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Performance of hair reinforced concrete

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Abstract
This project is intended to analyze the Performance of Hair Reinforced Concrete. 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. This particular project has been undertaken to study the effect of human hair on plain cement concrete on the basis of its compressive strength, flexural strength, and rheological parameter. Experiments were conducted on concrete beams and cubes with various percentages of human hair fibre i.e. 0%, 0.5%, 1%, 1.5% 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: Compressive strength, flexural strength, hair fibre (HF), non-degradable and rheological

1. Introduction
Definition & History of concrete is a material used in building construction, consisting of a hard, chemically inert particulate substance, known as an aggregate (usually made from different types of sand and gravel), that is bonded together by cement and water. In 1756, British engineer, John Smeaton made the first modern concrete (hydraulic cement) by adding pebbles as a coarse aggregate and mixing powered brick into the cement. In 1824, English inventor, Joseph Aspdin invented Portland cement, which has remained the dominant cement used in concrete production. Joseph Aspdin created the first true artificial cement by burning ground limestone and clay together. The burning process changed the chemical properties of the materials and Joseph Aspdin created stronger cement than what using plain crushed limestone would produce.

1.1 Fibre Reinforced Concrete
Fiber-reinforced concrete (FRC) is concrete containing fibrous material which increases its structural integrity. It contains short discrete fibers that are uniformly distributed and randomly oriented. Fibers include steel fibers, glass fibers, synthetic fibers and natural fibers – each of which lends varying properties to the concrete. In addition, the character of fiber-reinforced concrete changes with varying concretes, fiber materials, geometries, distribution, orientation, and densities. 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. 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.

1.2 Effects of Fibres in Concrete
Fibers 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 fibers produce greater impact, abrasion, and shatter–resistance in concrete. Generally fibers do not increase the flexural strength of concrete, and so cannot replace moment resisting or structural steel reinforcement. Indeed, some fibers actually reduce the strength of concrete. The amount of fibers added to a concrete mix is expressed as a

percentage of the total volume of the composite (concrete and fibers), termed "volume fraction" (Vf). typically ranges from 0.1 to 3%. The aspect ratio (l/d) is calculated by dividing fiber length (l) by its diameter (d). Fibers with a non-circular cross section use an equivalent diameter for the calculation of aspect ratio. If the fiber's modulus of elasticity is higher than the matrix (concrete or mortar binder), they help to carry the load by increasing the tensile strength of the material. Increasing the aspect ratio of the fiber usually segments the flexural strength and toughness of the matrix.

1.3 Hair as Fibre in Fibre Reinforced Concrete

Hair is used as a fibre because it has a high elasticity which is equivalent to that of a copper wire with comparable width. Hair, a non-degradable matter is making an ecological issue so its utilization as a fiber fortifying material can minimize the issue. It is additionally accessible in wealth and with ease. It fortifies the mortar and keeps it from spalling for this project we have used hair with fibre length between 15 mm to 60mm.

Fig 1: Hair Length of 15mm

Fig 2: Hair Length of 60mm

2. Methodology

The methodology adopted to test the properties and strength of hair reinforced concrete is governed by: Compressive Strength, Workability test, Flexure test, Rheology.

2.1 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 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 25 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.

2.2 Analysis of Data collected: The analysis of data collected is done in the following manner: 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, N/mm^2

2.3 Workability

The property of fresh concrete which is indicated by the amount of useful internal work required to fully compact the concrete without bleeding or segregation in the finished product. Unsupported fresh concrete flows to the sides and a sinking in height takes place. This vertical settlement is known as slump. In this test fresh concrete is filled into a mould of specified shape and dimensions, and the settlement or slump is measured when supporting mould is removed. Slump increases as water-content is increased. For different works different slump values have been recommended.

Fig 3: Slump Cone Apparatus

2.4 Flexural Strength test

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 4. 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 100 × 100 × 500 mm. 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 25 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 4. 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.

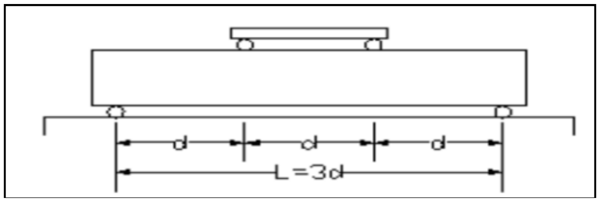

Fig 4: Flexural test

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. The results of flexural strength test and its corresponding bending stress is shown in table 3

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

We know that, Where, M = Moment of Resistance, I = Moment of Inertia about neutral axis, σ_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

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

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

2.5 Rheology

Rheology is the study of the flow of matter, primarily in a liquid state, but also as 'soft solids' or solids under conditions in which they respond with plastic flow rather than deforming elastically in response to an applied force. It applies to substances which have a complex microstructure, such as that of concrete. Rheology generally accounts for the behavior of non-Newtonian fluids, by characterizing the minimum number of functions that are needed to relate stresses with rate of change of strain.

In practice, Rheology is principally concerned with extending continuum mechanics to characterize flow of materials that exhibits a combination of elastic, viscous and plastic behavior by properly combining elasticity and (Newtonian) fluid mechanics. It is also concerned with establishing predictions for mechanical behavior (on the continuum mechanical scale) based on the micro- or nanostructure of the material. There are different sorts of stress (e.g. shear, torsion, etc.) and materials can respond differently for different stresses. Much of theoretical rheology is concerned with associating external forces and torques with internal stresses and internal strain gradients and flow velocities.

Rheology unites the seemingly unrelated fields of plasticity and non-Newtonian fluid dynamics by recognizing that materials undergoing these types of deformation are unable to support a stress (particularly a shear stress, since it is easier to analyze shear deformation) in static equilibrium. In this sense, a solid undergoing plastic deformation is a fluid, although no viscosity coefficient is associated with this flow. One of the major tasks of rheology is to empirically establish the relationships between deformations (or rates of deformation) and stresses, by adequate measurements. The result is obtained as a graph showing the yield stress of the concrete.

Fig 5: Rheology meter

3. Preliminary Data of Material Used For Experiment

3.1 Compressive Test Result

Grade of cement used: 43 Grade OPC (Ordinary Portland Cement) Water Cement Ratio used: 0.45 Grade of concrete: M25 concrete made by nominal mix design taking the ratio 1:1:2 (cement: fine aggregate: course aggregate) Course aggregate: 10 mm aggregate and 20 mm aggregate taken in the ratio of 1:2 Fine aggregate: Sand with specific gravity 2.67 Mould Taken: 150×150×150 Equipment Used: Compressive testing machine (CTM) Curing: 28 day curing in curing tank

Fig 6: Concrete in mould of 150×150×150 for compressive test

3.2 Flexure Test

Grade of cement used: 43 Grade OPC (Ordinary Portland Cement) Water Cement Ratio used: 0.45 Grade of concrete: M25 concrete made by nominal mix design taking the ratio 1:1:2 (cement: fine aggregate: course aggregate) Course aggregate: 10 mm aggregate and 20 mm aggregate taken in the ratio of 1:2 Fine aggregate: Sand with specific gravity 2.67 Mould taken: 100×100×500 Equipment used: Four Point flexural Test Curing: 28 day curing in curing tank

Fig 7: Beam under flexure test

3.3 Rheology

Grade of cement used: 43 Grade OPC (Ordinary Portland Cement) Water Cement Ratio used: 0.45 Grade of concrete: M25 concrete made by nominal mix design taking the ratio 1:1:2 (cement: fine aggregate: course aggregate) Course aggregate: 10 mm aggregate and 20 mm aggregate taken in the ratio of 1:2 Fine aggregate: Sand with specific gravity 2.67 Equipment Used: Rheology meter

4. Result and Discussion

The results are briefly tabulated and are shown in table 1, table 2 and table 3. Table 1 shows variation of slump value with varying fibre content rate table 2 shows the results of the test performed on cubes for compressive strength with the varying percentages of hair fibre by the weight of cement and table 3 shows the variation of flexure strength with variation in the percentage of hair reinforcement.

4.1 Workability

Table 1: Slump Value for different hair content

% hair	Slump Value (mm)
0%	92
0.5%	86
1.0%	83
1.5%	78

Slump Value v/s % hair

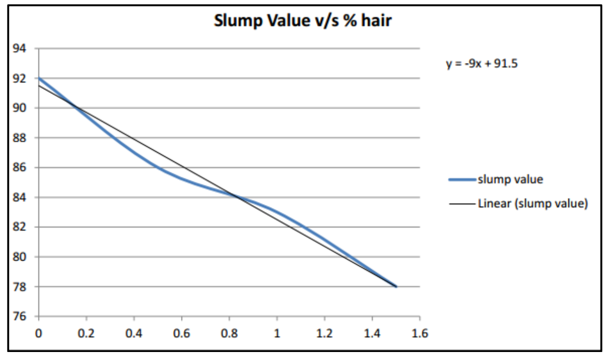

Fig 8: Graph of slump value vs hair content

4.2 Results from compressive testing machine for compressive strength

Table 2: Compressive Strength for different hair content

S. No.	% hair	Maximum Load Recorded (KN)			Compressive stress (N/mm^2)		
		Cube - 1	Cube - 2	Cube - 3	Cube - 1	Cube - 2	Cube - 3
1	0%	570	565	585	25.33	25.11	26
2	0.5%	665	650	680	29.55	28.88	30.22
3	1.0%	710	720	690	31.55	32	30.667
4	1.5%	800	785	760	35.55	34.88	33.77

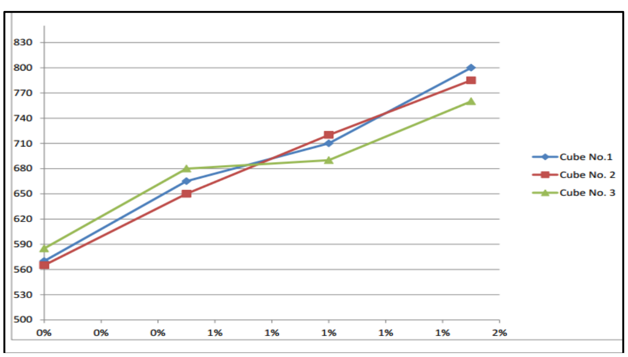

Fig 9: Compressive strength v/s hair content graph

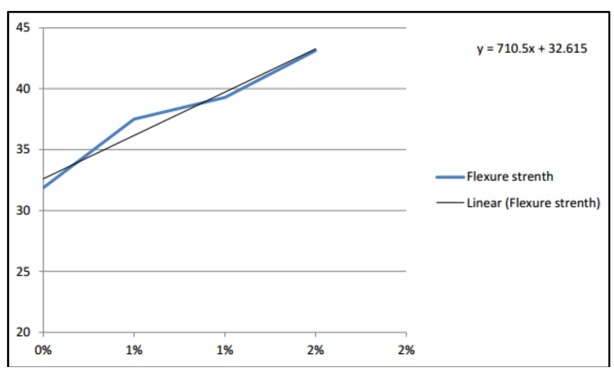

Fig 10: Flexure Strength v/s hair content

4.3 Flexure Strength

Table 3: shows the results of the test performed on beams for the flexural strength with varying percentages of hair fibre by the weight of cement.

S. No.	% hair	Maximum Load Recorded (KN)	Flexural Strength (N/mm^2)
1	0%	8.5	3.1875
2	0.5%	9	3.750
3	1.0%	10	3.9275
4	1.5%	11.5	4.3125

5. 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. The average compressive strength in concrete with different fibre loading is tabulated below.

Table 4: Avg compressive strength v/s hair content

S. No.	% hair	Avg. Compressive Strength
1	0%	573.33
2	0.5%	665
3	1.0%	706.667
4	1.5%	781.667

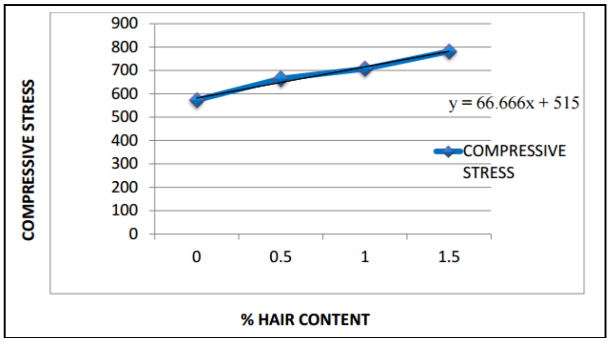

Fig 11: Graph showing avg. compressive strength v/s hair content

1. When concrete with 0.5% hair is compared with the plain cement concrete, it is found that there is an increase of 15.98% in compressive strength and 5.88% in flexural strength.
2. When concrete with 1% hair is compared with the plain cement concrete, it is found that there is an increase of 23.25% in compressive strength and 17.64% in flexural strength.
3. When concrete with 1.5% hair is compared with the plain cement concrete, it is found that there is an increase of 36.33% in compressive strength and 35.29% in flexural strength
4. By increasing the hair content in the concrete the workability is decreased. The graph showing the yield stress for different percentage of hair content i.e 0%, 0.5%, 1%, 1.5% shows increasing value of yield stress with increase in the percentage loading of hair. Hence it could be deduced that the workability decreases as we increase the hair content.
5. As the workability is decreasing with the increase in the hair content so it can be inferred that hair reinforced concrete should not be used in pumpable concrete.
6. Loss in workability with increase in hair content signifies that relatively more effort one has to employ in order to achieve proper mixing of concrete.

Hence 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. It is quite clear that a nominal percentage of hair would improve the various properties of concrete

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