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Reinforcement of AISI 304 Stainless-Steel Wire Mesh in A NFHC With Unsaturated Polyester Resin For Mechanical Behaviour

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ABSTRACT

The development of high performance (NFHC) composites from a cheap natural fibre (NF) such as Sugarcane bagasse and Banana Fibre are embedded with a stainless-steel wire mesh (SSWM) layer. This work carries the hybridising approach in improving the mechanical properties of natural fibre through the incorporation of SSWM by Unsaturated Polyester Resin laminates. The 6 various weight ratios and layers of composites from Sugarcane bagasse, Banana Fibre, unsaturated polyester resin and stainless steel mesh were used to fabricate sheet as per ASTM standard with the help of compression moulding. The mechanical characteristics of the composites are obtained using tensile, flexural, impact, hardness and water absorption test. The result outcome demonstrates that the reinforcement of SSWM with NFHC leads to better mechanical properties composition of sugar cane bagasse 35% and unsaturated polyester resin 65% with banana fibre and SSMW layer. In water absorption test, 5th sample (sugarcane bagasse 30% and unsaturated polyester resin 70%) has low absorption rate. Applications of these materials require a sustainable approach to make vehicle interior body panels and infrastructure roof panels.

Keywords — Natural fibre Hybrid composite (NFHC), stainless-steel wire mesh (SSWM), mechanical tests, Water absorption test.

I. INTRODUCTION

A composite material or a composite is a mixture of two or more distinct constituents all of which are present in reasonable proportions (> 5%) and have different properties so that the composite property is noticeably different from that of each of the constituents. Composite materials are mostly used in aircraft structural components, because of their excellent properties like lightweight, high strength to weight ratio, high stiffness, and corrosion resistance and less expensive. The experimental investigation of stainless steel wire mesh hybrid composite materials based on glass/epoxy consists of Tensile, compressive and flexural test [2]. The bagasse is then cut, sieved and dried before mixing with the adhesive resin.

Commonly used commercial resins are ureaformaldeyde and phenol which are mixed up to 15% in weight with the bagasse depending on the level of humidity resistance needed. Chemical additives may also be used to improve the properties of the composite and its resistance to fire and to the attack of fungi [1]. Natural-fibre-reinforced polymer (NFRP) composite embedded with a stainless-steel wire mesh (SSWM) layer. This work takes the hybridising approach in improving the mechanical properties of NFRP through the incorporation of SSWM into the laminates. The structure of the composite is such that the SSWM was placed in middle of the NFRP [3]. Thermoplastics are used in certain applications but constitute a relatively small sector of the structural composites market. Matrices used for structural composites are mainly thermosetting plastics, such as polyester resins, epoxy resins, phenolic resins and vinyl-ester resins. Polyester resins are the most widely used resin systems, particularly in the marine industry. By far the majority of dinghies, yachts and work-boats built in composites make use of this resin system. Thermosetting plastic systems generally consist of liquid mixtures of relatively low molar mass reactants, such as monomers and/or pre-polymers, which polymerise upon heating to form highly-crosslinked, network polymers [4]. Especially the fibres reinforced polyester (FRP) kind highlight how different materials can work in synergy. Analysis of these properties shows that they depend on (a) the properties of the individual components; (b) the relative amount of different phases; (c) the orientation of various components; the degree of bonding between the matrix and the reinforcements and (d) the size, shape and distribution of the discontinuous phase. The material involves can be organics, metals or ceramics [5]. By investigate environmental friendly, sustainable materials to replace existing ones and to solve the problems of recycling of agriculture waste. Composites due to their high potential as a material with suitable strength, low weight and low deformation. Fibre and epoxy as lamina are used to form composite laminates with desired directional properties. Mechanical properties for composites are derived starting from properties of fibre and matrix, using the rule of mixtures, and the fibre volume fraction plays a significant role in the determination of the mechanical properties [7].

✓ .EXPERIMENTAL PART

2.1 Materials

Sugar cane bagasse cellulose is a fibrous residue of cane stalks left over after the crushing and extraction of juice from the sugar cane. It is dried and taken as irregular short lengthen fibre.

Fig. 2.1 Sugar cane bagasse Short fibre

Unsaturated Polyester Resin is the matrix forms a significant volume fraction of a polymer composite and it has a number of critical functions; it binds the reinforcements together, maintains the shape of a component and transfers the applied load to the reinforcing fibres. It protects the reinforcing fibres from degradation, due to abrasion or environmental attack. It contributes significantly to the mechanical properties of structural polymer composites, acting to resist delamination between plies of reinforcements and to inhibit fibres buckling during compression.

Table 1: Unsaturated Polyester resin properties

Property	Polyester
Viscosity at 250C μ (cP)	250-350
Density ρ (g/cm3)	1.09
Heat Distortion Temperature	85
Modulus of Elasticity E (Gpa)	3.3
Flexural Strength (MPa)	45
Tensile Strength (MPa)	40
Maximum Elongation (%)	1

Banana fibre sheet individual sheaths were dried under sun for 2 weeks and then they were soaked in water for two more weeks. Once the lignin and cellulose were separated, the sheaths were dried again and the fibres were ripped off. Typical density of banana fibre is 1,350 kg/m3, cellulose/lignin ratio is 64/5, modulus is 27–32 GPa, ultimate tensile strength is 529–914 MPa and water absorption is 10–11 %. The elongation and toughness of typical banana fibres were 3.0 % and 816 MN/m2 respectively. Fibre is arranged in array and to form a sheet**.**

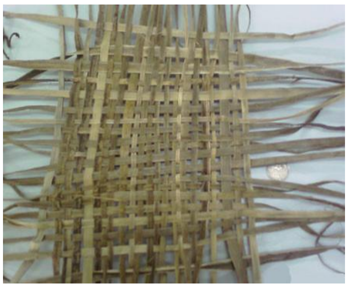


Fig. 2.2 Banana fibre Sheet

Stainless Steel Wire Mesh AISI 304 grade which provides excellent resistance to a wide range of atmospheric, chemical, textile, petroleum and food industry exposures. Type 304 is non-hardenable by heat treatment. The following figure 5.3 shows the one layer of stainless steel wire mesh which is made in size 270x270x1 mm for the making of composite material.

Fig. 2.3 Stainless Steel Wire Mesh

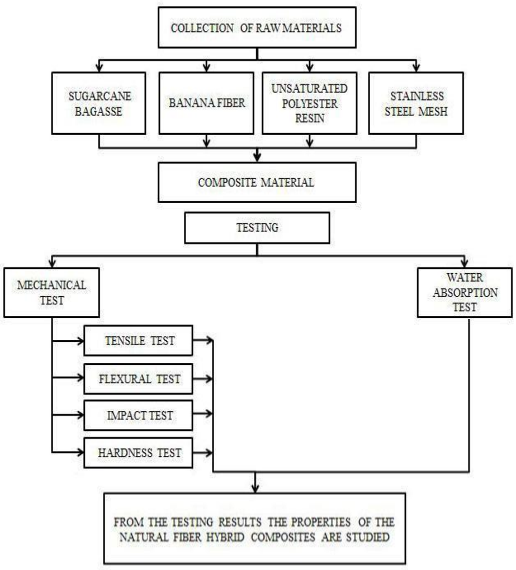
Properties of Stainless Steel Wire Mesh

The following table shows properties of stainless steel meshes.

Table 2: Properties of SSWM

Properties	**Values**
Grade	304
Mesh Configuration	64 meshes/inch
Tensile Strength	620.550138 Mpa
Yield Strength	275.80062 Mpa
Density	8.0 g/cm3
Melting Point	1420°C
Coefficient Of Thermal Expansion	17.6micro meter/m°C
Modulus of Rigidity	70.3 KN/mm2
Modulus of Elasticity	187.5 KN/mm2

2.2. Working Methodology



2.3. Composite material preparation:

For the preparation of the composite we calculate the percentage of fibres and polymer required. From the Table 3 - we come to know about the amount materials used accurately.

Table 3: Composition of Materials

Sample No.	Sugarcane Bagasse (volume) %	Banana Fibre (Number of layers)	Stainless Steel Mesh (Number of layers)	Unsaturated Polyester resin (volume) %
1	10	1	1	60
2	15	1	1	78
3	20	1	1	75
4	25	1	1	73
5	30	1	1	70
6	35	1	1	65

Compression Molding

Compression molding is a forming process in which a plastic material is placed directly into a heated metal mould, then is softened by the heat, and forced to conform to the shape of the mould as the mould closes. Compression molding is a method of moulding in which the molding material, generally preheated, is first placed in an open, heated mould cavity. The mold is closed with a top force or plug member, pressure is applied to force the material into contact with all mold areas, while heat and pressure are maintained until the molding material has cured. The process employs thermosetting resins in a partially cured stage, either in the form of granules, puttylike masses, or performs.

Fig 2.4 Natural Fibre Hybrid Composite Material Sheet

Cutting of Test Specimen as per ASTM Standards

Wire cutting machine is used for cutting the composite sheet as per the ASTM standards for various testing experiments. Refer figure 5.5 for the final composite sheet after wire cutting.

- Tensile test-250x25x3 mm (ASTM D-3039)
- Flexural test-125x13x3 mm (ASTM D-790)
- Impact test-65x13x3 mm (ASTM D-256)
- Hardness test-30x30x3 mm
- Water absorption test-20x20x3 mm

III EXPERIMENTAL RESULT

3.1 Tensile Test

Tensile test was carried out on UTM machine in accordance with ASTM D 3039 standard. All the specimens are cut in to 250x25x3 mm.

Table – 4 shows the tensile test results.

Sample no.	CsArea (mm^2)	Peak load (N)	Elongation (%)	UTS (N/mm^2)
1	75	836. 126	1.220	11. 144
2	75	657.780	1.707	8.770
3	75	606.699	1.667	8.093
4	75	774.745	1.333	10.330
5	75	524.541	1.533	6.995
6	75	1076.961	1.713	14.362

Fig – 3.1 Specimen Samples after Tensile Test

The following figure 3.2 shows the bar graph based on the tensile strength for the six samples.

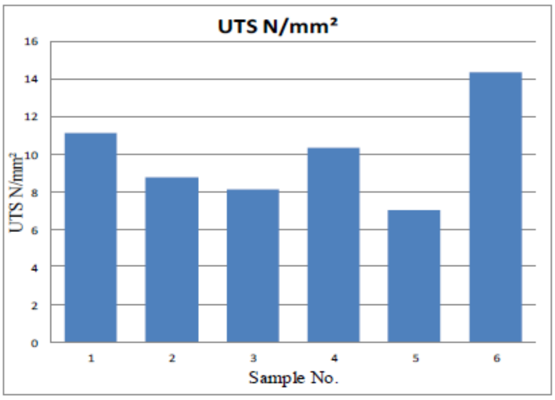


Fig – 3.2 Bar Graph for Tensile Test

From the above graph, the 6^{th} sample (sugar cane bagasse 35% and unsaturated polyester resin 65%) attain the maximum tensile strength (14.362 N/mm^2).

3.2. Flexural Test

Flexural test was also carried out on UTM machine in accordance with ASTM D790 standard. All the specimens are cut in to 125x13x3 mm.

The table - 5 shows the flexural test results

The table - 5 shows the flexural test results

Sample no.	Cs Area (mm^2)	Peak load (N)	Flexural Strength (MPa)	Flexural Modulus (GPa)
1	39	27.056	21.853	2749.983
2	39	27.527	22.233	1877.312
3	39	10.369	8.375	945.869
4	39	17.913	14.468	2515.608
5	39	13.793	11.141	2376.693
6	39	38.514	31.107	3920.074

Fig – 3.3 Specimen Samples after Flexural Test

From the above graph, the 6th sample (sugar cane bagasse 35% and unsaturated polyester resin 65%) attain the maximum flexural strength (31.107 MPa).

3.3. Impact Test

Impact test was carried out on Izod impact testing machine in accordance with ASTM D256 standard. All the specimens are cut in to 65x13x3 mm.

The table - 6 shows the Impact test results

The following figure 3.6 shows the bar graph based on the Impact load for the six samples.

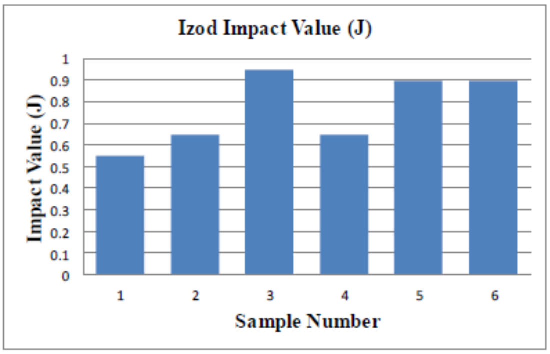


Fig. 3.6 Bar Graph for Impact Test

3.4. Hardness Test

Hardness test was carried out on Brinell hardness testing machine. All the specimens are cut in to 30x30x3 mm. Brinell hardness number is calculated with the help of formula given below.

BHN$=2P/\pi D\,[D-(D^2-d^2)0.5]$

Where P= Load applied (N),

D= Diameter of Ball indenter (mm), d = Diameter of impression (mm).

The hardness test for 6 samples has been conducted and the results are given in the following table 7.

The table - 7 shows the hardness test results

The table - 7 shows the hardness test results

Sample Number	Diameter of Ball indenter (mm)	Diameter of impression (mm)	Load (N)	BHN (N/mm^2)
1	5	3.5	5000	445
2	5	3.4	5000	477
3	5	3.2	5000	550
4	5	3.2	5000	550
5	5	2.5	5000	950
6	5	2	5000	1525

3.5. Water Absorption Test

The specimen samples are cut into 20x20x3 mm for the water absorption test. The table 8 shows the water absorption test results and the figure 3.9 shows the bar graph for water absorption test. In water absorption testing process the sample specimens are dipped in the water for 48 hours and the following results are taken. From the above graph, the 5th sample (sugarcane bagasse 30% and unsaturated polyester resin 70%) has less water absorbing capacity compare to the other samples.

IV CONCLUSION

The test result shows the characteristics of the natural fibre hybrid composite sheet. By the usage of this kind of natural fibre hybrid composite sheet material the weight of the roof panels can be reduced and it provides good strength compare to normal panels. Their low cost, availability and characteristics shows they can be better than others. The replacement of this natural fibre hybrid composite sheet material in vehicle can be done easily without need of an additional instrument. From the report we can understand this natural fibre hybrid composite sheet material can with stand large amount of load applied on it with less bending. The report describes that the impact test results shows 3rd sample (sugarcane bagasse 20% and unsaturated polyester resin 75%) attain the maximum Impact value (0.95 J) which can be withstand the sudden application of load on it. In tensile test, flexural test, hardness test results in 6th sample (sugarcane bagasse 35% and unsaturated polyester resin 65%) attain the max. tensile strength (14.362 N/mm²), max. flexural strength (31.107 MPa), max. Brinell hardness number (0.95 J) obtained higher and by water absorption test results 5th sample (sugarcane bagasse 30% and unsaturated polyester resin 70%) low water absorbing rate. Absorption of less amount of water indicates that this natural fibre hybrid composite sheet material.

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