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Internal bond strength (Scott type)

1. Introduction

Printing, converting and many product applications subject paper and paperboard to impulses, impacts and shock loads into or out of the plane of the sheet. These can cause structural failures such as surface picks, blistering or delaminations within the interior of the sheet. The common denominators of these failures are a) the high velocity of the impact loads b) the short time period during which the material is stressed, frequently one to a few hundred milliseconds, and c) the planar nature of the resultant sheet failure. Test results from this method may correlate with product failures of this type.

2. Scope

2.1 This method defines a test that measures the energy required to rapidly delaminate a sheet-type specimen. The “Z” directional rupture is initiated by the impact of a pendulum having both a controlled mass and a controlled velocity that exceeds 6000 times the velocity of tensile strength and other dead-weight testers. The geometry of the apparatus causes the tensile stress to be rotational in nature with negligible shear stress on the specimen.

2.2 The method is suitable for both single and multi-ply paper and paperboard, including coated sheets and those that are laminated with synthetic polymer films.

2.3 Because sample preparation entails pressing double-coated tape to both sides of the test specimen under relatively high pressures, this method may not be suitable for testing high strength handsheets or low basis weight (below 40 g/m²), porous, soft or low-density materials, such as tissue. Limitations include materials that permit significant migration of the tape’s adhesive into the sample with potential tape-to-tape bonding, or materials that could be structurally damaged or collapse during the press cycle.

2.4 To determine the applicability of the test method, it is important to visually inspect both sides of a set of at least 10 delaminated samples. The ability to rupture a sample within the measurement range of the instrument is an insufficient criterion. For interpretations of observations, see Section 9.2.

2.5 Because energy is absorbed during the elongation and stretching of the sample’s fiber network prior to rupture, this internal bond test responds to the semi-elastic nature of paper and paperboard. The test is a measurement of strain energy per unit sample area, which is proportional to the area under the stress-strain curve. Strength measurements by this method do not correlate with “Z” direction tensile strength tests (ZDT) that measure the maximum (peak) stress in

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a slow, constant rate of elongation or dead-weight rupture. Also, the constant rate of elongation specified in TAPPI T 541 "Internal Bond Strength of Paperboard (z-Direction Tensile)," (ZDT) and "X" and "Y" plane tensile tests per TAPPI T 494 "Tensile Breaking Properties of Paper and Paperboard (Using Constant Rate of Elongation Apparatus)," is several orders of magnitude less than the rate attained in this method.

3. Summary

A sandwich consisting of double-coated tape, the paper specimen, and double-coated tape is pressed between a flat metal anvil and an aluminum platen as shown in Figure 1. A pendulum impacts the top inside surface of the platen, causing it to rotate and split the paper specimen in the thin, "Z" direction (see Figure 2). The energy absorbed in rupturing the sample is computed by measuring the peak excess swing of the pendulum. The strength equation parameters include a) the potential energy of the latched pendulum, b) the peak excess swing, c) the energy required to accelerate a bare sample angle away from the pendulum, d) frictional losses, and e) internal vibration losses within the pendulum.

4. Significance

4.1 Internal bond strength as defined in this method is indicative of the serviceability and processability of many types of paper and paperboard. These include printing papers, cover, label, release, linerboard, carton, carrier, newsprint and others. Test results often correlate with high-speed surface and internal structural failures encountered in both printing and converting operations.

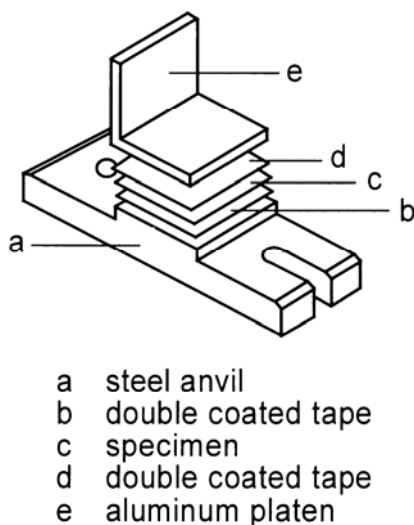


Fig. 1. Sandwich consisting of double-coated tape, the paper specimen, and double-coated tape is pressed between a flat metal anvil and an aluminum platen

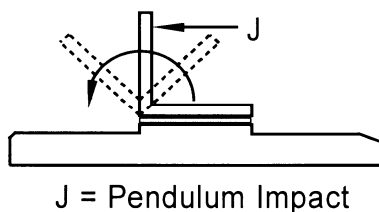


Fig. 2. Positioning of the specimen sandwich, anvil, and platen so that the pendulum strikes at the center of percussion of the platen when the center of oscillation (rotational axis) is at the outside corner of the right angle of the platen.

4.2 Some fiber processing and papermaking characteristics can also be correlated with this type of internal bond strength test. These include extent of refining, machine speed, pressing, interply bonding in multiple headbox operations, and furnish composition such as long-to-short fiber mix, recycled content and the effect of dry strength additives. The test responds to both individual fiber strength characteristics and to the degree of interfiber bonding, but does not isolate and distinguish between these factors.

4.3 The combination of internal bond strength data with other TAPPI test methods can provide additional strength and processability information. An example is the combination with porosity data derived from TAPPI T 460 "Air Resistance of Paper (Gurley Method)" or TAPPI T 547 "Air Permeance of Paper and Paperboard (Sheffield Method)" to predict blistering tendencies for coated web offset papers.

5. Apparatus and materials

5.1 A *multiple specimen preparation station* capable of pressing five 25.4 × 25.4 mm (1.00 inch × 1.00 inch) samples, the ability to accommodate specimens of varying caliper up to 1.25 mm (0.050 inches) thick, with optional clamping pressures on the specimen from 345 kPa (50 psi) to 1034 kPa (150 psi) in at least 345 kPa (50 psi) increments. Pressure control shall be within ±21 kPa (3 psi) at the most commonly used clamping pressure of 690 kPa (100 psi) and within ±34 kPa at the 1034 kPa (±5 at the 150 psi) level. A *strongback* is a component of the preparation station designed to temporarily retain and align the five aluminum platens and prevent their deflection during sample pressing.

5.2 A *pendulum* mounted on a pedestal, with an axle supported at two points on ball or similar low-friction bearings, and whose center of gravity is located 127 ± 0.6 mm (5.00 ± 0.025 inches) from the centerline of the axle. The pendulum should be free to rotate from a horizontal position through at least a 180° swing and the impact ball on the pendulum shall strike the aluminum platen (see Section 5.4) when it reaches the vertical 90° point in its swing. The resultant 5.00-inch drop in the center of gravity thereby determines the velocity of the pendulum at impact. If weights are added to the pendulum to extend its range, they must be positioned so that the center of gravity is not altered. In addition, if adding weights alters the center of percussion of the pendulum, this factor must be reflected in the high-range calibration for the instrument.

NOTE 1: For additional information regarding differences between manual and automated instruments, see Section 13.3.

5.3 A means for holding the pendulum in a horizontal position with provision for instantaneous release.

5.4 A *stationary anvil (base) and a separable aluminum platen (sample angle)* that is a right angle in cross section. The specimen sandwich, anvil and platen are held stationary on a sample stage and positioned so that the pendulum strikes at the center of percussion of the platen when the center of oscillation (rotational axis) is at the outside corner of the right angle of the platen. See Figure 2.

NOTE 2: The physical properties of aluminum vary with different alloys thus affecting the coefficient of restitution between the aluminum angle piece and the steel sphere impact point on the pendulum. It is recommended to use only aluminum angle pieces supplied by the manufacturer of the instrument and designated for use on that instrument. Do not mix aluminum plates between instruments.

5.4.1 Worn and blemished platens can produce measurement errors of 15% and greater.

5.5 A means of mechanically or electronically registering the peak angular swing of the pendulum after it is released and after it swings beyond the vertical (plumb) position.

5.6 A means to convert a measurement of the peak angular swing of the pendulum to internal bond strength and provide a visual display of this value. This non-linear calculation may be done with a mechanical scale and friction pointer or electronically with a digital computer. The minimum range of the instrument should be 0 - 525 joules/m² ($0 - 250 \times 10^{-3}$ ft-lb/in²).

5.7 An *optional means to extend the range of the instrument*. This may be done by changing the complete pendulum, adding weights to the pendulum or reducing the surface area of the test specimen by a percentage not exceeding 40%.

5.8 A *specimen cutter* for cutting specimens 25.4 mm (1.00 in.) wide with straight parallel sides within 0.1 mm (0.004 inches) and long enough for alignment in the specimen preparation station (see tolerances in Section 7.3).

5.9 A *knife or multi-blade cutting apparatus* for separating and trimming the five specimens to obtain edges without overlaps. The appropriate blade width is determined by the spacing of the anvils in the specimen preparation station and is specified by the apparatus manufacturer as either .025 or .038 cm (.010 or .015 in.).

5.10 *Double-coated paper tape* 25.4 ± 0.8 mm (1.00 ± 0.03 in.) wide with a release liner. The tape should exhibit a minimum adhesion to stainless steel of 45 oz/in. width when tested per ASTM D 3330, and should have a