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Hair Fibre Reinforced Concrete

Jain D. and Kothari A.
Sanghvi Institute of Management and Science, Indore, MP, INDIA

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Abstract

Fibre reinforced concrete can offer a convenient, practical and economical method for overcoming micro-cracks and similar type of deficiencies. 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 its compressive, crushing, flexural strength and cracking control to economise concrete and to reduce environmental problems. Experiments were conducted on concrete beams and cubes with various percentages of human hair fibre i.e. 0%, 1%, 1.5%, 2%, 2.5% and 3% by weight of cement. For each combination of proportions of concrete one beam and three cubes are tested for their mechanical properties. By testing of cubes and beams we found that there is an increment in the various properties and strength of concrete by the addition of human hair as fibre reinforcement.

Keywords: Fibre reinforced concrete, hair fibre, compressive strength, flexural strength, third-point loading method.

Introduction

Almost everybody has heard about the concrete and knows that it is something which is used in construction of structures. And also very few of us have heard about the fibre reinforced concrete. But what exactly is it?

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, 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 150.

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

Advantages of fibre reinforced concrete: Fibre reinforced concrete has started finding its place in many areas of civil infrastructure applications especially where the need for repairing, increased durability arises. FRC is used in civil structures where corrosion is to be avoided at the maximum. Fibre reinforced concrete is better suited to minimize cavitation /erosion damage in structures such as sluice-ways, navigational locks and bridge piers where high velocity flows are encountered. A substantial weight saving can be realized using relatively thin FRC sections having the equivalent strength of thicker plain concrete sections. When used in bridges it helps to avoid catastrophic failures. In the quake prone areas the use of fibre reinforced concrete would certainly minimize the human casualties. Fibres reduce internal forces by blocking microscopic cracks from forming within the concrete.

Disadvantages of fibre Reinforced Concrete: The main disadvantage associated with the fibre reinforced concrete is fabrication. The process of incorporating fibres into the cement matrix is labour intensive and costlier than the production of the plain concrete. The real advantages gained by the use of FRC overrides this disadvantage.

Why Fibres are used in Concrete? Fibres are usually used in concrete for the following reasons: i. To control cracking due to both plastic shrinkage and drying shrinkage. ii. They also reduce the permeability of concrete and thus reduce bleeding of water. iii. Some types of fibres also produce greater impact, abrasion and shatter resistance in concrete. iv. The fineness of the fibres allows them to reinforce the mortar fraction of the concrete, delaying crack formation and propagation. This fineness also inhibits bleeding in the concrete, thereby reducing permeability and improving the surface characteristics of the hardened surface.

Main Properties of Fibre in FRC: Type of fibres used, Volume percent of fibre (v_f =0.1 to 3%), Aspect ratio (the length of a fibre divided by its diameter), Orientation and distribution of the fibres in the matrix, It prevents spalling of concrete, Shape, dimension and length of fibre is important, Strength of the fibre.

Why Hair as a Fibre? Hair is used as a fibre reinforcing material in concrete for the following reasons: i. It has a high tensile strength which is equal to that of a copper wire with similar diameter. ii. Hair, a non-degradable matter is creating an environmental problem so its use as a fibre reinforcing material can minimize the problem. iii. It is also available in abundance and at a very low cost. iv. It reinforces the mortar and prevents it from spalling.

Methodology

The methodology adopted to test the mechanical properties and strength of hair reinforced concrete is governed by: i. Compressive Strength, ii. Flexural Strength

Various cubes and beams are tested and analysed for finding the effect of using hair as fibre reinforcement.

Test Performed: For determining the effect of hair as fibre in concrete following tests were performed: i. Compression test: It 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 as shown in figure 1 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. During the placing of concrete in the moulds it is compacted with the tamping bar with not less than 35 strokes per layer. Then these moulds are placed on the vibrating table and are compacted until the specified condition is attained. 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. ii. Flexural Strength test: Direct measurement of the tensile strength of concrete is difficult. Neither specimens nor testing apparatus have been designed which assure uniform distribution of the pull applied to the concrete. The value of the extreme fibre stress in bending depends on the dimensions of the beam and manner of loading. The system of loading used in finding out the flexural tension is Third-point Loading Method as shown in fig 3. In this method the critical crack may appear at any section, not strong enough to resist the stress within the middle third, 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 as shown in figure 4. During the placing of concrete in the mould it is compacted with the tamping bar weighing 2 kg, 400 mm long with not less than 35 strokes per layer. Then this mould is placed on the vibrating table and is compacted until the specified condition is attained. After 24 hours the specimen is removed from the mould and immediately submerged in clean fresh water. After 28 days the specimen is taken out from the curing tank and placed on the rollers of the flexural testing machine as shown in figure 5 for testing as shown in figure 3. Then the load is applied at a constant rate of 400 kg/min. The load is applied until the specimen fails, and the maximum load applied to the specimen during the test is recorded.

The specimen for both the test is made in the following manner: i. Compression test: Three cubes are made for each M-15, M-2O and M-25 with 0%, 1%, 1.5%, 2%, 2.5% and 3% hair by weight of cement. ii. Flexural Strength test: One beam is made for each M-15, M-2O and M-25 with 0%, 1%, 1.5%, 2%, 2.5% and 3% hair by weight of cement.

Analysis of Data collected: The analysis of data collected is done in the following manner: i. Compression test: The results from the compression test are in the form of the maximum load the cube can carry before it ultimately fails. The compressive stress can be found by dividing the maximum load by the area normal to it. The results of compression test and the corresponding compressive stress is shown in table 1.
Let,
P = maximum load carried by the cube before the failure
A = area normal to the load = 150 × 150 mm^2 = 22500 mm^2
σ = maximum compressive stress (N/mm^2)
Therefore,

$$\sigma = \frac{P}{A} \quad N/mm^2$$

Flexural Strength test: The results from the flexural strength test are in the form of the maximum load due to which a beam fails under bending compression. Using the fundamental equation of bending we can find the bending stresses as per figure 6. The results of flexural strength test and its corresponding bending stress is shown in table 2.

We know that,

$$\frac{M}{I} = \frac{\sigma_b}{y}$$

Where,

M = Moment of Resistance, **I** = Moment of Inertia about neutral axis, $\boldsymbol{\sigma_b}$ = Bending stress, **y** = Extreme fibre distance from neutral axis, **W** = Maximum load at which beam fails, **b** = width of the beam, **d** = depth of the beam, Now, the above equation can be written as

$$\sigma_b = M \times \frac{y}{I}$$

Now, from the fig 6. We get,

$$\sigma_b = \left(\frac{W}{2} \times \frac{l}{2} - \frac{W}{2} \times \frac{l}{4}\right) * \frac{\frac{d}{2}}{\frac{bd^3}{12}}$$

$$\sigma_b = \frac{3Wl}{4bd^2}$$

Figure-1
Cube Specimen

Figure2
Compression testing machine

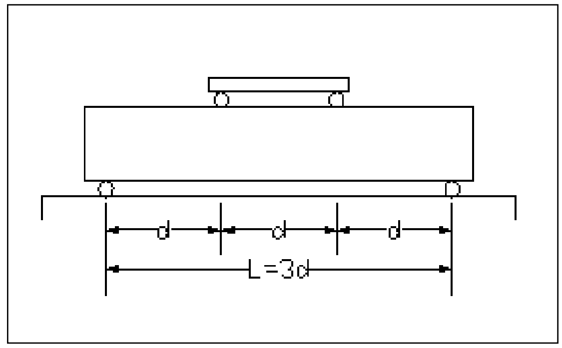


Figure-3
Third-Point Loading method

Figure-4
Beam specimen

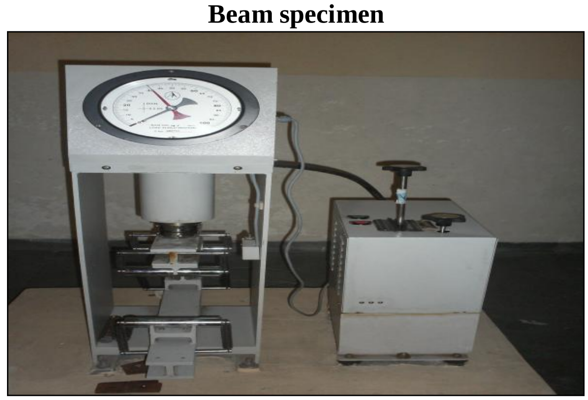


Figure-5
Flexural testing machine

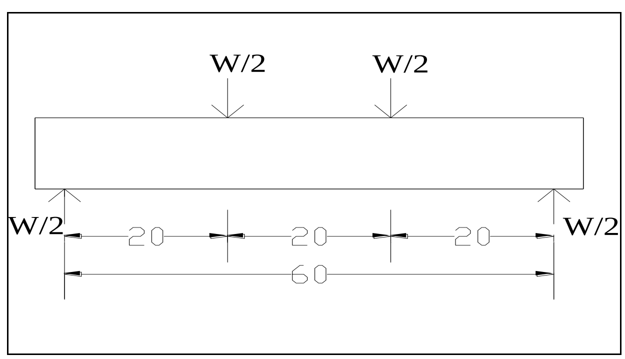


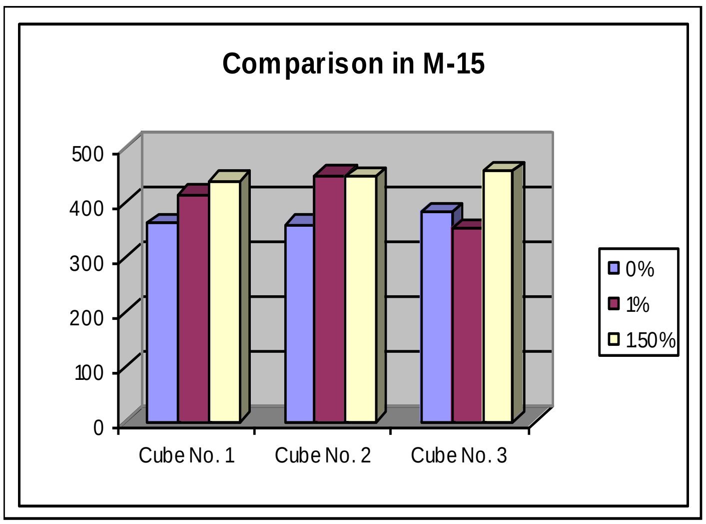
Figure-6
Loading pattern on beam

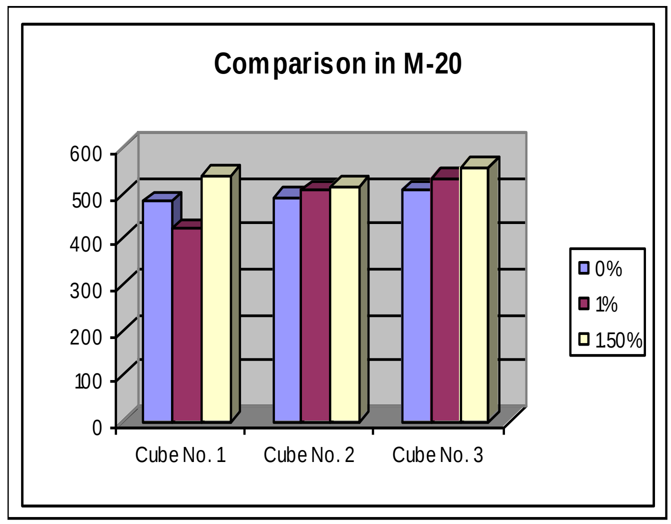
Results and Discussion

The results are briefly tabulated and are shown in table 1 and table 2. Table 1 shows the results of the test performed on cubes for compressive strength with the various proportions of concrete varying percentages of hair fibre by the weight of cement.

Table-1
Results obtained from compression test and the corresponding compressive stress

S. No	Mix	% hair	Maximum Load Recorded (KN)			Compressive stress (N/mm^2)		
			Cube No. 1	Cube No. 2	Cube No. 3	Cube No. 1	Cube No. 2	Cube No. 3
1	M-15	0%	362.5	359.8	381.2	16.11	15.99	16.94
2	M-20	0%	485.3	492.4	507.4	21.57	21.88	22.55
3	M-25	0%	567.9	566.3	570	25.24	25.17	25.33
4	M-15	1%	415.8	449.8	351.3	18.48	19.99	15.61
5	M-20	1%	423.2	506.7	534	18.81	22.52	23.73
6	M-25	1%	601.2	599.5	581.6	26.72	26.64	25.85
7	M-15	1.50%	440.5	448.1	459.6	19.58	19.92	20.43
8	M-20	1.50%	540.2	515.8	559.1	24.01	22.92	24.85
9	M-25	1.50%	623.8	652.2	617.7	27.72	28.98	27.45





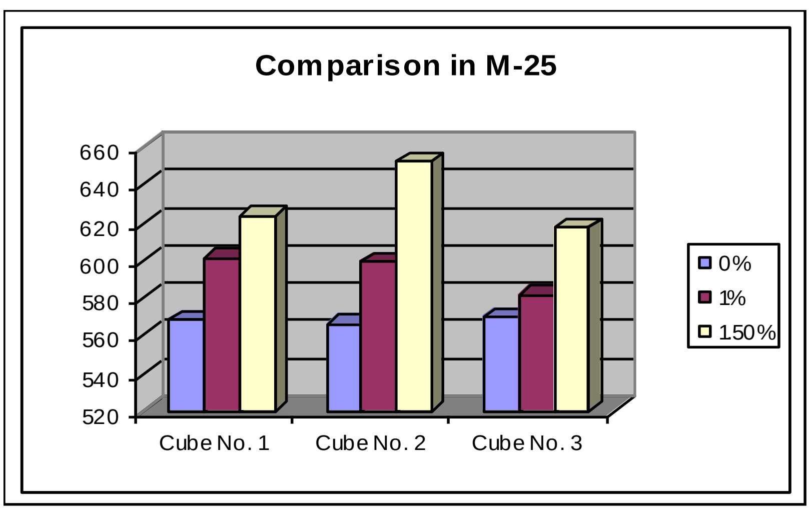


Chart - 1
Charts showing the comparison on the basis of maximum load carried with varying percentages of hair fibre

Table-2
Results obtained from flexural strength test and the corresponding bending strength

S. No	Mix	% hair	Maximum load (KN)	Bending stress (N/mm2)
1	M-15	0%	35.3	3.14
2	M-20	0%	42.9	3.81
3	M-25	0%	46	4.09
4	M-15	1%	36.5	3.24
5	M-20	1%	44	3.91
6	M-25	1%	47.3	4.21
7	M-15	1.50%	38.4	3.41
8	M-20	1.50%	45.2	4.02
9	M-25	1.50%	48	4.26

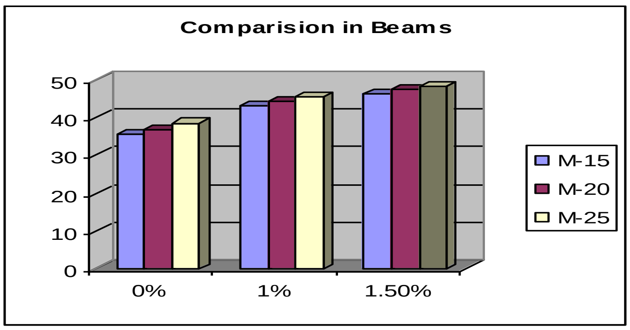


Chart-2
Chart showing the load at failure in beams with varying hair percentages

Table 2 shows the results of the test performed on beams for the flexural strength with the various proportions of concrete varying percentages of hair fibre by the weight of cement.

Fibre reinforced concrete (FRC) offers a numerous advantages in comparison to normal concrete. The addition of human hairs to the concrete modifies various properties of concrete like tensile strength, compressive strength, binding properties, micro cracking control and also increases spalling resistance. Since human hairs are in relative abundance in nature and are non-degradable provides a new era in field of FRC. Various properties of hair made it suitable to be used as fibre reinforcement in concrete. 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. But our research is in progress and the results regarding nominal percentages of hairs imparting maximum strength to concrete is yet to be determined. But it is quite clear that a nominal percentage of hair would improve the various properties of concrete.

Conclusion

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. When M-15 concrete with 1% hair is compared with the plain cement concrete, it is found that there is an increase of 10% in compressive strength and 3.2% in flexural strength. When M-15 concrete with 1.5% hair is compared with the plain cement concrete, it is found that there is an increase of 22% in compressive strength and 8.6% in flexural strength. When M-20 concrete with 1% hair is compared with the plain cement concrete, it is found that there is no increase in compressive strength and 2% in flexural strength. When M-20 concrete with 1.5% hair is compared with the plain cement concrete, it is found that there is an increase of 8.8% in compressive strength and 5.5% in flexural strength. When M-25 concrete with 1% hair is compared with the plain cement concrete, it is found that there is an increase of 4.6% in compressive strength and 3% in flexural strength. When M-25 concrete with 1.5% hair is compared with the plain cement concrete, it is found that there is an increase of 11% in compressive strength and 4% in flexural strength.

Problems Encountered: It is well said that: “The taste of defeat has a richness of experience all its own.” During our research work we also faced the problem of uniform distribution of hair in the concrete. So to overcome this problem we have adopted the manual method of distribution of hair in the concrete.

Future Scope: The use of waste human hair as a fibre reinforcement in concrete widens the door for further research in the given field. They are as follows: i. The distribution matrix of hair in concrete since the resultant matrix could affect the properties. ii. The study of admixtures and super plasticizer which could distribute the hairs without affecting the properties of concrete. iii. The use of animal hairs in concrete.

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