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COMPARATIVE RESEARCH ON THE DESTRUCTIVE BENDING MOMENTS OF END CORNER JOINTS OF FRAME STRUCTURAL ELEMENTS MADE OF SOLID SPRUCE WOOD WITH A CROSS SECTION OF 50 x 30 mm PART I: END CORNER BUT JOINTS AND FACE SPLINED JOINTS

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ABSTRACT

The results from the research on destructive bending moments of end corner but joints and face splined joints of structural elements made of solid spruce wood with a cross section of 50 x 30 mm are given, where these joints are used mainly in construction of sitting furniture, tables and beds.

It was found that the type of joints has significant influence on the destructive bending moment. This is defined by the type and size of joint elements and the area of the contact surfaces of the joints.

The splined joints are destroyed in a considerably higher bending moment in comparison with the other researched types of joints.

Miter joints and those strengthened with staples have higher destructive bending moment than but joints, and joints under right angle have higher destructive bending moment than lap joints, because the former have a bigger area of gluing.

It is recommended that the research results are taken into consideration in strength design of furniture.

Key words: end corner joints, frame structural elements, destructive bending moments, solid spruce wood

1. INTRODUCTION

In construction of the tables, beds and sitting furniture (chairs, arm-chairs, sofas, foot-chairs) commonly elements made of solid wood of conifer tree species are used. Important factors for the strength of the structure of these furniture types are the destructive bending moments of the corner joints. In the Laboratory for Construction Design and Testing of Furniture at the University of Forestry, Sofia, researches have been carried out and a series of articles (7 to 19) has been published concerning the strength and deformation characteristics of the joints of structural element made of solid wood from beech (*Fagus sylvatica* L.) and sweet chestnut (*Castanea sativa* Mill.).

There is insufficiency of evidence concerning the strength characteristics of joints of structural elements made of solid wood from conifer tree species. Having this in mind, this article is the beginning of a series of articles regarding the destructive bending moments of some of the most frequently used in practice corner joints of structural elements made of solid wood of one of the most commonly used conifer wood species – ordinary spruce (*Picea abies* Karst.).

In this part I data is given about the destructive bending moments of 14 types of glued end corner but joints and through face splinted joints of structural elements made of solid spruce wood with a cross section 50 x 30 mm, as stated in the Bulgarian State Standard 5527-73.

2. MATERIAL AND METHODS

The test samples of the joints are made of solid spruce wood, supplied from the Educational Experimental Forestry Enterprise of the University of Forestry at “Yundola”. For this purpose a sample tree with a diameter of breast height 520 mm was cut down. The tree was cut into sections with a length of 2500 mm which were then cut into radial boards dried naturally till air dry condition, initially under a shelter, and later in room temperature conditions (t ^{0}C 21 ± 3 ^{0}C and comparative air humidity 55 ± 10 %) up to 12 % water content.

The basic physical mechanical properties of timber are: density – 387 kg/m^3; radial, tangential and volumetric shrinkage – respectively 4,0, 8,6 and 12,7 %; radial, tangential and volumetric swelling – respectively 4,2, 7,8 and 11,7 %; bending strength – 56 N/mm^2; compressive strength parallel to grain – 34 N/mm^2; longitudinal elasticity modulus – 9 500 N/mm^2. The established strength characteristics of this wood are less than the data available in literature for spruce wood from Central Europe [1, 2, 3].

But joints (Fig. 1), lap and dowel joints (Fig. 2) and splined joints (Fig. 3, 4) were tested. The parameters of the joints correspond to the Bulgarian State Standard 5527-73 and are given at figures 1 to 4.

The joints of the structural elements were obtained by gluing with polyvinylacetate glue from the company Racoll Express, Austria with the following characteristics: outer appearance – cream homogeneous viscose mass; viscosity – 3 500 cP (middle viscosity suitable for brush coating); open time at 20 ^{0}C – not bigger than 10 min; temperature of film formation – +3 ^{0}C.

For each type of joint 30 numbers of test samples were manufactured – 15 numbers for arm opening bending load (Fig. 5 a) and 15 numbers for arm compression bending load (Fig. 5 b). Before testing, the samples were conditioned for 5 days and nights at temperature (21 ± 3) ^{0}C and relative air humidity (55 ± 10) %.

The type and schemes of loading of the samples in their testing (Fig. 5) correspond to the standardized methodology (BSS 9165-90), worked out at the Laboratory of Furniture Construction at the University of Forestry.

The experiment was carried out at a universal testing machine at an equal speed of loading in the length of (60 ± 30) s from the beginning of the loading and accuracy of reading of the results 1 % of the failure force of loading.

The destructive bending moments M_1 at arm opening bending test and M_2 at compression bending test have been calculated correspondingly by the formulas /1/ and /2/.

$$M_1 = \frac{F_1 . L}{4} \quad (1)$$

$$M_2 = F_2 . l \quad (2)$$

where F_1 and F_2 are the failure forces, at respectively arm opening and compression bending test, N;

L – the span distance of arm opening bending test, m;

l – the arm of bending in compression bending test, m.

The results of the experiments were processed by the variation statistics methods.

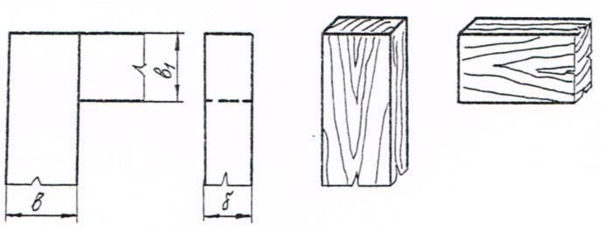
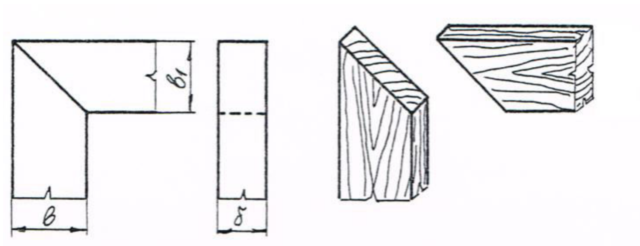
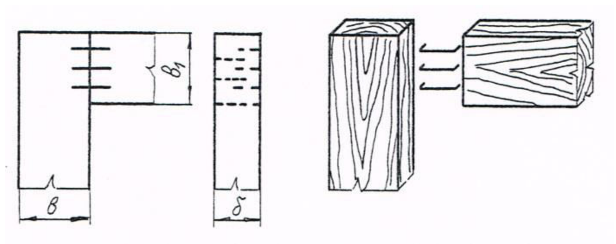
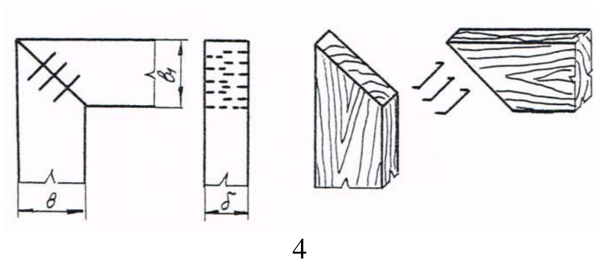
 1	$b = b_1 = 50$ mm $\delta = 30$ mm
 2	$b = b_1 = 50$ mm $\delta = 30$ mm
 3	$b = b_1 = 50$ mm $\delta = 30$ mm $n = 3$
 4	$b = b_1 = 50$ mm $\delta = 30$ mm $n = 3$

***Figure 1**. End corner but joints: 1 – but joint at right angle; 2 – miter but joint; 3 – but joint at right angle with staples; 4 – miter but joint with staples*

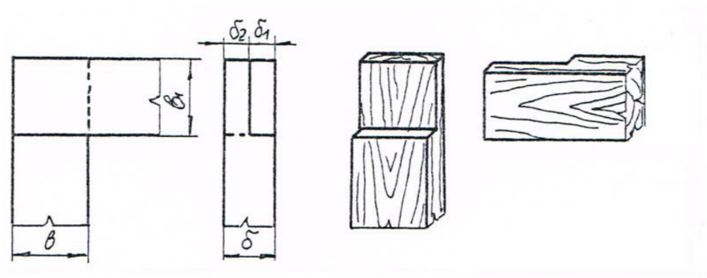
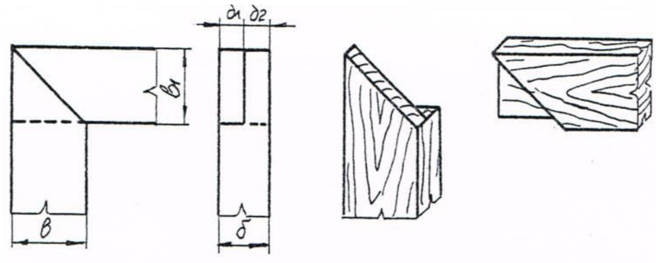
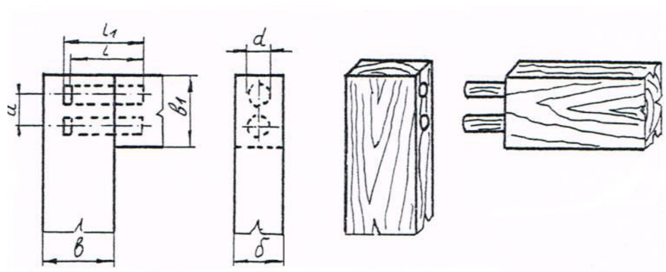
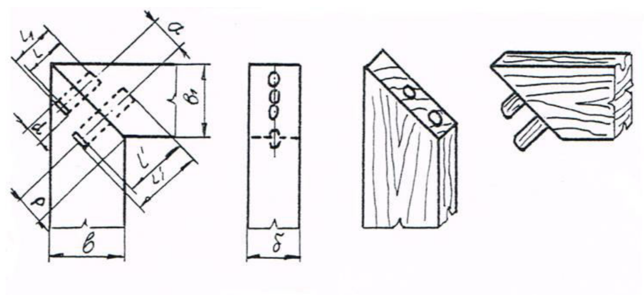
 5	$b = b_1 = 50$ mm $\delta = 30$ mm $\delta_1 = \delta_2 = 15$ mm
 6	$b = b_1 = 50$ mm $\delta = 30$ mm $\delta_1 = \delta_2 = 15$ mm
 7	$b = b_1 = 50$ mm $\delta = 30$ mm $L_1 = 34$ mm $L = 32$ mm $d = 12$ mm $a = 24$ mm
 8	$b = b_1 = 50$ mm $\delta = 30$ mm $L_1 = 32$ mm $L = 30$ mm $L^i = 34$ mm $L_1^i = 36$ mm $d = 12$ mm $a = 32$ mm $p = 6$ mm

Figure 2. *End corner lap and dowel joints: 5 – corner lap joint; 6 – corner miter lap joint; 7 – dowel joint; 8 – miter dowel joint*

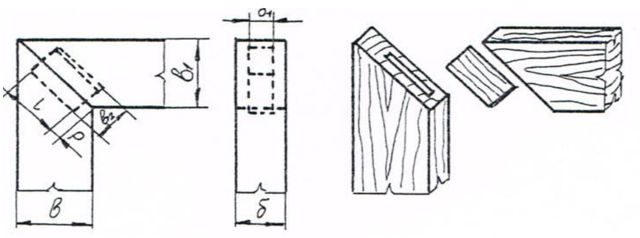
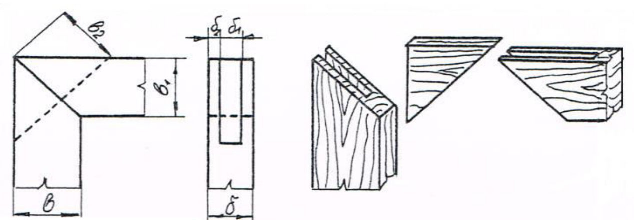
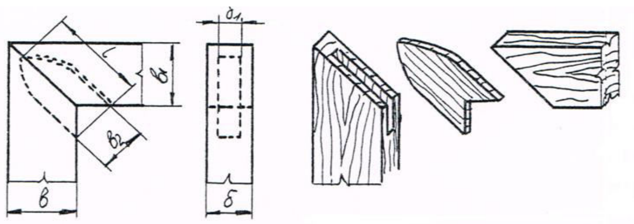
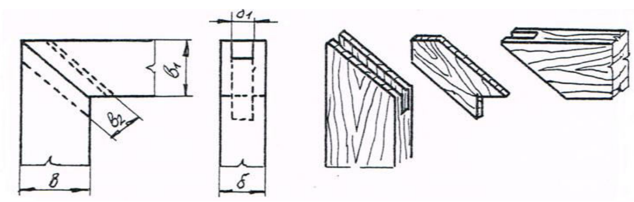
 9	$b = b_1 = 50$ mm $\delta = 30$ mm $\delta_1 = 12$ mm $b_2 = 25$ mm $p = 5$ mm $L = 40$ mm
 10	$b = b_1 = 50$ mm $\delta = 30$ mm $\delta_1 = 12$ mm $\delta_2 = 9$ mm $b_2 = 50$ mm
 11	$b = b_1 = 50$ mm $\delta = 30$ mm $\delta_1 = 12$ mm $L = 40$ mm $b_2 = 37{,}5$ mm
 12	$b = b_1 = 50$ mm $\delta = 30$ mm $\delta_1 = 12$ mm $b_2 = 25$ mm

***Figure 3**. End corner splined joints: 9 – blind splined miter joint; 10 – feather splined miter joint; 11 – half blind splined miter joint; 12 – splined miter joint*

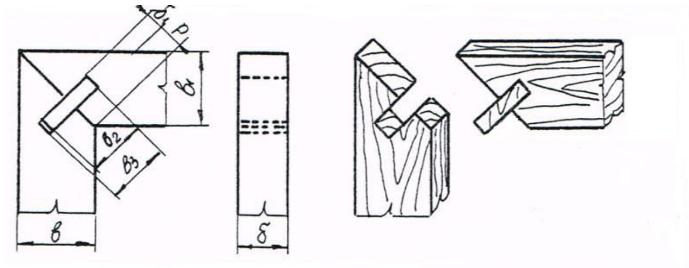
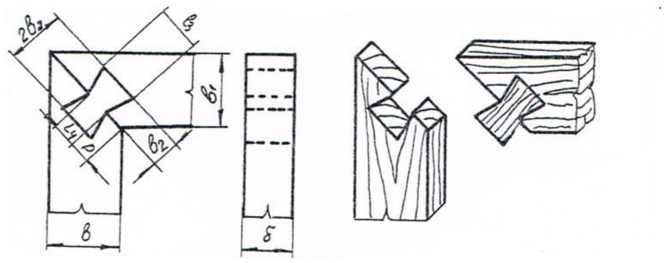
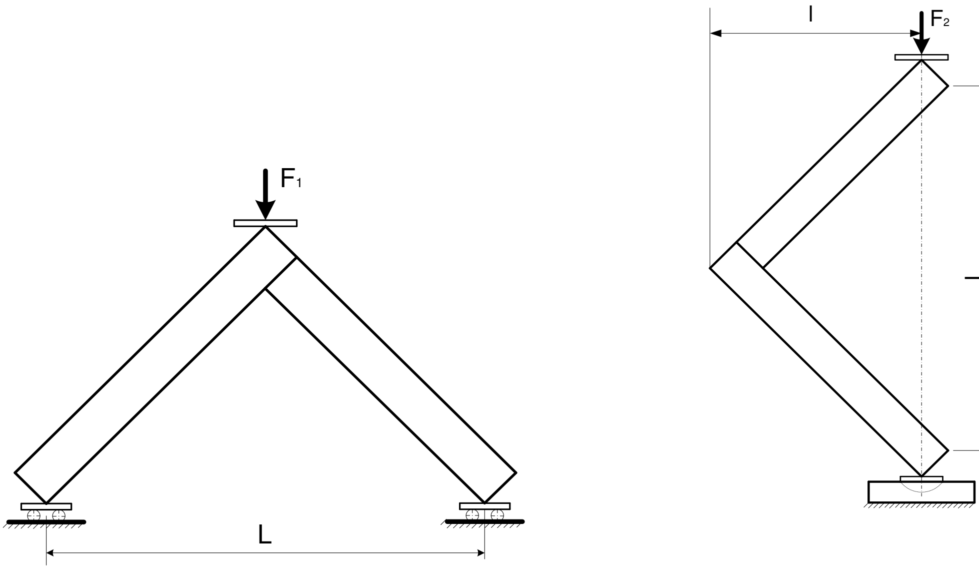
 13	$b = b_1 = 50$ mm $\delta = 30$ mm $\delta_1 = 9$ mm $b_2 = 40$ mm $b_3 = 42$ mm $p = 9$ mm
 14	$b = b_1 = 50$ mm $\delta = 30$ mm $b_2 = 15$ mm $L_3 = 30$ mm $L_4 = 16{,}5$ mm $P = 10$ mm

Figure 4. *End corner face splined joints: 13 – face splined miter joint;*
14 – face dovetail keyed miter joint



a **b**

Figure 5. *Scheme for testing of test samples of end corner joints:*
a – in arm opening bending load; b – in arm compression bending load

3. COMPARATIVE ANALYSIS OF THE EXPERIMENTAL RESULTS

The results from the research are given in Table 1, and the correlation between the destructive bending moments of the tested corner joints is presented graphically in the same order in Fig. 6.

Table 1. *Destructive bending moments at compression bending load of end corner joints of frame structural elements from solid spruce wood with a cross section 50 x 30 mm*

Type of joints	**Variation statistics parameters of destructive bending moment $M_{b,d}$**					
	$\bar{x}$, Nm	s, Nm	s_r, Nm	v, %	p, %	n, pc.
A. Arm opening bending load						
1. Corner but joint at right angle	65	6,9	1,8	10,6	2,7	15
2. Miter but joint	57	9,2	2,4	16,2	4,2	15
3. Corner but joint at right angle with staples	72	4,2	1,1	5,9	1,5	15
4. Miter but joint with staples	95	6,5	1,6	6,8	1,7	15
5. Corner lap joint	190	27,6	7,1	14,6	3,7	15
6. Corner miter lap joint	97	13,4	3,5	13,8	3,6	15
7. Dowel joint	111	17,7	4,6	9,6	4,1	15
8. Miter dowel joint	127	10,6	2,7	8,3	2,1	15
9. Blind splined miter joint	113	11,5	3,0	10,2	2,6	15
10. Feather splined miter joint	107	10,1	2,6	9,5	2,4	15
11. Half blind splined miter joint	149	12,0	3,1	8,0	2,0	15
12. Splined miter joint	104	12,5	3,2	12,0	3,1	15
13. Face splined joint	75	10,8	2,8	14,4	3,7	15
14. Face dovetail keyed miter joint	82	7,9	2,0	9,6	2,4	15
B. Arm compression bending load						
1. Corner but joint at right angle	111	9,4	2,4	8,4	2,2	15
2. Miter but joint	246	30,3	7,8	12,3	3,2	15
3. Corner but joint at right angle with staples	118	8,3	2,1	7,0	1,8	15
4. Miter but joint with staples	198	16,8	2,8	5,5	1,4	15
5. Corner lap joint	244	22,4	5,8	9,3	2,4	15
6. Corner miter lap joint	229	15,5	4,0	7,0	1,7	15
7. Dowel joint	185	7,0	1,8	6,3	1,0	15
8. Miter dowel joint	252	15,9	4,1	6,3	1,6	15
9. Blind splined miter joint	267	21,2	5,5	7,9	2,0	15
10. Feather splined miter joint	259	26,3	6,8	10,1	2,6	15
11. Half blind splined miter joint	238	26,9	6,9	11,3	2,9	15
12. Splined miter joint	226	28,2	7,3	12,4	3,2	15
13. Face splined joint	209	20,4	5,3	9,7	2,5	15
14. Face dovetail keyed miter joint	221	19,9	5,1	9,0	2,3	15

From the data in Table 1 and Fig. 6 it is obvious that the destructive bending moment depends upon the scheme on which the joint is loaded as well as the type of the joint. The destructive bending moments have a bigger value in joints' loading at compression bending test.

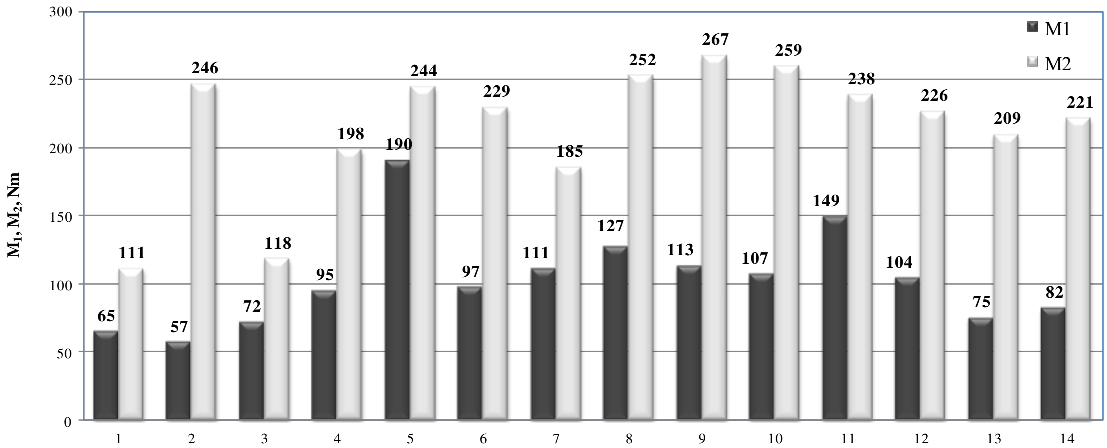


Figure 6. *Comparative data for the destructive bending moments of the tested end corner but joints and face splined joints of frame structural elements made of solid spruce wood with a cross section 50 x 30 mm: 1 to 14 as in Table 1*

The type of joints has a considerable influence on the destructive bending moment. This is defined by the type and dimensions of the joint elements and the area of the contacting surfaces of the joints, e.g. the surface of the glue line. The corner splined joints and dowel joints are destroyed at an appreciably higher bending moment than the rest tested types of joints. From but joints, miter but joints and those strengthened with staples have a higher destructive bending moment. From end corner lap joints, the joints at right angle have higher bending moment, due to their greater area of cohesion.

In both types of loading with a comparatively high bending moment, the destroyed joints are: the corner lap joint at right angle, the half blind splined miter joint, the miter dowel joint, the blind splined miter joint, the feather splined miter joint, the splined miter joint and the face dovetail keyed miter joint. In most of these joints the destruction of the samples is in the range of 30 to 100 % on the element outside the glue line.

4. CONCLUSIONS

The results from the research carried out give reasons to make the following more common conclusions:

1. The type of joint is a determining factor for its strength characteristic. It is defined by the type and dimensions of the joining elements and the area of the contact surfaces of the joints.
2. End corner splined joints and dowel joints are destroyed in a considerably bigger bending moment than the rest of the tested types of joints.
3. From but joints, miter joints and those strengthened by staples have higher destructive bending moment, and from the lap joints, it is those at right angle, because they have a greater cohesion area.
4. It is recommended that the results from the research should be taken into account in the strength design of sitting furniture, tables and beds.

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