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The influence of pilot hole on the moment resistance of screwed T-Type furniture joints

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Abstract: This study was carried out to determine the effects of pilot hole, screw diameter, and wood composite panel type on the diagonal compression and tension strength properties of particleboard surfaced with synthetic resin sheet (LamPb) and MDF surfaced with synthetic resin sheet (LamMDF). Two different diameter of screws (3,5 and 4 mm) and three types of pilot holes (either 70 or 85 % of the root diameter of the screws, and without pilot hole) were utilized for constructing the test specimens. Samples with pilot hole gave higher strength values than control samples of all T-type corner joints. Namely, the use of pilot holes of the proper diameter significantly increases the bending and tension strength of the screws in the material. Pilot hole diamater was found to have a larger influence on bending moment resistance than screw diameter and panel type. Results of means separations of moment resistances indicated that in general the joints loaded in bending have greater moment resistance than those loaded in tension. LamMDF corner joints were stronger than LamPb corner joints. As case furniture constructions are under bending forces, in LamPB using 3.5 x 50 screws with a pilot hole of 70 % of the root diameter of the screws, in LamMDF using 4 x 50 screws with 85 % of the root diameter of the screws can be recommended as the most robust corner joint type for case furniture. As case furniture constructions are under tension forces, in LamPB using 4 x 50 screws with a pilot hole of 85 % of the root diameter of the screws, in LamMDF using 3.5 x 50 screws with 85 % of the root diameter of the screws can be recommended.

Keywords: screws, pilot hole, wood composite material, case furniture

INTRODUCTION

For an efficient design of the case furniture constructed using screws requires specific design information on the the moment resistances of fasteners in LamMDF and LamPB. Several investigations have been made on the screwed corner joints that have yielded data on this design.

Published information is mostly related to direct withdrawal resistances of screw-type joints (Eckelman 1974, 1975a, 1975b, 1978, Rajak and Eckelman 1993, Eckelman and Martin 1980, Erdil et al. 2002, Tankut 2007). Efe and Kasal (2000) stated screwed joints gave better strength than the glued joints with a fiberboard. Research has been carried out to determine strength properties of comer joints connected with screws and dowels (Rajak 1989, Rajak and Eckelman 1996, Liu and Eckelman 1998, Ho and Eckelman 1994).

It was stated that withdrawal strength for each size of screw was affected by the diameter ratio of pilot hole for screw (Fujimoto and Mori 1983). Johnson (1967) noted that no significant difference was found in strength values obtained with pilot holes that were either 40 or 70 % of the root diameter of the screws. Withdrawal strengths were about 13 % higher when optimum pilot holes were used than when pilot holes were not used (Eckelman 1988, 1990). It is stated that the glue applied in pilot hole increased the withdrawal strength for screws (Ors et al 1998). Doganay et al. (1997) observed that the covered panels having glued-pilot hole showed the highest holding strength. Tankut (2004) stated that joint strength was strongly influenced by the type of particleboard used.

RESEARCH OBJECTIVE

The objectives were to:

1. Compare moment resistance of the screwed corner joints constructed of different panel materials, namely LamPB and LamMDF.
2. Determine the effects of pilot holes used in the joints on moment resistance of screwed corner joints.
3. Determine the effects of screw diameter utilized for connecting the specimens on bending moment resistance of the screwed corner joints.

MATERIAL AND METHODS

Material properties

Eighteen mm thick LamPb and LamMDF were selected for this study because of their common use by the Turkish cabinet manufacturers. In preparing specimens, 188 by 366 cm full-sized board sheets were first cut into face and butt member strips. These strips were subsequently cut into the desired member lengths. Members for joints were randomly selected from this common supply.

The stiffness and modulus of rupture of the materials were determined following the procedures given in ASTM standard D 1037-89. Specific gravity values of LamPb and LamMDF were calculated following ASTM Standard D 2395-93 Method A. Moisture contents were calculated on the same specimens and followed ASTM Standard D 4442-92 Method A, oven-drying method. IB (internal bond strength) tests of LamPb and LamMDF were performed following the procedure given in ASTM Standard D 1037-96a.

Screws

A total of two pan head, slotted, zinc plated, chipboard screws (3.5 x 50 and 4.0 x 50), having Turkish Standards TS 431 were used in this study. These screws were selected not only they are low-cost fasteners because they are readily available for the furniture industry, but also they have excellent holding strength in wood and woodbased materials. Properties of screws are given in Figure 1. Root diameter, outside diameter, and thread per mm were 2.4±0.25 mm. 4.0 ±0.3 mm, and 1.8 mm. respectively for 4-mm screws; and 3.0 ± 0.3 mm; 5.0 ± 0.35 mm, and 2.2 mm, respectively for 5-mm screws. Specification of screws used in this study is shown in Table 1.

Table 1.Specification of screws

Thread size		**3,5**	**4**
Major Dia	D	3.55	4.05
	min.	3.20	3.70
Minor Dia	d	2.20	2.55
	min.	1.60	2.15
Head height	A	7.50	8.05
	min.	6.64	7.64
Head height	H	2.00	2.35
Recess width	M	4.0	4.4
Drive Size	PH	2	2
Torque	min.	20	30
Recess depth	Q	2.16	2.51
	min.	1.76	2.05
Material		C1018-C1022	
Core hardness		240-450HV	
Surface hardness		min. 450HV	
Surface hardness		0.05-0.18 mm.	0.10-0.23 mm.

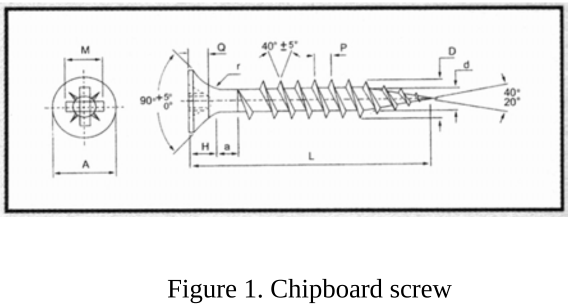
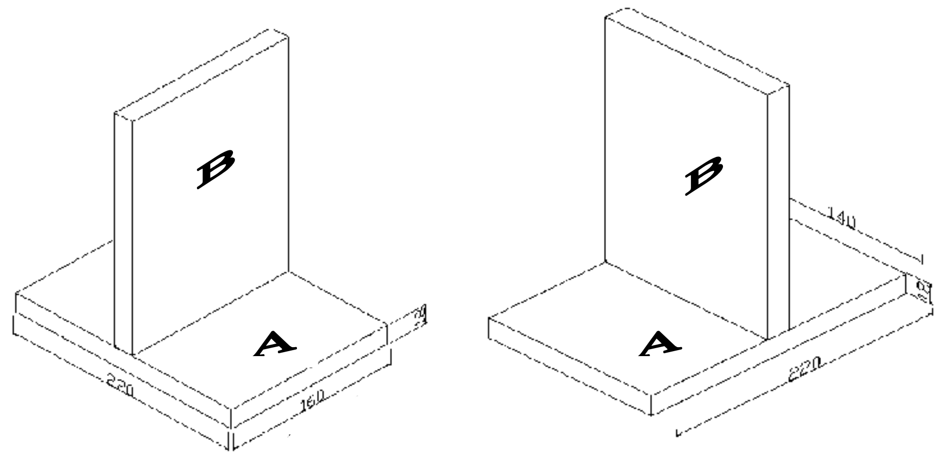


Figure 1. Chipboard screw

Joint configuration

The general configuration and detail of specimens is shown in Fig. 2. Zhang and Eckelman's (1993) work was used for the preparation of samples and testing. Each T-shaped specimen consisted of two principal structural members (A member and B member) jointed together. Before the tests, specimens were kept in an environment chamber at 20± 2 °C temperature and 65±5 % relative humidity until their weight became constant.



(a) (b)

Figure 2. General configuration of the specimens for bending (a) and tension (b) tests in mm

By using two different types of panels (LamPb and LamMDF), two different types of screw diameter (3.5 and 4 mm), three types of pilot holes (either 70 or 85 % of the root diameter of the screws, and without pilot hole) and two different types of forces as parameters, for both test methods (bending and tension), a total of 120 samples were prepared using 5 samples for each parameter.

Screws were drilled to the center of the thickness of rail members (Fig.3). When attaching screws, pilot holes were bored into the post side and end of the rail followed Eckelman 's (1990, 2003) work. The diameters of the pilot holes were equal to approximately either 70 or 85 % of the root diameter of the screws, and depths of the pilot holes were equal to approximately 75 % of the penetration of the screws.

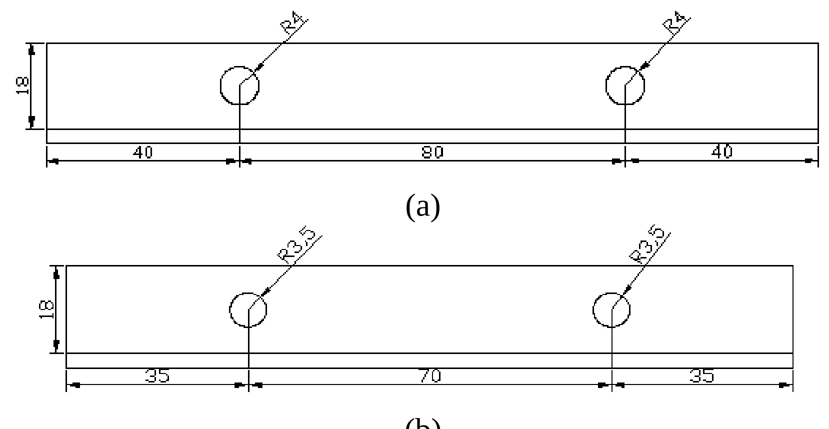


Figure 3. The distance between center of screw holes for bending (a) and tension (b) tests (in mm)

Test methods

‘‘T’’ joints were tested in a universal testing machine having 10 ton capacity fitted with a cast aluminum alloy angle plate to support the leg section while the rail section was loaded by means of a stirrup attached to the machine cross head. Universal test machine was equipped with jigs to hold the specimens and applying 1.5 mm/min loading time. A concentrated load was applied to the rail of each specimen at a point 21 cm from the front edge of the post as shown in Fig. 4.

The maximum bending and tensile strength were determined as the force applied to each experimental sample at the time of failure. Ultimate failure load values and joint failure modes were recorded. The loading was continued until a failure or full separation occurred in the specimens. The strength of joints was characterized by the bending moment value at which the joint was destroyed. Applied loads were converted to moment acting at the joint center per cm of joint width.

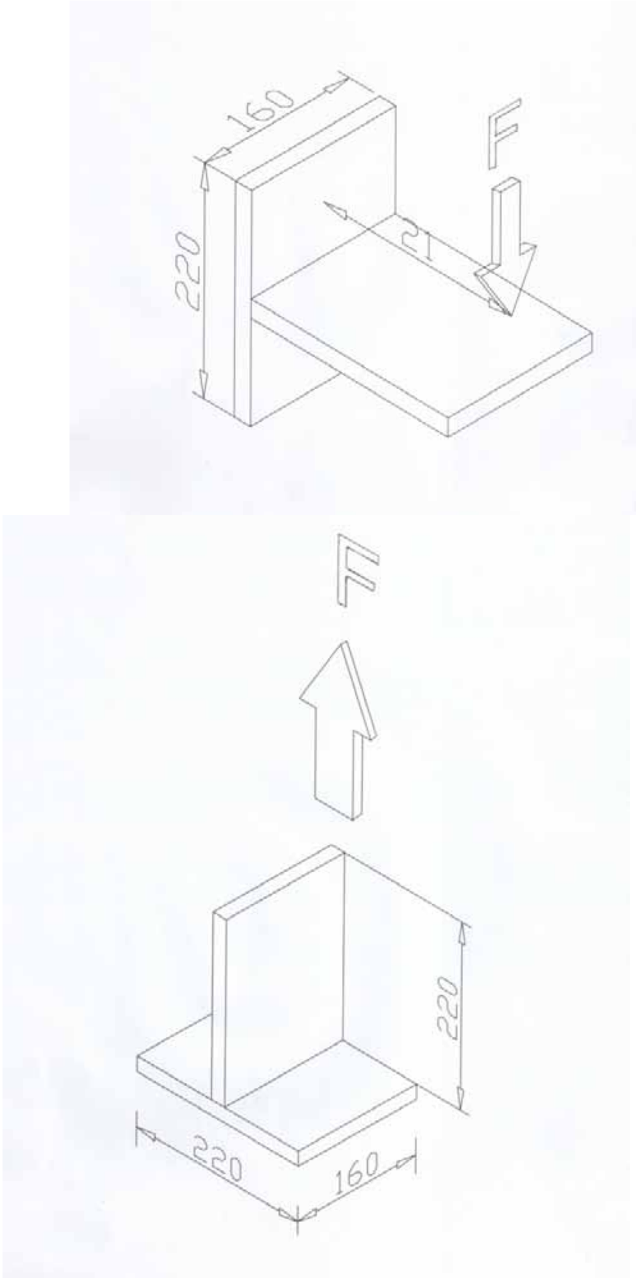


Figure 4. General configuration of the test setup used in the study.for bending (a) and tension (b) tests (in mm)

The ultimate moment capacity of the joint is calculated as the product of breaking load and the distance between the point of application of the load and the face of the joint. The ultimate moment capacity is, in fact, the bending moment required to break the joint and it is expressed in units of Ncm (Eckelman 2003). In this study the moment arm (L = 21cm) was measured from the point of load application to the face of the joints. Ultimate moment capacity, f, was calculated as

f= F x L (Ncm)

where F is the applied load (N).

RESEARCH RESULTS

Table 2 shows the average physical and mechanical properties of the LamPb and LamMDF used in the tests.

Table 2. Average moisture content and mechanical properties of the particleboard surfaced with synthetic resin sheet (LamPb) and MDF surfaced with synthetic resin sheet (LamMDF) used in the tests

Material	Moisture Content (%) (COV)*	Specific Gravity (COV)	Internal Bond (N/mm²) (COV)	Modulus of Elasticity (N/mm²) (COV)	Modulus of Rupture (N/mm²) (COV)
LamPb	6.5 (7.6)	0.648 (5.3)	0.502 (8.6)	1,986 (7.3)	17.47 (3.8)
LamMDF	6.1 (4.9)	0.762 (2.9)	1.520 (9.7)	2,868 (6.8)	33.32 (9.6)

* : Coefficient of variation

Pilot holes serve to locate screws and facilitate their insertion in a desired direction. It was found to be difficult to insert a screw into a specimen that lacked a pilot hole, and when it was inserted, the screw had a tendency to go off at an angle, i.e., to not "go straight." Results indicate that ultimate moment capacity of joints increases as pilot hole size is increased, until the pilot hole nears the root diameter of the screw. On the average, there was a 26.1% increase in strength when pilot holes were used compared to when no pilot holes were used as shown in Table 3 and Figs 5 and 6.

Table 3. Bending and tension strength values according to panel, pilot hole and screw diameter.

Panel Type	Pilot hole	Screw diameter (mm)	Loading method and number of specimens		Average bending strength (N)	Mean ultimate moment capacity (Ncm)	Average tension strength (N)
			Bending	Tension			
Lam Pb	Kontrol	4	5	5	105 (31.4)	2205 (21.15)	41,53 (19)
	Kontrol	3,5	5	5	77 (27.1)	1630 (12.33)	22,18 (12)
	2,5	4	5	5	84 (18.8)	382 (30.2)	26,86 (7)
	2	3,5	5	5	103 (41.7)	204 (20.1)	41,64 (14)
	2	4	5	5	50 (24.2)	247 (11.8)	32,62 (32)
	1,5	3,5	5	5	159 (29.3)	383 (21.7)	39,03 (12)
Lam MDF	Kontrol	4	5	5	115 (48.5)	300 (20.2)	55,99 (12)
	Kontrol	3,5	5	5	315 (22.8)	359 (19.3)	34,25 (14)
	2,5	4	5	5	383 (18.7)	515 (31.5)	41,64 (8)
	2	3,5	5	5	253 (19.9)	315 (20.8)	27,51 (7)

2	4	5	5	275 (22.4)	383 (11.7)	29,90 (6)
1,5	3,5	5	5	327 (34.2)	253 (11.9)	35,55 (21)

* standard deviation in parenthesis

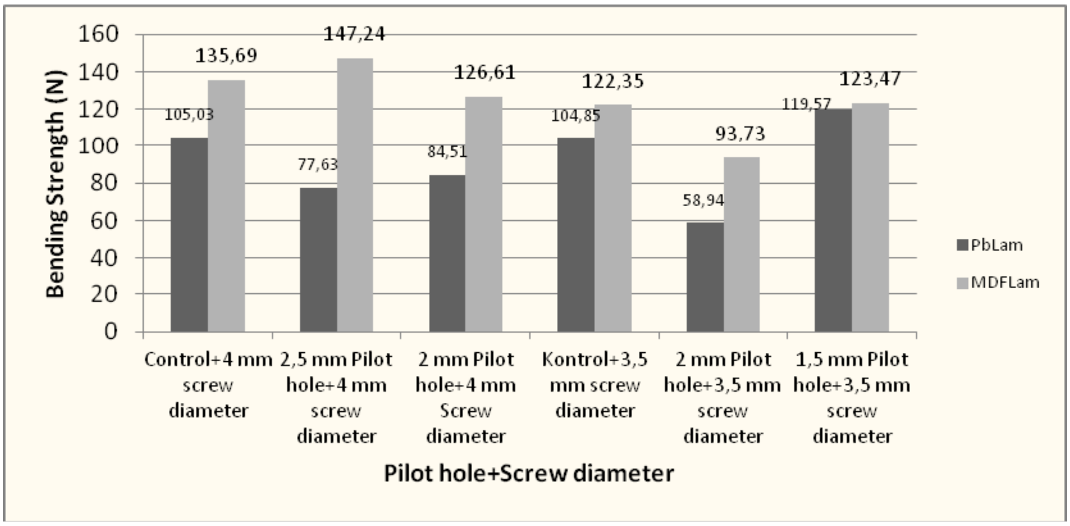


Figure 5. Effect of pilot hole and screw diamater on bending strength of T-type joints

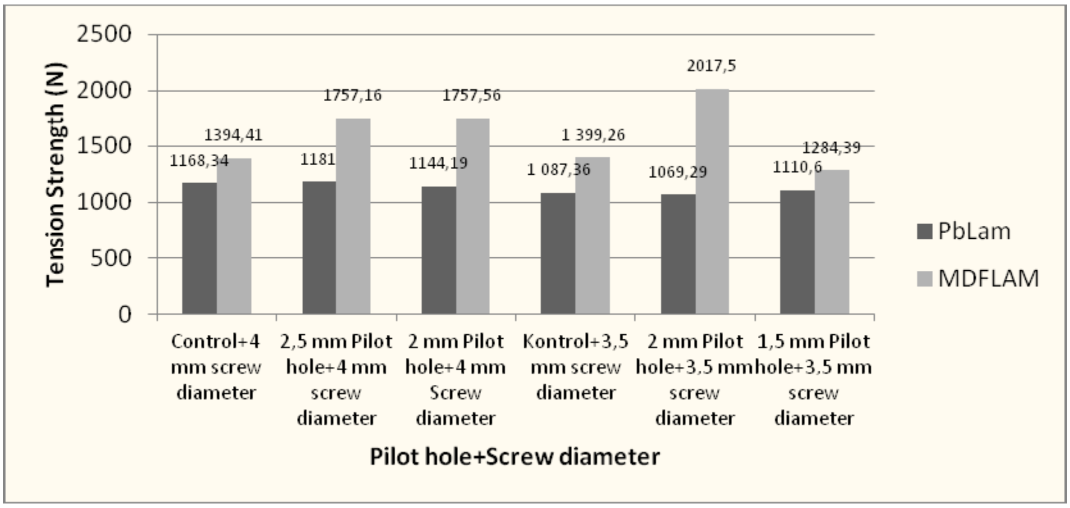


Figure 6. Effect of pilot hole and screw diamater on tension strength of T-type joints

The multiple variance analysis (Table 4) was performed to determine the differences among the factors (panel type, screw diameter, pilot hole). It was determined by Duncan test if there is a meaningful difference among the groups Table 4 and Figs 7,8. It was carried out on data at the 0.05 significance level.

Table 4. Multivariate analysis of variance results

Source of Variance	Degrees of freedom	Sum of Square	Mean Square	F Value	p Value
Pilot hole (A)	2	105384	12982	146	0,000
Screw diameter (B)	1	61556	129269	112	0,000
Type of panels (C)	1	12425	50476	74	0,000
AxB	2	1635.54	1635.54	50	0,000
AxC	2	757.29	757.29	12	0,000
BxC	1	762	938.28	422	0,000

AxBxC	2	25	25	545	0,000
Error	64	51790.4	64		
Total	80	324452	95		

Results of this analysis show that bending and tension strength of the screwed corner joints was a function of panel type, screw diameter, and pilot hole. In those specimens with pilot holes that increased from 70 to 85% of root diameter in LamMDF had a little effect on bending strength specimens. Results of means separations of moment resistances indicated that in general the joints loaded in bending have greater moment resistance than those loaded in tension.

Means comparisons results indicated that, in general, the joints constructed of LamMDF showed significantly higher moment resistance the ones constructed of LamPB. Tests results of the similar previous studies concerning the material effect (Tankut, A.N. and N.Tankut 2005, Tankut, N. 2006, Zhang et al. 2005, Kasal et al. 2006) agree with this study. This significant difference in moment resistance could be explained by the fact that LamMDF has higher IB strength and screw withdrawal resistance than LamPB (Table 2).

Screw Diameter and Pilot hole	$\bar{x}$	**HG**
3,5 mm Screw Diameter-2 mm Pilot hole	58,94	A
4 mm Screw Diameter-2,5 mm Pilot hole	77,63	AB
4 mm Screw Diameter-2 mm Pilot hole	84,51	AB
3,5 mm Screw Diameter-Kontrol	104,86	B
4 mm Screw Diameter-Kontrol	105,06	B
3,5 mm Screw Diameter-1.5 mm Pilot hole	119,57	BC

Figure 7. Duncan test results for bending forces

Screw Diameter and Pilot hole	$\bar{x}$	**HG**
3,5 mm Screw Diameter-1,5 mm Pilot hole	1284,39	A
4 mm Screw Diameter-Kontrol	1394,41	A
3,5 mm Screw Diameter-Kontrol	1399,26	A
4 mm Screw Diameter-2,5 mm Pilot hole	1757,16	AB
4 mm Screw Diameter-2 mm Pilot hole	1757,56	AB
3,5 mm Screw Diameter-2 mm Pilot hole	2017,50	B

Figure 8. Duncan test results for tension forces

When the screw is being driven, wood resists against it. Thus, it is necessary to apply pilot hole. As the proper pilot hole is applied to the hole, tension strength of screw is greater than the one which is not applied a pilot hole of screw. It can be said that a proper pilot hole is essential in order to avoid splitting of the face during insertion of screws as well as to obtain maximum strength.

Screw joints failed owing to withdrawal and bending of screws. The primary cause of failure in the joints was fracture of the wall through which the screw passed rather than splitting of the end of the member in which the point of screw was embedded. The common mode of failure for bending specimens was the pull-out of screws from the rail with some core wood materials attached to the screw. In the bending tests, joints opened up slowly and screws bent. In general, failures were not sudden, and they occured between 90 to 120 sn. Failures of joints constructed of LamPB and LamMDF started with the screw heads crushing into the face member followed by screw withdrawal from the butt members along with some core material together, with edge splitting around the screws. In LamPB specimens the amount of core material was considerably more than those the constructed with LamMDF; contrarily the amount of edge splitting around the screws in the joints constructed of LamMDF was significantly more than in the joints constructed of LamPB. The screws did not break.

CONCLUSIONS

- Material type, screw diameter, and pilot hole effects on the strength of T-type corner joints were investigated. Test results showed that significant differences occurred in bending moment resistances with respect to above mentioned variables.

- In general, joints constructed of LamMDF yielded higher moment resistances than those of LamPB. In both bending and tension tests, LamMDF corner joints were stronger than LamPb corner joints.
- The small diameter of screw gave the higher tension strength, because it did not split the wood.
- Samples with pilot holes gave higher bending and tension strength than control samples. It is necessary to use pilot holes in order to avoid splitting of the edge during insertion of screws as well as to obtain maximum, least variable strength.
- The tension strength was greater than the bending strength of all T-type corner joints.
- As case furniture constructions are under bending forces, in LamPB using 3.5 x 50 screws with a pilot hole of 70 % of the root diameter of the screws, in LamMDF using 4 x 50 screws with 85 % of the root diameter of the screws can be recommended as the most robust corner joint type for case furniture.
- As case furniture constructions are under tension forces, in LamPB using 4 x 50 screws with a pilot hole of 85 % of the root diameter of the screws, in LamMDF using 3.5 x 50 screws with 85 % of the root diameter of the screws can be recommended.
- These experiments revealed the construction methods that should be followed to produce the stronger T-type screwed corner joints constructed of LamPB and LamMDF.

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Streszczenie: *Wpływ wiercenia otworów na wytrzymałość na zginanie skręcanych połączeń półkrzyżowych w meblach.* Celem pracy było określenie wpływu wiercenia otworów, średnicy śruby oraz rodzaju materiału płytowego na wytrzymałość na zginanie oraz rozciąganie połączenia. W badaniach uwzględniono płytę wiórową laminowaną oraz MDF laminowaną, 2 średnice wkrętów oraz 3 rodzaje otworów (o średnicach 70% i 85% średnicy wkrętu oraz bez uprzednio wykonanego otworu). Wykazano, że odpowiednia średnica otworu zwiększa wytrzymałość na zginanie i rozciąganie połączenia.

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