and bottom even so as not to catch hoe or shovel so annoying to the mixer. The sand and cement should always be gauged and not guessed, or even measured by the shovelful, as is often done. For work in a small way this may be measured to procure the exact proportion by either basket or pail. But on work of considerable proportion a box is made by which to measure the sand; a sack of Portland cement is taken as the unit, say about 1,900 cubic inches. If the proportion wished to be used is cement 1, sand 3, then the sand measure must contain 1,900×3=5,700 cubic inches or 2′x2′x10″ high. The box only requires sides and ends, no bottom. There should be handles nailed across two opposite sides, by which the box may be lifted up to empty. When ready place measure box into mortar box and fill even full of sand, catch hold of handles and lift box, allowing the sand to spread over bottom of mortar box. On this empty one sack of cement and with mortar hoe or shovel mix this thoroughly while dry. Now add water, little at a time, thoroughly working this into the mass, until sufficiently plastic for work. Mortar must be thoroughly incorporated from corners and bottom of box. Tests have been shown that briquet mortar in box showed increased strength of from 30 to 50 per cent, hence the importance of thoroughly working. In all work it is best to use as little water as possible, only to make it sufficiently plastic for use, and this should be added a little at a time, while being constantly worked.

The mixer must also exercise care not to mix more than can be used at once or before the first set which in slow cement is from 1½ to 2 hours. In quick setting cement about one-half hour, though by constant working and the addition of a very little water this first set can be retarded for several hours with little if any loss in the quality of the cement.

Nature of Mortar.

Mortar must be capable of plasticity to admit its manipulation. It must be constant in volume—wet or dry. Must possess adhesion and cohesion; must have tensile and compressive strength; must be invariable under different temperatures, and must not be affected by climatic conditions.

A part of the water applied to mortar when mixing forms with the solids chemical combinations, this is all the water the mortar would require to do its best work, but more must be added to work the mortar plastic for use, this surplus evaporates again during hydration. Hence too lavish use of water renders mortars porous, as parts of the water remain suspended in the mass, causing pock marks, etc.

Freshly mixed mortars present the following appearance in succession:

The water will come to the top or surface; next this water will be absorbed by the cement and evaporation. The mortar now begins to heat, and lastly returns to its normal condition. This last stage is called the "first set." This is a physical and chemical process and at this stage should not be disturbed. Quick setting cements arrive at this point in about one-half hour; slow setting cements in about two hours.

This "set" is on when the surface resists a slight pressure of the finger nails.

Cement once set is capable of hardening in water or air, but if in the air it should be kept wet for 6 or 8 days; this is called "seasoning."

Mortar in a short time acquires a high degree of strength. "Setting" and hardening of cement mortar should not be confused, they are not the same thing. Hardening begins where setting leaves off, and then continues to the highest strength of which the cement is capable, which is attained only after many years. Tests have shown it to continue for 8 or 10 years.

Quick and slow setting cements may impress the inexperienced workman as representating quality in favor of the quick cement. This, however, is not the case. Cements are manufactured in their chemical composition to be either quick or slow setting to meet the requirements of use. Most Portland cements are slow setting as these are best adapted to most work. Sometimes in submerged work a quick set is desirable, also in cast work.

Tests show that initial activity is frequently accomplished at the expense of gradual increase in hardness, and that slow setting cements have gradually gained and overtaken after a time the quick setting varieties. At this point a question will suggest itself. Can mortar when once set be again reworked by the addition of water and safely used? In answer to this question we can name no more competent authority than S. B. Newberry, who says, "That it should not be again used, but should be cleaned from mortar box and boards and thrown away, and not again incorporated into a new bed of mortar, as is frequently done." Another writer of considerable practice, Adolf Cluss, says, "That for a day, or so long as the water has not all been evaporated or absorbed the bad effects may be mostly overcome by adding a minimum of water, and beating into plasticity, when a mortar with less hydraulic activity but of strong and sure increase of density will result." In fairness to both authors there might be too much play on the word "set." Much would depend upon the stage which the set had attained. Experiments are shown to corroborate the remix statement. Yet the practice must be admitted as dangerous, and should be discouraged. It is only too common in practice as workmen know—to rework mortar by the addition of water until all is used. Care should therefore be taken to mix up only such a quantity of mortar as can be conveniently used in the time available.

The surface of stone or brick to be bedded in mortar, also surfaces to be plastered, should be made wet before mortar is applied as only in this way can cement form contact or adhesion to surface, an important requisite in good work. The seasoning of cement work 24 hours after it is formed, and continuing for from 6 to 8 days, must not be neglected. Shade from hot sun and currents of air by covering over with cut grass, straw shavings, canvas or paper, or whatever is most convenient and will not discolor the work. Upon the top of this if porous, sprinkle water thoroughly each day. If covered with something that will not hold moisture, or that you do not wish to wet, remove, sprinkle and again cover. In cold or wet weather this is not important; cellars and basements need only sprinkling. Mortar used in bedding stone or brick is not usually treated in this way. But where they are kept wet for several days following the work, much is added to its strength and quality.

Where work is done in freezing weather the mortar must be worked with as little water as possible; the work must then be protected by covering until thoroughly set, which at near a freezing temperature may be for several days. At this point the danger is past and though freezing solid after this the hardening process is carried unimpaired until such a time when the temperature is favorable to its ultimate completion. This is not applicable to natural cement mortar. Salt is frequently used in freezing weather, but is objected to by many as being liable to impair the work, also discoloring same by white incrustations.

In conclusion on this subject I will quote from S. B. Newberry, who says, "That if one is careful not to allow any free water to separate out of the mortar and become absorbed by the dry surface of stone, brick or aggregate used there is scarcely anything to be feared from the action of heavy freezing, and when compelled to do cement work in freezing weather it is preferable to heat the water and sand, so as to accelerate the setting."

Cement Mortar can be used during the hottest weather of the season without any bad effect, only that great care must be taken in the seasoning. Seasoned cement is the greatest heat resisting material known to the building trade, while this had often been demonstrated in Europe and this country by actual tests, it remained for the Baltimore fire to give us a practical illustration of its real merits. In this conflagration of the 7th and 8th of February, 1904, which continued for 27 hours, destroying 2,500 buildings and producing a heat of 3,000 degrees Fahrenheit, when granite melted like lead, the steel skeleton buildings with terra cotta fire-proofing failed badly. The unequal expansion of the fire-proofing and the steel caused the terra cotta to become detached from the steel, leaving the building after the fire a distorted mass of iron, while the steel skeletons with concrete fireproofing stood the heat with little or no damage. Experts who visited the burnt district agreed that no building withstood the fire better than the Junker's Hotel and the International Bank Building, built entirely of reinforced concrete, under the supervision of Messrs. Parker and Thomas, architects, of Baltimore. The heat around these buildings was so intense that even the brick which elsewhere held out were entirely destroyed.

Kinds.

For convenience in treatment we have divided cement mortars into four classes, namely: Neat Mortar, Portland Cement Mortar, Natural Cement Mortar, and Cement Lime Mortar. We can treat on these only briefly.

Neat Mortar is composed of cement alone mixed into a paste by the addition of sufficient water to form a stiff mortar. This mortar attains high tensile strength in from 1 to 28 days, after which further development is slow. It is not used in building construction, but from it are made briquets for experimental use in testing cement.

Portland Mortar is composed of Portland Cement and sand, with enough water to work plastic for use. The proportion of sand varies with the different uses, but may be from 1 to 5 times the bulk of cement. This mortar stands at the head of all mortars in building construction, is reliable in all climates and invariable in bulk.

Natural Cement Mortar—Perhaps better known in many localities as common cement mortar. This is composed of natural cement and sand with water for mixing plastic. This cement carries less sand than the Portland and can be used only with safety with from 1 to 3 times its bulk of sand. This mortar is not so uniform as the Portland, frequently showing slight changes in volume, is affected by climatic conditions; is used mostly in massive foundations, concretes, cellar bottoms, and cisterns, and as an adjunct in lime mortar.

Cement Lime Mortar—This is composed of white lime, 1 part; cement (either Portland or Natural), 1 part, and sand, 1 to 7 parts. This mortar is not considered hydraulic, shows slight variation in volume, is very plastic, has considerable adhesive power, can be used wherever white lime mortar can be used, works smooth and easily with trowel and is slow to set, unexcelled in bonding stone or brick in ordinary walling.

PART III.

CONCRETES

The great bulk of cements the world over are used under this head. Concrete, as the word implies, is a compound or aggregation of foreign bodies into one mass.

Composition.

Concrete is composed of cement, sand and aggregate; this aggregate may be either crushed stone, gravel, slag, shells or cinders. In some localities one of these aggregates is most convenient and is used, and in other localities, others.

Widely varying proportions are used for mixing concrete in general practice, and in many cases the quantities are gauged in so crude a manner as to result in a waste of material and indifferent concrete.

This aggregate for most purposes should range in size from ¼ to 2 inches, the more variation in size and shape in the aggregate used, the more in bulk can be incorporated into the same amount of cement. The aggregate used must be hard, with clean surface for attachment. The sand as in mortar for quality of work must be clean and sharp, and for economy in work should be fine and coarse mixed. It is very difficult to lay down fast rules for mixing concrete with so wide a difference in the aggregate and sand to be used. It is, therefore, important that the proper proportion in each case of sufficient size should be ascertained in order to secure the best results with reasonable economy. This is easily done by filling a vessel of known capacity even full with the aggregate and sand mixed in the proportion wished for use. This must, however, be first thoroughly soaked so as to absorb no more water. Now pour in as much water as the vessel will contain and divide the volume of the water poured in by the volume of the vessel; the quotient will represent the proportion of voids. Or to more fully illustrate, say the vessel contains 4 gallons, and that after being filled it would still contain ½ gallon of water, then $\frac{1}{2} \div 4/1 = \frac{1}{2} \times \frac{1}{4} = \frac{1}{8}$, answer; or that in 8 volumes there are 7 sand and aggregate and 1 cement. In the same way find the proper proportion of sand to use with the aggregate, and cement with sand.

It is usually customary to add 10 per cent for coating over the particles, but when this is properly rammed into place as concrete, the voids are sufficiently reduced to allow enough cement for coating.

We attach so much importance to the true ratio of these component parts as a matter of economy and quality in concrete, that we venture still another method that may assist us in forming proper conclusions as to proportions of cement, sand and aggregate.

It is a mathematical fact that if sphere (round bodies) of equal size were placed into a measure their solids would equal ⅔ of the size of the measure and the spaces or voids would equal ⅓. If these spheres were aggregate of such even size and shape then we could still put into this measure, say of 6 gallons 2 gallons of sand and considering the sand to consist of equal sized and shaped spheres, then the voids in the sand would require ⅓ of 2 gallons or ⅔ gallons cement; to this we will add for the surface coating, 1/10 of ⅓ of 6 gallons, or 6/30 = ⅕ gallon; ⅔ × ⅕ gallon = 13/15, about ⅞ gallon of cement. This would make the proper proportions for 6 gallons concrete as follows: Aggregate, 6 parts; sand, 2 parts, and cement, ⅞ part. But since this would not occur that all the particles would be equal spheres, we can readily see almost any chance lot of aggregate would be more favorably shaped and of more promiscuous sizes which it will be seen would still more diminish the proportion of cement. Though it must be remembered that where much sand and less aggregate is used, while not necessarily increasing the voids, the surface coating is largely increased. The sand as well as the aggregate should range from fine to very coarse. We will give two formulas.

Formula No. 1.—Cement, 1 part; sand, 2 parts; aggregate, 4 parts. This concrete will be sufficiently strong for the most exacting use.

The seven volumes of this formula, when thoroughly tamped into place would fill 4½ or 5 volumes, showing from 2 to 2½ volumes had filled into interstices or voids of the mass.

Formula No. 2.—Cement, 1 part; sand, 3 parts, and aggregate, 6 parts. This concrete is used for most purposes, and could still be weakened to sand, 4 parts, and aggregate, 8 parts, for foundations and heavy body work.

The 10 volumes of this formula when tamped into place will fill 6½ or 7 volumes: **Mixing and Handling**—On large work, machine mixers are used. They consist of a rotary cylinder, into one end of which the proportions are regularly shoveled, automatically sprinkled and mixed, dropping from the other end of cylinder into wheel-barrow or other receptacle, ready for use. This is a very expeditious and also a very thorough way of mixing concrete.

But much of the work for some time to come will still be mixed by the shoveling process. The preparation for mixing should always depend on the magnitude of the work to be performed. But for an ordinary job prepare as follows: Prepare mixing flour of surfaced boards laid close and solid, and should be nearly level, this should be large enough that the mixing need not be hampered for want of room, say 8 x 12 feet. It should be placed convenient to materials and water, from which point when mixed it is carted or carried to the place where used.

This completed, we must have measures by which to gauge our proportions of materials. For sake of definite illustration we will use Formula No. 1. In using 1 sack of cement for the unit (one sack contains about 1,900 cubic inches), then our sand measure should contain $1{,}900 \times 2 = 3{,}800$ cubic inches; this box has no bottom, only sides and ends with strips nailed on two opposite sides for handles, and while the box in this case must contain 3,800 cubic inches, it can have any shape desired, say 18" x 24", or 432 cubic inches. Fill the surface one inch high, then $3{,}800 \div 432 = 9$ inches, about the height of this box inside measure.

This same measure would also do for the aggregate by using it twice full, but if desired another can be made for the aggregate in the same way only containing twice as much or 4 volumes.

Place sand measure near one end of the platform and fill even full of sand, take hold of handle, lift and allow sand to spread on platform, on top of this empty one sack of cement; next measure 4 volumes of the aggregate on the other end of platform; spread this out some and shovel the cement and sand over onto it, taking pains in the shoveling to mix the sand and cement somewhat evenly on the aggregate; shovel back and forth until the whole is evenly mixed, perhaps about 2 times if carefully done; now with spray nozzle and hose attached to hydrant, or with good sprinkling can, one man will sprinkle, watching to catch the dry surfaces while two men shovel back and forth 2 or 3 times or until the whole mass is alike mixed and wet. It is wet enough when it has the appearance of freshly dug earth, or when it will retain its shape when pressed in the closed hand. If it has been well mixed every particle of the aggregate will be evenly coated with the cement and sand. If some parts have been made too wet the surface will have been washed clean, which is faulty. We should have stated that in dry weather the aggregate should be kept moist by sprinkling while on the pile and always before the sand and cement are shoveled on it. This is important as the cement and sand will stick to the surface and cover more easily than when dry. The concrete is now ready to be placed where used. If near enough it may be shoveled into place, but must not be thrown a distance with the shovels or dumped into deep excavations, because in doing so the coarse and fine particles separate and destroy the uniform density and quality of the work. To illustrate, suppose you throw a shovelful of this evenly mixed concrete 12 or 16 feet, as is sometimes done, and it will be seen that on leaving the shovel the fine and coarse particles will separate, the fine and richer part will lay in mass where it falls while the coarse particles will bound and roll away to some lower place in trench, thus practically destroying what we had taken so much care to accomplish. For this reason it should be laid or thrown at a short range with the shovel or tipped into position from the cart, evened with shovel or hoe and no more than 4 or 6 inches in depth placed at one time until thoroughly rammed with iron tamper suited for this work. For a small job a wooden tamper could be made. Take wooden block 6 x 6 inches square with hole bored into the middle, in this place handle. When this layer is tamped sufficiently hard and even, water will slightly appear on the surface which indicates that the particles are driven into the voids, thus becoming dense and driving the water to the surface. If the concrete in tamping should quake this will indicate that it is too wet. The additional layers should now follow in the same way as the first and at short intervals or before the surface of any layer dries or sets. This is continued until the desired height is reached. If the surface should at any time become dry and hard before completed as might occur during night, then sprinkle with water and with fine sieve dust cement evenly and lightly over the surface. This will give a new base for adhesion. In light walks and floors the height is built up at one application of concrete.

The setting of concrete does not differ much from Mortar (which see), only that the aggregate acts to liquidate the heat incident to chemical action, thus slightly retarding the hardening process.

Nature.

The quality of concrete, like mortar, will depend upon adhesion, cohesion, compressive and tensile strength, and invariableness in bulk. These are attained by the irregular bonding or the interlocking of the coarser fragments, and upon the strength of each ingredient in the compound. The mass must be as dense and homogeneous as possible.

Enough cement is required to form a coherent film or matrix between the particles which by interlacements consequent upon tamping approach each other in numerous points and surfaces, which following crystalization of the cement in hardening becomes a dense mass.

In the combination of ingredients for concrete judgment must be used in the selection of sand and aggregate so that the voids in the aggregate will be thoroughly filled.

By a judicious variation in the size of the aggregate as well as the particles of sand, there might often be built twice the bulk of concrete with the same amount of cement without any sacrifice in quality. The cement must fill the voids in the sand, this in turn must fill the voids in the aggregate. Concretes must not be prepared before they can at once be used, as they can under no condition be reworked, and when set before placed are worthless.

For practice the following conclusions are then arrived at: A concrete properly proportioned has as much strength as the mortar used in mixing it. By diminishing the aggregate below the calculated quantity, the cost of the concrete is increased without benefit to its strength. Aggregate that is rain soaked to the extent that it is dripping wet should not be used until the water is slightly evaporated. Also aggregate hot and dry and with dusty surface must be watered sufficiently to make it moist.

It should be remembered that concrete for air or submerged work differ in their composition. Air concrete does not necessarily need be so dense as submerged, or water concrete. We herewith give two formulas for concrete for air and water use. They would apply to ordinary work:

Formula No. 1.—**Air Concrete**—Cement, 1; sand, 2; aggregate, 6 parts. This formula consists of 9 volumes, when tamped in place will fill 6 volumes, and would weigh green approximately 150 pounds per cubic foot, when seasoned, 130 pounds.

Formula No. 2.—**Water Concrete**—Cement, 1; sand, 3; aggregate, 3 parts. This formula consists of 7 volumes, but when placed and tamped dense will fill only 4 volumes, and when green would weigh approximately 160 pounds per cubic foot, when seasoned, 145 pounds.

Thus while slight porosity does not harm air concrete, for submerged work it must be dense and impervious to water. We speak of invariableness in volume as a requisite for building material. Strictly speaking, this does not exist. All materials change slightly from climatic conditions, such as temperature and moisture. But we do claim that in concrete it is reduced to the minimum.

Kinds.

For convenience in treatment as well as for reference to special work by the reader, we have classified concrete under four heads, namely: Ordinary Concrete, Reinforced or Armored Concrete, Liquid Concrete, Mortar Concrete and Pulp Concrete.

Ordinary Concrete is composed of cement, sand and aggregate, mixed as specified under Concrete Mixing, which see. When mixed it is rammed into excavations or molds prepared for its use. This form of concrete is perhaps most generally and widely used for massive foundations, walls, piers, retaining walls, cellar and barn walls, walks and drives, building blocks, and other cast masonry, dams, dykes, and many government and railroad structures. For further particulars see Part 4.

Reinforced or Armored Concrete is concrete used in every way as under Ordinary Concrete only that in addition it is strengthened by iron rods, expanded metal, wire netting, steel beams and columns, etc., imbedded in the concrete. This serves to lessen the bulk of concrete used, hence an economy in the most difficult construction with the great additional strength secured. It also makes concrete more elastic so essential in floors, beams, joist, etc. The concrete which is to be placed about this metal should be slightly wetter than for ordinary use so that it can be puddled about the metal close and dense. Formerly it was thought necessary that metal incorporated in concrete should first be well painted, and in some of the more important work this was even wrapped with a preparation of paper to prevent dampness from the concrete coming in contact with the metal, also prevent chafing in tamping the concrete. But extensive and elaborate tests along this line, recently made by Professor Norton, of the Massachusetts Institute of Technology, and other experts, it has been clearly established that paint and paper are objectionable, and that dense concrete, with contact to the metal, is in itself the best rust-proofing. It is also showed that slight corrosion of the surface of metal was favorable to proper adhesion. This adhesion is claimed to be equal to from 500 to 700 lbs. per square inch, and to form an air-tight covering. Its grip on the surface of the metal prevents shearing by elongated strength, which in the case of covering by paint or paper would be lost. Formerly it was thought, too, that the expansion and contraction of concrete and metal would be so unequal that adhesion was not even desired, but it is now known that they are the same and can be relied on, as was amply shown in the Baltimore conflagration, where the expansion incident to the great heat, showed no signs of ruptured cohesion of metal and concrete, while terra cotta on account of its rapid expansion buckled and broke its bonding on the metal. In this limited space we cannot give details for placing this metal in the various constructions. This will be the work of the engineer, and it will be enough to say that it must be so placed that it will give the greatest support to the concrete. It should be entirely enclosed in the body of the concrete and be near the opposite side from the pressure. Where possible should be placed so as to truss and equalize strains.

It is found that by the incorporation of metal in concrete, reasonable size can be easily maintained with ample safety in strength. And while the placing of metal for reinforcing requires some engineering skill, and perhaps properly would not come under the scope of this book.

Yet to meet the great demand by the ordinary workman for knowledge governing the primary principles in common construction, we venture in this revision, a few brief and simple directions for which the engineer will excuse the terms used and applications made in this talk with our laboring fellow craftsmen. Perhaps all work for whatever purpose constructed, must resist stress. Stress is force, and to designate the nature of stress, we will use the following terms: Compressive stress, crushing force; tensile stress, pulling apart force; torsional stress, twisting force; shearing stress, cutting force.

These are the most common stresses encountered in construction.

The compressive or crushing strength of concrete is its greatest strength attainable, and is approximately ten times its tensile strength, or from 2,000 to 4,000 lbs. per square inch. About the most that is accomplished in the best methods of reinforcing is to unify other stress and bring them up to compressive strength. Walls, columns and arches are instances of compressive stress. Tensile stress is pulling apart or tearing force, and is approximately 200 ot 400 lbs. per square inch. This is easily brought up to the compressive stress by tension rods. The lower side of beams and lintels, and the contraction incident to cement work, represent cases of tensile or tearing stress.

Torsional stress, or wrenching force is occasioned by side thrusts on wall columns, and is always present in beams. Shearing stress, or cutting force, is sometimes occasioned near walls or columns, in floors or beams, at times by reinforcing rods improperly placed.

Columns bearing up a perpendicular weight rarely need reinforcing with metal, but where they encounter side thrusts or extraordinary weight they are reinforced by perpendicular rods, and outside of these spiral bands these are placed nearest outside shell of hollow column and sufficiently near each other to prevent buckling of concrete.

Beams—short beams, lintels and caps are usually reinforced by a few tension rods near lower side. But beams and lintels carrying weight over large openings represent the most difficult methods of reinforcing, as they encounter what I am pleased to call compound stress compression in upper middle, and tensile in lower middle parts. The deflection downward in middle causing torsional stress near the end support of beam, while perpendicular with column or wall supporting beam shearing stress is present.

A common and practical method of reinforcing ordinary beams is to use two or more tension rods, extending length of beam, parallel with and near lower surface of beam. These prevent the beam from tearing at lower center and from shearing at column or wall; also hold lower ends of beam from crowding endways from center, thus disturbing the stress in the form of a sequent arch, having the radius of height of beam. The beam is further reinforced by two or more truss rods, extending from upper ends of beam to the lower middle, these overcome the deflection at center or torsional stress. These with a few U-shaped rods looped under lateral rods and projecting with open inverted T-shaped end near the upper surface of beam constitute all the reinforcing necessary for most ordinary work. The size of rods or bars used, as well as size of beam, must be determined by length of span and weight of load to be supported.

The general principles of reinforcing are agreed on by all engineers, but as to methods used in detail all do not concur. Some use round rods, some square rods, others use twisted square rods, some corrugated rods, others still use such devices as the Kahn system—heavy sheet metal, with ribs projecting at various angles into the body of beam above. When engineers do not agree we certainly do not venture an opinion, any more than to say: That personally with the most careful work in preparing and puddling concrete around the rods, there might not be much difference in ultimate strength; but that where this work is done with less care, adhesion to surface of metal is often imperfect, often the metal being jarred loose in concrete, in such cases losing elongated strength, where, in twisted, corrugated or ribbed rods or bars, though imperfect adhesion existed, the rods would still be held from slipping in the concrete sheath.

Before rods are placed in beams or lintels centering or the building of forms is completed, these require skill in their construction, and in face work requiring mouldings and panels. The molds must be thoroughly expanded 6 to 10 hours before concrete is placed in them, or the later expansion will replace edges of raised work and impair it.

Concrete for this work must be of the best and most suitable materials only. Where rods are many and sometimes space between them small, large particles in concrete must be avoided.

The concrete for this work must be wet enough so that no tamping is required, instead, puddle with a thin stick into all corners and between bars, jarring of rods in this semi-plastic condition helps to adjust the concrete to the surface, but this must be most carefully avoided when the concrete begins to set. We would not recommend using liquid concrete. This separates, becomes stratified and very unreliable; also, as the excess of water is forced to the top, the concrete settles, leaving open space along bottom of rods. Use only wet enough to puddle. This will not separate, or shrink in setting, but will become dense and hard as adamant.

The introduction of this method of concrete has vastly extended the use of cement in the building trade, not only in this country but as well in foreign lands. Among a few of its more common uses might be mentioned floors, roofs, partitions, ceilings, walls, columns, cornices, bridges, subways, reservoirs, flumes, vaults, tanks, dry kilns, dry docks, houses, factories, etc.

Liquid Concrete—This form of concrete, much used formerly, is still indispensable in some cases, though it is objected to by engineers of today as being unreliable. Liquid briquets invariably show lower ratings. It is claimed that by the excessive use of water the cement is diluted, that aggregate placed for filling is often "choked" (clogged), that the particles of sand separate from the cement in pouring, destroying uniformity in the mass.

While these objections are well taken, still much may be overcome by the careful workman; the choking entirely, and the separation of sand and cement partly.

It is necessary to use fine sand in order to avoid separaton; this will cost some additional cement for surface coating. In coarse sand the fine particles of cement will float with the water, leaving the heavy, coarse particles in the bottom of mixing vessel, or in pouring will settle to the bottom, leaving the richer part (fine particles of sand and cement) floating to the top. Some workmen place the aggregate first and pour the voids. Others think a safer way is to first pour the liquid, and into this place the aggregate in the following way: A tight box or mixing vessel is made suitable in size to the work at hand, say in this case 2 feet high, 2 feet wide and 6 feet long, with strips nailed on the sides and projecting at the ends for handles by which the box may be quickly turned over in emptying or carried about in using.

For our purpose in illustrating, will suppose this construction to be a foundation in excavated trench. Set box near trench so that when ready it can be turned over on one side emptying the contents into the trench without lifting or carrying; now pour into the box 4 pails of water, and with a man at each end of box with mixing hoe; put into box 1 sack of cement. While this is being stirred vigorously, throw in 4 times as much sand; when stirred until all is reduced and afloat, turn box quickly on side, dumping contents into the trench. Now having aggregate handy, place this into the liquid at once, but not in mass so as to choke; when this is filled proceed as before until the height is reached. Where trenches are large only a part must be treated at one time. Whenever it is thought best to place the aggregate first this may be done. Place the aggregate not over a foot in height, and this should be sufficiently coarse so that the liquid may fill into all the voids; pour the liquid on top of this, until it floats over the top, when place another foot of aggregate on top and continue as before, to the desired height. The liquid mortar should be as thin as gruel for most purposes, and the proportion of fine sand and cement may be, cement, 1 part, and sand, 2 to 5 parts, according to the requirement of the work. When it is required to use this grout or liquid in cast masonry, a water-tight form is prepared into which aggregate can be placed, or the cast may be entirely of liquid mortar as desired.

Another place where this liquid mortar is used with advantage is in pouring out beds and joints of massive stone in foundations and walls. When these stone blocks are laid into walls, the front and back bed joints are spread with mortar; into this the blocks are laid, making them liquid-tight. When the course is thus laid, the end or vertical joints of face and back are closed with mortar; these joints are now poured full of liquid mortar until the bed and end joints are filled even with top of course, in this way filling every space of bed and end joints.

This plan of work is highly recommended for retaining and abutment walls, which must hold great pressure from the bank crowding and shearing the wall.

It is the opinion of a practical engineer that a wall of this description with 4-foot bed would resist a bank pressure equal to a 6-foot bed laid up in the ordinary way.

Heavy walls with wide beds are sometimes built with two masonry faces, the face stone sometimes for bonding extending into the middle or across the wall, this middle is filled in with each course with waste stone from face dressing, etc., then poured out with liquid cement. This method of work, when care is taken that no uneven shrinkage or expansion occurs, has few equals, if indeed any. In this kind of work only Portland cement should be used, since natural cements are more variable, sometimes showing expansion and destroying the bonding. For this work the cement and sand are mixed dry and placed on or convenient to the wall, when the workman with a large pail suited to this work, fills the pail ⅛ full of water, as many shovels full cement and sand mixed as will make it when mixed about as thick as a thin gruel; before mixing in the pail, which he does with a large trowel, he takes the pail where it is to be turned into the joint; stirs it vigorously until evenly mixed and afloat, when it is at once turned into the joint. If not turned over quick the coarse sand settles into the bottom of the pail.

Mortar Concrete—In this concrete the cement and sand in the proportions desired, which may be from 1 to 6 parts coarse sand to 1 part cement, are mixed into a mortar of easy working plasticity, into which is incorporated the aggregate, which may be quite coarse. The need for this mortar concrete is that for aggregate, coarser materials are used than could well be used in ordinary concrete; the surface of the aggregate must be dampened and be clean in order to form contact. In some parts, small stone ranging from the size of a fist to 6 or 8 inches in diameter are abundant, while crushed stone, gravel, and the regular aggregate materials are scarce. In the mortar concrete these can be used advantageously, while costing slightly more in cement on account of the large voids, the handiness of the stone more than overcome this. If properly constructed little or no difference in the quality of work will result. The mortar is thrown into the form little at a time and the stone pressed into it, shoving the stone always toward the surface or face so as to leave it even and compact. If the stones are shoved down into the mortar along the form they displace the mortar between the form and the stone, leaving the stone exposed on the surface. Some care should also be used in filling the voids of the larger stone by smaller ones, etc., in this way reducing the quantity or mortar, but no stone should be placed on top of others dry. The mortar must form an unbroken matrix throughout the mass.

Pulp Concrete—Is composed of cement sand and wood pulp or saw dust. The matrix is composed of the cement and sand, and for the aggregate pulp is used in quantity to suit the use for which it is intended. It is not used for outdoor work, but for plastering, and fireproofing interior wall, veneering floors, etc. It has less tensile strength, is slightly elastic and much lighter in weight than ordinary concrete.

It is especially desirable for floor veneering, for market houses, butcher shops, saloons, etc., though practically non-absorbent, is slightly elastic and the rigidness for foot use, common in ordinary concrete is overcome. Lay paper over floor, on this spread concrete to thickness of 1½ inches, no joints are necessary, it will not check. Mix in the following proportions: Cement, 1 part; sand, 2 parts, and pulp or fine saw dust, 2½ parts. When more pulp is incorporated it becomes absorbent, since the matrix will be broken, finish top smooth.

PART IV.

CAST MASONRY

Under this head are included all artificial stone products, cast from concrete or mortar.

We do not aim to exhaust the large and constantly growing scope of these useful products, in the limits of this treatise, but rather it is our purpose to take some of the more commonly used and to give such general directions in their construction that the average workman may with some originality of thought and purpose apply himself to more complicated work with assurance of success. Though to be a thorough workman, unhampered and resourceful, it is important that the Parts preceding this on Cement, Mortar and Concrete, should be carefully read, since in these brief directions we presume our reader to be familiar with cement and its nature in mortar and concrete, also all about sand and aggregate and their mixing, etc.

For our own and the readers' convenience we will divide this Part into two sections, namely: Monolithic and Portable Cast Products.

Monolithic Cast Masonry.

By stationary cast masonry we mean that part of masonry which is built on the spot where used, either in excavations or forms, such as foundations, walls, floors, ceilings, fire-proofing, walks, drives, steps, cisterns, reservoirs, grave vaults, etc.

Foundations and Footings.

This embraces one of the chief uses of concrete. By foundations we mean bases or footings for walls. These may be submerged or above water. Submerged concrete is in some rare instances laid directly in water. In such cases a crib is built in the water, marking outline of the concrete, into this the concrete is deposited, the crib holding it in place until it has hardened. More commonly in the submerged work the space is inclosed by a tight crib or cofferdam, with steam pumps, or by compressed air, the water is then removed. The bottom now is excavated to a secure bed, and when soft and yielding bottoms are encountered for a considerable depth, this is piled sufficiently until the engineer is satisfied that it will sustain the strain for which it is intended. Where the crib does not form the outline of the foundation a form must be constructed, the piling is usually allowed to extend from bottom of trench into the concrete, but should be sawed off below low-water mark. Now we are ready to place the concrete: this submerged concrete may consist of cement, 1; sand, 3; aggregate, 3. See "Mixing Concrete" for mixing method of mixing and tamping. Where area of surface is large, it is best to bring up only a part at a time; place about six inches of concrete at once; even with hoe or shovel;

tamp solid and even. This is continued, layer after layer, until top is reached, where piled the tops of the piling are held firmly in place by the concrete tamped densely about them, and finally covering over them entirely. This more evenly adjusts the weight over the whole surface and on each pile than any other form of construction could possibly do. When the work is from 24 to 36 hours old it may be submerged with benefit to the work. It must not be forgotten that hydraulic concrete must be thoroughly tamped to make it impervious to water. This foundation could be continued in the same way its entire height if desired, only requiring forms to shape its outline, but this will more properly belong to walls of which we will speak later. Foundations are so varied that in this space we can not cite others, only to say that the work can easily be adjusted to meet any requirements. We will give another illustration of a foundation or footing above water. The object of a footing is to distribute the weight or bearing of a heavy wall or building over a greater bearing surface, thus preventing settlings.

Footings for buildings must project from either side of the wall the same distance, and the thickness should never be less than the projection. A string is stretched true to line of footing, from this the excavation is made sufficiently exact in line and depth of trench, that the concrete can be tamped in place, the trench serving as a form. If the ground inclines the trench must not follow the incline but be nearly level, and to meet the incline, the excavation should drop down at right angles, then continue again until another drop is necessary, etc. Soft or yielding places in the bed must be taken out in the same way, not scooped out but blocked out. When the excavation is completed the concrete is placed.

Above water we shall use air concrete, cement, 1 part; sand, 3 parts; aggregate, 6 parts. See "Mixing and Placing" of concrete.

Walls.

These of whatever nature or kind may be built from concrete and are declared by the engineers of the day to be superior to any other method of construction in vogue. They are made from ordinary concrete and reinforced concrete, to suit requirements. Walls built from cast blocks (portable) will be treated of in the second division of this Part, but all heavy and low walls can be built up by continuous masonry in their place, using suitable forms or molds. These forms are of two kinds in general use, which we will endeavor to describe at this point.

Box Form—This consists of a plank form set true with the face line in the same way as a stone is laid with the line, these are carried in courses, using some care with the first course to get the top level, the form is set on top of this course, the face line raised and the box or form set true with line and plumb with face; this is continued to the top course. This must be kept true and level for sill. If the forms are carefully trued each time the wall will have full and even faces, and is by most mechanics preferred to a plastered face, but if by amateur workmen the wall in all probabilities must be plastered to make it presentable. It is best to have two forms and to work them alternately on different courses or on different parts of the wall. This will give time for slight set before the form is removed. Where more than two or three hands are employed on the work more forms will be required. If it is desired to have the wall sloped or battered towards the top this can readily be accomplished by adjusting the box for this purpose. When the height is reached for door or window frames to be set they should be set and secured in position; the wall can now be continued over them, with a little care to batten the frames (if the wall is wider than frame, which it should be). This makes a nice, true and even jamb: a narrow strip should be so placed on the jambplanks of the door or window on the wall side, so that the wall will hold it in position when set.

For the box secure two straight and true planks, some stiff light wood is preferable. For ordinary work these should be 1 foot wide and about 12 or 14 feet long. Saw these off square at one end, and nail board the same width as sides across ends, making the space between the plank to correspond to the width of wall. Before nailing board across the end referred to, it is best to take square and mark across the board for the inside edge of each plank. In this way the sides, top and bottom will be parallel and at right angles. It is best if the board projects by the outside edges of the plank a few inches, forming hand hold. Our box now has sides and one end closed, the other end will be left open; turn bottom side of box up and about 12 inches from open end saw notch in lower edge of side plank 1½ inches deep and 2 inches wide and split out; repeat this in the same way half way between this notch and closed end; now take 4 strips 1 foot longer than width of wall, and 1½ inches square, into these saw notches 2¼ inches wide and half the depth of the stick ¾ inch, and so that when the plank is against the outer edge of the notch the space between the plank will be the exact width of the wall, and the same at each end, above and below The box is now ready for use, and some care is required that it is not strained out of shape in handling. To place the form in position for the first stone put closed end to corner; this will make square corner; set box on two strips at the notches and clap the other two strips across top above lower ones; now true box with face line, and with level set plumb and level, fill with concrete ½ full and tamp, fill balance and tamp again till even full; now set the other box in the same way on some other portion of the wall; when this is filled remove the first box by first removing the top strips; lift sufficiently at the open end of form to remove from notches; now spread the open end 6 inches from the wall on each side and at the same time lifting about 1 foot, so as to throw away at the top at closed end; now with another man at the closed end the box is lifted and at the same time pulled slightly toward the closed end, to avoid breaking the green block thus formed. Turning the box end for end, lap the open end slightly on block formed, place strips, true to line as before and continue in this way. In some cases the sticks can not be used below on the bottom course on account of not being able to remove them for bank, etc. In this case support the box for this course at the bottom in some other way, after this they can be used every time, and each time when the box is removed by slightly tapping them with the hand they are easily pulled from the wall and placed on the next form. This can be continued as rapidly as desired. Two hours after any block is out of the form, or 2 hours after it is made another can be placed on top as before. Three men with the proper materials handy will lay from 200 to 300 cubic feet per day. Where nice work is desired some care must be taken in working about the green blocks, so that corners are not chafed off or parts broken. If plastered this will not matter, but if left cast finish it should not show trowel marks or bruised surfaces. The strip holes in the wall may be closed at any time; close with concrete and rake off rough with trowel and they will not show, but if closed with mortar as they sometimes are they will show unless plastered. If the wall is plastered and a good finish is desired, when the plastering is partly set, go over the surface with stiff broom or wire brush, stroking in the same direction each time, or for rubbed sand stone finish rub with wood float, trace the walls into blocks with jointer, after sweeping or rubbing but before dry. This gives it a pleasing appearance.

In a battered wall (narrow at the top) the form must be changed each course to correspond with the battered width of wall for each course. When walls are not over 3 or 4 feet high and less than 18 inches wide and are laid in lengths of over 16 or 20 feet, there should be a continuous perpendicular joint to avoid "settling or shrinkage cracks." In still lower and lighter walls they should be laid in 6 or 8-foot lengths, while in the former 12 or 14-foot lengths would be allowed without danger of checking, but where the bottom is good, heavier walls can be continued to great lengths. To make this joint insert heavy metal, slate, or surfaced board ¼ inch thick, at the proper place in the form; tamp well on each side and before the form is removed, take hold of the top projecting above the form, move slightly until loose and then remove; insert the next divider directly above this and so on.

When the work is two or three days old point this joint as you would a stone joint with mortar. When this wall is 24 or 36 hours old it must be sprinkled once or twice each day and if very hot should be shaded from the sun and currents of air. After 8 or 10 days the wall is seasoned and need not be bothered with longer. For the mixing and handling of the concrete used for this wall see "Concrete, etc." A proper composition for such a wall would be, cement, 1; sand, 3, and aggregate, 5; the sand must be coarse.

We will present another method of form used frequently, having some advantages and some disadvantages over the box form method described. This is called the frame form method, in which 2 x 4 uprights are slightly set or driven into the ground along each side of the wall and four feet apart. These must be as true as a line, plumb or battered to suit for the desired wall. The uprights are directly across the wall from each other with a strip nailed across the form at the top and sufficiently high to clear the top of the wall when completed. It will be best to nail strips near the top of these uprights on the one side only, and let them project away from the wall to a stake firmly driven into the ground, to which nail as near the ground as possible. This will stiffen the frame and hold each pair of uprights exactly to the place; when these stand true as the wall desired, place against the inside of these, 2" x 4" stiff boards of even thickness and width if convenient, one board high on each side at a time; when this is filled as in the other case, another height of boards are placed; this is continued to the height of wall, which must be level and true to receive the sill or joist. This plan takes more lumber, but since it is not nailed it can again be used for a like purpose, or for sheathing if desired. The corners of the wall must be housed up in like manner; windows and doors may be set as in other method, also perpendicular joints carried through the stretches of long walls.

4 to 24 gauge steel and from ½ to 6-inch mesh, suited for all kinds of work. These sheets are entirely incorporated in the wall and reinforce in every way.

In wrought iron bonding many light rods at closer intervals are much better than fewer heavy ones. Where walls are reinforced it is not necessary to carry perpendicular setting joints, very The frame form is removed after 24 or 36 hours and well seasoned as in other.

At this point I wish to say that to make an even well filled face to these concrete walls considerable attention should be given to the placing and tamping of the concrete. When the aggregate is fine there is little or no trouble, but when coarse, the finer particles can be kept near the surface and the coarse near the middle; take trowel and while one man is filling into the form with shovel rake the coarse particles back, and with blade cut down sides, making face more compact, when proper tamping will do the rest.

In walls requiring great strength with light body of concrete, the work can be armored or reinforced at little additional cost, frequently cheaper, since it saves extra thickness of wall. In the more ordinary work, such as farm buildings, basements, etc., the reinforcing is simple. Walls of no greater height than 8 or 10 feet need only horizontal bonding. Take rod iron bars ¼ x ¾ inch; these rods should be twisted several rounds especially near the ends; when one stretch of wall is about two feet high, lay upon this ⅓ way in from one side the entire length of wall but not protruding from the corner or end, a continuous stretch of rods, lapping ends 6 inches but not touching each other, so that concrete can encase each rod independently of the other; on the next course, say a foot higher, lay another stretch, but this time on the opposite side ⅓ way in from surface. This can be continued to the top of wall. Where a wall turns a corner the bonding of metal should extend into the corner from each way.

Where perpendicular reinforcement is required, the bonding may be done similar, by placing twisted bars of suitable lengths perpendicular into the concrete at suitable distances, say every two feet. This now would make a reasonably good job of horizontal and perpendicular armoring. Where still more importance is attached to the reinforcing, expanded metal designed for this use should be used; this can be obtained in sheets of various sizes, and from Nos. necessary in ordinary concrete. In retaining walls it is sometimes advisable to carry blind or even exposed pilaster at ends and at regular intervals in the wall and between these and bound into the pilaster, build up sheet walls from 6 to 12 inches thick, reinforced. This reinforcing should be placed in such a way as to truss the sheet wall, and hang the sheering or crowding weight on the pilasters, which may be done in the following way: Place the rods at or near the bank side of the pilasters, then extend them forward so that at the middle of the sheet wall they are within 1½ inches of the front face. The distance between these pilasters, their size, and thickness of sheet walls, also the method of reinforcing, must depend on the height of wall, the nature of the soil to be held in place, etc., and can only be determined by the engineer.

Metal reinforcing must never extend to the surface so as to be exposed, in which case corrosion would follow.

We wish still to refer to another kind of wall; this is a basement or cellar wall. Where care has been exercised in the excavation for basement walls, it is sometimes only necessary to carry the outside face with a form, the back side can be built against the bank. In such a case use frame form, 2 x 4 upright, secured in ground at bottom, and on top, held in place by strip of board nailed to stake on bank; against this place suitable boards as the wall is carried up to the grade line. From this point the wall can be carried to the sill line, but will require an additional form for the face of the ashler work. But if the excavation is too irregular, or wide, causing waste of concrete, then it would be best to use the double frame form, or the box form, already described.

Cellar walls for frame buildings should be from 10 to 12 inches thick, ordinary concrete. For brick 14 to 24, according to the thickness of the brick wall; for these two only ordinary concrete is required. Barn walls should be as wide on top as sill and may have wider footings at bottom or battered as the weight and the height of the wall would most require. Where a barn has a bank wall, such as used in some of the states, for a drive above basement, this bank wall should be from 18 to 30 inches at bottom and from 14 to 20 inches on top; this will allow room for joists to rest on the wall, say 6 to 10 inches, and still leave room for concrete door sill coming up even with top of floor and against the top of which the door can close; this sill is built in the following way: When the joists are laid and barn up, place board along the end of joists extending across floor to posts, and high enough to come to top of floor line; place another board along the outside to conform to door line and two inches lower than inside one, secure this so it cannot shove out of place when concrete is tamped into it. Place the concrete, tamp and stroke even; any time after 24 hours the outside form board can be removed; the inside one is left.

The various walls needed about the house or farm can be constructed in a similar way to the methods herein given, and we will not dwell on further explanations.

A few fundamental requirements for all walls, either stone, brick or concrete, we think will not be amiss. A foundation must extend through the frost line. A foundation must extend through soft or yielding soil.

Cobble stone and other porous foundations must have drains from the lowest point of the trench, otherwise they are worse than no foundation, because the water settling in softens the bed and in freezing weather causing heavings, followed by excessive settlings. If the three cautions referred to are strictly observed walls will remain intact and stand as when built for time, otherwise the best and most carefully finished walls will be broken, yielding and unsightly after a few years. In localities where field stone are abundant, especially for farm work, where the farmer must pick them from his meadows each year and have many loads hauled on piles, which can be had in many cases for the hauling, these can be used for such wall purposes, and for method of using see "Mortar Concretes." Pillars for sheds, grain houses, etc., can easily be built in this way by first making suitable form. It should, however, be remembered that in the construction of all forms, that they must be so made as to be removed when desired, without pounding or in any way crowding, straining or breaking the cast. During warm or drying weather walls 6 or 8 days old are ready for the buildings.

Floors—Cellar or Basement.

Where there is no frost to penetrate beneath the bed, walks are at once laid on the hard ground, first evened off to bring the top of the concrete to the desired height and grade. These floors will range in thickness from 2½ to 4 inches, according to use. For floor 3 inches thick, first place over the bottom concrete 2½ inches thick well tamped down; for ordinary purpose this concrete can have the following proportions: Cement, 1; sand, 3; aggregate, 5 parts. Over this concrete spread with float or trowel evenly, ½-inch plastic mortar, made from sand and cement in the following proportions: Cement, 1 part; sand, 2 or 3 parts (2 parts if fine, 3 if coarse. This can be laid in one continuous block and as soon as one can walk on it without leaving marks, it should be sprinkled each day for 6 days.

Stable, Shed and Barn Floors.

Under this we have reference only to floors supported by the ground and do not include suspended floors of which we shall speak later. For these floors excavate all loose or yielding soil and sufficiently deep enough that from 9 to 12 inches of porous foundation can be placed below the floor; this may consist of cobble stone, gravel, cinders, etc., and must be evenly placed and tamped, so that no uneven settling may occur, which would check the blocks. This porous foundation must have an outlet at the lowest point so that no water will set in the foundation causing heaving in freezing weather. The foundation done we are now ready for the floor. This may vary in thickness from 3 to 6 inches, and should not be laid in one continuous floor, but blocked into nearly square blocks, which should measure on their sides in feet most nearly twice their thickness measured in inches, thus a floor 4 inches thick should lay in blocks 8 x 8 or 64 square feet. A floor for foot use need be only 3 inches thick; for horses and wagons, 4 to 5 inches; stalls for cattle, 3½ to 4 inches. In some cases these blocks can conform in size to the stalls, thus overcoming the need of remnant or smallish-sized blocks. The composition of the concrete for these floors would be amply safe at, cement, 1 part; sand, 3 parts; aggregate, 5 parts. On the top of concrete spread mortar nicely even, made of cement, 1 part; sand, 2 or 3 parts. The thickness of this mortar can vary from ½ inch on foot floors to 1 and 1¼ on stable floors, thus the 3-inch floor would consist of concrete, 2½ inches, and plastic mortar, ½ inch; the 4-inch floor, concrete, 3 inches; mortar, 1 inch; the 5-inch floor, concrete, 3¾ inches; mortar, 1¼ inches, and the blocks would be 6 feet square, 8 feet square and 10 feet square. In stables for cattle and horses, etc., there should be drain cups at the proper location in the stalls with the surface of the stall inclined to them so that liquid matter will at once be carried away from the stall. These drain cups consist of perforated cast iron drain lids or tops about 6 or 8 inches in diameter; the holes should be ¼ inch at top and ½ inch at bottom; these will not clog. For a 6-inch drain cup the hole through the floor should be 4 inches so that the lid may have a bearing of 1 inch around the circle or outer edge. This flange or collar which holds the drain lid and into which it lays with the top ¼ inch lower than the surface of the floor next to it, should be 3/16 of an inch larger in diameter than the drain lid so that it can easily be removed and the tile or sewer beneath it, and into which it drains, can, when necessary, be flushed or cleaned.

In the city the tiles from these cups should be carried into the sewer; in the country they should lead into the compost (manure) yard or liquid tank.

How to place the sewer pipe connecting these cups, etc.: First, put in the porous foundation for the floor with exact grade on top to receive the floor. Ascertain the exact location of the line sewers in back end of stalls, now along this line with true and equal fall lay 4-inch collar sewer pipe, connecting all the stalls in this stable and extending with sufficient fall into the barnyard or where wanted. These tile may extend above this porous foundation 1 inch and in laying the joints must all be made water tight by using mortar jointing, and should also be laid in mortar so that they will not move when placing concrete. At each stall where open cup is wanted, place sewer with collar opening made for this and similar uses. Upon this hole build the drain cup and with sufficient care that it may not leak. Some connections between drain cup and sewer may be longer than others, but these can be built up any lengths by placing a 4-inch turned stick or plug into the hole of the tile and letting it extend up above the floor line. When laying the concrete tamp around this, or better, place around it. When ready for the top mortar gently remove these plugs, which would be slightly tapered at bottom, to allow their easy removal. On the top of this concrete lay the perforated lids and when building mortar around them, when partly set, take spike, insert into one of the holes, and slightly move the lid sidewise until the collar is sufficiently large to admit their removal.

How to divide the floor into blocks. For illustration we will take a wagon shed floor; the shed is 16 x 30 feet, the floor is 4 inches thick. Procure scantling 2 x 4 inches and straight; set this crosswise 8 feet from the furtherest end of the wall of the shed. (In this we have supposed the foundation already down.) Across this section 16 x 8 feet in the middle place another 2 x 4 on edge 8 feet long, these must not be nailed, but secured in place by proppings or stakes, or could be secured by laying a few sacks of cement against the outer edge. Mix the concrete and place one section even full, tamp well, when within 1 inch of the top of the form, which can be ascertained with straight edge, remove cross form (2 x 4) and mark with pencil on form, and on opposite wall the exact edge of this block, so that when the mortar is placed and spread over this that in cutting this top you can strike the exact joint in the concrete below. Against this joint now made bare by the removal of the form, place several thicknesses of paper, 3/16 inch (cement sack paper would do), place concrete for the next block in the same way as the first; when this is done, with shears cut the paper off that extends above the concrete. Now over this place mortar and with straight edge resting on the form stroke off even with form, even nicely with wooden float. If desired mark edges with cement edger, and at the joint of the two blocks lay straight edge and with trowel cut top through along the joint; with double jointer follow through this cut, and the two blocks are done. Now set the 16-foot 2 x 4 8 feet further away, secure again and continue as before, only this time make two half blocks at each side with whole one in middle, etc.

If it is desired to place a drain cup, used in washing buggies, this can easily be done same as in sewer cups in stables; however, the surface grade must conform to cup for this purpose.

As soon as this surface bears one up without marks (perhaps from 24 to 36 hours) sprinkle thoroughly twice each day for 6 or 8 days. Horses sharply shod should not be taken on this for 28 days.

For methods of mixing and using mortar and concrete, see under Mortar and Concrete.

In seasoning floors it will not be necessary to cover, but in warm and windy weather close windows and doors to prevent currents of air which would evaporate the moisture from the surface. In some cases a door sill will be required, against which the door will close. This can be put in with the floor by first excavating deep enough so that the frost will not heave; place board or plank along outside or door line,in height 2 inches lower than floor, meet the floor line 8 inches in from face of sill, this makes an easy wheel riser, and is most suitable in implement and wagon shed. Just before the top coat is set take wall edger or trowel and dub off sharp corner on outer edge of sill, so that it will not chip off with use. In laying floors with concrete and mortar top as described, it should be remembered that when the concrete is once laid the mortar top must be placed before the concrete has set, which in drying weather would be about 2 hours. When this occurs with work left unfinished during night, the matrix may be renewed by sprinkling water over the surface and with a fine sieve sprinkling cement lightly over same.

Floors Supported on Joist.

Floors of concrete reinforced are now almost everywhere used in all extensive buildings. Germany and France, it may be said, were the pioneers in this method of fire-proofing. It is not so new as many in this country seem to think. Our engineers were slow to endorse its use at first, but today there is not a building of any note being built that does not contain some form or other of this fire-proofing.

The large fires in the cities continually justify the wisdom of their use, and without them the tall office building, the large tenement house and factory would be an impossibility. A suite of rooms with their contents are frequently rid by fire of every combustible article, without any dismay to the tenant on the opposite side of the wall or floor. In factories and large shops where heavy machinery is placed these floors are frequently solid, the bottom of the floor forming the ceiling beneath, and entirely encasing the heavy steel or reinforced concrete beams, which supports the expanded metal or corrugated wrought iron netting which is incased in the concrete, and forms one solid mass. In office, tenement and dwelling house, the floors and ceiling are independent of each other, the beams or joists are usually of steel, the floor takes its bearing over the top and on the lower flanges, differing with the many methods in use. The concrete is laid on false, removable bottoms; when about ⅓ of the concrete is tamped into place the metal reinforcing is placed on this, usually expanded sheet steel; over this and into its meshes connecting the whole into one mass, the balance of the concrete is placed; the floor is finished on top in different ways, in shops mostly with mortar top as already described, in other buildings tiles are frequently used and in many screeds or nail strips are placed on top with concrete between and on this a wooden floor is laid. In cinder concrete the floors are frequently nailed directly into this concrete. In dwellings and other buildings in some cases, strips are spiked on the sides of wooden joists, boards are sawed in lengths to fit into this, the concrete is placed on this and extended a few inches above the joists, when screeds are placed and the floor nailed to the top of these, with a suspended ceiling. This has proven fire-proof. Highway bridge floors are now in most cases constructed in a similar way as already described, while the fire-proofing in this is not required, yet in the best work the steel must be entirely covered to avoid corrosion. The thickness of floors will differ with use to which they are put; the distance between joists, and also to the method of reinforcing. Since this will be a work specially in the hands of the engineer, we shall make no further effort.

Ceilings

for fire-proofing are usually suspended from the joists by hangers made for this purpose. These support the metal lathing against which the plastering is placed; the space between this and the floor containing the piping and wiring. This same fire-proofing is also applied to the rafters.

Partitions.

These are used in fire-proof buildings and consist of solid or hollow wall. The solid partition is built up same as wall with two face forms supported against frame or uprights. In the middle of this concrete wall is incorporated continuous sheets of expanded metal. This wall is continued firmly against the floor above; the metal gives it support fundamental methods; these must be varied to each and adds elasticity. In thickness this can be carried to suit the work, usually from 3 to 6 inches. The hollow partition is studded and with metal fastenings the metal lathing is held from the studding on either side, this is plastered with heavy coat cf mortar on each side. The side walls, wooden beams, etc., are fire-proofed in this same way by metal lathing supported from the studding, etc. In this building the mop boards, some casings and molding are also made from cement with suitable molds. In light work only fine aggregates can be used.

Walks.

This embraces a very important and extensive line of cement work, and requires the most exacting care in the labor and the selection of materials. First in order, and as well first in point of importance, is the excavation for the foundation of the walk. This must be dug 3 inches wider on each side than the width of walk so as to have room for the form, and must not be sloped in, but be excavated perpendicular at sides, so that no lifting will occur in freezing. In clay land this excavation must be deep enough to admit of porous foundation 12 or 15 inches thick on which the walk is built. In sandy soil 6 to 8 inches would be equally good. To secure a well dug excavation stretch line on each side—these lines must conform to walk and grade line. From these a uniform depth can be gauged. When excavation is completed, if in clay, it is imperative that a tiled drain be placed from the lowest point of the excavation to a lower outlet, so that the water will not stand in this porous foundation, and in cold weather freeze, causing expansion and the breaking of the walk. When this is completed, place the materials for the foundation; this may consist of cobble stone, coarse gravel, cinders, slag or shells; these should be evened and rammed solid as they are placed into the trench. Stone should be sledged and lighter materials tamped with iron tamper. The common practice of filling these trenches by shoveling cinders, etc., from wagon without evening, etc., and often allowing it to be used for walk (path through middle) for some time before it is used, is very objectionable, and has proven ruinous to many walks otherwise well made. The regular walk builder will have heavy iron roller with which the cinders or gravel are kept evenly packed when put in. It is not so much that they are tamped hard as that they are even (edges and middle alike). When the foundation is brought up to the bed of the walk the forms are placed for the walk. The forms consist of 2-inch scantling set on edge, and in width being the height of the thickness of the walk (concrete and mortar top); these scantling side forms are laid with line, so that the walk will be true to grade and lot line when completed. The forms are held from crowding out by stakes, etc., sufficiently close that no bulging can occur when the concrete is tamped into place.

The scantlings are held in place from the inside by the cross scantlings put in at regular distances and at right angles with the side forms. These are used in dividing the walk into equal sized blocks, as the concrete is placed into each space they are removed and placed forward for new blocks. Where curves are desired in the walk, narrow boards are used instead of the scantlings. These can be sprung to suit the curve, but greater care must be taken to hold them in place, so they will not crowd between stakes in tamping. Walks are usually laid with ¼ inch inclination per foot towards the road side of the walk, shedding the water into the gutter.

The form placed we are ready for the concrete, but before placing this we should understand some of the preliminaries of walk construction.

Walks are constructed of a layer of concrete, and upon this a mortar top is spread; also walks are not built in one continuous stone, but in blocks of unit form size, and most nearly square. This must be determined by the width of walk, thickness of blocks, etc.

We herewith give table for relative size and thickness:

Walk 2 ft. wide should be	3 1-2 in. thick and	2 x 4 ft. block
Walk 3 ft. wide should be	4 in. thick and	3 x 4 ft. block
Walk 4 ft. wide should be	4 in. thick and	4 x 5 ft. block
Walk 5 ft. wide should be	4 1-2 in. thick and	5 x 5 ft. block
Walk 6 ft. wide should be	5 in. thick and	6 x 6 ft. block
Walk 8 ft. wide should be	6 in. thick and	8 x 8 ft. block

The thicknesses given include concrete and mortar top, and is designed for the most exacting use.

In dividing walks into blocks there are several methods employed. One is to place the cross form along the walk to correspond to the size here given, fill this section, tamp, and then remove cross form. Against this joint thus made bare, plaster clay or loam mortar ¼ inch thick, or place paper, or felt ¼ inch, or against it set a steel divider 6 inches high and ¼ inch thick. The steel divider is perhaps the most convenient for the regular workman. If three men are at work from 6 to 10 of these blocks can be made in this way with concrete before the top mortar is placed. Now, by slightly tapping, remove the steel divider leaving the joint dividing the stone open; if paper was used, with shears trim off the paper projecting above the concrete; if clay was used this is ready. Now with knife or pencil mark on top of each side form, exactly over the division of concrete block so that when the mortar is placed and ready to cut into blocks, by laying straight edge to these marks we can cut with trowel through the top mortar exactly into this division space below. If these are not exactly met the mortar or top surface will check across even with the lower joint, thus impairing the work.

Two formulas for concrete for walks:

No. 1—Cement 1, sand 2, aggregate 4 to 5 parts.

No. 2—Cement 1, sand 3, aggregate 6 to 8 parts.

No. 1 would answer for the best class of work (city wear), No. 2 would be suitable for ordinary work, but in this the sand and aggregate should be well graded. For the best methods of mixing and handling, also as to the selection of sand and aggregate, see Part III, on Concretes.

Two formulas for mortar for walks:

No. 1—Cement 1, sand 1 to 2 parts.

No. 2—Cement 1, sand 2 to 3 parts.

Formula No. 1 would represent mortar equal to the most exacting use. No. 2 ordinary.

For best methods of mixing and handling mortar, see Part II.

Where extraordinary resistance to wear must be secured crushed granite chips, or flinty pebbles are incorporated in the top mortar; this, however, is seldom necessary if the best hard and clean sand is used. For sake of more minute illustration we will build walk 6 feet wide and 5 inches thick; concrete 4 inches and mortar top 1 inch. Measure carefully and mix according to directions under "Concrete." When mixed and before placed take sprinkling can and sprinkle foundation and side forms so the dry surfaces will not evaporate the water from the concrete. When this is done place concrete and with concrete tamper tamp dense and evenly, when water will slightly appear on surface. If the concrete quakes it is an indication that too much water was used in mixing. The placing of the forms has been described, and in this case will be 5 inches high and the blocks 6 x 6 feet. In order to gauge off the concrete for this walk use straight edge 6½ feet long; this will leave 3 inches at each end to slide on the side forms; notch the straight edge 1 inch deep and 4 inches long in from each end; now by placing these notched ends on the form at the sides and stroking along, this will leave the concrete 1 inch below the top edge of the forms, this space to be occupied by the mortar top. When this block is finished in this way, even and well tamped, remove the joint or cross form, and place forward. Space another block 6 feet with run of the walk; after treating joint exposed as directed in "The Division into Blocks;" fill this section the same way. This can now be continued the whole length of the walk, if the force is so divided that some follow placing the top mortar before the top dries, or within 2 hours after concrete is laid. Otherwise the concrete men, after placing several blocks, must return and place the top mortar. Some care is required to keep the faces or edges of the sides full and dense; this can be done by keeping finer concrete near the side surface, and close tamping. The cross forms, called joint forms, must not be nailed, but held in position some other way so that no pounding will be required to remove them.

We will now place the mortar top. Notch or mark all the cross joints as directed, with trowel remove all dry and loose concrete, etc., near side edges and from form. Slightly sprinkle side forms again, also surface of concrete if dry. Place mortar and with trowel spread heavily on the surface of the concrete; watch that in using the trowel in the mortar no air spaces are covered; also use trowel along sides so that the edges will become dense. Do not try to smooth surface with trowel, but when spread over the surface so that it will stroke safely full, take a straight edge, the back of the concrete straight edge will do, if straight; with this resting on the side forms stroke the mortar off even. In holding straight edge slightly slanting it will pack the mortar some. When the space for several blocks is thus spread leave it for about 20 minutes, or until the water on the surface is about evaporated, when with wooden or cork float, dipped into the water, float the top surface. Do not float heavily so as to shove the mortar, but slightly, so as to compact the surface, and at the same time give it an even, unmarked appearance. Do not use steel trowel for this purpose, it gives it a glossy, streaked and cheap appearance, and in which hair checks may follow. With a trowel run along side forms as far as finished, cutting about 1 inch deep, and holding it in such a way as to crowd the mortar back from the form about ⅓ inch, then lay the straight edge across the walk at the marked joint places and with trowel sliding against side cut the top mortar through into the space of the concrete below. In cutting across walk, hold trowel to cut, and avoid dragging and tearing the edges.

Now, to finish, take suitable sidewalk edger, place cutter into trowel cut, slide along side form the whole length finished; repeat on other side in the same way, pressing only hard enough to make an even and straight furrowed edge about 1/16 inch deep. With sidewalk jointer pass through the cross joint at the place cut with trowel; this completes the walk so far. This is repeated until the entire length is laid. Mortar for the top of walk should not be too wet, only sufficiently to work slightly plastic for use. If too wet suspended water in the mass will rise to the surface causing pock marks.

In ordinary drying weather, after 24 hours this walk should be covered from the sun, and currents of air. This covering may be whatever is most convenient, either saw dust, shavings, straw, grass, cloth or paper. Freshly cut grass is about the best thing when it can be had, though anything that will absorb water and that can be sprinkled without removing can be used. When this covering is placed sprinkle thoroughly, repeat twice each day for 6 days and the walk is ready for use; remove covering and side forms.

It is a little difficult to set forms for walks so that while they are secure enough that at the same time they can be so easily removed as not to wrench or jar the cast, but with a little originality of method one can always find some easy way to secure these; in some cases he might fill against the outside of form ground slightly tamped, or by driving stakes away from the form and blocking out. We could give no fast rules for this work, since the conditions for each job may differ.

Three men who are accustomed to laying walks will lay 360 square feet of 5-inch walk per day. The amateur workman, if he possesses a 25-cent trowel, could lay walks not inferior in quality, though perhaps inferior in looks, without any other sidewalk tools. The edger and jointer should be dispensed with; the edges and joints could be dubbed off with trowel, and for want of an iron concrete tamper a wooden tamper could easily be made that would serve one in a small way for his own work. In walks the mixing of concrete and mortar must be thorough, slighted work will show, and be unreliable; also excessive troweling of the top must be avoided, especially if wet, as this brings the finer particles of cement out of the sand and to the top, giving it what is called a "skin cover," in which hair cracks will soon appear, rupturing this glossy top skin, when directly beneath this the surface is loose, being mostly sand, since in the suction of the troweling the cement floated with the water to the top while the coarser and heavier sand settled down, consequently beneath this skin cover there is imperfect crystallization.

Drives.

This work does not differ in any way from walks, only that they must be built to stand heavier and rougher usage. Drives should be from 6 to 10 inches in thickness, according to use, and the top mortar or stone from ½ to 2 inches thick.

Walk crossings should have wheel risers or approaches built to them on each side; these must have bed and thickness same as the drive. While the top of the riser projects downward to meet the road line the bottom must incline in the same way so as to maintain its strength. When the mortar top has been laid long enough after being floated even, to work heavy, pass over the surface with grooved roller, this will give it a ribbed appearance, making a safer footing for horses. A good driveway is built with slightly raised road bed, shallow gutters and curbing.

Curbing.

These are portable and monolithic in the building. Most curbing are built in the factory and after seasoning are hauled to the place where they are set. But under this heading we shall endeavor to describe the building or forming on the spot where used. Usually curbing are from 6 to 8 inches thick and from 1 1-2 to 2 1-2 feet wide. They are built in a straight line between street gutter and walk, and must conform to street grade and lot line. Their use is to hold the paving blocks and form the gutter line on the street side, and on the walk side protect the bank from washing. On the gutter side they project above the paving from 6 to 10 inches. On the walk or lawn side they are even, the ground filled to the top.

Excavate trench for the curbing to the depth desired; make form in the following manner: take two or three planks for each side to make the height desired; strip these at each end and in the middle, with the strips on the outside; the sides should be 8½ feet long. Securely nail boards against one end of these sides (sawed square), giving the form the space inside desired for the thickness of the curbing, with two notched strips to slip over top to hold in place, and the form is ready for use. Set the form into the trench with closed end in direction in which you desire to build. Set form with a line stretched true to grade and street; this may be secured by shoving slight blocks beneath the frame to support it in height to line; blocks at the side if needed between form and bank will hold it to street line. To keep from spreading below, near the middle place two blocks, one on each side. When the form is filled and well rammed and the top floated even and edges rounded with an edger, the top strips and the side blocking is removed, the form spreads at open end, and with one man in trench at closed end and one at each side at open end, the form is slipped along the trench for the next block. In making the blocks 8 feet long the form will lap on the last stone ½ foot. When trued to line and before again filling, put paper against the upright joint, or better, plaster with clay ¼ inch; this joint allows slight adjustment in weather conditions without breaking the stone. If doweling is desired drive iron pin ½ inch thick and 4 inches long half way into the last block and 6 inches from top down. Now proceed as before, watching that the exposed surface is compact. In the composition of the concrete for curbing it would be an economy in cost without any sacrifice in quality if two mixes of concrete were carried. The bottom could be coarse, with a fine concrete top in which the top can be finished without mortar; not more than 1 foot of the top will be exposed. For bottom take, cement, 1; sānd, 3; aggregate, 4 parts. After 24 hours the work can be carefully filled but should not be tamped much before 6 days. The top should be covered and kept wet for 6 days.

Posts.

Hitching posts, where desired, can be continued from the curbing in the following way: Take wrought iron ¼ x ¾ inch and 9 feet long; this should be twisted or crimped; double it over in the center so as to be about 3 inches across at closed or doubled end and about 6 inches at open end; set open end down into the curb form, with the top projecting perpedicularly above the curb, about 2½ feet; these could be placed at regular intervals or where posts were desired and afterwards with a post form most desirable for this work; the posts could be easily built from the curb up. These posts could be cast with 2-inch holes through the top; this should extend between the irons, or instead, a long link with ring might be bedded into the side or top as desired. These irons fastened or bedded in the curb and extending into the post would make an indestructible post, well out of the way and at the proper place. At this point we wish to say that heavy posts either for hitching or gates for mammoth resident drives in the city, cemetery and park entrances, with arched columns connecting them as desired, are built of reinforced concrete; this can be made with elaborate moldings and panels and at a very low cost as compared with stone in similar construction, and superior in quality in every way. Molds of this character would form an item in the cost, but if well made and carefully handled, could be used a number of times, thus reducing the first cost. In such work the excavation is made as for other work, and in depth must correspond to the top structure; instead of placing porous foundation, the concrete is begun at the bottom, encasing the reinforcing metal near the bottom. The kind of metal used and the method of placing must be regulated by the superstructure. After the molds are removed the surface is moistened and paste mortar applied with brush and with hand polisher rubbed into the surface. After the work is dried, or say 24 hours, the surface is again washed and cleaned; this now has the appearance of a hand rubbed stone surface. The molds are only required from the grade up; the excavation is built up against the bank or sides.

Cistern.

The concrete method of cistern construction now coming into use promises some points of excellence, but with cumbrous and costly forms the work is greatly hindered, or at least confined into the hands of a few operators. The best and strongest shape for a cistern is the circular or jug shape and is the most difficult to arrange for the forms. These are built in sections, small enough that they can be removed from the top opening when through. They should be made to set together and bind without any nailing; also that they can be removed without crowding or hammering; are most usually carried in height as the work progresses. Where the size of the form is known the excavation must be made to suit, and with care in excavation much waste in material can often be saved. When excavated and the form placed there should be 4 or 5 inches space between it and the bank. No metal reinforcement is needed in these circular walls. The concrete for these should be, cement, 1; sand, 3; fine aggregate, 3 to 4 parts. After a few days the form is removed, the sides plastered with mortar, cement, 1; sand, 2 or 3; the bottom is placed last, and should be dug concave (hollowed out) for strength and convenience in pumping the water nearly all out, for cleaning, etc. Place concrete over bed 3 or 4 inches thick; plaster this, and the interior is done. The inlet and outlet being placed into side wall as this was carried up. The top arch represents the shape of a jug and is carried continuously from the side wall to the opening; this should be 20 inches in diameter for common sized cistern. This opening or neck is continued to grade line and should be about 18 inches high.

The rectangular cistern is best suited to easy form constructions. Say 12 feet long, 5 feet wide and 6 or 8 feet high, for common house use, would be a fair size. With 5 pairs of uprights stayed across with stiff strips and wood screws 5 feet from outside to outside, one pair at each end, one in the middle, and one each between middle and end. This will leave 3 feet between uprights on sides, and on the ends another could be placed in the middle stayed to a stake in the ground. Thus it will be seen that boards in lengths of 2½, 3, 5 and 6 feet could be used, but should all be of one thickness and width. The boards are placed against the uprights, as the wall is carried up; when the top of the uprights is reached arch circles or segments are supported on the uprights, these segments have a rise of 1 foot in the space of 5 feet. These are fastened to the uprights so as to be easily removed and so that the arch will take its bearing on the walls; over this narrow boards are spread, say 6 inches wide; now the concrete is placed on them and must be rather wet since not much tamping can be done on these light boards. This arch should be 5 inches thick and sides 4 inches; these cisterns usually have a filter wall near the middle made of porous brick, and for this reason a man-hole will be left at each end of about 20 inches in diameter; these are built with two heavy sheet iron forms, which are so made that they can be slightly expanded or contracted, in order to remove. One is used on the inside, and the other on the outside, with 4 inches space between, with these man-holes are carried to the grade line. After a few days the form is removed, the interior plastered, cross filter wall laid. This wall is a single or double brick wall 4 or 8 inches thick, bedded in cement mortar carefully laid so the water in passing from inlet part into the outlet part, or pump part, must pass through the brick. The wall should be built slightly convex toward inlet part, so that in heavy rains when the water would set highest in the inlet part it would not shove the wall over. The filter wall must be carried a little higher than the outlet tile. The outlet and inlet tiles should both be built into the inlet part; also this filter wall must never be built on the ground or the cistern would leak through into the ground. The bottom is concave, with pump part of cistern slightly deepest. Concrete 2 inches deep is placed over this and plastered; this is done last, except the small strip where the filter wall is set. In larger work of this character when the span of the arch is longer, expanded metal should be incorporated in the arch, and when filter wall is not used inside, the long side walls should be 5 inches thick.

Reservoirs

are usually large storage receptacles for water variously used. City water works, for irrigation and large factory purposes, etc. Reservoirs are usually round, sometimes entirely buried in the earth; some others partly, while some are only set deep enough for solid and uniform foundation.

Their construction in whatever position is much the same, only the pressure of the water is counteracted when filled against the outside, and that the pressure decreases from the bottom to top. The diameter of a reservoir has little to do with the expanding power, but height has everything. The excavation is first made and when deep enough the bottom must be concave, with the sharpest angle near the wall, which partly takes its bearing on the bottom, distributing this bearing from circumference to center; though the circular wall is usually built first, there is a reinforced collar or projection built on the inside and about 8 or 10 inches from the bottom, where the wall and bottom connect. First a circular form is built for the inside; say the reservoir is to be 100 feet in diameter and 14 feet high, in this case we would take 16-foot 2 x 4 scantling, bury the bottom 1 foot in the ground, set them perfectly perpendicular, brace near middle and top securely by nailing bottom of brace strips to solid stake well driven into the ground; sheet this half way up with plain surfaced sheeting 4 or 6 inches wide; now place outside studding in same way, leaving the space for the wall between the sheeting, say 10 inches. The outside studding only need be braced in middle, when the wall is carried to this point, cross pieces are nailed across the top to hold the outside in place. Only sheet outside 2 feet high; clean the wall space ready for concrete; place 6 or 8 inches and thoroughly tamp. The reinforcing is now placed, and with some engineers expanded metal is used, carried continuously from bottom to top, and in about the middle of the wall, usually using lighter sizes toward the top. Others use wrought iron twisted rods suspended alternately from side to side; also perpendicular irons at regular intervals. But in either case care must be taken that the joints in the reinforcing are well broken and lap at least 6 inches, directly at this point where the bottom and wall are joined it is most essential that strong lateral bonding should be secured, for in addition to the great water pressure at the base the deflection caused by the bearing of the wall on the concave bottom would amount to a considerable strain, which must be overcome. But on work of such magnitude there must be a supervising engineer, whose business it is to direct as to the kind and method of reinforcing. I only wish in the space of this book to give general details of methods, so that the lay workman can come to it with a little more aptness. The concrete used among this reinforcing must be wet even to quaking and should not contain too coarse materials, cement, 1; sand, 3; fine aggregate, 2 or 3 parts; this is carefully tamped about the metal so that it is thoroughly and tightly encased by the concrete. As this is carried up the sheeting is continued; the top must be level. Ordinarily the sheeting can be removed when completed; wet sides, and plaster in and outside with mortar of cement, 1; sand, fine, 2. The bottom is now placed, usually there is an opening left in the side through which materials are taken which are afterwards closed. The bottom should be 6 or 8 inches thick, reinforced by light expanded metal sheets, laid about the middle of the concrete, since the pressure is about the same. The bottom is also plastered same as sides. Large vats, standpipes and many other similar structures are made in the same way.

Grave Vaults.

Of the rapidly increasing adoption of this method of burial it is not our purpose to speak. Simply as to the best plans of construction.

When the size of the casket for which the vault is desired is known, a form of suitable size is selected or made. This, in size and shape, would correspond to the "rough box" usually used over the casket. The form will be built similar to these, only that there is no bottom or top, and instead of nailing them as the "rough box" is, the strips in the corners of the form are held in place by wood screws, which when removed, will allow the ends to be slipped in, and afterwards the sides. The ends of these forms should be sawed beveling so that when one end is drawn in it does not bind or crowd on the other corner, but at once becomes loose. Dig grave large enough so that when form is placed there will be 5 inches room between form and bank for concrete. Before the form is set in place, put in bottom of concrete 3 inches thick. Place form and secure center of sides by cross stay; now fill concrete between form and bank, and tamp well; when carried to the top of form, even the top, and in two hours of drying weather the form can be removed. Plaster sides first, finishing with small wooden float; now finish bottom in the same way.

The proportion of concrete for this work should be, cement, 1; sand, 3; aggregate, 4. When ready for burial place drapery into the bottom of vault and extending up one end. When casket is placed fold the drapery up along and back over casket. Over the top of this place arch form; this must be tight so that nothing will drop into vault. The arch form should have circular top of about 4 inches rise in the middle, and is made of narrow strips of surfaced boards nailed on the arch lintels, one at each end, and the other in the middle, and the whole must be large enough, so that it will rest from 1 to 1½ inches on the end and side walls.

The concrete is now placed on this form 4 or 5 inches thick; this cannot be tamped and therefore must be mixed rather wet, but not so wet as to drip; in this way it can be worked down compact with trowel. With a little care in throwing on the first ground the grave can be filled at once. This vault is water tight, impenetrable, constant as stone, and will cost in the average location about $24. The shape and character of the vault can be varied from the simple vault described, to the most artistic, with panels, moldings, etc., in some cases extending above the ground, covered with artistic coping, surmounted with statuary, etc. We will give a brief description of a still more simple method, coming into extensive use and in every way as serviceable as the most expensive. For this dig grave same as in other described, put in bottom of concrete 3 inches thick, on this set the "rough box;" stay center of "rough box" so that the sides will not crowd in in tamping; now place lid on box to keep box clean, and place concrete in small layers, tamping solid. Since this is not plastered on the inside, extra tamping and fine concrete must make it dense and impervious to water. Use, cement, 1; sand, 3; fine aggregate, 3; when completed remove lid and place drapery; when casket is lowered into place fold drapery back over casket, place lid in position and over this place rather wet concrete 5 or 6 inches thick. This is a most simple method; can be placed in all kinds of weather and at short notice, and for all purposes of a vault is unexcelled.

Culverts.

These are coming into use in all sections of the country, in which well advanced ideas in road construction are prevalent. They are cheaper by from 25 to 50 per cent than any other method of equal merit.

By the proper reinforcing of the concrete with metal much is saved in the cost, and at the same time much is added to the strength and durability as compared to the old method of "Ordinary Concrete."

In the space of this little book we can only give fundamental methods; these must be varied to each particular job.

A most substantial culvert is built in the following way: Excavate safely below the erosion of the stream, and unless on stone it is usually better to use footings for the trench wall (see footings); also excavate, etc., the same for the wing wall. These are the walls that project back from the bench walls, at the most suitable angle, and which are extended to the top of culvert arch or even above. They serve the double purpose of holding the roadbed in place and securing against washing of roadbed back of wall; they also add strength to the whole structure.

When the excavation is done and the footing placed, the forms are now set in position. For illustration we shall suppose this culvert to have a 12-foot waterway and 24-foot roadway. Then in this case by using expanded metal in walls and arch we conclude that an 8-inch wall is heavy enough; this we will strengthen by 2 pilasters on the back side of each bench wall, dividing the space of each bench wall into 8-foot sections; also another pilaster at the end of each wing, making in all for this culvert, 8 pilasters; these should measure at the base 10 x 16 inches clear of wall and stand with narrow edge to the wall, their width the 16-inch way should be reduced to 6 inches at the top. In this case when the bench walls are 3 feet high, the arch is now placed, taking its bearing on the bench walls.

The arch may be a segment arch or a semi-circle arch; this must always depend on the depth of the stream from the roadway, and it must not be overlooked that in segment arches the bench walls must be constructed, to hold in addition to the perpendicular weight of arch and earth upon it, also a great lateral or deflected strain towards the bank. This must be overcome in the building of the bench walls, which would require greater thickness of these walls, or an inclination towards the arch would support the strain. The result of this deflection on the walls by the arch increase with the span of the arch. It would also be largely increased by every degree of flattening of the arch. The wall described would be suitable for a semi-circle arch or a segment arch of not less than 4 feet rise in center.

In building up the wall when the forms are placed, at once insert the expanded metal, leaving room on the face side for 3 inches of concrete and on back side for 5 inches. The tops of these metal sheets should project above the top of the bench wall 6 inches, from which point they are carried into the arch, with the arch metal. The wings are reinforced their whole height the same as bench walls and should connect with the arch metal when they join.

When ready for the arch, place arch lintels at suitable distances to support the weight of the arch; over these place 2 x 4 scantlings; this will form under face of arch; on this place concrete, beginning near the bench walls place 3 inches thick for a convenient space; on this place the expanded metal, and over this again place 5 inches of concrete.

The concrete for this work should be rather wet so that it will pack about and through the meshes of the metal in one continuous mass. The arch lintels should be set on wedges, which when the concrete is well set may be driven back to loosen the false work, so as not to crowd or break the arch.

The end or wing walls are carried to the height desired and could be finished with a coping top course, the ends plastered and blocked off into nicely broken stone work. The arch and wall should be seasoned, for which see "Concrete."

Another method of small culvert construction when water way required is not over 6 feet in diameter, is as follows: Upon excavated bed of the desired height, place from 2 to 4 inches of concrete, on this place expanded metal about 18 inches wide, over top place 2 inches more of concrete. On this lay collapsible circular form the size desired, build around this form shell of concrete with expanded metal contained in middle, the thickness of shell would vary with size, but would not need be over 6 inches for the most exacting requirements.

The ends of this circular shell could terminate in end retaining walls. Wash aprons or any other construction most suitable to overcome wash of stream.

Steps

are of two kinds; those cast in one solid piece of concrete—Steps and Sides or Housings.

Steps cast in separate pieces and afterward placed in position are described under "Heavy Blocks" in this Part. When the place for the steps is known, ascertain the entire height or rise, divide this into steps of equal height, not less than 6 inches nor more than 8 inches; next in the same way determine the width of the tread, like the height: their width must be the same, not less than 10 inches nor more than 14 inches unless made wide enough so that one or more steps can be taken on the tread, as 30 inches, etc. Steps with housings or closed ends should always be built wide, even wider than walk from which they lead so as not to look cramped. When all this is determined, a form is built to suit the requirement.

In the cities there are regular form builders, elsewhere a carpenter or mason, handy at such work could build a very good one. In this work we cannot give details for the building of these forms, simply to say a few things common to all form or molds. Upon the form will depend the appearance, and very largely the strength of the step.

First the form in no place should cut off proportionate strength of body work. The top should be open at all points possible, so the concrete can be well rammed into place; the bottom is also open only where necessary to bind together with light strips, for strength and holding form stiff.

With the judicious use of some moldings and panels the step will not be strong but can be made artistic. Molds are made with surfaced lumber, put together with wood screws, which can be easily removed when through and stored for another occasion. These molds cost from 3 to 15 dollars, yet the step when completed would not cost one-half as much as a cut stone step of similar design, and if skillfully done will be better in every way than a stone step.

The form ready, the next thing to do is to have a thoroughly good bed prepared to build on; this in clay soil should be 18 inches deep; a little wider and longer than step; must have outlet or drain to this porous pit, so no water will set in foundation. Now place form level and true as you would have the steps be; with sprinkling can thoroughly wet the form, so that it is thoroughly expanded before the concrete is placed in. The concrete for this, in order to give it nice and compact face must not contain coarse aggregate; surfaces patched always show and should be avoided. Cement, 1; sand, 2½; fine pebbles, 3 parts. (See "Mixing of Concrete.")

This proportion of concrete is given with a view to a regular and well filled face. With a little care in placing, the body work of the step could be made of coarser aggregate at a considerable saving of cost in materials. The concrete is placed into the form a little at a time and well tamped, with care to avoid air spaces and rough or loose places in the face of the work. This completed and the top surfaces of steps and housing smooth, with sharp edges rounded with sidewalk edger or trowel, the work is complete, ready to season and remove the form.

In most cases it is best to remove the form after 24 hours and before seasoning.

Sometimes when the forms are not properly expanded before they are used, if left on while seasoning the work the forms expand and chip the edges of panels and moldings.

Steps as described have two uses generally: First, that of a step against a bank, such as a step leading from the sidewalk upon the yard walk, etc. In this case the bed is prepared in line with the grade but enough deeper so as to contain the body of the step, and should be heavy enough at the back or lower edge of each step so that no checks will appear. This is built up in solid body from the foundation. The form must be built for this use of a step.

Second: This use is usually as leading from a porch down into the walk or grade line. These are set on the level and the form is built with the end housings extending down to the level or grade. When the steps are more than 6 feet long they should have a blind housing underneath in middle to support the step. The forms are so constructed for this use of a step that the space underneath and between the housings are left open, and since these steps are tamped on the hollow form below they should be built with rather wet concrete so they may become compact, with this disadvantage of tamping.

It should be remembered that no steps can be built to look well without some form of a molded projection extending forward from the top of the step. This can still be heightened by a narrow panel beneath the molding and on the front face of the step. The sides or housings must be heavy enough to look proportionate, and in addition to a projection representing a molded coping, they can have panels either molded or plain. It is not at all difficult to prepare the molds for these designs, when it is remembered the face of all moldings and trimmings represent reverse form of the cast product.

This molding must be so manipulated as to give a pleasing effect to the eye. Corner moldings can be so placed into the corners that the sharp edges can be avoided, etc.

Portable Concrete Cast Masonry.

Under this division are included cast products, built at factories for this purpose, and which are usually supplied to the trade in a commercial way. The many different wares produced in this line are usually made by machine mold, many of which are secured by patents. All cities and many villages have one or more of these factories. Their products cover a large and useful field, with an ever increasing demand and variation.

While the most of these molds are metal, some special or irregular products are frequently made with the use of wooden forms. At this point we wish to impress the importance of thorough expansion, by thoroughly wetting the forms before they are used. There are at least two reasons for this which should be known. First, the dry surface of the wood absorbs the moisture of the concrete next the face and arrests a chemical process in the hardening which leaves the surface of the product loose and pliable. Second, the form becoming moist from the concrete, expands, and when the work is partly or wholly set crowds shoulders or panels, and other irregular surfaces, straining them open and impairing their value. The importance of this, however, attaches mostly when the wares are seasoned in the mold, for when molds are at once emptied this can not matter.

Concretes for these products are usually composed of cement, 1; sand, (coarse and fine mixed), 3 to 4 parts. The coarser products and such as have extra facing could be made cheaper and even stronger by adding aggregate (not too coarse) to the above from 3 to 6 parts. For some work, such as cast statuary, cement and sand of equal parts are used. Sand for this work should be fine. The proportions must always be well mixed dry, then gradually sprinkled, and at the same time thoroughly worked over. Long and thorough working of concrete and mortar have shown by briquet tests increases of from 30 to 50 per cent in strength, so that nothing should be spared in this line if it is desired to obtain the best results.

Concrete for this work should be mixed wet enough to work compact, but should not quake in working or settle out of true when removed from the mold. We think that it is the practice in quick molded work to mix rather dry, since this allows the casting to come from the mold with well outlined face, sets up well on pallet and requires less material because less dense. While passable for light work, yet under tests this would show inferior tensile and compressing strength as compared with the slightly wetter.

Building Blocks.

These blocks are classified as of two kinds. The small and hollow blocks usually for light uses, and solid blocks mostly heavy. Of these we shall speak first, because of their size and use they require a different composition of concrete from most wares in this chapter. Also they are usually cast, convenient to the work on which they are used, and consequently would not come under the commercial qualifications applicable to most products under this division.

The composition of these blocks is cement, 1; sand, 2½; hard aggregate, 4 to 6 parts. This is varied according to the character of the work on which the blocks are used, and the quality of the sand and aggregate used in the composition. These blocks are usually large, sometimes weighing several tons, and represent a line of work requiring great strength. Custom houses, fortifications, docks, light houses, reservoirs, dams, canal locks, and many other government, railroad and corporation construction. The blocks are cast in metal forms, are usually tamped by power pressure, when removed from the form are seasoned (kept wet and covered from currents of air). In some cases, after a few days, while wet, the faces are buttered (mortar of cement, 1 part; granite dust or sharp fine sand, 2 parts); this is applied with brush and thoroughly rubbed into the face surface, making the face smooth, impervious to water, and uniform in color.

These blocks are superior to stone in either air or submerged work, and are used over the entire civilized world. Similar to these blocks, but frequently with wooden molds, steps large or small, belt courses, massive columns, wall copings, engine beds, well tops, etc., are constructed.

Hollow Blocks.

These are mostly used in buildings, large or small, and are made of every conceivable shape. The metal machines for their construction are plentiful and are usually secured by patents, each claiming for their product superiority over others. The yards or factories building them are found in almost every village in our country.

In this particular line (hollow blocks) the United States clearly takes the lead. The use of these blocks has rapidly found its way into building construction wherever modern engineering has been employed. They are cheaper, less easily penetrated by water, heat or cold, than solid blocks. They are made with rock face, smooth face, or ornamental face, as desired. In city construction they promise to entirely supplant stone because better and cheaper, and because of appearance have already largely taken the place of brick in face work. The rock face varieties in many cases not being easily detected from natural face stone.

Many of the block machines are so constructed that a thin facing is built into the block face. This is usually denser and in some cases is colored in imitation to the many different colored stone. Most of these block machines make many different sized block, in fact anything needed in the construction of a building: light and heavy wall blocks, different lengths and heights, corners, jambs, blocks with joist spaces, sills, lintels, chimney blocks and tops, water tables, belt courses, different designed faces, etc.

All other things being equal, the machine constructed to give strong power pressure to the concrete when placed into the mold, is superior to the hand tamped block because the latter are sometimes insufficiently or unevenly tamped, while the former would be evenly strong in all parts of the same block, and one block the same as another. This essential is required by all builders, but it is evident that by careless manipulation it is not always attained.

Also machines that allow of building the web and body of the block from coarse concrete, and at the same time, building into the face one inch or so of face concrete (finer and richer), are considered superior to others that will not allow of this. This cheapens the block without any diminution in quality, while the fine rich face gives it density, which secures for it impenetrability to water and beauty of face. It is objected by some that this veneering of the face will flake off. This, however, is never the case where the body and face of the block are built up continuously and at one molding, but if faced afterward, the objection may be sustained.

There is one serious objection to the concrete block wall which workmen and architects have worked to overcome, and even at this time not entirely successfully. This is the penetration of walls by dampness and water, called "Capillary Attraction." Continuous rain against many of these hollow walls will drip from the surface on the inside. Though hollow this passes through the web or bonding, and it may be said that for the first few years of the wall, this though lessened is not entirely overcome by the most careful tamping of the concrete into the molds, since exact density is impossible, but it is found that walls gradually become less penetrable to water or moisture. This would be true if the blocks were made of stone, for these as a rule would be even more porous still. This penetration of moisture is mostly objected to where decorations, plaster, paper, etc., are applied direct to the inside face of the wall. Many kinds of washes of solutions, chemicals, etc., have been used, but usually with little result. (In the next Chapter we will give the "Sylvester Process," the only one of any recognized value.) To avoid this moisture penetration there are two forms of blocks on the market which easily excel all others. The first block is a two-piece block—front and back—and is made with long, middle web and short end webs. The through upright joint is broken by a half length, when the upright joints occur alternately on face and back with the web also bonding alternately from one side and then the other, thus while forming one of the most scientific bondings known to the building engineer, it also possesses the advantage of disconnected lateral web, and in this way avoiding "Capillary Attraction" of moisture.

The second is an L-shaped two-piece block a most simple, yet sensible design, admitting of the greatest variation, damp proof, with ideal bond.

To the manufacturer of building blocks who wishes to maintain a reputation against competitors and a credulous public, three things are of utmost importance. First by tests a safe proposition of concrete must be established, when it must be strictly adhered to, the cement used should be tested or warranted by the company and must be a high grade, slow setting Portland cement; the sand should be screened and uniform. Second, in mixing the concrete for the blocks, only enough must be mixed at a time so that it can easily be worked up before the initial setting occurs. In mixing, the whole must be thoroughly and evenly incorporated while dry. It is then slowly sprinkled while it is being worked over until the whole mass is as moist as fresh earth, or wet enough so the water will show on surface if well tamped, but must not quake in tamping. Every batch must be mixed like it in every way, if the thorough and even mixing is not strictly observed, damaging results will follow. Third, when the molds are hand tamped the greatest care is necessary in the thorough and even tamping, also that the form is always properly closed in latch to secure uniformity of size, also that the face of mold is kept clean, making a clear cut impression each time. It should be remembered that a responsible manufacturer of blocks could be held for damages resulting from unreliable work. The writer has known where one block placed in an important building has shown careless or incompetent work, resulting in litigations and mistrust, entirely stopping a well equipped plant.

No careless or slipshod person should ever be employed in such exacting work.

It would be impossible to give fast formulas for blocks. This should be ascertained as shown under concretes or by actual briquet tests, but the formulas given will be found nearly right.

For facing for blocks, ½ to 1 inch: Cement,1; screened sand, 2 parts.

For body of blocks: Cement, 1; coarse sand, 3; aggregate, 4.

Where no facing is used the expense of the block will be more than in the above, since only sand can be used with the cement, thus requiring more surface coating, etc.

For complete block (face and body): Cement, 1 part; sand, 3 parts.

The blocks should remain on the pallets for 36 hours, and after 24 hours should be kept wet and covered from the sun and currents of air. In 6 or 8 days they are seasoned and in 14 days can be laid in wall. In cool weather the drying is retarded; they will require less water but more time to be ready for the wall.

In the last part of the book we will give directions for coloring of face work, which see.

Fence Posts.

We have already spoken of posts in this Part, but under the head of stationary castings. This concluded with the posts built directly on the spot where used. Under this head we will speak of the post as a commercial or portable product, which would include the smaller posts, such as fencing posts. In this line great demand is felt at the present time. Reliable post timber is rapidly disappearing from our country. In large sections this is already upon us. Iron in some cases has been tried, but on account of corrosion their life is comparatively short. Too, their body is so small that in soft and yielding ground and in thawing weather they are kept erect only with constant care. The uses of posts are varied, and in this little space we can only give general instructions, but these can be adjusted by the worker to suit the many needs such as posts for wire fence, for board fence, to hang gates, on, etc. For these posts as a commercial product, to handle, etc., it will be necessary to reduce the bulk to the minimum while retaining the strength, and at the same time secure slight elasticity by reinforcing by metal. This method is not so new as by some supposed. It has been well tested in this country, where in some sections they are extensively used and with assured success. In Belgium, France and Germany they have been tested by many years of use.

We will consider a post for farm fence use. This post should be 6½ feet long, 5 inches square at the bottom and 3 inches at the top end. Make two side form for this post of surfaced boards 5 inches wide at bottom and 3 at top. To make them stiff so they will not crowd out in tamping the concrete into them, nail edge of strip 1½ x 4 inches, and 4½ feet long against outside of each form, driving the nails from inside of side form through into the stiffening strip. This while light to handle, will remain true. Take board 5 inches wide, into it saw and cut out grooves at right angles with edge of board 5 inches apart and fitting over the bottom end of the side forms; take a board 3 inches wide and do the same for top end so that when the form is together the space on the inside will measure 3 x 3 at top and 5 x 5 at bottom end. The ends can be held in place by wood screws. Lay the form on a pallet (surface board 7″ wide and 7′ long), on which it can remain until seasoned. The board must be laid on floor or even ground, so that the concrete can be tamped without springing the board. When all is ready mix the concrete, cement, 1; sand, 2½; finish aggregate, 3 or 4 parts. See Mixing under "Concrete." When the concrete is ready place some into the form, only enough so that when tamped it will be about 1 inch thick in bottom of form; upon this place 2 crimped wires, No. 9, and about 6 feet long; place the wires along each side about 1 inch in from the out edge and in line with the edge. This will leave them about 1 inch apart at the top and 3 at the bottom; upon this place concrete and tamp until full within one inch of top; place in two more wires as before and fill to the top; tamp solid and stroke even with trowel. While it is desired to have the wires near the outer surface, yet they must in all cases be well covered at sides and ends or they will corrode. Crimped wire can be bought by the roll in any size to suit. If wire heavier than 3/16 inch thick is used they are apt to spring in tamping and in this way remain loose at some points in their length. It is the experience of the writer that where 4 wires are used, No. 9 is amply strong. Where it is desired to use only one bonding in the post as is often done, a ½ x ¼ inch iron rod is used; this should be twisted. Twisted wrought iron is carried in stock in the cities for the purpose of reinforcing concrete. When the post as described is molded, it is left where it is, on the pallet; the form is removed by first removing the wood screws, another is built in like manner and this can be continued at will. It should be remembered that green posts should not be carried on the pallets by taking hold of the ends as the springing of the board might break the bonding in the middle, thus causing defects. About the way of fastening the fencing to the post. Where it is desired to spike or nail to a post, a nail block or strip is bolted to the top and for this purpose, in making the post set an iron pin ⅜ inch thick into a hole bored into the pallet at the proper place, say 6 inches from top of the post and exactly in the middle; 3 feet from the top set another pin in the pallet in the same way; mold the post around these pins. When through and before removing form, slightly tap the bolts with hand to loosen, then pull them from the post. Through these holes ¼ inch bolts will pass into the nail strip, holding it into place. This post can be set to nail into the broad side of the 2 x 4, or set so that the nailing is attached to the edge, which we think the better way.

When it is desired to attach wire to the posts, bore holes at the proper places into the pallets to correspond to the spaces of the wire, and so as to be in the middle of the post; into these set ¼ inch pins; build around them; remove them when done.

Through these the wire can be stretched, or as some prefer, make grooves across the face ½ inch deep at the proper spaces for the wires; secure the wires into these grooves by passing a wire around the back of the post, holding them into position. There is still another way used by some.

Take a No. 12 wire and with wire pincers bend loops into the wire extending out from the line of the wire 1½ inches; these loops must be at the proper places or spaces for the wire. When the form is filled within 1 inch of the top, place this wire along the middle of the front face, with loops extending past the surface of the face ½ inch; build this in with the last inch of the concrete.

There are many other devices of fastenings, but these are mostly patented. A good fastening is a copper wire laid across face of post at proper space 1 inch deep and projecting from either side 3 inches. These ends are twisted about fence wire and will hold it in place. Should one end break with many changes of twisting and untwisting, the other is still left for use.

The cost would be the important thing in this work. While good it might be so expensive as to be prohibitive. Let us compute the cost. At this point, as perhaps almost anywhere, one sack of Portland cement could be bought by taking a small quantity for 40 cents; when measured it will be seen to contain about 1,900 cubic inches—the space occupied by the post described would be 1,248 cubic inches.

Now in the formula given for post concrete, cement, 1; sand, 2½; aggregate, 3 to 4, we would have approximately 7 volumes, and according to usual shrinkage in filling voids, and tamping, the 7 volumes would fill only 4¼ volumes when tamped into molds. Since a volume represents 1,900 cubic inches, 4¼ volumes equal $1{,}900 \times 4\frac{1}{4} = 8{,}075$ cubic inches. Since one post occupies 1,248 cubic inches, one sack of cement would build $8{,}075 \div 1{,}248$ posts. Then it will be seen that one post costs in cement at

45c per sack 7c
and ¾ bushel sand and gravel 3c
Reinforcing metal 2c

Labor (one man making 40 posts per day) 4c

Total cost of post (without forms) 16c

Thus it will be seen that for 16 cents a cement post could be built in an average locality. This would not be the price of a good timber post, the life of which would not be over 10 or 15 years, while the cement post would be practically indestructible. These posts must be seasoned—kept wet and shaded from hot sun and currents of air for 6 days. In 4 weeks they are ready for use. There are machine molds for fence posts. These are secured by patents, but where many posts are required, this method would be the cheapest in the end, because of the rapid and more systematic way of building.

Troughs.

For stock watering and storage purposes. In shape these are most usually built rectangular. A usual size for watering purposes is 8 feet long, 2 feet wide at top and 18 inches at bottom, and 18 inches high inside. They can be built directly on a porous foundation or on a bench block of concrete set in from each end 2 feet. These could be 2½ feet long, 1 foot wide, and the height desired. Block out the bottom between these benches, and to the end of the trough; over the concrete of the benches place heavy paper, so that the trough will form no contact, when it can be moved if desired. Where no reinforcing is used the bottom should be 5 inches thick and the sides and ends 4. With these dimensions in mind build the outside form, with rough boards, also an inside form in the same way. Set the outside form on the bottom already prepared; fill with concrete 5 inches deep; now set inside form, with equal spaces between sides and ends; secure so there can be no bulging in tamping; fill in the concrete and tamp. When even with form, smooth top and dub edges with trowel or edger. After it is set the outside form is removed, and the inside should be removed as soon as done or set, or the expansion will break the corners. Where it is desired to have drain hole near bottom, this can be accomplished in the following way: For a wooden plug opening, place a well rounded plug—well expanded in water before used—into the place where the outflow is desired; build around this with a few trowels of mortar, or if an iron faucet is desired use a common faucet, with a flange of sheet metal soldered to it and projecting a few inches from the faucet. This flange is built into the wall of concrete, and secures against leakage.

At the end of 24 hours the trough is sprinkled and against the wet surface is plastered inside and outside.

Concrete for this work should be as follows: Cement, 1; sand, 3; aggregate, fine, 3 parts.

Mortar for the surface coating: Cement, 1; fine sand, 2 parts.

Another method to build these troughs is similar to the one described, only that the inside form is not used. The concrete is used a little wetter and is built up with trowel against the outside form, the inside face being guaged with trowel. After a few hours the inside is plastered, etc.

A better and lighter trough is built with the use of expanded metal—light sheets. These are placed midway between the surfaces of the wall when the wall need only be heavy enough to cover the metal, say 3 inches, and the bottom in the same way 4 inches.

Circular troughs are now being built without form, in the following way: Build circular bottom on such foundation as desired. When the concrete on bottom is 2 inches thick, place expanded metal sheets over this surface and on top of this place 2 more inches of concrete. For the side have two metal hoops made, for bottom and top, 1 x ⅜ inch; see that they are circular, and to them fasten with light wire a sheet of expanded lath metal, 18 or 24 inches wide. The top hoop should be fastened about 4 inches down from the top of metal, and the bottom should extend down and meet the metal in the bottom; now with the hands or tongs bend the top of the metal out evenly. This will give the top a more pleasing appearance. When the lathing and hoops are set true and secure, plaster with heavy mortar the out and insides alternately until about 2½ inches thick. Care must be taken that the metal is not sprung in the last applications. This can be avoided by applying the last coats more plastic.

This same method could also be applied to rectangular tanks, but a circular tank, all other things being equal, is the strongest. Where the metal side sheet meets, it should be lapped 6 or 8 inches.

Also in the plastering, the surface should not become dry before the additional coat is applied, or adhesion will be imperfect, scaling off. Season properly, and after 36 hours fill with water if convenient.

Tanks

Usually for storage purposes, are built much like troughs, which see. However, they are mostly deeper, and consequently must withstand greater inside surface pressure. For this purpose, tanks are reinforced by metal, expanded metal, metal lathing, or wire netting, systematically encased in the shell of the wall. See Troughs. The shapes of tanks vary with their use, but are usually round, and where large should be built where used. The metal of the bottom and sides should be carried into each other, so that there will be no separation at the joining of the bottom and side walls.

These circular forms are usually built in sections in such a way as to be most easily placed, and again most easily removed when through without jar to the casting. The forms are laid by for similar work. In this way the cost of the form to the regular workman is greatly reduced. The inside face must always be well plastered, as soon as the body of the concrete is hard enough to allow trowel work.

The concrete and mortar used in the construction of tanks, as well as the plan of work is the same as for troughs, which see in connection with this article on tanks.

Chimney Tops

Can be built with concrete much cheaper than with stone. The form for these can be constructed quickly and is inexpensive. When the size, number of flue holes, and their position are known.

A small, even floor space is selected or made, upon which the form is built or set. The thickness will depend on the size, and the number of flue holes it is to cover, but will usually be from 3 to six inches. Tack together strips for outside edge; one corner should be held by a wood screw which when removed will allow the form to spread when it is removed, without any jar. This outside edge when desired could be made with molding, thus giving a better effect.

The flue holes are next blocked out. When the form is tamped half full of cement wire is spread over this in such a way as to bind most completely all parts; over this fill the form with concrete and finish. The tops are sometimes built direct in place. To support the frame on the chimney place two small rods across the chimney, on these set the form; when completed these are removed and the holes closed with trowel. Always wet the top of brick on chimney before laying on or building top, so as to form contact with surface.

The composition of the concrete for this work should be, cement, 1; sand, 3; aggregate, 4 parts.

Well Beds

For the ordinary use of covering wells or cisterns and supporting pump, etc., may be built from concrete in the following manner: These are usually from 3 to 6 feet square and if reinforced with expanded metal or heavy wire netting should be from 3 to 4 inches thick. When built without reinforcing they should be from 4 to 6 inches thick. Use scantling of proper height desired for the outside form. At three corners these can be nailed or spiked, but at the fourth corner should be secured in such a way as to admit of its easy loosening when it is spread and removed from the cast. This form can be laid on an even surface of ground lightly covered with sand; the holes for pump or pipes are blocked out; this now is filled with concrete well tamped in place to within ¾ inch of the top; this is filled with mortar as in sidewalks.

If reinforcing is used place the metal as near the bottom of the slab as convenient, and at the same time covering from the air. When carried to the top with concrete and mortar and top surfaced smooth with float, dub the outside edges with a sidewalk edger. The concrete and mortar top should have the same composition as for sidewalks (which see).

Sewers.

In many places these are built of concrete, round or spherical shape, to meet special requirements in city construction.

The molds are made of metal, set on smooth surface, with the flange up. Heavy sewers or those having thick shell are tamped with finish concrete, while the lighter ones are poured with liquid concrete. The shells vary with the use for which they are designed, and size; perhaps from 2 to 4 inches would cover the most common uses.

Expanded metal sheets or wire netting are usually used in their construction. The proper width of sheet is secured; they are then cut into suitable lengths, lapped like hoop, and secured with light wire ties. They are then set into the mold; when cast will be entirely encased in the shell of the sewer. The composition for these sewers is, cement, 1; coarse sand, 3 to 4 parts.

They are usually built by machine molds, but in a small way could be built from hand molds very simply constructed, but would require some skill in the management to insure satisfactory product.

Statuary and Ornaments.

On this subject we feel it useless to say much in this little work. Yet cement has entered this field of work so extensively that a few suggestions to the amateur may not be out of place.

The building or casting of forms for this line of work belongs to the specialist.

For ornamental work, only very fine sand can be used, which, as well as the cement, is run through a fine sieve, rejecting any coarse or lumpy particles in either sand or cement.

The proportion of cement and sand now mostly used are 1 to 1. Formerly cement only was used, but much better results have been obtained where sand as indicated has been used. The surface of neat cement casts usually showing hair cracks in time. One object in ornamental work is to show clean and distinct outline in the cast. The molds are usually poured out with liquid mortar—in some cases plastic mortar is also used.

If it is desired to color statuary or relief work, see Coloring, under Part V. I have seen many pieces of cement statuary so artistically executed, colored, filled and polished as to please the most critical observer. I have also seen a few pieces in this line, in which the molds as well as the cast figure were the product of an amateur and showed considerable skill, and I wondered whether indeed this cheapened method might not mount on pedestals many artistic urns, busts or other simple statuary in many rural homes.

Poverty does not take true poetry from the soul, but rather intensifies it, and but for the cost a Hercules would support upon his muscular shoulder the columns of many an humble home. Beautiful vases could be built on pedestals on the lawn, or from copings of porch or step walls. Niches in halls could contain busts of ideal characters.

PART V.

PRACTICAL NOTES ON CEMENT WORK.

Hair Cracks

Appear as fine lines like a hair net covering the whole surface of some troweled cement work. They only begin to appear in the last stages of the hardening, and mostly on work which has been seasoned in the open air. The causes of hair cracks may be either one or all of the following: Overrich, overwet, or overtroweled.

To prevent hair cracks in rich mortar, great care must be taken to finish top surface with as little troweling as possible, especially when using metal trowel or float. The stroking crowds the heavier particles of sand downward into the mass, this in turn forces the finer particles of cement with the water to the top surface covering the surface with a neat cement liquid which in drying forms a glossy cover called "skin cover." This in the later stages or hardening contracts, as all neat cement liquids will, leaving so-called "hair cracks." This is very faulty and will be rejected by the engineer or inspector. Mortar should first be spread with trowel, but the trowel should not be held in such a way as to cover air spaces, or suck them into the mass. Do not try to even the surface with trowel, but at this point take wooden float or straight edge and stroke the top off even. Now let lay until the water is mostly evaporated, but before set finish the top as desired. When mortar contains 50 per cent or more of sand, as all well regulated mortars should, and only enough water for plasticity, and with these directions on troweling observed, no hair crack will ever appear.

Settling and Shrinkage Cracks

in walls, walks or floors, may be caused by uneven settling, by heaving in frost, by jars in the early stages of setting, by shrinkage; in walks, by joints not being cut continuous, by irregular thickness and outline, causing weak points, or by too large blocks Entire freedom from shrinkage and expansion while reduced to a minimum in cement, is an ideal unknown to the building trade. For this reason walls, floors and walks must be divided into sections which will allow of slight settlings or variation without rupture

Long stretches of concrete in contracting will pull asunder at the point of least resistance or in expansion will buckle. Outlines, either in thickness or width, that disturb proportionate strength must be avoided. Some walks, either through carelessness or for deception, are heavier at the outer edges than through the center, while the reverse should be the practice. This invariably checks along these weak places; also a tree or telephone pole may hinder and is worked around. In this case unless enough heavier in depth to counteract width defects, this will check across. The thoughtful workman will avoid this by placing an open joint at this point. Care is also required in floors and walks that the top mortar layer is blocked off exactly with the lower concrete block or checks will result.

Irregular filling of the foundation will show in cracks; also freezing which heaves, caused by too shallow foundations or water in the foundations is sure to break the work, whether floor, walk or wall.

Tight joints in blocked work are but little better than none. These defects show in the first year or two of the work.

Pock Marks.

These are blotches or pippings in the smooth surface of mortar, and will show in the first few hours of the work. They are caused by the incorporation of air or water or foreign matter in the mass, which in the process of setting are forced to the surface. To avoid these causes would in itself be the remedy.

Freezing Weather.

When once hard no hydraulic material is less affected by extreme cold than Portland cement mortar or concrete, but in the early process of set and hardening it should be protected from freezing, though some cases are cited where solid freezing in this stage showed no damaging results. Most experts in this line agree, however, that freezing should be avoided, especially in surface work; zero weather must, if possible, be avoided. By adding 1 gallon of salt to 20 gallons of water used in working the mortar or concrete, and using only a minimum of this, would prevent freezing in ordinary cold weather, and outside of slight discoloring would have no bad effect on the quality of the work. Yet some good authorities on this subiect think that it is better to warm all the ingredients used, so as to hasten setting, and when placed protect from freezing by covering with wet paper, then saw dust or shavings or even manure, tarpaulin placed over this, leaving the whole until sufficiently hard, which at this temperature might be from 2 to 6 weeks. The effect of freezing is shown by scaling off, showing watery, loose surface. In freezing weather, where cement mortar is used, no free water should work from the mortar into the surface of brick, stone, or aggregate used as the water so escaped would freeze and expand the mass.

Hot Weather.

Cement work made in hot weather can be equal to that made at any other time, but greater care in the seasoning is imperative. It must be covered from the rays of the sun and currents of air, and kept wet 6 or 8 days; also greater care is required in plastering and bonding building materials, stone, brick, cement blocks, etc., but this may all be overcome by liberal application of water to the surfaces on which it is desired to form contact. This restores prime conditions for adhesion. It should also be remembered that during hot and windy weather the initial set is hurried, and mortar or concrete should be sooner placed, as they cannot be reworked.

Dry Surfaces and Adhesion.

In mixing concrete the stone or gravel forming the aggregate should not be incorporated into the sand and cement until their surfaces are moistened, but to have them dripping wet is equally objectionable. It is only required that their surface is moist enough so that the particles of sand and cement mixed when dry will adhere and cover all the surfaces of the aggregate. This alone constitutes one of the most vital requisites of concrete.

In walls of either brick or stone it is important that the mortar used in bedding should also form a bonding (binding surface to surface). This adhesion differs with the kind of mortar and materials used, but is from 9 to 15 pounds per square inch, and every workman should know that when a stone or brick with dry, hot and sometimes dusty surface is laid into mortar very little if any adhesion is formed, consequently in brick the hose should be turned on them in the pile, that while they are not dripping wet they may be moist through, and in shape to be laid to some purpose. Stone which cannot be so easily immersed should in all cases have beds and joints sprinkled before laid in mortar; in fact in work ably superintended the old dry surface, slip-shod way will not be tolerated. The writer has seen heavy walls constructed of large stone containing from 16 to 24 cubic feet each, removed with large derrick in which it was necessary after taking the weight with derrick to jar the bed loose with a heavy bar, and in some cases carrying with it two stones beneath, when less secure beds broke their bonds. When these fast bondings were broken asunder it was found that the cohesion of the cement mortar was not broken, nor was the adhesion at the stone broken, but a part of the surface was torn from the stone. If a brick with the most unfavorable conditions is laid into good cement mortar, after dry it can easily be lifted from the bond by the hand; it is loose. But on the other hand if the conditions are the most favorable it would require in a straight steady pull 448 pounds to pull it from its fastenings. This estimate is very conservative; some authors claim tests of 576 pounds.

All walls and surfaces to be plastered with cement must first be sprinkled, and if dirty must in addition be thoroughly cleaned.

Portland as Against Natural or Common Cement.

We have spoken on this subject before but lest some one should not distinguish between them we will repeat what has been said and in addition give some other facts.

In all formulas and directions given in this book reference is had to Portland cement, only when the Natural or Common is indicated can it be used. I use the word Natural or Common since I find that in some localities it is known by the name Natural, in others by the name Common. At this time established grades of Portland in this locality cost in car lots $1.20 per barrel and retail at $1.60 per barrel. The Natural in car lots 50 cents and retails at 80 cents. The Portland has 380 pounds net to the barrel, the Natural 300 ℔s. to the barrel. The producers of the Natural cement are admitt dly laboring under hopeless discouragements. With the increased facilities for the manufacture of Portland cement the prices have gradually gone down until today the competition has practically driven the Natural cements from the market. As indicated in this article while the price of the Natural is about one-half that of the Portland, and that the Portland is cheaper for any use than the Natural. Yet the cost of production of the one does not differ so much from the other. In four letters lying before me, received from four different cement manufacturers of note, three admit the passing of the more ordinary natural cements entirely from the market. The question would naturally occur to the reader, are all Portland cements equally good? They are not, and differ just as do other commercial products. Inferior Portland cement could not long hold up in a competing market where numerous tests are continually made by engineers and others using cement in a large way; also the different organizations of architects and engineers in each state pass on all cements largely used for construction, and in this way a rating is often established. Sometimes cement from the same mill falls below the requirements, but all good mills watch this closely and such inferior products are not placed on the market for good Portland. On large work cements are tested before used. The small consumer can usually feel secure in buying the standard Portlands largely used on important construction. We might name some popular brands which we know to be good, but think this unfair, because of the many brands of which we know nothing, but which are equally good. Foreign Portlands, at one time largely used in this country, and while still used by some, actual tests have shown our own Portland to be equal, though selling in the market at one-half the price of the foreign product. Portland and Natural cement should never be mixed in use, for in so doing the strength of the better is reduced to that of the weaker; nor should concrete made from the Natural be covered with mortar from Portland, for in nearly all such cases they separate at the bed joint, caused by unequal contractions and expansions. Sometimes face walls in brick work are carried up by Portland mortar and the backing courses laid in Natural mortar; this is objectionable for the same reason, in some cases lifting the bond courses entirely free from the other courses, ruining the work.

Seasoning Cement Work.

This begins when the work is completed and extends through the stage of chemical action and continues to the point of practical hardness. Ultimate hardness in some cases is only reached after 8 or 12 years.

The period of seasoning will vary with the temperature and moisture of the weather. At a temperature of about 70° seasoning would require from 21 to 28 days. In dry, hot weather all work either concrete or mortar should be covered after 24 hours old to protect it from currents of air, and from the sun. This covering should continue for from 6 to 10 days. In addition to covering the work must be kept wet or moist from 6 to 8 days, after it is 24 hours old. The work ordinarily should not be used for 21 days; this would depend on the use made; if a floor it could be lightly used when uncovered, but if a drive for heavy teaming it should lay 21 to 28 days. These conditions of seasoning are prescribed for a temperature of about 70°; as the thermometer goes lower less water is required, but this extends the period of seasoning.

Measuring Ingredients.

The components of concrete or mortar must never be guessed at or measured in such a slip-shod way as by the "shovelful." This method sometimes used is very unreliable. The size of a shovelful would depend on the dryness or moisture of the ingredients used; also upon the pile or box from which it was taken. A difference of 25 per cent has been shown when the greatest care was taken to have them alike. On small jobs the parts could be measured with a pail or basket, but on larger work make measures, using one sack or a number of sacks of cement as the unit. Make measure boxes for sand and aggregate of the proper size; these measures need no bottom and should have handles nailed on opposite sides by which the box can be lifted, allowing the contents to spread over mortar box or mixing floor. A sack of cement when poured into a basket will contain approximately 1,900 cubic inches; by this the measure boxes can be gauged to the desired size.

Reworking Mortar and Concrete.

The mixing of mortar should be so gauged with the time and use that it can always be used up before requiring reworking. Reworked mortar loses some of its first qualities and much of its initial hydraulic activity, and competent authority on this subject declares that it should be entirely discarded. Concrete must not be mixed before it can be used, as this can never be reworked after set, but must be thrown away.

Forms for Cast Masonry.

For portable work the forms are mostly of metal. We shall speak of wooden forms used on large and changeable castings. All form lumber must be surfaced, and the forms so constructed that they will not yield or bulge when the concrete is tamped in place. Forms also should be so fastened or latched as to allow their easy removal, without jarring, crowding or hammering. Forms can be removed in some cases of dryish concrete as soon as cast, others should remain until set; and some are even left until seasoned. Wooden forms should always be expanded before used.

Wood Forms Brushed with Hot Paraffin Wax.

The wax is forced into the wood by ironing with hot iron, This makes the forms impervious to wet, when they are easily kept straight and true.

Filling Surfaces of Cast Products.

When the proper care is taken in molding and removing forms cast products are turned from the molds finished. However, products are sometimes slightly damaged or show rough surfaces on the face. These can be retouched, but this requires some skill, since the retouching should not show. Moisten the point repaired and with mortar or concrete of similar consistency apply and brush over; do not use metal trowel. When the surface has become dry, new adhesion must be formed. This is accomplished by wetting the surface and with brush dipped into liquid mortar brush the surface to be repaired and then apply as before. Breaks in cement ware can be mended in this way: First, to make the surface impermeable to water and second, for appearance. Columns, statuary relief work and some massive building blocks, etc., are finished in this way, to acquire uniform faces in color and impenetrability to moisture. For this purpose when the cast is sufficiently hard so as not to rub loose the surface is soaked. Over this with brush apply liquid mortar (composed of cement, 1, and granite dust or ground stone, 1); thoroughly rub this into the pores of the surface with wooden trowel or such other instrument as will conform with the surface if not plain; wipe surface dry and in 24 hours treat again in the same way, only that at this stage rub with cork float. This finishes the face; the surface is dense, impenetrable, shows a surface to resemble rubbed stone. At this point the "Sylvester water proofing liquid" is in some cases applied, but mostly when the ware, if building blocks, etc., are placed into the wall. The method of mixing and applying is as follows: Dissolve ½ ℔. shaved Castile soap in 1 gallon of water; also dissolve ½ ℔. powdered alum in 4 gallons of water; when the surface is dry apply the soap-wash at boiling heat, with brush; do not froth the soap. After the soap-wash is thoroughly dry apply the alum-wash in the same way, only at a temperature of about 70°. The applications should be made twice when it is wished to secure perfect impenetrability to water. This securely closes all the pores on the surface, and its use on government buildings has shown its permanence by many years of satisfactory use.

Coloring Cement Work.

Coloring matters are sometimes used in mortar for decorative purposes. Mineral colors are the safest. To make colored stone, take the proportion of coloring and cement and mix them thoroughly while dry, then add the sand, etc., mix all together until of uniform color, then add water and continue to mix thoroughly until it is uniform throughout.

For White Stone—

White Portland cement 1 part	Pulverized marble 1-2 part
Pulverized lime 1-4 part	Light colored sand 1 part

On account of the inferiority of white Portland Cement the above is seldom used.

Red Stone
1 sack cement
200 ℔s. sand
5 ℔s. violet oxide iron (raw)

Bright Red Stone
1 sack cement
200 ℔s. sand
7 ℔s. English red

Brown Stone

Dark Blue Stone
1 sack cement
200 ℔s. sand
4 ℔s. ultra marine blue

Gray Stone
1 sack cement
200 ℔s. sand
1 lb. Excelsior carbon black

Black Stone

200 lbs. sand	1 sack cement
1 sack cement	200 lbs. sand
4 lbs. Brown ochre	3 lbs. Excelsior carbon, black

The ultra marine blue is found to add to the quality of mortar if not used excessively; most other coloring matter should be used sparingly.

Testing Cement.

When tests are made with neat cement only they show the rating of the cement as a commercial product; when cement and sand are used we have a mortar test, and when aggregate is added a concrete test.

The last two are the most practical to the workman, Cement mortars and concretes are tested to establish the chief characteristics desirable in building material. Hardening properties, tensile and compressive strength, permanence in air or water, resistance to weather conditions, adhesion, etc. The quality most frequently tested on account of convenience and because other qualities can be fairly well rated from this, is tensile strength (pulling apart). For this purpose briquets are formed, under regulation sizes and conditions. These briquets at the smallest or breaking point have a surface of one square inch in mortar, and in concrete briquets they are larger but the breaking strain is computed per square inch. The average of 5 briquets similarly constructed are taken as a fair test. The compressive strength (crushing weight) is not so simply tested, but is found to be almost uniformly 10 times the tensile strength for an equal surface.

For an illustration of the requirements in these tests I would suggest "The Standard Methods of Testing and Specifications of Cement," which any manufacturer of cement will be glad to send you free of cost and which is published under the direction of the American Society for Testing Materials.

To test constancy in volume of cement, make pat of cement on glass 2 or three inches in diameter and ½ inch thick in middle. After being covered with damp cloth for 24 hours place under water and watch for 3 or 4 days to see whether it becomes contorted or cracked. These cracks, if expansion cracks, are widest at outer edge of pat and extend toward the center. Shrinkage cracks may extend across center, but can be distinguished from expansion cracks. Shrinkage cracks might denote no fault of the cement, but expansion cracks, curling or twisting of the pat, indicate faulty or unseasoned cement.

If the time of setting of cement is to be known, make a pat not too wet, place on glass, cover from the air, and as soon as it will resist slight pressure of the finger nail or for more accuracy, as soon as it resists the pressure of a needle 1/24 inch in diameter, with pressure of 1 lb, the mortar is set. Tests are only valuable as they are made by experts; this is more especially true of tensile strength. Expansion can also be tested by filling a lamp globe with plastic mortar; if in hardening it is burst, expansion is indicated; also when hard if a colored liquid is poured on top and filters in between glass and cement it shows contraction. This test is very exacting and would condemn most cements on the market. We have not given details in making and testing briquets because for the amateur it would be worthless. But we think the methods and requirements given sufficient for the lay-workman, since the more important tests required in his work can be most clearly deducted from the directions here given.

We herewith give a table of tests made from an average of 5 briquets at each test: 1 part standard Portland cement to 2 parts sand:

Age of briquet	Tensile strength per square inch.
7 days	193 lbs.
28 days	238 lbs.
60 days	268 lbs.
90 days	273 lbs.

Cost of Cement Work.

To determine the cost of mortar or concrete and give fast rules and estimates that would be applicable in all localities, differing not only in the cost and character of materials, but also depending on the variation in prices of labor, and the methods of construction in general, would be impossible. In the vicinity of Cleveland, O., which is perhaps a fair average locality, the cost of a good quality of sand or aggregate, delivered convenient to the work, would be approximately 5c per cubic foot. This would differ slightly with localities near or remote from shipping points or points of natural deposit. Cement itself is perhaps most uniform in cost of any of the components, and will not deviate much either east or west, north or south, in price for a standard article. A good grade of Portland cement can be bought in the vicinity of Cleveland, O., at present, for about $1.20 per barrel in car lots, and from the retailer in small quantities for $1.50 per barrel. This price it will be known may not hold good for any number of days. Yet as a basis for several tables on the cost of mortars and concretes, we shall use them; from them the average workman can adjust the table to meet the conditions at hand. It should also be known that in a well proportioned mortar the volume of sand represents 90 per cent of the volume of mortar; this is true in the same way of a well balanced concrete; in this the aggregate represents 90 per cent of the concrete tamped into place.

This, by repeated tests, has proven true because if well balanced the voids are filled and in addition the surfaces coated, this latter adding 10 per cent to the volume of the coarser component—in mortar, sand; in concrete, aggregate. In the tables the labor is given by estimate and in some cases would vary. In measuring loose cement from a box or bin usually 1900 cubic inches make one sack, consequently 1 cubic foot, or 1,728 cubic inches would cost about 30c.

This table gives costs for 5 grades of mortar with cost of cement per cubic foot @ 30c and sand @ 5c per cubic foot.

Extra Rich—

C 1, S 1 equals 2 cub. ft. and costs 35c

The 2 cub. ft. will lay only 1 1-2 cub. ft. and costs when laid per cub. ft. (with 3c for labor) 26c

Rich—

C 1. S 2. equals cub. ft. and costs 40c

The 3 cub. ft. will lay only 2 1-4 cub. ft. and costs when laid (with 3c for labor) per cub. ft. 21c

Good—

C 1, S 3 equals 4 cub. ft and costs 45c

The 4 cub. ft. will lay only 3 cub. ft. and costs when

, laid (with 3c for labor) per cub. ft. 18c

Fair—

C 1, S 4 equals 5 cub. ft. and costs 50c

The 5 cub. ft. will lay only 3 3-4 cub. ft. and costs when laid (with 3c for labor) per cub. ft. 16c

Weak—

C 1, S 5 equals 6 cub. ft. and costs 55c

The 6 cub. ft. will lay only 4 1-2 cub. ft. and costs when laid (with 3c for labor) per cub. ft. 15c

Rich—

C 1, S 2 equals 3 cub. ft. and costs 40c

The 3 cub. ft. will lay only 2 1-4 cub. ft. and costs when laid (with 3c for labor) per cub. ft. 21c

Good—

C 1, S 3 equals 4 cub. ft. and costs 45c

The 4 cub. ft. will lay only 3 cub. ft. and will cost when laid (with 3c for labor) per cub. ft. 18c

Fair—

C 1. S 4. equals 5 cub. ft. and costs 50c

The 5 cub. ft. will lay only 3 3-4 cub. ft. and costs when laid (with 3c for labor) per cub. ft. 16c

Weak—

C 1, S 5 equals 6 cub ft. and costs 55c

The 6 cub. ft. will lay only 4 1-2 cub. ft. and costs when laid (with 3c for labor) per cub. ft. 15c

This last mortar is slightly porous, but for certain work is considered passable.

Concrete for light wares, and smooth-faced work is composed of coarse and fine sand mixed cement, costing 30c per cubic foot, and sand 5c per cubic foot.

Rich—(Dense)—

C 1, S 2, A 3 equals 6 cub. ft., cost 55c

The 6 cub. ft. will lay only 3 3-4 cub. ft. and costs with labor when laid, per cub. ft. 18c

Rich—(Porous)—

C 1, S 2, A 6 equals 9 cub. ft., cost 70c

The 9 cub. ft. will lay only 6 cub. ft. and costs with labor when laid, per cub. ft. 15c

Good—(Dense)—

C 1, S 3, A 5 equals 9 cub. ft., cost 70c

The 9 cub. ft. will lay only 5 1-2 cub. ft. and costs with labor when laid, per cub. ft. 16c

Good—(Porous)—

C 1, S 3, A 9 equals 13 cub. ft., cost 90c

The 13 cub. ft. will lay only 8 3-4 cub. ft. and costs with labor when laid, per cub. ft. 13c

Fair—

C 1, S 4, A 7 equals 12 cub. ft., cost 85c

The 12 cub. ft. will lay only 7 1-2 cub. ft. and costs with labor when laid, per cub. ft. 14c

Weak—

C 1, S 5, A 9 equals 15 cub. ft., cost $1.00

The 15 cub. ft. will lay only 9 1-2 cub. ft. and costs with labor when laid, per cub. ft. 13c

Concrete made from cement, sand and aggregate, cement costing 30c per cubic foot and the sand and aggregate 5c per cubic foot, with an allowance of 3c per cubic foot for mixing, laying and tamping, as follows:

Four Methods of House Construction in Cement.

The most popular method in house construction used in the United States is the hollow block method. For this the architect selects one or more of the many styles of blocks now in the market. The face of wall may be either rock face in courses or rubble work. Smooth face representing rubbled stone work. Tool or ornamental design, to suit the taste of builder. This usually is trimmed with belt courses, etc., in suitable style. The color may also be taken advantage of. But in this, as well as in wood work, "over effect" must be guarded against. For dwellings, if the hollow blocks have continuous webs, it will be best to stud and lath inside walls for plastering, or instead run brick or tile lining to receive plastering and decorating.

Another method, the veneer block, does not differ in outward appearance from the hollow block. For veneer work, use frame as for wood house, stud and sheet, but leave room on outer edge of wall for veneering, usually 4 or 5 inches. The veneering is carried up from this point to the height desired, in some cases bound to frame work by spikes driven into frame work and projecting into bed joints of wall.

A third method, largely used in Europe and coming into use in this country, is the monolithic method. This consists of a wall of cement concrete built up in one continuous piece, hollow or solid, as desired. The molds for this work are carried up as the wall progresses and are reinforced by the use of lateral rods, wires, expanded metal, or wire netting, as thought most practical for the requirements of walls. Sections weakened by perpendicular openings for windows or doors require extra reinforcing along these weakened lateral sections, or in the contraction incident to monolithic structures, perpendicular checks will occur from window sill to top of window below. This, however, is easily overcome in the reinforcing. When the concrete walls are completed they are sprinkled until thoroughly moistened, when they are plastered with cement mortar. floated nicely and even with wood float. Are sometimes brushed with wire brush in diagonal direction; sometimes laid in blocks in imitation of stone blocks. If for dwellings, the walls are usually studded and plastered for inside finish. Metal ties used for hollow walls or in some hollow blocks are objectionable, and though galvanized should have their surface covered with cement to prevent corrosion. Metal ties used for this purpose, through the capillary suction of moisture from outside wall, and through changing temperature, gather moisture, and after a time are worthless. How injudicious, a wall that should last a century, bound with a tigh, worthless after 15 years.

The fourth method is a plastered exterior wall, with wood body.

Veneered Plaster.

This method is coming into use, especially in cottage construction. For this work a frame is constructed as for wood house, only that building is kept back from face of wall 1 inch, which is taken up with plaster coat. The sheeting should be nailed diagonal to studding, securely nailed at edges. Strip outside perpendicular with plastering laths; against this lath as for inside and plaster with cement mortar, cement, 1; sand, 2½; where metal lathing is used, nail this against sheeting and plaster as on lath. The surface may be blocked to represent stone. Can be sanded or could be finished with white pebbles.

Silos

built from wood are short lived, when filled owing to the great moisture they are so thoroughly expanded, that when empty they shrink and are too open to again use, will collapse or blow over when empty. Concrete for this work has proven practical and is used where the best construction prevails. Some silos are built above ground, others partly, while others still are entirely in the ground, the latter perhaps all things considered are the best. They are usually built beneath basement of stables, or barn. Some convenient device is constructed above them by which the contents can be easily removed in feeding, they are built circular, and it is imperative that they must not leak. The walls require no reinforcing and are built much like cistern. Where silos project above ground they are reinforced by heavy wire carried continuously around near outside shell of wall, the thickness of wall or shell would depend on height, but need not be over 6" at bottom and 4" at top for height of 25 feet. On the side on which the doors are left, between doors the space should be reinforced with extra rods, and perpendicular rods should extend near side of doors upward into the continuous circle above. These openings are molded with a shoulder on inside against which a tight wood closure is set when filling. The form for the wall can be made very economically by the use of sheet iron form ⅛" thick and 18" wide, and the length required for circumference one for outside and one for inside face of wall. These are held to the size required by two flat-headed thumb screw bolts set in slots about 8" long, one at upper and one at lower corner, clamping the lap.

When first set, fill carefully so as to maintain a true circle, after which the perpendicular and circle can be easily kept. As the form when full is lifted only 1 foot, each time allowing a lap of 6 inches, keep top of form level at each set, when the sides will continue perpendicular. To lift form, loosen thumb screws; three or four men catching beneath will lift it to the height desired, holding it in place by inserting spikes in the concrete. This is continued to top, when both inside and outside are plastered smooth and dense against the damp surface. Cement, 1; sand, 3.