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Finite element prediction of stress-strain fields on sandwich composites

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Abstract

The main objective of this study was the assessment of the stress-strain fields of the sandwich core during bending tests. Finite element models (FEM) using Siemens NX10 and digital image correlation (DIC) were used to predict the behavior of sandwich beams in 3 and 4 point bending. Two different core thickness and two different sandwich length (short and long beams) with basalt fiber reinforced polymer (BFRP) faces were simulated. The numerical simulation using 3D finite element were compared and validated with experimental results obtained previously by DIC. This work validated innovative numerical simulations and experimental techniques for determining stress-strain fields in composite sandwich beams subjected to bending. The correlation between experience and analysis allowed a better knowledge and understanding of the complex stress-strain fields along the core thickness of sandwich beams in bending.

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Keywords: FEM, Composite Sandwich beams, stress-strain fields, 3PB, 4PB

1. Introduction

Structural sandwich panels consist of three main structural components: two flat or lightly profiled thin faces are bonded to relatively thick light core. The strong and stiff thin faces provide flexural load bearing capacity and rigidity of the panel. The low density and flexible thick core with adequate shear strength and stiffness transfers shear loads between the two faces. The result is a composite structural element with relatively high load-bearing

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capacity and bending stiffness showed by Davies (2001). Different face and core materials can be used in sandwich structures depending the practical employment. Among the non-metallic materials the composites are the modest utilized ones, because of its high elasticity while improves weight-bending stiffness. One of these fascinating materials with extraordinary properties is the basalt fiber that is a novel kind of inorganic fiber manufactured from the extrusion of melted basalt rock and is commercially available.

In this paper the stress–strain behavior of BFRP face materials in short and long sandwich beams under three- and four-point bending were compared and analyzed with FEM and DIC.

Nomenclature

v	Displacement along y direction [mm]
ε_{xx}	Strain along x direction

2. Experiment

2.1. Material

Basalt fiber reinforced polymer (BFRP) composite was used on the sandwich structures as face materials. The core was induced with polyurethane plates with two different thicknesses: 20 mm and 30 mm, enabling a wider range of tests and results to be analyzed.

The composite sandwiches with BFRP faces and polyurethane core were hand lay-up (HLU) with vacuum bag during 24hours with 850mPa of pressure and ambient temperature. Thus, four layers of 2x2 twill per side with lay-up $[(0/90)/(45/-45)]_4$ of basalt fiber fabric *Basaltex*^{TM} BAS 220.1270.T were cut into rectangular sections (430mm x 780mm) and added to polyurethane core with epoxy resin *Sicomin* SR1500 and SD2505 hardener. Afterwards specimens with 390mm x 70mm were cut with a diamond circular saw as by ASTM C393-00.

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The main properties of the materials used in this work are presented in Table 1 and Table 2.

Table 1. Material Properties

	Density (kg/m^3)	Poisson	Elastic modulus (GPa)	Shear modulus (GPa)	Thickness (mm)
Resin SR1500 + SD2505	1.0	0.26	3.2	-	-
Basalt (twill) 220.1270.T	2.8	0.35	78	-	0.13
Polyurethane	40	0.33	0.0106	$4 \cdot 10^{-3}$	$c = 20$ $c = 30$

Table 2. BFRP Properties

	Density (kg/m^3)	$\nu_{12} = \nu_{13}$	$E_{11} = E_{22}$ (GPa)	E_{33} (GPa)	$G_{12} = G_{13} = G_{23}$ (GPa)	Thickness	Fiber Volume Fraction (%)
Composite BFRP	1454	0.31	16	3.2	2.7	$t = 1$	49

2.2. Testing

Three point bending (3PB) and four point bending (4PB) tests according to ASTM C 393-00 standard (Fig. 1) were applied to the prepared sandwiches to measure the flexural properties such as core shear stress, face-sheet compressive and tensile strains and deflections. All specimens were tested and load vs. displacement results were