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COMPARATIVE STUDY ON THE DESTRUCTIVE BENDING MOMENTS OF SOME END CORNER JOINTS OF STRUCTURAL ELEMENTS OF SOLID BEECH WOOD WITH CROSS SECTION OF 50 X 25 MM

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ABSTRACT

The paper shows the results of the studies on the strength characteristics of the end corner joints of the structural elements of solid beech wood with a cross section of 50 x 25 mm used in the construction of seating furniture.

It has been found out that, on the basis of the values of the destructive bending moment, the non-dismountable end corner joints are arranged in the following descending order: half-open mortise and tenon joint; blind stub mortise and tenon joint with dowel and cross dowel; blind stub mortise and tenon joint and dowel joints.

It has been found out that, on the basis of the values of the destructive bending moment, the dismountable end corner joints are arranged in the following descending order: joints with two one-piece connectors "Confirmat" following by joint with two universal connectors with bolt and cross dowel.

It is recommended to use the studies' results in calculating the dimensions of seating furniture.

Key words: corner joint of details; destructive bending moments; beech solid wood

INTRODUCTION

It is well known that the strength of components made from solid wood depends on a number of factors – the size of the cross section of the components; type, parameters and fit of the joints; type of wood the components are made from and its physical and mechanical characteristics; roughness of the surface of the contact surfaces of the joining components; type and characteristics of the used glues; the quantity of the glue and etc. Structural elements made from solid beech wood, though it is the wood most often used in the construction of seating furniture.

There are not many publications about comprehensive studies including the impact of different possibilities of joining on the strength characteristics of the beech wood joints. Most of the studies are about the strength characteristics of joints common used in furniture construction. Comparatively less is the information about the strength characteristics of the dismountable corner joints of beech wood structural elements with modern furniture fittings.

This is the reason why the current paper provides information about the destructive bending moments of three types of the most widely used end corner joints in the construction of chairs and armchairs as well as of one innovative non-dismountable corner joint of structural elements made from solid beech wood under compression bending test. It includes the results from the testing of two types of the most widely used dismountable corner joints in the construction of seating furniture.

METHOD

The test samples for the compression bending test of end corner joints made of solid beech wood with 10 ± 2 % water content. The cross section of the components of

50x25 mm was selected as rectangular one is most often used in the skeleton of chairs and armchairs. The type and size of the samples (Fig.1a) are in accordance with the methodology developed at the Laboratory for furniture construction at the University of Forestry, which is standardized (BDS 9165-90). The compression bending test were done according the scheme on Fig.1, b.

The following types of end corner joints were tested:

- Non-dismountable end corner joint (Fig. 2): 1 – with blind stub mortise and tenon; 2 – half-open mortise and tenon; 3 – with two ϕ 10 mm dowels; 4 – with blind stub mortise and tenon and dowel and reinforced with second cross dowel.
- Dismountable end corner joints (Fig. 2): 5 – with two one-piece connectors "Confirmat"; 6 – joint with two universal connectors with bolt and cross dowel.

The parameters of the dismountable joints are in accordance with BDS 5527-73. The one-piece connectors are 7 x 70 mm (Fig. 2, 5), the screw of the dowel connector is 6 x 90 mm, with M6 thread and a 12 mm cross dowel with M6 thread (see Fig. 2, 6).

The test samples are made from solid beech wood, delivered from "Petrohan" Training Range and Field of the University of Forestry, Barzia village with the following physical and mechanical properties: density at 12 % water content – 713 kg/m^3; radial shrinkage – 6,3 %, tangential shrinkage – 12,8 %; volumetric shrinkage – 18,9 %; modulus of longitudinal bending elasticity – 14 600 N/mm^2; bending strength – 140 N/mm^2; compressive strength parallel to grain – 64 N/mm^2.

Fifteen test samples were produced for each type of joint. Prior to being tested they were placed at 15 to 30 °C and relative humidity (55± 10) % for 5 days periods.

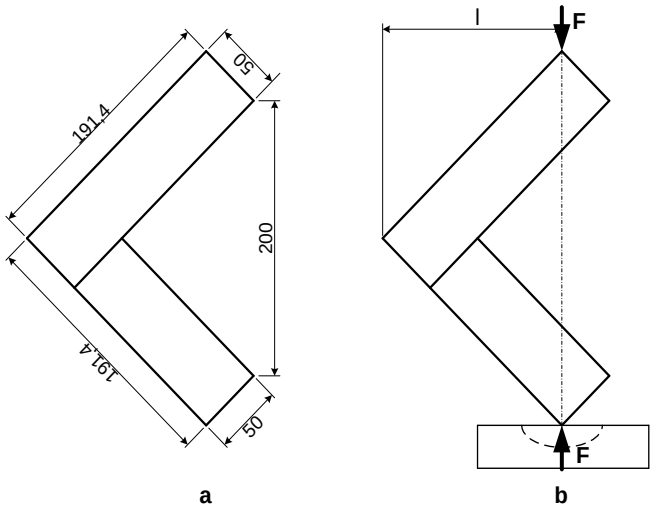

Figure 1: Test samples under compression bending test of the end corner joints of solid beech wood structural elements: a – Type, shape and sizes of the test samples; b – Scheme for testing the test samples under compression bending test.

Gluing is done with polyvinylacetate glue manufactured by Racoll express, Austria with the following characteristics – appearance – homogenous cream viscous weight; viscosity – 3 500 cP (semi viscous, appropriate for applying with a brush); open time at 20 °C – not more than 10 min; film-formation temperature - + 3°C).

Testing is carried out on a universal testing machine at steady pressure speed for

60 ± 30 s from the start of exerting pressure and reporting accuracy of 1 % of the destructive pressure strength.

The destructive bending moment $M_{d.b.}$ under compression bending load is calculated with the formula

$$\mathbf{M_{d.b.} = F.l,} \quad \mathbf{(1)}$$

where: F is the destructive force at bending pressure, N;

1 – bending arm, m.

The test results have been processed under the statistics methods.

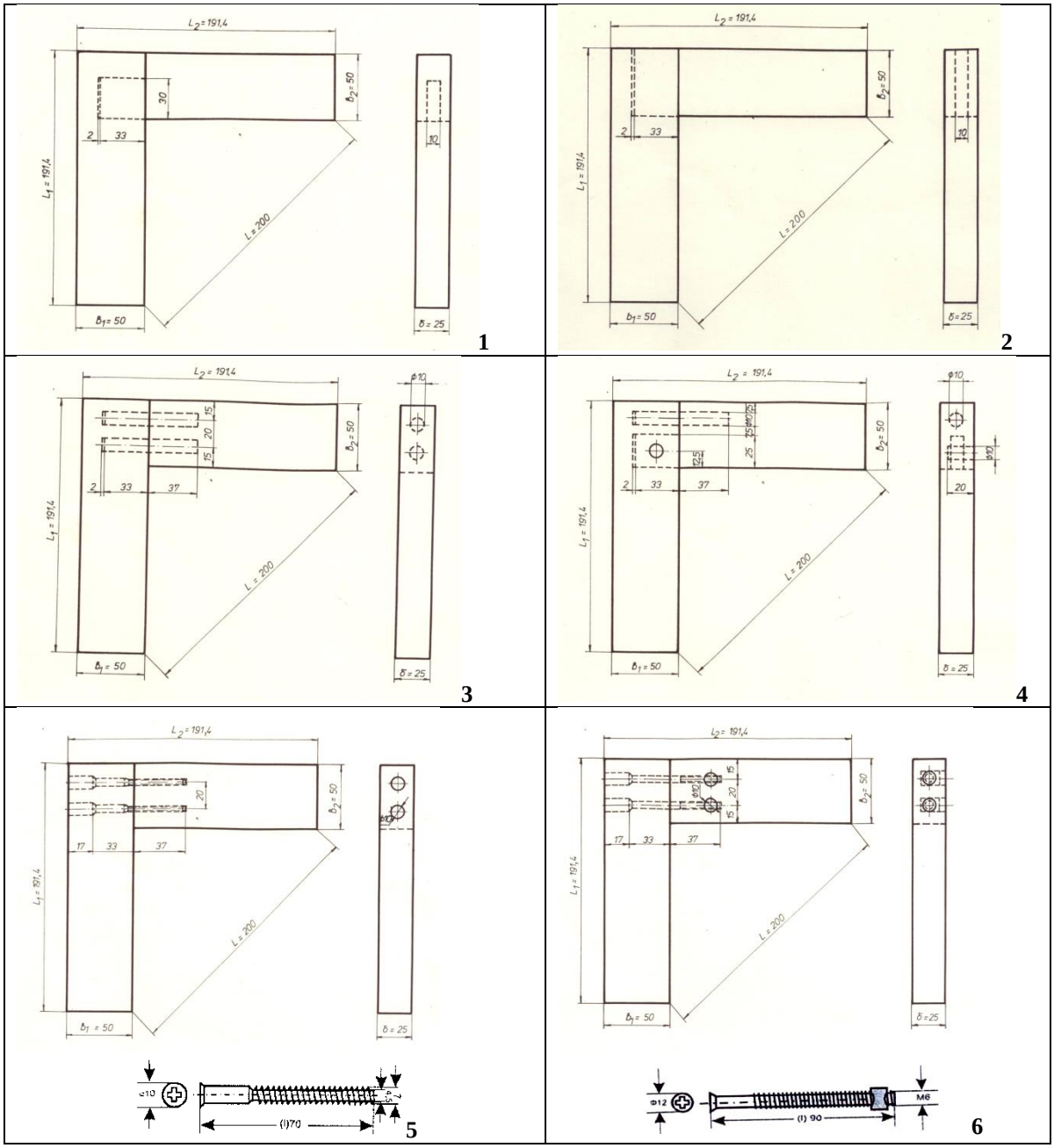

Figure 2: Type and parameters of the end corner joints: 1 – with blind stub mortise and tenon; 2 – with half open mortise and tenon; 3 – with 2 dowels ϕ 10 mm; 4 – with blind stub mortise and tenon with 1 dowels ϕ 10 mm and reinforced with second cross dowel; 5 – with two one-piece connectors "Confirmat"; 6 – with two connectors with screw and cross dowel.

COMPARATIVE ANALYSIS OF THE TEST RESULTS

The test results are presented in Table 1, whereas the ratio between the destructive bending moments of the tested corner joints is presented graphically in the same way on Fig. 3.

Table 1: Destructive bending moments under compression bending test of end corner joints of structural elements made from solid beech wood with cross section of 50 x 25 mm.

Types of end joints	Variation statistics for bending moment, $M_{d.b.}$					
	$\bar{x}$, Nm	s, Nm	v, %	s_r, Nm	p, %	n, pcs.
A. Non-dismountable corner joints:						
1 – with blind stub mortise and tenon	340	34	10,2	8,8	2,6	15
2 – with half opened mortise and tenon	490	37	7,5	9,5	1,9	15
3 – with two dowels ϕ 10 mm;	280	16	5,8	4,2	1,5	15
4 – with mortise and tenon with dowel ϕ 10 mm and reinforced with second cross dowel;	350	26	7,3	6,7	1,9	15
B. Dismountable corner joints:						
5 – with two one-piece connectors "Confirmat"	265	36	13,8	9,4	3,6	15
6 – with two connectors with screw and cross dowel	275	15	5,6	4,0	1,4	15

The data in Table 1 and Figure 3 shows that highest bending moment of all non-dismountable joints have half open mortise and tenon joints (490 Nm). Second highest bending strength achieved uncommon joint with blind stub mortise and tenon, with dowel and reinforced with a cross dowel (350 Nm) following by blind stub mortise and tenon (340 N/m) and dowel joint (280 Nm).

The difference between the destructive bending moment of the joint with half open mortise and tenon joint and the joint with dowels is about 1,75 times. This fact bears out the determining impact of the type of joint on its strength characteristic.

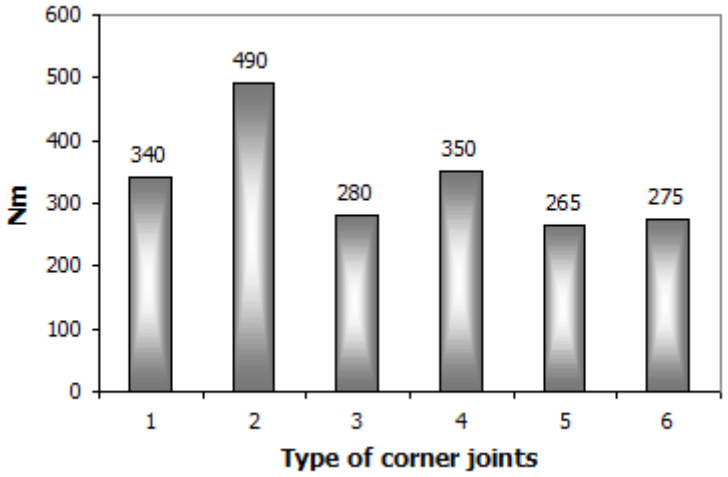

Figure 3: Comparative data about the destructive bending moments of the tested end corner joints of components made from solid beech wood with cross section 50 x 25 mm: 1 – with blind stub mortise and tenon; 2 – with half open mortise and tenon joint; 3 – with two dowels ϕ 10 mm; 4 – with mortise and tenon with dowel ϕ 10 mm and reinforced with cross dowel; 5 – with two one-piece connectors "Confirmat"; 6 – with two connectors with screw and cross dowel.

The data in Table 1 illustrate that the key factors determining the strength characteristic of the non-dismountable corner joints of structural elements made from solid wood are the parameters of their joining components and the contact gluing surface. Half open mortise and tenon joint has the largest cross section of the tenon and the biggest gluing surface of the studied end corner joints. The bending strength of the tenon is big enough to counteract its bending destruction. Due to all that the destruction of the joint is predominantly partly along the gluing line or through breaking the component (Fig. 4,2). The joint with two dowels with the smallest cross section of the joining components and the one with the smallest gluing surface is destroyed mainly through breaking or partial withdrawal of the dowels (Fig. 4,3). The smaller width of the tenon of the joint with mortise and tenon in comparison with the joint with half open mortise and tenon is the reason for the partial withdrawal and breaking of the tenon (Fig. 4,1). The nature of the destruction of the joint with blind stub mortise and tenon and dowels (breaking the dowels or breaking and distortion of the tenon), shown in Fig. 4,4), is due to its bigger cross section of the joining components and its bigger gluing surface compared with the joint with wedged mortise and tenon. This results in its bigger destructive bending moment.

The data in Table 1 also illustrate that the destructive bending moment of the dismountable end corner joints of components made from solid beech wood with screw connector and connector with cross dowel are almost identical. This can be explained with the relatively similar way of destroying the samples – the joint with screw connector – deformation and withdrawal of the screw (Fig. 5, 1), whereas the joint with connector with cross dowel – deformation of the screw or splitting of the detail in the area of the head of the screw (Fig. 5, 2).

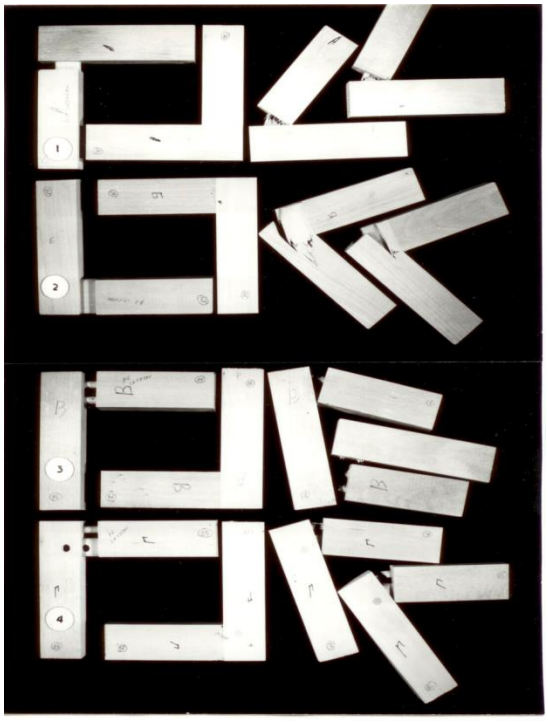

Figure 4: Typical way of destruction of non-dismountable end corner joints of components made from solid beech wood under bending load: 1 – with blind stub mortise and tenon; 2 – with half open mortise and tenon; 3 – with two dowels ϕ10 mm; 4 – with blind stub mortise and tenon with one dowels ϕ10 mm and reinforced with second cross dowel.

The data in Table 1 and Figure 3 show that the destructive bending moment of the non-dismountable corner joints of components made from solid beech wood considerably surpasses the destructive bending moment of the dismountable corner joints. This fact is not valid for all type of joints. For example, the two types of dismountable corner joints are destroyed under more or less the same bending moment like the joint with dowels.

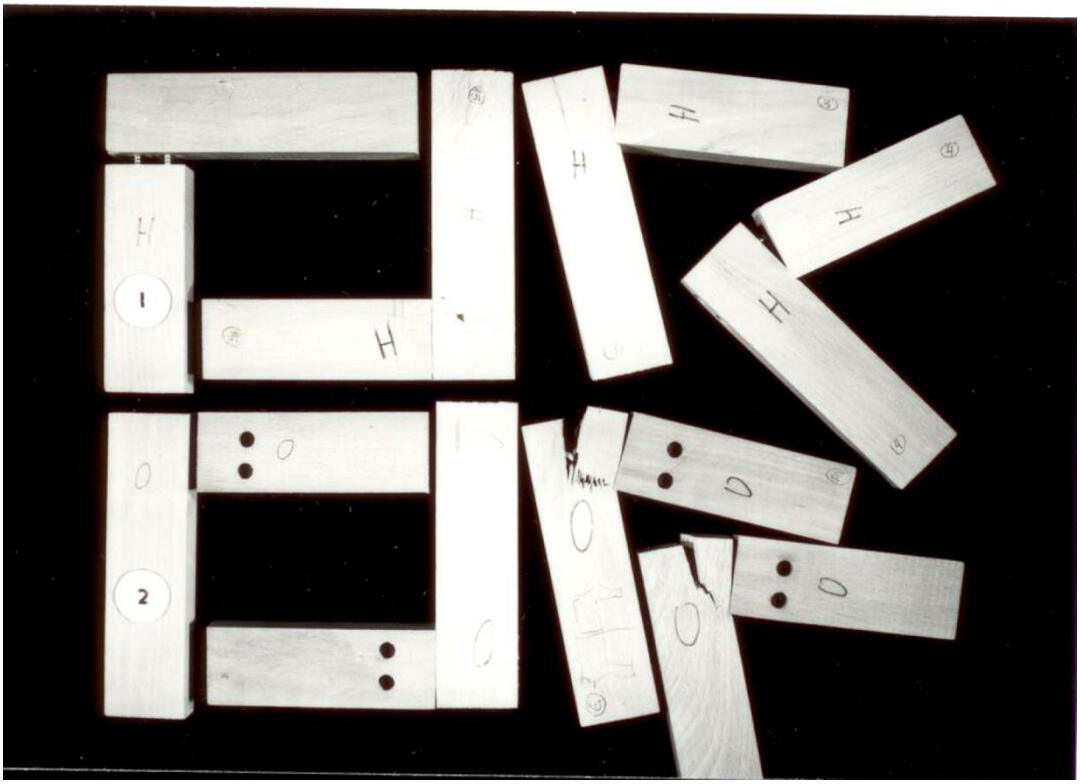

Figure 5: Typical way of destruction of dismountable end corner joints of components made from solid beech wood under bending load: 1 – with two one-piece connectors "Confirmat"; 2 – with two connectors with screw and cross dowel.

CONCLUSION

The results from the research give reasons for drawing the following more general conclusions:

1. The type of joint is a determining factor for its strength characteristic.
2. The non-dismountable corner joints are destroyed under relatively bigger bending moment than the dismountable corner joints. The non-dismountable corner joints with bigger contact gluing surface have higher carrying capacity under bending load.
3. Polyvinylacetate adhesives provide high bending strength of the non-dismountable corner joints of components made from solid beech wood. It is clear from the way of their destruction under bending load which is either outside or partially along the glued line.
4. The relatively high withdrawal resistance of screws from beech wood provides the required bending strength of the dismountable corner joints of components made from solid beech wood under bending load.
5. The specified destructive bending moments of the tested corner joints of structural elements made from solid beech wood should be taken in-

to consideration for dimensioning and strength design of the construction of seating furniture.

REFERENCES

1. Albin, R., Seeland, G. 1986. Passungseinfluβ auf Schlitz und Zapfenverbindungen bei Gestellmöbeln. Holz als Roh- und Werkstoff, Vol.44, №1, s.30.
2. Burdurlu E., Kiliç, M., Altun, S. 2003. The effect of the corner block and the joint type on bending strength in the rail to the leg joints. Journal of Science, 16(2), 257–367.
3. Eckelman, C.A. 2003. Textbook of Product Engineering and Strength Design of Furniture. Purdue University Press. West Lafayette, IN., USA.
4. Eckelman, C.A., Erdil, Y.Z., Haviarova E. 2002. Effect of cross holes on the strength of chairs and table legs. Forest Products Journal, Vol. 52, № 5, 67–70.
5. Eckelman, C.A., Haviarova, E., Erdil, Y., Akcay, H., Tankut, A, Denizli, N. 2004. Bending moment capacity of round mortise and tenon furniture joints. Forest Products Journal. 54: 192–197.
6. Erdil, Y. Z., Kasal, A., Eckelman, C.A. 2005. Bending moment capacity of rectangular mortise and tenon furniture joints. Forest Products Journal, Vol. 55, № 12, 209–213.
7. Gruevski, G. 2007. Izstrajuvanja na sostavite vo konstruktsiite na stolovi, izraboteni od kostenovo drwo. – Doktorska disertatsia, Faculty of forestry, Skopje.
8. Jivkov, V., 2001. Influence of the tolerances on the strength characteristics of the main glued joints of furniture. PhD thesis, University of Forestry, Sofia.
9. Jivkov, V., Genchev, J., Marinova, A. 2000: Bending strength and stiffness of some detachable end corner joints from beech wood. 14th Scientific Conference of Faculty of Wood Technology “Wood – Everlasting Material”, Warsaw Agricultural University, Warsaw, 13-15 November, 2000, 127–13
10. Karalivanos, A. 1992. Comparative studies on strength characteristics of joints in chair constructions made from beech wood. Ph.D. thesis, Aristotle University of Thesaloniki.
11. Kyuchukov, G., 1995. Konstruirane na mebeli. – Uchebnik, Sofia.
12. Kyuchukov, G., 2009. Konstruirane na mebeli, vrati I prozorci – Uchebnik, Sofia.
13. Marinova, A., G. Kyuchukov, 2001. Orazmerjavane na mebeli. Uchebnik, LTU, Sofia.
14. Tankut, A., Tankut, N. 2005. The Effects of Joint Forms (Shape) and Dimensions on the Strengths of Mortise and Tenon Joints. Turkish Journal of Agricultural
15. Der Große Häfele. 2009. Möbelbeschläge. Katalog, Nagold.