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Study of Compressive Force Effect on Biocomposite

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ABSTRACT

The aim of this paper is to study the influence of compressive force on mechanical (i.e. tensile strength and bulk density) and thermal properties of rice straw reinforced composites. The composite was prepared by Hand lay-up method. Different Compressive force were tried; namely, 15 kg, 20 kg, 25 kg and 30 Kg. The results revealed that 25 kg of compressive force exhibited the best tensile strength and thermal properties while increase in properties with increase of compressive force after a certain content it starts decreasing. It was found that rice straw fibre can be a good candidate for the reinforcement fibre of high performance biodegradable composites.

Key words: *Compressive force, Rice straw, Composite*

Introduction

A composite material is formed by combining two or more components having different qualities (Barbero, *et al.*, 2011). The three main perks of adopting composites are lessened weight, fewer parts needed, and susceptibility to corrosion. Inspite of these, Wear resistance, superior fatigue life, electromagnetic transparency, low thermal expansion, sound isolation ability, and high or low thermal conductivity are further advantages of composites that support their use. Despite the fact that composites have been around for a while, the technology's centuries-old growth has not lost its momentum. In reality, there has been a little twist in the quest for such novel materials recently (Malkapuram *et al.*, 2009)

To reinforce composite materials for sustainable development, natural fibers have been employed in place of synthetic fibers. Natural fibers like sisal, flax, hemp, bamboo, and coir are more affordable and lightweight than synthetic ones. They are a plentiful, cheap resource that is also renewable. Comparatively to synthetic fibres, cellulose fiber reinforced composites have received far less research. The primary downsides to using cellulose fibers as reinforcement for composites are a lack of knowledge about production methods, fiber strength, and the impact of fiber shape and size on composite performance.

India, which is primarily an agricultural nation, is only second to China in terms of its rice production. Throughout the world, rice production leaves behind rice straw. Rice straw can currently be disposed of by being used as animal feed, burned onsite at the farm, or added to the soil. Each approach demonstrates its unique benefits and drawbacks. Although burning at a field is thought to be the cheapest technique, it pollutes the air because it releases CO_2. Thus, the use of rice straw shows a high potential for fiber reinforcement in composite material. it has been reported that rice straw provide good thermal insulation and water stability. More research is therefore required on the effectiveness of cellulose fiber reinforced composites, especially the impact of compressive force on the characteristics of the fiber matrix.

In this work, agricultural residues namely, rice straw and epoxy resin as matrix were used without any treatment to prepare bio-composites. The effects of compressive force on the thermal insulation along with mechanical properties were tested.

Materials and Methods

Reinforcing Fiber: For the present research work, rice straw fibres of the variety PR 114 were collected from agricultural farms of Sirsa, Haryana, India. The collected rice straw fibres were chopped into short lengths of about 3cm with the help of electric chaff cutter. The chopped rice straw fibres were dipped in water for 30 mintues in plastic tub and thoroughly washed in running tap water in order to remove short fibres, dust particulates and other impurities and dried in shade at room temperature for 48 hours. The chopped rice straw was grounded into fine powder for one minute in grinder at the speed of 20,000 rpm

Matrix Materials: Matrix system is used to bind or hold the reinforcement materials together and serves as an intermediate by which an externally applied stress is transferred and distributed to the reinforcement materials. In the present study, for matrix reinforcement ratio epoxy resin and compatible hardener were purchased from Ananya Fabrication Pvt. Limited, Jaipur, India.

Mould: In the present experimentation, hand lay-up technique was used for the fabrication of composites. Stainless steel moulds consisting of bottom and top plates, opened from the top, were got prepared of dimensions 20×20×2.5 cm for casting of composite samples

Methods

a) Fabrication of composite

The hand lay-up approach was used to prepare the composite specimens. On the leveled surface, the 20 x 20 x 2.5 cm moulds were set. To ensure simple removal of the composite specimen from the mould plate and to prevent damage to the composite surface, a plastic sheet was initially placed at the foot of each plate mold. To obtain a composite specimen with a flat surface, a transparency film the size of the mold was additionally placed over the plastic sheet in each mould. A 20x20 cm piece of jute net was cut out and laid over the transparency. Rice straw powder was measured up, weighed, and applied to the jute net. To determine the fibre volume ratio, the thickness of the layers of jute net and rice straw were measured, and area was determined. Matrix ratio was subsequently computed to produce the appropriate thickness of the composite specimen. The calculated amount of epoxy resin and hardener in the ratio of 9:1(v/v) were thoroughly mixed in a beaker with a glass rod to prepare the matrix just before to the production of the composite. The layers of jute net and rice straw fiber were then covered with the matrix mixture. To prevent contact between the composite mixture and the top plate of the mould, another transparency sheet the size of the mold was placed over the mixture. The transparency film was covered with still another plastic sheet. The wet composite mixture was then rolled with a hand roller to ensure equal matrix distribution and, if necessary, release any trapped air bubbles. Over the plastic sheet, the top plate of the mold was placed, and a dead weight was placed on it. For optimization of compressive force, four different dead weights, i.e. 10, 15, 20 and 25 kg were applied on the composite samples prepared with optimum proportion of rice straw fibre using optimum matrix-reinforcement ratio. It was then dried for 24 hours at room temperature. The constructed composites were carefully removed from the mould after the allotted cure time.

Testing of composite: The created rice straw fiber reinforced composites underwent normal test procedures to determine their bulk density, tensile strength, and thermal conductivity. The produced composite samples underwent testing at the Central Sheep and Wool Research Institute's Textile Testing Laboratory, located in Avikanagar, Rajasthan, India.

Bulk Density: By measuring mass in the air and the composite sample's volume, the bulk density of each fiber-reinforced composite sample was calculated. A digital scale was used to weigh the test specimen with an accuracy of 0.0001 g. For each produced composite, a total of five observations were collected, and an average was computed. The following formula was used to determine the bulk density of the composite samples:

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

Tensile Test: The tensile strength of each sample of the created hybrid bio-composite reinforced with rice straw-wool fiber was assessed using the ASTM-D 638 test method on an Instron Universal Testing Machine with Bluehill3 software. The 165 x 13 mm samples were placed firmly in the bottom and top jaws, respectively, with roughly 30 mm of composite protruding from each side of the jaws at a distance of 75 mm, while the cross head speed was maintained at 5 mm/minute with a load of 5 kN. The instrument was turned on by raising the upper jaw till the sample burst. The tensile strength of each composite sample was calculated as the average of five readings.

Thermal Conductivity: On a Guarded hot plate, the thermal conductivity behavior of bio-composites reinforced with rice straw fiber was tested using a thermal conductivity equipment. The guard box heater was turned on and set to a steady 50 degrees Celsius. The thermostat was then set to 51°C before the hot plate was turned on. Each fiber-reinforced composite sample had a round specimen cut out using a round template, which was then set over the hot plate. The thermostat kicked on when the hot plate reached 52°C, causing the temperature to drop to 51°C. The hot plate's temperature was then allowed to drop to 50 °C, and the amount of time (in seconds) it took for the hot plate to cool from 50 to 49 °C was noted. For each composite sample, five of these values were taken in order to calculate the 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 physical and thermal properties of the rice straw reinforced biocomposite were evaluated. Table 1 displays information on the compressive force for various rice straw bio-composites parameters.

Optimization of compressive force for fabrication of composites: Compressive force is used to impart better fibre alignment that improves fibre volume fraction and leading to better mechanical properties. To optimize the compressive force, optimized proportion of rice straw (15 g) was combined with resin in 60:40 optimized matrix-reinforcement ratio and different pressures i.e. 15, 20, 25 and 30 kg were applied separately to each sample for fabrication of rice straw fibre reinforced composites. The composite samples were evaluated for bulk density, thermal conductivity and tensile strength. The data regarding optimization of compressive force are incorporated in Table 1.

It is clearly evident from data in the table that when 15 kg force was applied for fabrication of rice straw fibre reinforced composite, bulk density of composite sample was 0.87 g/cm^3. It was recorded as 0.90, 0.78 and 0.82 g/cm^3 when the compressive force gradually increased to 20, 25 and 30 kg respectively.

Table 1. Optimization of compressive force for fabrication of composites

Compressive force(kg)	Bulk density (g/cm^3)	Thermal conductivity (m^{2}k/w)	Tensile strength (MPa)
15	0.87	0.26	6.69
20	0.90	0.30	12.19
25	0.78	0.32	15.82
30	0.82	0.38	13.81

It was noticed that when compressive force of 15 kg was applied, the fabricated composite sample depicted 0.26 m^{2}k/w thermal conductivity and 6.69 MPa tensile strength. The findings of present study are supported by the findings of **Banga *et al.*, 2015** that 15 kg compressive force did better job in enhancing the mechanical and thermal properties of composite materials. As the compressive force was increased from 15 to 25 kg, an increase in thermal conductivity and tensile strength of respective composite samples was observed. Composite sample of maximum tensile strength and minimum bulk density was obtained when 25 kg compressive force was used for fabrication of composite. **James *et al.*, 2020** developed composites by different proportions of sisal/bagasse fibres by keeping under the load of 25 kg and allowed it for curing at room temperature under constant pressure. The results expressed that sisal fibres resulted in enhanced ultimate tensile strength and impact strength due to the presence of sisal fibres at the center and constant compressive force of 25 kg which caused better adhesion between matrix and sisal fibre. Similar results were reported by Khan *et al.,* 2020 who developed composite using 25 kg weight by varying the percentage of vetiver grass and kenaf fibres. It was observed that mechanical properties of epoxy composites were improved by hybridization with vetiver grass and kenaf fibres at 25 kg constant load. Boopalan *et al.,* 2013 studied the mechanical and thermal properties of jute and banana fibre reinforced epoxy hybrid composite and reported that 25 kg compressive force was best for the casting of composite.Further when compressive force for casting of composite samples was increased from 25 to 30 kg, increase in thermal conductivity from 0.32 to 0.38 m^2k/w and decrease in tensile strength from 15.82 to 13.81 MPa was recorded.

Thus, it is deduced that composite of higher tensile strength and lowest bulk density with comparable thermal conductivity was obtained when 25 kg of compressive force was applied. Hence, it was selected as optimum compressive force for fabrication of rice straw fibre reinforced composites.

Conclusion

Rice straw fiber and epoxy resin were combined to create an eco-friendly composite. The rice straw reinforced bio-composite made up with the optimum 25kg compressive force gives this composite exceptional mechanical and thermal qualities. For high performance biodegradable composites, rice straw fiber can provide a good reinforcement candidate as it is economical and sustainable solution to tackle the increasing shortage of raw materials in the construction field. Future studies will focus on creating environmentally friendly composite materials from rice husk fiber with biodegradable resin polymeric matrix and enhanced mechanical characteristics.

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