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AMERICAN SOCIETY FOR TESTING AND MATERIALS
100 Barr Harbor Dr., West Conshohocken, PA 19428

Standard Test Methods for Breaking Load and Flexural Properties of Block-Type Thermal Insulation[1]

This standard is issued under the fixed designation C 203; 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.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 These test methods cover the determination of the breaking load and calculated flexural strength of a rectangular cross section of a preformed block-type thermal insulation tested as a simple beam. It is also applicable to cellular plastics. Two test methods are described as follows:

1.1.1 *Method I*—A loading system utilizing center loading on a simply supported beam, supported at both ends.

1.1.2 *Method II*—A loading system utilizing two symmetric load points equally spaced from their adjacent support points at each end with a distance between load points of one half of the support span.

1.2 Either method can be used with the four procedures that follow:

1.2.1 *Procedure A*— Designed principally for materials that break at comparatively small deflections.

1.2.2 *Procedure B*— Designed particularly for those materials that undergo large deflections during testing.

1.2.3 *Procedure C*— Designed for measuring at a constant stress rate, using a CRL (constant rate of loading) machine. Used for breaking load measurements only.

1.2.4 *Procedure D*— Designed for measurements at a constant crosshead speed, using either a CRT (constant rate of traverse) or CRE (constant rate of extension) machine. Used for breaking load measurements using a fixed crosshead speed machine.

1.3 Comparative tests may be run according to either method or procedure, provided that the method or procedure is found satisfactory for the material being tested.

1.4 These test methods are purposely general in order to accommodate the widely varying industry practices. It is important that the user consult the appropriate materials specification for any specific detailed requirements regarding these test methods.

1.5 The values stated in SI units are to be regarded as the standard. The values given in parentheses are provided for information only.

1.6 *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.* For specific precautionary statements, see Section 11.

2. Referenced Documents

2.1 *ASTM Standards:*

C 133 Test Methods for Cold Crushing Strength and Modulus of Rupture of Refractories[2]

C 168 Terminology Relating to Thermal Insulating Materials[3]

C 390 Criteria for Sampling and Acceptance of Preformed Thermal Insulation Lots[3]

C 870 Practice for Conditioning of Thermal Insulating Materials[3]

D 76 Specification for Tensile Testing Machines for Textiles[4]

E 4 Practice for Force Verification of Testing Machines[5]

3. Terminology

3.1 Terminology C 168 shall be considered as applying to the terms used in this method.

4. Summary of Test Methods

4.1 A bar of rectangular cross section is tested in flexure as a beam as follows:

4.1.1 *Method I*—The bar rests on two supports and is loaded by means of a loading fitting or piece midway between the supports (see Fig. 1).

4.1.2 *Method II*—The bar rests on two supports and is loaded at the two quarter points (by means of two loading fittings), each an equal distance from the adjacent support point. The distance between the loading fittings is one half of the support span (see Fig. 2).

4.2 The specimen is deflected until rupture occurs, unless the materials specification indicates termination at a particular maximum strain level.

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[2] *Annual Book of ASTM Standards*, Vol 15.01.

[3] *Annual Book of ASTM Standards*, Vol 04.06.

[4] *Annual Book of ASTM Standards*, Vol 07.01.

[5] *Annual Book of ASTM Standards*, Vol 03.01.

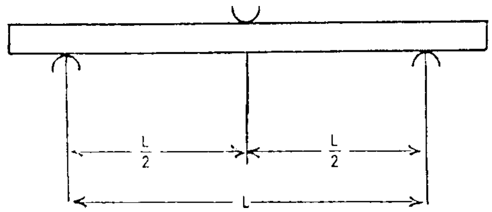

FIG. 1 Loading System for Method I

NOTE 1—One criteria used is to limit the strain to 5 %. If failure does not occur at 5 % strain, the strain rate is increased and the test repeated on a new specimen.

4.3 Procedures A and B allow for testing at two different strain rates. Procedure C specifies a stress rate. Procedure D specifies a rate of extension or traverse.

4.3.1 Procedure A specifies a strain rate of 0.01 in./in. (mm/mm) that is useful for testing insulations that are very stiff or break at quite low deflections.

4.3.2 Procedure B specifies a strain rate of 0.1 in./in. (mm/mm) which is useful for testing insulations that are relatively flexible or break at higher deflections.

4.3.3 Procedure C specifies a stress rate of 550 psi (3.79 MPa)/min except as recommended in the materials specification.

4.3.4 Procedure D specifies a CRE machine with a fixed crosshead speed, or a CRT machine with a movable load clamp, such as the Scott tester. Because the strain rate is a function of specimen geometry, this procedure does not give a constant strain rate for specimens of different thicknesses tested on the same loading fixture.

5. Significance and Use

5.1 These test methods may be used to determine the resistance of some types of preformed block insulation when transverse loads are normally applied to the surface. Values are measured at the maximum load or breaking point under specified conditions or specimen size, span between supports, and rate of load application. The equations used are based on the assumption that the materials are uniform and presume that the stress-strain characteristics below the elastic limit are linearly elastic. These assumptions are not strictly applicable to thermal insulations of certain types in which crushing occurs before failure is obtained in transverse bending; however, depending upon the accuracy required, these procedures may provide acceptable results.

5.2 Method I is especially useful when testing only for the modulus of rupture or the breaking load. This information is useful for quality control inspection and qualification for specification purposes.

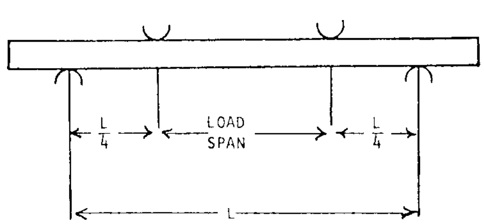

FIG. 2 Loading System for Method II

5.3 Method II is useful in determining the elastic modulus in bending as well as the flexural strength. Flexural properties determined by these test methods are also useful for quality control and specification purposes.

5.4 The basic differences between the two test methods is in the location of the maximum bending moment, maximum axial fiber (flexural or tensile) stresses, and the resolved stress state in terms of shear stress and tensile/compression stress. The maximum axial fiber stresses occur on a line under the loading fitting in Method I and over the area between the loading fittings in Method II. Method I has a high shear stress component in the direction of loading, perpendicular to the axial fiber stress. The resolved shear stress may be sufficient to produce failure by a shear mode rather than a simple tension/flexural failure. There is no comparable shear component in the central region between the loading fittings in Method II. Method II simulates a uniformly loaded beam in terms of equivalent stresses at the center of the specimen.

5.5 Flexural properties may vary with specimen span-to-thickness ratio, temperature, atmospheric conditions, and the difference in rate of straining specified in Procedures A and B. In comparing results it is important that all parameters be equivalent. Increases in the strain rate typically result in increased strengths and in the elastic modulus.

6. Apparatus

6.1 *Testing Machine*— A properly calibrated testing machine that can be operated at either constant load rates or constant rates of crosshead motion over the range indicated, and in which the error in the load-measuring system shall not exceed ±1 % of maximum load expected to be measured. The load-indicating mechanism shall be essentially free of inertial lag. The accuracy and calibration of the testing machine shall be verified in accordance with Practice E 4. If stiffness or deflection measurements are to be made, then the machine shall be equipped with a deflection-type measuring device. The stiffness of the testing machine shall be such that the total elastic deformation of the system does not exceed 1 % of the total deflection of the test specimen during test, or appropriate corrections shall be made.

6.2 *Bearing Edges*— The loading fittings and supports shall have cylindrical surfaces. In order to avoid excessive indentation, or failure due to stress concentration directly under the loading fitting or fittings, the diameter of these bearing edges shall be 1¼ ± ¼ in. (32 ± 6 mm). The bearing cylinders shall be straight and parallel to each other, and they shall be self-aligning to maintain full contact with the specimen throughout the test. They shall have a length at least equal to the width of the specimen.

6.3 Bearing cylindrical supports are described in Test Methods C 133.

6.4 See Fig. 1 for Method I; Fig. 2 for Method II.

6.4.1 CRL machines are described in Specification D 76.

6.4.2 CRE and CRT machines are described in Specification D 76.

7. Safety Precautions

7.1 Safety precautions consistent with the normal usage of any universal testing machine should be observed. Safety glasses should be worn when testing all brittle samples.

7.2 Smoking and open flames should be avoided when working with flammable or combustible specimens.

7.3 Respirators should be worn during preparation of specimens that are friable or composed of compacted powder when dust levels are above permissible limits. Laboratory clothes and gloves should be used when working with such materials or material that may be abrasive or a skin irritant.

8. Test Specimens

8.1 The number of specimens to be tested should be given in the materials specification. In the absence of such specification, test at least four samples.

8.2 The specific materials specification should be consulted for recommendation regarding the test specimen geometry and specific directions concerning selection or cutting of specimens. In the absence of such guidance, the preferred test specimen shall be 1 in. thick by 4 in. wide by 12 in. long (25 by 100 by 300 mm) tested on a 10 in. (250 mm) support span. The test specimens should be 4 in. (100 mm), but in no case less than 3 in. (75 mm) in width, and 1 in. (25 mm) thick. The test specimens shall be long enough to accommodate a support span of 10 in. (25 mm) in length. The width and thickness of test specimens shall be recorded to the nearest 0.01 in. (0.3 mm).

NOTE 2—When comparing test results, such data must be obtained using a common specimen size and the same procedure.

8.3 The following are recommended and minimum requirements for the test specimen geometry and test setup:

Recommended $L/d = 10$ Require $20 \geq L/d \geq 2$
(Recommend that the support span be ten times the thickness.)
Recommended $L/b = 2.5$ Require $L/b \geq 0.8$
(Recommend that support span be two and a half times the width.)
Recommended $b/d = 4$ Require $b/d \geq 1$
(Recommend that the width be four times the thickness.)

where:
L = support span, in. (or mm),
d = thickness of specimen, in. (or mm), and
b = width of specimen, in. (or mm).

NOTE 3—Examination of the minimum test requirements shows they are not compatible. They represent a compromise of industrial practices with the emphasis toward the recommended parameters. This incompatibility precludes a simple table of recommended and minimum dimensions.

8.4 The selection of the samples shall conform to Criteria C390. The specimens shall be cut from larger blocks or irregular shapes in such a manner to preserve as many of the original surfaces as possible. Only one sample shall be cut from a single block or board. Multiple specimens may be cut from a sample such as a large bun of insulation material. If the test specimen is cut to obtain a narrower width than as received, the cut shall be made lengthwise of the block. For anisotropic materials, flexural tests may be run in other than the length direction, such as the cross direction of the sample. When comparative tests are to be made on preformed materials, all specimens shall be of the same thickness, except as recommended in the materials specification. The bearing faces of the test specimens shall be approximately parallel planes. In preparing specimens from pieces of irregular shape, any means such as a band saw, or any method involving the use of abrasives such as high-speed abrasion wheel or rubbing bed, that will produce a specimen with approximately plane and parallel faces (parallel within 1°) without weakening the structure of the specimen may be used. The value obtained on specimens with machined surfaces may differ from those obtained on specimens with original surfaces. Consequently, the report must state if original surfaces were retained and when only one original surface was retained, whether it was on the tension or compression side of the beam.

9. Conditioning

9.1 Dry and condition specimens prior to test, following applicable specifications for the material. In the absence of definitive drying specifications, follow recommended practices for conditioning in Practice C 870. Where circumstances or requirements preclude compliance with these conditioning procedures, exceptions agreed upon between the manufacturer and the purchaser may be made, but they shall be specifically listed in the test report.

10. Procedure

10.1 *Method I, Procedure A*:

10.1.1 Use an untested specimen for each measurement. Measure the width and depth of the specimen to the nearest 0.01 in. (0.3 mm) at the center of the support span. It is desirable to measure each dimension at three points along the center line of the span and to use the average value of these measurements in order to get a better value in case the sides are not truly parallel.

10.1.2 Determine the support span to be used and set up the support span to within 1 % of the determined value. Measure this support span to the nearest 0.1 in. (3.0 mm) at three points and record this measurement.

10.1.3 Calculate the rate of crosshead motion as follows and set the machine for the calculated rate, or as near as possible to it:

$$R = ZL^2/6d \tag{1}$$

where:
R = rate of crosshead motion, in./min. (or mm/min.),
L = support span, in. (or mm),
d = depth of beam, in. (or mm), and
Z = rate of straining of the outer fiber, in./in.·min (or mm/mm·min). Z shall equal 0.01.

In no case shall the actual crosshead rate differ from that calculated from Eq 1, by more than ± 50%.

10.1.4 Align the loading fitting and supports so that the axes of the cylindrical surfaces are parallel and the loading fitting is midway between the supports. The parallelism may be checked by means of a plate with parallel grooves into which the loading fitting and supports will fit when properly aligned. Center the specimen on the supports, with the long axis of the specimen perpendicular to the loading fitting and supports.

10.1.5 Apply the load to the specimen at the specified crosshead rate, and take simultaneous load-deflection data. Measure deflection either by a gage under the specimen in contact with it at the center of the support span, the gage being mounted stationary relative to the specimen supports, or by measurement of the motion of the loading fitting relative to the supports. In either case, make appropriate corrections for indentation in the specimens and deflections in the weighing system of the machine. Crushing or indentation, or both, of the specimen at the support fixtures results in a downward translation in position of the specimen that would appear as a bending of the specimen if appropriate correction is not taken if and when necessary. Similar indentation may occur at the loading fixture(s); thus crosshead movement of the machine will not provide a true measure of the deflection due to bending alone in the specimen. A gage measuring the resultant specimen thickness at the supports can be used as an indication of the amount of indentation. The importance of this correction depends upon the desired accuracy of the results. It may not be necessary in screening or comparative testing or where only the failure load is the parameter of interest. Load-deflection curves may be plotted to determine the flexural yield strength, secant or tangent modulus of elasticity, and the total work measured by the area under the load-deflection curve.

10.1.6 Generally, the test should be terminated if the maximum strain in the outer fibers has reached 0.05 in./in. (mm/mm). See Note 1. Beyond 5 % strain, these test methods and equations are not applicable, and some other property might be measured. An exception might be in the case where the failure load is the only parameter of interest. The deflection at which this strain occurs may be calculated by letting ϵ equal 0.05 in./in. (mm/mm) as follows:

$$D = \epsilon L^2/6d \tag{2}$$

where:

D = deflection at center of sample, in. (or mm),
ϵ = strain, in./in. (or mm/mm),
L = support span, in. (or mm), and
d = depth of beam, in. (or mm).

10.2 *Method II, Procedure A*:

10.2.1 See 10.1.1.

10.2.2 See 10.1.2.

10.2.3 Calculate the rate of crosshead motion as follows, and set the machine as near as possible to that calculated rate:

$$R = ZL^2/6d \tag{3}$$

where:

R = rate of crosshead motion, in./min. (or mm/min),
L = support span, in. (or mm),
d = depth of beam, in. (or mm), and
Z = rate of straining of the outer fibers, in./in.·min (mm/mm·min). Z shall equal 0.01.

In no case shall the actual crosshead rate differ from that calculated from Eq 3 by more than ± 50 %.

10.2.4 Align the loading fitting and supports so that the axes of the cylindrical surfaces are parallel and the distance between the loading fitting (that is, load span) is one half of the support span. This parallelism may be checked by means of a plate containing parallel grooves into which the loading fittings and supports will fit when properly aligned. Center the specimen on the supports, with the long axis of the specimen perpendicular to the loading fittings and supports. The loading fitting assembly shall be of the type that will not rotate.

10.2.5 Apply the load to the specimen at the specified crosshead rate, and take simultaneous load-deflection data. The deflection may be measured by a gage under the specimen in contact with it at the common center of the span, the gage being mounted stationary relative to the specimen supports. Make appropriate corrections for indentation in the specimens and deflections in the weighing system of the machine. The importance of this indentation has been discussed previously in 10.1.5. Load-deflection curves may be plotted to determine the flexural yield strength, secant or tangent modulus of elasticity, and the total work measured by the area under the load-deflection curve.

10.2.6 If no break has occurred in a specimen by the time the maximum strain in the outer fibers has reached 0.05 in./in. (mm/mm), discontinue the test for the reasons discussed in 10.1.6. The deflection at which this strain occurs may be calculated by letting ϵ equal 0.05 in./in. (mm/mm) as follows:

$$F = \epsilon L^2/6d \tag{4}$$

or

$$D = \epsilon L^2/4.363d \tag{5}$$

where:

D = deflection, in. (or mm),
F = deflection, in. (or mm) at load fixture at position $L/4$ or $3L/4$ in Method II,
ϵ = strain, in./in. (or mm/mm),
L = support span, in. (or mm), and
d = depth of beam, in. (or mm).

10.3 *Methods I and II, Procedure B*:

10.3.1 Use an untested specimen for each measurement.

10.3.2 Test conditions shall be identical to those described in 10.1 or 10.2 except that the rate of straining of the outer fibers shall be 0.10 in./in.·min (mm/mm·min).

10.4 *Methods I and II, Procedure C*:

10.4.1 Use an untested specimen for each measurement.

10.4.2 Test conditions shall be identical to those described in 10.1 or 10.2 except that the basis of testing shall be based on a stress rate rather than a strain rate. The stress rate shall be 550 psi (3.79 MPa)/min, except as specified in the appropriate materials specification.

10.5 *Methods I and II, Procedure D*:

10.5.1 Use an untested specimen for each measurement.

10.5.2 Test conditions shall be identical to those described in 10.1 or 10.2 except that the basis of testing shall be based on a constant crosshead speed of 10 to 12 in. (250 to 305 mm)/min except as recommended in the materials specification.

11. Calculations

11.1 *Maximum Fiber Stress, Method I*—When a beam of homogeneous, elastic material is tested in flexure as a simple beam supported at two points and loaded at the midpoint, the maximum stress in the outer fibers occurs at mid-span. This stress may be calculated for any point on the load-deflection curve by the following equation:

$$S = 3PL/2bd^2 \tag{6}$$

The stress at any position, such as a non-central break between the supporting bearing edges, is as follows:

$$S = 3PX/bd^2 \tag{7}$$

where:
S = stress in the outer fibers, psi (or MPa),
P = load at a given point on the load-deflection curve, lbf (or N),
L = support span, in. (or mm),
b = width of beam tested, in. (or mm),
d = depth of beam tested, in. (or mm), and
X = minimum distance from non-central break to support bearing edge, in. (or mm).

Eq 6 applies strictly to materials for which the stress is linearly proportional to strain up to the point of rupture, and for which the strains are small. Use of the equations for simple beams cited in these methods assumes small deflection, linear beam theory which is applicable where $L/d \leq 16$, $D/d \leq 1.0$, $D/L \leq 0.2$.

11.2 *Maximum Fiber Stress, Method II*—When a beam is loaded in flexure at two central points and supported at two outer points, the maximum stress in the outer fibers occurs between the two central loading points that define the load span (Fig. 2). This stress may be calculated for any point on the load-deflection curve for relatively small deflections by the following equation:

$$S = 3PL/4bd^2 \tag{8}$$

where:
S = stress in the outer fiber throughout central load span between the two load fittings ($L/4 \leq X \leq 3L/4$), psi (or MPa),
P = load at a given point on the load deflection curve, lbf (or N), and
L = support span, in. (or mm).

11.3 *Flexural Strength (Modulus of Rupture)*—The flexural strength is equal to the maximum stress in the outer fibers at the moment of break. It is calculated in accordance with Eq 6, Eq 7, or Eq 8, by letting P equal the load at the moment of break. If the material does not break, this part of the test is not applicable. In this case, it is suggested that yield strength, if applicable, be calculated and that the corresponding strain be reported also (see 11.4, 11.5, and 11.6).

11.4 *Flexural Yield Strength*—Some materials that do not break at outer fiber strains up to 5 % may give load-deflection curves that show a point, Y, at which the load does not increase with an increase in deflection. In such cases, the flexural yield strength may be calculated in accordance with Eq 6, Eq 7, or Eq 8, by letting P equal the load at point Y.

11.5 *Stress at a Given Strain*—The maximum fiber stress at any given strain may be calculated in accordance with Eq 6, Eq 7, or Eq 8, by letting P equal the load read from the load-deflection curve at the deflection corresponding to the desired strain.

11.6 *Maximum Strain, Method I*—The maximum strain in the outer fibers also occurs at midspan, and may be calculated as follows:

$$\epsilon = 6Dd/L^2 \tag{9}$$

where:
ϵ = maximum strain in the outer fibers, in./in. (or mm/mm),
D = maximum deflection of the center of the beam, in. (or mm),
L = support span, in. (or mm), and
d = depth, in. (or mm).

11.7 *Maximum Strain, Method II*—The maximum strain in the outer fibers also occurs at midspan and may be calculated as follows:

$$\epsilon = 6Fd/L^2 \tag{10}$$

where D, d, L, and ϵ are the same as in Eq 4. Only for linear elastic materials is the strain uniform in the central region between the load fittings. In this case the strain can be calculated as follows:

$$\epsilon = 6Fd/L^2 \tag{11}$$

where F = deflection at load fixture at position $L/4$ or $3L/4$, in. (or mm).

NOTE 4—If the midspan deflection exceeds the depth of the test beam, the assumption of a small deflection, linear beam theory is of questionable validity. Corrections or a cautionary note, or both, must be included in the report for the large deflection case where either $D/d > 1$ or $D/L > 0.2$.

11.8 *Elastic Modulus*:

11.8.1 *Moment of Inertia*—The moment of inertia is calculated as follows:

$$I = bd^3/12 \tag{12}$$

where:
I = moment of inertia, in.^{4} (mm^4),
b = specimen width, in. (mm), and
d = specimen thickness, in. (mm)

11.8.2 *Elastic Modulus, Method I*—The elastic modulus in bending may be calculated by the following equation:

$$E = PL^3/48\,I\,D \tag{13}$$

where:
E = elastic modulus, psi (MPa),
D = corrected deflection at center of sample, in. (mm),
I = moment of inertia, in.^{4} (mm^4),
L = support span, in. (mm), and
P = load at a given deformation within the proportional limit of the specimen, lbf (N).

11.8.3 *Elastic Modulus, Method II*—The elastic modulus in bending may be calculated by the following equations:

$$E = 5PL^3/384\,I\,D \quad \text{or} \quad E = PL^3/96\,I\,\delta \tag{14}$$

where:
D = corrected deflection at center of sample, in. (mm), and
δ = corrected deflection at load fixture, in. (mm) and the rest of the parameters are as previously defined.

As discussed in 10.1.5, the apparent deflection of the specimen should be corrected to minimize errors due to any indentation of the specimen at the support fixture and at the loading fixture(s).

NOTE 5—Modulus of Elasticity (Young's Modulus) is defined as the rate of change of unit stress with respect to unit strain within the proportional limit of a material. The load, *P*, must be selected within the proportional limit.

11.9 *Arithmetic Mean*— For each series of tests, calculate the arithmetic mean of all values obtained to three significant figures and report as the "average value" for the particular property in question.

11.10 *Standard Deviation (Normal, Gaussian)*—Calculate the standard deviation (estimated) as follows and report to two significant figures:

$$s = \sqrt{\frac{\Sigma X^2 - n\bar{X}^2}{n-1}} \quad (15)$$

or

$$s = \sqrt{\frac{\Sigma (X - \bar{X})^2}{n-1}} \quad (16)$$

where:
s = estimated standard deviation,
X = value of single observation,
n = number of observations, and
$\bar{X}$ = arithmetic mean of the set of observations.

NOTE 6—The breaking loads may not follow a Gaussian distribution but possibly one such as the Weibull distribution.

12. Report

12.1 Report the following information:

12.1.1 Complete identification of the material tested, including type, source, manufacturer's code number, form, principal dimensions, and previous history,

12.1.2 Direction of cutting and loading specimens,

12.1.3 Conditioning procedure,

12.1.4 Depth and width of specimen,

12.1.5 Method used,

12.1.6 Procedure used,

12.1.7 Support span length,

12.1.8 Support span-to-depth ratio (L/d ratio); support span-to-width ratio (L/b ratio); width-to-depth ratio (b/d ratio),

12.1.9 Radius of supports and loading fittings,

12.1.10 Rate of crosshead speed,

12.1.11 Maximum strain in the outer fibers of the specimens,

12.1.12 Breaking load, average value, and standard deviation,

12.1.13 Flexural strength (if applicable), average value, and standard deviation. Average deflection to depth ratio and deflection to support span ratio at given flexural strength,

12.1.14 Flexural yield strength (if desired), average value, and standard deviation, and

12.1.15 Stress at any given strain up to and including 5 % (if desired), with strain used, average value, and standard deviation.

13. Precision and Bias

13.1 The precision and bias of the procedure of these test methods for measuring breaking loads and flexural strength of block-type thermal insulation is under investigation by a task group of C 16.32. No information can be presented on bias and precision of the procedure at this time because the interlaboratory round robin has not been completed.

13.2 Due to the nature of the equations involved, the accuracy of the resultant flexural stress depends on the accuracy of the measured variables such as load, span, specimen width, and thickness. For example, a variance or uncertainty of 2 % in each of these measured variables will lead to a variance of 4.5 % in the apparent flexural strength. If increased accuracy is desired or necessary, then the accuracy of the dimensional measurements of the specimen given in 10.1.1 should be increased.

14. Keywords

14.1 breaking load; breaking strength; flexural strength; modulus of elasticity; modulus of rupture