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Mechanical Behaviour of Hybrid Bio-composite Reinforced with Walnut (*Juglans regia* L.) Shell Particle and Coconut Fibre

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ABSTRACT: In this paper, walnut shell particle and coconut fibre are developed. The suitability of walnut particle and coconut fibre as a biocomposite reinforcing material was investigated. 20 wt% of walnut shell particle of size 1.618 μm - 2.685 μm and 10 wt% of coconut fibre of length 2-3 mm were mixed in epoxy CY 230 resin for preparation of hybrid biocomposite. The tensile properties and flexural test of hybrid biocomposite reinforced with walnut shell particle and coconut fibre were evaluated and analysed. Scanning electro microscopy was employed to characterize the tensile properties and fracture behaviour of biocomposite. The results show that ultimate strength, modulus of elasticity and yield strength of biocomposite material are about 54.3%, 86.4% and 88.3% of pure epoxy resin respectively. The compressive ultimate strength of biocomposite is 44.45 MPa as compared to 55.16 MPa of epoxy resin. This results reveals that the addition of 20 wt% walnut particles and 10 wt% coconut fibres yield better ultimate strength with approximately 80.58% of pure epoxy. The flexural modulus of biocomposite is 1706.15 MPa which is about 86.3% of pure epoxy. The flexural strength of biocomposite is 34.04 MPa which is about 35.7% of pure epoxy.

Keywords: Bio-composites, Walnut particle, Coconut fibre, SEM.

I. INTRODUCTION

Bio-composite is a material formed with two or more components, combined as a macroscopic structural unit with one component as a continuous matrix, and other as reinforcements with significantly different physical or chemical properties, which remain separate and distinct on a macroscopic level within the finished structure. Normally, the matrix is the material that holds the reinforcements together and has lower strength than the reinforcements. Most commercially produced composites use a polymer matrix material called as resin solution.

The optimum utilization of available natural resources is one of the major factors for the social and economical development of human being. During last few decades' researchers [1-6] have tried to use natural resources in fibres form or particle forms as reinforcing material to produce composite boards. Lignocellulosic material provides an adequate strength with low cost, low density, eco-friendliness and non-toxic. Walnut shell is a lignocellulosic material and it has no economical value and industrial uses in india and generally discarded or uses as a fire wood substitute material. In this study the mechanical and morphological properties of walnut shell and coconut fibre reinforced biocomposite was investigated.

II. MATERIAL AND METHOD

In this study 20 wt % of walnut shell particles and 10 wt% of coconut fibres were added as reinforcing material in epoxy resin CY 230 and hardener HY 951. Hardener was mixed in the solution at 40 ^{0}C which were pre heated to 100 ^{0}C and hold for 2 hours at 100 ^{0}C. The solution thus obtained was used to cast sheet in a mould of size 300 mm x 250 mm x 10 mm as shown in Fig. 1. After curing, the composite sheet was used for tensile test to fulfil the objectives of the present investigation. Detailed procedure of casting and curing process is described in the references [1-2]. The chemical compositions of wall nut shell and coconut fibers are shown in Table 1.

Fig.1. Moulding box for pouring solution.

Table1: Chemical composition of walnut shell and coconut fibre.

Material	Holocellulose (%)	α Cellulose (%)	Lignin (%)	Ash (%)
Walnut shell	46.6	25.4	49.1	3.6
Coconut fibre	56.3	44.2	32.8	2.2

Mechanical Properties:

Tensile Test

Tensile tests are conducted in a 100 kN universal testing machine (ADMET Make, USA) according to ASTM standard at 0.5 mm/min crosshead speed. The specimen geometry used is shown in Fig. 2. The gauge length and cross sectional area kept are 50 mm and 100 mm^2 respectively.

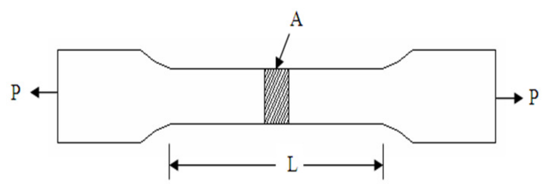


Fig. 2. Specimen geometry for tensile test

Compression Test

ASTM D 695 governs the compressive testing of biocomposite material and commonly used. It defines the axial compressive loading of a short prism like bar or tube specimen laterally restrained against column buckling. The short prism specimen is commonly used. These specimens for measuring compressive strength were conducted as circular in cross section, having a length twice the transverse dimension (i.e., a specimen with an aspect ratio of 2). A recommended specimen size for strength determination is 8 mm in cross-sectional dimensions and 16 mm long. A specimen of the same cross-sectional dimensions but twice as long is recommended for modulus and offset yield stress measurement. All compression tests were conducted on 100 kN universal tensile testing machine of ADMET make, USA at the crosshead speed of 0.5 mm/min.

III. RESULTS AND DISCUSSION

Tensile Properties

The tensile properties of biocomposite mainly ultimate tensile strength, modulus of elasticity and yield strength are presented in Table 2 along with their statistical parameters. The stress-strain curve of biocomposite is presented in Fig.3. These properties are evaluated to find out any improvement that may be occurred due to hybridization of walnut shell particle and coconut fibre. All the tensile tests were conducted in accordance with ISO-527-01(2012) at room temperature, using 100 kN universal testing machine at 0.5 mm/min crosshead speed. All mechanical tests were repeated five times and the average values are used for analysis.

The mechanical properties of particle and fibre based composites depends on the particle size, fibre length or aspect ratio, their degree of dispersion, interfacial adhesion and particle loading.

Modulus of Elasticity

The average value of modulus of elasticity of biocomposite and epoxy resin are 1411.22 MPa and 1632.75 MPa respectively. These results show that the addition of walnut particle and coconut fibre do not affect on the modulus of elasticity value. This can be attributed to the good adhesion between walnut particle, coconut fibre and matrix. 13.6% decrease of the modulus of elasticity has been observed, which is statistically insignificant obtained by t-test.

Table 2: Mechanical properties of walnut shell particle and coconut fibre biocomposite.

Properties	Materials					
	Epoxy			Biocomposite		
	Mean $\bar{x}_\rho$ (MPa)	Variance S_ρ (MPa)	$\frac{\sqrt{S_\rho}}{x_\rho}$ x100	Mean $\bar{x}_\rho$ (MPa)	Variance S_ρ (MPa)	$\frac{\sqrt{S_\rho}}{x_\rho}$ x100
Yield Strength	5.57	0.12	6.4	4.92	0.20	9.01
Ultimate Strength	44.93	1.43	2.65	24.43	15.38	16.06
Modulus of Elasticity	1632.75	361.81	1.16	1411.22	87467.93	20.96

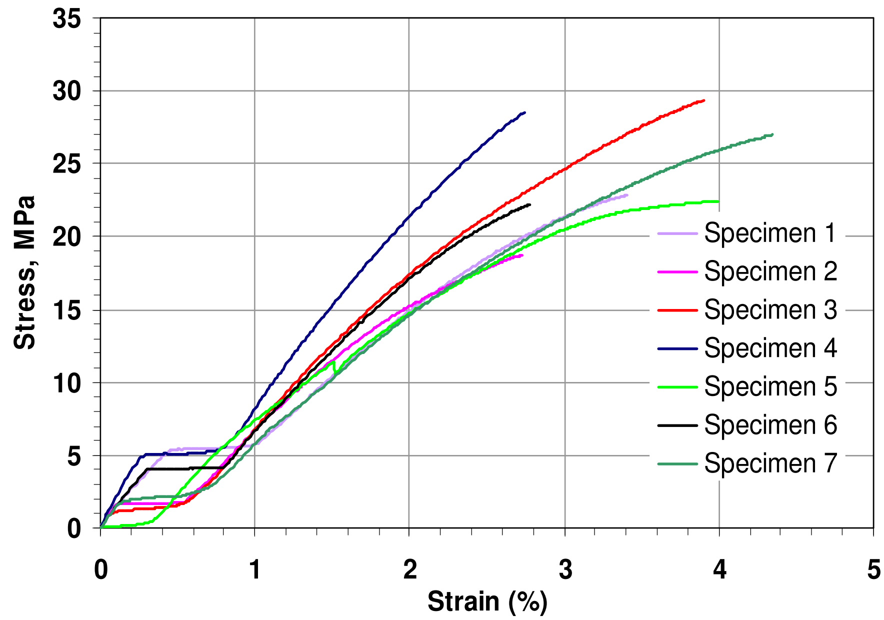


Fig. 3. Tensile stress strain behaviour of biocomposite reinforced with 20 wt% walnut shell particle and 10 wt% coconut fibre.

Ultimate Strength

The average values of ultimate strength of biocomposite and pure epoxy are 24.43 MPa and 44.93 MPa respectively. This shows that the ultimate strength of biocomposite is about 54.3% of pure epoxy. However the coefficient variance of biocomposite as compared to pure epoxy is about 6 times of the pure epoxy. In general, the coefficient of variance of metals is found to be less than 10%**.** Hence, the variance coefficient of biocomposite is found to be higher than the metal. The variance of any property depend upon the several factors such as dimensional accuracy, dispersion of particle / fibre with matrix material, uniformity in the distribution of reinforcing materials, adhesion quality etc. In general, from the error analysis the dimensional measurement error is about 2%. In pure epoxy resin the variance coefficient of ultimate strength is 2.65% which is mainly due to measurement error. But in biocomposite, the variances of mechanical properties are because of the factors mentioned above.

The results shown in Table 2 indicate that though there is a decrease in ultimate strength due to 20 wt% walnut particles and 10 wt% coconut fibre as compared to pure epoxy, but the modulus of elasticity remains almost same as that of pure epoxy.

The higher variance in biocomposite material also indicates that there is not single mechanism working for failure of the biocomposite material. It has been pointed out by many researchers [3-8] that reinforced material fails because of fibre cracking, fibre pull out, poor adhesion, poor dispersion of particles in metal matrix etc.

Compression Properties

The compressive stress strain behaviour of biocomposite and epoxy resin are shown in Fig. 4. and 5. A minimum of four samples were tested at a crosshead speed 0.5 mm/min. The mean, variance and coefficient of variance of compressive strength, compressive modulus and 0.2% offset compressive yield strength are shown in Table 3. The compressive modulus of biocomposite is 765.85 MPa as compared to 822.98 MPa that of epoxy resin. This result reveals that the addition of 20 wt% walnut particles and 10 wt% coconut fibre yield better compressive modulus with of pure epoxy. This may be because of good adhesion between reinforcing material and material. The compressive ultimate strength of biocomposite is 44.45 MPa as compared to 55.16 MPa of epoxy resin. This results reveals that the addition of 20 wt% walnut particles and 10 wt% coconut fibres yield better ultimate strength with approximately 80.58% of pure epoxy.

The walnut shell have lignin 49.1%, α cellulose 25.4%, holocellulose 46.6% and ash 3.6%. The high lignin contain increases the brittleness of the lignocellulosic material whereas high cellulose contain decreases it brittleness [Nemli G *et al.* (2009)]. The coconut fibre have holocellulose 56.3%, α cellulose 44.2%, lignin 32.8%.

The high lignin content of walnut shell as well as coconut fibre increases the brittleness of the material. The ash contains walnut shell and coconut fibre is about 3.6% and 2.2% respectively. The high amount of ash present in walnut and coconut has a negative effect on the bonding, as a result of which lower mechanical properties are found.

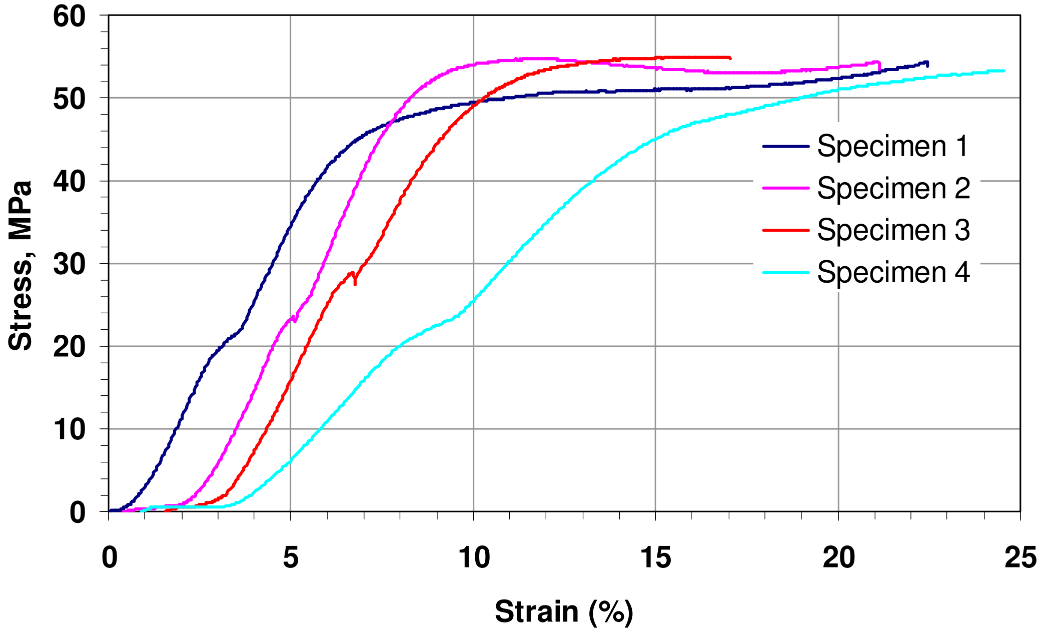


Fig. 4. Compressive stress strain behaviour of pure epoxy material.

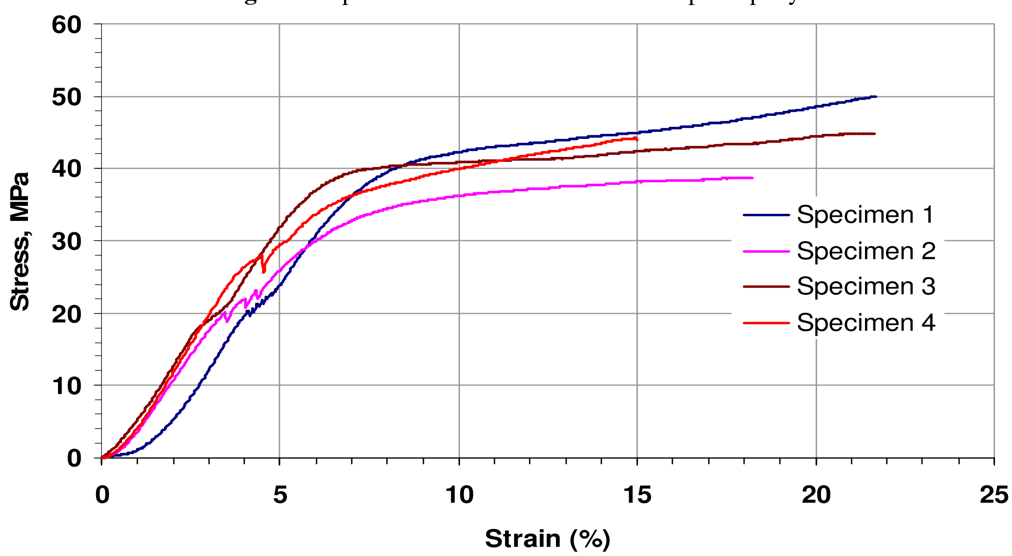


Fig. 5. Compressive stress strain behaviour of biocomposite reinforced with 20 wt % walnut particle and 10 wt % of coconut fibre.

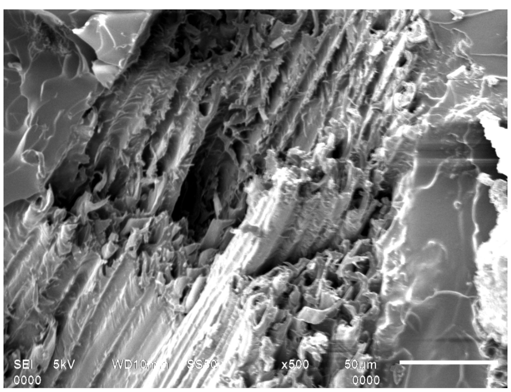
Table 3: The compressive properties of epoxy and biocomposite material.

Properties	Materials					
	Epoxy			Biocomposite		
	Mean $\bar{x}$ (MPa)	Variance S	$\frac{\sqrt{S}}{\bar{x}}$ x100	Mean $\bar{x}$ (MPa)	Variance S	$\frac{\sqrt{S}}{\bar{x}}$ x100
Yield Strength	20.53	40.75	31.09	19.05	16.19	21.13
Ultimate Strength	55.16	1.09	1.89	44.45	21.15	10.35
Modulus of Elasticity	822.98	33455.68	22.23	765.85	1308.31	4.72

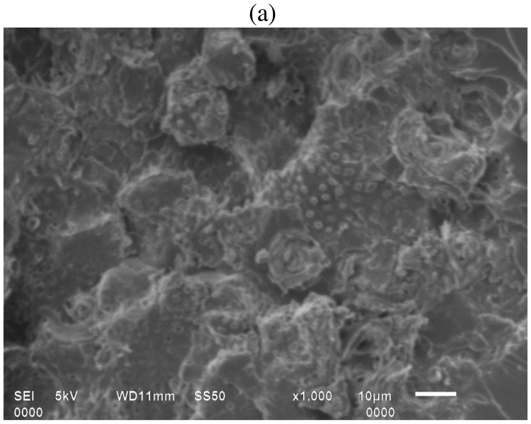
Scanning Electro-micrograph

Tensile results indicate that though there is a loss of strength due to addition of walnut particles and coconut fibre but the modulus of elasticity remains almost same as of the pure epoxy. The variance coefficients of ultimate strength and modulus of elasticity are 16.06% and 20.96% for biocomposite respectively. These values are at higher side as compared to metals. The higher variance indicates that the composite material made from walnut particle and fibre material failed because of the pullout or breaking of fibre from the matrix material. The composite failure mechanism thus can be attributed to the uniform distribution of fibre and or particles and thus the distribution of both reinforcing material in the epoxy plays a very important role in the load shearing phenomena. This can be seen from the micrographs shown in Fig. 6.

To get a closer overview of the phenomena, the scanning electro micrographs of tensile fracture specimen are shown in Fig. 6. The Fig. 6(a) clearly indicates that walnut particles are strongly bonded to the fibre and failure is because of cracking or splitting of the fibre. Where as Fig. 6(b) shows the pull out failure of the walnut particles. Fig.8 also reveals that distribution of coconut fibre is not uniform as compared to walnut particles.



(a)



(b)

Fig. 6. Scanning electron microscopic (SEM) test for tensile specimen.

CONCLUSIONS

The present study shows that 20 wt% walnut particle and 10 wt% coconut fibre mixed in epoxy resin improves the mechanical properties as well as fracture behaviour. The experimental result of study indicated that about 42% of tensile strength can be retained without lose in modulus of elasticity. Fracture of coconut fibre and pull out of walnut shell particles are main failure mechanism seen in this hybrid biocomposite. The flexural stress strain curve rises in non linear way until the maximum value reached where load drop suddenly. The non linear increase in the load demonstrates the ductile behaviour of the material and this may be because of the use of short coconut fibre. The variance and coefficient of variance of biocomposite are greater than 10%. It indicates that the failure of biocomposite depends upon several factors such as good dispersion, quality bonding and uniformity of the particle or fibre distribution in the matrix material. This results reveals that the addition of 20 wt% walnut particles and 10 wt% coconut fibres yield better ultimate strength with approximately 80.58% of pure epoxy.

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