TRIESKOVÉ A BEZTRIESKOVÉ OBRÁBANIE DREVA, 8(1): 161-167, 2012
Zvolen, Technická univerzita vo Zvolene, ISBN 978-80-228-2385-2

ANALYSIS OF PRACTICAL APPLICABILITY OF NON-FRAME HONEYCOMB BOARDS

Adam Kořený – Milan Šimek – Radek Neugebauer – Milan Novotný

Abstract

Our paper deals with a theme of practical experience with non-frame honeycomb board for manufacturing of carcass and table furniture. Use of current technologies and construction principles together with experimental testing preparation of a joints is described. Specific properties of honeycomb boards makes construction principles different and in combination with insufficient know-how makes decision for honeycomb difficult. Technology could be different as well as joints, on the other hand classical approaches could be possible. Authors focus on dismountable corner joints for carcass construction and plane constructions for tables. For carcass constructions different types of joints were tested and its configuration which seems to be suitable for use - specialized and common cam connectors, dowels and biscuits. For tables could be used specific construction approaches for reinforcing of whole construction and for joining of furniture parts. Those practical experience lead to the conclusion of advantages and disadvantages of different joints and advices for using of them.

Key words: *honeycomb, joints, lightweight, frameless, manufacturing, table*

INTRODUCTION

Lightweight panels are one of ongoing trends in furniture manufacturing. Manufacturers are focusing on new materials which are light, easy to use, eco friendly and which could be future in furniture manufacturing. Honeycomb board is not new approach however use of it without inner frame is still a query. We are focusing on experience of manufacturing of frameless honeycomb parts and practical use of dismountable connectors.

Honeycomb boards are advanced composite, sandwich materials which consists of light-weight cellular core with low modulus of elasticity and which is coated by a solid face layers with high modulus of elasticity. Composite of this type maximize stiffness and bending strength to weight ratio. *(Bianchi & et.al., 2007)*

Main mechanical properties of honeycomb boards could be highly different. For agglomerated materials is high strength variability present. Due to sandwich construction and manufacturing imperfections, behavior of honeycomb panels is even more complicated. *(Heimbs, 2008).* Given state could are illustrated by results from authors *(Pflug, Verpoest, & Vendepitte, 1999)* or *(Sam-Brew, 2006)*. Author Sam-Brew also confirms influence of edgeband.

Mendel University in Brno, Zemědělská 3; 61300 Brno, Czech Republic
e-mail: xkoreny@mendelu.cz; simek@mendelu.cz; xneugebauer@mendelu.cz;xnovotny@mendelu.cz

Not material properties but combination of material with fittings and connectors is main target of research intention. Optimal connector is not only strong or good looking, but quality in all areas is necessary. According to Eckelman (1993) and Joščák (1999), joint is the weakest point of a carcass construction. This statement is even more important for hollow core materials. Different types of joints were already widely tested by authors *(Barboutis & Vassiliou, 2009), (Bianchi & et.al., 2007), (Joščák, 1999), (Pflug, Verpoest, & Vendepitte, 1999)* or *(Smardzewski & Prekrad, 2002)*. Most of given tests were focused on most usual materials as is solid wood or chipboard or fiberboards.

MATERIAL AND METHODS

Presented materials, methods and results were gained during intention of experimental testing of dismountable joints for honeycomb board and during development of contemporary office table solution which could be seen in figure 1. For experimental purposes were developed parts of dimension 400 mm × 162 mm, 400 mm × 204 mm. Parts were assembled together into testing specimens of corner joints *(Joščák, 1999), (Eckelman & Lin, 1997)*. Partly were those parts manufactured out of 38 mm thick frameless honeycomb board and partly out of 38 mm thick chipboard. Those specimens were joined by dismountable joints of 5 different types which will be described further. Given joints in different combinations are going to be tested by method of bending in angular plane. Test will be done for compression and tension. *(Zhang & Eckelman, 1993), (Joščák, 1999).*

Manufacturing of frameless honeycomb parts

Parts were cut on a beam saw. Honeycomb board manufacturer advice pressure of 1 - 2 bar. Due to weight of a saw beam was pressure completely turned off. Machine feed speed was 55 $m \cdot min^{-1}$, tool speed 4200 min^{-1}, tool diameter 450 mm, number of blades 72 pcs. Further technology stew was edgebanding by speed of 20 $m \cdot min^{-1}$. For corner finishing of testing specimens were used straight milling tools, corners were not rounded. Rounding tools were used for table prototype. Edge band was 2 mm thick ABS. Manufacturing of workings on a CNC machine does not differ from manufacturing of chipboard. Important aspect is given by used connectors, where parts have to be drilled after CNC. Drilling of any type was done to defined depth, because of risk that wall of honeycomb core will be present in the hole. No special treatment was used for large dimension holes. *(Stotch, 2009)*

One part was developed for practical use in prototype of a table. Table desk of 2200 × 900 × 38 mm in dimension has been manufactured. Edges were finished by 2 mm ABS. For connection was used furniture screw nut with deep thread. Proposed construction under table was developed as a frame. Detail of a construction could be seen in figure 2.

Connectors types

Selection of connectors has been done by criteria of possible use in 8 mm thick top surface. Connectors are able to deduce tightening moment - cam type connector.

Type A - Cam type connector which is going through the edge and at the end of plastic body is present stabilizing pin with knock brace - brace is knocked after applying of connector. Metal dowel is screwed directly to the board surface.

Type B - Cam type connector which is going through the edge and at the end of plastic body is present stabilizing pin. Metal dowel is screwed directly to the board surface.

Type C - Is metal variation of type B. These were originally developed for chipboard.

Type D - Is type A in combination with glued reinforcing dowel. Into onset part is drilled hole and hollow dowel is inserted and glued. Into this dowel is then screwed metal dowel of the cam connector.
Type E - Is cam connector inserted into edge of inset part and then glued in. In onset part is used glued dowel into which is screwed metal pin. This fitting is invisible except of 8 mm service hole in plane of inset part.

Multi-criteria analysis of connectors
For multi-criteria analysis were selected criteria, which are by authors opinion most important for common practical use. One of given criterion is *price* gained 10.1.2012 by official manufacturer offer. *Manufacturing time* is based on measurements during manufacturing - time from starting of drilling of first hole of a connector until finish of last hole - this time could be different for different machine controller setup. Number *of drillings* for given connector. *Number of components*, assembly time (measured during manufacturing) and design (empirical examination). The analysis was prepared according to author (Friebelová, 2009).
Because of specific targeting of connector selection and knowledge of the problematic a pointing method has been used for criteria weight calculation. For calculation of the criterion weight was used pointing method. Each criterion has got points on scale 1-10 (1 - not important, 10 - very important) and those has been normalized by formula (1).

$$w_j = \frac{v_j}{\sum_{k=1}^{n} v_k}, j = 1,2,\dots,n \quad (1)$$

w_j - standard criterion weight, v_j - points assigned, v_k - total amount of points

For variations assessment was used method WSA - weighted sum product. For each variation K_j is assigned its benefit A_i. For each variation is calculated its benefit u_{ij} by formula (2). Functional values are in interval [0,1].

$$u_{ij} = \frac{y_{ij} - d_j}{h_j - d_j}; i = 1,2,\dots,m; j = 1,2\dots,n \quad (2)$$

y_{ij} - criterion value; d_j - worst criterion value; h_j - best criterion value

Finally is calculated aggregated variation benefit $u(A_i)$ for each variation by formula (3). Functional values are in interval [0,1]. Results are ordinal information (represents order of variants, but not how much better are variants to each other).

$$u(A_i) = \sum_{j=1}^{n} w_j u_{ij} \quad (3)$$

w_j - standard criterion weight; u_{ij} - variation benefit; $u(A_i)$ - aggregated variation benefit.

RESULTS

Preparation of a manufacturing process lead to a practical manufacturing of a testing samples and parts for a prototype table. Samples were assembled together by different types of fittings. Based on given experience results of technological steps are presented further.

Cutting - Even beam pressure was completely turned off, it was necessary to increase side cuts up to 60 mm (standard for chipboard is 20 mm). When rest of the board was under given dimension (60mm × 200 mm) honeycomb core collapsed (diameter of the honeycomb core 15 mm).
Edgebanding - 400 mm long parts went through all aggregates. Leveling with board plane of 2 mm ABS edge was produced in the same quality as for chipboard. According to information from honeycomb manufacturer buckling of the edge in a corners was not present, even after 3 month period.
Machining - Parts with edge were machined. Usability of machine was limited by sample dimensions which were sized according to suction cup size. Feed speed of drills was not reduced. Cleanness of holes edge was perfect, honeycomb core was not destructed. Main issue was dust extraction which was not able to remove all chips. Extraction by air blow was uneasy due to hollows in a honeycomb core.

Connectors application
type A - Connectors are designed to use plane of a board as a support, therefore area of connector on a face is large. This decreases aesthetical quality of joints, also knock of the connector is done in three steps (front and rear part of connector, knock of the stabilizing pin).
type B - Similar system to type A - during application is not necessary hammering of stabilizing pin.
type C - In comparison with type B is necessary to be aware of bending of metal body. When connector is not supported by board material cam could fall off into hollow core.
type D - Reinforcing dowel application starts by hammering and then glue is injected. Presence of splinters in the honeycomb core is serious issue, dowel is than not faced with board plane.
type E - Reinforcing dowel application is the same as for type D. Application of a cam into the edge is complicated regarding positioning in a depth. Position has to be adjusted and then fixed. After this glue could be injected. Assembly of connector is highly time spending.

Results of multi-criteria analysis of a connectors
Input data for multi-criteria assessment of connectors are presented in table 1. Results of analysis by methodic described above are presented in
chart 1. Result is presented as aggregated variation benefit. This is unit-less value which express variation satisfactory of given criteria. Higher value represents better properties in combination of selected criteria.

Connector type	Price €/100 pcs.	Drilling time (s)	Number of holes (ammo.)	Component number (ammo.)	Joint assembly time (s)	Design (1 - best, 5 - worst)
A	41,48	9	3	2	25	3
B	41,67	9	3	2	25	4
C	110,85	9	3	2	35	3
D	118,01	9	3	4	60	3
E	205,22	26	4	5	120	1
Ideal	41,67	9	3	2	25	1
Basic	205,22	26	4	5	120	4
Weight	**0,22**	**0,17**	**0,11**	**0,15**	**0,20**	**0,15**

Table 1: Criterions selected for multi-criteria analysis of connectors.

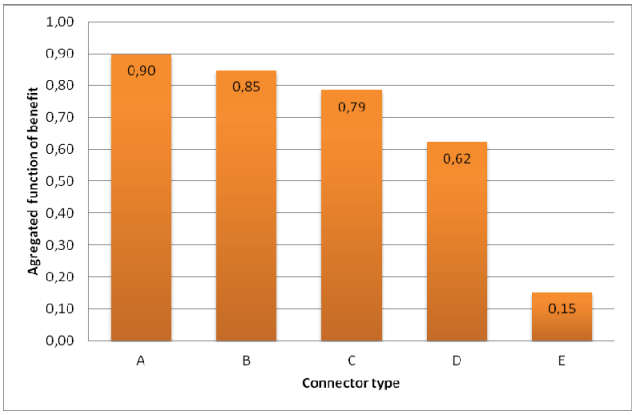

Chart 1: Results of multi-criteria analysis. Results shows aggregated variation benefit A_i for each connector.

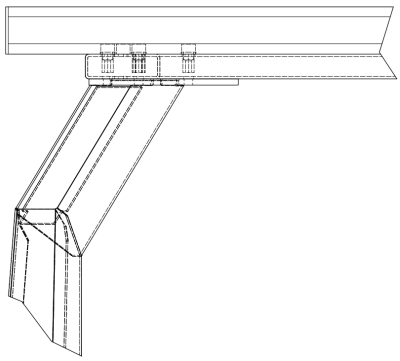

Figure 1: Table prototype.
Figure 2: Detail of connection of leg and frames with honeycomb board.

DISCUSSION AND CONCLUSION

Honeycomb panel for furniture manufacturing is known for more than 50 years already (Construction Dimensions Magazine, 1988). During so long time period has been used for wide range of applications. But as we can observe, till now sandwich panels generally are not major material in furniture industry. Through all attractive properties like low weight, savings of wood material, easy manipulation, recycling advantages and eco-marketing, there are still many queries - mainly for medium sized manufacturers. Custom made honeycomb furniture parts seems to be too much complicated and expensive way under present conditions. Only few manufacturers in area of Czech and Slovak Republic actively works in given way. With increasing trend of production of frameless honeycomb panels and development of available technologies, honeycomb seems to be prepared for use. On

the other side relatively big investments to honeycomb technology will be necessary to make honeycomb furniture production effective and flexible enough. Due to uncertain market conditions, honeycomb technology queries and designers experience are manufacturers aware of switch on honeycomb.
Presented methods and practical application of connectors and material in combination with common technology resulted into presented outcomes. On present level of knowledge we have to state, that currently offered honeycomb panels in combination with certain joints are suitable way how to make first steps with honeycomb technology without big risk and investments. For manufacturing was used honeycomb panel of 38 mm thickness with 8 mm top layers applied. Given material is with adjustments suitable for cutting, edgebanding and routing on common machines which are used for chipboard. Application will differ at every manufacturer and adjustments which will be necessary could wary.
Focusing on dismountable joints or possible combination with reinforcing elements could be suitable way for joining. By multi-criteria analysis, specialized connector without glued plastic dowel - type A seems to be ideal choice under selected criteria. Mainly due to its price and easiness of use. Joints of type B and C has got similar results do not bring any serious advantage in plastic even in metal variation. Connector was not supposed to be used in honeycomb core panel. Due to this issues with strength and assembly could occur. Joint type D is more expensive and also assembly is more complicated. Joint of type E has high number of parts, complicated joint application and extremely high price disqualifies this joint economically. Based on given criteria D and E don't seems to be correct choice. On the other hand we could assume high performance is strength characteristics and this could be break point for use of them. This hypothesis will be examined in further research.
Table desk made out of frameless honeycomb had positive influence on table weight and product utility. Weight of desk was 19,76 kg in comparision with chipboard version which reach 40,3 kg. Manipulation was easy not only for end user. Also ability of easy manipulation is important for machine workers. This could save man power and also lead to higher safety during the manufacturing.
Area of manufacturing technology is only pre-stage of final intention. Target is optimal joint or product construction and possible approaches to it. Issue in hollow core materials and sandwich materials generally is ability of edges to hold and fix connectors. Research of possibilities could have impact on use of any type of hollow core material in furniture construction.

ACKNOWLEDGEMENT

This research was kindly supported by the Internal Grant Agency (IGA) Faculty of Forestry and Wood Technology (FFWT), Mendel University in Brno – project number 16/2012.

REFERENCES

Barboutis, Ioannis and Vassiliou, Vassilios. 2009. *Holding strength of insert fitting compared to bending strength of their furniture corner joints. 67, 2009, pp. 627-632.*

Bianchi, B. and et.al. 2007. *Optimization of Bolted Joints Connecting Honeycomb Panels. Southampton, United Kingdom : s.n., July 19, 2007. 65075.*

Construction Dimensions Magazine. 1988. *Honeycomb Construction: It started with Pharaohs. Construction Dimensions Magazine. November 1988, pp. 49-50.*

Eckelman, Carl and Lin, Far-Ching. 1997. *Bending Strength of Corner Joints Constructed With Injection-Molded Splines. Forest Products Journal 47. 47, October 1997, 4, pp. 89-92.*

Friebelová, Jana. 2009. *Tvorba a softwarová podpora projektů. Tvorba a softwarová podpora projektů. [Online] 2009. [Cited: June 2, 2012.]*

http://www2.ef.jcu.cz/~jfrieb/tspp/.

Stotch, Martin. 2009. *Giving lightweight panels the edge. s.l. : Sonderveroffentlichung des BM Bau- und Mobelschreiner, 2009, BM Special, Lightweight Design, pp. 90-112.*

Heimbs, Sebastian. 2008. *Virtual testing of sandwich core structures using dynamic finite element simulations. Computational Materials Science. 45, October 23, 2008, 2, pp. 215-216.*

Joščák, Pavol. 1999. *Pevnostné navrhovanie nábytku. Zvolen : Technická Univerzita vo Zvolene, 1999. 80-228-0921-7.*

Pflug, Jochen, Verpoest, Ignaas and Vendepitte, Dirk. 1999. *Folded honeycomb cardboard and core material. Sandwich Constructions. Thessaloniki : EMAS, 1999. p. 12.*

Sam-Brew, Solace Araba. 2006. *The Development of Hollow Core Composite Panels for Value Added Applications. Vancouver : The University of British Columbia, 2006.*

Smardzewski, Jerzy and Prekrad, Silvana. 2002. *Stress Distribution in Disconnected Furniture Joints. 2, Wroclaw : Wydawnictwo Akademii Rolniczej we Wroclawiu, Květen 2002, Electronic Journal of Polish Agricultural Universities, Vol. 5. 1505-0297.*

Zhang, Ji-Lei and Eckelman, Carl. 1993. *Rational design of multi-dowel corner joints in case construction. Forest Products Journal. 43, February 1993, Vol. 11/12, 43, pp. 52-58.*