New rapid method for determining edgewise compressive strength of corrugated fiberboard

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ABSTRACT *The objective of this study was to determine if corrugated fiberboard specimens that had been necked down with a common router would yield acceptable edgewise compressive sgrength values. Tests were conducted on specimens prepared using a circular saw and router, and the results were compared with those obtained on specimens prepared according to TAPPI Test Method T 811. The materials used in the tests included single-wall constructions of A, B, anbd c flutes and samples of double-wall and triple-wall corrugated fiberboard. The results indicated that there was no practical significant difference in the edgewise compressive strength values obtained using the specimens necked down with a router and those obtained using the TAPPI test method, except for one of the waxed flute samples, which showed low strength because of failure at the loading edges.*

KEYWORDS:
Test methods
Edge crush tests
Compression strength
Strength tests
Corrugated boards
Sample preparation
Accuracy

The top-to-bottom compressive strength of a corrugated fiberboard container is one of its most important attributes. The compressive strength relationship among the container, the combined board, and the component paperboards has been and remains a subject of much research (*1*). Most reports on this subject define the relationship by connecting some property of the combined board with box strength. Edgewise compressive strength was recognized as the major combined-board property by McKee et al. (*2*) in 1963.

The edgewise compressive strength of combined board is determined using a short-column test, which is generally performed in accordance with procedures given in TAPPI Test Methods T 811 or T 823. Though the TAPPI test methods will give good results for most corrugated fiberboards, it is laborious and time-consuming to prepare the wax-dipped specimens. (The wax is used to reinforce the loading edges of the specimens and prevent edge failure.) This has led the European community to adopt an alternative method that uses an unwaxed specimen (25 mm high by 100 mm wide), even though this specimen shape was found to give low compressive strength values because of specimen failure at the loading edges (*3*).

The U.S. adopted the waxed specimen, although concern about the time needed to prepare the waxed specimen has hindered its universal adoption. Another area of concern and subsequent research was the method of cutting the test specimens. Research in this area was summarized by Eriksson in 1979 (*4*).

The objective of this study was to determine whether short-column tests using specimens that had been necked down with a router would perform as well as specimens that had been wax-dipped. In order to be judged effective, the router-necked-down specimens would have to

- Give the inherent compressive strength of the combined board
- Resist failure at the loading edges
- Have low variability
- Be equally applicable to single-wall, double-wall, and triplewall specimens, regardless of the type of paperboard or adhesive used
- Be simple and rapid to prepare.

Results and discussions

Results of the tests for single-wall constructions using A, B, and C flutes and the double-wall and triple-wall constructions are given in Table I and plotted in Fig. 1. It is apparent that the strength values obtained using the specimens that had been necked down with a router are not significantly different from the values obtained using the waxed specimens, with the exception of Material 746 (C flute), which gave low values for the waxed specimens because of failure at the loading edges. Differences greater than 10% were considered to be of practical significance, since the compressive strength of corrugated containers

I. Comparison of edgewise compressive strength using TAPPI wax-dipped and router-necked specimens

Material	TAPPI (waxed) Compressive strength, kN/m	TAPPI (waxed) Standard deviation, kN/m	TAPPI (waxed) Coefficient of variation, %	TAPPI (waxed) 95% confidence interval, [a] kN/m	Router-necked (unwaxed) Compressive strength, kN/m	Router-necked (unwaxed) Standard deviation, kN/m	Router-necked (unwaxed) Coefficient of variation, %	Router-necked (unwaxed) 95% confidence interval, [a] kN/m	Difference kN/m	Difference %
594 A-flute 205-127-205[b] Recycled	7.54	0.89	11.7	6.9-8.2	7.39	0.71	9.6	6.9-7.9	-0.15	-2.0
681 A-flute 205-127-205 100% Oak	9.34	0.47	5.0	9.0-9.7	8.91	0.65	7.3	8.4-9.4	-0.43	-4.6
701 A-flute 205-127-205 Recycled	8.85	0.99	11.2	8.1-9.6	9.17	0.84	9.2	8.6-9.8	+0.32	+3.6
342 A-flute 336-161-336 Commercial	13.98	0.63	4.5	13.5-14.4	14.72	0.51	3.5	14.4-15.1	+0.74	+5.3
1130 B-flute 205-127-205 Commercial	8.92	0.62	7.5	8.5-9.4	8.66	0.34	3.9	8.4-8.9	-0.26	-2.9
421 C-flute 205-127-205 Commercial	8.42	0.33	3.9	8.2-8.7	8.14	0.45	5.6	7.8-8.5	-0.28	-3.3
1131 6-flute 205-127-205 Commercial	5.22	0.45	5.5	7.9-8.5	8.80	0.64	7.3	8.3-9.3	+0.58	+7.1
741 C-flute 205-127-205 100% Birch	11.09	0.79	7.14	10.5-11.7	10.48	1.38	13.2	9.5-11.5	-0.61	-5.5
746 C-flute 439-205-432 PD Birch Med.	22.88[c]	1.39	6.1	21.9-23.9	25.48	1.03	4.0	24.7-26.2	+2.60	+11.4
1132 BC-flute DW[d] 205 — 127-205 Bal. Commercial	14.88	0.45	3.0	14.6-15.2	14.63	0.77	5.3	141-15.2	-0.25	-1.7
871 ABC-flute TW[d] 439-127-205 Bal. Commercial	27.07	1.08	4.0	26.3-27.8	29.29	1.22	4.2	28.4-30.2	+2.22	+8.2

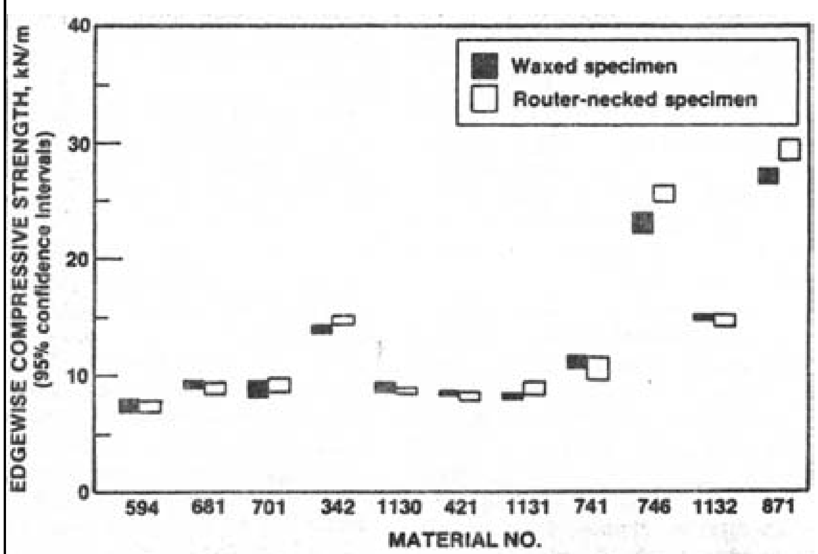
[a] 95% confidence interval = avg.±2.26S (std. deviation/10$^{1/2}$). [b] Nominal weights of component paperboards in g/m^2. [c] Failed at loading edge. [d] The DW and TW materials were balanced (Bal.) construction. Component weights for DW = 205-127-205-127-205; TW = 205-127-205-127-439.

typically varies by 10%. Using the same method of statistical analysis as reported in the literature (5), we found no statistical difference at the 5% level between the waxed specimens and those that had been necked down with a router, with the exception of the previously mentioned Material 746 and the triple-wall Material 871.

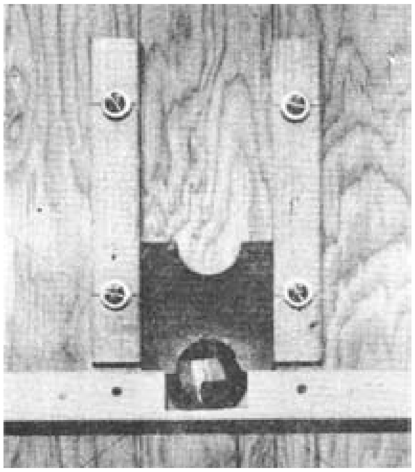
Though the difference was less than 10% between the two triple-wall specimens, the statistical analysis indicates that this difference is real. Considering the higher loads occurring in the triple-wall materials, it is probable that the difference can be explained partially by premature failure at the loading edges, as was clearly evident in Material 746, where the medium was press-dried paper. In fact, there was some evidence of edge-load failure for the triple-wall material tested using the waxed specimens, but it was not as great as that observed with Material 346.

These does not appear to be a significant difference in the variability of

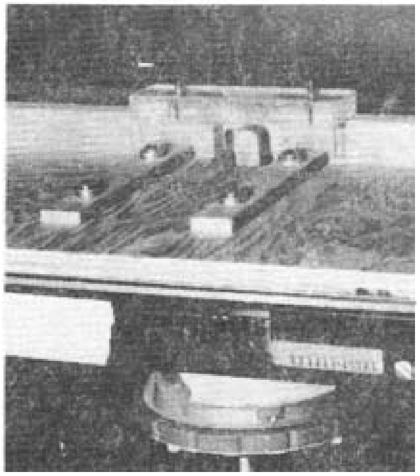
1. Edgewise compressive strength of single-wall (A, B, and C flutes), single-wall, double-wall, and triple-wall specimens. The numbers along the bottom axis refer to materials listed in Table I.



2. Top view of router guide with specimen in place.



3. Side view of router guide and finger protector.



the two test methods. The materials chosen for these tests covered a broad range, from single-wall constructions of A, B, and C flute to double-wall and triple-wall specimens, and all specimens were composed of commercial and experimental paperboards made from softwoods, hardwoods, and recycled fiber. Thus the specimens that had been necked down with a router gave results comparable to waxed specimens across a wide spectrum of materials. These results are essentially the same as the results reported for necked-down specimens that were prepared using a circle cutter instead of a router (*5*). Preparation of specimens with a circle cutter is very time-consuming and yields no benefits beyond the cosmetic appearance of specimens with clean edges.

The method for specimen preparation with the router is simple and rapid—200 specimens were necked down in 35 min. Once the guide is set up. the specimen uniformity is acceptable. The router-cut edges retain fragments of paperboard, but this has no effect on test results. Router wear on this limited number of specimens appeared minimal. The specimens that were cut last looked just like those that were cut first.

The use of router-cut specimens has other advantages. Specimen reconditioning, which is sometimes done when using waxed specimens, is eliminated along with the problems caused by the varying sensitivity of the different paperboards to wax flow.

Tests using necked-down specimens have a further advantage in that if a stronger corrugated fiberboard is developed and the necked-down specimen fails at the loading edges, the option of further reinforcement is possible using wax in combination with the necked-down specimen.

Limited tests using a twin-knife device to cut the 51-mm × 51-mm specimens also gave acceptable results. Limited tests using a hand-held knife gave the expected poor results—significantly lower strength values and increased variability.

Conclusion

Based on these data, a specimen that had been necked down with a router gave results that, with one exception, were comparable with those obtained using TAPPI test methods. One of the waxed C-flute samples gave low strength values because of failure at the loading edges.

Tests using specimens necked down with a router are fully comparable with TAPPI test methods, in terms of

- High strength values
- Low variability
- Resistance to edge failure
- Applicability to single-wall, double-wall, and triple-wall constructions.

Test specimens necked down with a router are easier and quicker to prepare, require no secondary conditioning, have higher potential for successful use with high-strength materials, and should be considered for universal adoption.

Experimental

Materials

The material number, type of flute, nominal paperboard weight combination, and type of paperboard material are given in Table I. Nominal weights of facings and medium are given in g/m^2.

Specimen preparation and testing

A radial-arm saw equipped with a small-tooth, no-set, hollow-ground blade was used to cut the specimens. Though a radial-arm saw was used for these specimens, satisfactory results can also be achieved using a table saw with a similar type of blade. However, it is important that the throat plate on the table saw have as little clearance between the saw blade and the plate edge as possible. This can be achieved by using a hardwood throat plate instead of the metal one that is usually supplied with the saw.

To form the necked-down portion, a commercial wood router with a 25.4-mm-diameter straight carbide bit with two flutes and a 635-mm shank was used (Ela Co.,[1] Cat. No. 68166). A low-cost specimen guide was fabricated using adjustable wood strips. A plexiglass shield was designed to protect the operator's fingers. Setup is shown in Figs. 2 and 3.

The specimens of each prepared according to TAPPI Test Method T 811.

Ten specimens of each material and shape were tested in compression using a TMI flexible beam tester operated at a movable head speed of 38.3 mm/min (1.5 in./min).

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Special appreciation is extended to Dave Schroeder, engineering technician at the Forest Products Laboratory, who conducted the tests and conceived. designed. and built the router guide and safety shield.

Received for review May 16.1985.

Accepted Aug. 20, 1985.

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