DEPARTMENT OF COMMERCE

CIRCULAR

OF THE

BUREAU OF STANDARDS

S. W. STRATTON, DIRECTOR

No. 33

UNITED STATES GOVERNMENT SPECIFICATION FOR PORTLAND CEMENT

This specification is the result of several years' work of a Joint Conference representing the United States Government, the American Society of Civil Engineers, and the American Society for Testing Materials. It was adopted by the United States Government and by the American Society for Testing Materials, to become effective January 1, 1917.

[3d Edition]
Issued January 18, 1917

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I. OFFICIAL ADOPTION OF THE UNITED STATES GOVERNMENT SPECIFICATION FOR PORTLAND CEMENT

DEVELOPMENT OF THE UNITED STATES GOVERNMENT SPECIFICATION FOR PORTLAND CEMENT BY GOVERNMENT DEPARTMENTAL CONFERENCE

In June, 1911, the Secretary of the Department of Commerce and Labor arranged, through the Secretaries of the various departments, for a conference of Government engineers for the purpose of unifying the specifications for Portland cement used by the United States Government. At this conference a committee was appointed to consider existing specifications and to recommend a single specification for Portland cement to be used by all departments of the Government. After an extended series of meetings of this committee, at which careful consideration was given to representative specifications for Portland cement as well as to all available data on methods of tests, a specification was adopted by the Departmental Conference February 13, 1912, and made effective, upon the approval of the Secretaries of the several departments by the Executive order of April 30, 1912.

On July 30, 1912, the Departmental Conference was reconvened. Many meetings have been held by the departmental committee and conferences secured with committees of engineering societies resulting after four years of work in agreement on a single standard specification which has been adopted for use by the recognized engineering societies as well as by the Government. It was agreed that the new specification, although an improvement over the old, can not be considered as final, but is subject to revision from time

to time as occasion requires and as improvement is made in the product, in the methods of testing, and in technical knowledge of the material.

EXECUTIVE ORDER

It is hereby ordered that all Portland cement that may hereafter be purchased by any department, bureau, office, or independent establishment of the Government, or that may be used in construction work connected with any of the aforesaid branches of the Government service, shall conform in every respect to the specification for Portland cement adopted by the Departmental Conference at the meeting held at the Bureau of Standards on February 13, 1912, and approved by the heads of the several departments (to be known as the United States Government Specification for Portland Cement): *Provided, however,* That such specification may be modified from time to time by any similar departmental conference, with the approval of the heads of the several departments.

WM. H. TAFT.

THE WHITE HOUSE,
April 30, 1912.

DEPARTMENTAL APPROVALS

The revised specification as contained herein has received the approval of the following departments and independent establishments to become effective January 1, 1917, and to be known as the United States Government Specification for Portland Cement:

Department of State,
Department of the Treasury,
Department of War,
Department of Justice,
Post Office Department,
Department of the Navy,
Department of the Interior,
Department of Agriculture,
Department of Commerce,
Department of Labor,
District of Columbia, and
Capitol Building and Grounds.

PERSONNEL OF THE DEPARTMENTAL CONFERENCE

NAME	REPRESENTING
S. W. Stratton, *Chairman of Conference* Director, Bureau of Standards.	Bureau of Standards, Department of Commerce.
Rudolph J. Wig, *Secretary of Conference* Engineer Physicist, Bureau of Standards.	Bureau of Standards, Department of Commerce.
[1] **Spencer Cosby, Colonel, U. S. Army** Formerly in charge of Public Buildings and Grounds, District of Columbia.	Office of Chief of Engineers, War Department.
[2] **H. C. Newcomer, Colonel, U. S. Army** Corps of Engineers.	Office of Chief of Engineers, War Department.
W. A. E. Doying Inspecting Engineer, Panama Canal.	Panama Canal, War Department.
[1] **B. F. Cheatham, Major, U. S. Army** Quartermaster Corps.	Quartermaster Corps, War Department.
F. B. Wheaton Advisory Architect, Office of Quartermaster General.	Office of the Quartermaster General, War Department.
[2] **E. V. Dunstan** Draftsman.	Office of the Quartermaster General, War Department.
A. P. Davis Director and Chief Engineer, Reclamation Service.	Reclamation Service, Department of Interior.
[1] **H. M. Wilson** Engineer, Bureau of Mines.	Bureau of Mines, Department of Interior.
[1] **A. T. Ruan** Formerly Disbursing Agent, Philippine Revenues, Bureau of Insular Affairs.	Bureau of Insular Affairs, War Department.
[2] **L. H. Camfield** Disbursing Agent, Philippine Revenues, Bureau of Insular Affairs.	Bureau of Insular Affairs, War Department.
[1] **Carl A. Carlson** Civil Engineer, Bureau of Yards and Docks.	Navy Department.
[2] **C. D. Thurber** Civil Engineer, Bureau of Yards and Docks.	Navy Department.
Asa E. Phillips Superintendent of Sewers, District of Columbia.	District of Columbia.
L. G. Randall Assistant Engineer, Sewer Department, District of Columbia.	District of Columbia.
[1] **John S. Conway** Formerly Chief Constructing Engineer, Bureau of Lighthouses.	Bureau of Lighthouses, Department of Commerce.
[2] **H. B. Bowerman** Chief Constructing Engineer, Bureau of Lighthouses.	Bureau of Lighthouses, Department of Commerce.
[1] **James C. Plant** Formerly Superintendent of Computing Division, Office of Supervising Architect.	Office of Supervingis Architect, Treasury Department.
[2] **J. W. Ginder** Superintendent of Computing Division, Office of Supervising Architect.	Office of Supervising Architect, Treasury Department.
[1] **H. C. Heald** Formerly Structural Engineer, Office of Supervising Architect.	Office of Supervising Architect, Treasury Department.
[2] **E. C. Ruebsam** Structural Engineer, Office of Supervising Architect.	Office of Supervising Architect, Treasury Department.
[2] **A. T. Goldbeck** Testing Engineer.	Office of Public Roads and Rural Engineering, Department of Agriculture.

[1] Former members of the Departmental Conference. [2] Members appointed since July 1, 1911.

PERSONNEL OF THE DEPARTMENTAL CONFERENCE—Continued.

NAME.	REPRESENTING.
[1] **W. H. Rose, Captain, U. S. Army** Formerly Director of Mechanical Engineering, Engineers School, Washington Barracks.	Alternate in absence of Col. Spencer Cosby.
[1] **S. S. Hunt, Captain, U. S. Army** Constructor, Office of Superintendent of United States Capitol Building and Grounds.	Office of Superintendent of United States Capitol Building and Grounds.
P. H. Bates Chemist, Bureau of Standards.	Bureau of Standards, Department of Commerce.
S. S. Voorhees Engineer Chemist, Bureau of Standards.	Bureau of Standards, Department of Commerce,

The following departmental committee was appointed by the conference to draft the specification and revision: A. P. Davis, *Chairman;* Rudolph J. Wig, *Secretary;* H. C. Newcomer, J. W. Ginder, C. D. Thurber, Asa E. Phillips, S. S. Voorhees, W. A. E. Doying.

[1] Former members of the Departmental Conference.

II. UNITED STATES GOVERNMENT SPECIFICATION FOR PORTLAND CEMENT

DEFINITION

1. Portland cement is the product obtained by finely pulverizing clinker produced by calcining to incipient fusion, an intimate and properly proportioned mixture of argillaceous and calcareous materials, with no additions subsequent to calcination excepting water and calcined or uncalcined gypsum.

CHEMICAL PROPERTIES

CHEMICAL LIMITS

2. The following limits shall not be exceeded:

	Per cent
Loss on ignition	4.00
Insoluble residue	0.85
Sulphuric anhydride (SO_3)	2.00
Magnesia (MgO)	5.00

PHYSICAL PROPERTIES

SPECIFIC GRAVITY

3. The specific gravity of cement shall be not less than 3.10 (3.07 for white Portland cement). Should the test of cement as received fall below this requirement a second test may be made upon an ignited sample. The specific-gravity test will not be made unless specifically ordered.

FINENESS

4. The residue on a standard No. 200 sieve shall not exceed 22 per cent by weight.[1]

SOUNDNESS

5. A pat of neat cement shall remain firm and hard, and show no signs of distortion, cracking, checking, or disintegration in the steam test for soundness.

TIME OF SETTING

6. The cement shall not develop initial set in less than 45 minutes when the Vicat needle is used or 60 minutes when the Gillmore needle is used. Final set shall be attained within 10 hours.

[1] The United States Government specification requires that on and after July 1, 1918, the residue on the standard No. 200 sieve shall not exceed 20 per cent by weight.

TENSILE STRENGTH

7. The average tensile strength in pounds per square inch of not less than three standard mortar briquettes (see sec. 51) composed of one part cement and three parts standard sand, by weight, shall be equal to or higher than the following:

Age at test	Storage of briquettes	Tensile strength, pounds per square inch
Days		
7	1 day in moist air, 6 days in water	200
28	1 day in moist air, 27 days in water	300

8. The average tensile strength of standard mortar at 28 days shall be higher than the strength at 7 days.

PACKAGES, MARKING, AND STORAGE

PACKAGES AND MARKING

9. The cement shall be delivered in suitable bags or barrels with the brand and name of the manufacturer plainly marked thereon, unless shipped in bulk. A bag shall contain 94 pounds net. A barrel shall contain 376 pounds net.

STORAGE

10. The cement shall be stored in such a manner as to permit easy access for proper inspection and identification of each shipment, and in a suitable weather-tight building which will protect the cement from dampness.

INSPECTION

11. Every facility shall be provided the purchaser for careful sampling and inspection at either the mill or at the site of the work, as may be specified by the purchaser. At least 10 days from the time of sampling shall be allowed for the completion of the 7-day test, and at least 31 days shall be allowed for the completion of the 28-day test. The cement shall be tested in accordance with the methods hereinafter prescribed. The 28-day test shall be waived only when specifically so ordered.

REJECTION

12. The cement may be rejected if it fails to meet any of the requirements of these specifications.

13. Cement shall not be rejected on account of failure to meet the fineness requirement if upon retest after drying at 100° C for one hour it meets this requirement.

14. Cement failing to meet the test for soundness in steam may be accepted if it passes a retest using a new sample at any time within 28 days thereafter.

15. Packages varying more than 5 per cent from the specified weight may be rejected; and if the average weight of packages in any shipment, as shown by weighing 50 packages taken at random is less than that specified, the entire shipment may be rejected.

TESTS

SAMPLING

NUMBER OF SAMPLES

16. Tests may be made on individual or composite samples as may be ordered. Each test sample should weigh at least 8 pounds.

17. (*a*) *Individual Sample.*—If sampled in cars one test sample shall be taken from each 50 barrels or fraction thereof. If sampled in bins one sample shall be taken from each 100 barrels.

(*b*) *Composite Sample.*—If sampled in cars one sample shall be taken from 1 sack in each 40 sacks (or 1 barrel in each 10 barrels) and combined to form one test sample. If sampled in bins or warehouses, one test sample shall represent not more than 200 barrels.

METHOD OF SAMPLING

18. Cement may be sampled at the mill by any of the following methods that may be practicable, as ordered:

(*a*) *From the Conveyor Delivering to the Bin.*—At least 8 pounds of cement shall be taken from approximately each 100 barrels passing over the conveyor.

(*b*) *From Filled Bins by Means of Proper Sampling Tubes.*—Tubes inserted vertically may be used for sampling cement to a maximum depth of 10 feet. Tubes inserted horizontally may be used where the construction of the bin permits. Samples shall be taken from points well distributed over the face of the bin.

(*c*) *From Filled Bins at Points of Discharge.*—Sufficient cement shall be drawn from the discharge openings to obtain samples representative of the cement contained in the bin, as determined by the appearance at the discharge openings of indicators placed on the surface of the cement directly above these openings before drawing of the cement is started.

TREATMENT OF SAMPLES

19. Samples preferably shall be shipped and stored in air-tight containers. Samples shall be passed through a sieve having 20 meshes per linear inch in order to thoroughly mix the sample, break up lumps, and remove foreign materials.

CHEMICAL ANALYSIS

LOSS ON IGNITION

20. METHOD.—One gram of cement shall be heated in a weighed covered platinum crucible of 20 to 25 cc capacity, as follows, using either method (*a*) or (*b*) as ordered:

(*a*) The crucible shall be placed in a hole in an asbestos board, clamped horizontally so that about three-fifths of the crucible projects below and blasted at a full red heat for 15 minutes with an inclined flame; the loss in weight shall be checked by a second blasting for 5 minutes. Care shall be taken to wipe off particles of asbestos that may adhere to the crucible when withdrawn from the hole in the board. Greater neatness and shortening of the time of heating are secured by making a hole to fit the crucible in a circular disk of sheet platinum and placing this disk over a somewhat larger hole in an asbestos board.

(*b*) The crucible shall be placed in a muffle at any temperature between 900 and 1000° C for 15 minutes and the loss in weight shall be checked by a second heating for 5 minutes.

21. PERMISSIBLE VARIATION.—A permissible variation of 0.25 will be allowed, and all results in excess of the specified limit but within this permissible variation shall be reported as 4 per cent.

INSOLUBLE RESIDUE

22. METHOD.—To a 1 g sample of cement shall be added 10 cc of water and 5 cc of concentrated hydrochloric acid; the liquid shall be warmed until effervescence ceases. The solution shall be diluted to 50 cc and digested on a steam bath or hot plate until it is evident that decomposition of the cement is complete. The residue shall be filtered, washed with cold water, and the filter paper and contents digested in about 30 cc of a 5 per cent solution of sodium carbonate, the liquid being held at a temperature just short of boiling for 15 minutes. The remaining residue shall be filtered, washed with cold water, then with a few drops of hot hydrochloric acid, 1:9, and finally with hot water, and then ignited at a red heat and weighed as the insoluble residue.

23. PERMISSIBLE VARIATION.—A permissible variation of 0.15 will be allowed, and all results in excess of the specified limit but within this permissible variation shall be reported as 0.85 per cent.

SULPHURIC ANHYDRIDE

24. METHOD.—One gram of the cement shall be dissolved in 5 cc of concentrated hydrochloric acid diluted with 5 cc of water, with gentle warming; when solution is complete 40 cc of water shall be added, the solution filtered, and the residue washed thoroughly with water. The solution shall be diluted to 250 cc, heated to boiling, and 10 cc of a hot 10 per cent solution of barium chloride shall be added slowly, drop by drop, from a pipette and the boiling continued until the precipitate is well formed. The solution shall be digested on the steam bath until the precipitate has settled. The precipitate shall be filtered, washed, and the paper and contents placed in a weighed platinum crucible and the paper slowly charred and consumed without flaming. The barium sulfate shall then be ignited and weighed. The weight obtained multiplied by 34.3 gives the percentage of sulfuric anhydride. The acid filtrate obtained in the determination of the insoluble residue may be used for the estimation of sulfuric anhydride instead of using a separate sample.

25. PERMISSIBLE VARIATION.—A permissible variation of 0.10 will be allowed, and all results in excess of the specified limit but within this permissible variation shall be reported as 2 per cent.

MAGNESIA

26. METHOD.—To 0.5 g of the cement in an evaporating dish shall be added 10 cc of water to prevent lumping and then 10 cc of concentrated hydrochloric acid. The liquid shall be gently heated and agitated until attack is complete. The solution shall then be evaporated to complete dryness on a steam or water bath. To hasten dehydration the residue may be heated to 150 or even 200° C for one-half to one hour. The residue shall be treated with 10 cc of concentrated hydrochloric acid diluted with an equal amount of water. The dish shall be covered and the solution digested for 10 minutes on a steam bath or water bath. The diluted solution shall be filtered and the separated silica washed thoroughly with water.[2] Five cubic centimeters of concentrated hydrochloric acid and sufficient bromine water to precipitate any

[2] Since this procedure does not involve the determination of silica, a second evaporation is unnecessary

manganese which may be present, shall be added to the filtrate (about 250 cc). This shall be made alkaline with ammonium hydroxide, boiled until there is but a faint odor of ammonia, and the precipitated iron and aluminum hydroxides, after settling, shall be washed with hot water, once by decantation and slightly on the filter. Setting aside the filtrate, the precipitate shall be transferred by a jet of hot water to the precipitating vessel and dissolved in 10 cc of hot hydrochloric acid. The paper shall be extracted with acid, the solution and washings being added to the main solution. The aluminum and iron shall then be reprecipitated at boiling heat by ammonium hydroxide and bromine water in a volume of about 100 cc, and the second precipitate shall be collected and washed on the filter used in the first instance if this is still intact. To the combined filtrates from the hydroxides of iron and aluminum, reduced in volume if need be, 1 cc of ammonium hydroxide shall be added, the solution brought to boiling, 25 cc of a saturated solution of boiling ammonium oxalate added, and the boiling continued until the precipitated calcium oxalate has assumed a well-defined granular form. The precipitate after one hour shall be filtered and washed, then with the filter shall be placed wet in a platinum crucible, and the paper burned off over a small flame of a Bunsen burner; after ignition it shall be redissolved in hydrochloric acid and the solution diluted to 100 cc. Ammonia shall be added in slight excess and the liquid boiled. The lime shall then be reprecipitated by ammonium oxalate, allowed to stand until settled, filtered, and washed. The combined filtrates from the calcium precipitates shall be acidified with hydrochloric acid, concentrated on the steam bath to about 150 cc, and made slightly alkaline with ammonium hydroxide, boiled and filtered (to remove a little aluminum and iron and perhaps calcium). When cool, 10 cc of saturated solution of sodium-ammonium-hydrogen phosphate shall be added with constant stirring. When the crystallin ammonium-magnesium orthophosphate has formed, ammonia shall be added in moderate excess. The solution shall be set aside for several hours in a cool place, filtered and washed with water containing 2.5 per cent NH_3. The precipitate shall be dissolved in a small quantity of hot hydrochloric acid, the solution diluted to about 100 cc, 1 cc of a saturated solution of sodium-ammonium hydrogen phosphate added, and ammonia drop by drop, with constant stirring, until the precipitate is again formed as described and the ammonia is in moderate excess. The precipitate shall then be allowed to stand about two

hours, filtered and washed as before. The paper and contents shall be placed in a weighed platinum crucible, the paper slowly charred, and the resulting carbon carefully burned off. The precipitate shall then be ignited to constant weight over a Meker burner, or a blast not strong enough to soften or melt the pyrophosphate. The weight of magnesium pyrophosphate obtained multiplied by 72.5 gives the percentage of magnesia. The precipitate so obtained always contains some calcium and usually small quantities of iron, aluminum, and manganese as phosphates.

27. PERMISSIBLE VARIATION.—A permissible variation of 0.4 will be allowed, and all results in excess of the specified limit but within this permissible variation shall be reported as 5.00 per cent.

PHYSICAL TESTS

DETERMINATION OF SPECIFIC GRAVITY

28. APPARATUS.—The determination of specific gravity shall be made with a standardized Le Chatelier apparatus which conforms to the requirements illustrated in Fig. 1. This apparatus is standardized by the United States Bureau of Standards. Kerosene free from water, or benzine not lighter than 62° Baumé, shall be used in making this determination.

29–31. METHOD.—The flask shall be filled with either of these liquids to a point on the stem between zero and 1 cc and 64 g of cement, of the same temperature as the liquid, shall be slowly introduced, taking care that the cement does not adhere to the inside of the flask above the liquid and to free the cement from air by rolling the flask in an inclined position. After all the cement is introduced, the level of the liquid will rise to some division of the graduated neck; the difference between readings is the volume displaced by 64 g of the cement.

The specific gravity shall then be obtained from the formula

$$\text{Specific gravity} = \frac{\text{Weight of cement (g)}}{\text{Displaced volume (cc)}}$$

30. The flask, during the operation, shall be kept immersed in water, in order to avoid variations in the temperature of the liquid in the flask, which shall not exceed 0°.5 C. The results of repeated tests should agree within 0.01.

31. The determination of specific gravity shall be made on the cement as received; if it falls below 3.10, a second determination shall be made after igniting the sample as described in section 20.

DETERMINATION OF FINENESS

32–33. APPARATUS.—Wire cloth for standard sieves for cement shall be woven (not twilled) from brass, bronze, or other suitable wire, and mounted without distortion on frames not less than 1½

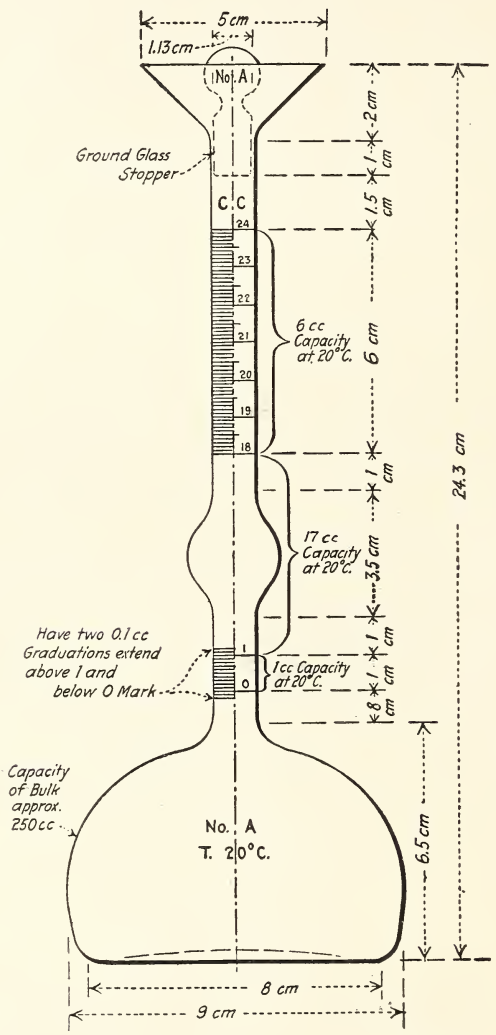


FIG. 1.—*Le Chatelier apparatus for specific gravity determinations*

inches below the top of the frame. The sieve frames shall be circular, approximately 8 inches in diameter, and may be provided with a pan and cover.

33. A standard No. 200 sieve is one having nominally an 0.0029-inch opening and 200 wires per inch standardized by the

United States Bureau of Standards, and conforming to the following requirements:

The No. 200 sieve should have 200 wires per inch, and the number of wires in any whole inch shall not be outside the limits of 192 to 208. No opening between adjacent parallel wires shall be more than 0.0050 inch in width. The diameter of the wire should be 0.0021 inch and the average diameter shall not be outside the limits 0.0019 to 0.0023 inch. The value of the sieve as determined by sieving tests made in conformity with the standard specification for these tests on a standardized cement which gives a residue of 25 to 20 per cent on the No. 200 sieve, or on other similarly graded material, shall not show a variation of more than 1.5 per cent above or below the standards maintained at the Bureau of Standards.

34–35. METHOD.—The test shall be made with 50 g of cement. The sieve shall be thoroughly clean and dry. The cement shall be placed on the No. 200 sieve, with pan and cover attached, if desired, and shall be held in one hand in a slightly inclined position so that the sample will be well distributed over the sieve, at the same time gently striking the side about 150 times per minute against the palm of the other hand on the up stroke. The sieve shall be turned every 25 strokes about one-sixth of a revolution in the same direction. The operation shall continue until not more than 0.05 g passes through in one minute of continuous sieving. The fineness shall be determined from the weight of the residue on the sieve expressed as a percentage of the weight of the original sample.

35. Mechanical sieving devices may be used, but the cement shall not be rejected if it meets the fineness requirement when tested by the hand method described in section 34.

36. PERMISSIBLE VARIATION.—A permissible variation of 1 will be allowed, and all results in excess of the specified limit but within this permissible variation shall be reported as 22 per cent.[3]

MIXING CEMENT PASTES AND MORTARS

37–38. METHOD.—The quantity of dry material to be mixed at one time shall not exceed 1000 g nor be less than 500 g. The proportions of cement or cement and sand shall be stated by weight in grams of the dry materials; the quantity of water shall be expressed in cubic centimeters (1 cc of water = 1 g). The dry materials shall be weighed, placed upon a nonabsorbent surface,

[3] See note 1 on p. 9.

thoroughly mixed dry if sand is used, and a crater formed in the center, into which the proper percentage of clean water shall be poured; the material on the outer edge shall be turned into the crater by the aid of a trowel. After an interval of one-half minute for the absorption of the water the operation shall be completed by continuous, vigorous mixing, squeezing and kneading with the hands for at least one minute.[4] During the operation of mixing, the hands should be protected by rubber gloves.

38. The temperature of the room and the mixing water shall be maintained as nearly as practicable at 21° C (70° F).

NORMAL CONSISTENCY

39. APPARATUS.—The Vicat apparatus consists of a frame *A* (Fig. 2) bearing a movable rod *B*, weighing 300 g, one end *C* being 1 cm in diameter for a distance of 6 cm, the other having a removable needle *D*, 1 mm in diameter, 6 cm long. The rod is reversible, and can be held in any desired position by a screw *E*, and has midway between the ends a mark *F* which moves under a scale (graduated to millimeters) attached to the frame *A*. The paste is held in a conical, hard-rubber ring *G*, 7 cm in diameter at the base, 4 cm high, resting on a glass plate *H* about 10 cm square.

40–41. METHOD.—In making the determination, 500 g of cement, with a measured quantity of water, shall be kneaded into a paste, as described in section 37, and quickly formed into a ball with the hands, completing the operation by tossing it six times from one hand to the other, maintained about 6 inches apart; the ball resting in the palm of one hand shall be pressed into the larger end of the rubber ring held in the other hand, completely filling the ring with paste; the excess at the larger end shall then be removed by a single movement of the palm of the hand; the ring shall then be placed on its larger end on a glass plate and the excess paste at the smaller end sliced off at the top of the ring by a single oblique stroke of a trowel held at a slight angle with the top of the ring. During these operations care shall be taken not to compress the paste. The paste confined in the ring, resting on the plate, shall be placed under the rod, the larger end of which shall be brought in contact with the surface of the paste; the scale shall

[4] In order to secure uniformity in the results of tests for the time of setting and tensile strength the manner of mixing above described should be carefully followed. At least one minute is necessary to obtain the desired plasticity which is not appreciably affected by continuing the mixing for several minutes. The exact time necessary is dependent upon the personal equation of the operator. The error in mixing should be on the side of overmixing.

be then read, and the rod quickly released. The paste shall be of normal consistency when the rod settles to a point 10 mm below the original surface in one-half minute after being released. The apparatus shall be free from all vibrations during the test. Trial pastes shall be made with varying percentages of water until the

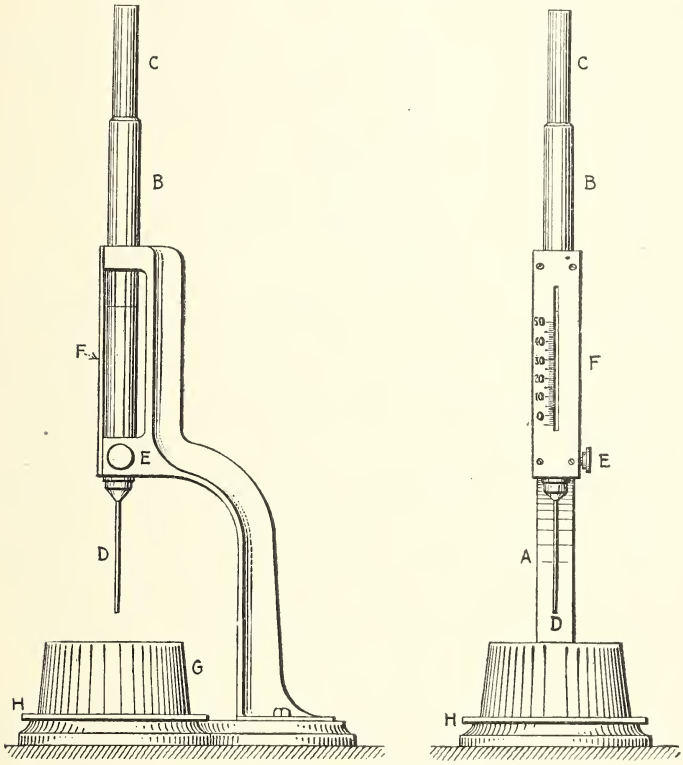


FIG. 2.—*Vicat apparatus*

normal consistency is obtained. The amount of water required shall be expressed in percentage by weight of the dry cement.

41. The consistency of standard mortar shall depend on the amount of water required to produce a paste of normal consistency from the same sample of cement. Having determined the normal consistency of the sample, the consistency of standard mortar made from the same sample shall be as indicated in Table 1, the values being in percentage of the combined dry weights of the cement and standard sand.

TABLE 1

Percentage of Water for Standard Mortars

Percentage of water for neat cement paste of normal consistency	Percentage of water for one cement, three standard Ottawa sand	Percentage of water for neat cement paste of normal consistency	Percentage of water for one cement, three standard Ottawa sand
15	9.0	23	10.3
16	9.2	24	10.5
17	9.3	25	10.7
18	9.5	26	10.8
19	9.7	27	11.0
20	9.8	28	11.2
21	10.0	29	11.3
22	10.2	30	11.5

DETERMINATION OF SOUNDNESS[5]

42. APPARATUS.—A steam apparatus which can be maintained at a temperature between 98 and 100° C, or one similar to that shown in Fig. 3, is recommended. The capacity of this apparatus may be increased by using a rack for holding the pats in a vertical or inclined position.

43–45. METHOD.—A pat from cement paste of normal consistency about 3 inches in diameter, one-half inch thick at the center, and tapering to a thin edge, shall be made on clean glass plates about 4 inches square, and stored in moist air for 24 hours. In molding the pat the cement paste shall first be flattened on the glass and the pat then formed by drawing the trowel from the outer edge toward the center.

44. The pat shall then be placed in an atmosphere of steam at a temperature between 98 and 100° C upon a suitable support 1 inch above boiling water for five hours.

45. Should the pat leave the plate, distortion may be detected best with a straight edge applied to the surface which was in contact with the plate.

DETERMINATION OF TIME OF SETTING

46. The following are alternate methods, either of which may be used as ordered:

47. VICAT APPARATUS.—The time of setting shall be determined with the Vicat apparatus described in section 39. (See Fig. 2.)

[5] Unsoundness is usually manifested by change in volume which causes distortion, cracking, checking, or disintegration. Pats improperly made or exposed to drying may develop what are known as shrinkage cracks within the first 24 hours and are not an indication of unsoundness. These conditions are illustrated in Fig. 4. The failure of the pats to remain on the glass or the cracking of the glass to which the pats are attached does not necessarily indicate unsoundness.

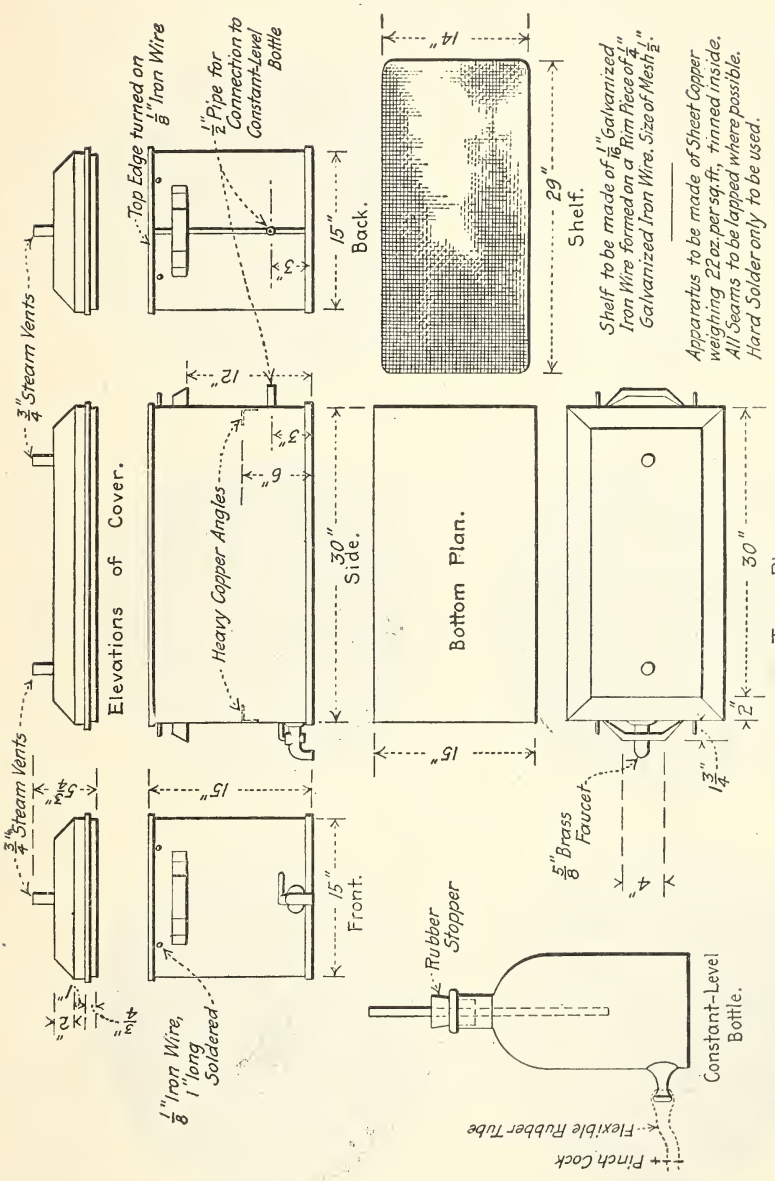


FIG. 3.—*Apparatus for making soundness test of cement*

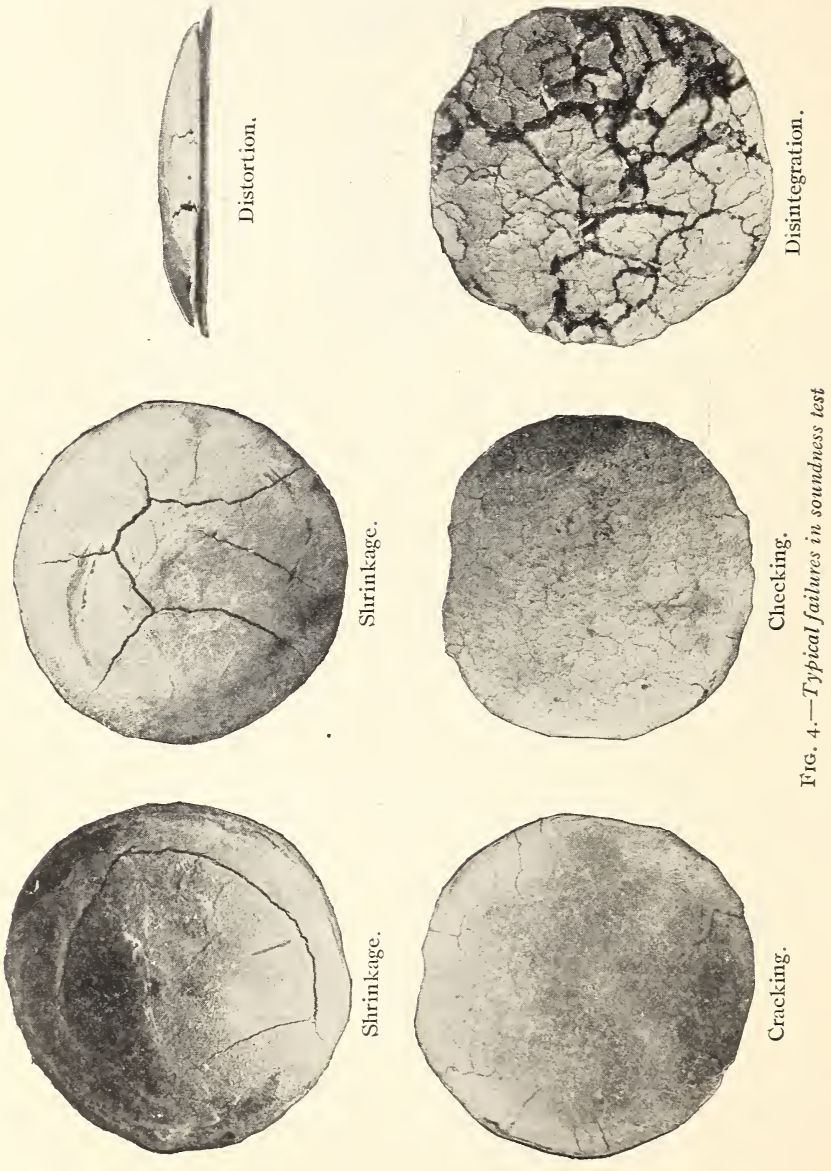
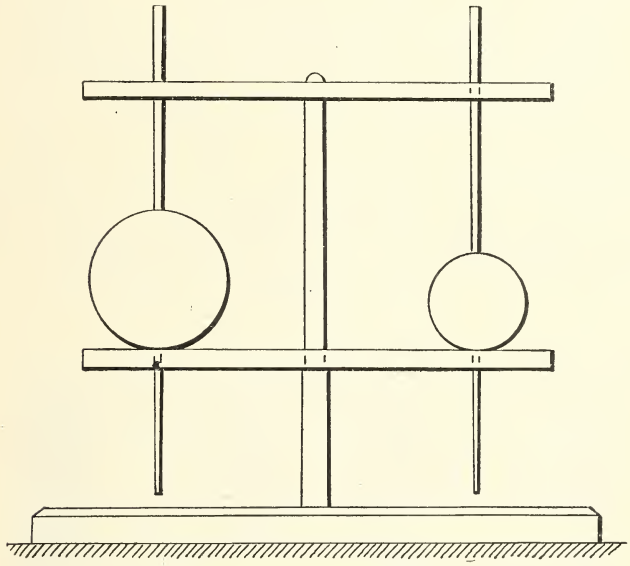


FIG. 4.—*Typical failures in soundness test*

48. VICAT METHOD.—A paste of normal consistency shall be molded in the hard-rubber ring *G*, as described in section 40, and placed under the rod *B*, the smaller end of which shall then be carefully brought in contact with the surface of the paste, and the rod quickly released. The initial set shall be said to have occurred when the needle ceases to pass a point 5 mm above the glass plate in one-half minute after being released, and the final set when the needle does not sink visibly into the paste. The test pieces shall

(*a*) Pat with Top Surface Flattened for Determining Time of Setting by Gillmore Method.



(*b*) Gillmore Needles.

FIG. 5

be kept in moist air during the test. This may be accomplished by placing them on a rack over water contained in a pan and covered by a damp cloth, kept from contact with them by means of a wire screen; or they may be stored in a moist closet. Care shall be taken to keep the needle clean, as the collection of cement on the sides of the needle retards the penetration, while cement on the point may increase the penetration. The time of setting is affected not only by the percentage and temperature of the water used and the amount of kneading the paste receives, but by the

temperature and humidity of the air, and its determination is therefore only approximate.

49. GILLMORE NEEDLES.—The time of setting shall be determined by the Gillmore needles. The Gillmore needles should preferably be mounted as shown in Fig. 5 (*b*).

50. GILLMORE METHOD.—The time of setting shall be determined as follows: A pat of neat cement paste about 3 inches in diame-

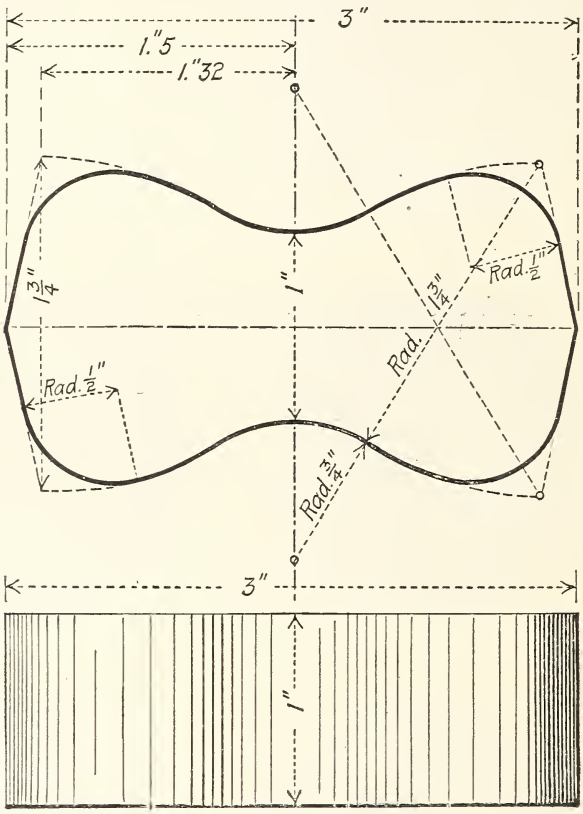


FIG. 6.—*Details for briquette*

ter and one-half inch in thickness with a flat top (Fig. 5 (*a*)), mixed to a normal consistency, shall be kept in moist air at a temperature maintained as nearly as practicable at 21° C (70° F). The cement shall be considered to have acquired its initial set when the pat will bear, without appreciable indentation, the Gillmore needle one-twelfth inch in diameter, loaded to weigh one-fourth pound. The final set has been acquired when the pat will bear without appreciable indentation, the Gillmore needle one-twenty-fourth inch in diameter, loaded to weigh 1 pound. In

making the test the needles shall be held in a vertical position and applied lightly to the surface of the pat.

TENSION TESTS

51. FORM OF TEST PIECE.—The form of test piece shown in Fig. 6 shall be used. The molds shall be made of noncorroding metal and have sufficient material in the sides to prevent spreading during molding. Gang molds when used shall be of the type shown in Fig. 7. Molds shall be wiped with an oily cloth before using.

52–54. STANDARD SAND.—The sand to be used shall be natural sand from Ottawa, Ill., screened to pass a No. 20 sieve and retained on a No. 30 sieve. This sand may be obtained from the Ottawa Silica Co., at a cost of 2 cents per pound, f. o. b. cars, Ottawa, Ill.

53. This sand, having passed the No. 20 sieve, shall be considered standard when not more than 5 g pass the No. 30 sieve after one minute continuous sieving of a 500 g sample.

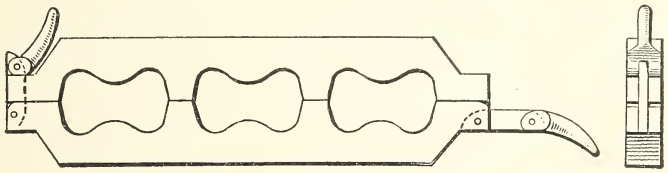


FIG. 7.—*Gang mold*

54. The sieves shall conform to the following specifications:

The No. 20 sieve shall have between 19.5 and 20.5 wires per whole inch of the warp wires and between 19 and 21 wires per whole inch of the shoot wires. The diameter of the wire should be 0.0165 inch and the average diameter shall not be outside the limits of 0.0160 and 0.0170 inch.

The No. 30 sieve shall have between 29.5 and 30.5 wires per whole inch of the warp wires and between 28.5 and 31.5 wires per whole inch of the shoot wires. The diameter of the wire should be 0.0110 inch and the average diameter shall not be outside the limits 0.0105 to 0.0115 inch.

55. MOLDING.—Immediately after mixing, the standard mortar shall be placed in the molds, pressed in firmly with the thumbs and smoothed off with a trowel without ramming. Additional mortar shall be heaped above the mold and smoothed off with a trowel; the trowel shall be drawn over the mold in such a manner as to exert a moderate pressure on the material. The

mold shall then be turned over and the operation of heaping, thumbing, and smoothing off repeated.

56–57. TESTING.—Tests shall be made with any standard machine. The briquettes shall be tested as soon as they are removed from the water. The bearing surfaces of the clips and briquettes shall be free from grains of sand or dirt. The briquettes shall be carefully centered and the load applied continuously at the rate of 600 pounds per minute.

57. Testing machines should be frequently calibrated in order to determine their accuracy.

58. FAULTY BRIQUETTES.—Briquettes that are manifestly faulty, or which give strengths differing more than 15 per cent from the average value of all test pieces made from the same sample and broken at the same period, shall not be considered in determining the tensile strength.

STORAGE OF TEST PIECES

59. APPARATUS.—The moist closet may consist of a soapstone, slate, or concrete box, or a wooden box lined with metal. If a wooden box is used, the interior should be covered with felt or broad wicking kept wet. The bottom of the moist closet should be covered with water. The interior of the closet should be provided with nonabsorbent shelves on which to place the test pieces, the shelves being so arranged that they may be withdrawn readily.

60–62. METHODS.—Unless otherwise specified, all test pieces, immediately after molding, shall be placed in the moist closet for from 20 to 24 hours.

61. The briquettes shall be kept in molds on glass plates in the moist closet for at least 20 hours. After 24 hours in moist air the briquettes shall be immersed in clean water in storage tanks of noncorroding material.

62. The air and water shall be maintained as nearly as practicable at a temperature of 21° C (70° F).

III. INTERPRETATION OF RESULTS

CHEMICAL

The composition of normal Portland cement has been the subject of a great deal of investigation, and it can be said that the quantities of silica, alumina, oxide of iron, lime, magnesia, and sulphuric anhydride can vary within fairly wide limits without materially affecting the quality of the material.

A normal American Portland cement which meets the standard specifications for soundness, setting time, and tensile strength has an approximate composition within the following limits:

	Per cent
Silica	19–25
Alumina	5–9
Iron oxide	2–4
Lime	60–64
Magnesia	1–5
Sulphur trioxide	1–2.00
Loss on ignition	0.5–3.00
Insoluble residue	0.1–0.85

It is also true that a number of cements have been made both here and abroad which have passed all standard physical tests in which these limits have been exceeded in one or more particulars, and it is equally true that a sound and satisfactory cement does not necessarily result from the above composition.

It is probable that further investigation will give a clearer understanding of the constitution of Portland cement, but at present chemical analysis furnishes but little indication of the quality of the material.

Defective cement usually results from imperfect manufacture, not from faulty composition. Cement made from very finely ground material, thoroughly mixed and properly burned, may be perfectly sound when containing more than the usual quantity of lime, while a cement low in lime may be entirely unsound due to careless manufacture.

The analysis of a cement will show the uniformity in composition of the product from individual mills, but will furnish little or no indication of the quality of the material. Occasional analysis

should, however, be made for record and to determine the loss on ignition and the quantity of sulphuric anhydride, magnesia, and insoluble residue present.

The ground clinker as it comes from the mill is usually quick setting, which requires correction. This is usually accomplished by the addition of a small quantity of more or less hydrated calcium sulphate, either gypsum or plaster of Paris. The maximum limit for sulphuric anhydride (SO_3) is 2 per cent, which is considered the maximum quantity necessary to control setting properties.

The specification prohibits the addition of any material subsequent to calcination except water and calcined or uncalcined gypsum, which latter is permitted to regulate the time of set. Other additions may be difficult or impossible to detect even by a careful mill inspection during the process of manufacture, but as the normal adulterant would be ground raw material, an excess of "insoluble residue" would reveal the addition of siliceous material, and an excess in "loss on ignition" would point to the addition of calcareous material when either is added in sufficient quantity to make the adulteration profitable.

The effect of relatively small quantities of magnesia (MgO) in normal Portland cement, while still under investigation, can be considered harmless. Earlier investigators believed that as magnesia had a slower rate of hydration than lime the hydration of any free magnesia (MgO) present would occur after the cement had set and cause disintegration.

The effect of magnesia was considered especially injurious when the cement was exposed to the action of sea water. More recent investigation has shown that cement can be made which is perfectly sound under all conditions when containing 5 per cent of magnesia, and it has also been found that the lime in Portland cement exposed to sea water is replaced by magnesia.

The maximum limit for magnesia has been set at 5 per cent, as it has been established that this quantity is not injurious and it is high enough to permit the use of the large quantities of raw material available in most sections of the country.

PHYSICAL

SPECIFIC GRAVITY

The specific gravity of a Portland cement is not an indication of its cementing value. It will vary with the constituents of the cement, especially with the content of iron oxide. Thus the

white or very light Portland cements, containing only a fraction of a per cent of iron oxide, usually have a comparatively low specific gravity ranging from 3.05 to 3.15, while a cement containing 3 to 4 per cent or more of iron oxide may have a specific gravity of 3.20 or even higher. It is materially affected by the temperature and duration of burning the cement, the hard-burned cement having the higher specific gravity. A comparatively low specific gravity does not necessarily indicate that a cement is underburned or adulterated, as large percentages of raw materials could be added to a cement with a normally high specific gravity before the gravity would be reduced below 3.10.

If a Portland cement fresh from the mill normally has a comparatively low specific gravity, upon aging it may absorb sufficient moisture and carbon dioxide to reduce the gravity below 3.10. It has been found that this does not appreciably affect the cementing value of the material; in fact, many cements are unsound until they have been aged.

The value of the specific gravity determination lies in the fact that it is easily made in the field or laboratory, and when the normal specific gravity of the cement is known, any considerable variation in quality due to underburning or the addition of foreign materials may be detected.

FINENESS

Only the extremely fine powder of cement called flour possesses appreciable cementing qualities, the coarser particles adding little or nothing to the cementing value. No sieve is fine enough to determine the flour in a cement, nor is there any other generally applied means of accurately and practically measuring the flour. Some cements grind easier than others, thus, although a larger percentage of one cement may pass the 200-mesh sieve than another, the former may have a smaller percentage of actual flour due to the difference in the hardness and the character of the clinker, and the method used in grinding. Thus the cementing value of different cements can not be compared directly upon their apparent fineness through a 200-mesh sieve. With cement from the same mill, with similar clinker and grinding machinery, however, it is probable that the greater the percentage which passes the 200-mesh sieve the greater the percentage of flour in that particular cement. Data at present available indicate that all Portland cements have greater cementing value as the fineness is increased.

MIXING

The homogeneity of the cement paste or mortar is dependent upon the thoroughness of the mixing, and this may have considerable influence upon the time of setting and the strength of the briquettes. Concordant results can be obtained only by using extreme care in mixing the paste or mortar.

NORMAL CONSISTENCY

The quantity of water used in making the paste or mortar from which the pats for soundness, tests of setting, and the briquettes are made is very important and may vitally affect the results obtained. The determination consists in measuring the quantity of water required to bring a cement to a certain state of plasticity.

SOUNDNESS

The purpose of this test is to detect those qualities in a cement which tend to destroy the strength and durability. Unsoundness is usually manifested by a change in volume which causes cracking, swelling, or disintegration. If the pat is not properly made, or if it is placed where it will be subject to any drying during the first 24 hours, it may develop what are known as shrinkage cracks, which are not an indication of unsoundness and should not be confused with disintegration cracks, as shown in Fig. 4, p. 22. No shrinkage cracks should develop after the first 24 or 48 hours. The failure of the pats to remain on the glass or the cracking of the glass to which the pat is attached does not necessarily indicate unsoundness. In molding the pats, the cement paste should first be flattened on the glass and the pat formed by drawing the trowel from the outer edge toward the center, as shown in Fig. 8.

TIME OF SETTING

The purpose of this test is to determine the time which elapses from the moment water is added until the paste ceases to be plastic and the time required for it to obtain a certain degree of hardness. The determination of the "initial set" or when plasticity ceases is the more important, as a disturbance of the material after this time may cause a loss of strength, and thus it is important that the mixing and molding or the incorporating of the material into the work be accomplished within this time. The time of setting by the Gillmore needles is usually determined upon the pat which is to be used for the soundness test,

the top surface being flattened somewhat, as shown in Fig. 5a, page 23. In using the Gillmore needles care should be taken to apply the needles in a vertical position and perpendicular to the surface of the pat. The rate of setting and hardening may be materially affected by slight changes in temperature. The percentage of water used in gauging and the humidity of the moist closet in which the test pieces are stored may also affect the setting some-what.

TENSILE TESTS

Consistent results can only be obtained by exercising great care in molding and testing the briquettes. The correct method

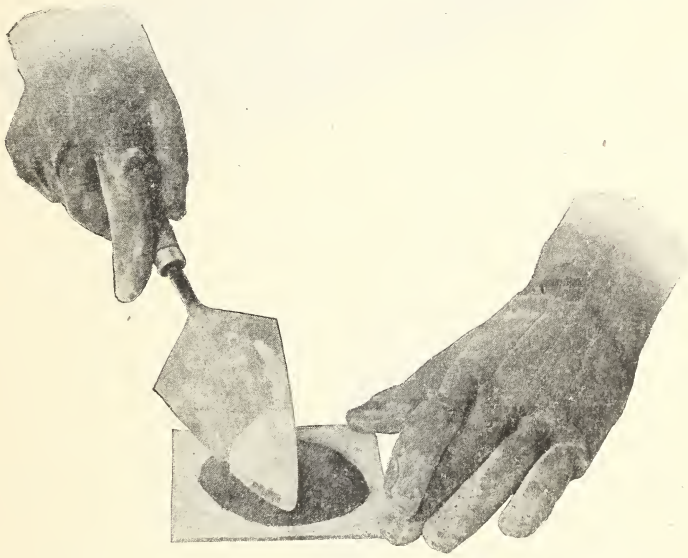


FIG. 8.—*Correct method of molding cement pat*

of filling the mold is shown in Figs. 9 and 10. In testing the sides of the briquette and the clips should be thoroughly cleaned and free from grains of sand or dirt which would prevent a good bearing and the briquette should be carefully centered in the clips so as to avoid cross strains. It may be considered good laboratory practice if the individual briquettes of any set do not show a greater variation from the mean value than 10 per cent for sand mixtures. The 28-day mortar tests should not be omitted except in cases of emergency.

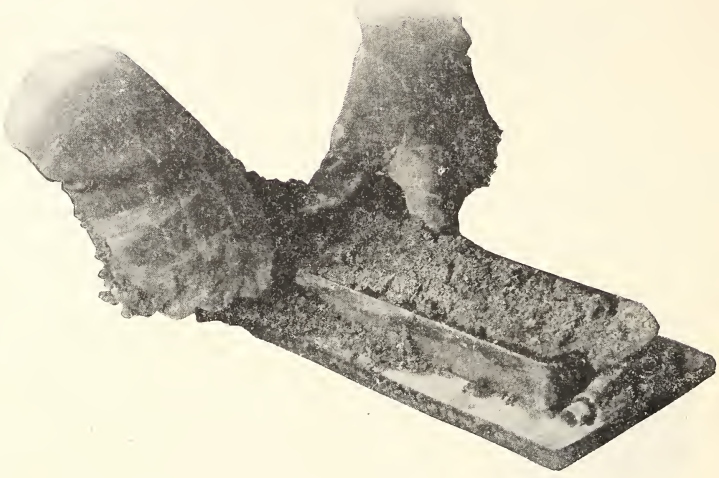


FIG. 9.—*Correct method of filling briquette mold*

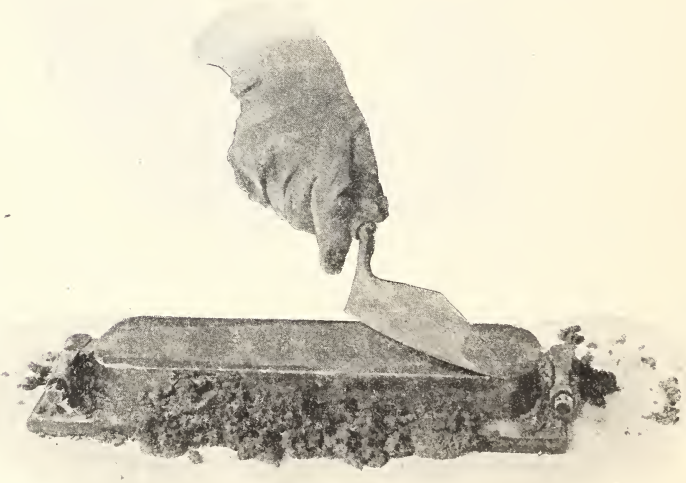


FIG. 10.—*Correct method of troweling surface of briquettes*

IV. EXPLANATION OF CHANGES MADE IN REVISING THE ORIGINAL UNITED STATES GOVERNMENT SPECIFICATION FOR PORTLAND CEMENT [6]

INTRODUCTION AND RECOMMENDATIONS

At a meeting of the Departmental Conference held July 30, 1912, consideration was given to the following communication, dated March 7, 1912, which was received from the committee on standard specifications for cement of the American Society for Testing Materials:

> In order to secure uniformity in specifications for cement, it is recommended that the board of direction of the American Society of Civil Engineers, the committee on standard specifications for cement of the American Society for Testing Materials, and the Government departmental committee on specifications for cement be each requested to appoint a committee of three to confer for the purpose of reconciling differences.

The Departmental Conference referred this matter to the departmental committee which had drawn up the present Government specification for Portland cement, with instructions to appoint a subcommittee to confer with committees of the American Society of Civil Engineers and American Society for Testing Materials.

The joint conference on "Uniform methods of tests and standard specifications for cement," as organized in conformity with the above resolution, was composed of the following:

Representing the American Society of Civil Engineers: Alfred Noble, George S. Webster, and R. L. Humphrey.

Representing the American Society for Testing Materials: George F. Swain, Olaf Hoff, and Clifford Richardson.

Representing the United States Government departmental committee: A. P. Davis, A. E. Phillips, and R. J. Wig.

This joint conference held nine meetings and the executive committee of the conference held 35 sessions of one or more days' duration.

Consideration was given to every detail of the specifications. Elaborate tests and investigations were made. Inquiries were

[6] Printed here in accordance with the action of the Government conference from the report of the departmental committee to the conference, submitted Sept. 7, 1916.

submitted to many engineers, laboratories, and manufacturers for information which would be of assistance to the committee. Agreement of the conference was reached in April, 1915. A report of 145 printed pages containing the findings of the joint conference was submitted to the respective parent committees for consideration. Further investigations were made by these committees and their recommendations were given final consideration by the joint conference June 1, 1916.

The cement committee of the American Society for Testing Materials adopted these specifications with some few changes June 28, 1916, since which time they have been adopted by that society.

While certain modifications desired by the Government departmental committee were not accepted by the cement committee of the American Society for Testing Materials, the latter committee did accept many of the changes recommended by the Government committee, and therefore it is recommended that the Government Departmental Conference adopt these specifications, copy of which is appended, to be issued as the United States Government specification for Portland cement with a note under the title reading:

This specification is the result of several years' work of a Joint Conference representing the United States Government, the American Society of Civil Engineers, and the American Society for Testing Materials. This was adopted by the United States Government and by the American Society for Testing Materials to become effective January 1, 1917.

It is also recommended that a footnote reference be placed upon the fineness requirement of the specification, as follows:

The United States Government specification requires that on and after July 1, 1918, the residue on the standard No. 200 sieve shall not exceed 20 per cent by weight.

It is further recommended that in case the American Society for Testing Materials does not signify its intention of approving this latter requirement another Government conference should be called and other changes made in the specification as desired by the Government committee, but which are waived at this time in order to obtain uniformity.

Following is a discussion and explanation of the changes made in the specifications in making the revision of 1916. For convenience of reference the old version and the new version of each requirement are given preceding the comments.

DEFINITION

Old Version.—The cement shall be the product obtained by finely pulverizing clinker produced by calcining to incipient fusion an intimate mixture of properly proportioned argillaceous and calcareous substances, with only such additions subsequent to calcining as may be necessary to control certain properties. Such additions shall not exceed 3 per cent, by weight, of the calcined product.

New Version.—Portland cement is the product obtained by finely pulverizing clinker produced by calcining to incipient fusion an intimate and properly proportioned mixture of argillaceous and calcareous materials, with no additions subsequent to calcination excepting water and calcined or uncalcined gypsum.

The old definition was considered to partake of the nature of a specification and to be improper in including quantitative chemical restrictions which were specifically provided for elsewhere. Furthermore, no test is available whereby one may determine whether the 3 per cent limitation is exceeded. The limitations under "Chemical properties" prevent adulteration and the use of gypsum in quantities considered to be harmful.

CHEMICAL PROPERTIES

Old Version.—In the finished cement the following limits shall not be exceeded:

	Per cent
Loss on ignition for 15 minutes	4
Insoluble residue	1
Sulphuric anhydride (SO_3)	1.75
Magnesia (MgO)	4

New Version.—The following limits shall not be exceeded:

	Per cent
Loss on ignition	4
Insoluble residue	0.85
Sulphuric anhydride (SO_3)	2
Magnesia (MgO)	5

The phrase "Loss on ignition for 15 minutes" was modified by omitting the words "for 15 minutes" as the time and other provisions of the method of making the determination are given in the methods of tests.

The insoluble residue limitation was reduced from 1 to 0.85. This was done as all unadulterated cements were found to be well within this limitation.

The maximum limit for sulphuric anhydride (SO_3) was increased from 1.75 to 2 per cent because there was no evidence that the quality of the material would be impaired by such a change, and because the increase in the fineness requirement and further restriction in the time of setting made such a change desirable and logical. This permissible increase will probably be taken advantage of only by a limited number of mills, for gypsum is more expensive than cement and it is the desire of the manufacturers to restrict its use to a minimum. The maximum con-

tent of sulphuric anhydride fixed by European practice is as follows:

	Per cent.
France	[7] 3.00
England	2.75
Germany	2.50
Austria	2.50
Holland	2.50

The magnesia limitation was raised from 4 per cent to 5 per cent. All data available demonstrated that cements containing magnesia even in excess of 5 per cent were equal in quality to those containing less than 4 per cent. The change in this requirement reduces the cost of manufacture in some cases, and should increase competition.

SPECIFIC GRAVITY

Old Version.—The specific gravity of the cement shall be not less than 3.10. Should the cement as received fall below this requirement, a second test may be made upon a sample heated for 30 minutes at a very dull red heat.

New Version.—The specific gravity of cement shall be not less than 3.10 (3.07 for white Portland cement). Should the test of cement as received fall below this requirement, a second test may be made upon an ignited sample. The specific-gravity test will not be made unless specifically so ordered.

While the specific-gravity requirement is still included in the specification, it was the general opinion that it furnished little or no information of value relative to the quality of the cement. A cement meeting all other requirements was considered to be satisfactory irrespective of its specific gravity. Sufficient data were not available to warrant the complete elimination of this requirement, but the following clause was added:

The specific-gravity test will not be made unless specifically so ordered.

This makes the requirement still obligatory although the test may not be made by the purchaser. A clause is also inserted making white Portland cements acceptable if the specific gravity is 3.07 or higher. This was thought desirable as white Portland cements have a very low iron content which gives them a correspondingly lower specific gravity.

FINENESS

Old Version.—Ninety-two (92) per cent of the cement, by weight, shall pass through the No. 100 sieve, and 75 per cent shall pass through the No. 200 sieve.

New Version.—The residue on a standard No. 200 sieve shall not exceed 22 per cent by weight.

NOTE.—The United States Government specification requires that on and after July 1, 1918, the residue on the standard No. 200 sieve shall not exceed 20 per cent by weight.

[7] Excepting in sea water, when it is 1.50.

The fineness requirement was changed by eliminating the requirement on the No. 100 sieve and requiring a residue of not more than 22 per cent in place of 25 per cent on the No. 200 sieve.

The Government committee desired to have the requirement raised to not more than 20 per cent residue on the No. 200 sieve. The cement committee of the American Society for Testing Materials, however, would not agree to this increased requirement, primarily on the basis that it would be a hardship upon certain manufacturers to meet such a requirement without ample time for changing plant equipment. All data available to the committees indicated that the finer the commercial cements are ground the more cementing value they possess, although the fineness of two cements of different manufacture may not furnish any indication of their relative cementing values in concrete.

The results of a rather comprehensive series of tests made in a number of laboratories with several brands of cement showed an average increase of 2 per cent in compressive strength at the age of one month for each 1 per cent increase in fineness between the limits considered, which vary from 77 to 83 per cent.

The information obtained indicates that the majority of cement mills are now meeting the 22 per cent residue requirement and a number are meeting the 20 per cent requirement. The departmental committee is of the opinion that fine grinding is a step in the right direction. For the sake of uniformity it has recommended that the 22 per cent residue requirement be temporarily adopted, the 20 per cent residue requirement to be made effective in 1918, which will give all manufacturers sufficient time to readjust their mills.

The study of available data showed that the relative fineness of that portion of cement which is retained on the No. 200 sieve is unimportant, as it has little or no cementing value. With present methods of grinding the great majority of cements meeting the present requirements of the No. 200 sieve will of necessity meet the requirements of the No. 100 sieve. Therefore the No. 100 sieve requirement has been omitted.

SOUNDNESS

Old Version.—Pats of neat cement prepared and treated as hereinafter prescribed shall remain firm and hard and show no sign of distortion, checking, cracking, or disintegrating. If the cement fails to meet the prescribed steaming test, the cement may be rejected or the steaming test repeated after seven or more days, at the option of the engineer.

New Version.—A pat of neat cement shall remain firm and hard and show no signs of distortion, cracking, checking, or disintegration in the steam test for soundness.

The soundness requirement was changed by omitting the test of neat cement pats exposed to air and water for 28 days and retaining only the test of a neat cement pat exposed in an atmosphere of steam for five hours.

Members of all committees expressed it as their experience that cements meeting the other requirements of the specification and the steam test for soundness never failed to meet the air and water soundness tests, therefore the latter were considered superfluous and were omitted.

The clause relative to retest before rejection has been inserted elsewhere in the specification under the heading "Rejection."

TIME OF SETTING

Old Version.—The cement shall not acquire its initial set in less than 45 minutes and must have acquired its final set within 10 hours.

New Version.—The cement shall not develop initial set in less than 45 minutes when the Vicat needle is used or 60 minutes when the Gillmore needle is used. Final set shall be attained within 10 hours.

The new specifications provide for the use of either the Vicat or the Gillmore needles, while the old specifications required the use of the Gillmore method only. There was a difference of opinion regarding the relative merits of these methods. After careful investigation it was decided to include both methods, as there was no material difference in their accuracy. Either one may be used as ordered by the engineer.

Tests have shown that the Gillmore needle requires on the average about 15 minutes more than the Vicat needle to indicate initial set, therefore the specific requirement is different for each needle.

The time of initial setting was increased from 45 minutes to 60 minutes by the Gillmore needle. This was deemed desirable, as it is not uncommon to find that cements which meet the old specification requirements in the laboratory become quick setting on the work where the temperature is 10° or more above that of the laboratory. This change was particularly desired by all members of the joint conference.

TENSILE STRENGTH

Old Version.—Briquettes made of neat cement, after being kept in moist air for 24 hours and the rest of the time in water, shall develop tensile strength per square inch as follows:

	Pounds
After 7 days	500
After 28 days	600

Briquettes made up of 1 part cement and 3 parts standard Ottawa sand, by weight, shall develop tensile strength per square inch as follows:

	Pounds
After 7 days	200
After 28 days	275

The average of the tensile strengths developed at each age by the briquettes in any set made from one sample is to be considered the strength of the sample at that age, excluding any results that are manifestly faulty.

The average strength of the sand-mortar briquettes at 28 days shall show an increase over the average strength at 7 days.

New Version.—The average tensile strength in pounds per square inch of not less than three standard mortar briquettes (see sec. 51) composed of one part cement and three parts standard sand, by weight, shall be equal to or higher than the following:

Age at test, days	Storage of briquettes	Tensile strength, pounds per square inch
7	1 day in moist air, 6 days in water	200
28	1 day in moist air, 27 days in water	300

The average tensile strength of standard mortar at 28 days shall be higher than the strength at 7 days.

The neat tests were eliminated from the specification, it being the general opinion that they were unreliable and misleading. For example, the results of tests of cements ground to increased fineness showed decreased strength in the neat tests, although there were substantial increases in the mortar and concrete tests. It was not uncommon to find retrogession with age in neat tests between 7 and 28 days, although substantial increases were obtained in mortar tests. This fact was recognized in the old Government specification by permitting such retrogression in neat tests.

The mortar strength requirement at 28 days was increased from 275 to 300 pounds. Tests substantiated by general experience showed that most cements gave strengths appreciably higher than the old requirement. It was also recognized that the increase in the fineness requirement would result in higher mortar strengths.

PACKAGES AND MARKING

Old Version.—Bids for furnishing cement or for doing work in which cement is to be used shall state the brand of cement proposed to be furnished and the mill at which made. The right is reserved to reject any cement which has not established itself as a high-grade Portland cement, and has not been made by the same mill for two years and given satisfaction in use for at least one year under climatic and other conditions at least equal in severity to those of the work proposed.

The cement shall be delivered in sacks, barrels, or other suitable packages (to be specified by the engineer), and shall be dry and free from lumps. Each package shall be plainly labeled with the name of the brand and of the manufacturer.

A sack of cement shall contain 94 pounds net. A barrel shall contain 376 pounds net. Any package that is short weight or broken or that contains damaged cement may be rejected, or accepted as a fractional package, at the option of the engineer.

New Version.—The cement shall be delivered in suitable bags or barrels with the brand and name of the manufacturer plainly marked thereon, unless shipped in bulk. A bag shall contain 94 pounds net. A barrel shall contain 376 pounds net.

The cement shall be stored in such a manner as to permit easy access for proper inspection and identification of each shipment, and in a suitable weather-tight building which will protect the cement from dampness.

The clause in the old specification relative to the rejection of cement not established as a high-grade Portland cement has been omitted from the new specification. The Government committee desired to have the following modified form of this clause inserted under the head of "Rejection":

The right is reserved to reject any mill product which is not established as a high-grade Portland cement.

The other committees, however, would not agree to the insertion of this clause and the Government committee waived its desires in the matter for the sake of uniformity.

The clause relative to rejection of packages short in weight is inserted in a modified form elsewhere in the specification under the heading "Rejection."

INSPECTION

Old version.—The cement shall be tested in accordance with the standard methods hereinafter described. In general, the cement will be inspected and tested after delivery, but partial or complete inspection at the mill may be called for in the specifications or contract. Tests may be made to determine the chemical composition, specific gravity, fineness, soundness, time of setting, and tensile strength, and a cement may be rejected in case it fails to meet any of the specified requirements. An agent of the contractor may be present at the making of the tests or they may be repeated in his presence.

In case of the failure of any of the tests, and if the contractor so desires, the engineer may, if he deem it to the interest of the United States, have any or all of the tests made or repeated by the Bureau of Standards, United States Department of Commerce, in the manner hereinafter specified, all expenses of such tests to be paid by the contractor. All such tests shall be made on samples furnished by the engineer.

New version.—Every facility shall be provided the purchaser for careful sampling and inspection at either the mill or at the site of the work, as may be specified by the purchaser. At least 10 days from the time of sampling shall be allowed for the completion of the 7-day test, and at least 31 days shall be allowed for the completion of the 28-day test. The cement shall be tested in accordanced with the methods hereinafter prescribed. The 28-day test shall be waived only when specifically ordered.

The inspection clause has been entirely rewritten. That part referring to rejection has been placed elsewhere in the specification under the heading "Rejection." The paragraph referring to retest by the Bureau of Standards in cases of dispute has been omitted. In the new specification a minimum time is specified for the completion of tests. Specific provision is also made for

the omission of the 28-day tests only when specially so ordered by the engineer.

REJECTION

New Version.—The cement may be rejected if it fails to meet any of the requirements of these specifications.

Cement shall not be rejected on account of failure to meet the fineness requirement if upon retest after drying at 100° C. for one hour it meets this requirement.

Cement failing to meet the test for soundness in steam may be accepted if it passes a retest using a new sample at any time within 28 days thereafter.

Packages varying more than 5 per cent from the specified weight may be rejected; and if the average weight of packages in any shipment, as shown by weighing 50 packages taken at random, is less than that specified, the entire shipment may be rejected.

This is a new section of the specification embracing all references to the rejection of cement as taken from other portions of the old specification. The only new matter is a clause relative to the permissible variation in the weight of packages.

METHODS OF TESTS

The description of the methods of tests are of too great length to be repeated here. However, following are comments relative to the changes made.

SAMPLING

The description of the method of sampling has been entirely rewritten making the method specific for individual and composite and for car and bin sampling.

The departmental committee is not in favor of an invariable rule concerning the number of samples that may be required but waived its objection to this feature of the new specification for the sake of uniformity.

CHEMICAL ANALYSIS

Much attention was given to the method of chemical analysis. With the cooperation of Dr. W. F. Hillebrand and Clifford Richardson numerous tests were made by many laboratories and the old methods modified in the light of the results obtained.

A tolerance or permissible variation is also allowed on each determination. The purpose of this tolerance is to prevent the rejection of cement where the analysis shows that the restricted element exceeds the limitations of the specifications by no more than the probable error due to lack of reproducibility of chemical determinations. The majority of the Government committee is opposed to the inclusion of any tolerance allowance in the specification, believing that sufficient margin should be provided by the manufacturer to cover the probable error of test.

DETERMINATION OF SPECIFIC GRAVITY

The method of determining specific gravity was not changed from the old specification, although the description was somewhat modified; the method of igniting sample for retest was changed and the required temperature raised. The temperature allowed will drive off carbon dioxide (CO_2) and some other gases if present and would be objectionable if the specific gravity test were important.

DETERMINATION OF FINENESS

The description of the method has been expanded and slightly changed to make it more definite.

The most essential difference from the old specification is the insertion of a "tolerance" or "permissible variation" clause which provides for the acceptance of the cement unless the results show that the cement is actually coarser than the requirement, after allowing 1 per cent for the lack of reproducibility of the determination. The majority of the Government committee is opposed to the inclusion of a tolerance clause for the reason previously stated under chemical analysis.

MIXING CEMENT PASTES AND MORTARS

The only change made is in the verbiage to make the statement more clear and specific.

NORMAL CONSISTENCY

The Vicat method is substituted for the Ball method for the determination of normal consistency. A comprehensive series of tests was made which showed that the Vicat method gave slightly more concordant results.

DETERMINATION OF SOUNDNESS

No change was made in the method other than omitting the description of the air and water pat. The verbiage is modified slightly and illustrations are shown of a steam apparatus and typical failures of pats in the steam soundness test.

DETERMINATION OF TIME OF SETTING

The old specification provided only for the use of the Gillmore method. In the new specification both the Gillmore and Vicat methods are described and the specification permits the use of either.

TENSION TESTS

No essential change has been made in the method although the verbiage has been changed somewhat to make it more specific.

STORAGE OF TEST PIECES

No essential change has been made other than the insertion of the description of a moist closet for the storage of test pieces and placing a minimum limitation on the time which briquettes should be retained in the molds.

GENERAL REMARKS

The Government committee is of the opinion that the new specification is an improvement over the old. Certain essential requirements such as strength, fineness, and setting properties, have been increased, certain unessential requirements, such as tests of neat cement, 100-mesh sieve requirement, air and water soundness pats, etc., have been omitted. Other limitations which did not improve the quality of cement but were a handicap to certain manufacturers such as the low sulfuric anhydride and magnesia limitations have been made more liberal.

While the Government committee desired certain changes in the substance and form of these specifications it is of the opinion that the securing of generally recognized uniform specification for Portland cement in the United States is of greater importance and it must be recognized that such uniformity is made possible only by compromise.

The new specification, although an improvement over the old, can not be considered as entirely satisfactory, as there is no test which furnishes specific information as to the relative value in concrete of the products of different mills. Under the specification for fineness the cement may contain a large percentage of worthless material which could be made valuable by finer grinding, and improvement in this direction should be steady and persistent. Furthermore, the methods of tests so far devised are not as accurate as they should be. With the continuation of investigations and research further improvement should be possible in the near future.

Respectfully submitted.

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