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EFFECT OF MATRIX REINFORCEMENT RATIO ON RICE STRAW REINFORCED COMPOSITE

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ABSTRACT

This study describes the development of bio-composites made of natural fibers(rice straw) with epoxy resin. The bio-composites were produced using a straightforward Hand lay-up technique. The major goal of this study is to create bio-composite reinforced with rice straw using various matrix reinforcement ratio in order to determine the most practical ratio and components for bio-composite manufacture. The obtained results demonstrated that mechanical properties and thermal stability increase with increases in matrix reinforcement ratio. When compared to other matrix reinforcement ratio, the bio-composite created from a 60:40 ratio had better mechanical as well as thermal properties. Additionally, the overall results of the created bio-composite panels show that they are a promising and cutting edge choice for the composite community in the future.

KEYWORDS: Bio-composite, Rice straw, Matrix-reinforcement

INTRODUCTION

In order to foster the circular economy, there is currently a global purpose to utilize all byproducts and waste sources. This interest has been focused on the use of sustainable biobased materials to reduce environmental burdens. The European industrial firms are looking for more biodegradable, robust, and cost-effective raw materials for the manufacture of composites. Additionally, a variety of plant-based materials are receiving a lot of attention because they are thought to be the most prevalent, well-known, and sustainable sources of raw materials worldwide.

Therefore, the idea of incorporating rice straw in the production of composite materials is a green and eco-friendly approach because it encourages recycling. Rice straw is being used in novel ways that could make it a viable marketing tool and a simple, dependable raw material. In addition, different uses for rice straw may result in a new product entering the market, making it a worthwhile and lucrative competitor to industrial insulating materials.

Epoxy resins were widely used as a matrix in composites. The matrix holds the fibers in place and transfers internal load between them whereas fibers provide strength and stiffness to the material. Due to its good mechanical, outstanding adhesion to different substrates, low shrinkage upon cure, and the ability to be processed under various conditions epoxy resins are frequently used. The major disadvantage of epoxy resins are brittleness. As a result, a reinforcement or filler material must be utilized to support the weight and offer the strength that the matrix is unable to deliver on its own. Researchers have shown that mixing fillers like silica, carbon, or graphite fibers with aromatic polyamides can increase the toughness of epoxy resins (Oleksy *et al*., 2014; Hulugappa *et al.,* 2016). In spite of these advantages, only simple equipments are required to produce fiber reinforced composite. They do not require high pressures or high temperatures. Consequently, there is a minimal likelihood of fiber damage and deterioration.

Since promoting sustainability has become a priority, the current study's goal is to assess the effects of varying the amount of rice straw used as low-cost natural filler in epoxy matrix material as well as the mechanical and physical characteristics of the resulting composite.

MATERIALS AND METHODS

Material: In the present investigation, for the development of fibre reinforced bio-composites, cellulosic fibres namely, rice straw waste were used as reinforcing fibres. The rice straw fibres of the variety PR 114 were collected from agricultural farms of Sirsa, Haryana, India. For the matrix reinforcement ratio, epoxy resin and compatible hardener were purchased from Ananya Fabrication Pvt. Limited, Jaipur, India. The physio-chemical properties of resin and hardener used in the study are given in Table 1.

Fabrication of composite: The composite specimens were prepared using hand lay-up technique. The moulds of 20×20×2.5 cm dimensions were placed on the leveled surface. At first, a plastic sheet was placed at the base of bottom of each plate mould to assure easy removal of composite specimen from mould plate and prevention from damaging of composite surface. A transparency film of mould size was also put over plastic sheet in each mould to get composite specimen with smooth surface. Jute net of size 20x20 cm was cut out and placed over the transparency film. For determination of optimum matrix- reinforcement ratio, three different ratios of matrix and rice straw fibre (v/v) i.e., 50:50, 60:40 and 70:30 were taken. According to matrix-reinforcement ratio, the calculated amount of rice straw powder was weighed and spread over the jute net. The thickness of jute net and rice straw layers was measured and area was calculated to get fibre volume ratio. Accordingly, matrix ratio was calculated to obtain the required thickness of composite specimen. For matrix preparation, just before the composite fabrication, the calculated amount of epoxy resin and hardener in the ratio of 9:1(v/v) were mixed thoroughly in a beaker with glass rod to prevent air entrapment. Then the matrix mixture was poured on the layers of jute net and rice straw fibre. Again a transparency film of mould size was put over composite mixture to avoid contact between mixture and top plate of mould. Another plastic sheet was placed over the transparency film. Subsequently, the wet composite mixture was rolled with a hand roller to ensure uniform distribution of matrix and remove entrapped air bubbles, if any. Top plate of mould was positioned over the plastic sheet and dead weight of 25 kg (pressure 0.06 kg/cm^2) was applied on the top plate. Thereafter, it was cured at room temperature for 24 hours. After the specified curing time, the fabricated composites were carefully removed from the mould**.**

Testing of composite

The developed rice straw fibre reinforced composites were tested for their apparent density, tensile strength and thermal properties as per standard test methods. The developed composite samples were tested in Textile Testing Laboratory of Division of Textile Manufacturing and Textile Chemistry, ICAR- Central Sheep and Wool Research Institute, Avikanagar, Rajasthan, India.

Tensile test: Tensile strength of all the developed rice straw-wool fibre reinforced hybrid bio-composite samples was determined by ASTM-D 638 test method using Instron Universal Testing Machine equipped with Bluehill3 software. The samples of 165 x13 mm were fixed tightly first in the bottom jaw followed by the top jaw with approximately 30 mm of composite protruding from each side of the jaws at a distance of 75 mm and cross head speed was kept at 5 mm/minute with a load of 5 kN. The instrument was started by moving the upper jaw in upward direction till the sample ruptured. An average of five reading of each composite sample was taken as tensile strength of the composite. The tensile strength was measured on universal testing machine based on ASTM D638 standard.

Apparent Density: The bulk density of each fibre reinforced composite sample was determined by finding mass in air and volume of the composite sample. The weight of test specimen was taken on electronic weighing balance with the accuracy of 0.0001 g. Total five observations were taken for each developed composite and average was calculated. The bulk density of the composite samples was calculated using the following formula:

$$\text{Bulk density} = \frac{\text{Mass of composite sample}}{\text{Volume of composite sample}}$$

Thermal conductivity: Thermal conductivity apparatus was used for testing thermal conductivity behaviour of rice straw-wool fibre reinforced hybrid bio-composites on guarded hot plate. The guard box heater was switched on and was stabilized at 50ºC. Then hot plate was switched on, after setting the thermost at at 51 ºC. Circular specimen of each fibre reinforced composite sample was cut with the help of round template and placed over the hot plate. As the temperature of the hot plate reached 52ºC the thermostat became operational and the temperature dropped to 51ºC. The temperature of the hot plate was then allowed to drop to 50ºC and the time (seconds) taken by the hot plate to cool down from 50 to 49 ºC was recorded. Five such readings were taken for each composite sample to find out average cooling time in seconds. The Clo value was calculated using the following formula:

$$\text{Clo value} = \frac{\text{Time (seconds)}}{2 \times 240}$$

RESULTS

The rice straw reinforced biocomposite were assessed for different properties i.e. physical and thermal properties. The data related to matrix reinforcement ratio on various parameters of rice straw biocomposites are presented in Table 6.

Optimization of matrix-reinforcement ratio: In order to determine the optimum matrix-reinforcement ratio for fabrication of composite samples, three different ratios of resin and rice straw viz 50:50, 60:40 and 70:30 were taken with optimized proportion of rice straw fibre and compressive force was kept constant. The data related to optimization of matrix-reinforcement ratio are presented in Table 1.

The optimum filler content varies with the nature of filler and matrix, filler aspect ratio, filler matrix interfacial adhesion etc., (Mishra, 2003). It is apparent from data in the table that when composite was fabricated with 50:50 ratio of resin and rice straw fibre, it displayed 0.81 g/cm^3 bulk density, 0.30 m^{2}k/w thermal conductivity and 15.87 MPa tensile strength Nurazzi *et al.*, 2018 stated that increase of glass fibre loading had a synergistic effect on the mechanical properties of the composite structure which contributed to the efficacy of stress transfer mechanism in the matrix. As the matrix-reinforcement ratio was increased from 50:50 to 60:40, stagnation in values of bulk density (0.81 g/cm^3), thermal conductivity (0.30 m^{2}k/w) and an increase in tensile strength (19.73 MPa) was observed in the resultant composite Nagaraja and Kanan, 2015 found that composites exhibited better mechanical properties with addition of fibres. The mechanical properties were found to be improved with optimum fiber matrixratio of 60/40. The flexural properties of isopthalic resin reinforced composites and vinyl ester reinforced composites showed 2.22 and 2.34 times improved values as compared to the polyester resin for a combination of 60/40 resin fibre volumetric composition. With further increase in matrix-reinforcement ratio from

Fig. 1(a) Epoxy Resin (b) Hardener (c) Rice straw fiber (d) mold design, (e) mold with a RS reinforced bio-composite with a pressure system (f) specimens of bio-composites reinforced with surface modified RS

Table 1. Properties of matrix materials

Properties	Specification of matrix materials		Test methods
	Resin	Hardener	
Appearance	Colourless	Colourless to pale yellow	Visual method
Density (g/cm^3)	1.15-1.2	0.94-0.95	ASTM D 4052
Epoxy content (g/eq)	185-192	-	ASTM D 1652
Flash point (^{0}C)	>200	>123	ASTM D 93
Storage life (years)	03	01	-
Viscosity (mPas)	9000-12000	<50	ASTM D 455

Table 1. Optimization of matrix-reinforcement ratio for fabrication of composites

	Resin: Rice straw fibre		
	Bulk density (g/cm^3)	Thermal conductivity (m^{2}k/w)	Tensile strength (MPa)
50:50	0.81	0.30	15.87
60:40	0.81	0.30	19.73
70:30	0.84	0.34	18.33

60:40 to 70:30, increase in bulk density (0.84 g/cm^3), thermal conductivity (0.34 m^{2}k/w) and decrease in tensile strength (18.33 MPa) was noticed in the fabricated composite sample.

It is concluded that bulk density and thermal conductivity of composites fabricated using 50:50 and 60:40 matrix-reinforcement ratios were same, whereas composite sample of 60:40 ratio exhibited higher tensile strength. Thus, on the basis of achieved maximum tensile strength, lower bulk density and thermal conductivity 60:40 matrix-reinforcement ratio was optimized to fabricate the composites of resin and rice straw fibre.

CONCLUSION

The creation of new composite goods from readily renewable natural materials has a great potential to produce innovative biodegradable and recyclable materials fit for use in the packaging sector, the automobile industry, and a variety of other applications. In the current study, we have tried to get an attention to use natural waste fibres, i.e. rice straw waste in the composite structures In the present study, three different matrix-reinforcement ratios, i.e. 50:50, 60:40 and 70:30 , 60:40 matrix-reinforcement ratio was optimized as composite of 60:40 matrix reinforcement ratio gave maximum tensile strength (19.77 MPa), minimum bulk density (0.81 g/cm^3) and thermal conductivity (0.30 m^{2}k/w). Thus, 60:40 matrix-reinforcement ratio represents an effective material for production of environment friendly composites for moderate applications.

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