CHAPTER 8
Experimental Study on Fiber Reinforced Concrete by Using Human Hair

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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 method of overcoming micro cracks and similar types 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 part of world and is a common constituent found in municipal waste material streams which cause environmental issues. Hair fibre, an alternate non-degradable matter is available in abundance and at cheap cost. This paper compares the strength and durability of ordinary concrete with fibre reinforced concrete of M25 grade with 1%, 1.5%, 2% addition of hair by weight of concrete. The result shows the addition of human hair fibres enhances the binding properties, micro cracks control, imparts durability 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 , concrete , binding properties, Human hair etc.*

INTRODUCTION

Concrete is a mixture of cement, water and stone aggregates 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, water voids and also the inherent porosity of gel, increases the durability of concrete. Fibre is a small piece of reinforcing material possessing certain characteristics

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properties. Addition of fibre to concrete influences its behaviour which significantly depends on the type and percentage of fibre. The property of fibre reinforced concrete is influenced mainly by physical and mechanical properties of fibre. A good fibre should have good adhesion within the matrix and adaptable elasticity modulus. It must be compactable 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 reinforcing of concrete in the 1940's, a great deal of testing has been conducted on various fibre materials to determine the actual characteristics and advantages of each product.

CHARACTERISTICS OF FIBRE REINFORCED CONCRETE

Fibre reinforced concrete is concrete containing fibrous material which increases as structural and is gaining importance. It contains short discrete fibres that are uniformly distributed and randomly oriented. The concept of using fibres as reinforcement is not new. Fibres have been used as reinforcement since ancient times. Historically horse hair was used in mortar and straw in mud bricks. In the early 1900's, asbestos fibres were used in concrete, and in the 1950's the concept of composite materials came into being and fibre reinforced concrete was one of the topic 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 fibres replaced asbestos for reinforcement.

A fibre is a small piece of reinforcing material possessing certain characteristic properties. Addition of fibres to concrete influences its mechanical properties which significantly depend on the type, length and percentage of the fibre. Generally, concrete is weak in tension and has a brittle character. Hence fibres are added to increase its tensile strength and improve the characteristics of construction materials.

USING HUMAN HAIR AS FIBRE

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

- It has tensile strength which is equal to that of copper wire with similar diameter.
- Hair, a non-degradable matter is creating an environmental problem, so it is used as fibre reinforcing material and can minimise the problem.
- It is also available in abundance and at a very low cost.
- It reinforces the mortar and prevents it from spilling.

TREATMENT OF HAIR FIBRE

The hair needed for the preparation of concrete cubes was collected from saloons and beauty parlour. It needs treatment before to be added in the concrete specimen. It is carried out as in the following step:

- Separating hair from other waste: depending one hair the source, the collected hair may contain waste. This has to be removed.

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- Washing: After sorting, the hair is washed with acetone to remove impurities.

- Drying: The hair is then dried under sun or in oven. After drying, the hair can be stored without any concern for decay or odour.

- Sorting: The hair is then sorted according to length, colour and quality. The hair fibres are checked at random for its length and diameter.

ADVANTAGES OF FIBRE REINFORCED CONCRETE

- FRC is used in civil structures when corrosion is to be avoided at the maximum.

- FRC is better suited to minimise cavitation/erosion damage in structures where high velocity flows are encountered.

- A substantial weight saving can be realised using relatively thin FRC sections having the equivalent strength of thicker plain concrete sections.

- When used in ridges it helps to avoid catastrophic failures. In quake prone areas the use of FRC would certainly minimise the human casualties.

- Fibre reduces internal forces by locking microscopic cracks from forming within the concrete.

- Studies have been proven that FRC is found to improve the following mechanical properties of ordinary concrete: Compressive Strength, Modulus of Elasticity and Flexural Strength, Toughness, Splitting tensile strength, fatigue strength and impact resistance.

OBJECTIVE OF INVESTIGATION

The main objective of this study is to provide an overview of incorporating fibre into the concrete using human hair fibre and its enhanced tensile strength of the concrete, reduced air voids and water voids and also the inherent porosity of gel, increased durability of the concrete have been discussed in this paper.

SCOPE OF INVESTIGATION

The scope of investigation can be summarized as follows:

- To choose proper materials and arrive at an optimum mix proportion for obtaining fibre concrete with hair fibre.

- Fibre reduces internal forces by locking microscopic cracks from forming within the concrete.

- Studies have been proven that the FRC is found to improve the following mechanical properties of ordinary concrete: Compressive Strength, Modulus of Elasticity and Flexural Strength.

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LITERATURE REVIEW

A brief summary of literatures about hair fibre reinforced concrete are given in this chapter. In current there are many tests that are conducted to efficiently utilise the industrial as well as agricultural wastes. Thus, these wastes are low cost engineering materials which are giving high strength to concrete. Many research works are still in progress of use of industrial and agricultural by-products. These studies help the usage of waste in future construction.

- Dr. Sinan Abdulkhaleq Yaseen, university of Salahaddin published a paper on "The Experimental Investigation into the Mechanical Properties of New Natural Fibre Reinforced Mortar" in 2013. This paper highlights use of human hair fibre (HHF) as reinforced material in cementatious material. Tests are carried to study the influence of fibre 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). Energy absorption capacity and durability factor were improved considerably with the fibre content increased, which makes using the HHF suitable for seismic force resistance structure.

- 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 and Neena Rose Davis: According to the test performed, it is observed that there is remarkable increment in properties of concrete according to the percentage of hair by weight of concrete. There was an overall increase of 1 to 12% in the compressive strength of concrete and up to 5% in the flexural strength of concrete test specimens by the addition of hair fibres in different quantities. It is well observed that the maximum increase is noticed in the addition of 2% hair fibres by weight of concrete, in all the mixes. It is the concrete mixes, making the hair fibre reinforced concrete best suitable. Crack formation and propagation are very much reduced showing that FRC can have its applications in seismic resistance constructions.

- Yadollah Batebi, Alireza Mirzgoltabar, Seyed Mostafa Shabanian and Sara Fateri, Department of Civil Engineering, Babol University of Technology. Basically most of the cement based mixtures are likely shrinking. Use of fibres is not a new idea in this case. Previously, there were evidences that horsehair, straw and cotton fibres were used in mud and mortars in ancient times. Then utilizing this fibre in concrete mixtures may increase concrete workability and decreases crack. 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 fibres where used in 0.4, 0.8 and 1.2 weight percentage and length of the fibre in each case varied between 15 to 60 mm. results are shown as considerable amount of hair may reduce in the shrinkage in the hair reinforced concrete.

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METHODOLOGY

In this study comparison has been made between plain cement concrete by FRC by adding hair fibre for M25 grade of concrete. The test to be conducted on hair fibre reinforced concrete with the partial replacement of cement at1%,1.5%and2%.

MATERIALS AND PROPERTIES

This chapter deals with the study of various materials used, material properties, mix design, experimental investigation and mathematical modelling.

MATERIALS USED

Cement: Ordinary Portland cement, 53 grade conforming to IS 12269-1987 of specific gravity 3.04.Fine Aggregate: Locally available M-sand conforming to IS10262-2009 Zone II of specific gravity 2.56.Course Aggregate: Locally available crushed grained stones conforming to graded aggregate of nominal size 20mm as per IS 10262-2009 Zone II and specific gravity 2.7. Hair Fibre: Collected from saloon s and beauty parlours which are non- degradable.Water: Portable water

CEMENT

The cement is the most important binding materials of concrete. The cement used for the experimental study is ordinary Portland cement of 53 grade.

Table 4.1: Chemical Properties of Cement

CHEMICAL PROPERTIES	PERCENTAGE
SiO_2	21.8
Al_2O_3	5.1
Fe_2O_3	3.9
CaO	64.8
MgO	<1.7
Cl	<0.03
SO_3	<2.0
L.O.I	<1.3
LnR	<0.6
F.CaO	<1.1
C_3A	<7.5
Total Alkali	<0.7

PROPERTIES OF CEMENT

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Table 4.2: Properties of Cement

Sl No.	PROPERTIES	VALUES
1	Initial Settling Time	30 min
2	Final Settling Time	600min
3	Specific Gravity	3.04
4	Fineness of Cement	4.33

COARSE AGGREAGATE

Crushed granite aggregate with specific gravity 2.7 and passing through 12.5mm sieve and will be used for casting all specimens. Several investigations concluded that maximum size of coarse aggregate should be restricted in strength of the composite. In addition to cement paste-aggregate ratio, aggregate type has a great influence on concrete dimension stability.

TESTING OF COARSE AGGREGATE

1. Specific gravity of coarse aggregate

Specific gravity of sand is 2.7

2. Aggregate impact test

Impact value of aggregate is 10.6%

HUMAN HAIR

Human hair is good in tension; hence it can be used as a fibre reinforcing materials. Hair fibre is a non-degradable matter available in abundance and at a very cheap coast. 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 height 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 aspect i.e. incorporating the nature 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 of hair waste. Present studies have been undertaken to analysis the effect of human hair on plain cement concrete on the basis of compressive and flexural strength and to control the cracking economically.

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

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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% 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 physics properties of hair involve resistance to stretching, elasticity and hydrophilic power. The resistance to breakage is a function of the diameter of thread, of the cortex condition. Hair fibre has an elastic characteristic, and it may undergo moderate stretching either wet or dry. When dry, the thread may stretch 20-30%of its length; and, in contact with water, this many reach up to 50%.

Fig 4.1 Human Hair

WATER

Casting and curing of specimens were done with the potable water that is available in the college premises. Water is an important ingredient to form a plastic mix in a concrete. It should be free from organic matter and ph value should be 6 to 7. So, the ph test was conducted with ph testing paper in the water, which was used in the project. The observed ph value of the water used is 7. Portable drinking water is only suitable for mixing. The workability of the concrete is depending upon the water added to the concrete.

MIX DESIGN

CONCRETE MIX DESIGN AS PER INDIAN STANDARDS

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The mix was designed for the characteristics compressive strength of 25N/mm2. As per IS guidelines and proportioning by weight and volume were arrived. All the materials were weighted and used.

1. DESIGN STIPULATIONS

- Characteristic compressive strength required at the field in 28 days = 25Mpa
- Maximum size of aggregate = 20mm

2. TEST DATA OF MATERIALS

- Specific gravity of cement = 3.15
- Specific gravity of coarse aggregate = 2.70
- Specific gravity of fine aggregate = 2.56

TARGET MEAN STRENGTH OF CONCRETE

Fck = fck + 1.65S

Fck = 20 + (1.65x 4) [IS 10262, Table 01]

=31.6N/mm2

EXPERIMENTAL INVESTIGATION

Testing of harden concrete plays an important role in controlling and confirming the quality of cement concrete works. One of the purposes of testing hardened concrete used at the site has developed the required strength.

MIX PROPORTION

In order to analyse the effects of fibre reinforced concrete using hair different mixes with a characteristic strength ranging from normal to high strength ones was prepared. The mix proportion is designed as per IS method. The mix design is done for a characteristic strength of 25Mpa.

WORKABILITY

The workability is defined as a property of concrete which determine the amount of useful internal work necessary to produce full compaction. The term workability is used to determine the ease or difficulty with which the concrete is handled, transported and placed the forms with minimum loss of homogeneity. Sometimes the term consistency and plasticity are used to determine the workability of concrete mix. The consistency of mix really means the wetness of the mix and a water mix need not have all the properties. On the other hand, an extremely wet mix and water mix need not have all the properties. On the other hand, extremely wet mix may

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cause segregation and may be difficult to place in moulds. Plasticity is the cohesiveness of the mix to hold the individuals grains together by cement mix.

SLUMP CONE TEST

The slump cone is the most well-known and widely used method to characterize the workability of fresh concrete. The apparatus of a mould in the shape of frustum of cone with a base diameter of 200mm, atop diameter of ,100mm and height of 300mm that typically slump test result of various water- cement ratio in ordinary concrete are shown in the table . Based on slump, concrete can be classified as:-

Fig 6.1 Slump Cone

MOULD PREPARATION

The moulds used for the preparation of test specimen are the standard cube mould and the cylinder mould. The standard dimension of the cube mould is 150mmX150mmX150mm and the cylinder is 150mm diameter and 300mm height.

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MIXING

The mixing is done in the ratio 1:1:2. Hand mixing is done in the project. As per our mix proportion water is added to the mix by taking the water cement ratio as 0.50.Cement and aggregates were mixed thoroughly. Then for the first mix we have added 1% of hair fibre.

CASTING

After the mixing of the concrete, the next step is the casting of the concrete. The size of the cube is 150X150X150mm and that of cylinder is 150mm diameter and 300mm height. Concrete of grade M25 is weighed, mixed, placed and compacted well in the respective moulds of cubes, cylinder and prism. By using the trowel the concrete is been casted to cube, cylinders and prism in standard size. Proper compaction is required during the casting of moulds. 25 number of compaction is done for the total three layers of mixing.

CURING

The cube, cylinder and prism are remould after 24 hours. The next step is curing of test specimen. Curing is done in water tank for finding the 7, 14 and 28 days strength of concrete blocks.

- The curing protects the concrete surface from sun and wind.

- The presence of essential to cause the chemical action which accompanies to setting of concrete that normally is adequate quality of water at the time of mixing to cause hardening of concrete. But it is necessary to retain water until the concrete has fully hardened.

- By proper curing the durability and permeability of the concrete are increased and the shrinkage is reduced.

- The resistance of concrete to abrasion is considerably increased by proper curing.

PERIOD OF CURING

This depends upon the type of cement and nature of work. The first three days is the most critical in the life of Portland cement concrete. In this period the hardening of concrete is susceptible to permanent damage on an average the one year strength of 28 days moist cured concrete, while no moist cured than lower strength to about 40%. Moist curing of the first 7-14 days may result in compressive strength of 70% to 80% of that of 28 days curing. The test specimens are properly cured in curing tank for 14 days and 28 days before tested.

TESTING OF SPECIMEN

The testing of specimen is in order to find the compressive strength, split tensile strength and flexural strength of specimen. The test is been carried out at every 7days, 14days and 28days of curing.

COMPRESSIVE STRENGTH TEST

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Cubical specimen of size 150x150x150mm were the cast of conducting compressive strength test for each mix. The compressive strength tests were carried out as per IS 516:1959. This test was carried out at the end of 7 days, 14 days and 28 days of curing. The compressive strength of every mix was taken as the average of strength of these cubes.

PROCEDURE

Remove the specimen from the water after specified curing time and wipe put excess water from the surface. Take the dimension of the specimen to the nearest of 0.2m. Clean the bearing surface of the testing machine. Place the specimen in the machine in such manner that the load shall be applied to the opposite side of the cube caste. Align the specimen centrally on the base plate of the machine. Rotate the movable portion gently by hand so that it touches the top surface of the specimen. Apply load gradually without shock and continuously to the rate of 140 kg per sq. Cm per minute till the specimen fails. Record the maximum load and not any unusual features in the type of failure.

CALCULATION

Size of cube = 150X150X150mm

Area of specimen = 22500 mm2 Maximum load applied = 654.7KN

= 654700N

Compressive Strength = Load/Area

=654700/22500

Compressive Strength = 29.1N/mm2

RESULT

Average compressive strength after 28 days of

SPECIMEN 1 = 25.1 N/mm2

SPECIMEN 2 = 26.0 N/mm2

SPECIMEN 3 = 28.4 N/mm2

SPECIMEN 4 = 29.1 N/mm2

SPLIT TENSILE STRENGTH

The split tensile strength test is the indirect measurement of the tensile strength by placing a cylindrical specimen horizontally between the loading surfaces. This method consists of applying a diametric compressive force along the length of the cylindrical specimen. This loading includes tensile stress on the plane containing the applied load. Tensile failure occures rather than

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compressive failure. Plywood strips are used so that the load is applied uniformly along the length of the cylinder and the load is applied until the failure of the cylinder, along the vertical diameter. The maximum load is divided by appropriate geometrical factors to obtain the splitting tensile strength of concrete are the ASTMC 496 splitting tensile test and the ASTMC 78 third point flexural loading test.

Split tensile strength, T = $2p/\pi LD$

PROCEDURE

Remove the specimen from the water after specified curing time and wipe put excess water from the surface. Draw diametrical lines on two ends of the specimen to ensure that they are on the same axial place. Note the weight and dimension of the specimen. Set the compressive testing machine for the required range. Place plywood on the lower plate and keep the specimen. Align the specimen so that lines drawn are on the ends of specimen are vertical centred over the bottom plate. Place other plywood strip above the specimen. Bring down the upper strip to touch the plywood strip. Apply the load continuously with shock at a rate of about 14-21 kg/sq.cm/ min.

CALCULATION

As per IS 456, split tensile strength of concrete = $2p/\pi LD$

= $2X\ 314500/(\pi X300X150)$

= 4.5 N/mm

RESULT

The split tensile strength after 28 days of

SPECIMEN 1 = 2.5 N/mm2

SPECIMEN 2 = 3.3 N/mm2

SPECIMEN 3 = 3.7 N/mm2

SPECIMEN 4 = 4.5 N/mm2

CONCLUSION

It has been observed on testing for compressive strength that the fiber reinforced concrete shows very less formation of cracks therefore use of fiber reinforced concrete using hair as a fiber can be used very efficiently for construction in seismic zones and where a construction free from cracks is desired as in case of pavement constructions. The maximum increase in strength is noticed when 2% hairs are used in concrete among all the set of cubes. It has also been observed that using of human hair not only increases compressive strength but also improves binding property of concrete as well as formation of micro cracks is reduced. Usually fiber reinforced concrete finds application in managing the formation of micro cracks and even turns out to be

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practical and an economical method. There is a remarkable increase in the concrete strength after adding human hairs as a fiber also the formation of cracks even got reduced. An alternate method for not only hair waste management but also has application in civil construction.

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