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Hair Fibre Reinforced Concrete

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Abstract: Fibre reinforced concrete offers a practical and economical method for overcoming micro-cracks and similar type of deficiencies. Fibres are usually used in concrete to control plastic shrinkage and dry shrinkage cracking and also to lower the permeability of concrete. It also reduces greater impact, abrasions and shatter resistances in concrete. It is an effective method of construction of light weight seismic resistant structures. Since concrete is weak in tension hence some measures must be adopted to overcome this deficiency. Human hair is strong in tension; hence it can be used as a fibre reinforcement material. Hair Fibre (HF), an alternate non-degradable matter, is available in abundance and at a very cheap cost. It also creates environmental problem for its decompositions. Present studies has been undertaken to study the effect of human hair on plain cement concrete on the basis of compressive, crushing, flexural strength and cracking control to economize concrete and to reduce environmental problems. Experiments were conducted on concrete cubes with various percentages of human hair fibre i.e. 0%, 1.5% and 2% by weight of cement. Also, very fine hair fibres can be used for the partial replacement of cement in concrete. For each combination of proportions of concrete three cubes are tested for their mechanical properties. By testing we found that there is an increment in the various properties and strength of concrete by the addition of human hair as fibre reinforcement which makes it suitable for an alternative additive for concrete to enhance its mechanical properties.

Index terms: fibre reinforced concrete; hair fibre; compressive strength; flexural strength

1. FIBRE REINFORCED CONCRETE

Fibre-reinforced concrete (FRC) is concrete containing fibrous material which increases its structural integrity. It contains short discrete fibres that are uniformly distributed and randomly oriented. Fibres include steel fibres, glass fibres, synthetic fibres and natural fibres – each of which lends varying properties to the concrete. In addition, the character of fibre-reinforced concrete changes with varying concretes, fibre materials, geometries, distribution, orientation, and densities. Fibres are usually used in concrete to control cracking due to plastic shrinkage and to drying shrinkage. They also reduce the permeability of concrete and thus reduce bleeding of water. Some types of fibres produce greater impact–, abrasion–, and shatter–resistance in concrete.

1.1. *Advantages of fibre reinforced concrete*

(1) FRC is used in civil structures where corrosion is to be avoided at the maximum.
(2) FRC is better suited to minimize cavitations /erosion damage in structures where high velocity flows are encountered.
(3) A substantial weight saving can be realized using relatively thin FRC sections having the equivalent strength of thicker plain concrete sections.
(4) When used in ridges it helps to avoid catastrophic failures. In quake prone areas the use of fibre reinforced concrete would certainly minimize the human casualties.
(5) Fibre reduces internal forces by locking microscopic cracks from forming within the concrete.
(6) Studies have been proven that fibre reinforced concrete is found to improve the following mechanical properties of ordinary concrete: Compressive Strength, Modulus of Elasticity and flexural strength, Toughness, Splitting Tensile Strength, Fatigue Strength, and Impact Resistance.

1.2. *Disadvantages*

The fibres have to be uniformly mixed and spread throughout the concrete mix. At times, this is found to be a difficult process and time consuming. If this limitation has been overcome by new and effective methods of fabrication, fibre reinforced concrete is found to be more adaptable for common concreting works.

1.3. ***Why hair is used as a fibre?***

Human hair is considered as a waste material in most parts of the world and is a common constituent found in municipal waste streams which cause enormous environmental problems. This particular topic has been first chosen as a method of finding the possibilities of hair rather than considering it as a non bio degradable waste material. It is also available in abundance and at a very low cost. It reinforces the mortar and prevents the spalling of concrete. The properties like high tensile strength, unique chemical composition, thermal insulation etc makes it suitable to be used as a reinforcing material.

2. PREPARATION OF SPECIMEN

2.1. ***Collection of materials required***

The materials required for the preparation of concrete cube specimens are given in table 1

Table1. Details of necessary materials required

MIX PROPORTION	M15	M20	M25
Quantity of cement (kg)	3.82	4.86	6.68
Quantity of sand (kg)	7.64	7.29	6.68
Quantity of coarse aggregate (kg)	15.27	14.58	13.36
Water cement ratio	0.48	0.5	0.55
Quantity of water (l)	1.834	2.43	3.67
Quantity of hair (kg) (1.5%)	0.0573	0.073	0.1
Quantity of hair (kg) (2.0%)	0.0764	0.097	0.134

2.2. ***Treatment of hair fibre***

The hair needed for the preparation of concrete cubes was collected from salons and beauty parlours. It needs treatment before to be added in the concrete specimens. It is carried out as in the following steps:

- Separating hair from other waste: Depending on the source, the collected hair may contain wastes. This has to be removed.
- Washing*:* After sorting, the hair is washed with acetone to remove impurities.
- Drying: The hair is then dried under sun or in oven. After drying, the hair can be stored without any concern for decay or odor.
- Sorting*:* The hair is then sorted according to length, color, and quality. The hair fibres are checked at random for its length and diameter.

3. METHODOLOGY

3.1. ***Compressive strength Test***

The following tests are conducted on concrete specimens to analyse its mechanical properties like compressive strength, flexural strength etc.

i. Compressive Strength test
ii. Flexural Strength test

3.1.1. *Compressive strength test (on cubes):*

The compressive strength of concrete is its ability to resist a crushing force. It is the ratio of load at failure to surface area of concrete specimen. Compressive strength test is the most common test conducted on hardened concrete as it is an easy test to perform and also most of the desirable characteristic properties of concrete are qualitatively related to its compressive strength. The compression test is carried out on specimens cubical in shape of the size 150 × 150 × 150 mm. The test is carried out in the following steps: First of all the mould preferably of cast iron, is used to prepare the specimen of size 150 × 150 × 150 mm. Calculated quantity of hair fibre is evenly added into the concrete mix manually. During the placing of concrete in the moulds it is compacted with the tamping bar with not less than 25 strokes per layer. After 24 hours the specimens are removed from the moulds and immediately submerged in clean fresh water. After 28 days the specimens are tested under the load in a compression testing machine. The load is applied uniformly at the rate of 14 N/mm^2 in the compression testing machine. The specimen for the test is made in the following manner: Three cubes are made for each M15, M2O and M25 with 0%, 1.5% and 2% hair by weight of cement.

The results from the compression test are in the form of the maximum load the cube can carry before it ultimately fails. The compressive strength can be found by dividing the maximum load by the contact area of the test specimen.

Let, P = maximum load carried by the cube before the failure

A = contact area normal to the load = 150 × 150 mm^2 = 22500 mm

σ = maximum compressive stress (N/mm^2), equals to the compressive strength.

Therefore, $\sigma = \frac{P}{A}$ N/mm^2 …. (1)

The results of compressive strength test and the corresponding compressive strength of the cube specimens are shown in table 2.

Table2. Compressive strength test results of cubes

Sl No.	**Mix Design**	**Date Of Casting**	**Tested On**	**Avg. Compressive strength(N/mm^2)**
1	M15 : without hair	2-3-2015	30-3-2015	16.89
	1.5% hair	10-3-2015	7-4-2015	18.33
	2% hair	12-3-2015	9-4-2015	18.88
2	M20 : without hair	19-1-2015	16-2-2015	20.587
	1.5% hair	13-3-2015	10-4-2015	20.77
	2% hair	13-3-2015	10-4-2015	21.885
3	M25 : without hair	3-3-2015	31-3-2015	24.995
	1.5% hair	19-3-2015	16-4-2015	25.215
	2% hair	19-3-2015	16-4-2015	26.105

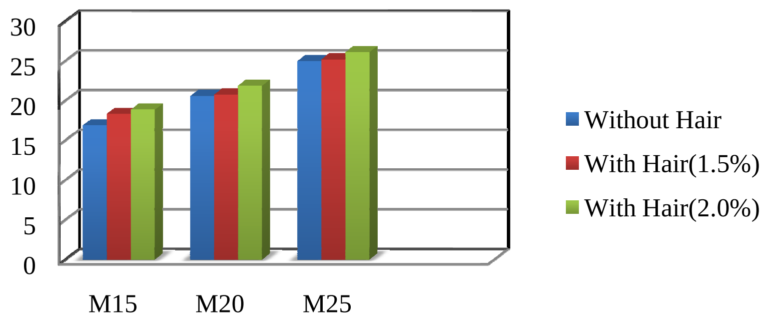

Fig.1. Comparison on the basis of maximum load carried with varying percentages of hair fibre

When M15 concrete with 1.5% hair is compared with the plain cement concrete, it is found that there is an increase of 8.5% in compressive strength and when M15 concrete with 2% hair is compared with the plain cement concrete, it is found that there is an increase of 12% in compressive strength. When M20 concrete with 1.5% hair is compared with the plain cement concrete, it is found that there is an increase of 1% in compressive strength and when M20 concrete with 2% hair is compared with the plain cement concrete, it is found that there is an increase of 6.3% in compressive strength. When M25 concrete with 1.5% hair is compared with the plain cement concrete, it is found that there is an increase of 1% in compressive strength and when M25 concrete with 2% hair is compared with the plain cement concrete, it is found that there is an increase of 4.44% in compressive strength.

3.1.2. *Compressive strength test (on cylinders):*

Compressive strength of cylinders is always less than that of cubes due to the following reasons: contact area of a cube with the upper platen in the testing machine is more which results in more confinement and it offers resistance to specimen against expansion resulting in more compressive strength. Studies have proven that there exists a ratio between the compressive strengths of cylinders to that of cubes and in normal case it ranges between 0.8-0.9. By taking this ratio to be 0.8, the compressive strength of cylinders can be roughly calculated as shown below:

Table3. Compressive strength of cylinders

Sl. No.	**Mix ratio**	**Average Compressive strength of cube(N/mm^2)**	**Average Compressive strength of cylinder(N/mm^2)**
1	M15: without hair	16.89	13.512
2	1.5% hair	18.33	14.664
3	2% hair	18.88	15.104
4	M20: without hair	20.587	16.47
5	1.5% hair	20.77	16.62
6	2% hair	21.885	17.508
7	M25:without hair	24.995	19.996
8	1.5% hair	25.215	20.172
9	2% hair	26.105	20.884

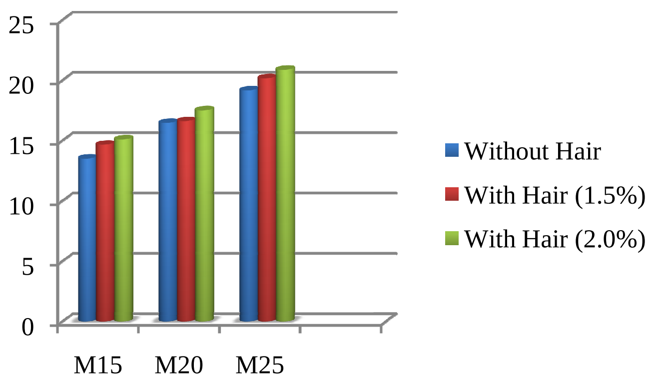

Fig.2. Comparison on the basis of maximum load carried with varying percentages of hair fibre

Compressive strength of cylinders also shows a remarkable improvement justifying the addition of hair into the concrete mix for enhancing the mechanical properties.

3.2. *Flexural strength test*

A flexural test is the most common procedure used to measure the tensile strength of concrete. Although concrete is not designed to resist direct tension, the knowledge of tensile strength is of importance in estimating the load under which cracking develop. The test is very useful especially in relation to the design of road slabs and runways because the flexure tension is a critical factor in these cases.

The system of loading used in finding out the flexural tension is Third-point Loading Method. In this method the critical crack may appear at any section, where the bending moment is maximum. The test is carried out in the following steps: First of all the mould preferably of cast iron, is used to prepare the specimen of size 150 × 150 × 700 mm. During the placing of concrete in the mould it is compacted with the tamping bar with not less than 25 strokes per layer. After 24 hours the specimens are removed from the moulds and immediately submerged in clean fresh water. After curing, place the specimen in the machine in such a manner that the load is applied to the uppermost surface along two lines spaced at a proper gauge length, at specified rate. Increase the load till the specimen fails. Note the appearances of the fractured faces of concrete.

Table4. Flexural strength of cubes

Sl. No.	**Mix ratio**	**Average Compressive strength of cube(N/mm^2)**	**Average flexural strength of cube(N/mm^2)**
1	M15: without hair	16.89	2.877
2	1.5% hair	18.33	2.997
3	2% hair	18.88	3.04
4	M20: without hair	20.587	3.176
5	1.5% hair	20.77	3.19
6	2% hair	21.885	3.275
7	M25:without hair	24.995	3.4996
8	1.5% hair	25.215	3.515
9	2% hair	26.105	3.5765

When M15 concrete with 1.5% hair is compared with the plain cement concrete, it is found that there is an increase of 4% in flexural strength and when M15 concrete with 2% hair is compared with the plain cement concrete, it is found that there is an increase of 5% in flexural strength. When M20 concrete with 1.5% hair is compared with the plain cement concrete, it is found that there is not any appreciable increase in flexural strength and when M20 concrete with 2% hair is compared with the plain cement concrete, it is found that there is an increase of 3% in flexural strength. When M25 concrete with 1.5% hair is compared with the plain cement concrete, it is found that there is not any appreciable increase in flexural strength and when M25 concrete with 2% hair is compared with the plain cement concrete, it is found that there is an increase of 2% in flexural strength.

4. REDUCTION IN CRACK FORMATION

According to Grimm, 1988, a crack may be defined as a "break, split, fracture, fissure, separation, cleavage or elongated narrow opening visible to the normal human eye and extending from the surface and into a masonry unit, mortar joint, interface between a masonry unit and adjacent mortar joint". The cracks are classified according to its damage level for load bearing masonry. In order to repair cracks up to a width of 5mm, either cement grouting can be used or steel wire meshes can be inserted into the cracks. But it is found that when fibre reinforced concrete is used, crack formation and propagation is very much reduced since fibres can form a strong bond with the concrete mix and can bridge the cracks to some extent.

Examining the concrete specimens after the tests, it is found that cracks were considerably reduced in specimens with hair fibre when compared with concrete specimens without hair fibre content.

Fig.3. Hair Fibre Reinforced concrete cube with fewer cracks after compression test

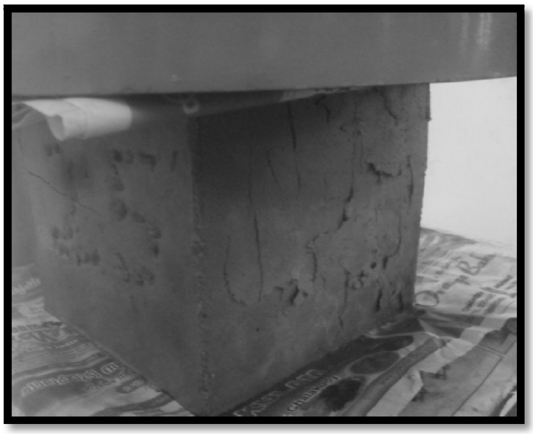

Fig.4. Ordinary concrete cube with more cracks after compression test

5. 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 cement in concrete. There was an overall increase of 1-12% in the compressive strength of concrete and up to 5% in the flexural strength of concrete test specimens by the addition of hair fibres in different quantities.
- It is well observed that the maximum increase is noticed in the addition of 2% hair fibre, by weight of concrete, in all the mixes.
- It is to be noted that maximum increase in the compressive strength is observed for lower concrete mixes, making the hair fibre reinforced concrete best suitable to use in the applications with those concrete mixes.
- Crack formation and propagation are very much reduced showing that FRC can have its applications in seismic resistant constructions.

5.1. *Future scope*:

- During our research work we also faced the problem of uniform distribution of hair in the concrete. So an efficient method of mixing of hair fibre to the concrete mix is to be found out.
- A wide study on partial replacement of cement using fine hair fibre is to be carried out.
- Applications of hair fibre reinforced concrete in the construction of seismic resistant structures.
- The distribution matrix of hair in concrete since the resultant matrix could affect the properties.
- The study of admixtures and super plasticizer which could distribute the hairs without affecting the properties of concrete.
- The use of animal hairs in concrete.
- The research can be further extended to study the influence of hair fibre on other properties of composites such physical, thermal properties and appearances.

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REFERENCES

[1] Jain D. and Kothari A: Hair Fibre Reinforced Concrete. Research Journal of Recent Sciences Vol. 1(ISC -2011), 128-133(2012)

[2] Tomas U and Ganiron Jr.: Effect of human hair additives in compressive strength of asphalt Cement mixture. Iranica Journal of Energy & Environment 4 (1) Special Issue on Nanotechnology: 68-72, 2013

[3] Yadollah Batebi, Alireza Mirzagoltabar, Seyed Mostafa Shabanian and Sara Fateri: Experimental investigation of shrinkage of nano hair fibre reinforced concrete. Middle-East Journal of Scientific Research 18 (12): 1738-1744, 2013

[4] Popescu C. and Hocker H. (2007): Hair the most sophisticated biological composite material. Chemical Society Reviews 37(8), pp.1282–1291

[5] Shakeel Ahmad, Farrukh Ghani, J. N Akhthar and M. Hasan (2009): Use Of Waste Human Hair As Fibre Reinforcement In Concrete. Proceeding, international symposium on innovation and sustainability of structures in civil engineering, ISISS, 2009, held at Guangzhou, China (Paper No. 341) November 28-30

[6] M. S. Shetty: concrete technology (Theory and practise)

APPENDIX

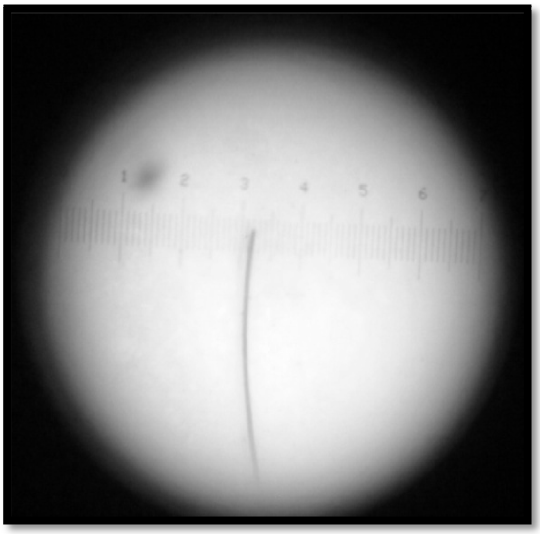

Fig.5. Selection of hair by measuring length and diameter through microscope

Fig.6. Cleaning hair using acetone

Fig.7. Drying of hair

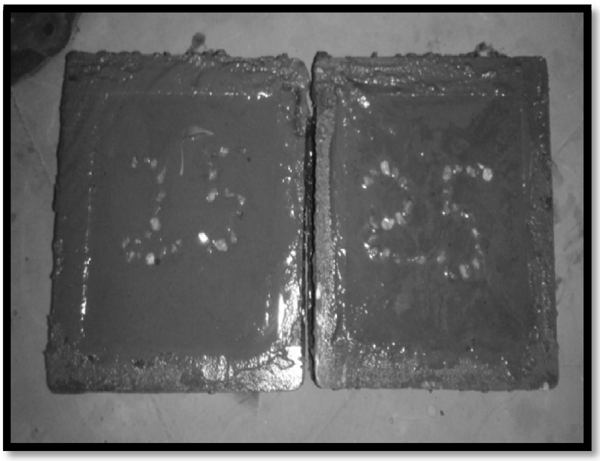

Fig.8. Concrete cube specimens after casting

Fig.9. Concrete specimens put for curing