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Analysis of the failure mechanism of the sandwich panel at the supports

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Abstract

The paper presents the problem of static structural behavior of sandwich panels at supports. The panels have a soft core and correspond to typical structures applied in civil engineering. To analyze the failure propagation, the numerical 3-D model with non-linear material constitutive relations is applied. The numerical results are compared to the values obtained using simple engineering formulas. The obtained results show that the existing approach of assessing the failure by the level of the core compression is incorrect. The study verifies the assumption concerning the uniformity of normal stress distribution and describes the failure mechanism.

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Keywords: sandwich panel; soft core; failure; numerical modeling; civil engineering, design;

1. Introduction

The paper considers sandwich panels applied in civil engineering. The panels are used as a building envelope (wall and roof). They consist of two thin external steel facings and a thick and soft core. As a result of the combination of the two different materials, sandwich panels play the role of a structural element and thermal insulation altogether. The complexity of a sandwich structure is revealed by different failure mechanisms, among which include: face yielding, global and local instability, debonding, shear and indentation of the core.

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For many years, quite a lot of attention is paid to the problems of core shear and face local instability, but the core compression and indentation were undertaken too infrequently and mainly in specific contexts: Wu and Sun [1] considered low velocity impact damage, Wen et al. [2] reported the great significance of an intender shape for the failure under quasi-static loading, whereas Flores-Johnson [3] presented results of experimental study of the indentation of panels with carbon fibre-reinforced polymer face sheets and a polymeric foam core. In paper [4] different failure modes were observed, but a lot of attention was paid to the phenomenon of indentation. The experimental results were compared with theoretical predictions. The work of Heslehurst [5] presents the overview of possible defects in composite structures (including indentation), and explains the influence of the defects on the composites behaviour and recommends repair actions to restore structural integrity.

In civil engineering applications, the problem of core indentation occurs in locations subjected to large concentrated forces, mainly at supports. The approach to this issue is dominated by the concept of proofing through testing. The results of experiments carried out on panels with a mineral wool core [6] and a polyurethane core [7] were summarised in [8]. Based on this approach, the respective rules of testing and design were developed [9]. Unfortunately, current research [10] shows that the design concept presented in [9] gives unsafe results and should be improved. The conclusions presented in [11] are even more far-reaching.

This paper discusses the failure mechanism of sandwich panel at the supports. The numerical models of one-span and two-span systems are examined. Particular attention was paid to the determination of the relevant material parameters of the core. For the considered models, the normal and shear stress distributions, as well as deformations of the core are analysed. The numerical values are compared with the theoretical ones in the context of failure propagation.

2. Description of the systems

To analyze the problem of failure at the supports, two systems presented in Fig. 1 are studied. In the case of the one-span system, the narrow support of a width $L_S = 0.04$ m is located on the right-hand side. In the case of the two-span system, the support interactions are observed at the intermediate support which has the width $L_S = 0.08$ m. The numerical model is 3-D and the supports are located at the bottom of the sandwich panel. The width of the panel is $B = 1.0$ m. Though various depths of the panel were analyzed, only the results obtained for the panel which has the total depth $D = 0.100$ m (the thickness of both facings $t_F = 0.0005$ m and the core thickness $d_C = 0.099$ m) are discussed in details. The assumed geometry ensures the significance of phenomena observed at the supports and the possibility of direct comparison of the two systems. Both structures are subjected to a uniform transverse loading q.

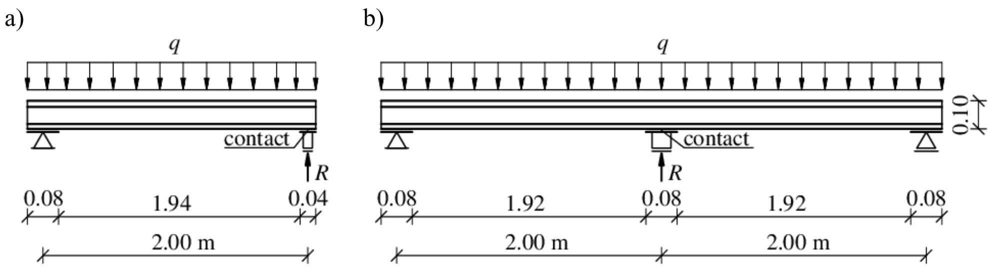

Fig. 1. The static system of analyzed sandwich structures: (a) the one-span system; (b) the two-span system.

3. The numerical model

3-D models of the presented sandwich systems were prepared in the Abaqus program. The parameters of the model correspond to the parameters determined in the laboratory tests. Steel facings (thickness $t_F = 0.0005$ m) were assumed as isotropic, elastic-plastic material with the modulus of elasticity $E_F = 210$ GPa and Poisson ratio $\nu_F = 0.3$. The actual relationship between stress and strain was introduced. The yield strength was 360 MPa and the ultimate