

BENDING STRENGTH OF T-SHAPE CORNER DETACHABLE JOINTS OF STRUCTURAL ELEMENTS MADE OF PLYWOOD

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ABSTRACT

In this study are given the results from investigation on bending strength of T-shape corner detachable joints of structural elements made of plywood. It has been established the bending moment under compression bending test. The highest bending strength were achieved with screw with cross dowel and *Confirmat* Ø7 x 70 and Ø7 x 50 mm and lowest bending strength have joints with bolt and nut and two types of eccentric connectors.

It is recommended that the comparative data of bending strength is taken into consideration when the designers and engineers have to choose the type of joints in the furniture constructions.

Key words: furniture construction, plywood, joint, bending strength, bending moment.

INTRODUCTION

Plywood is one of the most preferred furniture construction materials for all types of furniture.

Both the properties of the materials in the furniture and the strength and deformation characteristics of the joints have a significant influence on the strength of the structure, shape stability and durability of the furniture.

In Bulgaria there is data about studies on the physical and mechanical characteristics of plywood (Brezin et al. 2004, 2005; Kyuchukov et al. 1991; Panayotov et al. 2006; Shishkov et al. 1989; Jivkov et al. 2013). So in the world of scientific publications there are many data about studies on the physical and mechanical characteristics of plywood (Aydin et al. 2006; Aziri et al. 2013; Bal et al. 2012; Barboutis et al. 2011; Daoui et al. 2011; Hrazsky et al. 2005; Kilic 2011; Knorz et al. 2012; Popovska et al. 2013).

Researches into studies on strength and deformation characteristics of joints of structural elements made of plywood have not turned into any results in Bulgaria. In the world there are publications in the field of joints made from plywood and the greater

part refer to glued joints (Zhang et al. 2001; Erdil et al. 2001; Eckelman et al. 2002; Jensen et al. 2002) and a few publications about detachable joints (Erdil et al. 2003; Saar et al. 2002).

Studies on strength and deformation characteristics of corner non-detachable joints made of plywood, mainly concerned joints by dowels and several types of joints by staples and by metal planks. Most studies are for plywood of soft wood species.

The only data about tension and bending strength of detachable joints of structural elements made of plywood are about the joint with connector with cross dowel (Erdil et al. 2003) and a few detachable connectors (Saar et al. 2014). In the literature was not found other information concerning the study on strength characteristics of detachable joints of structural elements made of plywood.

All this gives reasons to conclude that due to insufficient information about the strength behaviour of detachable joints of structural elements made of plywood it is necessary to conduct research in order to establish those.

METHOD AND DISCUSSION

The study was carried out with test samples made of beech veneer plywood from peeled veneer, manufactured by “Nikrom-Veneer” Ltd, Petkovo. For the needs of the study in particular it is made entirely from veneer layers, quality A. The plywood panels are 20 mm thick with size 920 x 500 mm. Two-component urea formaldehyde resin by “DYNEA”, Hungary has been used. Resin consumption is 150 g/m². The plywood pressing is carried out on a “Vecciato VALTER” multi-storey pressing machine. Pressing temperature is 110 °C, the duration is 15 min and the pressure - 1,3 N/mm².

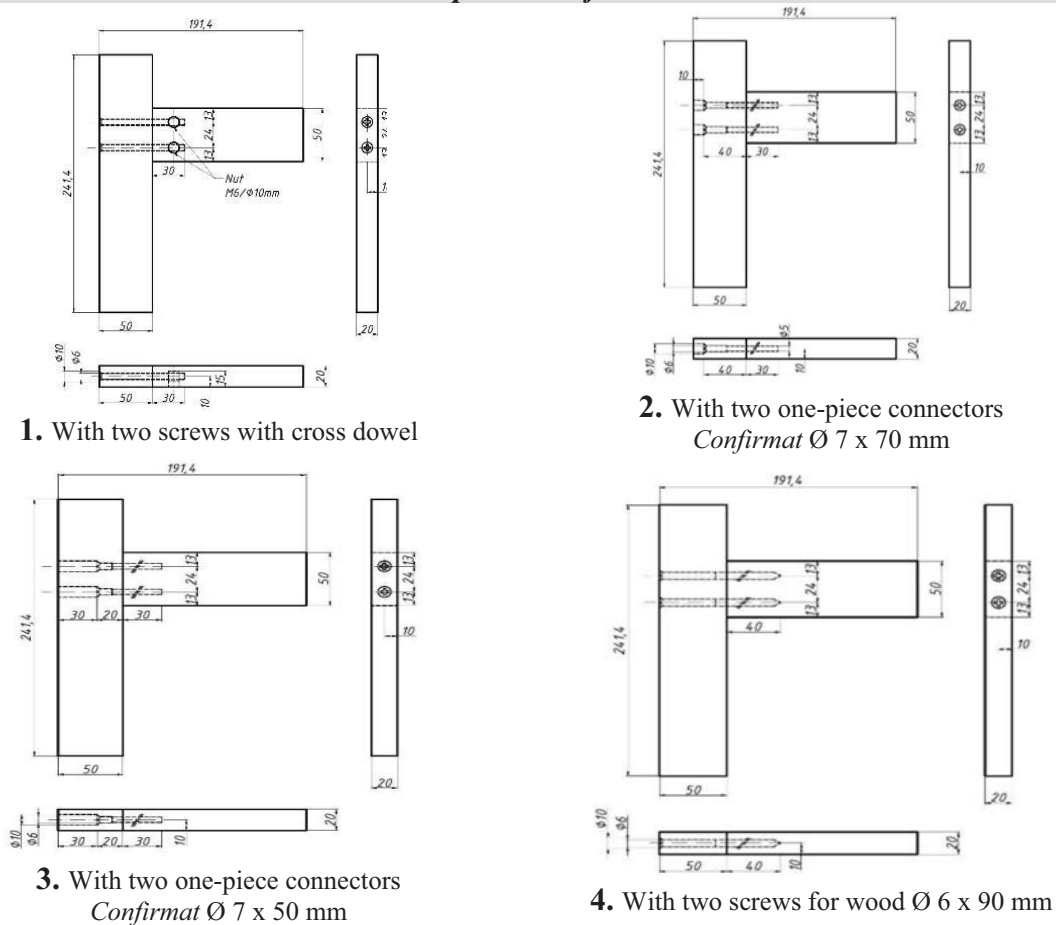
The plywood panels are cut out to make test samples for testing strength and deformation characteristics of various types of corner joints. The BDS EN 636, Plywood: specifications’ have been met. The physical

and mechanical characteristics of the manufactured plywood are as follows (Jivkov et al.):

- Density – 760.1 kg/m³;
- Bending strength under loading perpendicular to panel layers – 55.58 N/mm²;
- Bending strength under loading parallel to panel layers – 63.16 N/mm²;
- Modulus of elasticity in bending under loading perpendicular to the veneer layers – 5286 N/mm²;
- Modulus of elasticity in bending under loading parallel to the veneer layers – 6650 N/mm².

The test samples are made of elements with cross section 50 x 20 mm. All joints are made with hardware produced by „Häfele” – Germany. The type and sizes of the test samples are shown in figure 1.

T-shape corner joints



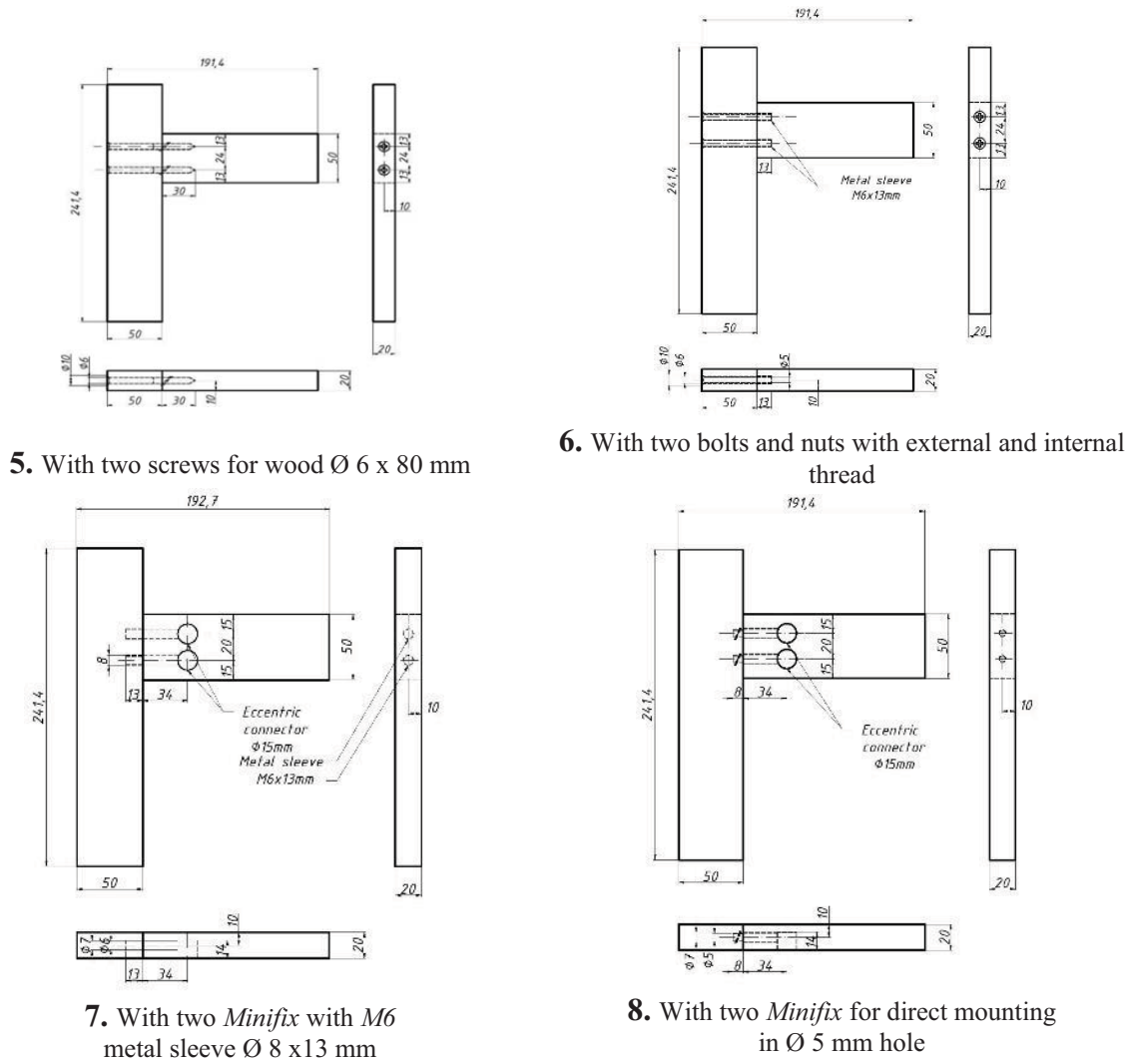


Figure 1: Type and sizes of the test samples

The test samples were loaded under compression bending as shown in Fig. 2a. and testing machine and test installation in Fig. 2b.

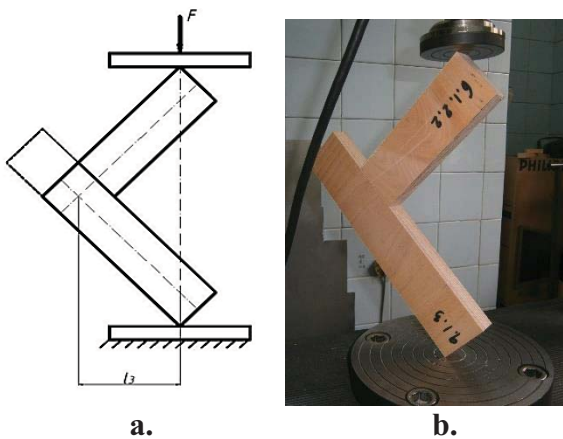


Figure 2: Scheme of loading the test samples a.; testing machine and test installation b.

The testing was carried out in the scientific and research laboratory at the Institute of Mechanics and Biomechanics, BAS, Sofia on a TIRA test 2300 testing machine. The maximum strength, deformation under maximum strength, strength and deformation at a point, determined to be the destruction point, were recorded. Temperature of the environment during testing: 22 ± 1 °C, humidity: 63 ± 5 %.

A criterion used to determine the strength of the detachable T-shape corner joints under compression loading is the maximum bending moment M_{max} , given by the formula:

$$M_{max} = F \times l_3, \quad (1)$$

where F is the maximum strength under compression loading, N ;

l_3 – arm of bending, m .

Data were processed following the method of variation statistics.

RESULTS AND ANALYSIS

Table 1 and Figure 3 show data about the bending strength of the studied detachable T-shape corner joints when loaded under compression.

Table 1: Bending strength

№	Type of the corner joints	Number of the test samples	Mmax, N.m					Coefficient of variation, %
			Average, N.m	Minimum, N.m	Median, N.m	Maximum, N.m	Standard deviation, N.m	
1	Two screws with cross dowel	10	347	329	346	380	16,6	4.8
2	Two one-piece connectors <i>Confirmat</i> Ø7x70	14	288	257	289	308,9	14,5	5.0
3	Two one-piece connectors <i>Confirmat</i> Ø7x50	15	227	203	227	244	12,3	5.4
4	Two countersunk screws for wood Ø6x90 mm	15	223	180	229	247	20,0	9.0
5	Two countersunk screw for wood Ø6x80 mm	13	220	207	217	245	11,5	5.2
6	Two screws with metal sleeve	11	155	115	160	184	20,2	13.0
7	Two connectors <i>Minifix</i> for metal sleeve	11	129	115	126	147	11,9	9.2
8	Two connectors <i>Minifix</i> for hole Ø5mm	11	121	113	121	134	6,1	5.0

The difference between the highest and the smallest value of the bending moments is more than three times. The difference between two types of connectors *Confirmat* Ø 7x70 mm и Ø 7x50 mm is 26.9 %; between two types of screw joints Ø 6x90 mm

and Ø 6x80 mm is 1.4 %; *Minifix* – 6.6 %. The difference between bending moments of the joint *Confirmat* Ø 7x50 mm and screw for wood Ø 6x90 mm is 1.8 %; screws with metal sleeve and *Minifix* for metal sleeve M6 for mounting in hole Ø 8x13 mm – 20.2 %.

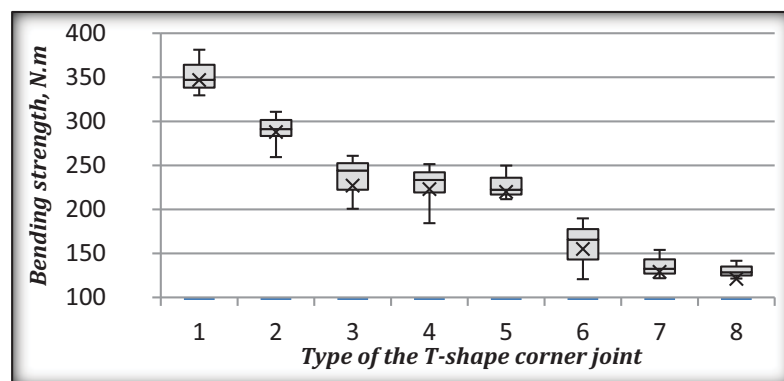


Figure 3: Bending strength.

Limits have been allocated values for maximum bending moments of the studied detachable T-shape joints made of plywood are with a wide range.

The data obtained shows that the type of detachable joint is a determinant of the bending strength. Considering the obtained average values of the maximum bending moments, the tested types of joints may be separated into three groups.

This grouping is based on a particularly rigid distinction of values shown in the chart on Fig. 3. and verification of importance of the results according to the criterion of Student.

The first group of joints with relatively high bending strength includes joints by two screws with cross dowel and this by two one-piece connectors *Confirmat* Ø 7x70 mm. Both connectors show relatively high bending moments in similar joints with other construction materials. Especially important is the factor that concerns connectors two screws with cross dowel goes through the whole width of one detail. The one-piece connectors *Confirmat* Ø 7x70 mm are with relatively good parameter (screw length), which has considerable influence on the bending strength. Furthermore, the length of the hole that receives the head of the screw has a considerably shorter length than that in *Confirmat* Ø 7x50 mm. This fact also affects on bending strength.

In the second group detachable T-shape joints with relatively lower bending strength is included by two one-piece connectors *Confirmat* Ø 7x50 mm, by screws Ø 6x90 mm and Ø 6x80 mm. The length of one-piece connectors *Confirmat* Ø 7x50 mm in this case has a key role in a significant reduction in bending strength of the joint, which takes it in the second group. Another prerequisite for a reduction in the strength of the bending is the larger length of the hole for the head.

On the other hand, the difference in the characteristics of joints with the screws Ø 6x90 mm and Ø 6x80 mm does not significantly affect. The differences between the values of the moments of the joints in this group are statistically insignificant according to Student's criterion. This makes them substitutable when the criterion is the bending strength.

In the third group detachable T-shape joints are the relatively lowest bending strength including by two connectors with bolts and nuts and *Minifix* for mounting in a metal sleeve M6 mounting hole Ø 8x13 mm and *Minifix* for direct mounting hole Ø 5 mm. In order to increase the bending capacity of these joints it is recommended additional dowel to be used in combination with connectors.

CONCLUSION

The analyses of the results of the current study show that the following important conclusions can be drawn:

1. The type of the connector has significant influence of the ultimate bending strength of the joints made of beech plywood.
2. The highest bending strength under compression loading of the studied T-shape corner detachable joints made of beech veneer plywood have the joints with screws with cross dowel and one-piece connector *Confirmat* Ø 7 x 70 mm.
3. The lowest bending strength of the studied T-shape corner detachable joints made of beech veneer plywood have the joints with two types with eccentric connectors.
4. Results of this study can be used for strength design of furniture.

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