BS 6319-3:
1990

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

Part 3: Methods for measurement of modulus of elasticity in flexure and flexural strength

Confirmed
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Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the Cement, Gypsum, Aggregates and Quarry Products Standards Policy Committee (CAB/-) to Technical Committee CAB/17, 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
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Department of the Environment (Building Research Establishment)
Department of Transport
Department of Transport (Transport and Road Research Laboratory)
Federation of Civil Engineering Contractors
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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 the Cement, Gypsum, Aggregates and Quarry Products Standards Policy Committee. It supersedes BS 6319-3:1983 which is withdrawn. This Part describes methods for measurement of modulus of elasticity in flexure and flexural strength and is one of a series of Parts describing methods for measuring basic physical properties of resin based and polymer modified materials.

In this revision of the 1983 edition, flexural strength is now measured under a four point loading system on longer specimens and a new test for modulus of elasticity in flexure using the same loading system has been added.

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

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 4, 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 measurement of modulus of elasticity in flexure and flexural strength of specimens of polymer based mortars and polymer/cement based mortars in the form of rectangular prisms.

These methods are not applicable to unfilled systems.

NOTE 1 The procedure described in BS 2782: Method 335A is suitable for unfilled systems.
NOTE 2 The titles of the publications referred to in this standard are listed on the inside back cover.

2 Definitions

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

2.1
elastic modulus

ratio of stress to corresponding strain below the proportional limit, where the proportional limit is the greatest stress which a material is capable of supporting without any deviation from the proportionality of stress to strain (Hooke's law)

2.2
modulus of elasticity in flexure

elastic modulus determined from the relationship between load and the deflection induced by that load in a simple freely supported beam

NOTE According to the classical theory of pure bending the deflection (δ) may be expressed in terms of the curvature $\left(\frac{1}{r}\right)$ according to the following relationship:

$$\delta = K\left(\frac{1}{r}\right)L^2 \qquad (1)$$

where

K is a constant depending upon the configuration of loading. For a beam in four point bending and loaded at the third points, K has a value of $\frac{23}{216}$;

L is the span of the beam between the supporting rollers.

The curvature may be expressed as:

$$\frac{1}{r} = \frac{M}{EI} \qquad (2)$$

where

M is the applied bending moment at the section considered;

E is the elastic modulus;

I is the second moment of area of the section.

Hence the modulus of elasticity in flexure (E) is given by:

$$E = K\left(\frac{M}{I\delta}\right)L^2 \qquad (3)$$

2.3 secant modulus in flexure

modulus of elasticity in flexure determined from the slope of a particular line on the load versus deflection relationship. This line passes through the origin and a point on the curve corresponding to the deflection necessary to cause a specified strain in the extreme tensile fibre of the beam at the section considered

NOTE To determine the deflection of a beam corresponding to a specified strain on the extreme tensile fibre, use may be made of the relationship:

$$\epsilon = \frac{MD}{2\,EI} \qquad (4)$$

where

D is the depth of the rectangular specimen;

ϵ is the strain on the extreme tensile fibre at the section considered.

Substituting in (1), the relationship between deflection and strain is given by:

$$\delta = \frac{2\,KL^2}{D}\epsilon \qquad (5)$$

3 Principles

The principle of the test for modulus of elasticity in flexure is the subjection of a test specimen of a defined geometry and in the form of a simple, freely supported, beam to controlled four point loading and relating the applied load to the deflection induced by that load.

The principle of the flexural strength test is the subjection of a test specimen of a defined geometry and in the form of a simple, freely supported, beam to four point loading until failure of the specimen occurs. Measurement of the apparent surface stress in bending is carried out to determine flexural strength.

4 Apparatus

4.1 *Flexural testing machine,* of suitable[1] capacity for the test. It shall be capable of applying the load as specified in **6.2.3** and shall comply with BS 1610-1 with regard to repeatability and accuracy.

[1] The capacity of a testing machine is suitable when the expected load at failure of the specimen lies above the lower one-fifth of the range of the machine being used.

The testing machine shall be equipped with a pair of steel rollers to support the specimen and two further steel rollers to apply the load. All four rollers shall be at least as long as the width of the specimen and shall have a nominal diameter of 10 mm or 0.25 times the width of the specimen, whichever is the greater. They shall be positioned so that their axes are normal to the specimen under test. The distance between the axes of the supporting rollers shall be:

a) for specimens not more than 25 mm wide: 300 ± 1 mm;

b) for specimens more than 25 mm wide: 12.0 times the width of the specimen ± 0.04 times the width.

The loading rollers shall be located at the third span points between the supporting rollers and shall be free to rotate in the vertical plane through their axes. Load shall be applied through a steel spreader beam spanning over the two loading rollers and at a point mid-way between them. The parallelism tolerance for the horizontal axis of one supporting roller with respect to the horizontal axis of the second supporting roller as datum shall be 0.04 mm wide.

NOTE Parallelism may be achieved by allowing one of the supporting rollers to be free to rotate in the vertical plane through its vertical axis.

4.2 *Moulds*, complying with BS 6319-1 and of a size to produce rectangular prisms in accordance with clause **5** of this standard.

4.3 *Deflection transducer*, capable of continuously monitoring the central deflection of the beam to an accuracy of 0.01 mm.

5 Test specimens

5.1 Dimensions of specimens

Specimens shall be rectangular prisms of size 25 mm × 25 mm × 320 mm unless the material contains an aggregate that, when sampled in accordance with BS 812-1, will not pass through a test sieve of 5 mm aperture size complying with BS 410. For such materials the width and depth of the prisms shall be at least 5.0 times the nominal size of the smallest aperture of a sieve complying with BS 410 through which 90 % of the aggregate will pass. The length to width ratio of the prisms shall be 13 : 1.

5.2 Preparation of specimens

Prepare the specimens, including the conditioning, proportioning and mixing of materials, and the conditioning and filling of moulds in accordance with BS 6319-1.

6 Procedure for measuring modulus of elasticity in flexure

6.1 Number of specimens

Test a minimum of three specimens at a time from each batch of material for each prescribed set of test conditions.

6.2 Testing

6.2.1 ***Temperature***

Carry out the test at 20 ± 1 °C unless, for a specific purpose, an alternative temperature is deemed more appropriate. Maintain the test specimens at the test temperature for not less than 16 h before testing commences.

6.2.2 ***Placing the specimen in the testing machine***

Wipe clean the bearing surfaces of the rollers and the sides of the specimen to remove any loose grit or other material. Locate the specimen symmetrically in the equipment for the determination of flexural modulus with the upper face, as cast, parallel to the movement of the testing machine crosshead and with the two moulded faces perpendicular to the upper face, in contact with the metal rollers.

6.2.3 ***Loading***

Apply the load without shock and at a uniform rate while continuously monitoring the deflection of the tensile face at mid-span. The rate of deflection shall be 1 mm/min. The maximum load, N_1, to be applied should be one-third of that necessary to cause failure in the flexural strength test described in clause **8**. In the absence of such information, the maximum load, N_1, to be applied should be that necessary to cause a strain on the extreme tensile fibre of 0.0022 for polymer mortars or 0.00022 for polymer/cement mortars.

Record the applied load, N_1. Smoothly remove and re-apply the load at least twice to ensure that the specimen and rollers are well seated and that the transducer is indicating consistently.

If the individual deflections are not within a range of ± 10 % of their mean value at N_1, centre the test specimen again and repeat the procedure. If it is not possible to reduce the differences to within this range, do not proceed with the test on that specimen. Select another specimen from the same batch and continue until three acceptable specimens have been found.

Zero the transducers (or the recorder) while the specimen is under a load, N_2, approximately 10 % of that previously applied. Measure the eight changes in deflection as the load is increased and decreased four times between loads N_2 and N_1.

7 Calculation of modulus of elasticity in flexure

Calculate the secant modulus, E, (in GN/m^2) of each specimen using the following equation:

$$E = \frac{23\,PL^3}{108\,BD^3\delta} \quad (6)$$

where

P is the difference between the two levels of applied load ($N_2 - N_1$) (in kN);

L is the span of the specimen (in mm);

B is the breadth of the specimen (in mm);

D is the depth of the specimen (in mm);

δ is the mean of the eight deflection changes (in mm).

Calculate the mean secant modulus for a minimum of three specimens originating from the same batch and express the value to the nearest 0.1 GN/m^2.

8 Procedure for measuring flexural strength

8.1 Number of specimens

Test a minimum of four specimens at a time from each batch of material for each prescribed set of test conditions.

8.2 Testing

8.2.1 ***Temperature***

Control the temperature in accordance with **6.2.1**.

8.2.2 ***Placing the specimen in the testing machine***

Place the specimen in accordance with **6.2.2**.

8.2.3 ***Loading***

Apply the load without shock and at a uniform rate such that the specimen fractures in 60 ± 30 s. Measure the deflection of the specimen at mid-span during loading.

NOTE 1 A rate of platen movement 1 mm/min to 5 mm/min will usually be appropriate.

Record the maximum load applied. Measure the breadth and depth of the specimen at the point of fracture to the nearest 0.1 mm. If the line of fracture occurs between a supporting and loading roller, do not use the result for calculating the flexural strength but declare the result in the test report. Conduct repeat tests at the same rate of loading.

NOTE 2 If the deflection before fracture exceeds one-fifteenth of the span of the specimen, the test should be discontinued on the grounds of insufficient rigidity of the material for a meaningful value of flexural strength to be measured.

9 Calculation of flexural strength

Calculate the flexural strength, σ_u, (in N/mm^2) of each specimen using the following equation:

$$\sigma_u = \frac{WL}{BD^2} \quad (7)$$

where

W is the maximum load recorded prior to fracture (in N);

L is the span of the specimen (in mm);

B is the breadth of the specimen at its point of fracture (in mm);

D is the depth of the specimen at its point of fracture (in mm).

Calculate the mean flexural strength obtained for a minimum of four specimens originating from the same batch and express the value to the nearest 0.2 N/mm^2.

NOTE If 12 or more specimens are tested, a standard deviation may be calculated and recorded.

10 Test report

10.1 The following information shall be included in the report on a test for modulus of elasticity in flexure and on a test for flexural strength:

a) date and site of specimen preparation;

b) date of test;

c) ambient conditions during the preparation, curing and testing of the specimens and their age when tested;

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

e) type of test machine used.

10.2 The following information shall be included in the report on a test for modulus of elasticity:

a) cross-sectional area at the centre of the test specimen;

b) upper (N_1) and lower (N_2) load levels used in the testing cycle;

c) mean deflection;

d) secant modulus of elasticity of each test specimen;

e) arithmetic mean secant modulus of elasticity;

f) type of transducer used.

10.3 The following information shall be included in the report on a test for flexural strength:

a) nominal sizes of each specimen prior to testing and the dimensions at the site of any fracture as a result of testing;

b) flexural strength of each specimen;

c) arithmetic mean flexural strength;

d) breaking loads, including those results excluded from the calculations because of the location of the fracture;

e) details of specimens excluded from the results due to excessive deflection (see note 2 to **8.2.3**).

Publication(s) referred to

BS 410, *Specification for test sieves.*
BS 812, *Testing aggregates.*
BS 812-1, *Methods for determination of particle size and shape.*
BS 1610, *Materials testing machines and force verification equipment.*
BS 1610-1, *Specification for the grading of the forces applied by materials testing machines.*
BS 2782, *Methods of testing plastics.*
BS 2782-3, *Mechanical properties.*
BS 2782:Method 335A, *Determination of flexural properties of rigid plastics.*
BS 6319, *Testing of resin compositions for use in construction.*
BS 6319-1, *Method for preparation of test specimens.*

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