18th International Conference
ENGINEERING MECHANICS 2012
Svratka, Czech Republic, May 14 – 17, 2012

pp. 875–878
Paper **#191**

REINFORCED ELEMENTS OF STRUCTURES FROM THE GLUED LAMINATED TIMBER WITH HIGH PERFORMANCE LAMELLA

L. Melzerová[*]

Abstract: *The paper is concerned with an optimal design of high-strength reinforcing lamella made from glued laminated timber structure controlled by the lamella thickness and material. The stepping stone for the present analysis are the results of nondestructive bending tests of thirty beams with different types of reinforcing lamellas adopting two material variants. Six different thicknesses were examined. The FEM models are created such as to exactly represent the tested beams which allows for a reliable comparison of measured and simulated data, e.g. center point deflection. As a next step, new FEM models are created for one particular real beam made from glued laminated timber reinforced by high performance lamella. Both thickness and material of this lamella are modified in individual numerical simulations to estimate an optimal degree of reinforcement with respect to the maximum deflection allowable for a given loading.*

Keywords: ***Glued laminated timber, High performance lamellas, FEM models***

1. Introduction

The paper is concerned with the search for optimal thickness and material of reinforcing lamella introduced into glued laminated timber beam structures. An extensive experimental as well as numerical investigation of real glued laminated timber beams with no additional reinforcements has been described in detail in our previous work suggesting the need for a detailed evaluation of the influence of Young's modulus of elasticity in the fiber direction.

Hereinafter, we extend the previous work by considering an additional reinforcing element in terms of a high strength composite lamella glued at the bottom surface of the beam. Thirty such beams were examined experimentally. The first half of specimens was enhanced by glass-fiber (G) reinforced composite lamella, while carbon (C) fibers based composites were adopted in the second half of the specimens. Three different thicknesses of the reinforcing lamella were considered for each group of composites. Thickness of 2, 4, and 6 mm were assumed for carbon fiber composites (notation C2, C4 and C6). For glass fiber composites the thicknesses of 5, 10, and 15 mm were adopted (notation G5, G10 and G15). The experimental measurements, performed up to failure, were then compared with numerical simulations using again the Finite Element Method (FEM).

Each of the tested specimens was represented by a unique FEM model taking into account not only the type of reinforcing lamella but also the particular material composition of timber selected randomly when preparing the specimens. The center point deflection has been selected again to compare the experimental and numerical results. Next, one of the specimens was selected to numerically investigate the influence of thickness and material of the reinforcing lamella on the beam response.

2. FEM models of thirty reinforced real tested beams

This section describes the simulation part of the work carried out for thirty FEM models split into six groups labeled as C2, C4, C6, G5, G10 and G15 thus resulting into five models for each group. One particular example of such a beam is illustrated in Figure 1.

The center beam deflection is used to assess the degree of agreement between experimental work and numerical simulations. First, this criterion is exploited for a comparative loading of 24 kN of each force in Figure 2 used in our previous study to assess the impact of reinforcing lamella in comparison

---

[*] Ing. Lenka Melzerová, Ph.D.: CTU in Prague, Faculty of Civil Engineering, Department of Mechanics, Thákurova 7; 166 29, Prague; CZ, e-mail: melzerov@fsv.cvut.cz

to the beams with no reinforcement. The comparison between laboratory and numerical experiments is evaluated next for the maximum loading, see Figure 3. As expected, we have not achieved such a good agreement owing to the no nonlinear response prior to fatal failure in experiments not captured by purely elastic simulations. On the other hand, such loadings are not acceptable for real structures in use and therefore the nonlinear branch of loading curve linked to the evolution of cracks has not been investigated in this study. The third loading state considered 48 kN for each force as depicted in Figure 4. In this case, a perfect match between the laboratory measurements and numerical results was achieved.

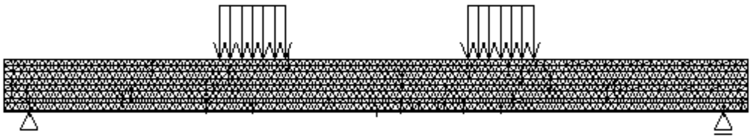

Fig. 1: FEM model of one particular beam

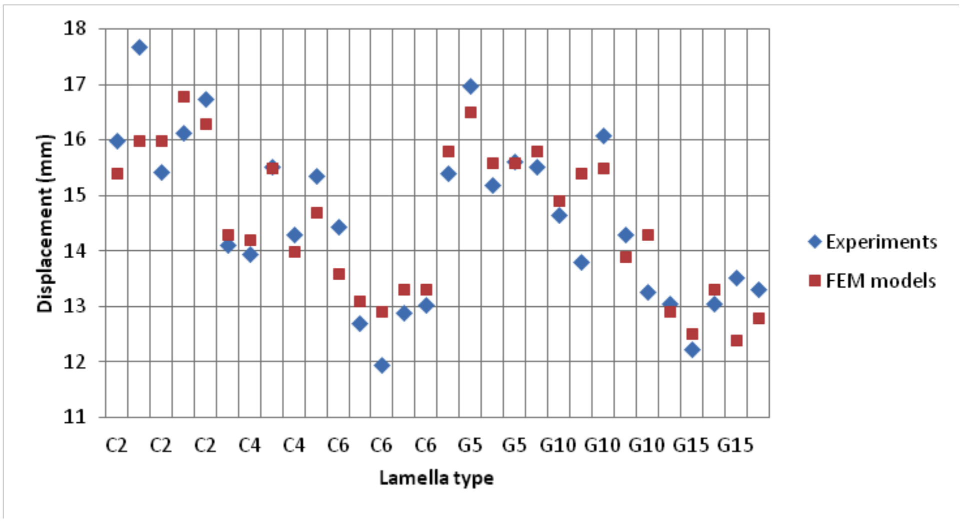

Fig. 2: Comparison between laboratory measurements and numerical simulations for thirty specimens loaded by two forces with the magnitude of 24 kN

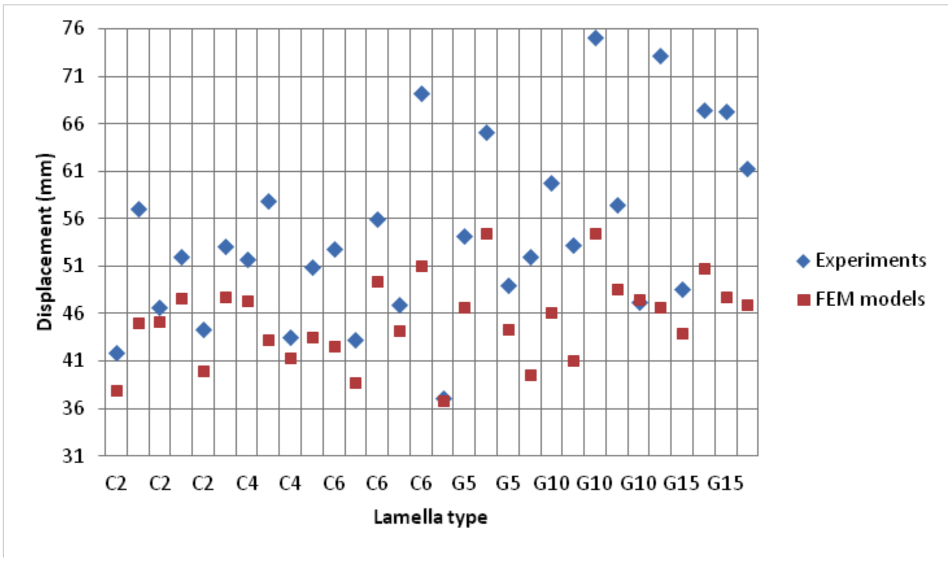

Fig. 3. Comparison between laboratory measurements and numerical simulations for thirty specimens subjected to maximum loading

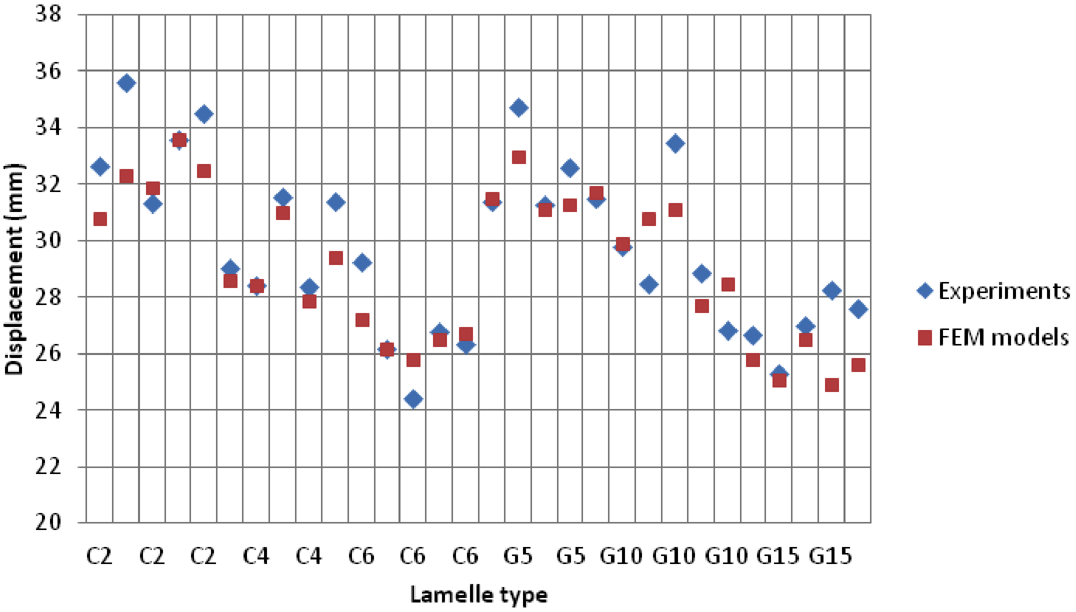

Fig. 4. Comparison between laboratory measurements and numerical simulations for thirty specimens loaded by two forces with the magnitude of 85 kN

3. FEM simulation of different thicknesses and materials of reinforced lamellas

The beam No. 16 was selected for the purpose of optimization. This beam experienced the lowest strength out of all investigated beams. It failed at the compression surface at the load level of 64 kN of each force. A randomly place lamella with low strength was introduced at the top, the most compressed, surface the during production step. The optimization procedure investigated the influence of the reinforcing lamella thickness and its material assuming the load level equal to 48 kN of each force, thus being well within the elastic response of the tested beam. The resulting deflections for both types of materials are plotted in Figure 5. The reinforcing lamellas assumed thickness from 2 to 20 mm with a 2mm step.

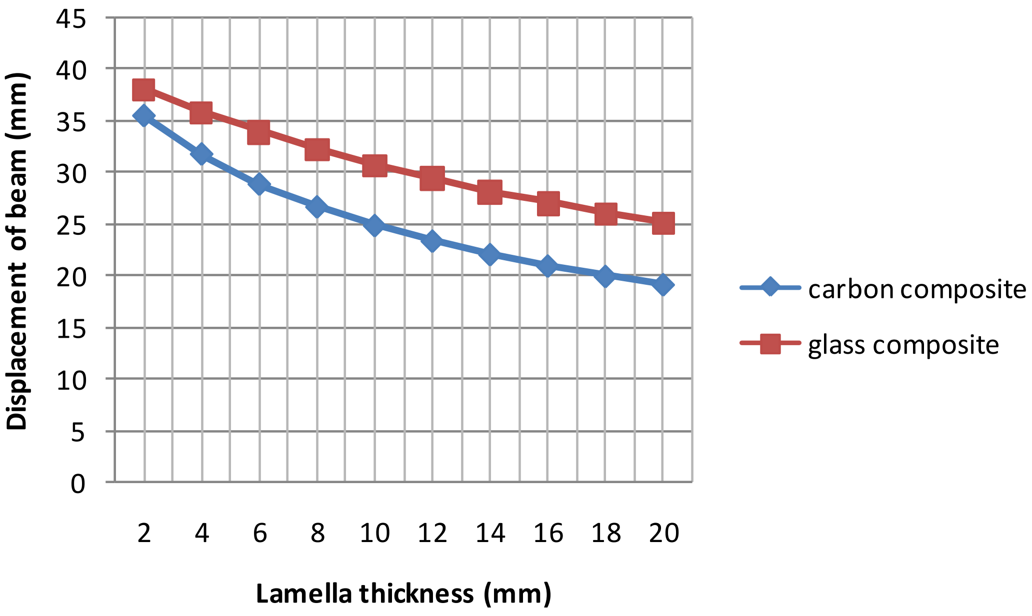

Fig. 5. Evolution of a center point deflection as function of the lamella thickness for the selected beam No. 16 for both types of composites for the loading level of 48 kN

4. Conclusions

It can be seen that the results provided by FEM simulations agree rather well with experimentally derived data. The positive impact of reinforcing lamella manifested by the reduction of maximum deflection is evident. The presented results allow for obtaining an optimal design with respect to three parameters (lamella thickness, deflection and loading). Optimizing thicknesses of both types of composite reinforcements enables to define an optimal reinforcing lamella for each of the beam. This will be subject of future research.

Acknowledgement

This outcome has been achieved with the financial support of the Ministry of Education, Youth and Sports of the Czech Republic, project No. LD12023 advanced methods for design, strengthening and evaluation of glued laminated timber and project No.SGS12/117/OHK1/2T/11.

References

Melzerova, L. and Kuklik, P. (2010) Variability of Strength for Beams from the Glued Laminated Timber, in *Proceedings of the 48th International Scientific Conference on Experimentalni Analyza Napeti 2010 Experimental Stress Analysis*, Smid P., Horvath P., Hrabovsky M., eds., pp. 257-260.

Melzerova, L. and Kuklik, P. (2010) Statistical Research of Mechanical Properties of Glued Laminated Timber Beams, *Metallurgy*, vol. 49, no. 2, pp. 376-380. ISSN 0543-5846.

Melzerova, L. and Kuklik P. (2011) Beams from the Glued Laminated Timber with the High Performance Lamellas and their FEM Models, in *Experimentalni Analyza Napeti 2011*, pp. 237-244.

Melzerova, L., Kuklik P. and Šejnoha M. (2011) Variable Local Modulus of Elasticity as Inputs to the FEM Models of Beams from the Glued Laminated Timber, in *2nd International Conference on Material Modelling.* Paris: TRANSVALOR-Presses des MINES, p. 313.