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EXPERIMENTAL STUDY ON THE ELASTICITY COEFFICIENT OF GLUE BONDS IN BEECH WOOD LAP JOINTS

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One of the factors which influencing the shear strength of the adhesive bond is its linear elasticity coefficient. This paper presents an indirect method of determining elastic traits of adhesive bonds with the aid of numeric calculations. Four types of glues were examined and values of their linear elasticity coefficients were approximated.

INTRODUCTION

Following abbreviations have been used: ν_{RL} – Poisson coefficient for *RL* direction, ν_{LR} – Poisson coefficient for *LR* direction, E_L – linear elasticity module in *L* direction, E_R – linear elasticity module in *R* direction, G_{LR} – shape elasticity module in plane *LR*, E – glue linear elasticity module.

Studying elastic properties of adhesive bonds is particularly important during optimization processes of furniture constructions by means of numerical methods [6], [7]. Equally important are experiments aiming at the determination of the elastic coefficient of glue bonds. No data have been found in literature concerning elastic coefficients of glue bonds for different kinds of glues. This is due to considerable difficulties encountered while trying to measure elastic deformations of the thin and irregular layer formed by the glue bond. Additionally, it is also very difficult to assess unequivocally the boundary of glue penetration in the wood [9].

It was, therefore, necessary to eliminate these difficulties by resorting to indirect methods which would still allow assay of elasticity coefficients of bonds. Such methods have already been described in literature [4], [5]. They consisted in calculating the elasticity coefficient of the bond formed from the tannin-formaldehyde [5] and polyvinyl acetate (PVA) [4] glues by comparing theoretical formulas expressing the elasticity coefficient at bending with empirical correlations by determining the elasticity coefficient of the bond as an unknown quantity. Values of the elasticity coefficient of adhesive bonds calculated in the above mentioned paper are by 67% higher than the values of the elasticity coefficient of glued wood. The same difference in paper [4] amounts to only 1.35%.

THE OBJECTIVE OF THE INVESTIGATION

The aim of the presented investigation was to determine the linear elasticity coefficient of adhesive bonds formed by different glues by means of comparison of experimental results with the results of numerical calculations.

METHODS AND DESCRIPTION OF EXPERIMENTS

The following materials were used in the experiments: beech wood, two PVA glues: wikol and rakol, glutin glue and a urea-formaldehyde (UF) glue on a resin base (silekol MZ).

The following were the constant experimental factors: type of wood, wood moisture content, type and dimensions of specimens and method of loading. The experimental variable factor was the type of glue, while the elongation of the bond was treated as the observed factor.

The dimensions and texture of specimens used in the experiment complied with the requirements of the German Standard DIN 53254. Ten specimens were made for each glue and they were seasoned in laboratory conditions for the period of one month at temperature $22 \pm 1°C$ and relative air humidity of $50 \pm 1\%$ until they reached equilibrium moisture content (EMC) of $8 \pm 1\%$.

Before the commencement of main experiments, introductory studies were carried out with the aim of establishing the essential elastic characteristics of beech wood, that is: ν_{RL}; ν_{LR}; E_R; E_L; G_{LR}. These investigations were conducted on block samples with dimensions and texture as shown in Fig. 1 with the aid

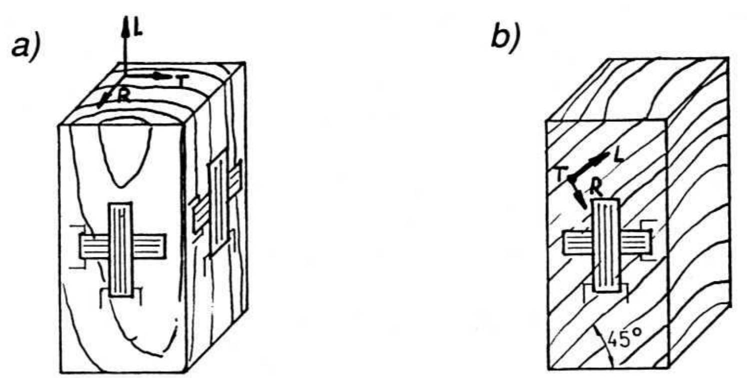

Fig. 1. Block specimens used to determine elastic features of wood:
Ryc. 1. Próbki blokowe służące do określenia cech sprężystych drewna:
a) E_L, E_R, ν_{LR}, ν_{RL}, b) G_{LR}

Table 1

Elastic properties of the wood and glue bonds used in the experiment
Właściwości sprężyste drewna i spoin klejowych użytych do badań

Material Materiał	Property Właściwość	Unit Jednostka	Value Wartość
Wood Drewno	E_R E_L ν_{LR} ν_{RL} G_{LR}	MPa MPa – – MPa	2040 16350 0.053 0.350 5720
Glues: Kleje:			
glutin glutynowy	E	MPa	245
wikol wikol	E	MPa	328
rakol rakol	E	MPa	284
silekol silekol	E	MPa	173

of electronic tensiometers RL 120 and a tensiometric bridge connected to the IBM PC computer.

Results of the experiments are presented in Table 1. These studies were followed by proper experiments in which specimens with single lap joints type DIN (Fig. 3) were subjected to stretching in the testing machine ZWICK. All the results of these tests were recorded in the system $dF - dL$ using the IBM PC computer with accuracy $d(dF)=0.01$ N, $d(dL)=0.01$ mm. Results of these assays as the average curves are shown in Fig. 2.

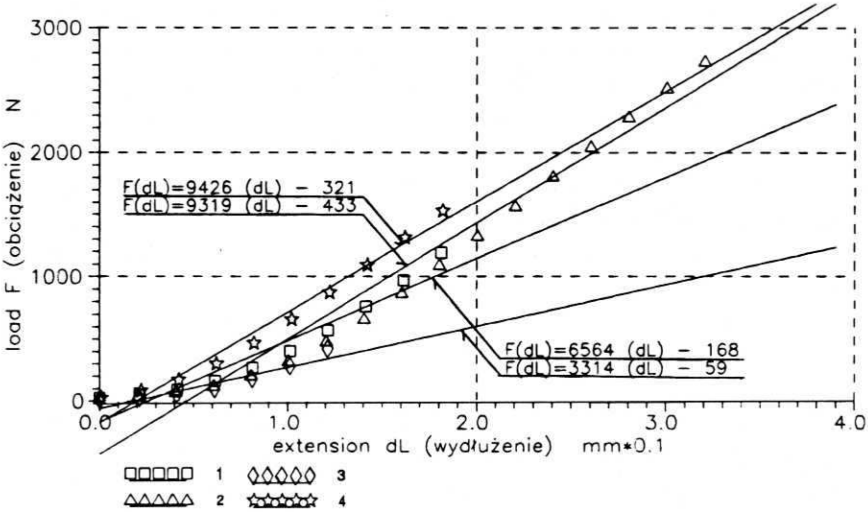

Fig. 2. Diagram of tension of joints glued with:
Ryc. 2. Wykres rozciągania połączeń klejonych klejem:
1 – glutin, glutynowym, 2 – rakol, rakolem, 3 – silekol MZ resin, żywicą silekol MZ, 4 – wikol, wikolem

Characterization of stiffness of glue bonds obtained in this way, as well as elastic features of the beech wood, allowed to perform numerical computations consisting in the appropriate selection of the E coefficient of the adhesive bond in such a way that a given load F would result in deformation L in agreement with empirical results. For this reason, the studied joint was covered with a network of rectangular orthotropic (wood) and isotropic (glue bond) finite elements (Fig. 3). The calculations were performed with the use of the IBM

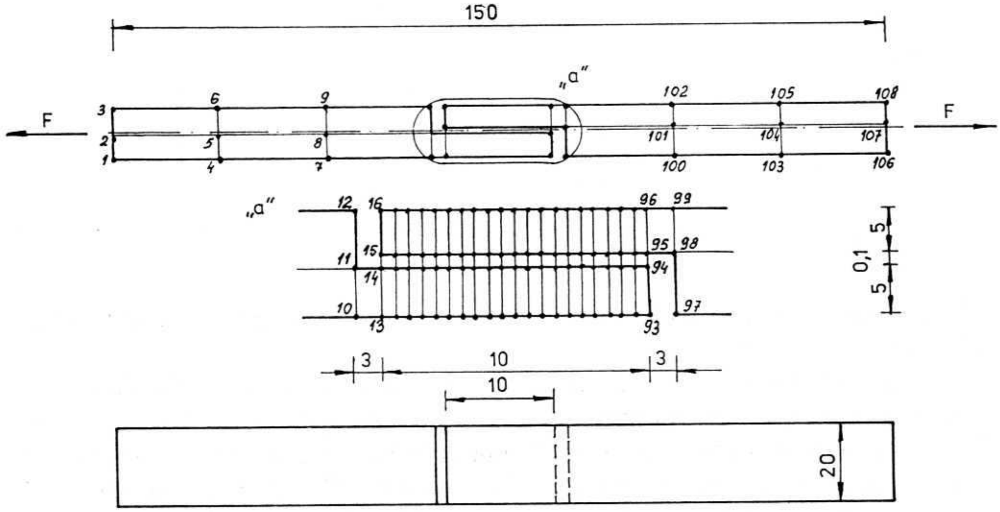

Fig. 3. Lap joint with the grid of finite elements
Ryc. 3. Połączenie zakładkowe z siatką elementów skończonych

386/33 MHz computer and of the program OK.MES/3. The constant input data for processing were: wood elastic traits, specimens dimensions as well as type, direction and value of the load. The only variable in the processing was the value of the linear elasticity coefficient E of the glue bond. In calculation process this value has been changed until moment when the result of the numeric calculations was the same as in the case of laboratory experiments. The estimated numerical values of the elasticity coefficients of experimental glues were set in Table 1 the against elastic characteristics of wood.

ANALYSIS OF EXPERIMENTAL RESULTS

In order to compare the stiffness of joints connected together with various types of glues, a linear approximation of mean values of individual characteristics $F(dL)=a^*(dL)+b$ was performed, as shown by curves presented on Fig. 2.

The comparison of slope coefficients a of the obtained linear functions shows that their values do not differ from one another very much; the coefficient for the wikol glue is 9426, while for the rakol glue – 9319. At similar loads ranging from 2000 to 2100 N, the joints exhibited comparable elongations dL ranging from 0.25 to 0.26 mm. There is no doubt that this is connected with a dispersive character of both the examined PVA glues. The comparison of the glutin glue with PVA glues (Fig. 2) reveals a decrease in the value of the scope coefficient, to $a = 6564$. Simultaneously, at similar range of loads, elongations dL exceed the value of 0.25 mm. This indicates that the glution glue is characterized by a higher flexibility and elasticity than PVA glues. The lowest proportionality factor a equalling 3314 was found in the case of the function approximating the results of the elongation of the adhesive joint glues with resin silekol MZ. Elongations dL were in this case the biggest of all the examined joints. This indicates that bonds formed by this glue are characterized by a relatively poor stiffness. This may be due to the enhanced penetration of resin molecules deep inside wood accompanied by a simultaneous flexibility of the joint. However, on the whole, bonds produced by UF resins are characterized by distinctive brittleness and high stiffness of the obtained joints. Therefore, it would be necessary to carry out additional experiments on other wood species in order to verify the above observation.

The performed calculations, allowed to estimate the approximate value of the linear elasticity coefficient for which empirical elongations were consistent with the elongations of the joint calculated theoretically. It is evident from Table 1 that wikol and rakol glues, which have similar physical properties, are also characterized by a similar value of the linear elasticity coefficient (the difference amounts to 15% in favour of wikol). Value $E = 328$ MPa determined for wikol using an estimation method is only slightly different (9.3%) from the value quoted in literature, i.e. $E = 358$ MPa [8]. No comparable data for the remaining examined glues were found in literature. It can only be presumed that the values of linear elasticity coefficients obtained using numerical simulations are really-true with reality because the rigidities of the joints showed definite regularities in comparison with research results found in available literature [1], [2], [3]. This regularity does not apply only to the UF glue whose low E value amounting to 173 MPa may raise doubts as to the quality of the obtained adhesive bond. However, in order to answer the question why the glue which usually produces hard and brittle bonds showed such a low level of its linear elasticity coefficient, it will be necessary to carry out additional investigations and calculations using different wood species and joint types.

CONCLUSIONS

The performed studies and their analysis allow to draw the following conclusions:

1. Application of numeric simulation and strength tests makes it possible to determine values of linear elasticity coefficients of adhesive bonds for various glues.

2. Dispersive glues exhibit highly comparable elastic properties apparent in the stiffness characteristics of the formed joints.

3. Glutin glue shows lower for 16% to 34%, elasticity coefficient than PVA glues contributing to the increase of its flexibility accompanied by the increase in deformations of the obtained bonds.

4. Further research on elasticity of bonds formed by the UF resin silekol MZ is needed because of considerable unstability of its properties affected by the quantities of hardening and filling agents.

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BADANIA EKSPERYMENTALNE NAD MODUŁEM SPRĘŻYSTOŚCI POŁĄCZEŃ ZAKŁADKOWYCH Z DREWNA BUKA

Streszczenie

Przeprowadzono badania wytrzymałości na ścinanie spoin klejów: wikol, rakol, glutynowy i mocznikowo-formaldehydowy uzyskując wyniki obrazujące zależność $F(dL)$ obciążenia w funkcji wydłużenia połączeń. Na podstawie ustalonych doświadczalnie cech sprężystych drewna oraz wydłużeń badanych połączeń wykonano wielokrotnie obliczenia numeryczne szacując wartość modułu sprężystości E spoiny klejowej. Uzyskane wyniki badań nieznacznie tylko odbiegają od wartości ustalonych w drodze złożonych badań eksperymentalnych z zastosowaniem technik

elektrooporowych. Stwierdzono również, że kleje polioctanowinylowe (wikol i rakol) cechują się prawie identycznymi cechami sprężystymi, powodującymi zbliżone wydłużenie połączeń. Spoiny kleju glutynowego wykazują w stosunku do spoin klejów dyspersyjnych wyższy od 16% do 34% wskaźnik elastyczności, co wpływało na wzrost odkształceń badanych połączeń.

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