

CHAPTER III

SPECIFICATIONS

In the following pages are given specifications for

- Cement, in brief, for the small purchaser. (See p. 29.)
- Portland cement, in full, for the large purchaser. (See p. 29.)
- Natural cement, in full, for the large purchaser. (See p. 31.)
- Concrete and Reinforced Concrete. (See p. 32.)
- First class steel for reinforced concrete. (See p. 38.)

These specifications cover all ordinary concrete construction, and are adapted as far as possible for direct use in placing contracts for material and construction, although concrete specifications for structures of intricate design will require the insertion of additional paragraphs referring specifically to the particular work.

If sand, screenings, gravel, stone, or steel are purchased on separate contracts, paragraphs 3, 4, 5, or 7 (pp. 33 and 34) may be extracted from the concrete specifications.

The full specifications for cement are advised for important work, whether large or small, although the brief specifications which precede them may be sometimes useful.

Even when purchasing by the full specifications it may often be unnecessary actually to test the cement, except for set soundness and fineness, but the strict detail specifications are necessary so that if the cement is found to work unsatisfactorily samples may be subjected to complete tests on the ground, or sent to testing laboratories, and the remainder of the shipment or subsequent shipments rejected.

Printed specifications are frequently preceded by a "Notice to Contractors" stating the place and time of receiving bids, the amount of the check to be deposited with each bid and the bond required, and specifying that the contractor shall give references and shall state what work of a similar character he has performed. A "Form of Bid" is also sometimes inserted.

The specifications and contract are based upon the authors' practice supplemented by a careful study of the reports of the Joint Committee on Concrete and Reinforced Concrete, the Reinforced Concrete Committee of the National Cement Users Association and the specifications of the American Society for Testing Materials, of the American Railway Engineering & Maintenance-of-Way Association, of the City of Philadelphia, of the

United States Army, of the United States Navy, of the Massachusetts Metropolitan Commissions, of the New York Rapid Transit Commission, and others.

BRIEF SPECIFICATIONS FOR PURCHASE OF CEMENT

The cement shall be a first-class Portland† cement of a standard brand bearing a good reputation. It shall conform to the standard specifications of the American Society for Testing Materials. It shall be free from lumps and shall be packed in sound barrels.‡

FULL SPECIFICATIONS FOR PURCHASE OF PORTLAND CEMENT

1. **Packages.** Cement shall be packed in strong cloth or canvas sacks.§ Each package shall have printed upon it the brand and name of the manufacturer. Packages received in broken or damaged condition may be rejected or accepted as fractional packages.
2. **Weight.** Four bags shall constitute a barrel, and the average net weight of the cement contained in one bag shall be not less than 94 lb. or 376 lb. net per barrel. A cement bag may be assumed to weigh one pound. The weights of the separate packages shall be uniform.
3. **Requirements.*** Cement failing to meet the seven-day requirements may be held awaiting the results of the twenty-eight-day tests before rejection.
4. **Tests.*** 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. (See Chapter VII, page 63.)
5. **Sampling.** Samples shall be taken at random from sound packages, one from every 10 barrels or 40 bags, and mixed. The total sample should weigh about 10 lb.
- 6.* The acceptance or rejection shall be based on the following requirements:
7. **Definition of Portland Cement.*** 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% has been made subsequent to calcination.

*Paragraphs designated by an asterisk are quoted from the Standard Specifications of the American Society for Testing Materials.

†Or Natural.

‡If stored in a dry place to be used immediately, it may be packed in stout cloth or canvas bags which are of course cheaper than barrels.

§If the cement is to be stored in a damp place or near the sea, it must be packed in well-made wooden barrels lined with paper.

¶Clayey.

¶¶Consisting chiefly of lime or calcium.

8. **Specific Gravity.*** The specific gravity of the cement, ignited at a low red heat, shall be not less than 3.10, and the cement shall not show a loss on ignition of more than 4%.

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

10. **Time of Setting.*** It shall not develop initial set in less than thirty minutes, and must develop hard set in not less than one hour nor more than ten hours.

11. **Tensile Strength.†** Briquettes one inch square in section shall attain at least the following tensile strengths and shall show no retrogression within the periods specified.

Neat Cement.		Strength†
Age		
24 hours in moist air	.....	175 lb.
7 days (1 day in air, 6 days in water)	.....	500 "
28 days (1 " " 27 " " )	.....	600 "

One Part Cement, Three Parts Standard Sand.		Strength†
Age		
7 days (1 day in moist air, 6 days in water)	.....	150 lb.
28 days (1 " " " 27 " " )	.....	200 "

12. **Soundness or Constancy of Volume.*** Pats of neat cement about three inches in diameter, one-half inch thick at the center, and tapering to a thin edge, shall be kept in moist air for a period of twenty-four hours.

- A pat is then kept in air at normal temperature, and observed at intervals for at least 28 days.
- Another pat is kept in water maintained as near 70° Fahr. as practicable, and observed at intervals for at least 28 days.
- A third pat is exposed in any convenient way in an atmosphere of steam, above boiling water, in a loosely closed vessel for five hours.

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

13. **Sulphuric Acid and Magnesia.** The cement shall not contain more than 1.75% of anhydrous sulphuric acid (SO₃), nor more than 4% of Magnesia (MgO).

*Paragraphs designated by an asterisk are quoted from the Standard Specifications of the American Society for Testing Materials.

†The American Society for Testing Materials gives minimum requirements as follows: Neat Cement—24 hours, 150-200 lb., 7 days, 450-550 lb.; 28 days, 550-650 lb. 1:3 mortar—7 days, 150-200 lb., 28 days, 200-300 lb.; the exact values to be fixed in each case by the consumer. If no minimum strength is specified the mean of these values is to be taken as the minimum strength required.

FULL SPECIFICATIONS FOR THE PURCHASE OF NATURAL CEMENT

1. **Packages.** Cement shall be packed in strong cloth or canvas sacks.† Each package shall have printed upon it the brand or the name of the manufacturer. Packages received in broken or damaged condition may be rejected or accepted as fractional packages.

2. **Weight.** Three bags shall constitute a barrel, and the average net weight of the cement contained in one bag shall be not less than 94 lb., or 282 lb. net per barrel. A cement bag may be assumed to weigh one pound. The weights of the separate packages shall be uniform.

3. **Requirements.*** Cement failing to meet the seven-day requirements may be held awaiting the results of the twenty-eight day tests before rejection.

4. **Tests.*** 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. (See Chapter VII, p. 63.)

5. **Sampling.** Samples shall be taken at random from sound packages, and the cement from each package shall be tested separately.

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

7. **Definition of Natural Cement.*** This term shall be applied 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.

8. **Fineness.*** It shall leave by weight a residue of not more than 10% on the No. 100, and 30% on the No. 200 sieve.

9. **Time of Setting.*** It shall not develop initial set in less than ten minutes, and shall not develop hard set in less than thirty minutes, or in more than three hours.

10. **Tensile Strength.** Briquettes one inch square in section shall attain at least the following tensile strength and shall show no retrogression within the periods specified:

*Paragraphs designated by an asterisk are quoted from the Standard Specifications of the American Society for Testing Materials.

†If the cement is to be stored in a damp place or near the sea, it must be packed in well-made wooden barrels lined with paper.

<i>Neat Cement.</i>		Strength†
Age		
24 hours in moist air.....		50 lb.
7 days (1 day in air, 6 days in water).....		100 "
28 days (1 " " 27 " ").....		200 "

<i>One Part Cement, Three Parts Standard Sand.</i>		Strength†
Age		
7 days (1 day in air, 6 days in water).....		25 lb.
28 days (1 " " 27 " ").....		75 "

II. **Constancy of Volume.*** Pats of neat cement about 3 inches in diameter, one-half inch 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.
- (b) Another pat is kept in water maintained as near 70° Fahr. as practicable.

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.

CONTRACT AND SPECIFICATIONS FOR PORTLAND CEMENT CONCRETE†

(These specifications essentially embody the recommendations of the Joint Committee on Concrete and Reinforced Concrete (1909) and the Report of the Reinforced Concrete Committee (1909) of the National Association of Cement Users.)

This agreement made this..... day of..... in the year 19.....
 by and between..... (Name of party letting the contract.) of.....,
 party of the first part, and..... (Name of accepted contractor.) of.....,
 party of the second part.

Witnesseth: That the parties to these presents, each in consideration of the covenants and agreements on the part of the other, herein contained, have covenanted and agreed, and do hereby covenant and agree, for themselves and their heirs, executors, administrators, and assigns, and under the

*Paragraphs designated by an asterisk are quoted from the Standard Specifications of the American Society for Testing Materials.
 †The American Society for Testing Materials gives minimum requirements as follows: Neat Cement — 24 hours, 50-100 lb., 7 days, 100-200 lb., 28 days, 200-300 lb. 1:3 mortar — 7 days, 25-75 lb., 28 days, 75-150 lb., the exact values to be fixed in each case by the consumer.
 ‡For Natural cement concrete paragraphs 1, 11 and 14 must be slightly altered, and paragraphs 7 and 13c omitted.

penalty expressed in a bond bearing even date with these presents, and hereto annexed, as follows:

The contractor shall begin work within..... days of the date of this contract, and shall, at his own proper cost and expense, provide and deliver all of the materials and perform all of the work called for by these specifications, and supply all implements, apparatus, and appliances needed in performing the work.

The entire work shall be completed on or before..... 19.....*

1. **Cement.†** The cement shall be first-class Portland cement of reputable brand which shall conform in all respects to the cement specifications herewith annexed. The cement shall be stored in a building which will protect it from the weather. The floor upon which the cement is placed shall be at least 6 inches above the ground. It shall be stored so as to permit of easy access for inspection and identification of each shipment. A sufficient quantity shall be kept on hand at all times so that the Engineer may have opportunity and time to make tests sufficient to determine its quality. At least 12 days shall be allowed for inspection and necessary tests.

2. **Fine Aggregates.** The fine aggregate shall consist of sand, crushed stone or gravel screenings passing when dry a screen having ¼ inch diameter holes or a screen having four meshes to the linear inch. It shall be clean, coarse, and free from vegetable loam and other deleterious matter. A gradation of the size of grain is preferred. 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% of the strength of 1:3 mortar of the same consistency made with the same cement and standard Ottawa sand. To avoid the removal of any coating on the grains which may affect the strength, bank sands shall not be dried before being made into mortar but shall contain natural moisture. The percentage of moisture may be determined upon a separate sample for correcting weight. From 10 to 40% more water may be required in mixing bank or artificial sands than for standard Ottawa sand to produce the same consistency.

*A premium and forfeiture clause may here be inserted, but a forfeiture clause without a premium in many cases cannot be legally enforced. The word "penalty" should never be employed.
 †It is often advisable that the cement be furnished by the party letting the contract or, to prevent waste of cement, that it be sold by them to the contractor at an arbitrary price per barrel,—say, about one-half the actual cost of the cement,—which price must be definitely stated in the contract.

3. **Coarse Aggregates.** The coarse aggregate shall consist of inert material such as crushed stone, or gravel, which is retained on a screen having $\frac{1}{4}$ inch diameter holes. The particles shall be clean, hard, durable, and free from all deleterious material. Aggregates containing soft, flat, or elongated particles, should be excluded from reinforced concrete. A gradation of sizes of the particles is advantageous. 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 size of the coarse aggregate may be such as to pass a 3 inch ring. For reinforced concrete a size to pass a 1 inch ring or a smaller size may be used.

4. **Gravel.*** The gravel shall be composed of clean pebbles free from sticks and other foreign matter and containing no clay or other material adhering to the pebbles in such quantity that it cannot be lightly brushed off with the hand or removed by dipping in water. It shall be screened† to remove the sand, which shall afterwards be remixed with it in the required proportions.

5. **Broken Stone.*** The broken or crushed stone shall consist of pieces of hard and durable rock, such as trap, limestone, granite, or conglomerate. The dust shall be removed by a sand screen, to be afterwards, if desired, mixed with and used as a part of the sand, except that if the product of the crusher is delivered to the mixer so regularly that the amount of dust, as determined by frequently screening samples, is uniform, the screening may be omitted and the average percentage of dust allowed for in measuring the sand.

6. **Water.** The water shall be free from oil, acid, strong alkalies, or vegetable matter.

7. **Reinforcing Steel.*‡** Steel for reinforcement shall have an "ultimate tensile strength of 55,000 to 65,000 pounds per square inch, an elastic limit of not less than one-half the ultimate strength (*i. e.* not less than 27,000 lb.) and a minimum elongation in 8 inches of 1,400,000 divided by the ulti-

*Omit paragraphs for materials which are not used. If two or more sizes of any aggregate are used, define them.

†In exceptional cases where the relation of pebbles to sand is very uniform, the mixture of sand and pebbles may be used without screening. Frequent tests shall then be made to see that the proportions of the coarse and fine grains are correct.

‡Specifications for high carbon steel are given in full on page 38. High carbon steel is distrusted by many, but may be safely employed if it fulfills the requirements there given, and owing to its greater strength will be more economical than ordinary merchant steel.

mate strength per cent."* The fracture shall be silky. Test specimens for bending shall be bent cold to 180° flat without fracture.

8. **Proportions.** The proportions of the raw materials for the concrete shall be exactly determined from time to time by the Engineer in accordance with the relative coarseness of the aggregate, so as to attain as dense a concrete as is consistent with the terms of the specifications which follow. The unit of measure shall be the barrel, which shall be taken as containing 3.8 cubic feet. Four bags containing 94 pounds of cement each shall be considered the equivalent of one barrel. The following paragraphs designate the average relative volumes of material for each class of work.

For‡, one barrel (376 lb.) cement to cubic feet sand§ to cubic feet broken stone,‡ the cement to be measured as packed by the manufacturer, and the fine and coarse aggregate to be measured separately as loosely thrown into the measuring receptacle. If the coarse aggregate contains sand or other fine material, that which passes a sieve with $\frac{1}{4}$ inch round holes shall be considered as sand in measuring proportions. In general, the concrete on the work shall contain enough and only enough mortar to cover all particles of stone and fill the voids without an appreciable excess of mortar.

9. **Hand Mixing.§** If the concrete is mixed by hand, the cement and aggregate shall be mixed and the water added on a tight platform large enough to provide space for the partially simultaneous mixing of two batches of not more than one cubic yard each. The sand and cement shall be spread in thin layers and mixed dry until of uniform color. This mixture may be spread upon the layer of stone or the stone shoveled upon it before adding the water, or it may be made into a mortar before spreading it with the stone. In the former method the materials shall be turned at least three times,—in addition to the mixing of the sand and cement already mentioned, the water being added on the first turning,—and in addition to the shoveling from the platform to place or into the vehicle for transportation. In the latter method, that is, if the sand and cement are first made into a mortar, the mass of mortar and stone shall be turned at least twice. Whatever method is employed, the number of turnings shall be sufficient to produce a resulting loose concrete of uniform color and

*Suggested for structural steel by the Committee on Boston Building Laws of the Boston Society of Civil Engineers.

‡Insert a description of portion of structure. Repeat paragraph as required.

§If other materials are selected for the aggregate alter the wording accordingly.

§With an experienced contractor this paragraph may be abbreviated to substantially the form of the final sentence.

appearance, with the cement uniformly distributed through the mass, the stones thoroughly incorporated into the mortar and the consistency uniform throughout, thus producing a concrete uniform in color and homogeneous.

10. **Machine Mixing.*** If the concrete is mixed in a machine mixer a machine shall be selected into which the materials, including the water, can be precisely and regularly proportioned, and which will produce a concrete of uniform consistency and color with the stones and water thoroughly mixed and incorporated with the mortar.

11. **Consistency.** (a) A medium or quaking mixture of a tenacious, jelly-like consistency, which quakes on ramming, shall be used for ordinary mass concrete, such as foundations, heavy walls, large arches, piers, and abutments.

(b) Wet or mushy concrete, so soft that it will flow when agitated, but not so wet as to produce a separation of the materials in transferring to the work, shall be used for rubble concrete, and for reinforced concrete, such as thin building walls, columns, doors, conduits, and tanks.

12. **Placing Concrete.** Concrete shall be conveyed to place in such a manner that there shall be no distinct separation of the different ingredients, or, in cases where such separation inadvertently occurs, the concrete shall be remixed before placing. It 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 shall be placed until the reinforcing steel has been placed and firmly secured by wiring or other methods to prevent displacement. Concrete shall be frequently wet for several days to prevent too rapid drying out. Concrete shall 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. This usually can be accomplished in still water by placing the concrete through a large pipe or tube, or in large work by means of a bottom dump concrete bucket.

Before placing fresh concrete, all shavings and debris of every nature must be removed and the old concrete surface thoroughly cleaned from all dirt and scum or laitance and drenched with water.† Noticeable voids or stone pockets discovered when the forms are removed shall be filled

*Mixing by machine is preferred because the most thorough and uniform consistency can be thus obtained.

†Tanks and other structures having thin walls to resist water pressure should be built preferably as monoliths, that is, with no interruption in the work, proceeding, if necessary, night and day.

immediately with mortar mixed in the same proportions as the mortar in the concrete. The lines and grades of the completed concrete shall accurately conform to the plan annexed to and forming a part of these specifications.

13. **Placing Reinforcement.** The reinforcement shall accurately conform in the finished structure to the plans annexed to and forming a part of these specifications. All reinforcement shall be free from rust, scale or coating of any character which would tend to reduce or destroy the bond. Before placing concrete the reinforcement must be placed in the position required in the finished structure, and each piece or member so firmly fixed as to positively prevent any subsequent displacement.

14. **Freezing Weather.*** Concrete for reinforced concrete structures shall not be mixed or deposited at a freezing temperature, unless special precautions are taken to avoid the use of materials containing frost and to provide means for preventing the concrete from freezing after being placed in position and until it has thoroughly hardened.

15. **Forms.** The lumber for the forms and the design of the forms shall be adapted to the structure and to the kind of surface required on the concrete. For exposed faces the surface next to the concrete shall be dressed. Forms shall be substantially built and secured to prevent movement or deflection during concreting, and tight to prevent leakage of mortar. Before the removal of forms, the concrete shall be carefully inspected and its strength ascertained. Much care shall be given to this portion of the work, which is fraught with danger under incompetent direction. No exact time for the removal of forms can be safely prescribed because of the varying character of the work, the variations in the setting of different cements and the influence of atmospheric conditions. Forms shall be thoroughly cleaned before being used again.

16. **Joints.** Temperature changes and shrinkage during setting necessitate joints at frequent intervals or else effective reinforcement, depending upon the range in temperature and the design of the structure. In massive work, such as retaining walls, abutments, etc., built without reinforcement, joints shall be provided approximately every 30 feet throughout the length of the structure. Girders shall never be constructed over freshly formed columns without allowing a period of at least two hours to elapse to permit settlement in the columns. Before resuming work the top of the column shall be thoroughly cleansed of foreign matter and laitance. To obtain tight joints between old and new concrete the old surface shall be roughened,

*Natural cement concrete must never be exposed to frost until thoroughly hard and dry.

thoroughly cleaned of all foreign material and laitance or scum, drenched, and slushed with neat cement or a mortar not leaner than one part Portland cement to two parts fine aggregate. Joints in reinforced concrete shall be avoided when possible by casting the entire structure at one operation. In building construction, joints may be made in the columns flush with the lower side of the girders, and joints in members of a floor system in general shall be made at or near the center of the span. In all cases joints shall be at right angles to their surfaces.

17a.* **Ordinary Surface.** Surfaces shall have no special treatment further than care in placing the concrete to avoid noticeable voids or stone pockets. Forms shall be wet (except in freezing weather) before placing the concrete against them.

17b.* **Exposed Faces.** Faces exposed to view shall be made smooth by thrusting a spade or chisel through the concrete close to the form to force back the large stones and prevent stone pockets. The forms shall be thoroughly wet or greased with crude oil before placing the concrete against them. On removal of the forms, surfaces shall be.....†

17c.* **Mortar Surface.** Moldings, cornices, and other ornaments requiring mortar surface, shall be formed by spreading plastic mortar upon the interior of finely constructed molds, just as the concrete is being laid.

18. **Construction Details.** (Here may be placed descriptive paragraphs referring to special parts of the structure.)

19. **General Requirements.** Imperfect work or materials, or work or materials which may become damaged from any cause before its acceptance, shall be properly replaced to the satisfaction of the Engineer.

Foremen employed by the contractor shall be skilled in concrete mixing, and they shall receive and obey orders from the Engineer.

No claims for extra work shall be allowed unless made in writing previous to its performance and signed by both parties or by their authorized representatives.

In case of disagreement as to the meaning of the terms of the contract or as to the manner of its execution, one arbitrator shall be appointed by each party within one week after notification in writing by either party, and in case these cannot agree, a third arbitrator shall be selected by these two, and the decision of the majority of the arbitrators shall be final and binding on both parties. The cost of this arbitration shall be divided equally between the two parties to this contract.

*Select one or more paragraphs from 17a, 17b and 17c.
†State kind of finish desired, see page 288.

20. **Prices for Work.** The following prices shall be paid to the contractor as full compensation for the furnishing and use of all materials and implements required on the work and for all labor.

(Here shall be inserted all unit prices for all divisions of the work, or the lump sum for the entire work, or the lump sums for different divisions of the work, or for alternate proposals, followed by a paragraph stating the manner and time of payments and the amount withheld each month.)

In witness whereof the parties to these presents have affixed their hands and seals this.....day of....., 19.....

Signed in the presence of(Seal)
.....(Seal)

BOND TO ACCOMPANY THE CONTRACT.*

Know all men by these presents, That we as sureties, are held and firmly bound unto..... in the sum of..... dollars (\$.....), to be paid said....., for which payment, well and truly to be made, we bind ourselves, our heirs, executors and administrators, jointly and severally, firmly by these presents.

The condition of this obligation is such, that if the above bounden heirs, executors, administrators or assigns, shall in all things stand to and abide by, and well and truly keep and perform, the covenants, conditions and agreements in the foregoing contract on his or their part to be kept and performed, at the time and in the manner therein specified, and shall indemnify and save harmless the said..... as therein stipulated, then his obligation shall become and be null and void; otherwise it shall be and remain in full force and virtue.

In witness whereof we hereunto set our hands and seals on this..... day of..... in the year nineteen hundred and(Seal)
.....(Seal)

Signed and sealed in presence of

*Form adopted by Metropolitan Commissioners, Mass.

SPECIFICATIONS FOR FIRST-CLASS STEEL TO BE USED IN REINFORCED CONCRETE.*

1. **Process of Manufacture.** Steel shall be made by the open hearth process.

2. **Chemical Properties.** Steel shall conform to the following limits in chemical composition:

Phosphorus shall not exceed 0.06.

Sulphur shall not exceed 0.06.

Manganese shall not exceed 0.80 or be below 0.40.

3. **Physical Properties.** The steel shall conform to the following physical qualities:

4. **Tensile Tests.** Tensile strength in pounds per square inch shall be not less than 85000
Yield point in pounds per square inch shall be not less than 52500
Elongation per cent. in eight inches shall be not less than 10

5. For material less than five-sixteenths inch ($\frac{5}{16}$ ") and more than three-fourths inch ($\frac{3}{4}$ ") in thickness the following modifications shall be made in the requirements for elongation:

(a) For each increase of one-eighth inch ($\frac{1}{8}$ ") in thickness above three-fourths inch ($\frac{3}{4}$ ") a deduction of one per cent. (1%) shall be made from the specified elongation.

(b) For material from $\frac{1}{4}$ inch to, but not including, $\frac{5}{16}$ inch thick the elongation shall be 8%.

For material from $\frac{3}{16}$ inch to, but not including, $\frac{1}{4}$ inch thick the elongation shall be 7%.

For material from $\frac{1}{8}$ inch to, but not including, $\frac{3}{16}$ inch thick the elongation shall be 6%.

For material less than $\frac{1}{8}$ inch thick the elongation shall be 5%

6. **Bending Test.** Test specimens for bending† shall be bent cold to the following angles without fracture on the outside of the bent portion:

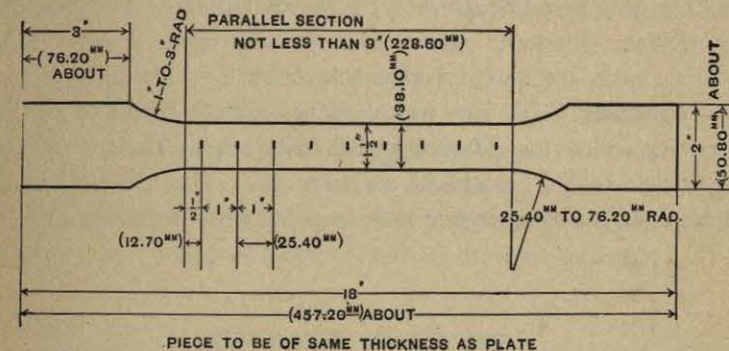
<i>Around twice their own diameter.</i>	<i>Around their own diameter.</i>
For specimens 1 inch thick 80°.	For specimens $\frac{1}{4}$ inch thick 130°.
For specimens $\frac{3}{4}$ inch thick 90°.	For specimens $\frac{3}{16}$ inch thick 140°.
For specimens $\frac{1}{2}$ inch thick 110°.	For specimens $\frac{1}{8}$ inch thick 180°.

*Steel of this hardness should not be used unless enough of it is to be bought to warrant the making of complete tests as per specifications. Ordinary mild steel may be purchased in the open market without specifications. In using steel bought in open market, it is not safe to count on a tensile strength greater than 55,000 lb.—FREDERICK W. TAYLOR.

†The most important test of all is the bending test, but any soft steel will stand the bending test, so that the tensile test is needed to secure a steel which is strong enough.

No steel which fails to pass the bending test shall under any circumstances be used.

7. **Test Pieces and Methods of Testing.** Where practicable the standard test specimen of eight-inch (8") gaged length shall be used to determine the physical properties specified in paragraphs Nos. 4 and 5. The standard shape of the test specimen for sheared plates shall be as shown by the following sketch:



For material from which it is impracticable to obtain test specimens like those for sheared plates, the test specimen may be planed or turned parallel throughout its entire length, and in all cases where possible two opposite sides of the test specimen shall be the rolled surfaces. Small rolled bars of uniform section shall be tested full size as rolled.

8. All test specimens shall be cut from the finished material as it comes from the rolls, unless such materials are to be annealed, in which case the test specimens will be taken after the annealing process. In case several shapes are rolled from one heat, two test specimens will be taken from two different shapes, representing their class, for tension, and two for bending. When only one shape is rolled from a heat, two test specimens for tension and two for bending will be taken from each ten tons or fraction thereof.

9. Where practicable the bending test specimen shall be one and one-half inches ($1\frac{1}{2}$ ") wide, and for material three-quarters inch ($\frac{3}{4}$ ") and less in thickness, this specimen shall have the natural rolled surface on two opposite sides. For material more than three-quarters inch ($\frac{3}{4}$ ") thick, the bending test specimen may be cut to one-half inch ($\frac{1}{2}$ ") thick.

10. The bending test may be made by pressure or by blows.

11. In case a test specimen develops flaws or in case it breaks outside of the middle third of its gaged length, it may be discarded and another test specimen substituted therefor.

12. For the purposes of this specification, the yield point shall be determined by the careful observation of the drop of the beam, or halt in the gage, of the testing machine.

13. In order to determine if the material conforms to the chemical limitations prescribed in paragraph No. 2 herein, analysis shall be made of clean drillings taken from a small test ingot.

14. **Variation in Weight.** A variation in cross section or weight of more than $2\frac{1}{2}\%$ from that specified will be sufficient cause for rejection.

15. **Finish.** Finished material must be free from injurious seams, flaws, or cracks, and have a workmanlike finish.

16. **Annealing.** All bars which, owing to their shape or size, are liable to be under strain after cooling, must be reheated to a temperature not less than 1250° (Fahrenheit) nor more than 1375° , and this heating and subsequent cooling must be done in an approved manner.

CHAPTER IV

THE CHOICE OF CEMENT

When the construction under consideration is not of a grade to warrant the testing of different cements before making a selection, the question often arises as to whether, for example, Portland or Natural cement is most desirable from the standpoint of economy, or whether common lime or a mixture of lime and cement is suitable for the purpose.

Although the decision must often depend upon local conditions, a few general rules may be formulated relating to the classes of construction for which different kinds of cement and lime are adapted, followed by illustrations of the methods for making a selection where there is a choice between two cements and between different brands of the same cement.

THE CLASS OF CEMENT

Portland Cement should be used in concrete and mortar for structures subjected to severe or repeated stresses; for structures requiring strength at short periods of time; for concrete building construction; for work laid under water or with which water will come in contact immediately after placing; for thin walls subjected to water pressure; for masonry exposed to wear or to the elements; and for all other purposes where its cost will be less than that of Natural cement concrete, or mortar of similar quality.

Natural Cement may be substituted for Portland in concrete, if economy demands it, for dry unexposed foundations where the load in compression can never exceed, say, 75 lb. per square inch (5 tons per sq. ft.) and will not be imposed until three months after placing; for backing or filling in massive concrete or stone masonry where weight and mass are the essential elements; for sub-pavements of streets, and for sewer foundations.

In mortar Natural cement is adapted for ordinary brickwork not subjected to high water pressure or to contact with water until, say, one month after laying, and for ordinary stone masonry where the chief requisite is weight and mass.

Natural cement concrete or mortar should never be allowed to freeze, should never be laid under water, in exposed situations, in columns, beams, floors or building walls, or in marine construction.