FEA Analysis of Steel-Timber Composite Beams

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Abstract. The present study investigated the structural behaviour of steel-timber composite (STC) beams. In the analysed system, a timber slab was connected to a steel beam with mechanical shear connectors. Non-linear 3D finite element (FE) models of the STC beams were verified against experimental results available in the literature. The comparison between the numerical and experimental results demonstrates that the adopted 3D model can adequately capture the response of the STC beams.

1. INTRODUCTION

The steel-timber composite structures (STC) were investigated by Hassanieh, Valipour and Bradford [1-3]. They conducted laboratory tests of the STC beams and connections. They also developed 1D frame and 2D continuum-based non-linear FE models of the STC beams using OpenSees and Abaqus software respectively. The authors of this paper prepared 3D FE models of the STC beams using the Abaqus program.

2. NUMERICAL MODEL AND ANALYSIS

The 3- and 6-meters-long STC beams were modelled in the Abaqus program. The timber slabs were connected with the steel beams using zero length wires which behaved as zero length springs. The spring stiffness was equal to the slip moduli $k_{s,0.6}$ of the connectors determined in [1]. The surface-to-surface "hard" contact and friction were defined between the upper flanges of the steel beams and the bottom edges of the timber slabs, and between the steel plates and the upper edges of the timber slabs. The friction coefficient was 0.3. The steel stiffeners were joined with the steel beams using the *tie* function. The timber slabs were divided into eight-node cuboidal finite solid elements (C3D8R), the steel beams, the steel stiffeners and steel plates were divided into four-node shell elements (S4R) (see Fig. 3). The total number of all elements was 7914 for 3 meter beam and 12 856 for 6 meter beam. The calculations were performed using the Newton-Raphson method. The dead load of the STC beams was taken into account. The mean density of the materials and the gravitational acceleration (9.81 m/s^2) were defined in the material models. Figure 1a presents the boundary conditions used in the computer model (blocked displacements and rotations).

A tri-linear stress-strain relationship was used for modelling 300PLUS grade steel (E = 200 GPa, f_y = 320 MPa, f_u = 440 MPa, ν = 0.3, γ = 7850 kg/m^3) and 350 grade steel (E = 200 GPa, f_y = 360 MPa, f_u = 480 MPa, ν = 0.3, γ = 7850 kg/m^3). The timber was modeled in four variants. In the first variant, it was modelled as an isotropic material (E = 13.2 GPa, ν = 0.4, γ = 600 kg/m^3) and using a multilinear stress-strain relationship. In the second variant, the timber was modelled as an orthotropic material (E_1 = 12.157 GPa, E_2 = E_3 = 0.426 GPa, Nu_{12} = Nu_{13} = 0.48, G_{12} = G_{13} = 0.85 GPa, G_{23} = 0.96 GPa, γ = 600 kg/m^3) and using a multilinear stress-strain relationship. In the third variant, the timber was modelled as an isotropic material (E = 13.2 GPa, ν = 0.4, γ = 600 kg/m^3) and using the Drucker-Prager model available in the Abaqus program (angle of friction = 30°, flow stress ratio = 1.0, dilatation angle = 40°, Drucker Prager hardening yield stress: 40.0 MPa, 60.0 MPa, 48.0 MPa, Drucker Prager hardening abs plastic strain: 0.0, 0.005, 0.009). In the fourth variant, the timber was modelled as an orthotropic material and using the Drucker-Prager model.

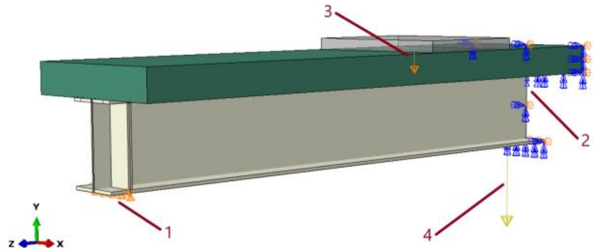

FIGURE 1. Boundary conditions: 1 – displacement in *y* direction (blocked), 2 – displacement in *z* direction (blocked) and rotation around *x* and *y* axes (blocked), 3 – displacement in *y* direction, 4 – dead load

3. RESULTS

Figure 2a shows the load versus the mid-span deflection from the laboratory tests [2] and FEM analysis. Figure 2b shows the load versus the end slip of the beam, obtained from the laboratory tests [2] and numerical calculations.

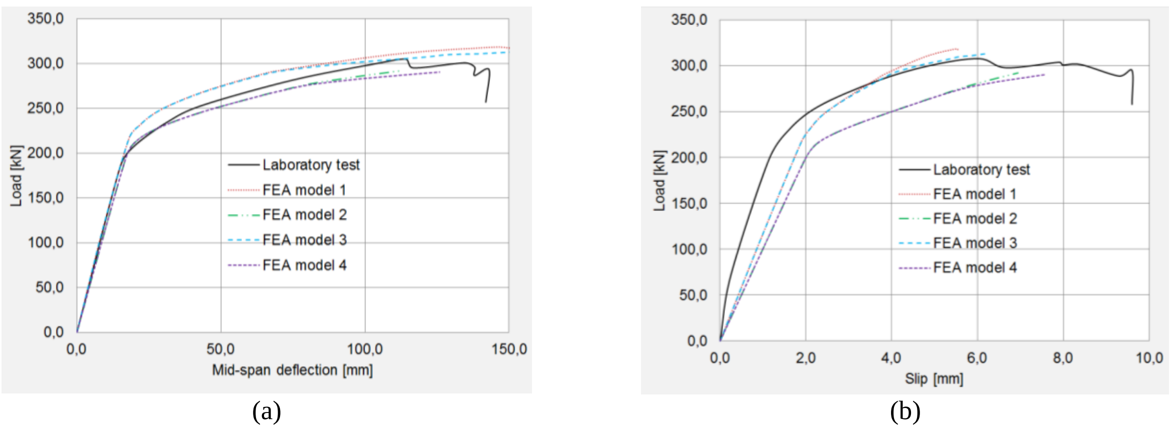

FIGURE 2. Results for the three-meter beam: a) load versus mid-span deflection, b) load versus end-slip

4. CONCLUSIONS

The main conclusions of this paper are:

- The adopted 3D FE models adequately captured the load-deflection relationship.
- In the case of FE models, there was an insignificant difference between using an isotropic material and using an orthotropic material for LVL. The difference between using a plastic model or using a Drucker-Prager model for LVL was also insignificant.
- The load-slip relationship was not reflected so well as the load-deflection relationship. The slip was calculated as a difference between the displacement of the timber slab and the displacement of the steel beam at the end of the STC beam. The authors did not have sufficient information about the slip measurement method during the laboratory tests.

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