# DIFFERENCES IN COMPRESSIVE AND TENSILE PROPERTIES OF CORE AND FACINGS IN SANDWICH PANELS

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## 1. Introduction

Sandwich panels are widely used in civil engineering due to their advantageous properties such as high strength to weight ratio, good thermal insulation and ease of transport and assembly. The idea of a sandwich structure allows the use of diverse core and facing material combinations to obtain a composite with properties customized for a specific application. However, the intrinsic difference in stiffness of facing and core layers makes predicting the panel's failure mode a difficult task. Depending on materials used, the panel's geometry, and the type of loading, failure might be caused by local facing buckling, global panel buckling or reaching a limit stress in any of the panel's layers [1, 2].

Accurate assessment of material parameter values for core and facings is essential in sandwich panel design. The current research concentrates on taking into account differences in property values caused by material response dependence on the stress state. The panel under consideration is composed of expanded polystyrene (EPS) core and magnesium-oxide (MgO) board facings and is classified as a composite structural insulated panel (CSIP) [3, 4]. Presented material property values for both constituents are based on own experimental research [5] and literature. Pertaining computational analysis consists of two stages: (1) numerical replication of small-scale bending tests on CSIP beams and (2) numerical simulation of flexure tests for full-scale panels [6]. FEA is performed using commercial Abaqus software [7] and a self-created user procedure.

## 2. Component material properties

Common core materials used in sandwich panels are structural foams, such as EPS, which have a complex microstructure that behaves differently in different loading conditions. As one can observe the microstructure's struts buckle quite easily in compression while in tension they typically stretch until fracture. In consequence effective material properties in macro-scale depend on the stress state in micro-scale [5, 8]. Such phenomena should be taken into account in cases where localised loads are involved. MgO board is a composite consisting of MgO cement mixture matrix and a glass-fibre mesh reinforcement on its top and bottom surfaces [3]. Reinforcement meshes carry loads in tension but are inactive in compression, which causes the difference in effective property values. Main material parameter values for both constituents in different loading conditions are presented in Table 1. EPS parameters given for three different densities (in kg/m$^3$) are provided as mean values, whereas MgO board properties are shown as extremes.

| | MgO min | MgO max | EPS 15 | EPS 19 | EPS 21 |
|---|---|---|---|---|---|
| $E^c$ [MPa] | 2430 | 3886 | 5.0 | 5.4 | 6.8 |
| $E^t$ [MPa] | 5750 | 8040 | 7.2 | 9.2 | 10.5 |
| $v$ [-] | 0.18 | 0.18 | 0.09 | 0.11 | 0.12 |
| $\sigma_y{}^c$ [MPa] | 5.0 | 18.2 | 0.07 | 0.09 | 0.10 |
| $\sigma_y{}^t$ [MPa] | 4.8 | 6.1 | 0.12 | 0.15 | 0.16 |

Table 1: Material properties of MgO board and EPS; $E$ – elasticity modulus, $v$ – Poisson number, $\sigma_y$ – yield stress, $c$ – compression, $t$ – tension.

## 3. Numerical analysis

Commercial Abaqus software [7] has been used to perform a numerical recreation of CSIP beam bending tests. Beams of three different lengths have been tested (Figure 1) under two types of loading conditions (12 samples in total). A half of the tests has been carried out as three-point bending (3PB) and a half as third span four-point bending (4PB) [5]. In FEA samples have been modelled with a dense mesh of plane stress 4-node reduced integration elements. Since no debonding has been observed in laboratory tests a perfect bond between adjacent constituents has been assumed. Supports and loads have been realized with rigid body objects. Geometrical nonlinearity has been taken into account as well as material nonlinearity for both core and facings. Drucker-Prager material model has been applied in all layers.

The most challenging part was associated with an automatic change of material parameters in accordance with changes of stress state. In order to do so, a user defined procedure has been created. The procedure generates an additional variable in every integration point, its value ranging from -1 to 1 and being updated with each increment. Material data for elastic, inelastic and failure states have been then linked with this variable in such a way, that compression values have been used for -1, tension values for 1 and linear interpolation has been used for intermediate states. Numerical results obtained were in a reasonably good agreement with the test data (Figure 1).

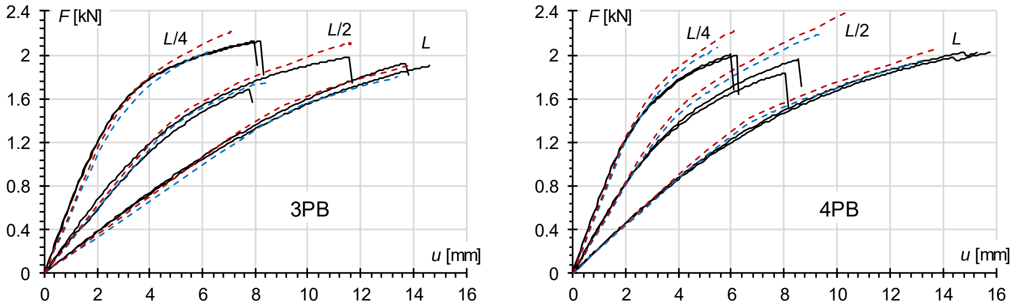

Figure 1: Comparison of FEA results (dashed lines) with test data (continuous lines) for 3- and 4-point bending; red – MgO max, blue – MgO min, *L* – CSIP beam length.

The final stage of this research will comprise of numerical experiments performed on full-scale panels of varying length to core thickness ratios. This analysis will aim to determine how sensitive to core crushing are the CSIPs in question and when it is necessary to take the advanced material phenomena into account.

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