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# The Influence of Amount of Layer on the Bending Strenght by Longitudinal Finger-Jointing Wood Elements

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**Abstract**

Test of bending strength section obtained through longitudinal connecting wooden elements was carried out by an experimental method. The test samples were formed of fir/spruce and using polyurethane adhesive PURBOND HB S609, a total of 243 samples has been formed. Testing the effects of the amount of adhesive on the bending strength of linear coupled sections was carried out on three levels (180, 200, 220) g/m$^2$. This paper attempts to prove assumption that excessive increase in the quantity of adhesive in the adhesive film comes to impairment glued joint strength.



*Keywords:* amount of adhesive layer; bending strenght; finger joint; glued laminated beams

## 1. Introduction

Length connecting of wood elements, among others, is performed in the production of laminated beams in the segment forming sections required length of the beams from shorter elements. Elements that enter into the process of forming sections should be formed without significant errors anatomical structure of wood and mistakes from previous processing. As part of production the laminated beams, especially when forming sections bonded through finger-jointing, an important parameter from the regime of bonding represents the amount of adhesive. This parameter directly reflects the strength of the bonded joint.

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The amount of adhesive that is applied to the surface of the wood should be sufficient to provide: the amount that penetrates into the wood, the amount that fills a variety of unevenness caused by surface processing and the amount which is necessary to achieve the joints thin, continuous and unbroken film of dried glue. The necessary amount of glue to be applied depends on:

- adhesive properties (dry substances content, viscosity and adhesive properties),
- properties of wood that is glued (structural unevenness, fines - surface roughness caused by processing, craters on the surface, etc.).

In addition, the strength of glued joint depends on the cohesion of the adhesive and its adhesion to wood, as well as the internal stresses in the bonded joint. Increasing the thickness of the adhesive layer reduces the cohesion and strength of the bonded joint.

Considering the prominence of different sizes, craters, holes, etc. around the glued joints, glue shrinkage in percentage is similarly but also because of different thickness and volume of the glue in some places in absolute terms is very different. This means that the internal stress in the joints, because of shrinkage of the adhesive, is different. Bearing in mind the fact that the shrinkage is done across the width, length and thickness of the joint and the thickness in some places is very different, it is clear that the internal stress due to the shrinkage of the adhesive is complex and diverse. Therefore, maximum attention should be paid to the preparation of surfaces for bonding wood and ensure that the areas with the lowest possible roughness and unevenness. You also need to give maximum attention to the choice of adhesive should have adequate flexibility when cured, it can be successful without the destruction that accompanies their shrinkage and deformations due to swelling or shrinkage of wood [1].

The quantity of deposited adhesive and the deformation of wood under the influence of external pressure significantly affects the temperature at which bonding is performed, which is directly or indirectly reflected in the necessary amount of glue and internal stress in the joints.

In the case of glued laminated beams for building construction should be applied (170 ÷ 220) g/m$^2$ glue. This amount is dependent on the type of used adhesive used, the content of dry substances and viscosity. Dry substances must be provided to create a continuous uninterrupted film of dried glue with sufficient penetration of the adhesive into the wood.

In previous research related to the amount of adhesive or adhesive film thickness was determined that an excessive amount of adhesive adversely affects the strength of the bonded joint. Interpreting the complementary effect, the amount of adhesive, it can be quite complex. [2] Below are presented some facts related to the impact of the amount of adhesive on the strength of adhesive joint.

The nature and dimensions of the destruction caused by the low strength of the bonded joint can be different depending on the thickness of the adhesive film. Visual and microscopic evaluation of destruction can be significant for the assessment of this phenomenon. The structure of the adhesive film can vary depending on the amount of adhesive and bonding requirements. Heterogeneous temperature changes, such as different temperature distributions, are influenced by the distance from the thermally conductive substrate. Analyses of the heat balance and measuring the thermal properties of surfaces that come in contact with the glue joints can help solve the problem structure changes of adhesive film.

The interface between the substrate and the adhesive properties can be changed if it increases the thickness of the adhesive film. This may be caused by the internal stresses that develop in the joint with migration of oxide from surfaces for bonding or stoichiometric changes within the adhesive and substrate [3]. The results of this experiment confirmed that the technological process of gluing affects on the physical and mechanical properties of gluing elements [4]. The migration of oxide from surfaces for bonding or stoichiometric changes within the adhesive and substrate. Roche and associates are thoroughly investigated this phenomenon [5]. Many techniques are used to detect properties of interfaces, based on changes in the chemical state (infra-red spectroscopy or micro-thermal analysis) and mechanical testing (extraction, nano-indentation and laser-acoustic method). For bonded timber elements such as glued laminated timber beams, it is assumed that the adhesive in use does not significantly influence the resistance of structural timber beams. [6]

Energy of dissipation can be changed by changing the distance between the substrates. Careful mechanical testing can be used to introduce this phenomenon. By changing the geometry of the sample with increasing thickness of the

adhesive layer can cause a change in the state of stress within the joint, so that the tests on samples of different sizes do not provide the same features bonded joint.

## 2. Materials and experiment

The paper examines through an experimental method the effect of the amount on adhesive strength of the adhesive finger joint in length connecting the wooden elements in sections for the production of glued laminated beams. Testing was carried out according to standard EN 408: Timber structures - Structural timber and glued laminated timber - Determination of some physical and mechanical properties.

During the experiment has been used glue PURBOND HB S609. PURBOND HB S609 is fluent, one-component, polyurethane adhesive based on isocyanatic prepolymers, without additives of solvent and admixture of formaldehyde. Bonding is done under the influence of humidity and moisture in the wood creating a strong adhesive joint that is not brittle. Under the influence of chemical reactions that occur in the process of bonding becomes a slight foaming.

In the experiment has been used a fir/spruce timber. Relative humidity of the wood is reached (11 ± 2)%. Adjacent elements had no difference in moisture content greater than 3%. Bonding elements in sections is carried out at a temperature (20 ± 2) ° C and relative humidity (60 ± 5) %. Visual assessment of the class the sections was C24 (80%) and C30 (20%).

Testing of bending strength as a function of the quantity of adhesive is done by forming 243 samples size (115x35x700) mm for the next levels of amount of adhesive:

- 180 g/m$^2$ : 81 sample,
- 200 g/m$^2$: 81 sample,
- 220 g/m$^2$: 81 sample.

In addition to these sample groups, formed an additional group of 10 samples of solid wood size (115x35x700) mm in order to compare the results obtained by testing bending strength of finger joint. Dimensions of the finger (Figure 1) formed by used device are: length of finger: l = 10 mm, step of finger: p = 4 mm, the width of the gap: $b_t$ = 1 mm, the length of the gap: $l_t$ = 1 mm. Centreline of finger is marked with *1)*.

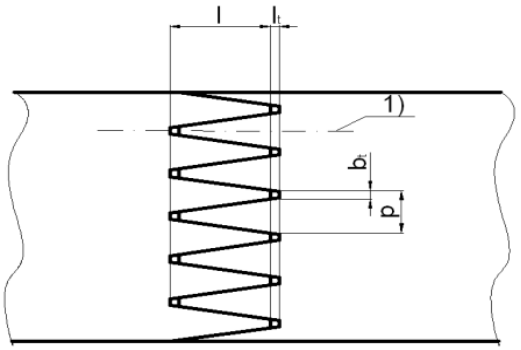


Fig. 1. Dimensions of the finger.

Testing of samples was performed in the climatic conditions in accordance with EN 408, temperature (20 ± 2) ° C and relative humidity (60 ± 5) %. Humidity test of samples (Figure 2.) amounted to (11 ± 2) %. During the testing process of bending strength were recorded visual assessment of destruction of samples.

Values obtained for bending strength was performed and statistical analysis of data using the student's t-test by testing the equality of means two basic a set of as double sided distribution (*t-Test:* Two Sample Assuming Equal Variances).

Fig. 2. The form of sections for samples and final appearance of samples.

Testing was carried out on the device Spanevello Tester KN 50. According to the standard EN 408, testing was done by properly positioning the samples on measuring device (Figure 3.). Samples dimensions and position of power in the process of testing the samples is a function of its thickness [7].

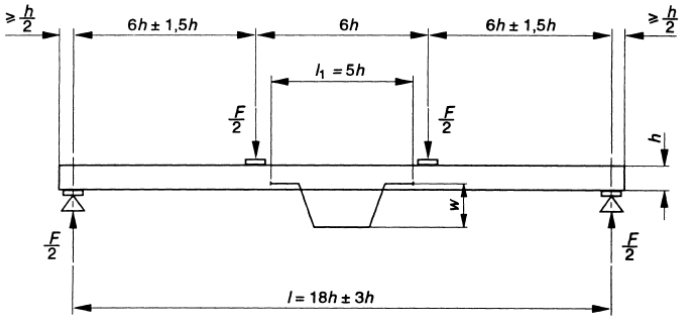


Fig. 3. Scheme of the test of samples for bending strength [7].

## 3. Results and discussion

In the process of testing the bending strenght of finger joint samples experiences some deformation and destruction. Destruction occurred in the following forms:

- destruction of wood,
- destruction of root the finger,
- destruction of bonded joint or
- combination of prevous forms of destruction.

Table 1. presents the number and percentage of destructed samples from these forms of destruction.

Table 1. Number and percentage values of destruction during the testing of bending strength.

| Form of joint destruction | Wood | Root of finger | Joint | Combination r.o.f./j. | Combination r.o.f./w. | Σ |
|---|---|---|---|---|---|---|
| Number of samples | 134 | 65 | 16 | 14 | 14 | 243 |
| Percentage of samples [%] | 55.14 | 26.75 | 6.58 | 5.76 | 5.76 | 100 |

The amount of adhesive in the production practice is the most important parameter from regime of bonding to optimize the consumption of adhesive without adversely affects the final value of the strength of the bonded joint. Influence of the amount of adhesive on the strength of adhesive bonded joint in length connecting elements whit finger joint connection is represented in the Figure 4.

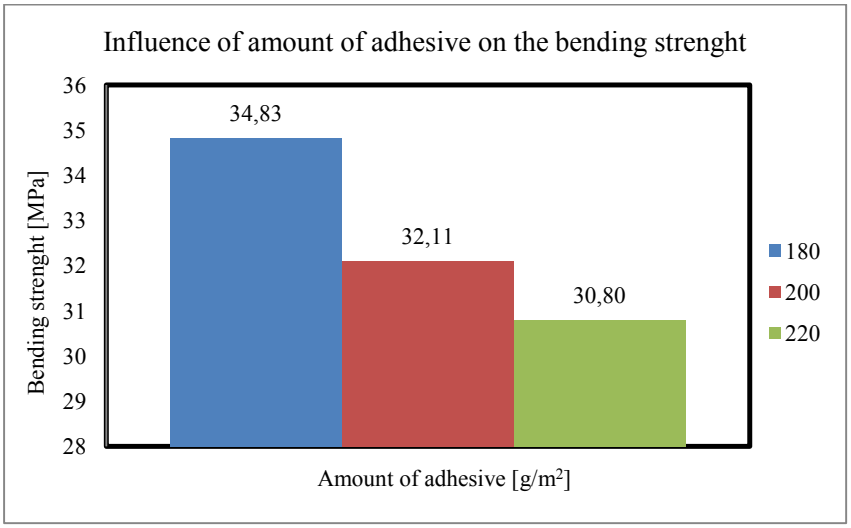


Fig. 4. Influence of amount of adhesive on the bending strength.

Based on the Fig. 4 it can be concluded that there are significant differences between the level of the amount of adhesive, and that the maximum value of bending strength reached a group of samples that are glued whit amount of adhesive in the value of 180 g/m$^2$. Results of *t*-test are presented in the following table 2.

Table 2. *t*-Test: Two-Sample Assuming Equal Variances 95 % (for the levels of amount of adhesive).

| Level of significance α = 0,05 | | | |
|---|---|---|---|
| Comparison of mean values | (180/200) g/m$^2$ | (180/220) g/m$^2$ | (200/220) g/m$^2$ |
| t Stat | 2.665115 | 3.343888 | 1.239583 |
| t Critical two-tail | 2.006647 | 2.006647 | 2.006647 |
| Accepted hypothesis | $H_{1\,(5\%)}$ | $H_{1\,(5\%)}$ | $H_0$ |

Between different levels of quantity of adhesive there is a significant difference that is manifested on the final value of bending strength test of tested samples. In the present case, denies the null and alternative hypothesis is adopted. In order to determine the level of significance was carried out and the *t*-test for the level of confidence of 99%, in table 3.

Table 3. *t*-Test: Two-Sample Assuming Equal Variances 99 % (for the levels of amount of adhesive).

| Level of significance α = 0,01 | | | |
|---|---|---|---|
| Comparison of mean values | (180/200) g/m$^2$ | (180/220) g/m$^2$ | (200/220) g/m$^2$ |
| t Stat | 2.665115 | 3.343888 | 1.239583 |
| t Critical two-tail | 2.673734 | 2.673734 | 2.673734 |
| Accepted hypothesis | $H_{1(5\%)}$ | $H_{1\,(1\%)}$ | $H_0$ |

Based on tables 2. and 3. for the tested samples can be concluded that between first and second level of amount of adhesive there is a significant difference, while the first and third level of amount of adhesive there is obtained a high significant difference. On the other hand, we can see that between the second and third level there was no significant difference (null hypothesis). Comparison of values of bending strength of finger joint with the values of bending strength of solid fir/spruce was performed in order to obtain the information that glued finger joints increases or decreases the value of strength of sections. For comparision has been taken 3 mean values of bending strenght from every level amount of adhesive, so we had 9 mean values. These values are presented in figure 5. and 6. Based on the figure 5. and 6. it can be concluded that the strength of the finger joint conected sections becomes more uniformly and a few percent higher value of bending strenght than the value of the bending strength of solid wood.

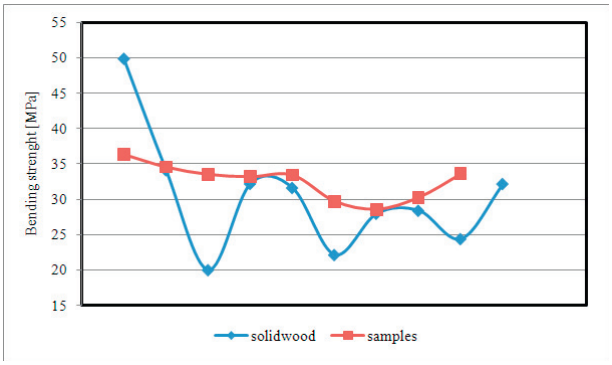


Fig. 5. Scattering of bending strength values of solid wood and finger joint samples.

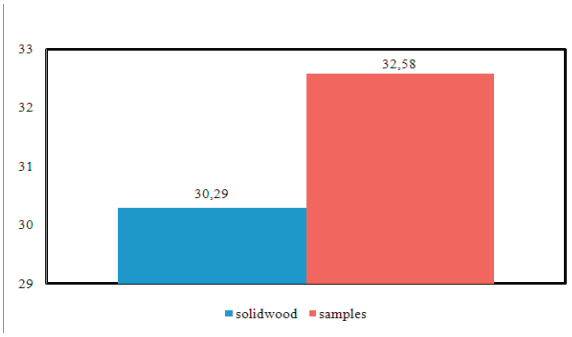


Fig. 6. Comparing the values of bending strength of solidwood and finger joint samples.

## 4. Conclusion

On the basis of this study it can be concluded that the proven assumption that an excessive increase in the quantity of adhesive in the adhesive film is coming to a reduction in the value of the glued joint strength. The optimum value of the quantity of adhesive for a given test is 180 g/m$^2$. Increasing this value leads to a significant reduction in bending strength of adhesive joint. Compared to solid wood, length merging or forming finger glued joint is an increase in the value of bending strength with uniformly values.

For a given sample, in future research should be oversized the finger joint and examine the lower levels of the amount of adhesive to establish the minimum allowable value of the quantity of adhesive to achieve maximum strength of the bonded joint in longitudinal connecting elements.

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