Evolution of Mechanical Behaviour of Polyester Polymer Mortars Modified With Recycled GFRP Waste Material

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Abstract- *The demand and rate of consumption increasing day by day with the potential growth in fabrication and manufacturing of new products. As a result, there is a huge number of end-of-life (EOL) products are continuously phase out which results in the increasing non-biodegradable waste leads to environmental pollution. To overcome this problem the recycling and reusing polymer composite have many advantages.*

This project aims to perform the development and evolution of mechanical behaviour of polyester polymer mortars modified with recycled GFRP waste material. The composite specimens are made with the weight proportion 60% recycled glass fibres and together with commercial epoxy resin AralditeBY158 and the commercial reagent Aradur21 which changes the viscosity. The properties like tensile, compression, impact, bending strength are evaluated by conventional destructive testing methods, and compared the properties with the composite made up of brand-new material.

Fabrication of material is done by hand layup technique, laminated by three layers which gives thickness of 6mm. To fabricate the composite, resign transfer moulds are was used with the weight proportion 60% recycled glass fibre and 40 percent epoxy resin. The specimens are prepared ASTM standards.

Finite element analysis is carried out on the two different specimens with the same volumetric ratio as part of comparing these conventional destruction test results. It has been observed there is no significant variation in the three evolutions. It has been concluded that there is no much change in reusing the GFRP when compared with brand new material.

Keywords- recycled GFRP, brand new GFRP, epoxy resin, fabrication, volume fraction, tensile test compression test, impact and bending test.

I. INTRODUCTION

Background:

Agreements are being made to enhance the generation of renewable energy and to enhance the energy efficiency of physical infrastructure and engineering components in order to lower greenhouse gas emissions globally, as awareness of global warming and the depletion of fossil fuels grows. Through improved mechanical qualities of engineering structures and buildings, there is a huge potential influence to increase energy efficiency and consequently reduce greenhouse gas emissions. The most obvious way to accomplish this would be to use thicker layers of easily accessible materials. However, in certain areas, this may lead to the usage of unfavorable thick constructions and associated modifications to building techniques, in addition to the loss of useful floor space and the ensuing higher costs.

Novel kinds of inexpensive, processable materials with higher efficiencies are being considered as an alternative to this one.

Composite Materials: Composites are mixtures of two or more materials wherein one or more of the components, referred to as the reinforcing phase, are embedded in the matrix phase, the base material, as fibers or particles. While the inclusion of fibers or particles in a composite enhances its mechanical properties like strength, stiffness, etc., the matrix's main purposes are to transfer stresses between the reinforcing fibers or particles and to protect them from mechanical and/or environmental damage. Thus, a composite is an insoluble mixture of two or more parts that have different physical forms and chemical compositions yet work well together.

In a number of light-weight and very robust applications, composites have effectively replaced traditional materials. Composites are chosen for these kinds of applications primarily because of their excellent creep resistance, high tensile strength at high temperatures, and toughness. In a composite, the matrix is often made of a ductile or tough material, while the reinforcing components are typically strong because to their low densities. Correct design and fabrication of the composite results in a combination of desirable features not found in any one traditional material: the strength of the reinforcement and the toughness of the matrix. The quantity, configuration, and kind of fiber and/or particle reinforcement in the resin are the main factors influencing the strength of the composites.

Compared to untreated fiber reinforced composites, the glass fiber reinforced composites after chemical treatment shown better mechanical qualities. The improved packing of the cellulose chains following the dissolution of the cementing ingredient, lignin, was shown to be the primary cause of the improved characteristics. Thermal deterioration of glass pseudo-stem (BPS) filled un-plasticized polyvinyl chloride (UPVC) composites was studied by Zainudin et al. According to the findings, BPS/UPVC composites treated with acrylic had higher thermal stability than BPS/UPVC composites left unaltered.

Composites made of glass and glass fiber reinforced polypropylene (BSGRP) were created and their characteristics assessed by Samal et al. Based on the findings, it is known that the BSGRP composites with MAPP are more affordable and have better melting points, improved storage moduli, enhanced crystallization and thermal degradation temperatures, and optimal viscosities.

After conducting degradation investigations on polycaprolactone glass fiber reinforced composites, it was found that the glass fibers treated with an alkali solution increased in density and surface roughness. Short glass fibers, either untreated or alkali-treated, were added to thermoplastic matrix materials (HDPE/PCL 80:20 blend and LDPE/PCL 70:30 blend) to enhance their mechanical capabilities.According to Shaktawat et al.'s investigation on the temperature dependency of the thermo-mechanical properties of polyester composites reinforced with glass fiber, the composites treated with alkali had the highest phase transition temperatures.

Overview of the Research Topic: This study is primarily an experimental examination of the mechanical properties of a recycled glass fibre reinforced polymer composites that contain glass fibers. When describing the mechanical characteristics of particulate-filled polymer composite systems, effective mechanical properties are a crucial factor to consider. The impact of extra reinforcement from recycled glass fibre on the polymer's mechanical properties is investigated. Additionally, the comparison is done on the furnished glass fibre and recycled glass fibre.

II. LITERATURE REVIEW

The materials and techniques utilized to process and characterize the composites under inquiry are covered in this chapter. It provides the specifics of the experiments conducted to characterize the natural glue composites that were created for the current study in terms of their physical, mechanical, microstructural, and thermal properties.

Glass fiber has already been reinforced with a number of thermoplastics, including poly vinyl chloride (PVC), polystyrene (PS), low-density polyethylene (LDPE), and high-density polyethylene (HDPE). Kristina et al. investigated the effects of flax, glass, jute, and sisal fiber shape on mechanical characteristics. The extrusion method is used to create the composites. Sisal fiber has superior impact qualities among the compared fibers due to its superior elongation to break. Sushanta et al. conducted a performance test of the glass/glass fibre hybrid composite with PP. Sanjay et al. investigated the biodegradability of glass, pineapple, and bamboo fibers reinforced in PP matrix.

Samrat Mukhopadhyay and colleagues conducted research on the different diameters of glass fiber. A hundred fibers were selected at Random from the glass fiber collection. The diameter varied greatly, ranging from 0.08 mm to 0.32 mm and beyond. based on a class interval of 0.029 mm, which shows that as fiber diameter increased, the standard deviation reduced, indicating that the fibers were more regular in character. As can be seen, most of the fibers have a diameter between 0.17 and 0.19 mm. For tensile testing, several types of fibers were used. Tensile test results showed that strain rates were crucial in determining the shape of the stress-strain curves, the strength of the fiber and nature of failure

In addition to discussing the global evaluation report on natural fibers and their applications, D. Chandramohan et al.'s study on natural fibers [9] focuses on the advancement of biomaterials in the field of orthopaedics. a project to produce biocomposite materials based on bio epoxy resin and natural fibers including Agave sisalana, Musa sepientum, and Hibiscus sabdariffa and their use as a bone grafting alternative while leveraging the benefits provided by renewable resources.

Objectives of the Present Work

The objectives of this work are outlined as follows:

- Fabrication of two sets of glass fibre compositeone is brand new glass fibre and second one is recycled glass fibre. measurement of their mechanical properties.
- Physical and mechanical characterization of the composites are evaluated.
- Study on the effects of brand newglassfibre reinforcement and recycled fibre reinforcement on effective mechanical properties.

III. MATERIALS AND METHODS

Thermal processes: Typically, thermal recycling involves applying heat to separate the fiber reinforcement from the matrix so that it can be reused and potentially have more added value, especially if the fiber reinforcement is made of carbon fibers.

1. Combustion: Recycling happens by co-processing, which is defined by this technique's integration of the material to be recovered during the processing of another material. In actuality, energy recovery rather than material recovery is the goal of the combustion process.

Combustion is mainly used via the cement kiln route where the polymer matrix is burned as fuel for the process, reducing the use of fossil fuel; the fibers containing E-Glass, which are based on alumina borosilicate, provide mineral feedstock to be used as part of the cement clinker (initial stage of the cement), with specific amounts of silica (Si), calcium (Ca), and alumina (Al). Further down the process, the clinker is ground to form cement.

The primary method of combustion is the cement kiln route, which uses the polymer matrix as fuel for the process and minimizes the use of fossil fuels. The fibers containing E-Glass, which are based on alumina borosilicate, provide mineral feedstock with specific amounts of silica (Si), calcium (Ca), and alumina (Al) that can be used as part of the cement clinker, which is the first stage of the cement. Cement is created by grinding the clinker later in the process.

Material Matrix:

Glass fibers, epoxy resin, acetone thinner, and catalyst methyl ethyl ketone peroxide (MEKP) were the ingredients employed in this experiment's creation. Glass fibers are gathered from the Coimbatore district in Tamil Nadu, India, in the form of leftovers. Methyl Ethyl Ketone Peroxide (MEKP), acetone thinner, and epoxy resin are bought from a nearby dealer in Chennai. Table 1 displays the glass fibers' physical characteristics.

Property	**Range**
Cellulose (%).	62- 63
Hemi cellulose (%).	19.21
Lignin (%).	5.1
Moisture (%).	10.1-11.5
Density (g/cm3).	1.1-1.53
Elongation at break (%).	4.55- 6.51
Young's modulus (GPa).	21
Microfibrillar angle (deg.).	10
Lumen size (mm).	6

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Material for Filler: Glass FiberGlass plants are the source of glass fibers. After fruit is harvested and glass is produced, the trunk (pseudostems) of the plant is left as agricultural waste. All types of glass plants produce fibers that are extracted from the stem. Glass fiber may be efficiently produced using these pseudostems. The pseudostems of the tree are soaked in water to soften and separate the fibers, which is then used to extract the fiber by hand or by a stripping machine before it is knotted to yarn to form glass fiber.

Glassfibre

Properties	**Value**
Fineness.	17.05
Moisture Regain.	13.10%
Elongation.	6.64
Total Cellulose.	80.20%
Alpha Cellulose.	61.50%
Residual Gum.	41.80%
Lignin.	15.10%
Tensile Strength (Mpa).	813
Specific Tensile Strength (Mpa).	436
Young's Modulus (Gpa).	31
Specific Young's Modulus (Gpa).	21
Failure Strain (%).	2.05
Density (Kg/m).	830

Properties of glass jute fibre.

Epoxy resin (lignins): Vascular terrestrial plants produce lignins, which are three-dimensional polymers. Cellulose, which is found in abundance in nature, acts as a natural adhesive to firmly hold plant fibers together. Lignins have both phenolic and polymeric properties. Not all adhesives can be used with this environmentally friendly adhesive. A porous surface is necessary to achieve the best adhesion when using eco-friendly gelatin or dextrin glue. Paper products, cardboards, and chipboards are all considered general applications.

Hardner and treated lignins

Getting ready for composites:

This preparation method uses manual lay-up, which is followed by compression molding to provide pressure. Glass fibers of a specific length were used to create the fiber mats with a consistent thickness. There are three layers to the composite. Epoxy resin was used to impregnate the mats. The catalyst used in the effective binding of epoxy resin is MEKP. The glass fibers are first dried in the scorching sun for longer than twenty-four hours in order to eliminate any moisture. Prior to fabrication, the fiber layers are cleaned in the acetone thinner. By doing this, the contaminants are removed from them and they are prepared for resin binding.

After mounting the glass fibers on the base plate, which is set on the table, the epoxy resin is poured into it entirely. After being combined with the fiber, the resin may tend to dry out in the open air under a strong sun for 48 hours. The second layer needs to be put on the resin before it dries. The procedure is likewise carried out for a second layer. A roller is used to apply the epoxy resin evenly across the surface, and a gentle squeeze is used to eliminate any air spaces that occurred between the layers during manufacturing. Subsequently, the specimen is compressed at 32°C, 6MPa of pressure, and 65% relative humidity on average. Three such samples were prepared with different lengths and volume fractions, tested and the average values are used for detailed analysis.

IV. EXPERIMENTAL SETUP

Specimen preparation: Specimen for tensile test and bending test is made according ASTM standards for plastic material and fibres. As shown in figure. The specimen is cut into rectangular block of length 100mm breath 10mm and thickness 6mm. and machined according to the required dimensions. Tensile test is performed using UTM.

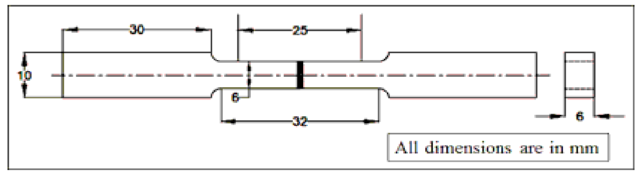


Fig-5: ASTM standard tensile test specimen dimensions for plastic and fibres,

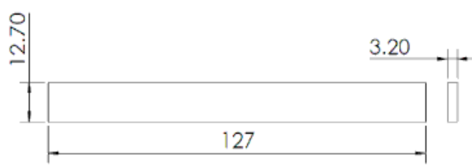


Fig-6: ASTM standard bending test specimen dimensions for plastic and fibres.

Total twelve specimens are prepared according to the orientation six specimens (3 tensile test and 3 bending test). According to the volume fraction six specimens (3 tensile test and 3 for compression test). Figure shows the pair of finished specimen.

Fig-7: Specimen for tensile and bending stress.

4.5. Tensile Test

A hand cutter is used to form the prepared specimen into the desired dimensions, and salt paper is used to polish the edges. It is made in compliance with ASTM D638 guidelines. The measurements, cross head speeds, and gauge length are selected in compliance with ASTM D638. The Universal Testing Machine (UTM) Make FIE (Model: UTN 40, S. No. 11/98-2450) is used to conduct the tensile test.The test sample is placed in the UTM, and tension is applied to it until the material fractures. Subsequently, the force is documented in relation to the gauge length increase. The gauge section's elongation is measured in relation to the applied force while tension is applied. Three categories of samples exist.

The specimens ready for the tensile test are displayed in Fig. 7.The force needed to break a polymer composite spec imen and the degree to which the specimen stretches or elonga tes to that breaking point are measured during testing using U TM.Here, a fractured component from the tensile test is shown in Fig. 2.There is a single load applied through both ends.The tensile strength of the composite samples is determined in the current study using the cross head speed of 10 mm/minute, wh ich is tested in the universal testing machine Instron 1195.The loading configuration is displayed in Fig. Fig. displays typical rectangular samples used in tensile tests. In this instance, the test is conducted three times on each type of composite, and the composite's tensile strength is determined by averaging the results.

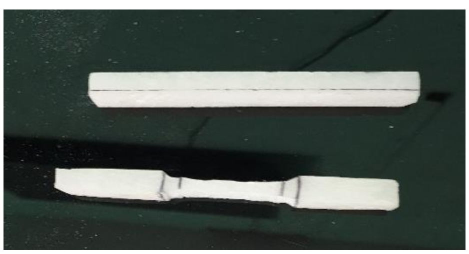


Fig -1: Tensile test specimens

Fig -2: Tensile specimen in UTM

Flexural Test: Using the same UTM, the test was conducted o n flexural specimens that had been prepared in accordance wit h ASTM D790 requirements.The most popular flexural test, th e 3point test, is employed in this experiment to evaluate the co mposite materials' bending strength.The test specimen is put in the UTM and force is applied to it until it breaks and fractures as part of the testing procedure.A material's flexural strength i s its capacity to withstand deformation under load.This test, kn own as the 3-point bend, typically encourages failure by inter-laminar shear.This test is performed using UTM in accordance with ASTM D790 standard.Figure 3 displays the configuratio n for the flexural test.

With respect to compressive strength, flexural MR ranges from 10 to 20 percent, contingent upon the kind, size, and volume of coarse aggregate utilized. In any case, laboratory testing for the specified components and mix design yields the best correlation for the particular materials. The flexural strength of a material is defined as the greatest fiber stress at failure on the tension side of a flexural specimen. Thus, the flexural strength in a three-point flexural test is determined by applying Equation (1) for a homogeneous beam.

$$\sigma_f = (3P_{max} L)/2bh^2$$

where,

P_{max} = maximum load at failure

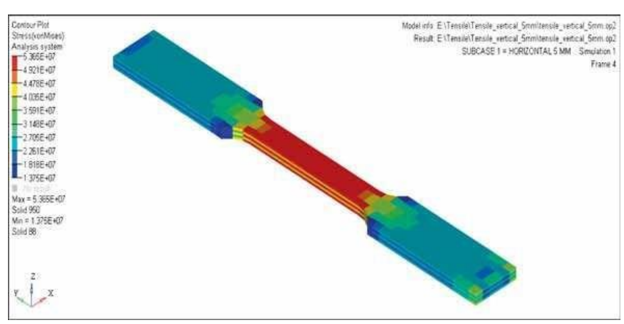
b = specimen width

h = specimen thickness

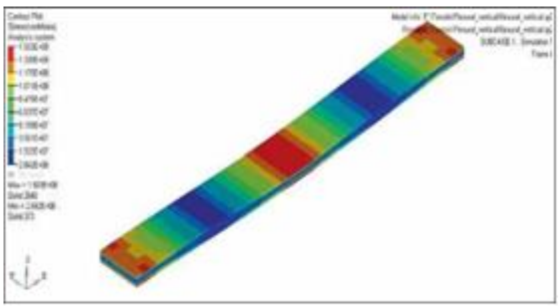
L = specimen length between the two support points

Fig -3: Flexural test arrangement

Results and discussions:



Simulation plot of tensile test specimen with 90◦ fibre orientation. Typical load *vs.* displacement curve generated directly from the machine during flexural loading.



Simulation plot of flexural test specimen with 90◦ fibre orientation.

The samples are tested in machines the results are evaluated for tensile strength and flexural strength in both of recycled and brand-new fiber orientation and compared with FEM analysis.

Samples	**Tensile strength (MPa)**	**Flexural strength (MPa)**	**Impact strength (Joules)**
Reused glass fiber	132.40	78.28	8.96
Glass fiber	134.50	79.53	8.89
FEM analysis	102.72	69.47	5.94

Table-2:results of reused fiber, brand new fiber and FEM analysis is tabulated for both tensile and flexural strength

V. CONCLUSION

The conclusion has been made by taking the results of conventional testing of specimens. In the present work the comparison is made between the furnishes glass fibre composite with recycled fibre reinforced polymer composite From the study we conclude that

- Recycled GFRP fibre reinforcement provides similar results as furnished glass fibre reinforcement with a small variation which can be used as the replacement of new once.
- The life of the reused glass fibre is considerably low, which leads to replacement of the product made with this earlier.
- Recycling the glass fibre may reduce the environmental imbalance.
- Recycled glass fibre gives similar results as of the refurnished glass fibre but should not use in the place where heat is not effect.

Applications of recycled glass fibers: Recycled glass fibers are used almost all the applications like as furnished glass finer. Where there are not affected with thermal and pressure most promptly there will be small sort of effect earlier when compared with forbidden products. As per my knowledge the life of the recycled once is low comparatively. FRP is a useful product that will continue to find new applications.This is the reason perhaps why fiberglass is widely used in industries given below:

- **Beverage industry**: Fiberglass grating is used in many areas like bottling lines and in brew houses.
- **Car washes**: Recently, fiberglass grating is greatly used for rust resistance and to give a contrast color to areas that previously looked forbidden. It brightens the inside of the carwash tunnel making the car look cleaner than it was.
- **Chemical industry**: In this industry, the fiberglass grating is used for anti-slip safety feature of the embedded grit surface and the chemically resistant feature of different resin compounds. The chemicals being used are matched with the resins.
- **Cooling towers**: Since cooling towers are always wet, they have to be protected from rust, corrosion, and other safety issues. Due to the excellent properties of fiberglass, it is used in these towers as screening to keep people and animals away from the danger zones.
- **Food processing**: In the chicken and beef processing plants, fiberglass grating is used for slip resistance and for holding up to blood which is corrosive. Most of the areas of food processing also use fiberglass as other grating materials are not suitable.
- **Fountains and aquariums**: All sizes of fountains and aquariums use fiberglass to support rocks to help in circulation and filtering from under the rocks. In large public fountains, fiberglass grating is used to protect spray headers and lights from getting damaged. This also keeps people from drowning in the fountains.

- **Pulp and paper industry**: The property of fiberglass which makes it chemical corrosion resistant is useful in pulp and bleach mills. Recently, fiberglass is used in many areas due to its corrosion resistance and anti-slip properties.
- **Automotive industry**: Fiberglass is extensively used in automobile industry. Almost every car has fiberglass components and body kits.
- **Aerospace &Defense**: Fiberglass is used to manufacture parts for both military and civilian aerospace industry including test equipment, ducting, enclosures, and others.

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