Method of Test for

RESISTANCE OF CONCRETE TO RAPID FREEZING AND THAWING

LDH DESIGNATION: TR 231-76

Scope

1. This 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.

NOTE 1. All material in this method not specifically designated as belonging to Procedure A or Procedure B applies to either procedure.

Apparatus

2. (a) *Freezing-and-Thawing Apparatus:*

(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.

(2) The apparatus shall be so arranged that, except for necessary supports, each specimen is: (*1*) for Procedure A, completely surrounded by approximately 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.

NOTE 2. For Procedure A, this requirement contemplates that the specimen and surrounding water will be kept in a suitable container while in the freezing-and-thawing apparatus. 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 container, and possibly to the specimens therein. Results of tests during which bulging or other distortion of containers occurs should be interpreded with caution.

Each specimen should be supported 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. A flat spiral of 1/8 in. (3.2 mm) wire or a paraffin-treated wood block 1/2 to 5/8 in. (13 to 16 mm) thick placed in the bottom of the container has been found adequate for this purpose.

NOTE 3. For Procedure B, it is not contemplated that the specimens will be kept in containers. The supports on which the specimens rest should 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. The use of relatively open gratings, metal roads, or the edges of metal angles has been found adequate for this purpose provided the heat-exchanging medium can circulate in the direction of the long axis of the rods or angles.

(3) The temperature of the heat-exchanging medium shall be uniform within 3.5 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 Procedure B, except during the transition between freezing and thawing and *vice versa.*

(b) *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 C (2 F).

(c) *Dynamic Testing Apparatus,* conforming to the requirements of ASTM Method C 215, Test for Fundamental Transverse, Longitudinal, and Torsional Frequencies of Concrete Specimens.

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

(e) *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 the specimens will be within a temperature range of 5.5 ± 3 C (42 ± 5 F). 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 serving this requirement, provided the specimens are tested for fundamental transverse frequency within the above temperature range.

Freezing-And-Thawing Cycle

3. (a) 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.

(b) The nominal freezing-and-thawing cycle for both procedures of this method shall consist of alternately lowering the temperature of the specimens from 4.5 to −18 C (or 40 to 0 F) and raising it from −18 to 4.5 C or 0 to 40 F in not less than 2 nor more than 4 h. For Procedure A, not less than 25 percent of the time shall be used for thawing, and for Procedure B, not less than 20 percent 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 −18 ± 2 C or 0 ± 3 F and at the end of the heating period the temperature shall be 4.5 ± 2 C or 40 ± 3 F, with no specimens at any time reaching a temperature lower than −20 C or −3 F nor higher than 6.5 C or 43 F. The time required for the temperature at the center of any single specimen to be reduced from 3 to −16 C or 37 to 3 F 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 −16 to 3 C or 3 to 37 F 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 1.5 to −12 C or 35 to 10 F 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 −12 to 1.5 C or 10 to 35 F 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.

(c) The difference between the temperature at the center of a specimen and the temperature at its surface shall at no time exceed 28 C (50 F).

(d) 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 5 (b).

Test Specimens

4. (a) The specimens for use in this test shall

be prisms made and cured in accordance with the applicable requirements of AASHTO T 126, Making and Curing Concrete Test Specimens in the Laboratory.

NOTE 5. This method contemplates the use of specimens not less than 3 in. (76 mm) nor more than 5 in. (137 mm) in width and depth and not less than 14 in. (356 mm) nor more than 16 in. (406 mm) in length. Difficulty may be experienced in complying with the requirements of the method if specimens are used which differ appreciably from the above dimensions.

(b) The curing requirements for the test specimens are to be as follows:

(1) The specimens will be stored in the 100 percent humidity room in saturated lime water for the first seven days.

(2) The specimens will then be removed from the saturated lime water in the 100 percent humidity room and placed in the 50 percent humidity room to cure for the next fourteen days.

(3) The specimens will then be placed back in the saturated lime water storage in the 100 percent humidity room for the last seven days of the curing period.

(4) The total curing time of the specimens is 28 days.

Procedure

5. (a) Immediately after the specified curing period, bring the specimen to a temperature 5.5 ± 3 C or 42.5 ± 5 F and test for fundamental transverse frequency, weigh, and measure in accordance with Method C 215. Protect the specimens against loss of moisture between the time of removal from curing and the start of the freezing-and-thawing cycles.

(b) 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 at a temperature of 5.5 ± 3 C or 42 ± 5 F, weigh, and return them to the apparatus (Note 6). 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 percent of the initial modulus, whichever occurs first, unless other limits are specified (Note 7). Whenever a specimen is removed because of failure, replace it for the remainder of the test by a dummy specimen. Each time a specimen is tested for fundamental frequency (Note 8) make a note of its visual appearance and make special comment on any defects that develop.

NOTE 6. When it is anticipated that specimens may deteriorate rapidly, they should be tested for fundamental transverse frequency at intervals not exceeding 10 cycles when initially subjected to freezing and thawing.

NOTE 7. It is not recommended that specimens be continued in the test after their relative dynamic modulus of elasticity has fallen below 50 percent. This is especially important when Procedure A is used because of the danger of damage to specimen containers.

NOTE 8. 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.

(c) When the sequence of freezing-and thawing cycles must be interrupted store the specimens in a frozen condition.

(d) If, due to equipment breakdown or for other reasons, it becomes necessary to interrupt the cycles for a protracted period, store the specimens in a frozen condition in such a way to prevent loss of moisture. For Procedure A, maintain the specimens in the containers and surround them by ice, if possible. If it is not possible to store the specimens in their containers, wrap and seal them, in as wet a condition as possible, in moisture-proof material to prevent dehydration and store in a refrigerator or cold room maintained at −18 ± 1.5 C (0 ± 3 F). Follow the latter procedure when Procedure B is being used. In general, for specimens to remain in a thawed condition for more than two cycles is undesirable, but a longer period may be permissible if this occurs only once or twice during a complete test.

Calculations

6. (a) *Relative Dynamic Modulus of Elasticity*- Calculate the numerical values of relative dynamic modulus of elasticity as follows:

$$P_c = \frac{n_1^2}{n^2} \times 100$$

where:

P_c = relative dynamic modulus of elasticity, percent, after c cycles of freezing and thawing,
n = fundamental transverse frequency at 0 cycles of freezing and thawing, and
n_1 = fundamental transverse frequency after c cycles of freezing and thawing.

NOTE 9. This calculation of relative dynamic modulus of elasticity is based on the assumption that the weight and dimensions of the specimen remain constant throughout the test. This assumption is not true in many cases due to disintegration of the specimen. However, if the test is to be used to make comparisons between the relative dynamic moduli of different specimens or of different concrete formulations, Pc as defined is adequate for the purpose.

(b) *Durability Factor* - Calculate the durability factor as follows:

$$DF = \frac{PN}{M}$$

where:

DF = durability factor of the test specimen,
P = relative dynamic modulus of elasticity at N cycles, percent,
N = number of cycles at which P reaches the specified minimum value for discontinuing the test or the specified number of cycles at which the exposure is to be terminated, whichever is less, and
M = specified number of cycles at which the exposure is to be terminated.

Report

7. (a) The report shall include such of the following data as are pertinent to the variables or combination of variables studied in the tests:

(b) *Properties of Concrete Mixture:*

(1) Type and proportions of cement, fine aggregate, and coarse aggregate, including maximum size and grading (or designated grading indices), and ratio of net water content to cement,

(2) Kind and proportion of any addition or admixture used.

(3) Air content of fresh concrete.

(4) Unit weight of fresh concrete,

(5) Consistency of fresh concrete, and

(6) Air content of the hardened concrete.

(c) *Mixing, Molding, and Curing Procedures*- Report any departures from the standard procedures for mixing, molding, and curing as prescribed in Section 4.

(d) *Characteristics of Test Specimens:*

(1) Dimensions of specimens at 0 cycles of freezing and thawing.

(2) Weight of specimens at 0 cycles of freezing and thawing, and

(3) Any defects in each specimen present at 0 cycles of freezing and thawing.

(e) *Results:*

(1) Values for the durability factor of each specimen and for the average durability factor for each group of similar specimens, and the speci-

fied values for minimum relative dynamic modulus and maximum number of cycles (Note 10),

(2) Values of weight loss or gain for each specimen and average values for each group of similar specimens, and

(3) Any defects in each specimen which develop during testing, and the number of cycles at which such defects were noted.

NOTE 10. It is recommended that the results of the test on each specimen, and the average of the results on each group of similar specimens, be plotted as curves showing the value of relative modulus of elasticity against time expressed as the number of cycles of freezing and thawing.