

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

AASHTO Designation: TP17-93^{1,2} (Reapproved 1996)

1. Scope

1.1 This method covers the determination of the resistance of concrete specimens to rapidly repeated cycles of freezing and thawing in the laboratory by three different procedures: Procedure A, Rapid Freezing and Thawing in Water; Procedure B, Rapid Freezing in Air and Thawing in Water; and Procedure C, Rapid Freezing in Air (moist cloth wrapped) and Thawing in Water. All three 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. The procedures are not intended to provide a quantitative measure of the length of service that may be expected from a specific type of concrete.

1.2 All material in this test method not specifically designated as belonging to Procedure A, Procedure B or Procedure C applies to any one of the procedures.

1.3 *This standard does not purport to address the safety problems 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 AASHTO Standards:

- M194 Chemical Admixtures for Concrete
- M210 Apparatus for Use in Measurement of Length Change of Hardened Cement Paste, Mortar, and Concrete
- T126 Making and Curing Concrete Test Specimens in the Laboratory
- T157 Air-Entraining Admixtures for Concrete
- T160 Length Change of Hardened Hydraulic Cement Mortar and Concrete

2.2 ASTM Standards:

- C215 Test for Fundamental Transverse, Longitudinal, and Torsional Frequencies of Concrete Specimens
- C341 Length Change of Drilled or Sawed Specimens of Hydraulic Cement Mortar Concrete
- C295 Petrographic Examination of Aggregates for Concrete
- C670 Preparing Precision and Bias Statements for Test Methods for Construction Materials
- C823 Examination and Sampling of Hardened Concrete in Constructions

3. Significance and Use

3.1 As noted in the scope, the three procedures described in this method are intended to determine the effects of variations in both the properties and conditioning of concrete in the resistance to freezing and thawing cycles specified in the particular procedure. Specific applications include specified use in M194, T157, 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 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.

¹ This standard is based on SHRP Product 2018.

² Approved in October 1993, this provisional standard was first published in June 1994. Reconfirmed January 2000.

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, 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 mm (1/32 in.) nor more than 3 mm (1/8 in.) of water at all times while it is being subjected to freezing and thawing cycles, or (2) for Procedure B or C, completely surrounded by air during the freezing phase. Specimens for Procedure C should be wrapped with cotton terry cloth to keep the specimens wet during freezing. 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 -- Freezing and Thawing apparatus used for Procedure C, having above-ground sumps, may need modification to allow excess water drainage from the cloth wraps to drain out of the chamber. A miniature sump (approximately 20 to 40-L (5 to 10-gallon) capacity) added to the drain line between the chamber and the drain pump, below the level of the bottom of the chamber, should be sufficient.

Note 2 -- 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.

Note 3 -- Experience indicates that cloth wraps which cover all sides and ends of specimens produce the same durability factor results as wraps that cover only the sides of the specimens. An advantage of wraps that cover both sides and ends is that material which falls off of specimens during freezing is retained in the cloth wrap, decreasing the frequency that the bottom of the apparatus chamber must be cleaned.

4.1.3 The temperature of the heat-exchanging medium shall be uniform within 3.3°C (6°F) 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 Procedures B or C, except during the transition between freezing and thawing and vice versa.

4.1.4 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 4 -- A flat spiral of 3 mm (1/8 in.) wire placed in the bottom of the container has been found adequate for supporting specimens.

4.1.5 For Procedure B or C, it is not expected 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 5 -- The use of the 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 1.1°C (2°F).

4.3 *Dynamic Testing Apparatus* conforming to the requirements of ASTM C215.

4.4 *Optional Length Change Test Length, Change Comparator*, conforming to the requirements of M 210. When specimens are longer than the nominal 286 mm (11 1/4 in.) length provided for in M210 are used for freeze-thaw tests, use an appropriate length reference bar, which otherwise meets the M210 requirements. Dial gage micrometers for use on these longer length change comparators shall meet the gradation interval and accuracy requirements for M210 for either the millimeter or inch calibrations 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 percent greater than the weight of the specimens and accurate to at least 4.5 g (0.01 lb) within the range of ± 10 percent of the specimen weight will be satisfactory.

4.6 *Tempering Tank*, with suitable provisions for maintaining the temperature of the test specimen in water, such that when removed from the tank and tested for fundamental transverse frequency and length change, the specimens will be maintained within -1.1°C and $+2.2^{\circ}$ (-2°F and $+4^{\circ}\text{F}$) 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 requirements, 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 significantly affect the length of the specimen.

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 all procedures of this method shall consist of alternately lowering the temperature of the specimens from 4.4 to -17.8°C (40 to 0°F) and raising it from -17.8 to 4.4°C (0 to 40°F) in not less than 2 nor more than 4 h; for Procedure A, at least 25 percent of the time shall be used for thawing, and for Procedures B and C, at least 20 percent of the time shall be used for thawing (Note 6). At the end of the cooling period the temperature at the centers of the specimens shall be $-17.8 \pm 1.7^{\circ}\text{C}$ ($0 \pm 3^{\circ}\text{F}$), and at the end of the heating period the temperature shall be $4.4 \pm 1.7^{\circ}\text{C}$ ($40 \pm 3^{\circ}\text{F}$) with no specimen at any time reaching a temperature lower than -19.4°C (-3°F) nor higher than 6.1°C (43°F). The time required for the temperature at the center of any single specimen to be reduced from 2.8 to -16.1°C (37 to 3°F) shall be no 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 -16.1 to 2.8°C (3 to 37°F) shall not be 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 1.7 to -12.2°C (35 to 10°F) shall not differ by more than one third of the length of the heating period from the time required for any specimen.

Note 6 -- 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 27.8°C (50°F).

5.4 The period of transition between the freezing and thawing phases of the cycle shall not exceed 10 minutes, except when specimens are being tested in accordance with 8.2.