Behavior of a new Heliopol/Stratimat300 composite laminate

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Stratimat300 glass fibers with 300 g/m^2 specific weight has been used to reinforce Heliopol 9431ATYX_LSE resin in hand lay-up process. A 6 mm thick composite laminate plate with five layers has been cured from which nine specimens have been cut using a diamond powder mill being under protection of a specific cooling system. Following main data have been recorded during three-point bend tests: Stiffness (N/m), Young's Modulus of Bending (MPa), Flexural Rigidity (Nm^2), Load at Maximum Load (kN), Deflection at Maximum Load (mm), Load at Maximum Deflection (kN), Deflection at Maximum Deflection (mm), Load at Break (kN), Deflection at Break (mm). Additional experimental data including twelve interesting mechanical properties have been also determined during three-point bend tests.

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1. Introduction

From a general point of view, a composite material is formed from at least two compounds combined at a macroscopic scale through mechanical and chemical bonds. The term "composite" defines a structure made from materials that maintain their identity even after its manufacture. This fact is very important since the interface between these compounds plays a significant role in the subsequent behavior of the composite under complex loads. Composite materials consist from at least two compounds: a compact material denoted "matrix" and a reinforcing one usually fibers [1-3]. For instance, polymer matrix composites present a polymeric resin as matrix in which a wide range of fibers can be embedded. In general, the mechanical properties of polymer matrix composites are strongly influenced by following factors:

- The compounds' nature and their mechanical properties;
- The fibers volume fraction and their orientation in composite;
- The mechanical strength of the interface between matrix and reinforcement.

The fibers orientation influences in a decisive way the material's anisotropy [4-6]. Numerical simulations as well as various experimental data regarding the mechanical behavior of polymer matrix composites with different types of fibers and matrices subjected to various complex loads have been carried out in papers [7-9]. Interesting approaches on thin composite sandwich structures subjected to three-point bend tests are reported in paper [10]. Polymer matrix composite structures using three compounds, namely resin, fibers and filler subjected to complex loads have been experimentally researched. Interesting results are presented in papers [11, 12]. Not only static but also cyclic tension-compression tensile tests to determine the hysteresis of various composite laminates have been carried out. Various number of cycles as well as different load limits as input data have been used for these tests [13]. In the last years, an increased number of mechanical tests have been accomplished on polymer matrix composite laminates reinforced with carbon fibers. Tensile, three and four-point bend tests have been done to determine the most important mechanical properties of these structures [14], [15], [16].

2. Material and method

A composite laminate plate with main dimensions of 400 ×200 × 6 mm has been manufactured and cured using following compounds:

- Resin: HELIOPOL 9431ATYX_LSE;
- Hardener: BUTANOX M50;
- Glass fibres: STRATIMAT 300 with 300 g/m^2 specific weight.

From cured plate, nine specimens have been cut using a diamond powder mill and a suitable cooling system to avoid introduce internal stresses in the composite laminate. The specimens have been subjected to three-point bend tests until break on a LR5KPlus Lloyd Instruments' materials testing machine with maximum 5 kN load cell. Other materials testing machine features include load resolution less than 0.01% and displacement resolution less than 0.1 μm. Some main three-point bend tests characteristics are presented in Table 1. Maximum, minimum, mean and median values have been automatically recorded during tests using the Nexygen

Software from Lloyd Instruments. Some statistic information including the coefficient of variance as well as two standard deviations (N and N-1) have been also computed.

Table 1. Mean three-point bend test features.

Feature	Value
Sample passed	*True 100%*
Direction	*Compression*
Test speed (mm/min)	*3*
Span (mm)	*80*
Specimens width (mm)	*9.8*
Specimens thickness (mm)	*5.9*
Specimens cross-sectional area (mm^2)	*57.76*

3. Three-point bend test results

Following data have been recorded during three-point bend tests using the Nexygen software: Stiffness (N/m); Young's Modulus Of Bending (MPa); Flexural Rigidity (Nm^2); Load at Maximum Load (kN); Maximum Bending Stress at Maximum Load (MPa); Machine Deflection at Maximum Load (mm); Deflection at Maximum Load (mm); Maximum Bending Strain at Maximum Load; Work to Maximum Load (Nmm); Load at Maximum Deflection (kN); Maximum Bending Stress at Maximum Deflection (MPa); Machine Deflection at Maximum Deflection (mm); Deflection at Maximum Deflection (mm); Maximum Bending Strain at Maximum Deflection; Work to Maximum Deflection (Nmm); Load at Break (kN); Maximum Bending Stress at Break (MPa); Machine Deflection at Break (mm); Deflection at Break (mm); Maximum Bending Strain at Break; Work to Break (Nmm).

Following distributions have been experimentally determined using data recorded by the materials testing machine:

- Load (N)-deflection (mm) plotted in Fig. 1;
- Stiffness (N/m) of each specimen, presented in Fig. 2;
- Young's Modulus of Bending (MPa) of each specimen, shown in Fig. 3;
- Flexural Rigidity (Nm^2) according to each specimen, plotted in Fig. 4;
- Maximum Bending Stress at Maximum Load (MPa)-Maximum Bending Strain at Maximum Load (Fig. 5);
- Work to Maximum Load (Nmm) of each specimen, presented in Fig. 6;
- Load at Break (kN)-Deflection at Break (mm), shown in Fig. 7;
- Maximum Bending Stress at Break (MPa)-Maximum Bending Strain at Break (Fig. 8);
- Work to Break (Nmm) of each specimen, presented in Fig. 9.

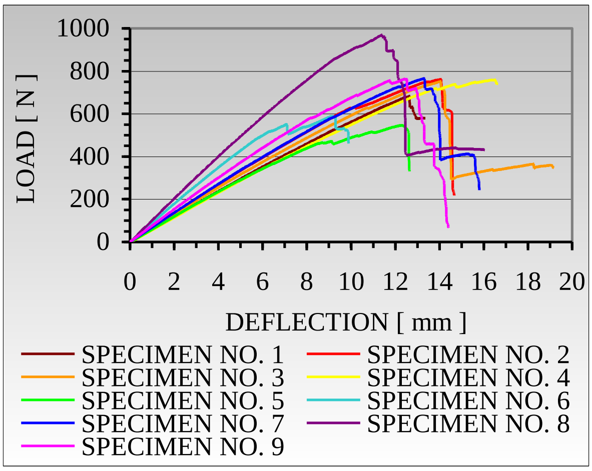

Fig. 1. Load-Deflection distribution of five layers Heliopol/Stratimat300 composite laminate.

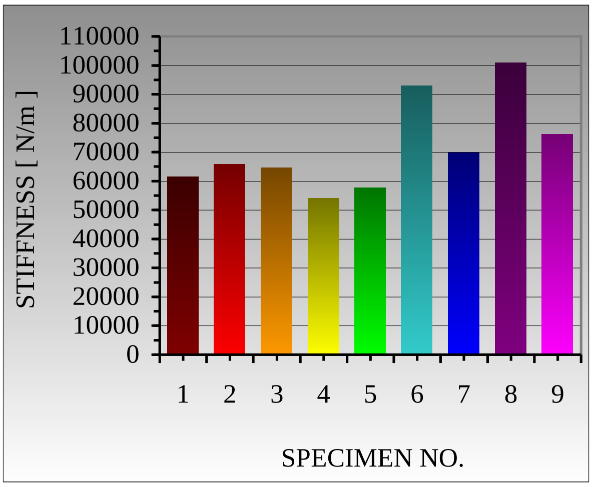

Fig. 2. Stiffness distribution of five layers Heliopol/ Stratimat300 composite laminate.

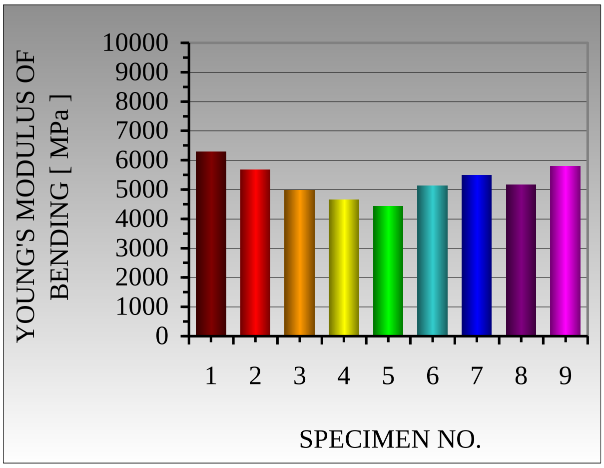

Fig. 3. Young's modulus of bending distribution of five layers Heliopol/Stratimat300 composite laminate.

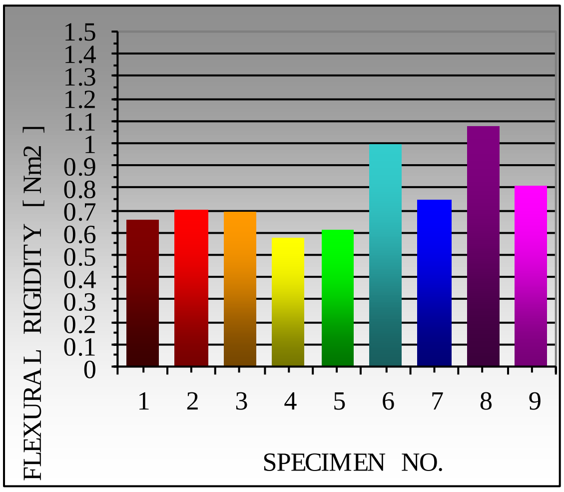

Fig. 4. Flexural rigidity distribution of five layers Heliopol/Stratimat300 composite laminate.

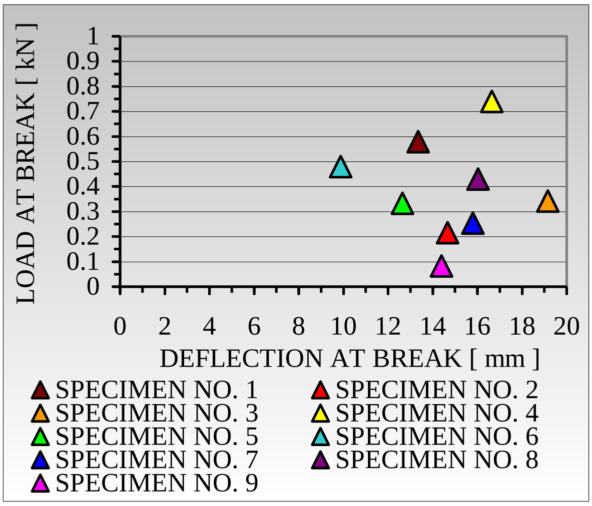

Fig. 7. Load-deflection at break distribution of five layers Heliopol/Stratimat300 composite laminate.

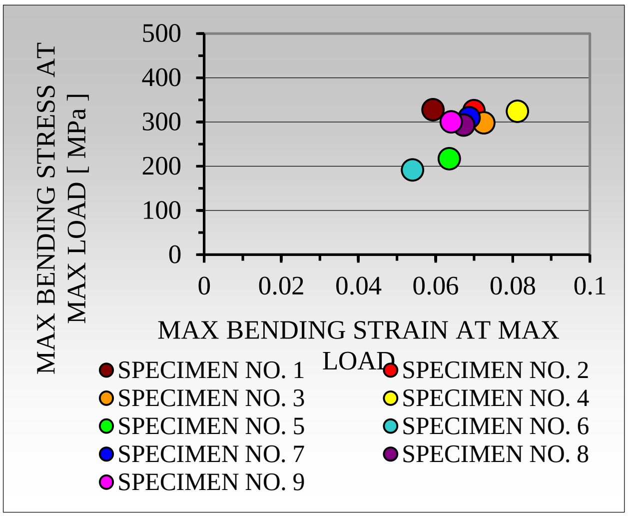

Fig. 5. Maximum bending stress at maximum load distribution of five layers Heliopol/Stratimat 300.

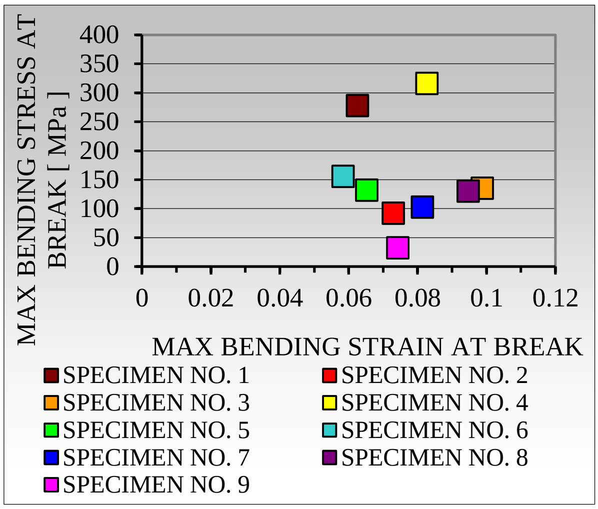

Fig. 8. Maximum bending stress at break distribution of five layers Heliopol/Stratimat300.

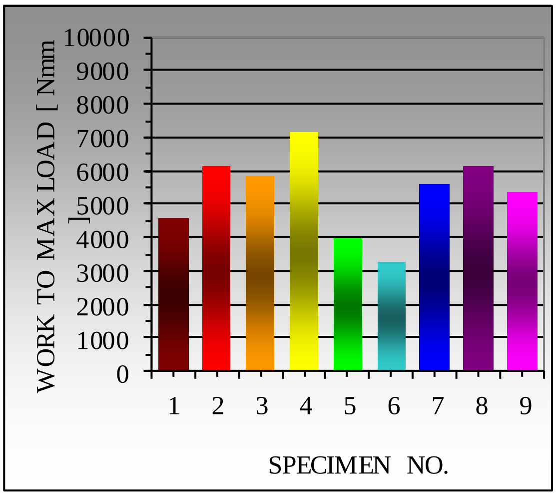

Fig. 6. Work to maximum load distribution of five layers Heliopol/Stratimat300 composite laminate.

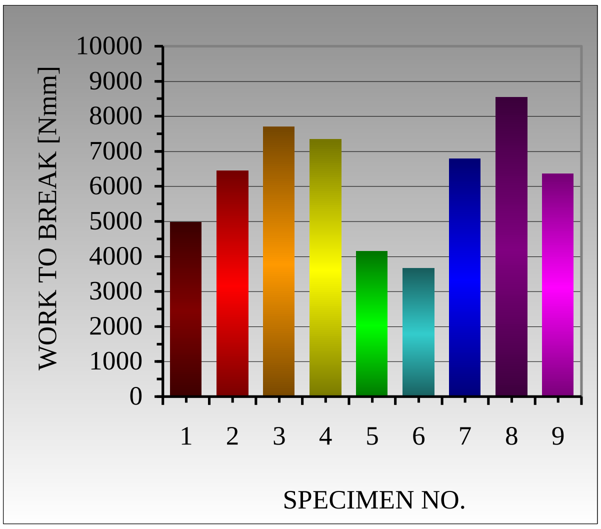

Fig. 9. Work to break distribution of five layers Heliopol/Stratimat300 composite laminate.

4. Discussion

Regarding load-deflection distribution of nine Heliopol/Stratimat300 specimens subjected to three-point bend tests, maximum load of 942.12 N has been reached at specimen number eight and a maximum deflection of 18.8 mm presents specimens number three (Fig. 1). Specimen number eight presents also maximum stiffness of 100911 N/m and specimens number four exhibits minimum stiffness of 54009.42 N/m (Fig. 2). Young's modulus of bending distribution is situated between a maximum value of 6.29 GPa at specimen number one and a minimum one of 4.43 GPa at specimen number five (Fig. 3). The maximum value of Young's modulus of bending represents an outstanding value for this kind of composite laminate subjected to three-point bend tests. The flexural rigidity distribution follows the stiffness distribution and exhibits a maximum flexural rigidity of 1.07 Nm^2 in case of specimen number eight and a minimum value of 0.57 Nm^2 reached by specimen number four (Fig. 4). Maximum bending stress at maximum load of 327.99 MPa has been obtained at specimen number one and maximum bending strain at maximum load of 0.08 presents specimen number four (Fig. 5). Regarding the work to maximum load distribution of nine Heliopol/Stratimat300 specimens subjected to three-point bend tests, maximum value of 7121.64 Nmm exhibits specimen number four and a minimum value of 3264.84 Nmm has been experimentally determined at specimen number six (Fig. 6). Specimen number four exhibits the greatest load at break of 0.74 kN and the greatest deflection at break of 19.15 mm has been reached by specimen number three (Fig. 7). Maximum bending stress at break follows the same distribution as the load at break distribution, the maximum value of 316.27 MPa being noted at specimen number four and the maximum bending strain at break of 0.098 exhibits specimen number three (Fig. 8). The work to break distribution of nine Heliopol/Stratimat300 specimens subjected to three-point bend tests present a maximum value of 8541.08 Nmm in case of specimen number eight and a minimum value of 3660.39 Nmm has been reached by specimen number six (Fig. 9).

5. Conclusions

The Heliopol 9431ATYX_LSE resin reinforced with Stratimat300 glass fibers with 300 g/m^2 specific weight presents outstanding mechanical properties in three-point bend tests. This kind of composite laminate can be used in many applications in which the hand lay-up process represents an economical choice for prototypes.

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