Designation: C 512 – 87 (Reapproved 1994)

Standard Test Method for
Creep of Concrete in Compression[1]

This standard is issued under the fixed designation C 512; 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 creep of molded concrete cylinders subjected to sustained longitudinal compressive load. This test method is limited to concrete in which the maximum aggregate size does not exceed 2 in. (50 mm).

1.2 The values stated in inch-pound 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 39 Test Method for Compressive Strength of Cylindrical Concrete Specimens[2]

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

C 470 Specification for Molds for Forming Concrete Test Cylinders Vertically[2]

C 617 Practice for Capping Cylindrical Concrete Specimens[2]

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials[2]

3. Significance and Use

3.1 This test method measures the load-induced time-dependent compressive strain at selected ages for concrete under an arbitrary set of controlled environmental conditions.

3.2 This test method can be used to compare creep potentials of different concretes. A procedure is available, using the developed equation (or graphical plot), for calculating stress from strain data within massive non-reinforced concrete structures. For most specific design applications, the test conditions set forth herein must be modified to more closely simulate the anticipated curing, thermal, exposure, and loading age conditions for the prototype structure. Current theories and effects of material and environmental parameters are presented in ACI SP-9, Symposium on Creep of Concrete.[3]

3.3 In the absence of a satisfactory hypothesis governing creep phenomena, a number of assumptions have been developed that have been generally substantiated by test and experience.

3.3.1 Creep is proportional to stress from 0 to 40 % of concrete compressive strength.

3.3.2 Creep has been conclusively shown to be directly proportional to paste content throughout the range of paste contents normally used in concrete. Thus the creep characteristics of concrete mixtures containing aggregate of maximum size greater than 2 in. (50 mm) may be determined from the creep characteristics of the minus 2-in. (minus 50-mm) fraction obtained by wet-sieving. Multiply the value of the characteristic by the ratio of the cement paste content (proportion by volume) in the full concrete mixture to the paste content of the sieved sample.

3.4 The use of the logarithmic expression (Section 8) does not imply that the creep strain-time relationship is necessarily an exact logarithmic function; however, for the period of one year, the expression approximates normal creep behavior with sufficient accuracy to make possible the calculation of parameters that are useful for the purpose of comparing concretes.

3.5 There are no data that would support the extrapolation of the results of this test to tension or torsion.

4. Apparatus

4.1 *Molds*—Molds shall be cylindrical conforming to the provisions of Practice C 192, or to the provisions of Specification C 470. If required, provisions shall be made for attaching gage studs and inserts, and for affixing integral bearing plates to the ends of the specimen as it is cast.

4.1.1 Horizontal molds shall conform to the requirements of the section on horizontal molds for creep test cylinders of Practice C 192. A horizontal mold that has proven satisfactory is shown in Fig. 1.

4.2 *Loading Frame*, capable of applying and maintaining the required load on the specimen, despite any change in the dimension of the specimen. In its simplest form the loading frame consists of header plates bearing on the ends of the loaded specimens, a load-maintaining element that may be

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[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregatesa nd is the direct responsibility of Subcommittee C09.61on Testing for Strength.

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

[3] Available from the American Concrete Institute, P. O. Box 19150, Detroit, MI 48219.

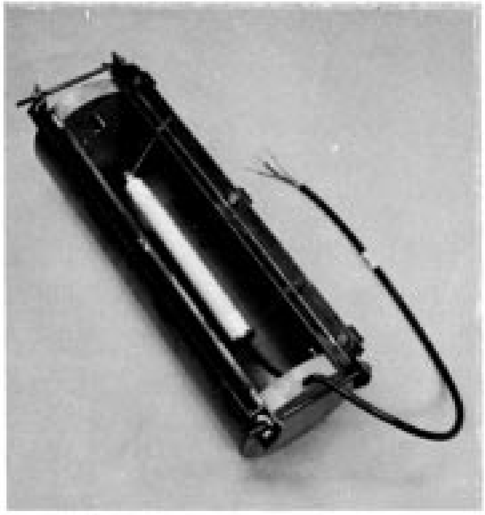

FIG. 1 Horizontal Mold for Creep Specimens

either a spring or a hydraulic capsule or ram, and threaded rods to take the reaction of the loaded system. Bearing surfaces of the header plates shall not depart from a plane by more than 0.001 in. (0.025 mm). In any loading frame, several specimens may be stacked for simultaneous loading. The length between header plates shall not exceed 70 in. (1780 mm). When a hydraulic load-maintaining element is used, several frames may be loaded simultaneously through a central hydraulic pressure-regulating unit consisting of an accumulator, a regulator, indicating gages, and a source of high pressure, such as a cylinder of nitrogen or a high-pressure pump. Springs such as railroad car springs may be used to maintain the load in frames similar to those described above; the initial compression shall be applied by means of a portable jack or testing machine. When springs are used, care should be taken to provide a spherical head or ball joint, and end plates rigid enough to ensure uniform loading of the cylinders. Fig. 2 shows an acceptable spring-loaded frame. Means shall be provided for measuring the load to the nearest 2 % of total applied load. This may be a permanently installed hydraulic pressure gage or a hydraulic jack and a load cell inserted in the frame when the load is applied or adjusted.

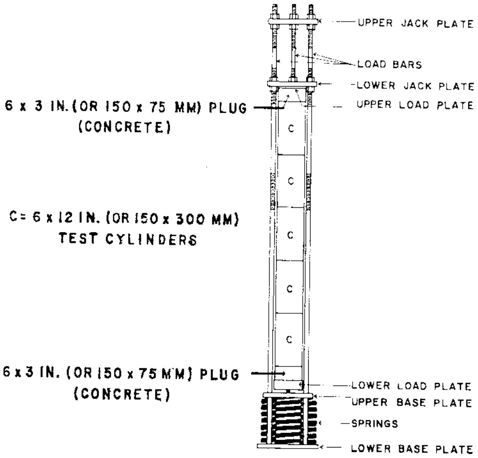

FIG. 2 Spring-Loaded Creep Frame

4.3 *Strain-Measuring Device*—Suitable apparatus shall be provided for the measurement of longitudinal strain in the specimen to the nearest 10 millionths. The apparatus may be embedded, attached, or portable. If a portable apparatus is used, gage points shall be attached to the specimen in a positive manner. Attached gages relying on friction contact are not permissible. If an embedded device is used, it shall be situated so that its strain movement occurs along the longitudinal axis of the cylinder. If external devices are used, strains shall be measured on not less than two gage lines spaced uniformly around the periphery of the specimen. The gages may be instrumented so that the average strain on all gage lines can be read directly. The effective gage length shall be at least three times the maximum size of aggregate in the concrete. The strain-measuring device shall be capable of measuring strains for at least 1 year without change in calibration.

NOTE 1—Systems in which the varying strains are compared with a constant-length standard bar are considered most reliable, but unbonded electrical strain gages are satisfactory.

5. Test Specimens

5.1 *Specimen Size*—The diameter of each specimen shall be 6 ± 1⁄16 in. (or 150 ± 1.6 mm), and the length shall be at least 11½ in. (292 mm). When the ends of the specimen are in contact with steel bearing plates, the specimen length shall be at least equal to the gage length of the strain-measuring apparatus plus the diameter of the specimen. When the ends of the specimen are in contact with other concrete specimens similar to the test specimen, the specimen length shall be at least equal to the gage length of the strain-measuring apparatus plus 1½ in. (38 mm). Between the test specimen and the steel bearing plate at each end of a stack, a supplementary noninstrumented cylinder whose diameter is equal to that of the test cylinders and whose length is at least half its diameter shall be installed.

5.2 *Fabricating Specimens*—The maximum size of aggregate shall not exceed 2 in. (50-mm) (Section 3). Vertically cast cylinders shall be fabricated in accordance with the provisions of Practice C 192. The ends of each cylinder shall meet the planeness requirements described in the scope of Practice C 617 (Note 2). Horizontally cast specimens shall be consolidated by the method appropriate to the consistency of the concrete as indicated in the methods of consolidation section of Practice C 192. Care must be taken to ensure that the rod or vibrator does not strike the strain meter. When vibration is used, the concrete shall be placed in one layer and the vibrating element shall not exceed 1¼ in. (32 mm) in diameter.When rodding is used, the concrete shall be placed in two approximately equal layers and each layer shall be rodded 25 times evenly along each side of the strain meter. After consolidation the concrete shall be struck off with trowel or float, then trowelled the minimum amount to form the concrete in the opening concentrically with the rest of the specimen. A template curved in the radius of the specimen may be used as a strikeoff to shape and finish the concrete more precisely in the opening. When cylinders are to be stacked, lapping of ends is strongly recommended.

NOTE 2—Requirements for planeness may be met by capping, lapping, or, at the time of casting, fitting the ends with bearing plates normal to the axis of the cylinder.

5.3 *Number of Specimens*—No fewer than six specimens (Note 3) shall be made from a given batch of concrete for each test condition; two shall be tested for compressive strength, two shall be loaded and observed for total deformation, and two shall remain unloaded for use as controls to indicate deformations due to causes other than load. Each strength and control specimen shall undergo the same curing and storage treatment as the loaded specimen.

NOTE 3—It is recommended that specimens be tested in triplicate although duplicate specimens are acceptable.

6. Curing and Storage of Specimens

6.1 *Standard Curing*—Before removal from the molds, specimens shall be stored at 73.4 ± 3.0°F (23.0 ± 1.7°C) and covered to prevent evaporation. The specimens shall be removed from the molds not less than 20 nor more than 48 h after molding and stored in a moist condition at a temperature of 73.4 ± 3.0°F until the age of 7 days. A moist condition is that in which free water is maintained on the surfaces of the specimens at all times. Specimens shall not be exposed to a stream of running water nor be stored in water. After the completion of moist curing the specimens shall be stored at a temperature of 73.4 ± 2.0°F (23.0 ± 1.1°C) and at a relative humidity of 50 ± 4 % until completion of the test.

6.2 *Basic Creep Curing*—If it is desired to prevent the gain or loss of water during the storage and test period, specimens shall at the time of fabrication or stripping be enclosed and sealed in moistureproof jackets (for example, copper or butyl rubber) to prevent loss of moisture by evaporation and shall remain sealed throughout the period of storage and testing.

6.3 *Variable Curing Temperature Regimen*—When it is desired to introduce the effect of temperature on the elastic and inelastic properties of a concrete (as, for example, the adiabatic temperature conditions existing in massive concrete or temperature conditions to which concrete is subjected during accelerated curing), temperatures within the specimen storage facility shall be controlled to correspond to the desired temperature history. The user shall be responsible for establishing the time-temperature history to be followed and the permissible range of deviation therefrom.

6.4 *Other Curing Conditions*—Other test ages and ambient storage conditions may be substituted when information is required for specific applications. The storage conditions shall be carefully detailed in the report.

7. Procedure

7.1 *Age at Loading*—When the purpose of the test is to compare the creep potential of different concretes, initially load the specimens at an age of 28 days. When the complete creep behavior of a given concrete is desired, prepare the specimens for initial loading in the following ages: 2, 7, 28, and 90 days, and 1 year. If information is desired for other ages of loading, include the age in the report.

7.2 *Loading Details*—Immediately before loading the creep specimens, determine the compressive strength of the strength specimens in accordance with Test Method C 39. At the time unsealed creep specimens are placed in the loading frame, cover the ends of the control cylinders to prevent loss of moisture (Note 4). Load the specimens at an intensity of not more than 40 % of the compressive strength at the age of loading. Take strain readings immediately before and after loading, 2 to 6 h later, then daily for 1 week, weekly until the end of 1 month, and monthly until the end of 1 year. Before taking each strain reading, measure the load. If the load varies more than 2 % from the correct value, it must be adjusted (Note 5). Take strain readings on the control specimens on the same schedule as the loaded specimens.

NOTE 4—In placing creep specimens in the frame, take care in aligning the specimens to avoid eccentric loading. When cylinders are stacked and external gages are used, it may be helpful to apply a small preload such that the resultant stress does not exceed 200 psi (1380 kPa) and note the strain variation around each specimen, after which the load may be removed and the specimens realigned for greater strain uniformity.

NOTE 5—Where springs are used to maintain the load, the adjustment can be accomplished by applying the correct load and tightening the nuts on the threaded reaction rods.

8. Calculation

8.1 Calculate the total load-induced strain per pound per square inch (or kilopascal) at any time as the difference between the average strain values of the loaded and control specimens divided by the average stress. To determine creep strain per pound-force per square inch (or kilopascal) for any age, subtract from the total load-induced strain per pound-force per square inch (or kilopascal) at that age the strain per pound-force per square inch (or kilopascal) immediately after loading. If desired, plot total strain per pound-force per square inch (or kilopascal) on semilog coordinate paper, on which the logarithmic axis represents time, to determine the constants $1/E$ and $F(K)$ for the following equation:

$$\epsilon = (1/E) + F(K)\ln(t + 1) \qquad (1)$$

where:

ϵ = total strain psi (or kPa),
E = instantaneous elastic modulus, psi (or kPa),
$F(K)$ = creep rate, calculated as the slope of a straight line representing the creep curve on the semilog plot, and
t = time after loading, days.

The quantity $1/E$ is the initial elastic strain per pound per square inch (or kilopascal) and is determined from the strain readings taken immediately before and after loading the specimen. If loading was not accomplished expeditiously, some creep may have occurred before the after-loading strain was observed, in which event extrapolation to zero time by the method of least squares may be used to determine this quantity.

9. Report

9.1 Report the following information:

9.1.1 Cement content, water-cement ratio, maximum aggregate size, slump, and air content,

9.1.2 Type and source of cement, aggregate, admixture, and mixing water (if other than fresh water is used),

9.1.3 Position of cylinder when cast,

9.1.4 Storage conditions prior to and subsequent to loading,

9.1.5 Age at time of loading,

9.1.6 Compressive strength at age of loading,

NOTICE: This standard has either been superseded and replaced by a new version or discontinued. Contact ASTM International (www.astm.org) for the latest information.

9.1.7 Type of strain measuring device,

9.1.8 Magnitude of any preload,

9.1.9 Intensity of applied load,

9.1.10 Initial elastic strain,

9.1.11 Creep strain per pound per square inch (or kilopascal) at designated ages up to 1 year, and

9.1.12 Creep rate, F (K), if determined.

10. Precision and Bias

10.1 *Precision*—The single-operator single-batch coefficient of variation has been found to be 4.0 %[4], and the single-operator-multi-batch coefficient of variation has been found to be 9.0 % [4], over the range of creep strains from 250 to 2000 millionths. The results of two properly conducted tests by the same operator on the same material should not differ by more than 6 %[5] of their average. The results of two properly conducted tests by the same operator on material cast from different batches should not differ by more than 13 %[5] of their average.

10.2 *Bias*—This test method has no bias because the values determined can only be defined in terms of the test method.

11. Keywords

11.1 compression; concrete; creep; creep strain; elastic strain

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[4] These numbers represent the (1s %) limit as described in Practice C 670.

[5] These numbers represent the (d2s %) limit as described in Practice C 670.

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