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Investigation of Mechanical Properties of Rice Straw Fibre Polypropylene Composites

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ABSTRACT
The main objective of present work is to investigate the mechanical properties of rice straw fibre reinforced polypropylene composites at different weight fractions (0%, 5%, 10%, 15%, 20% and 25%) of rice straw fibre. Rice straw fibre reinforced polypropylene composites were manufactured according to ASTM standards using injection moulding technique. The developed composites were then tested for their tensile, bending and impact properties. The standard test methods ASTM-D638M for tensile properties, ASTM-D790M for flexural properties and ASTM-D256M for impact properties of rice straw fibre composites, were used.
Keywords – composites, fiber, polypropylene

I. INTRODUCTION

The first uses of composites date back to the 1500s BC. when early Egyptians and Mesopotamian settlers used a mixture of mud and straw to create strong and durable buildings. Straw continued to provide reinforcement to ancient composite products including pottery and boats. Later, in 1200 AD, the Mongols invented the first composite bow. Using a combination of wood, bone and "animal glue," bows were pressed and wrapped with birch bark. These bows were extremely powerful and accurate.

1.2 Classification of Composites

<u>**(a) Based on matrix material:**</u>

- **Metal Matrix Composites (MMC).**
- **Ceramic Matrix Composites (CMC)**
- **Polymer Matrix Composites (PMC)**

<u>**(b) Based on reinforcing material structure:**</u>

- **Particulate Composites**
- **Fibrous Composites**
- **Laminate Composites**

1.3 COMPONENTS OF A COMPOSITE MATERIAL

In its most basic form a composite material is one, which is composed of at least two elements working together to produce material properties, that are different to the properties of those elements on their own. In practice, most composites consist of a bulk material (the 'matrix'), and a reinforcement of some kind, added primarily to increase the strength and stiffness of the matrix.

II. LITERATURE SURVEY

2.1WHEAT STRAW

Annual crop fibres are a cheaper and more rapidly renewable source of cellulose-rich fibre [21] With a renewal time of one year as against at least thirty years for softwoods, and their full potential as a polymer reinforcement has yet to be achieved. However, annual crop fibres such as jute and by products such as sugar cane biogases [22] have been used as fibrous reinforcement in composites. The key to the successful performance of these fibres depend on their cellulose content

Wood fibres and jute contain rather more cellulose than cereal straws, but in view of the several million tones of straw burnt in world every year an investigation of straw fibres for composites applications is justified. Furthermore, wheat straw offers the highest cellulose content of the common UK cereal crops

2.2. Wheat Straw Reinforced Composites

A useful composite material can be manufactured from straw and polyester resin. They considerably increase the strength of the resin alone and reduce its density The preparation of wheat straw fibres and. Their incorporation with a resin matrix are described and the resulting properties of strength stiffness and roughness are studied accordingly various fractions of wheat straw have been combined with an unsaturated polyester resin to produce straw reinforced polyester composites. They have an effective density of nearly5.1KN/m³ when combined with resin. When combined with resin, the composites have a flexural stiffness of 7.3GPa and flexural strength of 56GPa,

The specific flexural stiffness is about 2.5 times greater than that of polyester resin and about half that of softwoods and GRP. It is envisaged that alternative methods for processing the fibres and the use of a phenolic resin matrix will improve the composite properties further straw based composites are suitable as core material for structural board products.

III. PROBLEM STATEMENTS

3.1 RESEARCH NEEDS

The natural fibre-reinforced composite has the advantage of being light, strong, cheap, safe and more environment-friendly. But the use of natural fibre reinforced materials has opened up questions regarding how such material is to be tested for strength and durability. Natural fibres from 2000 odd plants with their complicated nature further entangle the formulation of unified approach, unlike in the case of synthetic fibres. Much work needs to be done before natural fibre reinforced composites can be used in highly demanding situations. Another factor that may be explored is how well the polymer matrix and natural fibre interact, given the contrasting characteristics of repelling water (hydrophobic) and loving water (hydrophilic), respectively. Daimler Benz have used door panels made from natural fibre-reinforced plastic for their Mercedes G class cars and also have plans to increase the usage of material containing natural fibre for other components. Once developed, the technology would be revolutionary making a vast array of Eco-friendly products.

3.2 ASPECTS OF THE PROPOSED RESEARCH WORK

The proposed research work is intended to exploit the advantages of using natural fibres as reinforcement material in composites. The work provides basic understanding of the behaviour and response of new natural fibres and lightweight materials. Under the proposed research work the following aspects of natural fibres and composites have been studied.

1. Identification of matrix material.
2. Extraction of natural fibre.
3. Preparation of natural fibre reinforced composite specimens.
4. Tensile, Bending and Impact testing of natural fibre reinforced composites at various weight fractions.

IV. EXTRACTIONS OF FIBRES & FABRICATION OF COMPOSITE SPECIMEN

4.1 COMPOSITE FABRICATION

Proper proportion of fibres (0, 5, 10, 15, 20 and 25%) by weight and polypropylene pellets were then properly mixed to get a homogeneous mixture The mixture was then placed in a 2.5 tonne plastic hydraulic plastic Injection Moulding Machine, Model JIM-1 HDB, supplied by. Texair Plastics Limited, Coimbatore as shown in fig 4.1. At a temperature of 210^0 C and at pressure of 1100 kgf/cm^2, all the five specimens were developed for each weight fraction of fibre composites Percentage of fiber in the composite is maintained by. weight fraction

. Test specimens with different weight fractions starting from 5% to 25% with regular intervals are made to standardize the results of testing. Five specimens are prepared for each weight fraction.

Fig 4.1 Injection Moulding Machine

V. TESTING OF COMPOSITES

5.1. EQUIPMENT FOR TESTING

5.1.1. Tensile Testing

A 2 ton capacity - Electronic tensometer (Fig.5.2), METM 2000 ER-I model (Plate II-18), supplied by M/S Microtech Pune, is used to find the tensile strength of composites. Its capacity can be changed by load cells of 20Kg, 200Kg & 2000 Kg. A load cell of 2000 Kg. is used for testing composites.

Fig 5.2 Tensometer used for testing tensile and bending strength

Five identical specimens of each weight fraction are tested. The standard test method for Tensile properties of fibre-resin composites, ASTM-D638M is used to prepare specimens as per the dimensions shown in fig.5.1 and were tested for their properties.

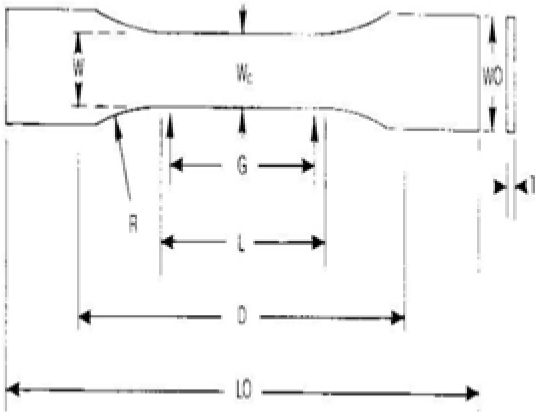

Fig. 5.1 Dumbbell Shaped Specimen Dimension for Type I as per ASTM D638M

Dimension	Value, mm (in)
Thickness, T	< 7mm (0.28in)
Width of narrow section, W	13 (0.5)
Length of narrow section, L	57 (2.25)
Width overall, WO	19 (0.75)
Length overall, LO	165 (6.5)
Gauge length, G	50 (2.00)
Distance between grips, D	115 (4.5)
Radius of fillet, R	76(3.00)

5.1.2. Flexural Testing

Three point bend tests are performed in accordance with ASTM D790M test method 1, Procedure A to measure flexural properties. The samples are 98 mm long by 10 mm wide by 4mm thick and five identical specimens are tested for each composition. In three point Bending test, the outer rollers are 64mm apart and the samples are tested at a strain rate of 0.2mm/min. A three point bend is chosen because it requires less material for each test and eliminates the need to accurately determine center point deflections with test equipment.

The flexural modulus $E_B = \frac{mL^3}{4bt^3}$

The maximum fibre stress $S = \frac{3PL}{2bt^2}$

Where L is the support span (64mm), b is the width and t is the thickness, P is the maximum load and m is the slope of the initial straight line portion of the load deflection curve.

5.1.3. Impact Testing

An analog Izod/charpy impact tester supplied by M/S International Equipments, Mumbai as shown in fig 5.3, was used to test the impact properties of fibre reinforced composite specimens. The equipment has four working ranges of impact strength and are 0-2.71 J, 0-5.42 J, 0-10.84 J and 0-21.68 J, with a minimum resolution on each scale of 0.02 J, 0.05 J, 0.1 J and 0.2 J, respectively. Four scales and the corresponding four hammers (R1, R2, R3 and R4) are provided for all the above working ranges.

Fig.5.3 Impact testing machine

The Impact strength is given by Impact Strength = EI/T Joules/m

Where,

EI = Impact Energy in joules recorded on the scale

T = Thickness of the sample used

Fig. 5.4 shows the fabricated specimens for tensile, flexural and impact testing

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VI. RESULTS AND DISCUSSION

6.1. Discussion on Tensile properties

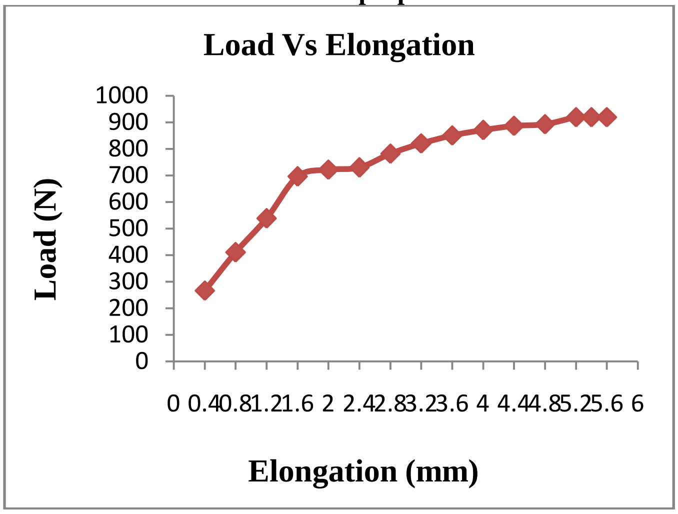


Fig 6.1: Load Vs Elongation for pure polypropylene

Elongation	Load (N) at different weight fractions of Rice Straw Fibre				
	5%	10%	15%	20%	25%
0.4	263.88	140.283	116.74	113.8	106.2
0.8	404.17	187.371	168.73	150.7	138.36
1.2	535.26	264.87	203.5	174.7	160.19
1.6	693.56	379.647	265.45	226.4	198.23
2	719.07	455.184	319.76	280.8	225.69
2.4	739.27	483.26	415.54	310.7	279.83
2.8	779.89	520.12	476.29	379.6	305.14
3.2	811.76	544.27	508.65	419.5	328.96
3.6	826.12	628.75	572.74	510.6	390.24
4	843.75	639.54	602.86	580.2	426.19
4.4	866.22	739.26	617.15	620.9	498.74
4.8	872.74	766.65	652.74	690.5	549.62
5.2	890.45	792.28	720.38	726.4	628.73
5.4	902.22	819.871	742.37	738.2	658.49
5.8	902.22	819.871	742.37	738.2	658.499

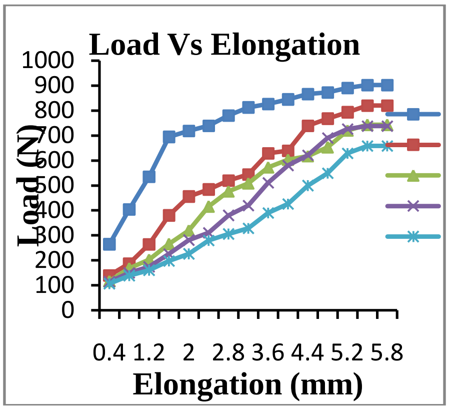


Fig 6.2: Load Vs Elongation for mixture of Rice Straw /PP composites

The results of tensile test for five specimens of Rice Straw PP composites for each weight fraction are shown in Fig. 6.2 Average tensile strength and modulus are calculated from the Stress-strain graphs using following relations.

Tensile strength = Maximum Load (N) / cross - sectional area (mm^2) Tensile Modulus = Stress / strain

The tensile strength and modulus of the pure polypropylene (Fig.6.1) are determined as 7.181 MPa and 0.0021 GPa, respectively. The average tensile strength and modulus of Rice Straw PP composites of the present work calculated from stress strain curves and plotted with respect to fiber weight fraction are shown in Figure.

% Wt of Rice Straw	0%	5%	10%	15%	20%	25%
Tensile strength (MPa)	7.18	7	6.4	5.8	5.77	5.14

Table 6.2: Tensile strength Vs Percentage Weight of Rice Straw

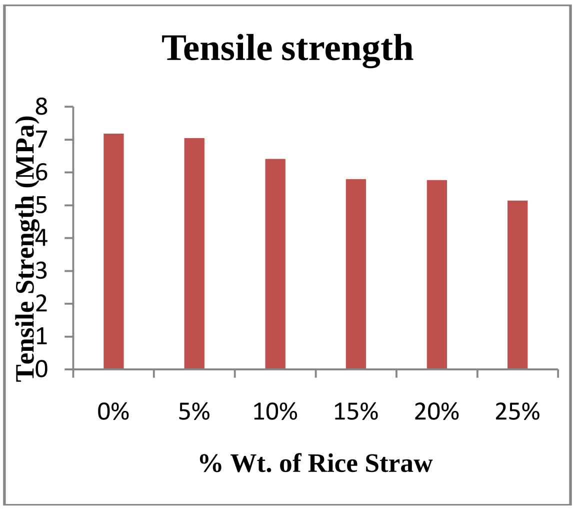


Fig 6.3: Tensile strength Vs Percentage Weight of Rice Straw

6.2.2 Discussion on Flexural properties

The load verses deflection curves for pure polypropylene are shown in Fig. 6.7. The results of flexural test for 5 specimens of Rice Straw PP composites for each weight fraction are shown in Fig. Average flexural strength and modulus at each weight fraction of fiber are calculated from the load-deflection curves of five specimens in flexural testing using following relations

The flexural modulus: $E = Lm/4bt3$
The flexural strength: $S = 3PL/2bt2$

Where L is the support span (64mm), ‘b is the width and‘t’ is the thickness of the specimen, ‘P is the maximum load and ‘m is the slope of the initial straight line portion of the load-deflection curve.

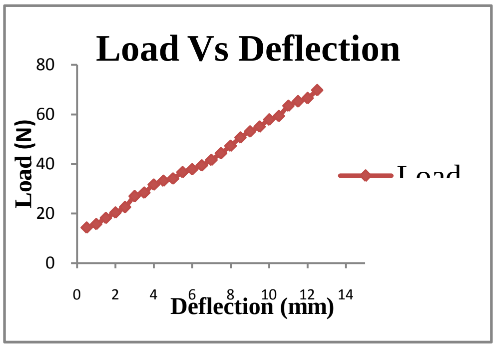


Fig 6.7: Load Vs Deflection for pure Polypropylene

Elongation	Load (N) at different weight fractions of rice straw fibre				
	5%	10%)	15%	20%	25%
0.5	11.03	6.23	7.11	11.23	9.34
1	13.56	11.39	10.41	14.24	13.39
1.5	16.29	14.86	12.25	17.16	16.81
2	20.31	16.11	18.11	21.68	17.65
2.5	22.45	19.53	23.11	22.71	19.34
3	24.67	21.68	24.68	23.19	21.91
3.5	30.28	22.98	26.25	25.26	28.13
4	30.28	24.16	28.42	28.31	33.33
4.5	33.76	28.35	30.65	30.29	35.65
5	35.19	30.67	32.27	35.62	37.22
5.5	39.42	32.19	34.18	42.81	40.18
6	40.01	38.23	36.42	50.79	42.71
6.5	41.23	40.79	38.33	55.45	49.87
7	43.68	42.09	40.61	61.75	52.19
7.5	48.21	43.65	44.87	62.04	58.36
8	50.73	43.65	46.213	62.04	58.36
8.5	55.62		49.61	62.04	58.36
9	60.13		52.91		
9.5	61.02		53.21		
10	61.02		53.21		

Table 6.6: Load Vs Deflection for mixture of Rice Straw /PP composites

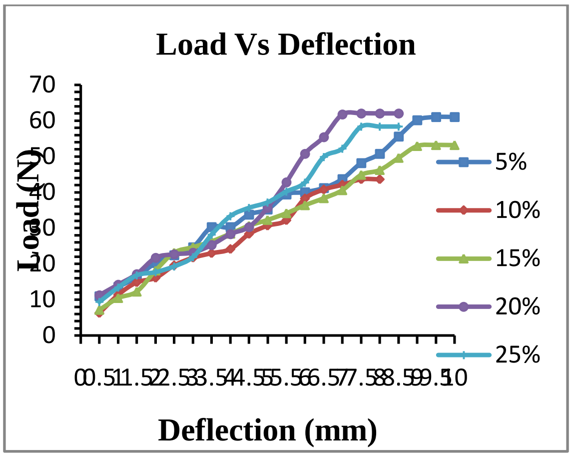


Fig 6.8: Load Vs Deflection for mixture of Rice Straw /PP composites

% Wt of Rice Straw	0%	5%	10%	15%	20%	25%
Flexural strength (MPa)	45.53	40.04	28.65	34.92	40.7	38.3

Table 6.7: Flexural strength Vs Percentage Weight of Rice Straw

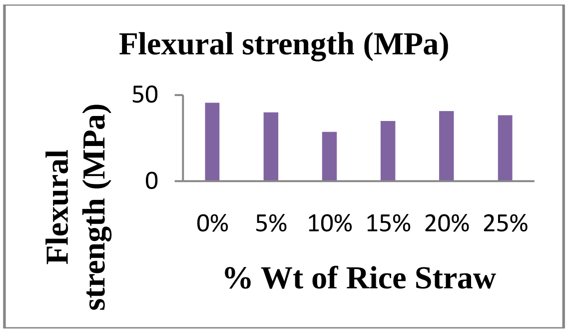


Fig 6.9: Flexural strength Vs Percentage Weight of Rice Straw

6.2.3 Discussion on Impact properties

The impact strength for five specimens of pure polypropylene and the results of Impact test for 5 specimens of Rice Straw PP composites for each weight fraction are shown in figures.

The Impact strength is given by

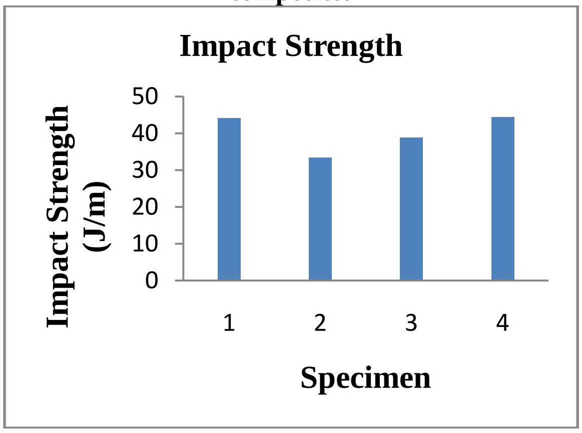
I S = EI / t Joules/m

WhereEI = Impact Energy in joules recorded on the scale
t = Thickness of the sample used

Specimen	Impact Strength (J/m) of composite at different weight fractions of rice straw fiber				
	5%	10%	15%	20%	25%
1	44.1	22.2	16.7	44.4	33.3
2	33.3	16.7	11.1	27.8	38.9
3	38.9	27.8	22.2	38.9	38.9
4	44.4	50	27.8	27.8	44.4

. Table 6.11: Impact Strength for mixture of Rice Straw /PP composites

Fig 6.13: Impact Strength for 5% Rice Straw /PP composites



VII. CONCLUSIONS AND SCOPE FOR FUTURE WORK

The main objective of this investigation is to gauge the possibility of utilizing the Rice Straw which is abundantly available as an alternative filler material in a polypropylene matrix.

SCOPE FOR FUTURE WORK

The future work will investigate the performance of other lower cost resin systems, particularly polypropylene resins. There may be chance of improvement in the mechanical properties of Rice Straw composites by chemical treatment of fibers and by changing the length of the fibers. Other natural fibers can be explored and tested for mechanical properties of those fiber polypropylene composites.

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