

## Canadian Society of Civil Engineers.

### REPORT OF COMMITTEE ON A STANDARD SPECIFICATION FOR PORTLAND CEMENT.

January 27th, 1903.

The Committee, consisting of Dr. H. T. Bovey (chairman), Messrs. M. J. Butler, C. B. Smith, T. Monro, P. A. Peterson, C. H. Rust, G. A. Mountain and J. A. Duff, recommends that the following be adopted as a Standard Specification for Portland Cement, and that all testing be done in accordance with the accompanying report:—

The whole of the cement is to be well burned pure Portland Cement, of the best quality, free from free-lime, slag, dust, or other foreign material.

(1) FINENESS.—The cement shall be ground so fine that the residue on a sieve of 10,000 meshes to the square inch shall not exceed ten percent of the whole by weight, and the whole of the cement shall pass a sieve of 2,500 meshes to the square inch.

(2) SPECIFIC GRAVITY.—The specific gravity of the cement shall be at least 3.09 and shall not exceed 3.25 for fresh cement; the term "fresh" being understood to apply to such cements as are not more than two months old.

(3) TESTS.—The cement shall be subjected to the following tests:

(a) *Blowing Test*.—Mortar pats of neat cement, thoroughly worked, shall be trowelled upon, carefully cleaned, 5-in. by 2½-in. ground glass plates. The pats shall be about ¼-in. thick in the centre and worked off to the sharp edges at the four sides. They shall be covered with a damp cloth and allowed to remain in the air until set, after which they shall be placed in vapour in a tank, in which the water is heated to a temperature of 130° Fah. After remaining in the vapour six hours, including the time of setting in

air, they shall be immersed in the hot water and allowed to remain there for eighteen hours. After removal from the water the samples shall not be curled up, shall not have fine hair cracks, nor large expansion cracks, nor shall they be distorted. If separated from the glass, the samples shall break with a sharp, crisp ring.

(b) *Tensile Test. (Neat Cement.)*—Briquettes made of neat cement, mixed with about twenty percent of water, by weight, after remaining one day in air, in a moist atmosphere, shall be immersed in water, and shall be capable of sustaining a tensile stress of 250 lbs. per square inch after submersion for two days; 400 lbs. per square inch after submersion for six days; 500 lbs. per square inch after submersion for twenty-seven days. The tensile test shall be considered as the average of the strength of five briquettes, and any cement showing a decrease in tensile strength on or before the twenty-eighth day shall be rejected. (*Sand and Cement.*)—The sand for standard tests shall be clean quartz, crushed so that the whole shall pass through a sieve of 400 meshes to the square inch, but shall be retained on a sieve of 900 meshes per square inch. The sand and cement shall be thoroughly mixed dry, and then about ten percent of their weight of water shall be added, when the briquettes are to be formed in suitable moulds. After remaining in a damp chamber for twenty-four hours the briquettes shall be immersed in water, and briquettes made in the proportion of one of cement to three of sand, by weight, shall bear a tensile stress of 125 lbs. per square inch after submersion for six days, and 200 lbs. per square inch after submersion for twenty-eight days. Sand and cement briquettes shall not show a decrease in tensile strength at the end of twenty-eight days, or subsequently.

(4) The manufacturer shall, if required, supply chemical analyses of the cement.

(5) *PACKING.*—The cement shall be packed either in stout air and water-tight casks, carefully lined with strong brown paper, or in strong air and water-tight bags.

(6) The manufacturer shall give a certificate with each shipment of cement, stating (1) the date of manufacture; (2) the tests and analyses which have been obtained for the cement in question at the manufacturer's laboratory; (3) that the cement does not contain any adulteration.

REPORT OF COMMITTEE TO CONSIDER STANDARD PORT-  
LAND CEMENT TESTS.

All experiments shall be carried on, as nearly as possible, at a uniform temperature of 65 deg. Fah., except when tests are being made for the purpose of ascertaining the comparative strength of cements required for winter use.

(1) PROPORTIONS.

All proportions shall be determined by weight.

(2) FINENESS OF CEMENT.

A maximum residue of ten percent shall be retained on a sieve of 10,000 meshes to the square inch, and the whole of the cement shall pass through a sieve of 2,500 meshes to the square inch. A mechanical sifter, working automatically by jig motion, and thus eliminating personal error, is recommended.

In the case both of hand mixing and sifting with the mechanical mixer, the process shall occupy a definite time, depending upon the weight to be sifted, and the diameter of the sieve. For example, with a weight of 10-oz. of cement and sieves 8-in. in diameter, the sifting shall be continued  $2\frac{1}{2}$  minutes on No. 120 sieve, 1 minute on No. 100,  $\frac{3}{4}$  minute on No. 80 and  $\frac{1}{2}$  minute on No. 50.

The introduction of small weights, such as washers, into the cement, while being sifted, is to be deprecated, as they tend to push an undue proportion of the cement through the mesh, to stretch the wires and to increase, to some extent, the grinding. Such practice should not be allowed, excepting on works of construction, where there may be a necessity for ordinary rough tests.

The sieves shall be periodically examined with great care, as moisture sometimes collects on the wire, so that, when a residue test is made, this moisture mixes with the cement, causing a coating of the wires, and often appreciably diminishing the area of the mesh.

The sand for standard tests shall be quartz, crushed so that the whole can pass through a sieve of 400 meshes to the square inch, but sufficiently coarse to allow of the whole being retained by a sieve of 900 meshes to the square inch.

### (3) SPECIFIC GRAVITY.

The specific gravity is for the purpose of determining the degree of calcination of a cement with certainty, and is, therefore, of great importance. The specific gravity of a Portland cement shall be at least 3.09, and shall not exceed 3.25 for fresh cements, the term "fresh" being understood to apply to such cements as are not more than two months old. The gravimetric system is recommended for the determination of the specific gravity.

Portland cement improves with age, provided it is properly stored and kept in air-tight bags or barrels. Specifications, therefore, should not prescribe *only fresh* cement.

The following description of the method of carrying out this test is taken from a paper on "Testing of Portland Cement," by Gary, Trans. Amer. Soc. of Civil Engineers, October, 1893.

"The determination of the specific gravity of the cement particles by the volume-meter of Schumann, is a well-known uniform method. This consists of a glass bottle of about 200 cu. cm. (12.2 cu. in.) capacity, with a calibrated glass tube in its neck. The bottle is nearly filled with oil of turpentine, the tube tightly inserted and filled by a pipette with the same oil to the zero mark of the scale, care being taken that all air bubbles are removed. One hundred gr. (3.5 oz.) of cement is put in through the tube, which is then closed by a cork. When the fluid becomes clear, the height of its top surface is noted on the scale. The weight of the cement, divided by its volume, as determined by the scale of readings, gives the specific gravity. To secure precise results, it is necessary that the temperature should remain uniform throughout the experiment, and hence vessels, cement and oil must have been kept in the same room for some considerable time. In hot weather the apparatus can be put into water of a known constant temperature. If 100 gr. of cement are used, a rise of 1° Cent. between the two readings decreases the specific gravity 0.8 percent."

(4) BLOWING TEST (FOR FREE LIME, ETC.)

The hot bath test for detecting the presence of free lime, etc., shall be carried out in the following manner: Mortar pats, prepared of neat cement and thoroughly worked, shall be troweled upon ground glass plates (carefully cleaned, preferably with acid) about 5 inches long by  $2\frac{1}{2}$  inches wide, and  $\frac{1}{4}$ -inch thick, so as to exclude all air and moisture.

The pats shall be about  $\frac{1}{2}$ -inch thick in the centre, and shall be worked off to sharp edges on the four sides of the plate. They shall then be covered with a damp cloth and allowed to remain in the air until set, after which they shall be placed in vapour in the Faija bath tank, in which the water is to be heated to a temperature of about 130 deg. Fah. After remaining in the vapour for six hours, including the time taken to set in air, they are to be immersed in hot water, and allowed to remain there for eighteen hours. Upon their removal from the bath, the samples should not be curled up, should not have fine hair cracks nor be distorted, and should not have large expansion cracks. The samples, if separated from the glass, should break with a sharp crisp ring. If these conditions are satisfactorily fulfilled, it is believed that no free lime is present in a form that will prove detrimental. Cements when very finely ground, even if slightly overlimed, are not so liable to blow.

(5) TIME OF SETTING.

The time of setting shall be determined by noting the time required for a sample under test to bear a needle of 1-12 inch diameter loaded with one-fourth of a pound, and 1-24 of an inch diameter loaded with one pound, the mortar under test being of the consistency of rather stiff plaster or mortar. The percentage of water used shall be stated in the report.

For more accurate determination, a brass or rubber mould, 10 c. m. in diameter and 4 c. m. high, is filled with neat cement, mixed to such a plastic consistency that a plunger of 1 c. m. diameter and loaded with 300 grammes, penetrates to a point 6 m. m. from the bottom. Setting commences when a needle, of 1 square m. m. section, first refuses to sink entirely through "the mould." Setting is complete when the needle rests upon without penetrating the surface.

## (6) TENSILE AND COMPRESSIVE TESTS.

The strength of Portland cements shall be determined by testing neat cement and, if required, a mixture of neat cement and quartz sand. The tests shall be made in a uniform manner (both for tension and compression) with briquettes of the same form and same cross section and with the same apparatus.

NEAT CEMENT.—Neat tests, except where fineness, specific gravity and hot bath blowing tests are also made, are misleading as to the value of a cement. Briquettes of neat cement, in which these characteristics have been determined and found to be satisfactory, shall bear a tensile stress of 250 lbs. per square inch at the end of three days; 400 lbs. per square inch at the end of seven days, and 500 lbs. per square inch at the end of 28 days. All briquettes shall be one day in air, under a damp cloth or in a damp chamber, and submerged in clean water for the remainder of the time periods. Any cement which shows a decrease in strength on or before the twenty-eighth day is to be rejected. The decisive tests shall be considered as the average of five briquettes, although for ordinary practice two or more briquettes may be sufficient and, in the latter case, only the highest test of the group is to be taken as the strength of the cement.

In determining the tensile strength of a briquette, the area of the broken surface shall be measured with great accuracy, as errors sometimes exceeding ten percent are possible unless such measurements are insisted upon.

SAND AND CEMENT.—In sand tests, the sand and cement must be thoroughly mixed together while dry. After the water has been added, either for neat or sand tests, the mortar shall be thoroughly mixed for a uniform time; suitable periods being two minutes for machine mixing and five minutes for hand mixing.

Briquettes made of one part cement and three parts standard sand, shall remain in a damp atmosphere for twenty-four hours, when they shall be immersed in water and shall then bear a tensile stress of 125 lbs. per square inch after submersion for six days and 200 lbs. per square inch after submersion for twenty-seven days.

At the end of the same period the minimum compressive strength of a mixture of one part cement to three parts sand shall be 2,000 lbs. per square inch.

[NOTE.—Quick setting cements generally show a lower strength than that specified above].

The tensile strength of briquettes, mixed in the proportion of three to one, or of other sand briquettes, shall not show a decrease either on the twenty-eighth day or subsequently.

In every case the quantity of water used in mixing shall be stated in the report.

The quantity of water to be used in neat tests, varies with the kind of cement, fineness, etc., and hence no arbitrary quantity can be specified, the correct method being to bring all mortars to the same degree of plasticity. An apparatus, similar to "Vicat's," and consisting of a needle having an area of 0.4 square inches, weighted to about 11 oz., may be used.

"The tests are made as follows: A ring, 1½-in. in height and 3-in. in diameter, made of non-absorbing material, is placed on a glass plate and filled with the mortar to be tested, the consistency being such that the needle does not entirely pierce it. (Trans. Amer. Soc. Civil Engineers, Oct. 1893).

A simpler method for determining the standard consistency for neat cement tests is to mould a ball of mortar in the hands to a plastic state and drop the same about twenty inches on to the table. If the ball of mortar neither flattens appreciably nor cracks, the consistency is satisfactory. This process corresponds practically with the previous method. The water for standard consistency of three to one sand briquettes shall ordinarily be ten percent of the sand and cement by weight. If the amount of water for standard consistency of neat cement of any particular brand be less than twenty percent, then the amount of water for standard consistency of three to one sand briquettes for this particular brand shall be one-half of the amount used in neat tests.

(7) PREPARATION OF BRIQUETTES.

(a) *Hand-Made.*

(1) NEAT CEMENT.—The moulds shall be slightly oiled on the inner side and placed upon a metal or glass plate. The mixture of cement and water shall then be thoroughly worked together (preferably in a Faija's mixer) for five minutes. The moulds shall then be filled well above the rim, so that the mortar presents a convex

surface. With an iron trowel the mixture shall then be patted, commencing at the side, first gently and then harder, until it becomes elastic and water appears upon its surface. No after addition of the mixture shall be allowed, as the briquettes must be of uniform density throughout. The superfluous cement shall then be removed and the surface smoothed by means of a knife or sharp-edged trowel. The moulds can only be removed when the cement has hardened sufficiently. The briquettes shall then be placed in a damp chamber (zinc lined) furnished with a lid (also zinc lined) to prevent the irregular drying of the briquettes under varying degrees of temperature. After a period of twenty-four hours the briquettes shall be laid in water and kept completely submerged during the whole period of hardening. The proportion of water used shall be stated in the report.

(2) SAND AND CEMENT.—Five pieces of blotting paper, soaked in water, shall be laid upon a metal or glass plate, and upon each piece of paper there shall be placed a mould, also moistened with water. The cement and sand, in their specified proportions, shall then be thoroughly mixed together, after which the water shall be added, and the whole thoroughly worked for five minutes. With the mortar thus obtained each mould shall be filled by one application so as to rise in a convex form above the edge of the mould. With an iron trowel the mortar shall then be patted, beginning from the side, first gently, then harder, until it becomes elastic and water appears upon the surface. No additional material must be added, as the briquettes must show a uniform density throughout. Superfluous mortar shall then be taken off by means of a knife or sharp-edged trowel, and the surface smoothed.

The moulds shall then be carefully removed and the briquettes laid in a damp chamber (zinc lined), furnished with a lid (also zinc lined), to prevent irregular drying. After a period of 24 hours the briquettes shall be laid in water and shall be kept completely submerged during the whole period of hardening.

(b) *Machine-Made.*

(1) If possible, briquettes, prepared as above, shall be subjected to a uniform specified pressure (say, for example, 20 lbs. per square inch) by means of a ram of the same gauge as the moulds, or,



(2) A Bhme apparatus may be used. In this case the moulds shall be filled with about 4-10ths of a lb. of mortar, prepared as in (a), and shall be placed in the machine; 150 strokes shall then be applied to the core with a hammer of about 4.4 lbs. in weight (2 killog). After removing the mould and the core the briquettes shall be smoothed off, taken off the subjacent plate and treated as in (a).

By care in following the instructions given in (a) and (b) it will be found that hand work and machine work will give fairly uniform results. Doubtful cases, however, should be invariably decided by machine made briquettes.

#### (8) TESTING MACHINES.

Testing machines shall be of the positive lever automatic type, so arranged as to apply the loads quietly and uniformly at the rate of two hundred pounds per minute.

#### (9) CLIPS.

The style of clips shall be such as will break the briquette at the line of least section. Clips with adjustable rubber or paper composition rollers are found to work satisfactorily and should be used.

#### (10) CHEMICAL TESTS.

Chemical tests and full quantitative analyses are strongly recommended, and preference will be given to cements, of which analyses are furnished by the manufacturers.

#### (11) ADULTERATIONS, ETC.

Any cement containing adulteration shall not be accepted as a Portland cement. There are also certain ingredients which should be strictly limited in their amount. If there is found to be more than two percent of sulphuric acid, or three percent of magnesia, the cement should be rejected. It is understood that Portland cements only are being specified for. The Silica, or sand cements, are in a class by themselves, need special specifications, and are not intended to be included in the present one.

## (12) PACKING.

Cement shall either be packed in paper-lined air-tight barrels, well constructed and hooped so that, under ordinary conditions of handling, no cement shall sift out, or if in sacks, the texture of the sacks shall be so strong and fine as not to permit of any sifting out or wasting of cement under ordinary conditions of handling. The net amount of cement, deducting the weight of the package, shall be 350 pounds per barrel.

## (13) CERTIFICATE.

The manufacturer shall give a written certificate with each shipment of cement, stating (1) the date of manufacture; (2) the tests and analyses which have been obtained at the manufacturer's laboratory for cement taken from the day's grinding, of which the shipment forms a part; (3) that the cement does not contain any adulteration.

## (14) FROST TEST.

In case of experimental tests, made for the purpose of determining the action of cements when exposed to severe frost, it is recommended that the cements be mixed at an atmospheric temperature below freezing, with cold water and cold sand, and kept exposed to ordinary winter weather, just as they would be exposed in actual construction of masonry. A description of what is done in this connection should be kept for comparison with other results, and the records of such experiments filed with the secretary of the Canadian Society of Civil Engineers.

## (15) HOT BATH TEST.

It has been observed in hot tests that little pustules or eruptions take place on the surface; instances are also given of the glass shattering in the hot bath test without separating from the cement, or without any other sign of failure on the part of the cement. Members of the Society are requested to observe the causes or reasons therefor and report the same to the Secretary of the Society.

## (16) MIXING.

Inasmuch as small consumers are rarely able to gauge or mix their test specimens with a mechanical mixer, it is advised that where tests are made by hand mixing, due discrimination shall be made in comparing the results with tests made by mechanical mixing. Hand mixing, done by an expert, will probably agree closely with mechanical mixing, but for ordinary testing the mechanical method will give more uniform results, inasmuch as no skill or dexterity is required to produce approximate uniformity.

## (17) TIME TESTS.

Cement testers, where possible, should make long time tests to see whether or not there is any connection between high early tests and future falling off in tensile strength, and whether, when mixed three to one with sand, the same or similar deterioration is observed. These tests should, if possible, be carried on for several years. It would be of the utmost value to the profession to obtain positive data on this point from engineers in charge of municipal, university or other laboratories, who are in a position to supply it.