INFLUENCE OF THE APPLIED PRESSURE ON FINGER JOINED END-TO-END WOOD

Todor Petkov, Vladimir Mihailov
University of Forestry, Sofia, Bulgaria
e-mail: todor_ltu@mail.bg; vladko86mihailov@gmail.bg

ABSTRACT

In the production of finger-jointed details, it is most important to provide the required applied pressure to achieve the desired adhesion strength of the joint. The results of the study of beech wood elements (Fagus Sylvatica) are presented, with applied different pressure for the face ends of the details (0,4 and 0,7 N/mm^2). The following properties have been determined of the tested samples: bending strength, modulus of elasticity and the density of wood. The pneumatic-piston system also provided for securing the bonding pressure in the longitudinal direction of the wood. In the carried – out experiments, it was used a polyvinyl acetate adhesive with a class of water resistance D3. The mechanical properties of the glued elements depend on their structure, the type of adhesive and the type of wood. The paper presents the values of strength and modulus of elasticity in static bending of elements derived from beech wood.

Key words: beech wood, finger-joint, polyvinyl acetate adhesive, pneumatic-piston system.

INTRODUCTION

Finger joint (Fig. 1) of wood details in length has in the recent years become more and more widely used in all branches of the woodworking and furniture industry [1;2]. Its application is aimed not only at utilization of waste and small-sized, but also on regular wood. The great advantage of glued elements compared to solid wood is reduced to considerably greater dimensional stability and to less lengthwise rolling [5;9]. The quality of the adhesion depends essentially on the type of adhesive mixture, the catalysts and the value of the applied external impact.

Figure 1: Appearance of a finger joint made of deciduous wood

As a criterion for sufficient applied pressure on wood elements, leakage of adhesive residues is generally taken along the entire length of the joint. Increasing the applied external pressure during the bonding process helps to create well-bonded surfaces by eliminating unevenness and at the same time determining the exact thickness of the adhesive seam and squeezing excess glue between the individual parts. Once the compression process has been completed, the adhesive seam is reliable and resistant to workpiece manipulations, but the test specimens should not be subjected to higher loads. The final strength of the compound is achieved after a certain period, depending on the compression time and the temperature at which the process took place. Under normal conditions, the curing time is two days. Following is the conditioning of the produced glued elements, which eliminates the occurrence of deformations, dimensional changes and cracking during operation [3;4;5;6;7;12].

The aim of this study was to determine the values of strength and modulus of elasticity in static bending of elements derived from beech wood.

MATERIALS AND METHODOLOGY

Preparation of the samples

Three series of 15 pieces of beech wood (*Fagus sylvatica*) were tested (2 series spliced with 4 atm (0.4 MPa = 0.4 N/mm^2) and 7 atm (0.7 MPa = 0.7 N/mm^2) pressure and a set of solid beech wood, all with dimensions 30x30x570 mm).

Figure 2: Moments of the splice (assembly) in length and finished details

Figure 3: Test specimens with dimensions of 30x30x570 mm during loading and after demolition

The values of the geometrical parameters of the teeth are regulated by the existing standards [3;4;5] and are actually predetermined by the milling tool used by the milling process. The tooth features are as follows: L (tooth length) – 10 mm; P (pitch between teeth) – 3.8 mm; T (teeth width at the tip) – 0.6 mm; S (gap between teeth) – 0.8 mm. They are milled on a universal spindle moulder with a cutting speed of 6,000 rpm and are bonded with the PVA adhesive grade D3, Jowacoll 102, produced by the German Jowat company. The working solution of the adhesive is as follows: dry matter content – 51%; Brookfield viscosity (rotary viscometer) 13500 mPa.s. The adhesive consumption is 150 g/m^2. The minimum time required to clamp the forehead for the wedge-joint is 2 s. The applied bonding pressure should be between 2-5 N/mm^2, but it should be chosen so that nocracksappear in the details and crushing of the teeth. The pressure varies according to the cross-section of the bonded material as well as the different wood species [3;4;5;8;9;10;11]. The density in dry air of all beechwood elements is 730 kg/m^3.

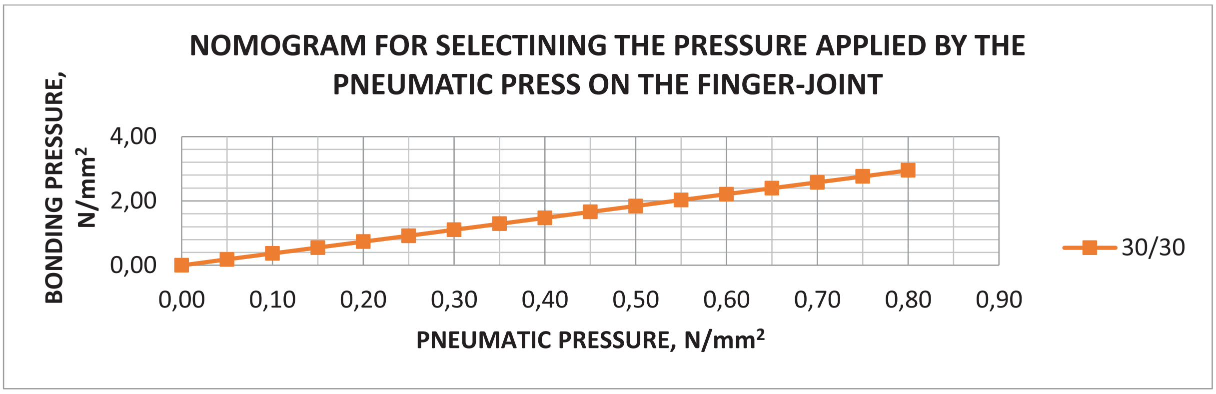

Figure 4: Nomogram for pneumatic press for finger joint

The nomogram of Fig. 4 illustrates the pressure by which the piston of the pneumatic cylinder presses the wood to obtain a high-strength wedge-shaped joint. The piston diameter of the cylinder is 63 mm, which is sufficient for the good joining of such cross sections. When compressing the joint, care should be taken not to apply excessive pressure and the deviations of the dimensions of its components must be negligible. Therefore, as a major technological and technical problem in the implementation of this process is the provision of a suitable specific pressing pressure.

TESTING PROCEDURE

Figure 5 shows schematically the experimental setting, and all the dimensions required for the conduct of the study.

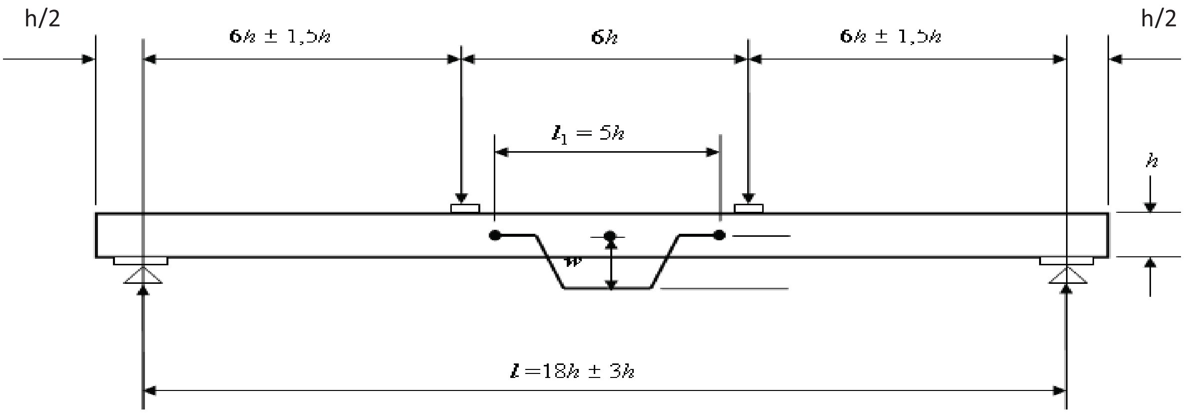

Figure 5: Scheme and the size of the test setting.

The bending strength (σ) and the modulus of elasticity in bending (E) are calculated by the formulas:

$$E = \frac{3.a.l^2 - 4.a^3}{2.b.h^3.\left(2.\frac{w_2 - w_1}{F_2 - F_1} - \frac{6a}{5.G.b.h}\right)} \quad (1)$$

$$\sigma = \frac{3.F_{max}.a}{b.h^2}, \quad (2)$$

Where: E – modulus of elasticity in bending, N/mm^2; σ – bending strength, N/mm^2; F_{max} – maximum load, N; a – distance between the loading plates in bending, mm; h – the thickness of the test specimen (tangential size), mm; b – width of test specimen (radial size), mm; G – shear modulus (assumed to be infinite and the expression 6a / 5G.bh – ignore), N/mm^2; l – length of the workpiece to determine the modulus of elasticity (19h), mm; F_2-F_1 – is an increase in the load in Newtons, respectively at 40 and 10% of F_{max} with a correlation coefficient of 0.99 or better; w_2-w_1 – an increase of deformation mm, corresponding to F_2 and F_1.

RESULTS AND DISCUSSIONS

The test pieces were tested in standard laboratory conditions (room temperature – 20 ± 1 ° C and relative air humidity – 60 ± 5%) and the following mean results of each series are presented in Table 1.

Table 1: Mechanical properties of finger-jointed and solid wood components

Dimensions, mm	F_{max}, N	σ, N/mm²	E, N/mm²	f_{max}, mm
Beech finger-joint (4atm) 30x30x570	3283,0	69,30	11202,81	16,92
Beech finger-joint (7atm) 30x30x570	3448,3	82,76	11879,40	15,16
Beech solid 30x30x570	4388,8	92,65	13070,08	28,12

Indications: Fmax – an average load; σ – average bending strength; E – average bending modulus; fmax. – average deflection (deformation).

The values of bending strength for solid beech wood elements ranging from 86.65 N/ mm² to 97.38 N/mm², and for beechwood finger-joint from 64.48 to 88.77 N/mm². Modulus of elasticity of bending values for beechwood elements ranging from 11987, 44 N/mm² to 14202.81 N/mm², and for beechwood finger-joint – from 9846.94 to 11982.56 N/mm². The absolute values of bending strength and flexural modulus depend on the values of the length of the test pieces, their cross-section and the intersupport distance. The flexural strength, maximum load, deformation, and modulus of flexural modulus of all tested solid wood elements are higher than those that are finger-jointed. The values σ and E ranging from 75 to 86% of solid details.

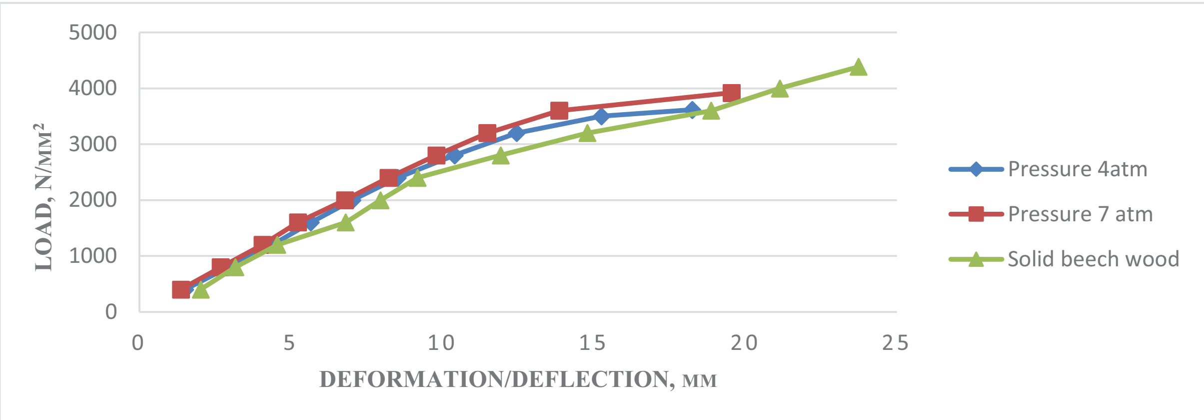

Figure 5: Load deformation (within the elastic deformation) of 3 series of Beech details – dimensions 30x30x570 mm

The graphic shows that the applied pressure of 4atm (0.4 N/mm²) is sufficient to produce quality compounds with a cross-section of 30x30 mm (according to the nomenclature of Figure 4). The differences in maximum force and deflection are small (165.3 N, 1.76 mm). The difference in the maximum load values of the two series is credible, as the Student criterion value is 6.13. As a result of applying a higher pressure of 0.7 N/mm², tensile compounds of sufficient strength are obtained but as long as it is within the permissible standard, so that no cracks and crushing of the teeth will occur under excessive pressure. Elements made from glued, spliced finger-joint wood have about 20%

lower mechanical properties (bending strength and modulus of elasticity in static bending). The finished spliced joints are reliable and have a relatively high bending strength compared to the corresponding solid wood (reaching 85.6% of the solid wood at a pressure of 7atm = 0.7 N/mm^2) and 82.4% of the strength of the array when applied 4atm (0.4 N/mm^2) pressure at forehead pressures.

CONCLUSIONS

Quality elements with a finger – joint were obtained, the teeth being barely noticeable on the front of the workpiece. The strength of the finger-joint beechwood details is as high as 85–86% of the massive wood. These high values make it possible to obtain larger and better quality beams made of small pieces of wood. The applied pressure in the longitudinal spliced joint (0.4 / 0.7 N/mm^2 / MPa) plays a significant role in the values of the tested parameters (bending strength and modulus of elasticity in static bending). Higher pressure promotes deeper penetration and even distribution of adhesive on the surfaces of the bonded layers.

REFERENCES

GOCHEV, G. 2000. Tools for micro-dowel splicing of wood. Jubilee collection of scientific papers, "75 years of higher forestry education in Bulgaria", section of forestry industry, University of Sofia – Sofia. 275–280.

DONCHEV, G., YOSIFOV, N. 1990. Small Waste Technology in Woodworking. Zemizdat, Sofia. 82–84.

BDS EN 385:2003. Joints with finger-joint teeth in wooden structures, Performance requirements and minimum requirements for production.

BSS EN 408 + A1: 2012. Wooden constructions. Construction timber and glued laminated timber. Determination of some physical and mechanical properties.

BDS ISO 3131 (1999). Wood. Determination of the density physical and mechanical tests.

Panayotov, P. and colleagues. 2005. Examination of bending strength and modulus of elasticity of monolayer cemented wood elements. Collection of reports. International Scientific Conference, 10 Years of Engineering Design. 233–242.

PETKOV, T., PANAYOTOV, P. 2016. Correlation between physical-mechanical properties of the wood. INNO, vol. V, 2016, 1, 13–20.

PANAYOTOV, P., KALMUKOV, K., PANAYOTOV, M., PETKOV, T. 2019. Quality of Cedrus atlantica man. wood. 4th International Scientific Conference Wood, Design & Technology, Skopje, 8(1), ISSN 1857 – 8381 (print), ISSN 1857 – 9140 (on-line), pp. 67–70.

SERRANO, E. 2000. Adhesive joints timber engineering – modelling and testing of fracture properties. Doctoral thesis. Department of Mechanics and Materials Structural Mechanics ISRN LUT-VDG/TVSM--00/1012--SE (1-173) ISBN 91-7874-095-9 ISSN 0281-6679.

ATANASOV V., G. KOVATCHEV. 2018. Determination of the cutting power in processing some deciduous wood species, Hardwood Conference – Volume 8, ISBN 978-963-359-096-6, ISSN 2631-004X, pp. 53–54.

MERDZHANOV, V. 2018. Comparative study of tensile bond strength for melted EVA glue on particleboards with different edge banding materials. Proceedings of the 5th International Conference on Processing Technologies for the Forest and Bio-based Products Industries, Freising, Germany, p. 101–105.

POPOVA R. 2018. Forest industry in republic of Bulgaria: state and prospects, International Academic Conference, London, Proceedings of the International Institute of Social and Economic Sciences ISBN 978-80-87927-51-9, 245–262.

UNIVERSITY OF FORESTRY

FACULTY OF FOREST INDUSTRY

INNOVATION IN WOODWORKING INDUSTRY AND ENGINEERING DESIGN

1/2020

INNO vol. IX Sofia

ISSN 1314-6149
e-ISSN 2367-6663

Indexed with and included in CABI

INNOVATION IN WOODWORKING INDUSTRY AND ENGINEERING DESIGN

Science Journal
Vol. 09/p. 1–78
Sofia 1/2020

ISSN 1314-6149
e-ISSN 2367-6663

Edition of
FACULTY OF FOREST INDUSTRY – UNIVERSITY OF FORESTRY – SOFIA

The Scientific Journal is indexed with and included in CABI.

Cover Design: DESISLAVA ANGELOVA

Printed by: INTEL ENTRANCE
Publisher address: UNIVERSITY OF FORESTRY – FACULTY OF FOREST INDUSTRY
Kliment Ohridski Bul., 10, Sofia, 1797, BULGARIA
http://inno.ltu.bg
http://www.scjournal-inno.com/

CONTENTS