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DEVELOPMENT OF HYBRID REINFORCED COMPOSITE STRUCTURAL PANELS USED IN DEFENCE APPLICATIONS

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Abstract: Hybrid composite panels reinforced with suitable synthetic and natural fibers have been established to enhance the properties especially strength, stiffness, acoustic damping and thermal insulation. The natural fibers and glass mat are used along with kevlar fabric to add the properties like acoustic damping and thermal insulation. The outer face sheets are made of kevlar-29 (200gsm) and natural fiber fabric, and the core material is chopped glass mat. Materials are selected through broad literature study. Four types of woven natural fibers 1) jute, 2) Flax, 3) Sisal and 4) Hemp fabric have been used to get varieties of composite panels. The volume fraction for various fabricated composite panels is in the range of 0.27-0.29. The performance of hybrid composite is vastly dependent on volume fraction percentage of reinforced fibers. In addition, chemical treatment of the natural fibers is carried out before reinforcement to reduce the moisture absorption and to improve interfacial bonding between natural fiber and resin matrix for superior hybrid composite. The current study is carried out to develop the composite panels for selected range of defense applications like high altitude structural panel, isolators, camouflage, acoustic dampers for automates, bunkers, communication and signal rooms etc.

Keywords: Natural fiber, Hybrid panel, Impact loading, Water absorption, Volume fraction.

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INTRODUCTION

Natural Fiber hybrid composite became a prevalent new material because of low cost, availability and eco- friendly properties. Natural Fibers as name submits are the fibers sourced from plants or animals and plenty of stock around world such as Sisal, jute, bamboo, coconut, Flax, kenaf, Ramie, banana, cotton, wool, feathers etc. Composites have now established their substance as weight-saving materials, the current challenge is to make them cost effective. [1]
Polymer composites are currently widely used in automobiles, aerospace vehicles, windmills, building, consumer industries, marine, sports etc. for their excellent properties such as lightweight, extraordinary strength, better corrosion resistance, high stiffness, design flexibility, fewer prone to environmental degradation, excellent thermal insulation, acoustic and decent aesthetic quality. To take the advantage of their properties such as acoustic and insulation behaviour for structural and infrastructure application in military usage, natural fiber composite could appear as a new alternative engineering material which can substitute the use of synthetic fiber composite. Natural fibers have many substantial benefits over synthetic fibers.
Polymer composite materials are usually used in the form of monocoque structures. The monocoque structure is heavy, expensive and the laminas of the middle region, adjacent to the neutral plane of the panel, are not used to full under flexural strength. To overwhelmed these restrictions of the monocoque structures, hybrid- structures are being developed. The hybrid-structures are comparatively lighter in weight and less expensive. It has shown that natural fiber composite can be developed into a load-bearing structural element for infrastructural uses. Manufacturing processes were also discussed for various types of natural fibers with more tensile strength in hand lay-up and vacuum assisted technique. [2]

More concern is now shown in the investigation of suitability of natural with synthetic fiber composites in structural and damping structures applications where moderate strength, less cost and eco-friendly features are required.

In this paper, an effort has been made to do the review related to material selections for improved static/dynamic and acoustic behavior, chemical treatment of natural fiber and fabrication of polymer composite materials. Which will be reassuring to develop synthetic and natural polymer composite hybrid panel suitable for preparing the outer cover or body of various machines, appliances, vibration isolators for various applications. [3] This paper is focused only to plant fibers. Traditionally in rural developing countries natural fibers have been cultivated widely for structural and no-structural applications such as rope, fishing net, roof materials, wall insulation, etc. Sisal fibers are extracted from long leaves of sisal bush and are hard with relatively grainy texture. Hemp and jute fibers are finer arrangement and reduced diameter compared to sisal. Flax is a linen natural fiber shows fine simple texture. A large distinction is observed in the properties of natural fibers depending upon harvested region, growing age and extracting methods. [1] Natural fiber composite [NFC] is an arrangement of various natural fiber and synthetic fibers layers with binder as resin. However, most of the hybrid composites for structural infrastructures are prepared out of thermoset resins. [2]

II. Material Selection

Several studies have been done to study the various properties of natural fibers composites depending upon the properties of fibers such as tensile strength, young's modulus and moisture content. Mechanical properties of natural fibers, especially jute, flax, hemp, sisal are reasonably good and may compete with glass fiber as specific strength and modulus is concern. The wide literature survey to select the natural fibers based on the necessities for acoustic and insulation properties demanded in structural application. Jute, flax, sisal and hemp natural fibers were selected as shown in the Table 1.

Glass insulation is one of the widely used insulating materials because of its better thermal and acoustic properties, light weight, superior tensile strength and outstanding resilience. Composite made up of synthetic and natural fibers with glass as main composition element can be explored for sound damping feature (acoustic duct, tiles and ceiling etc.).[4] Kevlar synthetic fabric mat (Kevlar 200gsm) is chosen as skin or outer layer material to get enhanced static and dynamic load bearing ability in the composite.

In natural fiber reinforced composite, interfacial strength among fiber and matrix plays a critical role in final composite properties. The hydrophilic nature of natural fibers will lead to absorption of moisture content results into presence of cavities at the interface of fiber and matrix. Chemical treatments/modification will improve mechanical properties of reinforced hybrid composite by improving the interference between matrix and fiber and reducing the moisture absorption.

Table 1. Mechanical properties of used natural and synthetic fibers.
***(Source: Green-India fibers Data sheet) and* [1]**

Type of Fibers	Diameter(mm)	Density(g/cm^3)	Tensile strength(MPa)	Young's modulus(GPa)	Moisture absorption (%)	% elongation at brake
Jute	0.07-0.18	1.3	230	26.5	12	1.7
Flax	0.8-1.2	1.52	348-580	19.8	7	2.9
Sisal	0.8-1.2	1.58	385-728	9-22	11	2.75
Hemp	0.8-1.2	1.47	421-800	21-72	8	1.62
Glass		2.55	2000-3500	70	-	2.5
Kevlar-29 (200GSM)	0.3	1.44	3600	99	-	3.6

III. CHEMICAL TREATMENT OF NATURAL FIBERS

Exact and optimum chemical treatment to natural fibers influences the overall properties including tensile strength, modulus and flexural strength. Principally, chemical treatment are intended to enhance the adhesion among the natural fibers and resin matrix to improve upon interfacial strength in the hybrid composite. The alkalization of plant fibers increases their performance as composite reinforcement.

Mohd. Westman M. P. et al. [5] organized preliminary research on usage of kenaf, Hibiscus natural Fibers with compression moulding method. Enhancement in strength and compatibility with synthetic fibers were witnessed. Fiber treatment necessities to be explore to reduce water absorption. Venkatesh R. [6] revealed addition of bamboo fibers in unsaturated polymer composite by hand lay-up method of upto 50% of weight reduction with increase in mechanical properties and reduce moisture absorption properties. Flexural strength of 54.12MPa and impact strength of 14.8KJ/m2 was attained. Interfacial bonding between fiber and matrix can be upgraded by chemical alkali treatment. Ashik K P [7] discuss various properties of NF to substitute glass fiber composite. Dheenadhayal S [8] worked on composite made up of sisal and sugarcane fibers with alkalization chemical treatment (NaOH solution). Results indicates better tensile strength in hand lay-up fabricated composite.

Saktivel R [9] considered hybrid composite of Banana-glass-banana (Using Hand lay-up method) with utmost mechanical properties which can be commonly used in transportation and marine industry. Chemical treatment especially NaOH will decrease the moisture content percentage by 30%. It is observed that for achieving comparable mechanical strength of the material, the volume fraction of natural Fiber should be greater than that of glass fiber. Moisture concentration can be reduced significantly by the chemical treatment with bio-degradable and environmental aspect.

Hoo Tien Kaun[10] studied increase the volume fraction of Glass SRPP(self-reinforced polypropylene) enhances the energy absorbing behavior of composite and increases the amount of glass fiber improves flexural modulus of hybrid composite. Vinay [11] made composite of glass fabric and chopped thread mat with epoxy matrix by vacuum bagging technique. Characterization was completed under impact and three point test show such types of hybrid are compatible for outer body of thin sandwich boat structure. Xue Li [12] shows use of chemical treatments of natural fibers in reinforced composite for improving the adhesion. O Chubuike et. al. [13] witnessed that alkaline treatment on jute fiber composite specifies improvement in impact strength by 20% with untreated fibers. Leonard Y [14] completed the chemical modification of hemp, sisal, jute fibers by alkalization using sodium hydroxide providing the rough surface for good adhesion of natural fiber and resin to increase required mechanical and thermal stability.

There are various chemical treatments like alkali, silane treatment, acetylation, benzoylation, acrylation, maleated coupling agents, iso-cyanates, permanganate treatment are available. Though the alkaline chemical treatment of natural fibers intended for improving the adhesion between the natural fiber surface and the polymer matrix, not only change the fiber surface but also improve fiber strength. The objective and intents of the chemical treatments is to take out the weak boundary layers of natural fibers which are supposed to protect the fiber particles, improve interfacial adhesion, decrease water absorption and better mechanical properties.

Alkaline Treatment

Alkaline treatment also acknowledged as mercerization is one of the frequently used chemical treatment method for natural fibers used to reinforce thermosets. The necessary modification done by alkaline treatment is the disruption of hydrogen bonding in the network structure, thus increasing surface coarseness. Chemical treatment removes a certain quantity of lignin content, wax and oils covering the exterior surface of the fiber cell wall, depolymerizes cellulose with exposing the smaller length crystallites. [15] Addition of aqueous sodium hydroxide (NaOH) to natural fiber helps the ionization of the hydroxyl group to the alkoxide. [16]

$$\text{Fiber} - OH + NaOH \longrightarrow \text{Fiber} - O - Na + H2O$$

Thus, alkaline treatment is the interference of hydrogen bonding in the network structure to increase surface coarseness. The chemical treatment changes the positioning of the highly packed crystalline cellulose order, creating the amorphous region. It has been identified that alkaline chemical treatment has two specific effects on the natural fiber:

- It increases surface coarseness ensuring superior mechanical interlocking.
- Increases the extent of cellulose exposed on fiber surface, thus increasing likely reaction locations.[12]

In alkalization, natural fibers used (jute, flax, sisal and hemp) are cut in size of 38cm x 62cm and immersed into low fragrance detergent to eliminate contaminations from the fiber surface for 17-20 mins followed by soaking in fresh water. Then sample of natural fiber was soaked in 1 liter of 0.1% concentration of aqueous NaOH solution for 8-10 mins. The soaked sample was taken out and rolled well to remove the solution and reduces thickness of fiber. The sample then allow to dry for 2 to 3 day in the atmosphere at room temperature. The NAAM shining agent was used to offer polish surface in the last to use the fibers for fabrication of composite as shown in the fig 1.

Fig1: Chemical treatment of Natural fiber of Jute, flax, sisal and hemp.

IV. FABRICATION OF HYBRID FIBER COMPOSITE PANEL

Constituent Materials

Synthetic and Natural fibers and resin were the important constituents for the development of the hybrid composite and its fabrication. For Hybrid panel fabrication natural fibers selected based on the application requirement are Jute, flax, sisal and Hemp was supplied by Go-Green Ltd, Chennai India. They are in natural fiber woven mat form of unidirectional- bidirectional fiber arrangement. Kevlar (200Gsm) was used as external layer for composite from synthetic fiber category with properties as shown in table 1. Thermoset Polymer Resin (DOBECKOT-520F) and Hardener (ELANTAS-758) for fabrication of composite were procured from M/s Shriniwas Pvt. Ltd from Pune. Chemicals like Acetone, NaOH pellets, Myler Sheet and other material like glass sheet, detergent etc. were procured from M/s ARG Fiber Glass Enterprises, Pune as presented in Fig 2.

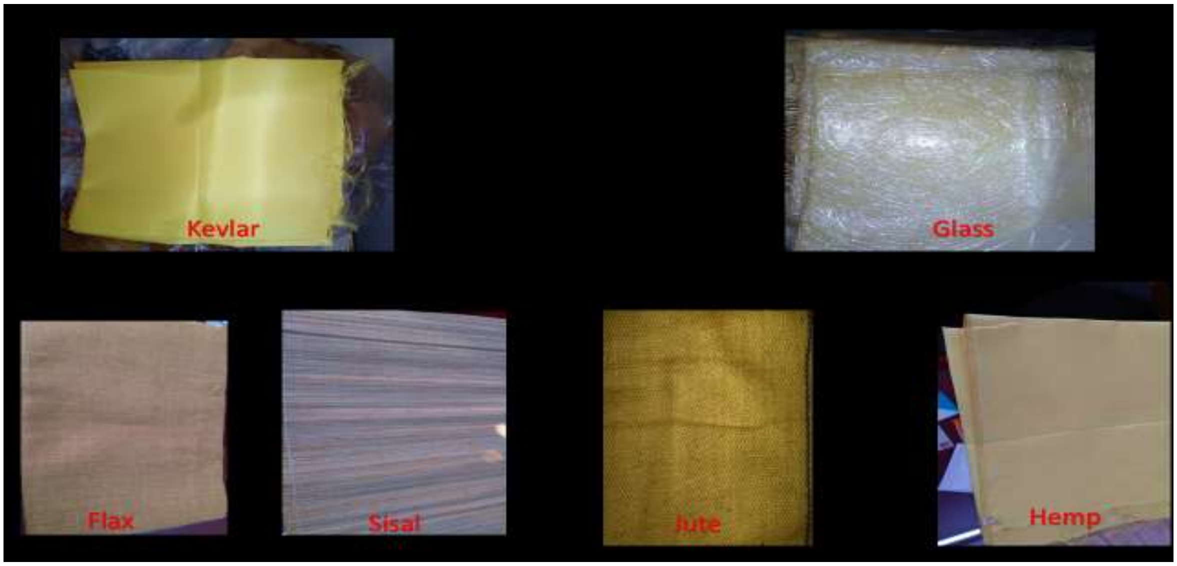

Fig: 2 Synthetic fibers (Glass & Kevlar) and Natural fibers (Jute, Flax, Sisal & Hemp)

Preparation of epoxy and hardener

Epoxy resin 520F of density of 1.15g/ml at 25^0C, mixed with hardener E-758 of specific gravity of 0.972-0.982g/ml at 20^0C is used to make the epoxy mixture for fabrication of composite. The weight ratio of mixing epoxy and hardener is 10:1. This has a viscosity of 15-35 mPa.s at 25^0C. The pot life for above blend of resin and hardener is 30-40 minutes and has to be stir well to form good epoxy mixture.

Fig 3: Polymer Resin (DOBECKOT-520F) and Hardener (ELANTAS- 758).

Development of hybrid composite panel.

Hand layup technique can be easily set up in the laboratory and is economical. Fabrication processes for thermosetting polymer matrix composites can be generally classified as wet forming processes and processes using premixes. There are several fabrication techniques to fabricate polymer composite. Fabrication set up consist of various items requisite as follows as shown in Fig 3.

1. Glass base plate – 2Nos (510 x 510mm & Tickness10mm)
2. Myler sheet of glass base size -2Nos.
3. Steel Roller (400mmx40mm) - 01No.
4. Plastic handle Brush of 2.5" size for making composite
5. Weighing M/C (Make : Master Ltd , Accuracy of .001gm)
6. Hand Gloves and pot for mixing resin & hardener with stirrer rod.

Fig 4: Fabrication Set-up for Fiber Reinforced Composite

The total preferred thickness of composite was achieved by placing various combination of layers on resin based previous layers. Four types of hybrid composite panel, made of woven natural fibers and kevlar as outer sheets were fabricated for the current study:

(1) kevlar-jute-glass-glass-jute-kevlar of thickness 4.13 mm (Wt of panel= 0.474Kg)
(2) kevlar-flax-glass-glass-flax-kevlar of thickness of 3.36mm (Wt of panel= 0.388Kg)
(3) kevlar-sisal-glass-glass-sisal-kevlar of thickness 6.2mm (Wt of panel= 0.536Kg)
(4) kevlar-hemp-glass-glass-hemp-kevlar of thickness of 3.76mm (Wt of panel= 0.436Kg)

The composite was made with each kevlar fabric layer on outer surface as skin layer to take up the static and dynamic load. The fabrication of hybrid composite was carried out through hand lay-up method. Two layer natural fibers were positioned on either side of composite next to synthetic fiber for better sound absorption and insulation and two layers of chopped glass were used to give strength and thickness to the composite. The layering sequence significantly affects the flexural and inter laminar shear strength for required type of applications. The stack of fiber layers were allowed to curing for 24 hrs. at room temperature. The sample of size 36 x

25cm are cut from long chemically treated natural and synthetic fiber sheets. The transparent myler sheet of sample size are cut and cleaned with acetone to remove any dust/marks to ensure proper clean regular surface available for composite fabrication and aligned on glass base plate. Afterwards epoxy mixture is prepared with the help of hardener and applied on the myler sheet and fiber layer efficiently with sufficient amount to wet surface of each fiber to make the stack of layers. The resins mixture is applied by hand brush and heavy steel roller is used to remove the spare resin in between the different layer to ensure removal of void gaps and uniform distribution of resin between the fiber layers. The whole stack of fiber layers the covered with myler sheet and top glass with top weight of 40Kg for suitable adhesion. The function of glass base plates to cover and compress the fiber after the epoxy is applied and also to avoid debris from entering into composite during curing.

Weight and volume fraction of the fibers.

The weight fraction (W_f) of composite panel was calculated by the ratio of summation of mass of individual fiber layer to the mass of panel. The volume fraction (V_f) is the ratio of summation of volume of all layer in stack to the volume of composite panel.

$$Wf = \frac{\sum \text{Mass of all constituent layers}}{\text{Mass of composite panel}}$$

$$Vf = \frac{\sum \text{volume of all constituent layers}}{\text{volume of composite panel}} = \frac{2\left(\frac{m_1}{\rho_1}+\frac{m_2}{\rho_2}+\frac{m_3}{\rho_3}\right)}{\text{volume of composite panel}} \quad (1)$$

Where m_1, ρ_1 are the mass and density of Kevlar fabric.
m_2, ρ_2 are the mass of respective natural fiber fabrics. And m_3, ρ_3 are mass and density of glass fiber.

The performance of hybrid composite is greatly dependent on volume fraction of reinforced fibers. The volume fraction for various fabricated composite panels is calculated using eqn. (1) and is in the range of 0.27-0.29 as shown in Table 2 below.

Table 2: Weight and volume fraction for all four specimens of hybrid composite.

Type of Hybrid composite specimen	Wight fraction (W_f)	Volume Fraction (V_f)
S1 (K/J/G/G/J/K)	37%	27%
S2 (K/F/G/G/F/K)	42%	28%
S3 (K/S/G/G/S/K)	48%	28%
S4 (K/H/G/G/H/K)	42%	29%

V. CONCLUSION

Hybrid reinforced composite of synthetic and natural fibers were developed using hand lay-up technique. Sodium hydroxide mercerization chemical treated natural jute, flax, sisal and hemp fibers are used to get four different varieties of structural panels. In all these panels, outer factsheet is made of kevlar-29 and core material is chopped glass mat. Though, the natural fabric sheet is positioned in between them. This configuration is decided through extensive literature survey where kevlar provides the sufficient impact strength while natural fiber and glass chopped mat adds the acoustic damping and thermal insulation property appropriate for certain defense applications like shelter in high altitude areas (structural panel), isolators, camouflage, acoustic dampers for automates, bunkers, communication and signal rooms etc. The performance of hybrid composite is dependent on volume fraction of reinforced fibers. The volume fraction for various fabricated composite panels and is in the range of 0.27-0.29

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