Towards an international standard method for the edgewise compression test of corrugated board—a second opinion

John W. Koning, Jr.

It is recommended that the router necked-down specimen and the test procedure outlined in TAPPI Test Method T 823 pm-84 be adopted as the international standard method.

I read with interest Ronald Stott's recommendation in January's issue (*1*) to adopt the FEFCO method No. 8 with mandatory use of a Billerud-type cutter as the international standard. I agree with Stott concerning the importance of the edge-crush test and its relationship to box performance (*2–6*). In refutation of Stott's recommendation, however, I recommend that the TAPPI procedure outlined in Test Method T 823 pm-84, using a router necked-down specimen for edgewise compression testing (ECT), be adopted as the international standard method.

One reason the International Standards Organization (ISO) has not adopted the FEFCO test method is that several important considerations have not been adequately addressed. These considerations must be taken into account in making the proper selection of an international standard.

Specimen cutting

Based on the work of Eriksson (*7*), there is no question that specimen cutting is important, especially for the rectangular specimen used in the FEFCO method. The FEFCO interlaboratory comparisons have also shown this to be true. The Billerud cutter does work satisfactorily for single-wall or double-wall, lightweight, corrugated fiberboard samples, but I have yet to see data that support any knife device as a satisfactory method for cutting heavyweight, double- or triple-wall corrugated fiberboard.

Until such data are presented, the use of a tablesaw equipped with a small-tooth, no-set, hollow-ground blade and a minimum-clearance throatplate is the only cutting method that is satisfactory for all grades and thicknesses of corrugated fiberboard. A cutting method should not be accepted as a standard if it has not been proven with certain grades, even though the production volume in those grades is not large.

Koning is program coordinator, Engineering Professional Development Department, College of Engineering, University of Wisconsin, Biotechnology Center, 1710 University Ave., Madison, Wis. 53705.

Specimen shape

This controversy has been going on since Kellicutt (*8*) proposed a rectangular specimen shape of 25 × 150 mm (1 × 6 in.). The FEFCO specimen shape differs from the Kellicutt specimen only by being 50 mm less in width. All of the specimens mentioned in Stott's article have been evaluated (*2, 9*), except for the latest IPC approach, and the results indicate that the necked-down or wax-dipped specimen gives the best results relative to the criteria suggested by McKee *et al.* (*2*). These criteria are:

1. Highest attainable load, not artificially achieved
2. Rupture resembling failure of the combined board in the box
3. Absence of bending
4. Favorable correlation with box compression strength (accounting also for the effect of flexural stiffness on box strength).

There is no question that the results obtained with the FEFCO shape are related to results achieved from some of the other shapes, as Stott points out (*10*). However, this relationship holds only for the weaker grades and is questionable with the stronger grades, as shown in previous work (*11*).

There is a much more fundamental problem with the 25 × 100-mm FEFCO specimen. It fails by mashing of the paperboards at the loading edges instead of by structural failure of the paperboard components, as occurs in a necked-down or wax-dipped specimen. This mashing failure results in low load values and does not give a good estimate of the actual compressive strength of the

I. Comparison of various ECT methods

Criteria	FEFCO (Billerud)	Necked-down (Saw/router)	Wax-dipped (Saw)	Clamped (Billerud)
Highest attainable load level not artificially achieved	No	Yes	Yes	. . .
Rupture resembling failure of the combined board in the box	No	Yes	Yes	. . .
Absence of bending	Yes	Yes	Yes	. . .
Favorable correlation with box compressions str.	Yes	Yes	Yes	. . .
Consistent with theory	No	Yes	Yes	. . .
Sensitive to material defects	Moderate	Yes	Yes	. . .
Acceptable within and between laboratory variability	Yes	Yes	Yes	. . .
Applicable to all grades of corrugated	No	Yes	No	No
Easy to prepare specimen	Yes	Yes	Moderate	Yes
Easy to test	Yes	Yes	Yes	Moderate
Specimen requires reconditioning	No	No	. . .	No

combined board. A more realistic failure is achieved by reinforcing the loading edges or reducing the cross-sectional area in the center of the specimen. Structural failure is the mode of failure in the corrugated fiberboard adjacent to the corners of a box, as pointed out by McKee *et al.* (*2*). Though it may be expedient to select a specimen shape that fails by a mode different than that of a box, it is a questionable choice for a standard.

Regarding other specimen shapes, so far they have all been found lacking—low strength values, poor reproducibility, bending, etc. (*2*, *9*). The exception is the necked-down specimen. The major problem with the necked-down specimen was its high preparation time while maintaining accuracy. The router approach solves this problem (*11*). However, there are three concerns with this method:

1. The router is noisy.
2. There is fiber dust.
3. The operator has to be safety conscious.

If these conditions are deemed unacceptable, the use of a wax-dipped specimen is a good second choice, but this technique does suffer from a few drawbacks, including reconditioning time, wax migration due to improper control of the wax temperature, and reduced loads with corrugated fiberboard of high strength. A study is underway to determine the importance of the need for reconditioning the specimen after waxing.

Though the economics of specimen preparation and testing are important, they are still secondary to the necessity of selecting a specimen and a test method that meet the primary purpose of conducting the test—to accurately evaluate the edgewise compressive strength of the combined board.

Clamping vs. not clamping

One of the most recent suggestions by the Institute of Paper Chemistry is to use an unwaxed rectangular sample clamped in a Japanese-designed test fixture (*1*). In 1960, McKinlay (*12*) suggested a similar approach in which only one edge was clamped, but the results were low load values. The more recent approach of clamping both loading edges raises the load values, but many specimens still fail at the loading edges, and this can lead to a need for additional specimens and testing time.

Another major drawback is that the use of clamps introduces a source of variability caused by varying clamping pressure. A method to control the clamping pressure would help but could lead to many disagreements on proper clamping pressures, if history is any guide. In our industry, we still have no way to standardize burst clamping pressures for corrugated fiberboard, and it appears we would be faced with a similar problem with ECT. Unless convincing data can be developed from extensive round-robin testing, it will be hard to convince many people that a test method that involves clamping will make a good standard.

Even if a successful clamping fixture is developed and clamping pressures are agreed on, it just adds further, unnecessary complications and testing time to the procedure.

Testing machine

Stott mentioned that the difference between Test Methods T 811 and T 823 (T 822 was printed in Stott's paper by mistake) is the machine used (*1*). Actually, the specimen sizes specified in the two methods are also different, but the most important aspect is that TAPPI recognized in T 823 the importance of a standard machine head speed.

This need for a standard speed was pointed out previously (*13*) and is important not only for edge-crush testing but also for flat crush and ring crush tests in reducing variability. Unfortunately, this important aspect is still not considered in many round robin tests, and it leads to all sorts of errors and improper evaluation of data. T 823 should be the basis for the international standard.

Variability

In Stott's paper under "Other Selection Factors," he talks about the FEFCO method having the most favorable variability within the laboratory. While it is desirable to have a test with low variability within the laboratory and between laboratories, this consistency should be achieved through a good method—not by use of a test specimen that is insensitive to flaws in the material and thus gives values of low variability.

Unfortunately, that is exactly what the 25 × 100-mm specimen tends to do, because it fails in a mashing action at the loading edge of the specimen. On the other hand, the necked-down or wax-dipped specimen fails in the paperboard components of the structure. If there is a glue skip or fractured flute, the necked-down or wax-dipped specimens will be more sensitive and will give a proper lower load value (*3, 14*). If a corrugated fiberboard with glue skips is evaluated and the specimens have been selected randomly, the necked-down or wax-dipped specimen will be expected to have a higher variability because it is more sensitive to defects.

If you are interested in quality, you want to know this. Thus, sensitivity to material variability becomes a desirable aspect of a test if it tells how nonuniform the material really is.

Other selection factors

Another serious concern is the acceptance of the additive formula for predicting the compressive strength of a short column (*15*). Based on this formula, the edgewise compressive strength of A-flute corrugated fiberboard is greater than C-flute fiberboard. The C-flute fiberboard is greater than B-flute fiberboard, because of the difference in take-up factor of the corrugating medium. However, in reality, the edgewise strength of B-flute fiberboard is greater than that of C-flute fiberboard, and the strength of C-flute fiberboard is greater than that of A-flute fiberboard. (In terms of box compressive strength, the order is generally: A-flute> C-flute> B-flute.)

Though the difference is small and generally masked when using the 25 × 100-mm specimen, the effect is real (*3*). Moody (*16*) explained this theoretically and presented equations that accurately predict the edgewise crush strength of the combined board based on the engineering properties of the component paperboards and the corrugated structure. This research was done using wax-dipped specimens.

A much more comprehensive analysis was made by Bormett (*17*), in which he compared the additive formula using ring crush data and data obtained with a vacuum-restraint, paperboard edgewise compression apparatus (VECA). Bormett used the engineering model developed by Johnson *et al.* (*6*) and the stress–strain properties of the component paperboards. The results indicated that the Johnson model gave the best predicted ECT values and that the necked-down specimen shape (*11*) provided the better test values. An ECT specimen that conforms with theory and is predictable from the strength properties of the component paperboards and structure is a more important consideration than the expediency of a method such as FEFCO or one using a clamped specimen.

A comparison of the various methods is given in **Table I.**

Conclusion

The selection of an international standard for ECT should not be based on mere popularity or personal familiarity. It should first meet the criteria previously suggested by McKee *et al.* (*2*). Second, it should be sensitive to material or structural defects, be consistent with theory, be applicable to all grades of corrugated fiberboard, and be easy to prepare and test. The necked-down specimen shape (substituted for the wax-dipped specimen in TAPPI T 823) and the TAPPI T 823 test procedure meet these criteria best.

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