

Hybridisation Effect on the Properties Of Prosopis Juliflora, Sisal/Glass Fiber Ceramic Composites

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ABSTRACT: The mechanical properties of ceramic composite plaster made using natural fibers as reinforcement for brittle plaster is studied. The fibers obtained from the bark of Prosopis juliflora tree, and sisal fibers ground to a particular size hybridised with glass fibre is used as a reinforcement material. In order to improve the adhesion between fiber and plaster matrix, natural fibers were subjected to alkali treatment with NaOH used at 6% concentration to modify the surface characteristics. The main drawback associated with plaster is its brittleness, especially under tensile stress. Adding fibres to gypsum to obtain a composite material is one way to improve the behaviour of the product especially after the failure of the matrix. The composite plasters were prepared using hand layup and cold press technique. It is inferred from the test results that laminates containing Prosopis juliflora fibers, sisal in mixed plaster favourably affected the mechanical properties such as flexural strength, compressive strength, split tensile, porosity and sorptivity of the composite. The effect of natural fibres on the water absorption characteristics of gypsum plaster were also evaluated after immersion of oven dried specimens in water. It is proved that though the natural fibres favoured mechanical strength it has a drawback on water absorption property which is to be mitigated by other methods.

KEYWORDS: Prosopis juliflora fibers, Agave sisalana, Glass fiber, Flexural Strength, Tensile Strength Test, Compressive Strength, Effect On Water Absorption

I. INTRODUCTION

Fiber reinforced composites are widely used due to its inherent advantages such as light weight, good corrosion resistance, high resistance against impact and fatigue loads, and high abrasive resistance against wear and tear. The fibers used for reinforcing polymer matrix include both artificial and natural. Some of the most commonly used artificial fibers are glass, aramid, Kevlar and carbon. Based on the source of origin, natural fibers are broadly classified as plant, animal and mineral fibers. Plant fibers are extensively used because of their abundant availability, low energy for processing, ease biodegradability and high strength. The main components of plant fibers are cellulose, hemicelluloses, lignin, pectin, waxes and other impurities. Cellulose fibrils embedded in lignin matrix offers the strength, stability and rigidity to the fiber. Plant fibers which have been used for making composites include cotton, flax, hemp, coir, sisal, jute and abaca. The presence of hydroxyl groups at the surface of cellulose fibers adversely affects the adhesion between the fiber and matrix. Various chemical treatments such as alkali treatment, permanganate treatment, benzoylation, silane, cyanoethylation, acetylation and acrylation are adopted to modify the surface of plant fibers so that better adhesion with the matrix is achieved..

was carried out by subjecting them to alkali treatment using NaOH solution at 5% concentration. Tests such as tensile, flexural, impact and water absorption were performed on the hybrid composite laminates and the results obtained were discussed.

II. PRE- EXPERIMENTAL INVESTIGATIONS

2.1 TESTS FOR GYPSUM

2.1.1 Fineness Test

The triple beam balance is taken and the reading of the balance is adjusted to zero. A pan is taken and its weight is noted. Some gypsum plaster was put in the pan placed on the balance, so that the weight of gypsum plaster becomes 100grams. This was noted to be weight w_1 of the gypsum plaster. The gypsum plaster was put in the sieve carefully and the sieve was closed tightly. The shaking of the sieve horizontally is started and the shaking of the sieve for 10 to 15 minutes was maintained regularly. After 15 minute the residue left in the sieve is taken and put it in a pre-weighed plate and the weight w_2 of the residue is noted with the help of triple beam balance. Then by using the following formula the percentage fineness of gypsum plaster is calculated.

W_1 = Total weight of gypsum plaster, W_2 = Weight of residue

Percentage of fineness = $((W_1 - W_2) \times 100) / W_1$

2.2 Fineness characteristics of Gypsum plaster

Trial	150 μ sieve	75 μ sieve	Average
1	Nil	7%	7.3%
2	Nil	8%	
3	Nil	7%	

2.3 Bulk Density Test

The plaster sample was poured directly into a cube container of volume $0.02m^3$, where the internal length of the side of the cube container is 271.5 mm, from a height of not exceeding 50mm above the top of the container and the extraneous material flat with the top of the cube was struck off. The tamping and other type of compaction was not used. The quantity of the plaster was weighed to an accuracy of $\pm 50g$ (W). The bulk density of the plaster sample was determined from the equation **Bulk density = $W \times 50 \text{ kg/m}^3$**

Table 2.3.1 Bulk Density Results

Trial	Bulk density	Average
1	1.1	1.1
2	1	
3	1.2	

2.4 Normal Consistency Test

The standard testing consistency can be determined by dropping ball penetrometer test. The paste was filled into a Vicat mould and the mould is rested on a non-porous plate. It is filled by using a flexible palette-knife or the like and the thumbs or fingers by introducing small quantities at a time and also to avoid voids or air bubbles. The surface of the plate was smoothed off level with the top of the mould. A 25mm diameter ball of weight $9.8 \pm 0.1 \text{ g}$ was

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dropped from rest from a height of 250 mm measured from the bottom of the ball to the surface of the paste, on to the surface of the paste. And this fell approximately at the centre of the mould. The distance from the lowest point of the ball to the level of the original surface of the material was recorded as a penetration.

A convenient method of measuring the depth of penetration is provided by the use of a bridge which is rested on the rim of the mould. A vertical sliding millimeter scale or micrometer was carried at the centre and measured down to the top of the ball without removing the latter from its seat in the paste. An allowance of 25mm was made for the diameter of the ball. The paste reached the correct consistency when the depth of penetration of the ball is 9 to 10mm.

Table 2.4.1 Consistency Results

Material	Gypsum Plaster
Consistency	60%

2.5 SETTING TIME TEST

Two methods were used to monitor the setting of the paste. The hardening of the paste is a good indicator of the degree of conversion of the hydration reaction. However, for composite materials containing fibers, the initial setting time was subject to variations due to the fact that bundles of fibers can block the needle penetration. The final setting time was a more reliable parameter for such materials. Moreover, the percentages of fibers were low enough (lower than 10% wt) to obtain consistent information with this technique.

Table 2.5.1 Setting Time of Gypsum Plaster

S.no	Test methods	Setting time (min)	
		Initial	Final
1	Vicat	12	14
2	Knife cut	8	11

2.6 TEMPERATURE RISE TEST

To confirm the Vicat test results, temperature measurements of the paste during the setting reaction were carried out. The exothermicity of the transformation of hemihydrate into dihydrate enabled the characterization of the behavior of the paste during the setting by temperature measurements. The mixture was poured into a standardized Vicat mould and closed in an adiabatic container. A temperature probe was introduced in the paste to follow the temperature change during setting.

Table 2.6.1 Temperature Rise of Gypsum Plaster

Time (min)	Temperature of gypsum	
	Without fibres	With fibres
0	33	32
5	34	34
10	37	36.5
15	45	38.5
20	49	42
25	51	45.5
30	53	47
35	54	48
40	54	48

2.7 Alkaline Treatment of Prosopis Juliflora Fibers

The dry Prosopisjuliflora were immersed in 5% (w/v) of NaOH solution at ambient temperature for 30,60,90 and 120 min. The treated fibers were washed thoroughly with de-ionized water several times until a neutral pH was obtained. Finally, they were rinsed with de-ionized water before drying them in an oven at 80°C for 4h and used for further analysis.

Table 2.7.1 Chemical composition of alkali-treated PJFs

NaOH concentration % (w/v)	Soaking time (min)	Cellulose (wt.%)	Hemicellulose (wt.%)	Lignin (wt.%)	Wax (wt.%)	Moisture content (wt.%)	Ash (wt.%)
5 % (w/v)	30	68.65	6.14	14.20	0.31	7.48	10.03
	60	72.27	4.02	12.09	0.10	6.36	13.22
	90	67.13	3.10	11.13	0.07	4.92	14.67
	120	62.01	2.43	9.02	0.05	3.01	15.11

2.8 WATER-PLASTER RATIO

The gypsum plaster was mixed at a constant w/p ratio of 0.6 because this was found typical of that used in several literatures and proved to be optimum. The maintenance of constant w/p ratio was also done in order to eliminate the influence of water content on the mechanical properties of gypsum plaster.

2.9 CASTING OF SPECIMENS

Flexural strength was determined by using 4x4x20 cm specimens tested under three-point loading on a span 10cm long gypsum prism. To determine compressive strength, 6.25x4x4 cm gypsum cuboids specimen were tested. The specimens used in split tensile process were 50 mm diameter x 10 cm height long gypsum cylinders. The water absorption was determined by using 50x50x50 mm cube specimen

S.No	Testing methods	Specimen				Proportion by weight%				w/p ratio
		Size	Shape	No's	Designation	Gypsum plaster	Fibre I	Fiber II	Fiber III	
1	Three point bending	200 x 40 x 40 mm	Prism	4	2%	100	0.5	0.5	1	0.6
					3%	100	1	1	1	
					4%	100	1	1.5	1.5	
					5%	100	1	2	2	
2	Compressive strength	62.5x40 x40mm	Cuboid	4	2%	100	0.5	0.5	1	0.6
					3%	100	1	1	1	
					4%	100	1	1.5	1.5	
					5%	100	1	2	2	

3	Split tensile strength	50 mm diameter & 100 mm height	Cylinder	4	2%	100	0.5	0.5	1	0.6
					3%	100	1	1	1	
					4%	100	1	1.5	1.5	
					5%	100	1	2	2	
4	Water absorption	50x50 mm	Cube	4	2%	100	0.5	0.5	1	0.6
					3%	100	1	1	1	
					4%	100	1	1.5	1.5	
					5%	100	1	2	2	

Table 2.9.1 Details of Specimen

Note:

Fiber I: Prosopis Juliflora, Fiber II: Agave sisalana, Fiber III: Glass fiber

2.10 CURING CONDITIONS

After the castings were made, the specimen were cured in laboratory conditions at 20°C and 65% relative humidity (RH) for 7 days followed by drying in an oven at 40°C for 24 hours.

III. TESTING OF SPECIMENS

3.1 Three point flexural test

In order to estimate the real efficacy of the reinforcement, in terms of ultimate strength and toughness, three point flexural tests were conducted on 200 x 40 x 40 mm specimens according to the standard IS . Short Prosopis juliflora, both raw and treated, were added to the binder at different percentages (1%, 2% and 3% by weight respect to binder). The dry mixture was firstly homogenized and then the compound was slowly added to the water and mixed for about 30 s. The mixture was casted into mold and compacted with a conventional vibration table for about 30 s. The specimens were cured following the same procedures described above. For each fiber typology, specimens were manufactured and measurements were performed. The flexural test was performed with an ASTM testing machine. Known the maximum load F reported by testing machine, it is possible to evaluate the flexural strength of the specimen $\sigma_{u,max}$ using the following equation where l is the span distance, b and d are respectively the width and the thickness of the specimen:

$$\sigma_{u,max} = 1.5 Fl/bd^2 \text{ [N/mm}^2\text{]}$$

3.2 Compressive Strength Test

The broken halves from the test for modulus of rupture were collected and they were cut into 62.5mm length. They were placed one at a time with the side surface resting on the bearing block on the compressive strength testing machine where compression is applied to the surface measuring 40 mm x 40 mm. A cellulose fibre wall board of 5 mm thickness was sandwiched and extended 50 mm or more over the edges between the specimen and the bearing

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blocks. The load is applied at a uniform rate of 1 KN/min until the test piece was broken. The breaking load was noted and the crushing strength was calculated from the formula:

$$S = W/A$$

where, S = crushing strength in MPa

W = total load in N at which the specimen failed

A = average of the gross areas in mm of the top and bottom side surface of the specimen subjected to load.

In other words, the compressive strength can be calculated as follows:

$$\text{Compressive strength (N/mm}^2\text{)} = \frac{\text{Maximum load at failure (N)}}{\text{Cross sectional Area (N/mm}^2\text{)}}$$

3.3 Split Tensile Test

The split tensile test were conducted as per IS 5816:1999. The size of cylinder is 100 mm length with 50 mm diameter. The specimens were kept in laboratory conditions for curing for 7 days and on removal were tested. The test is carried out by placing a cylindrical specimen horizontally between the loading surfaces of a compression testing machine and the load is applied until failure of the cylinder along the vertical diameter. The maximum load applied to the specimen was then recorded and the appearance of the concrete for any unusual features in the type of failure was noted. Average of three values was taken as the representative of batch. The test is carried out by placing a cylindrical specimen horizontally between the loading surfaces of a compression testing machine and the load is applied until failure of the cylinder along the vertical diameter. To find split tensile strength following equation has used. Fig shows the testing of split tensile test.

$$\text{Split tensile strength} = 2P / (\pi DL)$$

Where: P = split tensile load

D = diameter of the cylinder

3.4 Water Absorption Test

From the selected sample of plaster, a specimen measuring about 50 x 50 x 50 mm. These were taken out and weighed (W_1) after removing the surplus moisture with a damp cloth. The specimens was then placed in an air-oven capable of being raised to 105°C and are maintained at that temperature constantly. The specimens were dried until constant mass is attained and the mass was recorded for each specimen. The percentage absorption can be calculated from:

$$\text{Percentage absorption} = (W_1 - W_2) / W_1 \times 100$$

Where W_1 = mass of specimen after absorption

W_2 = mass of specimen after heating

The specimens should not be placed in contact with one another but they are distributed uniformly throughout the oven. Wet specimens were not introduced into an oven in which the drying of other specimens was already in progress.

IV. RESULTS AND DISCUSSION

4.1 GENERAL

The partial replacement of the Prosopisjuliflorafibers, Agave sisalana, Glass fiber at 2%, 3%,4% and 5% showed several effects on the Gypsum plaster which are explained in the following sections.

4.2 TESTING

The flexural strength test, tensile strength test, sem analysis were conducted in

4.3 FLEXURAL STRENGTH

The flexural strength was determined on 200x40x40 mm specimen tested under three point loading on a span on 10 mm in ASTM Machine. The modulus of rupture was calculated assuming the elastic behavior of simple bending. The relationship between flexural strength and the percentage of Prosopisjuliflora fibre, Agave sisalana, Glass fiber content is given which showed that the strength of the plaster composite increased and reached a maximum value at 2% content of the Prosopisjuliflora fibres, Agave sisalana, Glass fiber and then fell off. The fall in strength may be attributed to the decrease in the quantity of binder and improper compaction which induced voids in the composites. The composites made by the use of 2% Prosopisjuliflora fibres, Agave sisalana, Glass fiber had higher strength and modulus of rupture than the ones made without the fibres. The reference sample manufactured without the addition of fibres were realized as reference material and tested.

Table 4.3.1 Flexural Strength of Ceramic Plaster

Sample	Replacement Percentage (%)	Flexural load (KN)	Modulus of Rupture (M Pa)
1	2	0.38	4.695
2	3	0.35	2.597
3	4	0.27	2.406
4	5	0.33	2.705

The flexural strength obtained for the various percentagereplacement of fibers materials shown that 2% of replacement of fibers has high flextural strength and flextural load

4.4 TENSILE STRENGTH TEST

The Tensile strength showed no significant change with increase in the fibre content on gypsum plaster. The graph showing the tensile strength of the specimen showed negligible variation and thus proved that the addition of Prosopisjuliflora has no negative influence on the tensile strength of gypsum plaster.

Table 4.4.1 Tensile Strength of Ceramic Plaster

Sample	Replacement Percentage (%)	Tensile load (KN)	Tensile strength (N/mm ²)
1	2	0.10	0.0127
2	3	0.17	0.0216
3	4	0.21	0.0259
4	5	0.29	0.0360

4.5 COMPRESSIVE STRENGTH

In contrast to the modulus of rupture the compressive strength decreased with increase in the fibre content. This was due to the reduction in density of the resulting composite due to the low density of the natural fibres and the ineffective fibres distribution. It would be possible to obtain higher compressive strength than the ones achieved for the same fibre content if the compaction were improved by either higher suction or pressing.

Table 4.5.1 Compressive Strength of Ceramic Plaster

Sample	Replacement Percentage (%)	Compressive load (KN)	Compressive strength (MPa)
1	2%	12.8	5.12
2	3%	11.7	4.68
3	4%	11.5	4.60
4	5%	11.3	4.52

4.6 EFFECT ON WATER ABSORPTION

Water absorption is a very important test for natural particles and fibres reinforced composites to define their potential for outdoor working. The performance of these composites may suffer while they are exposed to environmental conditions for long time. The water absorption test provides information about the adhesion between the particles and the matrix in the interface region, as higher the adhesion between the matrix and the particles fewer will be sites that could store water and will lead to lower water absorption. Fig shows the percentage of water absorbed at different time intervals.

Table 4.6.1 Water Absorption of Gypsum Plaster

Sample	Replacement Percentage (%)	Water Absorption (%)
1	2%	24.2
2	3%	26.8
3	4%	28.1
4	5%	29.5

V. CONCLUSION

The effect of Prosopis juliflora fibres on the mechanical properties of gypsum based composite was investigated in this paper. Furthermore, the effect of NaOH treatment on fibres and its consequence on the setting time and temperature test were analyzed. The investigations on setting time period proved little or negligible effect on the setting of gypsum plaster and no significant delay on setting time was observed. Moreover the three point flexural tests showed that the addition of 2% natural Prosopis juliflora fibres to the gypsum enhanced the flexural strength and also contributed significantly to the workability of the plaster.

The compressive strength results were slightly reduced with the addition of the fibres when compared to the reference plaster without the addition of fibres. The split tensile test showed negligible increase in the indirect tensile strength of natural fibre reinforced gypsum plaster composites. On the other hand, the water absorption of the fibre increased with increase in the percentage of natural fibres in gypsum plaster which clearly indicates the hydrophilic nature of the natural fibres. Thus from the results obtained from the above experiments it can be concluded

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that the *Prosopis juliflora* fibre subjected to a pre-treatment by 5% NaOH can be effectively used with the gypsum plaster to manufacture gypsum plasterboards with enhanced mechanical features. However due to the water absorption characteristics of natural fibres these natural fibre reinforced gypsum boards are recommended for internal application only.

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