Edgewise crush test streamlined by shorter time after waxing

Thomas J. Urbanik, Arthur H. Catlin, Davide R. Friedman, and Richard C. Lund

ABSTRACT: *Measurement of edgewise compressive strength of corrugated fiberboard requires application of paraffin wax to reinforce the test specimen's loading edges. This requires specimen reconditioning after waxing. The traditional 24-h reconditioning is a conservative approach based on the moisture-response rate of cormgated containers. An interlaboratory study examined the effect of reconditioning time on the edgewise compressive strength of waxed specimens prepared by standard test methods. Results show that reducing reconditioning time from 24 h to 2 h produced no significant change in strength values.*

KEYWORDS: Compression strength, corrugated boxes, edge crush resistance, edge crush tests, test methods, time, waxing

Research shows that the edgewise compressive strength of corrugated fiberboard, in combination with the flexural stiffness, relates to the top-to-bottom compressive strength of corrugated fiberboard boxes (*1*). The edgewise compression test (ECT) performed on a rectangular short column of combined corrugated fiberboard determines strength.

The American Society for Testing and Materials (ASTM)'s former Standard Test Method for Compressive Strength of Corrugated Fiberboard (*2*) specifies one method to prepare short-column specimens and determine strength. The TAPPI Test Method on Edgewise Compressive Strength of Corrugated Fiberboard (*3*) specifies a technically identical method except that specimen size is a function of flute construction. A common feature of these two methods is that paraffin wax reinforces the edges of the short-column specimen that are in contact with the compression machine's platens. The wax reinforcement helps to direct the location of failure centrally. Both methods specify a conditioning test environment of 23°C (73°F) and 50% RH. In this environment, the moisture content of specimens increases from a dry, preconditioned environment to an equilibrium level.

The sequence of steps for preparing the test material involves cutting the specimens, dipping the ends in molten paraffin, preconditioning the specimens, and conditioning the specimens. The conservative assumption is that moisture loss resulting from the hot paraffin affects the strength of an already conditioned specimen. Users report that, in practice, specimens are normally cut, preconditioned, conditioned, waxed, and then reconditioned for **24** h.

Objective and scope

The ASTM Committee D-10 on Packaging received a proposal that the ASTM D 2808 Task Group address current issues concerning more-rapid ECT procedures. The Task Group recognized that the specified conditioning requirement of ASTM D 2808 arose as a conservative approach resulting from insufficient knowledge about how wax dipping affects specimen moisture content and short-column strength. The Task Group therefore decided that a pilot interlaboratory study was necessary.

The objective of the study was to measure the strength effects of reconditioning time after waxing using various grades of corrugated fiberboard and conditioned short-column specimens. This report summarizes the results of the interlaboratory study (*4*). The results justify a shorter reconditioning time after waxing.

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Test materials and procedure

Four interlaboratory study participant,~ representing five laboratories contributed to the study. Table I shows the composition of the laboratories by type of loading machine and machine speed. Table II indicates that two laboratories supplied corrugated fiberboard in eight bursting strength and flute-type combinations.

One of the five laboratories cut the single-wall and triple-wall specimens using a no-set circular saw blade according to ASTM D 2808. Another laboratory cut the double-wall specimens using a band saw considered equivalent to the circular saw. Cutting yielded specimens 31.8 mm (1.25 in.) high by 50.8 mm (2 in.) wide, with height in the axis direction of the flutes.

Each of the five laboratories received an equivalent batch of the cut test specimens to condition, wax, and test according to a specified test plan. Specimens of all eight materials first underwent preconditioning in a dry environment less than 35% RH followed by conditioning at 23°C (73°F) and 50% RH according to ASTM D 685 (*5*). The loading edges of the conditioned specimens were then dipped in molten paraffin. After treatment with wax, the specimens underwent reconditioning at 23°C (73°F) and 50% RH until tested for compressive strength. The time between waxing and testing was 1 h, 2 h, 3 h, 5 h, or 24 h.

I. Test conditions at study laboratories

Laboratory	Machine-type	Machine speed			
		N/s	(lbf/s)	mm/min	(in./min)
1	Flexible-beam	110	(25)		
2	Flexible-beam	110	(25)		
3	Rigid-platen			0.5	(0.02)
4	Rigid-platen			10	(0.39)
5	Rigid-platen			12.5	(0.49)

II. Nominal bursting strength and flute type of test fiberboards

Fiberboard type	MPa	(lb/in.)	Flute type
Single-wall	1.03	(150)	C
	1.38	(200)	C
	1.90	(275)	C
Double-wall	1.90	(275)	CB
	3.45	(500)	CB
	4.14	(600)	CB
Triple-wall	7.58	(1,100)	AAA
	8.96	(1,300)	AAA

Interlaboratory results

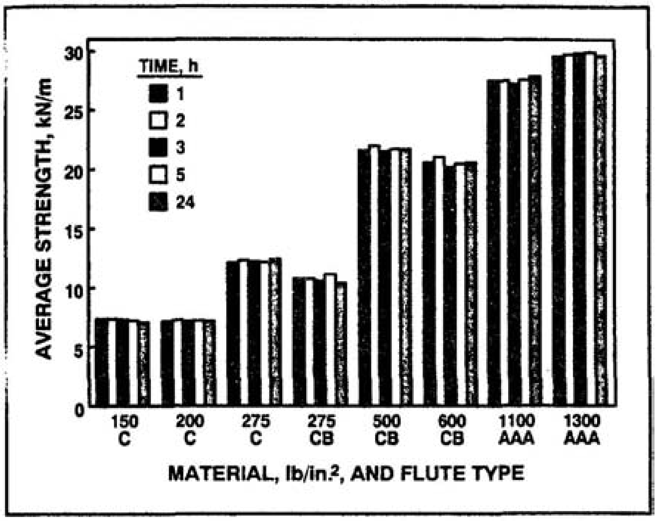
Five interlaboratory participants are less than the minimum of six required for a valid ASTM reproducibility analysis. Nevertheless, data were subjected to a precision analysis following procedures in ASTM E 691 *(6)*. The test data include a summary of results of the statistical analysis. Among the results are the repeatability and reproducibility standard deviations for evaluating within-laboratory and between-laboratory precision, respectively. The interlaboratory test data are available from ASTM.

Figures 1-5 summarize the results of the laboratory tests. Significant strength differences were not apparent among the test specimens as a result of different reconditioning times after waxing. Figure 1 compares the average overall strength values of test materials. **Figure 6** shows the effect of reconditioning on the average strength of materials by laboratory for the 2-h and 24-h reconditioning times after waxing. The results for the two reconditioning times are statistically the same.

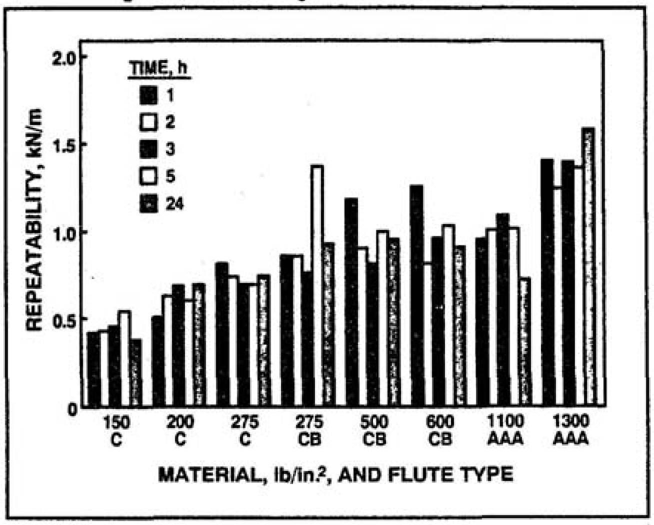
Moisture absorption test

The Forest Products Laboratory (FPL) measured the weight of corrugated fiberboard as a function of time as well as the variation following wax dipping for comparison with the results of the interlaboratory tests. The FPL tests involved short-column specimens cut from commercially purchased, 2.41 MPa (nominal 350 lb/in.), double-wall corrugated fiberboard. The specimens first underwent preconditioning in a dry environment at 27°C (80°F) and 30% RH. Subsequently a batch of six specimens was taken into a

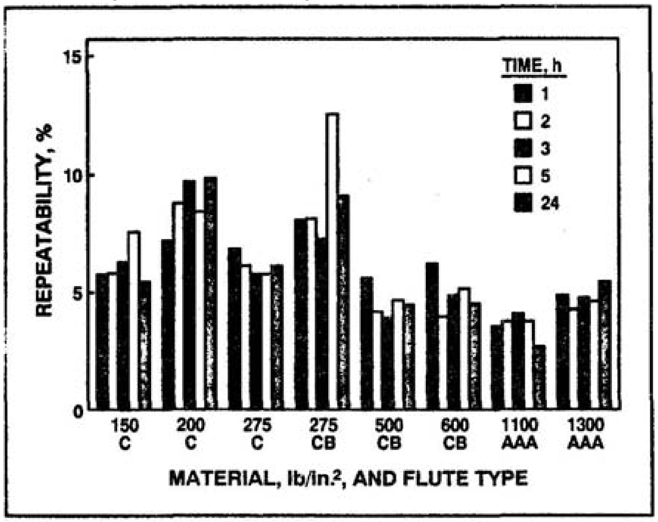
1. Average edgewise compressive strength of eight materials with various reconditioning times after waxing



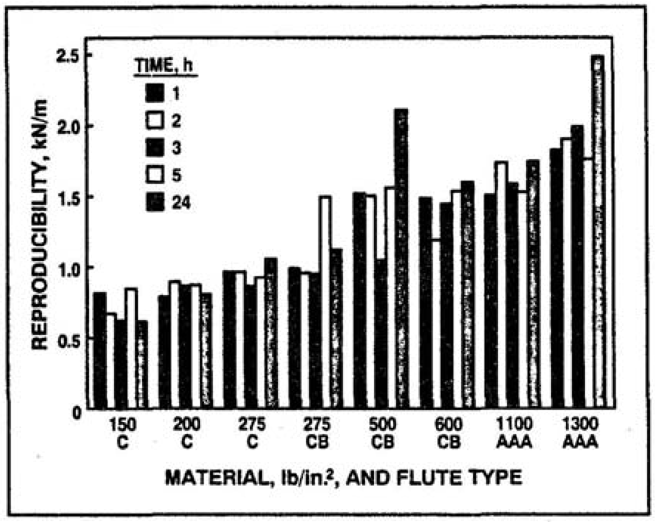
2. Repeatability standard deviation for eight materials with various reconditioning times after waxing



3. Repeatability coefficient of variation for eight materials with various reconditioning times after waxing



4. Reproducibility standard deviation for eight materials with various reconditioning times after waxing

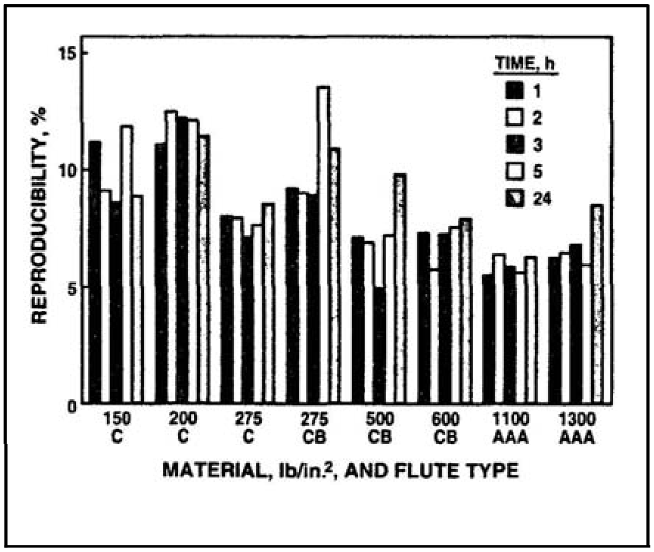


23°C (73°F), 50% RH conditioned room and placed on an electronic scale. The specimens had a surface-to-surface orientation to induce a conservative exposure to penetrating air. A digital oscilloscope connected to the scale continuously recorded weight as the specimens absorbed moisture. Because the room had circulation fans, the scale was away from direct air disturbances. The scale was not isolated within an enclosure. **Figure 7** provides the results of this test. One can ignore spikes in this figure resulting from analog to digital data conversion.

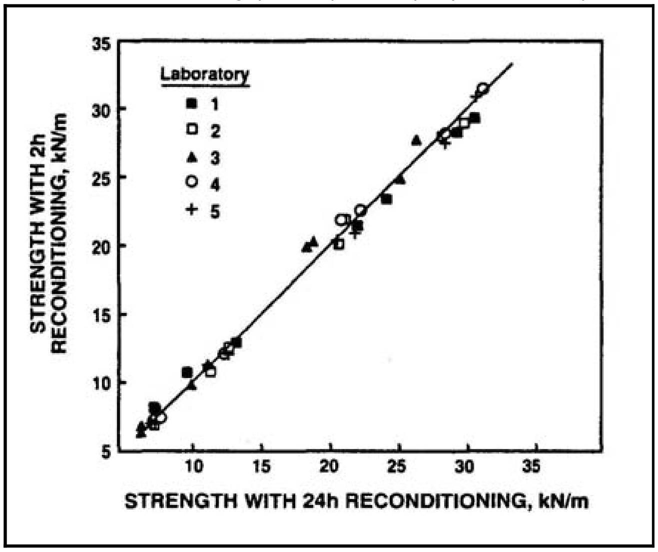
For the next test, equilibrated specimens were wax dipped in the same conditioning room according to ASTM D 2808 specifications and returned as soon as possible to the electronic scale. About 15 min elapsed between wax dipping and weighing. **Figure 8** shows the resulting weight change with moisture reabsorption. The difference between the initial weight in Fig. 8 and the terminal weight in Fig. 7 was due to the weight of wax gained minus the weight of moisture lost through waxing.

The material represented by the postwaxing weight as a function of time curve in Fig. 8 returned to an equilibrium moisture content between 1 and 2 h after waxing. The conservative surface exposure implies that equally rapid reconditioning is possible with triple-wall material. This independent experiment further corroborates the results shown in Figs. 1 and 6. From these we can infer that 2 his sufficient for postwaxing reconditioning.

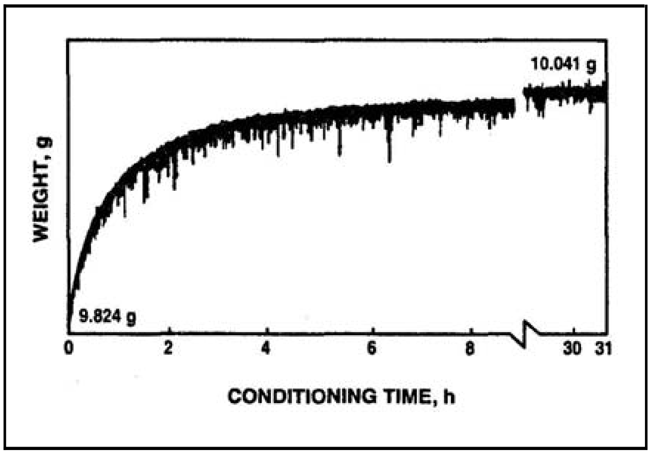
5. Reproducibility coefficient of variation for eight materials with various reconditioning times after waxing



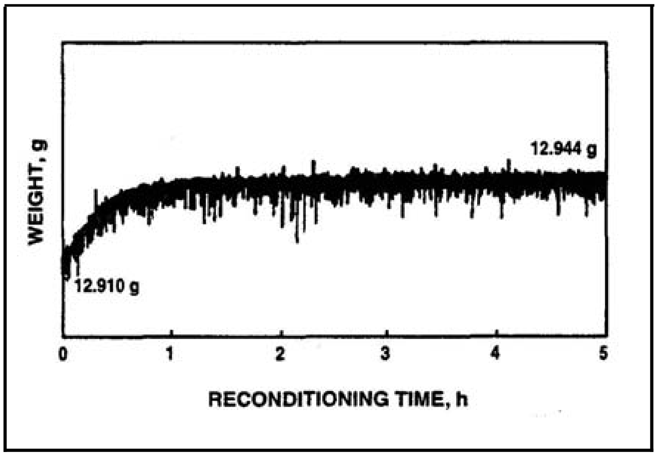
6. Average edgewise compressive strength of materials by laboratory 2 h and 24 h after waxing (Line is plot of equality; r^2 = 0.9937.)



7. Weight of corrugated fiberboard short-column specimens as a function of time in a 23°C (73°F), 50% RH conditioned room after removal from a 27°C (80°F), 30% RH preconditioning room



8. Weight of corrugated fiberboard short-column specimens as a function of time in a 23°C (73°F), 50% RH conditioned room after conditioning and waxing in the same room



Conclusions

Our results indicate that the procedures for the edgewise crush test of corrugated fiberboard should be changed to permit testing of reconditioned specimens 2 h after waxing. For referee testing, additional tests with more laboratories are necessary to determine repeatability and reproducibility criteria.

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