An American National Standard

Standard Test Method for Resistance to Bending of Paper of Low Bending Stiffness (Taber-Type Tester in 0 to 10 Taber Stiffness Unit Configuration)[1]

This standard is issued under the fixed designation D 5650; 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 a procedure used to measure the resistance to bending of papers which are of low grammage or high flexibility, or both, and which exhibit bending stiffness in the range from 0 to 10 Taber stiffness units.

1.2 The bending moment required to deflect the free end of a 38-mm (1.5-in.) wide vertically clamped specimen 15° from its center line when the load is applied 10 mm (0.39 in.) away from the clamp is determined. The resistance to bending is calculated from the bending moment.

1.3 The instrument used in this test method is identical to that described in Test Method D 5342, used in the modified configuration described in Section 9.

1.4 Test results obtained using the Taber-Type tester as described in this test method have been reported to be as much as 40 % different from those obtained using Test Method D 5342, and this test method shall not be used where Test Method D 5342 is specified.

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:*

D 585 Practice for Sampling and Accepting a Single Lot of Paper, Paperboard, Fiberboard, or Related Products[2]

D 685 Practice for Conditioning Paper and Paper Products for Testing[2]

D 1968 Terminology Relating to Paper and Paper Products[2]

D 5342 Test Method for Resistance to Bending of Paper and Paperboard (Taber-Type Tester in Basic Configuration)[2]

E 122 Practice for Calculating Sample Size to Estimate, With a Specified Tolerable Error, the Average for Characteristic of a Lot or Process[3]

3. Terminology

3.1 *Definitions*—Definitions shall be in accordance with Terminology D 1968 and the *Dictionary of Paper*.[4]

4. Summary of Test Method

4.1 A test specimen of defined dimensions is bent through a specified angle using a specific testing instrument. The resulting bending moment is read from the instrument scale.

4.2 The resistance to bending can be calculated from the bending moment.

5. Significance and Use

5.1 Bending resistance of paper relates to a number of end use applications including wrapping, printing, copy machine performance, high speed mechanical handling of documents, and other applications.

6. Apparatus

6.1 *Description*:

6.1.1 The basic instrument that has been used for the test described in this test method for nearly fifty years is a manually operated (crank-driven) instrument. Over the years, various improvements in the basic instrument have been made for improved ease of use or greater reproducibility of data, or both. These improvements include replacement of the manual (crank) drive system with a constant speed motor, addition of automatic data determination, and automated instrument (motor sequencing) operation. Fig. 1 shows the motor-driven version of the instrument (see 6.1.2). It is the motor-driven model of the basic instrument that is the basis for this test method. However, any of the instrument variations described in this section, when properly calibrated and operated, should yield the same result. The components of the basic instrument can be seen in Fig. 1 as follows:

6.1.1.1 A pendulum (A) supported in antifriction in bearings, carrying a vise (C) that has two clamping screws for

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[2] *Annual Book of ASTM Standards*, Vol 15.09.

[3] *Annual Book of ASTM Standards*, Vol 14.02.

[4] Available from the Technical Association of the Pulp and Paper Industry, P.O. Box 105113, Atlanta, GA 30348.

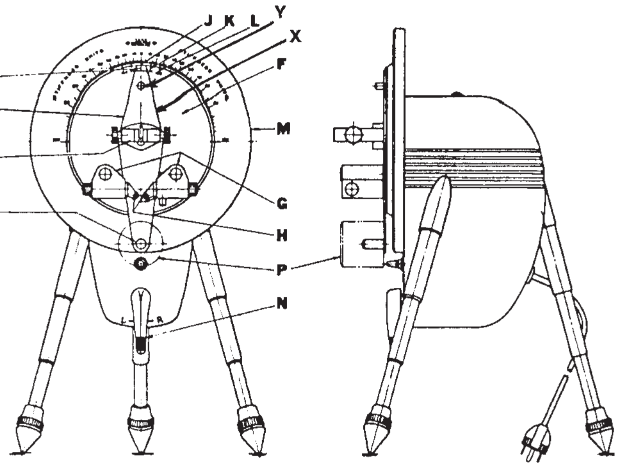

FIG. 1 Stiffness Instrument

holding and centering the test specimen, the lower edge of the vise coinciding with the center of the pendulum bearing. The pendulum is balanced, and at its lower end is a stud (D) to which weights may be attached and that loads the pendulum at a distance of 100 ± 0.025 mm (3.94 in.) from its center; without added weights the loading is 10 ± 0.001 g. A line (E) coinciding with the center line of the vise jaws and the weight stud (D), is engraved at the upper end of the pendulum.

6.1.1.2 A vertical disk (F), driven on the same axis as the pendulum by a driving mechanism, carries two driving arm attachments (G) so located as to provide the specimen with a cantilevered loading length of 50 ± 0.025 mm (1.97 in.) when it is deflected 15°. Fig. 1 does not show the crankdriving mechanism. The driving arms have rollers (H) that are adjustable to accommodate specimens of different thicknesses. On the periphery of the upper part of the disk is a marked line (J) coinciding with the center line between the driving rollers (H) and the axis, and two reference lines (K and L) are engraved on the periphery of the disk at angular distances of 7.5° and 15° on both sides of the center mark (J).

6.1.1.3 Located around the periphery of the disk (F) is a fixed annular disk (M) with a load scale from 0 to 100 on both sides of a zero point that is adjusted to coincide with the center line mark (J), the scale indicating the bending moment required to flex the specimen to the right or to the left, the divisions being in accordance with the sine of the angle through which the pendulum and weight are turned.

6.1.1.4 Various loading weights (P) for the pendulum, to give a maximum bending moment of 5000 g-cm (490 mN·m).

6.1.1.5 A 10 Unit compensating weight (X) to be mounted on the stud (Y) near the top of the pendulum when the instrument is used as described in this test method.

6.1.2 For operator convenience and improved testing reproducibility, the "driving mechanism" (crank) of the basic unit was replaced by a motor to drive the vertical disk (F) at a constant rate of 210 ± 20° per minute. Other than this change, the motor-driven instrument has the components of the "basic instrument" in accordance with 6.1.1. The motor is reversible using the switch (N), that preferably also operates an electric brake to stop the disk at any point on the scale. The motor-driven version of the instrument shown in Fig. 1 is the instrument in most wide use today, and is the basis of this test method.

6.1.3 More recently, automated versions of the basic instrument have become available. These are two types: automatic reading of results (only), and automation of instrument operation as well as reading of results.

6.1.3.1 Devices are available that may be retrofitted to the basic instrument for automatically determining and recording the scale readings (see section 10.2). Results are displayed on a digital readout device. In addition, the retrofitted unit may provide a signal output suitable for transmission to a stand-alone printer or an integrated acquisition system.

6.1.3.2 Totally automated versions of the basic motor-driven instrument (see 6.1.2), incorporating the components described in 6.1.2.1 , and in addition automatically controlling the entire sequence of operations described in 10.2 , are also available.

7. Sampling

7.1 *Acceptance Sampling*—Acceptance sampling shall be done in accordance with Practice D 585.

7.2 *Sampling for Other Purposes*—The sampling and the number of test specimens depends upon the purpose of the testing. Practice E 122 is recommended.

7.3 In sampling, take care not to bend, roll, score, or otherwise damage the area to be tested.

8. Test Specimens

8.1 From each test unit, cut ten square test specimens 38.1 ± 0.3 mm (1.50 ± 0.01 in.) in each dimension. At the very edge of each test specimen, mark or in some other way identify the machine direction of each square specimen, being careful not to damage the specimens in any way. All cut specimens must be free from scores or blemishes. A special cutter for cutting the samples may be available from the vendor, or a high-precision cutting board may be used.

9. Preparation of Apparatus

9.1 Place the instrument on a firm, level surface. A standard laboratory bench is generally quite satisfactory and should be checked with a carpenter's level to verify that it is level (front-to-back, side-to-side) when the instrument is initially installed. Set the loading disk (F) at zero and place a chosen weight (P) on the pendulum stud. If possible, choose a weight such that the resulting readings for the specimen to be tested are near the center of the measured test range. Close the two jaws of the vice (C) to meet on the center line of the pendulum and adjust the legs of the instrument so that the engraved mark (E) coincides with zero on the scale of M. Level the instrument front to back as well as side to side.

9.2 Displace the pendulum 15° and release it to check the bearing friction. It should make at least 20 complete swings before coming to rest. If it does not, check for obvious contamination by dust particles. In the absence of any obvious problem, contact the vendor to arrange service or maintenance.

9.3 If the instrument has a brake, check that it functions properly. It should "freeze" (stop and securely hold) the rotating disk (F) in place within less than a second of its application so that the result can be easily determined. (Operation of the brake on the automated instrument is automatically controlled as part of the automatic reversal from clockwise to counterclockwise (or vice versa) rotation.)

9.4 *Conversion of the Instrument to the 0 to 10 Taber Stiffness Unit Range*:

9.4.1 Remove and invert the roller assemblies (right and left), in accordance with the manual for the instrument being used, changing the effective test length of the from the 50 mm required in Test Method D 5342 to the 10 mm required in this test method.

9.4.2 Place the 10 Unit compensator weight on the stud near the top of the pendulum.

10. Calibration

10.1 Calibrate the instrument and check the accuracy of the apparatus at regular intervals. The method of calibration depends on the type of instrument and done following the manufacturer's instructions for the instrument used. Spring steel test pieces supplied by the manufacturer of the instrument for calibration purposes are generally used. If readings within the tolerance suggested by the manufacturer are not achieved, it may be necessary to return the instrument for servicing.

11. Conditioning

11.1 Condition the specimens and make the tests in an atmosphere in accordance with Practice D 685.

12. Procedure

12.1 Place a conditioned test specimen in the vise (C) with one end approximately level with its top edge and the other end between the rollers (H).

12.2 With the two clamping screws of the vise (C), align the specimen with the center line of the pendulum.

12.2.1 Pressure of the clamping screws may impact test results, and clamping pressure should be firm enough to hold the specimen, but not so firm as to compress or deform it.

NOTE 1—At the present time, use of calibration spring steel or specimens of samples of known stiffness as determined by this test method are the only recommendations for determining if vise pressure is so great or so slight that test results are affected adversely.

12.3 Turn each of the screws for adjusting the rollers (H) so that they just contact the specimen. Then, after taking up the backlash in one screw, back off one-quarter turn to give a distance between rollers of 0.33 + 0.03 mm (0.013 + 0.001 in.) greater than the thickness of the specimen.

NOTE 2—On instruments not equipped with adjustable rollers (H), use the appropriate set of rollers for the thickness of the board to be tested.

NOTE 3—It is not necessary for the pendulum to balance at zero with the undeflected specimen in place. Curvature of the specimen will result in a difference between the two readings which are averaged to give the stiffness of the specimen. This difference has been used as a measure of curl, but this should be done with caution, as this difference may also reflect a genuine difference in stiffness between the two orientations of the specimen with respect to the deflecting force. If the specimen is so badly curled that both readings fall on the same side of zero, take the lower reading as negative when calculating the average, but include mention of this occurrence in the report, as this much curl may make the material useless for its intended purpose.

12.4 *For the Basic Motor-Driven Instrument*—Switch on the motor to rotate the loading disk (F) to the left and thus deflect the specimen until the engraved mark (E) on the pendulum is aligned with the 15° mark (L) on the loading disk. Stop the motor, record the scale reading on the fixed annular disk (M) and immediately return the loading disk to zero (see Note 3). Take a similar reading by deflecting the specimen to the right. The stiffness of the specimen is taken as the average of the two readings multiplied by the factor required for the instrument range weight used (see the manufacturer's instructions). Test five specimens cut in each direction.

NOTE 4—When the motor is "stopped," an electric brake immediately stops the disk and holds it in place so a reading can be taken. On instruments not equipped with an electric brake, take the reading as the disk rotates over the end point.

12.4.1 For the basic motor-driven instrument retrofitted with digital readout, the scale readings are automatically "captured" and are recorded from a digital display. The motor is started, stopped, and reversed in accordance with 12.4.

12.5 *For the Automated Instrument*—The operations described in 12.4 are automatically done in sequence after the test is initiated. Scale readings (left and right) are displayed on the instrument readout.

13. Calculation

13.1 *Bending Moment*— Calculate the bending moment as the average of the two readings (left and right deflection) multiplied by 0.10, the factor required when the 10 Unit compensator weight is used.

13.2 Where SI results are desired, convert the value in stiffness to millinewton metres by multiplying by 0.098066.

13.3 *Resistance to Bending*—Divide the bending moment (mN·m) by the length (m). Result is force (mN) required to deflect the sample through the specified distance. (Length (m) = 0.010 metres)

14. Report

14.1 Report the following information:

14.1.1 *Bending Moment*:

14.1.1.1 The average value in stiffness units or millinewton metres of the specimen tested from each unit cut in each direction separately, to three significant figures.

14.1.1.2 The number of specimens tested in each direction.

14.1.1.3 The standard deviation for each test unit.

14.1.1.4 The test method used for the test, and that the 10 Unit compensator weight (or the 0 to 10 Taber stiffness unit instrument range) was used.

14.2 The resistance to bending calculated from the bending moment (see 13.3), to three significant figures.

15. Precision and Bias

15.1 *Precision*:

15.1.1 *Repeatability*— Based on limited information from one laboratory, the repeatability standard deviations and the 95 % repeatability limits are approximately 0.8 and 2.2 Taber stiffness units. These estimates are based on tests on five consecutive days in a single laboratory by a single operator of three samples having Taber stiffness results ranging from 3 to 7 Taber stiffness units as determined by this test method.

15.1.2 *Reproducibility*— An initial estimate of reproducibility of this test method is as follows: the reproducibility standard deviation has a range from 0.4 to 1.2 and the 95 % reproducibility limits range from 1.1 to 3.3 for samples having Taber stiffness values from 2.3 to 6.4 Taber stiffness units.

15.1.2.1 This reproducibility estimate is based on tests conducted by participants in the Collaborative Reference Program during the period July 1990 to April 1993, using Taber stiffness units in the 0 to 10 Taber stiffness unit configuration.

15.1.2.2 The number of laboratories participating in the testing upon which this reproducibility estimate is based ranged from 20 to 29.

15.1.2.3 The user of these precision estimates is advised that they must be considered preliminary. In the case of the reproducibility estimate, the user is advised that it is based on actual mill testing or laboratory testing, or both. There is no knowledge of the exact degree to which personnel skills or equipment were optimized during its generation. The reproducibility estimate quoted provides an estimate of typical variation in test results which may be encountered when the test method is routinely used by two or more parties.

15.1.2.4 The user of the reproducibility estimate is further advised that the actual written instructions upon which the testing used for the reproducibility estimate is based were a version of the vendor's operating instructions for use of the Taber-type instrument configured in the 0 to 10 Taber stiffness unit range supplied by Collaborative Testing Services to the participating laboratories. These instructions, however, were identical to those found in this test method.

15.2 *Bias*—Various styles of stiffness testers are available for making measurements similar to those described in this test method. Bias among them is undefined, as each uses specific test conditions and conventions in expressing results which are defined in terms of specific test methods associated with the various testers.

15.2.1 The procedure in this test method is reported to give results differing by as much as 40 % from those produced by Test Method D 5342, which uses the same style test instrument in a different configuration. A systematic study of the bias between these two procedures has not been completed.

16. Keywords

16.1 bending; flexible paper; low grammage paper; paper; resistance to bending; stiffness; taber stiffness