AN EXPERIMENTAL STUDY ON CHEMICAL EXPOSURE OF HUMAN HAIR FIBER REINFORCED CONCRETE (M40 GRADE)

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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 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. The experimental findings in our studies would encourage future research in the direction for long term performance to extending this cost-effective type of fibers for use in structural applications. Concrete cubes of M40 grade were casted and tested to examine various properties of concrete like workability, compressive strength and chemical exposure resistance. i.e. Sulphate attack, Sea water attack and Acid attack were carried out and cubes were tested after curing for 28 days, 56 days and 90 days. 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 applications.*

Keywords*: Chemical Resistance, fibre reinforced concrete, human hair fibre.*

INTRODUCTION:-

Concrete is an extensively used construction material for its various advantages such as low cost, availability, fire resistance etc. Concrete is the foremost necessary materials among the building materials in all kinds of civil engineering works. Since the variation of concrete as a building material, heap of researches and studies has been created to develop the superiority, strength and durability of it. Similar time efforts also are made to economize concrete construction compared to alternative materials. Concrete are often thought-about because the most generally employed in the construction area. The current day's construction follow together with the strength equivalent significance gives the durability of concrete. Efforts to improve the properties of concrete are continuously being made by researchers which led to the development of fibre reinforced concrete, Ferro-cement concrete etc. in recent years, improvement in concrete properties have been achieved by the invention of high-performance concrete (HPC). Improvements involving a combination of improved compaction, improved paste characteristics an aggregate-matrix bond and reduced porosity are achieved using super plasticizers. Further enhancements of some properties have been obtained through the addition of mineral admixtures such as metakaolin, silica fume and fly ash.

A concrete structure is built so as to last and maintenance free service as far as possible during the life of structure. Therefore, apart from strength, long term behavior under service conditions and environmental effects has also become important consideration in evaluating performance. To overcome various problems encountered in the field and to achieve better performance even in aggressive environments, use of high- performance concrete is becoming a more popular solution.

Concrete is weak in tension and has a brittle character. The concept of using fibres to improve the characteristics of construction materials is very old. Early applications include addition of straw to mud bricks, horse hair to reinforce plaster and asbestos to reinforce pottery. Use of continuous reinforcement in concrete (reinforced concrete) increases strength and ductility, but requires careful placement and labours kill. Alternatively, introduction of fibres in discrete form in plain or reinforced concrete may provide a better solution. The modern development of fibre reinforced concrete (FRC) started in the early sixties. Addition of fibres to concrete makes its homogeneous and isotropic material. When concrete cracks, the randomly oriented fibres start functioning, arrest crack formation and propagation, and thus improve strength and ductility. The failure modes of FRC are either bond failure between fibre and matrix or material failure.

Human Hair:- As a New Innovation to the field of Fibre Reinforced Concrete usage of Human Hair as a Fibre gained its importance. The hair thread is a natural fibre formed by keratin, a protein containing high concentration of sulphur coming from the amino acid cysteine. The main physical proprieties of the hair depend mostly on its geometry; the physical and mechanical properties of hair involve characteristics to improve: elasticity, smoothness, volume, shine, and softness due to both the significant adherence of the cuticle scales and the movement control (malleability), as well as the easiness of combing, since they reduce the fibres static electricity. The evaluation of these effects on hair may be carried out by several methods, as optical and electron microscopy, mechanical resistance measuring, shine evaluation and optical coherence tomography (OCT).

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 flexibility and mechanical resistance. Hair is considered as a dead mater and it is only alive when it is inserted in the scalp (pilose follicle). When the thread emerges, it becomes dead matter although it appears to be growing since the fibre follows increasing its length by a speed of about 1.0 cm/month. Human hair has about 65-95% of its weight in proteins, more 32% of water, lipid pigments and other components. Chemically, about 80% of human hair is formed by a protein known as keratin with a high grade of sulphur coming from the amino acid cysteine which is the characteristic to distinguish it from other proteins. Keratin is a laminated complex formed by different structures, which gives the hair strength, flexibility, durability, and functionality. Threads present remarkable structural differences, according to the ethnic group, and within the same group. These properties are related with fibres characteristics and with cosmetic attributes among the first ones we have: resistance, elasticity, diameter, bending, colour and shape of the cross section. In spite of depending on threads characteristics and on the morphological component's integrity, cosmetic properties are: shine, combing, volume, malleability, retention of styling, and ability of flying away. Hair has a particular genetic nature.

Anatomy and Physiology of Hair Fibre: Hair fibre is composed by three main structures: cuticle, cortex and medulla. The main factor to be considered in the human hair is the high amount of the amino acid cystine, which may be degraded and afterwards may be re-oxidized under a desulphated bounding form. This is the basis for the permanent curling process. Cystine is very stable; this is the reason why human hair may be found relatively intact, even after several years after the death of an individual.

Cuticle:-The cuticle covers the hair thread from the scalp to the end as overlapping layer and it is the most important component of the human hair, since it may be more or less affected by cosmetic treatments. On the cuticle, cosmetic products, such as conditioners, hair sprays, mousses and gels are deposited. Dyers, straightening and curling products also spread themselves through the cuticle to expand their effects by the hair fibre. There are approximately 8 to 11 layers of cuticle, which are overlapped in the distal direction of the thread, depending on the type, condition, and length of the hair. Each layer is formed by only one cell. Each cell of the cuticle has a rectangular shape and they overlap in such way, that only 1/6 of them are exposed which helps in inter bonding the hair fibre with concrete.

Cortex:-The cortex occupies most of the hair area (75%). In the same way as the cuticle, it has cells filled by cross links of cystine and hard cells separated by the cell membrane complex (CMC). Each one of the cortex cells has a spindle shape, with a 50-100 μm length and a 3 μm diameter. Each cell distal surface is rough, irregular, and they tie crossly to each other. This roughness and irregularity help in avoiding air voids formed between concrete and hair while binding and thus helps in forming a bond between them.

Medulla:-The medulla is a thin cylindrical layer in the center of the hair thread containing high lipid rate concentration and poor cystine. Its function is not yet completely elucidated, although its cells may become dehydrated and its spaces may be filled with air, which affects both color and shine in white brown and blond hair. The medulla has a small effect on most of the aspects of cosmetic hair treatments and they are only present in terminal hairs Recently, studies show that the medulla contains three distinct subunits (globular structures, unorganized cortical cells and smooth covering layer), which helped in advancing in the field of using Human Hair as fibre in concrete.

Physical and Mechanical Properties of Human Hair fibres

Hair physical proprieties:-Physical proprieties of hair depend mostly on its geometry. Caucasian hair is oval; Asian hair is circular; Afro hair is elliptic. Several mechanical proprieties are directly related with fibres.

Hair mechanical properties:-Hair is surprisingly strong. Cortex keratin is responsible for this propriety and its long chains are compressed to form a regular structure which, besides being strong, is flexible (Dias, 2004; Robbins, 1994). The physical proprieties of hair involve: resistance to stretching, elasticity and hydrophilic power.

Resistance to stretching:-In general, the weight needed to produce a natural hair thread rupture is 50-100 g. An average head has about 120,000 threads of hair and would support about 12 tons. The resistance to breakage is a function of the diameter of the thread, of the cortex condition, and it is negatively affected by chemical treatments.

When a certain load is applied on a hair and its elongation is measured we obtain the graphic representation of its several characteristic regions:

- Hookean's region or pre-recovering: during the stretching between 0 and 2% the elongation is proportional to the load applied.
- Recovering region: between 25-30% of stretching, the elongation considerably increases without a relationship with the load applied.
- After-recovering region: from 30% stretching load and fibre extension are proportional again.

Hair elasticity:- Hair fibre has an elastic characteristic, and it may undergo moderate stretching either wet or dry. Stretching is a hair attribute under the action of a distal force (length) and the thread returns to the original status, when this force stops acting. When dry, the hair thread may stretch 20-30% of its length; and, in contact with water, this may reach up to 50%. In contact with ammonia it becomes more elastic. Chemical and physical treatments, sun exposition and use of electric dryers and heated plates affect this property.

Absorption:-Hair surface retains the thread natural oils (sebum) composed by tensoactive ingredients and some dyers. Absorption of fatty substances is due to a physical process of surface tension. The sebum absorption over the hair occurs by contact with the scalp and transference from a thread to each other. Chemical treatments enhance the surface anionic nature of the hair thread, which becomes electronegative, causing its physical-chemical affinity with cationic components, as tensoactive and dyeing ingredients.

Friction:-Friction is the force resisting the movement when a body slide over another one. The cuticle surface has high friction coefficient due to its scale shape and it depends on the cuticle geometry and on the physical-chemical status of the hair. The continuous attrition of a thread over another one damages the cuticle. From the roots to the extremities the friction coefficient differs in the dry and wet hair thread, and it is enough combing to damage the hair.

Objective:- The aim of our project is to use the human hair fibres as fibre reinforcement in concrete. Our objective is to add human hair fibres to the concrete and to study the effects on chemical agents on human hair fibre reinforced concrete comparing it with conventional concrete. To study the strength of concrete (M-40 Grade) for fibre content of 1.5% at 28 days, 56 days and 90 days by effect of acid, sulphate & sea water attack.

Acid Attack:-Concrete is susceptible to acid attack because of its alkaline nature. The components of the cement paste break down during contact with acids. Most pronounced is the dissolution of calcium hydroxide which occurs according to the following reaction:

2 HX + Ca (OH) 2 > CaX2 +2 H2(X is the negative ion of the acid)

The decomposition of the concrete depends on the porosity of the cement paste, on the concentration of the acid, the solubility of the acid calcium salts (CaX2) and on the fluid transport through the concrete. In soluble calcium salts may precipitate in the void sand cans low down the attack. Acids such as nitric acid, hydrochloric acid and acetic acid are very aggressive as their calcium salts are readily soluble and removed from the attack front. Other acids such as phosphoric acid and humic acid are less harmful as their calcium salt, due to their low solubility, inhibit the attack by blocking the pathways within the concrete such as inter connected cracks, voids and porosity. Sulphuric acid is very damaging to concrete as it combines an acid attack and a sulfate attack.

Sulphate Attack:- The sulphates of Calcium, Sodium, potassium and magnesium represent in most soils, and ground water. Agricultural soil and water contain ammonium sulphate, from the use of fertilizers or from sewage and industrial effluents. Water used in concrete cooling towers can also be a potential source of sulphate attack. In marshy land decay of organic matters leads to the formation of H2S, this is converted into sulphuric acid by bacteria. Solid salts do not attack concrete, but when present in solution they can react with hardened cement paste. In the hardened concrete, sulphates react with the free calcium hydroxide [Ca (OH) 2] to form gypsum (Calcium Sulphate). Similarly, sulphates react with calcium aluminum hydrate (C-A-H) to form calcium sulphoaluminate, the volume of which is approximately 117% of the volume of original aluminates. The produce of the reactions, gypsum and calcium sulphoaluminate have a considerably greater volume than the compounds they replace, so that the reactions with the sulphates lead to expansion and disruption of the concrete. Of all the sulphates magnesium sulphate causes maximum damage to concrete. A characteristic whitish appearance in the indication of sulphate attack.

External Sulfate Attack:- This is the more common type and typically occurs where water containing dissolved sulfate penetrates the concrete. A well-defined reaction front can often be seen in polished sections; ahead of the front the concrete is normal, or near normal. Behind the reaction front, the composition and micro structure of the concrete will have changed. These changes may vary in type or severity but commonly include:

- Extensive cracking

- Expansion
- Loss of bond between the cement paste and aggregate

Alteration of paste composition, with mono sulphate phase converting to ettringite and, in later stages, gypsum formation. The necessary additional calcium is provided by the calcium hydroxide and calcium silicate hydrate in the cement paste. The effect of these changes in an overall loss of concrete strength.

Internal Sulfate Attack:- It occurs where source of sulfate is incorporated into the concrete when mixed. Examples include the use of sulfate-rich aggregate, excess of added gypsum in the cement or contamination. Proper screening and testing procedures should generally avoid internal sulfate attack.

Delayed Ettringite Formation:- Delayed ettringite formation (DEF) is a special case of internal sulphate attack. DEF has been a significant problem in many countries. It occurs in concrete which has been used. It was originally identified in steam-cured concrete. DEF causes expansion of the concrete due to ettringite formation with in the paste and can cause serious damage to concrete structures.

Figure-1 Human hair

Experimental Investigation:

In order to study the durability properties of human hair fibre reinforced concrete made with 1.5% replacement of cement by human hair (by weight) and compare them with conventional concrete, respective experiment was conducted on 66 cubes.

Each group consists of 33 cubes of size 150mm x150mm x 150mm.

1. The first group is the Plain concrete with 0% fibre (PCC).
2. The second group consisted of 1.5% of human hair fibre by weight of cement.

Table-1 Physical properties of O.P.C

S.No.	Properties	Test Results
1	Specific Gravity	3.15
2	Initial Setting Time	35 min

Table -2 Properties of fine aggregate

Property	value
Specific Gravity	2.68
Fineness Modulus	2.5

Table 3 Physical Properties of Coarse Aggregate (20mm)

Property	value
Specific Gravity	2.74
Fineness Modulus	7.07

HUMAN HAIR FIBRES:- Human hair has about 65-95% of its weight in proteins, more 32% of water, lipid pigments and other components. Chemically, about 80% of human hair is formed by a protein known as keratin, with a high grade of sulphur coming from the amino acid cysteine – which is the characteristic to distinguish it from other proteins. Keratin is a laminated complex formed by different structures, which gives the hair strength, flexibility, durability, and functionality.

PHYSICAL AND MECHANICAL PROPERTIES OF HAIR FIBRES

Physical proprieties of hair depend mostly on its geometry and several mechanical proprieties are directly related with fibres diameter. Some mechanical proprieties of hair involve: resistance to stretching, elasticity and hydrophilic power.

Property	value
Hair diameter	100 to 120 μm
Hair length	6cm
Aspect ratio	500 – 600
Tensile strength of Human Hair fibre	380 MPa

Super Plasticizer:- As we are dealing with fibres in concrete its mandatory to use super plasticizer to reduce the water content and achieve workability. Because the fibres make the concrete harsh. 20% reduction in the water has been considered. The super plasticizer used in this investigation is roof plast SP-45.

Property	value
Colour and form	Brown liquid
Based on	Sulphonated naphthalene
Complies to	polymers

codes	
Workability	IS 9103-1999
Dosage	BS 5057- III

Table 6 Design mix proportions

Cement	Fine aggregate	Coarse aggregate	water
1	1.94	2.52	0.4

Human Hair Fibre Quantity Calculations:

- Human hair required for 1 cube = 21.26 gm
- Quantity of human hair required for all casting process = 701.58 gm
- Human hair required for 1 cubic meter = 6299.25 mgs (6.29 kgs).

DETAILS OF NUMBER OF SPECIMENS PREPARED:- A total number of specimens prepared were 66. The cubes prepared were totally 33 in number, with 1.5% hair fixed. Out of 33 cubes mixed with hair, 3 cubes were tested for 7day strength and 3 cubes for 28 days strength which were cured in water. Later, 27 cubes were cured in different media. Out of 27 cubes, 3 cubes which were cured in acidic medium were tested for 28 days strength,3 cubes for 56 days strength and 3 for 90 days strength. Similarly, for basic and marine media. Remaining 33 cubes without hair Out of which, 3 cubes were tested for 7day strength and 3 cubes for 28 days strength which were cured in water. Later, 27 cubes were cured in different media. Out of 36 cubes, 3 cubes which were cured in acidic medium were tested for 28 days strength, 3 cubes for 56 days strength and 3 cubes for 90 days strength. Similarly, for basic and marine media.

Figure-2 Hand mixing of Concrete

Experimental Results

Concrete made from Portland cement, is relatively strong in compression but weak in tension and tends to be brittle. The weakness in tension can be overcome by the use of some fibre reinforcement and to some extent by the mixing of certain percentage of fibres by weight of cement. In this Experimental Study, we used Human hair as fibres in concrete which tend to increase the strength naturally as it has a good binding property. In this study, the main mechanical property like Compressive Strength is evaluated and compared with conventional concrete by plotting graphs and explaining its suitability.

Compressive Strength :-In this research work, the values of compressive Strength for 1.5% Human hair which were immersed in different media at 28 days, 56 days and 90 days as given in Table 3 & 4 respectively. These values are plotted which show variation of compressive strength of cubes which were immersed in acidic, basic, marine media (with 1.5% hair fixed) at curing ages of 28 days,56 days& 90 days respectively.

Table 7 Compressive strength of normal concrete at 7days and 28 days.

Curing period	Peak Stress (M pa)
1(7days)	29.32
2(7 days)	30.79
3(7 days)	29.80
1(28 days)	47.75
2(28 days)	46.92
3(28 days)	48.43

Table 8 Compression strength of HHFRC at 7 days and 28 days

Curing period	Peak Stress (M pa)
1(7days)	33.03
2(7 days)	32.59
3(7 days)	34.76
1(28 days)	51.56
2(28 days)	52.50
3(28 days)	51.09

Table 9 Compressive strength (Mpa) of normal concrete in different media

Medium	28 days	56 days	90 days
Acidic	44.90	40.22	34.92
Basic	45.76	42.08	38.40
Marine	45.02	40.78	38.34

Table 10 Compressive strength (MPa) of Hair Fibre Reinforced Concrete in different media

Medium	28 days	56 days	90 days
Acidic	50.18	46.02	40.72
Basic	51.02	47.89	42.33
Marine	51.31	48.11	43.02

Table 11 Average Weights (Kgs) of the Cubes in H2SO4 Solution

CONCRETE	28 days weight (water curing)	28 days weight	56 days weight	90days weight
Normal Concrete	8.585	8.580	8.525	8.490
HHFRC	8.443	8.435	8.362	8.265

Table 12 Average Weights (Kgs) of the Cubes in MgSO4 Solution

CONCRETE	28 days weight (water curing)	28 days weight	56 days weight	90days weight
Normal Concrete	8.500	8.490	8.340	8.336
HHFRC	8.450	8.435	8.289	8.280

Table 13Compressive Strength of Concrete Cubes in H2SO4 Solution

CONCRETE	28 days	56 days	90days
Normal Concrete	44.90	40.22	34.92
HHFRC	50.18	46.02	40.72

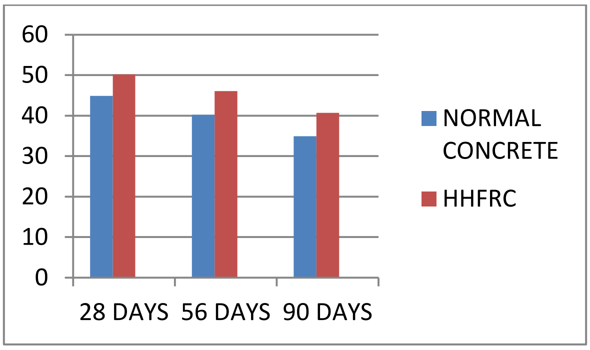

Figure- 3 Compressive Strength of Concrete Cubes in H2SO4 Solution

Table 14 Compressive Strength of Concrete Cubes in MgSO4 Solution

CONCRETE	28 days	56 days	90days
Normal Concrete	45.76	42.08	38.40
HHFRC	51.02	47.89	42.33

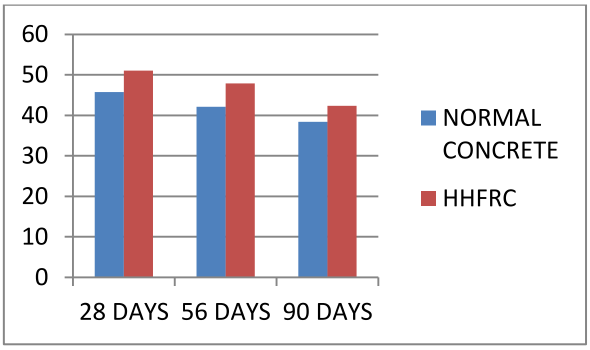

Figure- 4 Compressive Strength of Concrete Cubes in MgSO4 Solution

Table 15 Compressive Strength of Concrete Cubes in Sea Water

CONCRETE	28 days	56 days	90days
Normal Concrete	42.02	40.78	38.34
HHFRC	51.31	48.11	43.02

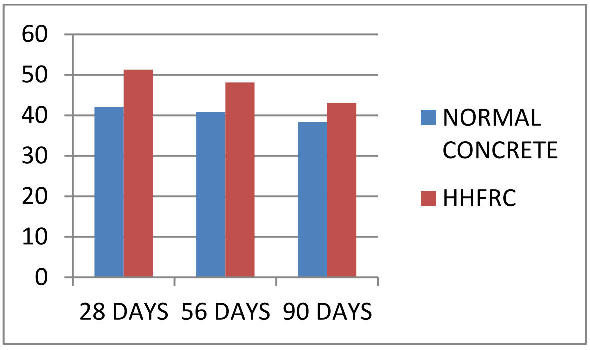

Figure- 5 Compressive Strength of Concrete Cubes in Sea Water

The concrete cubes which are casted and are weighted on 28th day and they are also weighted after immersion in MgSO4 solution. The average weight of each sample cubes is tabulated in the above table. The test results indicate that the weight decreases by 1.88% at 56days and 1.92% 90 days for normal concrete cubes in MgSO4 solution. Whereas 1.90% and 1.90% decrease for 56days and 90days respectively for human hair fibre reinforced concrete cubes in MgSO4 solution.

Figure-6 Curing of Cubes

Conclusions

When M-40 concrete (1.5% hair is fixed) when exposed to acidic, basic and marine conditions is compared with the plain cement concrete, it is found that

- 2.92% less decrement in compressive strength of HHFRC at 28 days when immersed in acidic medium.
- 4.68% less decrement in compressive strength of HHFRC at 56 days when immersed in acidic medium.
- 5.54% less decrement in compressive strength of HHFRC at 90 days when immersed in acidic medium.
- 2.73% less decrement in compressive strength of HHFRC at 28 days when immersed in basic medium.
- 4.4% less decrement in compressive strength of HHFRC at 56 days when immersed in basic medium.
- 1.36% less decrement in compressive strength of HHFRC at 90 days when immersed in basic medium.
- 4.84% less decrement in compressive strength of HHFRC at 28 days when immersed in marine medium.
- 7.54% less decrement in compressive strength of HHFRC at 56 days when immersed in marine medium.
- 2.81% less decrement in compressive strength of HHFRC at 90 days when immersed in marine medium.

The test results show that due to incorporation of human hair fibre the compressive strength and the chemical resistance characteristics of human hair fibre reinforced concrete can be elevated slightly.

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