Edge Reinforcement of Honeycomb Sandwich Panels

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Abstract

Protection of the fragile honeycomb core material in hollow-core panels has long been a subject of interest for the manufacturers because it is necessary to seal the panel edges to prevent damage. Traditionally this has been accomplished by using edge banding, which has the added benefit of improving panel bending strength and stiffness. This study focuses on evaluating the effects of edge banding on the bending strength and stiffness properties of honeycomb core panels. The honeycomb panels were made with a combination of different face sheet materials (3-mm hardboard or 6-mm medium-density fiberboard [MDF]), rail types (particleboard or yellow poplar [*Liriodendron tulipifera*]), and rail widths (10 or 38 mm), and had edge-band materials fixed to their long edges using either direct coating, stabilizer edge, or surface folding techniques.

Panels made with the 6-mm MDF face sheet and 38-mm poplar rails had the highest strength properties. To safely apply edge banding to honeycomb core panels, a solid edge reinforcement material is required to prevent the core material from being crushed during the process. The surface folding technique was the best method of edge banding and significantly enhanced the maximum bending moment of honeycomb core panels—more than twice that of panels without edge banding.

The use of lightweight honeycomb sandwich panels in the furniture industry poses a number of challenges, including how to effectively seal and reinforce the edges of the honeycomb panel. The edges must be sealed to protect the face and core materials from damage (liquids, moisture, and impact), provide support for conventional hardware to be inserted, and permit the panels to be fastened to other structures (Bitzer 1997, Moody et al. 2007).

Strips of solid wood veneer, polyvinyl chloride (PVC), or composite materials (medium-density fiberboard [MDF], particleboard, and oriented strand board) have been used as reinforcements for the edges of honeycomb panels during panel manufacture. Industry typically uses edge reinforcements that are large enough to bear a panel's loading requirement (Egger Eurolight 2007). Common edge-banding techniques for honeycomb panels include direct coating, stabilizer edge, and surface folding (Stosch 2008). The edge band runs along the long edges of the honeycomb panels sometimes over a strip of edge reinforcement termed the "stile." It serves to seal panel edges with a decorative finish and improve panel bending strength and stiffness.

There is a dearth of published information directly comparing the load-bearing capacity of honeycomb core panels made with different edge-banding techniques. To address these deficiencies, two experiments were designed to quantify the load-bearing properties of honeycomb core shelves made with different rail materials (i.e., solid wood or composite) using the three different edge-banding techniques. The information obtained was used to fabricate prototype honeycomb core bookshelves from different types of face sheet materials and fastening systems and different methods of edge band application.

Experiment 1 focused on edge rail type and rail width for honeycomb shelves because these edge materials stabilize and reinforce the panel as well as provide the substrate required to fasten the shelves to the gables of the bookcases. The hypothesis for this experiment was that increasing rail width will increase the load-bearing capacity of honeycomb shelves.

Experiment 2 investigated the effect of different edge-banding techniques on shelf strength. Three different techniques for edge band application were investigated with the hypothesis that a technique that maximizes the

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Forest Prod. J. 60(4):382–389.

adhesive contact area between the edge band and the panel will increase maximum bending moment.

Design of Honeycomb Shelves

A survey of local furniture companies that fabricate and use honeycomb core sandwich panels showed yellow poplar wood (*Liriodendron tulipifera*) and M2 grade particleboard to be the most commonly used materials for rails (short edge reinforcement), with screws and brackets as the predominant fastener systems for bookshelf assemblies (Semple et al. 2007). Research on sandwich construction (Zenkert 1997, Moody et al. 2007) has suggested that the strength properties of a sandwich panel are very much determined by the properties of the face material. Preliminary experiments conducted on sandwich panels with different face materials indicated the load-carrying capacities of the hardboard and MDF faces (commonly used ready-to-assemble furniture materials) to be between those of the Masonite sheets (the lowest) and the plywood (the best performing material).

Based on these preliminary results, and to easily identify the edge rail effects on sandwich panels, 3-mm hardboard and 6-mm MDF were used as face sheets for the sandwich construction with open-cell expandable honeycomb (cell size, 32 mm) as the core material. Rail widths of 10 and 38 mm were chosen so that differences in bending stiffness, maximum bending moment, and deflection of the sandwich panels could be detected; a wider rail would likely be so strong as to mask the effects we wanted to examine and would not be in keeping with the lightweight theme of this research.

In Experiments 1 and 2, a common bookshelf size of 1,067 by 305 mm (42 by 12 in.) with a thickness of 38 mm was chosen for the construction of the honeycomb shelves as illustrated in Figure 1. To ensure a common sandwich thickness of 38 mm for both the 3-mm hardboard and 6-mm MDF face materials, honeycombs with cell wall heights 32 and 26 mm, respectively, were used. Limitations on the width of the edge band material normally available for purchase led to the reduction of the shelf thickness to 32 mm in Experiment 2. As a result, the experimental design included control shelf samples that were fabricated in the same way as shelves in Experiment 1 but with a 32-mm thickness. Note that the guidelines for furniture construction (Architectural Woodwork Institute 1999) state that shelf thickness should be a minimum of 19 to 27 mm ($^3/_4$ to $1^1/_{16}$ in.).

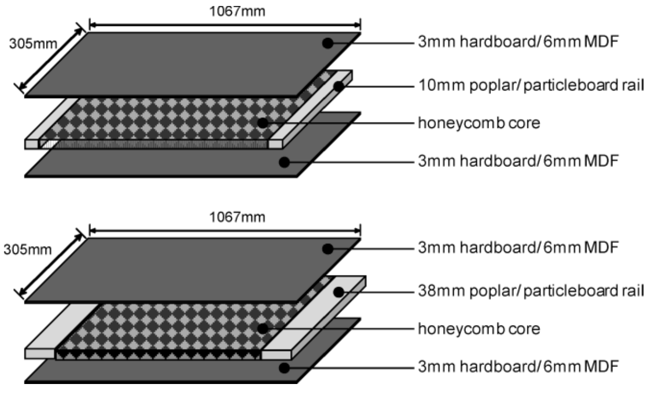


Figure 1.—Exploded view of two honeycomb core shelves (total sandwich thickness is 38 mm).

Sandwich Panel Assembly

The edges of the unexpanded Kraft paper honeycomb strips were first roughened with sandpaper to increase the surface area exposed to the adhesive. Before expansion incisions 2 mm deep were made at spaced intervals along the length of the paper honeycomb to create pathways for air flow during and after sandwich panel fabrication. The honeycomb strip was then evenly expanded on a nailed 1,219 by 2,438-mm (4 by 8-ft) oriented strand board and placed in a walk-in oven at 80°C for 3 hours to set.

The face sheet materials were cut to dimensions 1,067 by 305 mm, and the honeycomb core material to 1,047 by 305 mm. The particleboard and yellow poplar rails (edge reinforcements) were cut to a length of 305 mm and to two different widths, 10 and 38 mm. DURO-LOK 422150 glue (a cross-linked polyvinyl acetate containing a phenolic resin) was applied to the bottom face sheet, and the rails and honeycomb core were carefully placed onto it; no catalyst was used because none is required for interior applications. An average of 127 g of glue was applied to each face sheet. The rails and honeycomb material were kept in place with the aid of flat wooden sticks, and the top sheet was then glued in place. The sandwich panels were weighed down with a 26-mm-thick medium-density board evenly loaded with 50 kg of weight while the next sandwich was assembled. The stacks were left to cure for 2 days before removing the weights.

Experimental Designs

Experiment 1

Experiment 1, Part 1 focused on the edge rail material (type and width) and has the following factors and levels:

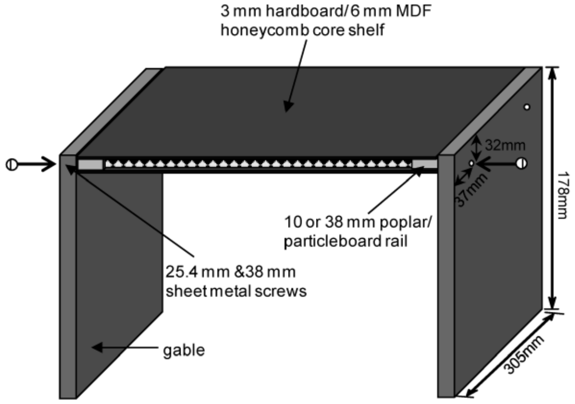
1. face sheets (3-mm hardboard and 6-mm MDF),
2. rail type (particleboard and yellow poplar), and
3. rail width (10 and 38 mm).

The honeycomb shelves were fixed to 305 by 178-mm particleboard gables using 25.4 mm and 38 mm no. 8 fully threaded sheet metal screws (with 14 tpi) according to System 32 (Architectural Woodwork Institute 1999) as illustrated in Figure 2a. The resulting treatment combinations were replicated three times for a total of 24 panels.

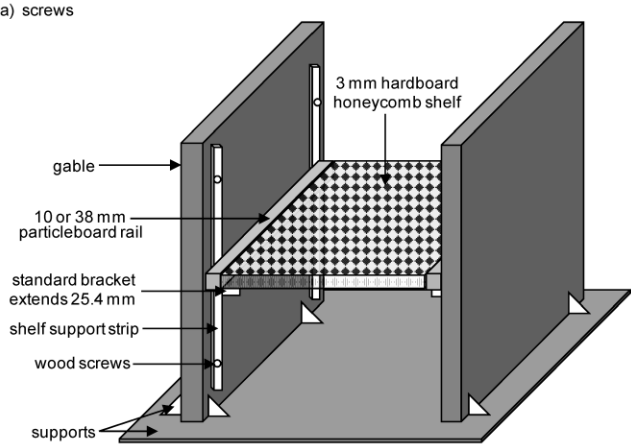
Part 2 of this experiment examined the bending properties for shelves supported by either the no. 8 fully threaded sheet metal screws or standard shelving brackets (Fig. 2b). Honeycomb shelves were made of 3-mm hardboard faces and particleboard rails in widths of 10 and 38 mm. Three replicate panels were fabricated for rail width and fastener combination, for a total of six panels.

Experiment 2

This experiment was designed to isolate the true effect of edge banding on the bending stiffness and load-carrying capacity of honeycomb core shelves. The rail width needed to be as small as possible to minimize any masking effects of wider rails; 10-mm particleboard rails were therefore selected as the smallest practical width. The honeycomb core shelves were fabricated using 3-mm hardboard faces and open cell expanded honeycomb. Shelves were attached to the particleboard gables using the standard shelf bracket system (Fig. 2b). Three different edge-banding techniques were evaluated: direct coating, stabilizer edge, and surface



(a) screws



(b) brackets

Figure 2.—Testing of (a) screw-fastened and (b) bracket-fastened honeycomb shelf assemblies.

folding. Each technique was replicated six times for a total of 18 panels.

Methods of edge band application

For all three techniques, a PVC edge band 3 mm thick and 32 mm wide was glued to sandwich panels using an automated SCM (Olimpic K 1000) edge-banding machine.

Direct coating technique.—In this process the PVC edge band was glued directly onto the edges of the sandwich panels as shown in Figure 3.

Stabilizer edge technique.—For this process, each face layer had a 3-mm recess cut from its inside edge (Fig. 4a). These recesses allowed for a vertical support edge in the form of a 3-mm strip of thick hardboard material to be manually inserted along both long edges of the honeycomb shelves using DURO-LOK glue. After the support edge had been inserted, the PVC edge band was glued to the outside (Fig. 4b).

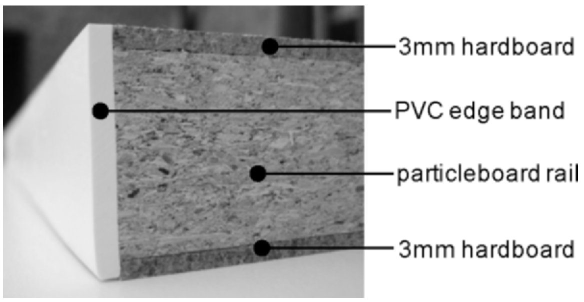


Figure 3.—Side view of a sandwich panel directly coated with a PVC edge band.

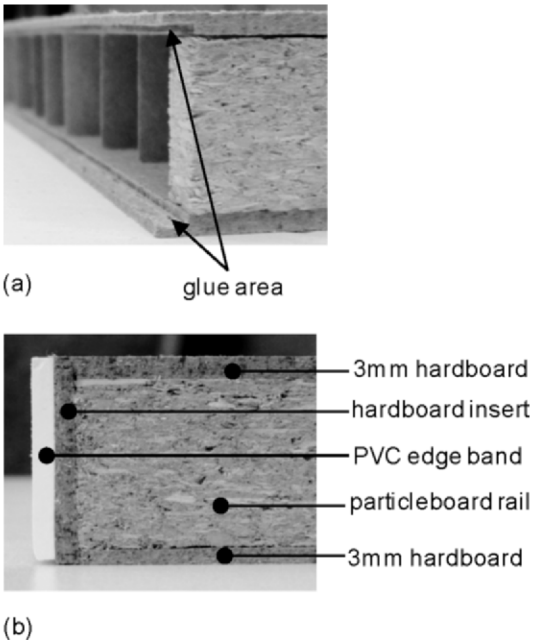


Figure 4.—Honeycomb shelf showing (a) top and bottom recesses for support edge insert and (b) inserted hardboard support edge attached to a PVC edge band material.

Surface folding technique.—This process used a vertical support strip similar to the stabilizer edge technique except that the top and bottom face sheets were cut in at a 45° angle (Fig. 5a). The hardboard insert (support strip) was also cut at a 45° angle along its edges to fit between the face sheets (Fig. 5b). The PVC edge band was then subsequently applied.

Testing honeycomb shelf strength properties

For each experiment the peak load and deflection value (y) of the sandwich panels were measured and the failure modes noted. The bending stiffness (D) and maximum moment (M) were computed in accordance with ASTM Standard C393-00 (American Society for Testing and Materials 2000) for hollow core sandwiches. A four-point bending test (third point loading) was conducted using the screw and standard bracket shelf assemblies at a loading rate of 4 mm/min on a Sintech 30D testing machine. Per the ASTM standard, rubber pads (102 by 305 by 25.4 mm) and a 3-mm-thick steel sheet were located directly beneath the loading noses to help dissipate the load and prevent localized crushing of the core directly beneath the loading noses.

The ASTM standard used in this study to test for flexure properties was issued under the fixed designation C393-00 and covered the determination of sandwich properties when subjected to flatwise flexure. In this standard, it was recommended that the speed of testing be set to ensure maximum failure occurred between 3 to 6 minutes after the test began. This standard also allowed for separate tests to be conducted for the core shear strength and modulus in accordance with test method C273-00.

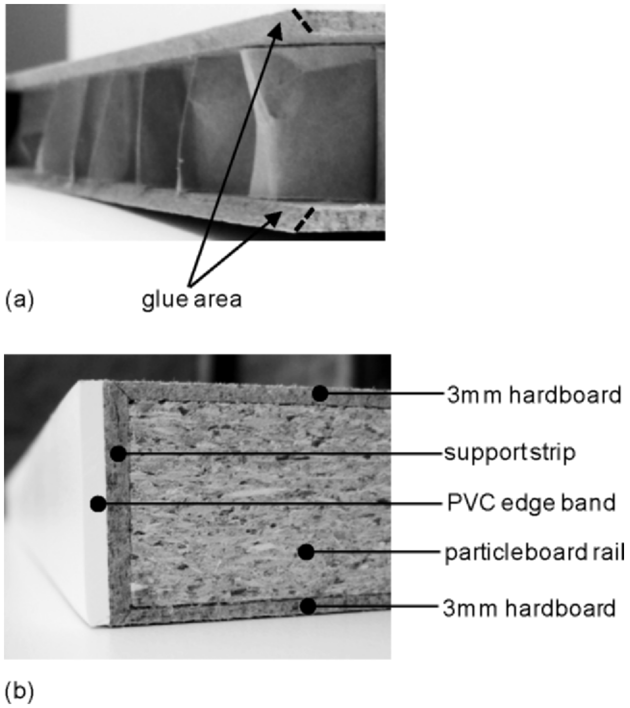


Figure 5.—Honeycomb shelf with (a) 45° beveled edges (the dashed line shows the edge of the 45° bevels) and (b) inserted support strip and PVC edge-band material.

Standard ASTM C393-00 has since been superseded by ASTM C393/C393M-06, which requires the use of ASTM D7250/D7250M-06 to determine the flexural and transverse shear stiffness of sandwich panels. Generally, the test specimen configuration remained the same. Major differences in testing procedure occur with the speed of testing, which has been set at a suggested standard rate of 6 mm/min, and the ability to test and calculate the flexural stiffness, shear rigidity, and core shear modulus on a single specimen with two loading configurations.

Results and Discussion

All experiments were designed using a completely randomized design fixed effects model and analyzed using a two-way analysis of variance. SAS version 9.1 was used in the analysis of the experimental data using a 5 percent significance level. Scheffé's multiple comparison method was used to identify significant differences between means.

Experiment 1

During testing failure in the honeycomb shelves generally occurred as follows.

1. The shelves flexed under load and the honeycomb cells directly beneath the loading noses were crushed. This crushing gradually spread to surrounding cells.
2. During loading, there was delamination of the honeycomb core from the face sheets (mostly the bottom faces) at the ends of the shelves where it was fixed to the gables. The debonding was attributed to the failure of the glue joint between the face and core materials due to the high shear stresses at this point.
3. The rails separated from the face sheets, mainly the bottom first then the top sheet; this was more pronounced for the narrower 10-mm particleboard rail than the 38-mm particleboard or yellow poplar rails. These separations indicated a failure in the glue joint between the rails and face material as a result of over-loading.
4. Finally, the combination of crushing of the core and delamination of the core material and rails from the face ultimately led to failure of the sandwich structure.

During loading, the joints between the gables and the shelves (hardboard and MDF) with 10-mm rails were greatly stressed resulting in a 2- to 3-mm gap between the edge of the shelf and the gable face. This observation indicates the substrate (rail) provided for the fastener was not sufficient to support the shear forces produced during loading. Most of the 10-mm particleboard rails cracked and split at the points where the 25.4-mm screws were inserted, some rails then broke off above the glue bond between the rail and the face sheet (Fig. 6a); only cracks were observed in the 38-mm particleboard rails (Fig. 6b). For the 6-mm MDF shelves, delamination of the MDF face sheet occurred at the ends adjacent to the gables (Fig. 6c). As core failure progressed, in two samples the face sheet broke right where the support from the 38-mm poplar rail ended (Fig. 6d). The failure modes observed in Figures 6c and 6d indicate the failure of the face sheet material caused by the high bending moments at the panel edges. Failure in the shelves assembled with brackets was usually within a few millimeters of the bond between the face materials and the rail (Fig. 6e).

Relationship between face sheet type, rail type, and rail width

The bending moment acting on the shelf is maximum at the point were the rail is attached to the gable. The rail

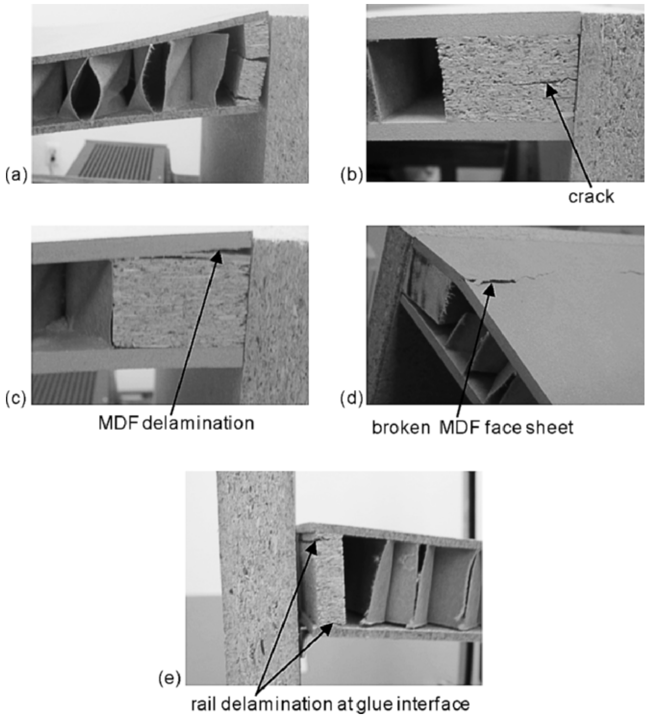


Figure 6.—Honeycomb shelf failure modes: (a) broken 10-mm particleboard rail, (b) cracked 38-mm particleboard rail, (c) delaminated MDF face sheet, (d) broken MDF face sheet, and (e) rail delamination at glue lines.

would tend to rotate and remain at 90° to the face materials but cannot because of the screw fastening it to the gable. This results in the screw effectively prying the rail apart and producing the crack seen at the midpoint of rail height in Figure 6a. Statistical analysis for the shelves indicated significant differences ($P = 0.0156$) between only the types of edge rail materials used (particleboard and yellow poplar), but no differences in the widths (10 and 38 mm). As shown in Figure 7a, the 3-mm hardboard honeycomb shelves reinforced with the yellow poplar rails recorded higher maximum moment values compared with those containing the particleboard rails, an observation consistent with the bending stiffness values (Table 1) for the respective shelves.

In contrast, the 6-mm MDF honeycomb shelves recorded a significant rail width effect ($P < 0.0001$) on the maximum bending moment of the shelves (Fig. 7b). Shelves with the 38-mm-wide rails (whether particleboard or yellow poplar) recorded higher strength values than the 10-mm rails. It is important to also note the differences in maximum bending moment values between the 3-mm hardboard and 6-mm MDF honeycomb shelves. The higher moment values obtained for the 6-mm honeycomb shelves are attributed to its greater stiffness under bending load (Table 1).

The computed cross-sectional properties (bending stiffness) of the honeycomb shelves are presented in Table 1, and these can be used to predict a panel's ability to resist bending moments and deflection. As the rail at each end of the shelf is screwed to the gable, little deflection occurs, whereas the maximum deflection occurs at the midpoint of the shelf between the loading noses. Therefore, the maximum deflection in the honeycomb shelves occurred in the section of the sandwich panel between the two loading noses where there is no rail material. The bending stiffnesses given in Table 1 are grouped according to the types of honeycomb shelves, 3-mm hardboard or 6-mm MDF.

For each honeycomb shelf there are two cross sections of importance, the ends of the shelves with the edge rail materials (particleboard or yellow poplar) and the middle section consisting of the paper honeycomb core. Irrespective of the combination of edge rail material and width, the middle sections of the hardboard and MDF shelves have the same bending stiffness value, 2,562 and 2,798 N·m^2, respectively. For any shelf type, the bending stiffness values for the particleboard or poplar rail section were equal because the cross-sectional area remained the same regardless of rail width. These bending stiffnesses suggest that shelves with particleboard rails would record relatively higher deflection values compared with those edged with poplar rails. As observed from the maximum bending moment results (Fig. 7), it would generally be expected that for each rail material (particleboard or yellow poplar), honeycomb shelves with the 10-mm rail width would experience comparatively more deflection than the 38-mm rails.

Table 1.—*Computed bending stiffness of honeycomb shelves with different combinations of face and rail materials and rail width.*

Shelf type	Rail width (mm) and material[a]	Bending stiffness (kN·m^2)	
		Middle section	Rail section
3-mm hardboard	10 PB	2.562	4.415
	38 PB		
	10 Poplar		11.64
	38 Poplar		
6-mm MDF	10 PB	2.798	4.075
	38 PB		
	10 Poplar		7.667
	38 Poplar		

[a] PB = particleboard rails; Poplar = yellow poplar rails.

The deflection values measured for the 3-mm hardboard shelves (Fig. 8) indicated a significant interaction ($P = 0.0023$) between the type of rail material and its width used for edge reinforcement. Statistically only the honeycomb shelf reinforced with the 10-mm particleboard with the lowest deflection value was significantly different from the other shelves. This was due to the split that occurred during loading in the rather thin particleboard rail at the point where the screws were inserted (as shown in Fig. 6a). The results therefore imply 3-mm hardboard shelves reinforced with edge rail materials (with exception of a 10-mm particleboard rail) and subjected to bending loads would have similar deflection values.

The deflection values for the 6-mm MDF shelves also indicated an interaction ($P = 0.0047$) between the type of rail material and its width. As was expected, shelves reinforced with particleboard rails recorded higher deflection values with those edged with the 10-mm rails having significantly larger deflections than the 38-mm rails. However, the same was not the case in the yellow poplar reinforced honeycomb shelves, for which the 38-mm rails recorded greater deflection values. Failure for the 38-mm particleboard rails occurred within a few millimeters of the glue line between the face material and the rail (Fig. 6c). For shelves made with solid yellow poplar rails, the face sheets failed in bending within a few millimeters from the edge of

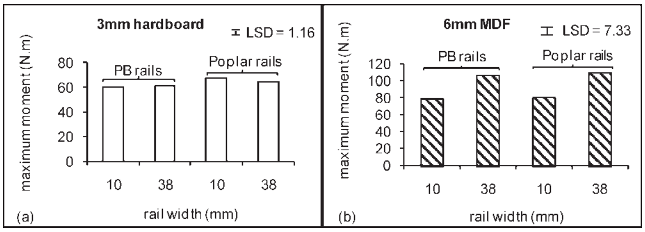


Figure 7.—Maximum bending moment of 3-mm hardboard and 6-mm MDF honeycomb shelves with combinations of different rail widths and rail materials. n = 3 *for each mean. Error bars represent the least significant difference between means. PB = particleboard; poplar = yellow poplar.*

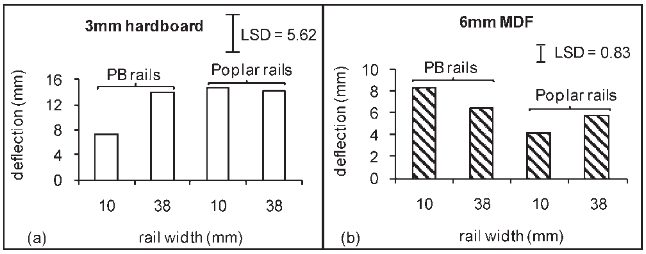


Figure 8.—Panel deflection values for 3-mm hardboard and 6-mm MDF honeycomb shelves. n = 3 *for each mean. Error bars represent the least significant difference between means. PB = particleboard; poplar = yellow poplar.*

the rail (Fig. 6d) likely due to the higher cohesive strength of the solid wood compared with the composite.

A comparison of the deflection values for the two types of honeycomb shelves indicates the values for the 6-mm MDF shelves were lower than those for the 3-mm hardboard shelves. This was largely due to the differences in their ability to resist bending moments (Table 1).

Effect of fastener system on shelf assemblies

The effect of fastener type (screws or brackets) on the load-bearing properties of honeycomb shelves is shown in Figure 9a. The results indicate that the bending moment properties of honeycomb shelves were significantly affected by fastener type ($P = 0.0090$); shelves fastened with brackets irrespective of the rail widths carried significantly higher loads compared with those fastened with screws.

Mechanistically, this result could have been anticipated. The failure for the shelves attached with screws (Fig. 6a) is the splitting of the rail material, and maximum bending moment is determined by the ability of the rail to resist splitting. In the case of the brackets, there was no wedging open of the rail and the failure occurred at much higher bending moments by the delamination in the glue lines between the rails and face sheet.

Figure 9b illustrates the effect the different fastener types had on the deflection of the honeycomb shelves. From the results the honeycomb shelves assembled with the screws deflected less during loading than shelves held in place by brackets. Further analysis of the bracket assembled shelves revealed no significant differences in deflection between panels with the 10- or 38-mm rails, unlike those for the screw assembly system.

Experiment 2

Three honeycomb shelves with no edge rails were run through the edge-banding machine to identify any effect that the rollers of the machine might have on the panels. Afterward, the PVC edge band was removed to examine the honeycomb core within the shelf (Fig. 10a). Examination of the honeycomb core material showed that it had been crushed vertically along the outer edges of the panel where it had been run through the edge-banding machine. Measurements of the panel thickness before and after edge banding revealed a decrease in panel thickness of 1 mm or more after edge banding.

A second set of honeycomb shelves, this time with 10-mm particleboard rails (the short edge), were also edge banded. The shelves in this case showed no crushing of the honeycomb core along the outer edges when the PVC edge band was peeled off (Fig. 10b). This difference showed that even though the panels were only supported along the short edges of the shelf, the presence of the 10-mm rails prevented the rollers from deforming the core. This suggests that rails are a necessary component for paper honeycomb sandwich panels destined for finishing by edge banding.

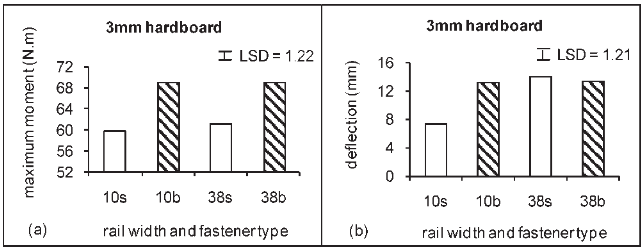


Figure 9.—Maximum moment and deflection properties of 3-mm hardboard honeycomb shelves with screw and bracket assemblies. n = *3 for each mean. Error bars represent the least significant difference between means.*

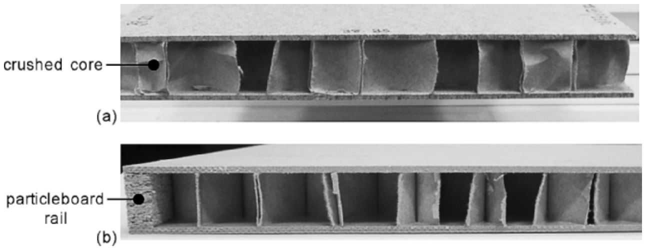


Figure 10.—Effect of edge banding on (a) honeycomb panel without rails, showing crushed core material and (b) honeycomb panel with edge rail material.

Figure 11 shows the average maximum bending moment and deflection values for honeycomb shelves finished with the three different edge-banding techniques. The method of edge band application significantly affected the load-carrying capacity ($P < 0.0001$) and deflection ($P = 0.0012$) of the honeycomb shelves. Shelves edge banded with the surface folding technique carried the largest bending moments compared with shelves edge banded with the direct coating and stabilizer edge techniques. This result subsequently reflected the deflection values for each edge-banding technique, while the surface folding method recorded the greatest resistance to deflection (lowest deflection values). A comparison of means indicated a significantly higher load is carried by the surface folding shelves compared with the other two techniques, while there was no statistical difference between the direct coating and stabilizer edge techniques.

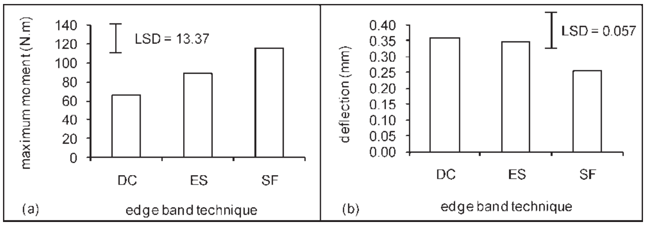


Figure 11.—Panel properties for honeycomb shelves edge banded with different techniques. n = *6 for each mean. Error bars represent the least significant difference between means.*

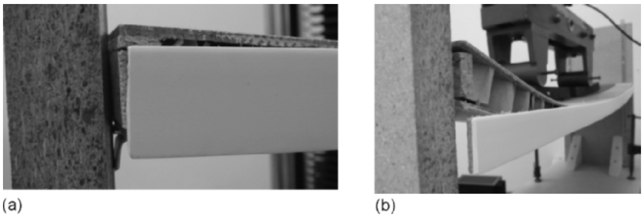


Figure 12.—Failure modes in edge banded honeycomb shelves during testing (a) direct coating and (b) stabilizer edge techniques.

Table 2.—Comparison of the average maximum moment and deflection values for the frameless and edge-banded honeycomb shelves.[a]

Shelf type (bracket assembly)	Maximum moment (N·m)	Deflection at midpoint (mm)	Adhesive contact area (mm^2)
No edge band (38 mm)	69.05 (1.64)	13.26 (0.54)	—
Control shelf (32 mm)	41.35 (0.97)	0.59 (0.03)	—
Direct coating shelf (32 mm)	66.04 (10.30)	0.36 (0.03)	6,402
Stabilizer edge shelf (32 mm)	88.91 (2.84)	0.35 (0.02)	9,603
Surface folding shelf (32 mm)	115.7 (4.83)	0.25 (0.03)	10,670

[a] $n = 3$. Values in parentheses are standard deviations of the means.

For all three methods of edge band application failure during testing ultimately came about by debonding of the PVC edge band from the honeycomb shelf as shown in Figure 12a, followed by the crushing of the Kraft paper honeycomb core directly beneath the loading noses and the subsequent delamination of the rails from the face sheet (Fig. 12b). Note the delamination in the interface between the 10-mm particleboard rail and the face sheet.

The effects of applying edge banding either as PVC edge band material itself (direct coating technique) or with hardboard insert (stabilizer edge and surface folding techniques) on the strength and stiffness of honeycomb shelves are compared in Table 2. The values for no edge band in the table were obtained from the 38-mm honeycomb shelves tested with the bracket configuration in the second part of Experiment 1. Also included in the table are values of the control honeycomb shelves (32 mm) fabricated and tested in a similar way as the no edge band shelves (38 mm), the only difference being their total panel thickness.

It can be seen in Table 2 that honeycomb shelves that were 38 mm thick carried more load in bending with high deflection values than the 32-mm shelves. A comparison of the maximum bending moment of the 32-mm-thick shelves (i.e., the control and the edge-banded shelves) shows a great increase in the load-carrying capacity of the honeycomb shelves with the application of edge band material. The bending strength (maximum moment) values were significantly higher for honeycomb shelves edge banded with the surface folding technique (more than three times higher compared with the frameless control shelves). The resistance of the honeycomb shelves to deflection also increased with the edge banding.

The differences observed between frameless and edge-banded shelves could be attributed to the increase in edge support for the edge-banded honeycomb shelves, while the variations recorded within the edge-banding techniques may be attributed to the differences in the total adhesive contact area provided by each technique for the edge band material. As shown in Table 2, shelves banded using the direct coating technique recorded lower bending strength because of the limited contact area: a total glued edge area of 6,402 mm^2 compared with greater than 9,500 mm^2 for the stabilizer edge and surface folding techniques. For the stabilizer edge technique (Fig. 4a), the 3-mm hardboard edge inserts had an adhesive contact area of 9,603 mm^2 with the two face sheets (top and bottom), while the surface folding technique (Fig. 5a) had an adhesive contact area of 10,670 mm^2 (Table 2). Given the greatly increased contact area for the stabilizer edge technique compared with the direct coating, its load-bearing ability was expected to be higher. Despite this difference in adhesive contact area between the two techniques, the stabilizer edge recorded no significant difference in deflection from the direct coating.

These findings support the idea that applying edge banding to frameless honeycomb shelves is not merely cosmetic but can also greatly improve panel strength and stiffness. Our results show that in the case of the stabilizer edge and surface folding techniques, the joints between the hardboard inserts and the honeycomb shelves were the weak points in the construction because the PVC edge band was still firmly attached to the outer surface of the inserts after those panels failed.

To redress this issue, the use of narrow stiles (10 mm) between the face sheets (behind the edge band and running along the long edges of the shelf) needs to be considered. These stiles will provide additional support to the edge inserts (stabilizer edge and surface folding) and in the case of the direct coating technique increase the adhesive contact area for the edge band material. This design is expected to further increase the strength and stiffness of the paper honeycomb shelves. This internal bracing would also be expected to enable honeycomb panels to be fabricated from thinner face sheet materials without compromising strength and stiffness properties.

Conclusions

For improved quality and performance of a simple shelving unit constructed from Kraft paper honeycomb core panels it is preferable to use thicker face sheets reinforced with an edge rail material 38 mm wide. This study also identified the presence of rails in honeycomb core shelves as essential to avoid crushing of the honeycomb core material during the application of edge-band material.

Finally, the application of edge banding to honeycomb sandwich panels contributes significantly to their load-bearing abilities and resistance to deflection. Of the three edge-banding techniques tested (direct coating, stabilizer edge, and surface folding), shelves edged with the surface folding technique carried twice the bending moment compared with frameless honeycomb panels.

Acknowledgments

Financial support for this research was provided by Natural Resources Canada (NRCAN) Value To Wood Program. The authors gratefully acknowledge Casewell Products, Henkel Adhesives, and Benson Inc. for their generous support in the form of technical assistance and sample provision. Sincere thanks go to Fraser Goldsmith, a Co-op student, for his help with the assembly of honeycomb shelf panels.

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