EAN 2014
52nd conference on experimental stress analysis

Influence of Knots on Character of Rupture and Strength of The Glued Laminated Timber Beams

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Keywords: Glued laminated timber, knots, FEM model, four-point bending, rupture.

Abstract. This article focuses on examination of the effect of the knots distribution on character of rupture and strength of glued laminated timber beams. To simulate glued laminated timber beams the finite element model was made with defects (knots) to simulate and predict behavior in areas containing knots while bending. Results from static bending test of glued laminated timber beam were then compared with the FEM model. The initial position of the rupture was then compared with FEM model [6], so the influence of knots on strength could be determined.

Introduction

In the production of elements made of glued laminated timber are the larger knots removed from lamellas with the help of mechanical sorting of timber, but even then there are areas of element where relatively large number of small knots can occur, which may negatively affect the strength of the material. That's why is important to know behavior of GLULAM beams when they are loaded. For this reason we created the FEM model of glued laminated timber beam to compare theoretical behavior with the reality, so we could make conclusions of what is the effect of knots.

Tested Material

Glued laminated timber beam was used to validate the model. GLULAM beam that was tested was made of spruce wood. Beam had length of 4,5 m, width of 0,1 m and height of 0,32 m. The strength type of glued laminated timber was GL28 (Table 1).

Table 1. Basic properties of GL28 indicated in ČSN EN 1194.

Description	Bending strength [MPa]	Shear strength [MPa]	Density [kg/m^3]	Modulus of elasticity [MPa]
GL28	**28**	**3,2**	**410**	**12 600**

FEM Modeling

Finite element model was constructed using the SCIA Engineer 2013 software, as isotropic beam with the value of modulus of elasticity determined by nondestructive method on actual beam [2, 3].

So the FEM model corresponds to reality as much as possible. Simulation of knots is then carried out by recording the location of larger knots on the beam, so it could be later transferred into the model (Fig. 1).

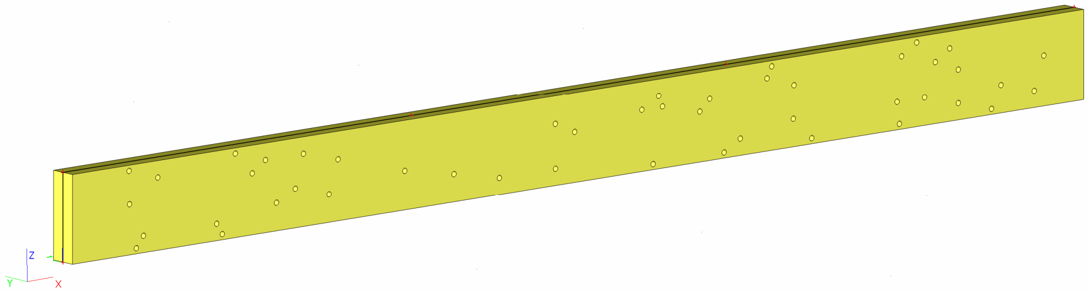

Fig. 1. FEM model with simulated knots.

Every knot with the diameter greater than 4 mm was recorder [5]. In the FEM model (Fig. 1) are then knots considered as holes through beam, with diameter of 2 cm (the average size of knot), in the beam, which is by *Bano V. et al. (2011, p. 8)* the most accurate simulation of the behavior of knots while loading when assuming the homogeneity and isotropy of the material, but the true behavior of the timber is more complex [1, 4, 8]. The loading setup of the model is than the same as it was at the 4-point bending test. The force applied on the beam in the model is corresponding with the force at which the beam ruptured during the four-point bending testing. For FEM model we used finite elements in form of triangles and squares with maximum length of each side of 20 mm.

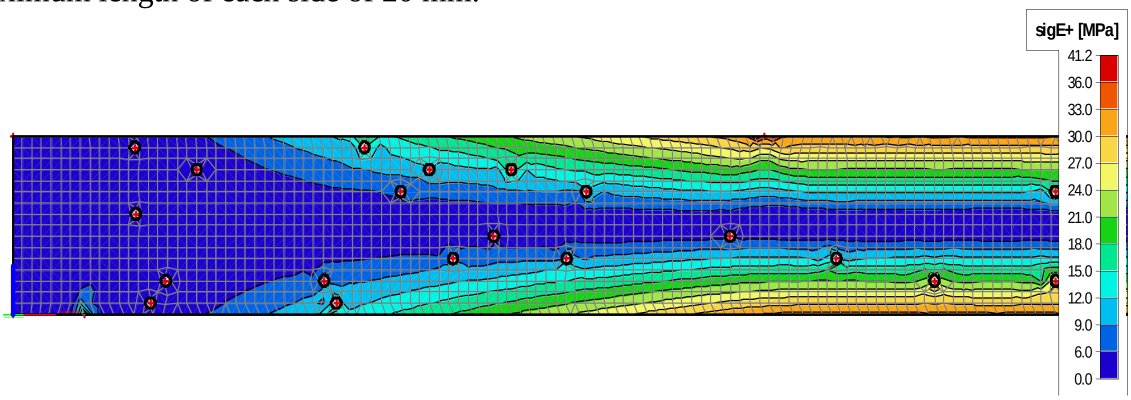

Fig. 2. Results from the FEM model – left half of the beam with grid of finite elements, knots and tension isolines.

When we obtained results from the FEM model (Fig. 2) in form of the picture with isolines of tension or pressure, we could compare those results with the photo of real beam on which the four-point bending test was performed.

Four-Point Bending Test

To measure the characteristics and behavior of the glued laminated timber beams during the real load the four-point bending test was chosen (Fig. 3), in which the beams were gradually burdened until their rupture. This test was performed at the laboratory of Experimental center of CTU in Prague. Testing laboratory of CTU in Prague is acredited to perform static loading tests, which are according to ČSN EN ISO/IEC 17025. The arrangement of the static test was performed so that the beam was imposed on roller bearings, so the actual imposition conditions were as close as possible to conditions contemplated in the theoretical calculations (simple beam). The beam was also secured against tilting in place by steel support brackets. A loading rate was of 2 kN/min until the beam collapsed . The value of the force needed for the beam to collaps was recorded and used in FEM model.

Fig. 3. Four-point bending test set up.

Conclusions

By creating quite a corresponding FEM model of glued laminated timber beam could be verified whether the rupture of the beam occurs in the areas around the outer knots, where at the model occurred a local concentrations of stress around the knots in the bottom lamella [7]. When comparing the model situation with reality, Fig. 1, it is apparent that the rupture occurred precisely at the point where the model showed around the knots the largest value of tension.

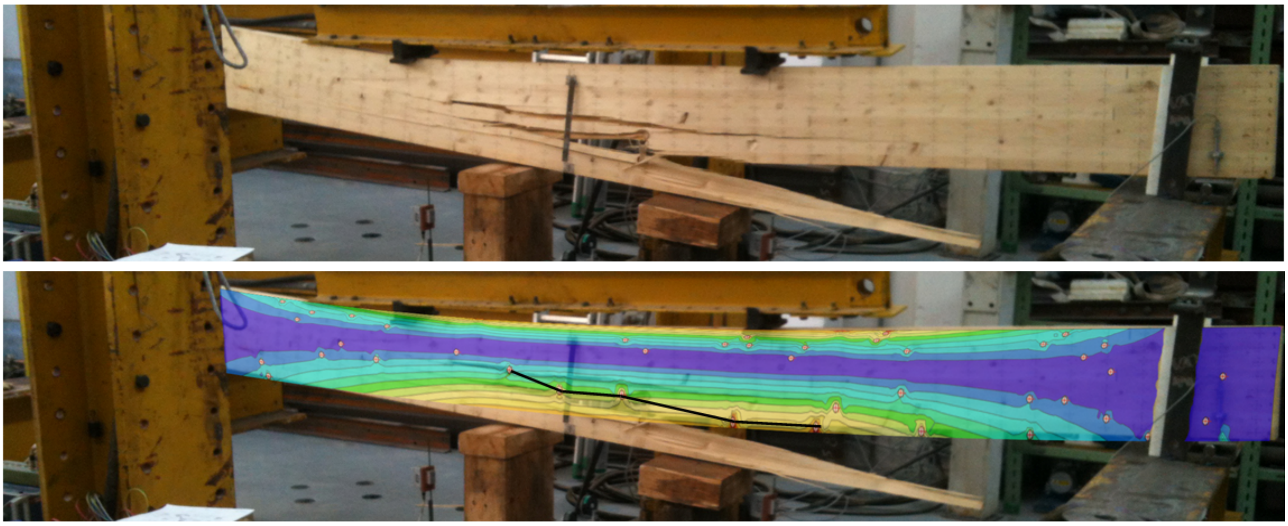

Fig. 4. Comparison of 4-point bending result and FEM model with rift line highlighted.

A rift then continued across the beam where there was another local concentration of stress in knots (as highlighted in detail in Fig. 5). Area of the beginning of the rift was located in the right part of the beam, but a common assumption states that the greatest stress should arise at midspan [5].

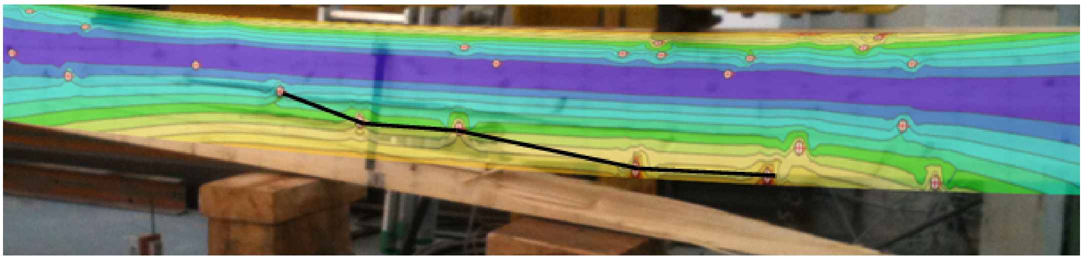

Fig. 5. Detail of rupture position according to FEM model and reality.

We can than conclude that the distribution of knots and their position can affect the overall load carrying capacity of glued laminated timber and especially the character of the rupture/rift. The FEM model can also indicate that the greatest influence on the load bearing capacity and position of rupture have knots that occur in the outer parts of the beam near the midspan. From this we can deduce, for example, recommendations for manufacturing etc.

All this research has been conducted on a single beam for now, but it will be and have to be conducted on more beams to validate the results. Whole research will expand and will be part of a more complex examination of glued laminated timber beams.

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 SGS 14/122/OHK1/2T/11.

References

[1] V. Bano, F. Arriaga, A. Soilan, M. Guaita, Prediction of bending load capacity of timber beams using a finite element method simulation of knots and grain deviation, Biosystems Engineering 109 (2011) 241-249.

[2] S. Cramer, Y. Shi, K. McDonald, Fracture modeling of lumber containing multiple knots, in: Proceedings of the international wood engineering conference, Lousiana State University, New Orleans, 1996, vol. 4, pp. 288-294.

[3] H. Danielsson, P.J. Gustafsson, A probabilistic fracture mechanics method and strength analysis of glulam beams with holes, European Journal of Wood and Wood Products 69 (2011) 407-419.

[4] P. Klapálek, Vliv rozložení suků na pevnost nosníků z lepeného lamelového dřeva, diplomová práce, Katedra mechaniky, Fakulta stavební, ČVUT v Praze, Praha, 2013.

[5] L. Melzerová, P. Kuklík, M. Šejnoha, Variable local moduli of elasticity as inputs to FEM-based models of beams made from glued laminated timber, Technische Mechanik 32 (2012) 425-434.

[6] L. Melzerová, M. Šejnoha, Interpretation of results of penetration tests performed on timber structures in bending, Applied Mechanics and Materials 486 (2014) 347-352.

[7] P. Padevět, P. Bittnar, Creep of cementitous materials with addition of fly ash in time, Advanced Materials Research 742 (2013) 182-186.

[8] T. Plachý, P. Tesárek, R. Ťoupek, M. Polák, Monitoring of mechanical properties evolution of the cast gypsum, Procedia Engineering 48 (2012) 562-567. (Conference Paper)