

ANALYSIS OF THE STATIC EQUILIBRIUM EQUATION OF THE OVAL MORTISE AND TENON JOINT ACCORDING TO V.N. MIHAJLOV AND V.D. BEKHTEJAROV

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ABSTRACT

The study analyzes the deviations of the strength values of the oval tenon-mortise joint obtained experimentally in relation to the values obtained by calculating the torsional moment M_3 , based on the Mihajlov and Bekhtejarov formulas presented by Tkalec and Prekrat (2000). The strength was analyzed by measuring applied load and by calculating ultimate bending moment. In the paper, only the ratio of the tenon side dimensions $l:b$ was varied (l —tenon length; b —tenon height). By analyzing the experimental results, it can be seen that the bending strength and stiffness of the joint increase as the tenon dimensions increase. The results have shown that joint stiffness depends first of all on the tenon width, and the effects of the tenon length are less significant. In the case when the tenon width is greater than its length the Saint–Venant coefficient cannot be applied in the form in which it is given in the analyzed literature. By applying the Saint–Venant coefficient in that form, the calculation results significantly deviate from the results obtained experimentally. The torsional moment equation should be used in its modified form only when the usual dimensions of tenon and mortise are applied.

KEYWORDS: Bending moment, mortise, tenon, dimensions.

INTRODUCTION

The factors affecting the strength of joints used in wood processing industry have been analyzed many times. The analysis of factors affecting the strength of joints has been approached from many sides, from purely static analysis (Eckelman 1970, Schmidt and Daniels 1999, Gavronski 2006, Wilczyński and Warmbier 2003) to the application of finite element method (Wengang et al. 2018, Zhang and Hu 2021). Listing the most significant works would burden the list of literature, and would take this work in a completely different direction. The reason for this research reflects to Hajdarevic et al. (2020). The work is based on the static analysis of

the oval mortise and tenon joint according to Mihajlov and Bekhtjarov (Tkalec and Prekrat, 2000). Original paper of Mihajlov and Bekhtjarov was not published in electronic form. In the literary citations of the mentioned work, Hajdarevic et al. (2020), the primary, as well as alternative source of static analysis is not listed, so it turns out that the mathematical presentation of static analysis is the part of the author's intellectual work. However, the analyzed mathematical equations, in addition that they do not including all factors that affect the strength of joints, also contain an error that will be proven experimentally and mathematically in this work. Whether the error occurred due to the incorrect adoption of the formula from the original source, or due to misinterpretation, is not important at this point. In any case, the formulas presented in the first part of this paper are identical to those in the university textbook Tkalec and Prekrat (2000), or later used in the work Hajdarevic et al. (2020).

Below is given a static calculation taken from University's textbook Tkalec and Prekrat (2000), pp.222, and according to V.N. Mihajlov and V.D. Bekhtjarov, which will be analyzed in the paper. Analyzing the frame connection with the oval mortise nad tenon (Fig. 1), it can be seen that during loading there is a moment which acts on it (tries to pull the tenon out of the mortise) and the reaction of the support (reactive moments). The moment „ $M=L \times F$ “ tends to turn the tenon in the mortise. Internal forces occur on the upper edge of the tenon "m-n", the lower edge "k-p" and on the lower part of the shoulder of the tenon "r-t", as well as on the mutually glued joints (both mortise nad tenon) "m-k" and "n-p" with the gluing surface " $A = l \times h$ ".

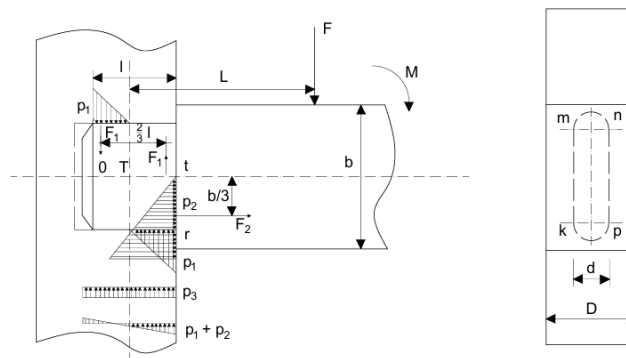


Fig. 1: Stress distribution within the joint with oval mortise and tenon (p_1 -highest pressure in the bearing (N/cm^2), p_2 -highest pressure in the support (N/cm^2), p_3 – specific resistance to the pressure of the lower side (N/cm^2), p_4 – pressure of the lower side of the tenon bearing due to reaction F (N/cm^2).)

In the case of static balance, i.e. in the case of a suitable joint strength, the moment M (moment of action) must be equal to the sum of reaction moments, whereby the Eq. 1 applies:

$$M = M_1 + M_2 + M_3 \quad (1)$$

where: M_1 – moment of force that resists bending on the sides of the tenon; M_2 – moment of force that resists bending at the tenon supports; M_3 – the moment of forces resisting the shearing of the glue from the sides of mortise and tenon.

The reactive moment M_1 at the upper “ $m-n$ ” and lower edge of the tenon “ $k-p$ ” can be represented in the form of the Eq. 2:

$$\begin{aligned} M_1 &= F_1 \cdot \frac{2}{3} l = p_1 \cdot \frac{d \cdot l}{4} \cdot \frac{2 \cdot l}{3} \\ M_1 &= p_1 \cdot \frac{l^2 \cdot d}{6} \end{aligned} \quad (2)$$

where: F_1 – resultant of the mortise bearing pressure (N), p_1 – maximum pressure in the bearing (N/cm^2), l – length of the tenon (cm), d – tenon thickness (cm).

The reactive moment M_2 which is resisting the bending at the tenon supports, is shown in the form of Eq. 3:

$$\begin{aligned} M_2 &= F_2 \cdot \frac{b}{3} = p_2 \cdot \frac{b}{4} \cdot (D-d) \cdot \frac{b}{3} \\ M_2 &= p_2 \cdot \frac{b^2}{12} (D-d) \end{aligned} \quad (3)$$

where: F_2 – resultant of the support pressure (N), b – tenon height (cm), p_2 – maximum pressure on the support (N/cm^2), D – thickness of the rail (cm), d – tenon thickness (cm).

The reactive moment of the glued surfaces of the joints (the surface to which the glue is applied) M_3 provides resistance in the form of a torsional moment around the axis of the mortise T. The greatest stress will be at points “ o ” and “ t ”. Each glued side of the tenon ($n = 2$) will provide a certain reaction moment (Eq. 4):

$$M_3 = n \cdot w_t \cdot \tau = 2 \cdot \alpha \cdot b \cdot l^2 \cdot \tau \quad (4)$$

where: w_t – torsional moment of resistance of the glued surface; α – coefficient that depends on the ratio of width and length of the tenon (b/l), $\alpha = 1/y$; y – Saint-Venant coefficient; τ – glue shear strength (N/cm^2).

The Saint-Venant coefficient (Eq. 5) depends on the ratio of the larger to the smaller side of the rectangle (the side of the tenon, b/l), and can be represented in the form:

$$\psi = 3 + \frac{2,6}{0,45 + \frac{b}{l}} \quad (5)$$

The strength of the glued joint mainly depends on the quality of the gluing and is directly proportional to the glued surface (Hitka et al. 2018) and the ratio of the dimensions of the sides of the tenon $l:b$. Assuming that the tenon connection is completely rigid (Smardzewski 2008, Wengang and Liu 2020, Imirizi et al. 2015), the moment M will initially be opposed only by

the torsional moment M_3 , so the system must fulfill the condition: $M = M_3$.

This paper will analyze the influence of the width and length of the tenon on the strength of the joint. The relationship between the influence of the length and width of the tenon on the strength of the joint has been analysed by various researchers, but with different results and opinions (Kilic et al. 2018, Kasal et al. 2016, Wilczyński and Warmbier 2003, Wengang and Liu 2020). In addition, the paper will analyze the deviations of the joint strength values obtained experimentally compared to the values obtained by calculating the torsional moment M_3 . Based on the results obtained by experiment, as well as on the basis of static calculations, the reliability of the formula, as well as its presentation, will be analyzed. For industrial usage, it is important which combination of the width and length of the oval mortise and tenon satisfies the exploitation strength of the chairs.

MATERIAL AND METHODS

In accordance with the aim of the work, 4 groups of samples (30 samples per group) were made with variations in the width and length of the tenon. All samples were made of beech wood (*Fagus sylvatica* L.). Based on research obtained by Skakić and Džinčić (2009), it was determined that the most common material for making chairs is beech. For this reason, beech was chosen as the basic material for making samples in this work. According to Šoškić et al. (1994), physical, mechanical and aesthetic properties make beech wood a suitable wood species for making chairs and furniture in general. The moisture of the samples was $8 \pm 2\%$.

The test was performed on the joints of the rear leg and the side rail of the chair's frames, which were connected using an oval mortise and tenon, with 10 mm thickness. The cross-sectional dimensions of the elements were 40 x 40 mm for the vertical element on which the oval mortise was cut, and 55 x 20 mm for the horizontal element on which the oval tenon was cut (Fig. 2). Tab. 1 shows the variations in the ratio of the width and length of the joint by sample groups.

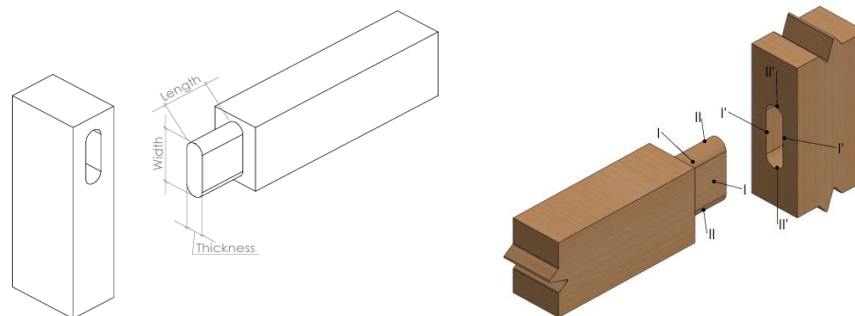


Fig. 2: Oval mortise and tenon. Fig. 3: Measurement points on the samples: I-I (thickness of the tenon); II-II (width of the tenon); I'-I' (width of the mortise); II'-II' (height of the mortise).

Tab. 1: Variations in the ratio of the width and length of the joint by groups of the samples.

Group	Tenon length (mm)	Tenon width (mm)	Gluing surface (mm ²)
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1	20	50	2228
2	23	45	2332
3	25	40	2285
4	27	35	2197,8

The width of the tenon of the fourth group is 30% smaller than the width of the tenon of the first group. Also compared to the tenon of the first group the width of the tenon of the second group is 20% smaller, and tenon of the third group by 9%. The length of the tenons of the fourth group is 26% larger than the width of the tenons of the first group, while the length of the tenons of the second group is 15% smaller, and of the third group by 8% both compared to the tenon of the fourth group. All deviations are observed in relation to the largest values of the joints. Tab. 2 shows the percentage deviations of the gluing surfaces between the groups.

Tab. 2: Variations in the gluing surfaces between the groups.

Group	1	2	3	4
1	x	4,5 %	2,5 %	1,4 %
2	4,5 %	x	2 %	6,1 %
3	2,5 %	2 %	x	3,9 %
4	1,4 %	6,1 %	3,9 %	x

From Tab. 2 it can be seen that with variation in the dimensions of the joints, brings differences in the gluing area within the limits from 1.4 to 6.1%. The joints, both mortise and tenons, were manufactured on the BALESTRINI VIVA numerical control center for the production of joints. During the production of the joints, the machining accuracy and the type of fit were controlled according to DIN68101. The control of the machining accuracy of the joints and the applied type of fit was carried out with a digital caliper, with an accuracy of 0,01 mm. The measuring points on the samples are shown in Fig. 3. On this occasion, the accuracy class TD10 (according to DIN 68101) in which the machines for the production of connection elements operate was established. In terms of height, as well as in terms of the thickness of the joint, a fit with an overlap was achieved that corresponds to the type of fit K/p (DIN 68101).

According to the results of the research by Vassiliou et al. (2016), glued joints using PVAc glue provide higher joint strength compared to those glued using PU glue. According to the results presented by Záborský et al. (2017), the choice of the type of glue has no effect on the strength of the joint if the base material is spruce, however, when using beech, PVAc glues provide significantly higher joint strength than when using PU glues. Based on the mentioned papers, the gluing of the joints was carried out using PVA-c glue (KLEIBERIT stress groups D2 according to DIN EN 204). The glue was applied to the joints on both sides manually. The spread of the applied glue was controlled (visual check that glue was spread both on mortise and tenon). The amount of glue applied was not controlled. The elements were joined on a horizontal frame press. Before testing, the samples were conditioned for 30 days at a room temperature of $23\pm 2^{\circ}\text{C}$ at a relative air humidity of $50\pm 5\%$. After conditioning, the moisture of the samples was checked, which was $9\pm 2\%$.

The samples were loaded in bending, on a universal tearing machine of the TIRA test SCal brand, type WT5UT. The clamp was attached to the machine base with screws (Fig. 4). The force acted at a distance of 180 mm from the vertical beam (arm $L=180$ mm), which on average corresponds to half the length of the chair side rail. This selection of the place of action of the force brings the experiment closer to real situations.

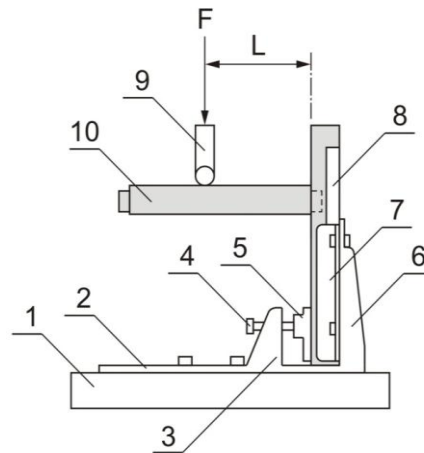


Fig. 4: Method of loading the specimens: 1. Testing machine base; 2. Clamp base; 3. Welded plate with side reinforcements; 4. Screw for clamping the sample; 5. Clamping plate; 6. Welded plate with side reinforcements; 7. Movable "L" clamping profile; 8. Metal stiffener; 9. Piston; 10. Sample; F -force; L -arm.

RESULTS AND DISCUSSION

The obtained results will be presented in two parts. In the first part, the values obtained experimentally will be analyzed, while in the second part, the applicability of the formula for calculating the moment M_3 will be presented. The experimental results based on the analysis of bending moments are presented in Tab. 3. The table shows the values of descriptive statistics for the bending moments for all four groups of samples.

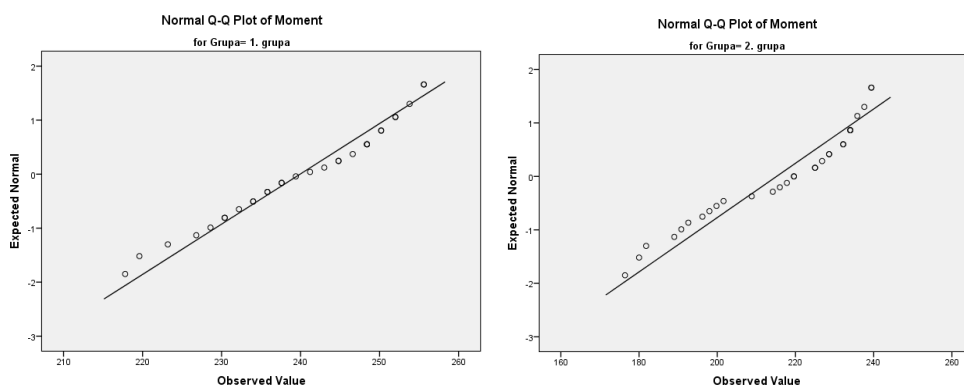
Tab. 3: Descriptive statistics values for bending moment (Nm).

Descriptives		Group 1		Group 2		Group 3		Group 4	
		Statistic	Std. error	Statistic	Std. error	Statistic	Std. error	Statistic	Std. error
Mean		239,9400	1,96072	215,1600	3,59455	166,1400	1,94163	138,7800	3,50709
95% Confidence interval for mean	Lower bound	207,8083		207,8083		162,1689		131,6072	
	Upper bound	222,5117		222,5117		170,1111		145,9528	
5% Trimmed mean		240,2667		215,9000		165,5667		138,6667	
Median		240,3000		219,6000		165,6000		135,9000	
Variance		115,333		387,623		113,098		368,991	
Std. deviation		10,73931		19,68815		10,63477		19,20915	
Minimum		217,80		176,40		149,40		109,80	
Maximum		255,60		239,40		198,00		171,00	

Range	37,80		63,00		48,60		61,20	
Interquartile range	17,10		35,10		13,05		35,55	
Skewness	-0,361	0,427	-0,551	0,427	0,800	0,427	0,173	0,427
Kurtosis	-0,787	0,833	-1,026	0,833	1,335	0,833	-1,386	0,833

The values registered during the experiment corresponded to the force value reached after the adhesive bond failed. In general, the analysis of the obtained results shows that changing the dimensions of the width and length of the tenon leads to a change in the values of the average bending moment. Samples of group 1 ($B=50$ mm; $L=20$ mm) showed the highest average values of bending moment.

The average value of the bending moment of group 1 was 239.9 Nm. The joints of group 2 reached an average value of bending moment lower by 11.3% compared to the samples from group 1. The joints of group 3 showed an even lower average value of bending moment compared to the previous two groups. Compared to group 1, the samples of group 3 showed a lower value by 30.7%, and by 22.7% compared to the samples of group 2. Compared to all 3 previous groups, the samples of group 4, where the width of the plug was 35 mm, and the length of the plug had a value of 27 mm, showed a lower average value of bending moment of only 138.7 Nm. Compared to the samples of group 1, the samples of group 4 showed a lower average value by as much as 42.2%. If we look at the data presented in Tab. 2, where we put in comparison the gluing area between the groups, it can be seen that the resulting variations in the values of the breaking moments are not caused by the difference in the gluing area. From Tab. 2 it can be seen that with the variation of the dimensions of the joints, the gluing area varies in the range of 1.4 to 6.1%. Based on the conclusions presented by Hitka et al. (2018), the strength of the glued joints mainly depends on the quality of the gluing, and is proportional to the gluing area, and the ratio of the dimensions of the sides of the tenon $L:B$. Since in the framework of this study the variation of the gluing area ranges in a relatively small range (1.4 to 6.1%) in relation to the variation of the average values of the bending moments, we can agree with the second part of the statement made by Hitka et al. (2018), which is that the strength of the glued joints is directly proportional to the ratio of the dimensions of the sides of the tenon $L:B$. If we analyse the normality test, we will see that the samples of all 4 groups obey the normal frequency distribution (Fig. 5).



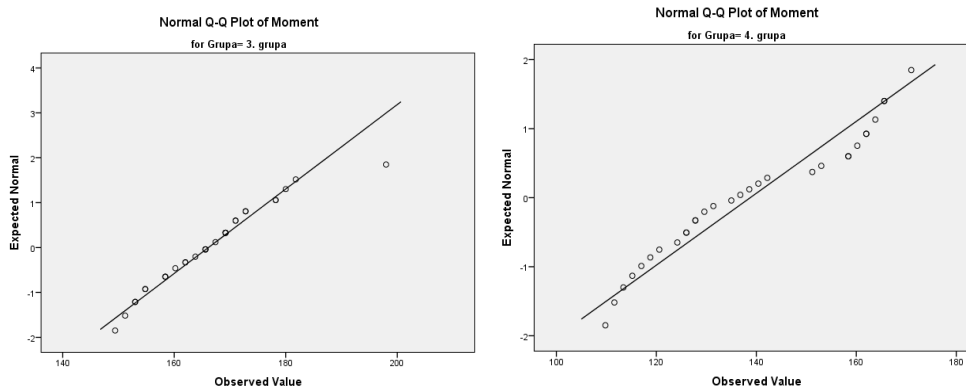


Fig. 5: Normal Q-Q plot of moment for all monitored groups of samples.

If we perform multiple comparisons test and significance analysis for the obtained values (Tab. 4), we will see that there is a difference between the groups of samples, but that the registered differences are significant (the mean difference is significant at the 0.05 level).

Tab. 4: Multiple comparisons values and significance analysis.

Groups		Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Group 1	2. group	24,78000	4,05184	0,000	14,2182	35,3418
	3. group	73,80000	4,05184	0,000	63,2382	84,3618
	4. group	101,16000	4,05184	0,000	90,5982	111,7218
Group 2	1. group	-24,78000	4,05184	0,000	-35,3418	-14,2182
	3. group	49,02000	4,05184	0,000	38,4582	59,5818
	4. group	76,38000	4,05184	0,000	65,8182	86,9418
Group 3	1. group	-73,80000	4,05184	0,000	-84,3618	-63,2382
	2. group	-49,02000	4,05184	0,000	-59,5818	-38,4582
	4. group	27,36000	4,05184	0,000	16,7982	37,9218
Group 4	1. group	-101,16000	4,05184	0,000	-111,7218	-90,5982
	2. group	-76,38000	4,05184	0,000	-86,9418	-65,8182
	3. group	-27,36000	4,05184	0,000	-37,9218	-16,7982

If we compare the results obtained in this paper with the values obtained by other authors, who also analyzed the influence of the ratio of the length and width of the tenon on the strength of the joint, we can see the following.

Kilic et al. (2018) analyzed the influence of the dimensions of the tenon on the strength of the wooden chair structure depending on the applied loading method. Among other factors, the gluing surface was varied within the work. The ratio of the length and width of the tenons was varied between the groups of samples. According to Hitka et al. (2018) the ratio of the dimensions of the sides of the dowel L:B. The test was carried out on Scots pine (*Pinus sylvestris* L.), with a tenon thickness of 7 mm. The ratio of the dimensions of the sides of the tenon L:B was varied in the range from 30 to 50mm in all combinations. Among other conclusions, the work authors presented the fact that with an increase in the gluing surface, the strength of the joint also increases. Chair frames constructed with 50 × 50 mm tenons had

the highest values of front to back loading performance, whereas the chair frames constructed with 30×30 mm tenons had the lowest front to back loading performance. The obtained values are not fully applicable, considering that the samples in this work were made from a type of wood that has a significantly lower volumetric mass than the beech from which the test samples presented in this work were made, which was also confirmed in the work of Derikvand et al. (2014).

In their work Kasal et al. (2016) reports the moment resistance, stiffness and numerical analysis of various sizes of round mortise and tenon joints. Joints were manufactured using nine combinations (three widths and three tenon lengths) of widths and lengths, made in beech wood. At the end they concluded that the joints became stronger and stiffer as either tenon width or length increased. Tenon length had more significant influence on moment resistance, while tenon width had a more significant effect on the stiffness.

Wilczyński and Warmbier (2003) investigated the influence of joint dimensions on the bending strength and stiffness of tenon joints. Joints were manufactured using 32 test combinations (four thicknesses, five tenon lengths, and also five tenon widths). All samples were made in beech wood with adequate ratio of moisture content, type of fit and machining accuracy. Obtained values are pretty similar to ones showed in this research. Bending strength obtained in this research is approximately around 240 Nm, and in the paper Wilczyński and Warmbier (2003), value of bending strength is around 220 Nm (tenon width 50mm and length 18mm). Wilczyński and Warmbier (2003) also concluded that the bending strength and stiffness of the joint increase as the tenon dimensions increase, and that the joint stiffness depends first of all on the tenon width, the effects of the tenon length and thickness are less significant.

Derikvand et al. (2014) analyzed the effects of bottom shoulder width, tenon depth of embedment, tenon width, and tenon wood species on the bending moment capacities of T-shaped mortise and loose-tenon furniture joints constructed with polyvinyl acetate adhesive. With all mentioned factors, the authors made variations in 20 sample groups. Among other conclusions, the results indicated that bending moment capacity was directly related to depth of embedment of the tenons and strongly related to shoulder width, whereas tenon width had a lesser effect.

All mentioned papers where the authors dealt with the influence of relations of the dimensions of the sides of the tenon on bending moment capacity, have in common conclusion that the greatest effect on the joint strength has the tenon length, the influence of the tenon width is less significant. This statement is absolutely true, but in the construction of solid wood furniture, vertical element, which usually takes over all loads from all other (horizontal) elements, has rather smaller dimensions of cross section. Within the chairs and stands of chest and drawers it reaches maximum dimensions of 50×50 mm (dining tables usually are constructed with knock down metal hardware, and don't have glued connection between legs and rails). In such, rather small cross section two plugs are facing each other, and there is not much space for tenons larger (in length) than 30 mm. From this stand we will proceed in further analysis of the mathematical equation for the calculation of the torsional moment M_3 (Eq. 4).

According to the established testing methodology, the applicability of the Saint-Venant equation for calculating the torsional moment M_3 (Eq. 4) will be analyzed. Based on

the verification of the applicability of the mathematical formula, as well as the results obtained experimentally, the influence of the width and length of the oval tenon on the strength of the joint will be determined. According to the calculation presented in the paper Hajdarević et al. (2020) in the formula for calculating the torsional moment M_3 (Eq. 4), the length of the plug was squared. For the purposes of the calculation, it will be assumed that: n – number of glued sides (number of sides on which the adhesive was applied), $n = 2$ pcs; t - shear strength of the adhesive; $t_{\min}^{\text{PVAc}} = 10 \text{ N/mm}^2$, according to Derikvand and Pangh (2016), and KLEIBERIT production catalogue stress groups D2 according to SRPS EN 204:2017. The results of the applicability of the form of the Saint-Venant equation for the calculation of the torsional moment M_3 are shown in Tab. 5. The modified forms of equation for calculating the torsional moment M_3 (with the variation of the Saint-Venant equation) are presented in Eqs. 6 and 7.

Tab. 5: The results of formula variation for calculating the torsional moment M_3 .

Group no.	l (mm)	b (mm)	n	t (N/mm ²)	a	y	M_3^1 (Nm)	M_3^2 (Nm)
1	20	50	2	10	0,257642	3,881356	103,0568	257,6419
2	23	45			0,245074	4,080397	116,6798	228,2866
3	25	40			0,234286	4,268293	117,1429	187,4286
4	27	35			0,222773	4,488865	113,6813	147,3646

$$\text{The 1}^{\text{st}} \text{ form of the equation: } M_3^1 = n \cdot t \cdot b \cdot l^2 \cdot a \quad (6)$$

$$\text{The 2}^{\text{nd}} \text{ form of the equation: } M_3^2 = n \cdot t \cdot b^2 \cdot l \cdot a \quad (7)$$

where: M_3 – the moment of forces resisting the shearing of the glue from the sides of mortise and tenon, a - coefficient that depends on the ratio of width and length of the tenon (b/l); $a = 1/y$; y - Saint-Venant coefficient; t - glue shear strength (N/cm^2), l – length of the tenon (cm), b – tenon height (cm), n - glued side of the tenon ($n = 2$).

Based on the values obtained by calculation according to different versions of the formula for calculating the torsional moment M_3 , the following can be observed. If we compare the values obtained experimentally (Tab. 3) with the values calculated based on the version of the formula M_3^1 (where the length of the tenon has an exponential effect on the torsional moment), it can be seen that there are significant deviations between the observed values. In addition, the values obtained by calculation are not arranged in a logical descending or ascending sequence. The highest value of torsional moment M_3 obtained by calculation was shown by the samples of 3rd group (117.1Nm), which completely deviates from the average values obtained experimentally. Looking at the experimental data, it can be seen that the highest average value of bending moment was achieved by group 1 (239.9Nm). In addition, this form of the formula would not be used in more complex static calculations, where we would have to determine the dimension of the joints based on the loading. With this form of the formula and the loads defined in EN12521, the dimensions of the oval mortise and tenon would be many times larger than those currently used in furniture industry.

If we compare the values obtained experimentally (Tab. 3) with the values calculated based

on the version of the M_3^2 formula (where the width of the tenon has an exponential effect on the torsional moment), it can be seen that there are significantly smaller deviations. The differences range from 5.5 to 11.1%, respectively. For example, the highest average value of the bending moment was achieved within group 1 (239.9Nm), while the value obtained by calculation according to the second formula was 257.6Nm. If we compare the values obtained experimentally with the values obtained by calculation, it can be seen that the second version of the formula, where the width of the tenon has an exponential effect on the torsional moment, reflects the real state of affairs much more realistically.

This result is consistent with the statement that the results indicated that the reactive moment obtained by the analytical calculation does not represent the value of the bending moment capacities of the joint, presented by Hajdarevic et al. (2020). Based on the stated above, it can be concluded that the formula for calculating the reactive moment M_3 obtained by the analytical calculation should be used in a modified form when the width of the tenon has an exponential effect on the torsional moment.

CONSLUSIONS

The performed investigations revealed the influence of the width and length of the oval mortise and tenon on the strength of a glued joint. Beside mentioned, scope of this paper was also analysis of the deviations of the joint strength values obtained experimentally in relation to the values obtained by calculating the torsional moment M_3 based on the formulas of Mihailov and Bekhtjarov, which were later presented in university textbooks and scientific papers. In the paper, only the ratio of the dimensions of the tenon sides $l:b$ was varied. The ratio of the dimensions was chosen in such a way as to least disturb the bonding surface, since the strength of the glued joint is directly proportional to the glued surface. All other factors, that affect the strength of the glued joint, were carefully selected and kept constant during the experimental part. In addition to the above mentioned, it is important for practice which combination of the width and length of the oval mortise and tenon satisfies the exploitation demands of the chairs.

By analyzing the results obtained experimentally, it can be seen that the bending strength and stiffness of the joint increase as the tenon dimensions increase. The results have shown that joint stiffness depends first of all on the tenon width, and the effects of the tenon length are less significant. In the case where the width of the tenon is greater than its length ($b > l$), the Saint – Venant coefficient cannot be applied in the form given in the analyzed literature. Applying the Saint – Venant coefficient in that form, the results obtained by values calculations significantly deviate from the results obtained experimentally. The differences in the values of bending moments obtained experimentally compared to the values obtained by calculation method, according to the second formula where the width of the tenon has an exponential effect on the torsional moment, range from 5.5 to 11.1%, respectively, while compared to the first formula (where the length of the tenon has an exponential effect on the torsional moment), these deviations are significantly larger and range from 17 to 56.8%. From the above stated, it can be

concluded that the equation for calculating the torsional moment should be used in a modified form only when the usual dimensions of mortise and tenon are applied.

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