Designation: C 682 – 94

Standard Practice for Evaluation of Frost Resistance of Coarse Aggregates in Air-Entrained Concrete by Critical Dilation Procedures[1]

This standard is issued under the fixed designation C 682; 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.

1. Scope

1.1 This practice covers the evaluation of frost resistance of coarse aggregates in air-entrained concrete. It was developed particularly for use with normal weight aggregates not having vesicular, highly porous structure.

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

2. Referenced Documents

2.1 *ASTM Standards:*

C 33 Specification for Concrete Aggregates[2]

C 138 Test Method for Unit Weight, Yield, and Air Content (Gravimetric) of Concrete[2]

C 143 Test Method for Slump of Hydraulic Cement Concrete[2]

C 150 Specification for Portland Cement[2]

C 171 Specification for Sheet Materials for Curing Concrete[2]

C 173 Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method[2]

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

C 231 Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method[2]

C 260 Specification for Air-Entraining Admixtures for Concrete[2]

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

C 671 Test Method for Critical Dilation of Concrete Specimens Subjected to Freezing[2]

E 104 Practice for Maintaining Constant Relative Humidity by Means of Aqueous Solutions[3]

2.2 *ACI Standard:*

211.1 Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete[4]

[1] This practice is under the jurisdiction of ASTM Committee C-9 on Concrete and Concrete Aggregatesand is the direct responsibility of Subcommittee C09.67on Resistance of Concrete to Its Environment.

Current edition approved March 15, 1994. Published May 1994. Originally published as C 682 – 71 T. Last previous edition C 682 – 87 (1992)$^{\epsilon 1}$.

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

[3] *Annual Book of ASTM Standards*, Vol 11.03.

[4] *Manual of Concrete Practice*, Am. Concrete Institute, Part I, 1985.

3. Significance and Use

3.1 This practice is primarily intended to provide the prospective user with a technique for estimating the frost susceptibility of concrete aggregates for known or assumed field environmental conditions. The significance of the results in terms of potential field performance will depend upon the degree to which field conditions can be expected to correlate with those employed in the laboratory. It is of utmost importance, therefore, that the user of this practice assess at first the following anticipated field exposure conditions:

3.1.1 The condition of the aggregate as it enters the concrete mixture (that is, stream wet, partially saturated, or dry),

3.1.2 The curing procedures anticipated for the concrete,

3.1.3 The age and degree of saturation of the concrete when first exposed to freezing,

3.1.4 The length of the season of potential exposure to freezing temperatures, the frequency of freezing and thawing cycles, and the minimum temperature to be reached by the concrete, at the given location,

3.1.5 The accessibility of water to the concrete during the period of potential frost damage, and

3.1.6 Effect of climatic conditions between seasons of freezing weather on the degree of saturation of the concrete at the onset of freezing.

3.2 The laboratory moisture conditioning procedures specified in 5.3 and 7.4 are intended to permit simulation of a range of environments that aggregates and concretes might be expected to encounter under field conditions. This approach provides information by which to estimate durability when there is a lack of knowledge as to actual field conditions.

4. Apparatus

4.1 The apparatus shall be in accordance with Test Method C 671.

5. Coarse Aggregate Preparation

5.1 *Sampling*—Sample in accordance with the applicable sections of Guide C 295.

5.2 *Grading*—When aggregates are to be compared using this practice, gradings of each must be within the limits set forth in Table 1 of Specification C 33. The nominal maximum aggregate size shall not exceed one third the minimum dimension of the test specimen to be used.

5.3 *Conditioning*—Whenever possible, maintain the aggregates to be tested in or bring to the condition representative of that which might be expected in the field. It should be noted, however, that aggregate moisture states other than dry or saturated are very difficult to maintain during preparation of tests specimens. Reproducibility of over-all test results is likely to be affected adversely by variability in aggregate moisture.

NOTE 1—If the aggregates are not processed in the manner described above, the following treatment may be used to simulate a relatively severe exposure. Air-dry the aggregate to constant weight, then vacuum saturate by placing it under a vacuum (2 mm Hg maximum absolute pressure) for 1 h followed by the introduction of water to the sample while still under vacuum. Following vacuum saturation, allow the aggregates to soak for 24 h before being incorporated into concrete specimens. Record a history of moisture conditioning since the effectiveness of vacuum saturation or resaturation will vary with aggregate type.

6. Concrete Mixture

6.1 *Ingredients*—The portland cement shall meet the requirements of Specification C 150. Use fine aggregate, intended for the project, graded in accordance with Specification C 33. Batches for a particular test series shall use cement and fine aggregate taken from the same lot. Use an air-entraining admixture meeting the requirements of Specification C 260.

6.2 *Proportions*—Using ACI Recommended Practice 211.1, proportion all concrete to conform to the following requirements:

6.2.1 The cement content shall be 517 ± 5 lb/yd^3 (307 ± 2.8 kg/m^3) except when tests are being made where mixture proportions are those proposed for the work.

6.2.2 The air content used in the computation of proportions for all concrete shall be in accordance with Table 1. The amount of air-entraining admixture used shall be such as to give an air content as prescibed in Table 1, ± 1 %, when tested according to Test Methods C 231 or C 173.

6.2.3 The water content and fine aggregate content shall be adjusted to obtain a slump of 2½ ± ½ in. (63.5 ± 12.7 mm) in accordance with Test Method C 143. The workability of the concrete mixture shall be suitable for consolidation by hand rodding.

6.3 *Mixing*—Machine mix the concrete as prescribed in Practice C 192. Mix the concrete for 3 min after all materials have been introduced into the mixer, allow to rest in the mixer for 3 min, remix for 2 min, and then discharge.

6.4 *Replication*—A minimum of two batches shall be made for each test aggregate.

7. Specimen Preparation and Conditioning

7.1 *Number of Specimens*—At least 12 test specimens should be made from each batch. If 7.4 is determined not to be practical, the minimum number of specimens may be reduced to six per batch and 7.4.1 is then followed.

7.2 *Specimen Preparation*—The type and size of the test specimen and the method for molding shall be in accordance with the Test Specimen Section of Test Method C 671, unless otherwise specified.

7.3 *Curing*—Immediately after molding the specimens and setting the gage studs, snugly cover the cylinders and seal with a material conforming to the requirements of Specification C 171 to minimize evaporation. After 1 day in the molds at a temperature between 65 and 75°F (18 and 24°C), remove the specimens from the molds and store in saturated limewater at 73 ± 3°F (23 ± 1.7°C) for 13 days.

7.4 *Conditioning*—Whenever possible, all the specimens from each batch should be brought to the moisture condition representative of that which might be anticipated in the field at the time of initial freezing. However, as noted previously, moisture states other than dry or saturated are difficult to achieve and maintain, and so the reproducibility of test results (for specimens at other moisture states) may be unacceptable. If it is not practical or possible to condition the concrete test specimens in the manner described above, employ the following procedure, which provides conditions that bracket the moderate to very severe range of conditioning.

7.4.1 After the 14 days of curing, condition a minimum of three specimens from each batch for 3 weeks in 35°F (1.7°C) water prior to testing. Condition a minimum of three other specimens from each batch for 1 week at 75 % relative humidity and 73 ± 3°F (23 ± 1.7°C) followed by 2 weeks in 35°F water. The relative humidity environment may be provided either by a humidity-controlled room or a saturated solution of sodium acetate (see Practice E 104).

NOTE 2—If specimens larger than 3 by 6 in. (75 by 150 mm) are used, they may require longer conditioning periods to reach similar average moisture contents.

8. Method of Test

8.1 Following completion of the specimen conditioning, immediately commence testing in accordance with the Procedure Section of Test Method C 671.

9. Interpretation of Results

9.1 Published reports and field experience **(1-5)**[5] have established that this practice can discriminate among aggregates of varying frost susceptibility. However, many years of experience with various freeze-thaw tests for concrete **(6-15)**and extensive study of this particular practice support the need for using extreme care in performing such tests and in interpreting the results. Items of particular concern include the following:

9.1.1 Minor changes in exposure conditions as simulated in the laboratory can obscure real differences in the performance of aggregates, particularly of those in the range of intermediate quality. Therefore, choice of exposure, and capability for repeating it in successive test programs are both extremely important.

TABLE 1 Recommended Total Air Content for Air-Entrained Concrete Under Severe Exposure Conditions

Total Air Content, %						
Nominal Maximum Size of Aggregate, in. (mm)						
⅜ (9.5)	½ (12.5)	¾ (19.0)	1 (25.0)	1½ (37.5)	2 (50.0)	3 (75.0)
7.5	7.0	6.0	6.0	5.5	5.0	4.5

[5] The boldface numbers in parentheses refer to the list of references at the end of this practice.

9.1.2 Major research on this approach to aggregate evaluation has been performed using relatively homogeneous aggregate fractions **(2, 3)**. A petrographer sorted the test aggregate into relatively homogeneous mineralogical fractions and these fractions into relatively homogeneous subclasses with respect to weathering, impurities, etc. (See Guide C 295.) This approach has several features to recommend it:

9.1.2.1 The probability of detecting differences in behavior is enhanced.

9.1.2.2 Many aggregate sources are frost susceptible in the as produced state because of the occurrence of minor but highly unsound fractions. Since beneficiation is a common solution in such cases, it is necessary that the several fractions be evaluated separately so that efficient beneficiation can be developed.

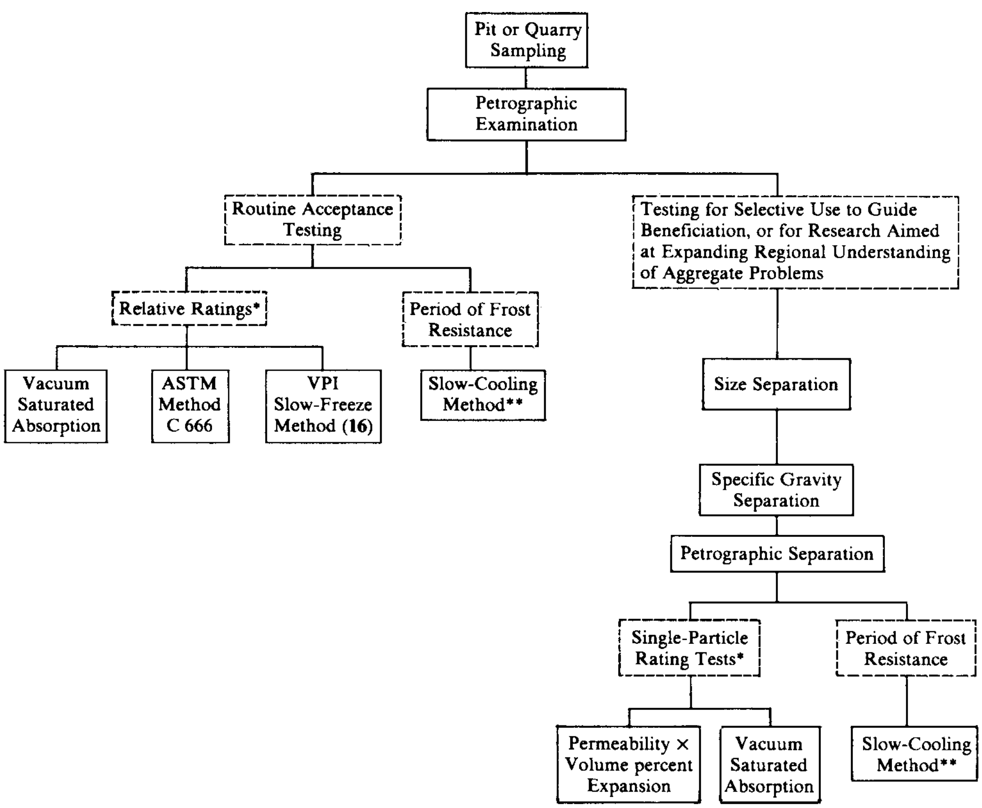
9.1.2.3 It may be hoped that data will be developed through studies of the significance of deleterious fractions that will facilitate intelligent decision making with regard to such matters as blending and selective usage.

9.1.3 There are alternative approaches in the framework of this approach for aggregates that are relatively homogeneous and for the many cases in which information on the frost susceptibility of the as produced material is needed. First, nothing in the approach described in 9.1.2 precludes a decision that the aggregate is adequately characterized as one fraction and should be tested as such. Moreover, if several fractions are identified, a decision can still be made to test the aggregate in bulk form.

9.1.4 It is unlikely that any single test for aggregate evaluation will display all the desired attributes of simplicity, low cost reliability, reproducibility, speed, etc., for all aggregate types. A systematic approach taking advantage of the services of a trained petrographer and a battery of tests seems more likely to provide the needed information. Fig. 1 indicates one such systematic approach in which this practice (identified as the slow-cooling method) serves a major role.

9.1.4.1 The left branch of Fig. 1 covers cases where general acceptance of a source as produced is to be determined. If field performance information is available on aggregates with similar characteristics, a relative rating by one or more of the methods listed may be sufficient. The slow-cooling method may be used for cases where the determination of a period of frost resistance is desirable and no field experience is available for similar aggregates.

9.1.4.2 The right branch of the chart may be appropriate in cases where economical aggregate sources in the intermediate field performance range must be evaluated. Here the sample is separated into relatively homogeneous fractions (see 9.1.2) and the performance of each rated by single particle tests or by the test described in this practice when the determination of a period of frost resistance is desired. Decisions regarding



* Interpretation depends on previous experience relating test results to field performance. This information generally is not available.

** As described in this practice.

FIG. 1 Procedural Approaches to Frost-Susceptibility Tests (see Larson and Cady **3)**

beneficiation can be based on results of testing along this branch (**3**).

10. Report

10.1 Because this practice permits variations in test conditions that greatly affect the performance of aggregates, the report should include the following information:

10.1.1 Identification and description of aggregate sample including location of source, special processing or separation employed in its preparation, and when applicable, petrographic description of the mineralogic subgroup selected for testing,

10.1.2 Saturation condition of the aggregate when incorporated into the concrete and a history of its prior moisture conditioning,

10.1.3 Concrete mixture proportions,

10.1.4 Measured characteristics of fresh concrete, including air content, slump, and unit weight,

10.1.5 Curing procedure, and

10.1.6 Conditioning procedure.

10.2 Determine the test period of frost immunity for each specimen and the average period of frost immunity for each group of similar specimens, together with the 95 % confidence interval of the mean in accordance with Test Method C 671.

11. Keywords

11.1 aggregate; frost resistance; coarse aggregate; frost resistance; critical dilation procedures; dilation; freezing and thawing; resistance; frost

REFERENCES

(**1**) *Test for Freeze-Thaw Resistance of Aggregates in Air-Entrained Concrete* (*Powers Procedure*), California Test Method 528-A, California Division of Highways, Materials and Research Department, May 1961.

(**2**) Larson, T. D., et al, "Identification of Concrete Aggregates Exhibiting Frost Susceptibility," *National Cooperative Highway Research Program Report 15*, Highway Research Board, 1965.

(**3**) Larson, T. D., and Cady, P. D., "Identification of Aggregates Exhibiting Frost Susceptibility," *National Cooperative Highway Research Program Report 66*, Highway Research Board, 1969.

(**4**) Tremper, B., and Spellman, D. L., "Test for Freeze-Thaw Durability of Concrete Aggregates," *Highway Research Board Bulletin 305*, 1961.

(**5**) Wills, M. H. Jr., "An Investigation of the Behavior of Two Frost Susceptible Concretes When Exposed to the Slow Freeze-Thaw Test Method," Unpublished Master's Thesis, University of Maryland, 1962.

(**6**) Bloem, D. L., "Factors Affecting the Freezing and Thawing Resistance of Concrete Made with Chert Gravel," *Highway Research Board Record No. 18*, 1963, pp. 48–60.

(**7**) Larson, T. D., et al, "A Critical Review of Literature Treating Methods of Identifying Aggregates Subject to Destructive Volume Change When Frozen in Concrete and a Proposed Program of Research," *Special Report 80*, Highway Research Board, 1964, 81 pp.

(**8**) Meininger, R. C., Fox, J. F., Jr., and Lepper, H. A., Jr., "A Single Particle Freezing Resistance Test for Concrete Aggregate," *Proceedings*, ASTM, Vol 65, 1965, pp. 801–808.

(**9**) Powers, T. C., "Basic Considerations Pertaining to Freezing and Thawing Tests," *Proceedings, ASTM*, Vol 55, 1955, pp. 1132–1155.

(**10**) Thomas, W. N., "Experiments on the Freezing of Certain Building Materials," *Building Research Technical Paper No. 17*, Dept. of Scientific and Industrial Research, 1938.

(**11**) Valore, R. C., "Volume Changes Observed in Small Concrete Cylinders During Freezing and Thawing Using a Mercury Displacement Dilatometer," *Journal of Research*, National Bureau of Standards, Vol 43, 1949, pp. 1–27.

(**12**) Verbeck, G., and Klieger, P., "Calorimeter-Strain Apparatus for Study of Freezing and Thawing Concrete," *Highway Research Board Bulletin 176*, 1958, pp. 9–22.

(**13**) Walker, R. D., "Identification of Aggregates Causing Poor Concrete Performance When Frozen," *National Cooperative Highway Research Program Report 12*, Highway Research Board, 1965, 47 pp.

(**14**) Wills, M. H., et al, "Volume Change as a Measure of Freezing-and-Thawing Resistance of Concrete Made with Different Aggregates," *Proceedings*, ASTM, Vol 63, 1963, pp. 946–965.

(**15**) Verbeck, G. and Landgren, R., "Influence of Physical Characteristics of Aggregates on Frost Resistance of Concrete," *Proceedings*, ASTM, ASTEA, Vol 60, 1960, pp. 1063–1079.

(**16**) Walker, R. D., Pence, H. J., Hazlett, W. H., and Wei Jen Ong, "One-Cycle Slow-Freeze Test for Evaluating Aggregate Performance in Frozen Concrete," *National Cooperative Highway Research Program Report 65*, Highway Research Board, 1969.