STATIC BENDING STRENGTH PERFORMANCES OF LAMINATED VENEER LUMBER (LVL)

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ABSTRACT
This paper presents results on the static bending properties, modulus of rapture (MOR) and bending strength at proportional limit (SPL) of small specimens of Laminated Veneer Lumber (LVL). LVL is a composite of wood veneers with wood fibres primarily oriented along the length of grain direction of face veneers. In our case, LVL consisted of 17 and 29 plies of veneers Fir (Abies Alba Mill) with a thickness 3.2 mm. Small specimens were tested flatwise and edgewise in the plane of bending forces. Results of immediate temperatures influence on LVL bending strength indicated that linear temperature relationship can be used for MOR and SPL. Obtained results show that values are decreased with temperature increase. Analysis and results are given for a temperature range of -28 ^oC to 63 ^oC. Mean value obtained at the temperature of 60 ^oC are inside range of values for MOR of fir solid wood given in the literature for 20 ^oC and the moisture contents of 12-15%. Mean values of SPL amount 65.3% (edgewise) or 57.7% (flatwise) of maximum bending strength MOR, with coefficient of variations of 14.1 % and 17.9 % respectively, for observed temperature interval. In this work we observed LVL as a possible substitution for a solid wood in the production of joinery (windows). For this reason moisture content of wood ranged in the interval that is tolerated in the production of joinery (windows).
Keywords: LVL, bending strength (MOR), Bending strength at proportional limit (SPL), temperature, joinery (windows).

1. INTRODUCTION
Laminated veneer lumber (LVL) as a relatively new composite material to the market is a result of the needs of the construction industry (USA, Canada, Australia) for a wooden roof (column) in length, which are limited to existing forest resources. In addition to this basic purpose, range of use of this material expands and seeks to replace wood.
LVL is a composite material made from sheets cut from rotary-peeled log veneers. The veneers sheets are graded and scarf jointed (butt, crushed lap) after the lager defects have been cut out. They are then dried, coated with glue and assembled into desired thicknesses, similar to plywood production but with the grain of all the veneers running in the same direction and with the joints on the individual veneers staggered vertically. They are then pressed and cured. This construction gives a product with

dimensional properties similar to high-grade solid wood but it can be produced from lower-grade, smaller, and therefore chipper logs.

The goal of substitution of solid wood with LVL being an important one, we are primarly interested in testing the specific conditions of exploitation. An example of the operational conditions is the joinery (windows), which can have temperatures in the outer parts of wooden elements at depth of 16 mm up to 60^{o}C.

Research on the influence of temperature on the physical mechanical properties of wood started in the 1940s. Kollman-Cote [4] cited research Thunell and Sulzberger. Their research can be summarized in the conclusion that the bending strength of wood decreases with increasing temperature and moisture contents and decreasing density.

Gerhard [2] also gives a bibliographical review of research in this field. Tests were performed in the temperature interval from -20 ^{o}C to 60 ^{o}C with a moisture content of 6% to 20%.

Akiyoshi [1] gives the dependence modules of elasticity due to bending strength and bending strengths of spruce in the interval -180 ^{o}C to 60 ^{o}C.

David W. Green [3] examined the immediate effects of temperature on the modulus of elasticity in bending and bending strength of commercial wood in the interval -26 ^{o}C to 66 ^{o}C including LVL, and LSL lumber .

Material used for testing is a clear wood (without defects). In the case of LVL test it is examined by the principle plywood in the full thickness.

Sorn [5] has studied the effect of temperature on the physical mechanical properties of LVL, with the effect of unsteady temperature [6] while this paper deals with an additional impact of lower temperatures and stationary effect of temperature. Testing samples were cut from elements LVL, so obviously violating LVL structure.

LVL is a material in which the defects have been deployed by the cross-section and surface plates, and the goal of work is to establish the effect of temperature on the bending strength. We expect the similar dependence of the impact of temperature on the LVL as well as the clear wood, but we are interested in the value of bending strength with respect to the conditions that are required by joinery. The results of bending strengths will be shown as a maximum values (MOR), and as bending strengths at proportional limit (SPL), in the temperatures interval that is possible in the exploitation of windows. LVL moisture content was within the limit allowed in the production of windows 10 – 15 %.

2. MATERIAL AND METHOD

As part of the research a panel was produced on the principle of the production of LVL. Samples LVL panels are made in industrial conditions. The material was fir veneer thickness of 3.2 mm made of logs, length 2.2 m Class III, diameter 40 cm. Melamine formaldehyde adhesive was used for the production of LVL.

Construction of LVL panel is simulated so that the veneer of 2.2 m length were cut to lengths of 300 to 800 mm and 3 to 4 pieces of these form length of 2100 mm, while respecting the rule that places of the veneer joints must be dislocated 100 mm. External veneer boards were full of sheets, while the interior arranged as in the butt joint, which are separated during the production so that they represent yet another error. There are produced two depths of slabs 50 mm (17 plies) and 78 mm (29 plies), width 1000 mm and length 2100 mm. From them, elements were cut, that had a width 75 mm and 990 mm in length as possible length for windows production.

Samples (dimensions 20x20x320 mm) were cut from the manufactured elements, and thus LVL panels treated as homogeneous (simulation of solid wood), in other words, that the results of tests showing high value of strength plates (material), regardless of the position in it. LVL samples are viewed as a replacement for a solid wood, veneer sheets as growth rings, and errors are spread by cross-section and the surface, what is the difference in comparison with sample made from solid wood. Samples were tested with a veneer flatwise and edgewise position.

Bending strength test occurred on the test machine of manufacturer "Zwick" with the possibility of force and deformation registration. Accuracy of registration of force was 5 N and deformation 0.1 mm. The cylindrical loading head had 25 mm diameter, and cylindrical roller-bearing supports had 50 mm diameter. Loading head was concentrated force in the sample middle. The force values at proportional limit were used from stress-strain diagrams.

The calculation of MOR and SPL are given below:

$$(MOR)SPL = \frac{3 \cdot F^* \cdot L}{2 \cdot b \cdot h^2}$$

where *L* is the span between the centres of support *(mm), F** is the ultimate failure load in the first case and proportional load in the second case *(N), b* is the sample width *(mm), h* is the sample height *(mm)*.

The temperature was measured by a Data Acquisition Aglient 3497OA in the middle and on the surface of samples with NiCrNi thermocouples.

Samples were heated-cooled in a separate air-chamber and then moved to additional chamber built on test machine. Because of this reason, samples were additional heated or cooled, but as a reference temperature was taken from the sample surface at fracture time. Difference of temperature in the middle and the surface of samples was not greater than 4 ^{o}C. Accuracy of reading the temperature was 0.1 ^{o}C.

3. RESULTS AND DISSCUSION

Effect of temperature on the bending strength and obtained regressions equitation are given in Figure 1 and Figure 2. Testing of regression parameters indicates the possibility of using a linear dependence of strength bending to the temperature.

Trend exist toward a decrease in bending strength of the MOR and SPL with increasing temperature regardless of the manner of load (edgewise or flatwise), which corresponds to previous research in solid wood.

According to Figure 1 and Figure 2 there are statistically significant results between bending strength relation to the position of veneer (flatwise and edgewise).

Deformation of LVL MOR increases with increasing temperature, while SPL decreases with increasing temperature depending on the position of veneer and load bearing.

Increase in flexural strength values below 0 ^{o}C is not as [1] but reduced, and shows similar effects as [6].

Mean values of bending strength at proportional limit SPL amounts 65.3% with coefficient of variations 14.1% (edgewise) and 57.7% with coefficient of variations 17.9 % (flatwise) of maximum bending strength MOR, for observed temperature interval. These values are greater for lower temperatures, while at higher temperatures values are smaller and tend towards a uniform distribution.

Mean value obtained at the temperature of 60 ^{o}C amounts 52.7 N/mm^2 for flatwise and 60.7 N/mm^2 for edgewise are is inside the range of values for bending strength (MOR) of fir solid wood given in the literature for 20 ^{o}C (60.8 N/mm^2) and the moisture content of 12-15%.

Results of MOR and SPL for LVL made from a lower class fir indicate that LVL can be used as structural material in both kind of loading for windows production.

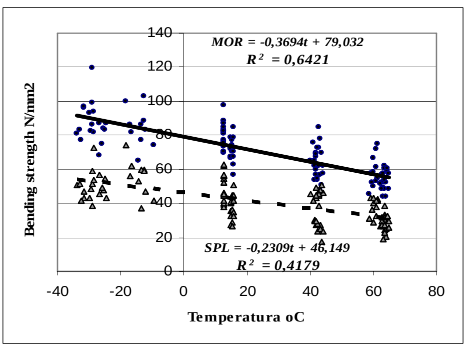

Figure 1. Effect of temperature on bending strength, MOR and SPL – flatwise

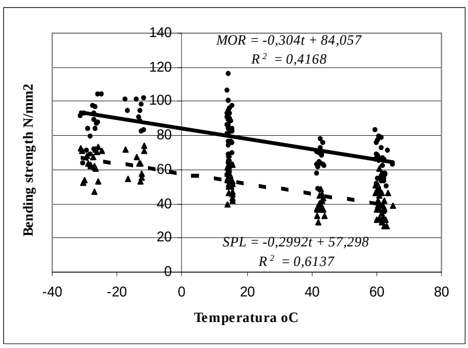

Figure 2. Effect of temperature on bending strength, MOR and SPL – edgewise

4. CONCLUSION

This study evaluated the immediate effect of temperature on bending strength MOR and SPL of LVL made of fir for temperature between -28 ^{o}C and 63 ^{o}C. Results indicate the following:

- For LVL, a linear relationship can be used to relate increase MOR and SPL with decreasing temperature.
- There is a difference between flexural strength and ways of LVL loading (position of veneer, edgewise or flatwise).
- Mean values of bending strength in the area of proportionality SPL amounts 65.3% (edgewise) or 57.7% (flatwise) of maximum bending strength MOR in the observed interval temperatures.
- MOR values at 60 ^{o}C are inside the range of values for bending strength fir/spruce for the temperature of 20 ^{o}C and the moisture contents 12 to 15%.
- Considering MOR and SPL LVL can be used such as structural material for doors and windows production.

5. REFERENCES

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