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THE MODEL OF SOLID WOOD BEAMS REINFORCED WITH CARBON FIBERS

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Abstract
The paper is focused on the definition of specialized FEM model which can be effectively used for the simulation of four-point bending beam fracture of solid wood. Reinforcement of wooden beams with high-strength fibers based on carbon brings many advantages over other methods of reinforcement and a very substantial effect on their behavior under load. On based a mathematical model to simulate the load of such beams will be possible to determine the detailed number of factors that will be directed to the precise of knowledge application and behavior of beams reinforced with these fibers. As part of this research was developed analytical computational model based on the possible mode of failure.

Keywords: *wood beams, carbon fibres, reinforcement*

INTRODUCTION

Mathematical processing of data is performed to assess the individual values of monitored variables and the finite element method so that it is possible with a fixed accuracy to confirm or reject a predetermined hypothesis. The main aspects involved in general designing reinforcement of supporting structures of high-strength fibers must take into account the tensile strength, density, mass, modulus of elasticity, corrosion resistance and many others. An equally important aspect is the combination of technology along with reinforcement material. The combination of these elements is most often performed adhesives, depending on the form and type of fiber and also on the type of trussing material. Fiber that was used for testing fiber-reinforced wooden beams was selected based on the type of stress. Since most elements of the beam is loaded with the bend, it was necessary to consider fibers with high tensile strength.

MATERIAL AND METHODS

Paper followed with the research focusing on finding the strength of solid wood reinforced with carbon fiber in the form of fabric [1]. Advantages of carbon fibers are high strength, low density and high elastic modulus. Tensile modulus are 600 GPa, tensile strength up to 4 000 MPa and density of the fibers is around 1.9 kg.m^{-3}. Another indisputable advantage is the high chemical resistance and stability of properties at temperatures up to 2 000 °C.

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They have low thermal and electrical conductivity and low coefficient of thermal expansion also.
For a realistic simulation of stress and violation of wooden beams were used software on the principle of spatial elements in which a mathematical model was created. In the analysis of finite element method (FEM) are used for composite materials (multi-component material) special constitutive models. Recovery software has a number of material models to ensure a successful simulation (reinforcement fibers with high strength, cohesion reinforcement with wooden beam, etc.). Reinforcement is modeled as diffuse stiffening, the specified degree of reinforcement and direction. In modeling the specimen material model will be used for spatial elements Solid 45. This is an 8 - point with spatial elements entering into the calculation not only isotropic, but orthotropic and anisotropic materials. Strips of carbon fiber are modeled by slab-type wall elements Shell 43. This is a 4 - point spatial elements.

Theoretically analyzed beam should ideally simulate the experimental verification of the beam. All beams are examined in carbon fiber reinforced versions. The beam is analyzed by the influence of variable quantities of material on the deflection, bending stress at the top of the beam and the maximum shear stress.

Derivation of the deflection of the beam is the theory of elasticitythan the equation of plane bending deformation line:

$$w'' = -\frac{M_y}{E \cdot I_y}.$$

The solution for the case of four-point bending, in which we use the general arrangement of the bending testing according to ČSN EN 408 [2] and beam with constant bending stiffness we get:

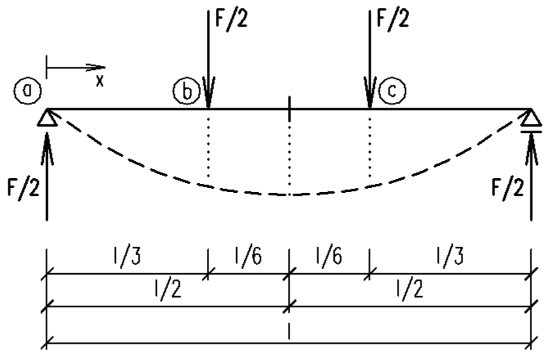

Fig. 1 The four-point bending flexural line, plotted according [3]

RESULTS AND DISCUSSION

To determine the numerical analysis using the theory of elasticity is necessary to describe the different materials, with relevant work (strain) diagrams. Wood will be modeled in the calculations, an ideal elastoplastic model (Fig. 2) without considering the linear hardening.

Tab. 1 Values of wood bending strength f_m, tension f_t, pressure f_c, flexural strength $f_{t,m}$ and bending strength $f_{c,m}$ (MPa), calculated according to [4]

f_m	f_t	f_c	theoretical calculation		testing elements	
			$f_{t,m}$	$f_{c,m}$	$f_{t,m}$	$f_{c,m}$
22	13	20	22	22	22	26
27	16	22	27	25	27	28
30	18	23	30	26	30	30
40	24	26	42	30	41	33
50	30	29	54	35	51	37
60	36	32	67	40	61	41
70	42	34	81	44	71	44

Limiting values of tensile strength and bending strength are taken from Tab. 1 [4].

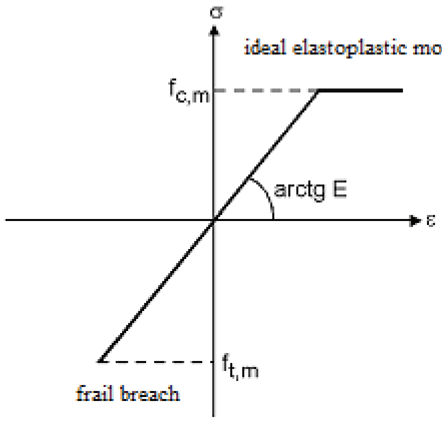

Fig. 2 The ideal elastoplastic model of bending wood [4]

The calculation is based on the stress section, which is spread under condition of linear distortion. During bending strength the beam with solid wood can happen different types of violation by individual conditions stress. Individual states of stress are shown in Fig. 3:

0 - general state of stress, a linear stress distribution over cross section
I - lower wood fibers reach the tensile strength in bending, tension in the upper fiber is less than or equal to the compressive strength in bending
II - upper wood fibers reach the limit of compressive strength in bending, tension in the lower fiber is less than or equal to the tensile strength in bending
III - cross section is partially plasticized, the neutral axis is shifting toward the reinforcement
fibers in the lower stress is less than or equal to the tensile strength in bending
IV - timber reaches the ultimate strength in shear

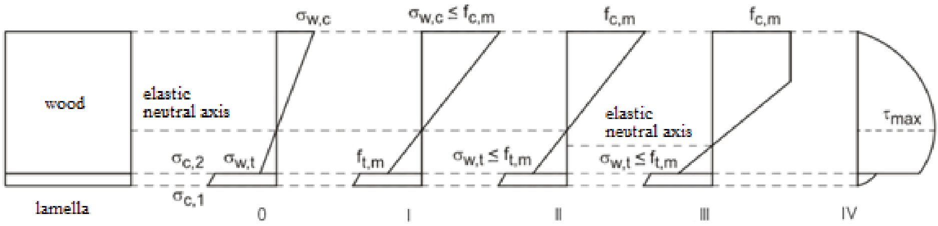

Fig. 3 The states of stress in the bending strength beam

For all states of stress are derived from the cross-resistance torques, ie. maximum shear force to shear stress. Stress Levels I and II are mutually exclusive. There is not considered in violation of lamellae, as is the assumption that the ultimate strength is much higher than the limit strength of the wood, as guaranteed by the manufacturer.

CONCLUSION

The processing methods of research findings in the field reinforcement of wooden beams also include numerical analysis, where the permitted states of stress and expression of their numerical solution. The basic assumption is such resistance of the reinforcing plates that when the load will always a violation of the wood. Then at distinguish bending ultimate load in the lower-drawn fibers, the upper compression fiber plastification compressed fibers and ultimate load in shear. In each state of stress reflect increased load factors reinforced section compared unreinforcing section.

Used carbon fibers are widely used, with one of the suitable options their use in combination with the type of adhesive penetration in composite reinforcing elements for building construction based on solid wood, as shown by simulation modeling of the load.

REFERENCES

1. ROMANI M., BLASS H. J., *Design model for FRP reinforced glulam beams,* International Council for Research on Inovation in Building and Construction, Working Commission W18 - Timber Structures, Meeting 34, Venice, Italy, August 2001
2. ČSN EN 408. Dřevěné konstrukce – Konstrukční dřevo a lepené lamelové dřevo – Stanovení některých fyzikálních a mechanických vlastností. 2004.
3. HOREJŠÍ, J. a kolektiv. Statické tabulky. Praha: SNTL, 1987. ISBN 04-705-88.
4. KUKLÍKOVÁ, A., Kompozitní dřevo-betonové konstrukce. Praha: CVUT, Fakulta stavební, Disertační práce, 2004.

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