Numerical analysis of the wood-base composite beam strengthened in the weakened zones by CFRP

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Abstract

This paper treads about the mechanical behaviour of the wood-based beams. The laboratory tests of I-beam show considerable decrease of capacity in the weakened zones e.g. connection between to parts of pine wood used as a flange. We propose to strength the zones by fibre composite tapes based on carbon CFRP. The main goal of the paper is to estimate the influence of the reinforcement by numerical analysis and finally predict the behaviour of the new structure taking into account the loss of connectivity between the both materials wood-CFRP.

Keywords: wood-base composite beam, strengthening, FRP, delamination, FEM, laboratory tests

Introduction

This paper concerns the analysis of deflections and stresses in I-beams made with wood and wood-based materials reinforced by CFRP [2, 3, 5]. The laboratory tests of I-beam show considerable decrease of capacity in the weakened zones e.g. connection between to parts of pine wood used as a flange. We propose to strength the zones by fibre composite tapes based on carbon CFRP. The main goal of the paper is to estimate the influence of the reinforcement by numerical analysis and finally predict the behaviour of the new structure taking into account the loss of connectivity between the both materials wood-CFRP. The presented numerical results are done with full adhesive assumption between CFRP and wood [2].

Laboratory test

Experimental investigations of I-beams made with wood and wood-based materials were conducted at the laboratory in the Institute of Building Engineering at the University of Zielona Góra.

Figure 1: I-beam in the laboratory

The I-beams of natural dimensions made of pine wood and OSB board, were examined in the four-point bending test (Fig. 1 and 4). The test equipment used shall admit testing in accordance with the principles given in EOTA TR 002 [1].The load-carrying capacity and flexural rigidity were measured during tests.

Figure 2: Destroyed connection in tension wooden flange

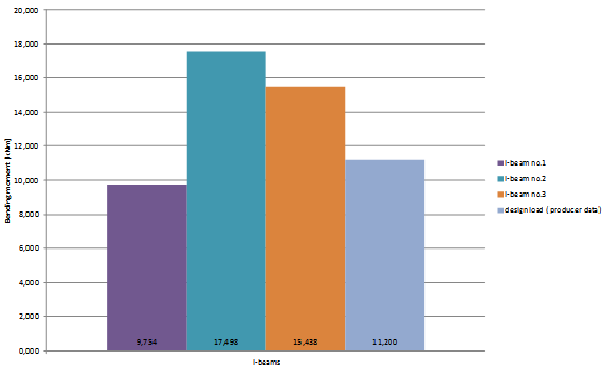

Figure 3: Decrease of the load-carrying capacity

The obtained experimental results demonstrate that the quality of tension wooden flange turned out to be decisive for the load-carrying capacity of the I-beams (Fig. 2 and 3).

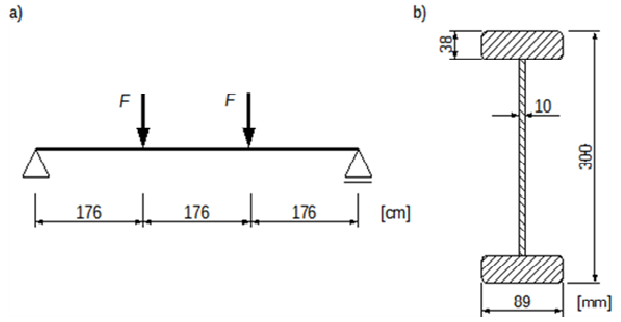

Figure 4: Static schema and cross section of I-beam

Decrease of the load-carrying capacity of the I-beams when poor quality connections are in the middle of the span, is shown in Fig. 3 (about 17%).

Strengthening layer

The carbon fibre reinforced polymer (CFRP) strips are widely used in the civil engineering to optimize the ratio between the weight of structure and load capacity [2, 3, 5, 6, 7]. Using CFRP as an additional layer the capacity of the new composite structure could be increased with-out change of cross section. In the work two cases are considered, one with the CFRP tape glued along whole bottom surface of the beam and the second one where the tape is strengthening the sectors where the bottom flange is connected (the weakened zone).The anchor length has to be determined for the segment reinforcement with the following formula:

$$l_{CFRP} \geq \frac{f_{m,k} W_g E_{CFRP} h_{CFRP}}{W_d E_{OSB} f_{v,k}} \qquad (1)$$

The CFRP tape is glued to the bottom surface of the bottom flange and the reinforcement percentage is equal 1%.

Numerical model

Numerical model of simply supported beam is developed in the ABAQUS 6.14-5 (Fig. 5).

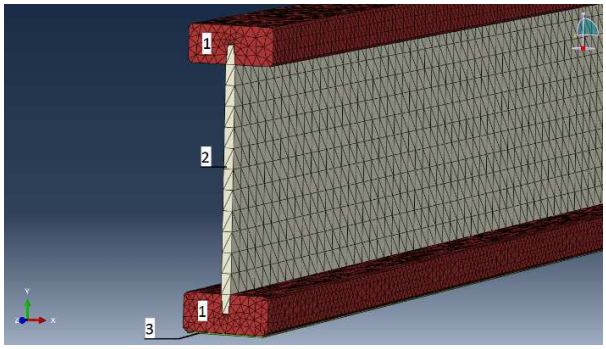

Figure 5: Numerical model of beam: 1) flange made of solid wood, 2) OSB-3 board, 3) CFRP

The finite element with family 3D stress (C3D10 An 10-node quadratic tetrahedron) is used in the model. The linearly-elastic material model and contact type Tie are applied in the first approximation. CFRP tape is glued along the entire length of the bottom.

The used material parameters:
OSB-3 board – E = 4.93 GPa, v = 0.2,
Solid wood – E = 11 GPa, v = 0.2,
CFRP – thickness =1.2 mm, width =80mm, E = 165 GPa, v = 0.2.

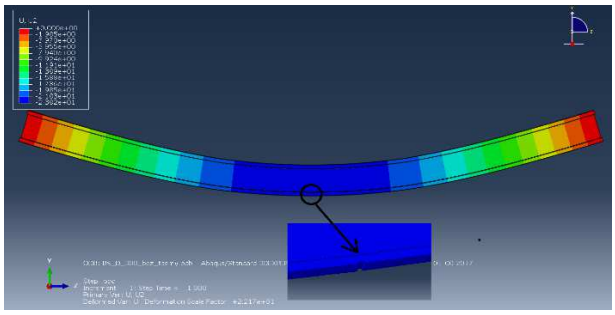

Figure 6: Distribution vertical displacements in the weakened beam.

Conclusions

The numerical results of the test with-out CFRP layer are in good agreement with laboratory test. The influence of reinforcement is considerable and increases the load capacity about 27%. In the future work the complex behaviour of a glue layer has to be taken into account. The layer is quite sensitive and some unexpected failure could appear in the layer especially in the surrounding of knots and the flanges connections (stress concentration). It could provide to the loss of connectivity called delamination [4].

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