Laboratory Investigation on Properties of Concrete on Reinforcing it with Human Hair Natural Fibre

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Abstract - *Basically most of cement based mixtures are likely shrinking which gives rise to micro crakes. Fibre reinforced concrete can offer a convenient, practical and economical method for overcoming micro-cracks and similar type of deficiencies. Generally the fibers are of two types; they are artificial fibers and natural fibers. In the artificial fibers steel, asbestos, glass, carbon, synthetics etc are used and in the natural fibers horse hair, sisal, coir, bamboo, jute, aware, elephant grass, coconut fibers etc are used. And in our investigation human hair is used as a natural fiber. Human hair is strong enough in tension to be used as a fibre reinforcement material. Hair Fibre (HF) is non-degradable matter is available in abundance and at low cost. Due to nano cross-section of hair and its proper tensile strength this project investigates its application to reduce the shrinkage of concrete mixtures. Present studies has been undertaken to study the effect of human hair on plain cement concrete on the basis of its compressive, crushing, flexural strength and cracking control to economise concrete. Experiments were conducted on concrete beams, cubes & cylinders with various percentages of human hair fibre i.e. 0%, 1%, 2%, 3% and 4% by weight of cement. For each combination of proportions of concrete three beam, three cylinders and six cubes are tested for their mechanical properties.*

***Key Words*: Human hair, Natural fibre, Compressive strength, Split tensile strength, Flexure strength**

1. INTRODUCTION

Concrete, basically made of Portland cement, aggregates, and water, is one of the most versatile construction materials. In its present form it has been used partially or completely in many structures for more than one century. Compared to other major construction materials such as steel, polymeric materials, and composites, concrete is the most ecologically friendly, needs the least amount of energy to produce, and can be proportioned to possess high strength. This aim is not only to ensure that the concrete is capable of withstanding compressive stress but that it is durable as well. In other words, the compressive strength of concrete is used not only as a basis of structural design and as a criterion of structural performance, but also as a criterion for the durability of a concrete structure.

Concrete is the most widely used man made construction material in civil engineering world. As the demand for concrete as a construction material increased, the world production of cement has greatly increased since 1990. Almost everybody has heard about the concrete and knows that it is something which is used in construction of structures.

Fibre Reinforced Concrete (FRC) was invented by French gardener Joseph Monier in 1849 and patented in 1867. The concept of using fibres as reinforcement is not new. This can be proved by the following: Fibres have been used as reinforcement since ancient times. Historically, horsehair was used in mortar and straw in mud bricks. In the early 1900s, asbestos fibres were used in concrete, and in the 1950s the concept of composite materials came into being and fibre reinforced concrete was one of the topics of interest. There was a need to find a replacement for the asbestos used in concrete and other building materials once the health risks associated with the substance were discovered. By the 1960s, steel, glass (GFRC), and synthetic fibres such as polypropylene fibres were used in concrete, and research into new fibre reinforced concretes continues today.

Fibre Reinforced Concrete can be defined as a composite material consisting of mixtures of cement, mortar or concrete and discontinuous, discrete, uniformly dispersed suitable fibres. Continuous meshes, woven fabrics and long wires or rods are not considered to be discrete fibres. Fibres include steel fibres, glass fibres, carbon fibres, synthetic fibres, and natural fibres. Fibre is a small piece of reinforcing material possessing certain characteristics properties. The fibre is often described by a convenient parameter called aspect ratio. The aspect ratio of the fibre is the ratio of its length to its diameter. Typical aspect ratio ranges from 30 to 75.

Hairs are used as a fibre reinforcing material in concrete to study its effects on the compressive, crushing, flexural strength and cracking control to economize concrete and to reduce environmental problems created by the decomposition of hair [2].

Fig no. 1. Hair fibre

2. MATERIALS AND METHODOLOGY

2.1. Materials used in tests are as follows:

1. Cement- 53 grade OPC cement
2. Fine Aggregates- Most of which passes through 4.75 mm I.S. sieve and retained on 150 micron.
3. Coarse Aggregates- Most of which passes through 63 mm I.S. sieve and retained on 4.75 mm IS sieve.
4. Water- Fresh potable water
5. Human hair- Human hair with length from 30 mm to 75 mm.

2.2. Mix proportions for 1 m³ M30 concrete:

Cement = 447.72 kg/m³

Water = 197 kg/m³

Fine aggregate = 800.85 kg/m³

Coarse aggregates = 1010.41 kg/m³

Water cement ratio = 0.44

Yield = 2455.98 kg

2.3. Concrete mixes:

In this study, the early age properties of fresh concrete and mechanical performance and tensile strength of hardened concrete were examined. All tests were conducted using the following sample groups:

(1) An ordinary cement paste or concrete,
(2) Pastes or concrete substituted with 1% Hair fibre by mass of cement.
(3) Pastes or concrete substituted with 2% Hair fibre by mass of cement.
(4) Pastes or concrete substituted with 3% Hair fibre by mass of cement.

2.3.1. Batching :

It is preferable to opt for weigh batching for a higher degree of accuracy in experimental work. Water is measured in terms of litres.

2.3.2. Mixing procedure:

The mixing procedures were divided into two stages. The first stage involves mixing the cement with the aggregates for about 5 minutes. At the final stage, dispersing hair fibres uniformly throughout the mix and mixing with spade manually or in laboratory mixer then measured water was added into the concrete mix. This step was crucially important to make sure that the water was distributed evenly so that the concrete will have similar water-binder ratios for every cube. After that, the concrete was then poured into the mould.

2.3.3. Preparing test cubes:

The size of the mould used to produce the cubes was 150 x 150 x 150 mm. six cubes were used for each concrete mix. The concrete was poured into the mould in two layers where each layer was compacted using a 16 mm steel bar. The cubes were removes from the moulds after 24 hours and cured using sacks in room temperature.

2.3.4. Preparing test cylinders:

The size of cylinder used for split tensile strength and durability studies was 150mm diameter and 300mm height. This test was conducted in accordance with IS: 5816-1999. The crude oil was applied along the inner surfaces of the mould for the easy removal of specimens from the mould. Concrete was poured throughout its length and compacted well.

2.3.5. Preparing test beams:

The size of beam used for flexural strength and durability studies was 500 x 100 x 100 mm. The crude oil was applied along the inner surfaces of the mould for the easy removal of specimens from the mould. Concrete was poured throughout its length and compacted well.

2.3.6. Curing:

In this study, the cubes were cured by dipping the specimens in water at 25°C at the end of 24 hours of casting after allowing for air drying.

2.4. Testing on concrete specimens:

2.4.1. Compressive strength test (IS-516-1959):

Concrete cubes of size 150mm×150mm×150mm were cast with and without copper slag. During casting, the cubes were mechanically vibrated using a table vibrator. After 24 hours, the specimens were demoulded and subjected to curing for 28 days in portable water. After curing, the specimens were tested for compressive strength using compression testing machine of 2000KN capacity. The maximum load at failure was taken. The average compressive strength of concrete and mortar specimens was calculated by using the following equation.

$$\text{Compressive Strength (N/mm}^2\text{)} = \frac{\text{Ultimate Compressive Load (KN)}}{\text{Cross Section Area of the Specimen (mm}^2\text{)}}$$

The tests were carried out on a set of triplicate specimens and the average compressive strength values were taken.

Fig no. 2. Compressive strength test on concrete

2.4.2. Split tensile strength test (IS -5816-1999):

Concrete cylinders of size 150 mm diameter and 300mm length were cast with incorporating copper slag as partial replacement of sand and cement. During casting, the cylinders were mechanically vibrated using a table vibrator. After 24 hours, the specimens were demolded and subjected to curing for 28 days in portable water. After curing, the cylindrical specimens were tested for split tensile strength using compression testing machine of 2000kN capacity. The ultimate load was taken and the average split tensile strength was calculated using the equation.

$$\text{Split Tensile Strength}\left(\frac{N}{mm^2}\right) = \frac{2P}{\pi LD}$$

Where,

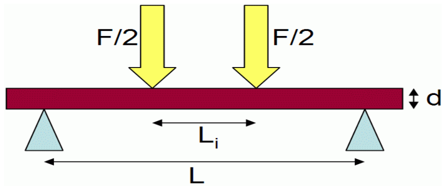
P=Ultimate load at failure (N),
L=Length of cylindrical specimen (mm),
D=Diameter of cylindrical specimen (mm).

The tests were carried out on a set of triplicate specimens and the average tensile strength values were taken.

Fig no. 3. Split tensile strength test on concrete

2.4.3. Flexural strength test (IS-516-1959):

Concrete specimen of size 500mm×100mm×100mm is cast in metal mould. The metal should be of sufficient. Test specimens are stored in water before testing. The bearing surface of support and rollers are wiped, cleared and any loose sand or other material is removed. The specimen is placed in machine shown in fig.



Position of Load on Beam

For the 4 pt bend setup, if the loading span is 1/2 of the support span (i.e. L_i = 1/2 L in Fig.):

$$f_{cr} = P_f L / bd^2$$

- *F* is the load (force) at the fracture point
- *L* is the length of the support (outer) span
- *b* is width
- *d* is thickness

Fig no. 4. Flexural strength test on concrete

2.4.4. Workability measurement:

Following tests are commonly used for measuring workability of concrete:

2.4.4.1. Slump cone test (IS -1199–1959):

Most universally used test, which measures only the consistency of mixtures of concrete with high consistency.

i. The equipment for the slump test is very simple and consists of a tamping rod and a truncated cone, 300 mm height and 100 mm diameter at the top and 200 mm diameter at the bottom.

ii. As shown in the following figure, the cone is filled with concrete in three layers, each layer given 25 number of blows with tamping rod, then cone is slowly lifted.

iii. The unsupported concrete cone slumps down by its own weight.

iv. The decrease in the height of the slumped cone is called the slump of concrete.

2.4.4.2. Flow Test -(IS 1199-1959):

This is a laboratory test, which gives an indication of the quality of concrete with respect to consistency, cohesiveness and the proneness to segregation. In this test, a standard mass of concrete is subjected to jolting. The spread or the flow of the concrete is measured and this flow is related to workability.

i. It can be seen that the apparatus consists of flow table, about 76 cm. in diameter over which concentric circles are marked. A mould made from smooth metal casting in the form of a frustum of a cone is used with the following internal dimensions. The base is 25 cm. in diameter upper surface 17 cm. in diameter and height of the cone is 12 cm. The table top is cleaned of all gritty material and is wetted. The mould is kept on the centre of the table, firmly held and is filled in two layers. Each layer is rodded 25 times with a tamping rod 1.6 cm in diameter and 61 cm long rounded at the lower tamping end. After the top layer is rodded evenly, the excess of concrete which has overflowed the mould is removed.

ii. The mould is lifted vertically upward and the concrete stands on its own without support. The table is then raised and dropped 12.5 mm 15 times in about 15 seconds. The diameter of the spread concrete is measured in about 6 directions to the nearest 5 mm and the average spread is noted. The flow of concrete is the percentage increase in the average diameter of the spread concrete over the base diameter of the mould.

$$\text{Flow, percent} - \frac{\text{Spread diameter in cm} - 25}{25} \times 100$$

iii. The value could range anything from 0 to 150 per cent. A close look at the pattern of spread of concrete can also give a good indication of the characteristics of concrete such as tendency for segregation.

2.4.4.3. Compaction factor test–(IS 1199-1959):

This test attempts to evaluate the compatibility characteristic of a concrete mixture.

i. This test developed in Great Britain, measures the degree of compaction achieved when a concrete mixture is subjected to a standard amount of work

ii. The degree of compaction, called compacting factor, is measured by the density ratio (i.e., the ratio of the density actually achieved in the test to the density of the same concrete when in fully compacted condition.

iii. The apparatus consists essentially of two conical hoppers fitted with doors at the base and placed one above the other, and a 150 x 300 mm cylinder placed below the hoppers.

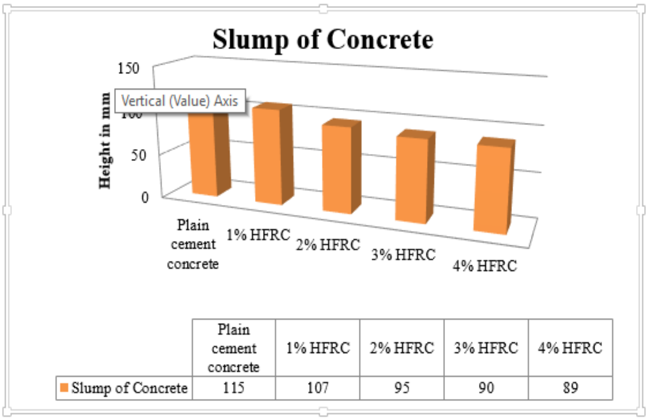
3. OBSERVATIONS & DISCUSSION

3.1. Result of compressive strength test on concrete:

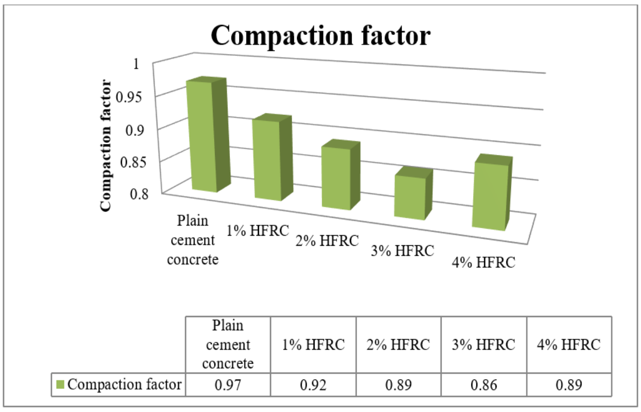
Table No. 1. Workability of individual blend of cement concrete

Sr. No.	Mix Combination	Slump of concrete	Compaction factor	Flow test	Workability
1.	Conventional concrete	115	0.97	92%	High workability
2	1% HFRC	107	0.92	90%	High workability

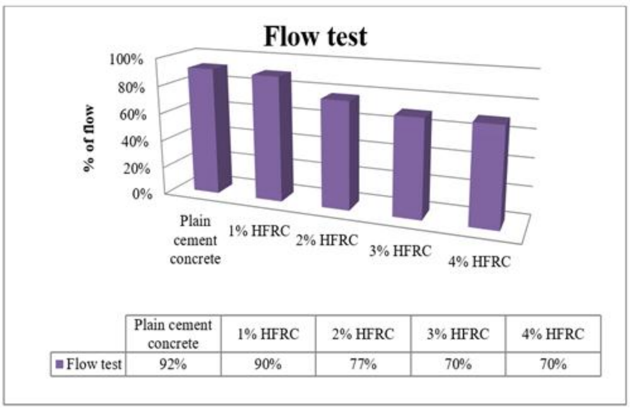
3	2% HFRC	95	0.89	77%	Good workability
4	3% HFRC	90	0.86	70%	Medium workability
5	4% HFRC	89	0.89	70%	Medium workability



Graph No. 2. Graph of slump cone test results



Graph No. 3. Graph of compaction test results



Graph No. 4. Graph of flow test results

3.2. Result of compressive strength test on concrete:

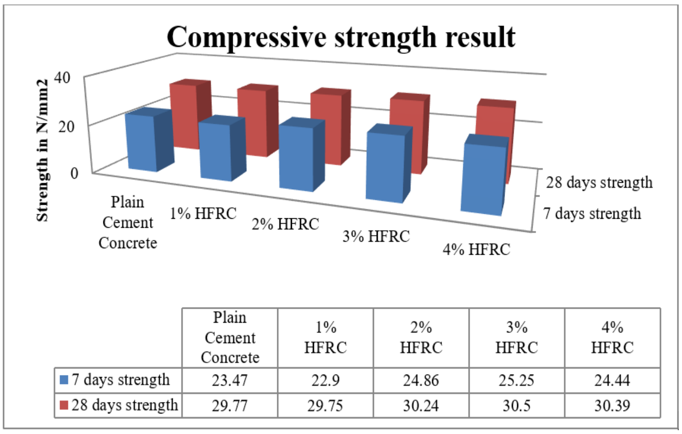
Table 3. Compressive strength of Hair Fibre Reinforced Concrete (7 days)

Sr. no.	Area (mm²)	% of Hair added	7 days strength of cube		
			Load (KN)	Strength (N/mm²)	Avg. Strength (N/mm²)
1	22500	0%	525.90	23.37	23.47
2			523.10	23.24	
3			536.10	23.82	
4	22500	1%	535.72	23.80	22.9
5			498.86	22.17	
6			511.46	22.73	
7	22500	2%	589.37	26.19	24.86
8			557.59	24.75	
9			531.64	23.62	
10	22500	3%	575.23	25.56	25.25
11			576.93	25.64	
12			552.66	24.56	
13	22500	4%	519.28	23.07	24.44
14			562.07	24.98	
15			569.13	25.29	

Table 4. Compressive strength of Hair Fibre Reinforced Concrete (28 days)

Sr. no.	Area (mm²)	% of Hair added	28 days strength of cube		
			Load (KN)	Strength (N/mm²)	Avg. Strength (N/mm²)
1	22500	0%	654.39	29.084	29.77
2			685.20	30.45	
3			661.10	29.38	
4	22500	1%	672.10	29.87	29.75
5			681.19	30.27	
6			655.28	29.12	
7	22500	2%	690.07	30.66	30.24
8			668.54	29.71	
9			683.49	30.37	
10	22500	3%	671.87	29.86	30.50
11			682.22	30.32	
12			705.29	31.34	
13	22500	4%	693.23	23.07	30.39
14			679.39	24.98	
15			578.73	25.29	

3.2.1. Graph and discussion on compressive strength on concrete:



Graph No. 5. Graph of compressive strength result

Discussions:

As shown in graph,

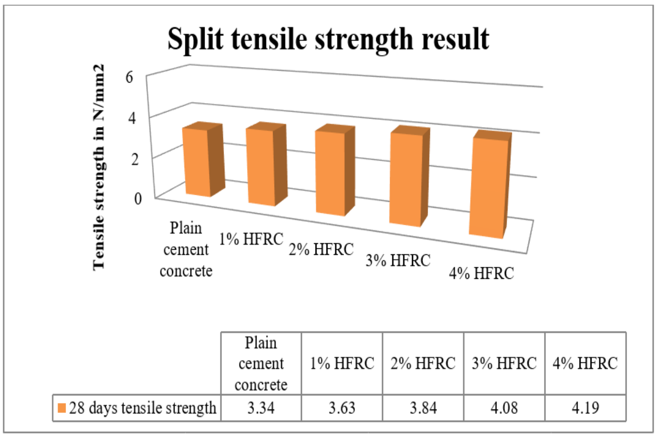
- As days increase the strength is achieved by the concrete because hydration process is going on.
- After 7 days it achieves nearly about 70% strength of designed strength.
- After 28 days it achieves full strength of designed strength.
- After 7 days, strength of HFRC has increased slightly as compared to Plain Cement Concrete.
- After 28 days, strength of HFRC has increased only 2.45% as compared to Plain Cement Concrete.

3.3. Result of split tensile strength test on concrete:

Table 5. Tensile strength of plain Concrete (28 days)

Sr. no.	% of Hair added	28 days strength on cylinder		
		Load (KN)	Strength (N/mm^2)	Avg. Strength (N/mm^2)
1	0%	236.65	3.347	3.34
2		242.89	3.436	
3		229.23	3.24	
4	1%	259.22	3.66	3.63
5		262.13	3.70	
6		249.93	3.53	
7	2%	271.48	3.84	3.84
8		268.67	3.80	
9		275.87	3.90	
10	3%	290.51	4.10	4.08
11		292.63	4.13	
12		285.42	4.03	
13	4%	310.16	4.38	4.19
14		286.32	4.05	
15		293.98	4.15	

3.3.1 Graph and discussion on compressive strength on concrete:



Graph No. 6. Graph of tensile strength result

Discussions:

As shown in graph,

- As hair content is increased, the tensile strength of concrete increases gradually.
- On addition of 1% hair to concrete, 8.68% increase in tensile strength is observed as compared to plain cement concrete.
- On addition of 2% hair to concrete, 14.97% increase in tensile strength is observed as compared to plain cement concrete.
- On addition of 3% hair to concrete, 22.15% increase in tensile strength is observed as compared to plain cement concrete.
- On further addition of hair content beyond 3%, a very slight increase in tensile strength is observed.
- On addition of 4% hair to concrete, 25.44% increase in tensile strength is observed as compared to plain cement concrete.
- Total increase of 0.85 N/mm^2 in tensile strength is observed.

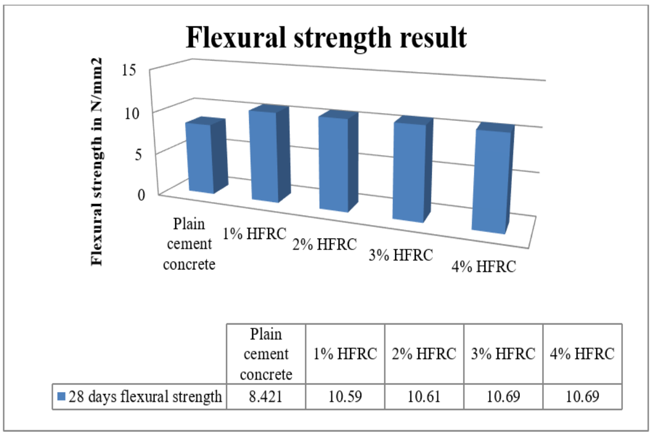
3.4. Result of flexural strength test on concrete:

Table 6. Flexural strength of plain Concrete (28 days)

Sr. no.	% of Hair added	28 days strength on cylinder		
		Load (KN)	Strength (N/mm^2)	Avg. Strength (N/mm^2)
1	0%	22.14	11.07	8.421
2		10.55	5.275	
3		17.85	8.92	
4	1%	21.15	10.57	10.59
5		22.55	11.27	
6		19.90	9.95	
7		20.65	10.32	

8	2%	20.45	10.22	10.61
9		22.60	11.3	
10	3%	22.5	11.25	10.69
11		20.7	10.35	
12		20.9	10.49	
13	4%	22.45	11.22	10.69
14		22.50	11.25	
15		19.25	9.625	

3.4.1 Graph and discussion on compressive strength on concrete:



Graph No. 7. Graph of flexural strength result

Discussions:

As shown in graph,

- As hair content is increased, the flexural strength of concrete is increased.
- On addition of 1% hair to concrete, 25.75% increase in flexural strength is observed as compared to plain cement concrete.
- On addition of 2% hair to concrete, 25.99% increase in flexural strength is observed as compared to plain cement concrete.
- On addition of 3% hair to concrete, 26.94% increase in flexural strength is observed as compared to plain cement concrete.
- On addition of 4% hair to concrete, 26.94% increase in flexural strength is observed as compared to plain cement concrete.
- Total increase of 2.26 N/mm^2 in flexural strength is observed.
- Not much exceptional increase in flexural strength is observed after adding hair beyond 1%.

4. CONCLUSIONS

According to the test performed it is observed that there is remarkable increment in properties of concrete according to the percentages of hairs by weight of in concrete.

1. From workability test, it is observed that workability of hair fibre reinforced concrete goes on decreasing with addition of hair to the concrete.

2. When M-30 concrete with 1% hair is compared with the plain cement concrete, it is found that there is an increase of 2.45% in compressive strength and which is not much remarkable.

3. As hair content is increased, the tensile strength of concrete increases gradually. On addition of 1% hair to concrete, 8.68% increase in tensile strength is observed as compared to plain cement concrete. On addition of 2% hair to concrete, 14.97% increase in tensile strength is observed as compared to plain cement concrete. On addition of 3% hair to concrete, 22.15% increase in tensile strength is observed as compared to plain cement concrete. On further addition of hair content beyond 3%, a very slight increase in tensile strength is observed. On addition of 4% hair to concrete, 25.44% increase in tensile strength is observed as compared to plain cement concrete. Total increase of 0.85 N/mm^2 in tensile strength is observed.

4. As hair content is increased, the flexural strength of concrete is increased. On addition of 1% hair to concrete, 25.75% increase in flexural strength is observed as compared to plain cement concrete. On addition of 2% hair to concrete, 25.99% increase in flexural strength is observed as compared to plain cement concrete. On addition of 3% hair to concrete, 26.94% increase in flexural strength is observed as compared to plain cement concrete. On addition of 4% hair to concrete, 26.94% increase in flexural strength is observed as compared to plain cement concrete. Total increase of 2.26 N/mm^2 in flexural strength is observed. Not much exceptional increase in flexural strength is observed after adding hair beyond 1%.

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