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THE INFLUENCE OF INHOMOGENEITY OF THE CORE MATERIAL ON THE BEHAVIOR OF THE SANDWICH PANEL

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1. INTRODUCTION

Polymer foams are widely used in various areas of engineering. In this paper sandwich panels, composed of thin metal sheets and a thick foam core, are considered. In the literature, it is possible to find many papers focused on sandwich structures, their applications, experimental tests or different approaches for modelling. The vast majority of them assume that the core consist of an isotropic, linear-elastic and homogenous foam [1-3]. Then, only two independent material parameters are needed to describe the material. Usually, they are the Young's modulus E and the shear modulus G. These parameters play significant role in a structural response. In fact, when the material has porous structure, like a polyurethane foam, the identification of mechanical properties is an intricate task [4]. The main problem is in their intrinsic anisotropy and non-homogeneity. Previous works concern the anisotropy of the core in sandwich panels [5-6]. Therefore, the aim of the present work is to extend this knowledge by studying the changeability of Young's modulus on the thickness of the sample and their influence on the wrinkling stress of sandwich panels. The impact of the size of geometric imperfections is discussed.

2. PROBLEM FORMULATION

Observing the sample during the tensile (or compression) test, changes in distribution of deformation on the thickness of the sample can be observed (Fig. 1). Intrinsically, it reflects the inhomogeneity of the material properties.

The aim of this work is to experimentally determine the variability of the Young's modulus on the thickness of the sample. Next, the impact of their variability on the load-bearing capacity of the sandwich panel will be studied. The analysis will be carried out for plates with various thicknesses and two different spans: $L = 3.0$ m and $L = 5.0$ m.

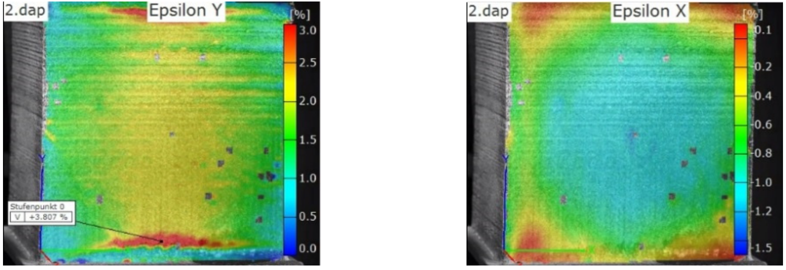
(a) (b)

Fig. 1: Tension test (a) longitudinal strains, (b) transverse strains.

3. NUMERICAL MODEL

Finite element method models are created in Abaqus simulation software package [7]. The geometrically nonlinear static analysis is used. The problem is solved using Newton-Raphson procedures. Numerical instability is used as a failure criterion. Geometric imperfections are introduced as a combination of five buckling modes with the multiplier equal to 1 mm, 0.5 mm and 0.1 mm.

In this paper, steel faces are modelled using four node thin shell nonlinear finite elements, referred as S4, with the size of 2 x 2 cm. The core is modelled using eight node linear brick elements C3D8 (3D element) with the size of 2 x 2 x 2 cm. S4 and C3D8 elements with full integration in stiffness computation are used in order to avoid non-physical phenomenon like hourglassing. Additionally, these elements give more accurate results in stress field for deformed elements, especially, when wrinkling phenomenon occurs. The "tie" interaction has been used between the layers facing-core-facing, what correspond to constrained degrees of freedom of corresponding sheet and core nodes. The core is divided into the parallel regions to enable the possibility of assigning various materials to core's layers. Each region corresponds to the particular layer of finite elements on the core's thickness.

The panel is supported by two basing plates ($b = 100$ mm) modelled as rigid bodies. The right supporting basing plate is free to rotate with respect to Y axis, whereas the left basing plate differs only in that, it has the possibility to move in the X direction (Fig. 2). The contact interaction between supports and sandwich panel (lower sheet) is used, with the friction coefficient equal to 0.3 and no penetration allowed. The panel is loaded by uniform pressure q.

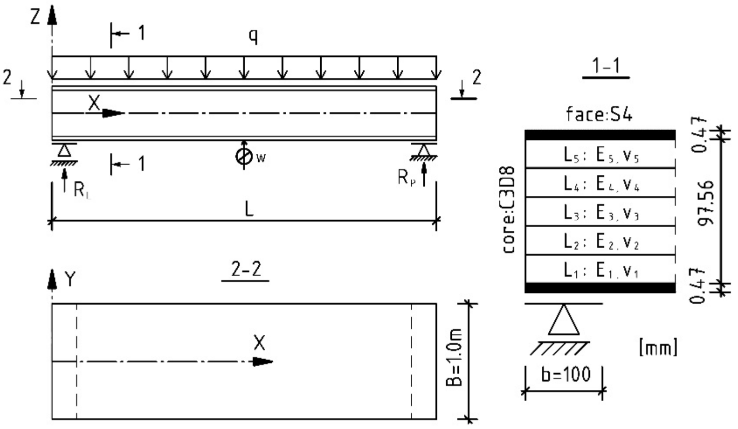

Fig. 2: Geometry and the scheme of simply-supported panel with layered core.

4. NUMERICAL SIMULATIONS

In numerical analyses, the steel facings are assumed flat and covered by zinc, what results in Young's modulus $E_F = 195$ GPa and Poisson's ratio $\nu_F = 0.3$. Moreover, the actual stress-strain relationship is introduced based on the laboratory test. In the tensile test, the obtained yield strength is equal to 360 MPa and the ultimate strength reached 436 MPa. These relationships are used for modelling of the elastic and plastic behavior of sheets. Foam material is assumed to be isotropic. The basic parameters are obtained from test performed in thickness direction of a sandwich panel. Young's modulus E_C and shear modulus G_C play crucial role if an isotropic material model is used for core modelling. These parameters are taken as: $E_C = 5.26$ MPa and $G_C = 3.0$ MPa [6].

The first example corresponds to the panel, which has non-layered core. So, the material parameters do not changes on the thickness. Panels with two different spans are analyzed: $L_1 = 3.0$ m and $L_2 = 5.0$ m. In the first step the influence of the size of imperfection is analyzed. Obtained results are shown in Fig. 3 and summarized in Table 1.

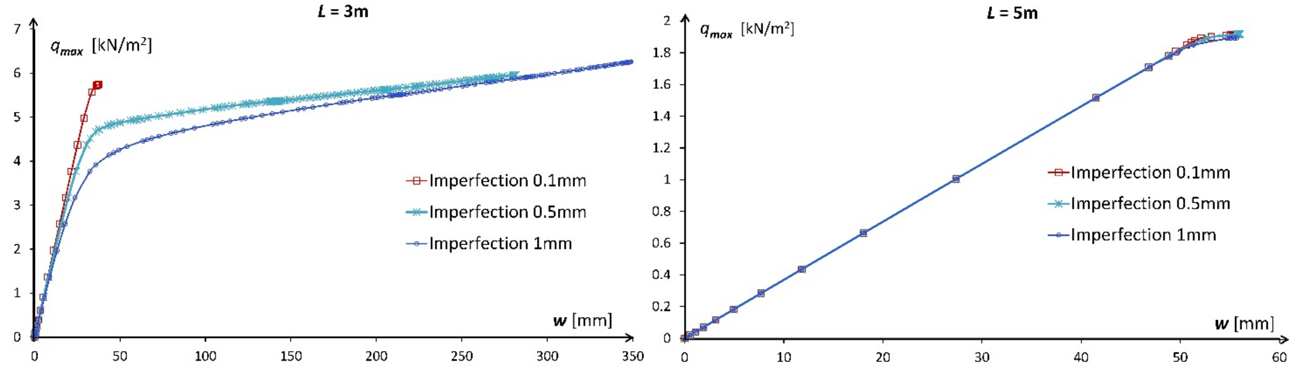

Fig. 3: The influence of the size of imperfections multiplier.

Table 1: Results.

Span	Imperfection [mm]	$q_{\max}$ [kN/m²]	w [mm]	σ_x [MPa]
$L_1 = 3$m	0.1	5.74	37.58 / 35.40*	141.0 / 138.71*
	0.5	5.96	281.44 / 36.77*	199.2 / 143.92*
	1.0	6.25	348.93 / 38.55*	212.6 / 151.09*
$L_2 = 5$m	0.1	1.91	55.71 / 54.78*	126.5 / 128.48*
	0.5	1.92	56.07 / 54.86*	128.5 / 128.68*
	1.0	1.89	55.81 / 54.18*	127.5 / 127.07*

* Value obtained from analytical equation [3]

It is observed, the long panel, where the bending deflection dominated, is less affected by the size of imperfections multiplier. However, for shorter panels the size of imperfection has to be chosen very carefully. Further analyzes are carried out for panels with the span of 3 and 5 m and for imperfection 0.1 mm.

In the next step, the influence of Young's modulus variability on the load-bearing capacity of the sandwich panel is studied. Value of Young's modulus in each layer is changed in accordance with the rule given in the Table 2. For isotropic material model only two out of three parameters are independent. Hence, operating on the Young's modulus and shear modulus changes the value of Poisson's ratio. So, the Poisson's ratios in individual layers are selected to remain G_C constant and equal 3.0 MPa.

Table 2: Adopted material parameters of the foam core.

Layer	Example 1	Example 2	Example 3	Example 4
	E_C [MPa]			
L_5	5.26	6.31	6.31	6.31
L_4	5.26	5.26	4.56	5.00
L_3	5.26	5.26	4.56	5.00
L_2	5.26	5.26	4.56	5.00
L_1	5.26	6.31	6.31	5.00
Average value	5.26	5.68	5.26	5.26

Obtained results are summarized in Table 3 and Fig. 4.

Table 3: Results.

	Example 1		Example 2		Example 3		Example 4	
	σ_x [MPa]	w [mm]	σ_x [MPa]	w [mm]	σ_x [MPa]	w [mm]	σ_x [MPa]	w [mm]
L = 3m	141.0	37.58	146.9	38.71	141.8	40.04	146.9	38.67
L = 5m	126.5	55.71	131.5	57.41	131.5	57.36	131.5	57.36

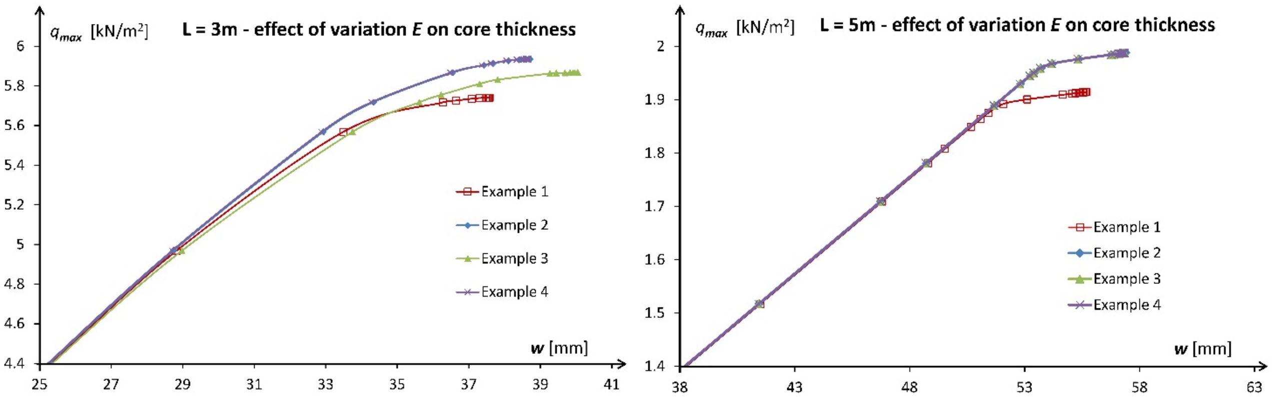

Fig. 4. The effect of E_C variation.

The load-displacement curves presented in Fig. 4 indicate that the Young's modulus of the layer situated directly under the compressed face is crucial for the structural behavior of the panel. It is observed, for longer panel the modification of E parameter in other layers are less influential.

5. FINAL REMARKS

Initial analyzes show that the change of the Young's modulus on the core thickness affects the behavior of the loaded sandwich panel. Considering this variability in the FE model contributes to a more accurate analysis of the sandwich panels. However, using nowadays methods, material parameters on the core's thickness can be experimentally determined. Hence, the next our step is to experimentally validate the model and use it to more comprehensive analyses. Obtained results will be presented during the conference.

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