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The Effect of Fastener Type (Clamex P14 and Tenso P14) and Adhesive Type on Diagonal Compression and Diagonal Tension Performance

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Abstract

In this study, the effects of different fasteners (Clamex P14 and Tenso P14) for medium density fiberboard (MDFLamM) surfaced with synthetic resin sheet wood-based materials as well as several adhesives (PVAc-D4) and PU-D4) on diagonal tension and compression forces, were analysed. In the study, melamine coated medium density fiberboard (MDF-Lam) was used as wood-based material, Clamex P14 and Tenso P14 were used as fasteners and polyvinylacetate (PVAc-D4) and polyurethane (PU-D4) glues were used as adhesive agents. The diagonal tension and compression force tests were applied on 120 pieces of test samples prepared in this respect based on the principles of ASTM D 1037. As a result, The diagonal compression and tensile forces values were found in the highest Clamex P14 fastener and polyvinylacetate adhesive bond (PVAc-D4), the lowest was in the joint with Tenso P14 fastener without any adhesive agent. For L type corner-joints, it is suggested to use Clamex P14 as a fastener and polyvinylacetate adhesive (PVAc-D4) as the type of the adhesive agent.

Keywords: Diagonal Tension Force, Diagonal Compression Force, Corner Joint, Fastener Type, Adhesives.

Bağlantı Elemanı Tipi (Clamex P14 ve Tenso P14) ve Tutkal Çeşidinin Diyagonal Çekme ve Diyagonal Basma Kuvvetine Etkileri

Öz

Bu çalışmada, ahşap esaslı malzemelerden (MDF Lam) levhada farklı bağlantı elemanları (Clamex P14 ve Tenso P14) ve çeşitli tutkalların (PVAc-D4 ve PU-D4) diyagonal basma ve çekme kuvvetine etkileri araştırılmıştır. Çalışmada ahşap esaslı malzeme olarak melamin kaplı orta yoğunlukta lif levha (MDF Lam), bağlantı elemanı olarak Clamex P14 ve Tenso P14, yapıştırıcı olarak ise polivinilasetat (PVAc-D4) ve poliüretan (PU-D4) tutkalları kullanılmıştır. Hazırlanan 120 adet deney örneğine ASTM D 1037 esaslarına göre diyagonal basma ve çekme deneyi uygulanmıştır. Sonuç olarak, diyagonal basma ve çekme kuvveti değerleri, en yüksek Clamex P14 polivinilasetat (PVAc-D4) tutkallı birleştirmede, en düşük; ise Tenso P14 tutkalsız birleştirmede bulunmuştur. L tipi köşe birleştirmelerinde bağlantı elemanı olarak Clamex P14 ile tutkal tipi olarak ise polivinilasetat (PVAc-D4) tutkalının kullanılması önerilebilir.

Keywords: Diyagonal Çekme Kuvveti, Diyagonal Basma Kuvveti, Köşe Birleştirme, Bağlantı Elemanı, Tutkal.

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1. Introduction

The success of the furniture construction is influenced by the correct choice of the structural composition. The usual process of designing furniture is based on the experience of the constructor and the knowledge of the properties of the applied structural compositions and materials. This means that during designing of the furniture, there are established rules and applicable assembly methods that will ensure the mechanical properties of the furniture.

Significant strength of joints, technological and operational-aesthetic functions in furniture constructions. This has been endorsed by legion publications that analyze it. the effect of diverse factors on the skeleton depending on the type of furniture joint strength: joint, as well as composite material and glue stress assigmnet (Smardzewski and Papuga, 2004). Joint stiffness has been shown to increase with the application of a greater number of connecting joints (Liu and Eckelman, 1998) and construction can be increased by increasing thickness applied materials (Tankut and Tankut, 2009). Additionally, studies by (Vassiliou and Barboutis, 2009) have shown that joint strength varies slightly relative to the manufacturer of the same type of connectors.

Tankut (2006) carried out moment resistance of corner joints connected with diverse RTA connectors in cabinet construction, and established that fastener type, materials type, loading type and have a significant effect on the strength of RTA connected joints. Tankut and Tankut (2009) carried out to determine the performance of diverse construction techniques on the diagonal compression and tension strength of case-type furniture corner joints, and to determine the joint type, composite type, such as some of the factors reviewed to determine the impact on the joints and glue. As a result, the diagonal tensile strength has been greater than the diagonal compression strength of all L-type corner joints. Furthermore, the highest diagonal tensile strength was achieved in MDF-lam with DVTKA glue and GDj while highest diagonal compression strength was obtained in melamine-coated particleboard with PVA D4 and Sj. It was indicated that for a joint length of 760 mm, dowels significantly support the cam connectors. Presumably, when two or more dowels are added, stresses arising as the joint is loaded in compression are distributed more evenly over the joint length (Simek et al. 2010). The effect of minifix were investigated with a dowel on the bending moment of L type corner joints in the Cabinet-type Furniture. According to experimental results, the highest bending moment value was obtained in the “2 minifix with 2 dowel” joint type. Bending moment values obtained from the tensile tests was obtained higher than values of compression tests. The effect of minifix were investigated with a dowel on the bending moment of L type corner joints in the Cabinet-type Furniture (Yerlikaya, 2013). Imirzi et al. (2016), the resistances of dowels and screws, which are widely used as joining material in ready-to-assemble furniture corners, were investigated against cross-direction stress and pressure resistances. According to the results, the highest moment carrying capacity values in the L-type corner combination were provided in the 18 mm GMP board combined with screw with PVAc glue and screw with PUR glue for both tests.

Most of the research that has been done on corner joints relates to determining the effect of the type of connecting element on the durability of the structure (Tankut and Tankut 2009; Koreny and Simek, 2011; Smardzewski et al. 2014; Imirzi et al. 2016; Jivkov and Marinova, 2016; Karaman et al. 2019), dimensions of the connecting element (Imirzi et al. 2015; Atar et al. 2017; Karaman et al. 2018), distances of connecting elements - fasteners (Simek et al. 2010; Smardzewski et al. 2014), type of material (Tankut and Tankut N, 2009; Altınok and Tas, 2010; Efe et al. 2012; Cagatay et al. 2013; Imirzi et al. 2015; Atar et al. 2017; Gou et al. 2019). All the above studies have been made to determine the technical quality, although for the overall quality of the product this is not the only criterion (Prekrat et al. 2019).

For the purpose of obtaining disassembled joints, a threaded bolt with a pivot pin (so called Minifix) is most commonly used as an example of connecting fittings. There is a great deal of data available on the influence factors affecting the strength of the composition with minifix: the addition of the dowel, the type of material, and the dimensions of minifix (Simek et al. 2010; Koreny and Simek, 2011; Smardzewski et al. 2014; Jivkov and Marinova, 2016; Simeonova, 2016; Atar et al. 2017; Gou et al. 2019), determination of shear strength performance of H-type furniture joints with disassembled type connectors (Clamex P14 and Tenso P14) (Karaman,. 2019). On the other hand, there are limited researches on topic how the length of the bolt affects the strength of the composition with the minifix (Jivkov and Marinova, 2016).

In this study, the effects of different fasteners (Clamex P14 and Tenso P14) and various adhesives (PVAc-D4 and PU-D4) on diagonal compression and tension perfomances on board from wood-based materials melamine coated medium density fiberboard (MDF-Lam) were investigated. Creating a database for furniture engineering design and conducting scientific studies to determine the factors affecting the strength of the joins will facilitate the work of furniture designers and manufacturers, and in this way it will be possible to produce furniture in accordance with the purpose and function of the design by designing more conscious furniture in the light of the scientific At the same time, unnecessary solid furniture is not produced, sufficient solid furniture will be produced and this situation will make important contributions to the economy of the country.

2. Materials and Methods

2.1. Materials

2.1.1. Wood based material

Tests were conducted on medium density fibrebord (MDF) of 18 mm in thickness melamine coated medium density fiberboard (MDF-Lam). This board material was obtained by random selection from Usak 1 September industrial site market. Prior to the manufacture of joints physic-mechanical properties of the boards were determined, including absolute moisture content (MC) according to TSE 322, density (D) according to TSE EN 323, modulus of elasticity (MOE) and modulus of rupture (MOR) according to TSE EN 310 and ASTM D 1037 using samples in the form of beams.

2.1.2. Adhesive

In this study, polyvinylacetate (PVAc-D4) and polyurethane (PU-D4) glues were used. Kronen Holzleim polyvinylacetate adhesive (PVAc-D4) (Semitas A.S., Banaz, Usak, Turkey) was used adhesive This polyvinylacetate glue, odorless and fireproof, easy to apply, quick setting, cold applied, D4. The properties of this glue used were determined as press compression 0.1-0.8 N / mm2, pH 3.5, viscosity (20 °C) 16000-15000 mPas, density 1.08 g / cm^3 and wood bonding time at 20 °C for 35-40 minutes determined by the company (Kronen, 2019). Romabond polyurethane adhesive (Starwood Building Market, Usak, Turkey) was used glue. This polyurethane adhesive is a one component, fast curing, polyurethane based wood adhesive. Easy to apply, low viscosity and high bonding strength, water resistant, 15-20 min. press time and 5-10 min. the surface has a drying time and is a transparent adhesive (Romabond, 2019).

2.1.3. Connector

Tenso P14 and Clamex P14 connectors from company Lamello-Switzerland were used in this study (Figure 1). These fasteners (Seritciooglu, Istanbul, Turkey) was obtained connector materials.

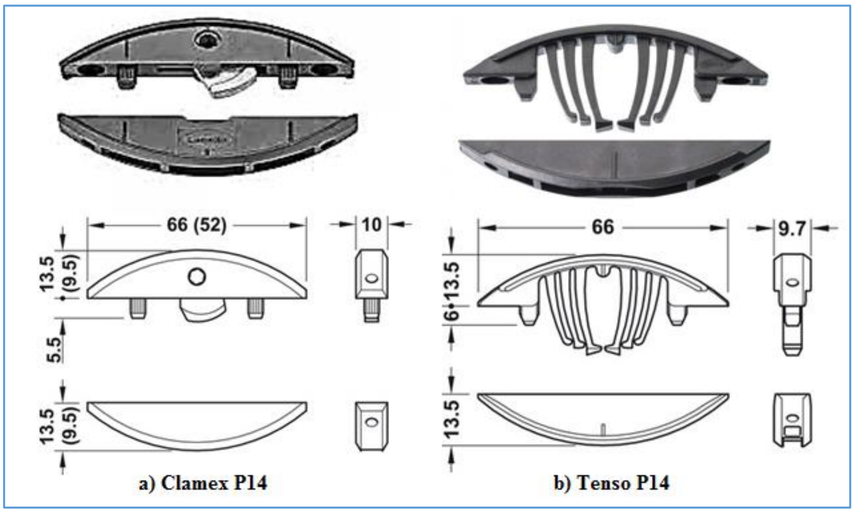

Figure 1. Fasteners used in tests (dimensions mm) (URL 1, 2019; URL 2, 2019).

2.2. Metot

2.2.1. Preparation of L-Type Corner Joints Specimens

The general configuration of the L-type corner joint specimens is shown in Figure 2. The specimens consisted of two structural parts, namely, a face member and a butt member (Kucuktuvek et. al., 2017). The face part measured 150 mm long 150 mm width 18 mm thick, whereas the butt member measured 150 mm long 132 mm width and 18 mm thick.

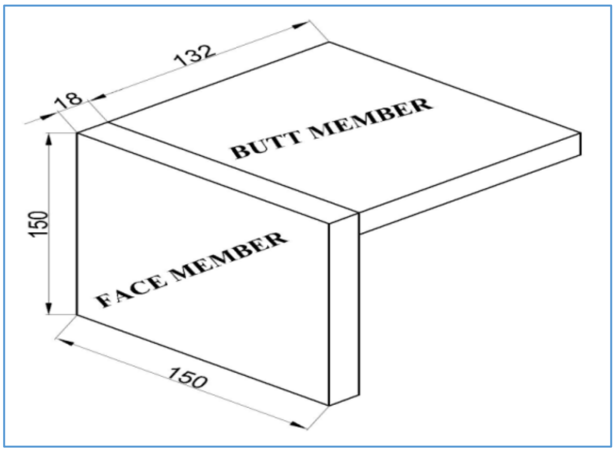

Figure 2. General configuration of L-type corner joint specimens (Kucuktuvek et. al., 2017).

The face member and butt member were connected to each other with two connectors. Lamello Zeta P2 hole making machine was given in Figure 3.The appropriate adjustments for Clamex P14 and Tenso P14 connectors were made and two grooves. Then, 75 mm inwards from the alcove to the center, 9 mm inwards from the grain to the center, with 9.5 mm thickness and 66 mm width, 13.5 mm deep for Clamex P14 and 9.5 mm deep for Tenso P14 were opened on the surfaces of the face member; and for grooves with the same dimensions were made on the windows of the butt member (Figure 4). Clamex P14 and Tenso P14 connectors were placed in the grooves and the parts were assembled. The joint intersection surfaces are shown in Figure 5 and the general view of the test samples is shown in Figure 6. 150 g/m^2 glue was applied to the ducts where the fastener elements were opened with the help of the scale injector according to the company recommendations. Clamex P14 and Tenso P14 fittings were placed in these glued channels and allowed to dry for approximately 2 hours. Then A and B elements were assembled.

Figure 3. Lamello Zeta P2 Grooving Machine. (URL 3, 2019).

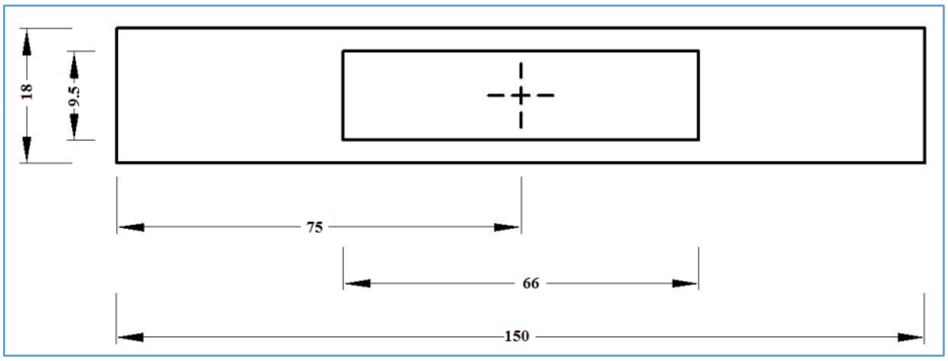

Figure 4. Connector hole centers and dimensions of test specimens (mm).

Figure 5. Grooves for disassembled fasteners and insertion of fasteners into the grooves

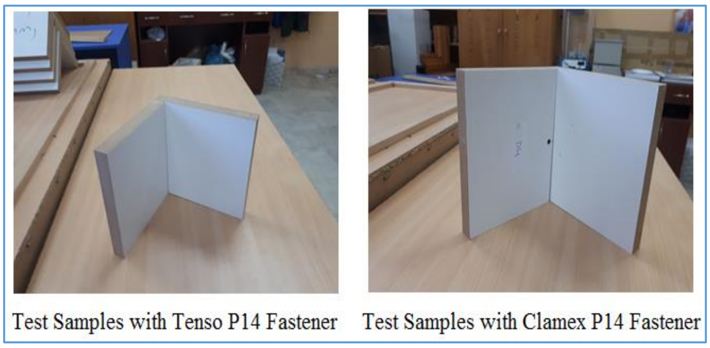

Figure 6. General view of type L test samples (mm).

In total 120 samples were prepared for this study. Overall, two different connectors type (Clamex P14, Tenso P14), two adhesives type (PVAc-D4, PU-D4) - with and one without glue and two different test methods (tension and compression) consisting of 10 replications each; or, a total of 120 L-type corner joint specimens (60 for diagonal compression, 60 for diagonal tension) were constructed for static tests. Before testing, all specimens were conditioned at 20 ± 2 °C and 65% RH for at least 48 h.

2.2.2. Method of Testing

The experiments were carried out in the University of Kutahya Dumlupınar, Simav Faculty Technology, Woodworking Industrial Engineering Mechanical Test Laboratory on a 10 kN capacity Universal Test Equipment. Static loading rate of 6 mm/min was used for all specimens. Figure 7 shows the loading diagrams that are experienced during testing corner joint moment resistances. Tension forces (Fig. 7a) tend to open the corner joints, and compression forces (Fig. 7b).

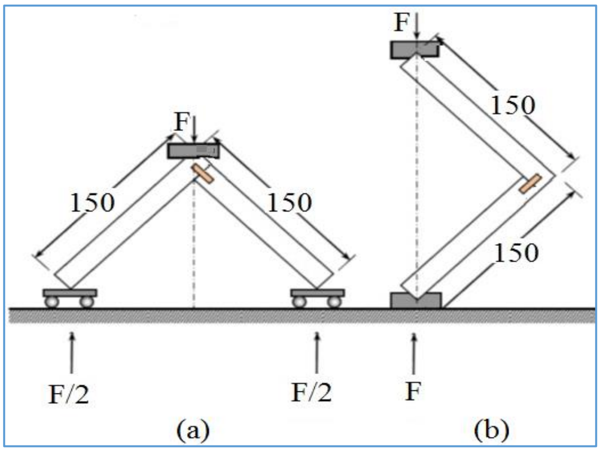

Figure 7. (a) Tension and (b) compression loading diagrams for corner joints (measurements in mm).

2.2.3. Analyses of Data

Multiple variance analysis was used with Minitab 18 program. The multiple variance analysis was carried out on the data at the 0.05 significance level for the individual data to examine the main factors (the connector, adhesive, test methods) and their interactions on the diagonal tension and compression forces of the joints. It was to be determined by the Tukey test. Tukey test carried out to determine the importance of the differences between the groups.

3. Result and Discussion

The moisture density of the MDF-lam material used in the experiments were determined as 0.762 g/cm^3, moisture contents was 6.5%, bending strength was 22.45 N/mm^2, modulus of elasticity values was 3350 N/mm^2 and respectively. Average and standard deviation values for diagonal compression and tension forces are included in Table 1 based on the type of the fastener and the adhesive, and the multiple variance analysis results regarding the same are included in Table 2.

Table 1. Diagonal tension-compression forces of the average and standard deviation values.

Joint Technique	Adhesive Type	Diagonal Tension Forces (N)				Diagonal Compression Forces (N)			
		Fastener Type							
		Clamex P14		Tenso P14		Clamex P14		Tenso P14	
		Mean	Std.	Mean	Std.	Mean	Std.	Mean	Std.
Adhesive	PVAc-D4	206.90	22.40	160.30	28.00	96.97	3.25	85.52	5.05
	PU-D4	189.50	37.20	141.83	12.91	81.12	3.89	76.94	6.87
	Control	168.80	24.60	128.16	7.522	76.79	3.25	68.69	5.91

According to the results of the test, diagonal compression force was obtained as the highest (96.97 N) in the tests samples, which were prepared by using Clamex P14 fastener and polyvinylacetate adhesive and the same was obtained as the lowest (76.79 N) in the test samples, which were prepared by using Tenso P14 fastener without any adhesive agent (Control). Diagonal tension force value was determined to be the highest (206.90 N) in the tests samples, which were prepared by using Clamex P14 fastener and polyvinylacetate adhesive (PVAc-D4) and the same was obtained as the lowest (128.16 N) in the test samples, which were prepared by using Tenso P14 fastener without any adhesive agent (Control). Consequently, it was determined that the combination of Clamex P14 fastener and polyvinylacetate adhesive was more successful with respect to the diagonal compression-tension force value. The results of the multiple variance analysis on diagonal tension and compression force are given in Table 2.

Table 2. Multivariate analysis of variance results for diagonal tension and compression force.

Sources of Variance	Degrees of	Freedom	Total of Squares	F Value	Probability of Error (P<0.05)
Results Related to Diagonal Tension Force (N)					
Fastener Type (FT)	1	15160.70	15160.70	28.02	0.000
Adhesive Type (AT)	2	6184.0	3092.0	5.72	0.009
FT x AT	2	72.80	36.40	0.06	0.940
Error	26	14065.3	541.0		
Total	29	35410.1			
Results Related to Diagonal Compression Force (N)					
Fastener Type (FT)	1	469.04	469.04	13.07	0.001
Adhesive Type (AT)	2	1770.36	885.18	24.67	0.000
FT x AT	2	66.51	33.26	0.92	0.412
Error	26	85.470	3.287		
Total	29	3172.29			

According to the results of multiple variance analysis, it was found out that the effects of the type of the fastener and the type of the adhesive on diagonal tension and compression forces were statistically significant ($P<0.05$). The type of the fastener and adhesive type were found out to be insignificant in dual interaction. Homogeneous groups were identified by conducting TUKEY test in order to determine whether the effect on the diagonal tension and compression forces are important among which group. The results of the comparisons made are included in Table 3 and Table 4. The diagonal compression and tension forces values and homogeneous groups based on the type of the fastener are included in Table 3.

Table 3. Comparison of diagonal tension and compression forces averages in terms of fastener type values.

Diagonal Tension Force (N)			Diagonal Compression Force (N)		
Fastener Type	**Mean**	**HG**	**Fastener Type**	**Mean**	**HG**
Clamex P14	188.40	A	Clamex P14	84.96	A
Tenso P14	143.44	B	Tenso P14	77.05	B

HG: Homogeneous Group

The corner-joint elements, which were prepared with Clamex P14 fastener elements, yielded 31% higher results on mean than the samples, which were prepared by using Tenso P14 fastener elements regarding diagonal tension forces values, and 10% higher results on average regarding diagonal compression forces values. This may stem from the fact that the mechanical and technological specifications of Clamex P14 fastener are better than that of Tenso P14 fastener. In a study conducted in this respect. Karaman (2019) reports that test samples produced with Clamex P14 fastener yielded 60% better results in comparison to the samples, which were prepared with Tenso P14 fastener as a result of the cutting test of the H type test samples, prepared by making use of demounted type fastener (Clamex P14 and Tenso P14) regarding YL-lam and MDF-lam materials. The research was compatible with the literature in this aspect. Diagonal tension and compression forces values based on the type of the adhesive as well as their homogeneous groups are included in Table 4.

Table 4. Comparison of diagonal tension and compression forces averages in terms of glue type values (N).

Diagonal Tension Force (N)			Diagonal Compression Force (N)		
Adhesive Type	**Mean**	**HG**	**Adhesive Type**	**Mean**	**HG**
PVAc-D4	183.66	A	PVAc-D4	91.24	A
PU-D4	165.66	AB	PU-D4	79.03	B
Control	148.46	B	Control	72.74	B

HG: Homogeneous Group

While the highest diagonal compression and tension forces values were obtained with the highest polyvinylacetate adhesive (PVAc-D4) based on the type of the adhesive. This was followed by polyurethane adhesive with the lowest value. However, the lowest diagonal tension and compression forces values were determined in the test samples without any adhesive agent. It can be said that the reason why polyvinylacetate (PVAc-D4) adhesive hows higher performance is the fact that it penetrates to the surface of the fastener and adhesion surface gaps much more and more quickly at a molecular level in comparison to polyurethane (PU-D4) glue and that the glue and material molecules create a strong adhesion surface in these areas as a result of the fact that the same forms a more strong and specific mechanical adhesion bond.

When the other studies conducted in the literature are reviewed, it is seen that tension strength of PVAc glue is higher than polyurethane glue. (Efe et al., 2012; Çağatay et al., 2013; Karaman et al., 2019). The study conducted in this respect also verifies this, and the same is in compliance with the results obtained from literature reviews.

4. Conclusion

In this study, the effects of fastener type (Clamex P14 and Tenso P14) and the type of the adhesive (PVAc-D4 and PU-D4) on the diagonal tension and compression forces of “L” type corner joints were analysed and it was concluded based on the results obtained in this respect that diagonal tension force is higher than diagonal compression force.

The diagonal tension and compression force perfomances of L-type corner joints connected with Clamex P14 were higher than those of joints connected with Tenso P14 fasteners. It was determined that the test samples produced with Clamex P14 fastener are 31% more successful in terms of diagonal tension force in comparison to the test samples prepared with Tenso P14 fastener and 10% more successful in terms of compression force based on the type of the fastener. Considering the functions of the furniture and the loads it will carry, knowing the properties of the fasteners to be used will positively affect the value and economic life of the furniture.

It was determined that both the diagonal and compression forces values were the highest in polyvinylacetate glue (PVAc-D4) based on the type of the glue and this was followed by polyurethane glue (PU-D4) and (Control) sample without any adhesive. It was determined that joints with glue have higher diagonal tension and compression force values than the joints without glue.

In terms of fastener type and the glue type interaction; the highest diagonal tension and compression forces svalue were found in corner-joints with Clamex P14 fastener with polyvinylacetate adhesive (PVAc-D4) and the same was the lowest in control samples with Tenso P14 fastener without any glue.

Considering the functions of the furniture and the loads it will carry, if clamex P14 is used as a fastener, and the use of polyvinylacetate adhesive (PVAc-D4) is used as glue will increase the economic life and value of the furniture. It will carry out considering the functions of the furniture and the loads, using Clamex P14 and glue will be used as the fastener, using polyvinylacetate adhesive (PVAc-D4) will increase the economic life and value of the furniture.

As box furniture constructions are under both diagonal tension and diagonal compression at the same time, the combined, Clamex P14 fastener and polyvinylacetate adhesive (PVAc-D4) can be recommended as the corner joint type for box furniture produced from melamine faced medium density fiberboard (MDF-Lam). Consequently, it can be suggested that Clamex P14 fastener and polyvinylacetate adhesive (PVAc-D4) should be preferred in the furniture requiring durability.

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