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Development and Testing of Coir Fiber Reinforced Sandwich Panel

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Abstract- *Sandwich panels are the composite materials consist of a core at the centre covered by skin material on the upper and lower surface of the core. Sandwich structures have recently been investigated for their lightweight and multifunctional Characteristics, as well as their resistance to blast. This paper deals with increment of strength to weight ratio in natural fiber composites. For this a sandwich panel is developed using Coir fiber and polyester resin to prepare skin material and aluminium honeycomb is used as core in the panel. In this work, coir composites are developed and their mechanical properties are evaluated. The results indicate that coir can be used as a potential reinforcing material for many structural and non-structural applications.*

I. INTRODUCTION

Composites have wide range of applications because of their adaptability to different situations and the relative ease of combination with other materials to serve specific purposes and desirable properties [1]. Composites provide ample scope and receptiveness to design materials and processes. The strength-weight ratio is higher when compared with other materials. Their mechanical properties like stiffness, cost effectiveness, apart from easy availability of raw materials, make them the obvious choice for various applications. Sandwich panels are the composite materials consist of a core at the centre covered by skin material on the upper and lower surface of the core. Sandwich structures are recently investigated for their lightweight and multifunctional Characteristics [2]. Various types of cores and skins are used for sandwich panels and are explained below.

Core forms the major portion of the sandwich panels. Usually it will be light in weight but supports make them stronger when loaded. The major types of cores are Polymer foam cores, Wood cores, Syntactic cores and Honeycomb/corrugated cores

The covering material on the upper and lower surface of the core is the skin. It will be of any of the composite material. Usually the composite materials are used as skin materials are Metal matrix composites, Ceramic matrix composites, Polymer matrix composites and Elemental matrix composites. The use of sandwich structures is steeply increasing in recent years as a result of their light weight and high stiffness [3]. Sandwich Panel Composites have been used in a variety of applications such as automotive bodywork, marine hulls, aircraft wing skins and satellite bodies and their solar panels. Special attention is contributed for improving the performance of those structures.

Basically two main tasks that were carried out to achieve the objectives of the paper. In the first task, a composite material has prepared by combining the polyester and coconut coir at various strength to weight ratios of fiber. Then it was continued by

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performing the mechanical test along with aluminium honeycomb as core to determine the physical characteristics of the studied composite.

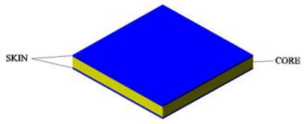

Figure 1: Structure of a Sandwich Panel

II. LITERATURE REVIEW

According to Bujang I.Z, et al, the influence of fibers volume on the mechanical properties and dynamic characteristic of the composites has analysed. The sheets are prepared for the variable volume from 5% to 15% and mechanical test is carried to prove that the volume of the fiber has great influence in the strength of the composite, i.e., whenever the volume of fiber increases the strength of the composite also will increase [4]. Flavio de Andrade Silva, et al explained that the need for cheap, sustainable, harmless, and secure shelter is an inherent global problem and numerous challenges remain in order to produce environmentally friendly construction products which are structurally safe and durable. The use of natural fiber with enhanced mechanical performance reinforcement in a cement based matrix is a promising opportunity. Sisal fibers were used as a fabric to reinforce a multi-layer cementitious composite with a low content of Portland cement [5]. Dr. Navdeep Malhotra, et al, explained that composites are one of the most advanced and adaptable engineering materials. The work reports the use of bio-fibers as reinforcement in developing polymer composites. Natural fiber offer many technical and ecological benefits for its use in reinforcing composites. Many types of natural fibers have been investigated for use in plastics including jute, straw, Flax, hemp, wood, sugarcane, bamboo, grass , kenaf, sisal, coir, rice husks, wheat, barley, oats, kapok, mulberry, banana fiber, raphia, pineapple leaf fiber and papyrus etc. and the matrix material used for reinforcing the fibers are classified as thermo sets, thermoplastics and elastomers. This study leaves an excellent knowledge to know about the Natural fiber polymer composites (NFPC) [6]. Olusegun David Samuel, et al, discussed the mechanical properties of banana, sisal, coconut, hemp and E-glass fiber reinforced laminates were evaluated to assess the possibility of using it as new material in engineering applications. Natural fibers form an interesting option for the most widely applied fiber in the composite technology. They possess desirable properties such as bio-degradability, renewability, combustibility, lower durability, excellent mechanical properties, low density and low price. Thus it is very important to study the mechanical properties of these natural fibers [7].Dixit S. et al, discussed the three most important and effective fibers among all the natural fibers are the coir, sisal and jute. The properties of these fibers are studied and the effect of hybridization on mechanical properties on Coir and Sisal Reinforced Polyester composite (CSRP), Coir and Jute Reinforced Polyester composite (CJRP), Jute and Sisal Reinforced Polyester composite (JSRP) were evaluated experimentally. The results demonstrate that hybridization play an important role for improving the mechanical properties of composites [8]. Sreekala M S et al, said that material selection is an important process in developing a new composite material. For this the database of the material properties of the various natural fibers are organized. The major material properties of the natural fiber includes density, tensile strength, cost, Young's modulus and durability are studied before selecting the material. Each of the fiber has its own properties which differ from others and thus the fibers are selected according to its application [9]. Mohd Yussni Hashim et al, explained that Natural fibers are available in abundance, low cost, lightweight polymer composite and most importance its biodegradability features, which often called "eco-friendly" materials. However, their applications are still limited due to several factors like moisture absorption and poor wet-ability. Therefore, to overcome this challenge, fiber treatment process is one common alternative that can be use to modify the fiber surface by chemically, physically or mechanically technique. Nevertheless, the focus onthe effect of mercerization treatment on mechanical properties enhancement of natural fiber reinforced composite. It specifically discussed on mercerization parameters, and natural fiber reinforced composite mechanical properties enhancement [10]. Henrik Herranen et al , discussed that sandwich composites have high strength to weight ratio, extended operational life, lower maintenance cost (due to less corrosion, and resistance to marine boring organisms), as well as a range of integrated functions, such as thermal and sound insulation, excellent signature properties, fire safety, good energy absorption, directional properties of the face sheets enabling optimized design and production of complex and smooth hydrodynamic surfaces [11].

Table I . Cellulose and Lignin Content of Natural Fibers

Sl.No	Fiber	Cellulose content (%)	Lignin content (%)	Diameter (µm)	Elongation Max.
1	Banana	64	5	50-250	3.7
2	Sisal	70	12	50-200	5.1
3	Pineapple	85	12	20-80	2.8
4	Coir	37	42	100-450	47
5	Polymer	40-50	42	70-1300	2.8

From the Table No 1 it is clear that the coir has effective amount of cellulose and lignin content [12]. Naveen et al. carried out an investigation to make use of coconut coir, a natural fiber abundantly available in India. Natural fibers are strong, lightweight, very low cost and easily available when compared with the other materials [13]. The literature review shows that the density of the coir fiber is very less, it is the lowest among cost, it is highly durable and its elongation is comparatively high when compared to other natural fibers, hence this fiber is selected for this research, which is effective with polyester resin [14].

III. MATERIALS AND METHODS

In this section we will discuss about the extraction of the coir, mould preparation, and preparation of composites. These materials will be used for the testing. The studied composite material has made by polyester reinforced matrix with coconut fibers which were arranged in chopped configuration. The coir fibers can obtain from coconut husk which was extracted from coconut fruit. After they had been extracted, the coir fibers were dried at 70°C to 80°C. The coir were treated to avoid the degradation factor. This process consists of immersing the coir fibers into 5% sodium Hydroxide (NaOH) solution for 24 hours to remove the first layer. The obtained fibers are washed abundantly with water to remove the NaOH , dried again in furnace at 70°C to 80°C for next 24 hours. The coir fibers were then soaked into 5% of silicone and 95% of methanol solution for 4 hour and dried at 70°C for next 24 hours curing time. The physical properties of coir fibers are shown in Table II [4].

Table II . Mechanical Properties of Coir Fiber

Sl.No	PROPERTY	RANGE
1	Density (kg/m^3)	1.15 – 1.33
2	Elongation at break (%)	18–30
3	Tensile strength (MPa)	140 – 150
4	Young modulus (GPa)	4 – 5
5	Water absorption (%)	130-180

The usage of polyester resin as a matrix was chosen because it is the standard economic resin commonly used [12]. The physical properties of polyester resin are shown in Table III.

Table No III . Mechanical Properties of Polyester Resin

Sl.No	PROPERTY	RANGE
1	Density (kg/m^3)	1.2 - 1.5
2	Young Modulus (GPa)	2 - 4.5
3	Tensile Strength (MPa)	40 – 90

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4	Compressive Strength (MPa)	90 -250
5	Tensile Elongation at break (%)	2
6	Water Absorption 24h at 20 °C	0.1 - 0.3

The mould used for coir fiber composite is made from mild steel, it was fabricated in machining lab whose length and width are 270 mm as shown as in Figure 2.

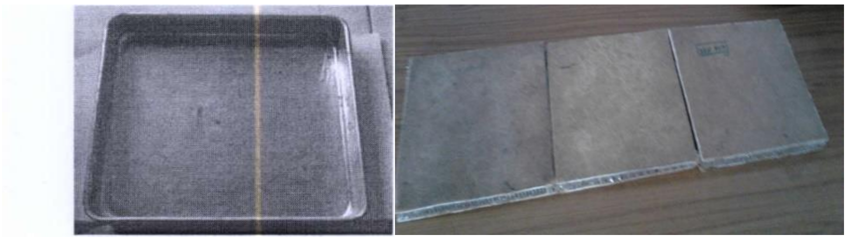

Figure 2. Mould for the composites and Coir fiber composite

Composites having different fibers content were prepared by varying the fiber volume as 25%, 30% and 35%. In the process of preparing the composite, a mould release agent was used to clean and dry the mould before the polyester can be laid up on the mould. The polyester was mixed uniformly with the coconut fibers by using a special brush in the mixed container [4]. The mixture was transferred carefully into the moulds and flattened appropriately by using the roller before being dried for 24 hours [13]. After the composite mixture was fully dried, they were separated from the moulds. In the similar manner two specimens are prepared at each weight fraction of the fiber. The specimens are shown in the Figure 2.

The aluminium honeycomb is light in weight but have high strength, since it is a honeycomb structure it is very low in density. The skin material is used with this aluminium to form the sandwich panel[11]. The Mechanical Properties of the Aluminium Honeycomb is shown in Table IV.

Table No IV . Mechanical properties of Aluminium Honeycomb

Sl.No	PROPERTY	VALUE
1	Density(kg/m^3)	91.2
2	Young's modulus(GPa)	1.288
3	Shear modulus(KPa)	42.6
4	Poisson's ratio	0.4

IV. ANALYTICAL CALCULATION

In the analytical calculation we calculate the weight fraction calculation for the composite material from the properties of the fiber and the matrix, using the rule of mixtures.

Table No V . Weight fraction of coir and polyester matrix

S.No	The entire weight of the single layer of the skin specimen is 300 g			
1	Fiber %	25	30	35
2	Weight of the coir (g)	75	90	105
3	Weight of the polyester (g)	225	210	195

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The properties of composite is related to fiber and matrix by the Rule of mixture:

Young's modulus of the composites:

$E_c = E_f W_f + E_m W_m$ [15] (1)

Where –E_c, E_f and E_m are the young's modulus of the composite, fiber and matrix respectively and W_f and W_m are the weight fraction of the fiber and matrix respectively.

Density of the composite:

$\rho_c = \rho_f W_f + \rho_m W_m$[15] (2)

Fiber and matrix respectively and W_f and W_m are the weight fraction of the fiber and matrix respectively.

V. MATERIAL TESTING

A. Tensile Testing

Tensile testing is the most common mechanical testing for determining the elongation property and elastic modulus of the material. The tests consist of applying a constant strain on the panel and measure the load. Universal Testing Machine with strain speed of 10 mm/min used for testing. The panels were cut in accordance with ASTM D790 (100mm x 25mm) standards [4] at each of the three specimens and the test is done. The Tensile testing is shown in the Figure 3 a.

B. Compression Testing

Compression testing is carried for determining the properties of materials such as strength, ductility, toughness and strain hardening. The compression test consists of applying a constant strain on the panel and measure the load. Universal testing machine was used with a constant load applied gradually. The panels were cut in accordance with ASTM C297-94 (25mm x 25mm) standards [10] at each of the three specimens and the test is done. The Compression testing is shown in the Figure 3 b.

C. Impact Testing

Impact test is carried to find the amount of sudden impact of energy applied to the specimen. This testing method consists of applying sudden impact of over the panel, which is done by charpy test. The panels were cut in accordance with ASTM D638M (100mm x 20mm) standards [10] at each of the specimen and the test is carried. The Impact testing is shown in the Figure3 c.

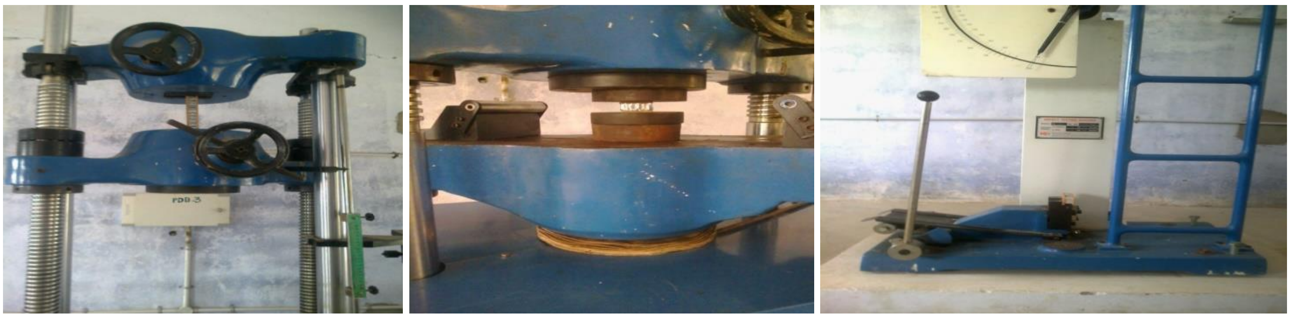

Figure 3. a) UTM Tensile Testing, b)UTM Compression c)Testing Charpy Impact Testing

VI. RESULTS AND DISCUSSIONS

The mechanical properties of the coir fiber reinforced composites are expected to depend on the content or volume or weight fraction of the fibers in the composites**.** Even a small change in the physical nature of fibers for a given Weight content of fibers may result in distinguished changes in the overall mechanical properties of composites. Therefore the influence of natural fibers content on mechanical properties of coir fibers reinforced composites was investigated and the mechanical properties of coir fibers reinforced sandwich panel with fibers weight changing from 25% to 35%. High

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percentage of coir fiber will result in poor wetting between the coir fiber and polyester matrix. The result indicates that the tensile, compression and the impact strength of the composite increases with the increase in weight of the fiber and those results are shown Table VI

Table No VI. Mechanical properties of fabricated composite result

S.No	Mechanical Properties	Fiber 25%	Fiber 30%	Fiber 35%
1	Young's modulus(MPa)	2500	2600	2700
2	Tensile strength (Newtons)	882.9	981	1079.1
3	Compression strength (Newtons)	2746.8	2844.9	2943
4	Impact Energy (joules)	40	58	68

Table VI shows that 30% fiber composite panel withstand 40% more impact strength than the 25% fiber composite panel and the 35% fiber composite panel withstand 25% more impact strength than the 30% fiber composite panel. From the above results of the various test conducted to the Coir fiber reinforced sandwich panel it is clear that it has better strength to weight ratio than the other natural fiber composites. It also proves that whenever the amount of fiber increases to certain extend in a composite material, the strength of the material also increased

VII. CONCLUSION

The project work carried to develop a natural fiber composite, the effective fiber among the various natural fiber i.e. coir fiber is selected, similarly cheap and effective resin in combination with the coir fiber is found to be polyester resin. Using this coir fiber and polyester resin, composite material is made in three different ratios of weight fraction of the fiber as 25%, 30% and 35%. In each ratio two specimens is made and each of which is used as skin material along with the core which is Aluminum honeycomb to form sandwich panels. Thus the Coir fiber reinforced sandwich panel is made. Then each of this panel is tested for its mechanical strength. The result of the tensile, compression and impact test proves that it has better strength to weight ratio than the other natural fiber composites and whenever the amount of fiber increases to a certain extend in a composite material, the strength of the material also increases. Since there is no end for invention and innovative ideas, this project work can be further developed by changing the types of fiber and resin, the thickness for the core and the skin material can also be changed and the tests can be carried and the results can be produced.

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