Investigation of Using Human Hair as Fiber Reinforcement in Concrete

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Doi: 10.23918/eajse.v7i2p194

Abstract: Overcoming deficiencies like micro-cracks and similar type of problems in concrete by functional and economical way can be done by using fiber reinforcement. Generally, fiber can be used to reduce the permeability in concrete, and to control both dry and plastic shrinkage cracking. It also can be used to decrease the smash resistances and scraping. For construction of light weight seismic resistant structures, it is an active method. Concretes weakness in tension shows the need for more measurement to cover this shortage. The strong ability to withstand tension in human hair was the reason for using it as a fiber reinforced material. Human hair is an accessible material with no cost, and it is a non-degradable material. It also makes environmental issue for its dissolution. It has been a concern in this study the alteration in concrete properties (compressive, flexural strength and cracking control) due to the impact of adding human hair to plain concrete. Adding human hair to concrete is a multi-advantage process because it improves the concrete properties, reduce the cost of producing concrete, and of course serve solving environmental problems. In this study, various percentages of human hair fiber: 0%, 2% and 2.5% by weight of cement were used in six concrete mixes of varying compressive strengths (ranging from 17 to 42 MPa) and tested to investigate the effect of fiber percentage on compressive and flexural strengths. The results show that there are improvements in concrete strength and other properties by using the human hair as fiber reinforcement.

Keywords: Fiber Reinforced Concrete, Compressive Strength, Flexural Strength, Hair Fiber

1. Introduction

Concrete is construction material and deem as a predominate material in this field. Compressive strength in concrete is good enough but is a relation between concrete strength and its ductility, the higher the strength of concrete, the lower its ductility, this inverse relation between strength and ductility is a serious drawback for the use of high strength concrete (Yaseen, 2013). The tensile strength is also so weak, to cover the tensile strength and the ductility shortages reinforcement should be used in concrete, either with steel or fibers. Fiber reinforced concrete is the mixture of concrete with discontinuous discrete fibers (Neville & Brooks, 2010).

1.1 Fiber Reinforced Concrete (FRC)

A concrete that includes fibrous material which improves its structural integrity can be named by fiber reinforced concrete. It can be defined as composite materials made with Portland cement, aggregate, and incorporating discrete discontinuous fibers. Unreinforced concrete is a brittle material, with low tensile strength and low strain capacity.

Received: October 16, 2021
Accepted: December 7, 2021
Ahmed, J.K., & Al Numan, B.S. (2021). Investigation of Using Human Hair as Fiber Reinforcement in Concrete. *Eurasian Journal of Science and Engineering, 7*(2), 194-200.

The main function of randomly distributed discontinuous fibers is to bridge across the cracks that developed. There are many types of fibers used in concrete such as: Glass Fiber Reinforced Concrete (GFRC), Steel Fiber Reinforced Concrete (SFRC), Natural fiber reinforced concrete (NFRC), Polypropylene Fiber Reinforced (PFR) concrete, Asbestos Fibers, and Carbon Fibers. The properties of fiber-reinforced concrete vary with the change of concrete type, fiber materials, distribution, geometries, orientation, and densities.

1.2 Human Hair as a Fiber Material

Natural waste materials are burden on the environment, therefore, recycling them is considered a sustainability measure (Al Numan & Ahmed, 2019). Human hair is a garbage material, and its elimination is an important environmental problem due to its non-biodegradable nature. The human hair has similar features to that of other synthetic fibers. The hair fiber reinforced concrete is the type of concrete with discontinuous discrete fibers which results in the tensile strength and also reduces the growth of micro cracks in the concrete (Alok Jain & Rajiv, 2016). To improve the physical and mechanical properties of the concrete hair fiber reinforcement is very efficient and cheap because of its high tensile strength, thermal insulation, unique chemical composition, etc. All the previous points can be considered as advantage of using hair as a fiber, but human hair like any other materials has disadvantage when it is used as fiber in concrete, and that disadvantage is the treatment of the hair (clean and dry) before adding to concrete, and the proses of uniform distribution of hair in the concrete.

2. Materials and Methodology

The methodology adopted to test the mechanical properties and strength of hair reinforced concrete is governed by

1. Compressive Strength
2. Flexural Strength.

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

2.1 Materials Used

Cement: The ordinary Portland cement is used.

Fine Aggregate: The sand was sieved first through 4.75mm sieve to remove any particles greater than 4.75mm and was then washed to remove dust. The properties of fine aggregates are as follows: Specific gravity – 2.65and Fineness Modulus – 3.35.

Coarse Aggregate: The material whose particles are of size as are retained on Sieve No. (4.75 mm) is termed as Coarse Aggregate. The size of coarse aggregate depends upon the nature of work. The coarse aggregate used in this experimental investigation are of 20mm (64%), 16mm (21%) and 12mm (15%) sizes, crushed angular in shape.

Water: drinking water was used in the mixture.

Human Hair Fibers: The properties of human hair are tabulated below:

Table 1: Properties of human hair

Properties	value
Hair diameter	95 to 120 μm
Hair length	50mm
Tensile strength of human hair fiber	375 MPa
Ultimate tensile strain	50.2%

2.2 Mix Design

Design mix proportions specimens are shown in Table 2:

Table 2: Concrete mix proportions

Concrete grade	Free water cement ratio	Free water content L/m^3	Cement content kg/m^3	Coarse aggregate content kg/m^3	Fine aggregate content kg/m^3	Total aggregate content kg/m^3	Total aggregate cement ratio
Mix 1	0.59	182.63	310.00	1124.92	758.56	1883.48	6.08
Mix 2	0.54	183.02	338.18	1129.29	730.02	1859.31	5.50
Mix 3	0.49	183.40	372.00	1130.58	700.90	1831.48	4.92
Mix 4	0.45	183.78	413.13	1127.03	669.50	1796.53	4.35
Mix 5	0.39	183.85	465.00	1099.96	671.09	1771.05	3.81
Mix 6	0.40	180.00	450	720	556	1611.02	3.73

The human hair fibers were added at percentage of 2 % and 2.5% by weight of cement to six different concrete mixes proportioned with trials to achieve a range of compressive strength of 17 to 42 MPa and compared with same concrete mixes with no fibers.

2.3 Procedure

After collecting the hair fiber form different salons, beauty centers and barbers, these fibers were treated before adding to the mixture. The first treatment was separating the hair from any waste materials, and then cleaning the hair by washing it and finally drying the hair by exposure to sun.

After treating the collected hair, the concrete mixture was prepared which consisted of (cement, sand, coarse aggregate, water, hair).

Cubes with size (150*150*150) and prism size of (150*150*700) have been prepared for the tests (compression for cubes and flexural test for the prisms).

2.4 Compressive Strength Test

The compression test was implemented on cubical specimens of the size 150 × 150 × 150 mm.

The specimen for the test was made in the following manner: Three cubes were made for each Mix 1, Mix 2, Mix 3, Mix 4, Mix 5, and Mix 6 with 0%, 2 % and 2.5 % hair by weight of cement. The results from the compression test were in the form of the maximum load the cube could carry before it ultimately failed. Table 3 shows the test results of compressive strength.

Table 3: The average compressive strength test results (MPA)

Specimen	Without Hair 0 %	With2% hair	With2.5 % hair
Mix 1	14.43	15.93	16.73
Mix 2	18.83	19.76	21.3
Mix 3	24.3	25.16	26.13
Mix 4	29.3	30.4	30.86
Mix 5	34.06	36.03	36.73
Mix 6	39.46	40.86	41.1

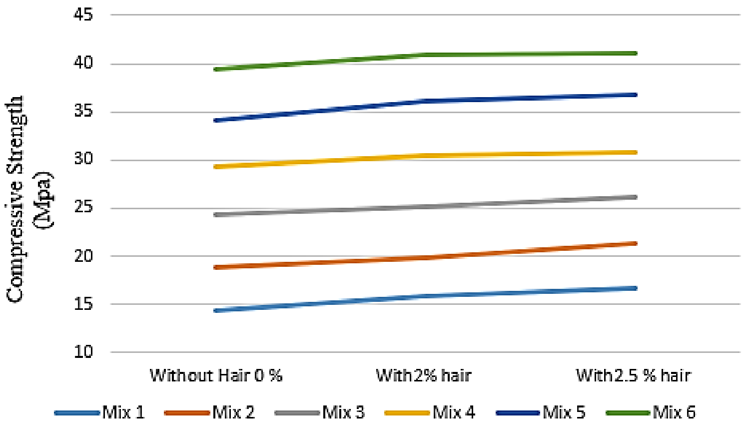

Figure 1: Compression strength for mixtures

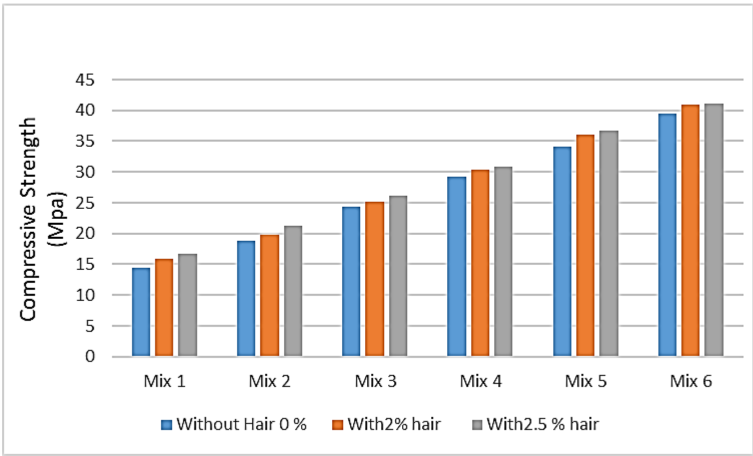

Figure 2: Compression strength for different mixtures

It is observed from Fig.1 and Fig.2 that the compression strength increases by adding human hair as a fiber. A comparison between hair fiber concrete and plain concrete reveals the following points:

For Mix 1 concrete (approximately 15 MPa average strength) with 2% hair fiber the compression increased 10.34% and the concrete with 2.5% hair fiber the compression increased 16%.

For Mix 2 concrete (approximately 20 MPa average strength) with 2% hair fiber the compression increased 5% and the concrete with 2.5% hair fiber the compression increased 13%.

For Mix 3 concrete (approximately 25 MPa average strength) with 2% hair fiber the compression increased 4% and the concrete with 2.5% hair fiber the compression increased 8%.

For Mix 4 concrete (approximately 30 MPa average strength) with 2% hair fiber the compression increased 4% and the concrete with 2.5% hair fiber the compression increased 5.3%.

For Mix 5 concrete (approximately 35 MPa average strength) with 2% hair fiber the compression increased 5.7% and the concrete with 2.5% hair fiber the compression increased 7.6%.

For Mix 6 concrete (approximately 40 MPa average strength) with 2% hair fiber the compression increased 3.5% and the concrete with 2.5% hair fiber the compression increased 4.1%.

It can be concluded that the hair effect is more obvious in increasing the compressive strength the low-grade concrete than that of high-grade concrete.

2.5 Flexural Strength Test

To measure the tensile strength of concrete the most common procedure used is flexural test. Due to the weakness of concrete to resist tension, it is important to study and estimate the load which will produce the cracks. 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 (Nila, Raijan, Antony, Babu, & Davis, 2015) . The system of loading used in finding out the flexural tension is Third Point Loading Method. At the section of maximum bending moment, it is expected to find the cracks. Specimens of size (150 × 150 × 700) mm were used, casted in three layers each layer compacted with a steel bar with 25 strokes. After one day the specimens were extracted from the mold and cured for 28 days in fresh water. After 28 days the tests were implemented by applying the load until the failure of the specimen. Fig 3 shows the failure of a specimen after testing in the flexural machine at TIU lab., Erbil, Kurdistan region of Iraq. Table 4 shows the flexural tests results.

Figure 3: Flexural machine test

Table 4: Flexural strength test results

Strength	Without Hair 0 %	With2% hair	With2.5 % hair
Mix 1	3.22	3.4	3.8
Mix 2	4.14	4.36	4.56
Mix 3	4.66	4.73	4.94

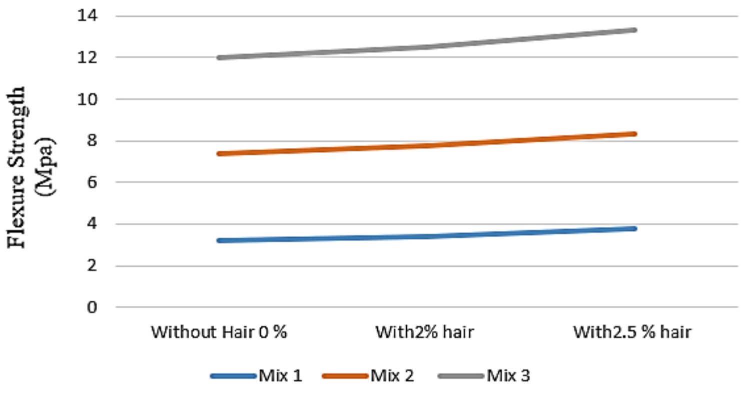

Figure 4: Flexural strength of mixtures

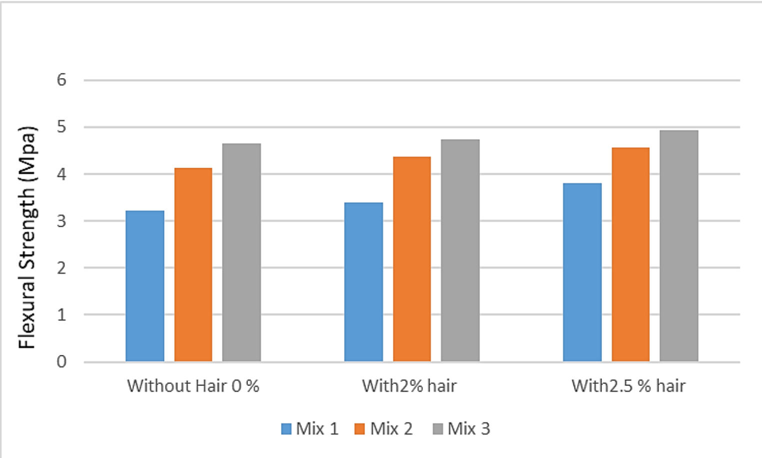

Figure 5: Flexural strength for mixes 1,2, and 3

There are appreciable improvements in the flexural strength of the concrete by adding hair fiber.

From Figures 4 and 5, the amount of increment can be calculated. For Mix 1 (approximately 15 MPa average compressive strength) concrete with 2% hair fiber the flexural strength increased 5.6% and for the concrete with 2.5% hair fiber the strength increased 18%. For Mix 2 (approximately 20 MPa average strength) concrete with 2% hair fiber the flexural strength increased 5.3% and the concrete with 2.5% hair fiber the strength increased 18%. For Mix 3 (approximately 25 MPa average strength) concrete with 2% hair fiber the flexural strength increased 1.5% and the concrete with 2.5% hair fiber the strength increased 6%.

It can be concluded that the hair effect is more obvious in increasing the flexural strength of the low-grade concrete than that of high-grade concrete. The 2.5% of hair fibers is shown with the greater strength increase.

Conclusion

1. It is observed that for concrete mixes with lower grade, the increase in the compressive strength is higher (approximately 16% for 15 MPa strength) than for high grade concrete, when hair fibers are added (approximately 4% for 40 MPa strength).

2. There is a remarkable improvement in the mechanical properties of concrete depending on the percentages of hairs by weight of cement. The amount of increase in compressive strength of concrete between 3.5 to 16 %, and for flexural strength of concrete the range of increment is (1.5 to 18) % depending on the quantities of hair fibers.
3. For both compression and flexural strength the maximum increase is obtained in the addition of 2.5% hair fiber, by weight of cement in all mixes.
4. With the increase in the amount of fibers, it will tend to create workability problem. Therefore, to get more homogeneous mixture of hair fiber, more effort and consideration are required during mixing to obtain a better workability result.

References

Al Numan, B. S., & Ahmed, J. K. (2019). Effect of wood-particles aggregate percentage on some physical properties of concrete. Paper presented at the IOP Conference Series: Materials Science and Engineering.

Alok Jain, M. I., & Rajiv, G. P. (2016). Use of Human Hairs in Concrete. *International Journal for Scientific Research & Development, 4*(6), 80-82.

Neville, A. M., & Brooks, J. J. (2010). *Concrete technology.* New York: Prentice Hall.

Nila, V. M., Raijan, K. J., Antony, S., Babu, R., & Davis, N. R. (2015). Human hair as fibre reinforcement in concrete: an alternative method of hair waste management and its applications in civil constructions. *Int J Curr Res, 7*(10), 21205-21210.

Pickering, K. L. (2008). Properties and performance of natural-fibre composites. Woodhead.

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

Shakeel Ahmad, Farrukh Ghani, J. N Akhthar and M. Hasan (2009): Use of Waste Human Hair as fiber 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.

Stephens, D., 1994. Natural fibre reinforced concrete blocks. IN: Pickford, J. et al. (eds). Affordable water supply and sanitation: Proceedings of the 20th WEDC International Conference, Colombo, Sri Lanka, 22-26 August 1994, pp.317-321.

Yaseen, S. A. (2013). An Experimental Investigation into the Mechanical Properties of New Natural Fiber Reinforced Mortar. *Eng. & Tech. Journal*, 31, 1870-1871.

Zheljazkov, V. D. (2005). Assessment of wool waste and hair waste as soil amendment and nutrient source. *Journal of Environmental Quality, 34*(6), 2310 – 2317. https://doi.org/10.2134/jeq2004.0332 .