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Designation: C 671 – 94

Standard Test Method for
Critical Dilation of Concrete Specimens Subjected to Freezing[1]

This standard is issued under the fixed designation C 671; 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 test method covers the determination of the test period of frost immunity of concrete specimens as measured by the length of time of water immersion required to produce critical dilation when subjected to a prescribed slow-freezing procedure.

1.2 The values stated in SI units are to be regarded as the standard.

1.3 *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 192 Practice for Making and Curing Concrete Test Specimens in the Laboratory[2]

C 490 Practice for Use of Apparatus for Determination of Length Change of Hardened Cement Paste, Mortar, and Concrete[3]

C 682 Practice for Evaluation of Frost Resistance of Coarse Aggregates in Air Entrained Concrete by Critical Dilation Procedures[2]

2.2 ASTM Adjuncts:

Adjunct C 671 Two detailed drawings of a strain frame, 1 drawing of gage point installation, and a table of metric equivalents.[4]

3. Significance and Use

3.1 This test method is suitable for ranking concretes according to their resistance to freezing and thawing for defined curing and conditioning procedures. 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.

3.2 This test method is suitable for estimating the frost susceptibility of aggregates in concrete as described in Practice C 682.

3.3 This test method is also suitable for use by those people engaged in research and development in the field of concrete durability. It is believed that a fundamental understanding of length change of concrete subjected to freezing will lead to more durable concrete.

4. Apparatus

4.1 *Cooling Bath*, of sufficient size and depth to completely immerse the test specimens in silicone oil or water-saturated kerosine (Note 1). The bath shall have a sufficient volume of kerosine per specimen and shall be provided with controls so as to permit lowering its temperature and that of the test specimens uniformly from 1.7 to − 9.4°C (35 to 15°F) at the rate of 2.8 ± 0.5°C/h (5 ± 1°F/h). Suitable bath temperature recording facilities shall be provided.

NOTE 1—Very little water is required to saturate kerosine. Excess water should be avoided as it will form ice crystals in the bath. As an alternative to kerosine, the use of silicone oil may be preferable to reduce odors and fire hazards.

4.2 *Constant-Temperature Water Bath*— A refrigerated water bath capable of containing the specimens completely immersed, and equipped with control facilities capable of maintaining the temperature of the specimens at 1.7 ± 0.9°C (35 ± 2°F) before and between test cycles.

4.3 *Strain-Measuring and Recording Facilities*, (Note 2) and a supply of strain frames to support the specimens in the cooling bath and to provide alignment for the strain-measuring apparatus (Fig. 1).[3] The strain-measuring apparatus shall have a capability for measuring 2 millionths or less.

NOTE 2—Linear variable differential transformers (LVDT) with the appropriate associated electronic actuating and indicating apparatus appear to give the best results with respect to stability, sensitivity, and reliability. Multichannel recording of outputs has been found to be practical and efficient (see Fig. 2). As an alternate to the recording apparatus shown in Fig. 2, a data logger[5] can be used to excite the LVDT and record the LVDT both temperature and time outputs. The data can be stored directly in a personal computer for graphing of test results.

4.4 *Room or Cabinet*, for storing specimens at the desired temperature and relative humidity with provision for constant circulation of air in the immediate vicinity of the specimens.

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[1] This test method 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.

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

[3] *Annual Book of ASTM Standards*, Vol 04.01.

[4] Available from ASTM Headquarters, 100 Barr Harbor Drive, West Conshohocken, PA 19428. Request ADJC0671.

[5] A suitable data logger is manufactured by Campbell Scientific Inc., Model 21X, P.O. Box 551, Logan, Utah 84321.

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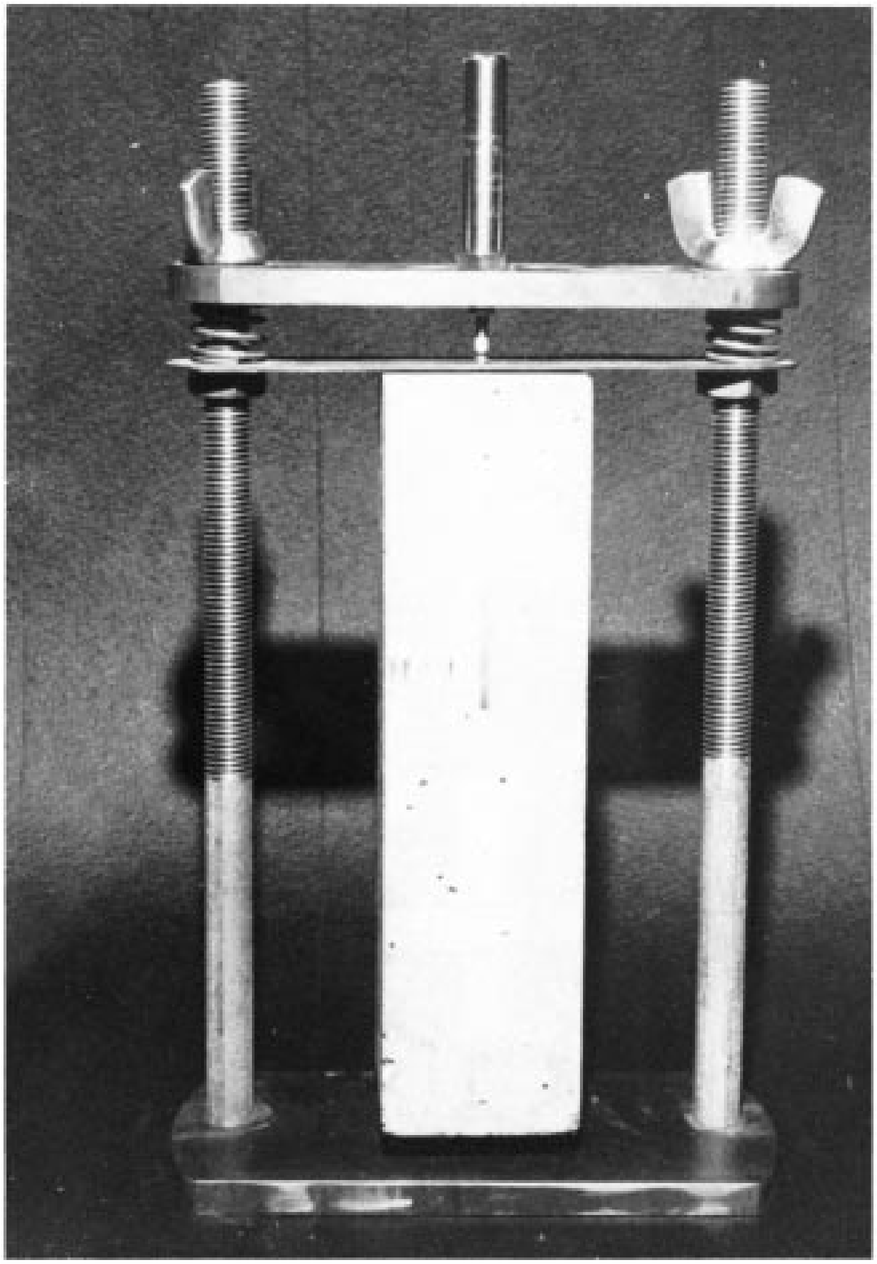

NOTE 1—The drawings in Adjunct C 671 show an experimental setup slightly different from this one.

FIG. 1 Specimen Positioned in Strain Frame

4.5 *Miscellaneous Equipment*—Specimen molds and apparatus specified in applicable sections of Practice C 192.

5. Test Specimens

5.1 Test specimens shall be concrete cylinders mixed, molded, and cured as prescribed in Practice C 192. Specimens shall be 75 mm (3 in.) in diameter by 150 mm (6 in.) high and shall be fitted with axially centered stainless steel gage plugs in both top and bottom. Gage studs shall conform to requirements of Practice C 490. Other sizes and shapes of specimens may be used at some expense of efficiency and convenience. A 1:3 ratio of aggregate to specimen size should be preserved, however. Comparison of concretes must be made on the specimens of the same size.

5.2 Test specimens may also be cores, cubes, 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 they were taken. This may be accomplished by wrapping the specimens in plastic or by other suitable means.

6. Calibration

6.1 Each strain frame and strain-measuring apparatus shall be calibrated using an invar bar with known thermal expansion characteristics.

6.2 With the invar bar in the strain frame, cool the apparatus as described in 8.2 and record the strain with change in temperature.

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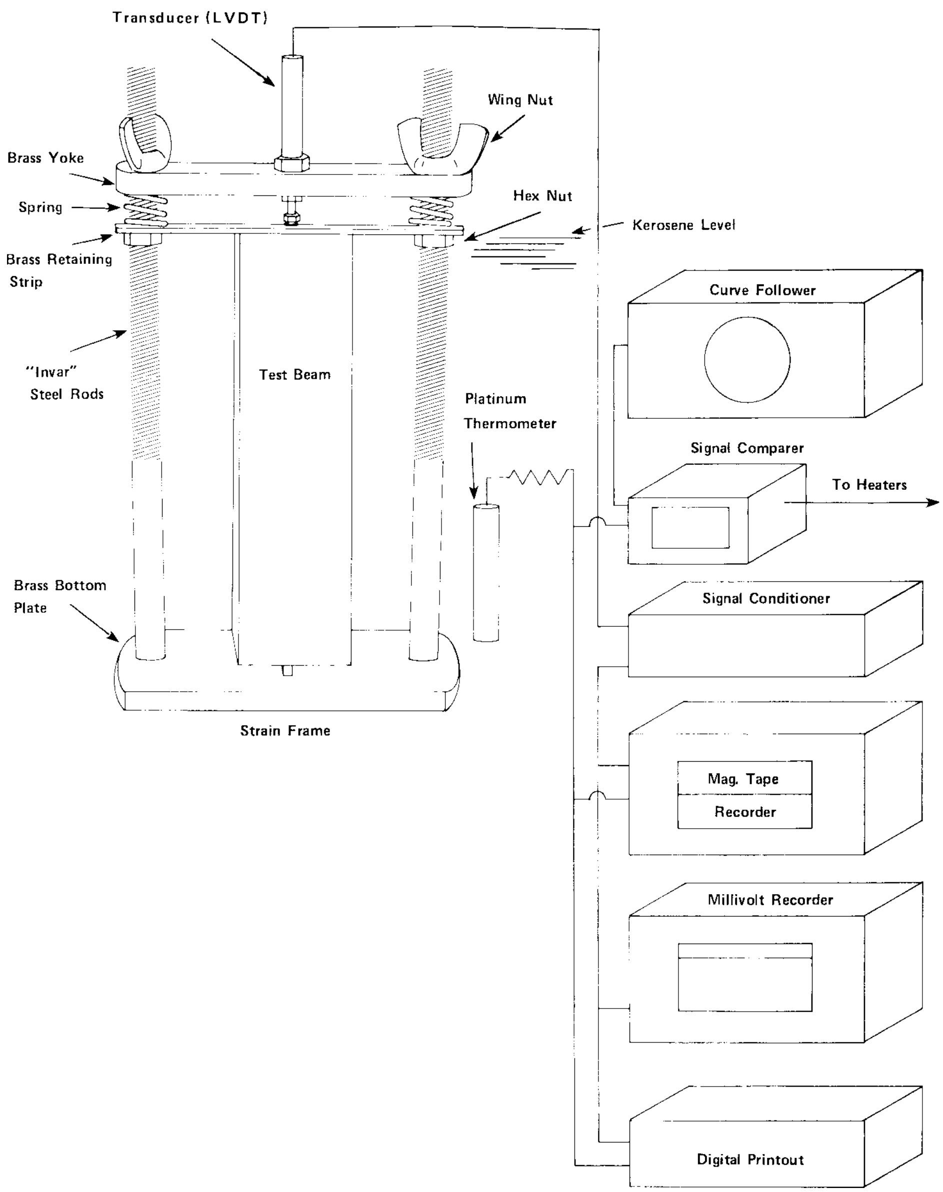

NOTE 1—Stainless steel gage plugs cast in concrete specimen top and bottom.
NOTE 2—Refrigeration is on continuously. Heaters controlled by signal comparer maintain desired temperature at all times.
NOTE 3—The drawings in Adjunct C 671 show an experimental setup slightly different from this one.

FIG. 2 Schematic of Length and Temperature Measuring System

6.3 Calculate the best fit line for the length change-temperature decrease.

7. Curing and Conditioning

7.1 Results of the use of this test method are strongly dependent on the curing and conditioning procedures to which the specimens have been subjected prior to testing. The most important variable related to conditioning is the degree of saturation of the specimens when tests are started. Therefore, the curing and conditioning procedures must be carefully described in terms of the purpose for which the test method is being used and must be closely followed.

8. Procedure

8.1 Testing shall commence immediately following completion of specimen conditioning.

8.2 *Test Cycle*—The test cycle shall consist of cooling the specimens in silicone oil or water-saturated kerosine from 1.7 to − 9.4°C (35 to 15°F) at the rate of 2.8± 0.5°C/h (5 ± 1°F/h) followed by immediate return of specimens to the 1.7°C (35°F) water bath, where they shall remain until the next test cycle.

8.3 *Frequency*—One test cycle shall be carried out every 2 weeks.

8.4 *Measurements*—The measured variables are the specimen length changes per unit length (strain) and the cooling bath temperatures during the cooling cycle. From observation of these changes, the dilation that occurs at the time of freezing in the specimens is determined (Note 3). Dilation is determined

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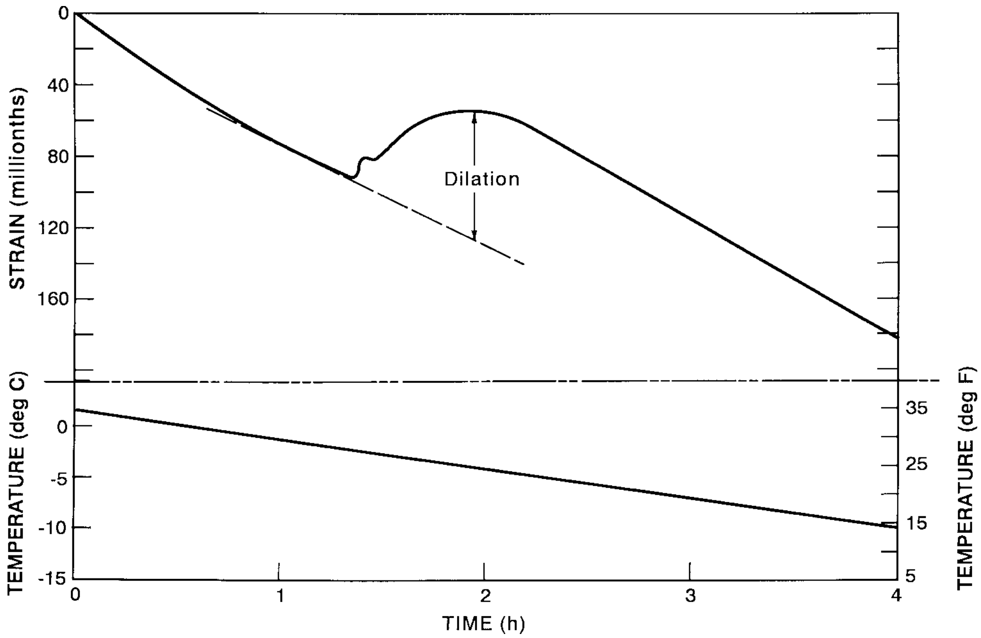

FIG. 3 Typical Length Change and Temperature Charts

by measuring the vertical distance from a straightline projection of the prefreezing, length- *versus*-time contraction curve (at constant cooling rate) and the maximum deviation of the strain trace from it (Fig. 3).

NOTE 3—Additional information of value can be obtained by measurement of residual expansion.

8.5 *Duration of Test and Critical Dilation*—Continue the test until the critical dilation of a specimen or the average value of a group of similar specimens is exceeded or until the specimens have been exposed for the period of interest. Determine the critical dilation by taking the differences between dilation values for successive cycles. Designate the number of cycles during which the difference between successive dilations remained constant as the period of frost immunity, and designate the dilation during the last cycle before the dilation began to increase sharply (by a factor of 2 or more) as the critical dilation.

NOTE 4—In one study, 80 % of critical dilations were found to be 100 millionths or lower.[6]

8.6 *Period of Frost Immunity*—During the period of frost immunity, the difference between dilation values for successive cycles will be relatively constant. When the numerical difference between dilations begins to increase sharply (by a factor of 2 or more) from one cycle to the next, the period of frost immunity has been exceeded. When dilations are very small (less than 0.005 %), the variability associated with the test method may be of sufficient magnitude to produce an apparent end point meeting the criterion presented in this paragraph. Therefore, when the critical dilation is less than 0.005 % (50 millionths) of the original gage length, run additional cycles to ensure that the difference between successive dilations continues to increase significantly. Highly frost-resistant concrete may never exhibit critical dilation.

9. Report

9.1 For each specimen record the test period of frost immunity. This period is the total test period for which critical dilation does not occur and is measured by the length of time in weeks from the start of soaking in the 1.7°C (35°F) bath to the time of occurrence of critical dilation (Note 5).

NOTE 5—No relationship has been established between the frost immunity of specimens cut from hardened concrete and specimens prepared in the laboratory.

9.2 Compute the mean (average) value, $\bar{X}$, and the coefficient of variation, V, for the test period of frost immunity for each mixture-conditioning combination. From these values, determine H, the 95 % confidence interval of the mean, from the appropriate curve in Fig. 4.

9.3 Report the period of frost immunity in the form $\bar{X} \pm (H\bar{X}/100)$. If the means of replicate mixtures differ by more than the square root of the sums of the squares of the standard deviations of the mixtures, then an additional mixture must be tested. This procedure must be repeated until two replicate mixtures meet the above criterion.

9.4 The report shall indicate if the test specimens are cut from hardened concrete, and if so, the size, shape, orientation of the specimens in the structure, and any other pertinent information available shall be included in the report.

10. Precision and Bias

10.1 *Precision*—The principal use of this test method is to rank or compare different concrete materials, mixtures, or treatment conditions as they affect the period of frost immunity determined by testing in the same laboratory.

10.1.1 There have been no interlaboratory tests using replicate specimens or materials, therefore; no interlaboratory

[6] T.D. Larson and P.D. Cady, HRB NCHRP Report "Identification of Frost Susceptible Particles in Concrete Aggregates," Appendix B, 1969.

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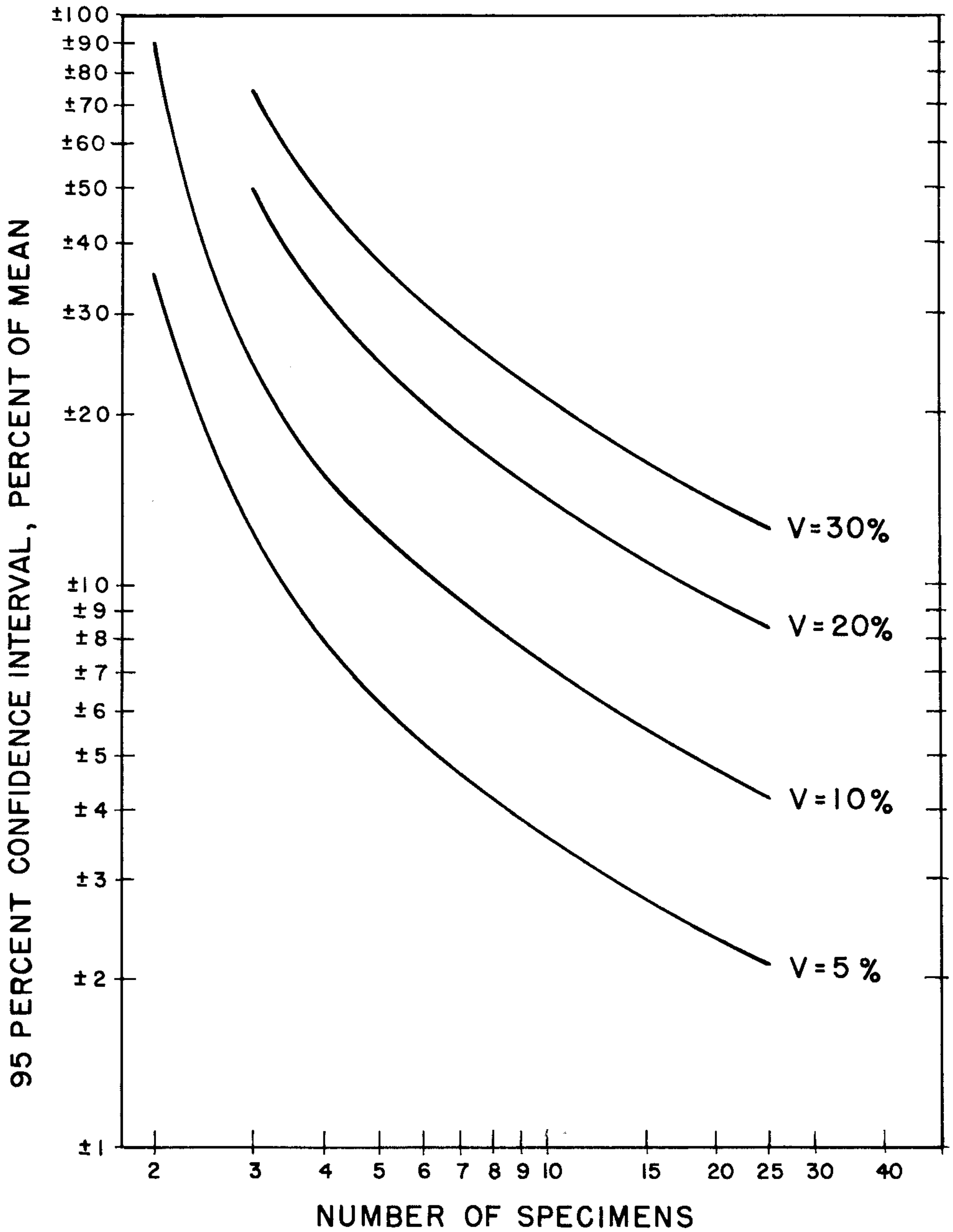

FIG. 4 Ninety-five Percent Confidence Interval Versus Number of Specimens for Determination of the Period of Frost Immunity[6]

statement is available at this time. It is expected that uncontrollable differences in specimens, conditioning, and equipment used in different laboratories may change the period of frost immunity obtained in these laboratories by large amounts, but that rankings or comparisons between different variables should hold.

10.1.2 Obtaining data on precision of repeated testing of variables within a single laboratory is a possibility as this test method is used in more laboratories. At this point, due to its limited use in only a few laboratories the needed data is not available yet.

10.2 *Bias*—Bias for this test method cannot be determined since there is no reference standard available for comparison.

11. Keywords

11.1 concrete; concrete aggregate; critical dilation; freezing and thawing; freezing resistance; frost immunity; length change

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