Short-span compressive strength testing: procedures and tools for improved tester accuracy

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Test instruments for measuring short-span compressive strength were found to differ by up to 15% even when operated side-by-side in the same testing room. An alignment gauge and procedures have been developed to eliminate these differences.

The short-span compressive strength test was developed by the Swedish Pulp and Paper Research Institute in the mid-1970s (*1*). The purpose of the test is to determine the edgewise compressive strength of linerboard and fluting medium. The test methods available for measurement of edgewise compressive strength have been reviewed by Johnson *et al.* (*2*). The mode of failure in compression depends upon the relative dimensions of the sample, the shape of the sample, and the end conditions where force is applied. The relatively small thickness of paperboard presents difficulty for compression testing without buckling failure. Tests for paperboard have been devised to minimize the span of the test, to put the sample in a stable shape (ring crush and Concora fluted crush test), and to provide lateral support over a relatively long span (Forest Products Laboratory vacuum restraint) (*3*). The short-span compressive strength test was designed to crush the sample before the sample buckles.

Specifications for the short-span compressive strength test have been developed by both SCAN (*4*) and TAPPI (*5*). Sample strips for testing are cut 15 mm wide and several inches long in either the cross-machine direction (CD) or machine direction (MD) of the paperboard. The test strip is clamped by the jaws of the tester (**Fig. 1**), which are separated by a narrow gap. The free span, or gap, is to be 0.7 mm (± 0.05 mm). The clamping force in the jaws of 2.3 kN (± 0.5 kN) results in an applied pressure of 5.2 MPa (± 1.1 MPa).

Straight clamping and precision of the tester are necessary to ensure minimal eccentric loading. As shown in **Fig. 2**, the orientation of the planes of the jaws with respect to each other are defined by the specifications. The maximum misalignment of the stationary jaws across the gap is 10 μm. All testers for the short-span compressive strength test must meet these specifications.

The work described in this paper was started in an effort to bring testers into agreement with specifications and into agreement with each other.

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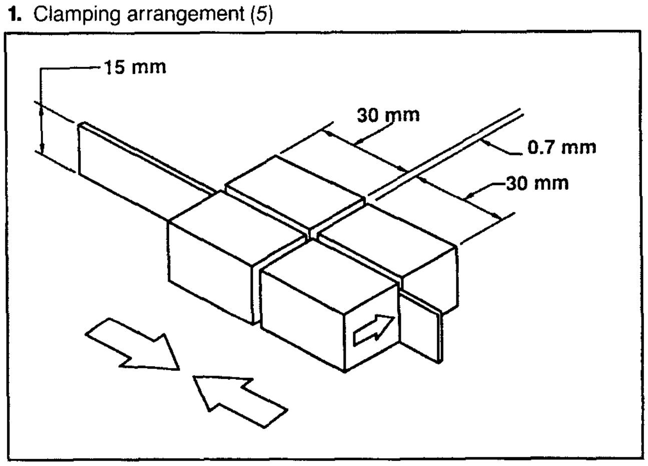
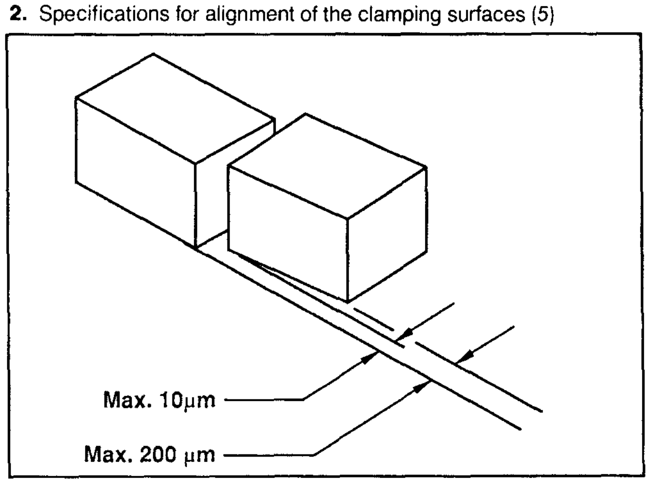
1. Clamping arrangement (5)



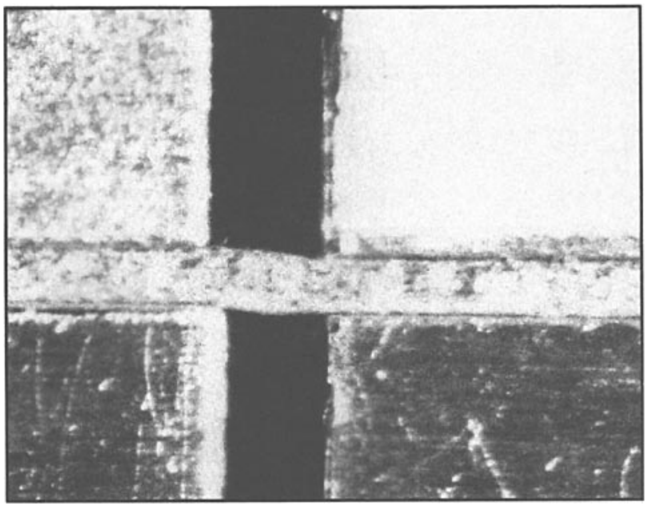
2. Specifications for alignment of the clamping surfaces (5)



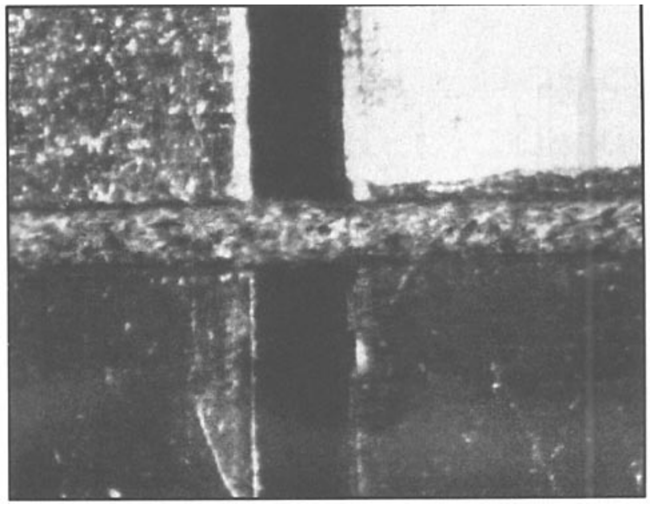
Jaw alignment

Figures 3 and 4 show samples under load that are about to fail. Tester A, the first tester examined, had low test values in comparison to another tester in the same conditioned space. When samples under test were watched with a microscope, they could be seen to fail by buckling

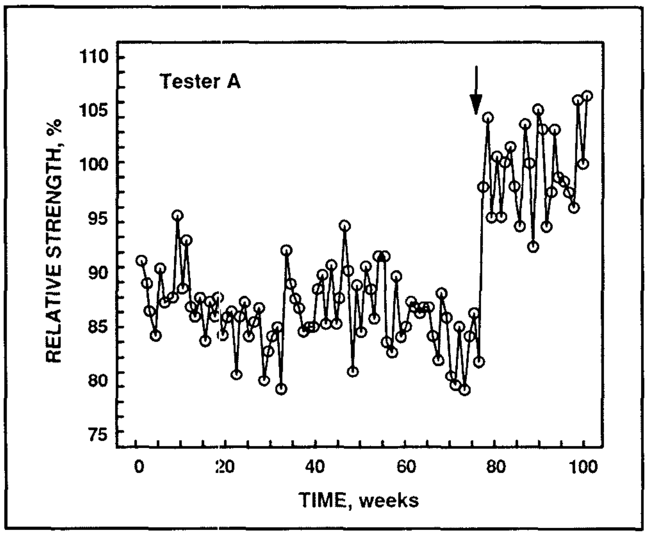
3. Misalignment of Tester A's jaws. Sample in compression near failure.



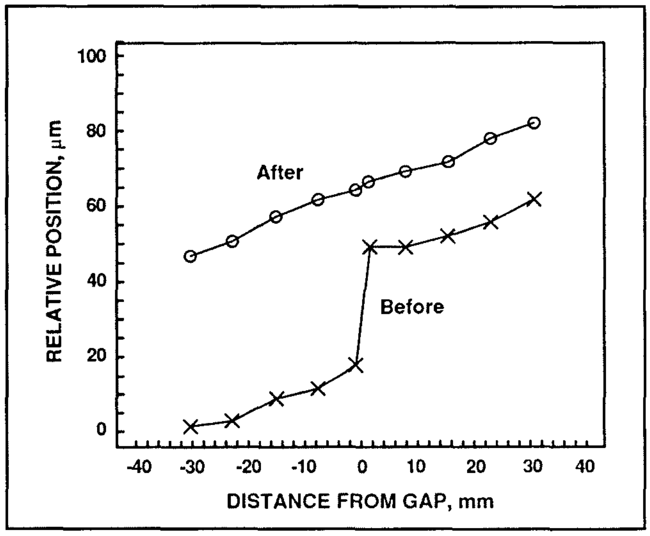
4. Jaws of Tester A after alignment. Sample in compression near failure.



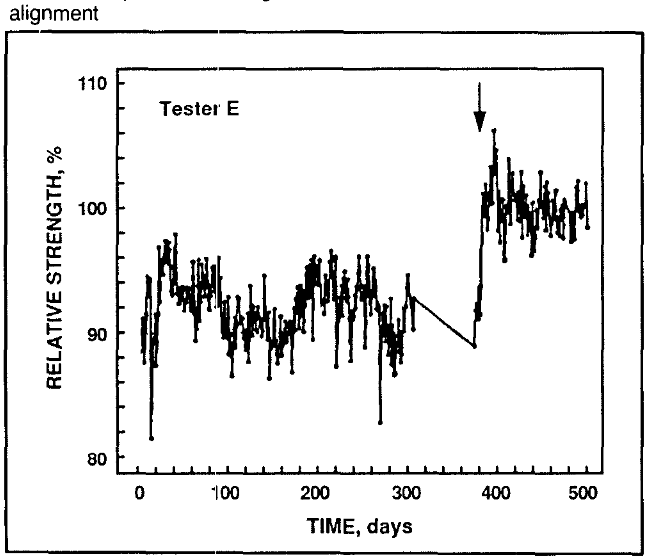
5. Measured compressive strength increased after jaw alignment



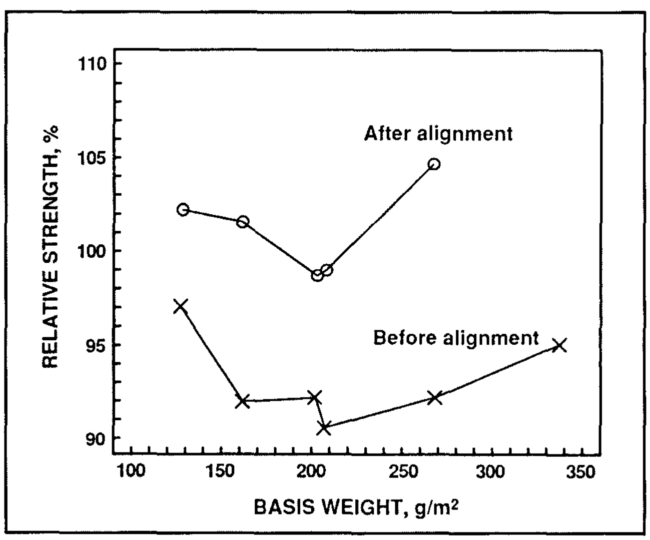
6. Jaw position measurements of Tester E before and after alignment



7. CD compressive strength measurements increased after jaw alignment



8. Improved alignment between testers after alignment of Tester B



(Fig. 3). At the time our technique was not refined sufficiently to enable measurement of the misalignment, but we were able to correct the misalignment. After this work, samples did not fail by buckling (Fig. 4) and measured strengths from Tester A increased by 15% (**Fig. 5**).

A gauge was built to measure alignment of the stationary jaws. The gauge attached to the framework for the jaw mechanism with the tester fully operational. The gauge was built around precision linear slides oriented in the three mutually perpendicular directions. An indicator, with a resolution of 1.3 μm, was mounted on the slides. The slides were adjusted to position the indicator parallel to the plane of one of the stationary jaws as a reference. Jaw alignment was determined by measuring the relative location of the other jaw.

Only small adjustments to jaw alignment were found to be possible. Adjustments were made by loosening the clamping bolts and moving a jaw within the tolerances permitted by the dowel pins in the jaw. A tool in the shape of a C-clamp provided the force necessary for some of the adjustments. Adjustment of jaw position was done by repeated trials. After an adjustment to jaw position, a series of samples were tested, and the position of the jaws was rechecked and adjusted, if necessary.

To determine jaw alignment, measurements were made on either side of the jaw gap and then at four other locations on each jaw. Tester E was out of alignment across the gap by 33 μm before alignment and less than 5 μm after alignment (**Fig. 6**). After jaw alignment, measured strength from Tester E increased by 8% in the CD (**Fig. 7**) and by 10% in the MD for a standard reference material. These results were in general agreement with predictions from a theory presented by Fellers (*6*).

Tester A, which was the first machine to be worked on, was measured and found to be in alignment to within 2.5 μm. Tester B shared the same laboratory and was found to be out of alignment by 36 μm. Alignment of Tester B brought its jaws to within 7.6 μm.

Agreement between the two testers was improved. Before alignment, Tester B was 8% lower than Tester A. After alignment, the testers agreed to within 3% (**Fig. 8**).

One machine, Tester C, has been measured at intervals over a six-month period. The jaws of Tester C were out of alignment by 18 μm. The jaws were brought into alignment to within 5 μm and have not changed in the time since they were aligned.

Jaw gap

The gap between jaws, or the free span of the test, was measured accurately with a dial indicator. With an indicator secured to the jaw mechanism frame and resting on one of the jaws, the gap was measured by squeezing the jaws together. With this method, jaw gap was measured to within 0.025 mm.

One of the testers examined had a gap between the jaws of 0.9 mm. After the jaw gap was corrected to the specified 0.7 mm, compressive strength values from the tester increased by 6% in the CD (**Fig. 9**) and 5% in the MD of the standard reference material. The same change in slenderness ratio, from 13 to 9, was not observed to affect compressive strength as reported by Fellers (*6*).

Clamping pressure

Samples slipped in the jaws of Tester C when the tester was examined initially. The slippage was detected after video recordings of tests were made through the microscope. Clamping pressure of the tester was measured with pressure sensitive film and found to be 60% of the specified pressure (**Fig. 10**).

Clamping pressure was compared to Tester B that did not show slippage at the manufacturer's recommended gauge pressure of 0.5 MPa. Clamping pressure of Tester C was increased to 80% of the specified pressure by lubricating sliding contacts in the linkage between the pneumatic load cylinder and the jaws. After lubrication, Tester C showed what appeared to be less sample slippage in the jaws.

The measured strength for Tester C increased by 3% after clamping pressure was increased (**Fig. 11**). A series of measurements, made with increasing air pressures supplied to the clamping cylinders, verified the magnitude of the observed change in measured values (**Fig. 12**). Compressive strength increased with increasing clamping pressure up to the manufacturer's recommended air supply of 0.5 MPa. At this air pressure, the pressure applied to the sample was 4.2 MPa, as measured by pressure-sensitive film. Fellers (*6*) has reported that measured strength increased with clamping force from low values to a plateau when clamping pressure reached 3.4-7.9 MPa (1.5-3.5 kN).

Materials and methods

Samples for compressive strength measurements were held in a conditioned space (23°C, 50% RH) for at least 24 hours prior to testing. Samples for comparisons were selected at random from a pool of 150-mm-long strips. Compressive strengths were reported without using the moisture measurement and compensation feature available on some of the testers. Values plotted for Collaborative Testing Service samples were averages of 20 tests. All other values were based on averages of 25 tests. Five tests were done per sample strip.

Conclusions

Methods for measuring three of the critical factors in the short-span compressive strength test—jaw gap, clamping pressure, and stationary jaw alignment—were presented. In testers examined, jaw alignment was found to have the greatest effect on measured compressive strength. These results show the importance of maintaining jaw alignment, jaw gap, and clamping pressure to ensure repeatable and comparable test results.□

Literature cited

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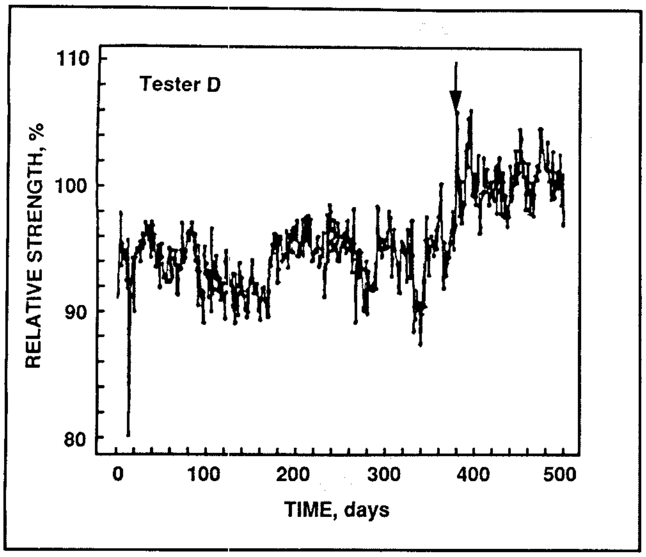
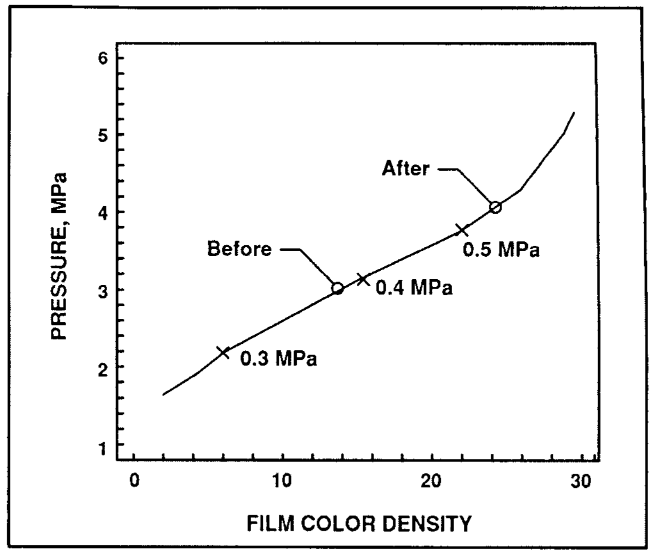
2. Johnson, J. A., Bennett, K. A., and Montrey, H. M., "Failure Phenomena" in Handbook of Physical and Mechanical Testing of Paper and Paperboard (R. E. Mark, ed.), Marcel Dekker, New York, 1983, Vol. 1, Ch. 5, pp. 181-190.
3. Gunderson, D. E., APPITA 37(2): 137(1983).
4. SCAN Method P46.83, Scandinavian Pulp, Paper, and Board Testing Committee, Stockholm, May 1983.

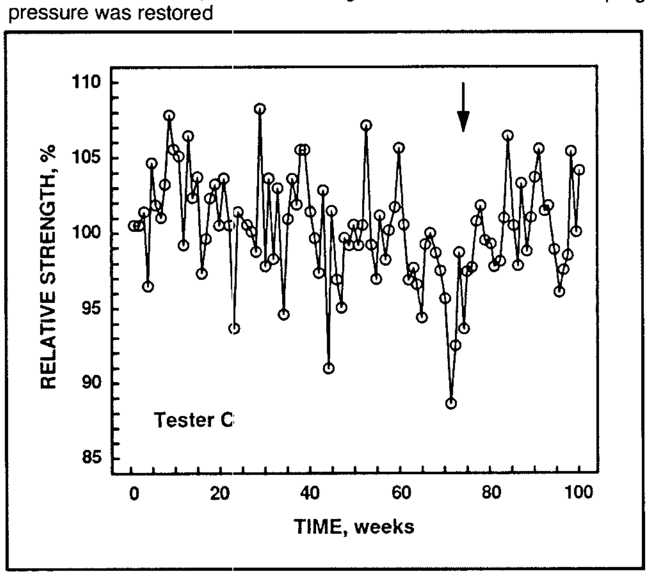
9. CD compressive strength increased after jaw gap was reduced



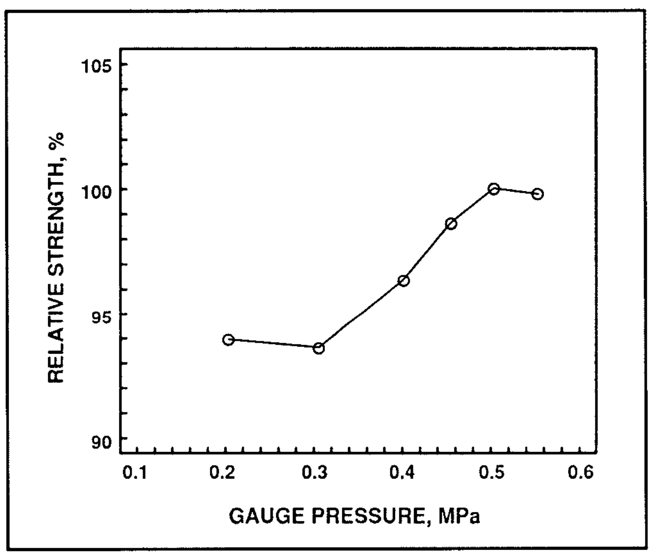
10. Clamping pressure between jaws measured with pressure sensitive film on Tester C (x = Tester B gauge pressures)



11. Measured compressive strength increased after clamping pressure was restored



12. Effect of clamping pressure on compressive strength



5. TAPPI Test Method T-826 pm-86, TAPPI PRESS, Atlanta, 1986.
6. Fellers, C., "Edgewise Compression Strength of Paper" in Handbook of Physical and Mechanical Testing of Paper and Paperboard (R. E. Mark, ed.), Marcel Dekker, New York, 1983, Vol. 1, Ch. 8, pp. 349–383.

The method for measuring jaw gap was devised by Clifford Persinger, machinist at Covington Research, who also gave advice and direction for making accurate measurements of jaw alignment.

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