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Hybrid Reinforced Polymer Composites from Water Hyacinth and Pineapple Leaves

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ABSTRACT
The utilisation of materials having high carbon content is causing adverse impacts on our environment. To reduce the impact of construction materials on the environment it has become necessary to develop advanced low carbon embodied materials for construction. Environment friendly materials from agricultural and other wastes that are sources of lignocellulose biomass are an ideal alternative for reducing the pollution caused by the construction sector. Agricultural wastes from pineapple cultivation and water hyacinth weed from water bodies are abundant sources of biomass in Kerala. The composition and economic viability of these materials as raw materials make them ideal for manufacturing composite panels for construction. This study includes the development and fabrication of hybrid reinforced polymer composites from water hyacinth and pineapple leaf wastes. The hybrid reinforcement in these materials is the non-uniform mixture of fiber and particulate materials of the lignocellulose biomass. The bio based composites developed from these wastes are suitable for application in interiors, ceilings and wall partitions.

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I. INTRODUCTION

Infrastructure development plays an important role in the development of a nation. But statistics show that the construction Industry in India is largely causing adverse impacts on the environment. The uncontrolled usage of natural resources has led to severe damage to the environment in the form of pollution and climate change. The effects of pollution caused by the construction industry include the occurrence of global warming and the greenhouse effect due to the excessive emission of pollutants. So, it has been necessary to introduce sustainable and eco-friendly construction materials as an alternative to the existing concrete and other high-energy materials-based construction technology (Begum & Islam 2013).

Innovative building materials from natural sources have a huge demand in the development of sustainable infrastructure. This can be done by adopting sustainable construction using composites from lignocellulose material or bio boards, green concrete with low carbon footprint, fiber reinforced polymers and geopolymer concrete. Among the materials, bio boards such as fiberboards or particle boards from lignocellulose materials. The particulates or fibers act as reinforcement members of the composite and by mixing the reinforcing material with a polymer matrix the composite is fabricated. These composites with multiple components as reinforcement or matrix are hybrid composites. Hybrid composites have larger scope in the affordable and sustainable housing sector. In this study, a sustainable approach for the manufacture of lignocellulose material-based hybrid composite is developed. The particulate and fiber mixed non-uniform lignocellulose biomass act as the reinforcement for the matrix to form sustainable building composite panels for construction.

Fig 1. Water Hyacinth in Akkulam Lake

Water Hyacinth is growing uncontrollably across the lakes of Kerala as a weed. This is now affecting aquatic life due to oxygen depletion caused by the weed. The mechanical removal of the weed is the most recommended method. This is an environment friendly method when compared to the chemical treatment method which is unsafe for aquatic life. To improve the economic feasibility of the mechanical removal process that uses advanced technologies we have to develop innovative materials from water hyacinth biomass waste for value addition of this waste material (Ruiz et al., 2019).
Pineapple cultivation is abundantly carried out in the Central region of Kerala. The graph given below shows the fluctuations in the pineapple market across a duration of 6 months in Kerala. The unpredictable variation in prices necessitates the need for the development of value-added products from the byproducts of pineapple cultivation. Also, the burning of these agricultural wastes can cause adverse effects on our environment. The fibers extracted from waste pineapple leaves show measurable properties and have the potential to be used in composites as a reinforcement for the matrix to enhance the strength of the material.

Fig 2. Pineapple Cultivation in Kottayam

The carbon footprint of the construction is drastically increasing especially due to the over utilisation of natural resources to solve this menace it has been necessary to develop advanced materials for which biocomposites from agricultural wastes are an ideal solution. Since pineapple leaf and water hyacinth wastes are abundantly available at low cost this method will be economically viable.

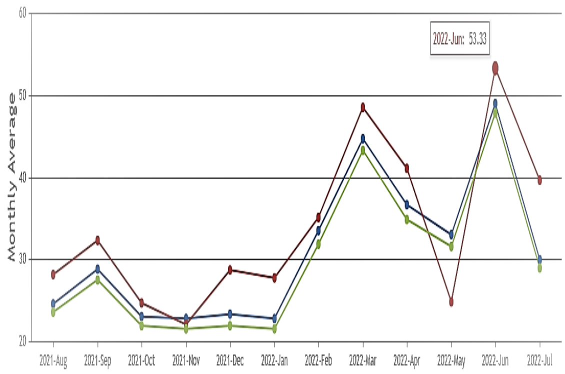

Fig. 3. Fluctuations in Pineapple Market: Kerala

II. MATERIALS

Lignocellulose Materials: Fibers are hair like components which are formed in continuous as well as discrete elongated pieces. The fibers used in the manufacture of the composite are classified into two which are artificial fibers and natural fibers. In artificial fibers like glass fiber or carbon fiber the chemical composition, structure of fiber and physical or chemical properties are enhanced during the manufacturing process. They can be designed into any orientation based on the requirement. But man-made fibers are not environment friendly. Here lies the importance of natural fibers.

Natural fibers and particulates have attracted the attention of scientists and technologists because of the advantages that these fibers provide over conventional reinforcement materials, and the development of natural fiber composites makes the composite more environment friendly and has a lesser carbon footprint. Natural fibers are low-cost fibers with low density and high specific properties. These are biodegradable and non abrasive, unlike other reinforcing fibers. Natural fibers from coir, pineapple, sisal and hemp are commonly used in developing advanced composite materials for high strength applications (Kumar et al., 2015).

Constituents	**Percentage**
Lignin	10
Cellulose	25
Hemicellulose	35
Ash	20
Nitrogen	03

Table 1. Composition of Pineapple Leaf

The economic viability of fiber reinforced composites in infrastructure applications is not favourable as the volume of the resin required is higher compared to particulate composites. Fiber reinforced composites are therefore preferred for high strength applications. In this study, discrete pineapple leaf fiber containing pineapple leaf particulate is opted as the reinforcement. Thus, the process of extraction of fiber can be saved thereby reducing the cost of manufacturing.Pineapple leaves are collected from the Kottayam district. In rubber plantations of Kerala pineapple is cultivated as an intermediate crop during the replanting of rubber trees.

Constituents	**Percentage**
Cellulose	66.2
Holocellulose	85.7
Hemi Cellulose	19.5
Lignin	4.2
Hot water soluble	32.5
1% NaOH soluble	39.7
Ash content	4.5

Table 2. Composition of Water Hyacinth

From the chemical composition of water hyacinth, it's clear that the percentage of cellulose in water hyacinth is low compared to other lignocellulosic materials. This will affect the mechanical strength of the material. To increase the cellulose content in the material paper wastes having high cellulose percentage can be mixed with the biomass.

Paper Wastes: Since particulates are mixed with the fiber the cellulose present in the mix gets reduced. This can affect the strength of the composite. To increase the strength of the composite, the cellulose content has to be increased. To increase the percentage of cellulose high cellulose containing paper waste is added upto 20% by weight. The cellulose content present in paper waste is above 85% of the total composition as per table 3.

Composition	**Percentage**
Cellulose	85
Holo Cellulose	85
Lignin	15
Hemi Cellulose	0

Table 3. Composition of Paper Waste

Polyester Resin:
Resin is the polymer used as a matrix medium in composite or a mixture of additives. The resin, its chemical composition and physical properties, fundamentally affect the processing, fabrication and ultimate properties of composite materials. Variations in the composition, physical state of a resin and the presence of impurities or contaminants in a resin may affect handleability and processability, laminate properties, and composite material performance and durability.

Fig. 4. Polyester Resin

The resin material used in this polymer matrix composite is unsaturated polyester. In this research unsaturated polyester resin is used as the matrix medium. The Methyl ethyl ketone Peroxide is used as an accelerator and Cobalt chloride is used as a catalyst for the thermosetting of polyester resin. The accelerator and catalyst added to the resin help in the fast setting and curing of the composite.

Fig. 5. Accelerator and catalyst

Properties	**Polyester**
Density (g/cm3)	1.16
Tensile Strength (MPa)	22.9
Elongation at Break (%)	1.60
Youngs Modulus (MPa)	580
Specific Strength (MPa)	19.7
Specific Modulus (MPa)	502

Table 4. Properties of Unsaturated Polyester

Acetone: Polyester resin is a highly viscous polymer. Due to this, the resin will not be able to penetrate into the particulate reinforcement and provide strong bonding. To solve this problem the viscosity of resin has to reduce so as to allow smooth flowing. For reducing the viscosity of the matrix 10% of acetone liquid is added as a thinner solution and mixed uniformly before mixing with the catalyst. As the viscosity becomes low the resin can easily flow through the particulates and form strong bonding.

III. METHODS

Hybrid composites are materials that are fabricated by combining two or more different types of fibers or particulates as reinforcement within a common matrix. Hybrid composites are fabricated to improve the mechanical and functional properties of the material compared to conventional composites. In this study, 2 types of hybrid particulate composites are developed from water hyacinth and pineapple leaf wastes. For this, the Water hyacinth plant was collected from Akkulam Lake in Trivandrum. The pineapple leaf waste was collected from the farmers in Kottayam. The Unsaturated polyester resin along with catalyst and accelerator was obtained from Devi Chemicals, Trivandrum. The Paper waste was collected from a Scrap Unit in Trivandrum. The study was conducted at the Chemical Laboratory of the College of Engineering Trivandrum. The reinforcement used in the composite is a hybrid composition of pineapple leaf or water hyacinth fibers and their particulates. Since the cellulose content of water hyacinth is low, 20% of paper waste by weight of reinforcement is also added to the mix to increase the strength provided by the reinforcement.

This hybrid reinforcement is added to the optimum amount of resin for attaining optimum strength. Through multiple trial and error methods, the percentage composition of reinforcement and matrix in the composite material was formulated. For this, small sized samples of varying proportions of 10%, 20%, 30%, 40%, and 50% by weight of the composite mix were developed. By analyzing these samples, it was concluded that the composite shows better performance for the sample of 30% by weight of both water hyacinth and pineapple leaf. Thus, the final formulation of the pineapple leaf composite includes 70% unsaturated resin along with 1.2 % catalyst and 1% accelerator and 30 % hybrid pineapple leaf reinforcement and 10% liquid acetone. While in the water hyacinth composite water hyacinth pulp of 22.5% and 7.5% of paper waste acts as the hybrid reinforcement in the matrix formed by unsaturated polyester resin. The composite panel as per the final composition of 30% reinforcement is developed through the hand layup method. A steel mould of 30 cm by 30 cm size was designed for the fabrication of the composite specimens as per IS standards. The hybrid reinforcement mix of pineapple leaf or water hyacinth of measured weight is laid uniformly in the mould. The unsaturated polyester resin of about 70% of the composite by weight is mixed with 10 % acetone to reduce the high viscosity of the resin and thus improve the penetration of the matrix across the reinforcement layer of lignocellulosic materials.

Fig 5. Demountable Steel Mould

Reinforcement: The lignocellulosic materials from water hyacinth and pineapple leaves are used as the reinforcement in the composite. The reinforcement material consists of a non-uniform mixture of fiber and particulate. In this method, the fibers are not extracted from the biomass to be used as reinforcement. The composites having extracted fiber as reinforcement are suitable for high strength applications. Such materials are not economically feasible to be used in wall partitions, ceilings and furnishing of interiors as an alternative for concrete bricks, gypsum panels and cement boards.

The mixture of fiber and particulate when used as reinforcement results in composite panels of admissible properties for application as building panels. Here the particulate acts as a voluminous filler material and fiber components improve the strength thus together they constitute a hybrid reinforcement.

Fig 6. Pineapple Leaf and Water Hyacinth Stem

The former research on natural fiber reinforced composites show that the reinforced polymer composites show maximum tensile strength when mixed with 30 mm long fiber as reinforcement. To maintain the size of fiber present in the hybrid reinforcement mixture as 30 mm by length the pineapple leaf waste and water hyacinth stem are cut down into 30 mm by length. The hybrid reinforcement containing fiber and particulate will thus be having the fiber size maintained at 30 mm by length This lignocellulose biomass is boiled in water to a temperature of 80 to 100-degree centigrade upto which the fiber can withhold its properties. The boiled biomass is ground into fine particulates thereby separating the fiber partially from the particulates. The separated mixture of fiber and particulate forms the reinforcement for the matrix. The moisture present in the grounded lignocellulosic pulp of both materials is removed by oven drying at a restricted temperature below 80-degree centigrade. The pineapple leaf pulp with a sufficient proportion of cellulose content is directly used as reinforcement. The water hyacinth pulp is mixed with paper waste so as to increase the cellulose content of the reinforcement. As the cellulose content increases the strength of the composite also increases. The hybrid reinforcement of both lignocellulose materials is crushed, sieved and laid in the mould as a randomly arranged non-uniform layer of reinforcement (Umadevi et al., 1996).

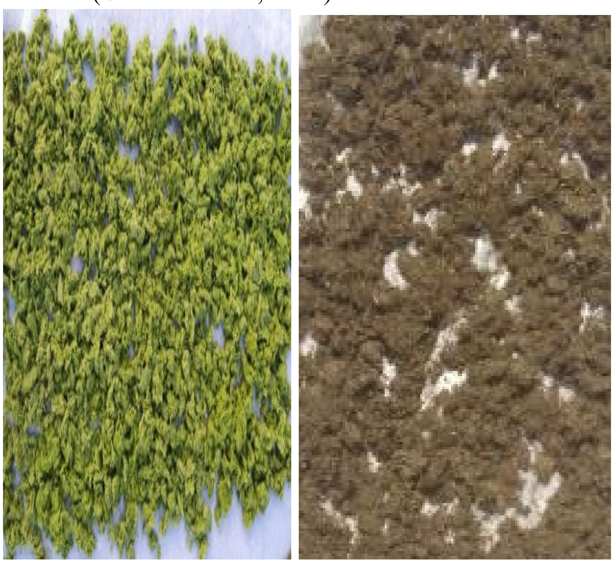

Fig 7. Water Hyacinth and Pineapple Pulp

Matrix: In this study, polyester resin is used as the matrix for manufacturing the hybrid reinforced polymer composite. Before polymerisation, the unsaturated polyester resin is mixed with 10% by weight of acetone solution for thinning the resin which is in a highly viscous state. This improves the thorough mixing of the matrix medium of the composite uniformly across the reinforcement layer. The resin is mixed with the required amount of methyl ethyl ketone peroxide and cobalt chloride solutions that act as an accelerator and catalyst for the rapid progress of the polymerisation reaction. On laying the matrix across the reinforcement layer inside the mould a controlled pressure of 5 KN is applied on the top plate of the mould for ensuring the uniform dispersion of the matrix across the reinforcement of the composite.

Fig 9. Cold Pressing Unit

This should be done instantly after mixing of resin with the catalyst and accelerator. After exerting the pressure on the mould the composite is left for setting under the compressed moulding. Once the thermosetting of the matrix resin is complete after undergoing an oven drying at 80-degree centigrade the composite is removed from the mould and is ready to be tested and used. During the fabrication of the composite layer of paraffin wax is coated on the mould to reduce the adhesion of the composite with the mould. The composite once removed from the mould can be reduced to the required size and dimensions based on the application of the material. This can be done using a wire cutting machine which is having high precision.

Fig 10. Hybrid Composite Panels (a)Water Hyacinth (b) Pineapple Leaves

The hybrid reinforced polymer composite is fabricated from water hyacinth and pineapple leaf waste. The application of fiber particulate mixture as reinforcement helps to improve the economic viability of the material as a building panel in the construction industry as the particulates of both the biomasses act as a voluminous filler for the panel.

From previous research and the trial and error approach, it was found that the strength of the polymer composite increases with an increase in the percentage of reinforcement. The composite exhibited optimum properties at 30 per cent by weight of reinforcement added to the composite. Also, the strength of the polymer composite from water hyacinth biomass as reinforcement showed improvement in strength while 25% of the reinforcement was constituted by cellulose rich paper waste. These lignocellulose materials containing hybrid reinforced polymer composites have the suitability to be used as building panels in the construction industry.

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