Concrete Reinforced with Human Hair Fibers

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ABSTRACT

The use of fibers is not a new idea in this case. According to some reports, straw, horsehair, and cotton fibers were used in ancient mud and mortars. These fibers can then increase workability and minimize shrinkage cracks in concrete mixtures. The nano cross-section of hair and its correct tensile strength make this project feasible. Experiments are being carried out to see how it can be used to reduce concrete shrinkage. Concrete tubes, balls, and prisms with different percentages of human hair fibers were used in the experiments. Cement concentrations of 3% and 5% by weight are used. Two grades of reference plain concrete were used, 25 and 50 MPa. The results showed that there is an increment in the various mechanical properties and strength of concrete by the addition of human hairs to concrete.

KEYWORDS: Hair Concrete, Bio Concrete, Compressive Strength, Splitting Tensile Strength. and Flexural Strength.

1) INTRODUCTION

Biological fibers were first used in composite material by the ancient Egyptians 3400 years ago when straw and clay were mixed to create mud bricks. Now a day there was a trend to use biomaterial in concrete to enhance the tensile properties of concrete elements. Some of these materials are human and horse hair fibers [1,2].

Human hair is a substance that is considered worthless in most cultures, and as a result, it can be found in almost every city and town on the planet's municipal waste stream. [3],[4]. In 2010, India alone exported approximately 1 million kg of human hair and its products worth US $ 238 million, and total global imports were valued at the US $ 1.24 billion [5].

Hair is used as a fiber reinforcement agent in concrete because of its high tensile strength, ability to control plastic shrinkage and dry shrinkage cracking, lower permeability of concrete, low cost, and ability to avoid spalling. [3],[6]. However, along with the benefits of using hair fiber in concrete, there are several drawbacks, the most significant of which is the fabrication process. Spreading fibers into the cement matrix is a labor-intensive and expensive method compared to making simple concrete or plain concrete. A convenient parameter called aspect ratio is often used to define the fiber. The length to diameter ratio of fiber is known as its aspect ratio. [7].

As per a report of 1981 which has been published in Britain, it has been stated that human hairs can be used in the form of fiber reinforcement in roofing where precast concrete is used especially in houses with lower cost (Ahmad et al, 2011)[3], The main purpose of fiber in concrete is to prevent cracks from growing. Additionally, using fiber reinforced concrete improves dynamic loading resistance, shear strength, wear resistance, shock resistance, impact resistance, and ductility against seismic and blast activities. In addition to improving the properties of concrete, fiber reinforced concrete is also economical and more durable as compared to the normal conventional concrete [5],[8].

Sinan A. (2013)[6] studied the experimental investigation into the mechanical properties of new natural fiber-reinforced mortar by using a human hair fiber (HHF) as reinforced material. Tests were carried to study the influence of fiber content on the compressive strength, splitting tensile strength, flexural strength, and load-deflection was presented for two w/c ratios (0.6 and 0.7). The addition of fiber increased energy absorption ability.

What is a hair fiber?

Human Hair as a Fibre has gained importance as an innovation in the field of Fibre Reinforced Concrete. Chemically, keratin is a protein that makes up approximately 80% of human hair and has a high sulfur content (derived from the amino acid cysteine), which distinguishes it from other proteins. Keratin is a laminated complex that gives hair power, flexibility, longevity, and functionality. The hair thread is shaped like a cylinder and is very solid.

Why fibres are used in concrete?

Generally, Concrete is weak in tension and has a brittle character. Hence fibers are added to increase its tensile strength and improve the characteristics of construction materials. As fibers are added to concrete, it becomes homogeneous. As concrete cracks, the randomly

focused fibers kick in to stop the crack from spreading and thus improve strength and ductility. Fibers are usually used in concrete for the following reasons:

- To control cracking caused by shrinkage of the plastic and drying shrinkage.
- They also reduce the permeability of concrete, resulting in less water bleeding.
- Some fibers in concrete are also more resistant to impact, abrasion, and shattering.
- The fineness of the fibers allows them to strengthen the concrete's mortar fraction, delaying the occurrence and spread of cracks. This fineness further reduces permeability and improves the surface properties of the reinforced surface by preventing bleeding in the concrete.

2) EXPERIMENTAL WORK

The experimental program was carried out to test fifty-four concrete specimens of cubes, cylinders, and prisms containing different percentages of human fibers. Two grades of concrete were used, 25 and 50 MPa.

2.1 Materials

a) Fine Aggregate (Sand)

Clean and round fine aggregate was used. The sand was washed and dried in an open area before used. The sand grading was maintained by using sieves according to ECP (Egyptian Code of Practice No 203, 2001)[9]. Very fine material was excluded from the mixture by using fine sieves. The properties of fine aggregates are given in Table1.

b) Cement

Ordinary Portland cement (Assiut Cement) was used throughout the program for making concrete. The fineness degree, Initial and final setting times and the mortar compressive strength were measured according to the Egyptian Code of Practice (ECP 203-2007) [9]. The properties of cement are mentioned in Table 1.

c) Coarse Aggregate (Gravel)

Round, well-graded and clean gravel was used in the mixture with two sizes of (10 and 20 mm). The gravel was washed using potable water to ensure the removal of dust or impurities that might exist. The properties of coarse aggregates are given in Table 2.

d) Water

Potable water was used in the mixes. Chemical analysis of such water showed that it was suitable for the used cement to allow for full hydration.

e) Additive

Two types of additives were used in concrete with grade 50 MPa, Silica fume, and addicted BVF.

f) Hair

Two types of hair were used in the experimental program, human hairs. The human hairs were collected from salons. The hair was separate from other wastes and washed to remove impurities. The hair was properly dried either under sunlight. After the hair is dried it is cut into small parts. The mechanical properties of used hair fiber are shown in Table 3.

Table 1. Properties of Cement.

% of Retained on Sieve No. 170		4.7
Initial setting times (min)		96
Final setting times (min)		254
Mortar compressive strength (MPa)	3 days	19.55
	7 days	29.14

Table 2: Properties of Aggregate.

Property	Fine aggregate (Sand)	Coarse aggregate (Gravel)
Water absorption (%)	1.19	0.74
Fineness modulus	2.83	6.98
Bulk density (kg/m3)	1.59	1.78
Specific gravity	2.62	2.76

Table 3. Properties of Hair Fiber.

Hair type	Human hair
Hair diameter (µm)	90 – 130
Hair length (mm)	20 - 60
Tensile strength (MPa)	325

2.2 Specimen Preparation

The concrete mix design is done in accordance with the Egyptian Code of Practice (ECP 203-2007) [9]. Two concrete compressive strengths were designed. The properties of the concrete mix are shown in Table 4. In the present experimental investigation, the total number

of specimens cast was 54. The cubes, cylinders, and prisms cast were (18, 18, 18) respectively. The main parameters of the experimental program were the percentages of hair fiber by weight of cement and the grade of concrete compressive strength. All the specimens were tested for 28-day strength. Table 5 summarized the experimental program of the tested specimens.

Table 4: Properties of the Concrete Mixture.

Target concrete strength (kg/cm2)	Cement kg/m3	Sand kg/m3	Aggregate (A) kg/m3	Aggregate (B) kg/m3	Silica Fume kg/m3	Addicrete (BVF) Liter/m3	Water Litter/m3
250	350	685	590	590	--	--	185
500	500	630	560	560	25	5	180

Table 5: Summarized the Experimental Program of the Tested Specimens.

Concrete grade	% Hair	No. of Cube	No. of Cylinder	No. of Prism
M25	0	3	3	3
	3	3	3	3
	5	3	3	3
M50	0	3	3	3
	3	3	3	3
	5	3	3	3

3) Test Performed

54 cubes, cylinders, and beams are tested and analyzed for finding the effect of using hair as fiber reinforcement on the mechanical properties of hair concrete. For determining the effect of hair as fiber in concrete following tests were performed.

3.1 Compressive strength test

The compressive strength for 18 concrete cubic specimens of concrete is one of the most important properties of concrete in most structural applications. The test was conducted as Egyptian Code of Practice (ECP 203-2007) [9]. Cubic specimens of dimensions 150 x 150 x 150 mm were cast for M25 and M50 grades of concrete shown in Fig (1). After curing, these cubes were tested on a compression shown in Fig (2) .The failure load was noted in each category three cubes were tested and their average value is reported. The compressive strength was calculated as follows;

Compressive strength (MPa) = Failure load / cross-sectional area.

3.2 Splitting tensile test

The tensile test for 18 concrete cylinder specimens with 150 mmx300 mm was carried out as shown in Figs (2), The samples were tested under a testing machine after a curing period of 28 days. The maximum load was noted and the splitting tensile strength was calculated as:

$$\textbf{Splitting tensile Strength } f_t = 2P/\pi DL$$

Where, P = Ultimate Load (N), D = diameter of cylinder (mm) and L = length of cylinder (mm).

3.3. Flexural Strength Test

A flexural test is the measure of the strength of concrete in bending. Normal concrete beams and hair-reinforced concrete beams for 18 concrete beams specimens of size 100 mm×100 mm× 500 mm are tested using a flexure testing machine. The specimen is simply supported on the two rollers of the machine which are 400 mm apart, with a bearing of 50 mm from each support. The load shall be applied on the beam from two rollers which are placed above the beam with a spacing of 130 mm. The load is applied at a uniform rate till the specimen fails. The maximum value of the load applied is reported and the flexural strength was calculated as

$$\textbf{Flexural Strength } f_{bt} = PL/bd^2$$

Where, P = Ultimate Load (N), L = span between two supports (mm), b = width of beam and d = depth of (mm)

Fig.1. Cubes, Prisms and cylinders Molds.

Fig.2. The machine of Test Specimens (Cubes and Cylinders)

4. RESULTS AND DISCUSSIONS

The mechanical properties of concrete are tested on M25 and M50 grades concrete specimens, with and without human hair reinforcement. The percentage of the hair fiber is varying from 0%, 3%, and 5% by weight of cement. During the casting of test samples, it was observed that mixing of hair in the concrete to achieve homogeneity is a problem at a concentration above 3% of human hair, resulting in balling and lumping of hair fibers. The

results are briefly tabulated, figured and the comparison between hair fiber reinforced concrete and plain cement concrete were shown below.

4.1 Compression Strength Test

The compressive strength results which were obtained after testing the samples are given in Table (6) and Figures (4, 5). The samples were tested after 28 days only. It was obvious from the Table and Figure that:

When M25 concrete grade was used 3 % human hair and compared with the plain cement concrete, it was found that there is an increase of 3.69% in compression strength.

When M25 concrete grade was used 5 % human hair and compared with the plain cement concrete, it was found that there is a decrease of 8.60 % in compression strength

When M50 concrete grade was used with 3 % human hair and compared with the plain cement concrete, it was found that there is an increase of 4% in compression strength.

When M50 concrete grade was used with 5 % human hair and compared with the plain cement concrete, it was found that there is a decrease of 6.60 % in compression strength

Concrete grade	% Hair	Average Concrete Compressive strength (MPa)
		Human hair
M25	0	26.26
	3	27.23
	5	24
M50	0	51.5
	3	53.56
	5	48.1

Table 6: Average Compressive strength of Hair Concrete

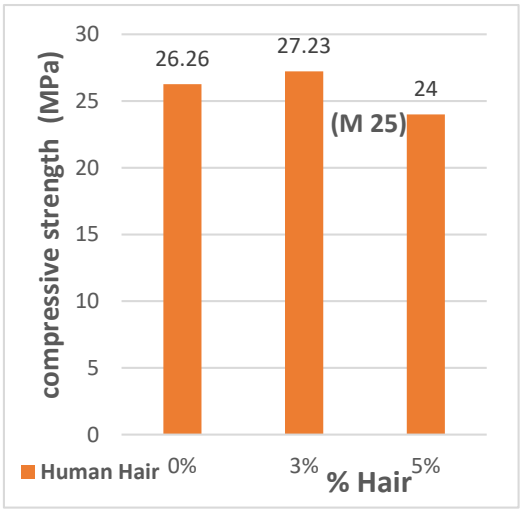

Fig.4. Variation of compressive strength with % hair for concrete grade 25 MPa.

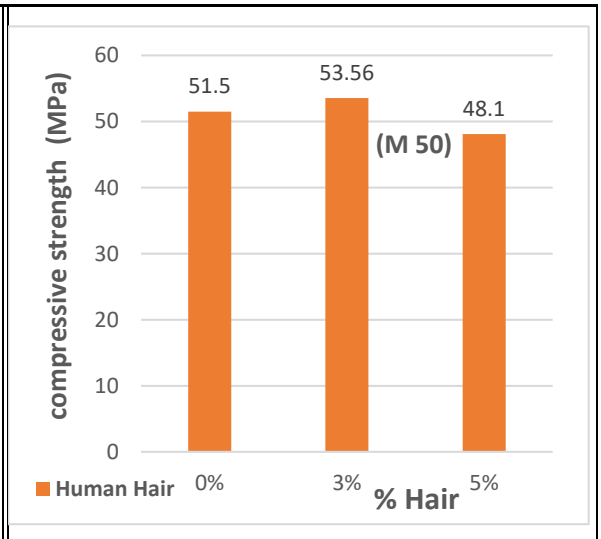

Fig.5. Variation of compressive strength with % hair for concrete grade 50 MPa.

4.2 Split Tensile Strength Test

The splitting tensile test was conducted on the standard samples of the cylinder concrete which is reinforced with hair fiber after 28 days. The results obtained were shown in the Table (7) and Figs (6,7). It is clear from the table and figures that:

When M25 concrete grade was used with 3% human hair and compared with the plain cement concrete, it was found that there is an increase of 4.34% in tensile strength.

When M25 concrete grade was used with 5 % human hair and compared with the plain cement concrete, it was found that there is a decrease of 2.17% in tensile strength.

When M50 concrete grade was used with 3% human hair and compared with the plain cement concrete, it was found that there is an increase of 8.16 % in tensile strength.

When M50 concrete grade was used with 5 % human hair and compared with the plain cement concrete, it was found that there is a decrease of 4.08 % in tensile strength.

Concrete grade	% Hair	Average Concrete Tensile strength (MPa)
		Human hair
M25	0	2.3
	3	2.4
	5	2.25
	0	
	3	
	5	

Table 7: Average Splitting Tensile Strength of Hair Concrete

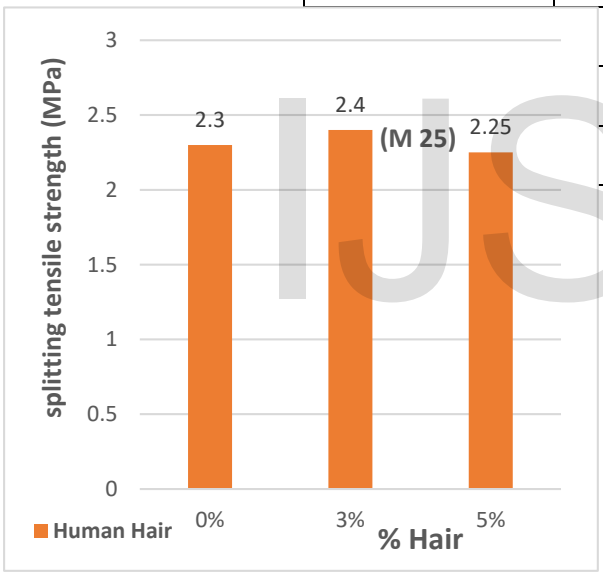

Fig.6. Variation of splitting tensile strength with % hair for concrete grade 25MPa.

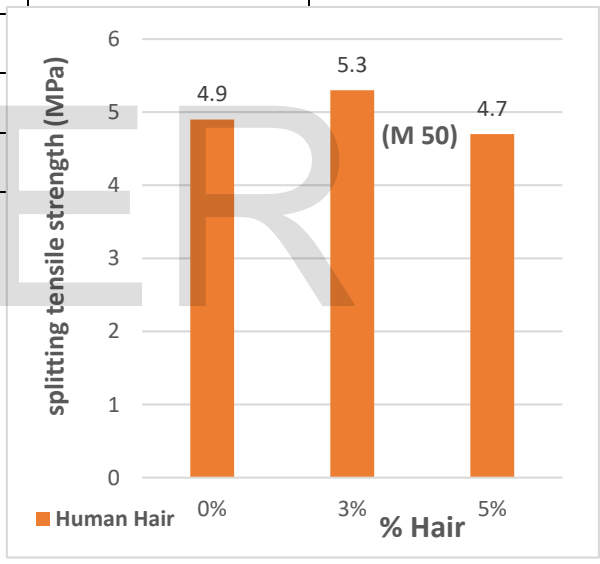

Fig.7. Variation of splitting tensile strength with % hair for concrete grade 50MPa.

4.3 Flexural strength Test

This test was carried out on beam samples whose dimensions are 10 cm width, 10 cm depth, and 50 cm length and cast with different amounts of hair fiber added as a percentage by

weight of cement, The values of flexural strength obtained were shown in Table (8) and Figs (8, 9). From the Table and Figures, it was clear that:

When M25 concrete grade was used with 3% human hair and compared with the plain cement concrete, it was found that there is an increase of 3.81% in Flexural strength.

When M25 concrete grade was used with 5 % human hair and compared with the plain cement concrete, it was found that there is a decrease of 5.50 % in Flexural strength.

When M50 concrete grade was used with 3% human hair and compared with the plain cement concrete, it was found that there is an increase of 3.99% in Flexural strength.

When M50 concrete grade was used with 5 % human hair and compared with the plain cement concrete, it was found that there is a decrease of 6.68 % in Flexural strength.

Concrete grade	% Hair	Average Flexural Strength (MPa)
		Human hair
M25	0	4.72
	3	4.90
	5	4.46
M50	0	9.27
	3	9.64
	5	8.65

Table 8: Average Flexural Strength of Hair Concrete

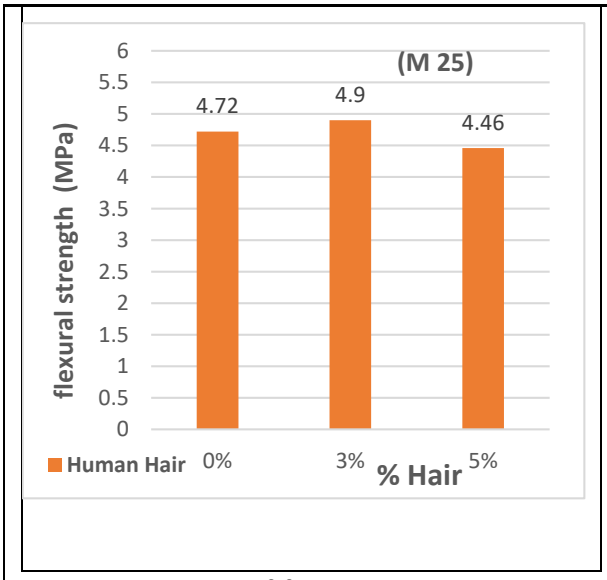

Fig. 8 . Variation of flexural strength with % hair for concrete grade 25MPa.

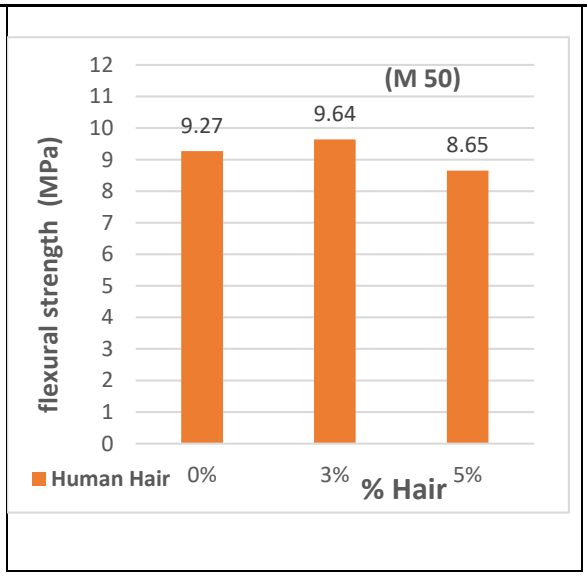

Fig.9. Variation of flexural strength with % hair for concrete grade 50MPa.

5. CONCLUSION

This research work can be concluded under the following points as per the results:-

- It was found that M25 and M50 concrete grade with 3% human hair was compared with the plain concrete, it was found that there was an increase of (3.69, 4.00) % in compressive strength, (4.38, 8.16) % in splitting tensile strength, and (3.81, 3.99) % in flexural strength respectively.
- It was found that M25 and M50 concrete grade with 5% human hair was compared with the plain concrete, it was found that there was a decrease of (8.60, 6.60) % in compressive strength, (2.17, 4.08) % in splitting tensile strength, and (5.50, 6.68) % in flexural strength respectively.
- The amount of fibers added to a concrete mix is measured as a percentage of the total volume of the composite (concrete and fibers) .But the use of a higher percentage of fiber is likely to cause segregation and harshness of concrete and mortar

➢ **Disadvantages of using hair fibers**

The main disadvantages 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.

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