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Effect of water absorption on the mechanical properties of *Grewia optiva* fiber reinforced biocomposites

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Abstract
As the global population is increasing, so does its demand for various resources which in turn is increasing global economic pressure. The need of the hour is to frame and work on the concept of green economy and focus on the adoption of biodegradable construction materials to achieve sustainable architecture. Sustainable architecture is seeking the research and development of new materials to minimize the negative environmental effect of the existing materials. This paper presents the research work on the development of *Grewia optiva* Natural Fiber Reinforced Biocomposite which is found to possess excellent mechanical properties and can be potentially used for a number of applications in architecture. The exposure of different weather conditions on the structural materials can cause significant effects on its properties. This paper deals with an investigation of the effect of water absorption on the mechanical properties of *Grewia optiva* Natural Fiber Reinforced Biocomposites.

Keywords: Sustainable architecture, natural fiber polymer biocomposites, green economy

Introduction
As the global population is increasing, so does its demand for various resources which in turn is increasing global economic pressure [1-4]. Environmental sustainability has become a prevailing concern, which has affected the profession of architecture [5]. The need of the hour is to frame and work on the concept of a green economy. A green building is one of the important sectors of the green economy [6] which focus on the adoption of non-biodegradable construction materials to achieve sustainable architecture. Sustainable architecture is seeking the research and development of biodegradable materials to minimize the negative environmental effect of the existing materials. A material fabricated using the reinforcement of a new natural fiber (*Grewia optiva*) in epoxy resin which has been rarely explored by material scientists till now, has been studied and presented in this paper. *Grewia optiva* (G.O.) is a medium sized tree of typically 12-15 m height which is abundantly available in the sub-Himalayan terrains where day temperatures vary from -2 °C to 38 °C and where summer and autumn months are dry. It belongs to the Tiliaceae family. It is named after Nehemiah Grew (1964-1712) one of the founders of plant physiology [7]. It is very popular among the local farmers because of its multipurpose utility. This tree is often planted in hedges and field boundaries. Its other vernacular names are Bhimal, Bhengal, Biul, Bihul, in Hindi and Shayalphusro, Phusre, Ghotli, Bhimal in Nepali language [8]. Every part of this tree is utilized in some way by the local farmers. Its fruits are edible. Its leaves are considered as an excellent fodder especially in winters when usually no other green fodder is available. The wood is used as shafts, poles, frames, agricultural tools and other purposes where strength and elasticity are required. Dried wood is also used as fuel. The mucilage obtained from its bark is used to make shampoos. The bast-fiber obtained from the *G.O.* tree is used for making ropes and different craft items by local farmers [9]. A large number of literatures are available which have explored different natural fibers like hemp [10], jute [11], sisal [12], coir [13], bamboo [14], banana [15] and other popular natural fibers as reinforcements for biocomposites. While the bast-fiber obtained from the G.O. tree has been used by very few researchers [16-19]. This fiber has an excellent strength and a potential to be employed in the need of the hour is to frame and work on the concept of a green economy.

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Materials and Methods

Epoxy-CY230 and Hardener-HY951 in the ratio of 10:1 are used as the matrix material. The reinforcement of 10% *Grewia optiva* bast fibers has been done in the epoxy. The transparent acrylic sheets have been used to make the mold for casting the composite laminates shown in Fig. 1(a). The *Grewia optiva* bast fibers were carded in a card machine in order to separate and loosen the fiber strands and then processed into a non-woven sheet. The non-woven sheet was then used to fabricate the biocomposite laminate using hand lay-up technique. The casted composite was by a dead weight to remove air bubbles if any. Then it was allowed to cure for 24 hours before cutting into tensile and bending specimens. The tensile and bending test were performed on 10 kN capacity universal testing machine (Model AMT-SC of A.S.I. Sales Pvt. Ltd., India make) at the rate of 1 mm/min as shown in Fig. 1(b) and 1(c).

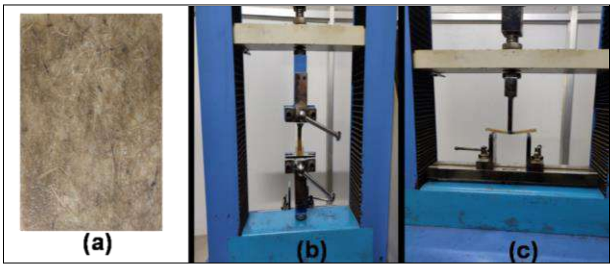


Fig 1: (a) Composite laminate (b) Tensile Test Set-up (c) Bending test Set-up

Results & Discussion

Water Absorption Test

The water absorption test has been performed as per ASTM D 570. Firstly the tensile and bending specimens cut from the casted laminate were dried at 105°C for 24 hours in the hot air oven to remove the moisture content. The specimens were weighed immediately after cooling (W_1). Then the specimens were immersed in distilled water for 20 days. After 20 days the specimens were taken out and dried with a cloth to absorb extra water and then weighed (W_2). The percentage increase in the weight of specimens after water absorption is calculated by Eq. (1) and its mean value has been calculated as 2.63% and plotted in Fig. 2. The increase in weight of the *Grewia optiva* biocomposites is initially linear and later the water absorption achieves saturation with a very little or no change in the weight. This type of behavior of water absorption can be modeled as Fickian diffusion behavior [21].

$$\text{Increase in weight (\%)} = [(W_2-W_1)/W_1] \times 100\% \qquad (1)$$

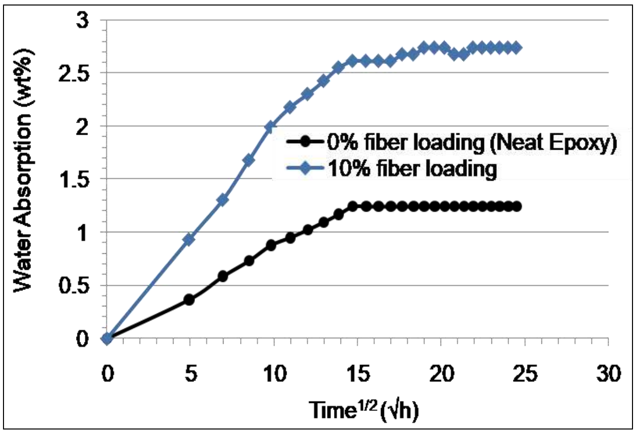


Fig 2: Water Absorption Behaviour of composites

Tensile Properties

The tensile properties of the composite fabricated in this work have been determined as per ASTM D3039. Fig. 3(a) shows the stress strain curves for different specimens under tensile loading. For each test 3 samples have been tested and the results obtained have been shown in Fig. 3. The tensile strength of the composite with 10% fiber loading is found to increase by 25.97% (46.10 MPa) as compared to that of neat epoxy shown in Fig. 3 (b). Similarly the young's modulus has increased by 126.9% while the percentage elongation has decreased by 57.83% as compared to that of un-reinforced epoxy shown in Fig 3(d) and 3(c) respectively. When the specimens were immersed in distilled water for 20 days, their tensile properties were observed to decrease (as shown in Fig. 3) but still higher than the neat epoxy. Particularly the tensile strength decreased by 19.09%, young's modulus decreased by 9.87% and percentage elongation decreased by 2% only. These observations show that the composites fabricated using *Grewia optiva* fiber have more strength as compared to neat epoxy but are more brittle than that of epoxy. Moreover the reinforcement of *Grewia optiva* natural fiber in epoxy resin increases its resistance to elastic deformation. Hence the *Grewia optiva* fiber reinforced biocomposites are suitable for structural applications like wall panels, false ceilings, etc.

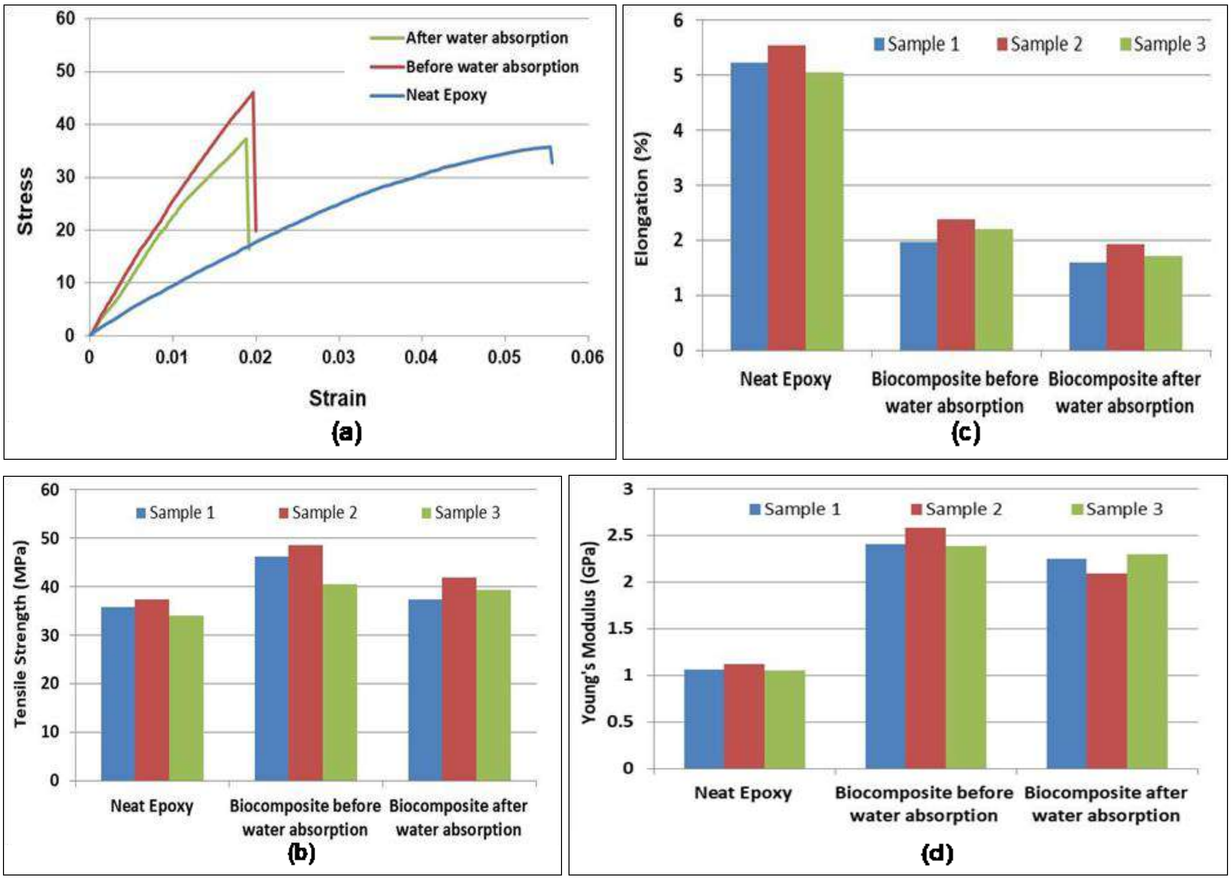
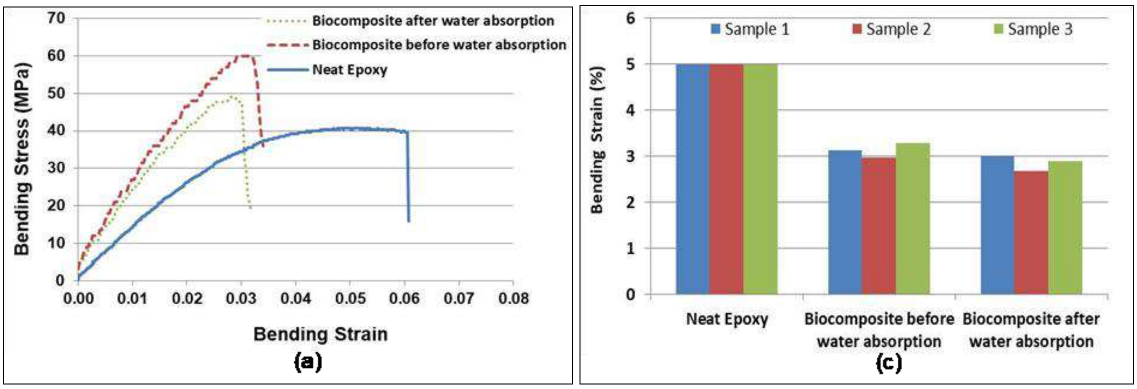


Fig 3: Effect of water absorption on tensile properties (a) stress-strain curve (b) ultimate tensile strength (c) elongation and (d) young's modulus

Bending Properties

Bending properties have been determined in accordance with the ASTM D790 using a three-point bend loading arrangement. The Fig. 4(a) presents the stress strain behaviour of the specimens when loaded in a 3-point bending pattern. The Fig. 4(b) shows that the bending strength of the composites has increased by 48.62% (60.23 MPa) as compared to that of neat epoxy. The bending strain has decreased by 37.6% while the modulus of elasticity under bending increases by 57.56%. After immersion of the composites in water, their bending properties were observed to decrease. The bending strength decreases by 18.18%, modulus of elasticity under bending decreases by 19.81% and bending strain by 3.84% only. The results indicate that the *Grewia optiva* fiber reinforced biocomposites possess much better bending properties as compared to neat epoxy and can be used for different architectural applications like wall panels, false ceilings, doors etc.



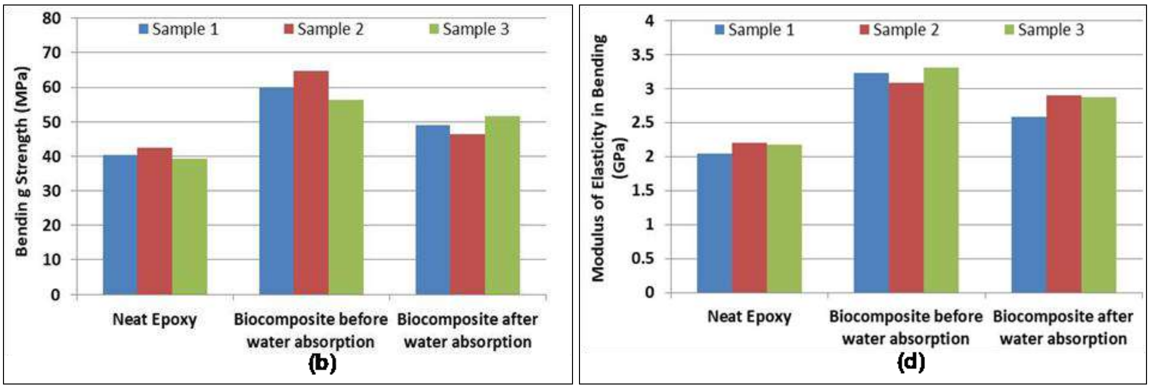


Fig 4: Effect of water absorption on (a) stress-strain behavior under 3-point bending (b) bending strength (c) bending strain and (d) modulus of elasticity under bending.

Conclusions

Sustainable architecture is seeking the research and development of new materials to minimize the negative environmental effect of the existing materials. This paper presents the research work on a novel *Grewia optiva* natural fiber which possesses excellent mechanical properties and can be potentially used as reinforcement in structural material. The study shows that the biocomposites fabricated using *Grewia optiva* fiber have more tensile strength (46.10 MPa) as compared to neat epoxy but are more brittle. Moreover, the biocomposites under investigation possess high resistance to elastic deformation (2.46 GPa) and far better bending properties (bending strength = 60 MPa; elastic modulus under bending= 3.23 GPa) as compared to neat epoxy (bending strength = 40.37 MPa; elastic modulus under bending = 2.05 GPa). The effect of water absorption on the mechanical properties of biocomposites under study has also been investigated. It has been calculated that the water absorption decreases the mechanical properties of the biocomposites by a small amount but still remains much higher as compared to that of the neat epoxy. Hence the *Grewia optiva* biocomposites have potential to be used in different architectural applications like wall panels, false ceilings, doors, tiling etc. Moreover the increase in the percentage of fiber reinforcement may further improve the mechanical properties of composites.

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