BRITISH STANDARD

BS 6319-11: 1993

Testing of resin and polymer/cement compositions for use in construction —

Part 11: Methods for determination of creep in compression and in tension

Committees responsible for this British Standard

The preparation of this British Standard was entrusted by Technical Committee B/517, Concrete, to Subcommittee B/517/8, Protection and repair of concrete structures, upon which the following bodies were represented:

British Adhesives and Sealants Association
British Cement Association
British Railways Board
Building Employers Confederation
Cement Admixtures Association
Concrete Repair Association
Concrete Society
County Surveyors' Society
Department of the Environment (Building Research Establishment)
Department of Transport
Department of Transport (Transport Research Laboratory)
Federation of Civil Engineering Contractors
FeRFA
Institution of Highways and Transportation
Institution of Structural Engineers
Plastics and Rubber Institute
Sprayed Concrete Association

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Contents

Foreword

This Part of BS 6319 has been prepared under the direction of Technical Committee B/517, Concrete. This Part describes methods for determining creep in compression and in tension and is one of a series of Parts describing methods for measuring basic physical properties of resin and polymer modified materials.

This Part of BS 6319 should be read in conjunction with BS 6319-1 which provides general information and describes the method for preparing test specimens.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations. In particular, attention is drawn to the Health and Safety at Work etc. Act 1974 [1].

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 8, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

1 Scope

This Part of BS 6319 describes methods for the determination of the creep of specimens of polymer and polymer/cement mortars. Creep in compression is measured on rectangular prisms and creep in tension on necked specimens having a maximum aggregate size of 2.4 mm.

The prime objective of the methods is to provide comparative data on materials in order to establish whether or not creep is likely to be significant in the intended application. The methods provide an estimate of creep strains within ± 10 % of the absolute value under the particular environmental conditions in which the test is conducted. For comparative purposes, it is necessary to control the temperature to within ± 2 °C of the specified temperature but control of humidity is not essential.

NOTE For specific applications where a higher level of accuracy is required, additional requirements for measurement of load, achieving axiality and environmental conditions should be agreed before testing commences.

2 References

2.1 Normative references

This Part of BS 6319 incorporates, by reference, provisions from specific editions of other publications. These normative references are cited at the appropriate points in the text and the publications are listed on the inside back cover. Subsequent amendments to, or revisions of, any of these publications apply to this Part of BS 6319 only when incorporated in it by updating or revision.

2.2 Informative references

This Part of BS 6319 refers to other publications that provide information or guidance. Editions of these publications current at the time of issue of this standard are listed on the inside back cover, but reference should be made to the latest editions.

3 Definitions

For the purposes of this Part of BS 6319 the definitions given in BS 6319-1:1983 apply, together with the following.

3.1
compressive stress

force per unit area of the original cross section of a member in compression

3.2
elastic strain

deformation produced by a stress up to the elastic limit and expressed as the change per unit of original dimension

3.3
elastic compressive strain

elastic strain measured immediately following the application of compressive load

3.4
tensile stress

force per unit area of the original cross section of a member in tension

3.5
elastic tensile strain

elastic strain measured immediately following the application of tensile load

3.6
creep strain

time-dependent strain measured over and above elastic strain under the application of a constant load

3.7
creep coefficient

ratio of creep strain to elastic strain at the same applied stress

3.8
elastic recovery strain

amount of elastic strain lost by a member immediately on unloading to zero stress

3.9
creep recovery strain

amount of creep strain lost by a member following unloading to zero stress

3.10
creep recovery coefficient

ratio of creep recovery strain to elastic recovery strain

4 Principle

In the test for creep in compression, a prism of 4 : 1 aspect ratio is subjected to a constant compressive load and change in creep strain with time is related to the elastic compressive strain.

In the test for creep in tension, a necked specimen is subjected to a constant tensile load and change in creep strain with time is related to the elastic tensile strain.

5 Apparatus

5.1 *Compressive creep rig,* capable of applying the constant load, derived as in **7.2.5**, for at least 30 weeks along the axis of the test specimens described in **6.1**.

NOTE A suitable hydraulic compressive creep rig capable of testing two specimens simultaneously is illustrated in Figure 1. The incorporation of a gas/oil accumulator in the hydraulic system serves to extend the time between occasions when it will be necessary to pump oil in order to maintain the pressure applied to the flat jack and hence the load applied to the specimen at constant values for the duration of the test. The compressive load and hence the compressive stress applied to the specimens is monitored by a load cell conforming to grade **2.0** of BS 1610-2:1985 inserted between the upper specimen and the upper platen of the rig.

The rig is capable of applying load at the rate specified in **7.2.5** by the use of a needle valve in the hydraulic line upstream of the flat jack.

The platens have a stiffness (axial load/central deflection) of not less than 2 500 kN/mm to avoid excessive deformation during loadings. The flatness tolerance for the area of the platen in contact with the load cell conforms to clause **5** of BS 1881-115:1986.

Spacing blocks are used between the specimens and the flat jack to reduce the test space and to compensate for any bow developed in the faces of the flat jack when under pressure. The spacing blocks are either circular or square in section, enable the specimens to be correctly centered and support them over the whole area of their ends. The properties of the material, the surface flatness, and the surface texture of the contact faces of all spacing blocks conform to clause **7** of BS 1881-115:1986. A spherical seating is incorporated between the load cell and the top end piece of the upper specimen.

The vertical pillars connecting the platens of the rig have a stiffness (axial load/axial deflection) of not less than 250 kN/mm. They incorporate a means of adjustment to provide a parallelism tolerance between the upper and lower platens of 0.06 mm (see **10.8.4** of BS 308-3:1990).

5.2 *Tensile creep rig,* capable of applying the constant load, derived as in **8.2.5**, for at least 30 weeks along the axis of the test specimens described in **6.2**.

NOTE A suitable dead weight tensile creep rig is illustrated in Figure 2. This comprises a loading frame, a lever system and weights to apply a constant tensile force to three specimens mounted in series. The end and intermediate specimen anchorage units are detailed in Figure 3. They consist of 3 mm thick rectangular plates drilled to give a close tolerance fit to 16 mm diameter anchorage pins. The end anchorage plates are attached to the bottom of the straining frame and to the loading beam at the top through universal anchorage couplings. The anchorage plates are manufactured to the tolerances specified in **3.1.2** of BS 6319-1:1983.

5.3 *Moulds,* conforming to **3.1** of BS 6319-1:1983 and of a size to produce rectangular prisms in accordance with **6.1** or necked specimens in accordance with **6.2**.

5.4 *Strain gauges.* Two strain gauges shall have a gauge length of 100 mm and maximum sensitivity 20 μm/m for measuring compressive strain on each specimen. Eight strain gauges shall have a gauge length of 50 mm for measuring tensile strain. The strain gauges shall be connected to equipment capable of providing a continuous indication of strain. They shall be calibrated by a method traceable to a national or International Standard of length measurement. In the UK, this is the responsibility of the National Physical Laboratory (NPL). The error shall not exceed 2 % of the actual strain.

5.5 *Environmental chamber* (optional), to control the ambient temperature of the tensile creep specimens. It shall be able to maintain a steady temperature for individual control settings within a range from – 25 °C to + 50 °C to an accuracy of ± 1 °C. It shall be constructed so that only the loading bars at the top and bottom of the line of tensile creep specimens protrude.

5.6 *Thermocouple* (optional), for measuring the temperature in the environmental chamber (**5.5**), capable of measuring to the nearest 0.2 °C over a range from – 25 °C to + 50 °C. It shall be connected to equipment capable of providing a continuous indication of temperature.

6 Test specimens

6.1 Dimensions of compressive creep test specimens

Compressive creep test specimens shall be rectangular prisms of nominal size 40 mm × 40 mm × 160 mm unless the material contains an aggregate of which at least 90 %, when sampled in accordance with BS 812-102:1989, will not pass through a 5 mm test sieve conforming to BS 410:1986. For such materials the width and depth of the prisms shall be between 7.0 and 8.0 times the nominal mesh size of the smallest test sieve conforming to BS 410:1986 through which 90 % of the aggregate will pass. The length to width ratio of the prisms shall be 4 : 1.

6.2 Dimensions of tensile creep test specimens

Tensile creep test specimens shall have a necked length of 150 mm and a cross section of 40 mm × 12 mm as shown in Figure 4. The internal radius of the anchorage sections shall be 9 mm.

6.3 Preparation of test specimens

Prepare the test specimens, including the conditioning, proportioning and mixing of the materials and the conditioning and filling of the moulds, in accordance with BS 6319-1:1983. Specimens for measuring tensile creep shall not contain aggregate of size greater than 2.4 mm.

7 Procedure for measuring creep in compression

7.1 Number of specimens

Test a minimium of two specimens at a time cast from one batch of material for each prescribed set of test conditions. Use a further specimen from the same batch as a control specimen.

7.2 Testing

7.2.1 *Temperature*

Carry out the test at (23 ± 2) °C unless, for a specific purpose, an alternative temperature has been agreed. Maintain the test specimens at the test temperature for not less than 16 h before testing commences.

7.2.2 *Age at loading*

Commence the test when the test specimens have attained an age of 28 days unless, for a specific purpose, an alternative age has been agreed.

7.2.3 *Measurement*

Measure the width and thickness of each specimen at its centre to the nearest 0.1 mm and calculate its cross-sectional area.

7.2.4 *Placing the test specimen in the creep rig*

Fit two strain gauges (**5.4**) to opposite cast sides of the test and control specimens, their gauge lengths being centrally located over the axis of the test specimens.

NOTE BS 1881-206 gives guidance on the use of strain gauges.

Wipe clean the bearing surfaces of the creep rig (**5.1**) and any spacing blocks. Remove any loose grit or other material from the ends of the test specimens that are to be loaded. Place the test specimens in the rig in such a manner that the load is applied axially, i.e. parallel to the long axis of the specimens, and centre it carefully as described in **7.2.5**.

Do not use packing at any of the interfaces between the test specimen, spacing blocks, load cell and platens.

7.2.5 *Loading*

Apply the load smoothly at a rate between 200 N/s and 1 000 N/s until the specified load P_1 for the creep test is indicated. The load P_1 shall be one-quarter of that necessary to cause failure in a test to measure compressive strength carried out in accordance with BS 6319-2:1983. In the absence of such information the maximum load P_1 to be applied should be that necessary to cause a compressive strain of 0.002 m/m unless, for a specific purpose, an alternative load has been agreed.

Smoothly reduce the load to 0.1 P_1 and re-apply the load at least twice to ensure that the specimens and platen are well seated and that the strain gauges are indicating consistently.

If the individual strains are not within a range of ± 10 % of their mean value at load P_1, centre the test specimen again and repeat the procedure. If it is not possible to reduce the difference to within this range do not proceed with the test on that specimen. Select another specimen from the same batch and continue until two acceptable specimens have been found.

Next, zero the strain gauges at zero load, re-apply the load P_1 smoothly, maintain the load and immediately take a reading from both strain gauges. Whilst maintaining the load constant at load P_1 take readings from both strain gauges at 15 min intervals for the first hour, at hourly intervals for the next 11 h, four hourly intervals for the next 12 h, daily intervals for the next 6 days and thereafter twice weekly until the termination of the creep phase of the test. Check regularly that the load P_1 is maintained and restore it when necessary.

Unload the specimen smoothly and immediately take a reading from both strain gauges. Thereafter take readings at zero load at daily intervals until the termination of the creep recovery phase of the test.

7.2.6 *Duration of the test*

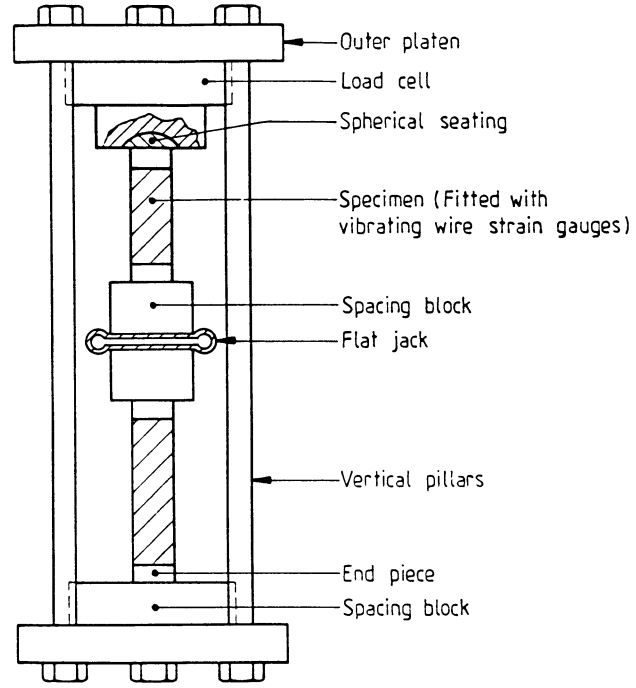
The duration of the creep phase of the test shall be 26 weeks and that of the creep recovery phase 4 weeks unless, for a specific purpose, alternative durations have been agreed.

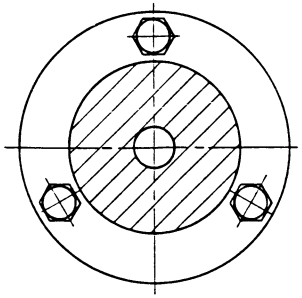
7.2.7 *Compressive strength on completion of the test*

Following the creep recovery phase, load each specimen in axial compression in accordance with BS 6319-2:1983 and record the maximum load up to the point of failure.

7.2.8 *Control specimen*

Keep the control specimen in the same ambient conditions adjacent to the loaded specimens and take strain readings at the same time intervals as for the specimen under load.





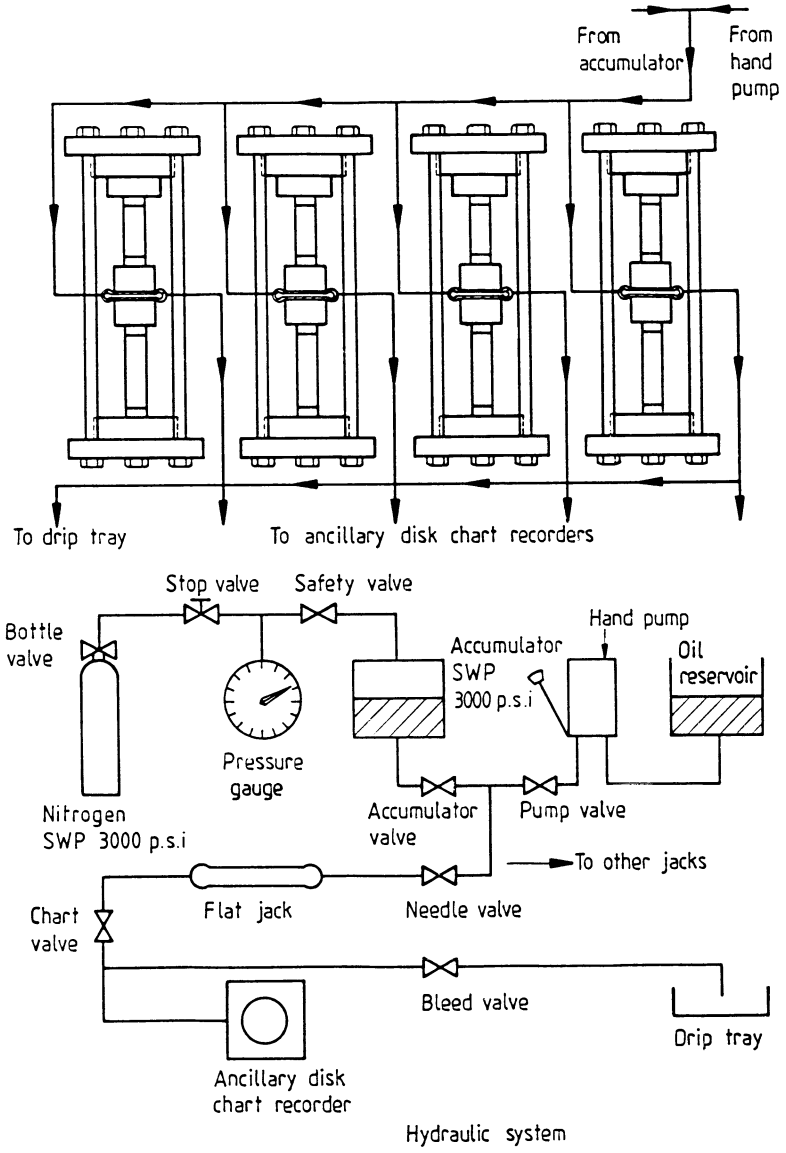


Figure 1 — Typical hydraulic compressive creep rig

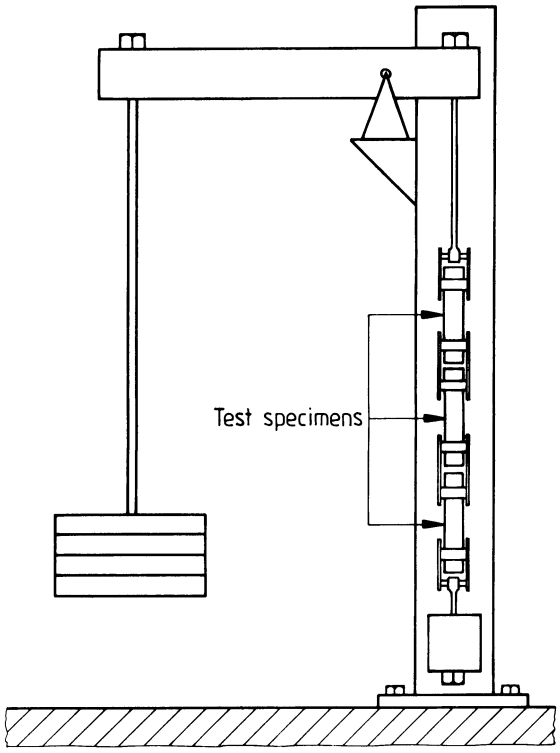


Figure 2 — Typical dead weight tensile creep rig

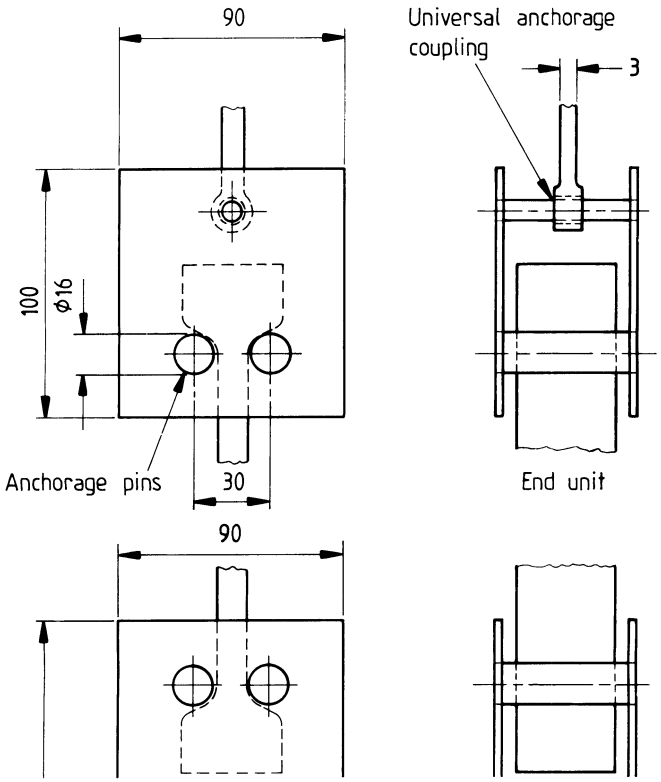


Figure 3 — End anchorage plates for tensile creep specimens

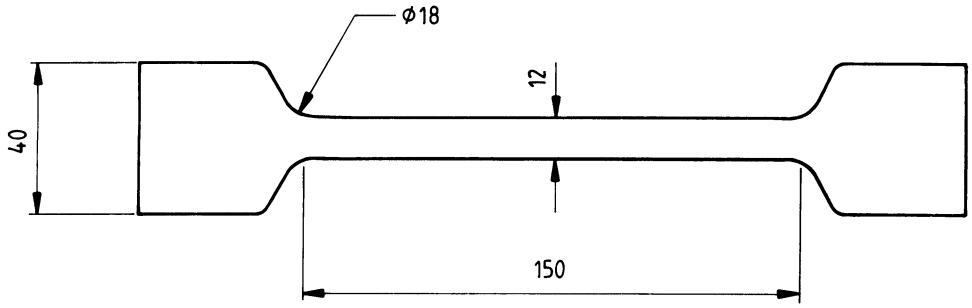


Figure 4 — Necked specimens for tensile creep testing

8 Procedure for measuring creep in tension

8.1 Number of specimens

Test three specimens cast from one batch of material. Use a further specimen from the same batch as a control specimen.

8.2 Testing

8.2.1 *Temperature*

Control the temperature in accordance with **7.2.1**.

8.2.2 *Age at loading*

Load the specimens at the age given in **7.2.2**.

8.2.3 *Measurement*

Measure the specimens in accordance with **7.2.3**.

8.2.4 *Placing the test specimens in the testing machine*

Fit two strain gauges to opposite cast sides of the test and control specimens, their gauge lengths being centrally located over the axis of the test specimens.

NOTE BS 1881-206 gives guidance on the use of strain gauges.

Wipe clean the bearing surfaces of the anchorage pins. Remove any loose grit or other material from the surfaces of the test specimens that are to be in contact with the anchorage pins. Place the test specimens in the rig in such a manner that the load is applied axially, i.e. parallel to the long axes of the test specimens, and centre it carefully. Adjust the nut on the upper loading bar so that the loading beam is horizontal prior to the application of load.

8.2.5 *Loading*

Apply the load instantaneously by releasing the dead weights onto the applied load bar. The load to be applied shall induce a stress of 25 % of the ultimate tensile strength of the material under investigation determined in accordance with BS 6319-7:1985. Alternative values of the proportion of ultimate tensile strength may be agreed for specific purposes. Take strain readings immediately on application of the load. If the individual strains are not within ± 10 % of their mean value remove the load, adjust the alignment of the specimens and re-apply the load. Repeat this procedure until the individual strains are within this tolerance. If this cannot be achieved, the test on these specimens shall be abandoned and a further set of specimens used.

When a successful loading has been achieved, if required, fit the environmental chamber (**5.5**) containing the thermocouple (**5.6**) around the test and control specimens and take strain and temperature readings at 15 min intervals for the first hour, hourly intervals for the next 11 h, four hourly intervals for the next 12 h and daily for the next 6 days. Thereafter take readings at weekly intervals for the remainder of the creep phase of the test.

Unload the specimens and measure creep recovery at the same time intervals following removal of the load with the environmental chamber still in place if it has been used during the loading phase.

8.2.6 ***Duration of the test***

Test the specimens for the durations given in **7.2.6**.

8.2.7 ***Control specimen***

Treat the control specimen in accordance with **7.2.8**.

9 Calculation

Calculate the creep strains for each loaded specimen as the mean strain measured by the strain gauges minus the algebraic value of the mean strain measured on the control specimen.

For each loaded specimen plot a curve of mean strain against time for the loading, creep and creep recovery phases of the test. Clearly identify on the curve the magnitude of the elastic strain at the applied load, the creep strains at durations of loading of 1 week, 4 weeks and 26 weeks, the elastic recovery strain and the creep recovery strains at durations of 1 week and 4 weeks following unloading.

Calculate the creep coefficients (see **3.7**) at durations of loading of 1 week, 4 weeks and 26 weeks.

Calculate the creep recovery coefficients (see **3.10**) at durations of 1 week and 4 weeks after unloading.

Calculate the compressive strength of each loaded compressive creep specimen by dividing the maximum load at failure (see **7.2.7**) by the nominal cross-sectional area.

10 Test report

The following information for each loaded specimen shall be included in the test report:

a) date and site of sample preparation;

b) date and age of sample at commencement of test;

c) ambient conditions during the preparation and curing of the test specimen;

d) ambient conditions during the test;

e) complete identification of the material tested including type, source, manufacturer's code numbers and history;

f) cross-sectional area of the centre of the test specimen;

g) the compressive or tensile stress applied during the test and the compressive or tensile strength from which it was derived;

h) the ratio of compressive or tensile stress to strength on completion of creep;

i) curve of mean strain against time for the loading, creep and creep recovery phases of the test;

j) the creep coefficients at durations of loading of 1 week, 4 weeks and 26 weeks;

k) the creep recovery coefficients at durations of 1 week and 4 weeks following unloading;

l) the compressive strength of each loaded compressive creep specimen;

m) type of creep rig used;

n) type of strain measuring system used.

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List of references (see clause 2)

Normative references

BSI standards publications
BRITISH STANDARDS INSTITUTION, London

BS 410:1986, *Specification for test sieves.*
BS 812, *Testing aggregates.*
BS 812-102:1989, *Methods for sampling.*
BS 6319, *Testing of resin and polymer/cement compositions for use in construction.*
BS 6319-1:1983, *Method for preparation of test specimens.*
BS 6319-2:1983, *Method for measurement of compressive strength.*
BS 6319-7:1985, *Method for measurement of tensile strength.*

Informative references

BSI standards publications
BRITISH STANDARDS INSTITUTION, London

BS 308, *Engineering drawing practice.*
BS 308-3:1990, *Recommendations for geometrical tolerancing.*
BS 1610, *Materials testing machines and force verification equipment.*
BS 1610-2:1985, *Specification for the grading of equipment used for the verification of the forces applied by materials testing machines.*
BS 1881, *Testing concrete.*
BS 1881-115:1986, *Specification for compression testing machines for concrete.*
BS 1881-206:1986, *Recommendations for determination of strain in concrete.*

Other reference

[1] GREAT BRITAIN. Health and Safety at Work etc. Act 1974. London: HMSO.

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