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Experimental Studies on Coconut Fibre and Banana Fibre Reinforced Concrete

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Abstract: This research describes experimental studies on the use of coconut fibre and banana fibre to enhance the strength and applications of concrete. These natural fibres have excellent physical and mechanical properties and can be utilized more effectively. They are economical (zero cost), with no chemicals. The addition of coconut-fibres and banana fibres significantly improved many of the engineering properties of the concrete notably compressive strength, tensile strength and flexural strength. The ability to resist cracking and spalling were also enhanced. Thus it acts as a natural admixture giving additional properties to the ordinary cement concrete. In this context six different percentages of coconut fibres and banana fibres (5%, 10%, 15%, 20%, 25% and 30%) having 40mm length were used. M20 concrete and Ordinary Portland cement of grade 43 was used. The coconut fibre and banana fibre reinforced concrete are tested for compressive strength, splitting tensile strength, flexural strength at different ages.

Keywords: *Fibre Reinforced Concrete, Coconut Fibre, Banana Fibre, Material Properties, Hardened Concrete Properties*

1. Introduction

Even though the market for fibre reinforced concrete is still small compared to the overall production of concrete, the worldwide yearly consumption of fibres used in concrete is 300,000 tons. Concrete containing hydraulic cement, water, aggregate, and discontinuous discrete fibers is called fibre reinforced concrete. Fibres can be in form of coconut fibre, banana fibre, steel fibre, glass fibre, natural fibre , synthetic fibre, etc. The fibres are used to reduce shrinkage cracking. Main role of fibres is to bridge the cracks that develop in concrete and increase the ductility of concrete elements, improvement on post cracking behavior of concrete. It increase more resistance to Impact load, controls plastic shrinkage cracking and drying shrinkage cracking and lowers the permeability of concrete matrix and thus reduce the bleeding of water. The fibre enhances the toughness property of concrete. Toughness is the ability of a material to absorb energy and plastically deform without fracturing. It can also be defined as resistance to fracture of a material when stressed.Disperse fibres offer various advantages of steel bars and wire mesh to reduce shrinkage cracks. The fibres are less sensitive to corrosion than the reinforcing steel bars and the fibres can reduce the labor cost of placing the bars and wire mesh. Coconut and banana fibre reinforced concrete have been used for making roof tiles, corrugated sheets, pipes, silos and tanks. Concrete made with Portland cement has certain characteristics; it is strong in compression but weak in tension and tends to be brittle. The weakness in tension can be overcome by the use of conventional steel bar reinforcement and to some extent by the inclusion of a sufficient volume of certain fibres. The use of fibres also alters the behavior of the fibre-matrix composite after it has cracked, thereby improving its toughness. The objective of this research is to experiment on the use of coconut fibres and banana fibres as an enhancement of concrete.

2. Material Properties

2.1. Cement

Ordinary Portland cement of 43 grades available in local market was used. The specific gravity of cement that was taken was 3.15

Table 1: *Physical Properties of 43 Grade Ordinary Portland cement*

Physical Properties	Values of OPC used	Requirements as per IS 8112-1989
Standard Consistency	29.2%	-
Initial Setting Time	45 Minutes	Minimum of 30 minutes
Final Setting	Time 265 Minutes	Maximum of 600 minutes
Specific gravity	3.15	-
Compressive strength in N/mm2 at 3 days	29	Not less than
Compressive strength in N/mm2 at 7	38.5	Not less than

days		
Compressive strength in N/mm2 at 28 days	48	Not less than

2.2. Fine Aggregate

The sand sieved through 4.75 mm sieve and retain in 600 microns sieve is used having specific gravity of 2.6 and fineness modulus of 2.5 is used.

Table 2: *Physical Properties of Fine Aggregate*

PHYSICAL PROPERTIES	VALUES
Specific gravity	2.6
Fineness modulus	2.83
Water absorption	0.75%
Bulk density(kg/m^3)	1654
Free moisture content	0.1%

2.3. Coarse Aggregate

Locally available coarse aggregate having the maximum size of 20 mm and fineness modulus of 8.75 is used. The specific gravity of coarse aggregate that was taken was 2.6

Table 3: *Physical Properties of Coarse Aggregate*

Physical Properties	Values
Specific gravity	2.6
Fineness Modulus	2.73
Water Absorption (%)	0.5%
Bulk density (kg/m3)	1590
Free moisture content (%)	0.2%
Aggregate Impact value (%)	11.2
Aggregate Crushing value (%)	25.12

2.4. Coconut Fibre

Coconut fibre is extracted from the outer shell of a coconut. Coconut fibre of diameter 1mm, tensile strength of 160 MPa and length of 40mm were used. Density of coconut fibre is 1.4g/cc.

Table 4: *Physical Properties of Coconut Fibre*

PHYSICAL PROPERTIES	VALUE
Length(in inches)	6 to 8
Density(g/cc)	1.40
Tenacity(g/Tex)	10.0
Breaking elongation (%)	30
Diameter(in mm)	0.1 to 150
Rigidity of modulus	1.9dyne/cm^2
Swelling of water(dia)	5%
Moisture at 65% RH	10.5%

Table5: *Chemical Properties of Coconut Fibre*

Chemical Properties	Values (%)
Lignin	45.84
Cellulose	43.44
Hemi cellulose	0.25
Pectin's and related compound	3.00
Water soluble	5.25
Ash	2.22

2.5. Banana Fibre

The banana fibre collected as by-product in agro based industries are dried. Banana fibre of diameter 1mm, and length of 40mm were used. Density of coconut fibre is 1.35g/cc.

Table6: *Physical Properties of Banana Fibre.*

PROPERTIES	VALUE
Width or Diameter(in mm)	80 to 250
Density(g/cc)	1.35
Tenacity(MN/m^2)	529 to 754
Elastic Modulus(GN/m^2)	9 to 16

Table7: *Chemical Properties of Banana Fibre.*

CONSTITUENTS	PERCENTAGE (%)
Cellulose	56
Lignin	17
Extractives	7
Moisture	11
Ashes	9

2.5. Water

Water is an important ingredient of concrete as it actually participates in the chemical reaction with cement. Water cement ratio used in the mix is 0.50%.

3. Experimental Investigation

3.1. Mix Proportions

Concrete mixture design or proportioning involves deciding the amount of cement, water, fine and coarse aggregate in a concrete mixture, to achieve a combination of the desired strength and workability.The procedure for designing concrete mix as per new code is highlighted using an M20 concrete. This mix is designed using Indian standard 10262:2009.

3.2. Hardened Properties of FRC

3.2.1. Compressive Strength Test

In order to find the mechanical properties Compressive strength tests were conducted at 7 days and 28 days of cube (150 X 150 X 150 mm) specimens. For each combination, two specimens were tested.

Figure 1.*Compressive Strength Test*

The following tables show the Compressive strength of FRC with Coconut fibre:

Table8: *Compressive Strength of FRC with Coconut Fibre*

Sl No	% of fibres	7 days compressive strength(N/mm^2)	28 days compressive strength(N/mm^2)
1	0	16.02	24.15
2	5	18.22	25.30
3	10	21.36	32.44
4	15	17.30	23.56
5	20	15.51	18.21
6	25	12.43	16.50
7	30	9.40	13.71

The following graph shows the variation in the Compressive strength of FRC with Coconut Fibre:

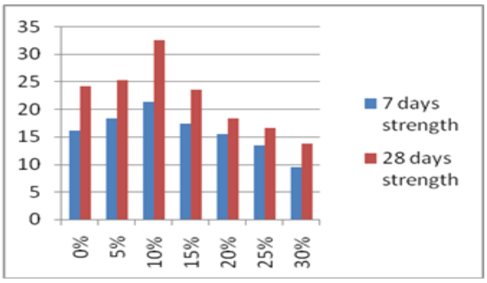

Figure 2.*Chart for Compressive Strength of FRC with Coconut Fibre*

The following tables show the Compressive strength of FRC with Banana fibre:

Table9: *Compressive Strength of FRC with Banana Fibre*

Sl No	% of fibres	7 days compressive strength(N/mm^2)	28 days compressive strength(N/mm^2)
1	0	16.02	24.15
2	5	16.33	24.87
3	10	21.20	25.70
4	15	19.85	21.77
5	20	14.62	16.43
6	25	12.10	14.60
7	30	10.21	11.52

The following graph shows the variation in the Compressive strength of FRC with Banana Fibre:

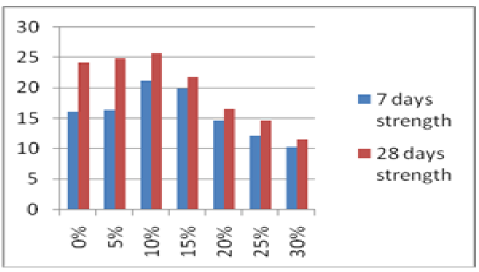

Figure 3.*Chart for Compressive Strength of FRC with Banana Fibre*

3.2.2. Split Tensile Strength Test

In order to find the split tensile strength of concrete 7 days and 28 days of cylinder (150 X 300 mm) specimen are cast. For each combination, two specimens were tested.

Figure 4.*Split Tensile Strength Test*

The following tables show the Split Tensile strength of FRC with Coconut fibre:

Table10: *Split Tensile Strength of FRC with Coconut Fibre*

Sl No	% of fibres	7 days compressive strength(N/mm^2)	28 days compressive strength(N/mm^2)
1	0	1.70	3.57
2	5	2.54	3.88
3	10	3.25	4.24
4	15	2.12	3.25
5	20	1.84	2.40
6	25	1.55	2.12
7	30	1.27	1.69

The following graph shows the variation in the Split Tensile strength of FRC with Coconut Fibre:

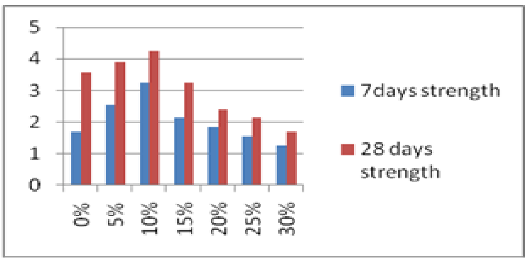

Figure 5.*Chart for Split Tensile Strength of FRC with Coconut Fibre*

The following tables show the Split Tensile strength of FRC with Banana fibre:

Table11: *Split Tensile Strength of FRC with Banana Fibre*

Sl No	% of fibres	7 days compressive strength(N/mm^2)	28 days compressive strength(N/mm^2)
1	0	1.70	3.57

2	5	2.40	3.60
3	10	2.68	3.82
4	15	1.98	3.53
5	20	1.55	2.54
6	25	1.13	2.00
7	30	1.00	1.55

The following graph shows the variation in the Split Tensile strength of FRC with Banana Fibre:

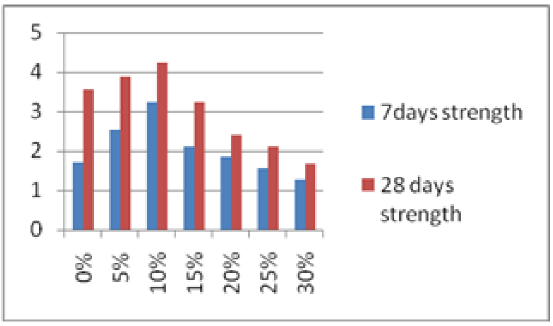

Figure 6.*Chart for Split Tensile Strength of FRC with Banana Fibre*

4. Flexural Strength Test on Beam

As expected, the flexural cracks are initiated in the pure bending zone. As the load increased, existing cracks propagated and new cracks developed along the span. In the case of beams with larger tensile reinforcement ratio some of the flexural cracks in the shear span turned into inclined cracks due to shear effect of shear force. Near peak load the beam deflected significantly, thus loading that the tensile steel must have yielded at failure. The final failure of the beams occurred when the concrete in the compression zone crushed, accompanied by buckling of the compressive steel bars. The failure mode was typical of that an under reinforced concrete beam. The crack pattern and failure mode of several test beams are shown in figures below:

Figure 7.*Initial Crack pattern*

Figure 8.*Flexural cracks at Ultimate Load*

The following tables show the Flexural strength of FRC with Coconut fibre:

Table12: *Flexural Strength of FRC with Coconut Fibre*

Normal Concrete		Coconut Fibre Concrete	
Load (kN)	**Deflection (mm)**	**Load (kN)**	**Deflection (mm)**
0	0	0	0
10	0.18	10	0.15
20	1.33	20	0.52
30	2.52	30	1.48
40	3.25	40	2.68
50	4.02	50	3.45
55	4.55	63	4.25
52	12.3	57	10.4

The following graph shows the variation in the Flexural strength of FRC with Coconut Fibre:

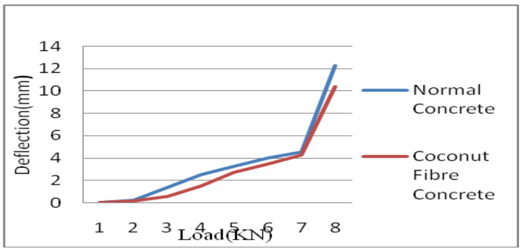

Figure 9.*Chart for Flexural Strength of FRC with Coconut Fibre*

The following tables show the Flexural strength of FRC with Banana fibre:

Table13: *Flexural Strength of FRC with Banana Fibre*

Normal Concrete		Banana Fibre Concrete	
Load (kN)	**Deflection (mm)**	**Load (kN)**	**Deflection (mm)**
0	0	0	0
10	0.18	10	0.32
20	1.33	20	1.59
30	2.52	30	2.77
40	3.25	40	3.56
50	4.02	50	4.35
55	4.55	58	5
52	12.3	55	11.1

The following graph shows the variation in the Flexural strength of FRC with Coconut Fibre:

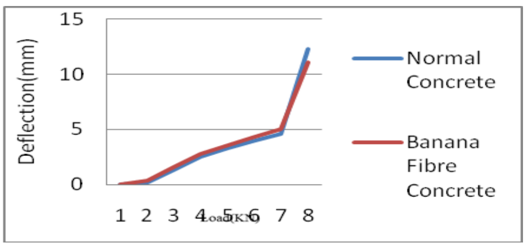

Figure 10.*Chart for Flexural Strength of FRC with Banana Fibre*

5. Conclusion

The findings of experimental investigations on the strength characteristics of concrete enhanced with coconut fibres and banana fibres are reported. The following conclusions can be derived.

The addition of coconut fibres and banana fibres significantly improved many of the engineering properties of the concrete, notably compression, and tensile strength. The ability to resist cracking and spalling also enhanced. However, the addition of fibres poorly affected the compressive strength, as expected, due to difficulties in compaction which consequently led to increase of voids. Despite its excellent properties, coconut fibre and banana fibre as an enhancement of concrete is unlikely to replace steel for the vast majority of structures.

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