Influence of sandwich panels flexural stiffness on the capacity of thin-walled elements

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Abstract

The paper deals with the phenomenon of the lateral torsional restraint of the thin-walled Z-beams provided by the sandwich panels. The interaction between the thin-walled Z-beam and the sandwich panel was investigated by means of laboratory experiment and numerical simulations. The sandwich panels flexural stiffness was investigated in the context of the lateral restraint of thin-walled Z-beams. The sandwich panel flexural stiffness was expressed by varied thickness of the core layer and varied span length of the sandwich panel. The laboratory experiments allow for the validation of the FE model. The satisfactory agreement between FE simulations and laboratory trails were obtained. The results demonstrated that the sandwich panels provide lateral restraint of the thin-walled elements, nevertheless the increase of the flexural stiffness of the sandwich panels has minor influence on the efficiency of this lateral restraint.

Keywords: sandwich panels, thin-walled beams, laboratory tests, numerical analysis, lateral resistant

1. Introduction

Thin-walled beams connected with sandwich panels are widely used in industrial buildings as roof and wall cladding systems. The lateral torsional restraint of the thin-walled elements provided by the sandwich panels leads to noticeable material savings. Therefore, the research on this phenomenon has been conducted very recently. European programme EASIE [3] is the largest project dealing with this phenomenon. This topic was also considered by Dürr at al. [2] and Georgescu and Ungureanu [4]. One of the most interesting conclusions of these works is the statement that the sandwich panels may provide stiffness against flexural, lateral and torsional buckling of steel elements.

2. Problem formulation

The lateral restraint of the thin-walled beams provided by the sandwich panels depends on the several factors i.e. shape of the cross-section of the steel element, type of the sandwich panel (lightly profiled, deeply profiled), type of the load, and the number of fasteners connecting sandwich panels with steel structure [5]. Please note that increase of number of fasteners increases the capacity of the thin-walled beam. Moreover, even freely placing of the sandwich panel on the thin-walled members provides partial lateral restraint of the thin-walled elements, see Ciesielczyk and Studziński [1].

In this paper the phenomenon of global loss of stability of the thin-walled beam interacting with the sandwich panel, depending on the flexural stiffness of the sandwich panels, is investigated by experimental tests and numerical simulations. Figure 1 presents the scheme of the test bed which consist of two thin-walled simply supported Z-beams (height h_Z=100 mm, thickness t_Z=1.5 mm, constant length L_Z=3200 mm) and two sandwich panels with flat facings. The six different thicknesses (d_C) of sandwich panels core layer were analysed. The thicknesses of the facings were constant (t_{Fext}=0.545 mm, t_{Fint}=0.491 mm) in every case while the thickness of the soft core was variable.

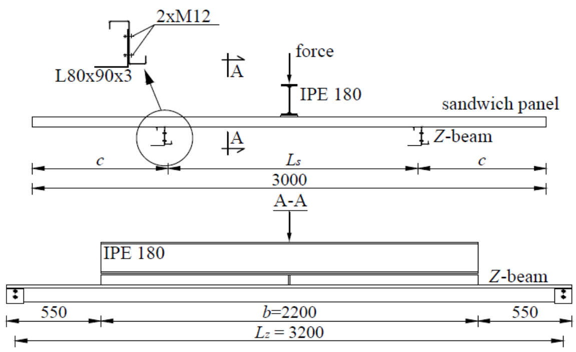

Figure 1: Scheme of the test-bed

During the laboratory test the relations between the force and the horizontal and vertical displacements of the thin-walled elements and vertical displacement of the sandwich panels were measured. In Table 1 the set of the design parameters is presented, where the β ratio (Eq. 1) represents the relation between flexural stiffness of the sandwich panel B_S (Eq. 2) and flexural stiffness of the thin-walled element B_Z (Eq. 3).

Table 1: The dimensions of the conducted research

d_C [mm]	L_S [mm]	c [mm]	e [mm]	β [-]	approach*
50	1480	760	49.482	6.08	NS
60	1785	608	59.482	7.28	LE/NS
70	2050	475	69.482	8.65	NS
80	2340	330	79.482	9.92	LE/NS
90	2650	175	89.482	11.10	NS
100	2800	100	99.482	12.98	LE/NS

*LE – laboratory experiment, NS – numerical simulations

$$\beta = \frac{B_S}{B_Z} \tag{1}$$

$$B_S = L_S^{-1} \cdot \left(\frac{E_{Fext} t_{Fext} b \, E_{F\,\mathrm{int}} t_{F\,\mathrm{int}} b}{E_{Fext} t_{Fext} b + E_{F\,\mathrm{int}} t_{F\,\mathrm{int}} b} e^2 \right) \quad (2)$$

$$B_Z = L_Z^{-1} \cdot \left(E J_y \right) \quad (3)$$

where: L_S is the span of the sandwich panel, L_Z is the span of the thin-walled beam, E_{Fext} (E_{Fint}) and t_{Fext} (t_{Fint})is the Young's modulus and thickness of the external (internal) facings of the sandwich panel respectively, b is the width of sandwich panel, e is the distance between the centroids of the facings of the sandwich panel, E and J_y is the Young's modulus and second moment of inertia with respect to major axis of the thin-walled beam respectively.

3. Numerical model

The conducted laboratory tests were used to validate the FE model created in Abaqus/CEA environment. The components of the laboratory test assumed in FE model are presented in Table 2. Freely placing the sandwich panels on the thin-walled beams was modelled using surface-to-surface contact: "hard" contact (normal behaviour without penetration of the connected elements) and tangential behaviour with friction coefficient equal to 0.15. The materials parameters applied in the numerical model were investigated by authors in former experimental tests [1, 6].

The comparison of the relation between force and vertical displacement in the middle of the thin-walled beam (restraint by 80 mm thick sandwich panels) is presented in Figure 2.

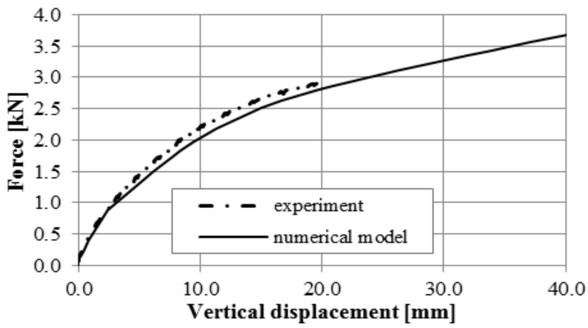

Figure 2: The dependence of the force and vertical displacement in the middle of the thin-walled element

Table 2: Applied finite elements in numerical model

	Finite elements				
	Shape	Type	Integration type	Size [mm]	Number of elements
IPE	hex	8-node linear brick	reduced	10x10x10	13200
external facing	quad	4-node doubly curved thin shell	reduced	40x40	1998
core	hex	8-node linear brick	reduced	30x30x30	~10000*
internal facing	quad	4-node doubly curved thin shell	reduced	20x20	8250
Z-beam	quad	4-node doubly curved thin shell	reduced	10x10	7260
angle support	quad	4-node doubly curved thin shell	reduced	10x10	180

*depending on the thickness of the plate

As a result of carried out numerical computations in Figure 3 the graph of force-displacement (vertical displacement in the middle of the thin-walled beam) relation is presented. It can be noticed that the force-displacement curves for every sandwich panel thickness (flexural stiffness) have very similar shape. Moreover, the form of failure mechanism of the thin-walled beam (global loss of stability) does also not depend on the relation between flexural stiffness of the sandwich panel and steel element (β ratio).

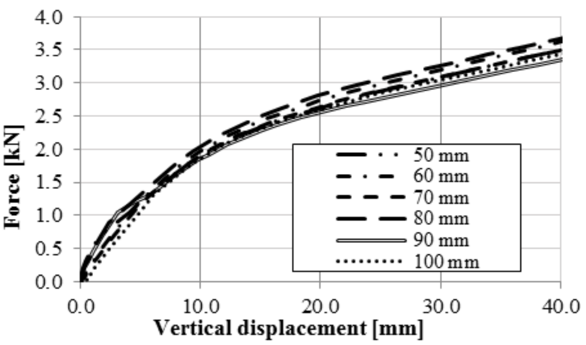

Figure 3: The comparison of vertical displacement of thin-walled element in dependence of the thickness of the sandwich panel.

4. Conclusions

In this paper the phenomena of global loss of stability of thin-walled beam interacting with sandwich panel, depending on the flexural stiffness of the sandwich panels was presented. The performed research confirmed that sandwich panel may provide lateral torsional restraint of the thin-walled Z-beams. However, the ratio between flexural stiffness of the sandwich panel and flexural stiffness of the thin-walled element has no significant influence on magnitude of this restraint.

References

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