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RESEARCH ON STUDY HEMP FIBER SUBJECTED TO THREE-POINT BEND TESTS

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Abstract: *In this paper, the most important mechanical features determined in three-point bend tests of a hemp fiber composite are presented. Following main mechanical properties have been determined: stiffness, Young's modulus of bending, flexural rigidity, load/stress/strain at maximum load, load/stress/strain at maximum extension, load/stress/strain at minimum load, load/stress/strain at minimum extension, work to maximum load/extension, work to minimum load/extension and load/stress at break.*
Keywords*: Three-point bend, Hemp Fiber, Composite*

1. INTRODUCTION

The no woven polyester mat can be used as core material in thin sandwich structures to increase their stiffness. As skins used in sandwich constructions we can commonly encounter fiber-reinforced composite materials like glass fiber-reinforced polyester resins, carbon/aramid fiber-reinforced epoxies or metal sheets. Since composite materials present anisotropies, the micromechanics of these materials are more complex than the metallic ones [1]. A "polymer matrix composite" is usually a structure known also as a composite laminate formed by a number of unidirectional reinforced laminate or fabrics layers of different types. As common reinforcement types there are fiber hemp and fabrics of various specific weights. These reinforcement materials, usually with high strengths and stiffness, are embedded in matrices with lower values of these features [1].
In general, a polymer matrix composite material is formed of at least two components: resin and reinforcement. Most common composites present three-phase compounds: resin, reinforcement and filler. For such anisotropic composites to predict their elastic properties, homogenization as well as averaging methods can be used. [1].
Tensile, compression and three-point bend tests are the most common tests to determine the mechanical properties of a composite material. For three-phase composites, static cyclic tension-compression tests have been also carried out in order to determine their hysteresis. These materials have been subjected to different number of cycles as well as load limits [2].
Elastic properties like Young's module Ex, Ey, shear modulus Gxy and Poisson's ratio have been computed in composite

2. DETERMINING MECHANICAL PROPERTIES USING THREE-POINT BEND TEST

From the fiber hemp plate, ten specimens have been cut according to SR EN ISO 14125:2000 and subjected to three-point bend test until break occur. The composite plate has been manufactured at Compozite Ltd., Brasov and tested in the Materials Testing Laboratory within Transilvania University of Brasov, Romania. The materials testing machine used in tests is a LR5KPlus type, produced by Lloyd Instruments, with following characteristics (Fig. 1):

- Force range: up to 5 kN;
- Test speed accuracy: < 0.2 %;
- Load resolution: < 0.01 % from the force cell;
- Extension resolution: < 0.1 microns.

Following main features have been determined:

- Stiffness (N/m);
- Young's modulus of bending(MPa);
- Flexural rigidity (Nm^2);
- Load/stress/strain at maximum load;
- Load/stress/strain at maximum extension;
- Load/stress at break;
- Work to maximum load/extension.

Test and specimens features are:

- Test speed: 5 mm/min;
- Median span: 64 mm;
- Median specimens width: 14,300 mm;
- Median specimens thickness: 5,5150 mm;
- Median cross-sectional area: 78,864 mm^2.

The materials testing machine allows determination of experimental results in electronic format by help of the NEXYGEN Plus software.

Figure 1. LR5KPlus materials testing machine

Figure 2. TA Plus materials testing machine in a three-point bend test

3. THREE- POINT BEND TEST RESULTS

Basic mechanical properties determined in three-point bend tests are presented in table 1.

Table 1. Basic mean mechanical properties of a hemp fiber composite

Feature	Value
Stiffness (N/m)	133440
Young's modulus of bending (MPa)	3559.4
Flexural rigidity (Nm^2)	0.72875
Load at maximum load (kN)	0.25351
Maximum bending stress at maximum load (MPa)	55.130
Extension at maximum load (mm)	2.7235
Maximum bending strain at maximum load (-)	0.022133
Work to maximum load (Nmm)	387
Maximum bending stress at maximum extension (MPa)	39.483
Extension at maximum extension (mm)	4,1705
Maximum bending strain at maximum extension (-)	0.033963
Work to maximum extension (Nmm)	428
Load at minimum load (kN)	0.00043888
Extension at minimum load (mm)	0.79157
Maximum bending stress at minimum load (MPa)	0.092288
Maximum bending strain at minimum load (-)	0.0065489
Work to minimum load (Nmm)	35
Load at minimum extension (kN)	0.000004152
Maximum banding stress at minimum extension (MPa)	0.00088132
Extension at minimum extension (mm)	0.000000176
Maximum banding strain at minimum extension (-)	0.0065489

The distribution shows a nonlinear tendency due to the nonlinearity of polyester resins and materials anisotropy. Load-extension distributions for all ten specimens subjected to three-point bend loads as well as other important characteristics are presented in Fig. 3-8.

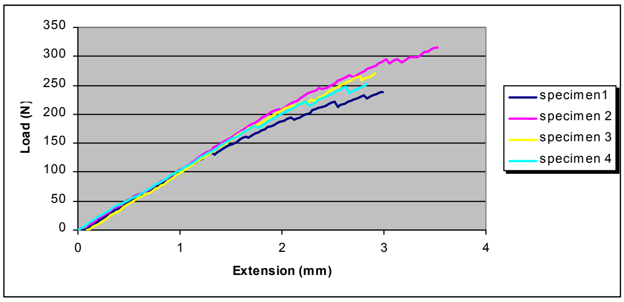

Figure 3. Load-extension distribution of specimens 1-4

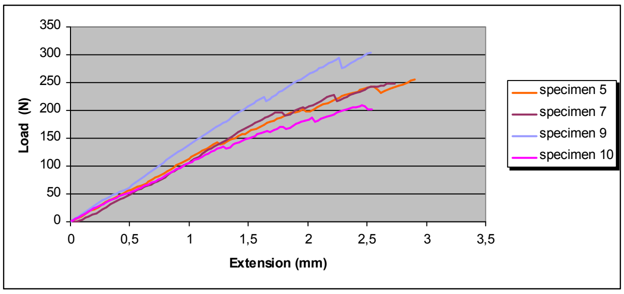

Figure 4. Load-extension distribution of specimens 5-10

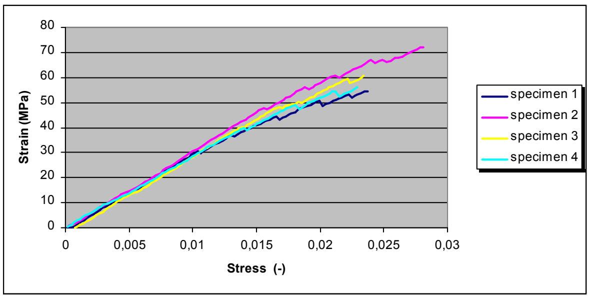

Figure 5. Strain-stress distribution of specimens 1-4

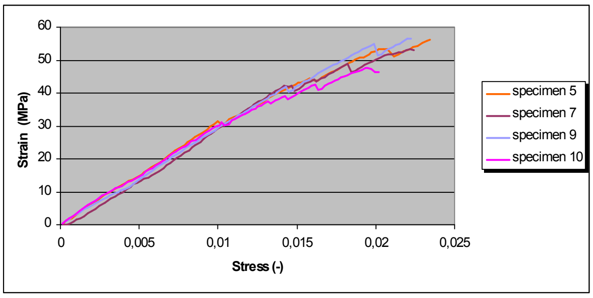

Figure 6. Strain-stress distribution of samples 5-10

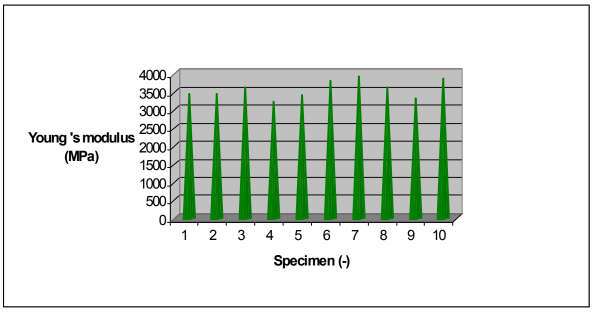

Figure 7. Young's modulus of bending distribution

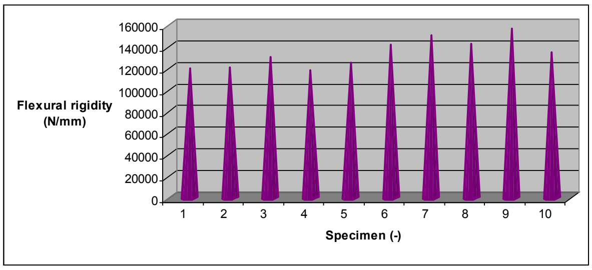

Figure 8. Flexural rigidity distribution

4. DISCUSSION

Regarding the maximum bending stress-maximum bending strain distribution of specimen's number 1-4 as shown in Fig. 5, in the strain range between 0 and 0.0130 the stress-strain distribution is almost linear. The stiffness decrease occurred at specimen 4 at 0.0142 strains and approximately 39.03 MPa stress stress due to core failure. Finally, the specimen 4 has been broken at 0.0022 strains and a stress of 55.96 MPa.
Regarding the maximum bending stress-maximum bending strain distribution of specimen's number 5-10 as shown in Fig. 6, in the strain range between 0 and 0.0100 the stress-strain distribution is almost linear. The stiffness decrease occurred at specimen 10 at 0.0101 strain and aproximately 31,016 MPa stress stress due to core failure. Finally, the specimen 10 has been broken at 0.0201 strains and a stress of 46.24 MPa.
Regarding the failure modes of the specimens, some of them presented delamination core at specific strain values and other specimens presented both delamination and core break at high strain values. Some failure modes of the hemp fiber structure are presented as side views in Figs. 9-10.

Figure 9. Typical failure mode in side view 1

Figure 10. Typical failure mode in side view 2

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