

COMPARATIVE STUDY ON ULTIMATE TENSILE STRENGTH OF SOME T-SHAPE CORNER JOINTS OF STRUCTURAL ELEMENTS OF SOLID BEECH WOOD WITH CROSS SECTION OF 50 x 25 mm

Borislav Kyuchukov, Georgi Kyuchukov, Vassil Jivkov

University of Forestry, 10 Kliment Ohridski blvd, 1797 Sofia, Bulgaria

ABSTRACT

In this work, the ultimate tensile strength of some T-shape corner joints of structural elements of solid beech wood with cross section 50 x 25 mm used in the construction of seating furniture is investigated. It has been found that with reference to the value of ultimate tensile strength, the glued T-shape corner joints are arranged in the following descending series: with stub mortise and tenon; with wedged mortise and tenon; with stub mortise and tenon and dowel, with dowels. With reference to the value of the ultimate tensile strength the dismountable end corner joints are arranged in the following descending series: with two connectors with screw and cross dowel; with two one-piece connectors “Confirmat”. It is recommended that the results from this research can be utilized when calculating the dimensions of seating furniture.

Key words: corner joints for structural elements, ultimate tensile strength, solid beech wood

INTRODUCTION

Strength characteristics of joints in the construction of furniture for seating are an underlying factor for their endurance and sustainability during exploitation. The established strength characteristics of the joints can be used when dimensioning seating furniture following the method of final elements using computer software. Considering that, the team at the furniture construction laboratory at the University of Forestry – Sofia (UF) has published a number of articles concerning the strength and deformation characteristics of the joints of structural elements made of solid wood under bending and tensile load (Gruevski 2007, Jivkov 2001, Jivkov *et al.* 2001, Karalivanos 1992, Kyuchukov B. *et al.* 2012, 2013, Kyuchukov G. 1995, 2009, Kyuchukov G. *et al.* 2008a, 2008b, 2009, 2010, 2011, 2012a, 2012b, 2013, Marinova and Kyuchukov G. 2001). The current article presents the results from the study on the ultimate tensile strength of some T-shape corner joints of components from solid beech wood with cross section

50x25mm. The study focuses on two of the most widely used glued T-shape corner joints in the construction of seating furniture (with stub mortise and tenon and two dowels) as well as two glued not standard T-shape corner joints – the first one with a combination between a mortise and tenon and dowels, the second one with stub mortise and tenon and in the process of assembling the components the rectangular tenon becomes wedged (of the dovetail type). The article also presents the results from the testing of two of the most widely used dismountable corner joints – with one-piece connectors “Confirmat” and with connectors with screw and cross dowel.

MATERIALS AND METHODS

The structural elements for the tested corner joints are made of solid beech wood, provided from the University Training and Experimental Forest Range in Petrohan with water content 10 ± 2 %. The density and mechanical properties of beech wood tested are as follows: density with 12 % water content – 713 kg/m^3 ; longitudinal elasticity modulus – $14\ 600 \text{ N/mm}^2$; bending strength –

140 N/mm²; compression strength parallel to the grain – 64 N/mm² (Kjučukov, G. and Karalivanos A. 1991).

We have selected the most widely used cross sections of the structural elements – 50 x 25 mm. The type and size of the tested samples are shown in Fig.1. They have been tested under tensile strength (Fig.2) in compliance with the standardized methodology (BDS 9165-90), developed at the Laboratory of Furniture construction, University of Forestry, Sofia.

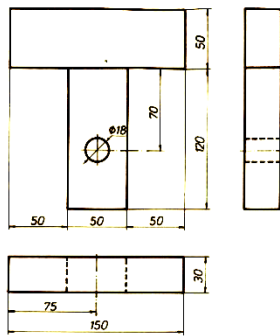


Figure 1: Type and parameters of the test samples for carrying out tests under tension.

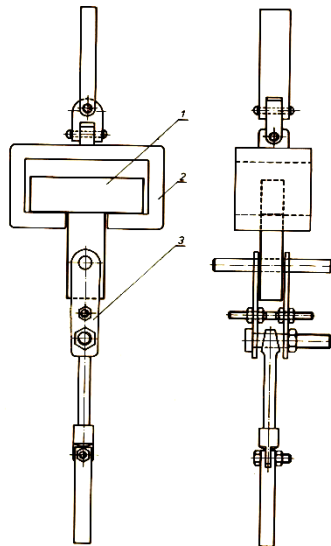


Figure 2: Scheme of testing the samples under tensile strength: 1 – testing sample; 2 – device for holding the upper part of the sample; 3 – device for holding the bottom part of the sample

The type and parameters of the tested T-shape corner components are given in Fig. 3 and 4 as follows:

Glued T-shape corner joints (Fig.3): 1 – with stub mortise and tenon; 2 – with two ϕ 10 mm dowels; 3 – with mortise and tenon and ϕ 10 mm dowels; 4 – with wedged mortise and tenon.

Dismountable T-shape corner joints (Fig.4): 5 – with two one-piece connectors “Confirmat”; 6 – with two connectors with screw and cross dowel.

The parameters of the glued joints are in compliance with BDS 5527-73. The one-piece connectors are 7 x 70 mm (see fig.4), the screw of the connector with cross dowel is 6 x 90 mm, with M6 threading, while the dowel is 12 mm in diameter and M6 threading (Der Große Häfele. 2012).

Fifteen testing samples were prepared for each type of joint. Prior to testing they were conditioned for 5 days and nights at temperature of $(21 \pm 3)^\circ\text{C}$ and relative air humidity of $(55 \pm 10)\%$. Gluing has been done with polyvinyl acetate adhesive manufactured by Rakoll Express, Austria and has the following characteristics: description – cream-coloured homogenous viscous mass; viscosity – 3 500 mPa.s (average viscosity appropriate for applying with a brush); open time at 20°C – not more than 10 min.

Testing has been carried out on a universal testing machine at constant load speed for (60 ± 30) s from the beginning of loading and accuracy of 1 % of the ultimate load strength.

The test results have been processed under variational statistics methods.

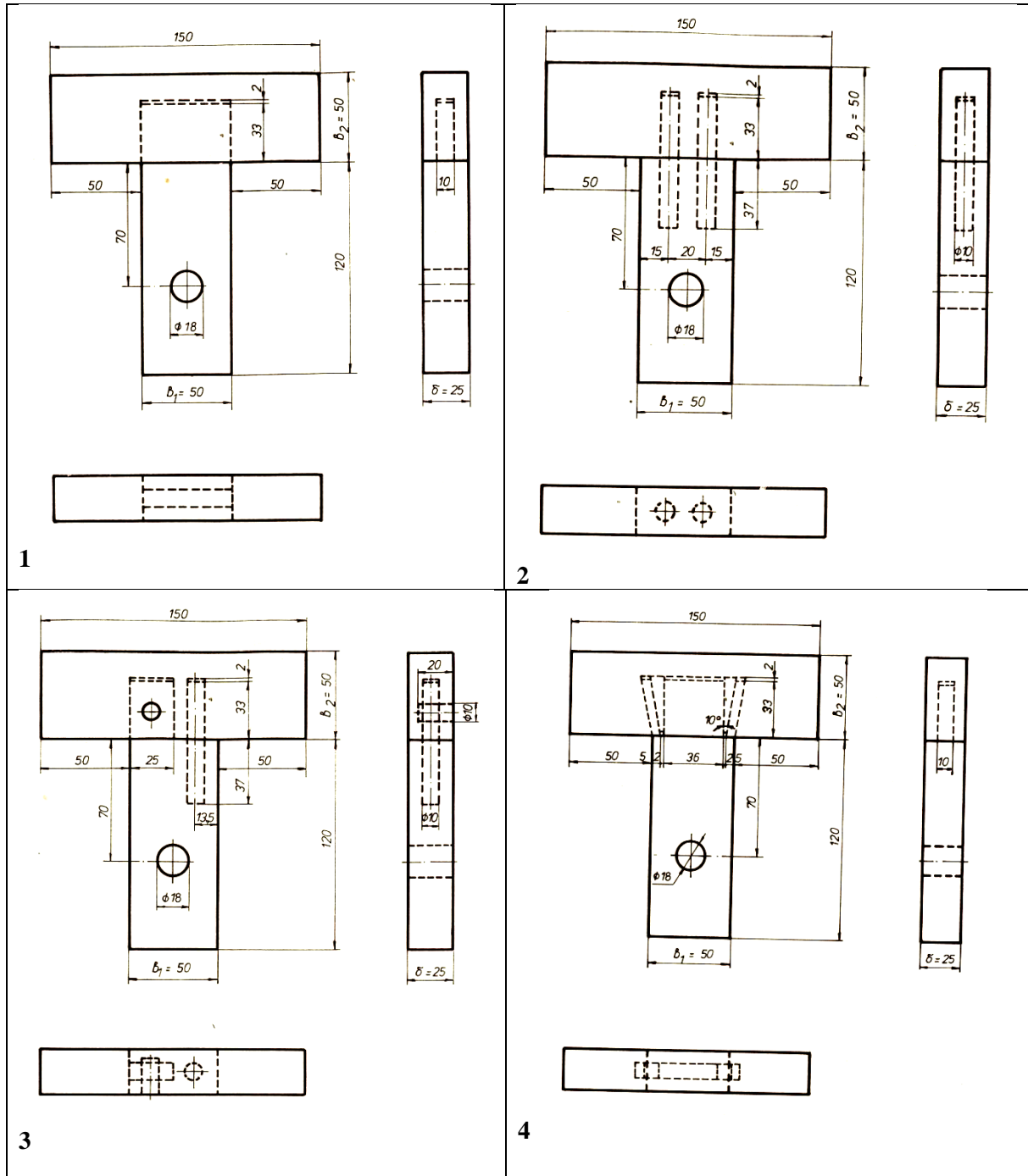


Figure 3. Type and parameters of glued T-shape joints of testing samples: 1 – with stub mortise and tenon; 2 – with two dowels ϕ 10 mm; 3 – with stub mortise and tenon and dowels ϕ 10 mm; 4 – with wedged mortise and tenon

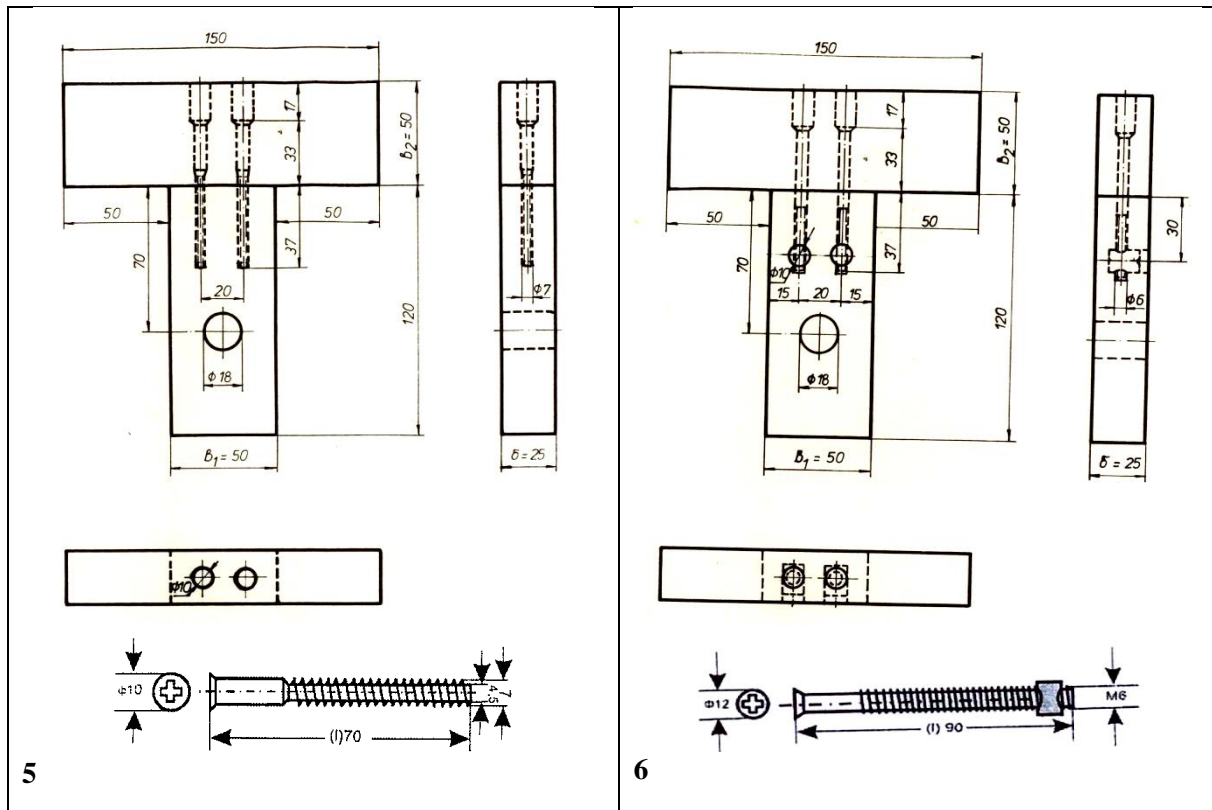


Figure 4. Type and parameters of dismountable T-shape joints of testing samples: 5 – with two one-piece connectors “Confirmat”; 6 – with two connectors with screw and cross dowel with M6.

RESULTS AND DISCUSSION

The results of ultimate strength for different type of joints tested are presented comparatively in Table 1 and the correlation between the ultimate tensile strengths of the tested T-shape joints is presented graphically in the same order in Fig. 5.

The data in Table 1 and Fig. 5 show that out of the glued corner joints the joint with stub mortise and tenon (21 390 N) destroys under the greatest strength, followed by the

authentic joint with wedged mortise and tenon (18 700 N). Third comes the untypical joint with stub mortise and tenon and dowels (11 820 N) and the last to be destroyed is the joint with two dowels (9 380 N). This gradual change in the strength characteristics of T-shape corner joints under tensile pressure matches their gradual change under bending load (Kyuchukov et al. 2012b).

Table 1: Ultimate tensile strength of the tested T-shape joints of components from solid beech wood.

Name of joint	Variational statistical indicators for the ultimate tensile strength, $F_{op.r.}$					
	\bar{x} , Nm	s, Nm	v, %	s_r , Nm	p, %	n, бр.
A. Glued T-shape joints:						
1 – with stub mortise and tenon;	21 390	1 809	8,5	467	2,2	15
2 – with two dowels ϕ 10 mm;	9 380	455	4,9	118	1,3	15
3 – with stub mortise and tenon and dowels ϕ 10 mm;	11 820	609	5,2	157	1,3	15
4 – with wedged mortise and tenon.	18 700	1 035	5,5	267	1,4	15
B. Dismountable T-shape joints:						
5 – with two one-piece connectors “Confirmat”	9 940	893	9,0	230	2,3	15

Name of joint	Variational statistical indicators for the ultimate tensile strength, $F_{op.r.}$					
	\bar{x} , Nm	s, Nm	v, %	s_r , Nm	p, %	n, бр.
6 – with two connectors with screw and cross dowel	12 060	1 660	13,7	428	3,5	15

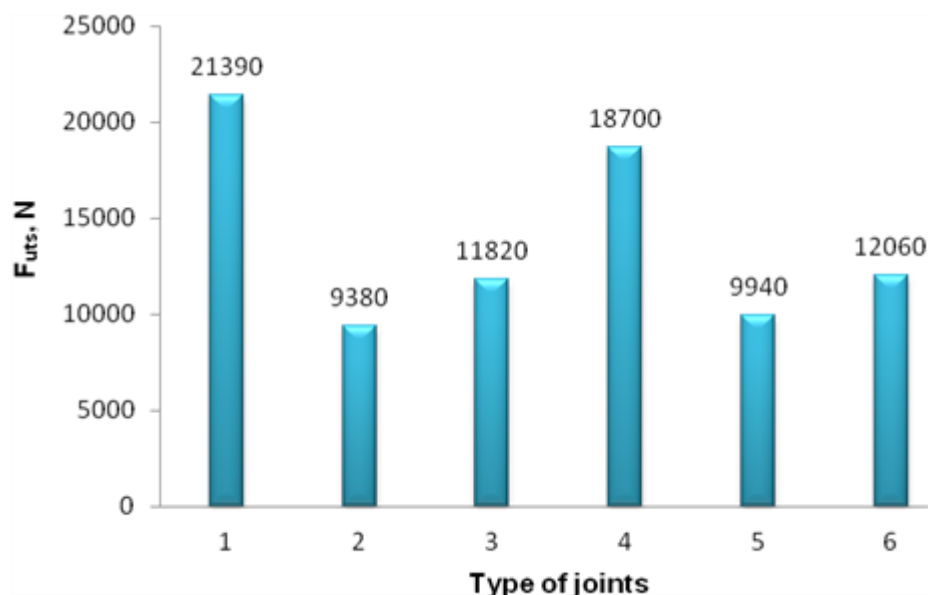


Figure 5: Comparative data about the ultimate tensile strengths of the tested T-shape corner joints of components from solid beech wood with cross section 50 x 25 mm: 1 – with stub mortise and tenon; 2 – with dowels ϕ 10 mm; 3 – with stub mortise and tenon and dowel; 4 – with wedged mortise and tenon; 5 – with two one-piece connectors “Confirmat”; 6 – with two connectors with screw and cross dowel.

If we accept that the ultimate tensile strength of the T-shape corner joint with stub mortise and tenon is 100 %, the ultimate tensile strengths of the remaining T-shape corner joints is as follows: for the joint with wedged mortise and tenon – 88 %, for the joint with mortise and tenon and dowels – 55 % and for the joint with dowels – 44 %. The reasons for this gradual change in the resilience indicators of the tested T-shape corner joints of the components from solid beech wood can be substantiated by the mode of their destruction under tensile strength (Fig. 6) of the joint, which is as follows:

- for the joint with mortise and tenon – withdrawal of the tenon and destruction of the wood in the area at the bottom of the mortise (Fig. 6.1);

- for the joint with wedged mortise and tenon – rupture of the tenon in the area from the outer sides of the slot or destruction of the wood in the area of the mortise (Fig. 6.4);

- for the joint with stub mortise and tenon and dowels – withdrawal or rupture of the dowel and tenon and breakage of the cross dowel (Fig. 6.3);

- for the joint with dowels – withdrawal of the dowels (Fig. 6.2).

It becomes obvious that under greater tensile strength the joints that get destroyed are the ones with bigger cross section or larger gluing surface of the joining components.

With dismountable corner joints the greater ultimate tensile strength is typical of the joint with connectors with cross dowel

with M6. The explanation for that can be found in the way the joint is destroyed. For the joint with connectors with screw the screws get withdrawal from the hole from the head of the screw (Fig. 7.1) and for the joint with connector with cross dowel – the dowels get extracted from the hole at the heads of the

screws or it splits the wood in the area at the head of the screws (Fig. 7.2). The reason for that can be explained with the fact that the withdrawal of screws from the beech wood in joints with connectors with screw and cross dowel is more difficult than in one-piece connectors “Confirmat”.

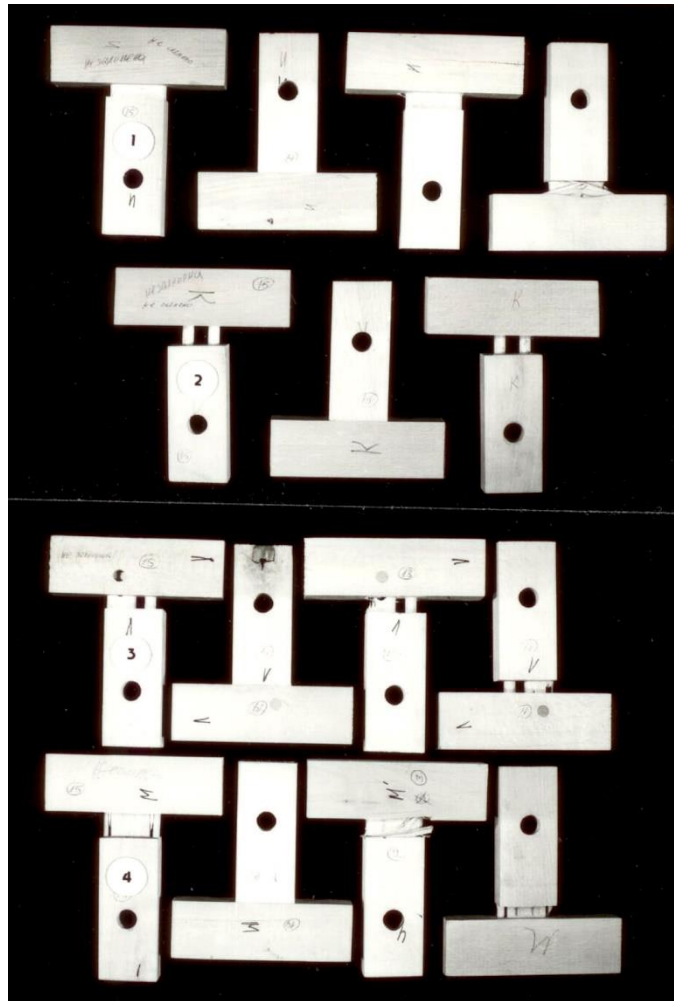


Figure 6: Typical mode of destruction of glued T-shape corner joints of structural elements from solid beech wood under tensile pressure: 1 – with stub mortise and tenon; 2 – with dowels ϕ 10 mm; 3 – with stub mortise and tenon and dowel ϕ 10 mm; 4 – with wedged mortise and tenon.

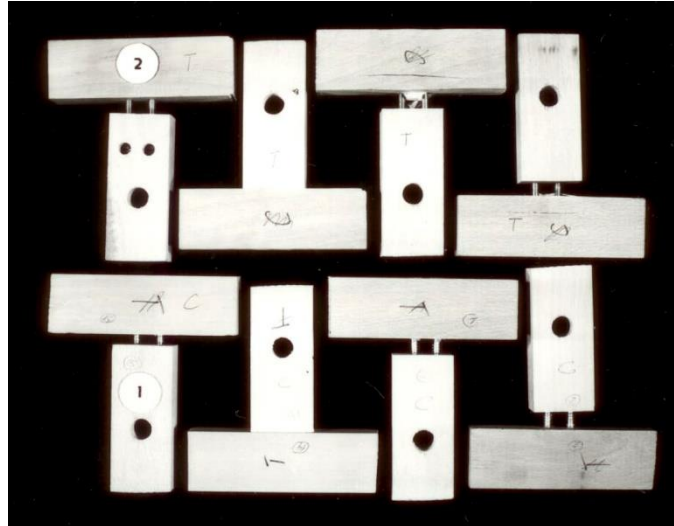


Figure 7: Typical mode of destruction of dismantlable T-shape corner joints of structural elements from solid beech wood under tensile pressure: 1 – with two one-piece connectors “Confirmat”; 2 – with two connectors with screw and cross dowel.

The comparative analysis of ultimate tensile strength on both glued and dismantlable T-shape corner joints of components from solid beech wood with cross section 50 x 25 mm tested shows that the values in joints with one-piece connectors “Confirmat” exceed the values of the ultimate tensile strength in joints with dowels. Similar conclusion can be drawn when we compare the ultimate tensile strength of joints with connectors with screw and cross dowel and with stub mortise and tenon and dowels. These facts once again bear out the favourable opportunity provided by dismantlable T-shape joints when used in the construction of seating furniture.

CONCLUSIONS

The results from the experimental study on the strength characteristics of the tested types of T-shape corner joints of structural elements made of solid beech wood under tensile load give grounds for drawing the following general conclusions:

1. The type of T-shape joint is the key factor to their strength characteristics.
2. The glued T-shape corner joints with smaller cross section of the joining elements and larger gluing surface of

the joining components guarantee higher value of their strength characteristics.

3. The gradual change in the tested glued T-shape corner joints of the structural elements made of solid beech wood in terms of the ultimate tensile strength is as follows: with mortise and tenon, with stub mortise and tenon, with mortise and tenon and dowels and with dowels.
4. The strength characteristic of dismantlable T-shape corner joints of structural elements made of solid beech wood is determined by the parameters of the connecting elements.
5. The joint with universal connectors with cross dowels provides nearly 14 % higher ultimate tensile strength in comparison with the joint with screw connector “Confirmat”.

It is recommended that the determined strength characteristic of the tested T-shape corner joints of structural elements of solid beech wood be taken into consideration for strength design of the construction of seating furniture.

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