Scientific Research and Essay Vol. 4 (5) pp. 479-483, May, 2009
Available online at http://www.academicjournals.org/SRE
ISSN 1992-2248 © 2009 Academic Journals

Full Length Research Paper

Load carrying capacity of spline joints as affected by board and adhesives type

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Accepted 21 April, 2009

The main factor for strength performance of corner construction is resistance to diagonal compression and diagonal tension forces acting on joints. The strength at these points varies according to the type of joint and adhesive used. The present study examined the effects of diagonal compression and tension forces upon spline joints. Joints were constructed using three types of wood-based board and either polyvinyl acetate or desmodur-vtka adhesives. Joint strength was determined experimentally by diagonal compression and tension test methods. The results showed that the diagonal compression and tension strengths were lower in all spline-jointed wooden board structures which used polyvinyl-acetate glue and were higher in those structures which used desmodur-vtka glue.

Key word: Glue, wooden joint, strength of diagonal compression, strength of diagonal tensile.

INTRODUCTION

The use of wood in furniture construction has been replaced by larger, more economical and more decorative wood based boards. These materials vary widely in both style and cost, with the result that the strength of these materials, in terms of joining and adhesive type, are not known. This can lead to many groundless views among small-scale tradesmen, on even the strongest materials. This situation contributes to a number of problems include miss-information amongst tradesmen and consumers and the miss-application of products. The strength of joints in furniture construction is regarded as a new research topic. A number of researchers have previously investigated similar construction techniques (Lin and Eckelman, 1987; Zhang and Eckelman 1993a, b; Cai et al., 1995). Taş et al., (2007) studied spline-jointed experimental samples constructed from veneer-covered fiberboard (MDF) and glued with polyvinyl acetate (PVAc) and desmodur-vtka Glue (Polymarine). It was found that the highest resistance to diagonal pressure in samples glued with polymarine adhesive was 0.78N/mm², compared with 0.51 N/mm² in the samples glued with PVAc. The highest tension strength in the samples glued with polymarine adhesive was found to be 13.14 N/mm², compared with 10.04 N/mm² in the samples glued with PVAc.

It was researched effects of glue type to diagonal tensile strength at the corner joint with tenon-motrise. At the end of tests it has been determined that fibreboard has provided superiority to chipboard and that the PVAc (Polyinilacetat) glue has provided the best strength values in L-type corner joints (Efe and Kasal, 2000). It has been stated that "Moltinject" type joints provide greater strength compared to dowel joints in case furniture constructions using chipboard (Liping et al., 1995). It has been revealed that the highest tensile strength and pressure resistance for dowel joints in wood-based chipboard material is achieved when the distance between two dowels is 7.5 cm (Zhang and Eckelman, 1993a). It has been determined that in case furniture constructions using chipboard; rebated, rebated with wire hook and wedged rebated joints - among the corner joint samples prepared with PVAc glue - have respectively produced the highest strength values during the tests for bending resistance (Ching and Yiren, 1994). Compressive strength and tensile strength have found out to increase in parallel to the increase in dowel size in the single dowel case-construction corner joints using chipboard material (Zhang and Eckelman, 1993b).

Compressive strengths of the dowel corner joints glued with various pastes and used in box construction were compared. At the end of the compression tests conducted according to ASTM D 143-83 principles, it was found out that fibreboards produced better results than particle

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boards and that, among the pastes used in the study, polyvinylacetat showed the best performance (Efe et al., 2002).

Fibreboard and particle board corner joints were tested under compression and tensile loads. Fibreboard corner joints were found to develop higher resistance than particle board corner joints in both compression and tensile tests (Tankut, 2005).The mixture of the two conventional joint types that is, dowels and splineing joint was detected to considerably increase the resistance of the non-structural cupboard corner joints (Altınok et al., 2009). In addition, obtained scientific results are parallel to those obtained by Efe et al. (2002) and Tankut (2005).

Özen (1996) found that dowel joints gave the best results for theoretically calculating the strength characteristics of some joint points whereas spline joints were ranked second.

Dinç (2000) investigated the diagonal compression and tension performance of samples which were prepared from particle board, fiberboard and artificial resin plaque and joined with plastic and metal minifix joining elements. The combination of plastic minifix joining elements and processed fiberboard was observed to give the strongest results.

Atar (2006) has stated that the melamine-impregnated-paper adhered to the surfaces of the board equipments have badly affected the adherence resistance of the glue on the combination plane due to their oil structure.

The purpose of the present study is to investigate how the diagonal compression and diagonal tension strength of spline-jointed wooden boards varies according to the board material and the type of adhesive used for the joint. Diagonal compression and diagonal tension tests were applied to the samples, which were constructed with particleboard, medium-density fiberboard, melamine-faced particleboard. Polyvinyl acetate and desmodur-vtka type of adhesives were applied to the splines.

MATERIALS AND METHODS

Material

The present study utilized some of the most widely-used materials in the furniture construction, namely: fiberboard (MDF), particleboard (PB), melamine-faced particleboard (PB-L). Beech plywood (3 mm-thick), utilized polyvinyl acetate (PVAc) and desmodur-vtka (polymarine) adhesive for spline joints.

Polyvinyl acetate (PVAc): The PVAc adhesive used in the study was produced by Polisan. It was used as its supplied viscosity (Nemli, 1995) of 500 ± 10 cp (20°C), pH: 5 (20°C) and its density was 1.12 g/cm$^{3.}$

Desmodur – VTKA (Polymarine): Polymarine is solvent-free unicomponent polyurethane-based adhesive which is resistant to wet and humid environments (Anonymous, 1999). It is commonly used in marine and freshwater vehicles and for weather-proofing wooden cladding on the exterior of dwellings. It is also suitable for use in humid environments such as bathroom and kitchen (Anonymous, 1998). In the present study, polymarine adhesive was used at its supplied viscosity in accordance with the manufacturer's recommendations.

Preparation of experimental samples

A total of 120 board samples were prepared, of which 10 samples were used for each glue type and experimental method (2 x 3 x 2 x 10 = 120) (Figure 1).

As seen from the sample in Figure 1. 9 mm-deep grooves were cut in the three board types, representing half the depth of the spline insert (18 mm total by 3 mm width) according to the measurements shown. Adhesive was applied to the grooves, on the surface of the splines and on the adjoining surface of A element. Both types of adhesive were applied at 160 g/m². Strange (which is not one of the known splines) spline was first placed on A element and then on B element. A pressure of 2 N/mm² was applied to the surface of the joining cross-section. After almost 1 h under pressure, all samples were stabilized at 65% ± 5% relative humidity and 20°C for three weeks. It was balanced at 12% humidity and so the glue could achieve its full strength.

Experimental method

Diagonal forces on a corner construction attempt to fold the vertical elements onto the horizontal sections, thereby exerting leverage upon the joints the places these points under tension or compressive stress (Özçifçi, 1995). Therefore, the experimental method focused on measuring the diagonal tension and compression pressures representing openings and closings on the surface of cross-sections (Figure 2).A gradual static force was applied using a universal testing machine. A wheel system was used in diagonal tension testing so as to prevent friction on basic points of the sample. The applied force during the destruction of samples (F_{max}) was measured and recorded as N (Newton) by the quadrant of the device. Since all the dimensions of the samples are the same maximum load that the sample has been destroyed as strength or load carrying capacity.

Statistical evaluation

The empirical test results were subjected to statistical analysis, in order to determine the effect of board and glue type on diagonal compression and tension strength in case constructions using spline joints. Analysis of variance (ANOVA) was applied to the results. DUNCAN test was applied to the mean values of diagonal compression strength (using a 95% confidence interval) in order to determine which factors were statistically significant.

RESULTS AND DISCUSSION

Load carrying capacity values obtained from experimental test samples are shown in Table 1 and their multiple variance analysis results are shown in Table 2.

According to the results of the analysis of variance (AN OVA), the difference between the groups was found to be statistically significant at the 95% confidence level. A least significant difference DUNCAN test was appliedto the mean test data in order to determine which test, board and glue type groups exhibited a significant difference. DUNCAN test indicates that joints are more resistive to tension forces than compression forces. This is somewhat expected because in compression test forces are

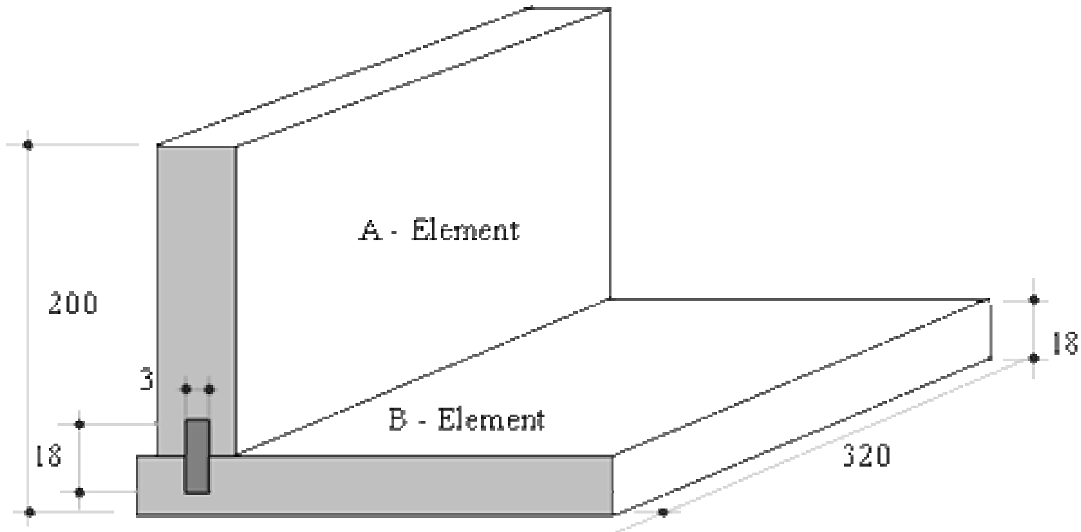

Figure 1. Sample construction method for testing diagonal compression and tension strength - dimensions in mm (Tas, 2000).

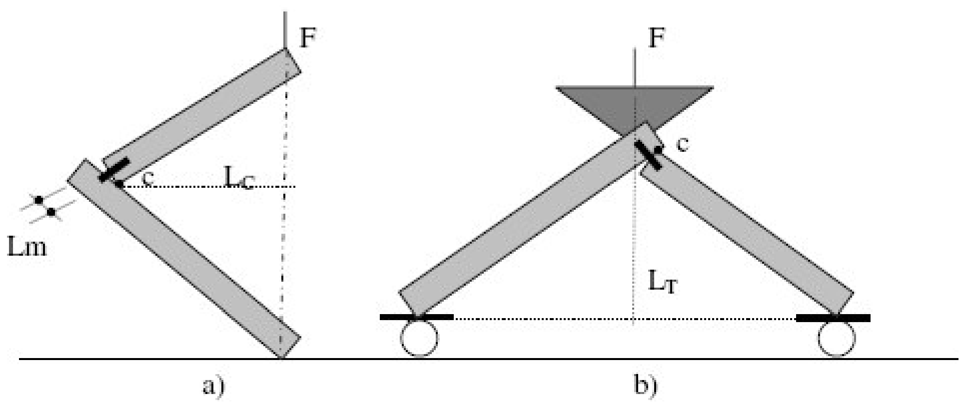

Figure 2. Diagonal compression and tension tests. (a) Diagonal compression test. (b) Diagonal tension test

Table 1. Diagonal load carrying values of spline-joints (N).

Test type	Material	Adhesive	Mean	Std. dev.	Min.	Max.
Compression	MDF	POL	563.14	65.45	479.35	640.48
		PVA	404.43	68.86	338.37	515.60
	SLAM	POL	351.46	16.59	324.27	374.62
		PVA	348.24	16.67	324.27	374.62
	PBOARD	POL	566.36	60.71	479.35	640.48
		PVA	350.45	17.48	324.27	374.62
Tension	MDF	POL	1620.22	98.37	1407.61	1737.52
		PVA	1493.02	160.84	1264.65	1730.19
	SLAM	POL	627.56	66.61	553.51	725.80
		PVA	626.09	107.87	476.53	762.46
	PBOARD	POL	2119.85	210.21	1818.16	2401.00
		PVA	1129.02	171.82	967.73	1370.95

Table 2. ANOVA table for load carrying capacity of spline joints.

Source	DF	Sum of squares	Mean square	F value	Pr > F
Model	11	39078211.96	3552564.72	306.92	<.0001
Test	1	21098194.84	21098194.84	1822.76	<.0001
Material	2	7856411.26	3928205.63	339.37	<.0001
Adhesive	1	1868328.45	1868328.45	161.41	<.0001
Test*Material	2	4774952.44	2387476.22	206.26	<.0001
Test*Adhesive	1	458371.84	458371.84	39.60	<.0001
Material*Adhesive	2	1976590.28	988295.14	85.38	<.0001
Test*Material*Adhesive	2	1045362.85	522681.42	45.16	<.0001
Error	108	1250082.72	11574.84		
Corrected Total	119	40328294.68			
R-Square	Coeff Var	Root MSE	Mean		
0.969002	12.65744	107.5864	849.9854		

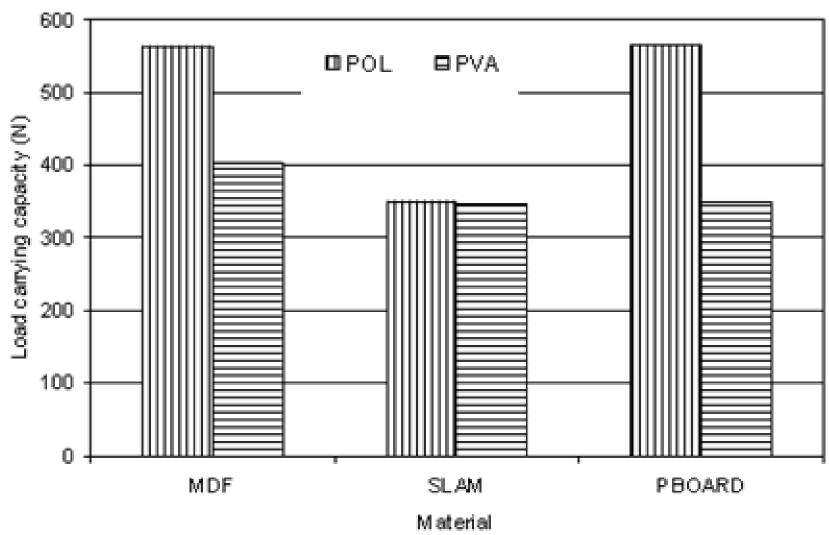

Figure 3. Comparison of spline joints in compression test.

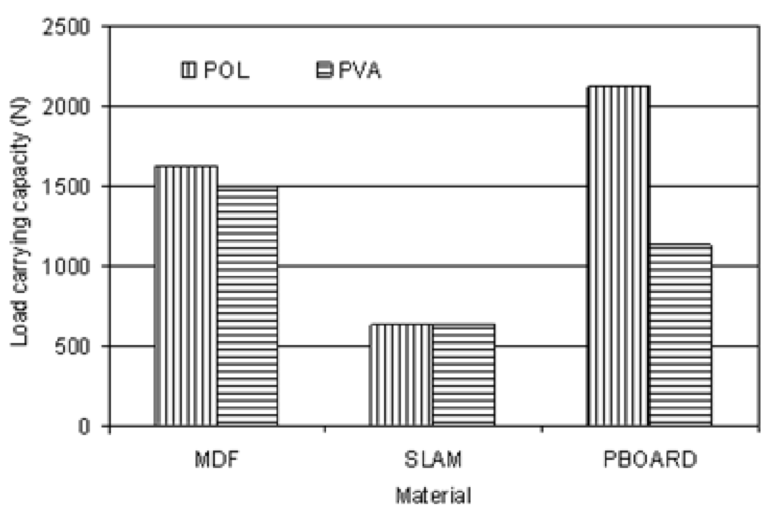

Figure 4. Comparison of spline joints in tension test.

are exerted perpendiculars to the side of the joint elements which have low edge breaking strength. In tension test forces are exerted similarly but, internal bond strength is higher. Likewise, joints constructed with MDF and Particleboard is stronger than joints constructed with SL-AM. It is well known that MDF has higher density, thus higher mechanical properties than particleboard. Density is a major measurement of mechanical properties in wood and wood based composites. Polimarin adhesive can be used to construct stronger joints. Comparison of joints is presented in Figures 3 and 4.

Conclusion and Suggestions

In conclusion, YL with a wood-based surface or MDF have been shown to be preferable materials spline-joint case construction using both PVAc and polymarine glue types. In the case of YL Lam use, it is suggested that the resin-based plaque be adequately removed from the cross-section surface of the joint.

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