African Journal of Biotechnology Vol. 8 (20), pp. 5265-5270, 19 October, 2009
Available online at http://www.academicjournals.org/AJB
ISSN 1684–5315 © 2009 Academic Journals

Full Length Research Paper

Effect of various factors on the rigidity of furniture cases

Nurgul Tankut

Bartin University, Faculty of Forestry, Department of Forest, Industrial Engineering, Bartin, 74200, Turkey.

Accepted 9 April, 2008

Cases are one of the most important types of furniture produced, yet relatively little research has been done on the case rigidity. In this study, types of the fastener properties to overall case rigidity were investigated along with the effect of material type and thickness on stiffness. A total of sixteen cases were constructed and tested. Results indicated that panel thickness and material type significantly increased structural stiffness of case type furniture. The results of experiments showed that the stiffness of case furniture could be increased by increasing the material thickness from 16 to 18 mm. Medium density fiberboard (MDF) cases, in both doweled and screwed ones, were stiffer than particleboard cases. Results indicated that the stiffness of case furniture could be increased by increasing the stiffness of corner joints, e.g. by using screw with glue instead of using only screw or applying glue to the dowels and whole edges instead of dowels only. Case furniture designs using screws with glue resulted in higher case stiffness than similar designs using glued dowel joints. In general, the stiffer the end connection, the less the deflection of the case was observed. The results also indicated that rigidity of case furniture comes mainly from the gluing of the joining surfaces. Therefore, knowing the rigidity of the case furniture made of wood composites is fundamental to the design of safe, cost efficient and aesthetic design.

Key words: Furniture, case furniture, dowel joint, screw joint.

INTRODUCTION

One of the main problems encountered with casegoods is called ‘’loose cases’’ which most manufacturers and customers have trouble with it. This is lack of rigidity in the case body so that openings for drawers or doors do not stay square but are deformed into a parallelogram. Distortion of the front opening is especially objectionable in cases like wardrobes or china closets with a big door which fits inside of an opening in the case. If the opening becomes distorted, the door will bind in the opening or in extreme situations will fail to close into the opening at all. While case distortion is most troublesome where big doors are involved, it can also become a problem on large chests of drawers or large triple dressers. When such a case is distorted, the drawer fronts fail to line up properly in a vertical direction. They also do not properly fit into the openings which are no longer rectangles but parallelograms. This can happen if the case sits on an uneven floor or someone pushes the case to move it. To find a solution for this problem, manufacturers slap in a lot of glue blocks some places in the case. Some of these blocks may not help rigidity at all and would be needless expense.

Because of increasing liability costs associated with the manufacture of poorly designed case furniture, the use of rational design methods for case furniture will become a primary concern, especially in the case type furniture industry where large quantites of the same design are sold to each customer. Rational methods of furniture design not only eliminate waste but also result in the most economical design.

The first known study of the structural characteristics of case furniture was published by Kotas (1957). This research dealt with the relationship of the rigidity of a five-sided case to the stiffness of the panels comprising the

*Corresponding author. E-mail: nurdez@yahoo.com.

case. Kotas (1958a) indicated that when loads are applied to an opened-face, five-sided case, the case always deforms into the same shape regardless of the direction of the loads. This follows because of the unique geometric behavior within the case in which the deflection of each panel is geometrically related to the deflections of the adjoining panels. He also stated that panels are easily twisted about a longitudinal axis, but they are difficult to distort in their own plane. Then, the results of his research were later incorporated into a small design manual (Kotas, 1958b). Dubravsky (1963) investigated the rigidity of corner constructions and their effect on case rigidity. Kamenicky (1974) indicated that the flexibility of furniture joints varies greatly and joint rigidity significantly influences the resulting values.

Eckelman (1967, 1968) subsequently developed a method of analysis for a five sided case based on the interrelated deflections of the various corners and stiffness of the individual panels. He showed that the strength and rigidity of a paneled structure is almost totally dependent on the torsional rigidity of its plates. Ganowicz and Regozinski (1972) applied the principles of internal work to the analysis of case furniture, and Ganowicz et al. (1978) extended formulas for calculating redundant forces acting at the corners of the panels through energy methods.

Ganowicz and Kwiatkowski (1978) subsequently carried out tests on a case and experimentally evaluated the forces acting at the corners. Ganowicz et al. (1983) extended this work through energy methods and developed formulas for calculating redundant forces acting at the corners of the panels comprising the case. Hata (1982) analyzed the effect of the back panel and the depth of a case on stiffness. Eckelman and Resheidat (1983) evaluated case stiffness and presented formulas for determining the forces acting at each corner of the panels in a case. Subsequently, they (1984) presented a simplified method of deflection analysis of shelves and case tops and bottoms for typical case construction. Then, Eckelman and Rabiej (1985) developed a method for modeling complex cases containing partitions and shelves that allows case furniture to be analyzed by means of a finite element type of analysis. Eckelman and Munz (1987) extended this method to include cases with front frames.

Lin and Eckelman (1987) in which the deflections of cases with three types of joints with varying degrees of rigidity were evaluated. Test results indicated that the rigidity of the joints does have a significant effect on case stiffness. Albin et al. (1987) carried out an investigation of corner joints of the type used in cases. These joints were not tested as part of a case, however. Chai and Wang (1993) investigated the effect of the stiffness of corner joints on overall case rigidity and concluded that the strength of case furniture could be increased by increasing the dowel quantity of corner joint. Denizli-Tankut et al. (2003) determined the effect of various construction practices on the deflection characteristics of bookcases constructed of wood composites.

There is a widespread lack of knowledge as to the various causes of loose cases and consequently a lack of knowledge as to what to do stiffen up a case and make it more rigid against distortion of the front opening (Willard, 1968). For this reason engineering design along with experimental study are required.

It is important, therefore, that the effects of various construction factors be investigated in order to obtain realistic estimates of their effect on case stiffness. Such research is necessary to obtain both realistic estimates of stiffness for design purposes and to determine factors which most effectively stiffen a case. The objective of this study, accordingly, was to investigate the rigidity of frameless cases, and to broaden and extend the overall body of knowledge of case performance behavior. The specific objectives of this paper were to determine the performance of the bookcases constructed with dowel and screw joints and to investigate the effect of different panel materials, (laminated particleboard and laminated medium density fiberboard), panel thicknesses (16 and 18 mm), and fastener type on case rigidity.

MATERIALS AND METHODS

Eight specimens were constructed with laminated particleboard; 4 of these were connected with screws and 4 of these were dowel connected. In addition to these, eight specimens were constructed with laminated medium density fiberboard (MDF); 4 of those were jointed using dowels and 4 using screws. Therefore, sixteen cases were evaluated during this study.

When a vertical force is applied to the free corner of a case which is supported as shown in Figure 1, deflection Y will occur as shown. Because of their rigidity, it can be assumed that the common edges between two supports remain undeformed when the vertical load, F, acts at this free corner. Thus, these two edges of the bottom plate were fixed but the free corner displaced an amount Y.

Dowel jointed cases

Eight cases were used to investigate the effect of glue on dowel jointed case stiffness. All specimens were glued either 1) dowels only referred to as "unglued" (UG) or 2) whole edges and dowels referred to as "glued"(G).

As shown in Figure 1, the cases were of the same nominal size and configuration with a height, width and depth of 90 by 60 by 30 cm, respectively. The top, bottom, and side panels of the cases were constructed of 16 and 18 mm thick of particleboard or MDF. Dimensions of the parts are shown in Table 1. To obtain these cases, the two vertical case sides were cut to a finished size of 60 by 30 cm from 188 by 366 cm full size sheets of 16 and 18 mm thick particleboard and MDF panels. The rear panels were cut to 90 by 60 cm from 3 mm thick tempered hardboard and attached to the cases with brads.

Each case had a fixed top and bottom panels. The top and bottom of the cases were joined to the sides with two 8 mm diameter by 38 mm long multigrooved beech dowels. Depths of penetration of the dowels in the faces of the boards were 15 and 12 mm for the 19 and 16 mm boards, respectively. Dowel spacing was 20 cm. The left and right sides overlapped the ends of the top and

Table 1. Dimensions of the parts for cases.

Part description	Number of parts	Dimension	
		16-mm thick Material (PB or MDF)	18-mm thick Material (PB or MDF)
Sides	2	600 x 900 x 16 mm	600 x 900 x 18 mm
Top panel	1	300 x 600 x 16 mm	300 x 600 x 18 mm
Bottom panel	1	300 x 600 x 16 mm	300 x 600 x 18 mm
Rear panel	1	Tempered Hardboard 600 x 900 x 3 mm	

PB = particleboard; MDF = medium density fiberboard.

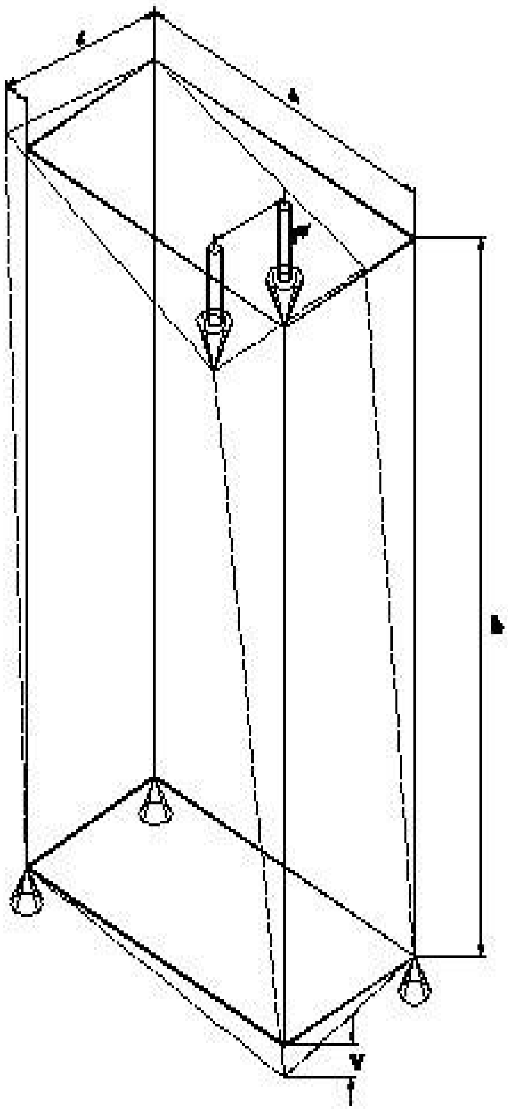

Figure 1. Case deformation as a result of applying load.

bottom. All joints were glued with a PVA adhesive with 65% solids content. Double spread technique was used, in which adhesive was applied to both the walls of holes and the surfaces of the dowels. Another set of samples referred to as "glued"(G) had adhesive applied to the whole edges and dowels.

All cases were clamped with pressure to bring joints tightly together and allowed to cure under pressure before testing.

Screw jointed cases

One set of samples are referred to as "screwed" (S1). Construction of the S1 cases was identical to that of the doweled case. The cases were of the same nominal size and configuration with a height, width and depth of 90 by 60 by 30 cm, respectively. The sides, top, and bottom of the case were connected together with two screws, at each common edge. Mating parts were clamped together while drilling pilot holes and driving the screws. Pilot holes not only increase the strength of the connection but also locate the position of the fastener and guide the fastener while it is being inserted, and prevent the wood composite from splitting. 4 mm diameter by 50 cm long particleboard screws, which were placed 20 cm apart, was used in the study because they are low cost fastener, readily available to the furniture industry. Rear panels were cut to 60 by 90 cm from 3 mm tempered hardboard and attached to the case using brads.

Construction of another set of samples, referred to as "screwed and glued" (S2), differed from the first in that the adhesive applied to whole edges of the side members. A PVA adhesive was used. Otherwise, construction was identical to that of the previous case, namely S1. Glued cases were allowed to cure for at least one week before testing.

All cabinets were checked for squareness by measuring diagonally from corner to corner. Any out of squareness was corrected at this stage by angling the clamps in the direction of the longer diagonal measurement.

Testing case stiffness

There is no certain standard to measure rigidity of cases. In this study, the testing procedure used to carry out the rigidity tests were identical to those used in previous studies (Eckelman and Resheidat, 1983; Kotas, 1958b). All tests were carried out on a Universal testing machine. A 5 cm thick cast iron panel was used as the general support surface for the apparatus used in testing the cases. The cases were supported for testing by means of 4 x 4 cm and 3 mm thick steel angle attached along the 2 - 3 edge of the sides of the case by means of bolts. The steel bars were used to distribute the load uniformly along the length of the cases.

Each case supported at three corners and left free to deflect vertically at the fourth. Namely, the cases were supported for testing at the left front, left rear, and right rear corners (joints 1, 2, 5 in Figure 2). Vertical loads were applied to the unsupported right front corner (joint 4 in Figure 2). Dial gage was used to measure the deflection of the case at point 4. The test set up for evaluating case stiffness is shown in Figure 2.

Table 2. Percent change in dowel jointed case deflection values.

Material	Without reinforcement	With reinforcement	Improvement (%)
16 mm PB	0.800	0.551	45.19
18 mm PB	0.454	0.340	33.53
16 mm MDF	0.650	0.454	43.17
18 mm MDF	0.352	0.254	38.58

PB = particleboard; MDF = medium density fiberboard.

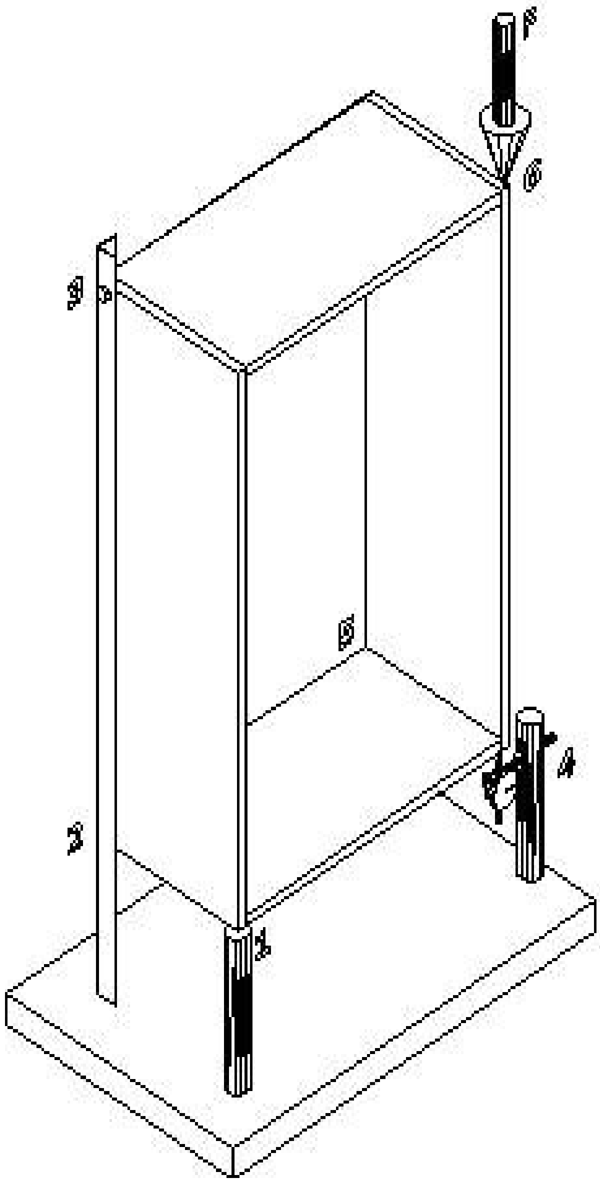

Figure 2. Test setup for evaluating case stiffness under vertical point loading.

Loads were applied to the case in increments of 100 N until a maximum load of 500 N was reached. The displacement of every load and the corresponding load value were recorded.

RESULTS AND DISCUSSION

Figure 3 shows the deflection of the cases in relation to the type of fastener, material, and panel thickness. Substantial differences occurred in stiffness with respect to thickness of material. When the panel thickness is increased from 16 mm to 18-mm, the case deflection values decreased significantly. For example, the cases constructed with 16 mm thick particleboard have higher case deflections than the ones constructed with same thickness of MDF for all construction types. It is possible to conclude that the deflection of the case can be improved by increasing its thickness.

MDF cases, in both doweled and screwed ones, were stiffer than particleboard cases. Manufacturers may want to use composite panels that provide the greatest stiffness in their constructions. Namely, rigidity and density of the side panels, which come with the combination of choice of materials, their thickness and case design, is important because the sides carry the weight downward to the base or floor.

In terms of fastener type, the increase in stiffness values for G (dowel with glue) cases was 45, 33, 43, and 38% over UG (doweled) cases for 16 mm particleboard, 18 mm particleboard, 16 mm MDF and 18 mm MDF materials, respectively (Table 2). On the other hand, the increase in stiffness values for S2 (screw with glue) cases was 66, 42, 49 and 47% over S1 (screwed) cases for 16 mm particleboard, 18 mm particleboard, 16 mm MDF and 18 mm MDF materials, respectively (Table 3).

The least case deflection was observed in S2 cases constructed with 18 mm thick MDF material, and the most deflection in UG case constructed with 16 mm thick particleboard.

The conclusion can be drawn that the stiffness of case furniture could be increased by increasing the stiffness of corner joints, for example, by using screw with glue instead of using only screw or applying glue to the dowels and whole edges instead of dowels only.

Results of the Analysis of Variance (ANOVA) test showed that there were significant differences in structural stiffness of case type furniture in terms of material type, material thickness, and adding glue to the case construction. The cases constructed with screws were significantly stiffer than the cases constructed with dowel at the 0.01 significance level as shown in Table 4.

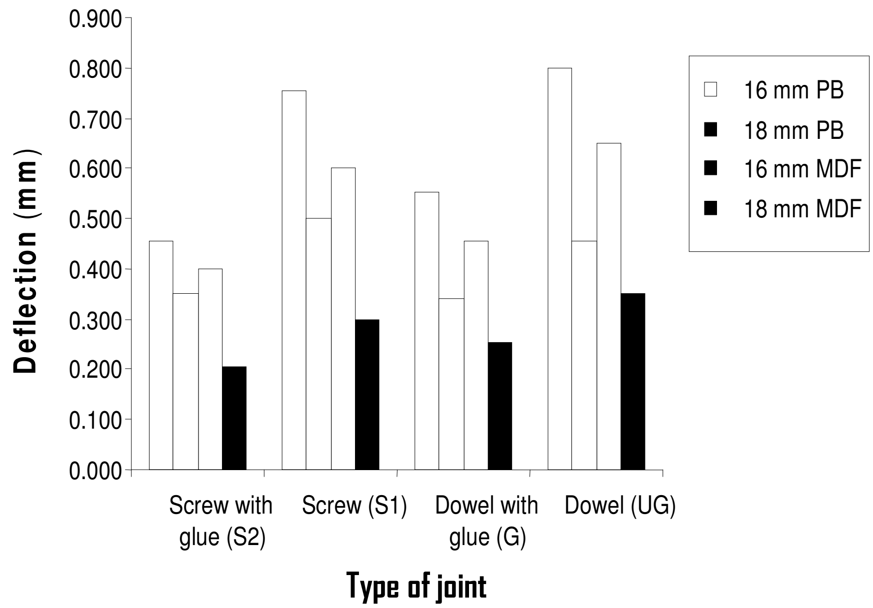

Figure 3. Deflection of the cases in relation to the type of fastener, material, and panel thickness. PB = particleboard; MDF = medium density fiberboard.

Table 3. Percent change in screw jointed case deflection values.

Material	Without reinforcement	With reinforcement	Improvement (%)
16 mm PB	0.754	0.454	66.08
18 mm PB	0.500	0.351	42.45
16 mm MDF	0.601	0.401	49.88
18 mm MDF	0.300	0.204	47.06

PB = particleboard; MDF = medium density fiberboard.

Table 4. Analysis of variance results.

Source of variance	Sum of squares	df	Mean square	F ratio	Level of significance
Main Effects A = Fastener type	0,3992	3	0,1330	8317	***
B = Panel thickness	0,1830	1	0,1830	11439	***
C = Material types	0,6840	1	0,6840	42751	***
Interactions AxB	0,0093	3	0,0031	193	***
AxC	0,0476	3	0,0159	992	***
BxC	0,0013	1	0,0012	78	***
AxBxC	0,0039	3	0,0013	81	***
Residual	0,0005	32	0,0013		
Total	1,3289	47			

***Highly significant with probability less than 0.01.

Conclusion

As seen this results, significant differences occurred in stiffness with respect to type of material, thickness of the panel and fastener type. The results of experiments showed that the stiffness of case furniture could be increased by increasing the material thickness from 16 to 18 mm, or using MDF composite boards instead of particleboard, or using reinforced joints.

Based on the results of the effect of the joint rigidity on case deflection, it can be concluded that the performance of existing designs whose present case deflection characteristics are unsatisfactory can be improved also by making the joints stiffer. The results also indicated that applying glue to whole edges significantly contributed overall case rigidity in all construction combination of cases. Thus, rigidity of case furniture comes mainly from the gluing of the joining surfaces. Meanwhile, statistical analysis of data supported the experimental findings at the significance level of 0.01.

The stiffness characteristics of cases with significantly stiffened joints are also important. Meanwhile, it is necessary to understand fastening and improvements in joinery and to develop construction techniques best suited for use with composites such as the use of local reinforcements of the composite itself. In this respect, it is worthwhile to consider the stiffening effect of corner blocks in practical case construction.

REFERENCES

Albin R, Muller, Scholze H (1987). Investigation on the Strength of Corner Joints in Core Type Furniture. Holz als Roh-Und Werkstaff 49(9): 171-178.

Chai, L, Wang F (1993). Influence of the Stiffness of Corner Joint on Case Furniture Deflection. Holz als Roh-und Werkstoff 51: 406-408.

Denizli-Tankut N, Tankut A., Eckelman C, Gibson H (2003). Improving the Deflection Characteristics of Shelves And Side Walls In Panel-Based Cabinet Furniture. For. Prod. J. 53(10): 56-64.

Dubravsky S (1963). The Rigidity of Corner Construction Joints and Their Effect on Case Furniture Typology. Habilitation Work. Forestry and Wood Technology University. Zvolen, Cz.

Eckelman CA (1967). Furniture Mechanics: The Analysis of Paneled Case and Carcass Furniture. Purdue Univ. Agri. Expt. Sta. Res. Prog. Rept, W. Lafayette, Indiana. p. 274.

Eckelman CA (1968). Furniture Frame Analysis and Design. Unpublished Ph.D. Thesis, Purdue University, p. 231.

Eckelman CA, Resheidat M (1983). The Analysis of Five-Sided Furniture Case. Purdue Univ. Agric. Exp. Sta. Res. Bull. p. 981.

Eckelman CA, Rabiej R (1985). A Comprehensive Method of Analysis of Case Furniture. For. Prod. J. 35(4): 63-68.

Eckelman CA, Munz S (1987). Rational design of cases with front frames andsemi-rigid joints. For. Prod. J. 37(6): 25-30.

Ganowicz R, Rogozinski J (1972). Analysis of Case Furniture. Prezem. Drzenwy 23(7): 20-23. Warszawa.

Ganowicz R, Diziuba T, Ozarska-Bergandy B (1983). Theory of deformation of cabinet constructions: Deformation of multipart carcasses. Holztechnologie 24(4): 231-235.

Ganowicz R, Kwiatkowski K (1978). Experimental Testing of the Theory of Deformations of Cabinet Designs. Holztechnologie, 19: 100-106.

Hata M (1982). The Structural Analysis of Furniture. Part V. Effect of Back-panel on Strength of Storage Furniture. Bull. Ind. Art Inst. Fujuyama, Japan. 9: 7-11.

Kamenicky J (1974). The Method of Static Analysis of Furniture Structures. Drevarsky Vyskum 19(4): 155-166.

Kotas T (1957). The Theoretical and Experimental Analysis of Cabinet Structures. Furniture Development Council Research Rept. London, p. 6.

Kotas T (1958a). Stiffness of case Furniture. Przemysl Drzewny. Warszawa. No: 10 and 11: 10-14, 15-18.

Kotas T (1958b). A design manual for case furniture. Furniture Development Council, Pergamon Press. New York, p. 49.

Lin, S-C, Eckelman CA (1987). The Rigidity of Furniture Cases with Various Joint Constructions. For. Prod. J. 37(1):23-27.

Willard R (1968). Furniture Construction Research Results. Industrial Extension Service, School of Engineering, N. Carolina State Univ. Raleigh, N Carolina.