EFFECTS OF REINFORCED MATERIALS ON MECHANICAL PROPERTIES OF 3D COMPOSITE STRUCTURE

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Abstract- In this study the mechanical performance of sandwich composite panels based on "green" 3D warp knitted composites is presented and discussed. Different 3D sandwich knitted fabric performs have been produced in which leek and bamboo fibers were used with the comparison of carbon fiber as reinforcement for "green" composites. Composite panels using these performs have been produced using hand lay-up technique. Experimental results revealed that the polyester resin reinforced by the 3D knitted spacer fabrics with reinforced fibers exhibited improved tensile, three point bending and impact behaviors. The obtained results show that the mechanical performances vary according to the type of reinforced fibers.

Index Terms- green composite, three-dimensional, spacer fabric, high performance.

I. INTRODUCTION

Environmentally friendly green composites were fabricated from renewable resources bring very promising potential to provide benefits to companies, natural environment and end-customers due to dwindling petroleum resources [1]. Therefore, there has been a growing interest in the use of broad-spectrum green alternatives for the replacement of petroleum-based fibers towards cost reduction and global sustainability during the last several decades [2]. Most of the fiber-reinforced composites are non-degradable or very difficult and expensive to recycle. Hence they pollute the land, water and air. Compared to the synthetic fibers, natural and plant based fibers demonstrate many advantages of low cost and low density. These natural fibers also gain importance because of the necessity to decrease the amount of carbon dioxide in atmosphere.

On the other hand, production rate of 3D knitted reinforced composite structures have grown dramatically in popularity over the recent years in different applications due to the excellent structural capabilities and improved properties. In general, they demonstrate high tensile, flexural, impact and crash properties, which lead to replacement of the conventional structures with the composite structure [3]. In addition, nowadays the development of textile reinforced with resin matrix composite is one of the important issues for various industries. The textile material gives the strength while the matrix creates the composite unity and transmits the strains. Usage of the textile reinforced composites has many precious advantages. Maintaining the integrity and behavior of materials under extreme conditions, a better weigh/strength ratio compared with the classic materials and an improved fatigue life are the most valuable advantages which are obtained by using textile reinforcements. These advantages cause to produce improved materials [5]. Moreover, usage of textile reinforced increase in importance for the manufacturing of lightweight structures [4].

The aim of this study is to obtain high performance and durable novel "green" 3D warp knitted composites in which leek and bamboo fibers were used with the comparison of carbon fiber as reinforcement for "green" composites. Experimental results revealed that the polyester resin reinforced by the 3D knitted spacer fabrics with reinforced fibers exhibited improved tensile, three point bending and impact behaviors.

II. MATERIALS AND METHODS

A. Materials

3D spacer fabric (Table 1.), polyester & cobalt & metyl etyl ketone peroxid (MEKP) provided by ESKİM KİMYA SAN. TİC. A.Ş., and 03k carbon fibers were obtained from AKSACA Carbon Fiber in Turkey. Bamboo fiber and fresh leek were purchased in Turkey.

TABLE I. 3D fabric properties

Type	Composition	Thickness	Color	Weight
Knitted Mesh Fabric	100 % Polyester	10 mm	Raw White	600 g/m^2

B. Preparation of 3D Knitted Fabrics Reinforced By Fibers

As seen in Figure 1, carbon fiber, leek and bamboo fibers were placed in warp direction of 3D fabric to prepare the composite materials for tensile test and weft direction for impact and three point bending tests. 10 strands of carbon fibers were knitted into a unit yarn then these unit carbon yarns were used in 3D spacer fabric. Leeks were separated into its fibers then dried for 48 h in 60 ºC in the oven. Bamboo and leek fibers were placed in 3D spacer fabric with average diameter of 1 mm was prepared by adding

catalyst (MEKP) and accelerator (Cobalt) with ratio of 1%. The prepared fiber-reinforced 3D structures were put in the mold and then they were fully impregnated with polyester resin. In order to cure these mixtures, they were stayed in the oven for 48 h at 60 ºC.

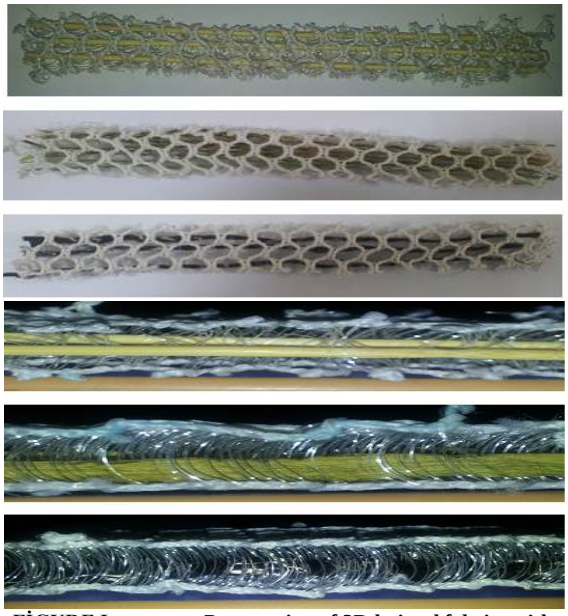


FİGURE I. Preparation of 3D knitted fabrics with fibers.

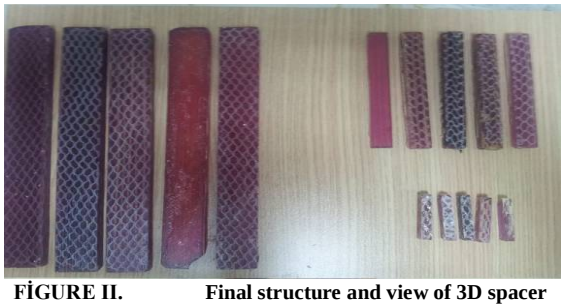


FİGURE II. Final structure and view of 3D spacer fabrics.

TABLE II. Structural parameters of composites for a) impact test (IT); b) three point bending test (TPB); and c) tensile test (TT).

	PES % ratio	3D % ratio	Fiber % ratio
IT			
PES+3D	97	3	-
PES+3D+LF	96.4	3	0.6
PES+3D+BF	95.5	2.8	1.7
PES+3D+CF	95	3	2
TPB			
PES+3D	93	7	-
PES+3D+LF	92.1	6.4	1.5
PES+3D+BF	88.5	6.5	5
PES+3D+CF	89	6.3	4.8
TT			
PES+3D	93	7	-
PES+3D+LF	92.5	6	1.5
PES+3D+BF	90.5	5	4.5
PES+3D+CF	91.6	5	3.4

Impact Test

Energy absorbed per unit area of the sample is the measurement of impact toughness. According to ASTM A370, the standard specimen size for impact testing was prepared as 10 mm × 10 mm × 55 mm. The tester of MFL PSW 300 pendulum impact tester was used for the purpose. Charpy impact test loading velocity was set at 5.83 m/s.

Three Point Bending Test

Three point bending tests were performed to determine the flexural resistance of the composite materials. The tester of MFL pendulum impact tester was used with the dimensions of 300 mm × 40 mm × 20 mm. Furthermore, the testing velocity was set 2.5 m/h.

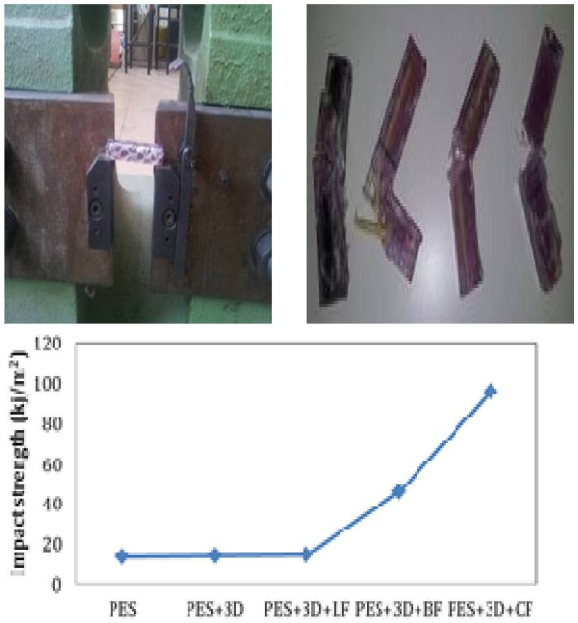


TABLE III Schematic of impact test with performance of the samples.

TABLE IV. Sample weights with results of impact test.

	Empty 3D (g)	3D+Fiber (g)	Composite Materials (3D+ Fiber+PES) (g)	Absorbed Energy (J)	Impact Strength (KJ/m²)
PES	-	-	6.700	2	14.0
PES+3D	0.627	-	8.210	2	14.3
PES+3D+LF	0.614	0.760	8.860	2	14.9
PES+3D+BF	0.631	1.109	8.552	6	46.2
PES+3D+CF	0.574	1.017	8.280	12	96.0

Tensile Test

The tensile test experiments were done by using SHIMADZU AG-BS series tensile tester with a 250 KN load cell at a crosshead speed of 3 mm/min. According to the ASTM D 638M , the test samples for tensile tests were prepared by the dimensions of 150 mm × 20 mm × 10 mm.

III. RESULTS AND DISCUSSION

Impact Test

It has been known that the impact test determines the amount of energy absorbed by a material when it

destroys. The impact tests with the results of all materials are shown in Figure 3 and Table 3. Even if there is no any significant difference between only cured PES resin, 3D spacer fabric with fully impregnated PES resin and reinforced with leek fibers, which demonstrated about absorbed energy of 2 joule and the impact strength of approximately 15.0 KJ/m2; a dramatic increase of 3 and 6 times for absorbed energy were observed when bamboo and carbon fibers were used, respectively. Furthermore, the impact strength was increased from 14.0 KJ/m2 to 46.2 and 96.0 KJ/m2 with the increasing of ca. 330% and 685.7% when 3D reinforced with bamboo and carbon fibers. Unlike the rupture behavior of typical PES resin without 3D knitted fabric, bamboo and carbon fiber reinforced composites showed brush-like failure that bridging the crack faces and thereby hindering crack opening as indicated in Figure 3.

Three Point Bending Test

The three point bent tests were conducted to determine the flexural resistance of the control and composite samples which are shown Figure 4 and Table 4. From the results obtained, the maximum load applied increased from 441.3 to 1765.2 and 7060.8 N by improving ca. 300% and 1500% by using 3D knitted fabric reinforced via bamboo and carbon fibers, respectively.

On the other hand, it can be seen that the influence of the supporting ability of 3D knitted fabrics with or without leek fibers is not the mainly factor(s) to improve the bending strength of the samples. Furthermore, it is worth noting that the sample which was produced by only PES resin was broken and directly separated into two parts during the flexure test however the other samples did not separate but cracked instead.

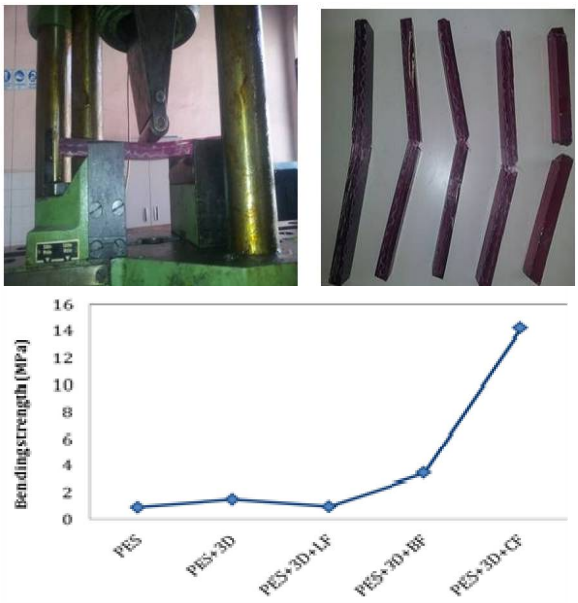


FİGURE III. Experimental setup for three-point bend test with the images of composites after the test and bending strength of the samples.

TABLE I. Sample weights and results of three point bending test.

	Empty 3D (g)	3D+Fiber (g)	Composite Materials (3D+Fiber+PES) (g)	Maximum Bending Load (N)	Bending Strength-σ(MP)
PES	-	-	278	441.3	0.916
PES+3D	8.748	-	274.4	735.5	1.527
PES+3D+LF	8.647	10.355	282.2	490.3	0.957
PES+3D+BF	8.514	13.747	291.7	1765.2	3.412
PES+3D+CF	8.997	15.073	290.6	7060.8	14.177

It was also found that with the addition of only 1.8 wt.% bamboo or 2 wt.% carbon fibers, the bending strength was greatly improved by ≈272.5 and 1447.8%, respectively compared to neat PES resin. These fibers attributed to a strong interfacial interaction between the fibers and 3D matrix which leads to favorable stress transfer across the polymer to the fibers. Of most interest was using 3D with leek fibers did not influence the three point bending performance although there was some degree improvement to occur in 3D knitted fabric impregnated by PES resin. This is quite surprising probably because of no enough interfacial adhesion between the leek fibers and matrix. Accompanied with using carbon fibers the crack was occurred under about 2900 N load but the effects CF that caused to increase the final load up to 7060 N.

Tensile Test

The tensile test is the one of the most fundamental types of mechanical test in order to investigate the material behaviors because of its simplicity with relatively inexpensive and fully standardized technique. Figure and Table 5 present tensile behaviors of all the samples. It should be noted that except only cured PES resin, all the other samples with expecting ultra-high tensile strength were slipped between the grips in the mid of testing. Therefore the results, which are shown in Figure and Table 5, do not fully represent the structural composites' behaviors. It lends credence to the statement that our tensile test design is not suitable to determine tensile strength and modulus measurement since the slipping usually occurs during the test. On the other hand, as seen in Figure 5, the improvement of fiber-matrix interface strength especially for bamboo and carbon fibers that will lead to a brush-like fracture which indicate high performance composite supported by 3D knitted fabrics.

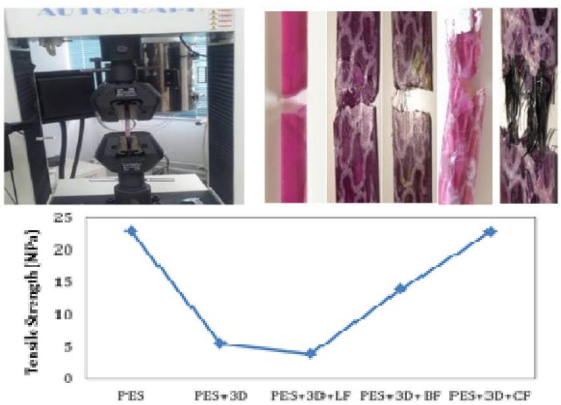


FİGURE IV. Experimental setup for tensile test with the images of composites after the test and tensile strength of the samples.

TABLE II. Samples weight with results of tensile test.

	Empty 3D (g)	3D+Fiber (g)	Composite Materials (3D+ Fiber+PES) (g)	Maximum Tensile Load (N)	Tensile Strength - σ (MPa)
PES	-	-	37.798	4671	22.915
PES+3D	3.236	-	44.11	1406	5.399
PES+3D+LF	2.992	3.662	45.823	1117	3.818
PES+3D+BF	2.360	4.473	44.010	3789	13.879
PES+3D+CF	2.601	4.429	48.859	6460	22.847

CONCLUSIONS

High performance and durable novel 3D warp knitted composites with unique properties were produced by using especially bamboo and carbon fibers as reinforcements. In the second step of the research, there will be comparison for the performance values of carbon and natural fiber with investigation of the effect of different combination of natural (starch, soy protein) and synthetic (epoxy, polyester) resins on thermal diffusion and sound absorption performance in addition to mechanical properties. Polyurethane foam which has a very low coefficient of thermal diffusion will be used to produce a sandwich structure that consist of a core material, polyurethane foam, and faced with a skin material of 3D bio-composites is expected to have very good thermal insulation value. As a result, these "green" 3D composite materials can be used in automotive, marine, floors, separation panels and different parts of buildings.

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