Designation: C 666 – 97

Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing[1]

This standard is issued under the fixed designation C 666; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This test method covers the determination of the resistance of concrete specimens to rapidly repeated cycles of freezing and thawing in the laboratory by two different procedures: Procedure A, Rapid Freezing and Thawing in Water, and Procedure B, Rapid Freezing in Air and Thawing in Water. Both procedures are intended for use in determining the effects of variations in the properties of concrete on the resistance of the concrete to the freezing-and-thawing cycles specified in the particular procedure. Neither procedure is intended to provide a quantitative measure of the length of service that may be expected from a specific type of concrete.

1.2 The values stated in inch-pound units are to be regarded as the standard.

1.3 All material in this test method not specifically designated as belonging to Procedure A or Procedure B applies to either procedure.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

C 157 Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete[2]

C 192 Practice for Making and Curing Concrete Test Specimens in the Laboratory[2]

C 215 Test Method for Fundamental Transverse, Longitudinal, and Torsional Frequencies of Concrete Specimens[2]

C 233 Test Method for Testing Air-Entraining Admixtures for Concrete[2]

C 295 Guide for Petrographic Examination of Aggregates for Concrete[2]

C 341 Test Method for Length Change of Drilled or Sawed Specimens of Hydraulic–Cement Mortar and Concrete[2]

C 490 Practice for Use of Apparatus for Determination of Length Change of Hardened Cement Paste, Mortar, and Concrete[2]

C 494 Specification for Chemical Admixtures for Concrete[2]

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials[2]

C 823 Practice for Examination and Sampling of Hardened Concrete in Constructions[2]

3. Significance and Use

3.1 As noted in the scope, the two procedures described in this test method are intended to determine the effects of variations in both properties and conditioning of concrete in the resistance to freezing and thawing cycles specified in the particular procedure. Specific applications include specified use in Specification C 494, Test Method C 233, and ranking of coarse aggregates as to their effect on concrete freeze-thaw durability, especially where soundness of the aggregate is questionable.

3.2 It is assumed that the procedures will have no significantly damaging effects on frost-resistant concrete which may be defined as (*1*) any concrete not critically saturated with water (that is, not sufficiently saturated to be damaged by freezing) and (*2*) concrete made with frost-resistant aggregates and having an adequate air-void system that has achieved appropriate maturity and thus will prevent critical saturation by water under common conditions.

3.3 If as a result of performance tests as described in this test method concrete is found to be relatively unaffected, it can be assumed that it was either not critically saturated, or was made with “sound” aggregates, a proper air-void system, and allowed to mature properly.

3.4 No relationship has been established between the resistance to cycles of freezing and thawing of specimens cut from hardened concrete and specimens prepared in the laboratory.

4. Apparatus

4.1 *Freezing-and-Thawing Apparatus*:

4.1.1 The freezing-and-thawing apparatus shall consist of a suitable chamber or chambers in which the specimens may be subjected to the specified freezing-and-thawing cycle, together with the necessary refrigerating and heating equipment and controls to produce continuously, and automatically, reproducible cycles within the specified temperature requirements. In the event that the equipment does not operate automatically,

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[2] *Annual Book of ASTM Standards*, Vol 04.02.

provision shall be made for either its continuous manual operation on a 24-h a day basis or for the storage of all specimens in a frozen condition when the equipment is not in operation.

4.1.2 The apparatus shall be so arranged that, except for necessary supports, each specimen is: (*1*) for Procedure A, completely surrounded by not less than 1⁄32 in. (1 mm) nor more than 1⁄8 in. (3 mm) of water at all times while it is being subjected to freezing-and-thawing cycles, or (*2*) for Procedure B, completely surrounded by air during the freezing phase of the cycle and by water during the thawing phase. Rigid containers, which have the potential to damage specimens, are not permitted. Length change specimens in vertical containers shall be supported in a manner to avoid damage to the gage studs.

NOTE 1—Experience has indicated that ice or water pressure, during freezing tests, particularly in equipment that uses air rather than a liquid as the heat transfer medium, can cause excessive damage to rigid metal containers, and possibly to the specimens therein. Results of tests during which bulging or other distortion of containers occurs should be interpreted with caution.

4.1.3 The temperature of the heat-exchanging medium shall be uniform within 6°F (3.3°C) throughout the specimen cabinet when measured at any given time, at any point on the surface of any specimen container for Procedure A or on the surface of any specimen for Procedure B, except during the transition between freezing and thawing and *vice versa*.

4.1.3.1 Support each specimen at the bottom of its container in such a way that the temperature of the heat-exchanging medium will not be transmitted directly through the bottom of the container to the full area of the bottom of the specimen, thereby subjecting it to conditions substantially different from the remainder of the specimen.

NOTE 2—A flat spiral of 1⁄8-in. (3-mm) wire placed in the bottom of the container has been found adequate for supporting specimens.

4.1.4 For Procedure B, it is not contemplated that the specimens will be kept in containers. The supports on which the specimens rest shall be such that they are not in contact with the full area of the supported side or end of the specimen, thereby subjecting this area to conditions substantially different from those imposed on the remainder of the specimen.

NOTE 3—The use of relatively open gratings, metal rods, or the edges of metal angles has been found adequate for supporting specimens, provided the heat-exchanging medium can circulate in the direction of the long axis of the rods or angles.

4.2 *Temperature-Measuring Equipment*, consisting of thermometers, resistance thermometers, or thermocouples, capable of measuring the temperature at various points within the specimen chamber and at the centers of control specimens to within 2°F (1.1°C).

4.3 *Dynamic Testing Apparatus*, conforming to the requirements of Test Method C 215.

4.4 *Optional Length Change Test Length Change Comparator*, conforming to the requirements of Specification C 490. When specimens longer than the nominal 11¼ in. (286 mm) length provided for in Specification C 490 are used for freeze-thaw tests, use an appropriate length reference bar, which otherwise meets the Specification C 490 requirements. Dial gage micrometers for use on these longer length change comparators shall meet the gradation interval and accuracy requirements for Specification C 490 for either the inch or millimetre calibration requirements. Prior to the start of measurements on any specimens, fix the comparator at an appropriate length to accommodate all of the specimens to be monitored for length change.

4.5 *Scales*, with a capacity approximately 50 % greater than the weight of the specimens and accurate to at least 0.01 lb (4.5 g) within the range of ±10 % of the specimen weight will be satisfactory.

4.6 *Tempering Tank*, with suitable provisions for maintaining the temperature of the test specimens in water, such that when removed from the tank and tested for fundamental transverse frequency and length change, the specimens will be maintained within − 2°F and + 4°F (−1.1°C and + 2.2°C) of the target thaw temperature for specimens in the actual freezing-and-thawing cycle and equipment being used. The use of the specimen chamber in the freezing-and-thawing apparatus by stopping the apparatus at the end of the thawing cycle and holding the specimens in it shall be considered as meeting this requirement, provided the specimens are tested for fundamental transverse frequency within the above temperature range. It is required that the same target specimen thaw temperature be used throughout the testing of an individual specimen since a change in specimen temperature at the time of length measurement can affect the length of the specimen significantly.

5. Freezing-and-Thawing Cycle

5.1 Base conformity with the requirements for the freezing-and-thawing cycle on temperature measurements of control specimens of similar concrete to the specimens under test in which suitable temperature-measuring devices have been imbedded. Change the position of these control specimens frequently in such a way as to indicate the extremes of temperature variation at different locations in the specimen cabinet.

5.2 The nominal freezing-and-thawing cycle for both procedures of this test method shall consist of alternately lowering the temperature of the specimens from 40 to 0°F (4.4 to − 17.8°C) and raising it from 0 to 40°F (−17.8 to 4.4°C) in not less than 2 nor more than 5 h. For Procedure A, not less than 25 % of the time shall be used for thawing, and for Procedure B, not less than 20 % of the time shall be used for thawing (Note 4). At the end of the cooling period the temperature at the centers of the specimens shall be 0± 3°F (−17.8 ± 1.7°C), and at the end of the heating period the temperature shall be 40 ± 3°F (4.4 ± 1.7°C), with no specimen at any time reaching a temperature lower than − 3°F (−19.4°C) nor higher than 43°F (6.1°C). The time required for the temperature at the center of any single specimen to be reduced from 37 to 3°F (2.8 to − 16.1°C) shall be not less than one half of the length of the cooling period, and the time required for the temperature at the center of any single specimen to be raised from 3 to 37°F (−16.1 to 2.8°C) shall be not less than one half of the length of the heating period. For specimens to be compared with each other, the time required to change the temperature at the centers of any specimens from 35 to 10°F (1.7 to − 12.2°C) shall not differ by more than one sixth of the

length of the cooling period from the time required for any specimen and the time required to change the temperature at the centers of any specimens from 10 to 35°F (−12.2 to 1.7°C) shall not differ by more than one third of the length of the heating period from the time required for any specimen.

NOTE 4—In most cases, uniform temperature and time conditions can be controlled most conveniently by maintaining a capacity load of specimens in the equipment at all times. In the event that a capacity load of test specimens is not available, dummy specimens can be used to fill empty spaces. This procedure also assists greatly in maintaining uniform fluid level conditions in the specimen and solution tanks.

The testing of concrete specimens composed of widely varying materials or with widely varying thermal properties, in the same equipment at the same time, may not permit adherence to the time-temperature requirements for all specimens. It is advisable that such specimens be tested at different times and that appropriate adjustments be made to the equipment.

5.3 The difference between the temperature at the center of a specimen and the temperature at its surface shall at no time exceed 50°F (27.8°C).

5.4 The period of transition between the freezing-and-thawing phases of the cycle shall not exceed 10 min, except when specimens are being tested in accordance with 8.3.

6. Sampling

6.1 Constituent materials for concrete specimens made in the laboratory shall be sampled using applicable standard methods.

6.2 Samples cut from hardened concrete are to be obtained in accordance with Practice C 823.

7. Test Specimens

7.1 The specimens for use in this test method shall be prisms or cylinders made and cured in accordance with the applicable requirements of Practice C 192 and Specification C 490.

7.2 Specimens used shall not be less than 3 in. (76 mm) nor more than 5 in. (127 mm) in width, depth, or diameter, and not less than 11 in. (279 mm) nor more than 16 in. (406 mm) in length.

7.3 Test specimens may also be cores or prisms cut from hardened concrete. If so, the specimens should not be allowed to dry to a moisture condition below that of the structure from which taken. This may be accomplished by wrapping in plastic or by other suitable means. The specimens so obtained shall be furnished with gage studs in accordance with Test Method C 341.

7.4 For this test the specimens shall be stored in saturated lime water from the time of their removal from the molds until the time freezing-and-thawing tests are started. All specimens to be compared with each other initially shall be of the same nominal dimensions.

8. Procedure

8.1 Molded beam specimens shall be cured for 14 days prior to testing unless otherwise specified. Beam specimens sawed from hardened concrete shall be moisture-conditioned by immersing in saturated lime water at 73.4 ± 3°F (23 ± 1.7°C) for 48 h prior to testing unless otherwise specified.

8.2 Immediately after the specified curing or conditioning period, bring the specimen to a temperature within − 2°F and + 4°F (−1.1°C and + 2.2°C) of the target thaw temperature that will be used in the freeze-thaw cycle and test for fundamental transverse frequency, weigh, determine the average length and cross section dimensions of the concrete specimen within the tolerance required in Test Method C 215, and determine the initial length comparator reading (optional) for the specimen with the length change comparator. Protect the specimens against loss of moisture between the time of removal from curing and the start of the freezing-and-thawing cycles.

8.3 Start freezing-and-thawing tests by placing the specimens in the thawing water at the beginning of the thawing phase of the cycle. Remove the specimens from the apparatus, in a thawed condition, at intervals not exceeding 36 cycles of exposure to the freezing-and-thawing cycles, test for fundamental transverse frequency and measure length change (optional) with the specimens within the temperature range specified for the tempering tank in 4.6, weigh each specimen, and return them to the apparatus. To ensure that the specimens are completely thawed and at the specified temperature place them in the tempering tank or hold them at the end of the thaw cycle in the freezing-and-thawing apparatus for a sufficient time for this condition to be attained throughout each specimen to be tested. Protect the specimens against loss of moisture while out of the apparatus and turn them end-for-end when returned. For Procedure A, rinse out the container and add clean water. Return the specimens either to random positions in the apparatus or to positions according to some predetermined rotation scheme that will ensure that each specimen that continues under test for any length of time is subjected to conditions in all parts of the freezing apparatus. Continue each specimen in the test until it has been subjected to 300 cycles or until its relative dynamic modulus of elasticity reaches 60 % of the initial modulus, whichever occurs first, unless other limits are specified (Note 5). For the optional length change test, 0.10 % expansion may be used as the end of test. Whenever a specimen is removed because of failure, replace it for the remainder of the test by a dummy specimen. Each time the specimen is tested for fundamental frequency (Note 6) and length change, make a note of its visual appearance and make special comment on any defects that develop (Note 7). When it is anticipated that specimens may deteriorate rapidly, they should be tested for fundamental transverse frequency and length change (optional) at intervals not exceeding 10 cycles when initially subjected to freezing and thawing.

NOTE 5—It is not recommended that specimens be continued in the test after their relative dynamic modulus of elasticity has fallen below 50 %.

NOTE 6—It is recommended that the fundamental longitudinal frequency be determined initially and as a check whenever a question exists concerning the accuracy of determination of fundamental transverse frequency, and that the fundamental torsional frequency be determined initially and periodically as a check on the value of Poisson's ratio.

NOTE 7—In some applications, such as airfield pavements and other slabs, popouts may be defects that are a concern. A popout is characterized by the breaking away of a small portion of the concrete surface due to internal pressure, thereby leaving a shallow and typically conical spall in the surface of the concrete through the aggregate particle. Popouts may be