Development of Structural Concrete Via Waste Hair Fibers

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Abstract

Concrete is weak in tension due to micro cracks, the inherent property of concrete, which cannot be fully prevented in the hardened concrete. However, the occurrence of micro cracks can be mitigated by introducing human hair as an organic fiber. Human hair being a waste material, cause environmental pollution and badly disturbed the aquatic life. It is a cheap material and works as a function of steel reinforcement due to its contribution in the tensile strength of concrete. Hair also increases the compressive strength of concrete to some extent and reduces the permeability and volumetric expansion of concrete. For the purpose of this research, hair fibers have been collected from the barber shops near UET Taxila. The size of the hair fibers used ranges from 1.5 to 2 inches and added in the concrete mix by weight of the cement. Concrete mix of 1:2:4 were prepared for the target mean strength of 3000 psi. Cement was replaced with human hair weight of 65 grams, 130 grams, 195 grams and 260 grams in different batches. Compressive Strength Test, Splitting Tensile Strength Test, Permeability Test and Slump test were performed on 6 x12 inches cylinders for each batch at the age of 14 and 28 days. As a result, the tensile and compressive strength of concrete decreased at replacement of cement with 260 grams of hair by same amount. Water Permeability test performed on concrete for 3 days at 30 psi pressure showed that the permeability of concrete decreases by increasing the percentage of hair fiber.

Keywords: Hairs, Permeability, Compressive strength, Tensile Strength, Concrete,

1. INTRODUCTION:

Human hair is a material considered useless in most societies and therefore is found in the municipal waste streams in almost all cities and towns of the world [kumar, 2009]. Fiber are used in construction from old days. However, then only the small pieces of ropes were used in mud for construction of mud structure. Those small pieces increased the overall strength of the mud. Hair is used as a reinforcement in construction due to high frictional coefficient and tensile strength. In different areas of many European countries, India and Syria [Heyman, 2002] human hair is used in plastering of walls. Research shows that hair reinforcement increases the insulation capacity of structures [Pillai, 2012]. Human hair reinforcement reduces the cracks in cement mortar due to plastic shrinkage up to 92% [Al-Darbi, 2006]. Due to hair reinforcement compressive strength of concrete increases by over three times [Akhtar, 2009]. Fibers are used in plaster to increase its properties. In 1950s the concept of fiber reinforcement was a point of interest, but later on due to its health risks the use of asbestos fibers in concrete was discouraged [Naveen, 2015]. A problem discussed in local newspaper, the barber shops and parlors in and around UET Taxila caused serious environmental issues. There was no system present in Taxila Punjab to safely treat and decompose the human hair waste generated by the locals. Currently, this waste is thrown in the Gumrah Kas (near UET Taxila), which pollutes and disturbs the aquatic life adversely. After conducting a survey of the barbershops and hair salons near the UET Taxila, most of the shops agreed that the presence of human adversely affects the lives of locals. It was in this context that we decided to use hair as a reinforcement, in order to have safely channeled this waste for further use. Hairs are elastic in nature. In dry condition they increase their length 20 to 30% under stress, but in wet state the increase can be observed up to 50%. The resistance to breakage of hair is function of hair and diameter of thread. When the length of hair increases its elasticity decreases. Hair reinforcement also reduce the erosion of concrete by increasing its durability. Another additive feature of hair reinforcement is that if small micro-cracks appear in concrete, there is no chance of corrosion. It is better to use hair reinforcement in Hydraulic structures such as piers, sluice gates, where structural member are subject to high velocity water. Finally, human hair reinforces the concrete and prevents the sapling effect [Jain, 2012].

2. RESEARCH SIGNIFICANCE:

The main purpose of this research is to investigate the properties of hardened cement concrete after introducing specific percentages of human hair through performing the Compressive Strength test, Splitting Tensile Strength test, Permeability test and Slump test. The second major purpose is to introduce the idea of using human hair in concrete as a reinforcement material to decrease the environmental pollution. No work has been carried out in Pakistan on the utilization of human hair in concrete as organic fiber, so this work might improve the properties of the concrete by utilizing the waste material. Moreover, it will also reduce the environmental pollution caused due to non-utilization of human hair.

3. MATERIALS:

The material used in the test specimens were human hair (as fiber reinforcement), cement, sand, coarse aggregate and water. Hair were collected from barber shops and from hair

salons around UET Taxila Punjab Pakistan. Sand source was of Lawrencepur and the coarse aggregate were brought from Margalla hills having size of less than 20 mm. Hydraulic Fauji cement was used as binding material. Initial and final setting time of cement were determined using ASTM C 191-04a [ASTM C191]. The initial setting time was found to be 34 minutes and final setting time came out to be 175 minutes. The consistency of the cement paste was 30. Hair were washed with acetone, separated, and left for drying purposes before utilizing for concrete preparation [Neville, 1990].

4. METHODOLOGY:

Compressive Strength, Splitting Tensile, Permeability and workability test were performed on each concrete batch containing human hair as fiber reinforcement. Concrete Cylinders of 6 inch diameter and 12 inch height were casted for compressive strength and splitting tensile test. For permeability test, cylinders of 6 inch diameter and 6 inch height were used. The amount of cement in each batch was replaced with hair fiber by 65g, 130g, 195g and 260g. Control mix of concrete was also prepared to compare results of different tests. For each batch, three samples were casted with mix ratio of 1:2:4 and fixed water cement ratio of 0.58.

5. TEST RESULTS:

Results of various tests performed on concrete sample containing human hair are discussed as under.

5.1 Workability Test:

For ensuring the workability of hair reinforced concrete, slump test and compacting factor test were performed as per ASTM C143-90a and British standard respectively. Results of compacting factor and slump test are tabulated in table 1.

Table 1: Comparison of the slump and compacting factor test results

Hair (grams)	Slump(mm)	Compacting Factor
00	28	0.81
65	31	0.85
130	33	0.91
195	30	0.88
260	26	0.76

Table 1 showed the workability of fresh concrete and it indicates that the workability of concrete increased initially till 130 grams' addition of hair fibers and then it started to reduce by increasing hair fiber as a reinforcement for the development of structural concrete. When slump decreases workability of concrete also decreases [Neville, 1990].

The value of compacting factor test also reduced to 0.76 which shows the decrease in workability.

5.2 Compressive strength Test:

Concrete cylinders were prepared for compressive strength of concrete by using different weightage of hairs with respect to mix ratio for different formulations. The compressive strength test was performed according to ASTM C 39-04a. [ASTM C39] at the age of 14 and 28 days. Results are tabulated in table 2 and are compared in fig 1.

Table 2: Compressive strength of concrete at 14 days & 28 days

Hairs by weight of cement (grams)	Mean Compressive Strength (psi)	
	at age of 14 days	at age of 28 days
0	2236.48	3237.24
65	2268.39	3285.1
130	2238.01	3280.83
195	2387.20	3427.24
260	2324.95	3321.36

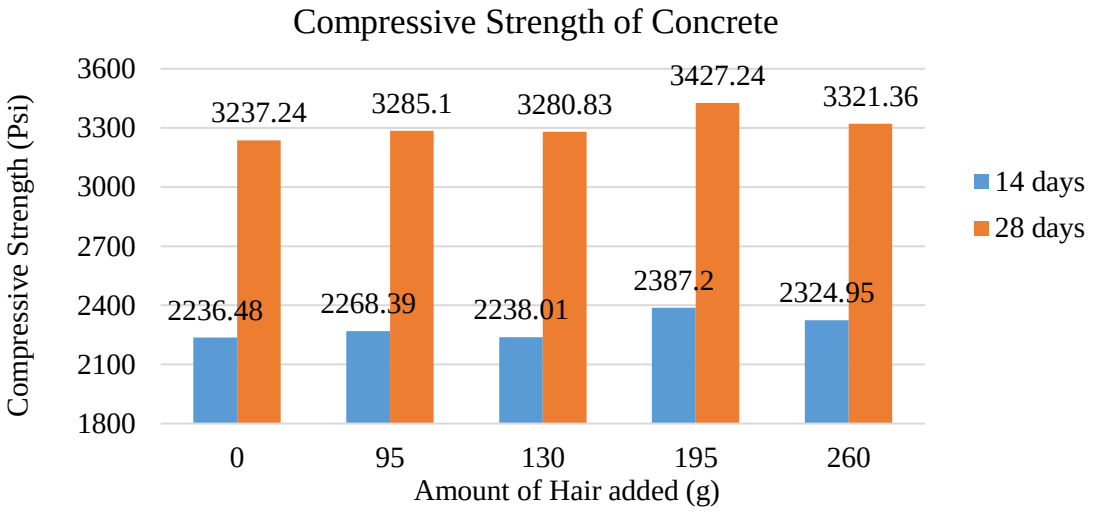

Fig 1: Comparison of Compressive strength of Concrete at the age of 14 and 28 days

From Table 2 and fig 1, it was inferred that the compressive strength of concrete initially increases but when the amount of hair fibers exceeds 195 grams, it starts decreasing at the age of 14 days and 28 days. This can be due to excessive volume of hair fibers in the cement paste matrix which ultimately decrease the density and hence compressive strength of concrete. Moreover, figure 2 showed the failure/cracking pattern of concrete cylinders and it was obvious that there was resistance against cracks due to hair reinforcement otherwise specimen would split into pieces.

Figure 2: Failure pattern of concrete cylinders

5.3 Split Tensile Test:

Splitting tensile test was performed on cylinders according to ASTM standard [ASTM C-496], indirect tensile strength of concrete was determined at age of 14 days and 28 days as shown in table 3. The splitting tensile strength of concrete increased with increasing weight of hairs upto 195g. After that, the tensile strength of concrete decreased due to weak bonding between hair fibers and cement. During the testing of hair reinforced concrete, it was noticed that concrete showed only cracks without splitting into pieces contrary to as it split in control mix (concrete without reinforcement). This could be the reason hair reinforcement reduced swelling in concrete as shown in figure 4.

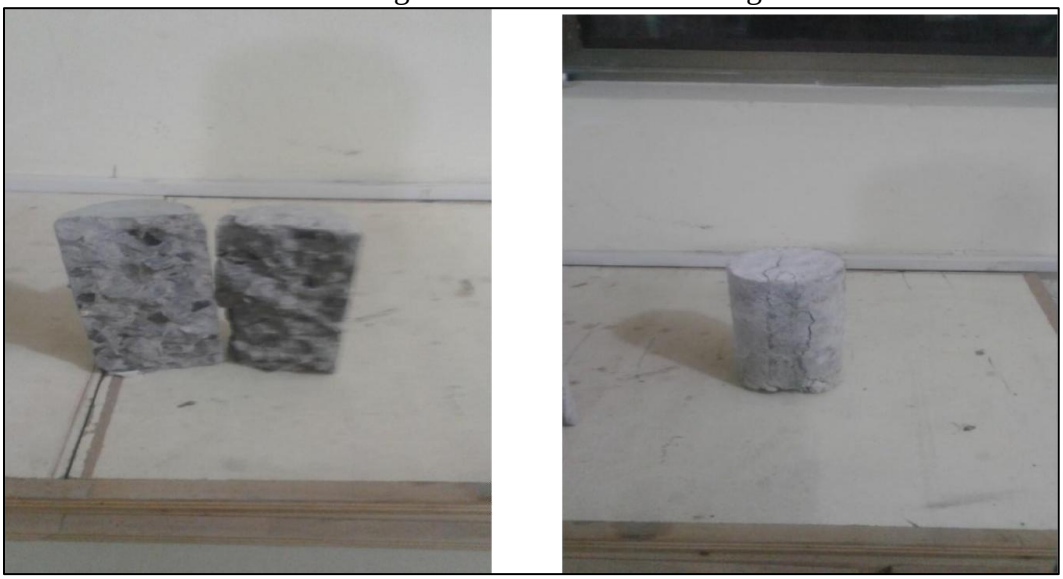

Figure 4. Internal structure of Concrete Cylinders

Table 3: Tensile strength of concrete at the age of 14 and 28 days

Hairs by weight of cement (grams)	Tensile Strength (psi)	
	at age of 14 days	at age of 28 days
0	494.6	603.4
65	509.0	617.9
130	530.8	639.6
195	546.8	655.5
260	514.9	623.7

5.4 Water Permeability Test:

The "Four Cell Automatic Concrete Water Permeability Apparatus" shown in figure 5 was used for investigating water permeability of concrete specimens. Figure 5 and figure 6 showed the pictorial and schematic layout of apparatus along with testing cell details. Cylindrical specimens of 6x6 inch were used to evaluate water permeability of concrete. Permeability test was performed as per ASTM standards [ASTM D2324-68]. Prior to test, samples were oven dried at 105˚C. Blue Emulsion paint was used to coat sides of specimens so that water can permeate through top and bottom Surfaces only. The specimens were subjected to hydrostatic pressure and water permeated was directly collected in graduated cylinder and measured. Table 4 showed the results of permeability test. For research purpose split the cylinder and measure the depth of penetration from those samples to measure the penetration of water.

Figure 5: Water Permeability Test apparatus

Figure 6: Application of Blue Emulsion pain to prevent penetration of water from sides

Table 4: Water permeability Test Results

Hairs by weight of cement (grams)	Penetration depth (mm)
0	18
65	13
130	9
195	6
260	3

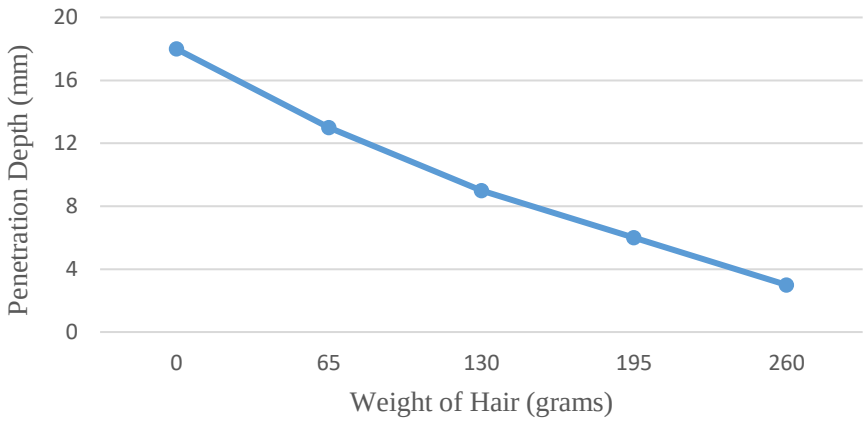

Figure 7: Variation of penetration depth with amount of hair reinforcement added

The graph between weight of hair and penetration depth, shown in figure 7, depicted that permeability of concrete decreased by increasing weight of hair in hair reinforced concrete. Initially in control mix, penetration depth of water is more but with the increment of hairs, penetration depth of water decreases. In other words, permeability of water decreases in hair reinforced concrete by increasing amount of water.

6. CONCLUSION:

The following conclusion can be drawn from the study:

1) Workability of hair reinforced concrete initially increases then decreases by increasing the amount of hair fibers.

2) Compressive strength of concrete increases at 65 grams, 130 grams and 195 grams of hair fibers addition while it decreases at addition of 260 grams possibly due to decrease in the density of concrete. Maximum 7.26 % increment in compressive strength of concrete was observed with addition of hair fibers as compared to control mix.
3) Due to elastic behavior of hair, tensile strength of concrete increased at 65 grams, 130 grams, and 195 grams of hairs but decreased at 260 grams of hairs addition in the cement matrix. Tensile strength of hair reinforced concrete increased by 8.64% as compared to control mix.
4) Permeability of hair reinforced concrete decreased by increasing weight of hair because hair fibers act as bridging elements and reduce the porosity of concrete.

7. Future Recommendation:

Concrete is week in tension. To improve tensile properties of concrete we use steel reinforcement. Due to micro-cracking, there is a possible chance to corrode steel embedded in concrete. If we use hair as a reinforcement in concrete it reduced the propagation of cracks and prevent steel from corrosion.

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