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Research Article

DEVELOPMENT AND TESTING OF COIR BASED SANDWICH COMPOSITE FOR AUTOMOBILE APPLICATION

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A B S T R A C T

Development of composite products made of natural fibres is ever increasing in manufacturing wide variety of automotive applications. This work is focused on the development and testing of sandwich composite based on natural materials such as woven jute and latex spayed coir acting as a core. The characteristics of the developed laminates are evaluated based on flatwise compression test, tensile test and flexural test for replacement of automobile floor panels. Based on experimental results, the developed composite material was found to have compatible mechanical properties suitable for the proposed application.

INTRODUCTION

Currently there is a clear trend of substituting synthetic and non-renewable materials by natural and renewable materials with similar or even better properties.

In this work, sandwich structures made from natural materials are developed. The core consists oflatex sprayed coir and the skins are woven jute fibres reinforced by epoxy resin. This new compound was developed by keeping a balance between sustainability and mechanical properties, proposing a green structure without compromising the mechanical performance. Standard sandwich structures are mainly used due to their strength and weight, being constituted by two outer thin layers responsible for the structure strength and by a softer core responsible for absorbing most of the energy and also for its low weight.

The skins are usually made from fibres such as carbon, Kevlaror even aluminium sheets. On the other hand, the core is usually made of low density materials such as polymeric or metal foams. These structures can be employed in applications such as aerospace, civil construction, automotive and sports. [1]. basically, the surface where the force is applied is under compression and the outer one under tension. On the other hand, the sandwich core supports the shear loads.

Metals have good advantages such as high rigidity, good impact resistance and low cost.

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However, these are relatively denser, relatively harder and can oxidize. Composite materials are usually made of a polymeric matrix and fibres of same nature. The matrix is responsible for the material adhesion. Currently, the more common are polyester resins, vinyl and epoxy. The fibres orientation is very important for the overall structure strength.

The core material of a sandwich structure is also very important, since it greatly influences the structure performance. Thus, the final application deeply influences the choice of the core material. The core structure can be a solid block or even a honeycomb. Nevertheless, researchers are looking for new natural and recyclable materials, which can be a better option if these structures can have a similar mechanical behaviour to those typically used.

Literature survey has been made in order to identify various combinations of sandwich composites (preferably green composite) that can be developed and how their mechanical properties play a vital role in engineering applications.Akash *et al*. [2] studied the flammability and moisture absorption behaviour of Sisal/coir fibre reinforced hybrid composites. Asasutjarit *et al*. [3] developed a green sandwich composite. Properties of coir fibres with different coir pre-treatment condition were discussed. It is observed that the mechanical properties of coir-based green composites; modulus of rupture and internal bond, increase as a result of chemical composition modification and surface modification. Fernandes *et al*. [4] developed structures based on natural fibres and cork acting as a core. After carefully analyzing the test results of impact and bending tests, itwas possible to conclude that the proposed materials show compatible mechanical properties. Gon *et al*.

[5] stated Jute fibre as a promising reinforcement for use in composites on account of its low cost, low density, high specific strength and modulus, no health risk, easy availability, renewability and much lower energy requirement for processing. Krzyhak *et al*. [6] showed that the method of manufacturing, more precisely the pressure while forming sandwich panels, influences some mechanical properties of sandwich structured polymer composites such as flexural strength, impact strength, and compressive strength. Obele and Ishidi [7] studied the mechanical properties of coir fibre reinforced epoxy resin composites for helmet shell. Sasikumar *et al*. [8] developed coir composites and their mechanical properties were evaluated. Their results indicated that coir can be used as a potential reinforcing material for many structural and non-structural applications. Velmurugan *et al*. [9] has concluded that utilizing natural fibres as reinforcement in polymer composite for making cost effective construction materials in recent years.

MATERIALS AND METHODS

In this work, natural fibres are used in order to create an environmental friendly solution. Natural fibres are hair-like threads obtained directly from plants, animals, and mineral sources. They are obtained as continuous filaments or discrete elongated pieces similar to thread. Examples are wool, jute, silk, hair, hemp, and linen.The composites reinforced with natural fibres like juteas shown in Figure 2.1 is abundant, cheaper and of low density, biodegradable and carbon dioxide-neutral. Woven jute have properties such as Unbreakable, maintenance free, durable, Fire retardant and water resistant, Less abrasive, Less costly, Low thermal conductivity, Biodegradable, Renewable, Eco-friendly and Stronger than wood.

Since one of the objective of this work is to test a green sandwich, resins were also used. The resin used is Epoxy LY556 with the hardener HY951.

Regarding the core material, Rubberized Coir was chosen as shown in Figure 2.2. It is a seed-hair fibre obtained from the outer shell of the coconut. It is a flexible material, capable of absorbing considerable amount of energy and can be used to manufacture complex product shapes. In this work, latex sprayed coir is used as core material. Rubberised coir is a product used largely as a less expensive substitute cushioning material for foam rubber in furniture and mattresses. Rubberised coir is made from curled fibre, which should be free from dust. The coir is made into endless fleece which is conveyed to the first set of rubber latex spray gums. Thickness of sheets are built by fixing multilayers fleeces and spraying is repeated to get a good bonding of layers. Then the sheet is hydraulically pressed and vulcanised to set the fibres. The rubberised coir required for our project has been sourced by spraying the latex. The manufacturing processes were studied. Multi layered rubberised coir sheets were available in various densities and in various dimensions. Some of the characteristics of rubberized coir are mentioned in Table 1.

Table 1 Characteristics of rubberized coir.

Density [kg/m^3]	Thickness [mm]
125	10

Figure 1 Woven jute

Figure 2 Coir

Sandwich samples were manufactured by hand lay-up process as shown in Figure 2.3. Hand lay-up process is the simplest method of composite processing. The infrastructural requirement for this method is also minimal. The mould is coated by a release anti-adhesive agent, preventing sticking the moulded part to the mould surface. The prime surface layer of the part is formed by applying gel coating. A layer of fine fibre reinforcing tissue is applied. Table 2.Shows all the sandwich sample analysed in this work. Figure 2.4 shows the manufactured sandwich composite structure.

Figure 3 Sandwich samples manufacturing: Hand lay-up process

Table 2 Sandwich sample details

Sample no	Top face	Layers	Core	Bottom face	Layers	Thickness (mm)	Resin
1	Woven Jute	3	Rubberized Coir 125 kg/m^3	Woven Jute	3	16	Epoxy LY556 Hardener HY951

Figure 4 Coir based sandwich composite panel.

Experimental tests

Flatwise Compression test (C365)

ASTM C365 determines the compressive properties of structural sandwich construction in a direction parallel to the sandwich facing plane. Permissible core material forms include those with continuous bonding surfaces as well as those with discontinuous bonding surfaces. This test method consists of subjecting a sandwich panel to monotonically increasing compressive force parallel to the plane of its faces. The force is transmitted to the panel through either clamped or bonded end supports. The specimen is placed between compressive plates parallel to the surface. The specimen is then compressed at a uniform rate. The maximum load is recorded along with stress-strain and force-deformation data. Specimens can be blocks For ASTM, the typical blocks are 25 x 25. Tests were performed using Zwick/ Roell 100 kN universal testing machine with the pre-load of 45 N at a crosshead speed of 10 mm/min. Figure 5 shows the samplesplaced inside the fixture.

Flexural test (C393)

The test method ASTM C393 determines flexural strength, core shear strength and facings compressive and tensile strengths in the direction the core would be placed in a structural construction. Core materials applicable include continuous (foams) and discontinue bonding surfaces (honeycomb). Install the conditioned specimens (if required) into a 3-point or 4-point loading fixture on the Universal Test Machine and initiate at a specified grip separation significant enough to produce failure within 3 to 6 minutes. The standard speed is 10 mm/min. The standard loading configuration is a 3-point configuration with a support span of 150 mm. Three rectangular specimens, 75 mm x 200 mm tested at thickness of 16 mm. Three point loading tests were performed using Zwick/ Roell 100 kN universal testing machine at a pre-load of 5N. Figure 6 shows the sample placed inside the fixture.

Tensile test (C297)

The test ASTM C297 provides information on core-to-face bonding stability, load transfer and flatwise tensile strength of sandwich core material. ASTM C297 is applicable for continuous bonded surfaces such as foams or discontinuous bonded surfaces such as honeycomb materials. The data is often used to specify a material, to design parts to withstand application force and as a quality control check of materials. A typical test speed for standard test specimens is 2 mm/min. The most common specimen for ASTM C297 is a constant rectangular cross section, 20 mm wide and 250 mm long. Tests were performed using Zwick/Roell 100 kN universal testing machine at a crosshead speed of 2 mm/min. Figure 7 shows the samples placed inside the fixture.

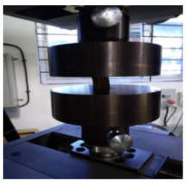

Figure 5 Flatwise compression specimen

Figure 6 Flexural test specimen

Figure 7 Tensile test specimen

RESULTS AND DISCUSSIONS

Flatwise Compression test (C365)

The average compression strength of 3 sandwich laminate specimen was found to be 61 MPa. A maximum compressive strength of 67 MPa is observed in laminate 1 which is followed by laminates 2 and 3 as shown in Figure 8. The maximum compressive stress of 12.4 MPa is observed in laminate 1. The average young's modulus of laminates was found to be 261 MPa. The maximum force at preselected deformation was found to be 7740 N. The maximum force was found to be 42kN. The test result table is represented in the Table 3.

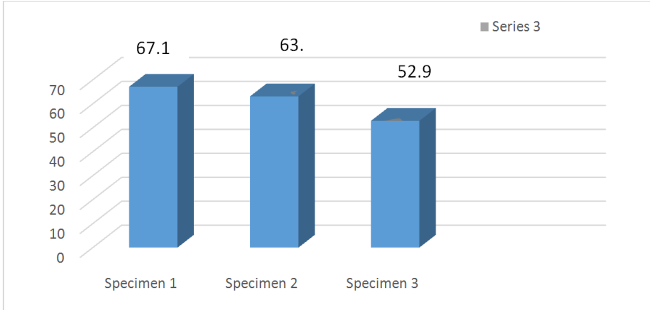

Figure 8 Compressive strength plot

Table 3 Flatwise Compression test result

S.NO	Young's Modulus (MPa)	Compressive Stress (MPa)	Maximum Force (kN)	Compressive Strength (MPa)
1	301	12.4	42	67.1
2	247	8.39	39.4	63.1
3	235	7.63	33	52.9

Flexural test (C393)

Flexural strength is the resistance generated by the laminate when it is subjected to bending load. This is tested by conducting a three point bending test. Cover layer flexural stress at maximum force of the laminate specimens is presented in Figure 9. A maximum flexural stress of 12.59 MPa is shown by laminate 2 and this is followed by laminates 1 and 3. A Maximum force of 2950 N is observed in laminate 2. The maximum core shear stress at maximum force was found to be 1.51 MPa.The test result table is represented in the Table 4.

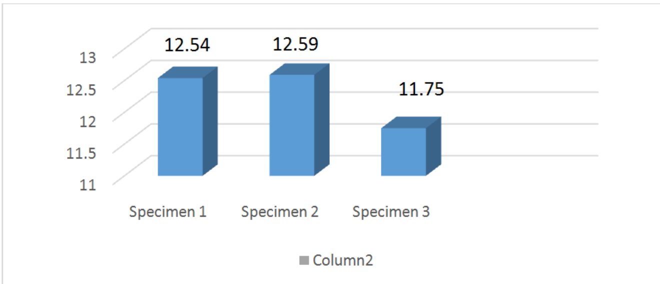

Figure 9 Flexural stress plot

Table 4 Flexural test result

S.NO	Core shear stress at maximum force (MPa)	Cover layer flexural stress at maximum force (MPa)	Maximum Force (N)
1	1.51	12.54	2940
2	1.51	12.59	2950
3	1.41	11.75	2750

Tensile test (C297)

Maximum tensile strength of the laminate specimens is presented in Figure 10. A maximum tensile strength of 16.4 MPa is shown by laminate 1and this is followed by laminates 2 and 3. A Maximum force of 5250 N is observed in laminate 1. The average young's modulus was found to be 1020 MPa.The test result table is represented in the Table 5.

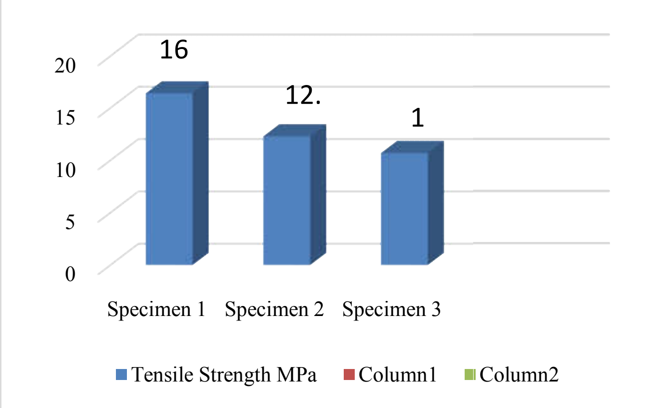

Figure 10 Tensile strength plot

Table 5 Flexural test result

S.NO	Young's Modulus (MPa)	Tensile strength (MPa)	Maximum Force (N)
1	939	16.4	5250
2	1180	12.3	3930
3	937	10.7	3430

Comparison of Coir based sandwich composite with Cork based sandwich composite

Fernandes *et al.* [10] developed sandwich composites with natural fibres and cork acting as a core. The natural fibres used resulted from compounding flax fibres with bio-resin. The core material is agglomerated cork. The aim of this study was to compare natural structures against similar synthetic sandwiches based on fiberglass and epoxy resin. The details of the sandwich composites manufactured by them are given in Table 6.

Table 6 Cork based synthetic and natural sandwich composites specifications.

Sample	Top face	Core	Bottom face	Thickness [mm]	Resin
1	Fiber glass 500 g/m^2	CoreCork NL10	Fiber glass 200 g/m^2 (double layer)	4	Epoxy
2	Flax fiber 500 g/m^2		Flax fiber 400 g/m^2	5	Bio
3					Epoxy
4	Flax fiber 100 g/m^2		Flax fiber 200 g/m^2	4	Bio
5	Flax fiber 200 g/m^2				
6	Flax fiber 100 g/m^2		Flax fiber 100 g/m^2		

Three point bending tests were carried out as per ASTM 393. These results are compared with the coir based sandwich composite of density 125kg/ m^3 and 16mm thickness manufactured by hand layup method. Although the ASTM C 393 standard determines the mechanical properties such as shear stress in the core and the stress at the compression faces, in this work the objective is just to study the behaviour of the samples regarding bending strength. Thus, it was analysed by comparing the relation between load and displacement during the tests. This allows the calculation of the maximum deflection without failure and the load necessary to create failure at the faces. Observing the samples, two types of failure modes were observed in both coir and cork based sandwich composites:

- Indentation (crushing) on the loading surface, probably due to the penetration of the loading tool on the samples' surface. This behaviour was only observed on fiberglass samples.
- Rupture by tensile stress on the opposite face where the load was applied. This kind failure was observed on the majority of Coir and flax-fibre composites.

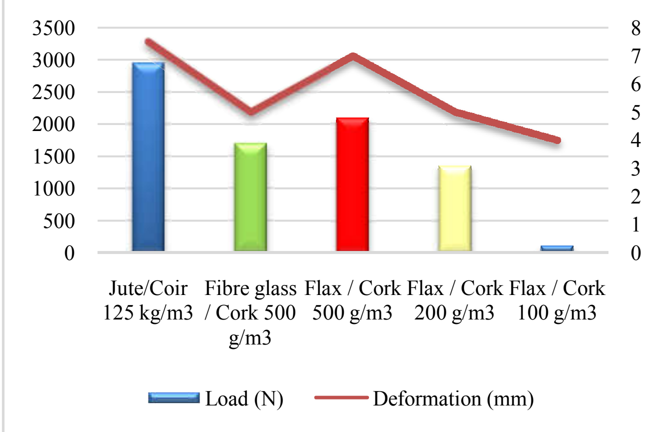

Figure 11 Load versus Deformation curve (Three point bending)

Analysing these results, it is possible to conclude that there is a relationship between the load and the fibre's surface density. The greater the density, the greater the load needs to be to cause failure. Therefore, from the point of view of wood substitution, jute / Coir based composites could be an ideal solution. The jute-coir boards proving superior over the natural materials under research for the replacement of plywood boards find potential in bus flooring in bus , railway coaches etc. The use of jute fibre mats in combination with polymer films potentially offers a rapid and simple means of manufacturing composites through film stacking and drying.

CONCLUSIONS

After the onset of synthetic sandwich materials over the last decades, environmental concerns are bringing back attention to natural materials, both fibres and core materials. The natural sandwiches herein studied, based on woven jute fibres and latex sprayed coir, and were subjected to tensile, flexural and flatwise compressive test, showing very promising results in terms of specific strength and toughness. Large scale production has to be done to deliver cost-reduction. Bearing in mind that not only coir structural properties can be very interesting, future research lines will certainly try to ally its well-known acoustic, thermal and vibration properties.

- Rubberized coir, woven jute and epoxy has been purchased and a sandwich composite was fabricated using a hand layup process.
- It has been observed that the weight of the coir based composite sandwiches were 26% -30% of the weight of the chequered plate used in bus flooring.
- The tests were conducted on composite specimens as per ASTM standards. It is observed that the 4500 g/m^3 density coir core has excellent properties and the specific strength of the woven jute reinforcement is reasonable.
- The mechanical characterisation has been done for manufactured composite sandwich structures in terms of their tensile strength, flatwise compressive strength and flexural properties. It is observed that the tensile and flatwise compression properties of coir based sandwich composite can be competed against the existing material, but the core shear stress at the maximum force is found to be minimum.
- The floor panel material is made with jute as reinforcement and 125 kg/m^3 density coir as core and bonded using epoxy resin and hardener solution. This

material was compared with the other natural fibres under research. Based on the mechanical characterization performed it is expected to serve the purpose of the floor panels without failure.

- Finally it shows that there is a great future ahead for coir based composites sandwich in construction and automobile fields.

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