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Full Length Research Paper

Strength properties of L-profiled furniture joints constructed with laminated wooden panels

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This study analyzed the effects of L-profiled corner joint design on maximum load-carrying capacity of case furniture. For massive panels material (Red Pine), two test groups were formed using Polyvinyl Acetate (PVAc), Desmodur-VTKA (Polymarine) and Purocal (polyurethane-based) adhesive types. First group test samples were prepared using L-profiled corner joint and second group test samples were prepared without using these. Both test samples were prepared using dowel joints. Maximum load-carrying capacity values obtained after diagonal compression and tension tests on test samples were analyzed. The evaluations indicated that the load carrying capacity of the test samples prepared by using L-profiled corner joints was four times greater than that of other group.

Key words: Joint type, adhesive type, massive panels.

INTRODUCTION

A wide variety of production variables affect the performance of case furniture. Among those, board and joint types have primary importance. The behaviour of case furniture under external loads depends on the board and joints used in the construction. Although particle-board and medium density fibreboard (MDF) are the most common board types used in case construction, a wide variety of joining materials are available. Strength and stiffness of board materials are usually known and controlled by the density of the material. By establishing the properties of the board materials, deflection in the shelves / horizontal members and their load-carrying capacity can be calculated. Several studies reported that joints constructed with MDF have higher strength and stiffness properties than joints constructed with particleboard (Efe et al., 2002; Guntekin, 2003; Tankut, 2005).

However, prediction of joint behaviour is more complicated and effected by a wide variety of variables, including the type and number of fasteners, adhesives used, etc. In the case of dowel joints, the number of dowels, spacing, dowel diameter and length, embedment depth and types of adhesives determine the behaviour of the joints (Zhang and Eckelman, 1993a; Zhang and Eckelman, 1993b). Dowel joints are stronger and stiffer than ready-to-assemble fasteners for case furniture (Guntekin, 2003). Dowel joints are also stronger than glued rebated and spline joints (Ozciftci, 1995; Ozciftci et al., 1996).

Among the adhesive types investigated, polyvinyl acetate (PVA) seems to provide higher performance for case construction (Ching and Yiren, 1994; Efe and Kasal, 2000; Efe et al., 2002). It seems that PVA has better gap filling properties than other adhesives. It has also been observed that overlaying materials may detrimentally affect the performance of glued joints in case construction (Atar, 2006).

A combination of the two conventional joint types that is, dowel and lathing joint was shown to considerably increase the resistance of the case furniture joints (Altınok et al., 2009). The objective of the present study is to determine the effects of L-profiled corner joints on case furniture resistance.

MATERIALS AND METHODS

Massive panel (Red Pine)

Massive panels (Red pine) are produced from rectangular profiled parts of trees such as pine, spruce and beech. They are produced using a “finger joint system “, by fixing finger joints long sections, parallel to fiber direction, from side alcoves. Environmentally friendly PVA D3 adhesive was used in joints and junctions of the material. The surfaces were smoothed using 120 grade emery, to give a decorative look. Massive panels (Red pine) are produced to different quality standards with dimensions of 1300 (mm) width, 12, 16, 18, 22, 25, 30 (mm) thickness and 2450, 3000 or 3500 (mm) length. (Anonymous, 2009).

The mechanical properties of the massive panel red pine material used for test samples are given in Table 1.

Adhesives

Polyvinyl Acetate (PVAc), glue has advantages such as being non-abrasive to cutting tools, being odour-free and non-flammable, being applicable cold, easy to apply and quick setting. Depending on the type and surface properties of the material to be joined, the application of 150 – 200 g/m^2 of glue on one of the surfaces is sufficient for good adhesion. The values specified for the adhesive are density 1.1 gr/cm^3,viscosity 160 - 200 cps, pH value 5, pressing duration; 20 min in cold application at 20℃, 2 min in 80℃ and it is recommended that it is left to stand in the pressing environment until it cools down (T.S.I, 1963). In the present study, Polyvinyl Acetate (PVAc) adhesive was used at its supplied viscosity in accordance with the condition of the T.S.I.

Desmodur-VTKA (Polymarine) is solvent-free uni-component polyurethane-based adhesive which is resistant to wet and humid environments. 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, 1999). In the present study, polymarine adhesive was used at its supplied viscositiy in accordance with the manufucturer’s recommendations.

Purocal is a silicone-like polyurethane-based adhesive that has recently started to be used in the furniture production sector. It is used to bond many different construction materials, such as fibreboard, concrete, metal, plastic and is used particularly for bonding wooden-based materials of 30% moisture content. The adhesive is transparent, non-dripping, rapidly penetrates bonding holes, resistant to water and chemicals and has an operational temperature range of -30 to 100℃. The surface to which the adhesive will be applied should be clean and free from oil. Soffits should be humidified to accelerate adhesive penetration into the bonding holes and to improve adherence. When applied on any surface, it should be clamped using a bench clamp for 30 min and left to dry. Application temperature is 35 ± 5℃. The adhesive should be stored in cool, dry conditions (Anonymous, 2006). In the present study, purocal adhesive was used at its supplied viscositiy in accordance with the manufucturer’s recommendations.

Preparation of samples

First, L-profiled joints to be used in corner joints of (60) samples were produced. The joint shown in Figure 1 was made of red pine (40 x 40 x 400 mm) having a thickness of 18 mm. The massive panels (Red pine) samples to be attached to the L-profile joints(n = 120) were prepared by processing wooden boards 18 x 200 x 400 mm in size, by using a panel saw and milling machine. The pieces were categorized into groups: horizontal and vertical and joined as shown in Figures 1 and 2. Their properties, amount and dimensions are presented in Table 2.

Experimental method

The factors that affect the load-carrying characteristics of box furniture constructions are the wooden-based board material selected, corner joint type and the strength of the adhesive used (Altınok, 1995). Compressive and tensile loads on the vertical and horizontal elements of the construction either force opening of the elements or compress them towards each other. When transferred to the joint between the two elements, these forces may result in joint-failure. Therefore, the study used diagonal compression and tension tests (Figure 3). The maximum compression resistance and tensile load were determined as the force applied to each experimental sample at the time of failure. The result for each of the samples was displayed by the computer to which the test device was connected.

Data evaluation

Homogeneity of the data was achieved by excluding outlying results that were not within a normal distribution obtained from the experiments. Multivariate analysis of variance (ANOVA) was used to analyze the data. Where the ANOVA results indicated a significant difference between groups, the Duncan test was used to compare the factors within the group. The success rankings of these factors were determined by classifying their average values into homogeneous groups.

RESULTS

Averages and standard deviations of the diagonal compression and tensile values related to joint and adhesive type are given in Table 3. The results indicates that dowel joints with polymarine adhesive performed well under compression, whereas those with silicone adhesive performed well under tension (compression value 321.60 N, tension value 393.50 N). However, it was found that mean compression values for L-profiled and dowel joints were high when using polymarine adhesive, while the tensile values were high when using silicone adhesive (compression value 839.70, tension value 1847.70).

Table 4 shows the results of Multivariate ANOVA to determine whether these differences were statistically significant. ANOVA results indicated that the difference between the groups was statistically significant at the 5% level in terms of test and joint type, while there was no significance in terms of adhesive types. In terms of the interactions between bilateral different groups, there was a statistical significance of 5%. However, there was no significant difference between the groups in terms of triple interactions.

The coefficient of variation is (11.9 %) and the (R^2) value is (0.97) that make results of the experiment rather reliable.

Tables 5, 6 and 7 show the results of Duncan test comparisons to determine the smallest significant difference between the related variables. Table 5 indicates that tension values obtained from test samples (1009.62 N) are two times greater than compression values (559.15 N).Table 6 indicates that L-connected tension values had four times greater resistance (1239.98 N) than that of conventional dowel joint test samples (328.78 N). Table 7 indicates that silicone and polymarine

Table 1. Mechanical properties of red pine (Erten and Önal, 2001)*.

Compression strength parallel to fibers, N/mm^2	43.83
Bending strength, N/mm^2	80.56
Elasticity module in bending, N/mm^2	8826
Tension strength perpendicular to the fibers, N/mm^2	19.22
Cleavage strength (Tangential direction), N/mm^2	0.558
Cleavage strength (Radial direction), N/mm^2	0.500

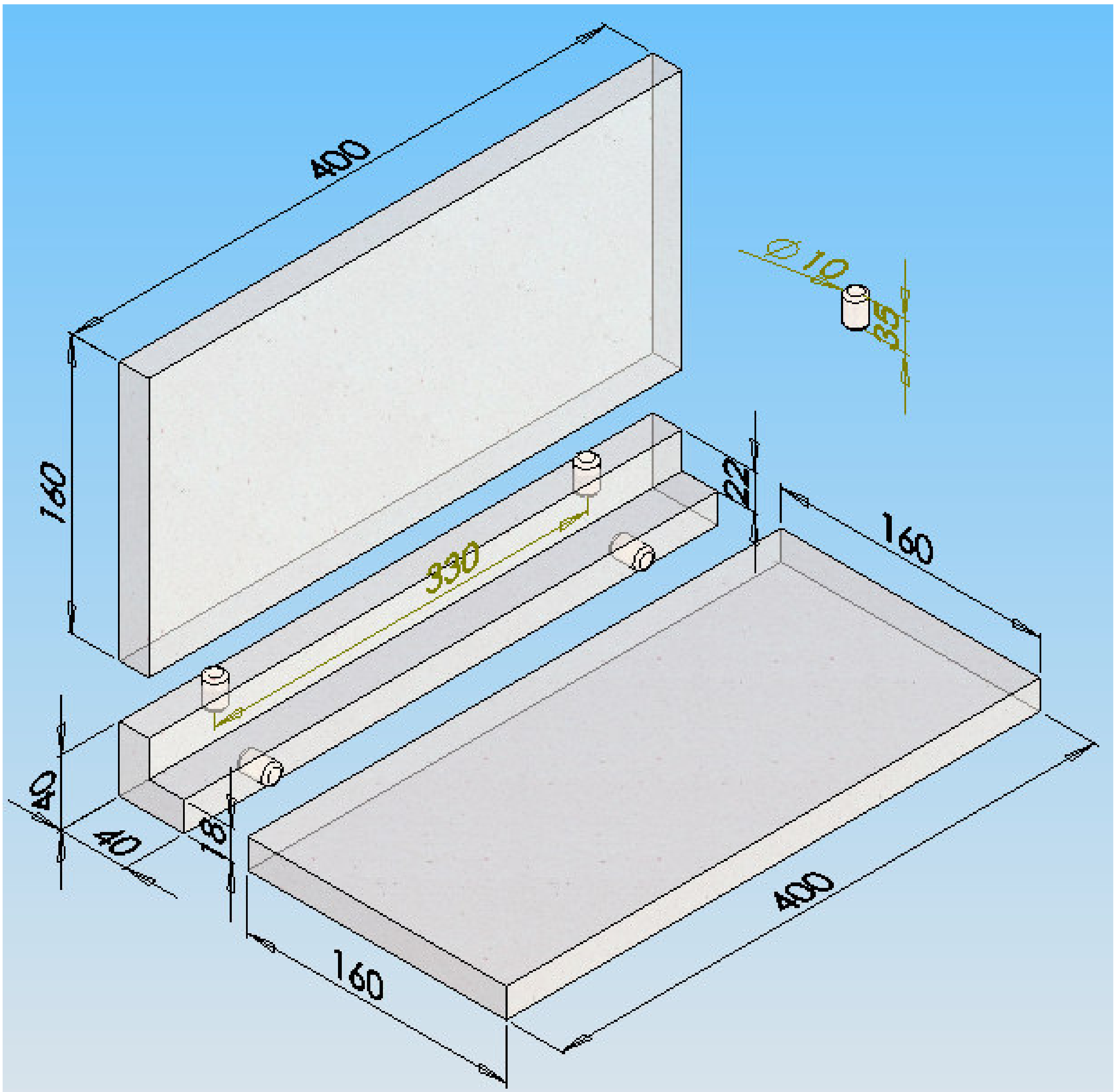

Figure 1. L'connected-and Dowel joint.

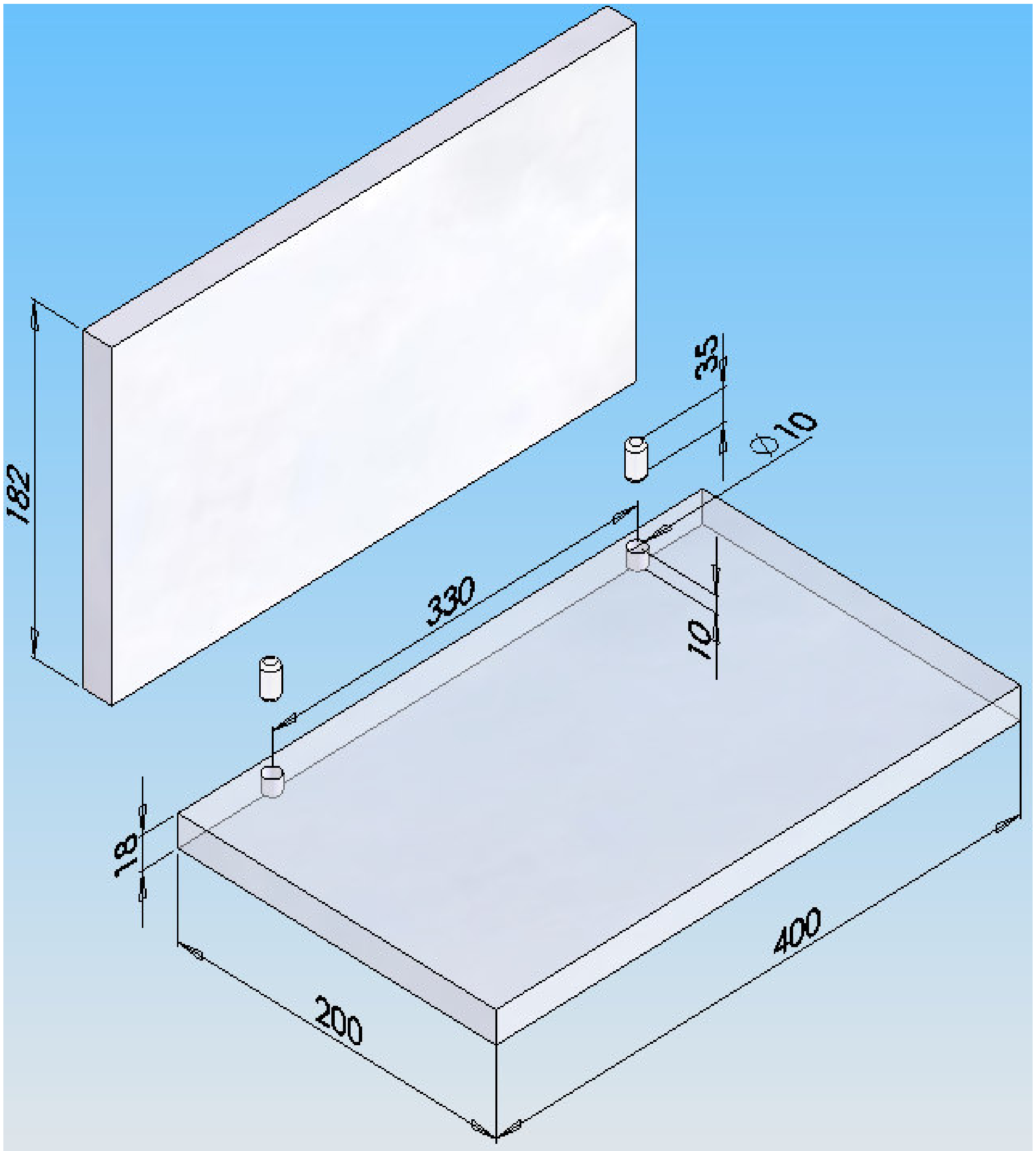

Figure 2. Dowel corner joint test sample.

Table 2. Properties, amounts and dimensions of the test samples.

Type of material	Corner joint method	Loading method and number		Table size (mm)		Joint component dimensions		Adhesive type
		< Compression	^ Tension	Length	Width	Dowel (mm)	L-Connected (mm)	
						L	L	
Massive panel (Red pine)	L-Connected-and Dowel joint (A)	10	10	400	200	Ø 10 x 35		PVAc
		10	10	400	200	Ø 10 x 35	40 x 40 x 400	Polymarine
		10	10	400	200	Ø 10 x 35		Silicone
	Dowel joint (B)	10	10	400	200	Ø 10 x 35		PVAc
		10	10	400	200	Ø 10 x 35		Polymarine
		10	10	400	200	Ø 10 x 35		Silicone

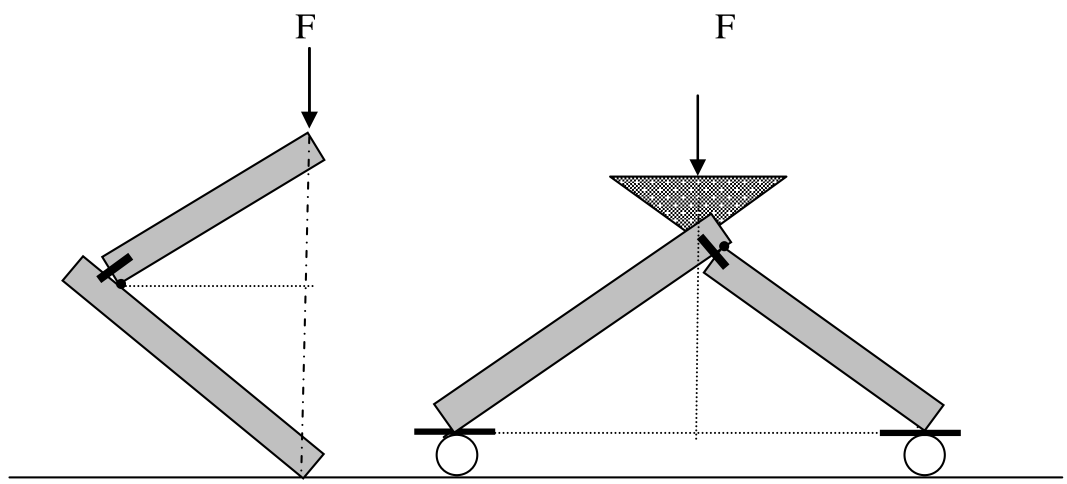

Figure 3. Diagonal compression (a) and Tensile (b) Tests.

Table 3. Diagonal compression and tension values related to joint and adhesive type.

Corner joint method	Adhesive type	Compression load (n)		Tension load (n)	
		$\overline{X}$	s	$\overline{X}$	s
L-Connected and Dowel joint (A)	PVA	804.10	73.61	1522.10	214.57
	Polymarine	839.70	73.51	1618.10	156.52
	Silicone	808.20	76.88	1847.70	116.28
Dowel joint (B)	PVA	320.80	17.35	308.40	39.78
	Polymarine	321.60	20.23	367.90	30.24
	Silicone	260.50	20.89	393.50	28.13

$\overline{X}$: Arithmetic mean, *s*: standard deviation.

Table 4. Multivariate analysis of variance (ANOVA) results for compression and tension loads.

Variance source	Sum of squares	S.D	Average of squares	F - value	P-value
Test type A	6087606.53	1	6087606.53	694.16	< 0.0001
Corner joint method B	24908563.20	1	24908563.20	2840.29	0.0001
Adhesive type C	157445.52	2	78722.76	8.98	0.0002
A x B	4676800.83	1	4676800.83	533.29	0.0001
A x C	294287.72	2	147143.86	16.78	0.0001
B x C	127180.55	2	63590.27	7.25	0.0001
A x B x C	51191.22	2	25595.61	2.92	0.0583

R^2 = 0.974574, Coefficient variance = 11.93891.

Table 5. Duncan comparison test results by test type.

Test type	Test samples number	Mean (Newton)	Duncan group
Tension	60	1009.62	A
Compression	60	559.15	B

Table 6. Duncan comparison test results by joint type in tension tests.

Joint method	Test samples number	Mean (Newton)	Duncan group
L-connected and Dowel joint	60	1239.98	A
Dowel joint	60	328.78	B

Table 7. Duncan comparison test results by adhesive type in tensile tests.

Adhesive type	Test samples number	Mean (Newton)	Duncan group
PVA	40	738.85	A
Polymarine	40	786.83	B
Silicone	40	827.48	B

adhesives have similar load-carrying values that are greater than the load-carrying capacity of PVA adhesive.

DISCUSSIONS AND CONCLUSION

The present study found that joint type and adhesive type affected the diagonal compression and tension load-carrying capabilities of furniture case constructed from Massive panels (Red pine) material.

Duncan test comparisons of load types indicated that tension test values were two times greater than compression values. These results are in agreement with those reported by Özçiftçi (1995, 1996) and Güntekin (2003).

Duncan test comparisons of joint types indicated that L corner joint samples had four times greater tension resistance than that of dowel joint samples. The reason for this difference is the L profiled joint. The fact that this L profile made from red pine is produced without any joint makes it more resistant to loads in the corners of the furniture. In addition, it can be stated that, in conventional massive panels (Red pine) case furniture joints (Dowel-Lathly Joint, Mixed; Dowel Lathly Joint, Grooved), joint strength is weak, due to overlap of the surfaces. In L profiled corner joint massive panels (Red pine) case furniture, vertical and horizontal elements are joined parallel to their axis from the side surface of the L profile and thus joint strength increases.

Duncan test comparisons of adhesive types indicated that silicone adhesive was in the same Duncan group as polymarine adhesive and had a higher load-carrying capacity than PVAc adhesive.

Based on the test results, it can be suggested that L profile dowel joints and silicone adhesive should be used in the production of massive panels (Red pine) case furniture, in order to increase the quality and life span of the furniture.

REFERENCES

Altınok M (1995). Sandalye tasarımında gerilme analizlerine gore mukavemet elemanlarının boyutlandırılması, Gazi Üniversitesi, Fen Bilimleri Enstitüsü doktora tezi,Ankara.

Altınok M, Taş HH, Çimen M (2009). Effects of combined usage of traditional adhesive joint methods in box construction on strength of furniture. Materials and Design doi:10.1016/j.matdes.2008.12.004.

Anonymous (1999). Bıson product catalogue, Turkey.

Anonymous (2006). Purocol data sheets, Turkey.

Anonymous (2009), Mobipan product catalogue, Turkey.

Atar M (2006). Melamin Reçineli Kağıtla Kaplanmış Yonga levhanın Çeşitli Malzeme ve Tutkallarla Yüz Yüze Yapışma Direnci. J. Polytech. 3(4): 1-9.

Ching SW, Yiren W (1994). A study on bending moment resistance of particleboard corner joint in carcass furniture. Department of forest products industry, National Chia-yi Institute of Agriculture Taiwan Forest Products Industries 13 (4): 600-610.

Efe H, Kasal A (2000). Tabla tipi kavelalı köşe birleştirmelerde tutkal çeşidinin cekme direncine etkileri. J. Polytech. 3(4): 67-72.

Efe H, Kasal A, Gürleyen L (2002). The compressive strength of corner joints with dowel bonded with various types of adhesives on case construction. J. Ind.l Arts Edu., Faculty of Gazi University 10: 39-56.

Erten P, Önal S (2001). Kızılçam odununun özellikleri, kullanım yerleri, korunması ve reçine üretimi. Kızılçam El Kitabı, Muhtelif Yayınlar serisi: 52, Erol Öktem, Ormancılık Araştırma Enstitüsü, Ankara, pp.169-178.

Güntekin E (2003). Performance of ready-to-assemble (RTA). Süleyman Demirel Univer. For.Faculty J. 2: 37-48.

Ozciftci A (1995). An investigation of strength properties on corner joints of furniture prepared with particleboard. MSc dissertation, Gazi University, Ankara, Turkey.

Ozciftci A, Altınok M, Özen R (1996). Kutu mobilyada bazı köşe birleştirmelerin mukavemet özelliklerine ait deneysel sonuçların istatiksel analizi ve değerlendirmesi. J. Sci. Res. Found. 1(2): 63-70.

T.S.I 3897 (1963). Yapıştırıcılar-polivinilesetat emilsiyon,Ankara.

Tankut A (2005). Optimum dowel spacing for corner joints in 32-mm cabinet construction Forest Prod. J. 55 (12): 100-104.

Zhang J, Eckelman CA (1993a). Rational design of multi-dowel corner joints in case construction, Forest Prod. J. 43 (11/12): 52-58, 1993a.

Zhang J, Eckelman CA (1993b). The bending moment resistance of single dowel corner joints in case construction. Forest Prod. J. 43 (6): 19-24.