Evaluation of improvement in performance of FRP composite by using Al (OH₃) as secondary reinforcement

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Abstract: Composites are the materials of this century, and it uses are predominately occupied in all areas, starts from kitchen utilities to aerospace sectors. Among different type of composite materials, the fiber reinforced polymeric (FRP) composite materials are the most used and accepted one. There are many researches undergoing to further improve the performance of these fiber reinforced polymeric composites. One of the proven methods for performance improvement is adding secondary reinforcement into the base matrix material. There are different types of secondary reinforcement like rice husk, MgCO₃, Boron nitride powders, which are often used and their respective performance recorded by different researchers. In this work, laminate of size 300 X 300 mm with 3 mm thickness fabricated using hand layup method in which epoxy has been chosen as the base matrix material. The laminate consisting of 3 layers (Glass-Flax-Glass) with 2% wt of Al (OH₃) as secondary reinforcement and compared with the mechanical properties without using secondary reinforcement. From the result we understood that the tensile strength and flexural strength of laminate is increased by the addition of secondary reinforcement.

Keywords: Fiber reinforced plastic composites, secondary reinforcement, mechanical properties, Glass, Flax, Al (OH₃).

1. Introduction

Composite materials are considered as the new age materials which found wide applications in both industrial and service sector. Composite is a material system composed of two or more physically distinct phases whose combination produces aggregate properties that are
different from those of its constituents. It is a combination of Matrix and Reinforcement. Composite materials are the leading materials in various industries like ship building, aerospace and automobiles [1-3]. When a set of materials have been physically assembled to form one single bulk without physical blending, the resulting material is a composite material [4]. Fiber reinforced composites gains more importance because of its high strength to weight ratio as well as stiffness to weight ratio. The properties of composites can be enhanced by the addition of different chemicals. With this note, Changlei Xia in his paper established that the mechanical properties and the water absorption resistance of a composite material is significantly improved using Aluminium hydroxide impregnated fibers, and he also implied that the thermal conductivity of the composites was increased by adding natural fiber [5-7]. Similarly, Gyanendra Singh, in his research paper found out that the tensile test, impact test and hardness test showed a promising result with the addition of aluminum in epoxy based composites [8].

In this research work, epoxy resin has been used as the base matrix material. Similarly, the NaOH treated flax fiber has been used as the reinforcement agent, as well, the glass fiber was also used as the another reinforcement agent in order to fabricate the hybrid laminate. Along with the epoxy the aluminium hydroxide have been as the secondary reinforcement agent. To verify the physical strength of the fabricate laminate, two sets of hybrid laminate have been fabricated, one with aluminium hydroxide (2%) and another laminate without aluminium hydroxide. Both the materials are subjected to various tests to determine their mechanical property and the same compared with each other. The tensile and flexural tests were performed on the composites and the result were compared and analysed for the effect of addition of Aluminium hydroxide in the composite [9-10].

2. Materials and methods

This paper is about the preparation of composite laminates and the experimental procedure for the mechanical characterization. The raw materials used are Glass fiber, Flax fiber, Epoxy resin

2.1 Fibers

Glass fiber is the most commonly used reinforced material in the fiber reinforced composites. It is very cheaper and less brittle. The glass fibers are in different forms like chopped fibers and woven fabrics. In this work, bidirectional glass fiber mats are used. The flax fiber mat belongs to the jute fiber family; the properties of both the fiber used are given in table 1.

| Material   | Density (g/cm$^3$) | Tensile strength (MPa) | Elastic modulus (GPA) |
|------------|--------------------|------------------------|-----------------------|
| Glass fiber| 2.54               | 3450                   | 72                    |
| Flax fiber | 1.45               | 800 to 1500            | 60 to 80              |

2.2 Flax fiber Treatment

The mechanical strength of the composite mainly depends upon the interfacial bonding between the matrix and the fiber. Flax fiber treatment is done based on the work in paper. The fiber mat is treated as follows:

1. Flax fiber mat is washed with distilled water and then dried for 2hrs.
2. In a separate tray the fiber mat is treated with 10% NaOH solution at room temperature for
3. The treated fibers are again washed with distilled water to remove excess NaOH adhered to the fiber mat. Then the washed fiber mats are dried for 5 hrs and then over dried for 2hrs at 50°C.

2.3 Resin

Epoxy resin is the most used resin in the manufacturing of adhesives, plastics, paints, coatings, and sealers, flooring and materials that are used in building and construction applications. It is one of the commonly used moulding resin and properties of the resin are given in table 2.

| Name of the resin | Density (g/cm³) | Viscosity (cps) | Tensile Strength (MPa) | Flexural Strength (MPa) |
|-------------------|-----------------|-----------------|------------------------|------------------------|
| Epoxy             | 1.1-1.4         | 200             | 85                     | 112                    |

2.4 Secondary Reinforcement

The secondary reinforcement enhances the properties of the composite like Flexural strength, Tensile strength, fire resistance and water resistance. Materials which we can use as secondary reinforcement are MgCO₃, Al(OH)₃, Bagasse, Rise husk. In this composite, Aluminium hydroxide Al(OH)₃ (2% wt) was used which was shown in figure 1.

Figure 1 Aluminium Hydroxide

2.5 Fabrication of Composite

In this work, hand layup method is used for fabricate the composite laminate. Epoxy resin and Hardener are mixed in 10:1 ratio and the Glass and Natural fiber mats are of size 300 x 300 mm. The thickness of the laminate is 3mm. The laminates prepared consist of three layers of fibers filled in between Epoxy resin. The voids produced while preparing the laminates are squeezed out by using a roller. The fabrication procedure followed is as same as in the ply arrangement scheme is given in table 3 and the laminates are shown in figure 2 [11-13].

| Name of the composite | Type of Composite | Layer 1            | Layer 2           | Layer 3            |
|-----------------------|-------------------|--------------------|-------------------|--------------------|
| C₁                    | Hybrid fiber reinforced composite (HFRP) | Glass fiber mat    | Flax fiber mat    | Glass fiber mat    |
C	extsubscript{2}  |  Hybrid fiber reinforced composite (HFRP-S) with secondary reinforcement  |  Glass fiber mat  |  Flax fiber mat treated with Al(OH)3  |  Glass fiber mat  \\

|  Figure 2. Hand layup Process  \\

2.6. Testing Procedure

Composite laminates prepared are cut as per ASTM standards samples using water jet cutting process. The standard samples are used to test the tensile and flexural strength of the laminates.

2.6.1 Tensile Test

The samples are cut into the size according to ASTM Standards D-638. The tensile test was carried out in Universal Testing Machine with maximum capacity of 600 kN at room temperature in order to find out the ultimate tensile strength. The results are analyzed and tensile strength is calculated. The test samples are shown in Figure 3 and 4 [14-15].

|  Figure 3. Tensile Test samples before testing  \\
|  Figure 4. Tensile Tested samples  \\


2.6.2 Flexural Test

The samples are cut into flat shape of cross section (125 x 13 x 3) mm according to the ASTM standards (D-790). The flexural test is carried out in a Universal Testing Machine in order to find out the material’s ability to resist deformation under loading. The results of the test are correlated and the flexural strength of the material is identified. The flexural test samples before and after the test are shown figure 5 (a) and (b) [16-17].

![Figure 5. Flexural test Specimen: A. Before test B. After test](image)

2.7 SEM Analysis

The laminates of the composites are visualized using scanning electron microscope to reveal the morphology of the laminates at microscopic level and identify and analyze the arrangement of fibers in the laminate. The laminates are revealed using Quanta FEG-250 SEM in different magnifications at the testing laboratory in Alagappa Chettiar Government College of Engineering and Technology, karaikudi, Tamilnadu, India. The equipment is shown in Figure 6.

![Figure 6. Scanning Electron Microscope (Quanta FEG-250)](image)

3. Results and Discussion

The composite laminates are prepared and its mechanical properties are observed and compared from the below table we found that the average tensile strength of the GFG composite without reinforcement is observed as 45.24 N/mm² and the Flexural strength as 152.38 N/mm². The average tensile strength of the GFG composite with secondary reinforcement is observed as 57.08 N/mm² and the average flexural strength as 214.833 N/mm². From the above results, it was understood that by the addition of secondary reinforcement the flexural strength and tensile strength are increased with significant amount, especially the flexural strength increases by 40%. The increase in the mechanical strength with the usage of secondary reinforcement may be due to the improvement in bonding between the matrix and the reinforcement which can be further
analyze using scanning electron microscopic test. The sample wise test result is given in table 4 and
the comparison of average value comparison is shown in figure 7 [18-19].

| Test Type/ Specimen Number | Tensile Strength (N/mm²) | Flexural Strength (N/mm²) |
|----------------------------|--------------------------|---------------------------|
|                            | 1            | 2           | 3           | 1            | 2           | 3           |
| HFRP                       | 30.13        | 49.34       | 56.25       | 136.24       | 148.28      | 172.64      |
| HFRP (With Secondary Reinforcement) | 35.52 | 60.32 | 75.4 | 168.34 | 232.54 | 243.62 |

Figure 7. Comparison of average tensile and flexural strength for the fabricated composites

3.1. Scanning Electron Microscopic Analysis

The comparison of delamination of the tensile test samples of laminates with and without secondary reinforcement is given in fig: 8. The Fig: 8 (A) shows the delamination between the fiber and the matrix due to improper bonding where us at the same time, Fig: 8 (B) shows a strong bonding between the resin and the fiber which could be due to the presence of secondary reinforcement. From this comparison, It was understood that the secondary reinforcement improves the bonding between the fiber and the Matrix [20-22].

Figure 8. (A) Laminate without secondary Reinforcement. (B)Laminate with Secondary reinforcement
4. Conclusion

From the above advance hybrid fiber reinforced composite laminate with Al OH$_3$ secondary reinforcement fabrication and mechanical characterization the following conclusions are drafted.

- The inclusion of the secondary reinforcement (Al(OH)$_3$) improves the mechanical properties of the fabricated laminates. The tensile strength improved by 26.66% and the flexural strength improved by 40.42%.
- From the improvement percentage we understood that the addition of secondary reinforcement influences the flexural strength.
- Strong bonding between the resin and fiber revealed by Scanning Electron Microscope due to the presence of Secondary Reinforcement.

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