54. Recycling of Human Scalp Hair as Environment Friendly Material in Cement Concrete

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Abstract

This research paper presents the quantitative analysis of the human scalp hairs (HSH) as fibers in cement concrete. The objective of this study are to use HSH (waste stuff in most of societies), as potential abundant materials for construction industry and to reduce environmental impact of HSH waste. A sustainable construction development has become a great concern and challenge faced by construction industry of world due to depleting of natural resources and high speed of consumption of natural materials. In the recent time, due to significant increase in population large amount of HSH waste is being generated and dumped in municipal solid waste. Therefore, majority of the developed/developing countries are facing the problem of handling and disposal of such wastes. HSH are utilized in cement concrete as fiber with three different proportions i.e. 1%, 2% and 3% by weight of cement. Total 24 numbers of cement concrete cylinders were casted for checking the compressive strength of cement concrete with two mix ratios which are very commonly being used in our construction industry, i.e. 1:2:4 and 1:1.5:3, at 0.50 water/cement ratio and tested after 28 days curing period. The compressive strength of cylinders was determined with 1:2:4 mix ratio and it was observed increase in compressive strength of about 26.8% at 1% HSH fiber and it was reduced to 8.2% and 9.1% at 2% and 3% addition of HSH respectively. On the other hand, cylinder tested at 1:1.5:3 mix ratio, there was increase in compressive strength 2% at 1% addition of HSH and then reduction of 21.3% and 33.7% in compressive strength at 2% and 3% addition of HSH respectively.

Keywords: "Human Scalp Hair; Sustainable Construction Material; Muncipal Solid Waste Management; Enviroment Friendly; Fiber Reinforceed Concrete; Compressive Strength"

1. Introduction

A sustainable construction development has become a great concern and challenge faced by construction industry of world in general and Pakistan in particular due to depleting of natural resources and high speed of consumption of natural materials. Sustainable development is *"an economic activity that is in harmony with the earth's eco-system"*. In other words, it represents the possibility of meeting the present needs without preventing future generations from meeting their needs. In the recent time due to significant increase in population, large amount of human scalp hair (HSH) waste is being generated and dumped in municipal solid waste (MSW). Therefore, majority of the developed/developing countries are facing the problem of handling and disposal of such wastes. The rate or speed of scalp hair growth is about 1.25cm or 0.5inches per month or about 15cm or 6inches per year; weighing approximately 80 to 100gm per annum [1]. By considering that every individual Pakistani on average sheds of ~80gm of hair annually by haircuts, with population of ~18million [2], produces 14400tonns of scalp hair annually. While considering the total population of world i.e. 7billion [3], produces ~$6x10^5$ tons of scalp hair. On the other hand, similar amount of hair is being dumped in the MSW from past years that has not been decomposed. Considering this aspect, there has been a growing emphasis on the utilization of waste materials and by-products in construction activities. Use of waste materials not only helps in getting them utilized but also has numerous indirect benefits such as saving in energy and protection of environment.

Concept of using fibre reinforcement is age-old. In 1849 French Gardner Joseph Monier invented FRC [4]. Though, reinforcing a brittle composite with discrete fibres is an old age concept but now a day's use of fibre in concrete for improving the ductility and flexural strength started in the early 1900's [5]. Due to high tensile strength and high friction coefficient, human hair has been used for reinforcing clay based construction in rural areas of India, Bangladesh and Syria [1] [6-8] and in European countries [9] with clay and other binders in plastering house walls. Using human hair as fibre can reduce the shrinkage more than 90% [10]. It improves tensile resistance and enhances the compressive strength of cement concrete by more than three times [10]. When 1.5% hairs by volume added in plain concrete can raise the

flexural strength up to 8.6% [4].
Human hair considered as MSW and useless or waste material in most of the societies. Therefore, it is found in municipal waste streams in almost all urban cities and towns throughout world [1] [11]. Its presence in waste streams causes many environmental and social problems. When human hair thrown in domestic sewers it blocks the sewer and ultimately sewer water overflows into the streets through manholes. Human hair when dumped with solid waste and burn openly it causes several respiratory problems. Open dumps of hairs produce hair dust which causes discomfort among the locality that dwell besides them. In low population areas the hair is thrown away in nature where it takes several years for decomposition. Burning of human hair produces foul odour and harmful gases such as ammonia, carbonyl sulphide, hydrogen sulphide, sulphur dioxide, phenols, nitrites, pyrroles and pyridines [1] [12], which leads the environment towards its degradation.
Concrete is composite material, consisting of cement as binding medium, fine and coarse aggregates as body of the concrete all this is possible by adding water. Concrete is elastoplastic in nature and it is very strong in compression but week in tension. For this reason, steel is used in the tension developing zone to encounter the induced tensile stresses in the concrete. But this steel is unable to control the tensile cracks which produced due to drying, shrinkage and creep on surface of concrete. Due to this reason fibres (glass, steel, synthetic etc.) having length 0.5" to 2.5" are used in concrete to control the shrinkage cracks by improving the tensile strength of concrete [13].
FRC (Fibre Reinforced Concrete) is a concrete made with hydraulic cement, containing fine and coarse aggregate and discontinuous fibres. The fibres can be made from natural material (e.g. asbestos, sisal etc.) or are manufactured such as glass, steel carbon and polymer [2] [14].

2. Materials and Methods

Materials used for preparation of fibre reinforced concrete (FRC) were obtained from local sites. Fine and Coarse aggregates obtained from *Bolahari-hill sand* and *Petaro Crusher Plant* respectively. Cement used in this research was ordinary Portland cement (OPC) with brand name LUCKY CEMENT. HSH were collected from salon and hair cut shops in polyethene hand bags, located at *Qasimabad Hyderabad*. HSH used in this research are irrespective of size, all mixed sizes are incorporated; which may probably vary from few millimetres to 3 or 4inches. Hair washed three times; first with washing powder followed by two times with drinking water for separating the dirt and oil. HSH, then spread in pan for drying in sunlight. Hair, after washing becomes lumps due to high affinity to itself. Therefore, they were beaten with wooden stick, to separate the lumps as shown in Fig.1 (a).

(a) **(b)**

Figure.1. Human Scalp Hair (a) beaten with wooden stick for its separation (b) wet mixing in concrete.

Hair mixed in wet concrete rather dry concrete, slowly and gradually as shown in Fig. 1(b). This technique worked effectively and hair mixed thoroughly in concrete than dry mixing (in this method hair became lumps and not thoroughly

mixed with concrete). However, mixing time increases in former case due to slowly mixing of hair which reduced the workability of concrete.

All preliminary tests of material were carried out for ensuring the quality of material with respect to standard code of practice i.e. American Society of Testing Materials (ASTM). Aggregates were washed with drinking water before using for mixing. Batching of material is done by weight of ingredient. Casting and testing were performed at Concrete and Structural Laboratory of Civil Engineering Department, Mehran UET Jamshoro.

Table 1. Summary of preliminary material properties

S. No	Material/Test/Property Name	(in FPS System)
1	**Cement**	
i	Normal Consistency	0.33
ii	Initial Setting Time	50mints
iii	Final Setting Time	150mints
2	**Coarse Aggregates**	
i	Size	0.75inches
ii	Gs(apparent)	2.63
iii	Water Absorption	0.54%
iv	Bulk Density(compacted)	93.485 lbs. / cu. ft
3	**Fine Aggregates**	
i	Fines Modulus	2.11
ii	Gs(apparent)	2.6
iii	Water Absorption	1.8%
iv	Bulk Density(compacted)	121.65lbs. / cu. ft

In this study, methodology adopted to use HSH as fibre in cement concrete for analysing the mechanical property of hardened concrete i.e. compressive strength. In this consequence total 24number of standard concrete cylinders were casted at two different mix ratios i.e. 1:2:4 and 1:1.5:3 at water cement ratio of 0.50. HSH are added in three proportions 1%, 2% and 3% by weight of cement. Three cylinders were casted at each proportion of HSH and then average of three taken as result at particular percentage. The compression test is carried out on standard cylinder specimens, cylindrical in shape as shown in Fig.2 (a) having size 6" diameter and 12" height. Standard cylinder tested in Universal Testing Machine (UTM) at 28days curing period as shown in Fig.2 (b). Casting and testing is carried out under the umbrella of **ASTM**.

(a)   **(b)**

Figure.2. Compressive Strength testing; (a) standard concrete cylinders (b) cylinder under the jaws of UTM

3. Experimental Results and Analysis

The obtained results from tests are summarized in table.1, table.2 and table.3. These tables show the results of material testing and various cylinders tested and analysed for finding the effect of using HSH as fibre reinforcement in cement concrete. Fig.3, Fig.4 and Fig.5 are the graphical representation of analysed results. For both mix ratios; when 1% of hair added there is considerable increase in compressive strength. But more increase in compressive strength at 1:2:4 than 1:1.5:3. However, there is decrease in strength, when proportion of hair exceeds 1%. On the other hand, workability of concrete decreases as percentage of hair increases.

Table 2. Compressive Strength of cylinders with mix ratio 1:2:4 at W/C = 0.50

S. No	Cylinder I. D	%age of Hair	Max. Load (in N)	Max. Load (in lbs.)	Strength (in psi)	Avg. Strength (in psi)
1	S-3-0-28	0	376690	84649	2993	
2	S-3-0-28	0	329900	74135	2621	2518
3	S-3-0-28	0	243900	54809	1938	
4	S-3-1-28	1	493218	110836	3919	
5	S-3-1-28	1	389810	87598	3098	3439
6	S-3-1-28	1	415476	93365	3301	
7	S-3-2-28	2	282916	63577	2248	
8	S-3-2-28	2	275667	61948	2191	2312
9	S-3-2-28	2	314329	70636	2498	
10	S-3-3-28	3	276690	62178	2199	
11	S-3-3-28	3	292831	65805	2327	2290
12	S-3-3-28	3	294937	66278	2344	

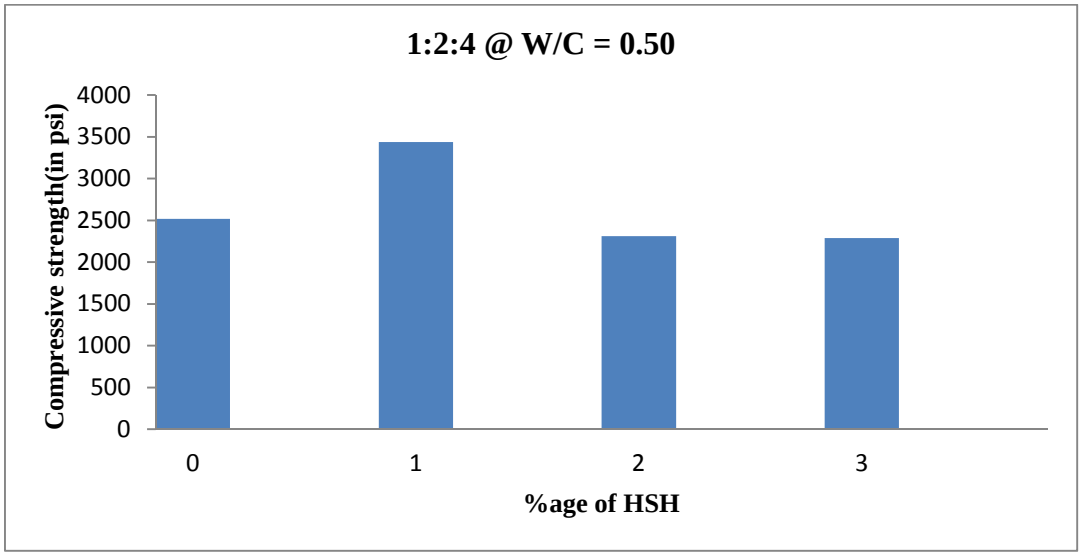

Figure.3. Representation of compressive strength at various percentages of HSH at 1:2:4 mix ratio

Table 3. Compressive Strength of cylinders with mix ratio 1:1.5:3 at W/C = 0.50

S. No	Cylinder I. D	%age of Hair	Max. Load (in N)	Max. Load (in lbs.)	Strength (in psi)	Avg. Strength (in psi)
1	S-4-0-28	0	403915	90767	3210	
2	S-4-0-28	0	426410	95822	3388	3442
3	S-4-0-28	0	469296	105460	3729	
4	S-4-1-28	1	427501	96068	3397	
5	S-4-1-28	1	427589	96087	3398	3508
6	S-4-1-28	1	469296	105460	3729	
7	S-4-2-28	2	327082	73502	2599	
8	S-4-2-28	2	384511	86407	3055	2710
9	S-4-2-28	2	311632	70030	2476	
10	S-4-3-28	3	269539	60571	2142	
11	S-4-3-28	3	290679	65321	2310	2282
12	S-4-3-28	3	301232	67693	2394	

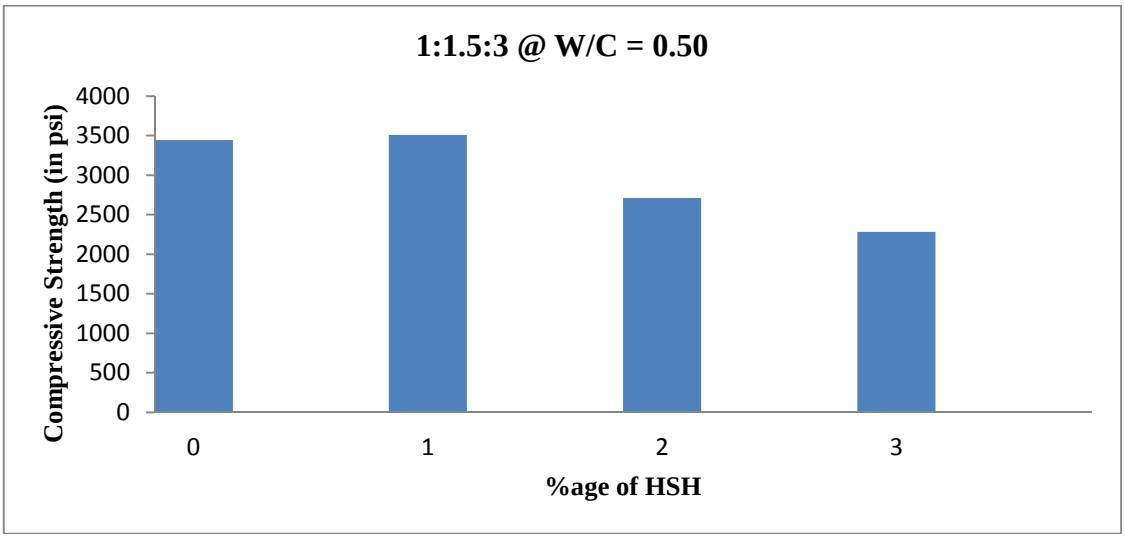

Figure.4. Representation of compressive strength at various percentages of HSH at 1:1.5:3 mix ratio

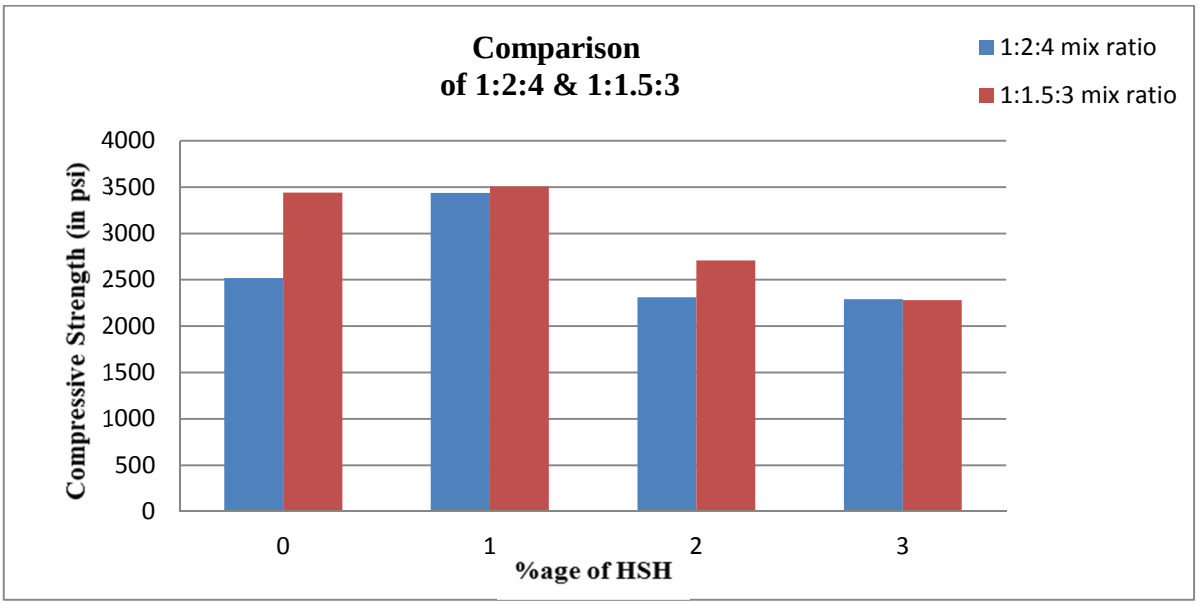

Figure.5. Representation of comparison of compressive strength at 1:2:4 & 1:1.5:3 mix ratio

4. Conclusion

From the experimental analysis it is observed that:

- Compressive strength of concrete cylinders when tested at 1:2:4 mix ratio, there is increase of 26.8% at 1% addition of HSH. However, the reduction of 8.2% and 9.1% in compressive strength at 2% and 3% addition of HSH respectively.
- Similarly, concrete cylinders when tested at 1:1.5:3 mix ratio, there is increase of 2% at 1% addition of HSH. However, the reduction of 21.3% and 33.7% in compressive strength at 2% and 3% addition of HSH respectively.
- The reduction in workability of concrete observed with increase in percentage of HSH.
- This study shows that 1% replacement of concrete materials i.e. Cement, F.A. and C. A. with HSH would have significant positive impact on material recycling and recovery.

5. Future Recommendation

Although, at 1:2:4 mix ratio with addition of 1% HSH, there is considerable increase in compressive strength of concrete but yet there is need of analysis of strength by varying the proportion of HSH below 1% and at different W/C ratios; so that one can get the better and precise results in this regards. At this end of research, experimental results on compressive strength gives the clue for improvement in strength of concrete but it is not yet recommended to use HSH in concrete as fibre because detail analysis is required by considering the various aspects of concrete and its long term durability. Furthermore, environmental friendly concrete can be produced and cheap concrete can be mobilized in construction industry and in this regard detailed research is required.

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