CONCRETE INSPECTION

A MANUAL OF INFORMATION AND INSTRUCTIONS FOR INSPECTORS OF

CONCRETE WORK

WITH

STANDARD AND TYPICAL SPECIFICATIONS

BY

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PREFACE.

Careful inspection is a vital factor in securing safe and enduring concrete work. No matter how well the engineer may design, his work will come to naught unless his design is accurately carried out by careful and skillful workmanship with good materials. The construction must be good and assurance of good construction is had in conscientious and competent inspection alone. The duties of concrete inspection are various and numerous. It is the purpose of this volume to give a schedule of these duties and such general and specific instructions as are necessary to insure their performance. The book consists of a series of rules and directions to be followed in inspecting concrete work with brief explanations of the reasons for each rule and of their importance. It is believed that everything said is based on sound practice and acknowledged authority, and that the young inspector will not be led astray, even if the old experienced inspector is taught nothing that he does not already know. Where it is possible to say so much, it is not easy to tell when to stop or when one has stopped short of saying all he should, and the author will not be surprised to find that he has erred at times in both respects. If those of his readers who discover such errors will tell him of them, the author will see that they are corrected. By working together in this manner it will be possible to produce a manual which will be of increasing influence toward good inspection in concrete work, and this is the sole purpose of the author's work.

C. S. H.

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CHAPTER I. INSPECTION OF CONCRETE MATERIALS.

The materials used must be of good quality if a good quality of concrete work is to be obtained. The materials for making concrete are hydraulic cement, sand, a coarse aggregate like crushed stone or gravel and water. If the quality of any one or more of these materials is poor, an inferior concrete is produced. They must all be inspected for quality, and the cement at least should be carefully tested for quality.

CEMENT.

The commercial unit of measurement of concrete is the barrel; the unit of shipment is the bag. A barrel of Portland cement contains 380 lbs. of cement, and the barrel itself weighs 20 lbs.; there are four bags (cloth or paper sacks) of cement to the barrel and the regulation cloth sack weighs 1½ lbs. The amount of cement in a barrel varies, due to differences in weight of cement and to differences in compacting the cement into the barrel. A light burned Portland cement weighs 100 lbs. per struck bushel; a heavy burned Portland cement weighs 118 to 125 lbs. per struck bushel. The number of cubic feet of packed

Portland cement in a barrel ranges from 3 to 3½. Natural cements are lighter than Portland cements. A barrel of Louisville, Akron, Utica or other western natural cement contains 265 lbs. of cement and weighs 15 lbs. itself; a barrel of Rosendale or other eastern cement contains 300 lbs. and the barrel itself weighs 20 lbs. There are 3¾ cu. ft. in a barrel of Louisville cement. Usually there are three bags to a barrel of natural cement. When cement is emptied and shoveled into boxes (loose cement) it measures from 20 to 30 per cent more than when packed in the barrels. When loose, dry Portland cement is wetted it shrinks about 15 per cent in volume. The amount of cement paste produced by a barrel of Portland cement ranges from 3.2 to 3.8 cu. ft. The amount of cement in a cubic yard of concrete varies with the voids in the sand (see sand) and in the aggregates (see aggregates) and with the proportions of the mixture; the following rule will give the approximate amount:

*Add together the number of parts of cement, sand and aggregate and divide this sum into ten, the quotient will be approximately the number of barrels of cement per cubic yard.**

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*Concrete Construction — Methods and Costs," Gillette and Hill.

Cement is generally shipped in carload lots (100 to 150 bbls.) and the usual practice is to test a sample from each shipment or carload.

Tested Cement.—Tested cement is required for practically all concrete work —it is the duty of the inspector to make certain that only tested cement is used in the work.

Mill Tested Cement.—When cement is tested at the mill, be on guard: (1) For substitutions in transit. (2) For deterioration in transit.*

(1) To guard against substitution, the cement should be loaded for shipment at the mill under the eye of the mill inspector and the car sealed by him or the shipment otherwise marked by him in such a manner that any tampering with the individual packages or with the shipment as a whole can be detected. Notice of each shipment and a record of all identifying data should be forwarded to the field inspector. The field

*The conditions surrounding cement during transportation may readily be of such a nature as to alter its physical properties completely—so that the material received in the field is radically different from that tested at the mill. Some engineers object to mill tested cement for this among other reasons. The matter concerns the field inspector only in the respect that it emphasizes the necessity of extra watchfulness to make sure, in so far as inspection is able, that the cement has not suffered in the interval between the mill test and the receipt of the material in the field.

inspector should make certain that the shipment as received corresponds in every particular with the description furnished by mill inspector.

(2) *To guard against deterioration make sure that the packages are received unbroken and dry, that the cement is of good appearance, and that it is free from injurious lumpiness. Old well seasoned cement is frequently lumpy, but the lumps can be easily crushed and powdered in the fingers. If the lumps can be crushed by the fingers only with difficulty the presumption is that wetting has occurred and partial setting taken place. Such cement should be rejected or held for field tests.

Field Tested Cement.—The preferred practice of engineers is to test the cement after it has been received in the

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*Sometimes cement has to be stored for long periods of time, say over winter, in sheds with thin walls. The pressure in high piles sometimes makes the bags hard and very often it is thought to have partly set. If the hardening is due to pressure the bags should be carried into the sun and turned over rather roughly every half hour for three or four hours. Then turn it over about a dozen times and put through a 29 mesh screen. This screen should be a rectangular shaking screen and the cement should be run into the sacks on scales and weighed to get the required weight. The lumps retained on the screen should be thrown away and not be crushed. They should not be mashed so as to go through the screen. The cost of this handling is seldom over 3 cts. per bag—including the cost of the cement thrown away.

field. The duty of the field inspector is to see that no cement is used in the work until it has been tested and accepted by the field testing laboratory. To this end the packages should be so stacked and marked for identification (see Storage of Cement) (1) that the untested material is separated and easily distinguishable from the tested material, (2) that each shipment, which is the subject of a separate test, is separated and easily distinguishable from the other shipments. The field inspector should receive notice from the testing laboratory of the "acceptance" or "rejection" of each shipment and that shipment should be marked to correspond. He should allow no cement to be taken from storage onto the work until it has been "accepted" by the testing laboratory. "Rejected" cement should be removed from the field. (See Rejected Cement.)

Untested Cement.—The use of untested cement depends wholly on the reputation of the manufacturer (the brand) for reliability. It is not good practice. The inspector, when untested cement is used, can do little more than make certain that the cement is so stored as to be protected from injury and be watchful for substitution. There is little danger of cement being wrongly branded when it is bought direct from the manufacturers, but dealers sometimes sell inferior cement in bags having the brand mark and name of well known, reliable cements. Comparison of the cement received with cement known to be of the brand purchased, to see that it corresponds in color, texture and general appearance and that it behaves similarly in the work, will often detect such substitution. The inspector cannot do much more than this without making tests. Shipment by the manufacturer of inferior quality cement can be guarded against only by tests.

Rejected Cement.—Rejected cement should be removed from storage at once under the eye of the inspector, and some or all of the packages marked with a private mark so that it can be recognized if attempt is made to ship it back again.

Storage of Cement.—The requisites for proper storage of cement are protection from dampness and excessive heat, and ventilation with plenty of dry air. The storage house should have a floor raised from the ground and be thoroughly rain and snow proof. The cement should be so stored that separate shipments are separated and easily accessible for marking, inspection and removal. (See Field Tested Cement.) An ideal arrangement is to divide the house into bins, each holding a car load shipment

(100 to 150 bbls.); over each bin fasten a placard giving: (a) the brand; (b) the number of packages; (c) the name and number of the car; (d) the date received; (e) a space for the mark "accepted" or "rejected," with date. Whatever the arrangement selected by the contractor may be, the inspector should insist upon a thoroughly damp-proof structure and upon the shipments being so stacked that each is accessible for inspection, marking and removal. Storage of cement in the open should be limited to small quantities to be used immediately in the work. The bags should not be piled on wet ground, but on planking, sidewalk, pavement, etc., and they should be stacked in compact piles which can be covered with tarpaulin in case of showers. The inspector should see that tarpaulins are provided and are ready for immediate use.

SAND.

Sand constitutes from one-third to one-half of the volume of concrete. Sand composed of round grains makes quite as strong mortar as does sand composed of angular or sharp grains. Sand containing up to at least 10 per cent evenly distributed fine mineral matter, such as clay, is not objectionable. Sand composed of a mixture of fine and coarse grains is the best; as between a coarse and a fine sand of one size of grains, the coarse sand is the better. Sand containing mica should be rejected. Natural sand is employed for the majority of concrete work. Practically the only substitute for natural sand that is much used is pulverized stone, either the dust and fine screenings produced in crushing rock or an artificial sand made by reducing suitable rocks to powder. The technology of sand for mortars is quite complex and the inspector desiring a more complete knowledge should study the standard treatises on concrete. Sand plays an important role in the strength and durability of concretes, and its inspection allows of neither neglect nor carelessness.

Specifications for Sand.—Specifications for sand commonly stipulate its nature, whether natural or artificial; the mineral composition; the shape and size of the grains; the allowable content of loam, clay or other foreign matter, and the allowable percentage of voids. Engineers differ in their requirements and the inspector must be bound by the specifications; his duty is to determine whether the sand employed meets the requirements of the specifications and to see that only sand of the specified quality and character is used.

Determinations for Sand.—The usual

determinations for sand are: Shape of grains, size of grains, mineral composition of grains, cleanliness and amount of voids. These determinations elaborated and enlarged by specific gravity tests and strength tests of mortars constitute the usual laboratory investigations of sand. Frequently all sand determinations are made in the works' laboratory and the inspector has only to see that none but approved sand is used, but the inspector should be prepared to make at least approximate determinations. The following methods can be employed:

Shape of Grains.—Determination of the shape of the sand grains is best made by examining them through a magnifying glass. A pinch of the sand rubbed between the thumb and finger will by its "feel" tell whether the grains are sharp or rounded.

Size of Grains.—Determine the size of grains by sieving the sand. For complete analysis the following sizes of sieves are recommended by Mr. W. B. Fuller: Nos. 10, 15, 20, 30, 40, 60, 74, 100, 150, and 200. Fewer sieves will serve all the ordinary demands of field inspection; a No. 5, No. 15 and a No. 50 will give as complete an analysis as is ordinarily necessary.

Mineral Composition. — The mineral

composition of sand can be determined accurately only by laboratory analysis. A sufficiently close determination for ordinary purposes can, however, be made by visual examination aided by a magnifying glass, by one reasonably familiar with the different rocks. The glassy look of quartzite forming the bulk of the grains of silicious sands is familiar to all. The visual determination of feldspar and basalt is almost as easy, and mica is familiar in appearance to every one.

Cleanliness.—Cleanliness can be determined with sufficient accuracy by elutriation as follows: Place a weighed quantity of sand in a glass beaker, add clean water, and stir vigorously; allow to settle for 15 seconds and decant off the water into a vessel; repeat the process until the water pours off clear; evaporate the water that has been decanted off and weigh the residue; divide the weight of the residue by the total weight of the sand put into the beaker and the result will be the percentage of impurities. A less exact method, but one that will suffice in many instances, is to agitate a sample of sand with water in a test tube or an even size glass vessel or bottle and allow the solid matter to settle; the sand will settle first and on top of it the fine dirt and the relative proportions of the two can be estimated by observing their relative depths.

Voids.—Determination of voids can be made in the following ways: (1) Fill a 1,000 c. c. cylinder with sand and weigh it; divide net weight of sand in grains by 1,000 c. c., or the volume, to get the net weight per c. c.; divide this by specific gravity of sand (2.65) and multiply by 100 to get percentage of solid content; subtract per cent of solid content from 100 to get percentage of voids.* (2) Calculate by the following equation:†

$$\text{Percentage of voids}=(1-\frac{S-Sp}{R})100.$$

in which

S=Net weight of a cubic foot of sand.
p=Percentage of moisture.
R=Weight of cubic foot of solid rock from accompanying table.

Material.	Specific gravity.	Weight of cu.ft. of solid rock.
Sand	2.65	165
Gravel	2.66	165
Conglomerate	2.6	162
Granite	2.7	168
Limestone	2.6	162
Trap	2.9	180
Slate	2.7	168
Sandstone	2.4	150
Cinders (bituminous)	1.5	95

Note: To find p, dry 10 lbs. of sand at even temperature of at least 212° F., until there is no further loss of weight. Subtract weight of dried sand from original weight (10 lbs.) and divide remain-

*"Practical Cement Testing," W. P. Taylor.
†"Concrete Plain and Reinforced," Taylor and Thompson.

der by original weight (10 lbs.) to get percentage of moisture or *p*.

Neither of the preceding methods is much more intricate or tedious than the method of filling a measure of sand with water and both are much more accurate.

In any method of determining voids care should be taken to fill the sand into the measure always in the same manner; that is, always loose or always shaken, since the void space is affected by the manner of filling.

AGGREGATES.

The aggregates commonly used in making concrete are crushed or broken stone, gravel, clay and cinders. Slag and cinders are used chiefly for fire proof building work; being the products of combustion they are supposed to make a specially fire-resisting concrete. Stone produced by crushing any of the harder and tougher varieties of rock is suitable for concrete. Perhaps the best stone is produced by crushing trap rock. Crushed trap besides being hard and tough is angular and has an excellent fracture surface for holding cement; it also withstands heat better than most stone. Next to trap the hard, tough crystalline limestones make perhaps the best all around concrete aggregate; cement adheres to limestone better than to other rocks. Limestone, however, calcines when subjected to fire, and is, therefore, objected to by many engineers for building construction. The harder and denser mica-schists, granites and syanites make good stone for concrete. Gravel makes one of the best possible aggregates for concrete. The conditions under which gravel is produced by nature make it reasonably certain that only the harder and tougher rocks enter into its composition. The rounded shape of the component particles permits gravel to be more closely compacted than broken stone; the mixture is also generally a fairly well balanced composition of fine and coarse particles. The surfaces of the particles being generally smooth give perhaps a poorer bond with the cement than most broken stone. In the matter of strength recent tests show that there is very little choice between gravel and broken stone concrete. Cinders for concrete should be steam cinders free from unburned coal and soot, and are best when screened from fine ash. Slag for concrete is blast furnace slag broken to proper size. It should be free from sulphur; a slag some months old is preferable, as aeration has had opportunity to remove the sulphur.

Specifications for Aggregates.—Specifications for aggregates usually stipulate the kind, the mineral nature of the particles, the size and shape of the particles, the cleanliness, the amount of voids and whether or not it shall be screened. Specifications vary in their requirements and the inspector must be bound by the particular specification under which the work is being done. His duty is to determine that the aggregate used meets the requirements of the specification and to make certain that no other aggregate is used in the work.

Determinations for Aggregate.—The usual determinations for aggregates are: Shape of particles, size of particles, mineral composition of particles, cleanliness and amount of voids.

Methods.—Any of the methods used in making determinations for sand can be used in making determinations for aggregates. As a matter of fact, visual examination is usually all that is necessary for any of the determinations except that for voids and for exact analysis of the various sizes of particles composing the aggregate. Voids can be determined with fair accuracy by filling a measure of aggregate with water; owing to the larger particles the error due to entrapped air is small. The other methods as described for sand are, however, nearly as simple.

WATER.

Reasonably clean and pure sea water

or fresh water are both suitable for concrete.

Pure Water.—If any doubt exists as to the purity of the available water it should be analyzed or given a practical test. Water which contains salts in solution in small quantities is suitable for concrete, but strongly acid or strongly alkaline water is doubtful and may be dangerous. Water from streams into which manufacturing wastes are discharged, bog water and water in alkali country are always open to doubt. Brackish sea water or sea water from harbors receiving sewage and industrial wastes is also open to doubt. The inspector should ascertain and report these facts to the engineer.

Clean Water.—Water carrying in suspension considerable quantities of mineral or vegetable matter is objectionable, as is also water containing sewage sludge. The inspector should, in lack of specified directions, report such facts to the engineer.

Quantity of Water.—The quantity of water required for concrete varies with the consistency of the concrete specified and this may vary from an earth damp mixture to one that is a veritable slop The proper amount of water is that amount which will produce a mixture of the specified consistency—the consistency of the mixture should be watched and not the dose of water. For wet concrete, such as is now most commonly employed, the amount of water can be calculated by the following rule:

Multiply the parts of sand by 8, add 24 to the product, and divide the total by the sum of the parts of sand and cement.

This gives the per cent by weight of water required. When "soupy" concrete is specified, the soupy consistency of thick broth is meant.

CHAPTER II. INSPECTION OF PROPORTIONING AND MIXING.

PROPORTIONING.

American engineers proportion concrete mixtures by measure, thus a 1-2-4 concrete is one composed of 1 volume of cement, 2 volumes of sand, and 4 volumes of aggregate. The duty of the inspector is to make certain that the specified proportions are accurately and uniformly adhered to. This is simply a task of accurate measuring—it requires (1) that definite measuring units be employed; (2) that the accuracy of the measuring boxes, hoppers, etc., be verified; (3) that the filling of the measuring boxes, hoppers, etc., be exact, and (4) that, when two or more box or hopperfuls, etc., go to make up a batch, the exact number is employed for each and every batch. The inspector should bear in mind that while splitting hairs is not warranted by the exactness of the process of concrete making as it is conducted in practical construction work, slipshod and careless methods and practices should not be tolerated.

Method of Measuring.—When the method of measuring is not stipulated in the specifications, it is tacitly understood that it shall correspond to accepted practice in respect to accuracy, etc. Beyond this qualification the contractor's choice is unrestricted. The inspector shall see that a method is adopted whose accuracy can be readily verified and which is sufficiently simple for the ordinary workman to carry out without likelihood of frequent error.

Standard Units of Measure.—Determine the units of measure at the beginning. If they are not stated in the specifications see that a definite understanding is had by both engineer and contractor of what they shall be. Cement is different in volume when measured loose and when packed in the barrel; cement barrels vary in volume of contents. It should be definitely understood by engineer, contractor and inspector: (1) Whether the volume of cement used is its volume measured loose or its volume as packed in the barrel; (2) what the cubic contents of a barrel of cement, or a bag of cement, shall be called.* If the stone is measured in empty cement barrels have it understood whether a barrelful is

*The contractors' unit of measurement of cement is the bag. Contractors universally count one bag as being equal to 1 cu. ft. and many engineers specify this figure. It is the most convenient unit of measure in actual construction work and for this reason and because of contractors' practice, the author would urge its adoption as standard practice. The following is a clause covering this point taken from the specifications for concrete of Mr. Ernest McCullough:

"The unit of measurement for cement shall be the bag as received from the manufacturer having a gross weight of not less than 95 lbs. Such a packed bag shall be considthe volume measured with the heads knocked out or the volume contained between heads; there is ¾ cu. ft. difference. If the sand and stone are measured in wheelbarrows have it definitely understood what the volume of a wheelbarrow load shall be called; there is a cubic foot difference between the capacity of a wheelbarrow, water measure, and the load usually carried by men in wheeling.

Verification of Measures.—The measures used should be verified to make sure that each holds the amount intended. This can be very simply done by using a known measure to fill the measuring box, etc., employed, or the volume of the box, etc., can be computed mathematically.

Accurate Measuring.—See that the filling of the measures is reasonably exact, and, when several measures of each material are required to make up a batch, that the exact number is adhered to. When the men are being rushed or have grown care-

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ered as being equal to one cubic foot of cement. The contractor shall mix his concrete in batches calling for even bags when possible. If compelled to use fractions of bags said fractions shall be weighed upon the assumption that the neat cement weighs not less than 94 lbs. per cubic foot. If bags received from the manufacturer contain less than 94 lbs. net of cement the contractor shall bring up the weight with additional cement. If the bags weigh uniformly more than is here called for the contractor shall be allowed to remove the excess cement provided each bag thus altered is altered by weight. The inspector shall weigh one bag in forty as the cement is received, in order to check weights."

less through lack of watching, they are very likely to partly fill or to overfill the measures; this is especially liable when filling buckets, hoppers or cars to mark by means of chutes from overhead bins, also when the measuring is being done by wheelbarrow loads. Skipping a measureful when several measurefuls are required to make up a batch is another common error. Lack of system is chiefly responsible for this error. The operations of measuring should follow a regular routine or sequence which should not be varied from and a double check system should be used by which both the cement man and the mixer operator check the number of measures. While skipping a measureful of sand or aggregate entails no dangerous consequences (a batch of extra rich concrete results simply) the skipping of a measureful of cement results in a weak spot in the work. In reinforced concrete building work it results in a weak girder or column and is dangerous. No chances which vigilance and caution can avoid should be taken in measuring and charging the cement content of concrete for reinforced concrete work. Only a man of intelligence should measure and feed the cement and he should be made to understand that safety to life and property depends on the accuracy of his work.

Automatic Measuring Devices.—When automatic measuring devices are used to proportion the concrete see: (1) That they are regulated to give the proper proportions, (2) that the materials do not clog, choke or arch in the feed hoppers; (3) that the feed hoppers are kept amply supplied with materials.

Sizes of Batches.—See that the batches are of such size that they can be proportioned without using fractions of measures. If the batch calls for parts of bags or barrels of cement or parts of barrows of sand or stone the proper division is hard to get from workmen in the rush of work.

MIXING.

Concrete is mixed by (1) hand turning with shovels and hoes, (2) by concrete mixing machines. Mixing by hand usually is employed only where the amount of concrete to be mixed is small or where frequent moves of the place of mixing are necessitated as in sidewalk work. The increasing portability of mixing machines is doing away rapidly with the last named reason for hand work. Except for isolated small jobs the use of mixing machines is general practice.

Methods of Hand Mixing.—One of the following two general methods is usually employed in mixing concrete by hand: (1) The materials are spread in layers one on top of the other and turned dry with shovels; after being dry mixed water is added to the mixture and the mass is again turned with shovels. (2) The cement and sand are mixed into a wet mortar, to which the stone is added, and the whole mass is incorporated by turning with shovels. The number of turnings, the order of the various operations and other details of both methods vary with the practice of the individual engineer.

Specifications for Hand Mixing.—See that the specifications are clear as to the method of doing hand mixing and as to the perfection of the results required. Specifications are most likely to be ambiguous concerning the number of turns required and as to what constitutes a turn. The inspector should make his mind clear on these points and should see that the understanding between engineer and contractor is definite. In case the specifications do not stipulate the methods of mixing, etc., see that it is definitely understood by engineer, contractor and inspector what methods and results will be accepted as satisfactory.

Mixing Boards.—See that a suitable platform is provided on which to do the mixing and that it is kept clean from adhering material and from foreign matter. See that the planking is tight enough to prevent material leakage of water carrying cement. See that the platform is large enough to admit of efficient and rapid mixing.

Size of Batch in Hand Mixing.—See that the quantity of concrete in each batch is no greater than the quantity that, under the conditions, can be mixed and deposited in permanent position in the work before the cement begins to set.

System in Hand Mixing Operations.—See that the mixing operations are conducted according to a regular system. This permits the inspector to check the work and tends to produce uniformity of product that decreases the necessity of constant inspection for and correction of faults in the mixture.

Hand Mixing for Reinforced Concrete.—See that hand mixing for reinforced concrete work is done deliberately and carefully. Hand mixing should be avoided for reinforced concrete work if possible, but if allowed in an emergency, the inspection should be rigid. Hand mixing as done for ordinary mass concrete work will not do for reinforced concrete work.

Concrete Mixing Machinery.—Concrete mixers are of two types: (1) batch mixers in which the materials are charged, mixed and discharged in batch units, (2) continuous mixers in which the materials are charged, mixed and discharged in a continuous stream. A third division is sometimes made into gravity mixers; some gravity mixers are batch mixers and some are continuous mixers. General practice favors batch mixers for reinforced concrete work and wherever a specially uniform, well mixed concrete is required. Continuous mixers are considered satisfactory for mass concrete work, foundations, etc.

Type of Mixer.—See that the mixer used is of an approved type and that it is erected and operated in such a manner that the charging, mixing, discharging and regulation of the materials is uniform, efficient and certain.

Charging Batch Mixers.—See that the batch is composed of the proper proportions and that it is so charged into the mixer that the principle of batch unit mixing is fulfilled. This means that all the batch must be in the mixer and held there as a unit throughout at least the minimum number of turns or other operations necessary to produce a mixture of the required perfection.

Charging Continuous Mixers.—See that the materials are fed evenly into the mixer in the proper proportions. If the mixer has automatic measuring attachment see that the various feed hoppers are kept amply full and that the material does not "bridge" or "choke" and so cease to feed into the mixer drum. If the mixer is fed by shoveling see that the shoveling is done from properly proportioned piles of cement, sand and aggregate, that each shovelful contains a proper mixture of materials, and that the shoveling is done at a uniform rate. Even feeding is essential to good results from a continuous mixer and the inspector should watch this operation carefully.

Number of Turns.—See that the mixer is given the requisite number of turns for each batch. A certain number of turns is required to produce a concrete of any standard perfection of mix, if less than this number of turns is given to the batch an inferior concrete results. The requisite number of turns can readily be determined by trial mixing of a few batches and when once determined that number should be set as the minimum allowable.

Discharging with a Drop.—See that the concrete, in discharging the mixer, does not drop or fall for any considerable distance. Such a free fall has a tendency to segregate the stone from the mortar.

Cleaning the Mixer.—See that the mixer is cleaned of all adhering mortar or concrete when work is discontinued at night or for other reasons. A mixer caked with cement operates with reduced efficiency and in addition the caked cement is liable to break or jar loose in large pieces and be discharged with the fresh concrete in which it forms a dangerous body.

CHAPTER III. INSPECTION OF FORM WORK.

Forms are the molds in which the concrete is shaped to its purpose. They are constructed of wood or of steel; wood forms are most used. The cost of forms is a very large item in the cost of most kinds of concrete work; the contractor should, therefore, be assisted in every legitimate effort to make the greatest possible use of his forms. Safety must always come first, however; a great many concrete building failures have been chargeable to unwise handling of forms, particularly to the removal of forms before the concrete was hard and strong enough to carry its loads unsupported. The inspector should watch with care all portions of formwork having any bearing on safety. Forms being the molds in which the concrete is shaped, any error in dimensions or alignment means a corresponding error in the molded concrete member. The inspector should also make certain that the forms are perfect for their purpose in these respects. It should be accepted as a cardinal principle in form inspection that: *The accuracy of no detail shall be taken for granted; it must be verified.*

Construction of Forms.—See that the construction of forms is such that they can be removed without injury to the concrete, and that they can be erected accurately. Construction which necessitates the use of heavy crow-bars or hand sledging to take the forms apart is dangerous to the concrete. The best form construction is one in which the parts are assembled by means of clamps and wedges, and not by nails.

Alignment of Forms.—See that all forms are erected in exact alignment, both vertically and horizontally; that column and wall forms are plumb; that girder boxes and wall forms are without winds or twists; that slab centers are level, etc. If the forms stand any considerable time between erection and time of depositing the concrete, check the alignment just before placing the concrete. Check the alignment after storms and high winds. Keep careful check on the alignment of movable panel forms used in wall construction; they require especial skill and care to keep in line. Watch the alignment during the placing of the concrete; the loading may distort the forms.

Strength of Forms.—See that all forms have ample strength to support properly the loads they are called upon to carry. Proper support of concrete in construction work means immovable support, not merely support sufficient to prevent collapse.

Rigidity of Forms.—See that the forms are rigid, immovable under the loads they have to carry.

Loads on Forms.—See that the loads on forms are restricted to those for which the forms are designed. These comprise the weight of the concrete and such necessary construction loads as the weight of workmen, runways, wheelbarrows, etc. Storage on the forms of construction materials for future use should be prohibited.

Wetting of Forms.—See that all forms, if not coated with some oil, are thoroughly wetted on both sides before concrete is poured. A soaking wetting is necessary; see that the water is thoroughly applied to the boards until they will take up no more moisture. Even when the inside of the forms is oiled it is a good plan, especially on hot days, to wet down the outside of the forms thoroughly.

Oiling Forms.—See that the forms are oiled at each setting, just before depositing the concrete. Take care that an excess of oil or other unguent is not used; take care that spots from which adhering concrete has been cleaned are especially well oiled, concrete shows a tendency to stick again to the places on which it has once stuck. Never grease or oil forms where concrete is to be plastered or whitewashed; the grease will discolor the work and make the bond between coating and wall concrete poor.

Cleaning Forms.—See that all forms (beam boxes, column molds, wall forms, etc.) are carefully and thoroughly cleaned from shavings, chips, sawdust and adhering or accumulated foreign matters of all kinds before concrete is allowed to be deposited. The cleaning should be done just previous to placing the concrete.

Removing Forms for Finishing.—Where the surface is to be finished by scrubbing or other process requiring the concrete to be still green, see that proper provision is made, in the construction of the forms, for laying bare the concrete as fast as it reaches the required hardness.

Lumber for Forms.—See that the lumber for forms is of such quality, size and finish that it promises absolute stability and reasonably perfect work under the conditions. It is the contractor's right, if unrestricted by the specifications, to use such lumber as he pleases, providing he gives the results required, but it is the inspector's right to insist that the lumber used promises the specified results with reasonable certainty.

Quality of Lumber.—Lumber from weak and treacherous woods,* that is cross-grained, that contains knots, wind-shakes, or rot which endanger its safety under the conditions, should not be allowed. See that the lumber is not so dry that when soaked by the concrete it will swell so as

*White pine, yellow pine, spruce, Oregon pine and redwood are suitable for forms; hemlock is unreliable.

to bulge and distort the forms; see that the lumber is not so green that it will shrink so as to leave open joints.

Size and Finish of Lumber.—See that the size of the lumber is such that it will not deflect, bulge or warp unduly under the conditions. See that it is straight and true and of even thickness. See that the finish is such as will give the surface results desired.

Cleaning Form Lumber.—See that form lumber which has been previously used is thoroughly cleaned of adhering concrete or dirt. The cleaning should be done before the lumber is again built into forms.

Fabrication of Forms.—See that the carpentry is workmanlike, the measures accurate, the lines true and square, the joints close, and the finish neat. Form work is not cabinet-makers' work, but it is good all around carpenters' work, and it should be done in a workmanlike manner. Watch particularly the piecing out of beam boxes, the alteration of column molds, etc.

Tight Joints.—See that all joints in forms are fairly tight. Absolute water tightness is not demanded, but the joints should be close enough to prevent leakage of the liquid mass which will bleed the concrete of any material portion of its cement.

Beveling Strips and Moldings.—When beveled or rounded edges are specified, see that the proper beveling strips or moldings are placed in the forms. This is a minor detail, very likely to be overlooked by carpenters.

Spacing and Squaring Column Molds. See that column molds are accurately spaced in all directions and that they are

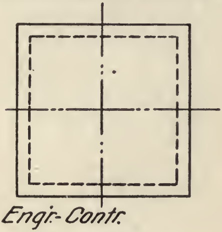

Fig. 1—Correct.

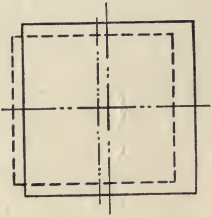

Fig. 2—Incorrect.

set square with the lines laid down on the plans. Figures 1, 2 and 3 indicate the kind of errors in spacing and squaring that should be watched for.

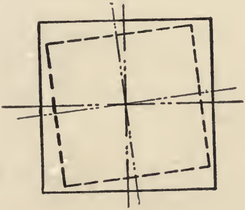

Fig. 3—Incorrect.

Cleaning Column Molds.—See that the column molds are cleaned with scrupulous care. The bottoms of column molds are particularly likely to get the sweepings from girder boxes and other debris, and they are particularly hard to clean unless special provision is made for cleaning. A good practice is to require the bottom of the mold to be left open on one side until ready to pour the concrete. This opening gives access for cleaning, permits examination for cleanliness and gives light by which the lodging of sticks or blocks in the reinforcement can be detected by peering up through the mold.

Camber of Beam Forms.—See that beam and girder boxes are given a camber to provide for settlement under load. By camber is meant making the box slightly higher at mid span than at the ends. A common camber is ½ in. for every 10 ft. of span.

Wire Ties and Spacers.—See that the wire ties for wall forms are in place and are made taut so as to pull the sides close against the spacers. The form of tie shown by Fig. 4 is the best. See that the spacers are removed from the forms as soon as the concreting reaches them. Careless or lazy workmen will often simply knock them out and leave them embedded in the wall, or bury them as they stand.

Projecting Ends of Wire Wall Ties.—See that the projecting ends of wire ties used to hold together the sides of wall forms and left embedded in the concrete are cut off smoothly and flush with the face of the wall. A rust spot invariably forms on the face of the wall where the tie is cut off so that such ties should not be used where the presence of rust spots is prohibited.

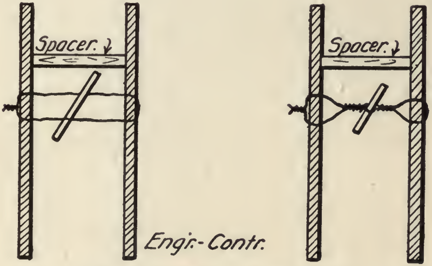

Fig. 4—Wire Tie For Forms.

Bolt Ties and Spacers—See that the bolts are tightened against spacers set between the two sides of the forms inside. See that the bolts are enveloped inside the form with sleeves or are thoroughly greased, otherwise the bolt will stick and can be drawn out only by wrenching and tearing the concrete, and perhaps cannot be removed at all. See that bolt ties are not located close to a corner or face or the concrete may be spalled off in pulling them.

Anchoring Pyramidal or Batter Forms. —See that forms for retaining walls with battered sides, pyramidal forms for column footings, etc., are firmly anchored down to resist the up-thrust or floating effect of the semi-liquid concrete.

Arch Centers.—See that arch centers are framed, assembled and erected in a workmanlike manner. See that substantial foundations are provided for the center. See that suitable means are provided for striking or lowering the center gradually and without shock or jar to the concrete. See that allowance is made, in erecting centers, for settlement under load and for permanent camber. See that the lagging is of even thickness and is made smooth to give a good surface to the soffit of the arch.

Forms for Arch Sections.—See that suitable forms are provided to hold in place sections of arch ring being concreted. If the concreting is done in longitudinal sections see that the forms are set vertical and parallel with the face of the arch. If the concreting is done in transverse sections see that the forms are set in radial planes and straight across the arch at right angles to the faces.

Molds for Ornaments.—See that the molds are so constructed that they can be removed piece by piece without injuring the casting. See that their strength and rigidity is ample to withstand tamping and other strains without distortion.

Time of Removing Forms.—See that forms are not removed until the concrete is capable under the conditions of standing safely without support. The setting and hardening of concrete are variable factors depending on the cement, the temperature, etc., and set rules cannot be made for time of removing forms. Specifications often state the minimum time after concreting for removing forms; where they do not state this time the inspector should ascertain the ideas of the engineer and in important cases had better obtain specific orders from the engineer. The forms should not be removed until the concrete which they support has been examined for hardness; the concrete should not only be hard, but should ring when struck with a hammer. Forms should remain longer under beams and arches than around columns or walls, and longer under beams and arches of long spans than of short spans. Forms should remain in place longer if the weather is cool and damp than if it is warm and dry. To sum up, the time for removing forms is that time when, in the best judgment of the engineer, the contractor and the inspector, they can be removed without injury or danger to the concrete which they support. The following are the times for removing forms practiced by one competent firm of contractors:

Walls in mass work, 1 to 3 days, or when the concrete will bear pressure of the thumb without indentation.

Thin walls, in summer, 2 days; in cold weather, 5 days.

Slabs up to 6-ft. span, in summer, 6 days; in cold weather, 2 weeks.

Beams and girders and long span slabs, in summer, 10 days or 2 weeks; in cold weather, 3 weeks to 1 month. If shores are left without disturbing them, the time of removal of the sheeting in summer may be reduced to 1 week.

Column forms, in summer, 2 days; in cold weather, 4 days, provided girders are shored to prevent appreciable weight reaching columns.

Conduits, 2 or 3 days, provided there is not a heavy fill upon them.

Arches of small size, 1 week; for large arches with heavy dead load, 1 month.

Method of Removing Forms.—See that the method of removing forms is one which does not jar or chip the concrete or bring sudden shocks on the molded members. See that prying with bars and sledging is not resorted to; if the forms are properly designed and constructed neither is necessary. See that the forms when being taken down are not dropped onto floors and banged against columns and walls. See that a regular procedure is followed in removing forms, and if possible have the work done by regular gangs so that the men become trained in the requirements and methods of the work.

Removing Column Forms.—See that column forms, if removed first, are so removed as not to disturb the beam and slab forms. Column forms may safely be removed considerably before beam and slab forms, and it is wise to do so both to give the air access to the concrete and to enable the columns to be inspected for faults before any load is brought onto them, but if the removal of column forms necessitates loosening or shifting the beam and slab forms they should not be disturbed until it is time safely to remove the beam and slab forms.

Removing Beam Forms.—See that the bottom of the beam form remains in place until after the side forms have been removed. This permits the sides of the beam to be exposed for inspection and to the curing action of the air without lessening the support of the beam against collapse.

Striking Centers.—See that arch centers are not struck or removed in less than the specified time after concreting is finished. If the specifications do not stipulate this time get instructions from the engineer. See that centers are removed without shock or jar to the arch ring. See that centers particularly for long spans are lowered evenly and very gradually, so as to allow the ring to settle slowly and uniformly. For very long spans the engineer will usually provide special directions for striking centers.

Swelling of Forms.—See that the forms are so framed that swelling will not fracture the concrete or prevent easy removal. For example in molding walls having face panels or moldings, long continuous studs cut to the profile of the wall face will by swelling and the weight of the concrete be difficult to remove without fracturing cor-

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Fig. 5—Sketch Showing a Method of Providing for Swelling of Lagging.

ners and edges of the panels or moldings. The swelling of lagging, as ordinarily formed, will do little more than "take up" the joints; too well seasoned lumber should not be used for lagging. When dangerous swelling of lagging may be anticipated, a single narrow lagging board may be arranged to be withdrawn after initial set into notches left in the studding (Fig. 5), thus leaving an open space to take up the expansion.

Bracing of Forms.—See that all forms are securely braced: (1) to withstand the loads that come upon them; (2) to preserve their alinement. Bracing is frequently done carelessly and must be watched particularly in regard to its sufficiency to preserve accurate alinement. See that the braces are firmly fixed at the foot and top and that they are stiff.

Location of Shores.—See that shores are not located hap-hazard. They should come at mid-span, one-third span, quarter-span, etc., points. See that shores in each story are located over the shores in the story below.

Length of Shores.—See that shores are cut to proper length for the work. If much too short excessive blocking up is necessitated and the support is liable to be unstable; if too long they have to be hard driven into place with danger t the form-work, the length should be just such that the cap and footing pieces can be placed and the double wedges can be started and tightened.

Square Ends on Shores.—See that the ends of shores are sawed off square so as to have uniform bearing on wedges.

Wedges.—See that uprights supporting centers, girder boxes, etc., are set on double wedges.

Footings for Shores.—See that ample footings are used under posts to distribute the load over soft ground or green concrete.

Caps for Shores.—See that posts used to support floor slabs or beams after the forms have been removed are capped with plank or scantling to distribute the pressure.

Time of Removing Shores.—See that shores for floors, girders, or arches are not removed before the time specified. If time is not specified secure instructions from the engineer. In ordinarily good weather shores should remain in place two weeks, in cold. damp weather four weeks. For extra long spans the time should be longer. The proper time for removing shores is a matter of good judgment; omit no precaution to ensure safety.

Method of Removing Shores.—See that shores are removed without shock or jar by pulling the double wedges at the bottom. See that the shores are not removed one at a time and then replaced; this is sometimes done to permit removal of bottom boards of beam molds, etc., before final removal of shores. See that the shore is lowered gently and not allowed to drop heavily onto the floor below. When shores are finally removed see that they are taken out for a beam or a panel at a time; do not permit all the shores under a floor to be knocked down rapidly in succession.

Runways.—See that runways are not laid directly on the steel but are supported above the steel by horses or trestles.

CHAPTER IV. INSPECTION OF REINFORCEMENT.

Concrete is weak in tension, i. e., a strain tending to pull it apart, but it is strong in compression, i. e., a strain tending to crush it together. Reinforcement is the steel rods, bars, or netting inserted in concrete to make up for its weakness in tension. Their number, size and spacing are computed by the engineer so as exactly to supply the lacking tensile strength in the concrete member being designed. If either number, size or spacing is varied from, the strength of the concrete member is not what it was designed to be and injury results. The inspector's first duty is to see that no detail of the engineer's design of reinforcement is varied from in construction—this duty is imperative.

Checking, Assorting and Storing Steel. —See that as the steel is received it is checked, assorted and stored in such a manner that it can be readily inspected, that it is reasonably protected from rust, dirt, oil, paint, etc., and that those portions needed first may be reached without disturbing the remainder.

Assembling of Reinforcement. — See that in the assembling of the reinforcement the exact number, size, form, spacand location of [illegible], stirrups, ties, ars, etc., [illegible] the plans is [illegible] to in every [illegible]. This is a vital and should [illegible] watched with great and checked [illegible] before the con- is poured. [illegible] lar watchfulness cessary where [illegible] reinforcement ployed [illegible] etc., are placed e concre[illegible] es.

Number of Bars [illegible] that the exact ber of bars, [illegible] ties, etc., called y the engineer [illegible] goes into every ber.

Sizes of Bars.—S[illegible] the size of bars in any member [illegible] respond exactly to engineer's plans.

Form of Bars.—[illegible] that the form of bar is the exact form called for by engineer's plans.

[illegible]

Bending of Bars.—See that the bending of bars is done in such a manner that they do not break or crack at the bend. The bending force should be applied gradually and not with a jerk. Cold bending is always preferable; if hot bending is allowed see that the bending is not so done that the bar is weakened or burned. See that the bends are accurate in line and plane; the accompanying sketch, Fig. 6, shows the

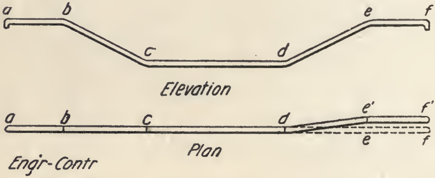

Fig. 6—Sketch Showing Common Error in Bending Reinforcing Bars.

nature of the error to be watched for, the bends are not all in one plane *a f*, but the one at *d* is twisted to one side *d e′ f′*.

Splicing of Bars.—See that the splicing of bars is done exactly according to the engineer's plans. Various forms of splices are in use and if not definitely instructed by the plans and specifications the inspector should learn from the engineer what form or forms will be acceptable.

Protruding Ends of Bars.—See that the ends of bars which are left protruding for splicing are, if they are likely not to be connected up for some little time, painted with cement paint to diminish rusting and so guarded that they are not bent down or knocked loose.

Fastening Reinforcement.—See that all reinforcement is securely fastened to preserve spacing, location, alignment, etc. Braces, blocks, suspenders, spacers, ties, etc., should be used in ample number to make certain of this feature. See that all temporary fastenings are removed as fast as the concreting reaches them.

Wiring Reinforcement.—See that the wiring of reinforcement at intersections is done carefully and strongly. Soft black iron wire, No. 16 to No. 18 gage, should be used and the ties should be made taut and be well fastened.

Placing Column Reinforcement.—See that the reinforcing frame is concentric with that of the column below, that the bars are vertical, that all ties are in place and are taut, that all splices are made, and that no part of the steel touches the walls of the form but that there is uniform open space all around between the steel and the form.

Spacing Column Bars.—See that templets are used particularly at bottom and top to insure accurate spacing of column bars. This is necessary to ensure that the bars of successive columns will fit when spliced. If the bars are bent as shown by

Fig. 7, to connect with the bars of the column above, the spacing should be verified with particular care.*

Tying Column Bars.—See that the wire ties or hoops holding the vertical bars are taut, or, if punched straps or hooked bars

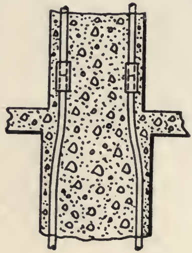

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Fig. 7—Sketch Showing Bending of Column Bars at Connections.

are used, that they fit exactly. See that the vertical spacing of the ties is exact and according to plans. Figure 8 shows correct and incorrect way of fastening ties.

*The connection shown by Fig. 7 has been and is used by some designers which is the reason for calling attention to the bar splicing. The author considers this to be an example of bad detailing which should never be employed. All column reinforcement should be perfectly straight. One way to accomplish this is to set the steel in the lower columns closer to the inside so that in the top columns it will be within the required distance of the face. The best position anyway is near the center.

Splicing Column Bars.—See that column bars are spliced exactly according to the

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Fig. 8—Showing Correct and Incorrect Method of "Tying" Column Bars.

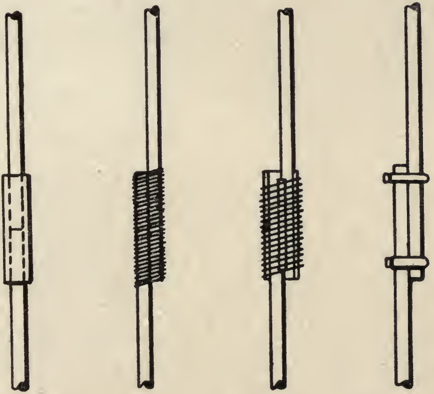

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Fig. 9—Sketch Showing Typical Column Bar Splices.

plans. If a butt joint is specified see that the butting ends are square and the bearing uniform and that the joint is held true to line by sleeves or splice bars. If lap joints are allowed see that the wire wrapping, cable splices, etc., are made taut and secure. Various styles of column splices are shown by Fig. 9. The splice is a vital point and should be watched with care.*

Placing of Beam Reinforcement.—See that beam reinforcement is placed symmetrical with the axis of the beam, that the bottom bars are held the required height above the bottom of the beam, that the proper space is maintained between the reinforcement and the sides of the beam, that the required connections are made at the ends of beam with the column bars or the reinforcement of abutting beams or walls, that all planes and lines are true, and

*The splices illustrated are all used by designers. The author does not favor splicing column bars except by butt joints or by screwing the rods together within sleeves. He would eliminate all the splices shown except the one on the extreme left in Fig. 9. A better way (if butt joints are not used) is to let the rods from the lower columns project up into the upper column about 2 ft. Beside them set pieces about 4 ft. long going into the top of the lower columns 2 ft. and into the upper columns 2 ft. These bars will span the joint. Then set the steel for the upper column and remember to leave between the bars at these joints, an amount of concrete such as is generally required in beams; that is, the distance between pieces of steel should be equal to 1½ times the thickness at least. Wiring and splicing column reinforcement introduces danger of eccentric loading and splitting of the concrete.

that all parts of the reinforcement are wired together or otherwise held firmly to position.

Placing Wall Reinforcement.—See that the reinforcement is placed the required distances from the faces of the wall and in the exact planes laid down in the engineer's plans. See that the stipulated spacing of the bars is accurately followed. See that the bars are straight and true to line.

Placing Conduit Reinforcement.—See that the spacing of bars is according to plan, that the planes of the circumferential bars are perpendicular to the axis of the conduit, that the alinement of the longitudinal bars is parallel to the axis of the conduit, that the reinforcement as a whole is concentric with the axis of the conduit and conforms exactly to the circumferential curve called for by the engineer's plans.

Placing Reinforcement for Circular Tanks.—See that the spacing of bars is according to plan, that the circumferential rings are true circles, that splices are according to plans and are made with particular care, and that the reinforcement as a whole is concentric with the vertical axis.

CHAPTER V. INSPECTION OF CONCRETING.

A decade ago when dry and medium mixtures were almost entirely used, specifications invariably required that concrete should be deposited in uniform horizontal layers and that each layer should be thoroughly tamped. When dry and medium mixtures are used this is still the invariable rule of procedure. Much and probably most of the concrete work done at the present time is done with very wet mixtures that cannot be tamped, and pouring and puddling are now the methods of placing and compacting concrete. The filling still naturally takes the form of horizontal courses, but there is no distinction between individual courses as is the case with separately tamped layers of dry concrete. The pouring is done at different points of the area to be filled, both because the flow of even sloppy concrete is sluggish and time is saved by pouring at several points, and because a streaky concrete is likely to result if flowing from a single pouring point is entirely depended upon to fill the forms. Puddling or slicing take the place of tamping and consist in churning and cutting the wet mixture with rods or slice bars to work out air bubbles, close up pockets, and settle the materials.

Depositing in Buckets.—See that buckets just clear the work when discharged; a drop (1) jars the forms and may displace the reinforcement and (2) tends to produce separation of the stone from the mortar. See that the bucket is not allowed to rest on the reinforcement and in swinging does not accidentally hit the forms or staging. See that the bucket does not leak and spill concrete over the work.

Depositing Through Chutes.—See that segregation or separation of the stone from the mortar does not occur in depositing concrete through chutes. Fear of segregation causes engineers generally to object to chuting concrete into place. The inspector, of course, will be governed by the engineer's decision in the matter. As a matter of fact, however, concrete can be deposited safely through chutes and prejudice against the method is gradually disappearing.

Method of Pouring.—See that the pouring is done at several points over the area to be filled so as to reduce flowing and spreading to a minimum. See that the pouring is so regulated that the rush of the semi-liquid concrete does not sweep the reinforcement out of place. See that shock due to too sudden discharge is avoided.

Time of Pouring.—See that the time elapsing between mixing and pouring the concrete is well within the time of set of the cement. As a rule the elapsed time should not exceed 30 to 60 minutes; some specifications restrict it to 10 minutes.

Tamping Dry and Medium Concrete.—See that the concrete is deposited in even layers not to exceed 6 to 8 ins. in thickness and is thoroughly tamped with tampers heavy enough to thoroughly compact the concrete and bring a film of water to the surface, if a dry mixture is used, and to cause the mass to quake under the blow if a medium mixture is used. If reinforced, see that the tamping is done with particular care to get the concrete around and into close contact with all reinforcing metal and so as not to displace the reinforcement.

Puddling Wet Concrete.—See that the puddling is thoroughly done so as to work out air bubbles and pockets and bring the concrete into close contact with the reinforcement at every point. See that the poles or slice bars are small enough to enter well into the spaces between and around the reinforcement. See that care is used not to strike the reinforcement and displace it.

Pouring Slabs.—See that the full thickness of floor and roof slabs is poured in one continuous operation and that the concrete is got well under the slab reinforcement.* If possible, slab and beam should be poured in one continuous operation.

*To make certain that the bars are covered underneath some engineers require that a layer of concrete be spread over the slab centers and that the reinforcing net or bars be laid on top of it. Where wire mesh or expanded metal slab reinforcement is used working the concrete underneath it can be facilitated by lifting the mesh slightly by means of bars having a hook at one end.

Pouring Beams.—See that beams are poured in one continuous operation from bottom to top; that the concrete is worked closely around the reinforcement and into corners by thorough puddling; that the stone is worked back from the sides to permit the mortar to flow to the faces and give a smooth surface when set; that the space between the bottom of the mold and the bottom reinforcing bars is tightly filled. If possible beam and slab should be poured in one continuous operation.

Pouring T-Beams.—See that when beam and slab are designed to act together as a T-beam that both are poured in one operation.

Pouring Columns—See that columns are poured well ahead of the beams; that the pouring is a continuous operation* from bottom to underside of supported beam or girder; that the concerte is freed from air bubbles and worked closely around the reinforcement and into corners by thorough puddling.

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*By "continuous" the author means that no delay between batches long enough to permit the old concrete to set before fresh concrete is added should be permitted. The best way to pour columns is as follows: Pour not to exceed 4 ft. at a time. Allow not less than 20 nor more than 30 minutes to elapse before pouring another 4 ft. Keep stirring the concrete (churning it) while pouring and have men with hammers tapping the outside of the forms while pouring.

Puddling Columns—See that the tampers used in concreting columns are small enough to go easily between the outside of the reinforcement and the inside of the form. See that the tampers are handled carefully so as not to strike and displace the reinforcement.

Places for Stopping Concreting.—See that concreting is stopped for the night or at other times at predetermined points and in a predetermined manner. If any unforseen contingency compels concreting to be stopped at other points than those named as permissable use every precaution in bonding the fresh concrete to the old to secure a solid joint.

Stopping Slabs.—Stop the concrete in a vertical plane at right angles to the span either (1) at midspan, or, (2) over the center of the supporting beam or girder. Never stop the concrete in a horizontal plane at partly the height of the slab; never stop the concrete where the shear is great near the end of the span or under concentrated load; never slope the joint, always make it vertical. (See Fig. 10.)

Stopping Beams and Girders.—Stop the concrete in a vertical plane at right angles to the length of the beam either (1) at midspan or (2) over the center of the supporting column. Never stop the concrete on a horizontal plane at partly the height of the beam; never stop the concrete near

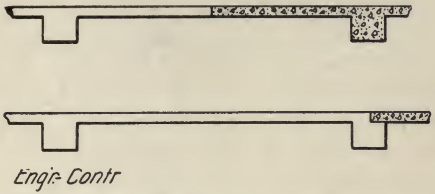

Fig. 10—Methods of Stopping Off Concrete Slabs.

the ends of beams where the shear is great; never slope the joint, always make it vertical. (See Fig. 11.)

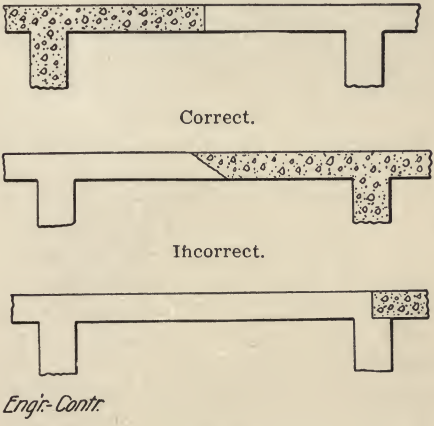

Fig. 11—Methods of Stopping Off Concrete Girders.

Stopping Columns.—Stop column at the level of the bottom of the beam or girder which it supports and never at any other place unless compelled.

Stopping Walls.—Stop walls in vertical planes across the wall and locate stop, if practicable, where expansion joints are to come.

Joining New Concrete to Old.—See that every precaution is taken to secure good bond when joining fresh concrete to concrete that has already set. The surface of concrete which has hardened has a skin or coating to which fresh concrete will not adhere. This skin must be removed and the surface prepared for the new material. The following methods are employed:

(1) Treat the surface with an acid wash, such as "Ransomite," which etches off the surface skin. Wash all the acid off with plenty of pure water and apply the fresh concrete, thoroughly tamped in places. The thorough removal of the remaining acid by washing with pure water is absolutely essential.

(2) "For connections made after a lapse of 24 hours or more, break back the surface concrete to firm material and clean the fresh surface with steam, air blast or forceful water streams, so as to remove all fine, loose material. Saturate well, but not so that water stands on the surface

or oozes from the material. Paint completely with neat cement grout, mixed to the consistency of thin cream, just before new concrete is deposited, and see that the latter is of proper mixture, containing a proper proportion of mortar, which should be worked against the joint so as to be certain that no voids exist in its vicinity." —E. P. Goodrich.

(3) "For connections made after long intervals, so that the old cement has set hard, and where the expense of rough-pointing the whole surface is greater than is required because of the nature of the desired bond, use commercial muriatic acid, diluted with clear water, 1 to 5, or the commercial bonding powders, dissolved in clear water at the rate of 5 lb. of powder to 10 gals. of water. First wet the old concrete surface with so much water that a fresh wetting is not immediately absorbed. Remove any excess of moisture, and when the surface appears as if commencing to dry paint on the old surface three successive coats of acid, one after the other. Let this remain for about 30 minutes, after which carefully clean the surface of unspent acid, soluble salts, and fine material, with plenty of water, finally cleaning with a steam jet or air blast if obtainable. Just before the fresh concrete is to be deposited, and while the old material is still very damp, apply a thin coat of neat cement grout mixed to the consistency of thin

cream, just before the new concrete is deposited, and see that the latter is of proper mixture, containing a proper proportion of mortar, which should be worked against the joint so as to be certain no voids exist in this vicinity."—E. P. Goodrich.

Concreting Connections.—See that particular care is exercised in concreting connections, such as the juncture of a column and a girder. The number of reinforcing rods at such points increases the liability of void spaces among and around the bars.

Coping Construction.—See that copings for walls are molded particularly straight and true to grade. The coping is the portion of the wall on which any variation from true alignment shows most objectionably, and its alignment should be watched with particular care. Where the body of the wall is for any reason slightly out of true, the defect can be largely corrected by capping it with a straight and true coping. The coping form should be capable of alignment independently of the wall form proper.

Filling Bolt Holes.—See that holes left in the wall after withdrawing bolts used for wall form ties are closed with mortar well forced into the ends of the hole and troweled off flush with the wall face. The "pointing" must be carefully done, since the grease from the bolt remaining on the walls of the hole makes it difficult for the mortar to stick.

Cutting Finished Concrete.—See that steamfitters, plumbers, electricians, etc., do not cut through or into the finished concrete in placing pipes, wires, etc. The proper holes, channels, etc., should be provided for in designing the work; if they are not provided for, consent to cut them in the finished work should come direct from the engineer.

Concreting Arches.—See that the arch ring is divided into sections of such size that the concreting of each section can be made a continuous operation. See that the concreting is made a continuous operation for each section.

Concreting in Transverse Sections.—See that the sections are concreted in pairs, corresponding sections on both sides of the crown being concreted simultaneously. If the concreting is begun at the skewback sections, see that the center does not rise at the crown; weight it down with a temporary load if necessary. The better practice is to concrete the crown section first and work toward both skewbacks a pair of sections, one on each side, at a time. In arches of moderate span the sections are concreted in succession, but in long-span arches alternate sections are concreted.

Concreting in Longitudinal Sections.—See that the concreting is begun simultaneously at both skewbacks and is continued uniformly and continuously to the crown.

Filling Over Arches.—See that the fill over arches is not put in too soon after concreting. Generally speaking, two weeks should elapse after concreting is completed before any fill is placed over the arch, but conditions sometimes necessitate shortening this time. In such cases get definite instructions from the engineer.

Drainage.—See that inserted pipes, gutters, etc., intended for drainage are clear and unobstructed. Keep such channels plugged or protected from accidental choking or filling with concrete or other material until they are finally covered or capped.

Expansion Joints.—See that expansion joints are constructed exactly according to the engineer's plans.

Wetting Finished Work.—See that the concrete after the removal of the forms is not allowed to dry out too rapidly. When necessary keep the surface well wet by sprinkling, coverings of wet sand, burlap, etc. The persistence and amount of sprinkling required will depend on local conditions; the idea is to prevent the water needed for hardening the concrete from being evaporated, and the inspector's judgment must be exercised to determine when and what amount of sprinkling, etc., are necessary.

Depositing Concrete Under Water.—See that the concrete while being deposited is kept as free as possible from wash which will float off the fine cement from the mixture. See that the concrete is never allowed to drop loose through any considerable depth of water. The standard methods of depositing concrete under water are: in bags, in closed buckets, and through tremies.

Depositing Through Tremie.—A tremie is a tube of wood or sheet metal long enough to reach from above the surface of the water to the bottom; it is operated by filling the tube with concrete and keeping it full by successive additions while allowing the concrete to flow gradually out at the bottom by raising the tube slightly to provide the necessary opening. See that the tremie is filled full before allowing any concrete to flow out at the bottom, and see that the tremie is kept full as long as concreting is in progress. See that the tremie is moved back and forth so as to deposit an even layer over the area to be covered. See that the movement of the tremie is not so rapid or that the tremie is not raised so quickly that all the concrete runs out and is "lost." Every time the tremie is charged anew it results in washed concrete until the tube is again full. A concrete that is mixed not quite wet enough to be plastic works best; if mixed very wet the chance of "losing" the charge is increased; if mixed too dry it is more liable to choke in the tube.

Depositing in Buckets.—Bottom dumping buckets with close covers are best. The idea is to keep the concrete closed away from the water until it is finally in place. See that the bucket is one which will dump close to the bottom, and that in dumping it is lowered as close to the bottom as it will go. See that the bucket is properly closed and latched, and that it is lowered vertically to the bottom as rapidly as practicable and is dumped without delay. See that successive bucketfuls are deposited so as to form as nearly as possible uniform layers over the area to be covered. Do not permit isolated piles of concrete to be placed.

Depositing in Bags.—Fill the mixed concrete into bags of gunnysack or other porous cloth and pack the bags closely into position. The bags keep the cement from free wash and yet when placed allow enough cement to ooze through the meshes to cement the whole mass together. Paper bags are sometimes used in place of cloth bags, the paper breaking open when soaked, so that the separate bagfuls are cemented into one mass. See that the bags are not filled too full to settle readily and closely together when piled in place. See that the bags are lowered rapidly through the water into place to reduce the time of wash. See that no delay occurs in the process of depositing which will permit concrete in place to become set before succeeding bagfuls are deposited. See that the delay between mixing the concrete and filling and depositing the bags is not long enough to permit the concrete to have set.

Detecting Wash.—The existence of "washing" in concrete deposited under water is shown by the rising to the surface of a milky scum *(laitance.)* The presence or absence of laitance indicates quite clearly the presence or absence of "washing."

Protection from Currents.—Where there are currents a dangerous amount of washing may result after the concrete is in place. The only remedy in such cases is to deflect or break the current by shields or other means, and the means adopted must be determined for each case separately. The inspector should watch for trouble of this sort and promptly notify the engineer when it appears.

Rubble Concrete.—See that the rubble stones are solidly and completely imbedded in the concrete. When the rubble stones are irregular in shape a sloppy concrete must be used to get them thoroughly embedded; if the stones have flat beds they can be laid upon layers of dry concrete and have the vertical interstices filled with dry concrete by tamping. See that the rubble stones are well joggled or worked to a good bed with crow bars, and that vertical spaces are prodded and puddled to prevent arching and voids.

CONCRETING IN FREEZING WEATHER.

Concrete work can be safely done in freezing weather if precautions are taken to counteract the action of frost. Three methods are commonly employed to accomplish this result: (1) Add some substance to the mixing water which produces a brine or emulsion which freezes at some temperature below 32° F., determined by the substance added and the richness of the brine. (2) Heating the concrete materials so as to delay the action of frost until the concrete has had time to set. (3) Housing in the work and supplying artificial heat until the concrete has had time to set. Any combination of these three methods may also be employed. Methods one and two have rather narrow limitations of efficiency, but the third method can be used with any degree of frost. Its cost is great, however, so that it is employed only under special conditions.

Adding Substances to Mixing Water.—See that no substance is added to the mixing water, the effect of which on the concrete is not well known. If any other substance than sodium chloride (common salt) or calcium chloride is proposed for the purpose, see that the approval of the engineer is had before its use is permitted.

Salt in Mixing Water.—See that the amount of salt used in mixing water to reduce the freezing temperature does not exceed in amount 10 per cent by weight of the water. Tests show that the strength of cement is injuired when mixed with water having an excess of 10 per cent by weight of added salt. It is wise to keep the salt well below 10 per cent. See that the salt addition is determined by actual weight; such determinations as enough salt to "float an egg" or to "float a potato" are untrustworthy—it takes 15 per cent of salt to "float an egg." A good rule to follow is: Add 1 per cent of salt by weight for each degree Fahrenheit below 32° up to a maximum of 10 per cent.

Calcium Chloride in Mixing Water.—It is probable that the best all-around results with the addition of calcium chloride are secured when the addition is about 2 per cent by volume of the mortar. This is substantially a 15 to 20 per cent solution, the freezing point of which is 14° F. to —2° F. Richer solutions quicken the set of the cement and the strength of the mortar is reduced as compared with the 2 per cent solution.

Heating Concrete Materials.—See that concrete materials—sand, stone and water —are not heated to excess. Ordinarily the heat cannot be so great as to injure the material itself, but it may be great enough to hasten the setting of the cement so much as to cause trouble or to so dry out the stone that it will absorb enough water to rob the cement of necessary moisture in dry mixtures.

Frozen Lumps in Concrete.—See that lumps of frozen sand and stone do not get into the mixture in freezing weather. The use of hot mixing water cannot be depended upon always to thaw such lumps.

Covering the Concrete.—See that the concrete is protected from loss of heat until set, by covering it so as to prevent radiation of the heat. Tar paper nailed to the outside of wall form studding so as to form a dead air space, coverings of hay or straw or a wood covering on floors, etc., are among the means possible. See that manure is not used; it keeps the concrete warm, but it also stains it and frequently causes disintegration.

Artificial Heaters.—See that the concrete and the forms are not allowed to dry out when artificial heaters like salamanders or brick ovens are used to keep the work warm. Moisture is essential to the proper setting of concrete, and the loss due to evaporation from concrete and forms by dry heat must be replaced by sprinkling or other means.

FINISHING SURFACES.

Special surface finishes are often required. Specifications should be particular and explicit regarding the character and the nicety of the finish required. If they are not, the inspector should learn from the engineer the quality of work he has in mind and should see that the contractor clearly understands the requirements. Perfection of finish is a matter of attention and skillful workmanship, and the inspector has chiefly to watch the workmen. Finishes are of two classes: (1) Those in which the molded surface is treated after the forms are removed; (2) those in which the molding is so done that the finish is a part of the molding process. Faults in finishes of the second class must be prevented during molding by careful workmanship, for after the concrete has once set they can be remedied only by patching, which is unsatisfactory, or by giving the whole surface one of the finishes belonging in the first class.

Spaded Finish.—See that the coarse aggregate is brought well back from the face and that the fine mortar is flushed well against the forms. Spading is best done with a special flat-bladed spade, having the blade perforated with holes or slots, which will screen back the stones and allow the mortar to pass, but the ordinary spade or shovel can be used. The spade is shoved down between concrete and face forms and the stones are pulled away from the face.

Spaded and Troweled Finish.—See that the coarse aggregate is well pulled back from the face of the form to allow the mortar to flush to the surface. See that the forms are stripped while the concrete is still green enough to be worked down with a trowel.

Mortar Face Finish.—See that the facing mortar and the concrete backing are placed at the same time and are tamped together. See that the tamping is not so hard that pieces of stone are forced through the facing to appear on the surface, but that it is hard enough to bond thoroughly the facing mortar and the backing.

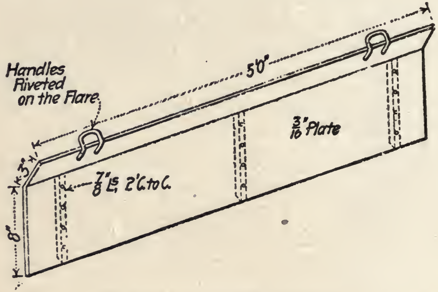

Fig. 12—Facing Form.

The preferable method of construction is to use a facing form like that shown by Fig. 12; fill between the facing form and the lagging with mortar, then fill behind the facing form with the backing, and finally withdraw the facing form and tamp backing and facing together.

Dry Concrete Facing.—See that the facing mixture is mixed so dry that hard tamping will not flush water to the surface. The theory of dry concrete facing is that the imprints of joints and other form marks are not readily received by it. Proportions of 1 part cement, 3 parts screenings and 3 parts ¾-in. crushed stone have proven most satisfactory.

Grout Washes.—See that holes are filled and joint marks are smoothed down before the grout wash is applied. See that the grout is applied in a thin film. If applied with a brush the grout should have about the consistency of ordinary whitewash. If applied with a trowel, the grout should be quite stiff and applied in a very thin coat and troweled or rubbed so that only the pores are filled and no body of mortar left on the surface.

Tooling Concrete.—See that the concrete has aged sufficiently to give a good, clean tool cut; it should be at least 30 days old, and preferably 60 days old. The amount and character of the tooling will be determined by the specifications; ordinary stone cutting methods are employed.

Scrubbed Finish.—See that the scrubbing continues just long enough to remove the surface cement and to expose partially the sand or aggregate without loosening it. See that the cement particles removed by the brush are thoroughly flushed off the surface by clean water, else they will adhere in patches and form rough blotches.

The time for doing the scrubbing is when the concrete is still green, but is firm enough to prevent the particles of sand or stone from being easily torn from the embedding cement; this time varies with the temperature, the wetness of the mixture, the activity of the cement, etc., and is a matter of judgment for each particular case. When just right a few strokes of an ordinary scrubbing brush with plenty of water will do the work.

Acid Wash Finish.—See that the acid wash is not allowed to remain too long and is thoroughly removed by washing with clean water. The acid wash should be allowed to "work" just long enough to remove the surface film of cement and to partly expose the sand grains without loosening them. Unless the surplus acid is all removed by washing, it will continue to etch out the cement in places and give a pitted and blotched surface.

Gravel or Pebble Finish.—Either the scrubbing or the acid process previously described is used for securing gravel or pebble finish. See that the etching or scrubbing process is continued just long enough partly to expose the pebbles without loosening them in their cement bed. Under normal weather conditions an age of about 24 hours is about right for scrubbing; etching with acid can be done at any age.

Plaster Finish.—See that the concrete surface to be plastered is specially treated to receive the plaster coat. Plaster will not adhere well to concrete unless the surface film or skin is removed, or at least very thoroughly cleaned. The surface skin may be removed by acid washing, scrubbing or tooling. Cleaning must be done thoroughly. McCullough* gives the following directions: "Clean the surface with steam, afterwards using wire brushes and then the steam again. Wet with water, paint with neat cement and immediately follow with two coats of one to three mortar, the lower coat scratched and the top coat wood floated to a sand surface."

Painting Concrete Surfaces.—See that the concrete is perfectly dry and that its surface is prepared to receive the paint. This direction refers to painting with oil paints. Special paints are on the market for concrete which are claimed not to require dry or specially prepared surfaces. When these paints are used the inspector must follow the printed directions for applying each. The following method of preparing concrete surfaces to receive oil paints has been found successful: Wash the surface thoroughly with a 7 to 8 per cent solution of muriatic acid and follow with a good wash of clean water. After the treated surface has thoroughly dried apply the paint, using enough turpentine in the priming coat to make it almost flat

*"Reinforced Concrete, A Manual of Practice," by Ernest McCullough.

and increasing the amount of oil each succeeding coat. The concrete should have thoroughly dried out before painting is attempted.

CHAPTER VI. INSPECTION OF SIDEWALK CONSTRUCTION.

Cement sidewalk construction is a task for experienced and skillful workmen which is often undertaken by unskilled and inexperienced workmen. Its inspection demands close attention to many small structural details and to the skill and honesty of the men doing the work. More sidewalks by far fail because of poor workmanship and neglect of correct principles of construction than because of poor materials.

Preparation of Foundation—See that the excavation in cut reaches to firm soil; never permit sub-base to be laid on sod. See that soft, spongy spots, roots of shrubs, etc., are taken out and the cavities filled with firm soil. See that fills are of ample width and are thoroughly compacted. If fills are narrow they wash or cave down so that the edge of the sidewalk slab is left overhanging to tip or break down under load.

Material for Sub-Base.—See that the material used for sub-base is of such a character that it will withstand tamping without crushing to an extent that will prevent proper drainage.

Compacting Sub-Base.—See that the sub-base is thoroughly compacted by tamping or rolling; see that the top is made smooth and to grade.

Wetting Sub-Base.—See that the material of the sub-base is properly wetted before placing base concrete on it. If too dry it will absorb from the base the water necessary for the perfect hardening of the concrete.

Material for Forms.—See that forms are constructed of clean lumber not less than 2 ins. thick and 5 or 6 ins. wide. See that the top edges of the boards are true; they form the templets for striking the surface of the walk to grade.

Alignment and Level of Forms.—See that the alignment of the forms is exact and that their level conforms to the finished grade. The top edges of the forms serve as templets for finishing the walk and they must be true to grade.

Staking of Forms.—See that the forms are securely staked in place; the side forms by stakes about 2 ft. apart and alternating inside and outside, the cross forms by stakes on the opposite side from that on which the concrete is being deposited.

Spacing of Forms.—See that all the forms are spaced so that the inside measurements are exactly those of the "blocks" being molded. The side forms should be marked to show where joints are to come and the cross forms should be placed so that the face against which the concrete is placed is in line with the marks indicating positions of joints.

Mixing.—See that the concrete is thoroughly mixed to as wet a consistency as will permit thorough tamping. Mixing is frequently neglected in sidewalk work and it must be watched. See that excess of water is not used to get the plasticity of mixture that should be got by thorough mixing.

Size of Batch Mixed.—See that the size of batch mixed is not greater in amount than the quantity that can be placed, tamped and surfaced before initial set has

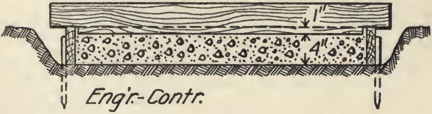

Fig. 13—Templet for Sidewalk Work.

commenced. Usually all concrete should be deposited within 40 minutes from time of mixing. Retempered concrete should not be used. Any concrete left over at quitting time should be discarded.

Placing Base Concrete.—See that as nearly as practicable the exact amount of concrete is deposited which when tamped and leveled will give a surface below the finished surface (the top edges of the forms) just the depth of the surface finish. A templet of the general form shown by

Fig. 13 will guarantee the proper surface grade of the base.

Tamping Base.—See that the base concrete is thoroughly tamped. The concrete should be of such consistency that thorough tamping will bring just a film of water to the surface. See that the tamping is as thoroughly done at edges and corners as in the center of the slab.

Preserving Joints in Base.—See that the joints in the base between slabs are rigidly preserved.

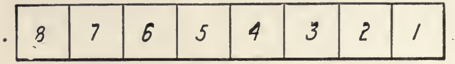

Fig. 14—Sketch Showing Method of Concreting Alternating Slabs.

(1). After the slab has been thoroughly tamped remove the wood cross-form and stakes so as to preserve the vertical face; tamp the concrete of the next base block against this face.

(2). Use a thin metal cross-form and leave it in place until both slabs are completed, then lift it out vertically.

(3). Construct alternating slabs independently as shown by Fig. 14. After the first series of slabs, 1, 3, 5, etc., has been completed, construct the second series, 2, 4, 6, etc.

Expansion Joints.—See that expansion joints are constructed as specified. The usual practice is an across-walk expansion joint at approximately every 50 ft., where new walk abutts old walk (cement or stone) and, where new walk abutts on curb in place. A recommended construction is to replace one of the wooden cross-forms with a metal parting strip which is left in place until the walk is hard and is then removed and the crevice filled with paver's pitch.

Method of Placing Top Mortar.—See that the method of placing the top mortar is one which is recognized to guarantee successful work when properly carried out. One of the following methods is commonly used:

(1). Mix the top mortar quite thin, spread it regularly, and work down with a straight-edge until the surface is a true plane flush with the top edges of the forms.

(2). Mix the top mortar stiff; spread it evenly and somewhat deeper than the final surface coat, tamp it level and thoroughly into the base concrete, strike concrete with a straight-edge and bring low spots up to grade.

(3). Use a base concrete rich in cement and tamp it until the mortar rises to the top and can be leveled and smoothed by straight-edge or trowel.

Consistency of Top Mortar.—See that top mortar to be placed by floating under straight-edge is mixed wet enough to "float" readily. If too stiff it cannot be properly worked into place, and if too thin it takes too long to dry out ready for finishing and is liable to result in sandy spots. A mushy consistency about like mortar for brick work is nearly right. See that top mortar to be placed by tamping is dry enough to permit thorough tamping, the tamping should bring just a film of moisture to the top.

Time of Placing Top Mortar.—See that the top mortar is placed immediately after the base is tamped into position. If before placing the top mortar the base has begun to set or has even become dry or has had a film of dust or dirt blown over it, the top mortar will not bond with the base concrete unless special precautions are taken in placing it.

Bonding Top Mortar to Hardened Base.—See that special means of securing bond are employed if for any reason the top mortar has to be placed on base concrete which has become hard. Two methods of bonding with success are:

(1). Wash the top surface of the base concrete thoroughly with water and brush off all dirt and loose material; apply to the washed surface a thin coat of cement grout well brushed in; apply top mortar in usual way before the grout has dried.

(2). Apply an acid wash, such as "Ransomite," to cut the surface film on the concrete; after the acid wash has worked, wash the concrete off with clean water until every trace of acid and dirt is removed; apply the top mortar to the wet surface in the usual way.

Placing top mortar on hardened base concrete should be permitted only in case of absolute necessity.

Marking Wearing Coat.—See that the marking of the wearing coat into blocks is directly over the block joints in the base. This rule should be rigidly enforced. See that the marking is done with a tool which cuts clear through to the base and that the joint is finished by a grooving tool, which leaves a rounded edge.

Finishing Edges of Walk.—See that the edges of the walk are finished by being rounded off to a curve of about ½-in. radius. A special tool called an edger gives the best finish.

Protection from Frost.—Sidewalk work should not be done in freezing weather unless it cannot be avoided. If construction in freezing weather is unavoidable the rules given previously for concreting in freezing weather should be followed.

Protection from Rain.—See that the finished walk is protected from the direct impact of rain while it is still soft. Rain falling on soft mortar washes and pits the surface. Any covering that will prevent the direct impact and wash of the rain on the green mortar is satisfactory.

Protection from Sun.—See that the walk is protected from the sun until thoroughly hardened. Too rapid drying weakens the mortar and causes hair checking. Too rapid drying by warm winds must also be guarded against.

Various methods of protecting sidewalks from too rapid drying are available. One of the best is a thick covering of sand placed directly on the top as soon as it has been finished. The sand conserves the moisture and can be wet down if more moisture is deemed necessary. Canvass, tar paper, boards, etc., are other means of covering that may be adopted.

Fractional Slabs.—See that a slab is not left partly completed at quitting time. The new concrete may not bond with the old concrete when work is resumed and a joint will result. In no case should the base be left at quitting time with the surface finish unplaced. The entire slab should be finished complete before work is stopped.

CHAPTER VII. INSPECTION OF MOLDING AND DRIVING CONCRETE PILES.

Concrete piles are constructed by two methods: (1) A hole is formed in the ground by driving a metal pile or by other means and is filled with concrete; (2) a concrete pile is cast in molds and after it has become hard is driven like a timber pile. The various methods of molding piles in place are controlled by patents and pile construction by these methods is done only by certain firms. Cast piles of certain special forms are also patented, but if these special forms be excepted, cast piles may be made and driven by anyone. In piles molded in place the chief uncertainties are whether the concrete is properly placed and tamped and remains uninjured until it has hardened and gained its strength. With cast piles the uncertainty is whether the pile after driving is still sound or has been injured by the driving. These uncertain points are the chief ones to be watched out for by the inspector.

Driving Piles in Place.—See that the driving of shells or cores for new piles does not injure adjacent piles which have been concreted but in which the concrete is still fresh or green. The jar in driving is considerable in certain kinds of ground and may readily endanger the setting and hardening of adjacent concrete work.

When piles are close driven the formation of the new holes may also so compress and shift the surrounding soil as to constrict or distort fresh concrete which has been placed in adjacent holes previously formed.

Constructing Piles in Place.—See that the concrete is deposited with care to prevent seggregation of stone from mortar and to prevent admixture of dirt with the concrete. A strong, dense concrete is needed for piles and the usual precautions for securing it should be observed.

Reinforcing Piles in Place.—See that the reinforcement is set parallel and concentric with the axis of the pile. The best practice is to assemble the reinforcement into a unit frame and to place it as a unit.

Cast Piles.—See that cast piles are straight, that the metal points, if such are used, are firmly attached, that there are no cracks, that the surface is not deeply chipped and that none of the reinforcing metal is exposed. If cored for sinking by water jet see that the cores are open and unobstructed; if fluted on the sides to provide passages for rise of water used in jetting see that the flutes or corrugations are not obstructed.

Molds for Cast Piles.—See that the molds are constructed straight and are kept level and true to line. Surface roughness joint marks, etc., are not objectionable, but a pile which is not straight is liable to fracture in driving or under load. See that the molds are supported by a rigid level foundation or molding bed.

Reinforcing Cast Piles.—See that the reinforcement is set parallel to and concentric with the axis of the mold, and is held rigidly in this position during concreting. The best practice is to assemble and wire the reinforcement into unit frames for placing.

Casting Piles in Tiers.—See that independent supports are provided for each tier of molds in casting piles in tiers to save room.

Concreting Cast Piles.—See that the concrete is poured at several points along the mold; concrete which is all poured at one point and made to fill the mold by flowing is likely to be streaky.

Driving Cast Piles.—See that the driving of cast piles is so done that the pile is not fractured in the body. See that the head is protected by a cushion cap to take the direct blow of the hammer. Watch the driving carefully to discover cracks, excessive spalling, etc. If the driving is done by water jet see that the pile is settled to a firm bearing.

Handling Cast Piles.—See that the method of handling the piles to the driver is such that damaging strain is not brought on the pile. Cast piles may be cracked by roughly dragging them with one end on the ground or by swinging them clear by a fastening at mid-length.

CHAPTER VIII. INSPECTION OF CAST CONCRETE WORK.

Cast concrete work comprises hollow building blocks, lintles, beams, columns, or other molded members, and ornamental shapes. The blocks, etc., are produced by pouring, tamping or compressing concrete into molds and permitting it to harden to the molded shape. The casting or molding is commonly done in factories when the inspection relates usually to the finished block alone, but sometimes it is done on the work when the inspection relates to methods of manufacture as well as to the finished product. The methods of molding and hardening are so many that only general directions for inspection can be given; for special variations in process the inspector must devise in addition rules to fit the particular characteristics of the work in hand.

Methods of Molding.—Three general processes are employed for molding cast concrete work: (1) A dry mixture is heavily tamped into a mold and the block is immediately released and set aside for curing; (2) a liquid mixture is poured into molds where the blocks remain until hard; (3) a medium wet mixture is compressed into molds by hydraulic presses or other means of securing great pressure.

Mixing for Dry Mixture Blocks.—See that the mixing is thorough and uniform. The amount of water used for dry mixture blocks is so small that it can be evenly distributed through the material only by careful and thorough mixing.

Consistency of Dry Mixtures.—See that the mixture is as wet as can be used without sticking to the molds and without sagging or sloughing when the molds are removed. The proper consistency has to be determined by experimenting on the materials being used. The block should part from the molds without sticking and should preserve its molded form perfectly.

Size of Dry Mixture Batches.—See that the size of batch mixed is not greater in amount than the quantity that can be molded into blocks before the cement begins to set.

Molds for Dry Mixture Blocks.—See that the molds are rigid and are rigidly bolted, clamped or locked together. See that the molds are so constructed that they can be removed or "released" without injury to the green blocks. See that the platens or working plates on which the block is carried and stacked are stiff enough not to spring under the load and can be gotten hold of for carrying without wrenching or tilting the green block.

Tamping Dry Mixtures.—See that the tamping is done from the bottom up as the mixture is filled into the mold. See that the tamping is thorough, that the material is thoroughly compacted in corners and around edges as well as in the center of the blocks. Do not permit the mold to be half filled before beginning tamping, fill the mold a little at a time and continue tamping from the first shovelful until the mold is filled. Unless the tamping is even and uniform there will be soft spots in the block.

Facing Dry Mixture Blocks.—See that the facing mixture is well bonded with the concrete backing by tamping the two together. The common practice is to place the facing mixture against the bottom or sides of the mold and fill above or behind with the concrete backing, which is tamped as the filling proceeds.

Removing Dry Mixture Blocks From Molds.—See that the block is removed from the mold to the curing skids without cracking it or injuring corners or arrises. A dry mixture block when taken from the mold has no cohesion except the tamping density; it has to be removed and handled with great care to prevent injury. Arrises and corners, if not badly damaged, can be repaired, but a block which is cracked cannot be satisfactorily repaired; it should be broken up and the material thrown back and molded over.

Stacking Dry Mixture Blocks.—See that the green blocks are stacked for curing in a horizontal position on unyielding supports and so as not to touch or to bring any weight on adjacent blocks.

Protecting Dry Mixture Blocks.—See that blocks are molded and stored for curing so that they cannot be acted upon by direct rays of the sun, warm air currents or frost. A shed or housing should be provided for both molding and storing, and the molded blocks had better remain under cover for at least a week. If shed room cannot be provided for a week's output of blocks, the blocks may be carried outside after setting and covered with canvas, straw or other covering that will preserve the moisture and shield the blocks from the sun and wind.

Sprinkling Dry Mixture Blocks.—See that the blocks are freely supplied with water by sprinkling. A dry mixture block does not have enough mixing water to enable the cement to set and harden perfectly and this deficiency has to be supplied by sprinkling. The sprinkling should begin as soon as the cement is hard enough not to wash, within an hour after molding, and should continue for at least ten days. See that the sprinkling, particularly while the block is still soft, is done by means of a gentle spray which will not "wash" the concrete.

Removing Dry Molded Blocks from Platens.—See that the block is removed from the platen by up-ending or tipping it onto a sand cushion and that the platen is loosened by tapping it lightly and not by wrenching or prying. Generally the platens are removed within at most 24 hours and the blocks are still green and will not stand abuse.

Curing Period for Dry Mixture Blccks.—See that the blocks have cured for at least 30 days before they are removed from the storage yards for use in construction.

Puddling Wet Mixtures.—See that the mixture is thoroughly stirred and churned to eliminate air voids, prevent arching and fill compactly corners and edges of mold. The mold may be filled in one pouring if size permits and if two or more batches are required for filling see that the pouring is as nearly continuous as practicable.

Removing Molds from Wet Mixture Blocks.—See that the mold is not removed until the concrete has thoroughly set and is strong enough to do without the support of the mold. The time of safe removal depends on the nature of the molded piece; its size, shape, weight and the strains which will come upon it in the process of removing the forms. A small compact block can be turned out of the molds as soon as the cement has set if care is used; a heavy molded girder can have the sides of the mold removed in 12 to 24 hours but it cannot be handled for a much longer period depending on conditions.

Provision for Handling Molded Blocks.—See that, in molding heavy blocks, suitable provision is made for handling by molding dog and clevis holes in the block, inserting pins or eye-bolts, etc. See that these holes or fastenings are liberal in size and are not located too near corners or faces, else the strain of lifting will shell off the concrete.

Accuracy of Shape and Dimensions.—See that the block is true to shape and exact in dimensions, with faces true to plane and edges true to line. See that moldings and other ornamentations are perfect. A molded block should be equal in perfection to cut stone in all particulars of shape and dimensions.

CHAPTER IX. STANDARD AND TYPICAL SPECIFICATIONS.

Specifications are the written instructions defining the duties of the inspector. He should be familiar with their characteristics and requirements both generally and specifically. A study of specifications is essential to an inspector who desires to keep abreast with his work. It is only by such study that he will be able to interpret their requirements quickly, accurately and fairly on any work with which he is connected. The following specifications are given here for study. They are not selected as being ideal, but as representing general practice, and therefore as being exemplifications of what the inspector may expect to find his business to interpret and enforce in practical work.

SPECIFICATIONS FOR CEMENT.*

General Conditions.

1. All cement shall be inspected.

2. Cement may be inspected either at the place of manufacture or on the work.

3. In order to allow ample time for inspecting and testing, the cement should

*Standard specifications adopted by the American Society for Testing Materials, Nov. 14, 1904.

be stored in a suitable weather-tight building having the floor properly blocked or raised from the ground.

4. The cement shall be stored in such a manner as to permit easy access for proper inspection and identification of each shipment.

5. Every facility shall be provided by the contractor and a period of at least 12 days allowed for the inspection and necessary tests.

6. Cement shall be delivered in suitable packages with the brand and name of manufacturer plainly marked thereon.

7. A bag of cement shall contain 94 lbs. of cement net. Each barrel of Portland cement shall contain 4 bags, and each barrel of natural cement shall contain 3 bags of the above net weight.

8. Cement failing to meet the 7-day requirements may be held awaiting the results of the 28-day tests before rejection.

9. All tests shall be made in accordance with the methods proposed by the Committee on Uniform Tests of Cement of the American Society of Civil Engineers, presented to the society January 21, 1903, and amended January 20, 1904, with all subsequent amendments thereto.

10. The acceptance or rejection shall be based on the following requirements:

Natural Cement.

11. **Definition.**—This term will be ap-

plied to the finely pulverized product resulting from the calcination of an argillaceous limestone at a temperature only sufficient to drive off the carbonic acid gas.

12. **Specific Gravity.**—The specific gravity of the cement thoroughly dried at 100° C. shall be not less than 2.8.

13. **Fineness.**—It shall leave by weight a residue of not more than 10 per cent on the No. 100 and 30 per cent on the No. 200 sieve.

14. **Time of Setting.**—It shall develop initial set in not less than 10 minutes and hard set in not less than 30 minutes, nor more than 3 hours.

15. **Tensile Strength.**—The minimum requirements for tensile strength for briquettes 1 in. square in cross section shall be within the following limits and shall show no retrogression in strength within the periods specified:*

Age.	Strength. Lbs.
Neat Cement.	
24 hours in moist air	50-100
7 days (1 day in moist air, 6 days in water)	100-200
28 days (1 day in moist air, 27 days in water)	200-300
One Part Cement, Three Parts Standard Sand.	
7 days (1 day in moist air, 6 days in water)	25- 75
28 days (1 day in moist air, 27 days in water)	75-150

*For example, the minimum requirement for the 24-hour neat cement test should be some specified value within the limits of 50 and 100 lbs., and so on for each period stated.

16. **Constancy of Volume.**—Pats of neat cement about 3 ins. in diameter, ½ in. thick at center, tapering to a thin edge, shall be kept in moist air for a period of 24 hours.

(*a*) A pat is then kept in air at normal temperature.

(*b*) Another is kept in water maintained as near 70° F. as practicable.

17. These pats are observed at intervals for at least 28 days, and, to satisfactorily pass the tests, should remain firm and hard and show no signs of distortion, checking, cracking or disintegrating.

Portland Cement.

18. **Definition.**—This term is applied to the finely pulverized product resulting from the calcination to incipient fusion of an intimate mixture of properly proportioned argillaceous and calcareous materials, and to which no addition greater than 3 per cent has been made subsequent to calcination.

19. **Specific Gravity.**—The specific gravity of the cement, thoroughly dried at 100° C., shall be not less than 3.10.

20. **Fineness.**—It shall leave by weight a residue of not more than 8 per cent on the No. 100, and not more than 25 per cent on the No. 200 sieve.

21. **Time of Setting.**—It shall develop initial set in not less than 30 minutes,

but must develop hard set in not less than 1 hour, nor more than 10 hours.

22. **Tensile Strength.**—The minimum requirements for tensile strength for briquettes 1 in. square in section shall be within the following limits, and shall show no retrogression in strength within the periods specified:*

Age. Neat Cement.	Strength. Lbs.
24 hours in moist air	150-200
7 days (1 day in moist air, 6 days in water)	450-550
28 days (1 day in moist air, 27 days in water)	550-650
One Part Cement, Three Parts Sand.	
7 days (1 day in moist air, 6 days in water)	150-200
28 days (1 day in moist air, 27 days in water)	200-300

23. **Constancy of Volume.**—Pats of neat cement about 3 ins. in diameter, ½ in. thick at the center, and tapering to a thin edge, shall be kept in moist air for a period of 24 hours.

(*a*) A pat is then kept in air at normal temperature and observed at intervals for at least 28 days.

(*b*) Another pat is kept in water maintained as near 70° F. as practicable, and observed at intervals for at least 28 days.

(*c*) A third pat is exposed in any convenient way in an atmosphere of steam,

*For example, the minimum requirement for the 24-hour neat cement test should be some specified value within the limits of 150 and 200 lbs., and so on for each period stated.

above boiling water, in a loosely closed vessel for 5 hours.

24. These pats, to satisfactorily pass the requirements, shall remain firm and hard and show no signs of distortion, checking, cracking or disintegrating.

25. **Sulphuric Acid and Magnesia.**—The cement shall not contain more than 1.75 per cent of anhydrous sulphuric acid (SO_3), nor more than 4 per cent of magnesia (MgO).

SPECIFICATIONS FOR PORTLAND CEMENT CONCRETE AND REINFORCED CONCRETE.*

1. Cement shall be Portland and shall meet the requirements of the standard specifications.

2. Fine aggregate shall consist of sand, crushed stone, or gravel screenings graded from fine to coarse and passing when dry a screen having ¼-in. diameter holes; it shall preferably be of siliceous material, clean, coarse, free from vegetable loam or other deleterious matter, and not more than 6 per cent shall pass a sieve having 100 meshes per linear inch.

3. Mortars composed of one part Portland cement and three parts fine aggregate by weight when made into bri-

*Adopted by the American Railway Engineering and Maintenance of Way Association.

quettes shall show a tensile strength of at least 70 per cent of the strength of 1—3 mortar of the same consistency made with the same cement and standard Ottawa sand.

4. Coarse aggregate shall consist of crushed stone or gravel, graded in size, and which is retained on a screen having ¼-in. diameter holes; it shall be clean, hard, durable and free from all deleterious material. Aggregates containing soft, flat or elongated particles shall not be used.

5. The maximum size of the coarse aggregate shall be such that it will not separate from the mortar in laying and will not prevent the concrete fully surrounding the reinforcement or filling all parts of the forms. Where concrete is used in mass the maximum size of the coarse aggregate may, at the option of the engineer, be such as to pass a 3-in. ring. For reinforced concrete, sizes usually are not to exceed one inch in any direction, but may be varied to suit the character of the reinforcement.

6. The water used in mixing concrete shall be free from oil, acid, alkalies or vegetable matter.

7. The metal reinforcement steel shall be manufactured from new billets, and shall meet the requirements of the following specifications, and be free from rust, scale or coatings of any character

which would tend to reduce or destroy the bond.

Specifications for Steel Reinforcement.

8. Steel shall be made by the open hearth process.

9. The chemical and physical properties shall conform to the following limits:

Elements Considered.	Structural Steel.	High Carbon Steel.
Phosphorus, max. { Basic....	0.04%	0.085%
Phosphorus, max. { Acid	0.06%	0.075%
Sulphur, maximum	0.05%	....
Ultimate tensile strength.	Desired.	Desired.
Pounds per square inch......	60,000	85,000‡
Elong., min. % in 8"	1,500,000* / Ult. tensile strength	1,400,000 / Ult. tensile strength
" " " 2"	22	....
Character of fracture........	Silky	....
Cold bends without fracture..	180° flat†	180° $d=4t$

*See paragraph 16. †See paragraphs 17, 18 and 19. ‡See paragraph 20.

10. The yield point, as indicated by the drop of beam, shall be not less than 60 per cent of the ultimate.

11. If the ultimate strength varies more than 4,000 lbs. from that desired, a retest shall be made on the same gage, which, to be acceptable, shall be within 5,000 lbs. of the desired ultimate.

12. Chemical determinations of the percentages of carbon, phosphorus, sulphur and manganese shall be made by the manufacturer from a test ingot taken

at the time of the pouring of each melt of steel, and a correct copy of such analysis shall be furnished to the engineer or his inspector. Check analyses shall be made from finished material, if called for by the purchaser, in which case an excess of 25 per cent above the required limits will be allowed.

13. **Plates, Shapes and Bars.**—Specimens for tensile and bending tests for shapes and bars shall be made by cutting

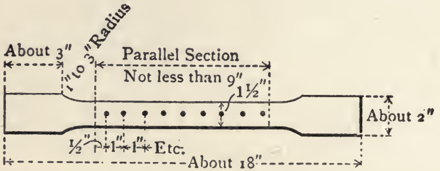

Fig. 15—Test Piece for Testing Reinforcing Steel.

coupons from the finished product, which shall have both faces rolled and both edges milled to the form shown by Fig. 15, or with both edges parallel, or they may be turned to a diameter of ¾ in. with enlarged ends.

14. Bars shall be tested as rolled.

15. At least one tensile and one bending test shall be made from each melt of steel as rolled.

16. For material less than 5/16 in. and more than ¾ in. in thickness the follow-

ing modifications will be allowed in the requirements for elongation:

(a) For each 1/16 in. in thickness below 5/16 in., a deduction of 2½ will be allowed from the specified percentage.

(b) For each ⅛ in. in thickness above ¾ in., a deduction of 1 will be allowed from the specified percentage.

17. Bending tests may be made by pressure or by blows. Shapes and bars less than one inch thick shall bend as called for in paragraph 9.

18. Structural steel one inch thick and over, tested as rolled, shall bend cold 180 degrees around a pin, the diameter of which is equal to twice the thickness of the bar, without fracture on the outside of bend.

19. Finished material shall be free from injurious seams, flaws, cracks, defective edges or other defects, and have a smooth, uniform and workmanlike finish.

20. Every finished piece of steel shall have the melt number and the name of the manufacturer stamped or rolled upon it, except that bar steel and other small parts may be bundled with the above marks on an attached metal tag.

21. Material which, subsequent to the above tests at the mills, and its acceptance there, develops weak spots, brittleness, cracks or other imperfections, or is found to have injurious defects, will be

rejected at the shop and shall be replaced by the manufacturer at his own cost.

Preparation and Placing of Mortar and Concrete.

22. The materials to be used in concrete shall be of uniform quality and so proportioned as to secure as nearly as possible a maximum density.

23. The unit of measure shall be the barrel, which shall be taken as containing 3.8 cubic feet. Four bags containing 94 lbs. of cement each shall be considered the equivalent of one barrel. Fine and coarse aggregate shall be measured separately as loosely thrown into the measuring receptacle.

24. The fine and coarse aggregate shall be used in such relative proportions as will insure maximum density.

25. For reinforced concrete construction a density proportion based on 1:6 shall be used; i. e., one part of cement to a total of six parts of fine and coarse aggregates measured separately.

26. For massive masonry or rubble concrete a density proportion based on 1:9 shall be used.

27. The ingredients of concrete shall be thoroughly mixed to the desired consistency, and the mixing shall continue until the cement is uniformly distributed

and the mass is uniform in color and homogeneous.

28. Methods of measurement of the proportions of the various ingredients, including the water, shall be used, which will secure separate uniform measurements at all times.

29. When the conditions will permit, a batch mixer of a type which insures uniform mixing of the materials throughout the mass shall be used.

30. When it is necessary to mix by hand, the mixing shall be on a watertight platform and especial precautions shall be taken to turn the materials until they are homogeneous in appearance and color.

a. Tight platforms shall be provided of sufficient size to accommodate men and materials for the progressive and rapid mixing of at least two batches of concrete at the same time. Batches shall not exceed one cubic yard each, and smaller batches are preferable, based upon a multiple of the number of sacks of cement to the barrel.

b. Spread the fine aggregates evenly upon the platform, then the cement upon the fine aggregates, and mix thoroughly until of an even color. Add all the water necessary to make a thin mortar and spread again; add the coarse aggregates, which, if dry, should first be thoroughly wet down. Turn the mass with shovels or hoes until thoroughly incorporated and all the aggregates are covered with mortar; this will probably require the mass to be turned four times.

c. Another approved method, which may be permitted at the option of the engineer in charge, is to spread the fine aggregates, then the cement, and mix dry, then the coarse aggregates; add water and mix thoroughly as above.

31. The materials shall be mixed wet enough to produce a concrete of such a consistency as will flow into the forms and about the metal reinforcement and which, on the other hand, can be conveyed from the place of mixing to the forms without separation of the coarse aggregate from the mortar.

32. Retempering mortar or concrete—i. e., remixing with water after it has partially set—shall not be permitted.

33. Concrete after the addition of water to the mix shall be handled rapidly from the place of mixing to the place of final deposit, and under no circumstances shall concrete be used that has partially set before final placing.

34. The concrete shall be deposited in such a manner as will permit the most thorough compacting, such as can be obtained by working with a straight shovel or slicing tool kept moving up and down

until all the ingredients have settled in their proper place by gravity and the surplus water forced to the surface.

35. In depositing the concrete under water, special care shall be exercised to prevent the cement from floating away, and to prevent the formation of laitance.

36. Before placing the concrete the forms shall be thoroughly wetted and the space to be occupied by the concrete free from debris.

37. When work is resumed, concrete previously placed shall be roughened, thoroughly cleansed of foreign material and laitance, drenched and slushed with a mortar consisting of one part Portland cement and not more than two parts fine aggregate.

38. The faces of concrete exposed to premature drying shall be kept wet for a period of at least seven days.

39. The concrete shall not be mixed or deposited at a freezing temperature, unless special precautions, aproved by the engineer, are taken to avoid the use of materials containing frost or covered with ice crystals, and to provide means to prevent the concrete from freezing after being placed in position and until it has thoroughly hardened.

40. Where the concrete is to be deposited in massive work, clean stones thoroughly embedded in the concrete as

near together as is possible and still entirely surrounded by concrete may be used at the option of the engineer.

41. Forms shall be substantial and unyielding and built so that the concrete shall conform to the designed dimensions and contours, and so constructed that the leakage of mortar is prevented.

42. The forms shall not be removed until authorized by the engineer.

43. For all important work, the lumber used for face work shall be dressed to a uniform thickness and width, and shall be sound and free from loose knots, secured to the studding or uprights in horizontal lines.

44. For backings and other rough work undressed lumber may be used.

45. Where corners of the masonry and other projections liable to injury occur, suitable moldings shall be placed in the angles of the forms to round or bevel them off.

46. Lumber once used in forms shall be cleaned before being used again.

47. In dry but not freezing weather the forms shall be drenched with water before the concrete is placed against them.

Details of Construction.

48. Wherever it is necessary to splice the reinforcement by lapping, the length of lap will be decided by the engineer on the basis of the safe bond stress and the

stress in the reinforcement at the point of splice. Splices shall not be made at points of maximum stress.

49. Concrete structures, wherever possible, shall be cast at one operation, but when this is not possible the work shall be stopped, so that the resulting joint will have the least effect on the strength of the structure.

50. Girders and slabs shall not be constructed over freshly formed wall or columns without permitting a period of at least two hours to elapse to provide for settlement or shrinkage in the supports. Before resuming work the top of the supports should be thoroughly cleansed of foreign matter and laitance.

51. In massive work, such as retaining walls, abutments, etc., built without reinforcement, joints shall be provided, approximately, every 50 feet throughout the length of the structure to take care of temperature changes. To provide against the structures being thrown out of line by unequal settlement, each section of the wall may be tongued and grooved into the adjoining section. To provide against unsightly cracks, due to unequal settlement, a joint shall be made at sharp angles.

52. The desired finish of the surface shall be determined by the engineer before the concrete is placed, and the work shall be so conducted as to make it pos-

sible to secure the finish desired. Plastering of surface will not be permitted.

SPECIFICATIONS FOR MATERIALS AND WORKMANSHIP FOR BUILDING CONSTRUCTION.*

Quality of Materials.

Portland cement shall conform to the requirements of the specifications of the American Society for Testing Materials, as adopted June 14, 1904, with all subsequent amendments thereto.

Aggregates.—Fine aggregates shall be well graded in size from the finest to at least the size retained on a No. 10 sieve. Coarse aggregates shall also be well graded in size from the finest to at least the size retained by a 9/16-in. ring. Fine aggregates may contain not more than 5 per cent, by weight, of clay, but no other impurities. Coarse aggregates shall contain no impurities.

Sand shall be equal in quality to the Mississippi River sand.

Broken stone shall be either limestone, chatts, or granite, or some other stone equal to one of these in the opinion of the commissioner of public buildings.

Hard burned clay shall be made from suitable clay free from sand or silt.

*Extracts from the Building Ordinance of the City of St. Louis, Mo.

burned hard and thoroughly. Absorption of water should not exceed 15 per cent.

Concrete.—The solid ingredients of the concrete shall be mixed by volume in one of the following proportions:

(a) Not more than 3 parts fine aggregate to 1 of cement.

(b) Not more than 2 parts of fine aggregate and 4 parts of coarse aggregate to 1 of cement; but in all cases the fine aggregate shall be 50 per cent of the coarse aggregate.

Concrete shall have an ultimate strength in compression in 28 days of not less than the following:

Burned clay concrete, 1,000 lbs. per sq. in.

All other concrete, 2,000 lbs. per sq. in.

Steel shall be medium steel or high elastic limit steel. The physical properties shall conform to the following limits:

	Medium Steel.	High Elastic Limit Steel.
Elastic limit	Not less than 30,000	Not less than 50,000
Percentage of elongation, min. in 8 ins	$E=\frac{1,800,000}{f-10,000}-10$	$E=\frac{1,800,000}{f-10,000}-10$
Cold bend without fracture on outer circumference ..	180° flat	90° to radius=5 times th'kness
Character of fracture	Silky	Silky or fine granular

f=unit stress in steel at ruptures.

Tests shall be made on specimens taken from the finished bar, and certified copies of test reports shall be furnished the commissioner of public buildings.

Bending tests shall be made by pressure.

Finished material shall be free from seams, flaws, cracks, defective edges or other defects, and have a smooth, uniform and workmanlike finish, and shall be free from irregularities of all kinds.

The net area of cross section of finished steel members shall not be less than 95 per cent of the area shown in the approved design.

Execution.

All reinforced concrete work shall be built in accordance with approved detailed working drawings. These drawings shall be submitted to the Commissioner of Public Buildings for approval and no work shall be commenced until the drawings shall have been approved by him.

The steel used for reinforcing concrete shall have no paint upon it, but shall present only a clean or slightly rusted surface to the concrete. All dirt, mud and other foreign matter shall be removed.

If the steel has more than a thin film of rust upon its surface it shall be cleaned before placing in the work.

In proportioning materials for concrete, one bag containing not less than 93 lbs. of cement shall be considered 1 cu. ft.

The ingredients of the concrete shall be so thoroughly mixed that the cement shall be uniformly distributed throughout the mass and that the resulting concrete will be homogeneous.

The concrete shall be mixed as wet as possible without causing a separation of the cement from the mixture, and shall be deposited in the work in such manner as not to cause the separation of mortar from coarse aggregate.

Concrete shall be placed in the forms as soon as practicable after mixing, and in no case shall concrete be used if more than 1 hour has elapsed since the addition of its water. It shall be deposited in horizontal layers not exceeding 8 ins. in thickness and thoroughly tamped with tampers of such form and material as the circumstances require.

The steel shall be accurately placed in the forms and secured against disturbance while the concrete is being placed and tamped, and every precaution shall be taken to insure that the steel occupies exactly the position in the finished work as shown on the drawing.

Before the placing of concrete is suspended the joint to be formed shall be in such place and shall be made in such manner as will not injure the strength of the completed structure.

Whenever fresh concrete joins concrete that has set, the surface of the old concrete shall be roughened, cleaned and thoroughly slushed with a grout of neat cement and water.

No work shall be done in freezing weather, except when the influence of frost is entirely excluded.

Until sufficient hardening of the concrete has occurred, the structural parts shall be protected against the effects of freezing, as well as against vibrations and loads.

When the concrete is exposed to a hot or dry atmosphere special precautions shall be taken to prevent premature drying by keeping it moist for a period of at least twenty-four hours after it has taken its initial set. This shall be done by a covering of wet sand, cinders, burlap, or by continuous sprinkling, or by some other method equally effective in the opinion of the Commissioner of Public Buildings.

If during the hardening period the temperature is continually above 70° F., the side forms of concrete beams and the forms of floor slabs up to spans of eight feet shall not be removed before four days. The remaining forms and supports not before ten days from the completion of tamping.

If during the hardening period the temperature falls below 70° F., the side forms of concrete beams and the forms or floor slabs up to spans of 8 ft.

shall not be removed before seven days; the remaining forms and the supports not before fourteen days from the completion of the tamping. But if during the hardening period the temperature falls below 35° F., the time for hardening shall be extended by the time during which the temperature was below 35° F.

Forms of concrete shall be sufficiently substantial to preserve their accurate shape until the concrete has set, and shall be sufficiently tight so as not to permit any part of the concrete to leak out through cracks or holes.

Before placing the concrete, the inside of the forms shall be thoroughly cleaned of all dirt and rubbish, the forms of all beams, girders and columns being constructed with a temporary opening in the bottom for this purpose.

If loading tests are considered necessary by the Commissioner of Public Buildings, they shall be made in accordance with his instructions, but the stresses induced in all parts of a structural member by its test load shall be the same as if the member were subjected to twice the dead load plus twice the assumed load.

All tests of material herein required shall be made by testing laboratories of recognized standing, and certified copies of such test reports shall be filed with the Commissioner of Public Buildings.

THE NATIONAL ASSOCIATION OF CEMENT USERS' PROPOSED STANDARD BUILDING REGULATIONS FOR THE USE OF REINFORCED CONCRETE.

I. General.

1. The term "Reinforced Concrete" shall be understood to mean an approved concrete which has been reinforced by metal in some form so as to develop the compressive strength of the concrete.

2. Reinforced concrete may be used for all clases of buildings if the design is in accordance with good engineering practice and stresses are figured as indicated in these regulations.

3. There shall be no limit upon the height of buildings of reinforced concrete except as limited by the requirements in these regulations.

4. Before permission is granted by the Building Department to erect any reinforced concrete building, complete plans, accompanied by specifications, signed by the engineer and architect, must be filed with the Building Department and remain on file for public inspection until the building is completed.

5. The Building Department shall have access to the computations, which shall give the loads assumed separately, such

as dead and live loads, wind and impact, if any, and the resulting stresses.

6. The specifications shall state the qualities of the materials to be used for making the concrete, and the proportions in which they are to be mixed.

7. Upon the completion of the building the engineer and architect shall issue, under the approval of the Building Department, signed certificates, to be posted on each floor of the building, stating the safe carrying capacity per square foot.

8. There shall be kept an exact record of the progress of each operation where the same can be inspected by the Building Department. These records shall show the date of placing of all the concrete and date of removal of the forms, and must be turned over to the Building Department when the building is completed.

9. Reinforced concrete walls may be used in place of brick or stone walls with reduced thickness. Curtain walls shall not be less than 4 ins. thick.

10. Concrete walls must be reinforced in both directions. The maximum spacing of reinforcing bars shall be 18 in. centers, reinforcement in either or both faces of the wall being considered. Reinforcement shall be not less than one-fourth of 1 per cent.

11. Wherever floor constructions are

built with a combination of tile or other fillers between joists, the following rules regarding the dimensions and methods of calculations of construction shall be observed:

(a) Ratio of minimum depth to clear span of joist shall not be greater than one to eighteen.

(b) Wherever a portion of the slab above the tile joist shall be considered as acting as a tee-beam section, the slab portion must be cast monolithic with the joist and must have a minimum thickness of at least 2 ins. on all spans. Otherwise all regulations applying to tee beams shall apply to tile and joist construction.

(c) Where the joists are figured as rectangular beams, in accordance with the standard regulations for this type of beams, the slab shall be considered as independent of the structural part of the building.

(d) Wherever porous tiles, or other materials which by their nature will absorb water from the concrete, are used between the joists, care must be taken to thoroughly saturate the tiles or other materials with water immediately before the concrete is placed.

(e) Reinforcement for slabs over joist construction below 30 in. centers need not be closer than 24 ins. in each direction.

II. Materials.

12. a. **Cement.**—Only Portland cement shall be used in reinforced concrete structures. Portland cement shall meet the requirements of the Standard Specifications for Cement of the American Society for Testing Materials. (See Standard No. 1 of the National Association of Cement Users.)

13. Tests of cement used in building operations shall be made from time to time under the supervision of the Building Department in accordance with the preceding specifications. No brand of cement which has not met these requirements shall be used.

14. b. **Aggregates.**—Extreme care shall be exercised in selecting the aggregate for mortar and concrete, and careful tests must be made, where any doubt exists, of the materials for the purpose of determining their qualities and the grading necessary to secure maximum density or a minimum percentage of voids.

15. Fine aggregate shall consist of sand, crushed stone or gravel screenings, passing when dry a screen having one-quarter inch diameter holes, and not more than 6 per cent passing a sieve having 100 meshes per lineal inch. It shall be of clean, silicious material free from vegetable loam or other deleterious matter.

16. Mortars composed of one part Portland cement and three parts fine aggregate by weight when made into briquets should show a tensile strength of at least 70 per cent of the strength of 1:3 mortar of the same consistency made with the same cement and standard Ottawa sand.

17. Coarse aggregate shall consist of inert material, such as crushed stone or gravel, which is retained on a screen having one-quarter inch diameter holes, the particles shall be clean, hard, durable and free from all deleterious material. The maximum size of the coarse aggregate shall be such that it will not separate from the mortar in laying and will not prevent the concrete fully surrounding the reinforcement or filling all parts of the forms.

18. The maximum size for reinforced concrete shall be such that all the aggregate shall pass a one and one-quarter inch diameter ring.

19. Cinder concrete shall not be used for reinforced concrete structures; it may be used for fire proofing. Where cinders are used as the coarse aggregate they shall be composed of hard, clean, vitreous clinker, free from sulphides, unburned coal or ashes.

20. c. **Reinforcement.**—Medium steel for reinforcement of concrete shall be

made from billets and shall conform to the requirements of the specifications for structural steel adopted by the American Railway Engineering and Maintenance of Way Association.

21. High carbon steel shall be made entirely from new billets, having (1) a desired ultimate strength of 88,000 lbs. per sq. in. with an allowable range of 8,000 lbs. from the desired ultimate strength, (2) an elongation in per cent in eight (8) inches of $\frac{1,200,000}{\text{ultimate strength}}$ and (3) capable of cold bending 180 degrees around four diameters without fracture.

22. Where wire or rods up to one-quarter inch diameter are used for reinforcement of slabs or for the prevention of shrinkage cracks, either material manufactured from the Bessemer billet (not rerolled rails) or drawn from basic open hearth steel may be used.

III. Details of Construction.

23. a. **Mixing.—General.—**The ingredients of concrete shall be thoroughly mixed to the desired consistency, and the mixing shall continue until the cement is uniformly distributed and the mass is uniform in color and homogeneous.

24. Methods of measurement of the proportions of the various ingredients,

including the water, shall be used, which will secure separate uniform measurements at all times.

25. **Machine Mixing.**—When the conditions will permit, a machine mixer of a type which insures the proper mixing of the materials throughout the mass shall be used.

26. **Hand Mixing.**—When it is necessary to mix by hand, the mixing shall be on a water-tight platform, and especial precautions must be taken to turn the materials until they are homogeneous in appearance and color.

27. **Consistency.**—The materials must be mixed wet enough to produce a concrete of such a consistency as will flow into the forms and about the metal reinforcement, and which, on the other hand, can be conveyed from the mixer to the forms without separation of the coarse aggregate from the mortar.

28. Retempering mortar or concrete—i. e., remixing with water after it has partially set—shall not be permitted.

29. b. **Placing of Concrete.—General.**—Concrete shall be placed in the work immediately after mixing and deposited and rammed or agitated by suitable tools in such a manner as to produce thoroughly compact concrete of maximum density. No concrete should be placed until the reinforcement has been placed and firmly

secured by wiring or other methods to prevent displacement.

30. The faces of concrete exposed to premature drying shall be kept damp for a period of at least seven days.

31. Before placing the concrete care shall be taken to see that the forms are substantial and thoroughly wetted and the space to be occupied by the concrete free from debris. When the placing of the concrete is suspended, all necessary grooves for joining future work shall be made before the concrete has had time to set.

32. When work is resumed, concrete previously placed shall be roughened, thoroughly cleansed of foreign material and laitance, drenched and slushed with a mortar consisting of one part Portland cement and not more than two parts fine aggregate.

33. **Placing in Water.**—Concrete should not be placed in water, unless unavoidable. Where concrete must be placed under water, unusual care must be taken to prevent the cement from being floated away.

34. **Freezing Weather.**—Concrete shall not be mixed or deposited at a freezing temperature unless special precautions are taken to avoid the use of materials containing frost or covered with ice crystals, and to provide means to pre-

vent the concrete from freezing after being placed in position and until it has thoroughly hardened.

35. c. **Placing of Reinforcement.**—The reinforcement shall be accurately located in the forms and secured against displacement.

36. d. **Joints.**—Reinforcement.—Wherever it is necessary to splice reinforcement by means of lapping, the length of the lap shall be determined upon the basis of the safe bond stress and the stress in the bar at the point of splice, or a connection shall be made between the bars of sufficient strength to carry the stress. Splices at the point of maximum stress must be avoided.

37. In columns large bars shall be properly butted and spliced. Small bars may be treated as indicated in paragraph 36.

38. **Concrete.**—Reinforced concrete work shall be stopped at such points that the joints will have the least possible effect on the strength of the structure. Footings shall be cast to their full depth at one operation.

(a) **Columns.**—Work in columns shall be stopped at the under side of the lowest beam or girder bearing on the column.

(b) **Beams and Girders.**—Construction joints in beams and girders shall be vertical and within the middle third of the span. Any concrete which may run past the bulkheads must be cleaned up before the concreting of the next section is started. Where brackets are used, the bracket shall be considered as a part of the beam or girder.

(c) **Slabs.**—Construction joints in slabs shall be near the center of the span. No joint will be allowed between slab and beam or girder.

39. e. **Removal of Forms.**—Under no consideration shall forms be removed until the concrete has hardened sufficiently to permit their removal with safety.

40. **Floor Slabs and Beams.**—Forms shall not be removed from floor slabs in less than seven days. Sides of beams may be removed at the same time as the floor slabs provided original supports under beams and girders are left in place.

41. **Columns.**—Where original supports remain under beams and girders coming to the columns, the forms shall not be removed from the columns in less than four days.

42. **Beam and Girder Supports.**—The original supports for all beams and girders must remain in place at least ten days, but all beams and girders having more than 30 ft. span from center

to center of support shall be considered as special cases and shall be subject to inspection of the Building Department before removal of supports.

IV. Design.

43. a. **General Assumptions.—Internal Stresses.**—As a basis for calculations for the strength of reinforced concrete construction, the following assumptions shall be made:

(a) A plane section before bending remains plane after bending.

(b) The modulus of elasticity of concrete in compression within the usual limits of working stresses is constant.

(c) In calculating the moment of resistance of beams the tensile stresses in the concrete shall be neglected.

(d) Perfect adhesion is assumed between concrete and reinforcement. Under compressive stresses the two materials are therefore stressed in proportion to their moduli of elasticity and their distance from the neutral axis.

(e) The ratio of the modulus of elasticity of steel to the modulus of elasticity of concrete shall be assumed to be 15.

(f) No allowance shall be made for tension in concrete.

(g) Initial stress in the reinforcement due to contraction or expansion in the concrete may be neglected.

(h) In columns the ratio of least diameter to height shall be taken as one-fifteenth. Greater ratios shall be deduced by satisfactory column formulas.

44. **Length of Beams and Slabs.**—The span length for beams and slabs shall be taken as the distance from center to center of supports, but shall not be taken to exceed the clear span plus the depth of beam or slab. Brackets shall not be considered as reducing the clear span.

45. Length of columns shall be taken as the maximum unsupported length.

46. Where slabs and beams are figured as simple beams the length shall be considered as the clear distance between supports excluding brackets.

47. b. **Loads.**—The dead load shall include the weight of the strcture and all fixed loads and forces.

48. The weight of the reinforced concrete shall be taken as 150 pounds per cubic foot.

49. The live load shall include all loads and forces which are variable.

The minimum live load for floors and roofs shall be as generally provided by building codes.

50. **Roof and Floor Loads.**—The roof shall be figured to carry 30 pounds live load per square foot unless otherwise noted.

51. A reduction of live load coming to the column supporting the floor below

the roof of 5 per cent to be allowed and a further reduction of 5 per cent of the live load of each story below until the total reduction shall amount to 50 per cent of the live load of any floor, after which all loads shall be figured net to the foundations. These reductions shall not apply to storage warehouses.

52. **Reduction of Loads.**—No reduction of loads shall be allowed for figuring floor slabs.

53. No reduction of loads shall be allowed for figuring beams.

54. A reduction of 15 per cent live load may be allowed in figuring the girders, except in buildings used for storage purposes.

55. In assuming the load coming to the columns all beams and girders shall be considered as carrying a net load consisting of 100 per cent each of live and dead load, subject to the above reductions.

56. c. **Bending Moments.—Slabs.**—The bending moment of slabs uniformly loaded and supported at two sides only shall be taken as $\frac{1}{8} wl^2$ where $w =$ unit load and $l =$ span.

57. **Continuous Slabs.**—For interior slabs overhanging two or more supports the bending moment shall be taken as $1/12\ wl^2$. The reinforcement at the top of the slab over supports must equal

that used at the center. The reinforcement in the bottom of the slab must equal at least ¼ of that used at center.

58. **Slabs Reinforced in Both Directions.**—Slabs that are reinforced in both directions and supported on four sides and fully reinforced over the supports (the reinforcement passing into the adjoining slabs) may be figured on the basis of bending moments equivalent to $\frac{wl^2}{F}$ for load in each direction. When span under consideration is not continuous, $F = 8$; when continuous over one support, $F = 10$; when continuous over both supports, $F = 12$. The distribution of the loads to be determined by the formula:

$$r = \frac{L^4}{L^4 + b^4}$$

in which r equals proportion of load carried by the transverse reinforcement, L equals length of span and b equals breadth of slab.

59. The slab area may be reduced by one-half, as above figured, when the reinforcement is parallel to and not farther from the supports than one-quarter of the shortest side.

The reinforcement spanning the shortest direction shall be below the reinforcement spanning the longer direction, and shall not be further apart than 2½ times the thickness of the floor including the finish.

60. **Simple Beams.**—The bending moment of beams supported at the ends only shall be figured as of simple beams.

61. **Partially Restrained Beams.**—Beams supported at one end and continuous at the other to be figured partially restrained with a bending moment of eight-tenths (0.8) that of a simple beam.

When the overall vertical distance of the tension members is greater than one-sixth of the total depth of the beam the stresses in each member shall be computed in proportion to the distance from the neutral axis.

62. Beams supporting rectangular slabs reinforced in both directions shall be assumed to take the following load: The beams on which the shortest sides of the slab rest shall take the load of that portion of the slab formed by the isosceles triangle having this side as its base and half this side as its height. The load from the remaining portion of the slab shall go to the beams on which the long side of the slab rests.

63. **Continuous Beams.**—When beams or girders are continuous over two or more supports, the interior beams may be considered as partially restrained, and the bending moments at the center and

support figured as two-thirds (2/3) that of a simple beam, unless the concrete at the bottom of the beam at the support shall by this consideration receive excess compression.

64. **Tee Beams.**—In beam and slab construction, an effective metallic bond should be provided at the junction of the beam and slab. When the principal slab reinforcement is parallel to the girder, transverse reinforcement shall be used extending over the girder and well into the slab.

65. Where adequate bond between slab and web of beam is provided, the slab may be considered as an integral part of the beam, but its effective width shall not exceed one-eighth (1/8) of the span length of the beam on either side of the beam.

66. In the design of tee beams acting as continuous beams, due consideration should be given to the compressive stresses at the support at the bottom of the beam.

67. d. **Working Stresses.**—Concrete composed of materials meeting the requirements of these regulations, mixed in proportion of one part of cement and six parts of aggregate (fine and coarse), shall develop a compressive strength of 2,000 lbs. per sq. in. in 28 days when tested as 8 in. diameter cylinders 16 ins.

long under laboratory conditions of manufacture and storage, using the same consistency as is used in the field. When the proportion of cement is increased, using the best quality of aggregates, an increase may be made in all w rking stresses proportional to the increase in compressive strength at 28 days, as determined by actual tests. On this basis the following working stresses shall be allowed in construction:

68. Bearing compression, 650 lbs. per sq. in.

69. Compression in extreme fiber, 650 lbs. per sq. in. With increase of 15 per cent near supports in continuous beams.

70. Axial compression in columns without hoops, 450 lbs. per sq. in. and 6,750 lbs. per sq. in. on vertical reinforcement.

71. Axial compression in columns with 1 per cent of hooping, 540 lbs. per sq. in., and 6,750 lbs. per sq. in. of vertical reinforcement.

72. Axial compression in columns with 1 per cent hooping and 1 to 4 per cent of vertical reinforcement, 650 lbs. per sq. in. on the concrete and 9,750 on the vertical reinforcement.

Bars composing longitudinal reinforcement shall be straight and shall have sufficient lateral support to be securely held in place until the concrete is set.

The clear spacing of bands or hoops shall be not greater than one-fourth the diameter of the inclosed column. Adequate means must be provided to hold bands or hoops in place so as to form a column the core of which shall be straight and well centered.

Bending stresses due to eccentric loads must be provided for by increasing the section until the maximum stress does not exceed the values above specified.

73. Compression on columns reinforced with structural steel units which thoroughly encase the concrete core, 540 lbs. per sq. in. on the concrete and 8,100 lbs. per sq. in. on the structural steel.

74. **Web Stresses.**—In calculating web reinforcement the concrete shall be considered to carry 40 lbs. per sq. in., the remainder to be provided for by means of reinforcement in tension.

Members of web reinforcement shall be embedded in the compression portion of the beam so that adequate bond strength is provided to fully develop the assumed strength of all shear reinforcement. They shall not be spaced to exceed three-fourths of the depth of the beam in that portion where the shearing stresses exceed the allowable shearing value of the concrete. Web reinforcement, unless rigidly attached, shall be placed at right angles to the axis of the beam and looped around the extreme tension member.

75. Bond between plain bars and concrete, 80 lbs. per sq. in. of surface of bar; where adequate mechanical bond is provided the stress shall not exceed 150 lbs. per sq. in. of surface of bar.

76. The ratio of modulus of elasticity cf concrete to steel shall be considered as one to fifteen.

77. The allowable tensile stress in reinforcement to be 16,000 pounds per square inch for medium steel and 20,000 pounds per square inch for high carbon steel with adequate mechanical bond.

78. The compressive stress in the steel reinforcement to be fifteen times the allowed compression in concrete in which the steel is embedded.

79. e. **Fireproofing.**—The main reinforcement in columns shall be protected by a minimum of two inches of concrete, reinforcement in girders and beams by 1½ ins. and floor slabs by 1 in.

SPECIFICATIONS FOR MATERIALS AND WORKMANSHIP FOR ARCH BRIDGE CONSTRUCTION.*

Cement.—No cement will be allowed to be used except established brands of

*Extracts from the Specifications of the Concrete Steel Engineering Co., New York.

high grade Portland cement which has been in successful use under similar conditions to the work proposed for at least 3 years, and has been seasoned or subjected to aeration for at least 30 days before leaving the factory. All cement shall be dry and free from lumps, and immediately upon receipt shall be stored in a dry, well covered and ventilated place, thoroughly protected from the weather. If required the contractor shall furnish a certified statement of the chemical composition of the cement and of the raw material from which it is manufactured.

The fineness of the cement shall be such that at least 90 per cent will pass through a sieve of No. 40 wire, Stubbs gage, having 10,000 openings per square inch, and at least 75 per cent will pass through a sieve of No. 45 wire, Stubbs gage, having 40,000 openings per square inch.

Samples for testing may be taken from every bag or barrel, but usually for tests of 100 barrels a sample will be taken from every tenth barrel. The samples will be mixed thoroughly together while dry and the mixture be taken as the sample for test.

Tensile tests will be made on specimens prepared and maintained until tested at a temperature not less than 60°

F. Each specimen will have an area of 1 sq. in. at the breaking section, and after being allowed to harden in moist air for 24 hours will be immersed and maintained under water until tested.

The sand used in preparing test specimens shall be clean, sharp, crushed quartz retained on a sieve of 30 meshes per lineal inch, and passing through a sieve of 20 meshes per lineal inch. In test specimens of 1 cement and 3 sand, no more than 12 per cent of water by weight shall be used. Specimens prepared from a mixture of 1 part cement and 3 parts sand, parts by weight, shall after 7 days develop a tensile strength of not less than 170 lbs. per sq. in. and not less than 240 lbs. per sq. in. after 28 days. Cement mixed neat with from 20 per cent to 25 per cent of water to form a stiff paste shall after 30 minutes be appreciably indented by the end of a wire 1/12 in. in diameter loaded to weigh ¼ lb. Cement made into thin pats on glass plates shall not crack, scale nor warp under the following treatment: Three pats will be made and allowed to harden in moist air at from 60° to 70° F.; one of these will be placed in fresh water for 28 days, another will be placed in water which will be raised to the boiling point for 6 hours and then allowed to cool, and the third is to be kept in air of the prevailing outdoor temperature.

Portland Cement Concrete.—The concrete shall be composed of cement, sand and broken stone or gravel mixed with clean water in the proportions hereafter mentioned.

The sand shall be clean, sharp and coarse, or coarse and fine mixed, free from sewage, mud, clay and all foreign matter.

The broken stone shall be clean and hard, broken into approximately cubical pieces, and free from long, thin scales.

The gravel shall be of assorted sizes screened or washed entirely free from clay, loam or foreign matter, and be free from scale, slime or humus.

Whenever the amount of work to be done is sufficient to justify it, and for all work exceeding 1,000 cu. yds., approved mixing machines shall be used. The ingredients shall be placed in the machine in a dry state and in the volumes specified, and be thoroughly mixed, after which clean water shall be added and the mixing continued until the wet mixture is thorough and the mass uniform. The mixture shall be sufficiently wet for the water to come to the surface with moderate ramming. As soon as the batch is mixed it must be deposited in the work without delay. For small bridges, if the mixing is done by hand, the cement and sand shall first be thoroughly mixed dry, in the proportions specified.

The stone, previously drenched with water, shall then be deposited in this mixture. Clean water shall be added and the mass be thoroughly mixed and turned over until each stone is covered with mortar, and the batch be deposited without delay.

The concrete shall be deposited in layers of 6 or 8 ins. and be thoroughly rammed until all voids are filled and the water flushes to the surface.

The grades of concrete to be used are as follows:

(a) For the arches, slabs, girders, beams, floors, walls subject to transverse stress, posts and tanks, 1 part Portland cement, 2 parts sand and 4 parts broken stone that will pass in any direction through a 1½ in. ring, if not otherwise marked on plans.

(b) For spandrel walls, 1 part Portland cement, 3 parts sand and 6 parts broken stone or gravel that will pass through a 2-in. ring.

(c) For the piers, abutments, foundations and retaining walls, 1 part Portland cement, 3½ parts sand and 7 parts broken stone or gravel that will pass through a 3-in. ring.

Artificial Stone.—(a) All keystones, brackets, consoles, dentiles, pedestals, parapets, hand railings, posts and panels and other ornamental work when used, also curbs and gutters, shall be of the design shown on plans and be molded in smooth and suitable molds. For moldings containing curved surfaces, sharp curves, carvings or other delicate work, the molds shall be plastered with a semi-liquid mortar composed of 1 part cement and 2 parts of fine sharp sand. The mortar coating must be followed up with a backing of only earth damp concrete composed of 1 part cement, 2 parts sand and 4 parts of fine broken stone, or 1 part cement and 6 parts of gravel that will pass through a ¾-in. ring. The concrete backing must be rammed thoroughly in thin layers.

(b) For plain flat surfaces the concrete may be rammed directly against the molds, and after the molds have been removed all exposed surfaces shall be floated to a smooth finish with a mortar the same as specified for artificial stone, care being taken that no body of mortar is left on the face, sufficient only being used to fill the pores and give a smooth finish.

When pedestal posts carry lamp posts a 4-in. wrought iron pipe shall be built into the concrete from top to bottom, and at bottom it shall be connected with a 3-in. pipe extending under the sidewalk and connected with gas pipe or electric wire conduit. The pipes shall have no sharp bends, all changes in direction being made by gentle curves.

Plastering.—No plastering will be allowed on the exposed faces of the work, but the inside faces of the spandrel walls covered by the fill shall be plastered with mortar composed of one part cement and two and one-half parts sand, the surface being well dampened before plastering.

Mixtures. — The volumes of cement, sand, broken stone, or gravel in all mixtures of mortar or concrete shall be measured loose.

Connections.—In connecting concrete already set with new concrete, the surface shall be cleaned and roughened, and mopped with a mortar composed of 1 part cement and 1 part sand to cement the parts together.

Expansion Joints.—Expansion joints shall be made in the spandrel walls, cornices and parapets of each arch above the springing lines, at points one-sixth span from the springing lines and at such points, if any, as are shown on plan.

Spandrels.—The spandrel walls shall have a thickness of not less than 18 ins. at any point and a thickness at bottom of not less than four-tenths of the height of the wall measured from the top of cornice.

Arches.—For square arches the concrete shall be laid in transverse sections of the full width of the arch, between timber forms normal to the center line of the arch, the length of sections being such that the center section, or a pair of intermediate or end sections, shall constitute a day's work. Work shall be started at the center section and carried towards the ends, the end sections being laid last.

For skew arches the concrete shall be started simultaneously from both ends of the arch and be built in longitudinal sections at least 5½ ft. in width, and wide enough to constitute a day's work. The concrete shall be deposited in layers, each layer being well rammed in place before the previously deposited layer has had time to partially set. The work shall proceed continuously day and night if necessary to complete each longitudinal section. These sections while being built shall be held in place by substantial vertical timber forms, parallel to the face of the arch and to each other, and these forms shall be removed when the section has set sufficiently to admit of it. The sections shall be connected as specified under "Connections," and also by steel clamps spaced about 5 ft. apart, connecting the adjacent steel ribs.

Drainage. — Provision for drainage shall be made at each pier as follows: A wrought iron pipe of sufficient diameter shall be built into the concrete, extending from the center of each space over piers to the soffit of the arch near the springing line, and project 1 in. below the soffit. The surface of the concrete over piers shall be so formed that any water that may seep through the fill above will be drained to the pipes. The line of drainage will be covered with a layer of broken stone, and the top of pipes will be provided with screens to prevent clogging.

Steel.—Steel ribs shall be imbedded in the concrete of the arches. They shall be spaced at equal distances apart. The design, location, dimensions, and connections of the ribs, also the sections of steel of which they are composed, shall be as shown on the plans.

Steel rods shall be imbedded near the tension side of all members subjected to transverse stress. No reliance will be placed on the adhesion between the steel and the concrete, but our patented rods, specially designed for this purpose, shall be used in all cases. The distance of the center of the rods from the outside of the concrete shall not be less than the diameter of the rods. All steel must be free from paint and oil, and all scale and rust must be removed before imbedding in the concrete.

The tensile strength, limit of elasticity and ductility shall be determined from a test piece cut from the finished material and turned and planed parallel. The area of cross section shall not be less than ½ sq. in.; the elongation shall be measured after breaking on an original length of 8 ins. Each melt shall be tested for tension and bending.

Either soft or medium steel may be used in all concrete steel structures. If soft steel is used it shall have an ultimate strength of from 54,000 to 62,000 lbs. per sq. in., an elastic limit of not less than one-half the ultimate strength, shall elongate not less than 25 per cent in 8 ins. and bend cold 180° flat on itself without fracture on outside of bend. If medium steel is used it shall have an ultimate strength of from 60,000 to 68,000 lbs. per sq. in., an elastic limit of not less than one-half the ultimate strength, shall elongate not less than 22 per cent in 8 ins. and bend cold 180° to a diameter equal to the thickness of the piece tested without fracture on outside of bend. In tension tests the fracture must be entirely silky. The workmanship must be first class.

Casing.—When concrete facing is used all piers, abutments and spandrel walls shall be built in timber forms. These forms shall be substantial and unyielding, of the proper dimensions for the work intended, and all parts in contact with exposed faces of concrete shall be finished to a perfectly smooth surface by plastering or other means, so that no mark or imperfection shall be left on the work.

Concrete Facing.—If concrete facing is used the concrete shall be deposited in smooth molds, and after the molds have been removed the exposed flat surfaces shall be finished in the same manner as specified.

If the arch faces, quoins or other exposed surfaces are marked to represent masonry or other division lines, either straight or curved, are shown in the faces of the arch or spandrels, such division lines shall be made by triangular moldings of wood 2 ins. wide and 1 in. deep, fastened to the casing in true lines as shown on plans. The face of the arch at intrados shall be beveled to correspond, and all angles or intersections of the moldings shall be neatly beveled and fitted in a workmanlike manner to give a smooth finish. Before depositing the concrete the moldings shall be coated in the same manner as specified for artificial stone.

The soffits of the arches shall be floated and finished in the same manner as specified for artificial stone (b).

Other Facing.—If ashlar masonry, boulder, brick, terra cotta, or other facing is used on the work, it will be shown or noted on the drawings, and a specification therefor will be attached.

Centering.—The contractor shall build an unyielding falsework or centering. The lagging shall be dressed to a uniform thickness so that when laid it shall present a smooth surface, or it shall be made smooth by plastering or other efficient means.

In framing the centers allowance shall be made for settlement of centerings, deflection of arch after the removal of centerings and for permanent cambre. The centers shall be framed for a rise of arch greater than the rise marked on drawings by an amount equal to one-eight hundredth part of the span, and shall not be struck until at least 28 days after the completion of the arch, and not until the fill has been put on. Great care shall be used in lowering the centers evenly and uniformly, preferably by means of sand boxes, so as not to throw undue strains upon the arches. The tendency of the centers to rise at the crown as they are loaded at the haunches must be provided for in the design, or, if not, the centers must be temporarily loaded at the crown and the load so regulated as to prevent distortion of the arch as the work progresses.

Water Proofing.—After the completion of the arches and spandrels, and before any fill is put in, the top surface of the arches, piers and abutments and the lower 6 ins. of the inner surface of the spandrel walls shall be coated with a heavy coat of semi-liquid mortar consisting of 1 part cement, ½ part thoroughly slaked lime and 3 parts sand, spread to leave a smooth finish, and after this has set hard it shall be given a heavy coat of pure cement grout.

Fill.—The space between the spandrel walls shall be filled with sand, earth, cinders or other suitable material, thoroughly compacted by ramming or rolling, and be finished to the proper grade to receive the curbing and pavement. The fill over any arch shall not be put in until at least two weeks after the arch concrete has been completed.

SPECIFICATIONS FOR SIDEWALKS.*

Materials.—The cement shall meet the requirements of the specifications for Portland cement of the American Society for Testing Materials and adopted by this association (Standard No. 1) January, 1906.

Aggregates.—Fine aggregate shall consist of sand, crushed stone, or gravel screenings, graded from fine to coarse,

*Standard specifications adopted by the National Association of Cement Users, January, 1908. Revised January, 1909.

passing when dry a screen having ¼-in. diameter holes, shall be preferably of silicious materials, clean, coarse, free from vegetable loam or other deleterious matter, and not more than 6 per cent shall pass a sieve having 100 meshes per linear inch.

Mortars composed of one part Portland cement and three parts fine aggregate by weight when made into briquets shall show a tensile strength of at least 70 per cent of the strength of 1:3 mortar of the same consistency made with the same cement and standard Ottawa sand.

Coarse aggregate shall consist of inert material, graded in size, such as crushed stone or gravel, which is retained on a screen having ¼-in. diameter holes, shall be clean, hard, durable, and free from all deleterious materials. Aggregates containing soft, flat or elongated particles shall be excluded.

The maximum size of the coarse aggregate shall be such that it will not separate from the mortar in laying and will not prevent the concrete fully filling all parts of the forms. The size of the coarse aggregate shall be such as to pass a 1¼-in. ring.

Water shall be clean, free from oil, acid, strong alkalies or vegetable matter.

Forms.—Forms shall be free from warp and of sufficient strength to resist springing out of shape. All mortar and dirt shall be removed from forms that have been previously used.

The forms shall be well staked to the established lines and grades, and their upper edges shall conform with finished grade of the walk, which shall have sufficient rise from the curb to provide proper drainage; but this rise shall not exceed three-eighths (3/8) of an inch per foot, except where such rise shall parallel the length of the walk.

All forms shall be thoroughly wetted before any material is deposited against them.

Size and Thickness of Slabs.—Slabs without reinforcement shall not contain more than 36 square feet or have any dimension greater than 6 feet. For greater area, slabs shall be reinforced with one-quarter (1/4) inch steel rods, not more than nine (9) inches apart, or other reinforcement equally as strong.

The minimum thickness of the pavement shall not be less than four (4) inches.

Sub-Base.—The sub-base shall be thoroughly rammed, and all soft spots removed and replaced by some suitable hard material.

When a fill exceeding one foot in thickness is required, it shall be thoroughly compacted by flooding and tamping in layers of not exceeding six (6) inches in thickness, and shall have a slope of not less than one to one and a half (1:1½).

The top of all fills shall extend at least 12 inches beyond the sidewalk.

While compacting, the sub-base shall be thoroughly wetted and shall be maintained in that condition until the concrete is deposited.

Base.—The concrete for the base shall be so proportioned that the cement shall overfill the voids* in the fine aggregate by at least five (5) per cent, and the mortar shall overfill the voids in the coarse aggregate by at least ten (10) per cent. The proportions shall not exceed one (1) part of cement to eight (8) parts of fine or coarse aggregates.

When the voids are not determined,

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*To determine voids, fill a vessel with sand and let net weight of sand equal B. Fill same vessel with water and let net weight of water equal A.

$$\text{Per cent voids} = \frac{A \times 2.65 - B}{A \times 2.65} \times 100$$

This formula may also be used in determining voids in crushed stone and screenings by substituting for 2.65 the specific gravity of the stone.

The following is a more simple method for determining voids in coarse aggregate. Fill a vessel with the aggregate and let net weight equal B. Add water slowly until it just appears on the surface and weigh. Let net weight equal A. Fill same vessel with water and let net weight equal C.

$$\text{Per cent voids} = \frac{A - B}{C} \times 100$$

Use a vessel of not less than one-half (½) cubic foot capacity. The larger the vessel the more accurate the result.

the concrete shall have the proportions of one (1) part cement, three (3) parts fine aggregates and five (5) parts coarse aggregates. A sack of cement (94 pounds) shall be considered to have a volume of one (1) cubic foot.

Mixing.—The ingredients of concrete shall be thoroughly mixed to the desired consistency, and the mixing shall continue until the cement is uniformly distributed and the mass is uniform in color and homogeneous.

a. **Measuring Proportions.**—Methods of measurement of the proportions of the various ingredients including the water shall be used which will secure separate uniform measurements at all times.

b. **Machine Mixing.**—When the conditions will permit, a machine mixer of a type which insures the proper mixing of the materials throughout the mass shall be used.

c. **Hand Mixing.**—When it is necessary to mix by hand, the mixing shall be on a water-tight platform and the materials shall be turned until they are homogeneous in appearance and color.

d. **Consistency.**—The materials shall be mixed wet enough to produce a concrete of such a consistency as will flush readily under light tamping and which, on the other hand, can be conveyed from the mixer to the forms without separation of the coarse aggregate from the mortar.

e. **Retempering.**—Retempering mortar or concrete—i. e., remixing with water after it has partially set—shall not be permitted.

Placing of Concrete.—a. **Methods.**—After the addition of water the mix shall be handled rapidly to the place of final deposit, and under no circumstances shall concrete be used that has partially set.

b. **Freezing Weather.**—The concrete shall not be mixed or deposited at a freezing temperature unless special precautions are taken to avoid the use of materials containing frost or covered with ice crystals, and in providing means to prevent the concrete from freezing after being placed in position and until it has thoroughly hardened.

Sidewalks shall be laid in such a manner as to insure the protection of the pavement from injury due to changes in foundations or from contraction and expansion.

Workmen shall not be permitted to walk on freshly laid concrete, and where sand or dust collects on the base it shall be carefully removed before the wearing surface is applied.

Wearing Surface.—The wearing course shall have a thickness of at least one (1) inch.

The wearing surface shall be mixed in the same manner as the mortar for the base, the proportion one (1) cement to two (2) of fine aggregate, and it shall be of such consistency as will not require tamping, but will be readily floated with a straight edge.

The wearing surface shall be spread on the base immediately after mixing, and in no case shall more than fifty (50) minutes elapse between the time that the concrete for the base is mixed and the time that the wearing course is floated.

After being worked to an approximately true surface, the slab markings shall be made directly over the joints in the base with a tool which shall cut clear through to the base and completely separate the wearing courses of adjacent slabs.

The slabs shall be rounded on all surface edges to a radius of not less than one-half (½) inch.

When required, the surface shall be troweled smooth.

The application of neat cement to the surface in order to hasten the hardening is prohibited.

On grades exceeding five (5) per cent the surface shall be roughened. This may be done by the use of a grooving tool, toothed roller, brush, wooden float or other suitable tool, or by working coarse sand or screenings into the surface.

Where color is used it shall be incorporated uniformly and the quantity and quality shall be such as to not impair the strength of the wearing surface.

Single Coat Work.—Single coat work shall be composed of one part of cement, two parts of fine aggregate and three parts of coarse aggregate, and the slabs separated as provided for in the specifications for two coat work.

The concrete shall be firmly compacted by tamping and evenly struck off and smoothed to the top of the form. Then with a suitable tool the coarser particles of the concrete shall be tamped to a depth which will permit of finishing the walk as under "Wearing Surface."

Protection and Grading.—When completed, the walk shall be kept moist and protected from traffic and the elements for at least three days.

Grading after the walks are ready for use should be on the curb side of the sidewalk, one and one-half (1½) inches lower than the sidewalk, and not less than one-quarter (¼) inch to the foot fall towards the curb or gutter. On the property side of the walk the ground should be graded back at least two (2) feet and not lower than the walk; this will insure the frost throwing the walk alike on both sides.

Curbs.—The trench shall be excavated to a depth not greater than the bottom of the curb and a width not greater than the thickness of the curb plus six (6) inches.

The thickness of the curb shall not be less than six (6) inches.

After the forms are set about one (1) inch of wearing surface shall be placed on the inside of the curb form, then the concrete shall be deposited at one operation and firmly tamped to within one (1) inch of the top of forms. The top wearing surface shall then be placed and be of the same composition as that specified for sidewalks.

Joints shall be made three-fourths (¾) the depth of the curb, continuous with joints of the sidewalk and in no case more than six (6) feet apart.

The forms shall be removed as soon as practical and the faces finished at one operation, floating down six (6) inches with a one to one mixture of cement and fine aggregate of sufficient thickness to produce a smooth surface.

Where a combination curb and gutter is required, they shall be cast at the same time and finished at one operation.

SPECIFICATIONS FOR HOLLOW BUILDING BLOCKS.*

Regulations Governing Use and Manufacture.—Hollow cement blocks made in accordance with the following specifications and meeting the requirements thereof may be used in building construction, subject to the usual form of approval, required of other materials of construction, by the bureau of building inspection.

The cement used in making blocks shall be Portland cement, capable of passing the requirements as set forth in the "Standard Specifications for Cement," of the American Society for Testing Materials, and adopted by this association (Standard No. 1) January, 1906.

The sand used shall be suitable siliceous material, passing the one-fourth inch mesh sieve, clean, gritty and free from impurities.

This material shall be clean broken stone, free from dust, or clean screened gravel passing the three-quarter (¾) inch, and refused by the one-quarter (¼) inch, mesh sieve.

The barrel of Portland cement shall weigh 380 pounds net, either in barrels or sub-divisions thereof, made up of cloth

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*Standard specifications adopted by the National Cement Users Association, January, 1908. Revised January, 1909.

or paper bags, and a cubic foot of cement shall be called not to exceed 100 pounds or the equivalent of 3.8 cubic feet per barrel. Cement shall be gauged or measured either in the original package as received from the manufacturer or may be weighed and so proportioned; but under no circumstances shall it be measured loose in bulk.

For exposed exterior or bearing walls.

(a) Hollow cement blocks, machine made, using semi-wet concrete or mortar, shall contain one (1) part cement, not to exceed three (3) parts sand and not to exceed four (4) parts stone of the character and size before stipulated. When the stone shall be omitted the proportions of sand shall not be increased, unless it can be demonstrated that the percentage of voids and tests of absorption and strength allow in each case of greater proportions with equally good results.

(b) When said blocks are made of slush concrete, in individual molds, and allowed to harden undisturbed in same before removal, the proportions may be one (1) part cement, not to exceed three (3) parts sand and five (5) parts stone, but in this case also, if the stone be omitted the proportion of sand shall not be increased.

Thorough and vigorous mixing is of the utmost importance.

(a) **Hand Mixing.**—The cement and sand in correct proportions shall first be perfectly mixed dry, the water shall then be added carefully and slowly in proper proportions and thoroughly worked into and throughout the resultant mortar; the moistened gravel or broken stone shall then be added, either by spreading the same uniformly over the mortar or spreading the mortar uniformly over the stones, and then the whole mass shall be vigorously mixed together until the coarse aggregate is thoroughly incorporated with and distributed throughout the mortar.

(b) **Machine Mixing.**—Preference shall be given to machine mixers of suitable design and adapted to the particular work required of them; the sand and cement or sand and cement and moistened stone shall, however, be first thoroughly mixed before the addition of water, and then continued until the water is uniformly distributed or incorporated with the mortar or concrete; provided, however, that when making slush or wet concrete (such as will quake or flow) this procedure may be varied with the consent of the bureau of building inspection, architect or engineer in charge.

Due care shall be used to secure density and uniformity in the blocks by tamping or other suitable means of compression. Tamped blocks shall not be finished by simply striking off with a straight edge, but, after striking off, the top surfaces shall be trowelled or otherwise finished to secure density and a sharp and true arris.

Every precaution shall be taken to prevent the drying out of the blocks during their initial set and first hardening. A sufficiency of water shall first be used in the mixing to perfect the crystallization of the cement, and, after molding, the blocks shall be carefully protected from wind currents, sunlight, dry heat or freezing for at least five (5) days, during which time additional moisture shall be supplied by approved methods, and occasionally thereafter until ready for use.

Hollow cement blocks in which the ratio of cement to sand be one-third (1/3) (one part cement to three parts sand) shall not be used in the construction of any building until they have attained the age of not less than three (3) weeks.

Hollow cement blocks in which the ratio of cement to sand be one-half (1/2) (one part cement to two parts sand) may be used in construction at the age of two (2) weeks, with the special consent of the bureau of building inspection and the architect or engineer in charge.

Special blocks of rich composition, required for closures, may be used at the age of seven (7) days with the special consent of the same authorities.

The time herein named is conditional, however, upon maintaining proper conditions of exposure during the curing period.

All cement blocks shall be marked, for purposes of identification, showing name of manufacturer or brand, date (day, month and year) made, and composition or proportions used, as, for example, 1—3—5, meaning one cement, three sand and five stone.

The thickness of bearing walls for any building where hollow cement blocks are used may be ten (10) per cent less than is required by law for brick walls. For curtain walls or partition walls, the requirements shall be the same as in the use of hollow tile, terra cotta or plaster blocks.

Hollow cement blocks shall not be permitted in the construction of party walls, except when filled solid.

Where the face only is of hollow cement block and the backing is of brick, the facing of hollow block must be strongly bonded to the brick, either with headers projecting four (4) inches into the brick work, every fourth course being a header course, or with approved ties, no brick backing to be less than eight (8) inches. Where the walls are made entirely of concrete blocks, but where said blocks have not the same width as the wall, every fifth course shall extend through the wall, forming a secure bond, when not otherwise sufficiently bonded. All walls, where blocks are used, shall be laid up with Portland cement mortar.

Wherever girders or joists rest upon walls so that there is a concentrated load on the block of over two (2) tons, the blocks supporting the girder or joists must be made solid for at least eight (8) inches from the inside face. Where such concentrated load shall exceed five (5) tons, the blocks for at least three courses below and for a distance extending at least eighteen (18) inches each side of said girder, shall be made solid for at least eight (8) inches from the inside face. Wherever walls are decreased in thickness, the top course of the thicker wall shall afford a full solid bearing for the webs or walls of the course of blocks above.

No wall nor any part thereof composed of hollow cement blocks shall be loaded to an excess of eight (8) tons per superficial foot of the area of such blocks, including the weight of the wall, and no blocks shall be used in bearing walls that have an average crushing strength of less than 1,000 lbs. per square inch of area at the age of twenty-eight (28) days; no deduction to be made in figuring the area for the hollow spaces.

Concrete sills and lintels shall be reinforced by iron or steel rods in a manner satisfactory to the bureau of building inspection and the architect or engineer in charge, and any lintels spanning over 4 feet 6 inches shall rest on block solid for at least 8 inches from the face next the opening and for at least three courses below the bottom of the lintel.

The hollow space in building blocks used in bearing walls shall not exceed the percentage given in the following table of different height walls, except where blocks containing a greater percentage shall be proven by actual test to meet all the test requirements herein specified to the satisfaction of the bureau of building inspection, and in no case shall the walls or webs of the block be less in thickness than one-fourth their height. The figures given in the table represent the percentage of such hollow space for different height walls:

Stories	1st	2d	3d	4th	5th	6th
1 and 2	33	33				
3 and 4	25	33	33	33		
5 and 6	20	25	25	33	33	33

Before any such material be used in buildings, an application for its use and for a test of the same must be filed with the bureau of building inspection. In the absence of such a bureau, the application shall be filed with the chief of any department having such matters in charge. A description of the material and a brief outline of its manufacture and proportions used must be embodied in the application. The name of the firm or corporation and the responsible officers thereof shall also be given, and changes in same thereafter promptly reported.

No hollow cement blocks shall be used in the construction of any building unless the maker of said blocks has submitted his product to the full tests required herein, and placed on file with the bureau of building inspection or other duly authorized official a certificate from a reliable testing laboratory showing that representative samples have been tested and successfully passed all the requirements hereof, and giving in detail the results of the tests made.

No cement blocks shall be used in the construction of any building until they have been inspected and approved, or, if required, until representative samples be tested and found satisfactory. The results of all tests made, whether satisfactory or not, shall be placed on file in the bureau of building inspection. These records shall be open to inspection upon application, but need not necessarily be published.

The manufacturer and user of such hollow cement blocks, or either of them, shall at any and all times have made such tests of the cements used in making such blocks or such further tests of the completed blocks or of each of these, at their own expense and under the supervision of the bureau of building inspection, as the chief of said bureau shall require.

In case the result of tests made under this condition should show that the standard of these regulations is not maintained, the certificate of approval issued to the manufacturer of said blocks will at once be suspended or revoked.

Following the application called for in clause No. 18 and upon the satisfactory conclusion of the tests called for, a certificate of approval shall be issued to the maker of the blocks by the bureau of building inspection. This certificate of approval will not remain in force for more than four months, unless there be filed with the bureau of building inspection, at least once every four months following, a certificate from some reliable physical testing laboratory showing that the average of at least three (3) specimens tested for compression and at least three (3) specimens tested for transverse strength comply with the requirements herein set forth, the said samples to be selected by a building inspector or by the laboratory from blocks actually going into construction work.

Hollow cement blocks must be subjected to the following tests, transverse, compression and absorption, and may be subjected to the freezing and fire tests, but the expense of conducting the freezing and fire tests will not be imposed upon the manufacturer of said blocks.

The test samples must represent the ordinary commercial product, of the regular size and shape used in construction. The samples may be tested as soon as desired by the applicant, but in no case later than sixty days after manufacture.

Transverse Test.—The modulus of rupture for concrete blocks at twenty-eight days must average 150, and must not fall below 100 in any case.

Compression Test.—The ultimate compressive strength at twenty-eight days must average one thousand (1,000) pounds per square inch, and must not fall below 700 in any case.

Absorption Test.—The percentage of absorption (being the weight of water absorbed divided by the weight of the dry sample) must not average higher than 15 per cent, and must not exceed 22 per cent in any case.

Any and all blocks, samples of which, on being tested under the direction of the bureau of building inspection, fail to stand at twenty-eight (28) days the tests required by this regulation shall be marked "condemned" by the manufacturer or user and shall be destroyed.

Cement brick may be used as a substitute for clay brick. They shall be made of one part cement to not exceeding four parts clean sharp sand, or one part cement to not exceeding three parts clean sharp sand and three parts broken stone or gravel passing the ½-inch and refused by the ¼-inch mesh sieve. In all other respects cement brick must conform to the requirements of the foregoing specifications.

Standard Method of Testing.—1. All tests required for approval shall be made in some laboratory of recognized standing, under the supervision of the engineer of the bureau of building inspection or the architect or engineer in charge, or all of these. The manufacturer may be present or represented during said tests, if he so desires. Approval tests are made at the expense of the applicant.

2. For the purposes of the tests, at least twelve (12) samples or test pieces must be provided. Such samples must represent the ordinary commercial product and may be selected from stock by the bureau of building inspection or, in the absence of such a bureau, by the architect or engineer in charge.

In cases where the material is made

and used in special shapes or forms, too large for testing in the ordinary machines, smaller sized specimens shall be used as may be directed.

3. In addition to the tests required for approval, the weight per cubic foot of the material must also be obtained and recorded.

4. Tests shall be made in series of at least three (3), except that in the fire tests a series of two (four samples) are sufficient.

Transverse tests shall be made on full sized samples. Half samples may be used for the crushing, freezing and fire tests. The remaining samples are kept in reserve, in case duplicate or confirmatory tests be required. All samples must be marked for identification and comparison.

5. The transverse test shall be made as follows: The samples shall be placed flatwise on two rounded knife edge bearings set parallel 7 inches apart. A load is then applied on top, midway between the supports, and transmitted through a similar rounded knife edge, until the sample is ruptured. The modulus of rupture shall then be determined by multiplying the total breaking load in pounds by 21 (three times the distance between supports in inches) and then dividing the result thus obtained by twice

the product of the width in inches by the square of the depth in inches. $R = \frac{3wl}{2bd^2}$ No allowance should be made in figuring the modulus of rupture for the hollow spaces.

6. The compression test shall be made as follows: Samples must be cut from blocks, so as to contain a full web section. The sample must be carefully measured, then bedded flatwise in plaster of Paris, to secure a uniform bearing in the testing machine, and crushed. The total breaking load is then divided by the area in compression in square inches, no deduction to be made for hollow spaces; the area will be considered as the product of the width by the length.

7. The absorption test shall be made as follows: The sample is first thoroughly dried to a constant weight, at not to exceed 212° F. The weight must be carefully recorded. It is then placed in a pan or tray of water, face downward, immersing it to a depth of not less than 2 inches. It is again carefully weighed at the following periods: Thirty minutes, four hours, and forty-eight hours, respectively, from the time of immersion, being replaced in the water in each case as soon as the weight is taken. Its comprehensive strength, while still wet, is then determined at the end of the forty-

eight hours' period, in the manner specified in Section 6.

8. The freezing test shall be made as follows: The sample is immersed, as described in Section 7, for at least four hours, and then weighed. It is then placed in a freezing mixture or a refrigerator, or otherwise subjected to a temperature of less than 15° F. for at least twelve hours. It is then removed and placed in water, where it must remain for at least one hour, the temperature of which is at least 150° F. This operation is repeated ten (10) times, after which the sample is again weighed while still wet from the last thawing. Its crushing strength should then be determined, as called for in Section 6.

9. The fire test is made as follows: Two samples are placed in a cold furnace in which the temperature is gradually raised to 1700° F. The test piece must be subjected to this temperature for at least thirty minutes. One of the samples is then plunged in cold water (about 50° to 60° F.) and the results noted. The second sample is permitted to cool gradually in air, and the result noted.

10. The following requirements must be met to secure an acceptance of the materials: The modulus of rupture for concrete blocks at twenty-eight days must average 150, and must not fall be-

low 100 in any case. The ultimate compressive strength at twenty-eight days must average 1,000 pounds per square inch, and must not fall below 700 in any case. The percentage of absorption (being the weight of water absorbed divided by the weight of the dry sample) must not average higher than 15 per cent and must not exceed 22 per cent in any case. The reduction of compressive strength must not be more than 33⅓ per cent, except that when the lower figure is still above 1,000 pounds per square inch the loss in strength may be neglected. The freezing and thawing process must not cause a loss in weight greater than 10 per cent nor a loss in strength of more than 33⅓ per cent, except that when the lower figure is still above 1,000 pounds per square inch, the loss in strength may be neglected. The fire test must not cause the material to disintegrate.

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