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EXPERIMENTAL TESTING OF COMPOSITE SANDWICH PANELS WITH DIFFERENT FACE SHEETS

Summary

An experimental tests performed on two series sandwich panels with composite face sheets differed by the type of the used matrix are presented in this paper. Using linear load in the middle of the span these sandwich panels were subjected on three points bending. The analysis was performed in order to evaluate the influence of the matrix type on the ultimate mechanical characteristics of the sandwich panels. Analyzing the F-δ behavior of the sandwich panels, as well the F-σ behavior of the composite face sheets the influence of the matrix type used in the composite face sheets has been evaluated.

Key words

Composite sandwich panels, mechanical properties, experimental testing

EKSPERIMENTALNO ISPITIVANJE KOMPOZITNIH SENDVIČ PLOČA SA RAZLIČITIM SPOLJAŠNJIM PLOČAMA

Rezime

U ovom radu prezentirani su eksperimentalni rezultati o dvije serije sendvič panela sa spoljašnjim kompozitnim pločama koje se razlikuju po upotrijebljenoj matrici. Sendvič ploče ispitivane su primjenom linijskog opterećenja u sredini raspona. Analize su izvedene kako bi se ocijenio uticaj tipa matrice na granične mehaničke karakteristike sendvič panela. Uticaj tipa matrice kompozitnih spoljašnih ploča je ocijenjen analizom F-δ ponašanja sendvič ploča, kako i F-σ ponašanjem kompozitnih ploča.

Ključne riječi

Kompozitne sendvič ploče, mehaničke karakteristike, ekperimentalna ispitivanja

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1. INTRODUCTION

Sandwich structures are being often used as constructive elements in the civil engineering. The usage is mostly based on their high performance, such as high stiffness and high strength compare with their weight. Based on the concept of increasing the bending bearing capacity and stiffness sandwich panels are defined as structures that have low weight. They are multi layered composites formed of two thick, but strong and stiff face sheets, and lower core. Depending on the specific application of the final product different materials could be used for fabrication of sandwich panels.

Any constructive product available as a thin plate could be used for the face sheets [2]. Material are chosen so that face sheets will have high bending stiffness, high tensile and compressive strength and excellent resistance to external influences. Composite materials, as anisotropic materials, especially as materials with high strength to weight ratio, high stiffness to weight ratio and as non-corrosiveness easy handling material that offer many options in the design process, are very often used as materials for the face sheets.

Lingaiah and Suryanarayana [5] in their work present experimental research of sandwich panels with composite face sheets and aluminum honeycomb core subjected on bending, while the Alias [1] did experiments on sandwich panel with steel face sheets and polyvinylchloride core statically loaded with concentrated force. The fracture mechanism should be well-known in order to determine the mechanical characteristics of sandwich panels. Fracture types of sandwich panels in linear part are studied and discussed by Allen [2], Ashby and Gibson [3] and Plantema [8]. In order to simplify the mathematical operations numerous analyses of sandwich panels are being performed on beam model. Swanson and Kim [9] and Mines and Alias [7], focused on analyses of sandwich beam fracture. Fracture of the sandwich elements could occur as a result of reaching the ultimate compressive or tensile strength of the face sheets or as a result of reaching the ultimate shear strength of the core [6, 4]. According to the available literature the mechanical characteristics and the fracture type of the sandwich panels depend on the used materials. Mechanical characteristics of sandwich panels with composite face sheets depend also on the components used for the composite material.

This paper presents an experimental tests performed on two series of sandwich panels with composite face sheets differed by the type of the used matrix. Two types of matrix material-polyester and epoxy based resins are used for this experiment. Sandwich panels in the experimental tests were subjected on three points bending. The analysis was performed in order to evaluate the influence of the matrix type on the ultimate mechanical characteristics of the sandwich panels. Influence of the matrix type used in the composite face sheets was evaluated by analysis of F-δ behavior of series sandwich panels, as well as by analysis of F-σ behavior of the composite face sheets.

2. PROPERTIES OF SANDWICH PANELS AND TEST SET UP

2.1. COMPONENTS OF SANDWICH PANELS

For the purpose of the experimental testing two different series of sandwich panels have been fabricated. The examined sandwich panels were fabricated of polyurethane core and thin composite face sheets. The core of sandwich panels is 60 mm hard foam polyurethane with density of 30 kg/m^3. Actually, the sandwich panels' series differ by type of matrix used for the thin composite face sheets. The thin composite face sheets were fabricated using two type's matrix and fiber glass reinforcement, rowing with density 0,535 kg/m^2, in two plies. The materials types used for production of the sandwich panels are summarized in Table 1.

The sandwich panels were marked in accordance to the components used for the production of composites face sheets: the first symbol refers to the sandwich panel (S), the second symbol refers to the type of the matrix (P or E), the third symbol refers to the number of reinforcement plies (2) and the last fourth symbol (R) denotes the type of used reinforcement.

Table 1. Components of series tested sandwich panels

Sandwich panels	Core	Face sheet		
		Matrix	Reinforcement plies	Reinforcement
SP2R	Polyurethane	Polyester resin	2	Rowing
SE2R	Polyurethane	Epoxy resin	2	Rowing

2.2. SPECIMEN GEOMETRY

Test specimens were fabricated by hand lay-up of the composite face sheets on the hard foam polyurethane. Their geometry was defined by the properties of the test machine, Figure 1. All test specimens had a constant length of 1000 mm and rectangular cross section with width of 300 mm. The depth of each sandwich panel differs depending on the depth of the composite face sheets. For precise determination of the relative strain of each composite face sheet of the tested sandwich panel, strain gages in longitudinal direction were used.

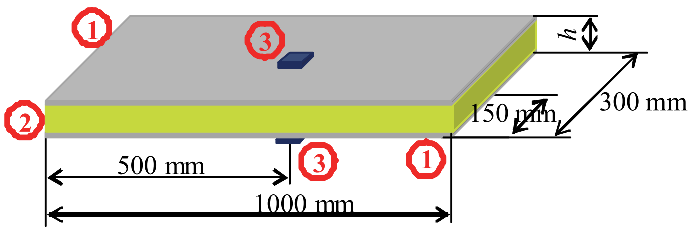

Figure 1. Geometry of sandwich panel specimens
1) composite face sheets; 2) core; 3) strain gages

2.3. EXPERIMENT TEST SETUP

The final surface preparation was carefully examined for each test specimen prior to the flexural tests. The dimensions of the specimens were measured before flexural testing. In order to record the average area of the specimens' their area was measured at three places.

Experiments were performed by the testing machine SCHENCK HYDROPLUS-PSB, that has capacity of 250 kN. Tests were made in range up to 25 kN. The tests specimens were subjected on three point bending. Additional device was set on the test machine in order to test the flat beams loaded on flexure. The specimens were carried by steel supports with 50 mm width set on 50 mm diameter steel cylinders which permit slip and deformation of the sandwich panels during the experiments. Slip on the contact surface was avoided by using of 2 mm neoprene layers between sandwich panels and a steel support. Line load was applied through 100 mm width steel beam mounted on steel cylinder with diameter of 50 mm. A 40 mm square hole was made in the middle of the steel beam in order to set a strain gage on the top face sheet of the sandwich panel in the middle of the span. By placing a 4 mm thick neoprene layer between steel beam and sandwich panel the local fracture of the top layers of the composite face sheet was avoided. The actual span of the sandwich beam was 800 mm and the load was applied with constant speed of 5 mm/min.

Flexural force was determined with force transducer integrated in the testing machine. The full bridge strain gage type force transducer was used. Head displacement of the testing machine was determined by displacement transducer of inductive type. Strain data were determinate using strain gage in longitudinal direction. The strain gage with resistant of 350 Ω, type HBM 10/350LY11 were selected in order to reduce the heating effects due to the low conductivity of the used composite materials. The surface preparation and the selection of bonding agent for the strain gage installation was done in consultation with the strain gage producer. The temperature compensation was done by a passive strain gage, connected in half-bridge. The force versus head displacement and the force versus strain were continuously recorded with sampling rate of 50 Hz. The HBM Spider 8 and software HBM CATMAN 4.0 were used for data acquisition.

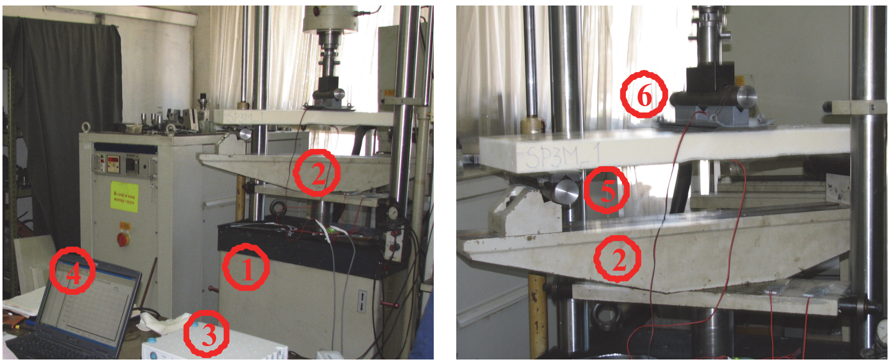

Figure 2. Testing machine and equipment for flexural test of sandwich specimens: 1) testing machine; 2) additional device for testing flat beams; 3) acquisition unit; 4) computer; 5) steel support lay on cylinder; 6) loading steel beam on cylinder

3. EXPERIMENTALLY OBTAINED RESULTS AND DISCUSSION

The flexural testing have been performed on two different series of specimens. Two specimens of each serial were tested for the purpose of the experiment. The geometry and the experimentally obtained results for tested sandwich specimens are summarized in the Table 2.

Table 2. Geometrical and mechanical properties of tested sandwich specimens

Sandwich specimen	Face sheet thickness, *t* [mm]	Sandwich panel thickness, h [mm]	Load [N]	Deflection [mm]	Tensile strength [MPa]
SP2R_1	1,5	62	3340	30,67	34,65
SP2R_2	1,7	63	3367	29,08	29,18
SE2R_1	1,3	62	3538	32,27	41,48
SE2R_2	1,2	63	3511	32,58	45,07

From the performed tests can be concluded that the behavior of the tested sandwich panels subjected on three points bending can be divided in three characteristic parts. Behavior of the sandwich panels is linear up to the point where cracking of the polyurethane foam occurs reducing their stiffness. In the nonlinear part, by increasing the load, new micro cracks appear and spread through the depth of the core, while the composite face sheets are still in elastic part caring out the applied load. In the last stage crash of the top composite face sheet and core occur followed by a considerable drop in the stiffness of the sandwich panels.

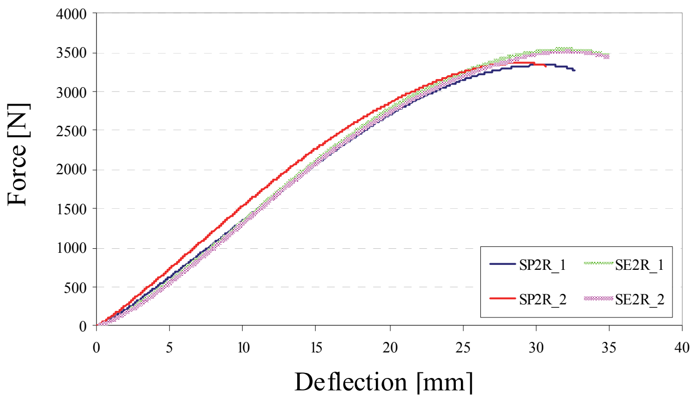

Figure 3. F-δ diagrams for specimens SP2R and SE2R subjected on three point bending

The F-δ behavior of the tested sandwich panels SP2R and SE2R in the middle of the span is similar, as can be concluded from the Figure 3. The ultimate strength of the series sandwich panels SE2R is minimally higher in comparison to the series of sandwich panels SP2R. In particular, the behavior of the both series of sandwich panels is in the linear part with the approximately equal stiffness and minor differences observed in the ultimate deformations.

In order to observe the influence of the used matrix on the mechanical properties of the sandwich panels, comparative analyses of the experimentally obtained results for the stress on the bottom face sheet were carried out, Figure 4. The analysis of the results summarized in Table 2 lead to conclusion that the deflections and ultimate tensile strength in the bottom face sheets in each series of sandwich panels are approximately equal under the ultimate load. Under the equal loading, the series of sandwich panels SE2R have minimal higher stress in the bottom face sheet in comparison to series sandwich panels SP2R, as can be seen in Figure 4. Nevertheless, it should be mentioned that the stresses in the composite face sheets are very small in comparison with the strength of the composite material, and the properties of the composite material are not completely used.

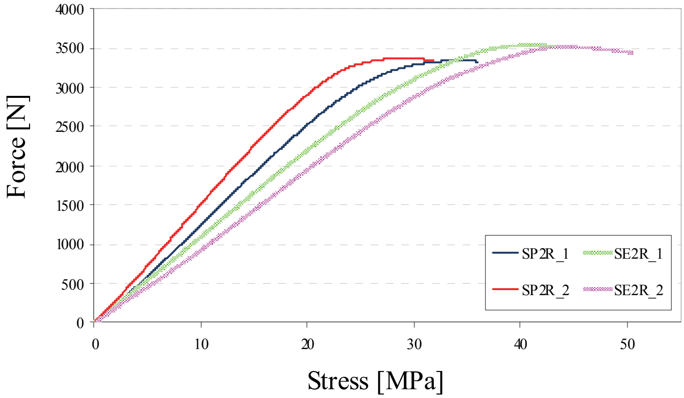

Figure 4. F- σ diagrams for specimens SP2R and SE2R subjected on three point bending

The results of the performed experiments state that the fracture of the sandwich panels was followed by fracture of the top composite face sheet and fracture of the polyurethane foam core in the top of the sandwich panel, while the bottom composite face sheet remained undamaged with no visible cracks, Figure 5.

Figure 5. Fracture of the sandwich panels SP2R and SE2R subjected on three points bending

4. CONCLUSIONS

This paper presents results from the experimental tests of two series of sandwich panels subjected on three points bending. Analyzing the experimentally obtained results it can be concluded that the type of used matrix in the composite face sheets doesn't have a great influence on the initial strength of the sandwich panels and on their deformation. Similarly, the type of the used matrix in the composite face sheets doesn't have an influence on the stress in the bottom face sheet, on the stiffness of the sandwich panel and on their ultimate bearing capacity.

Experiments show that the fracture of the sandwich panels is driven by the characteristics of the polyurethane foam core. Its low strength and deformation characteristics have great influence on the fracture of the sandwich panels. It does not permit an utilization of the characteristics of the composite materials used for the face sheets.

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