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THE INFLUENCE OF PRESSURE BY THICKNESS BONDING ON THE SHEAR STRENGHT OF GLULAM

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ABSTRACT
Test of the shear strength of glued laminated beams obtained through thickness gluing of wooden elements was carried out by an experimental method. The test samples were formed of fir/spruce and using polyurethane adhesive PURBOND HB S609. Examined levels of pressing pressure were 12, 14 and 16 MPa. The highest value of shear strength of the laminated beam is obtained on samples formed whit a pressing pressure of 14 MPa. Using statistical analysis has been proven the variety of shear strength between tested levels.
Keywords: pressure, glued laminated beam, shear strength, thickness bonding of wood

1. INTRODUCTION
During the process of production the glued laminated beams we have two different types of gluing wood elements:

- longitudinal gluing – for becoming a desired length and
- thickness gluing – for becoming a desired thickness of the beam.

In this paper has been examined the influence of external pressure on the shear strength of samples formed by thickness gluing of sections during the process of production the flat laminated beams.
For the high quality of bonding of wood, it is necessary to carry out two conditions:

- realization of full contact of the wood surfaces that are glued over the liquid adhesive applied on one or both surfaces and
- forcible retention of contact between surfaces of the wood that are glued while the glue hardened to the extent that allows him to continue to constantly keep in touch.

The surfaces of the wood that came into the bonding process are not perfectly smooth and flat. When they overlap to each other they achieve the contact on only few places. If at such contact occurred curing, bonding a large part of the area would not be high quality. Pressing pressure affects the convergence of the surfaces to be glued. Depending on the intensity of pressure, surface roughness and type of wood increase the contact between the surfaces. (Dunky, 2003.).
Increasing the pressure during the formation of the glued joint is not uniformly reflected to the strength of himself. Initially increasing pressure results an increase of the strength of the glued joint. Strength remains constant specific time, and then rapidly decreases. Therefore, it is necessary for certain types of adhesives to choose the optimum pressure to achieve satisfactory strength, without his additional increase that may be unnecessary or even harmful to the strength.
For the gluing of soft wood species is necessary to be used pressures value from 0,7 to 1,2 MPa, and for hard species of timber from 1,5 to 2,0 MPa (Obućina et al. 2013).

The duration of the pressure depends on the type of glue and form of the bonding structure. Bonding of curved or complex structures using high values of pressure develops large initial stresses. In that case, it is required to predict the effect of pressure until the final curing. For the bonding with physical curing adhesives, pressing time depends on the moisture content of wood, because it affects on the speed of the separation water from the adhesive. Increasing the temperature into glue line results a shortening the time of pressing. When adhesives, in which at the same time occurs chemical reaction and separation of dispersant, are curing it is required to control the conditions so that the speed of both processes are fully compliant. Additionally it must be removed all water from the glued joint, but this separation should not be too fast. In the case of quickly removing the water, chemical reaction of polycondensation is not carried out until the end and this leads to lower cohesion of adhesive and lower adhesion with wood. If, however, the removal of water takes place slowly and the chemical reaction is fast, the adhesive will be harden before and it remains part of "trapped" water therein.
The minimum time of pressing for flat laminated beams on the temperature of 20 °C by relative air humidity in value of 65 % and wood moisture of 12 % is 150 minutes, provided that the secure bonding of finger joint by longitudinal connecting of wood elements into sections is done. If that is not guaranteed, time of pressing must be minimum 170 minutes (Starley et al. 2013.).

Figure 1. Glued laminated beams obtained through thickness bonding of wood sections (www.chegg.com)

In accordance with EN 386, the maximum permissible moisture of sections that will be bonded is 15 % in the workspace temperature of about 20 °C (minimum 18 °C). Quality control is carried out in accordance with EN 385 and/or EN 14090 or other standards relating to the quality of thickness gluing.

2. MATERIALS AND EXPERIMENT

This study examined through an experimental method the influence of pressing pressure on shear strength directly in the process of production of flat laminated beams. Testing was performed in accordance with standard EN 393 : Glued laminated timber – Shear test of glue lines.
During the experiment has been used fluent one-component polyurethane adhesive PURBOND HB S609, based on isocyanatic prepolymers, without additives of solvent and admixture of formaldehyde. Bonding is carried out under the influence of humidity and moisture in the wood creating a strong adhesive joint that is not brittle. In the experiment has been, also, used a fir/spruce timber respectively timber sections (120x40x14010-*zbog slike2* mm) obtained through longitudinal finger-jointing wood elements. Relative humidity of the sections was reached (11 ± 2)%. Adjacent elements had no difference in moisture content greater than 2%. Gluing of sections in glulam was carried out at a temperature (20 ± 2) ° C and relative humidity (60 ± 5) %.
Shear strength of laminated beams evaluates the quality of lamination or thickness bonding of sections to the laminated beam. In addition to flexural strength, it is one of the main factors that determine the quality of the laminated beam and its suitability utilization under a certain degree of load in the process of exploitation. Bonding of the sections for laminated beam is performed with following bonding parameters: the amount of layer: 200 g/m^2; lateral pressure of 4,5 MPa; closed time (contraction): 3 s; longitudinal pressure: 3,5 MPa. Amount of layer by thickness bonding was 200 g/m^2.

The pressing process of sections to the beam was done using a cold pressing device, manufacturer SORMEC (Figure 2.), whit total pressure values of 12, 14 i 16 MPa. For each listed value was formed 6 laminated beams and from them was cutted out 3 testing samples.
According to standard EN 393 was done an adequate testing procedure for examination of the shear strength with proper positioning and clamping of samples to the measuring device and exposure to the power whit certain intensity that leads to the destruction of the glued joint between adjacent sections. Testing of the shear strenght was done using testing machine ZWICK (Figure 3).

Figure 2. Cold press SORMEC 2000 S.r.l.

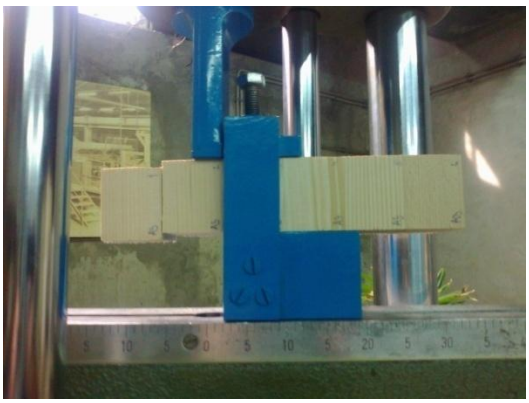

Figure 3. Testing sample during the process of examination on testing machine ZWICK

Based on the readings of values of loads and the measuring of values of the thickness and width of the shear surface has been done a calculation of shear strength, according to the form:

$$\tau = \frac{F}{b \cdot t}$$

where is:

τ – shear strength [MPa],
F – breaking force [N],
b – width of sample [mm],
t – thickness of sample [mm].

Statistical analysis was performed in order to analyze the significance of individual influence from each tested level of pressure on obtained results. During statistical processing of data did not used maximum and minimum shear strength values for a given level of pressure. Used method for that analyze was Student *t*-test (Two-Sample Assuming Equal Variances) as a two-sided distribution.

3. RESULTS AND DISCUSSION

After the experiment has been done a calculation of values of the shear strength and the results are presented on figure 4. On the basis of obtained results, it can be seen that by changing the values of pressing pressure occur the change in the final value of shear strength of laminated beam. Because of that, it is required to choose adequate value of the pressing pressure by forming the regime of thickness gluing of laminated beams. In the end, this value directly affects on the final quality of the laminated beam in terms of strength and durability of glued laminated beam.

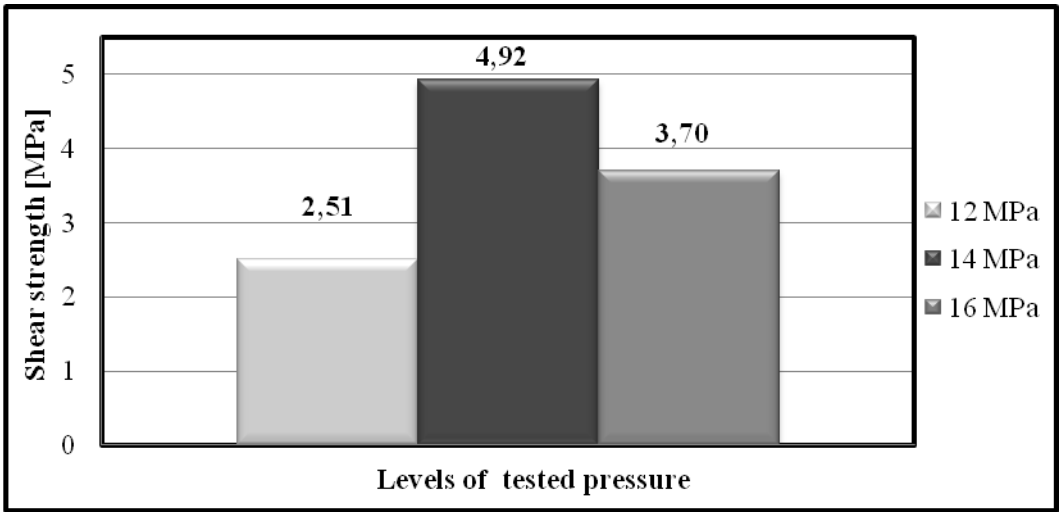

Figure 4. Influence of the pressure on the shear strength of glulam

In order to establish the statistical differences between the various levels it was made the *t*-test and the results are presented in table 1.

Table 1. t-Test: Two-Sample Assuming Equal Variances 95 % (for tested levels of the pressure):

Level of significance α = 0,05			
Comparison of values	(12/14) MPa	(12/16) MPa	(14/16) MPa
t Stat	2.39938	2.978022	2.446789
t Critical two-tail	2.032244	2.032244	2.032244
Accepted hypothesis	H_1	H_1	H_1

On the basis of statistical data analysis has been proved that between tested values of the pressure there are significant differences for level of significance of 5 %. The highest value of the shear strength is obtained whit the pressure of 14 MPa.

4. CONCLUSION

Based on listed results it can be concluded that the pressure gives nonlinear effect on the shear strength. The default value of the pressure must have sufficient intensity to carry out a proper process of tightening and overcome internal resistance force, but may not exceed the appropriate value in order not to upset the internal structure of the elements to be bonded and developed additional internal stresses of wood that would have a negative effect on the strength of the bonded joint. For the tested samples optimal value of pressing pressure was 14 MPa. In comparison with the other two levels of pressure, there are significant differences in the values of final shear strength. In future researches, it is necessary to determine the optimal pressing pressure for different thicknesses of wood and different number of sections in the construction of glued laminated beam.

5. REFERENCES

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