ROCZNIKI INŻYNIERII BUDOWLANEJ – ZESZYT 13/2013
Komisja Inżynierii Budowlanej Oddział Polskiej Akademii Nauk w Katowicach

SANDWICH BEAMS WITH SHORT FIBER REINFORCED COMPOSITE FACES

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1. Introduction

The sandwich concept provides and efficient structural system suitable for a variety of applications, including roof and wall panels for buildings in civil engineering industry. A typical sandwich structure consists of two faces, made of metallic or composite laminated material, separated by a core that is usually made of low-weight and low strength non-metallic foam [1, 2].

The Finite Element Method (FEM) is a common and most effective tool for structural analysis of sandwich structure. A number of modeling techniques of sandwich panels have been developed, including analytical models and numerical approaches.

2. Experimental procedure

The experimentally examined sandwich beams were assembled from hot zinc dipped steel sheet face layers, coated by plastic (CSS) and low-density rigid polyurethane (PUR) foam core. It was also considered with short fiber reinforced composite faces, which are currently used by some producers of sandwich panels. The behavior of this type of sandwich under four-point bending test was examined only numerically. Static-mechanical tests were preliminary conducted on constituents to acquire important parameters for the mechanical characterization of the sandwich structure and to implement the numerical simulations. A brief summary of composites tension tests and four-point bending tests are provided. Further details of the described tests and rest mechanical tests on the constituents.

The short fiber reinforced composites were made of chopped glass fibers in polyester resin. There were used composites termed as G 600, commonly manufactured in Vetroresina SpA company in Italia. The tension tests were done according to standard EN ISO 527-4.

Tension tests were performed using a Zwick-Extensometer testing machine with wedge-type mechanical grips. Outputs from strain gages were recorded using a catmanEasy software via a Spider8 device. The stress-strain curves and failure modes of tested specimens in longitudinal direction under tension test are illustrated in Fig. 1.

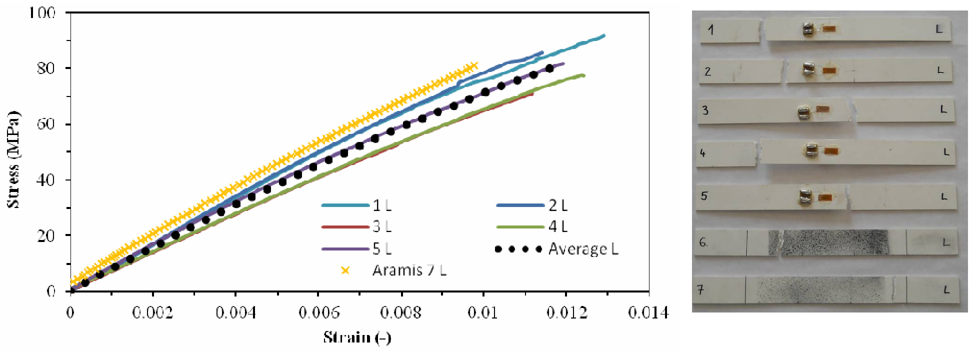

Fig. 1 Stress-strain curves of G 600 composite and failure modes in longitudinal direction

For determining the shear strength and shear modulus of the sandwich core material the four-point bending test (FPBT) is typically used according to standard EN 14509. There were used four tested specimens, 80 mm thick and 100 mm wide. The face layers were made from coated steel sheets. Span L = 1000 mm was chosen so that a shear failure was obtained. Deflections of the tested specimens were measured at midpoint of the span with the help of inductive transducers (IT) WA100 from HBM company. Schematic illustration of the four-point bending test and one of the tested specimens are illustrated in Fig. 2.

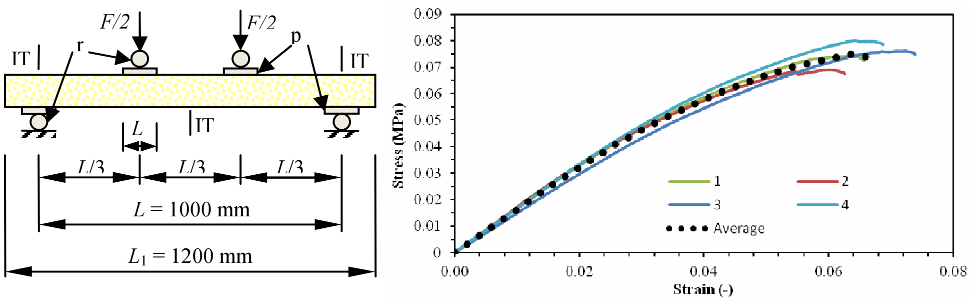

Fig. 2 Schematic illustration of the four-point bending test and stress-strain curves

F – applied load, r – rollers, radius 15 mm, p – steel load spreading plate, IT – inductive transducer

3. Numerical Modeling

The simulations of the four-point bending tests have been carried out by using the ANSYS program. It was considered linear and nonlinear finite element analysis. The large displacement approach (LARGE) was included. The composite face layers G 600 were also used in computations.

An approach, taking advantage of the plane stress condition of the sandwich beam in one-way bending was applied. There was used a combination of beam and plane elements. The face layers and spreading plates were modeled using beam element BEAM189. The polyurethane foam core was modeled using eight-node quadrilateral plane stress elements PLANE183 with capability of thickness effect.

It was used a half symmetry of the models (Fig. 3, 2419 elements, 6530 nodes).

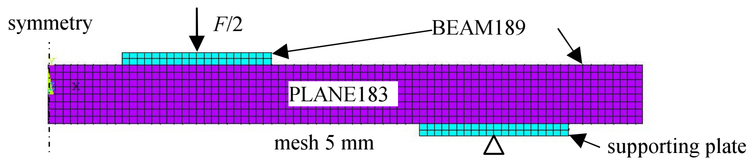

Fig. 3 2-D model, combination of BEAM189 and PLANE183 elements

There were created contacts (CON) using contact pairs between the loading steel plates and the top face layer and also between the bottom face layer and the supporting plates.

The constituent materials have a nonlinear behavior, especially the polyurethane foam. The non-linearity of coated steel sheet (CSS) was accounted in the finite element model by specifying a multilinear inelastic material model. The behavior of G 600 composite was described by bilinear isotropic hardening model. For the polyurethane foam material, a hyperelastic material polynomial curve fitting was used to fit the material tension, compression and shear stress-strain responses. It was carried out by the ANSYS program. The polynomial used was of a fifth order.

The beam load-deflection diagrams obtained from the finite element models are plotted along with the experimental result in Fig. 4.

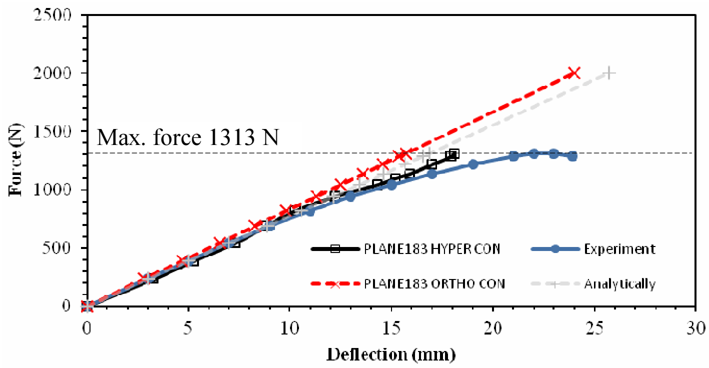

Fig. 4 Load-deflection diagrams of sandwich beams, CSS face layers

The comparison of sandwich face layer type on its flexural behaviour using an ORTHO material model of the core is illustrated in Fig. 5.

The differences between experimental and computed value of deflections at the midpoint of the beams, respectively, are up to 40.02% by model PLANE183 ORTHO CON and 22.71% by model PLANE183 HYPER CON CSS at their maximum load 1313 N.

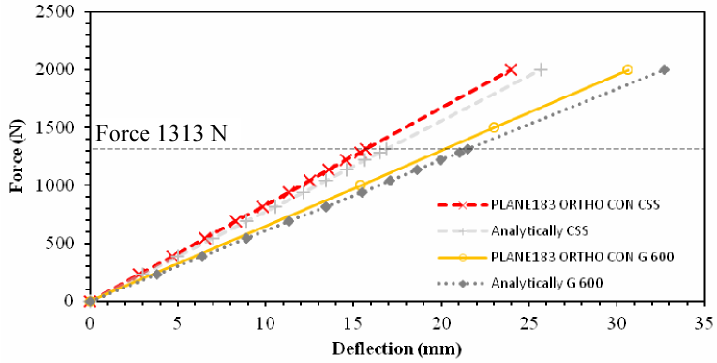

Fig. 5 Comparison of sandwich beam load-deflections diagrams, CSS and G 600 face layers

4. Conclusion

The four-point bending test results of sandwich beam with steel sheet face layers and soft core made of rigid polyurethane foam were used as a benchmark in numerical simulations using commercial finite element program – ANSYS. An advantage of plane stress condition was applied in numerical models. The static-mechanical behavior of the simulated sandwich beam was in a very good agreement with experiment in its elastic domain at both material models of the core. The better prediction was obtained using hyperelastic material model of the core at higher load.

References

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Summary

The paper deals with numerical modeling of sandwich beams with polyurethane foam core and two types of face layers – short fiber reinforced composite faces and hot-zinc dipped steel sheet, coated by plastic. The experimental results of four-point bending test are used as benchmark in the commercial ANSYS program simulations.

This paper has been supported by the project VEGA 1/0201/11 Progressive methods for the solution of structural elements made of composite and other new-age materials.