Designation: D3752 – 98 (Reapproved 2011)

Standard Test Method for Strength Imparted by Asbestos to a Cementitious Matrix[1]

This standard is issued under the fixed designation D3752; 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 measurement, on a laboratory scale, of the contribution of asbestos fibers to the strength of asbestos-cement products. The results obtained are used in the primary assessment of different fiber grades prior to their application on a larger scale.

1.2 This test method covers the determination of the modulus of rupture (*MR*), adjusted to a dry density of 1.60 Mg/m^3 (MR_A), of asbestos-cement test specimens that contain the asbestos fiber to be evaluated at a concentration of 10 mass %, whereby the degree of fiberization of that fiber is specified in terms of specific surface area as determined by Test Method D2752. The relative reinforcing value of the fiber under test is established by comparison with MR_A values obtained with a fiber of known characteristics at a fiber concentration of 10 % and a dry density of 1.60 Mg/m^3 (1.60 g/cm^3).

NOTE 1—The adjusted modulus of rupture (MR_A) at any intermediate fiber concentration may be interpolated from results suitably determined over a limited spanning range of fiber concentrations. For example, the MR_A at 10 % fiber concentration may be graphically determined from data at 3 and 17 %.

1.3 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.4 **Warning—**Breathing of asbestos dust is hazardous. Asbestos and asbestos products present demonstrated health risks for users and for those with whom they come into contact. In addition to other precautions, when working with asbestos-cement products, minimize the dust that results. For information on the safe use of chrysotile asbestos, refer to "Safe Use of Chrysotile: A Manual on Preventive and Control Measures."[2]

1.5 *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:*[3]

C150 Specification for Portland Cement

C184 Test Method for Fineness of Hydraulic Cement by the 150-µm (No. 100) and 75-µm (No. 200) Sieves (Withdrawn 2002)[4]

C204 Test Methods for Fineness of Hydraulic Cement by Air-Permeability Apparatus

D1193 Specification for Reagent Water

D2589 Test Method for McNett Wet Classification of Dual Asbestos Fiber

D2590 Test Method for Sampling Chrysotile Asbestos

D2752 Test Methods for Air Permeability of Asbestos Fibers

D2946 Terminology for Asbestos and Asbestos–Cement Products

D3879 Test Method for Sampling Amphibole Asbestos (Withdrawn 2009)[4]

E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

2.2 *Other Standard:*[5]

Quebec Asbestos Mining Association (QAMA) Standard Designation for Chrysotile Asbestos Grades

3. Terminology

3.1 *Definitions*—For definitions of asbestos terms used in this test method, refer to Terminology D2946.

4. Summary of Test Method

4.1 This test method covers the preparation and flexural testing of asbestos-cement specimens consisting of disks, 107 mm in diameter, which are obtained by vacuum filtration of an aqueous slurry of asbestos fiber, cement, and silica of standard

[1] This test method is under the jurisdiction of ASTM Committee C17 on Fiber-Reinforced Cement Products and is the direct responsibility of Subcommittee C17.03 on Asbestos - Cement Sheet Products and Accessories.

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[2] Available from The Asbestos Institute, http://www.chrysotile.com/en/sr_use/manual.htm.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[4] The last approved version of this historical standard is referenced on www.astm.org.

[5] Available from the Asbestos Institute, 1002 Sherbrooke St. W, Suite 1750, Montreal, QC, Canada H3A 3L6.

composition. The disks are compressed to a designated nominal pressure (Note 2), and cured under standard conditions prior to testing in flexure. The calculation of the modulus of rupture (*MR*) and its adjustment to a common dry density of 1.6 Mg/m^3 (MR_A), based on the flexural strength and the density of the specimens, is also described.

NOTE 2—The spacer ring may support part or all of this pressure unless the mix being pressed is bulky enough to prevent full closure of the mold.

4.2 The preparation of the test specimens and the determination of the flexural modulus of rupture includes the following steps:

4.2.1 Treatment of the asbestos fiber including sampling, blending, and fiberizing in a suitable apparatus,

4.2.2 Dry blending of asbestos fiber, cement, and silica and the wet mixing of these materials using water saturated with lime and gypsum.

4.2.3 Formation of disk-shaped filter cakes from the aqueous slurry in a cylindrical filter vessel and the pressing of those cakes,

4.2.4 Curing of the pressed cakes by storage under conditions of high humidity and autoclaving,

4.2.5 Determination of the volume and density of the specimens based on dry mass, saturated mass, and immersed mass,

4.2.6 Testing of the flexural strength of the cured specimens after drying, and

4.2.7 Calculation of the flexural modulus of rutpure (*MR*) of the specimens and the modulus of rupture adjusted to a dry density of 1.6 Mg/m^3 (MR_A).

5. Significance and Use

5.1 This procedure facilitates the comparison of different types or grades of asbestos based on their contribution to the flexural modulus of rupture; that is, the reinforcing value, which is considered the most pertinent property for the manufacture of asbestos-cement products.

5.2 This test method is primarily intended for fiber grades used normally in asbestos-cement products (Group 6 to Group 4 fibers). Longer fibers (Group 3) or shorter fibers (Group 7) may present difficulties during the preparation of the filter cake because of poor dispersion and uneven settling.[6]

6. Apparatus

6.1 *Fiberizing*—Optimum fiberization in terms of reinforcing strength (based on measurement of specific surface area (as determined by Test Method D2752) varies with the type of asbestos fiber; for example, approximately 900 m^2/kg for amosite, 1200 to 1500 m^2/kg for crocidolite and 1000 to 1800 m^2/kg for chrysotile. It should be noted that optimum fiberization based on filtration properties may require different surface areas. It should also be noted that optimum fiberization in terms of reinforcing strength varies with the fiberizing procedure. To produce the desired degree of fiberization, the following types of apparatus have been found suitable:

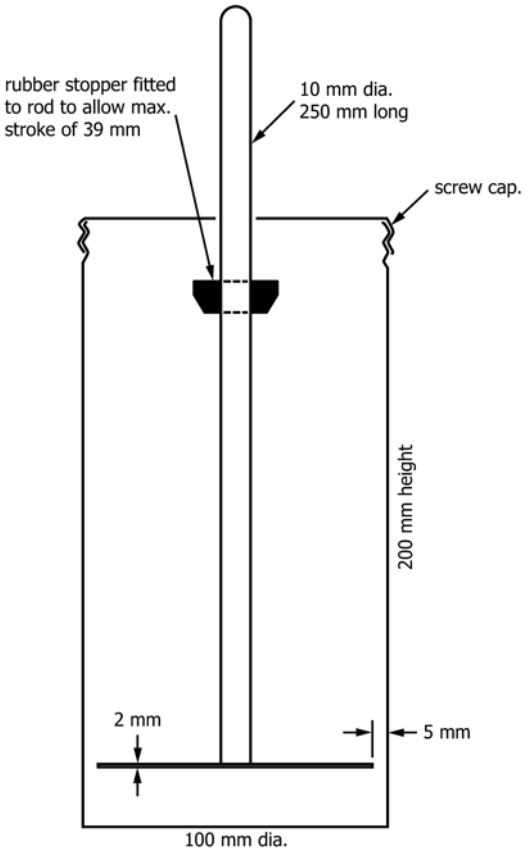


FIG. 1 Plastic Mixing Vessel and Mixing Rod

6.1.1 *Laboratory Fan Opener.*

6.1.2 *Pallman Mill.*

6.1.3 *Christie-Norris Mill.*

NOTE 3—The choice of the fiberizing method and the degree of fiberization is dependent upon the type of fiber under test, the application for which the fiber is intended, and the specific purpose of the test program. Increasingly higher surface areas obtained by fiberization produce increasingly higher modulus of rupture values up to an observed optimum. Beyond that point, due to the production of greater proportions of fines coinciding with increasingly higher surface areas, modulus of rupture values may diminish.

6.2 *Dry and Wet Mixing:*

6.2.1 *Wide-Mouth Plastic Containers,* 100 mm in diameter, 200 mm high, with screw lid.

6.2.2 *Metal Mixing Rod,* 10 mm in diameter, 250 mm long, with a disk fixed to its end, leaving 5-mm clearance to the inner wall of the plastic container (Fig. 1).

6.2.3 *Spare Screw Lids,* with 10-mm hole in center to receive stem of mixing rod.

NOTE 4—A Patterson-Kelly mixer with a one litre capacity shell has also been found to be suitable for dry and wet mixing, using mixing times of 5 min each.

6.3 *Forming of the of the Specimens:*

6.3.1 *Vacuum Filtering System* (Fig. 2):

6.3.1.1 *Vacuum Pump,* capable of displacing 180 L/min and capable of attaining 9.5 kPa (710 mm Hg).

[6] The term "Group 3, 4, 5, 6, or 7" refers to the Standard Designation for Chrysotile Asbestos Grades by the Quebec Asbestos Mining Association (QAMA).

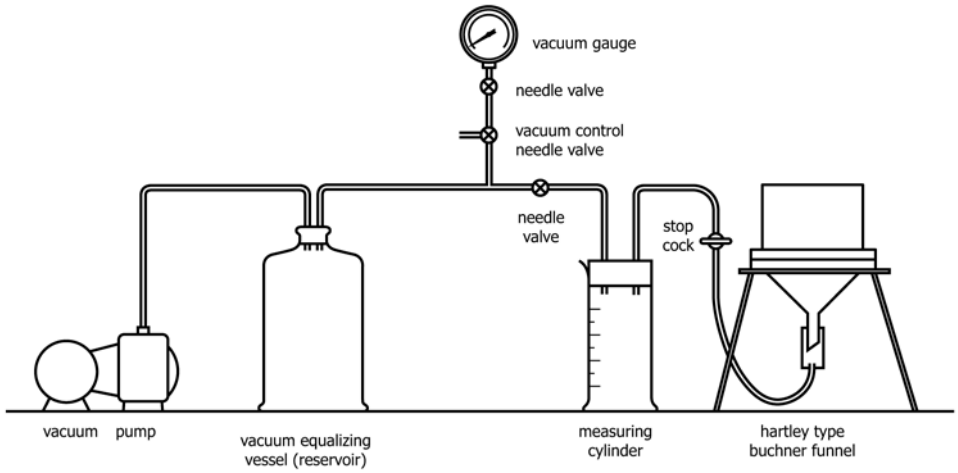


FIG. 2 Vacuum Filter system

6.3.1.2 *Vacuum Gage Assembly,* consisting of one 10 kPa (0 to 750-mm Hg) vacuum gage, needle valves, or a vacuum controller.[7]

6.3.1.3 *Filter Funnel, Hartly-type* , three-piece Büchner funnel, 107 mm in diameter.

6.3.1.4 *Filter Papers,* 100 mm in diameter, hardened and fast filtering, or filter cloth.

6.3.2 *Spatula,* stainless steel, narrow blade, approximately 150 mm long.

6.3.3 *Stopwatch.*

NOTE 5—Test specimens of 100 to 150 mm may be prepared and tested by this test method, in which case appropriate changes should be made in the quantities of materials used and the size of the equipment, such as mold and filter paper.

6.4 *Pressing of Specimens:*

6.4.1 *Hydraulic Press,* capable of exerting 200 kN load.

6.4.2 *Mold Assembly* (Fig. 3)—The thickness, *t*, is in the order of 6 mm.

6.4.3 *Plastic Squares,* 130 mm wide by 3 mm thick.

NOTE 6—Although a spacer ring as shown in Fig. 3 is used to control the thickness of the specimen (see Note 2) and to obtain a dry density of approximately 1.6 Mg/m^3, an adjustment by calculation (see 13.4) to a dry density of exactly 1.6 Mg/m^3, although small, is still required.

6.5 *Curing of Specimens:*

6.5.1 *Humidity Cabinet,* designed for >90 % relative humidity at 20°C.[8]

6.5.2 *Laboratory Autoclave,* capable of maintaining a saturated steam pressure of 834 to 1079 kPa for 16 h and with a capacity of approximately 100 L.[9] If an autoclave is not available, the disks can be water-cured (see 11.3).

6.5.3 *Drying Oven,* standard mechanical or gravity-convection oven, capable of maintaining 105± 2°C and with an internal capacity of approximately 0.2 m^3.

6.6 *Testing of Specimens:*

6.6.1 *Laboratory Balance,* capable of weighing 0.6 kg to 100 mg.[10]

6.6.2 *Flexural Tester,* capable of applying 600 g to 100 mg[11] accuracy for a transverse load up to 2.5 kN to the center of a span of 82.6-mm with a steady crosshead speed of 5 mm/min. The loading bar and supports should be 25-mm diameter steel rods.

6.6.3 *Micrometer,* approximately 50-mm throat, 0.02-mm graduations.

6.6.4 *Graduated Cylinder,* 500-cm^3 capacity.

7. Reagents and Materials

7.1 *Portland Cement,* Type 1 in accordance with Specification C150, or equivalent, with a Blaine surface area of 340 ± 20 m^2/kg as determined by Test Method C204, and pulverized silica passing the 180 µm (No. 80) sieve but retained on the 75 µm (No. 200) sieve as determined by Test Method C184, with a Blaine surface area of 300 ± 20 m^2/kg as determined by Test Method C204 shall be used when the test results are intended for comparisons between laboratories. Other portland cements and silica may be used for in-house laboratory comparisons.

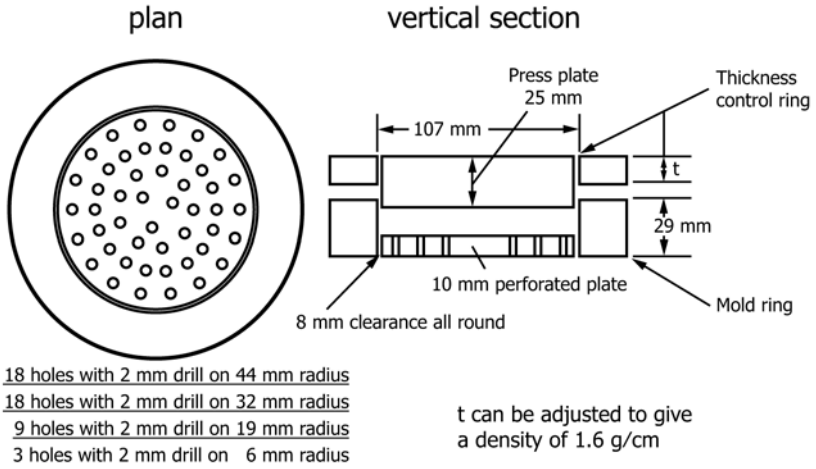
[7] An Edwards Model 1A has been found suitable. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

[8] A Harshaw No. H-18877 stainless steel desiccating cabinet has been found satisfactory for this purpose. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

[9] A Cenco laboratory autoclave Model 126X has been found suitable. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

[10] A Mettler top-loading balance Model P-1200N with a capacity of 1.0 kg and a 0.2-kg tare, has been found suitable. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

[11] A 250-g proving ring with a Carver press has been found suitable.



NOTE 1—*t* can be adjusted to give a density of 1.6 g/cm^3.

FIG. 3 Press Mold

Small amounts of these materials should be dried to constant weight at 100°C, mixed thoroughly, and stored separately in airtight containers. (Blaine surface area determinations are obtained by Test Method C204.)

7.2 *Water Saturated with Lime and Gypsum Water*—Add 2 g each of calcium sulfate dihydrate ($CaSO_4 \cdot 2H_2O$) and calcium hydroxide $Ca(OH)_2$ (reagent grade) to 1 dm^3 of Type IV reagent water as defined by Specification D1193 at 20°C. Stir the water mechanically or by shaking for 2 min, and after settling of the undissolved solids for 24 h, siphon the solution into another container for storage without exposure to air. (**Warning—**See 1.4.)

8. Sampling

8.1 *Chrysotile Fiber*—Sample each chrysotile fiber in accordance with Test Method D2590.

8.2 *Amphibole Fibers*—Sample amphibole fibers in accordance with Test Method D3879.

9. Fiber Treatment (Opening)

9.1 *Fiberizing*—If the surface area of the asbestos fiber to be tested is below those mentioned in 6.1, a fiberizing step may be required prior to testing. A variety of methods (see 6.1) have been found suitable for fiberizing or opening asbestos fiber. During the fiberizing process, the surface area of the asbestos fiber is increased and, depending upon the method and length of treatment used, the abestos fiber is generally shortened. Therefore, it is recommended that in addition to the treatment method and the surface area, the fiber length, as determined by Test Method D2589, be recorded prior to and after the fiberizing treatment.

10. Specimen Preparation

10.1 *Dry and Wet Mixing*—Weigh asbestos fiber, portland cement, and silica accurately to the nearest 0.1 g in the appropriate proportions to obtain a combined weight of 0.100 kg. (For a fiber concentration of 10 %, prepare 0.010 kg of fiber, 0.054 kg of cement, and 0.036 kg of silica.) Place fiber, cement, and silica into the plastic container, seal and shake for 1 min, holding the container horizontally and using horizontal motions. Add 400 cm^3 of water saturated with lime and gypsum, and mix for 1 min using the mixing rod with 30 rapid vertical strokes. (Care should be taken not to entrain air into the slurry.)

10.2 *Forming of Specimen*—Prior to the transfer of the slurry to the Büchner funnel, adjust the vacuum to 53 kPa (400 mm Hg) with the stopcock between the funnel and vacuum source in the closed position. Then pour the mixed slurry into the three-piece Büchner funnel containing a wetted filter paper disk and wash the remaining slurry from the beaker into the funnel using 50 cm^3 of water.

10.3 *Dewatering of Specimen*—When the slurry has been transferred, apply the vacuum. Assist the formation of a smooth surface of the cake by gently pressing the surface of the cake with the mixing rod without disturbing the filter cake. As soon as the water has been drawn off, as indicated by a change in vacuum, apply a vacuum of 8.0 kPa (600 mm Hg) for 2 min to assure that any liquid remaining in the bottom of the Büchner funnel is removed. After the vacuum is released, remove the disk by dismantling the Büchner funnel, but do not remove the filter paper or cloth. Mark each disk with a code number and stack between plastic plates. Prepare five disks in an identical fashion and press immediately.

10.4 *Pressing of Specimen*—Place each disk into the mold or cloth. Apply a load of 200 kN. Maintain this pressure for 2 min, after which the pressure should be released and the disk removed. Place the cake without filter paper or cloth between tared plastic squares. Determine the mass of the cake prior to curing, by weighing both the cake and the tared plastic squares.

11. Curing of Specimens

11.1 *Initial Curing*—When a series of five cakes has been prepared, stack these cakes and store in the humidity cabinet at >90 % relative humidity at 20°C for a period of 16 to 24 h.

11.2 *Autoclave Curing*—After the initial curing period, remove the cakes from the humidity cabinet and autoclave using saturated steam at 834 to 1079 kPa for 16 to 24 h. Select a fixed time period to maintain consistency between batches.

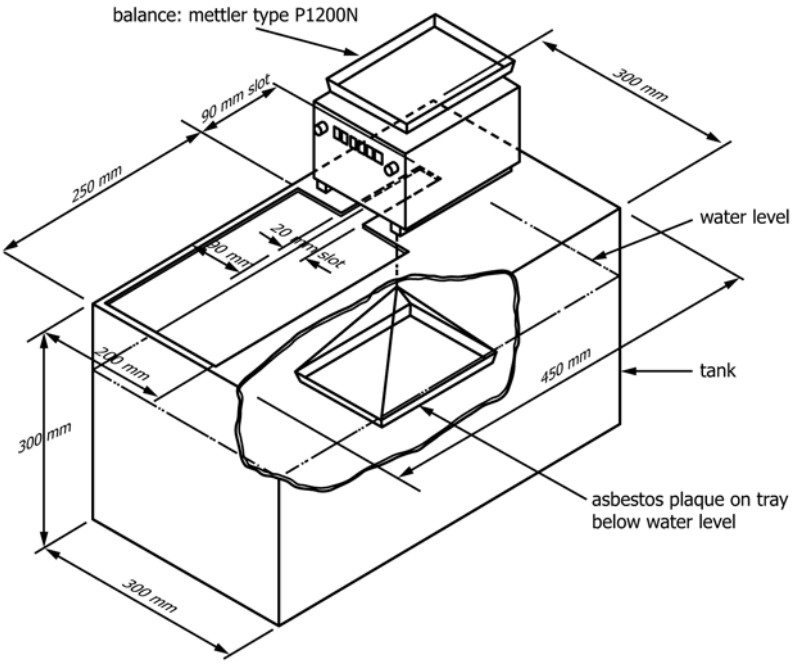


FIG. 4 General Arrangement for Determination of Immersed Weight

11.3 *Water Curing*—The cakes can be water-cured if an autoclave is not available. In this case, replace the silica with an equal mass of cement (see 10.1). Prepare the cakes by the same procedure up to and including the initial 16 to 24-h period in the humidity chamber. After this period, place the cakes under water at a controlled temperature of 20 ± 2°C for a fixed period of 28 days. This period is mandatory. After water curing, test the cakes in the normal fashion.

12. Procedure

12.1 *Saturating and Weighing*—After curing, immerse the specimens in water at 20°C for 24 h. Weigh each specimen while completely immersed in water. (A tank and balance arrangement as shown in Fig. 4 has been found to be suitable for this purpose.) Remove from tank, drain in the vertical position for not more than 5 min to remove all excess water, and immediately weigh to determine the saturated mass.

12.2 *Determination of Disk Thickness*—During the period of saturating, remove the disks from the water and mark them by drawing two lines across the diameter of each side, perpendicular to each other. Measure the thickness of the disks to the nearest 0.02 mm using a micrometer at four places about 25 mm inside the two extremities of each line. (Avoid making this measurement within 2 h of the end of the saturating period.) Replace the disks under water until the 24-h period has elapsed.

12.3 *Breaking in Flexure*—Test each 107-mm specimen in flexure on an 82.6-mm span applying a transverse load along one of the marked diameters until failure occurs. After the first break, retain the two halves together, reverse, and rotate the specimen 90° so as to test the other face in flexure. Record the breaking load for each test and the average thickness of the specimen along the length of each break. Repeat this test on five similarly prepared specimens. (Different spans must be used for disks of different diameter, maintaining a constant ratio of span to disk diameter.)

NOTE 7—The disks may be tested in flexure after drying, that is, in a dry condition. This variation from the normal procedure should be clearly stated when the data are reported, since higher MR_A values are obtained with dry disks. The modulus of rupture values should be identified, respectively, as MR_{AW}, for results on wet (saturated specimens or MR_{AD} for dry testing results). Our results may be some 30 % higher. However the standard deviation from specimen to specimen may be increased in the order of 50 %.

12.4 *Drying*—Dry the disks separated from each other at 105 ±2°C to constant weight, which may require a period of at least 24 h. Cool the disks in a desiccator and weigh to the nearest 100 mg.

13. Calculations

13.1 *Volume*—Determine the volume of each specimen using the following equation:

$$V = (S - I)/D_w \quad (1)$$

where:

V = volume of specimen, m^3,
I = immersed mass, kg,
S = saturated mass, kg, and
D_w = density of water (1.00 Mg/m^3).

13.2 *Density*—Determine the dry density of each specimen using the following equation:

$$D = M/V = MD_w/(S - I) \quad (2)$$

where:

D = dry specimen density, Mg/m^3,
M = dry specimen mass, kg, and
V = volume of the specimen, m^3.

NOTE 8—As an alternative approach, the volume and dry density of a specimen may be determined by measuring its diameter, thickness, and dry mass (see 12.2).

13.3 *Flexural Modulus of Rupture*—For each disk, calculate two modulus of rupture values, one for each fracture, using the following equation:

$$MR = \frac{30Bl}{2wt^2} \times 10^6 \quad (3)$$

where:

MR = modulus of rupture, MPa,
B = maximum load, N,
l = span, m,
w = width, m, and
t = average thickness, mm.

13.3.1 For a specimen with a diameter of 0.1067 m and a span of 0.0826×10^6 m, the following equation applies:

$$MR = \frac{30 \times B \times 0.0826}{2 \times 0.1067 \times t^2} = \frac{11.6B}{t^2} \times 10^6 \quad (4)$$

Report the average of the two values determined for each disk.

13.4 *Adjusted Flexural Modulus of Rupture*—Correct the modulus of rupture (*MR*) to an arbitrarily chosen dry density of 1.60 Mg/m^3, using the following equation (this correction is applicable only for a density range of 1.60 ± 0.07 Mg/m^3):

$$MR_A{}^2 = \frac{1.6^2 MR}{D^2} \quad (5)$$

where:

$MR_A{}^2$ = adjusted modulus of rupture, MPa,
MR = test modulus of rupture, MPa, and
D = dry specimen density, Mg/m^3.

Eliminate any individual $MR_A{}^1$ value varying from the average by more than 7.5 % (of the average of five specimens), and calculate a new average strength. If more than two values must be eliminated, repeat the entire test.

13.5 *Calculation of Relative Strength*—Determine the relative strength (*RS*) of the fiber under test as compared to a known fiber, at a fiber concentration of 10 % and a dry density of 1.6 Mg/m^3, using the following equation:

$$RS = \frac{MR_A{}^2}{MR_A{}^1} \times 100 \quad (6)$$

where:

RS = relative strength, %,
$MR_A{}^1$ = modulus of rupture of comparison fiber, adjusted to 1.6 Mg/m^3, MPa, and
$MR_A{}^2$ = modulus of rupture of fiber under test, adjusted to 1.6 Mg/m^3, MPa.

14. Interpretation of Results

14.1 *Modulus of Rupture* (adjusted to a dry density of 1.60 Mg/m^3) (MR_A)—This value expresses the reinforcing characteristics of a fiber. When compared with the modulus of rupture values obtained with fibers of known reinforcing values, it can be used to determine the relative strength of the fiber.

14.2 *Relative Strength*—When the relative reinforcing value of an unknown fiber is determined, comparisons should be made with a known fiber of similar grade. If the modulus of rupture values differ greatly, another comparison fiber should be selected. Since the modulus of rupture values depend upon the degree of fiberization (specific surface area) of the fiber, comparisons should be made at similar surface areas.

15. Report

15.1 Report the following information:

15.1.1 Flexural modulus of rupture of fiber under test (13.3), at a 10 % fiber concentration, and adjusted to a dry density of 1.6 Mg/m^3 (MR_A).

15.1.2 Relative strength (*RS*) (13.5) expressed as a percentage of the strength obtained with a known comparison fiber also at 10 % fiber concentration and at a dry density of 1.6 Mg/m^3.

15.1.3 Method of fiberizing, specific surface area, and, if available, the fiber length distribution (McNett) data.

15.1.4 *Optional Procedures*—Include a statement to that effect if any optional procedures were used for the following steps:

15.1.4.1 Dry and wet mixing procedure.
15.1.4.2 Size of test specimens.
15.1.4.3 Curing method.
15.1.4.4 Condition of disks on breaking (wet or dry).

16. Precision and Bias

16.1 *Repeatability:*

16.1.1 For specimens with an adjusted flexural modulus of rupture MR_{AW} level of 1.6 kPa (165 kgf/cm^2), the difference between two test results obtained by a single technician, sample, apparatus and laboratory should not exceed 0.10 kPa (10.2 kgf/cm^2) in 95 % of cases.

16.1.2 For specimens with an adjusted flexural modulus of rupture MR_{AW} level of 3.4 kPa (340 kgf/cm^2), the difference between two test results obtained by a single technician, sample, apparatus and laboratory should not exceed 0.29 kPa (28.9 kgf/cm^2) in 95 % of cases.

16.2 *Reproducibility (as defined by Practice E177):*

16.2.1 For fibers yielding an adjusted flexural modulus of rupture MR_{AW} at the level of 1.6 kPa (165 kgf/cm^2) the difference between two test results obtained on multiple samples of the same fiber by multiple apparatus and technicians intralaboratory should not exceed 0.16 kPa (16.0 kgf/cm^2) in 95 % of cases.

16.2.2 For fibers yielding an adjusted flexural modulus of rupture MR_{AW} at the level of 3.4 kPa (340 kgf/cm^2), the differences between two test results obtained on multiple samples of the same fiber by multiple apparatus and technicians intralaboratory should not exceed 0.39 kPa (38.8 kgf/cm^2) in 95 % of cases.

16.3 *Bias*—Bias cannot be established for lack of a suitable referee method.

17. Keywords

17.1 asbestos; asbestos-cement; cement matrix; determination; evaluation; reinforcement potential; strength