CRD-C 114-97

Test Method for Soundness of Aggregates by Freezing and Thawing of Concrete Specimens

1. Scope

1.1 This test method covers the procedures to be followed in testing aggregate combinations to determine their influence on the resistance to rapid freezing and thawing of concrete specimens, under standardized conditions of size and grading when confined in a standardized concrete mixture.

2. Freezing-and-Thawing Apparatus and Procedure

2.1 The freezing-and-thawing apparatus and procedure shall conform to the requirements in CRD-C 20 (ASTM C 666). Procedure A.

3. Materials and Characteristics of Concrete Mixture

3.1 The standard concrete mixture from which specimens for test by this method will be made shall conform to the following requirements for materials and characteristic s:

3.1.1 Cement. The mixture shall be made with cement from a single lot meeting the requirements for Type II (CRD-C 201) (Note).

Note: In the event that it is desired to do so, a blend of two or more cements, all of which conform to the requirements for Type II (CRD-C 201), may be used. In the event that samples of the cement that will be used in the work for which the aggregates under test have been proposed are available, they may be used. It is essential that all aggregate combinations, whose influence on the resistance of concrete to accelerated freezing and thawing are to be compared, be tested in concrete made of cement from the same lot.

3.1.2 Air-Entraining Admixture. The mixture shall include a proper amount of an air-entraining admixture complying with the requirements of CRD-C 13 (ASTM C 260). The amount of admixture used shall be that required to produce an air content of the freshly mixed concrete of 6.0 ± 0.5 percent.

3.1.3 Fine Aggregate. The mixture shall contain either the test or standard fine aggregate. The fine aggregate (either standard or test) used in this test shall be separated, if necessary, into individual sieve fractions and recombined, and shall comply with the following grading:

Sieve, mm	Percent Passing	Sieve, µm	Percent Passing
4.75	100	600	45 ± 5
2.36	85 ± 3	300	21 ± 5
1.18	65 ± 5	150	7 ± 2

3.1.4 Coarse Aggregate. The mixture shall contain either the test or standard coarse aggregate. The coarse aggregate shall be separated, if necessary, into individual sieve fractions and recombined, and shall comply with the following grading:

Sieve	Percent Passing
19.0-mm	97 -100
12.5-mm	66 ± 3
9.5-mm	33 ± 3
4.75-mm	0 -3

3.1.5 Standard Aggregates. The standard aggregates shall consist of the materials stocked for use in making the concrete mixtures described in CRD-C 13. Concrete made to evaluate a test coarse aggregate alone will contain the standard fine aggregate; concrete made to evaluate a test fine aggregate alone will contain the standard coarse aggregate.

3.1.6 Water-Cement Ratio. The mixture shall be proportioned to have a water-cement ratio of 0.49 by mass.

3.1.7 Air Content. The mixture shall be proportioned to have an air content of 6.0 ± 0.5 percent, as determined on a sample of the freshly mixed concrete.

3.1.8 Slump. The mixture shall be proportioned to have a slump of 2-1/2 ± 1/2 in. (64 ± 13 mm).

3.1.9 Cement Content. The cement content will be adjusted to that necessary to achieve the desired slump. It is not believed that theoretical cement factors outside of the range 279 to 390 kg/m^3 will be required.

3.1.10 Aggregate Combinations. This method is particularly adapted to testing a combination of fine and coarse aggregate proposed for use together. Such a combination will be tested by fabricating and testing 89- by 114- by 406-mm beams containing the test fine and test coarse aggregates. In those cases where a test fine or a test coarse aggregate must be tested by itself, no test coarse or test fine aggregate being available to complete the combination, the combination will be made using the standard coarse or standard fine aggregate, respectively, and the resulting combination will be tested by fabricating and testing 89- by 114 by 406-mm beams. Combinations consisting of a test aggregate together with a "standard" material may give misleading results owing to the superior soundness of the standard material which will serve to mash the effects of the test aggregate on the resistance of the concrete to freezing and thawing.

4. Preparation of Materials

4.1 Follow the requirements of CRD-C 10 (ASTM C 192) and 49 in the preparation of cement and aggregates for use in the mixture. Prepare the aggregates for use in a saturated condition. A satisfactory procedure for preparing the aggregates in the desired condition is described below.

4.2 Uniformly wet the fine aggregate prior to the day the concrete is to be made, with surface moisture present in a sufficiently small amount to preclude loss by draining. Keep the fine aggregate covered to prevent evaporation prior to use in concrete. On the making day, determine the amount of surface moisture in the fine aggregate and make appropriate corrections in the calculated amount of mixing water to be used.

4.3 Select the amount of dry coarse aggregate for each batch of concrete by mass on a day preceding that on which the concrete is to be made, and place it in individual watertight containers. Then add water in sufficient quantity to cover the coarse aggregate. On the making day, after the determination of the amount of surface moisture in the fine aggregate has been made and the calculated amount of mixing water has been corrected both for this value and for the absorption by the coarse aggregate, decant the water from each coarse-aggregate container until the precise weight of free water desired for mixing water remains for use as the mixing water in the concrete batch.

5. Mixing Concrete

5.1 Mix the concrete in 0.034 m^3 batches in a 0.0708 m^3 tilting-drum mixer in accordance with the applicable provisions of CRD-C 10 and 49.

6. Tests of Freshly Mixed Concrete

6.1 Discharge the mixed concrete into a moist pan, turn it over with a shovel, cover it with wet burlap, and sample it according to the procedures in CRD-C 4. Use a sample so taken to make an air-content determination in accordance with the procedures described in CRD-C 41. Determine the slump according to CRD-C 5. Keep the portion of the batch not used in these tests covered with wet burlap undisturbed.

7. Making and Curing Test Specimens

7.1 Represent each aggregate combination tested by not fewer than three groups of three similar beams, each group made from a single batch of concrete on a different day (Note). Take the concrete to be used in test specimens from that portion of the batch remaining after the samples for the air content and slump tests have been taken. Follow the applicable provisions of CRD-C's 10 and 49.

Note: If considerations of time make it necessary that the test be completed without the delay required by making the three groups on three different days, the three groups may be made on two, or, if necessary, on a single day. Whenever practicable, however, the three groups should be made on three different days.

8. Test Procedure

8.1 Remove the test specimens from curing and test them in a damp condition for fundamental transverse frequency, using the procedure set forth in CRD-C 18, on the fourteenth day after making. Keep the specimens moist during these determinations and keep the time during which they are exposed to ambient temperatures above 23 ± 1.1 C to a minimum. After these determinations, place the specimens in specimen containers, covered with fresh water (see para 2.1), and place the containers in the tank of 4 ± 1.7 C water for a period of not less than 1 hr, then place them in the freezing-and-thawing apparatus. Remove the specimens, in a thawed condition, and determine their fundamental frequency after one cycle of freezing and thawing, at about the tenth cycle, and again at intervals not exceeding 36 cycles until the value for dynamic E calculated from such determinations has decreased to 50 percent of that at 14 days age, or until the test has been continued for 300 cycles. Immediately after removal from the apparatus for test, place the specimens, still in containers, in a tank of water maintained at a temperature of 4 ± 1.7 C where they will remain except while actually being subjected to test for fundamental frequency. Just prior to a test for fundamental frequency, remove the specimens carefully from the container and wash them free of sludge and clinging ice. Each time a specimen is tested for fundamental frequency, make a note of its visual appearance and make special comment on any defects that develop. After each test, turn the specimens end for end before replacing them in the specimen containers and return the containers to random positions in the freezing-and-thawing apparatus. Should the regular sequence of freezing-and-thawing cycles be interrupted as a result of breakdown of equipment or for other cause, store the specimens in a frozen condition until the cycles can be resumed. Such interruption may be expected to cause a slight variation from the results that would have been obtained if the interruption had not occurred. The expected variation will, in most cases, be within the normal range of results of the test method; but when greater precision of results is desired, repeat the test. When the freezing-and-thawing exposure has been completed, make the final determination of fundamental frequency.

9. Faulty Specimens

9.1 Specimens Found to Be Faulty upon Stripping. When the specimens in any group of three are removed from the molds, examine them for defects. If, upon examination, any specimens are found to contain imperfections of such magnitude as to be expected to cause test results of the specimens to be nonrepresentative, discard them. If any group of three specimens is found to contain more than one specimen that must be discarded for this reason, discard that group in its entirety and make a new group of specimens. If each of the three groups of specimens made in connection with the testing of any one aggregate combination contains one test specimen that is to be discarded, discard the third group of specimens in its entirety and make a new group.

9.2 Specimens Broken in Handling During Testing. Discard any specimen accidentally broken in handling during the test. If the discarding of specimens for this cause results in less than seven specimens representing a single aggregate combination, make an additional group (or groups) of three specimens so that the results of the test on the aggregate combination will be based on the testing of not less than seven specimens. In cases where a specimen (or specimens) is discarded for this reason after having undergone a considerable number of test cycles, and the completion of the testing of the new group would require a period of time such that the reporting of the test results would be appreciably delayed, make a preliminary report based on results of less than seven specimens if necessary. Include a note in the preliminary report to the effect that an additional group (or groups) of specimens has been made and is under test, and that a final report will be submitted when the data developed from the testing of the additional group (or groups) are available.

9.3 Specimens Giving Anomalous Results. When the results of the test or any given specimen (or specimens) deviate from those of the other specimens tested by a sufficient amount so that in the judgement of the operator they should be omitted from the average, discard such results. A decision to discard results should not be made until the specimen (or specimens) has been thoroughly examined, preferably by a petrographer, and the cause or causes of the deviation determined. If the discarding of results for this cause results in there being data from tests of fewer than seven specimens representing a single aggregate combination, make an additional group (or groups) of three specimens so that the results will be based on the testing of not less than seven specimens. When the time required to complete the testing of such an additional group (or groups) would seriously delay the reporting of the test, a preliminary report based on the results of less than seven specimens may be made, and should include a note similar to that described in Subparagraph 9.2 above.

9.4 Reruns. Whenever, because of discarding specimens or results for any of the reasons outlined above, fewer than seven individual values remain to be used in calculating average DFE, repeat the test.

10. Calculations

10.1 Relative Dynamic Modulus of Elasticity. After each determination of fundamental flexural frequency, calculate the square of the value so determined as a percentage of the square of the original value at the 14-day age. Maintain a graph on which these values (relative moduli) are plotted against the number of cycles of freezing and thawing to which the specimen has been subjected.

10.2 Average Relative Dynamic Modulus of Elasticity. The average relative dynamic modulus of elasticity for a group of three specimens will be the arithmetic mean of the values for Rel E for the individual specimens when all values for Rel E are 50 or greater. When one or more of the specimens in a group have been discontinued owing to Rel E having fallen below 50, and it is necessary to have Rel E values for calculating average Rel E for the group, calculate the Rel E for any specimen at any number of cycles greater than N as follows:

$$Rel\ E_y = \frac{50\ N}{y}$$

where:

y = number of cycles, greater than N, at which Rel E is to be calculated, and

N = number of cycles at which Rel E = 50.

10.3 Durability Factor (Modulus of Elasticity). Calculate the durability factor (DFE) based on dynamic modulus of elasticity for each specimen from the following formula:

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

where:

DFE = durability factor (based on relative dynamic modulus of elasticity),

P = relative dynamic modulus of elasticity in percentage of the dynamic modulus at zero cycles,

N = number of cycles at which P teaches the limiting value in percentage or the ultimate number of cycles of the test if P does not teach the limiting value prior to the ultimate cycle (Note), and

M = ultimate number of cycles of the test

Note: The limiting value for P may be taken at any value for relative dynamic modulus. Limiting values of less than 50 are not recommended since determinations of fundamental frequency are not reliable when made on specimens with a relative dynamic modulus of less than 50.

10.4 For the particular conditions of this method the following relations exist:

When Rel E_{300} = 50 or more:

$$DFE_{300} = Rel\ E_{300} \ldots.. \qquad (1)$$

When Rel E_{300} = less than 50:

$$DFE_{300} = \frac{N}{6} \ldots.. \qquad (2)$$

where:

N = number of cycles at which Rel E = 50.

10.5 Since in most cases determinations of fundamental flexural frequency will not be made at precisely 300 cycles or at precisely the number of cycles at which Rel E = 50 for any particular specimen use the following procedures to obtain values for Rel E_{300} or N, respectively.

$$Rel\ E_{300} = Rel\ E_B + (Rel\ E_A - Rel\ E_B) \times \frac{B - 300}{B - A} \ldots.. \qquad (1)$$

where:

A = number of cycles at which last reading before 300 cycles was made,

B = number of cycles at which reading after 300 cycles was made.

$$N = \frac{(Rel\ E_A - 50)(B - A)}{(Rel\ E_A - Rel\ E_B)} + A \ldots.. \qquad (2)$$

where:

A = number of cycles at which last reading giving Rel E more than 50 was made,

B = number of cycles at which reading giving Rel E less than 50 was made,

Rel E_B = Rel E calculated from determination of flexural frequency (Note).

Note: This value for Rel E_B is used only in the determination of N. For calculating average relative E values at B cycles the procedure of Paragraph 10.2 will be followed in which

$$Rel\ E_B = \frac{50\ N}{B}$$

The value of Rel E_B equaling $\frac{50\ N}{B}$ shall not be used in determining the value of N in formula 2 above. The value of Rel E_B will be the value obtained by direct determination with the specimen involved, as indicated above, for use with formula 2.

10.6 Average Durability Factor. The average durability factor for a group of three beams is the arithmetic mean of the individual values for the DFE_{300} of the three beams calculated as described above. The average durability factor for a series of three-beam groups is the arithmetic mean of the DFE_{300} values for the several groups.

11. Report

11.1 Report the average durability factors (DFE) for each group of three specimens and the average DFE for the three groups of similar specimens, and include a graph showing average progressive change in relative dynamic modulus versus number of cycles of freezing and thawing for the three groups of similar specimens (Fig. 1). Also include any relevant comments concerning faulty specimens of the sorts described in Paragraph 9 or concerning defects that were noted during the course of the test.

Note: The procedure of reporting averages by groups and an average of the three groups is regarded as appropriate in a majority of cases, especially when a single value is needed for use in comparing aggregate combinations. In certain cases, especially when an aggregate contains small percentages of undesirable materials, information of value may be provided if test results on individual beams are reported. In such cases it may be desirable to report even those results which deviate sufficiently from the average to justify being omitted from the averages, as described in Paragraph 9. The range in results of individual specimens appears generally to increase as the average DFE value approaches the range of 40 to 60.

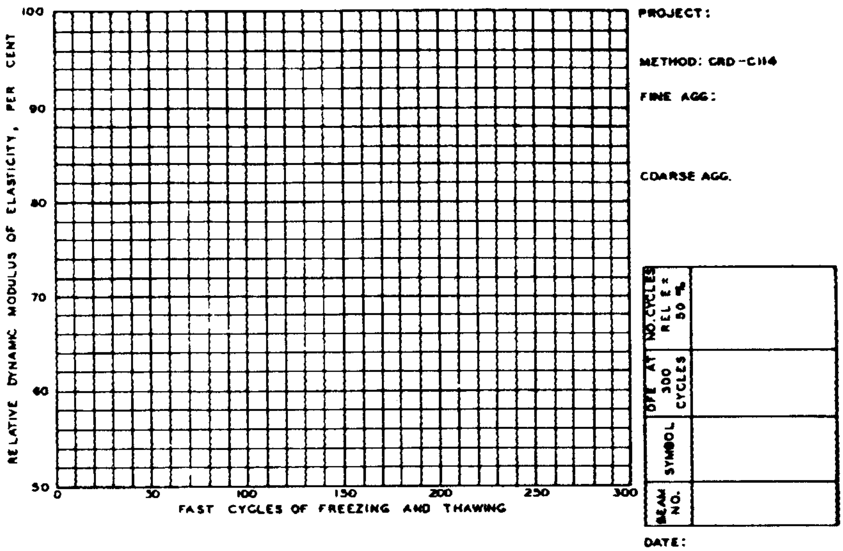

Figure 1. Resistance of concrete beams to accelerated freezing and thawing