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Investigate Technical Viability to Fabricate Wood Polymer Composites Made of Waste Wood Powder and Epoxy Resin

K C Devendrappa[1], *Pradeep N R*[2]
(*1,2. Department of Mechanical Engineering, BIET college, VTU University, Karnataka*)
Email: kcdbiet16@gmail.com, pradeepbiet@gmail.com

Abstract

This study investigates the technical viability of fabricating wood polymer composites (WPCs) from waste wood powder and epoxy resin, emphasizing their applications in engineering fields such as construction, marine, automotive, and aerospace. By using wood fibers as reinforcement within a polymer matrix, WPCs combine the benefits of both materials, leveraging waste wood from low-quality, fast-growing trees to create high-quality composites. These composites offer enhanced lightness, strength, and stiffness, tailored for specific applications. The paper reviews critical material and manufacturing variables affecting WPCs' mechanical behavior and proposes solutions to challenges like hygroscopicity and dispersion, aiming to optimize the use of vegetal fillers and promote sustainability.

Keywords - Waste wood powder, Epoxy composites, Mechanical behavior

1 Introduction

In this context, a composite refers to materials where wood or wood fibers are used as reinforcement within a polymer matrix. Wood-based composites have been employed in various applications for a long time, leveraging wood in multiple forms such as flours or fibers. These composites are engineered from wood sourced from lower quality, fast-growing, smaller diameter trees, making them environmentally appealing. Unlike solid wood, wood composites can be tailored to meet specific end-use requirements, utilizing lower quality wood to produce high-quality products, which is a significant advantage.

Wood composites are created by impregnating wood with monomers, which are then polymerized within the wood to tailor the material for specialized applications. These materials exhibit enhanced properties such as lightness, improved physical and mechanical characteristics, and greater sustainability, leading to their growing application in construction, marine, automotive, and aerospace engineering.

Wood-based composites consist of particles of varying lengths and thicknesses bonded together in a matrix to provide cohesive strength. The inherent strength and stiffness of wood particles, combined with sufficient length for adequate overlap, facilitate stress transfer. The scarcity of high-quality wood has increased the importance of reconstituted wood materials like particleboards, plywood, and fiberboards in wood-based industries. Natural fiber-reinforced polymers, incorporating fillers such as sawdust and wood flour, are less expensive than original matrices and offer good processability. A wide range of mechanical and physical properties can be developed through appropriate compounding of polymers and fillers, which improve thermal and mechanical properties. However, enhancing the stiffness and strength of wood fiber composites often comes at the expense of toughness and ultimate elongation.

Vegetal fillers and fibers, such as sawdust, wood flour, sisal, and bagasse, are favored for their low density and relatively good mechanical properties and reactive surfaces. The main challenges in using these fibers in composites are their hygroscopicity and difficulties in achieving acceptable dispersion levels within a polymer matrix. These issues are typically mitigated by modifying the interface, which can significantly improve dispersion quality and adhesion between the polymer and filler. Efficiently engineering wood composite products requires a thorough understanding of the material and manufacturing variables that affect their mechanical behavior.

2 Preparation of Wood Polymer Composites

The concept of wood polymer composites (WPC) generating interest as new methods of combining the materials are developed. They combine the best features of wood and polymer. Processing of WPCs is an expert task but the results can meet the most demanding customer requirements. WPCs are made using a variety of raw materials. The basic are wood and polymer mix must be modified with hardener to improve the final properties of the WPC. One of the major concerns with wood plastic composites in the past has been the difficulty in combining thermoplastics intimately with the wood flour.

The term "wood flour" for which no clear-cut definition has been adopted, is applied somewhat loosely to wood reduced to finely divided particles approximating those of cereal flours in size, appearance and texture. A specific method of production is not involved in the name "wood flour." Wood flour in general is neither a uniform nor a standardized product. Fig 1. shows the wood flour and fibers used for the fabrication process.

Fig.1.Wood flour and wood fibers

2.1 Resin

Wood polymer composites are composed of wood granules within a resin matrix, typically cured at room temperature. These composites exhibit superior performance due to their high-strength, high-modulus fibrous reinforcements embedded in distinct matrix interfaces. The matrix serves as an adhesive to hold the fibrous reinforcements in place, deforming under applied force to distribute stress effectively. When selecting a thermoset resin, factors such as tensile strength, modulus, strain, compression strength, impact resistance, heat deflection temperature, durability, material availability, ease of processing, and price are considered. Epoxy resins are favored by structural engineers for their balance of chemical and mechanical properties and versatility. Used in aerospace and recreational industries, epoxies produce complex composite structures, providing high strength, low shrinkage, excellent adhesion, effective insulation, chemical resistance, low cost, and low toxicity. Their ability to cure without by-products and compatibility with most substrates makes them ideal for composites.

2.2 Hardeners and Hardening Methods

The various forms and types of epoxy resins, in their thermoplastic are uncured state are converted or hardened into useful thermosets by a reaction with variety of hardeners. These hardeners, curing agents, activators are catalyst may organic or inorganic, acidic or basic and of the room temperature or heat setting types.

Depending upon the resin and hardener compressing the system, the amount of hardener can vary as low as one part of hardener per 100 parts of resin. The reaction between resin and hardener normally occurs without evolution of by-products. Some hardeners promote curing by catalytic action and others directly participate in the reaction and are chemically bonded into resin chain. Epoxy resins are hardened into thermoset compounds by any of three general reactions.

- Self-polymerization forming direct linkages with epoxy groups.
- Linkage of epoxy groups with aromatics or aliphatic hydroxyl.
- Cross linkages with hardener with various radicals.
- The most widely used hardener in structural applications is either of the amine or acid anhydride types, many other chemical and resinous types can be applied.

2.3 Filler

A wide variety of epoxy fillers can be used with epoxy systems to reduce cost, shrinkage, exothermic reaction and co-efficient of thermal expansion. They also alter other properties such as electrical, mechanical and thermal behavior. Adhesion, abrasion resistance, appearance and processing characteristics are also affected. The filler or combination of fillers used in epoxy systems must be carefully selected to obtain the desired properties. Some filler will improve certain properties (usually at the expense of the other) and so optimum can be achieved through proper combination of filler types, particle size and method of incorporating it into the system. Over and above all these, addition of filler considerably reduces the production cost. When compounding filled systems, variables to be taken into considerations are volume, fraction of the filler, particle characteristics like size, shape, surface area, and the strength, the modulus of the filler, adhesion of the filler to the resin, the viscosity of the base resin and toughness of the base resin.

A better combination of fiber and polymer is achieved by impregnation of the reinforcing fabrics with polymer matrices compatible to the polymer. For this purpose polymer solutions or dispersions of low viscosity are used. ARALDITE LY 554 is an unfilled non-modified epoxy resin of low viscosity for the laying up of laminate, which may be converted to the solid, infusible state with hardener. The choice of hardener is governed by the curing temperature, pot life and heat resistance required, as well as by the application method used. Hardener HY 951 is used if curing is to take place at room temperature or within a shorter time, at 50 to 120ºC it gives laminate with excellent water resistant.

2.4 Epoxy-Bonded With Wood Interfaces

Structural epoxy adhesives remain the primary choice of adhesive to form the bond to fiber-reinforced plastics and are the generally accepted adhesives in bonded FRP–wood connections. Advantages of using epoxy adhesives in comparison to common wood-laminating adhesives are their gap-filling qualities and the low clamping pressures that are required. Consequently because of these qualities, epoxy adhesives are an appropriate selection for applications involving bonded in rods and bars in the upgrade or repair of timber members [85–87]. However epoxy adhesives have in only recent years been applied to timber and therefore, only limited knowledge is available on the bond quality formed. Despite developing dry shear strengths that exceed the shear strength of the wood itself, serious concerns have been expressed regarding durability of the bond formed between the FRPs and wood without the application of an appropriate coupling agent to the wood substrate surfaces.

Another test study undertaken concentrated on the bonding of wood–wood bonded specimens using ten epoxy adhesives with thick bondlines. Results showed that only two adhesive types displayed shear strengths equal to or higher than those of solid wood specimens and also strengths in the wet state which surpassed half those of ambient tested strengths of the bonded specimens.

3 Wood Epoxy Composites

Wood epoxy is particular type composite, which comprises of epoxy resin, hardener and graded wood floor as ingredients. In this work the following epoxy resin is employed Waste Wood composites.

- Epoxy resin : Araldite LY- 554
- Hardener : Hardener HY951
- Reinforcement : Waste wood flour

Wood epoxy is particular type composite, which comprises of epoxy resin, hardener and graded wood floor as ingredients. The wood residues are collected and refined for fabrication of polymer composites. The length of the fiber varies from 0.497mm to 2.25 mm and the average diameter of the fiber is 410µm. Fig.2 Reveals that they are randomly oriented, with the wood flour content.

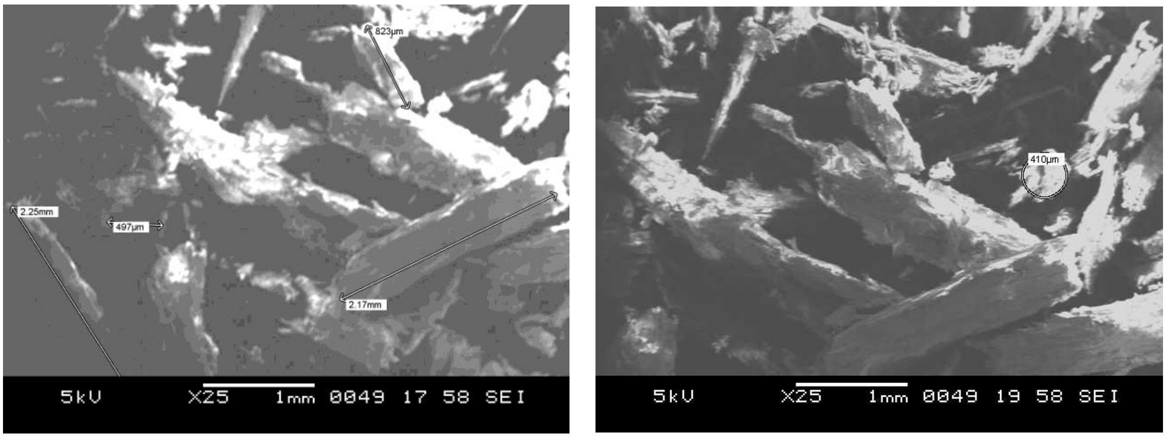

Fig. 3. Dimensions of wood fibers

3.1 Procedure

Following is the procedure for preparing the constituents of wood-epoxy composite. The volume of the mould is calculated and the corresponding proportions of combination of Wood fibers and wood flour epoxy and hardener is measured according to the composition.

- The weighed mixture of 'wood fiber and wood flour' and epoxy is poured into a clean moisture free bowl and mixed well uniformly.
- The mixture is left overnight for better wetting.
- The hardener corresponding to the amount of resin used is then poured and mixed well and left for few minutes.
- The Molten Wax is applied to the inner walls of the mould for easy removal of casting.
- The mixture is then poured into the mould and the surface is compressed with the flattener.
- The casting is removed after 1 day by removing the side plates of the moulds.
- The procedure was repeated for fabrication of wood polymer composites by varying wood waste reinforcement from 30% to 50% by weight.

3.2 Mould Design

The dimension of the waste wood fibers composite was 300mm (L) x 300 mm (W) and the boards had 10 mm thickness. Fig.3 shows the mould for casting. The required equipments for the mould that was used to lay the material down into mats were including glass, transparency plastic for the bottom layer and spacer frame.

Fig.3. Mould for casting the composite

Conclusion

This study demonstrates the technical feasibility of fabricating wood polymer composites (WPCs) from waste wood powder and epoxy resin, highlighting their potential applications in construction, marine, automotive, and aerospace engineering. By integrating wood fibers as reinforcement within a polymer matrix, WPCs effectively combine the advantageous properties of both materials. Utilizing waste wood from low-quality, fast-growing trees, these composites offer significant benefits such as enhanced lightness, strength, and stiffness, which can be tailored for specific applications. The research addresses key material and manufacturing variables that influence the mechanical behavior of WPCs and suggests strategies to overcome challenges like hygroscopicity and dispersion. This optimization promotes the use of vegetal fillers and enhances the sustainability of these composites, making them a promising solution for various engineering applications.

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