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Finite Element Modeling of Fiber Reinforced Polymer-Based Wood Composites Used in Furniture Construction Considering Semi-Rigid Connections

Primjena metode konačnih elemenata za modeliranje drvno-plastičnih kompozita ojačanih vlaknima za uporabu u konstrukciji namještaja s polukrutim vezovima

Original scientific paper • Izvorni znanstveni rad
Received – prispjelo: 11. 3. 2020.
Accepted – prihvaćeno: 15. 7. 2020.
*UDK: 630*824.32; 630*824.52*
https://doi.org/10.5552/drvind.2020.1916

ABSTRACT • *In this study, control samples of pine (Pinus slyvestris L.), beech (Fagus orientalis L.) and oak (Quercus petreae L.) species were obtained by using fiber reinforced finger corner joints. Teknobont 200 epoxy and polyvinyl (PVAc) adhesives were used as glue. Bearing in mind the critical loads that may affect their use, experimental samples were tested under diagonal loads. Experimental samples were also analyzed by a computer program using the finite element method (FEM). Finally, experimental data were compared with the results of FEM. The comparisons clearly showed that experimental results and finite element solutions (SAP2000 V17) including semi-rigid connections are in good agreement. As a structural analysis program in furniture engineering designs, FEM can be preferred in terms of reliability and cost.*

Keywords: *fiber reinforced polymer (FRP); furniture; glue; diagonal tension loading; finite element method (FEM)*

SAŽETAK • *U radu se prikazuju rezultati istraživanja uzoraka borovine (Pinus slyvestris L.), bukovine (Fagus orientalis L.) i hrastovine (Quercus petreae L.) spojenih kutnim zupčastim spojevima i ojačanih vlaknima. Kao ljepilo upotrijebljeno je epoksidno ljepilo Teknobont 200 i polivinilacetatno ljepilo (PVAc). Imajući na umu opterećenja koja se pojavljuju tijekom uporabe, eksperimentalni su uzorci ispitivani pri dijagonalnim opterećenjima. Uzorci su također analizirani računalnim programom primjenom metode konačnih elemenata (FEM). Eksperimentalni podatci i podatci dobiveni FEM analizom uspoređeni su te se jasno može vidjeti da se ti podatci za polukrute vezove podudaraju. Glede pouzdanosti i troškova, kao strukturnom programu analize u dizajniranju namještaja prednost se može dati FEM analizi.*

Ključne riječi: *polimer ojačan vlaknima (FRP); namještaj; ljepilo; dijagonalno opterećenje; metoda konačnih elemenata (FEM)*

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1 INTRODUCTION
1. UVOD

In recent years, Fiber Reinforced Polymer (FRP) plates have been widely used because of their low density, due to their light weight, high resistance to corrosion and chemical effects, and easy application. Engineers and technical staff consistently work on concrete, steel, wood, stone, plastic, glass materials with the aim of obtaining various shapes and proportions of higher strength and more useful materials. In addition, new materials such as high strength glass, carbon, boron, aramide fiber have been developed recently.

In today's wooden structure design, the use of solid wood material, as one-piece in large-sized elements, is not feasible - both economically and technically. In addition, the use of single piece solid wood is limited in the production of load bearing elements. Complete removal of defects is not possible. This situation greatly affects the safety of the wooden structure. On the other hand, the use of solid single piece wood in the production of load bearing elements increases the rate of waste making it economically not viable. For this reason, in the design of wooden structures, it is possible to obtain the structural elements by joining the wood in the desired dimensions. However, the deformations caused by the service load in the wooden joints affect the material negatively. In order to eliminate this negative effect, studies on strengthening the joint regions should be carried out (Akgül, 2007).

In recent years, in the reinforcement of steel and reinforced concrete buildings, the number of applications with fiber reinforced plastics (FRP) in wood structures has been quite common. In wooden structural design, the size of the element depends on the proper joining details. In the performed studies, it has been determined that the joining areas of the designed wooden structures show high performance and that these regions are reinforced by using fiber reinforced plastics (glass reinforced composite plastic (GFRP), etc.) to increase the resistance to tension loads.

There are some reports in the literature on the effects of simulation of wooden materials in furniture construction (Gustafsson, 1995; Gustafsson, 1996; Gustafsson, 1997; Smardzewski, 1998; Smardzewski, 2002; Nicholls and Crisan, 2002; Guindos and Guaita, 2013; Tankut *et al*., 2014). Yorur (2012) reported that using FEM computer modeling enables faster, less costly, more optimized product development and examination of detailed product performance that cannot be observed experimentally. Nestorović *et al*. (2011) performed stiffness tests by using chair models and compared them with modeling analysis. The results of the study showed that the chair should not only be designed to achieve durability but also that the material should be designed properly and material properties should be changed. The literature on the use of finite element method in wooden construction is abundant, but there is not sufficient information on wood glass fiber reinforced material using FEM computer modeling.

In the skeletal system forming a wooden structure, the carrier elements are usually subjected to pressure, shrinkage and bending. Therefore, in this study, reinforcement of the wooden frame constructions, obtained by glass reinforced plastic (GRP) bars, was applied to the corner fasteners, which were subjected to pulling. The internal forces and deformations at the joints were determined by computer-aided structural analysis and then the theoretical and experimental deformations were compared.

2 MATERIALS AND METHODS
2. MATERIJALI I METODE

2.1 Wood
2.1. Drvo

Yellow pine, beech and oak wood used in the preparation of the test samples were obtained from the timber mills in Zonguldak region by random method. The wood samples used were kept in the climate room at a temperature of 20 ±2 ºC and relative humidity of 65 ±5 % until the air dried reached the required parameters.

2.2 Glue
2.2. Ljepilo

Epoxy glue: Teknobond 200 type epoxy, which is produced as a two-component bonding and assembly epoxy, was used for joining wooden surfaces and bonding GRP bars to wooden surfaces.

PVAc glue: It does not wear the cutting tools, it is odorless and non-flammable, cold applied, easy sliding and hardening.

2.3 Glass Fiber Reinforced Plastic (GFRP)
2.3. Plastika ojačana staklenim vlaknima (GFRP)

GFRP materials can be produced by various methods. The profile drawing method is used in CTP molding, especially in the construction sector, in the structure of profile type products, used as both the main material and complementary material. In addition to the box, pipe, I, T, L and U profiles produced by the profile drawing method, profiles with no fixed shape can be produced (Figure 1). In addition to the superior mechanical strength of GFRP material, its lightness, corrosion resistance, low density and good strength/density ratio, low thermal conductivity, lack of additional services such as maintenance and painting for many years, simple production with low labor force, and being easy to cut and machine, CTP profiles are advancing rapidly in the construction sector as an alternative to many materi-

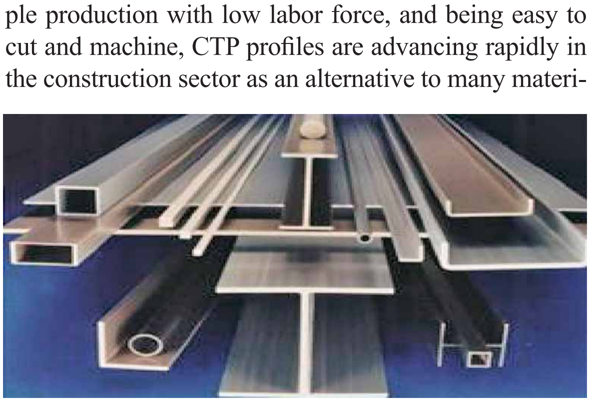


Figure 1 CTP profile samples produced by profile drawing method
Slika 1. CTP uzorci profila proizvedeni metodom crtanja profila

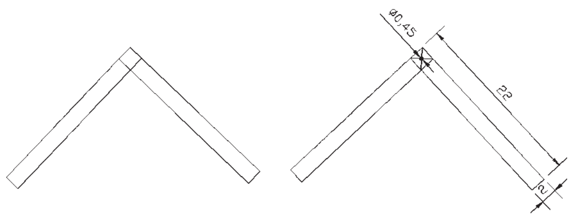


Figure 2 Control and CTP as corner joining elements (cm)
Slika 2. Kontrolni i CTP kutni elementi (cm)

als (www.strongwell.com) due to the fact that they can be easily machined, complex geometry shapes can be easily produced, and they can be produced with different fiber layers and combinations to obtain different mechanical properties (www.strongwell.com).

2.4 Preparation of experiments
2.4. Priprema eksperimenta

Wood test specimens were prepared to be parallel to fiber directions from first class dried, cracked, knotless wood materials with dimensions of 20 mm × 46 mm and length of 220 mm. GFRP rods provided for the strengthening were cut to 5 cm each and placed in a form suitable for wood thickness. In this way, gear corner assemblies, which are especially used in frame constructions, were prepared. Adhesive was applied to the intersection surface of the prepared joints with a total of 160 g/m^2 for both types of glue. The diagonal tension loading was applied to the samples according to the principles set forth in ASTM-D 1037 (Figure 2). 8 samples were repeated in each group.

2.5 Test method
2.5. Metode ispitivanja

The diagonal drawing method, which represents the opening and closing of corner joints due to applied external forces, was determined as the test method (Figure 3). For the experiments, a universal test device was used in Bartin University Forest Faculty Laboratories. Static loading was carried out at a speed of 2 m/s. The

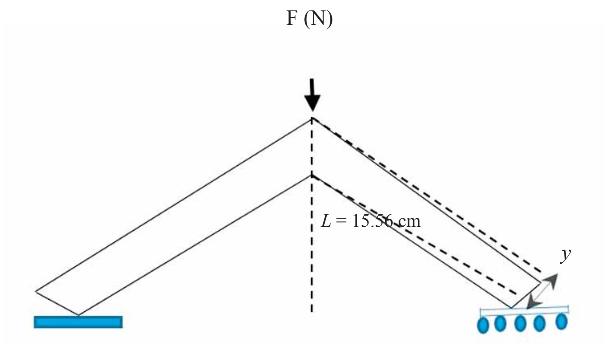


Figure 3 Diagonal tension testing setup (cm)
Slika 3. Postavljanje dijagonalnog ispitivanja (cm)

maximum force values at the time of breaking or joining of the test specimens were recorded on the computer-programmable display connected to the test device.

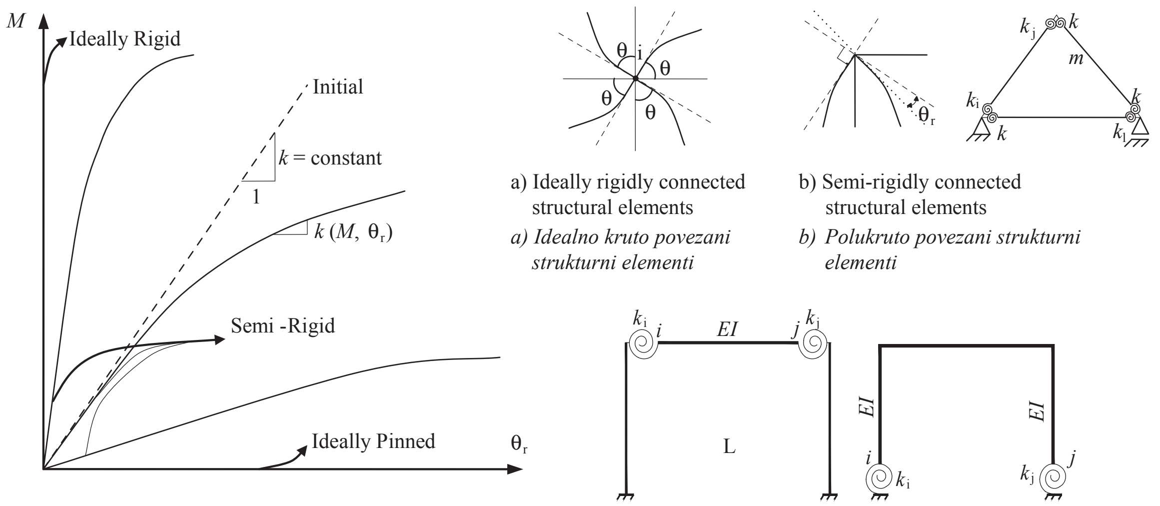
The difference of diagonal tension loading values in CTP samples with respect to the control samples was found by the formula in Eq. 1.

$$\%difference = \frac{Cnt - CTP}{Cnt} \cdot 100 \tag{1}$$

When there is a difference of diagonal tension loading values, *Cnt* represents the values of control samples and *CTP* the values of CTP samples.

2.6 Semi-rigid connection in finite element method
2.6. Polukruti vez u metodi konačnih elemenata

Structural elements and joints are designed based on some idealizations. The joints of idealized frame elements are assumed to be made by ideally rigid connections. However, another assumption is that structural members of truss systems have ideally pinned connection at joints. Actually, structural connections should be named according to their moment-rotation curves. These curves are usually derived by fitting suitable curves to the experimental data. Various types of M-θ_r models have been developed as described by Chen and Lui (1991). As seen from M-θ_r curves given in Figure 4, the



a) Ideally rigidly connected structural elements
a) Idealno kruto povezani strukturni elementi

b) Semi-rigidly connected structural elements
b) Polukruto povezani strukturni elementi

c) Schematic representation of rotation and springs
c) Shematski prikaz rotacije i opruga

Figure 4 Structural connections
Slika 4. Strukturni vezovi

moment (M) is dependent on a function of relative rotation between structural members connected to the same joint. The finite element analyses are mostly performed assuming semi-rigid connections as rigid or pinned connections for simple calculation.

Connection flexibility is defined by various methods. To obtain an initial opinion on stiffness of rotational springs, the use of the modulus of elasticity (E), moment of inertia (I) and length (L) of related beam with constant cross-section is very effective and understandable. Stiffness matrix of a beam in local coordinates can be written using the attributes of this beam as follows (McGuire *et al.*, 1999).

$$[k]=\begin{bmatrix} \frac{12EI}{L^3}\theta_1 & \frac{6EI}{L^2}\theta_2 & -\frac{12EI}{L^3}\theta_1 & \frac{6EI}{L^2}\theta_3 \\ \frac{6EI}{L^2}\theta_2 & \frac{4EI}{L}\theta_4 & -\frac{6EI}{L^2}\theta_2 & \frac{2EI}{L}\theta_5 \\ -\frac{12EI}{L^3}\theta_1 & -\frac{6EI}{L^2}\theta_2 & \frac{12EI}{L^3}\theta_1 & -\frac{6EI}{L^2}\theta_3 \\ \frac{6EI}{L^2}\theta_3 & \frac{2EI}{L}\theta_5 & -\frac{6EI}{L^2}\theta_3 & \frac{4EI}{L}\theta_6 \end{bmatrix} \quad (2)$$

Where $\theta_{1\text{-}6}$ are the coefficients given as follows:

$$\theta_1=\frac{\alpha_i+\alpha_j+\alpha_i\alpha_j}{4(3+\alpha_j)+\alpha_i(4+\alpha_j)} \quad (3.a)$$

$$\theta_2=\frac{\alpha_i(2+\alpha_j)}{4(3+\alpha_j)+\alpha_i(4+\alpha_j)} \quad (3.b)$$

$$\theta_3=\frac{\alpha_j(2+\alpha_i)}{4(3+\alpha_j)+\alpha_i(4+\alpha_j)} \quad (3.c)$$

$$\theta_4=\frac{\alpha_i(3+\alpha_j)}{4(3+\alpha_i)+\alpha_j(4+\alpha_i)} \quad (3.d)$$

$$\theta_5=\frac{\alpha_i\alpha_j}{4(3+\alpha_i)+\alpha_j(4+\alpha_i)} \quad (3.e)$$

$$\theta_6=\frac{\alpha_j(3+\alpha_i)}{4(3+\alpha_i)+\alpha_j(4+\alpha_i)} \quad (3.f)$$

Here, α_i and α_j are the stiffness indexes and can be used to obtain rotational spring stiffness as follows:

$$k_i=\alpha_i\frac{EI}{L} \quad (4.a)$$

$$k_j=\alpha_j\frac{EI}{L} \quad (4.b)$$

Where, k_i and k_j are the rotational spring stiffness at i and j ends of the beam, respectively, and those change in 0-∞ range.

Semi-rigid connection may also be identified by connection percentage. Then, the parameters of θ_i can be written as follows (Chen and Lui, 1991; Kartal, 2004; Filho *et al.*, 2004):

$$\theta_1=\frac{r_i+r_j+r_{ij}}{3} \quad (5.a)$$

$$\theta_2=\frac{2r_i+r_{ij}}{3} \quad (5.b)$$

$$\theta_3=\frac{2r_j+r_{ij}}{3} \quad (5.c)$$

$$\theta_4=r_i \quad (5.d)$$

$$\theta_5=r_{ij} \quad (5.e)$$

$$\theta_6=r_j \quad (5.f)$$

Where, r_i, r_j and r_{ij} are the correction factors obtained as follows:

$$r_i=\frac{3\cdot\nu_i}{4-\nu_i\cdot\nu_j} \quad (6.a)$$

$$r_j=\frac{3\cdot\nu_j}{4-\nu_i\cdot\nu_j} \quad (6.b)$$

$$r_{ij}=\frac{3\cdot\nu_i\cdot\nu_j}{4-\nu_i\cdot\nu_j} \quad (6.c)$$

Here, ν_i and ν_j are the fixity factors and represent the semi-rigid connection as percentage. If the Eq. 3 and 5 are equalized, a set of equations, which provides a direct relation with initial spring stiffness and connection percentage, is achieved as presented in Eq. 7 (Monforton and Wu, 1963; Sekulovic and Salatic, 2001),

$$k_{i,j}=\frac{3\cdot EI\cdot\nu_{i,j}}{(1-\nu_{i,j})\cdot L} \quad (7)$$

Where $\nu_{i,j}$ is the fixity factor, which represents the connection percentage.

After the stiffness matrix [K] and force vector {F} of the system are formed, the displacement vector {U} is obtained from Eq. 7.

$$\{F\}=[K]\{U\} \quad (8)$$

Then the internal forces and moments occurring in the structure, including semi-rigid connections, may be easily acquired.

3 RESULTS AND DISCUSSION
3. REZULTATI I RASPRAVA

The average maximum fracture load in diagonal tension loading obtained from the glue combinations of wood species used in the experiments are given in Figure 5.

As shown in Figure 5, the diagonal shrinkage value of oak species combined with PVAc glue, with respect to the control samples, shows a decrease of about 3 % in CTPs. When combined with epoxy glue, the diagonal tension loading of oak species increases by about 8 % in CTPs. With respect to the control samples, the diagonal shrinkage value of yellow pine species combined with PVAc glue decreases by approximately 9 %. When the connection with epoxy glue is provided, the maximum fracture load in diagonal tension loading of yellow pine species shows a decrease of about 32 % in CTPs. With respect to the control samples, the average maximum fracture load in diagonal tension loading of beech species combined with

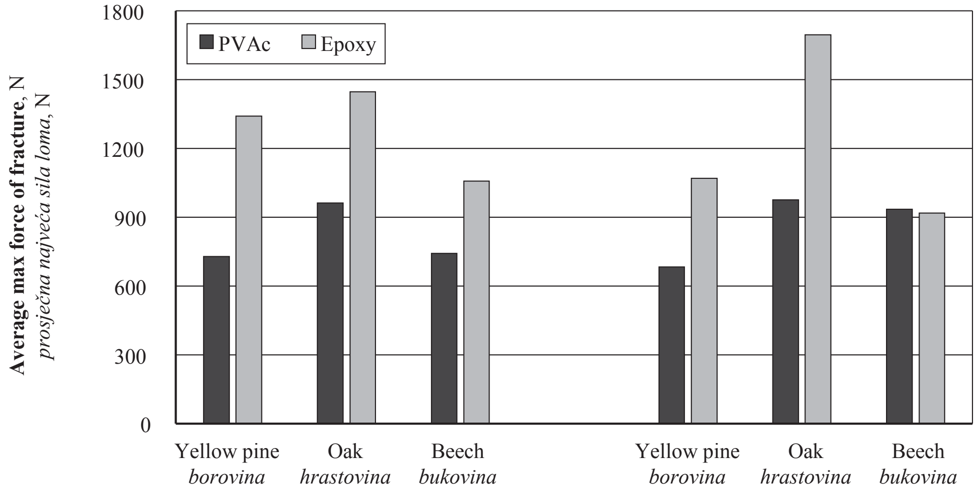


Figure 5 Average max force of fracture in diagonal tension loading
Slika 5. Prosječna najveća sila loma pri dijagonalnom opterećenju

PVAc glue increases by about 30 % in the GFRP samples. When combined with epoxy glue, the average of maximum fracture load in diagonal tension loading of beech species is reduced by about 11 % in CTPs. As a result of the strengthening process, a good result was obtained for oak species combined with epoxy with the combination of beech and PVAc.

The deformations were obtained as a result of finite element analysis carried out using the SAP2000 program under certain load for the wooden frame system. The comparisons of deformation for PVAc and epoxy groups are shown in Figure 6 and Figure 7.

As seen in Figure 6, the results obtained from the experiments of PVAc with respect to the results of

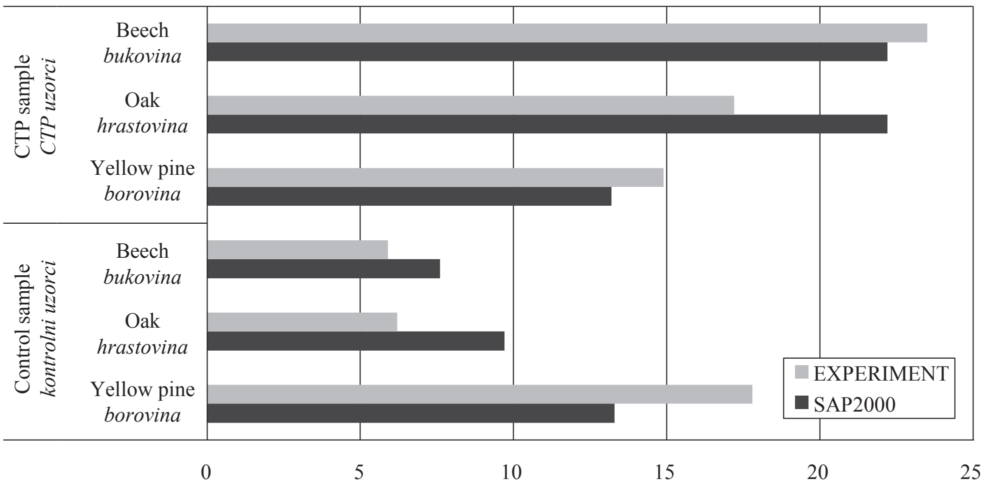


Figure 6 Comparison of PVAc group values obtained by SAP2000 program with experimental results
Slika 6. Usporedba vrijednosti PVAc grupe dobivenih uz pomoć programa SAP2000 s eksperimentalnim rezultatima

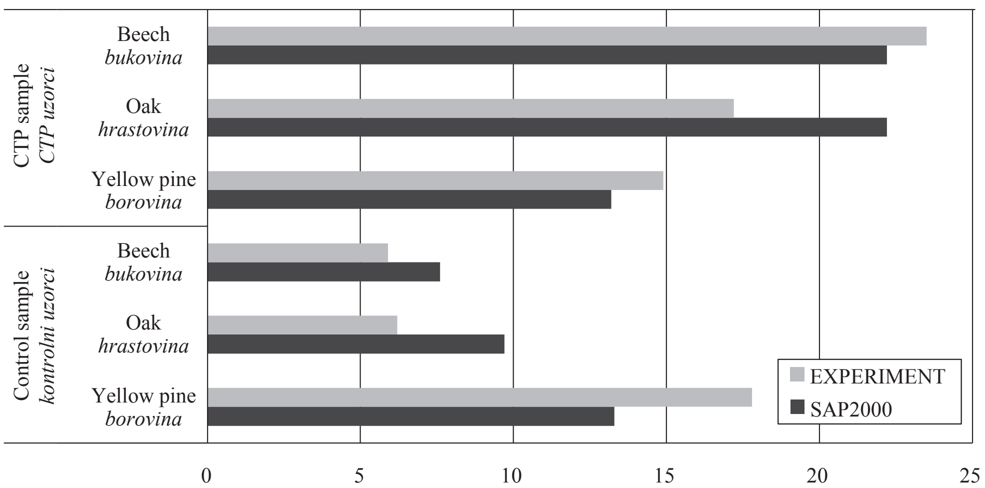


Figure 7 Comparison of epoxy group values obtained by SAP2000 program with experimental results
Slika 7. Usporedba vrijednosti *epoxy* grupe dobivenih uz pomoć programa SAP2000 s eksperimentalnim rezultatima

Table 1 Material properties used in SAP2000
Tablica 1. Svojstva materijala korištenih u programu SAP2000

Wood type *Vrsta drva*	**Density, g/cm³** *Gustoća,* g/cm³	**Modulus of elasticity, N/mm²** *Modul elastičnosti,* N/mm²	**Length of material, mm** *Dužina uzorka,* mm	**Poisson ratio** *Poissonov omjer*
Yellow Pine / *žuti bor*	0.51	11760	220	0.30
Oak / *hrast*	0.71	12500	220	
Beech / *bukva*	0.65	12250	220	

SAP2000 show an agreement of approximately 80-90 %. It was observed that the control samples had less deformation than CTP samples.

As seen in Figure 7, the results obtained from the epoxy group experiments are close to 70-80 % with respect to the results of SAP2000. The control samples showed less deformation than the GFRP samples. At the joining point of CTP bars, the deformation values were found to be higher than those of the control samples and the strength was low.

Static analysis of the load bearing systems consisting of wooden bar elements made of yellow pine, beech and oak were performed. In the analyses, the load effects of the wooden structural elements and the load effects applied in experimental studies were taken into consideration. Table 1 presents the properties of the materials used for wooden structural elements. In the finite element analyses made by SAP2000 program, with the application of FEM, semi-rigidity was used. The geometry of the experimental models used in this study is constant and the finite element model representing these models is given in Figure 8.

In the FEM, yellow pine wooden frame system is considered as control group. In this case, separate combination percentages of PVAc and epoxy glues were determined for yellow pine group. Then, using these percentages, the rotational spring stiffness of the rod ends of the other wood groups were calculated and finite element analysis was performed. As a result of the analysis, comparison was made with the vertical deformation values obtained from the experimental results as shown in Table 2. The same solution algorithm was also performed for GFRP reinforced timber bar systems.

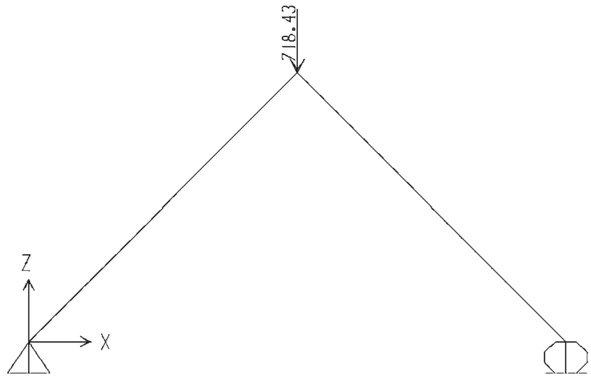


Figure 8 Finite element model of beech wood frame system and loading case (N)
Slika 8. Model konačnih elemenata okvira od bukovine tijekom opterećenja (N)

The finite element analysis and the deformation values obtained from experimental studies are seen in good agreement - about 80-90 %.

4 CONCLUSIONS
4. ZAKLJUČAK

According to the experimental results, a slightly higher diagonal tension loading was obtained from oak combined with epoxy glue and beech combined with PVAc as a result of the strengthening process. When the circle type is selected in the CTP rod corner as the joining element, it is seen that it does not give a good result in the diagonal tension loading.

In this study, wood frame construction was modeled with the SAP2000 finite element program and the

Table 2 Comparison of experimental results with SAP2000 program
Tablica 2. Usporedba eksperimentalnih rezultata s rezultatima dobivenim programom SAP2000

Groups *Grupe*	**Wood type** *Vrsta drva*	**Glue type** *Vrsta ljepila*	**Vertical deformation, mm** *Vertikalna deformacija,* mm	
			Experimental results *Eksperimentalni rezultati*	**SAP2000 Results** *Rezultati programa SAP2000*
Control samples *Kontrolni uzorci*	Yellow pine / *borovina*	PVAc	14.49	14.42
		Epoxy	8.15	8.48
	Oak / *hrastovina*	PVAc	18.03	17.77
		Epoxy	8.5	9.96
	Beech / *bukovina*	PVAc	13.07	13.19
		Epoxy	5.5	7.3
CTP samples *CTP uzorci*	Yellow pine / *borovina*	PVAc	17.37	17.06
		Epoxy	17.62	17.79
	Oak / *hrastovina*	PVAc	24.83	22.29
		Epoxy	10.82	33.45
	Beech / *bukovina*	PVAc	22.62	22.17
		Epoxy	22.2	14.66

obtained analysis results were compared with the results obtained from the experimental study. In the finite element solutions, the rotational spring stiffness of the wooden elements at the connection points is considered as a variable parameter. Based on the above solutions, the results of the SAP2000 analysis showed an agreement of 80-90 % in combination with PVAc glue and 70-80 % in combination with epoxy glue. This case shows that approximate results can be obtained by the boundary conditions of the computer model of experimental mechanism. The boundary conditions are easily applied in the computer program and the restrictions can be met when creating the experimental setup. Inevitably, there can be some mismatch between the experiment and the model in terms of the bearing conditions, initial conditions and approximations. Therefore, this situation leads to a discrepancy in the results. In terms of the bending moment bearing capacity, it may be assumed that the corner connection point should be further tested with the L-type or T-type bars instead of the circular bars. Furthermore, by determining the ratio of partial fixity for each material, the differences between experimental and numerical results can be clearly decreased for further expanded studies.

Acknowledgements – Zahvala

The authors would like to thank the head of the Department of Wood Mechanical Technology and Bartin University for allowing the use of equipment.

5 REFERENCES
5. LITERATURA

1. Akgül, T., 2007: Reinforcement of wood and joints with fiber reinforced polymers. Graduate School of Natural and Applied Sciences, Department of Building Education, Master Thesis. Sakarya University.
2. Çağdaş, S., 2004: Static and dynamic analysis of applied SAP2000 building systems. Turkmen Bookstore, Istanbul, 593 p.
3. Chen, W. F.; Lui, E. M., 1991: Stability Design of steel frames. CRC Press, Boca Raton, FL. Pg: 380.
4. Efe, H.; Kasal, A., 2000: Tensile strength in box assemblies with fixed and disassembled furniture corner joints, G. Ü. Journal of Industrial Arts Education Faculty, 8(8): 61-74.
5. Filho, M. S.; Guimarães, M. J. R.; Sahlit, C. L.; Brito, J. L. V., 2004: Wind pressures in framed structures with semirigid connections. Journal of the Brazilian Society of Mechanical Sciences and Engineering, 26(2): 180-189. http://dx.doi.org/10.1590/S1678-58782004000200010.
6. Guindos, P.; Guaita, M., 2013: A three-dimensional wood material model to simulate the behavior of wood with any type of knot at the macro-scale. Wood Science and Technology, 47: 585-599. http://dx.doi.org/10.1007/s00226-012-0517-4.
7. Gustafsson, S. I., 1995: Furniture design by use of the finite element method. Holz als Roh- und Werkstoff, 53(4): 257-260.
8. Gustafsson, S. I., 1996: Finite element modelling versus reality for birch chairs. Holz als Roh-und Werkstoff, 54(5): 355-359.
9. Gustafsson, S. I., 1997: Optimishing ash wood chairs. Wood Sci Technology, 3: 291-301.
10. Kartal, M. E., 2004: The effect of partial fixity at nodal points on the behavior of the truss and prefabricated structure. MS Thesis, Zonguldak Karaelmas University (in Turkish).
11. Monforton, G. R.; Wu, T. S., 1963: Matrix analysis of semi-rigidly connected frames. Journal of Structural Division, ASCE, 89(6): 13-42.
12. Nestorović, B.; Grbac, I.; Nestorović, P.; Milošević, J. 2015: Application of Reduced Stiffness of Complex Laminate in Finite Elements for Chair Analysis. Drvna industrija, 66(4): 339-346. http://dx.doi.org/10.5552/drind.2015.1445.
13. Nestorović, B.; Skakić, D.; Grbac, I., 2011: Determining the Characteristics of Composite Structure Laminae by Optical 3D Measurement of Deformation with Numerical Analysis. Drvna industrija, 62(3): 193-200. http://dx.doi.org/10.5552/drind.2011.1103.
14. Nicholls, T.; Crisan, R., 2002: Study of the stress-strain state in corner joints and box-type furniture using FEA. Holz als Roh- und Werkstoff, 60: 66-71. http://dx.doi.org/10.1007/s00107-001-0262-0.
15. Sekulovic, M.; Salatic R., 2001: Nonlinear analysis of frames with flexible connections. Computers and Structures, 79(11):1097-1107. http://dx.doi.org/1097-1107.10.1016/S0045-7949(01)00004-9.
16. Smardzewski, J., 1989: Construction optimization of window sashes (in Polish). Przemysl Drzewny, 4: 21-24.
17. Smardzewski, J., 2002: Strength of profi le- adhesive joints. Wood Science and Technology, 36: 173-183. http://dx.doi.org/10.1007/s00226-001-0131-3.
18. Tankut, N.; Tankut, A. N.; Zor, M., 2014: Finite Element Analysis of Wood Materials. Drvna industrija, 65: 159-171. http://dx.doi.org/10.5552/drind.2014.1254.
19. Yorur, H., 2012: Determination of Technological Properties in Simulation (ANSYS) Occasion for Wooden Corner Joints. Phd. Thesis. Bartin Univ., Bartin, Turkey.
20. ***www.strongwell.com (Accessed Feb. 26, 2019).

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