

STRENGTH PROPERTIES OF LIGHTWEIGHT PAPER HONEYCOMB PANELS FOR THE FURNITURE

Ioannis Barboutis and Vassilios Vassiliou

Aristotle University of Thessaloniki, Faculty of Forestry and Natural Environment,
Department of Harvesting and Forest Products Technology

Abstract

Lightweight honeycomb sandwich panels constitute a new raw material for the furniture and joinery industry that is produced economically by automated in-line processes due to the recent development of the machinery technology comparing to the traditional batch like production processes. At the same time, new furniture connectors of these panels have been developed. The honeycomb panels offer high strength-to-weight ratio and are produced in thicker panels than the conventional wood-based panels (particleboards, medium density fiberboards, plywoods, etc.) more than 50mm. In this paper the strength properties (bending strength, impact bending strength) of the paper honeycomb panels 51.7mm thick constructed with a core of recycled paper honeycomb (cell size 30 x 30mm, weight 210 g/mm²) and surface layers of thin particleboard 7.8mm in thickness were studied. The samples were prepared according to EN 310 for the bending strength and according to DIN 52189:1992 for the impact bending strength, and the tests were carried out with a SHIMADZU machine for the modulus of rupture (MOR) and modulus of elasticity (MOE), and with an AMSLER machine for the impact bending strength. It was found that modulus of rupture and modulus of elasticity of the tested material were low comparing to the particleboards of 7.8mm and 16.1mm thick. The impact bending strength and the impact bending strength to the density ratio of the honeycomb panel tested was found to be much higher comparing to the particleboard of 7.8mm and 16.1mm thicknesses. Also, in the paper the lightweight honeycomb sandwich panels are shortly presented (raw materials, technical characteristics, technology of their production) and the prospects of the new panels in the furniture and joinery production are discussed.

Key words: furniture, lightweight paper honeycomb panels, bending strength, impact bending strength

INTRODUCTION

During the last years an increasing interest for lightweight panels can be observed from the furniture industry worldwide, which could replace the conventional wood-based panels that are now in use (particleboards, medium density fiberboard, plywoods, etc) with a density of about 0.650 - 0.750 g/cm³ at relevant furniture and joinery applications (IKEA 2004, Busch 2004).

The most promising panel seems to be the sandwich panel with paper honeycomb core.

Actually, the lightweight paper honeycomb panel is not a new material, since it has been in use for many years for manufacture of door leaves and before that it has been in use in aerospace and automobile industries since many decades (Pflug et al 2004).

Paper honeycomb are produced traditionally by the conventional expansion process (Figure 1). It is remarkable that in the rapidly growing Asian furniture industry a majority of all furniture panels are already paper honeycomb core panels (Weber and Schatz 2004). However, cell size and core height of these paper honeycombs are usually above 10mm, because the cutting and bonding production steps are much more time consuming at lower cell sizes (Pflug et al 2004).

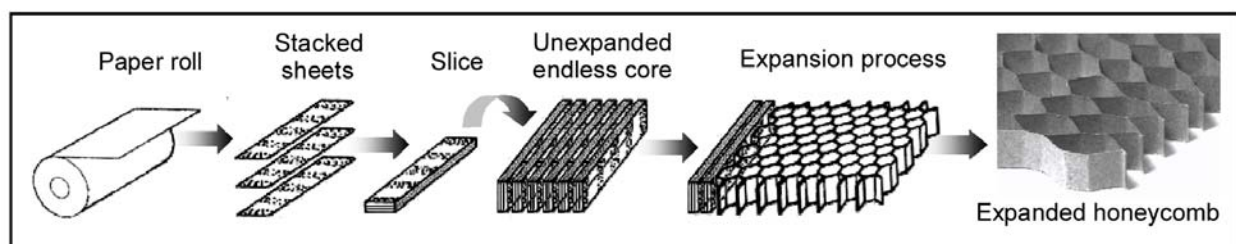


Figure 1. Traditional paper honeycomb production process by expansion (Pflug et al 2004)

A second traditional process for honeycombs is the corrugation process (Figure 2). With standard corrugated cardboard sheets, a small cell size of 5mm can be realized, bearing to a larger density compared to expanded honeycomb cores (Paul and Klasmeier 1997).

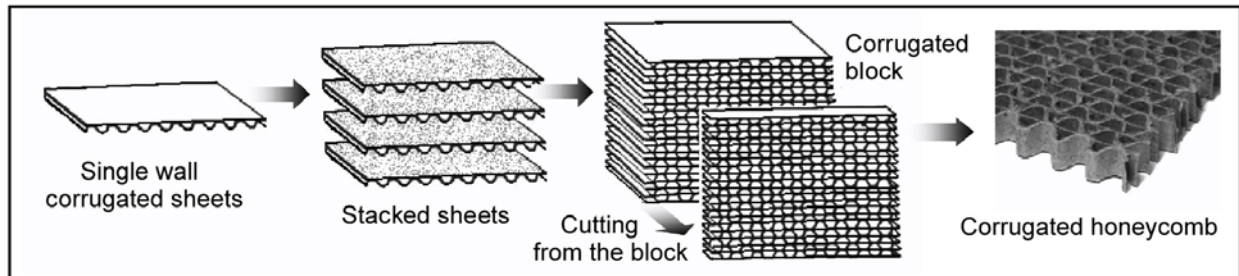


Figure 2. Paper honeycomb production process from corrugated cardboard (Pflug et al 2004)

Up to now, paper honeycomb sandwich panels had to be build with an internal frame construction to allow edge profiling and the use of conventional connectors. This implies exact planning and manufacture of the individual furniture components, prohibitive for furniture mass production (Pflug et al 2000, Häfele 2004). Nowadays, lightweight paper honeycomb panels can be produced economically by automated in-line processes, due to the recent development of the machinery technology, whereas, new furniture connectors of these panels have been developed (Bitzer 1996, Engelen 2003, Häfele 2004). The main benefits of the lightweight paper honeycomb sandwich panels for the furniture industry are, lighter and easier to transport and handle products, cheaper transportation costs and good load bearing capacity with high strength to weight ratio (Figure 3) (Bush 2004, Häfele 2004).

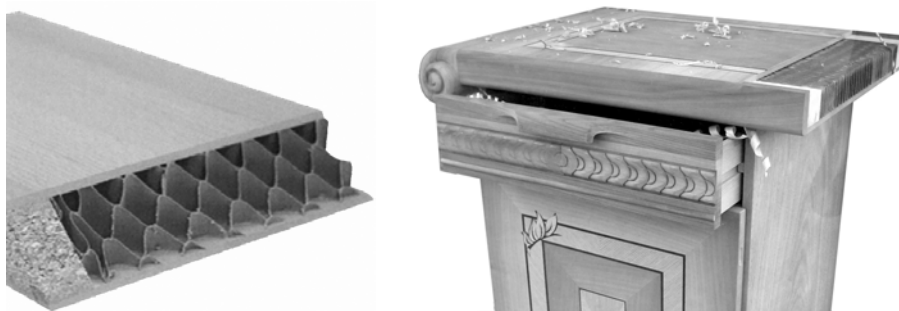


Figure 3. Example of paper honeycomb panel use in furniture construction

Although, honeycomb sandwich panels are widely used in aerospace and automobile industries since many decades, there is limited information available concerning the strength properties of the thick lightweight paper honeycomb panels used in furniture applications.

Pflug et al (2004) studied the compression strength and stiffness of two paper honeycomb panels produced by the corrugated cardboard process (TorHex), and found that the compression strength of the tested material ranged from 0.25 N/mm^2 up to 0.94 N/mm^2 . Petutschnigg et al (2004) studied the main properties of furniture corner joints constructed of lightweight paper honeycomb panels of 38mm thickness with biscuits.

This study was performed to provide information about the strength properties of the paper honeycomb panels produced with the conventional process by expansion for the furniture. The objectives of the study were to evaluate: a) the bending strength, and b) the impact bending

strength of a lightweight panel constructed with a paper honeycomb core and the surfaces with particleboard sheets of 8mm thickness.

MATERIALS AND METHODS

The tested paper honeycomb panels were constructed with a honeycomb core and two surface-layers of thin particleboard sheets 8mm in nominal thickness. The core was produced with the traditional process by expansion, from recycled un-impregnated paper (weight 210 g/m², cell size 30 x 30mm, thickness 36mm). The bonding of the two surface-layers to the honeycomb core was assembled with a Urea-Formaldehyde adhesive (UF).

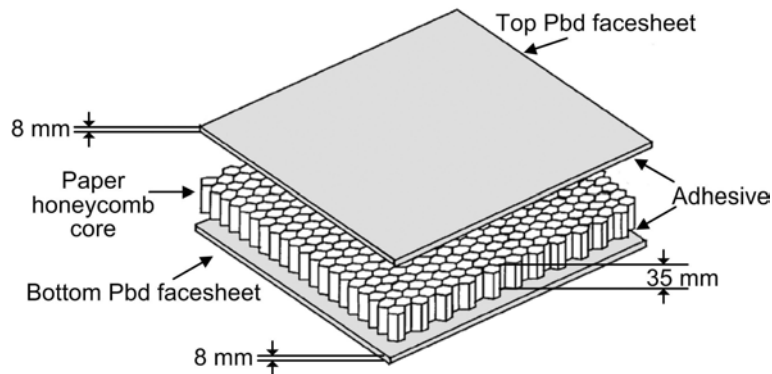


Figure 4. Configuration of the lightweight paper honeycomb panel tested

The samples for the bending strength tests were prepared in dimensions as follows: a) 51.7x60x550 mm for the honeycomb panels, b) 7.8x60x210 mm for the particleboard of 8mm nominal thickness and c) 16.1x60x370 mm for the particleboard of 16mm nominal thickness, according to EN 310:1993. The samples for the impact bending strength measurements were prepared in dimensions 7.8(16.1-51.6)x60x300 mm, in accordance to DIN 52189:1992.

The properties of the particleboards used in the construction of the panels were: density 0.766 g/cm³ (Std 0.013), internal strength 0.43 N/mm² (Std 0.02) for the Pbds of 8mm thickness, and density 0.658 g/cm³ (Std 0.011), internal strength 0.48 N/mm² (Std 0.03) for the Pbds of 16mm thickness, respectively. The density of the honeycomb panel was 0.321 g/cm³ (Std 0.007).

The samples were allowed to cure for a week before testing in a conditioning room at 20o C and 65% relative humidity.

The bending strength tests were carried out with a SHIMADZU machine, and the samples were compressed with a cross head displacement of 10 mm/min. From the measurements the modulus of rupture (MOR) and the modulus of elasticity (MOE) were calculated. On the other hand, the impact bending strength (IBS) tests were carried out with an AMSLER machine.

RESULTS AND DISCUSSION

The results of the strength properties tested are indicated in the table 1.

As we can see, the bending strength of the tested paper honeycomb panel was very low (MOR = 0.92 N/mm² and MOE = 505), and quite lower in comparison to the particleboards tested. This is attributed mainly to the large cell size of the honeycomb core (30x30mm). This low MOR value is also confirmed by Pflug et al (2004). On the contrary, the impact bending strength of the honeycomb panel was higher than that of the Pbds tested (from 80.1% up to 299.2%).

Table 1. Strength properties of paper honeycomb panels and of the Pbd panels used in the construction

Material panel (Nominal thickness)	Bending strength		Impact bending strength (IBS) (kJ/mm ²)
	Modulus of rupture (MOR) (N/mm ²)	Modulus of elasticity (MOE) (N/mm ²)	
Honeycomb 8+36+8 mm	0.92(0.07)*	505(63)	4.79(0.39)
Particleboard 16 mm	14.62(0.63)	2730(227)	2.30(0.08)
Particleboard 8 mm	15.27(0.47)	2741(362)	1.20(0.04)
Particleboard 2 x 8 mm	14.31(0.56)	2680 (325)	2.66(0.06)

* Mean values of 15 samples and standard deviation in parenthesis

We know that the main reason to use honeycomb sandwich construction is that it provides high strength to weight and strength to thickness ratios. This is clearly demonstrated in the next Table 2, where the panel of 2 Pbd of 7.8mm thickness (which corresponds to the surface-layers of the honeycomb panel tested) is considered as the basis (value 1) for the calculation of the other panels' relative properties.

Table 2. Comparative strength properties of the honeycomb panels and of the Pbd panels used in the construction

Strength property	Pbd thickness 7.8 mm	Pbd thickness 2x7.8 mm	Pbd thickness 16.1 mm	Honeycomb thickness 51.7 mm
Relative thickness	0.5	1*	1.03	3.31**
Density (g/cm ³)	0.766	0.766	0.658	0.321
Relative density	1	1	0.859	0.419
Relative MOR	1.07	1	1.02	0.06
Relative MOE	1.02	1	1.02	0.19
Relative Impact bending strength	0.45	1	0.86	1.80

* It is considered as the basis (value 1)

** Calculated values in relation to the basis value

Also, the strength to density ratio of the honeycomb panel tested is demonstrated in Figure 5 for the bending strength, and in Figure 6 for the impact bending strength.

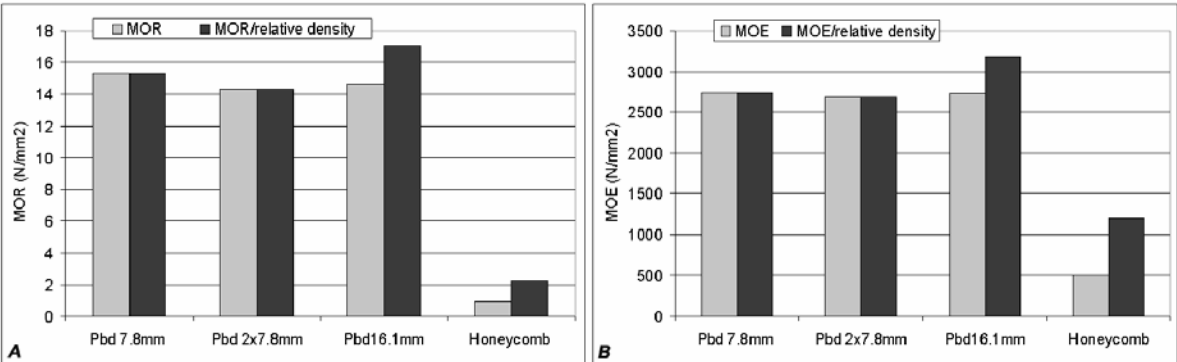


Figure 5. Effect of panel type on bending strength properties

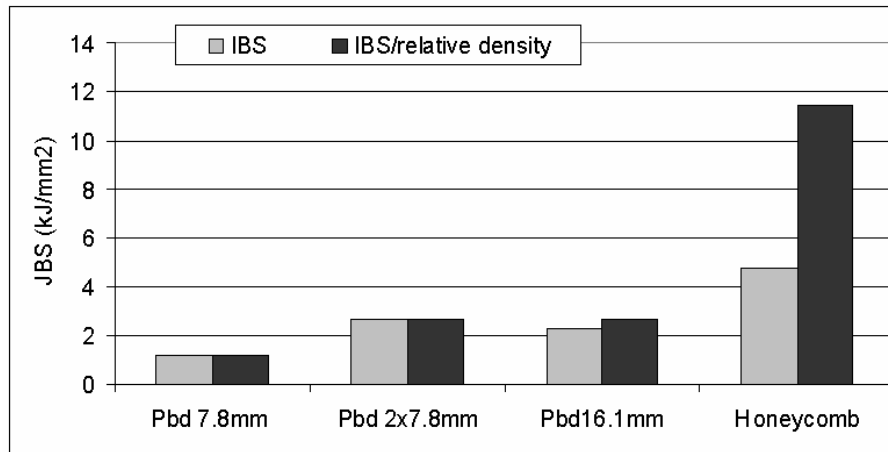


Figure 6. Effect of panel type on impact bending strength

We see that even though the strength of the honeycomb panel is improved when the bending strength to density ratio used, it still remains insufficient for the furniture requirements. On the contrary, the impact bending strength becomes much higher in relation to the Pbd's tested.

CONCLUSIONS

Nowadays, the lightweight paper honeycomb panels constitute a relatively new raw material for the furniture and joinery industry, which is produced economically. Within the range of parameters of the 51.7mm thick panel investigated in this study the following conclusions can be drawn:

- The bending strength properties (MOR and MOE) of the paper honeycomb panel were low. This implies to say that this material does not fulfill the basic requirements, of the most furniture applications, sufficiently.
- The impact bending strength of the paper honeycomb panel was very high.
- The impact bending strength to density and the impact bending strength to thickness ratios were very high, and much higher than that of the particleboards tested.
- Additional research is necessary on the further processing of paper honeycomb panels (effect of cell size, weight of paper etc) to fulfill the mechanical requirements of the furniture and joinery industry.

LITERATURE

- BITZER, T.N., 1996, Recent Honeycomb Core Developments. Proceedings 3rd "Sandwich Construction Conference", Southampton, U.K. Pages 555-563.
- BUSCH, K., 2004, Lightweight Panel Production gets Real. Surface and Panel, Summer 2004; 62-63.
- EN 310:1993. Wood-based panels - Determination of modulus of elasticity in bending and of bending strength. European Committee for Standardization, Brussels.
- ENGELN, G., 2003, Die Homag AG geht innovativ das Thema Leichtplattenbau an, Homag Press Release.
- HÄFELE, 2004, Tab A cabinet connector from Häfele, Häfele ZOW 2004.
- IKEA, 2004, IKEA's Big Idea, Spring 2004 issue, Surface and Panel.
- PAUL, R. and W. Klusmeier Struchthan ®. 1997. A composite with a future. Status report. Bayer AG. Leverkusen.

- PETUTSCHNINGG, A.J., KOBLINGER., R., PRISTOVNIK., M., TRUSKALLER., M., DERMOUZ. H. and B. ZIMMER., 2004, Leichtbauplatten aus Holzwerkstoffen - Teil I: Eckverbindungen.. Holz Roh Werkstoff, Vol. 62:405-410.
- PFLUG.J., VANGRIMDE, B. and I.VERPOEST, 2000, Folded Honeycomb Cardboard and Core Material for Structural Applications. Proceedings 5th "Sandwich Construction Conference", Zürich.
- PFLUG.J. et al. 2003. Honeycomb core materials: New concepts for continuous production. Sample Journal Vol. 39(6):22-30.
- PFLUG.J., VANGRIMDE, B. and I.VERPOEST, 2003, Material efficiency and cost effectiveness of sandwich materials. Sample Conference, Longbeach, USA.
- PFLUG.J., VANGRIMDE.B., VERPOEST.I., VANDERITTE.D., BRITZKE.M. and A. WAGENFÜHR, 2004, Continuosly produced paper honeycomb sandwich panels for furniture applications, 5th Global Wood and Natural Fibre Composites Symposium, April 27 -28, Kassel, Germany.
- PFLUG.J., XINYU.F., VANGRIMDE.B., VERPOEST.I., BRATFISCH.P. and D.VANDEPITTE, 2004, Development of a Sandwich material with polypropylene/natural fibre skins and paper honeycomb core.
- WEBER, H. G. and J. SCHATZ, 2004, Honeycomb technology - Homag plant concept for the production of lightweight paper honeycomb panels in through feed, Honeycomb Colloquium 1, Schopfloch.

Author's addresses:

Aristotle University, Faculty of Forestry and Natural Environment, Department of Harvesting and Technology of Forest Products, Box 243, Thessaloniki 54124, Greece. Email: jbarb@for.auth.gr, vass@for.auth.gr