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Sustainable Natural Fiber Composites: A Study on Mechanical Performance and Moisture Behavior

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Abstract: *This study investigates the synthesis, mechanical behavior, and performance potential of natural fiber-reinforced epoxy composites as sustainable alternatives to conventional synthetic materials. Emphasis is placed on understanding how different fibers sisal, Aloe-vera, and Bamboo influence the composite's mechanical properties. Composites were fabricated using various processing techniques, including hand lay-up, vacuum infusion, and compression molding. These methods affect fiber distribution and interfacial adhesion, which play a vital role in determining the final mechanical performance. Critical factors such as fiber type, surface treatment, and epoxy matrix formulation were carefully controlled during synthesis. Experimental data show significant variation in mechanical properties based on fiber selection. For instance, aloe vera-reinforced composites demonstrated tensile strength around 26 MPa, with a Young's modulus of 1 GPa and 7.4% elongation at break. In contrast, bamboo-reinforced composites achieved tensile strengths up to 307 MPa, while some reports suggest aloe vera fibers can yield strengths between 350–500 MPa under optimized conditions. Additional parameters such as fiber orientation, matrix compatibility, and fiber-matrix interfacial bonding were found to influence tensile strength, impact resistance, and thermal stability. Aligned fibers in the epoxy matrix significantly improved strength in specific loading directions, underscoring the need for optimized composite design. The results highlight the feasibility of using treated natural fibers to engineer high-performance, eco-friendly epoxy composites for structural applications in automotive, aerospace, and construction industries.*

Keywords: Natural fiber-reinforced composites, Epoxy matrix, Sustainable materials, Mechanical properties