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Bending stiffness, four point method

1. Scope

This procedure specifies the method of determining the bending stiffness, also called flexural rigidity, in the machine and cross directions, of corrugated board using four-point loading. The procedure may also be used for solid boards and paperboard. The method is applicable to boards with a bending stiffness of 0.5 - 200 Nm (4.4 - 1770 lbf • in.).

2. Summary

2.1 A rectangular test specimen is clamped at each end with a clamping pressure P over the length s , leaving a free span l in the center (see Fig. 1).

2.2 Each clamp can be turned around a rotation axis r . A force F is applied at each clamp at a distance h from the rotation axis. The bending moments $F \cdot h$ cause the test specimen to bend, and maximum deflection from the plane through the rotation axes (the distances δ_B in Fig. 1) is measured

2.3 The bending stiffness is calculated from the bending moment, the width of the test specimen, the free span and the deflection. The time from the application of the force to the measurement is 10 ± 3 s (see Fig. 2).

3. Significance

It has been shown that the top-to-bottom compression strength of corrugated boxes is partly dependent on the load-carrying ability of the central panel areas. The ability of these central areas to resist bending under load will increase the stacking strength of the box. The difference in box compression strengths between boxes of identical size made from the same components but of different flute sizes (if the load is applied parallel to the flutes) is primarily due to differences in the bending stiffness of the box panels. Bending stiffness measurements of the combined board when used with the edge crush test and box dimensions, can accurately predict the top-to-bottom compression strength of a box.

Approved by the Standard Specific Interest Group for this Test Method



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4. Definitions

4.1 *Bending stiffness*, the bending moment per unit width of a rectangular specimen, divided by the curvature according to the expression:

$$S^b = \frac{M}{kb} \quad (1)$$

where

S^b	=	bending stiffness
M	=	bending moment
k	=	curvature (the inverted value of the radius of curvature)
b	=	width of the specimen

5. Apparatus

5.1 Use either an instrument specially designed for the measurement of bending stiffness or a universal testing machine having suitably designed attachment. The apparatus shall meet the following requirements:

5.2 The specimen shall be clamped firmly over its full width at both ends. Each clamp shall be 50 mm (2 in.) deep and at least 100 mm (4 in.) wide. The clamping pressure at right angles to the plane of the specimen shall be 14 ± 4 kPa (2 ± 0.6 psi).

NOTE 1: For certain board grades, other clamping pressure may be needed. Boards with low strength properties in the thickness direction may need a lower clamping pressure, and boards with high strength properties may need a higher clamping pressure to ensure that the test specimen surface is plane.

NOTE 2: Make sure that the clamping force is adapted to the width of the specimen to give the standardized clamping pressure.

5.3 The clamps shall be free to move to allow for changes in free span at larger deflections.

5.4 The deflections δ_B (see Fig. 1) shall be measurable to an accuracy of $\pm 2\%$ of the reading down to 0.5 mm (0.02 in.) deflection or better. The sum of any deflection indicator and rotation moment of the clamps shall not impart to the specimen an additional bending force greater than 1% of the total bending force.

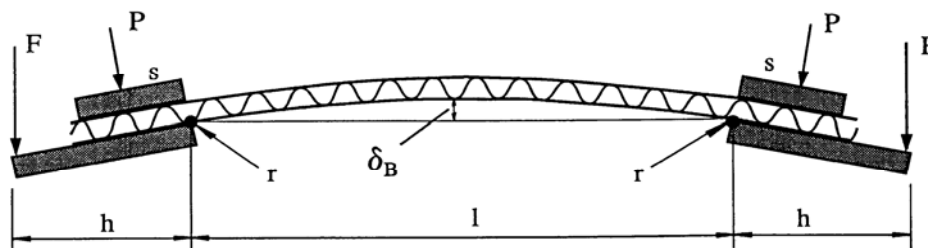


Fig. 1. The four-point test configuration (testing corrugated fiberboard in machine direction). Fig. legends: F = force; h = moment arm; l = free span; δ_B = deflection; r = rotation axis; P = clamping pressure; s = clamping length.

5.5 The bending force F shall be applied at right angles to the plane of the specimen at the beginning of the test (assuming that the specimen is perfectly flat). The bending force shall be known to an accuracy of 2% or better.

5.6 The rotation axes of the clamps shall be perpendicular to the long side of the specimen.

5.7 The free span shall be adjustable in three steps length: 150, 200 and 300 mm (5.9, 7.8 and 11.8 in.). The free span l and the distance h shall be known to an accuracy of $\pm 1\%$ or better.

NOTE 3: The free span is defined as the distance between the rotation centers of the clamps (Fig. 1).

5.8 Table 1 lists the free spans and widths to be used for corrugated fiberboards of different types. For other board types the thickness range given in Table 1 determines the free span. The 50-mm (2-in.) width is recommended for boards with a thickness above 10 mm (0.4 in.).

5.9 The strain in the liners shall be in the range of 0.03 to 0.05%. The deflection δ_B (Fig. 1) and the strain ε in the outer liners of a corrugated fiberboard or multi-layer board are related as given by the equation:

$$\delta_B = \frac{\varepsilon \cdot l^2}{400 \cdot t} \quad (2)$$

where:

δ_B	=	deflection of the specimen, mm (in.)
ε	=	strain in the outer liner, %
l	=	free span used, mm (in.)
t	=	corrugated board thickness, mm (in.)

NOTE 4: Check the allowable deflection before testing unknown samples. In a preliminary test, apply a force, record the deflection δ_B and calculate the strain ε from the expression:

$$\varepsilon = \frac{400 \cdot \delta_B \cdot t}{l^2} \quad (3)$$

to check that ε is in the range 0.03% to 0.05%.

5.10 Furthermore, if the board crushes during bending, the strain must be reduced.

5.11 Table 2 gives guidance with regard to allowable deflections for corrugated fiberboards at different thickness at an allowable strain of 0.03% to 0.05%.

Table 1. The free spans and the widths to be used when testing corrugated fiberboards of different thickness.

Type of corrugated fiber board	Test specimen width, mm (in.)	Free span, mm (in.)	Approximate thickness
Single-wall F-,E-flute	100 (3.9)	150 (5.9)	0.5 - 2.29 (0.02 - 0.09)
Single-wall B-,C- and A-flute	100 (3.9)	200 (7.9)	2.30 - 5.99 (0.1 - 0.24)
Double-wall Triple-wall	100 (3.9) 50 (2.0)	300 (11.8)	6.00 - 20.00 (0.24 - 0.79)