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ABOUT BENDING TESTS FOR TWO COMPOSITE MATERIALS: FABRIC MAT 300 GLASS FIBERS AND COREMAT

Luminiţa CODREA, Mihai-Sorin TRIPA, Daniel OPRUŢA, Mihaela SUCIU

Abstract: *Rapid development of advanced composite materials, especially applicable in vehicle and aeronautical industries, is the motivation for doing this research and presenting the results in this paper. Composite materials are very reliable alternatives to classic materials, but their use involves a series of inconveniences, related to insufficient knowledge of their behavior under different demands, due to their manufacturing method and their complex and variable structure. Two existing composite materials, Fabric MAT 300 glass fibers – Type 1, and COREMAT – Type 2, have been studied on three-point bending tests. Future our research will focus to made of new sandwich composite material, which is very important for automotive and aeronautical industries.*
Key words: *bending test, sample, Fabric MAT 300 glass fiber (Type 1), COREMAT (Type 2).*

1. INTRODUCTION

Composite materials are very reliable alternatives to classic materials, but their use involves a series of inconveniences, related to insufficient knowledge of their behavior under different demands, due to their manufacturing method and their complex and variable structure. In this paper is presented the three-point bending test for two types of composite materials: in the first case it will test the Fabric MAT 300 glass fibers material (Type 1), and in the second case it will request the COREMAT material (Type2). The bending tests presented in this work are very important for future research. Many tests have been made on composite materials, the proof is the numerous publications in the field of testing and calculus of composite materials.

Study about bending behavior is presented in [1], that is an experimental investigation on the three-point bending behavior of composite laminate. A mathematical simulation of nonlinear problem of three-point composite sample bending test is given in [2]. [3] studies a bending test in three points of glass/epoxy composite health monitoring by acoustic emission. [4] presents a review about composite sandwich structure in aeronautic applications. [5] gives experimental results for bending fatigue behavior of glass-epoxy composite materials. [6] gives a study about the failure of composite sandwich materials loaded in three-point bending. Design map of sandwich beams loaded in three-point bending is presented in [7]. In [8] it can seen design, fabrication, and bending test of shape memory polymer composite hinges for space deployable structures. In [9] is studied the bending reinforcement of timber beams with composite carbon fiber and basalt fiber materials. Material characterization of laminated composite materials using a three-point bending technique is given in [10]. [11] gives experimental and numerical study of the bolt reinforcement of a composite-to-steel butt-joint under three-point bending test. In [12] it sees comparative study on mechanical properties of CR340/CFRP composites through three-point bending test by using theoretical and experimental methods. In [13] was studied the influence of dimensional differences on mechanical properties of composite. In [14] is studied the behavior for tensile loaded composite materials used in

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automotive industry. In [15] is presented the determination of young modulus for CFRP using three point bending test at different span lengths. [16] gives a static behavior of composite structure with special applications. In [17] is presented an experimental investigation on bending behavior of existing RC beam retrofitted with SMA-ECC composite materials. In [18] it can be seen an experimental data reduction method for mixed mode bending test based on J-integral approach. [19] presents a study about buckling bio-composite sandwich bars. [20] gives the classical strength calculus for bending beams. The calculus of fatigue resistance to limited durability for thermoplastic polyurethane membrane presented in [21] is a very interesting method which can be applied to fatigue calculus of various composite materials. In [22] is given a study about advanced pultruded glass fibers-reinforced isophthalic polyester resin. An experimental method for dynamic delamination analysis of composite materials by impact bending is given in [23]. [24] is about the determination of bending temperature under load. [25] presents the determination of flexural properties for fiber-reinforced plastic composites. In [26] we see shown the determination of apparent interlaminated shear strength by short-beam method for fiber-reinforced plastic composites. [27] presents the general conditions for methods of producing test plates for fiber-reinforced plastics. [28] presents the preparation of test specimens by machining for plastics. [29] is about the specification of tensile, flexural and compression types (constant rate of traverse) for rubber and plastics test equipment. [30] is about calcination methods for determination of the textile-glass and mineral-filler content textile. [31] gives us the production of test panels for glass fiber reinforcing moldings and sandwich composites. [32] is a website about Fabric MAT 300 glass fibers and [33] is a website about COREMAT.

This study is an original research on the two Types of composite materials that will be used later in future research. The test stand used is a Lloyd's Instruments testing machine, type LR5K Plus with *Nexygen* software and two types from two different composite materials. Samples are manufactured by S.C. Composites S.R.L. Brașov, Romania and experimental research was carried out in Materials Testing Laboratory, Department of Mechanics, "Transylvania" University of Brașov, Romania.

2. CONDITIONS FOR BENDING TESTS

Each component of the composite material has certain mechanical characteristics that will influence the mechanical characteristics of the composite, these characteristics have been determined by three-point bending tests. Samples were cut from the same plate and then subjected to three-point bending tests, samples made with a dimensions in accordance with current standards

Samples were produced in accordance with standards [25], after which bending tests can be performed (as in Fig. 1., sample with the width equal to *b*, and extracted of geometrical characteristics from the Table given in [25]).

Samples are parallelepipedal in shape, having the total length $l \geq 80$ *mm* or $l=80+10$*mm*, distance between supports $L = 64 \pm 1$ *mm*, width $b = 15 \pm 0,5$ *mm* (after manufacturing the samples to be tested, width of the two types of samples was measured $b = 10$ *mm)* and after manufacturing the samples to be tested, the tickness of the two types of samples was measured $h = 3$ *mm*.

The test stand for the three-point bending tests, the machine tests, use the *Nexygen* software. For the test machine, the geometrical characteristics of samples were used as input data for software. In Fig. 1., is presented a sample subjected to three-point bending. After each test, *Nexygen* gives the mechanical characteristics also given in [20].

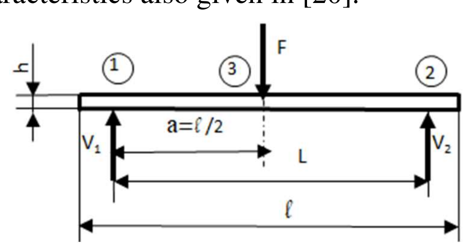

Fig. 1. Composite sample requested by three bending points.

After each three-point bending test, the test machine also gives diagrams.

3. EXPERIMENTAL THREE-POINT BENDING TESTS FOR TWO TYPES OF COMPOSITE MATERIALS

They were made two Types of samples for three-point bending tests: Type 1 of samples is made of a material called Fabric MAT 300 glass fibers and Type 2 of samples is made of COREMAT. Each of the two Types of composites and the results obtained after the three-point bending test will be presented.

3.1 Type 1 of samples

Type 1 with 300g/m^2 density is manufactured identically to the composite material presented in [20]. Geometrical characteristics measured for the first Type of composite samples, based on polyester and Fabric MAT 300 glass fiber are presented in Table 1., details to allow others to replicate and build on the published results.

Table 1. Dimensions for the Type 1 of samples.

Sample no.	Span L [mm]	Width b [mm]	Thickness h [mm]	Area A [mm²]
1	64	10	3	30
2	64	10	3	30
3	64	10	3	30
4	64	10	3	30
5	64	10	3	30
6	64	10	3	30
7	64	10	3	30
8	64	10	3	30
9	64	10	3	30
10	64	10	3	30

After bending tests, is obtained, with the test machine and with *Nexygen* software, numerical values, presented in Table 2., and 10 diagrams for the each sample. Mesured quantities and units of measure are given directly by the test machine.

Table 2. Mesured quantities obtained after bending tests for Type 1 of samples.

No	Name of mesured quantities	Type 1
1	Stiffness [N/m]	29160,67
2	Young's Modulus [MPa]	7078,05
3	Flexural Rigidity [Nm²]	0,159256
4	Load at Maximum Load [kN]	0,279168
5	Maximum Bending Stress at Maximum Load [MPa]	297,7793
6	Machine Extension at Maximum Load [mm]	11,94884
7	Extension at Maximum Load [mm]	11,94884
8	Maximum Bending Strain at Maximum Load	0,05251
9	Work to Maximum Load [Ncm]	182,6774
10	Load at Maximum Extension [kN]	0,04655
11	Maximum Bending Stress at Maximum Extension [MPa]	49,65317
12	Machine Extension at Maximum Extension [mm]	18,58857
13	Extension at Maximum Extension [mm]	18,58857
14	Maximum Bending Strain at Maximum Extension	0,081688
15	Work to Maximum Extension [Ncm]	237,8284
16	Load at Break [kN]	0,279427
17	Maximum Bending Stress at Break [MPa]	298,0556
18	Machine Extension at Break [mm]	12,62407
19	Extension at Break [mm]	12,62407
20	Maximum Bending Strain at Break	0,055477
21	Work to Break [Ncm]	224,3862

One of the diagrams obtained after the three-point bending tests for the Type 1 is presented below: Fig. 2., for Sample no. 1.

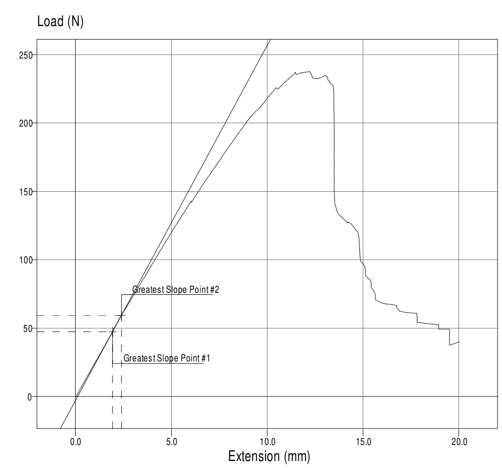

Fig. 2. Type 1, Sample no. 1.

Bending behavior of the 10 samples from the Type 1 of three-point bending tests, is given by curves, the force, on the ordinate, that is dependent on the extension, on the abscissa. The stress being directly proportional to the load, according to the diagrams obtained, the variation of the tension in the 10 samples can be seen.

Studying the bending behavior diagrams of samples, for the Type 1, it was found that the load up to the moment when the irreparable damage occurred in sample varied between 200 N to 350 N. Deformation where the irreparable damage occurred in composite sample from Type 1 varied between 8 mm to 15 mm. The most common value of deformation where irreparable damage occurred was 12 mm.

3.2. Type 2 of composite samples

For the Type 2, it is used COREMAT Xi presented in [20].

Type 2 of composite samples for three-point bending tests are made up of 10 samples, whose geometric characteristics are given in Table 3.

Table 3. Dimensions for Type 2 of samples.

Sample no.	Span L [mm]	Width b [mm]	Thickness h [mm]	Area A [mm²]
1	64	10	3,5	35
2	64	10	3,5	35
3	64	10	3,5	35
4	64	10	3,5	35
5	64	10	3,5	35
6	64	10	3,5	35
7	64	10	3,5	35
8	64	10	3,5	35
9	64	10	3,5	35
10	64	10	3,5	35

Bending tests and *Nexygen* software give numerical values, presented in Table 4. and 10 diagrams for each composite sample of Type 2.

Table 4. Mesured quantities obtained after bending tests for Type 2 of samples.

No	Name of mesured quantities	Type 2
1	Stiffness [N/m]	6990,353
2	Young's Modulus [MPa]	1068,501
3	Flexural Rigidity [Nm²]	0,038177
4	Load at Maximum Load [kN]	0,022204
5	Maximum Bending Stress at Maximum Load [MPa]	17,40038
6	Machine Extension at Maximum Load [mm]	6,483476
7	Extension at Maximum Load [mm]	6,483476
8	Maximum Bending Strain at Maximum Load	0,03324
9	Work to Maximum Load [Ncm]	7,754594
10	Load at Maximum Extension [kN]	0,003322
11	Maximum Bending Stress at Maximum Extension [MPa]	2,603426
12	Machine Extension at Maximum Extension [mm]	6,568894
13	Extension at Maximum Extension [mm]	6,568894
14	Maximum Bending Strain at Maximum Extension	0,033679
15	Work to Maximum Extension [Ncm]	7,915163
16	Load at Break [kN]	0,02203
17	Maximum Bending Stress at Break [MPa]	17,26397
18	Machine Extension at Break [mm]	6,546951
19	Extension at Break [mm]	6,546951
20	Maximum Bending Strain at Break	0,033566
21	Work to Break [Ncm]	7,893782

Below there is presented one of the 10 diagrams for Type 2 of composite samples given by the test machine with *Nexygen*: Fig. 3. for Sample no. 1.

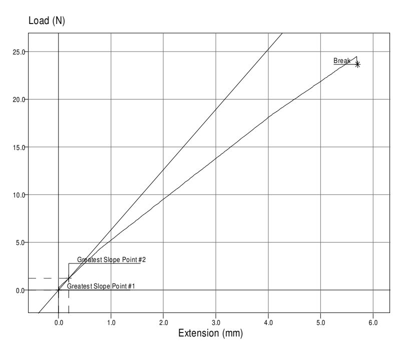

Fig. 3. Type 2, Sample no. 1.

In these diagrams, the load is on the ordinate and the extension on the abscissa ending behavior of the 10 composite samples from the Type 2 of three-point bending tests, is given by curves, the force on the ordinate, that is dependent on the extension, on the abscissa.

From these curves, it was observed that the force until the moment when irreparable damage occurred in Type 2 of composite material, varied between 15 N to 25 N and the deformation where the irreparable damage varied between 5 mm to 8 mm. The most common value of deformation where irreparable damage occurred was 7 mm.

4. RESULTS

In Table 5., it is presented the comparative experimental results for the two Types of composite samples tested in three-point bending. In general, higher experimental values were obtained for Type 1 than for Type 2.

Table 5. Comparative numerical results for the two Types of samples tested for three-point bending

No	Name of mesured quantities	Type 1	Type 2
1	Stiffness [N/m]	29160,67	6990,353
2	Young's Modulus [MPa]	7078,05	1068,501
3	Flexural Rigidity [Nm²]	0,159256	0,038177
4	Load at Maximum Load [kN]	0,279168	0,022204
5	Maximum Bending Stress at Maximum Load [MPa]	297,7793	17,40038
6	Machine Extension at Maximum Load [mm]	11,94884	6,483476
7	Extension at Maximum Load [mm]	11,94884	6,483476
8	Maximum Bending Strain at Maximum Load	0,05251	0,03324
9	Work to Maximum Load [Ncm]	182,6774	7,754594
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18	Machine Extension at Break [mm]	12,62407	6,546951
19	Extension at Break [mm]	12,62407	6,546951
20	Maximum Bending Strain at Break	0,055477	0,033566
21	Work to Break [Ncm]	224,3862	7,893782

Comparatively from Table 5., it can be seen for some experimental values:

1. for stiffness, the highest value was obtained for samples of Type 1, that is 4 times higher than Type 1;
2. for Young’s modulus, the highest value was obtained for Type 1, and the lowest for Type 2, Young’s modulus for Type 1 is 6,6 times highest than Type 2;
3. for flexural rigidity, the highest value was obtained fpr samples of Type 1, flexural rigidity for Type 1 is 4 times bigger than Type 2;
4. for Type 1, the load at maximum load is 12,6 times bigger than the Type 2;
5. for maximum bending stress at maximum load, the highest value was obtained for Type 1, that is 17 bigger than Type 2;
6. for machine extension at maximum load, the highest value was obtained for Type 1, 1,8 times bigger than Type 2;
7. for xtension at maximum load, for the Type 1 it was obtained a value 1,8 times bigger than Type 2;
8. for the maximum bending strain at maximum load, the value was obtained for Type 2 is almost 1,6 times bigger than Type 1;
9. the work to maximum load for Type 2 is almost 24 times bigger than Type 1;
10. for the load at maximum extension, the highest value was obtained for Type 1, that is ***1,4*** times bigger than Type 1;
11. for maximum bending strain at maximum extension, the value obtained for Type 1 is 19 times bigger than Type 1;

12. the machine extension at maximum extension is 2,8 times bigger for Type 2 than Type 1;
13. for extension at maximum extension, for Type 2, the value obtained is 2,8 times bigger than Type 1;
14. for maximum bending strain at maximum extension, the highest value was obtained for Type 1, 2,4 times bigger than Type 1;
15. for the work to maximum extension for Type 2, the value is 30 times bigger than Type 1;
16. the load at break for the Type 1 is 12,7 times bigger than Type 2;
17. the value of Type 1 is 17 times bigger than Type 2 for the maximum bending stress at break;
18. the machine extension at break fro Type 1 is 2 times bigger than the value of Type 2;
19. the value of extension at break of Type 1 is 2 times bigger than the value of Type 2;
20. the value of Type 1 is 1,65 times bigger than Type 2 for the maximum bending strain at break;
21. for the work to break, for the Type 1 is ***28*** times bigger than Type 2.

5. CONCLUSIONS

Based on experimental three-point bending tests, this work was necessary due to desire to manufacture a new composite materials, with special impact properties. The two Types of composite materials and their mechanical properties were studied at three-point bending tests are: Type 1 (Fabric MAT 300 glass fibers) and Type 2 (COREMAT). Their were made, each Type containing 10 samples, according to existing standards. Each Type of samples was subjected to three-point bending tests on the Lloyd's Instruments testing machine, type LR5K Plus. The obtained experimental comparative centralizing results was in Table 5., results were entered in Tables 3 and 4, and the variation curves that were obtained for each sample of each Type were also presented.

Table 5. shows that the values obtained for Type 2 are always higher than the values obtained for Type 1. The biggest difference between the two Types of composite materials was obtained for the work to break, the value for Type 1 is ***28*** times bigger than Type 2. The smallest difference between the two Types of composite materials was obtained for the load at maximum extension, the value was obtained for Type 1 is ***1,4*** times bigger than Type 1,

This results are very important for our future research and applications.

Conclusions of this experimental and original research is that the composite of Type 1 is good for a future sandwich composite as layers with a Type 2 as core.

It is wanted to manufacture elements that must have high resistance to impact. Future research will focus to made a new samdwich compozite material, resistant to the impact testing, which is very important for the automotive industry and also in other important fields, such as the aeronautical industry.

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Asupra testelor la încovoiere pentru două materiale compozite: Fabric MAT 300 fibre de sticlă şi COREMAT

Rezumat: Dezvoltarea rapidă a materialelor compozite avansate, aplicabile în special în industriile vehiculelor și în aeronautică, este motivația pentru realizarea acestei cercetări și prezentarea rezultatelor în această lucrare. Materialele compozite sunt alternative foarte fiabile la materialele clasice, dar utilizarea lor presupune o serie de inconveniente, legate de cunoașterea insuficientă a comportamentului lor la diferite solicitări, datorită metodei de fabricație și structurii lor complexe și variabile. Două materiale compozite existente, Fabric MAT 300 și COREMAT, au fost încercate la încovoiere în trei puncte. Se dorește să fie fabricată o parte a caroseriei mașinii și alte elemente ale mașinii, care trebuie să aibă rezistență mare la impact. Cercetările viitoare se vor concentra pe fabricarea unui nou material compozit sandwich, care este foarte important pentru industria auto și aeronautică.

Luminiţa CODREA, Drd. Eng., Technical University of Cluj-Napoca, Department of Mechanical Engineering, luminitaopruta@gmail.com, Phone: 0765257840
Mihai-Sorin TRIPA, Conf. Dr. Eng., Technical University of Cluj-Napoca, Design Engineering and Robotics Department, Mihai.Tripa@muri.utcluj.ro, Phone: 0720723012
Daniel OPRUŢA, Drd. Eng., Technical University of Cluj-Napoca, Department of Mechanical Engineering, opruta@yahoo.com, Phone: 0765257837
Mihaela SUCIU, Prof. Dr. Eng., Technical University of Cluj-Napoca, Mechanical Engineering Department, Mihaela.Suciu@rezi.utcluj.ro, Phone: 0723878112