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EXAMINATION OF PROPER SPAN/DEPTH RATIO RANGE IN MEASURING THE BENDING STRENGTH OF WOOD BASED ON THE ELEMENTARY BENDING THEORY

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ABSTRACT

In this paper, the method of measuring the bending properties of wood using spruce (Picea abies Karsten) by elementary bending theory has been examined. Three-point bending tests (EN 310) were conducted under various span/depth (L/h) ratios. Load-deflection diagram was simultaneously measured. Modulus of rapture MOR, bending strength in proportional limits SPL and Modulus of elasticity in bending MOE, were conducted under 3.4 to 30 span/depth ratios. The results suggest that for testing solid wood spruce the ratio should be L/h ≥ 20. This principle can be used as an aid to engineering purposes, particularly in controlling the production process.

Key words: bending strength, bending strength at proportional limit, modulus of elasticity in bending, span/depth *L/h*, solid wood spruce

1. BACKGRAUND

Application of wood and composite materials based on wood are treated as unloaded elements in most of the wood industry. In accordance with that and with the European standard EN 310 [2], bending strength and modulus of elasticity in bending are tested by method of three point.The adopted method for flexural strength test ignores the effect of transverse forces or shear stresses caused by loading and reduces the calculation of bending strength of the Euler-Bernoulli theory to pure bending. Many factors influence the mechanical properties of wood, as non-homogeneous and orthotropic material: moisture contents, slope of grain, temperature, annual ring width, density, etc. Given the adopted method of testing, bending depends on the specimen, span/depth ratio, load, loading speed etc.

Authors [6] observed different values of span/depth ratio for the different standards. The span/depth ratio is defined as 14 by the American Society for Testing and Materials (ASTM) [1] as well as by Japanese Industrial Standards (JIS) [6]. Values from 12 to 16 are defined by ISO standard (International Organization for Standardization) [3]. Value, span/depth ratio, 14 is defined by JUS standard (Yugoslavian standard) [4] and value 20 is defined by European standard (EN) [2] both of which are used in Bosnia and Herzegovina. According to these standards, the bending properties are obtained based on elementary bending theory and the span/depth ratio ranges might be determined so as to restrict the influence of deflection caused by the shearing force.

The aim of this paper is to experimentally obtain the behavior of bending strength and modulus of elasticity of solid wood spruce from the changing relationship between the height of specimen, and the range of supports.
Wood as a natural material will have a different resistance to external forces depending on of the span/depth ratio. By decreasing of the span/depth ratio, the maximum breaking force of specimens is increased, and with it the resistance activity of spaceman perpendicular to the grain.The compressive strength of spruce perpendicular to the grain is small, the hardness of spruce wood perpendicular to the grain is also small, which leads to deformation of the specimen in the zone affected by the load and supports trials in cases of small distances of supports. This disturbs the relationship between the geometric and the neutral axis of the specimen, which further affects the results of flexural strength under the given method.
The ratios *L/h* are interesting due to several aspects. Using shorter specimens we need to determine the feasibility of using the obtained results. Long probes are not practical for use in FPC (Factory Production Control) especially in small and medium enterprises. Having in mind theglobalization of markets and adopting the European standards, which are one of the goals of quality assurance and service under the supervision, this study is interesting for the wood industry and for the use the results obtained by the tested probes of different sizes with the aim of keeping the manufacturing process under control.

2. MATERIAL AND METHOD

The paper is based on experimental data of the small specimens of the clear solid wood spruce. Spruce (*Picea abies Karst*) measuring 22x22 mm, with the slope of annual rings approximately 45^o compared to the force, was used as the material for testing. Density of spruce specimens used in the experiment was 4.43 g/cm^3, standard deviation 0.388 g/cm^3 and coefficient of variation of 8.7 % and moisture content of wood was 11.3 % with a standard deviation of 0.74 % and 6.53 % coefficient of variation. Time of loading test for the whole set was 64.6 s, standard deviation 12.3 s and coefficient of variation 19.1 %. The test method is based on EN 310. Bending strength test was performed on test machine of manufacturer “Zwick” with possibility of load and deflection registration. Accuracy of registration of load is 5 N and deflection 0.1 mm. The thickness or height of the specimens was constant while the length of specimens is changed. Interval ratio of height and length (span/depth) *L/h* of specimens ranged from 3.4 to 30. Load-deflection relations were registered for each test. In this way, calculation of the bending strength in the zone of proportionality (*SPL*) and the maximum bending strength or modulus of rapture (*MO*R) was feasible. Modulus of elasticity in bending (*MOE*) was also calculated on the basis of data obtained from the diagram. This method of testing and calculating the load test is valid for “three-point bending test” in proportion to the area of stress and strain. However, in practice, bending strength is approximated by the maximum strength *MOR*. Because of these reasons, the impact of *L/h* at bending strength in the zone of proportionality was examined.
Comparing the results of the load-deflection the deformation of specimens (as a result of shear stress) as a function of the range of *L/h* has been shown. In other words, this way we wanted to show the influence of shear stress on the function of the range of the supports, or when the shear stresses are negligible.

3. RESULTS AND DISCUSSION

Diagrams show results of testing of bending strength and modulus of elasticity in bending specimens of spruce depending on the ratio of span/depth *L/h*.
Figure 1 shows *MOR* and *SPL* corresponding to the span/depth ratio *L/h*. Figure 2 shows *MOR* corresponding to the span/depth ratio *L/h* of specimens from Baumann (1922). Figure 1 and Figure 2 shows how the bending strength decreases with decreasing ratio of span *L* to depth of the specimens *h*. Only for values $L/h \geq 20$ the bending strength becomes approximately constant.

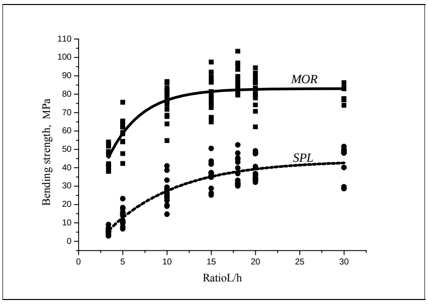

Figure 1. Dependence of bending strength and the ratio of span L to height h of the specimens.

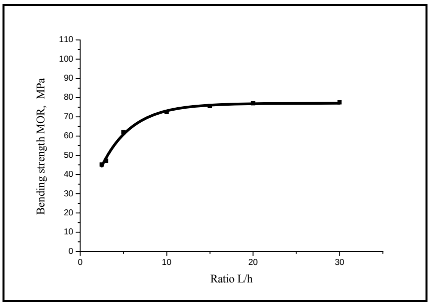

Figure 2. Dependence of bending strength and the ratio of span L to height h of the specimens. From BAUMANN(1922)[5]

In the small span/depth ratio range, the nonlinear behavior caused by contact of loading head produces the extra deformation (dent) on specimens. This deformation is caused by larger loading, which is shown in figure 4. Figure 4 shows rapture load F_{MAX}, load at proportional limit F_{SPL} and deflection f_{MAX}, f_{SPL} corresponding to the span/depth ratio *L/h*. The model was used for the approximation of experimental data given in Figures 1, 2 and 3 shown relation *(1)*. Using nonlinear regression corresponding parameters in model are as follows:

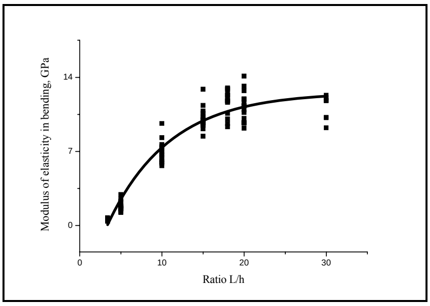

Figure 3. Dependence of modulus of elasticity MOE and the ratio of span L to height h of the specimens.

$$y = a - b \cdot c^x \qquad ... (1)$$

$$MOR = 83{,}1 - 93.9 \cdot 0.76^x \quad MPa \qquad ... (2)$$

$$MOR_{Baumann} = 77{,}1 - 66.3 \cdot 0.75^x \quad MPa \qquad ...(3)$$

$$SPL = 43{,}9 - 58.5 \cdot 0.88^x \quad MPa \qquad ...(4)$$

$$MOE = 12{,}6 - 19.6 \cdot 0{,}88^x \quad GPa \qquad ...(5)$$

Where is:

y - MOR, SPL or MOE

x - L/h

a,b i c – parameters of regression

Software-Origin 8 (exponential fit - asymptotic1) was used.

Figure 3 shows *MOE* corresponding to the span/depth ratio *L/h*. Values of *MOE* decrease with decreasing of ratio of span *L* to depth of the specimens *h* and for values *L/h* ≥ 20 the modulus of elasticity becomes approximately constant. According to Kollman [5] modulus of elasticity obtained by the „method of three-point" of *L/h* values of 14, 15 and 20 was lower by about 9.5 %, 8.8 % and 4.8 % respectively. For this experiment, these values are lower for *L/h* 15 and 20, *MOR* 1.8 %, 0.43 %, *SPL* 17.2 %, 8.6 % and the *MOE* 18.9 %, 8.3 %, respectively, (Figure 5).

For engineering purposes the values of *L/h* ≥ 20 are problematic. In factories of wood industry there is less clear solid wood with larger dimensions, in particular which are intended for quality control. Small wooden parts are joined together (usually a finger jointing) and properties of this material and other wood species should be examined.

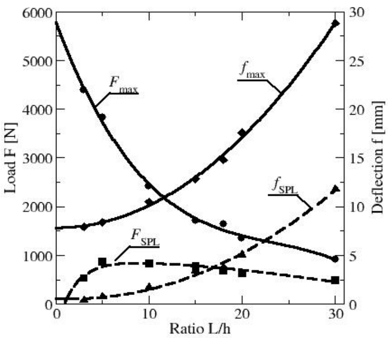

Figure 4. Dependence of load-deflection at ratio span/depth L/h of specimens

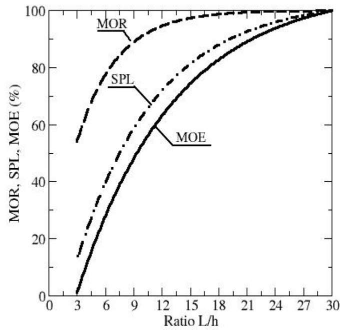

Figure 5. The behavior of MOR, SPL and MOE, compared to the maximum value, according to equitation's (2),(4) and (5)

4. CONCLUSION

To test the modulus of rapture, bending strength at the proportional limit and modulus of elasticity in bending the recommended values are *L/h* ≥ 20. It was confirmed that the value of the span/depth ratio *L/h = 20*, given in the European norm EN 310, for testing the modulus of rapture but not for the modulus of elasticity in bending.

The influence of the span/depth ratio on modulus of rapture was less significant than that on modulus of elasticity in bending.The influence of span/depth ratio on the loading at proportional limit was not significant.

The point of this paper is the need of using correction results for the monitored properties of the span/depth ratio *L/h* < 20 and especially for the bending strength at proportional limit and modulus of elasticity in bending. Further researches are recommended for determination of these correction factors. Influence of span/depth ratio on flexural strength for other wood species should be examined.

5. REFERENCES

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