(REFEREED RESEARCH)

BAMBOO FIBRE REINFORCED COMPOSITE STRUCTURES AND THEIR MECHANICAL PROPERTIES

BAMBU ELYAF TAKVİYELİ KOMPOZİT YAPILAR VE MEKANİK ÖZELLİKLERİ

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ABSTRACT

Generally felt and woven fabrics are used as a reinforcement component of fibre in composite structures. Glass and carbon fibres are the most widely used materials in multiaxial fabrics to increase the mechanical properties of reinforced composites. In this study, it has been aimed to study the natural fibres to observe the mechanical properties of the composite structures that are produced. For this purpose bamboo fibres are used, instead of glass and carbon. The research was carried out with the Nm 0.93 bamboo slivers by using vinyl ester resin at different reinforcement ratios to produce the hand lay-up composite structures. The produced reinforced composite samples were then tested for their three point bending and tensile strength tests. The fracture surfaces of the tensile strength samples and three point bending samples were also inspected on the scanning electron microscope. According to the results, it has been evaluated that bamboo fibres with 3mm fibre length and above increases the mechanical properties of composite structures. As a result, the produced bamboo fibre reinforced composite structures have presented good mechanical properties.

Key Words: Bamboo sliver, Reinforced composite, Hand lay-up method, Mechanical properties, Fracture surface.

ÖZET

Genel olarak keçe ve dokunmuş kumaşlar, kompozit yapılarda elyaf takviyesi olarak kullanılmaktadır. Cam ve karbon lifleri, elyaf takviyeli kompozitlerde çok eksenli kumaşların mekanik özelliklerini arttırmada yaygın olarak kullanılan materyallerdendir. Bu çalışmada, doğal elyaf kullanılarak üretilen kompozit yapıların mekanik özelliklerinin incelenmesi hedeflenmiştir. Bu amaçla, cam ve karbon elyafı yerine bambu elyafı kullanılmıştır. Araştırmada, Nm 0.93 bambu fitili kullanılarak vinilester reçine ile farklı takviye yüzdelerinde el yatırma yöntemine göre kompozit yapılar üretilmiştir. Üretilen elyaf takviyeli kompozit numunelere, üç nokta eğilme ve çekme dayanımı testleri uygulanmış ve ayrıca bu numunelerin kırık yüzey analizleri de elektron mikroskobunda incelenmiştir. Elde edilen sonuçlara göre bambu elyaf takviyeli kompozitlerde, 3mm ve üstü uzunluklarda lif kullanımının kompozit yapıların mekanik özelliklerini iyileştirdiği görülmüştür. Genel sonuç olarak, bambu elyaf takviyeli üretilen kompozit yapıların oldukça iyi mekanik özeliklere sahip olduğu söylenebilir.

Anahtar Kelimeler: Bambu fitili, Elyaf takviyeli kompozit, El yatırma metodu, Mekanik özellikler, Kırık yüzey.

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1. INTRODUCTION

For the past several years, public attention has grown on natural fibres due to their environmental friendly origin and so researchers could not stay unconcerned on this. Studies on composites have also been concerned on natural fibre reinforced structures. Bamboo is one of the natural fibres which are traditionally used to create various living facilities and tools; the high strength value to its weight is derived from fibers longitudinally aligned in its body. Therefore bamboo fibre composites are generally called “natural glass fibre” (1) even though they have not been studied as many as glass fibres.

H.İsmail et.al (2) studied the effects of bamboo fibre filler loading with and without the presence of bonding agent; they observed that the adhesion between the bamboo fibre and the natural rubber were enhanced by the use of bonding agent and this also leads to an increase in both tensile modulus and hardness of the composites. K. Okuba, T.Fujii, Y. Yamamoto (1) developed bamboo based polymer composites and studied their mechanical properties; it has been found that bamboo fibre bundles have a potential ability to work as the reinforcement of polymer matrix and shown higher tensile strength than that of jute fibres. S-H.Lee et.al (3) improved the bio-composites from biodegradable polymers and bamboo fibres by using lysine-diisocyanate as a bio-based coupling agent and expressed that tensile properties and water resistance of the samples were appreciably improved by this process.

Bamboo fibre, which is a regenerated cellulose fibre, can be easily blended with the other natural fibres as well as recyclable under the 100 % sun light or at the soil with the micro organisms; therefore it is known as a “natural green and economic fibre” of the 21st. century’s textile material which also has an antibacterial properties (4). Therefore, we have conducted the study described in this paper to investigate the bamboo fibre reinforced composite structures and their mechanical properties to be able to benefit from the fibre's natural qualities and reasonable good physical properties, such as moisture absorption (60 % more moisture absorption than cotton) and high elasticity. The tensile strength at the dry state of the bamboo fibre is 2.33cN/tex and wet state is 1.37cN/tex and dry breaking elongation is 23.8 % (4). Hence, we have studied various reinforcement ratios of bamboo sliver with vinyl ester resin to produce composite structures and report the effects of these proportions on the mechanical properties of the composites. Scanning electron microscopy (SEM) studies were also made to determine the failure mechanism of these samples.

2. EXPERIMENTAL

2.1 Sample Preparation and Tests

In this work, Nm 0.93 bamboo slivers were used to produce the reinforced composite samples. Both tensile strength (5) and three point bending tests (6) were carried out in four ratios which are 15, 25, 35 and 40%. Reinforcement ratios used for this study is given in Table 1.

All of the reinforced composite samples were produced by the hand lay-up method using the vinyl ester resin. The pure resin test results are given in Table 2.

Table 1. Different reinforcement ratio (%) of Bamboo sliver

Weight of reinforcement / resin proportion	
Tensile strength test	Three point bending test
15	15
25	25
35	35
40	40

Samples for the tensile strength were prepared according to the TS 1398 EN ISO 527 (5) (dimensions of 195 x 115 x 5 mm) and their results are given in Table 3.

Three point bending test samples were also prepared (dimensions 80 x 10 x 4 mm) according to the TS EN ISO 178 (6); the samples were tested under the 1 mm/min head speed. The results of these samples can be seen at the Table 4.

All fibres were laid on the mold surfaces and 40 ml of resin, 2% hardening and % 0.2 cobalt naftelat was mixed and added on to the samples in the mould. All the uni-directional (UD) produced samples were then post-cured in three hours consecutively at the temperatures of 50°C, 80 °C and 110 °C.

2.2 Electron Microscopy Studies

The fracture surfaces of the tensile strength samples and three point bending samples were examined by the scanning electron microscope JEOL JSM – 5910 LV. The photographs of these samples are given in Figures 1-12.

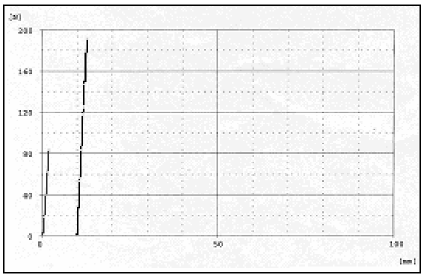

Figure 1. Force-elongation diagram of the pure resin

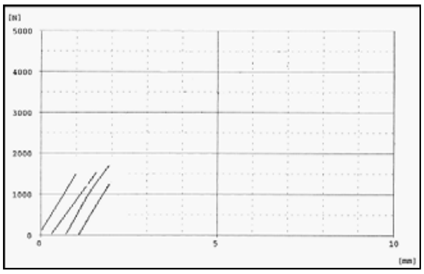

Figure 2. Force-elongation diagram of the tensile strength test of the 15 % bamboo sliver reinforcement sample

Table 2. Mechanical properties of the pure resin

Elastic Modulus (MPa)	Max-Load (kgf)	Strain Strength (MPa)	Elongation on Max.Load (%)	Breaking Strength (kgf)	Breaking Elongation (%)	Width (mm)	Thickness (mm)	Flexural Strength (Mpa)
4425.37	8.8604	39.8249	1.07934	9.2284	1.07945	9.7900	5.30000	160

Table 3. Tensile strength test results of the bamboo sliver reinforcement samples

Reinforcement Ratio of the Samples (%)	Elastic Modulus (MPa)	Max-Load (kgf)	Strain Strength (MPa)	Elongation on Max.Load (%)	Breaking Strength (kgf)	Breaking Elongation (%)	Width (mm)	Thickness (mm)
15	3301.30	175.8050	40.424	1.35783	175.6138	1.35739	10.4550	4.08
25	4182.70	290.3637	68.0129	2.20072	288.664	2.20841	10.27	4.08
35	3858.98	362.254	83.2906	3.40305	357.028	3.44261	10.4100	4.10
40	4063.52	450.7143	102.024	4.04899	441.9681	4.0644	10.2667	4.25

Table 4. Three point bending test results of the bamboo sliver reinforcement samples

Reinforcement Ratio of the Samples (%)	Elastic Modulus (MPa)	Max-Load (kgf)	Strain Strength (MPa)	Elongation on Max.Load (%)	Breaking Strength (kgf)	Breaking Elongation (%)	Width (mm)	Thickness (mm)
15	5003.03	22.5229	120.440	2.99832	20.9424	3.00462	10.4933	4.20000
25	4834.51	24.5624	132.514	3.84621	21.6009	4.05755	10.2667	4.18667
35	5619.22	42.1142	162.090	4.46265	41.1168	4.49577	10.2450	4.85500
40	5750.57	52.5448	176.502	7.14244	42.9385	7.77742	10.1867	5.37333

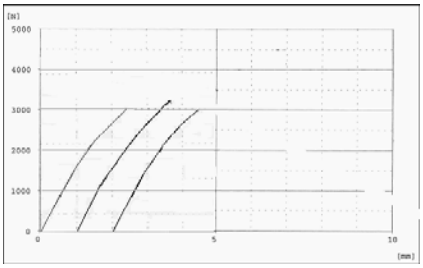

Figure 3. Force-elongation diagram of the tensile strength test of the 25 % bamboo sliver reinforcement sample

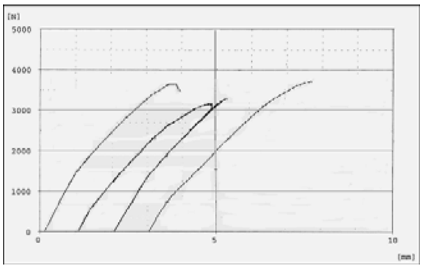

Figure 4. Force-elongation diagram of the tensile strength test of the 35 % bamboo sliver reinforcement sample

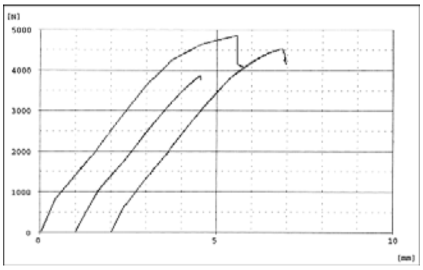

Figure 5. Force-elongation diagram of the tensile strength test of the 40 % bamboo sliver reinforcement sample

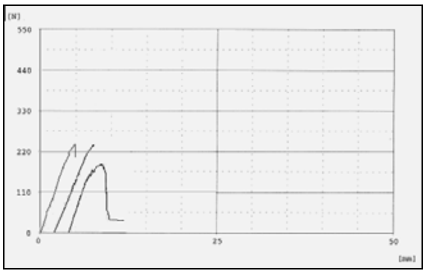

Figure 6. Force-elongation diagram of the three point bending test of 15 % bamboo sliver reinforcement sample

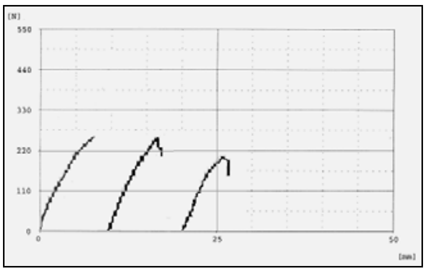

Figure 7. Force-elongation diagram of the three point bending test of 25 % bamboo sliver reinforcement sample

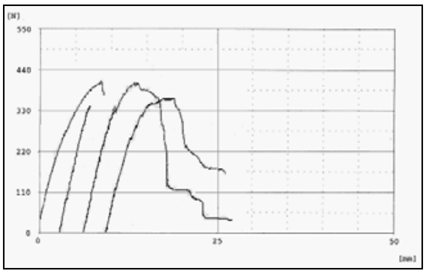

Figure 8. Force-elongation diagram of the three point bending test of 35 % bamboo sliver reinforcement sample

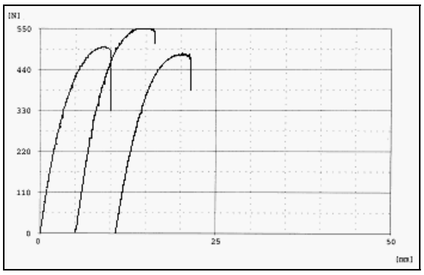

Figure 9. Force-elongation diagram of the three point bending test of 40 % bamboo sliver reinforcement sample

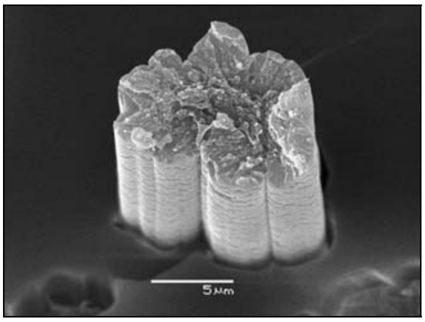

Figure 10. SEM photograph of the bamboo fibre

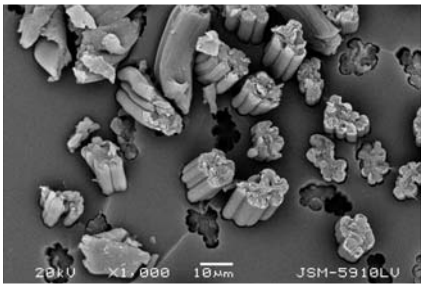

Figure 11. SEM photograph of the tensile strength sample of 15 % bamboo sliver reinforcement (X 1000)

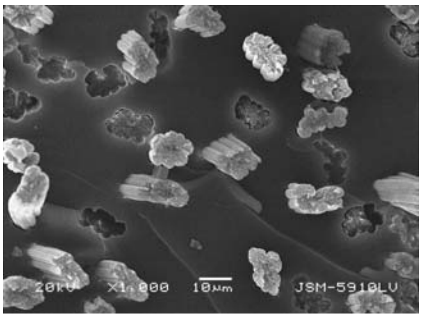

Figure 12. SEM photograph of the tensile strength sample of 25 % bamboo sliver reinforcement (X 1000)

3. RESULTS AND DISCUSSION

3.1. Evaluation of the Force-Elongation Diagrams

Force-elongation diagrams can be seen from the Figures 1-9; according to the results bamboo slivers increase the tensile strengths and elongation at the maximum load of the materials. It was observed that tensile strengths of the produced composite materials do show a linear increase regarding to the fibre percentage that is made of; the reason for this is probably due to bamboo sliver which consist of continuous long fibres within the structure.

3.2. Evaluation of the SEM Photographs

SEM photographs of the bamboo fibre reinforced composite structures were given in Figures 10-16; the tensile strengths of these samples are shown in Figures 11 and 12, the three point bending test samples are given in Figures 13-16.

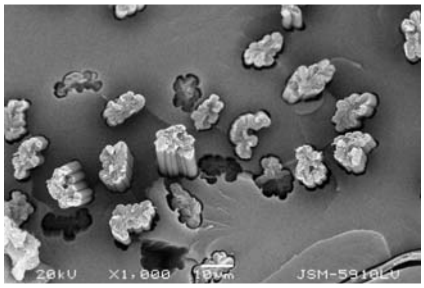

Figure 13. SEM photograph of the three point bending sample of 15 % bamboo sliver reinforcement (X 1000)

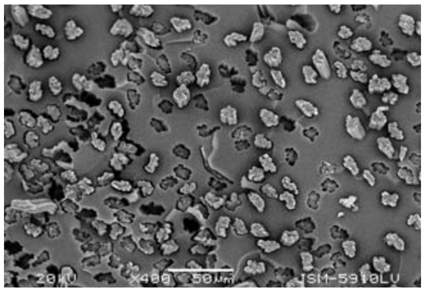

Figure 14. SEM photograph of the three point bending sample of 25 % bamboo sliver reinforcement (X 400)

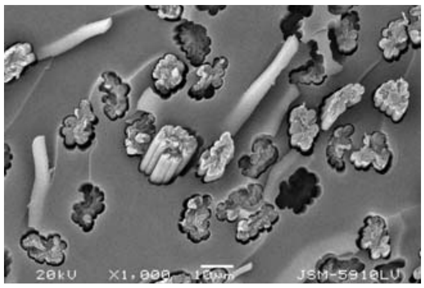

Figure15. SEM photograph of the three point bending sample of 35 % bamboo sliver reinforcement (X 1000)

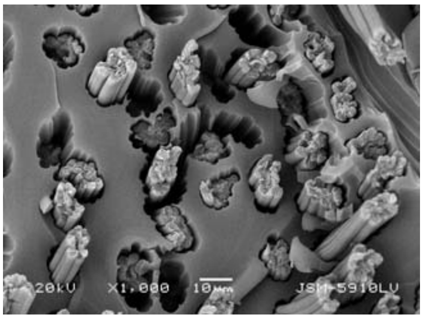

Figure 16. SEM photograph of the three point bending sample of 40 % bamboo sliver reinforcement (X 1000)

It is known that cellulose is one of the most important natural fibres and its main component is –OH groups; it attracts more moisture than that of glass and carbon fibres which are mainly used as a reinforced composite. In other words natural fibres do exhibit much more sensitive structure to the moisture than that of "hydrophobic" nature of glass and carbon fibres. In the same way, as polymeric matrices have hydrophobic structure it has been observed that if the moisture removed from the fibre it will be much better to have mishmash intermediate surface between natural fibres and matrices. From the previous studies, it has been known that humidity has more roles on the mechanical properties of the natural reinforced fibre composites.

In this study, bamboo fibre was not applied to any pre-production processes, however a high level of intermediate surface cohesion was observed even its hydrophobic character was not developed. Although the main reason for this is bamboo fibre's hydrophilic structure, if its cross-section has been studied it can be seen that it has a lobed structure (see Figure 10). Lobed structure takes rapidly water molecules into and hence moisture resumes at a minimum level on the fibre surface. This however may lower the single fibre strength where it has made a positive impact on to the inter-surface of fibre-matrix combination.

If bamboo fibre reinforced composite structures were studied, the SEM photographs of the tensile strengths can show that during the test some of the fibres were broken (see Figures 11 and 12). Fibre break is expected to occur at a good matrix-inter surface cohesion. However, some of the fibre gaps at broken surfaces indicate that there is not a good inter surface mixture and therefore it can be perceived that the fibre has been drawn from the structure of the three point bending test of the sample (see Figure 16). The main reason for this structure is, although bamboo fibre has a partly low strength it has also a high breaking elongation. For this reason, fibres do get thinner during the strength tester and hence break at some point just below the fracture surface of the sample; (see Figure 12). If the surface images were examined, for example see Figures 11, 12 and 13, it can be seen that there is no gap between the fibre and the matrix yet again some broken fibres may be observed from the SEM photographs.

3. CONCLUSIONS

1. Bamboo slivers increase the elastic modulus of the pure resin about 10%-30% and its bending resistance between 3 and 4.4 times.
2. Bamboo slivers have also a positive effect on the elongation of the composite structures; elongation was observed at the maximum force was around 2.8-6.6 times more.
3. Improvement on the bending resistance has not offered a comparable trend on the fibre percentage changes; the most distinct increase was obtained between 25 % and 35 % of the fibre proportions.
4. Elastic modulus and elongations on the maximum load increases as the bamboo fibre percentage regularly increases within the reinforced composite structures.
5. Although single bamboo fibre strength is low because of its fineness, the produced composite structures allowed carrying significant amount of bamboo fibres at the cross-section and therefore having a good mechanical properties on the produced bamboo reinforced fibre composites.

We believe that bamboo fibre reinforced composites can be easily used such as fibre form, sliver or filament forms at the composite material applications. Beside of its low specific gravity (1.31 g/cm^3), high elongation (23 %) and because of being a natural fibre it is also a "green composite" and therefore it is environmental friendly; consequently we recommend bamboo sliver as a reinforced structure due to improvement on the mechanical properties of the composites.

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