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AN EXPERIMENTAL STUDY OF HUMAN HAIR IN CONCRETE AS FIBRE REINFORCEMENT

Tanveer Khan*1, Deepak Aggarwal*2, Rahul Kumar*3

*1Scholar, B. Tech Civil Engineering, Sanskar College Of Engineering And Technology, Ghaziabad, Uttar Pradesh, India.

*2,3Assistant Professor, Dept. Of Civil Engineering, Sanskar College Of Engineering And Technology, Ghaziabad, Uttar Pradesh, India.

ABSTRACT

Since the ancient times, many researches and advancements were carried to enhance the physical and mechanical properties of concrete. Fiber reinforced concrete is one among those advancements which offers a convenient, practical and economical method for overcoming micro cracks and similar type of deficiencies. Since concrete is weak in tension hence some measures must be adopted to overcome this deficiency. Human hair is generally strong in tension; hence it can be used as a fiber reinforcement material. Human hair Fiber is an alternative non-degradable matter available in abundance and at cheap cost. It also reduces environmental problems. Also addition of human hair fibers enhances the binding properties, micro cracking control, Imparts ductility and also increases swelling resistance. The experimental findings in our studies would encourage future research in the direction for long term performance to extending this cost of effective type of fibers for use in structural applications. Experiments were conducted on concrete cubes, cylinders and beams of standard sizes with addition of various percentages of human hair fiber i.e., 0%, 0.5%, 1% and 1.5% by weight of cement, fine & coarse aggregate and results were compared with those of plain cement concrete of M-20 grade. For each percentage of human hair added in concrete, four cubes, three cylinders and three beams were tested for their respective mechanical properties at curing periods of 3 , 7 and 28 days. Optimum hair fiber content was obtained as 1.5% by weight of cement.

Keywords: **Human Hair, Concrete, Fibre Reinforcement, Workability, Compressive Strength, Tensile Strength**

I. INTRODUCTION

Fiber Reinforced Concrete (FRC) is concrete containing fibrous material which increases as structural and is gaining importance. It contains short discrete fibers that are uniformly distributed and randomly oriented. The concept of using fibers as reinforcement is not new. Fibers have been used as reinforced since ancient times. Historically, horsehair was used in mortar and straw in mud bricks. In the early 1900s, asbestos fibers were used in concrete, and in the 1950s the concept of composite materials came into being and fiber reinforced concrete was one of the topics of interest. Later, the use of asbestos for concrete reinforcement was discouraged due to the associated health risks. New materials like steel, glass, and synthetic fibers replaced asbestos for reinforcement.

A fiber is a small piece of reinforcing material possessing certain characteristics properties. Addition of fibers to concrete influences its mechanical properties which significantly depend on the type, length and percentage of fiber. 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.

Fibers are usually used in concrete for the following reasons:-

1) To control cracking due to both plastic shrinkage and drying shrinkage.

2) They also reduce the permeability of concrete and thus reduce bleeding of water.

3) They produce greater impact, ductility, strength, abrasion and shatter resistance in concrete.

4) The fineness of the fibers allows them to reinforce the mortar fraction of the concrete, delaying crack formation and propagation.

This fineness also inhibits bleeding in the concrete, thereby reducing permeability and improving the surface characteristics of the hardened surface. But use of higher percentage of fiber is likely to cause segregation and harshness of concrete and mortar.

The fiber is often described by a convenient parameter called aspect ratio. The aspect ratio of the fiber is the ratio of its length to its diameter. Its value varies for different fibers. Reinforced Concrete with high aspect ratio was found to have improved effectiveness. The modulus of elasticity of matrix must be much lower than tough fiber for efficient stress transfer. The interfacial bond between the matrix and the fiber also determine the effectiveness of stress transfer, from the matrix to the fiber. A good bond is essential for improving tensile strength of composite. Basically, the hair thread has a cylindrical structure, highly organized, formed by inert cells, most of them keratinized and distributed following a very precise and pre-defined design. Hair forms a very rigid structure in the molecular level, which is able to offer the thread both flexible and mechanical resistance. Human hair has about 65-95% of its weight in proteins, 32% of water, lipid pigments and other components Why human hair a fiber?

Hair is used as fiber reinforcing material in concrete for the following reasons :

1) It has high tensile strength which is equal to that of copper wire with similar diameter.

2) Hair, a non-degradable matter is creating an a environmental problem so it used as fibro reinforcing material can minimize the problem.

3) It also available in abundance and at a very low cost.

4) It reinforces the mortar and prevents it from spelling.

In this experimental study, human hair fibers are incorporated into concrete at content of 0.5, 1 and 1.5% by weight of cement. Cubes, beams and cylindrical specimens are casted and cured properly for evaluating various mechanical properties. These specimens made of human hair fiber reinforced concrete are tested at 3, 7 and 28days and the change in mechanical properties when compared to plain cement concrete is observed.

II. LITERATURE REVIEW

This chapter presents the background information on the issues to the to be consider in the present research work and to focus the significance of the current study.

- **Dr. Sinan Abdulkhaleq Yaseen**, University of salahaddin published a paper on “An Experimental Investigation into the mechanical properties of New Natural Fiber Reinforced Mortar” in 2013. This paper highlights use of human hair fiber (HHF) as reinforced material in cementitious 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). When M20 concrete with 1% hair is compared with the plain cement concrete, it is found that there is an increase of 10% in compressive strength and 3.2% in flexural strength. When M20 concrete with 1.5% hair is compared with plain cement concrete, it is found that there is an increase of 22% in compressive strength and 8.6% in flexural strength. When M20 concrete with 1% hair is compared with the plain cement concrete, it is found that there is no increase in compressive strength and 2% in flexural strength.

When M20 concrete with 1.5 % hair is compared with the plain cement concrete, it is found that there is an increase of 8.8 % in compressive strength and 5.5 % in flexural strength.

- **Jain. D and Kothari. A**, observed that there is remarkable increment in properties of concrete according to the percentage of hairs by weight of in concrete. When M20 concrete with 1% hair is combined with the plain cement concrete, it is found that there is an increase of 10% in compressive strength and 3.2% in flexural strength when M20 concrete with 5% hair is combined with plain cement concrete, it is found that there is an increase of 22% of compressive strength and 8.6% of flexural strength. When M20 concrete with 1% hair is combined with plain cement concrete it is found that there is no increase in compressive strength and 2% in flexural strength.

- **Nila V. M, Raijan K. J**, **Susmitha Antony, Riya Babu M, Neena Rose Davis**, According to the test performed it is observed that there is remarkable increment in properties of concrete according to the percentages of hairs by weight of concrete. There was an overall increase of 1 – 12% in the compressive strength of concrete and up to 5% in the flexural strength of concrete test specimens by the addition of hair fibers in different quantities. It is well observed that the maximum increase is noticed in the addition of 2% hair fiber, by weight of concrete, in all the mixes. It is concrete mixes, making the hair fiber reinforced concrete best suitable to u the applications with those concrete mixes. Crack formation and propagation are very much reduced showing that FRC can have its applications in seismic resistant constructions.

- **Yadollah Batebi, Alireza Mirzagoltabar, Seyed Mostafa Shabanian and Sara Fateri**, Department of Civil Engineering, Babol University of Technology. Basically most of cement based mixtures are likely shrinking. Use of fibers is not a new idea in this case. Previously, there were evidences that horse hair, straw and cotton fibers were used in mud and mortars in ancient times. Then, utilizing these fibers in concrete mixtures may increases concrete workability and decreases cracks. Due to nano cross-section of hair and its proper tensile strength this project investigates its application to reduce the shrinkage of concrete mixtures. For this purpose, human hair fibers were used in 0.4 and 0.8 and 1.2 weight percentage and the length of the fibers in each case varied between 15 and 60 millimeters. Results are shown as considerable amount of hair may reduce in the shrinkage in the hair reinforced concrete.

- **M.Manjunatha et al., (2021)** In this research, the authors have explored the utilization of naturally available chopped human hair (HH) as a reinforcement material in concrete to enhance its performance. Human hair is a non-biodegradable material found in nature. The primary objectiveof this study is to determine the optimal quantity of HH as a fibreadditive in concrete, with varying percentages ranging from 0%, 0.5%, 1%, 1.5%, 2%, to 3% by weight of cement in the concrete mixture. The authors conducted a comprehensive investigation into the effects of HH on various concrete properties, including fresh, hardened, and durability characteristics.The experimental findings of this investigation indicate that incorporating HH as a fibrereinforcement improves the bonding between the concrete components, resulting in property enhancements of up to 2.5% HH dosage. In summary, the study establishes that the optimal utilization of HH as a concrete fibreis within the range of 2% to 2.5%. Furthermore, ultrasonic pulse velocity test results demonstrate that the introduction of human hair into the concrete mixture enhances the quality criteria of the concrete up to the 2.5% dosage; however, beyond this dosage (3%), the quality of the concrete begins to deteriorate.Additionally, mechanical tests on concrete properties, such as flexural strength, compressive strength, and split tensile strength, corroborate the optimal usage of human hair as a concrete fibre, which falls within the 2% to 2.5% range, particularly for structural applications.

- **Dr. A. S. Kanagalakshmi et al., (2021)** Human hair fibreis employed as a natural reinforcement material to enhance the strength characteristics of both concrete and mortar. Human hair possesses notable tensile strength, making it a suitable choice for fibrereinforcement. Additionally, human hair is readily available in large quantities and is cost-effective.The inclusion of human hair fibres in concrete results in several improvements, including enhanced micro-crack control, enhanced binding properties, increased ductility, and improved resistance to swelling. In a study, it was observed that the addition of 0.5% hair fibres led to a 7% increase in compressive strength, and further incorporation of 0.5% yielded a 12.8% increase. However, beyond this point, additional hair fibrecaused a reduction in strength.Furthermore, the study revealed that the introduction of 0.5% hair fibres resulted in a 2% increase in flexural strength, and a further addition of 0.5% led to a significant 22%

increase. During a Sulphate attack test, it was observed that the percentage of strength loss and weight loss decreased as the percentage of human hair fibreincreased. The study's findings indicated that the minimum weight loss and strength loss were achieved at 1% and 1.5% hair fibreby weight of cement, respectively.

- **Hummaira Kanwal et al., (2020)** Human hair exhibits notable tensile strength, making it a viable option for reinforcement purposes. This non-degradable material is also readily available at a cost-effective rate.Experimental trials were conducted on cylindrical specimens of fibre-reinforced concrete (FRC) containing different proportions of human hair—namely, 0%, 0.5%, 1%, and 1.5% by weight relative to the cement content. In total, seventy-two cylinders were prepared, each with varying hair content.Workability, compressive strength, and split tensile strength were assessed at three different curing periods: 7 days, 14 days, and 28 days. Over time, both compressive strength and split tensile strength increased for all concrete mixtures. Notably, the concrete mixture labeled "M4," which contained 1.5% human hair, exhibited higher strength compared to "M2" (0.5% hair) and "M3" (1.0% hair). This outcome underscores the effectiveness of human hair as a fibrereinforcement material for achieving superior strength in concrete beyond that of normal concrete.

- **Geeta Batham (2019)** Human hair serves as a natural fibreto augment the strength characteristics of both concrete and mortar. Numerous studies have been conducted to assess the performance of human hair in this regard. This study presents a parametric experimental investigation conducted in a laboratory settingto assess the impact of human hair on cement concrete.Concrete of M-25 grade was produced and reinforced with varying percentages of human hair content. Various concrete specimens were cast in the laboratory, with human hair content ranging from 0%, 0.5%, 1.0%, 1.5%, 2.0%, to 2.5% by weight relative to the cement used.The utilization of human hair content as a natural fibreresulted in an increase in compressive strength. Among the concrete cubes tested, those containing 2.0% and 2.5% human hair content demonstrated superior performance in terms of strength. However, it was determined that a human hair content of 2.0% represented the optimum percentage for both strength and workability.
- **Navneet Singh et al., (2019)** Concrete stands as one of the most extensively utilized building materials. Comprising three primary components—cement, sand, and aggregates—it binds together under the influence of cement, forming concrete, essentially a man-made stone. While its compressive strength meets acceptable standards, its tensile strength remains considerably lower, at approximately ten percent of its compressive strength.To explore potential enhancements, experiments were conducted using concrete cubes with varying proportions of human hair fibre—specifically, 1%, 2%, and 3% by weight relative to the cement content. The testing outcomes revealed notable improvements across various concrete properties and strengths due to the incorporation of human hair as a fibrereinforcement material. This suggests its suitability as an alternative additive for concrete, enhancing its mechanical properties.Furthermore, hair fibre-reinforced concrete offers a promising approach to hair waste management. The compressive strength of the concrete specimens was determined through testing using a universal testing machine, with the results indicating that the highest compressive strength was achieved with a 2% addition of human hair fibre.
- **Er. Chinnadurai et al., (2017)** Human hair fibreserves as a reinforcement material. Human hair fibres (HF), being non-degradable and readily available at a low cost, present an alternative option. However, their slow decomposition can pose environmental concerns.This study was conducted to investigate the impact of human hair on plain cement concrete, focusing on compressive, crushing, flexural strength, and crack control. The objective is to promote cost-effective concrete practices while mitigating environmentalissues.For each concrete mix, three cubes were tested to evaluate their mechanical properties. The test results revealed a notable enhancement in concrete properties corresponding to varying percentages of hair by weight of cement in the concrete mixture. Specifically, there was an overall increase of 1% to 12% in compressive strength and up to 5% in flexural strength for concrete test specimens due to the addition of hair fibres in different quantities. This increase was most pronounced when adding 1.5% to 3% of hair fibre, by weight of concrete, in all the mixtures.
- **T. Naveen Kumar et al., (2015)** This study aims to investigate the impact of human hair on M-40 grade plain cement concrete, with a focus on its mechanical properties—specifically, compressive, flexural, and split tensile strength. Additionally, the study seeks to address environmental concerns. Experiments were conducted using concrete cubes, beams, and cylinders of standard sizes, with varying percentages of human hair fibre(1%, 1.5%, 2%, 2.5%, and 3%) added by weight relative to the cement content. The results were then compared to those of plain M-40 grade cement concrete.The

experimental findings revealed that the optimal content of human hair fibreto be added to M-40 grade concrete is 1.5%. This addition led to notable improvements in the properties of M-40 grade concrete, particularly in terms of its compressive strength, flexural strength, and split tensile strength, with the degree of improvement corresponding to the percentage of hair by weight of cement in the concrete mixture.

- **Jain D et al., (2012)** The project's objective is to examine the impact of human hair on plain cement concrete, with a focus on its compressive, crushing, flexural strength, and cracking control. This investigation aims to promote cost-effective concrete practices while addressing environmental concerns.Experimental trials were conducted on concrete beams and cubes, incorporating varying percentages of human hair fibre(0%, 1%, 1.5%, 2%, 2.5%, and 3%) relative to the weight of cement. Each concrete proportion was tested using one beam and three cubes to evaluate their mechanical properties.The results, when compared to plain cement concrete, revealed an increase in both compressive and flexural strength up to a certain percentage. Specifically, the addition of 1.5% human hair by weight of cement led to improvements in compressive and flexural strength across different concrete grades (M10, M15, M20, and M25).

III. METHODOLOGY

In this study mixes, we are planned to make with fiber with varying proportion of 0.5%, 1% and 1.5%.Control mix was taken with 0%fiber.

A. Collection of Raw Materials

The materials used in this study are: Ordinary Portland cement (OPC): 53grade ACC Cement Human hair fiber: Human hair fiber collected from the saloon shop.

These fibers are chapped into 3.5cm length and washed these fibers in the acetone for washing or polishing purposes.

FIG: Sample Of Human Hair Fibre

1) Water
Collected from the local fresh water sources

2) Fine Aggregate
River sand passing through 4.75mm sieve size

3) Coarse Aggregate
Aggregate sizes of 20mm

4) Basic Test Results of Materials
For all the materials used in the project following basic tests were conducted according to the IS specifications.

B. Basic Test Results for Cement

– fineness of cement=7.16%
– specific gravity of cement=3.195
– Normal consistency of cement=31.5%
– Penetration depth for initial setting time=5mm
– Penetration depth for finial setting time=32mm

C. Basic Test Results for Fine Aggregate

– Sieve analysis for fine aggregate=zone-1
– Specific gravity of fine aggregate=2.519
– Water absorption for fine aggregate=0.2

D. Basic Test Results for Coarse Aggregate

– Sieve analysis for coarse aggregate=table 2 of IS 383- 1970
– Specific gravity for coarse aggregate=2.707
– Water absorption for coarse aggregate=1.689

IV. EXPERIMENTAL WORK

A. Mixes

Four mixes are planned by cement content with human hair in percentages of 0, 0.5, 1, 1.5 by weight of cement material was incorporated in all the mixes. Plain concrete in which 0% human hair fiber was taken as control mix. For each mix 4Cubes of 150x150x150mm size and 3Cylinders of 150mm dia and 300mm length and 3 beams of 700mm x150mm x150mm sizes were casted.

Mix Proportions (M20 Grade, As per IS 10262-2009)

Material	Water	Cement	Fine Aggregates	Coarse Aggregates
In kg/m^3	186	294	724.888	1169.640
Ratio	0.5	1	2.466	3.978

Mix proportions for human hair fiber reinforced concrete blended with concrete (M20grade): Taking control mix proportions as reference, mix proportions for other mixes were calculated. Here, the mix proportions for the mix in which and 0.5% fiber was incorporated are given below.

Material	Water	Cement	Fine Aggregates	Coarse Aggregates
In kg/m^3	186	294	724.888	1173.946
Ratio	0.5	1	2.466	3.992

Casting the specimens taking the control mix design (i.e. 0% fiber) as reference weights of materials are calculated as shown above. In all the concrete mixes human hair fiber was varied in the percentages of 0.5%, 1.0%, 1.5%, by the weight of cement material content was incorporated for the w/b ratio 0.5. Total 16 Cubes (150x150x150mm), 12 Cylinders (150mm dia and 300mm length) and 12 beams (700mmx150mmx150mm) for all the 4 mixes including control mix.

Mix 1: 0% fiber
Mix 2: 0.5% fiber
Mix 3: 1.0% fiber
Mix 4: 1.5% fiber

B. Workability

To determine workability of fresh concrete the following tests were conducted.

1) Slump cone test
2) Compaction factor test

C. Tests

To know the hardening properties of concrete the following tests are conducted on the specimens for 3, 7 and 28 days from time of mixing the water to the dry materials

1) Compressive strength test (Cubes)
2) Split tensile strength test (Cylinders)
3) Flexural strength test (beams)

V. RESULTS

A. Workability

Workability of human hair fiber reinforced concrete is decreased than the control mix, due to the presence of human hair fiber. The results of workability are shown in the following Table-1.

Table 1: Results of Workability of Mixes

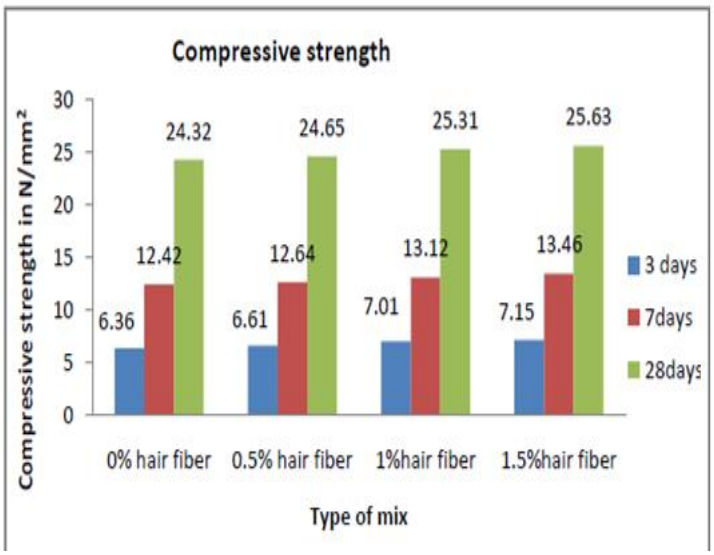
S.No.	Mix No.	Slump value (cm)	Compaction Factor
1	Mix 1	5	0.9
2	Mix 2	6	0.92
3	Mix 3	6	0.93
4	Mix 4	4	0.95

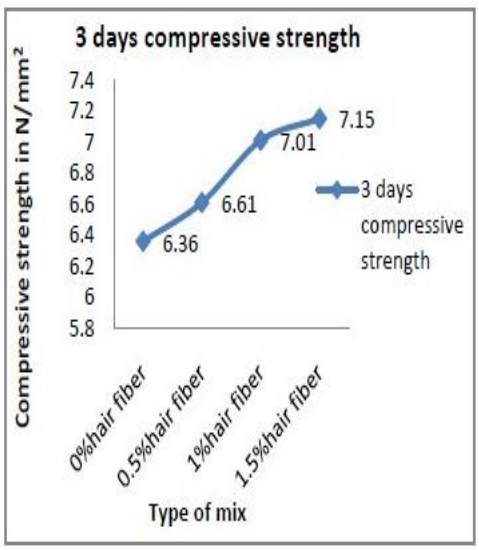
B. *Compressive Strength*

The compressive strength of concrete is determined by testing the cubes under compressive testing machine. The results of compressive strength are shown in the Table-2. Maximum compressive strength occurred at (1.5%fiber) and it is nearer to the target strength.

Table 2: Results of Compressive Strength

S.No.	For Days	Compressive strength in N/mm²			
		Mix 1	Mix 2	Mix 3	Mix 4
1	3	6.36	6.61	7.01	7.15
2	7	12.42	12.64	13.12	13.46
3	28	24.32	24.65	25.31	25.63





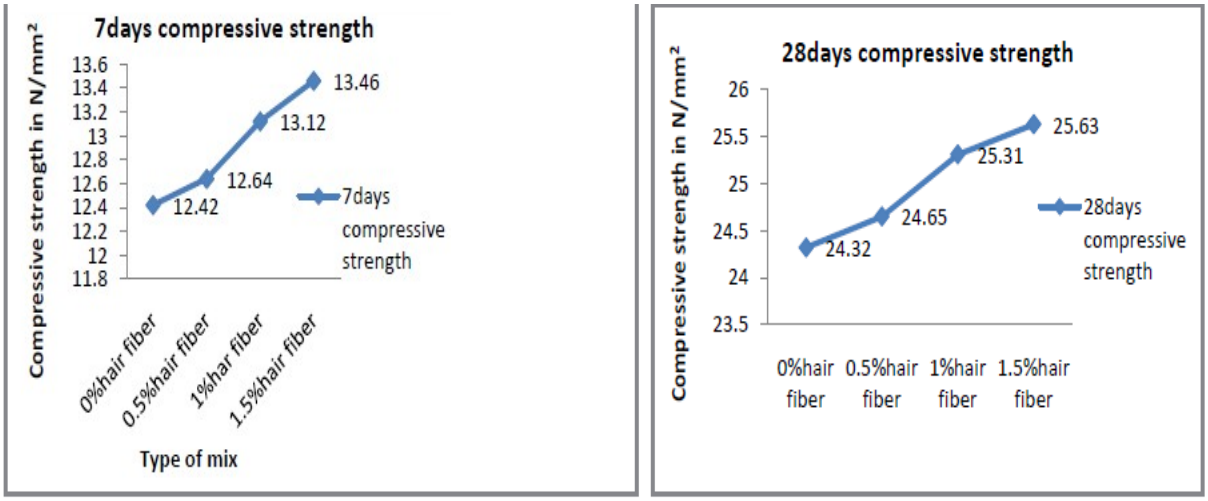


Fig. 1: Variation of Hair Fiber Content v/s Compressive Strength at 3, 7 and 28 Days

A. Split Tensile Strength

Split tensile strength test was conducted for the cylinders of 150mm dia and 300mm length. The obtained values are tabulated in Table-3.Compared to conventional concrete crack width is for this fiber reinforced concrete. Splitting of specimens into two pieces can be controlled completely with this fiber.

Table 3: Results of Split Tensile Strength

S.No.	For Days	Compressive strength in N/mm^2			
		Mix 1	Mix 2	Mix 3	Mix 4
1	3	1.35	1.63	1.73	1.82
2	7	2.24	2.38	2.46	2.58
3	28	3.16	3.26	3.41	3.52

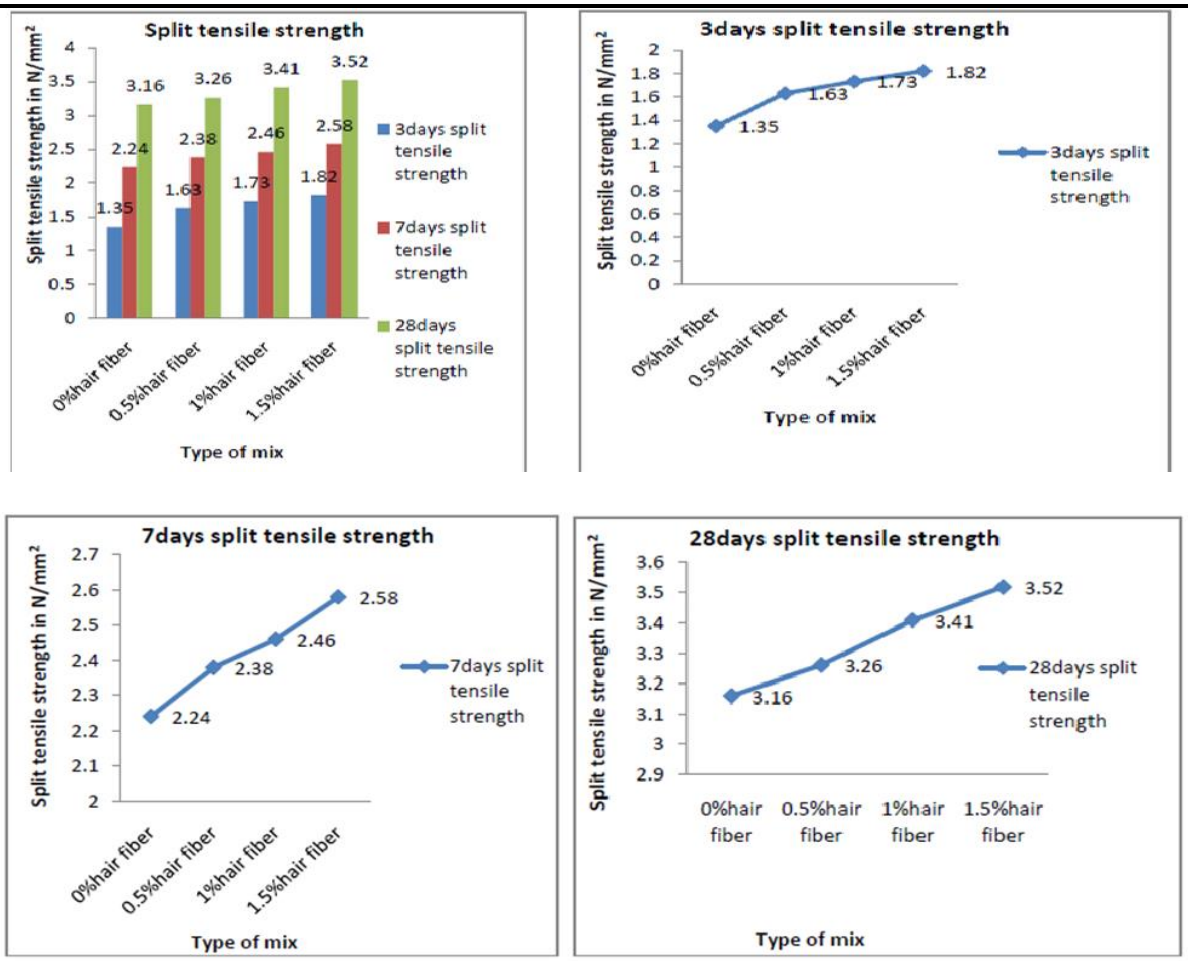


Fig 2: Variation of Hair Fiber Content v/s Split Tensile Strength at 3, 7 and 28 Days

B. Flexural strength

Flexural strength test was conducted for the beams of 700mm length, 150mm wide and 150mm depth. The obtained values are tabulated in Table-4

Table 4: Results of Flexural Strength

S.No.	For Days	Compressive strength in N/mm²			
		Mix 1	Mix 2	Mix 3	Mix 4
1	3	1.42	1.78	1.82	1.96
2	7	2.31	2.46	2.61	2.73
3	28	3.28	3.51	3.81	4.05

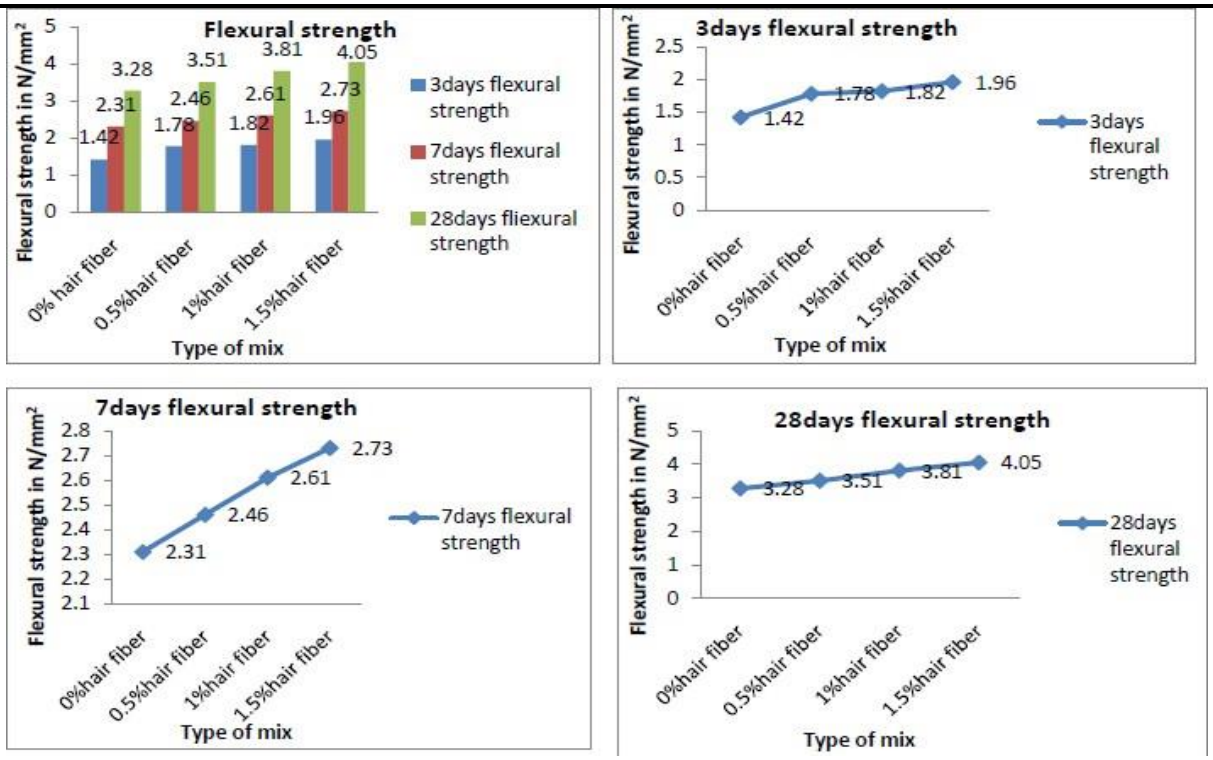


Fig 3 :Variation of Hair Fiber Content v/s Flexural Strength at 3, 7 and 28 Days

VI. CONCLUSION

- Human hair waste can be effectively managed to be utilized in fiber reinforced concrete constructions
- According to the test performed it is observed that there is remarkable increment in properties of concrete according to the percentages of hairs by weight of cement in concrete.
- The human hair fiber concrete has the high compressive strength compared to the normal Concrete.
- Better split tensile strength was achieved with the addition of the human hair in concrete. The strength has increased. When compared to that of the conventional concrete specimen.
- It is well observed that the maximum increase is noticed in the addition of 1.5 % hair fiber, by weight of concrete, in all the mixes.
- Crack formation and propagation are very much reduced showing that FRC can have its applications in seismic resistant constructions.
- The addition of human hairs to the concrete not only modifies various properties of concrete like tensile strength, compressive strength but also enhances the binding properties, micro cracking control and also increases spalling resistance. The crack width is reduced to a greater extent.

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