STATE OF CALIFORNIA—BUSINESS, TRANSPORTATION AND HOUSING AGENCY

DEPARTMENT OF TRANSPORTATION
DIVISION OF ENGINEERING SERVICES
Materials Engineering and Testing Services
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TEST FOR FREEZE-THAW RESISTANCE OF AGGREGATES IN AIR-ENTRAINED CONCRETE (POWERS PROCEDURE)

CAUTION: Prior to handling test materials, performing equipment setups, and/or conducting this method, testers are required to read "SAFETY AND HEALTH" in Section H of this method. It is the responsibility of the user of this method to consult and use departmental safety and health practices and determine the applicability of regulatory limitations before any testing is performed.

A. SCOPE

This method has been adapted from a proposal by T. C. Powers. It describes the procedure used to evaluate the resistance to deterioration of aggregates in air-entrained concrete when subjected to a specified period of soaking in water with intervening cycles of freezing and thawing. Values given for maximum size of aggregate, size of test specimen, conditioning prior to soaking, and length of soaking period are intended to be appropriate for construction in localities of severe winter exposure in California. The test conditions are subject to modification if exposure conditions at the site of the work so warrant. When tests are performed for work on a particular project, the test conditions given in this method shall be followed unless otherwise provided in the contract.

B. APPARATUS

1. Apparatus specified in ASTM Designation: C 192 for making and curing concrete specimens in the laboratory.

2. One or more refrigerated baths of a size and depth required to contain the test specimens immersed in water-saturated kerosene, and having suitable controls to provide a lowering of the temperature at the rate of 2.8 ± 0.6°C per hour from room temperature to -17.8°C. Household type deep freezing chests with a copper liner have been found to be satisfactory. Two or more baths are desirable unless the number of specimens to be tested at one time is small.

3. One or more water baths of a size and depth required to contain the specimens immersed in water, and equipped with water supply and overflow outlet.

4. A supply of frames, with linear variable differential transformers attached, for supporting test specimens for automatic measurement of length changes during cooling. A satisfactory design is shown in Figures 1 and 2.

5. A supply of 114 x 229 mm cylinder molds which are equipped with top and bottom detachable plates for holding gage studs.

6. A comparator, which meets the requirements of ASTM Designation: C 157, for use in measuring permanent length changes of test specimens, and a standard reference bar.

7. A balance sensitive to 1 g and having a capacity of at least 6,000 g.

8. Closed corrosion-resistant containers large enough to contain one or more 114 x 229 mm test specimens with free space of at least 19 mm from all faces, and equipped with means of supporting the specimens at least 57 mm above the bottom.

9. A strain recorder[1] with suitably ruled paper. It shall consist of a multipoint displacement recorder having one channel for each specimen being tested for dilation during cooling. The switching sequence from one channel to the next shall be accomplished automatically at a rate such that the time interval between prints for a particular channel does not exceed 5 minutes. The system shall have sensitivity sufficient to indicate displacements of 635 millionths mm equal to one chart division through
a range of 0.1 mm. Displacements indicated by the linear variable differential transformers in contact with the studs of test specimens shall be recorded. A calibration bar shall be furnished.

10. An automatic temperature recorder [1] connected to thermocouples embedded in companion concrete cylinders of the same size as the test specimens. Use one in each bath in which dilations are measured. The temperature of each thermocouple shall be printed on a chart within an accuracy of 0.6°C through a range from room temperature to -23.3°C. Prints for each channel shall be recorded at a frequency of not more than 5 minutes.

C. SECURING AND PREPARING AGGREGATE SAMPLES

1. Secure samples of aggregates under the direct supervision of the engineer in charge of the work. Take samples of existing stockpiles of processed aggregate from washed materials that are visibly damp. Obtain samples of materials in place in a proposed source at depths from the surface that will ensure the presence of the full quantity of groundwater. Make excavations for the purpose of securing samples to the full depth of intended operations. Protect samples against loss of contained water until they are delivered to the laboratory.

2. Ship samples to the laboratory in containers with tight fitting covers[2]. Add water to each container before it is sealed.

3. In the laboratory, handle the samples in such a manner that there will be no loss of absorbed water. Process the samples by washing if required, separate into sieve sizes and recombine to the required grading in the presence of excess water. If particles larger than 37.5 mm are present in the sample, crush and add to the finer material or waste if the oversize particles are to be wasted during manufacture.

D. MOLDING AND CURING TEST SPECIMENS

1. Proportion concrete mixtures with 37.5 mm or 25 mm maximum size aggregate graded to conform to the specifications for the work.

2. Mix concrete in accordance with ASTM Designation: C 192. Use cement factor and slump within the limits specified for the work. If testing is being done prior to designation of source for any specific project, use 305 kg of cement per m^3 and 75 ± 25 mm slump.

3. Incorporate an air-entraining agent consisting of neutralized Vinsol resin solution in the quantity required to result in an air content of 5.0 ± 1.0% for 37.5 mm maximum size aggregate and 6.0 ± 1.0% for 25 mm maximum size aggregate.

4. Determine slump, air content, and cement factor for each batch. Use a size of batch sufficient to provide at least four 114 x 229 mm test specimens.

5. Mold four or more 114 x 229 mm cylinders from each batch. An external vibrator such as a vibrator packer may be used in lieu of rodding to compact the concrete in the molds.

6. Embed stainless steel gage studs 25 mm long in the fresh concrete so as to project 3.8 mm at each end of the longitudinal axis of the specimens.

7. For each aggregate or combination of aggregates to be tested, mix at least three

[1] Manual means of measuring length changes and temperature may be substituted for automatic recorders provided the apparatus has a sensitivity equal to that of the automatic apparatus. Length change observations shall be made at least once every 5 minutes on each specimen under test during the time the temperature of the specimen is lowered from 0°C to -3.9°C.

[2] 19-liter food buckets have proven to be satisfactory.

batches of concrete, each on a different day, providing a minimum of 12 test specimens.

8. After molding, cover the specimens with wet mats (keep mats wet at all times). When the specimens are 24 ± 4 hours old, remove them from the molds and place them in the moist curing room.

9. Continue standard moist curing to the age of 14 days.

E. CONDITIONING OF TEST SPECIMENS

1. At the end of the moist curing period, weigh the specimens to the nearest 1 g in a surface-dry condition and measure for length to the nearest 0.003 mm, using the comparator (Section B.6)[3]. Record the temperature of the concrete at the time of measurement. (Subsequent measure-ments are made at this temperature.)

2. Place the specimens in air at 50% relative humidity at a temperature of 23 ± 1.7°C for 2 days. At the end of 2 days, weigh and measure for length.

3. Place the specimens in closed containers over a saturated solution of sodium acetate, with an excess of the salt, for a period of 5 days at a temperature of 23 ± 1.7°C. The solution shall be at least 38.9 mm in depth and shall not be closer than 19 mm to the bottom of the test specimens. At the end of the 5 days, remove the specimens, weigh, and measure for length.

4. Then immerse the specimens in water at room temperature and soak for 14 days.

5. At the end of the 14-day soaking period, remove the specimens from the water bath, (total age at this point is 5 weeks), wipe free of surface water, weigh, and again measure for length.

6. If more severe conditioning is desired, eliminate step 2 and condition in accordance with step 3, with the exception that the time in the closed containers shall be increased to seven days. Then follow the procedures in steps 4 and 5.

F. FREEZE–THAW AND SOAKING CYCLES

1. Place the specimens in the frames used to measure and record strains during cooling.

2. Immerse the specimens in the frames in water-saturated kerosene in the refrigerated baths, connect to the strain-recording instrument, and start the strain-recording instrument.

3. Place a companion specimen containing a thermocouple in the bath, connect to the temperature-recording instrument, and start the temperature-recording instrument.

4. Keep the specimens in the bath for $1^1/_2$ hours or until the temperatures of the specimen and the bath are equal. Then place the cooling equipment in operation. The temperature at this point shall be above 7.2° C.

5. Cool the bath at a rate of 2.8° ± 0.6° C per hour until the temperature reaches -17.8° ± 2.8° C. Then remove the specimens and record the time on the charts.

6. Immerse the specimens in water and allow to warm to within ± 1.1° C of the temperature at which initial length measurements were made (Section E.1). Then weigh and measure for length. At the conclusion of the test, make the measurement for length at a temperature within ± 0.6° C of the temperature at initial measurement.

7. Keep the specimens in the water bath continuously, except while cooling them in kerosene as described in Step 5 above at the rate of five times per week, until a total soaking period of 10 weeks has elapsed. (The total age of the specimens at this point is 13 weeks.)

8. Cooling to –17.8° C, except during the first cycle and each succeeding 10^{th} cycle, may be performed without connecting the specimens to the strain-recording device.

9. At the end of each one-week soaking period, weigh and measure the specimens for length. At the end of each two-week soaking period, connect to the strain-recording device during one cycle of cooling.

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[3] The method of inserting gage studs does not ensure that they coincide absolutely with the vertical axis of the specimen. For this reason, the needle of the dial gage may not remain stationary as the specimen is rotated. Reproducible results are obtained by rotating the specimen until the minimum reading is found.

10. At the conclusion of each recorded cooling cycle, mark the charts to show equal time periods of 15 minutes.

11. Plot the recorded strain, estimated to the nearest one-half chart division, divided by the gage length, 191 mm, against the temperature recorded at the same time through the range 4.4°C to -12.2°C.

12. Examine the curve for evidence of dilation at the approximate freezing point. If dilation is evident, measure it as the distance between the start of dilation at the apparent freezing point and the greatest succeeding length. Record the result as the dilation in millionths[4].

G. REPORTING OF RESULTS

Report each individual specimen to have "passed" the test if:

1. The dilation at any measured period did not exceed 50-millionths, and

2. The final length at the conclusion of the soaking period does not exceed the length at the conclusion of the 14-day moist curing period by more than 0.006% of the gage length (measured between inner ends of the gage studs).

Report the specimen to have failed the test if it failed to meet any of the requirements set forth above to qualify as "passing."

Report the aggregate or combination of aggregates under test to have "passed" the test if 65% or more of the individual specimens of the group passed the test. If less than 65% of the individual specimens of the group passed the test, report the aggregate or combination of aggregates to have "failed" in the test.

H. SAFETY AND HEALTH

Prior to handling, testing or disposing of any waste materials, testers are required to read: Part A (Section 5.0), Part B (Sections: 5.0, 6.0 and 10.0) and Part C (Section 1.0) of Caltrans Laboratory Safety Manual. Users of this method do so at their own risk.

REFERENCES:
ASTM Designations: C 192 and C 157
T. C. Powers, "Basic Considerations Pertaining to Freezing-Thawing Tests," Proceedings ASTM, Volume 55, p. 1132 (1955)

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California Test 528

[4] Usually, a satisfactory measurement of dilation can be obtained directly from recorded strains on the original chart. In such cases, do not prepare a separate temperature-strain curve unless it is wanted for illustrative purpose.

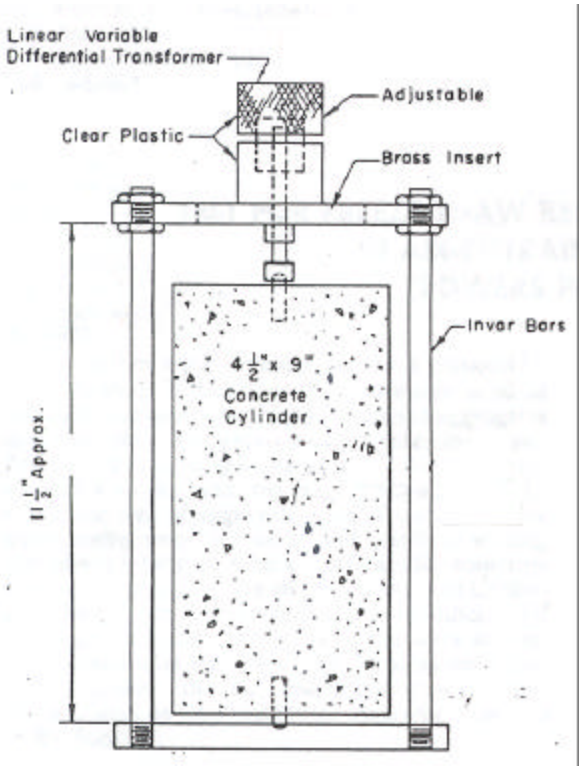

FIGURE 1
Frame for Continuous Measurement of Dilation

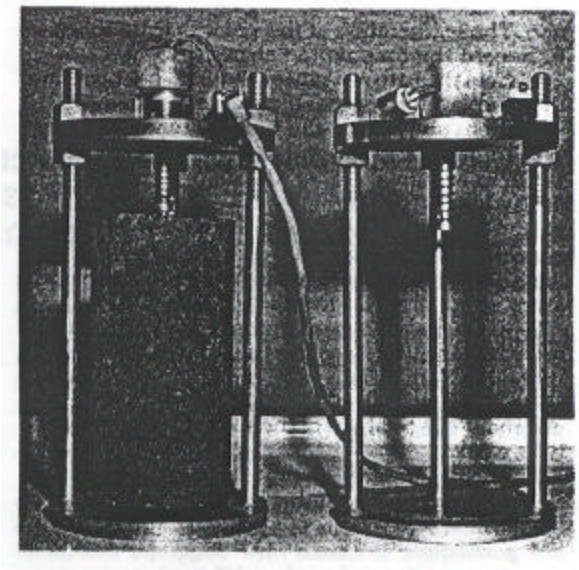

FIGURE 2
Frames for Continuous Measurement of Dilation