International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 03, March-2017

Human Hair Fibre Reinforced Concrete

Ajna Manaf, U G Student
Adarsh M V, U G Student
Alphy Jomichan, U G Student
George M Varghese, Assistant Professor
Department of Civil Engineering, Amal Jyothi College of Engineering
Kanjirapally, Kottayam, Kerala, India

***Abstract*: - Enhance the physical and mechanical properties of concrete are a potential area of research. Fibre reinforced concrete is one among those advancements which offers convenient, practical and economical methods for overcoming micro cracks and similar type of deficiencies. Since the concrete is weak in tension, fibre help to overcome this deficiency. There are several types of fibre which serves this purpose, this paper investigates the suitability of human hair. Human hair is considered as a waste material in most parts of the world and is a common constituent found in municipal waste streams which cause environmental issue. Hair fibre, an alternate non-degradable matter is available in abundance and at a very cheap cost. This paper compares the strength and durability of ordinary concrete with hair fibre reinforced concrete of M20 grade with 0%, 0.5%, 1% 1.5%, 2% addition of hair by weight of cement. The result shows that addition of human hair fibre enhances the binding properties, micro cracks control, imparts ductility and also increases the spalling resistance. The experimental findings in overall studies would encourage further research in this direction for long term performance to extending this cost effective type of fibres for use in structural application.**

Keywords: Fibre Reinforced Concrete, Human Hair Fibre, Compressive Strength, Flexural Strength And Crack Resistance.

1. INTRODUCTION

Concrete is a mixture of cement (usually Portland cement), water and stone aggregate possessing low tensile strength, limited ductility and little resistance to cracking. Since concrete is weak in tension hence some measures must be adopted to overcome this deficiency. Hence, incorporating fibre into the concrete can increase the properties of concrete like the tensile strength of the concrete, reduce the air voids and water voids and also the inherent porosity of gel, increases the durability of the concrete.

Fibre is a small piece of reinforcing material possessing certain characteristics properties. Addition of fibres to concrete influences its behaviour which significantly depend on the type and percentage of fibre. The properties of fibre reinforced concrete is influenced mainly by the physical and mechanical properties of the fibre. A good fibre should have good adhesion within the matrix and adaptable elasticity modulus. It must be compatible with the binder, which shouldn't be attacked or destroyed in the long term. It should be short, fine and flexible to permit mixing, transporting and placing and also strong enough to withstand the mixing process.

Since the advent of fibre reinforcing of concrete in the 1940`s, a great deal of testing has been conducted on the various fibrous materials to determine the actual characteristics and advantages for each product. Addition of fibres to concrete makes it more homogeneous and isotropic, and transforms it from a brittle to a more ductile material. Fibres are usually used in concrete to control plastic and dry shrinkage cracking, lower the permeability and impart greater impact, abrasion and shatter resistance. Fibre reinforced concrete can offer a convenient, practical and economical method for overcoming micro-cracks and similar type of deficiencies. It is an effective method of construction of light weight seismic resistant structures.

Human hair fibre

Human hair is good in tension; hence it can be used as a fibre reinforcing material. Hair Fibre (HF) is a non-degradable matter available in abundance and at a very cheap cost. Human hair is considered as a waste material in most parts of the world and is a common constituent found in municipal waste streams which cause enormous environmental problems from its degradation. Also the high tensile strength, unique chemical composition, thermal insulation etc. makes the hair fibre suitable to be used as a reinforcing material.

This study tries to combine both the above mentioned aspects i.e. incorporating the natural human hair as fibre reinforcement in concrete and to check the enhancement in its long term properties. Thus this is an attempt to find the possibilities of using hair as fibre reinforcement in concrete, thereby forming an alternative way for the safe management of hair waste. Present studies have been undertaken to analyse the effect of human hair on plain cement concrete on the basis of compressive and flexural strengths and to control the cracking economically.

Experiments were conducted on concrete specimens with various percentages of human hair fibre i.e. 0%, 0.5%, 1%, 1.5% and 2% by weight of cement. Researchers found that there is an increment in the various properties and strength of concrete which makes it a suitable additive for concrete to enhance its mechanical properties. Hair fibre reinforced concrete can be an effective method for the hair waste management.

Composition and properties of hair

The hair thread has a highly organized cylindrical structure, formed by inert cells of keratin, following a very precise and pre-defined design. In terms of raw elements, on an average, hair is composed of 50.65% carbon, 20.85% oxygen, 17.14% nitrogen, 6.36% hydrogen, and 5.0%

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 03, March-2017

sulphur. Keratin gives the hair strength, flexibility and durability. Cortex keratin is responsible for this property and its long chains are compressed to form a regular structure which, besides being strong, is flexible. The physical proprieties of hair involve: resistance to stretching, elasticity and hydrophilic power. The resistance to breakage is a function of the diameter of the thread, of the cortex condition. Hair fibre has an elastic characteristic, and it may undergo moderate stretching either wet or dry. When dry, the hair thread may stretch 20-30% of its length; and, in contact with water, this may reach up to 50%.

II. MATERIAL PROPERTIES

Ingredients used are portland pozzolana cement (PPC), coarse aggregate, fine aggregate, water and human hair as fibre.

A). Portland Pozzolana Cement:

Shankar PPC brand, conforming IS code – IS: 1489-1911 was used. The properties of cement are mentioned in table 1.

B). Aggregate:

Various characteristics of aggregate such as partial shape, particle size distribution, mechanical properties and possible chemical reaction between aggregate and paste, (which affect the bond) as well as grading governs the properties of concrete.

Table 1: Properties of Cement

Property	Average value of PPC from experiment	Standard value of PPC
Specific Gravity	2.86	2.9
Consistency(%)	36	-
Initial Setting Time (min)	90	>30
Final Setting Time (min)	145	<600

- *Fine Aggregate:* The sand used for the experimental programme confirmed to grading zone II.

- *Coarse Aggregate:* The size of coarse aggregate depends upon the nature of work. The coarse aggregate used in this experimental investigation are of nominal size 20mm. The properties of coarse and fine aggregates are given in table 2.

Table 2: Properties of Aggregate

Property	Fine Aggregate	Coarse Aggregate
Fineness modulus	2.85	7.2
Specific gravity	2.64	2.68
Water absorption (%)	1.21	1
Bulk density (kg/m^3)	1.58	1.76

C). *Human Hair Fibre*

The properties of human hair are given in table 3.

Table 3: Properties of Human Hair

Property	Value
Hair diameter	100 to 120µm
Hair length	60mm
Aspect ratio	500-600
Tensile strength of human hair fibre	380Mpa
Ultimate tensile strength	50.16%

III. SPECIMEN PREPARATION

The concrete mix design is done in accordance with IS 10262-2009. Cement content in the mix design is taken as 394kg/m^3, which satisfy the minimum requirement of 300kg/m^3 in order to avoid the balling effect. A sieve analysis conforming to IS 383-1970 was carried out for both the fine and coarse aggregate. In the present experimental investigation, the total number of specimens casted was 120. The cubes casted were totally 105 in number, of which each set of 3 cubes were meant for different percentage of hair (i.e., 0%, 0.5%, 1%, 1.5% and 2%). Similarly, 15 beams were casted with varying percentage of hair by weight of cement. All the specimens were tested for 28-day strength.

IV. TEST PERFORMED

Various cubes and beams are tested and analysed for finding the effect of using hair as fibre reinforcement. For determining the effect of hair as fibre in concrete following test were performed.

A). Compressive strength test

The test was conducted as per IS 516-1959. The test is carried out on specimens cubical in shape of the size of 150mmx150mmx150 mm. Specimens were placed on the bearing surface of compression testing machine. A uniform rate of loading was applied till the failure of the cube. The maximum load was noted and the compressive strength was calculated.

B). Flexural Strength Test

This test was carried out as per IS 516-1959 specifications. Normal concrete beams and human hair reinforced concrete beams of size 150mm×150mm× 700mm are tested using a flexure testing machine. The specimen is simply supported on the two rollers of the machine which are 600mm 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 200mm. The load is applied at a uniform rate such that the extreme fibres stress increases at 0.7N/mm^2/min i.e., the rate of loading shall be 4kN/min. The load is increased till the specimen fails. The maximum value of the load applied is noted down.

C). Rebound Hammer Test

Rebound hammer test is done to out the compressive strength of concrete by using rebound hammer as per IS 13311(part 2)-1992 Rebound hammer test was conducted on cubes and beams (without crack) at 25 selected

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 03, March-2017

points, with the instrument in vertically downward direction and in horizontal direction. In order to take readings in horizontal direction, a load corresponding to 20% of design strength was applied. In cubes, the points were marked on each of its face. In case of beams, three sections were selected accordingly (say A, B, C) and points were marked on each face along the length of beam.

D). UPV Test

This test is done to assess the quality of concrete by ultrasonic pulse velocity method as per IS 13311(part 1) – 1992. The underlying principle of this test is the method consists of measuring the time of travel of an ultrasonic pulse passing through the concrete being tested. Comparatively higher velocity is obtained when concrete quality is good in terms of density, uniformity, homogeneity etc.

E). Water Absorption Test

Based on ASTM C140 the procedure for water absorption test is as described. Three full size blocks shall be completely immersed in clean water at room temperature for 24hours. The blocks shall then be removed from the water and allowed to drain for one minute by placing them on a 10mm or coarser wire mesh, visible surface water being removed with a damp cloth, the saturated and surface dry blocks immediately weighed. After weighing all blocks shall be dried in a ventilated oven at 100 to 1150C for not less than 24hours and until two successive weighing at intervals of 2hours show an increment of loss not greater than 0.2 percent of the last previously determined mass of the specimen.

F). Sulphate Attack Test

The resistance of concrete to sulphate attacks was studied by determining the loss of compressive strength or variation in compressive strength of concrete cubes immersed in sulphate water having 5% of sodium sulphate (Na_2SO_4) and 5% of magnesium sulphate ($MgSO_4$) by weight of water and those which are not immersed in sulphate water.

The concrete cubes of 150mm size after 28days of water curing and dried for one day were immersed in 5% Na_2SO_4 and 5% $MgSO_4$ added water for 28days. The concentration of sulphate water was maintained throughout the period. After 28days immersion period, the concrete cubes were removed from the sulphate waters and after wiping out the water and girt from the surface of cubes tested for compressive strength following the procedure prescribed in IS 516-1959.

G). Acid Attack Test

The concrete cube specimens of various concrete mixtures of size 150mm were cast and after 28days of water curing, the specimens were removed from the curing tank and allowed to dry for one day. The weights of concrete cube specimen were taken.

The acid attack test on concrete cube was conducted by immersing the cubes in the acid water for 28days after 28days of curing. Hydrochloric acid (HCl) with pH of about 2 at 5% weight of water was added to water in which the concrete cubes were stored. The pH was maintained throughout the period of 28days. After 28days of immersion, the concrete cubes were taken out of acid water. Then, the specimens were tested for compressive strength. The resistance of concrete to acid attack was found by the percentage loss of weight of specimen and the percentage loss of compressive strength on immersing concrete cubes in acid water.

V. RESULTS AND DISCUSSIONS

The mechanical properties of concrete are tested on M-20 grade concrete specimens, with and without human hair as fibre reinforcement. The percentage of human hair fibre is varying from 0% to 2% with an increase of 0.5% in each iteration. During the casting of test samples, it was observed that mixing of human hair in the concrete to achieve homogeneity is a problem at concentration above 1% of human hair, resulting in balling and lumping of hair fibres which will ultimately affect the mechanical properties of the concrete. The results are briefly tabulated and comparison between human hair fibre reinforced concrete and plain cement concrete were shown below.

A). Strength Test

a). Compression Test

With 0.5% addition of hair an increase in 7% was observed and a further 0.5% addition enhances it to 12.8%. With further increase the strength reduces. The results are shown below:

Table 4: Average Compressive Strength of Hair Fibre Concrete

Sl. No.	% Hair	Compressive Strength(N/mm^2)
1	0	26.6
2	0.5	28.4
3	1	30
4	1.5	26
5	2	22

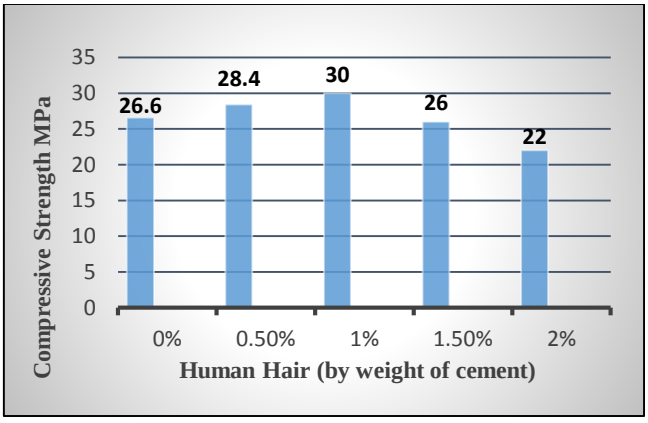

Fig. 1. Variation of compressive strength with % hair

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 03, March-2017

b). Flexural Strength Test

With 0.5% addition of hair an increase in 2% was observed and a further 0.5% addition enhances it to 22%.

Table 5: Average Flexural Strength of Hair Fibre Concrete

Sr. No.	% Hair	Flexural Strength (N/mm^2)
1	0	4.67
2	0.5	4.77
3	1	5.7
4	1.5	5.72
5	2	5.68

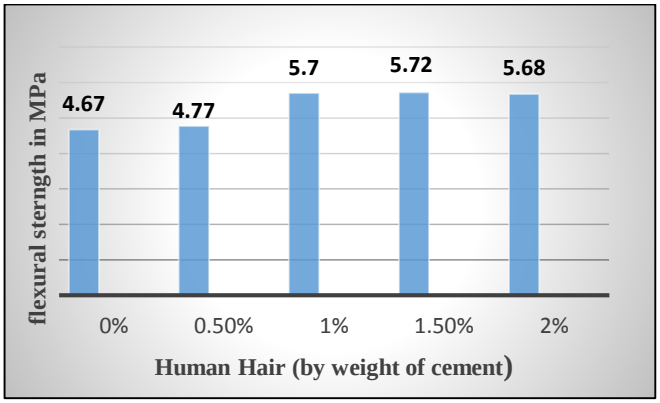

Fig. 2. Variation of flexural strength with % hair

c). Rebound Hammer Test

From the non-destructive test done vertically downwards, the compressive strength was obtained from the rebound hammer test. The result proves that addition of hair does not affect the strength of concrete.

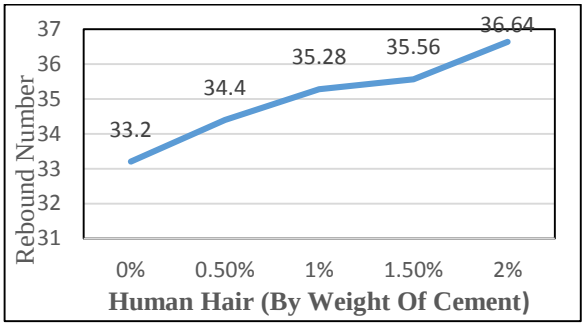

Fig. 3. Variation between rebound number with % hair

Table 6: Rebound Number of Hair Fiber Concrete

Sl. No.	% Hair	Compressive strength (N/mm^2)	Rebound number
1	0	34	33.2
2	0.5	35	34.4
3	1	37	35.28
4	1.5	37	35.56
5	2	38	36.64

B). Durability Tests

a). Water Absorption Test

If the percentage of water absorbed by the concrete increases, the durability of the concrete gets decreased. From the tests conducted, it is observed that there is a decrease in amount of water absorbed when incorporating hair as reinforcement in concrete and the minimum value of 2.67% is obtained when adding 0.5% hair by weight of cement.

Table 7: Percentage of Water Absorption

Sr. No.	% Hair	Dry weight (kg)	Wet weight (kg)	% absorption
1	0	8.388	8.652	3.14
2	0.5	8.160	8.378	2.67
3	1	8.160	8.386	2.76
4	1.5	8.392	8.631	2.83
5	2	8.394	8.640	2.94

b). Sulphur Attack Test

In Sulphur attack test, the percentage of weight loss and percentage of strength loss will decrease with increasing the percentage of hair fiber. From the observations it is found that minimum percentage of strength loss and weight loss is obtained for 1.5% and 1% of hair by weight of cement respectively.

Table 8: Sulphate Attack of Hair Fiber Concrete

Sr. No.	% Hair	Weight loss (%)	Strength loss (%)
1	0	1.3	14.3
2	0.5	1.2	14
3	1	1.18	12
4	1.5	1.21	11.5
5	2	1.2	13

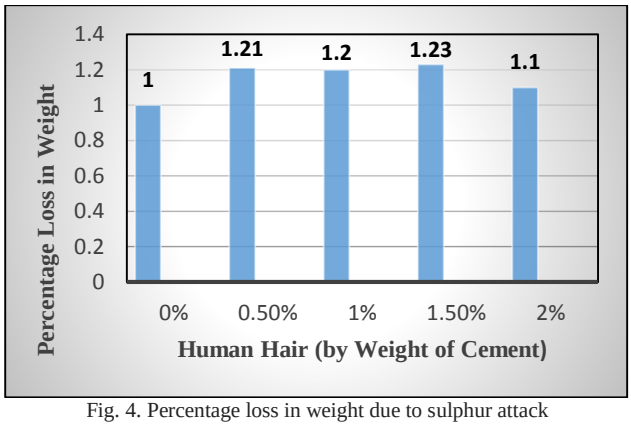

Fig. 4. Percentage loss in weight due to sulphur attack

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 03, March-2017

c). Acid Resistance Test

Table 9: Acid Resistance of Hair Fiber Concrete

Sr. No.	% Hair	Weight loss (%)	Strength loss (%)
1	0	1.1	14
2	0.5	1.2	12.5
3	1	1.18	12
4	1.5	1.21	12.2
5	2	1.2	13

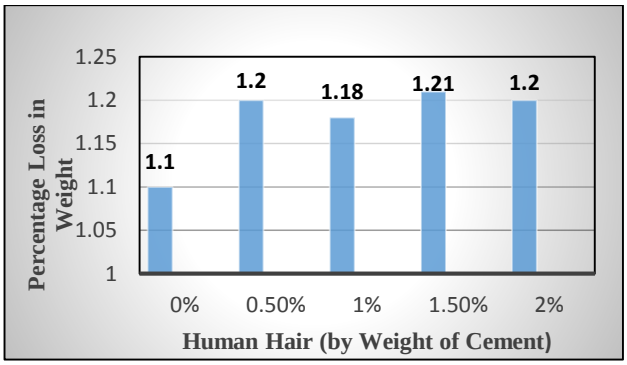

Fig. 5. Percentage loss in weight due to acidity

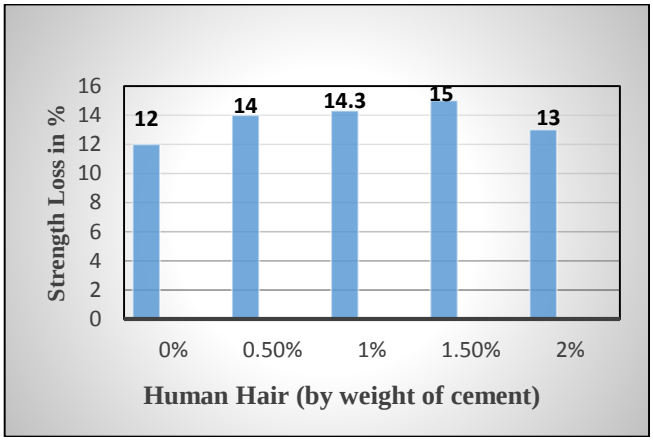

Fig. 6. Percentage loss in strength due to acidity

In acid resistance test, the percentage of weight loss and percentage of strength loss will decrease with increasing the percentage of hair fiber. From the observations it is found that minimum percentage of strength loss and weight loss is obtained for 1% of hair by weight of cement respectively.

d). Ultrasonic Pulse Velocity Test

Table 10: UPV of Hair Fiber

Sl. No.	% Hair	Ultrasonic pulse velocity (28 days)
1	0	4121
2	0.5	4237
3	1	4298
4	1.5	4491
5	2	4237

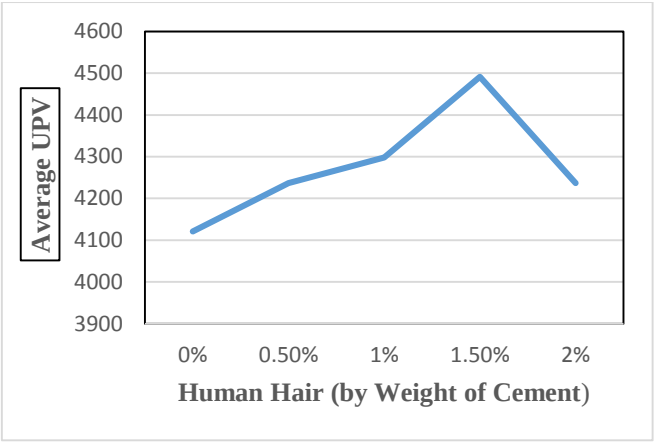

Fig. 7. Effect of ultrasonic pulse velocity

Ultrasonic pulse velocity test noted an increase in pulse velocity with increase in percentage of hair fiber in concrete. This shows that the internal structure of concrete is good with increase in hair fiber.

V. CONCLUSIONS

Hair is used as an additive in various percentage by weight of cement in concrete. Strength and durability tests were conducted on hair fiber reinforced concrete and the results shows that there is an increase in compressive strength by 12% and 22% increase in flexural strength on addition of 1% hair fibre by weight of cement. Increase in flexural strength indicates the reduction in micro-cracks, which is a threat to durability. Addition of 1% hair fibre by weight of cement shows better result in strength as compared to other percentages. Further addition shows declination in result even though there is no loss less than the target strength.

Normal reinforced concrete will be adversely affected by the effect of moisture and other corrosive agents. The attack is due to the generation of micro cracks in the latest stages of the concrete structures. The test results show that due to the incorporation of hair fiber, the durability characters can be elevated slightly. From the durability tests, it is observed that loss of strength is reduced by addition of 1% hair by weight of cement. Hence, we can conclude that hair fibres are a profitable additive to concrete, which diminishes the crack formation, enabling the long life of structures.

REFERENCES

[1] Tomas U. Ganiron Jr. (2014) “Effects of Human Hair Additives in Compressive Strength of Asphalt Cement Mixture”, International Journal of Advanced Science and Technology Vol.67, pp-11-22.
[2] Jain D. and Kothari A. (2012), “Hair Fibre Reinforced Concrete”, Research Journal of Recent Sciences, Vol.1, pp-128-133.
[3] Nila, V. M., Raijan, K. J., (2015), “Human hair as fibre reinforcement in concrete: an alternative method of hair waste management and its applications in civil constructions”, International Journal of Current Research, Vol. 7, pp.21205-21210.
[4] A Study On Mechanical Behavior of Hair Fiber Reinforced Epoxy Composites

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 03, March-2017

[5] Khansaheb A. P. (2015), "Experimental Investigation on Properties of Concrete Using Human Hair & Sugarcane Bagasse Ash", International Journal of Innovative and Emerging Research in Engineering, Vol. 2, Issue 5.

[6] T. Naveen Kumar1, (2015), "An Experimental Study on Mechanical Properties of Human Hair Fibre Reinforced Concrete" IOSR Journal of Mechanical and Civil Engineering, Vol. 12, pp 65-75.

[7] Akarsh Verma1, V. K. Singh1, S. K. Verma and Anshul Sharma, (2016)," Human Hair: A Biodegradable Composite Fiber", International Journal of Waste Resources, Vol. 6, Issue 2.

[8] Ashish Kumar Dwivedi, Dr. Arvind Saran Darbari, Vinod Kumar Verma, (2015), "Compressive strength evaluation of Human hair and Polypropylene fabricated reinforced composite", The International Journal of Engineering and Science (IJES), Vol. 4, pp-2319-1805.

[9] Sameer Ahmad, (2014), "Preparation of Eco-Friendly Natural Hair Fiber Reinforced Polymeric Composite (FRPC) Material by Using of Polypropylene and Fly Ash: A Review", International Journal of Scientific & Engineering Research, Vol.5, Issue 11.

[10] Hamidullah Naik, Nissar Ahmad Naikoo, Sahil Ayoub Dar, Mir Showket4, Sheikh Abbas Muhamm, (2015), "Use of horse hair as fiber reinforcement in concret", International Journal of Advanced Research, Vol. 3, pp-1569-1572

[11] Yadollah Batebi, Alireza Mirzagoltabar, Seyed Mostafa Shabanian and Sara Fateri (2013), "Experimental Investigation of Shrinkage of Nano Hair Reinforced Concrete", IJEE an Official Peer Reviewed Journal of Babol Noshirvani University of Technology, Vol.2, pp- 68-72