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Full Length Research Paper

Determination of mechanical performances of the portable fasteners used on case furniture joints

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In this study, it has been searched that the strength performances of montable fasteners which are made up from particleboard, fiberboard and particleboard surfaced with synthetic resin sheet used for case furniture joints. 10 specimens were prepared for each material, load type and fasteners, and a total of 300 specimens were tested under withdrawal, diagonal tensile and diagonal compression loads. As a result, in the diagonl tension and the diagonal compression tests the processed fiberboard with plastic minifix fastener and in the withdrawal tests the processed fiberboard with metal minifix fastener have given the best result, particleboard with metal minifix fastener and the processed particleboard with plastic minifix have given the worst result.

Key words: Case construction, wood based boards, corner joints, minifix type fasteners, withrawal strength, diagonal compression strength, diagonal tensile strength.

INTRODUCTION

Furniture, which is an interior equipment member, has an important place in goods culture because it satisfies both physiological and cultural needs. It is generally thought of as a furniture joint, in that the ends and the edges of the members are joined together and the fasteners are used to hold them together. The structural characteristics of furniture depend on the structural behavior of the joints which are used in its construction (Eckelman, 1978).

The house has gradually become smaller and the furniture has to move from somewhere to another place owing to the various reasons. This situation has caused many problems in practice. It has been developed mechanical fasteners from metal and plastic, ready to assemble, for joining furniture members each other, due to solve these problems which are given before.

The technical developments have enhanced the production of new materials. This situation makes it possible to develop both new constructions and orginal products multi-purpose mechanical fasteners, which have provided facility in applications and solving details among these products; but the furniture should have a good engineering design which can safely carry the external forces and internal stress, which occurs because of the external forces in service. For this reason, the durability and stability of furniture must be determined.

Eckelman (1974), has compared screw holding strength pulling seven different types of screws which are highly used on the market from 12 mm thick particleboard. As a result of the tests, it is stated that there are no practical differences among the screws.

Özen and Efe (1992) have investigated the strength properties of screw-nut as a fastener element in furniture industry. They have emphasized that the length of screw-nut has line rate, while its diameter has opposite rate on holding strength of screw-nut in the tests which they have done with 6 different screw-nuts on pine, beech and oak. Also, they have stated that diameter rate of pilot hole, screw thread pace and screw thread height have effects on holding strength of screw-nut.

Zhang and Eckelman (1993) in compression and tension tests of single dowel corner joint members with particleboards, have found out that as dowel diameter and dowel length increase, the strength proportionally increases. Zhang and Eckelman (1993) have changed the specimen width and dowel space in tension and compression tests for the corner joints that were done using different numbers of dowel on particleboards. According to results of tests; on condition that space between two dowels is 75 mm it will be the highest strength.

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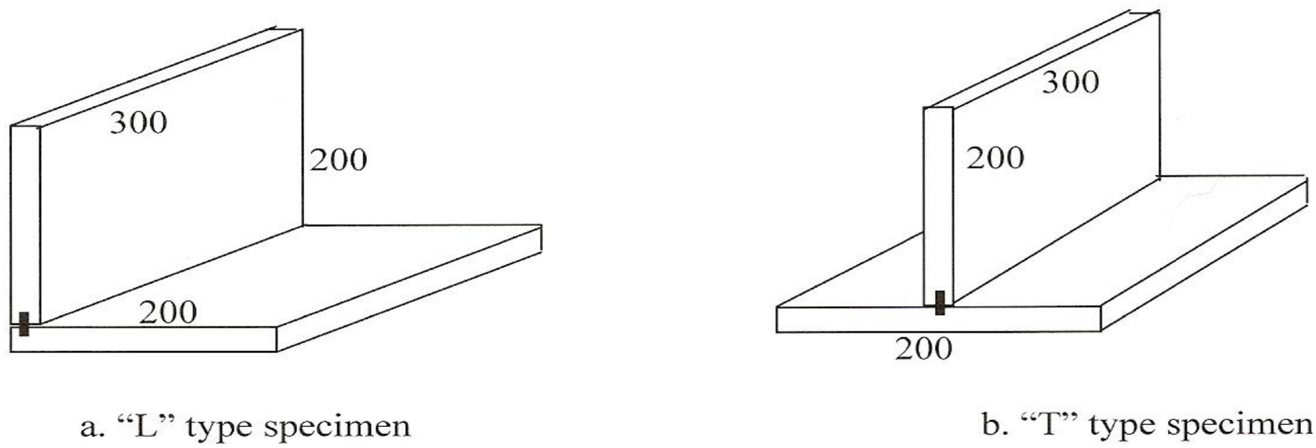

Figure 1. Test specimens (in mm).

Örs et al. (1995) have researched surface parallel and perpendicular position holding strength of three different screws chosen as fastener on particleboard, medium density fiberboard, werzalit and beech wood widely used by furniture industry. As a result, beech wood has given the highest holding strength both in the face position and in the edge position. Pouring glue into the pilot holes drilled for screws significantly increases the screw holding strength.

Örs and Altınok (1995) have emphasized that the durability of the chair is not related to the strength of its members, it's related to carrying loads by the mortise and tenons, according to the diagonal compression test results of real size chairs constructed of beech and pine (Ors et al., 1999).

Özen at al. (1995) have researched the strength properties of dowel, spline and dado and rabbet joints applied on case furniture corner joints. After their research, they have informed that dowel corner joints give the best result while dado and rabbet joints give the worst (Özçifçi et al., 1996).

Örs and Efe (1998) have investigated the mechanical properties of furniture fasteners used in the frame construction furniture design, and have demonstrated that the joints constructed with minifix and multyfix type fasteners are better than the traditional joint techniques.

Efe and Kasal (2000) have compared tensile strength properties of stable and portable corner joints with case construction which are prepared from particleboard and medium density fiberboard. As a conclusion, medium density fiberboard and portable joints have given better results than particleboard and stable joints (Efe et al., 2000).

The aim of this research, to investigate the mechanical properties of the joints which are prepared from processed and without process particleboard and medium density fiberboard and special fasteners (metal and plastic minifix), and to determine the performances of the fasteners and the materials under the withdrawal, diagonal tension and diagonal compression loads which are the furniture exposed to them in servise.

MATERIALS AND DESIGN OF SPECIMENS

In the tests, processed (which is solid wood thickness of 10 mm with adhesive joining the edges of A and B elements and both surfaces of the elements is covered with beech veneer that has a thickness of 0.5 mm by hot press) and without process particleboard and covered paticleboard with syntetic resin (P-covered) and medium density fiberboard have been used as test material, metal and plastic minifix have been used as fasteners. Test materials have been obtained from furnituremakers market, fasteners have been obtained from producer firm. Specimens consist of two elements as A and B. Two connection type have been applied to the specimens (Figure 1a and b).

The surfaces and edges of the boards were drilled with floor and bench model drill machine for applying the metal and plastic minifix which are used as fasteners in corner joints. A and B elements of "L-type" and "T-type" specimens were cut to their own sizes, and 10 specimens were prepared for 5 material types and 2 fastener types which are metal and plastic minifix (Figure 2).

In this study, a joint has been provided on the middle axis of B element of "T-type" specimens with metal minifix fastener (Figure 3). Between A and B elements of "L-type" and "T-type" specimens it has been providet join to drill pilot holes on the B member diameter of 25 mm and for contrary on the A element diameter of 4 mm (Figures 4 and 5).

METHOD OF LOADING AND TESTING

In mechanical stress that happened in case construction furniture, coercing diagonal forces have tried to open joints of case furniture system toward outside (diagonal tensile) and to close it toward inside (diagonal compression). Because of this reason, forcing of diagonal tension and compression which sembolizes the opening and closing of case furniture corner joints have been used as test methods (Figure 6).

The tests were carried out on a Universal Testing Machine. The force degree of testing machine was adjusted about 800 kgf

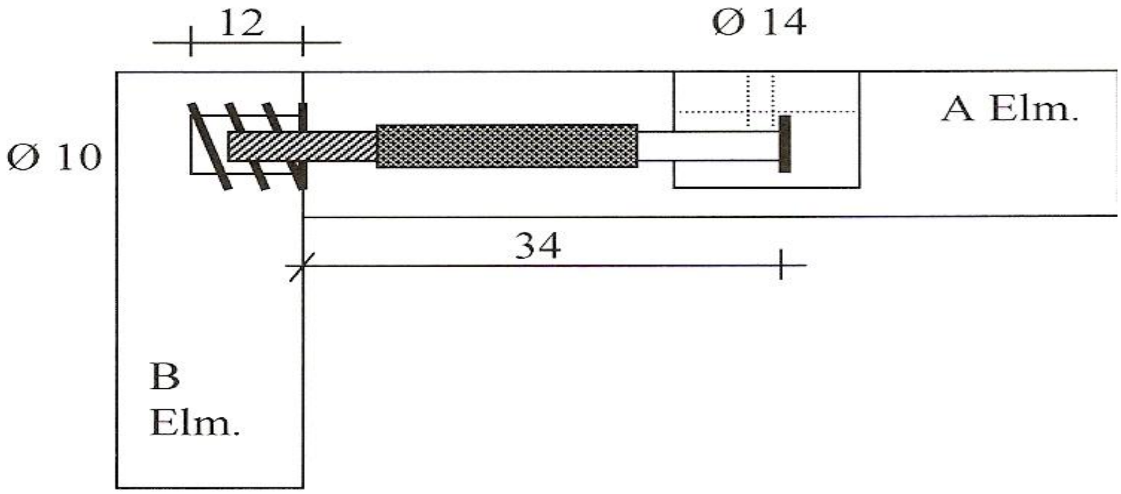

Figure 2. Details of L-type specimen joined with metal minifix (in mm).

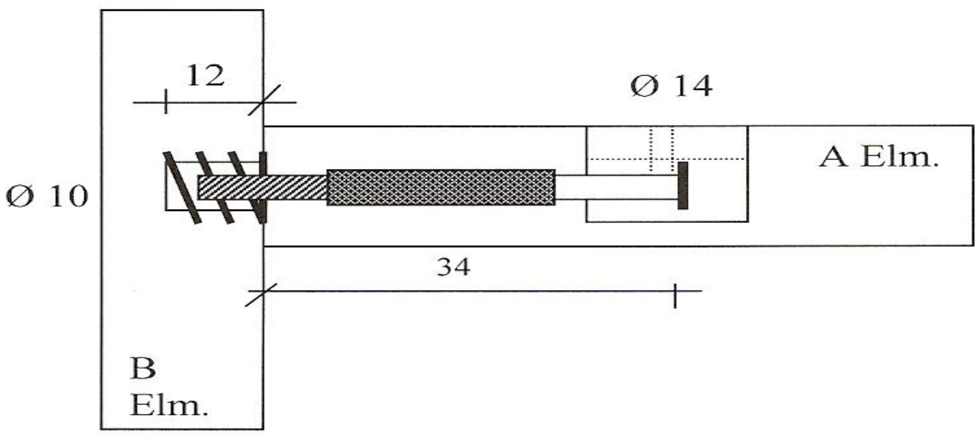

Figure 3. Details of T-type specimen joined with metal minifix (in mm).

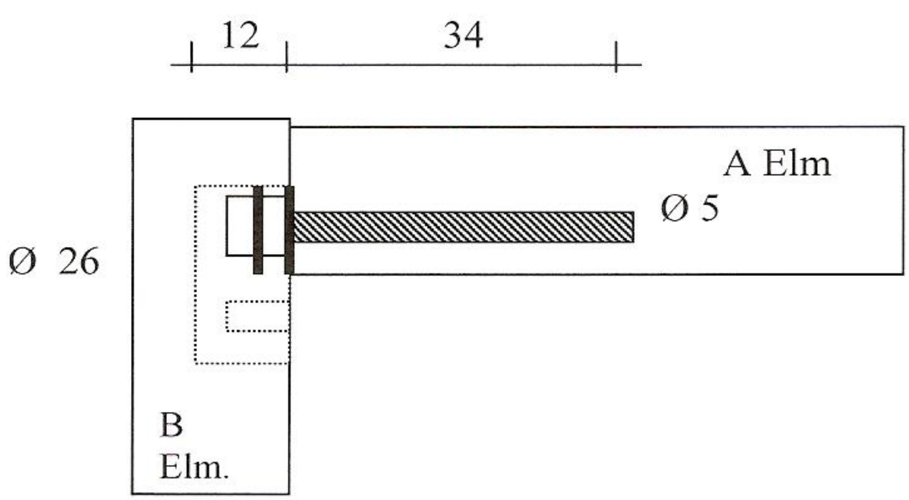

Figure 4. Details of L-type specimen joined with plastic minifix (in mm).

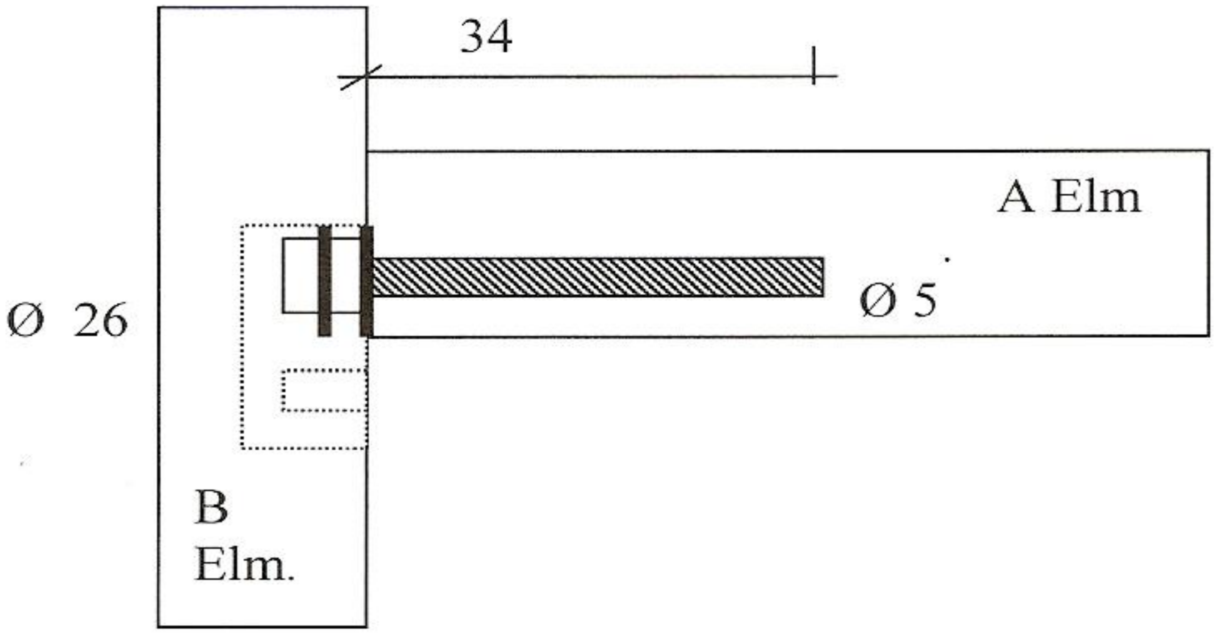

Figure 5. Details of t-type specimen joined with plastic minifix (in mm).

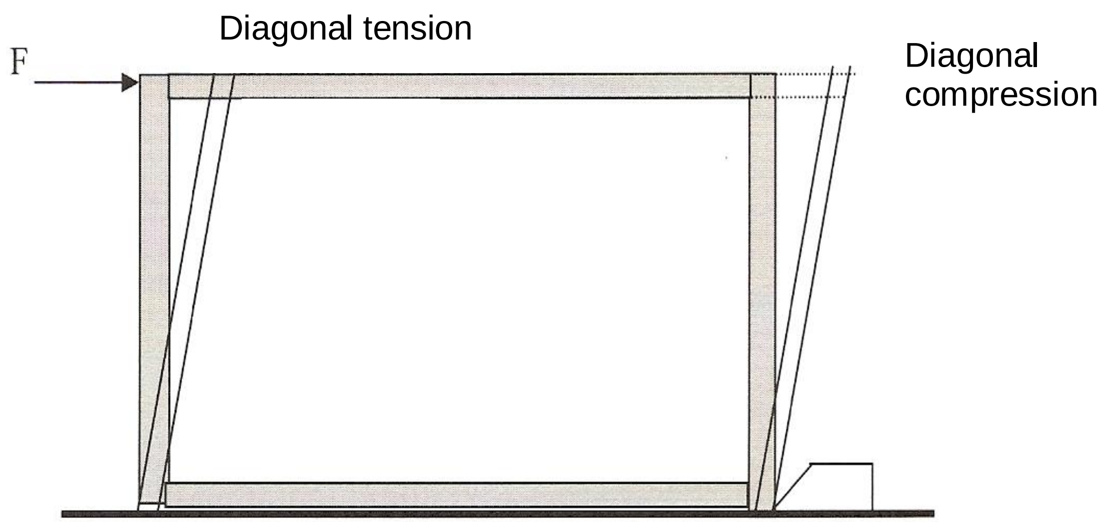

Figure 6. Simulated diagonal compression and tension loads.

during the tests. In the tension test setup, the bottom of each of the two legs of the joints were placed on stainless steel plate so that the two joint members will be free to move outwardly and free of restraint as the joint was loaded. The ultimate loads of joints carry were recorded in newton (Figure 7).

The withdrawal tests were carried out on 800 kgf force degree of testing machine too. It was attached the mechanism which is given in Figure 8 to the testing machine for withdrawal tests.

Analysis

The specimens, which are tested under diagonal and tension loads were made as half frame shape and have two axises. The joint area on the specimens of diagonal compression and the supporting on the specimens of diagonal tension are out of force's direction. Because of these reasons, the external bending moment occurs at the joint area.

The external bending moments have been calculated by means of the expression:

For compression, $M_c = F_{max} \times L_c$ (Nmm) (1)

For tension, $M_t = F_{max} / 2 \times L_t$ (Nmm) (2)

where, M_c and M_t = the bending moment in compression and

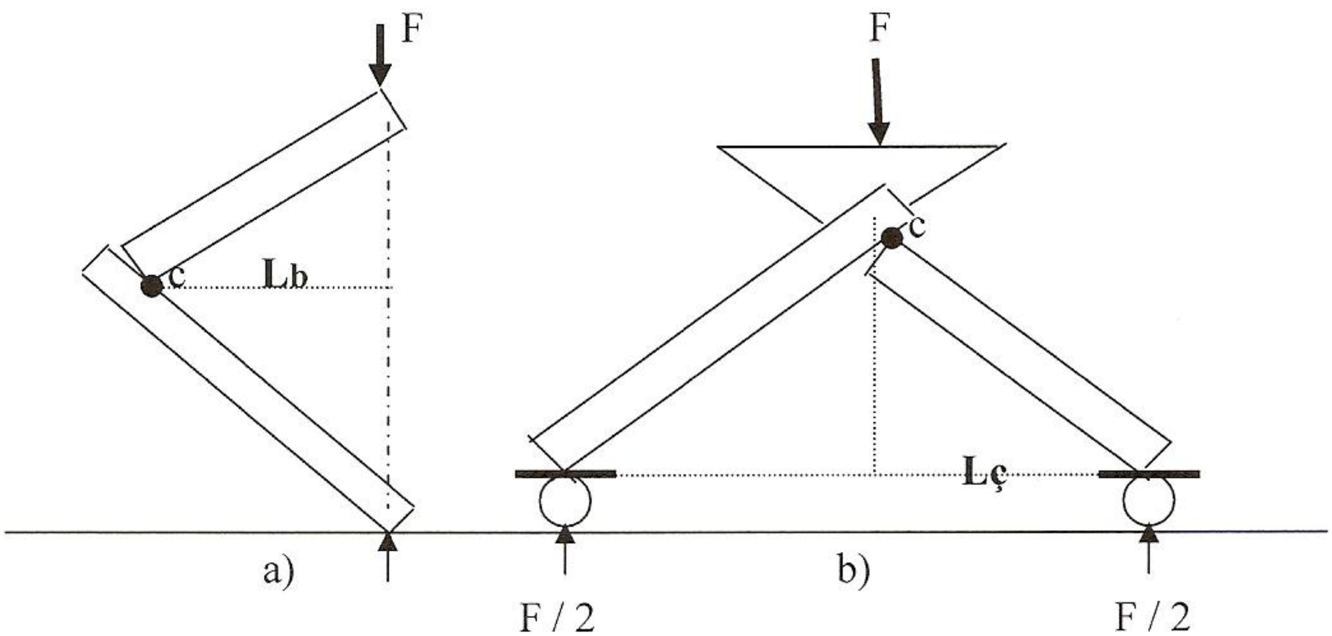

Figure 7. Specimens under the diagonal compression and tension tests.

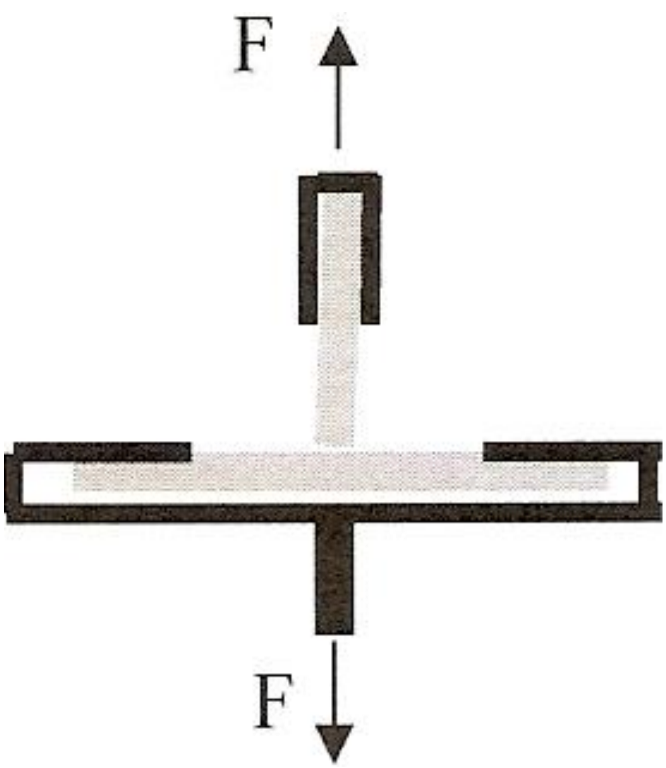

Figure 8. Specimen under the withdrawal test.

tension, respectively in newtonmetre and F_{max} = the ultimate applied force in newton and L_c and L_t = the moment arm for compression and tension in milimetre, respectively.

The moment arm has been found as L_c=116 mm for compression specimens, as L_t=128,7 mm for tension specimens using right triangle relation. The durability of joint area has been counted as load carried only by minifixes. Friction on the supports and other forces has been ignored. Furthermore, the distances between the centroid of joint areas and rotation points have changed according to the position of specimens in the compression and tension tests.

Withdrawal strength

In the withdrawal tests, the theorical withdrawal forces which is changing according to the material and fastener type, for T-shapped specimens has been calculated by means of the formula:

$$F_T = 30 \times d \times m \text{ (N)} \qquad (3)$$

where, F_T =theorical withdrawal force in newton, 30= constant number for screw; d = screw diameter in milimetre, m = screw penetration in milimetre.

In the T-type specimens, the tension stress which occurs during the withdrawal test has been counted according to the weakest screw-nut in fastener which was obtained with Equation (5). The withdrawal strength has been calculated by means of the expression (4), considering the tension stress occurs at the joint area:

$$\sigma_w = F_{max}/n\ (30 \times m \times d) \qquad (4)$$

where, σ_w = the withdrawal strength in N/mm^2 and F_{max} = the ultimate applied force in newton and n = number of fastener.

Compression and tension strength

In the diagonal tension and compression specimens, it has been

Table 1. Values of tension, compression and withdrawal strength (N/mm^2).

Material type	Values	Tension strength		Compression strength		Withdrawal strength	
		Metal minifix	Plastic minifix	Metal minifix	Plastic minifix	Metal minifix	Plastic minifix
P	x	15.83	25.61	27.08	31.34	37.89	18.63
MDF	x	18.02	35.86	40.62	36.31	51.27	24.54
P-(Covered)	x	13.85	27.43	31.59	29.79	37.37	19.95
P-(Processed)	x	17.20	29.59	31.59	54.31	35.98	17.04
MDF-(Process)	x	23.89	46.56	34.06	54.62	56.84	21.91

P: particleboard, MDF: medium density of fiberboard.

Table 2. The result of variance analysis for diagonal tension strength.

Source	Degree of freedom	Sum of squaers	Mean square	F Value	Probability
Fastener (A)	1	239.012	239.012	160.5968	0.0000
Material (B)	4	111.907	27.977	18.7982	0.0000
A. x B	4	23.769	5.942	3.9928	0.0000
Error	90	133.944	1.488		
Total	99	508.633			

considered that the normal stress occurs at the joint area of A and B elements. The external bending moment which occurs at the joint area has been calculated with Equation (1) for compression specimens, with Equation (2) for tension specimens. The stress calculations has been made according to the fastener which has weakest safety factor for holding. The safe screw holding force for plastic minifix:

$$\text{(plastic)}\ F_{screw\text{-}nut} = 30 \times m \times d = 30 \times 0.5 \times 3.4 = 51\ \text{kgf}\ (510\ \text{N})$$

$$\text{(Metal)}\ F_{screw\text{-}nut} = 30 \times m \times d = 30 \times 1 \times 1{,}2 = 36\ \text{kgf}\ (360\ \text{N})$$

For metal minifix:

$$F_{plastic\ minifix} = 30 \times m \times d = 30 \times 2{,}6 \times 1{,}4 = 109{,}2\ \text{kgf}\ (1092\ \text{N})$$

$$F_{metal\ minifix} = 30 \times m \times d = 30 \times 1.4 \times 1.2 = 50.4\ \text{kgf}\ (504\ \text{N})$$

Because of this, the calculations of diagonal compression and tension have been made for B element in which the screw-nut is the weakest fastener in it. The tension and compression strengths have been calculated by means of the expressions:

$$M_b = [n\ (30 \times m \times d) \times y\ \sigma_t] \quad (5)$$

$$M_ç = [n\ (30 \times m \times d) \times y\ \sigma_c] \quad (6)$$

where, y= internal moment arm in mm and σ_t and σ_c = the tension and compression strengths, respectively in N/mm^2. In this study, each specimen has been calculated.

Data analysis

The multiple variance analysis has been used in order to determine the effects of material types and fastener types on withdrawal, diagonal tension and diagonal compression strengths for case construction portable corner joints. If the differences between the variables and interactions have been meaningful with a 5% error, the Duncan tests were applied for determine the importance of differences between the groups.

RESULTS

The minimum, maximum and average strength and standard deviation values for diagonal compression, diagonal tension and withdrawal strength are given in Table 1. The results of multiple variance analysis in regard to the effects of fastener type and material type on diagonal tension strength are given in Table 2.

According to variance analysis results, the effects of fastener type and material type and their interactions on tension strength have been statistically significant with a 5% error. The results of the Duncan test regarding fastener type and material type are listed in Table 3. The results of multiple variance analysis conducted to determine the effects of fastener type and material type on diagonal compression strength are listed in Table 4.

According to the variance analysis, the effects of fastener type and material type and their interaction on compression strength have been obtained meaningful with a 5% error. The Duncan test results about the fastener type and material type are given in Table 5. The multiple variance analysis results in regard to the effects

Table 3. Averace diagonal tension strengths regarding the interaction of fastener and material type.

Faseteners type	Material type	Diagonal tension strength (N/mm^2)	
		X	HG.
Metal minifix	P	3,272	E
	MDF	3,433	E
	P-(Covered)	2,692	E**
	P-(Processed)	3,435	E
	MDF-(Processed)	4,675	D
Plastic minifix	P	5,115	CD
	MDF	7,168	B
	P-(Covered)	5,482	CD
	P-(Processed)	5,914	C
	MDF-(Processed)	**9,288**	A*

LSD ± 1.084.

Table 4. The results of variance analysis for compression strength.

Source	Degree of freedom	Sum of squaers	Mean square	F Value	Probability
Fastener type	1	19.457	19.457	84.1859	0.0000
Material type	4	40.239	10.060	43.5261	0.0000
F. T. x M. T.	4	29.158	7.290	31.5403	0.0000
Error	90	20.801	0.231		
Total	99	109.655			

Table 5. The Duncan test results for the interaction of fastener type and material type.

Faseteners type	Material type	Diagonal compression strength (N/mm^2)	
		X	HG.
Metal minifix	P	3,131	DE
	MDF	3,627	BC
	P-(Covered)	2,976	DE
	P-(Processed)	5,425	A
	MDF-(Processed)	5,456	A*
Plastic minifix	P	2,700	E**
	MDF	3,971	B
	P-(Covered)	2,987	DE
	P-(Processed)	3,151	DE
	MDF-(Processed)	3,395	CD

LSD : 0.4270.

of fastener type and material type on withdrawal strength are given in Table 6. At the end of the results of the multiple variance analysis, the effects of fastener type and material type and their interaction on withdrawal strength have been statistically significant with a 5% error. The results of the Duncan tests are listed in Table 7.

Conclusions

Average values of each three diagonal tension, diagonal compression and withdrawal strengths are shown in Table 8. Interactive relations between material and fastener type, diagonal tension and diagonal compression

Table 6. The results of multiple variance analysis for withdrawal strength.

Source	Degree of freedom	Sum of squaers	Mean square	F value	Probability
Fastener type	1	139.240	139.240	973.4536	0.0000
Material type	4	26.826	6.706	46.8863	0.0000
F. T. x M. T.	4	10.049	2.512	17.5641	0.0000
Eror	90	12.873	0.143		
Total	99				

Table 7. Average withdrawal strengths regarding the interaction of fastener type and material type.

Fasteners type	Material type	Withdrawal strength (N/mm^2)	
		X	HG.
	P	3,912	C
	MDF	5,039	B
Metal minifix	P-(Covered)	3,740	C
	P-(Processed)	3,611	C
	MDF-(Processed)	5,682	A*
	P	1,859	EF
	MDF	2,448	D
Plastic minifix	P-(Covered)	1,991	EF
	P-(Processed)	1,699	F**
	MDF-(Processed)	2,187	DE

LSD ± 0.3360.

Table 8. Average values of diagonal tension, diagonal compression and withdrawal strengthes.

Material type	Fastener type	Diagonal load type		
		Tension strength	Compression strength	Withrawal strength
P	Plastic minifix	5.11	3.13	1.85
	Metal minifix	3.27	2.70	3.91
MDF	Plastic minifix	7.16	3.62	2.44
	Metal minifix	3.43	3.97	5.03
P- (Coated)	Plastic minifix	5.48	2.97	1.19
	Metal minifix	2.69	2.98	3.74
P-(Processed)	Plastic minifix	5.91	5.42	1.69
	Metal minifix	3.43	3.15	3.61
MDF-(Processed)	Plastic minifix	9.28 *	5.45 **	2.18
	Metal minifix	4.67	3.39	5.68 ***

strength were obteined highest (9,288 N/mm^2, 5,45 N/mm^2) on the MDF-(processed) with plastic minifix. Withdrawal strength was obtained highest (5,68 N/mm^2) on the MDF-(processed) with metal minifix.

Contrary part (minifix-nut) of plastic minifix has been screwed to edge of MDF-(processed) and just over there solid wood provided supportive effects to it. Because of this reasion, diagonal tension and diagonal compression strength were obteined highest on the MDF-(processed) with plastic minifix.

On the MDF-(processed) with metal minifix, contrary part (minifix-nut) of metal minifix has large threads and they are tightly joined to screw between layer of fibers. Because of this reasion, withdrawal strength was obtained highest on the MDF-(processed) with metal minifix.

As a result of the diagonal tension and diagonal compressions specimens, the highest strength was obtained on the MDF-(processed) with plastic minifix. But on the withrawals specimens, the highest strength was obtained on the MDF-(processed) with metal minifix. Because of this technical reasons, the plastic minifix is proposed as just useful on the joint area of montable furniture where forcing of the diagonal tension and compression happened and the metal minifix is proposed as just useful on the joint area of montable furniture where forcing of withdrawal happened.

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