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Research Article

ANALYSIS OF FIBRE REINFORCED CONCRETE: USING HUMAN HAIR AS A FIBRE REINFORCEMENT

Akash Sharma., Derrick Singh., Dhriti Kashyap., Sachin Kumar., Suraj Chamola and Sakshi Gupta*

Department of Civil Engineering, Graphic Era University, Dehradun (248002), Uttarakhand

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ABSTRACT

Compressive strength is the primary measure of the strength parameter of concrete. It depends upon the quality of the materials used to prepare the concrete *i.e* cement, fine aggregates and coarse aggregates. As technology is getting advance day by day due to commercialization, new findings are being made to explore the possibility for increasing the compressive strength of the concrete within an economic spectrum. As human hair offers resistance to tension and it is also found in abundance in nature therefore it can be used as fibre reinforcement in concrete. This work analysis the possibility of using human hair as a fibre reinforcement material by testing concrete cubes in compression testing machine at the laboratory for comparing the compressive strength of plain cement concrete with fibre reinforced concrete having human hair in different percentages like 1%, 1.5%, 2% and 8% by weight of cement for the curing period of 7, 14 and 28 days as per IS 456:2000 (Indian standard Plain and Reinforced Concrete-Code of Practice). The main result of this current research work will lead to the finding of the fact that whether the compressive strength increases or not by using human hair as a fibre reinforcement material in concrete mixture.

INTRODUCTION

Most of us know that what is concrete and where it is used. It is a common term which means a mixture of materials generally used in the construction work. Compressive strength is the primary measure of the strength parameter of concrete. It depends upon the quality of the materials used to prepare the concrete *i.e* cement, fine aggregates and coarse aggregates. But many of us are not familiar with the term fibre reinforced concrete. Fibre reinforced concrete is concrete containing fibrous material which imparts greater binding to the concrete and increases its structural integrity as a whole. It contains of short discrete fibres which are randomly oriented and distributed uniformly. It can be basically defined as the concrete containing mixture of cement, fine aggregates, coarse aggregates and discrete, discontinuous and uniformly dispersed fibres. The various fibres which can be used as the fibre reinforced material are glass fibres, synthetic fibres, steel fibres and natural fibres.

Human hair can be used as fibre in fibre reinforced concrete as well owing to the various reasons. It imparts higher tensile strength which can be equal to the tensile strength of copper wire having same diameter (*Jain D and Kotahri A, 25th Jan, 2012*). It has a cortex which is made of parallel fibrils & a corresponding matrix. The way these two parts work together is what helps the hair to withstand stress and strain. They undergo structural change when hair is stretched before the actual breaking occurs. Recently a discovery has been made by University of California scientists who recently published their findings in the journal Materials science & Engineering have found that the faster the hair is stretched the stronger it becomes. It can be stretched 1.5 times of its initial length before breaking *(Source: "Verse: Science & Chill")*. Human hair not only offers higher compressive strength but also serves up the purpose to reduce the micro cracking and increasing structural stability *(T. Naveen Kumar, Komarshetty Gautami et al, Aug 2015)*. Also 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% *(Nila V, Raijan et al, October 2015)*. And as it is found in abundance so this is within economic limit as well.

Fibre reinforced concrete has started gaining its importance in the various applications of civil engineering works where there is greater stress on increasing durability and repairing operations. It is used in the civil engineering works where the

*Corresponding author: **Sakshi Gupta***
Department of Civil Engineering, Graphic Era University, Dehradun (248002), Uttarakhand

motive is to curb the corrosion to the maximum limit. Fibre reinforced concrete caters to minimize erosion/cavitation damage in the hydraulic structures like bridge piers, sluice ways and navigational blocks where there are flows with high velocity. Fibre reinforced concrete is substantially lighter than as compared to heavy plain cement concrete but offers the equivalent strength hence making itself more workable. Fibres present in concrete reduce internal forces by blocking microscopic cracks from forming within the concrete. The uses of fibre reinforced concrete in civil sector are as follows: The hair fibre reinforced concrete is used in the laying of runways, aircraft parking pavements and other type of pavements. It is used for lining of tunnel and rock stabilization. It neglects need for mesh reinforcement at scaffolding. In the preparing of spherical domes, thin shells, walls, pipes and manholes the fibre reinforced concrete was used. The fibre reinforced concrete is used for the construction and repairs of dams and other hydraulic structures to provide resistance to cavitation and erosion caused by the impact of large waterborne debris.

METHODOLOGY

This current experimentation is done by comparing the strength parameter of concrete. Human hairs is added to plain cement concrete in different % as 0, 1, 1.5, 2 and 8 by weight of cement and is compared for 7, 14, & 28 days curing period.

The entire work was divided into two major portions i.e firstly making concrete cubes of normal plain cement concrete with M20, M25 and M30 grade having 3 cubes for each grade for the curing period of 7, 14 and 28 days *(Figure 1)* and after completion of this task concrete cubes were casted with hair as a fibre reinforcement taken 1%, 1.5%, 2% and 8% by weight of cement with M20, M25 and M30 grade of concrete with 3 cubes for each grade and percentage of hair taken for the same duration of curing period which is mentioned earlier *(Figure 2).* The water cement ratio was taken as 0.5 by weight of cement. *(IS 456:2000).*

Figure 1 Cast iron moulds prepared for casting concrete cubes

Figure 2 Preparation of concrete mixture

The hairs needed for the preparation of concrete cubes were collected from salons and beauty parlours and were further separated from other waste and after sorting, the hair were washed with water and then dried under sun, then the hair were sorted according to length, colour and quality *(Achal Agarwal et al-2016).*

The weight of hairs was calculated by using sensitive weighing machine. It was made sure that the addition of hairs in the mixture is uniformly done and the hairs should be free from other waste matters. Water was not added till the time the whole mixture of fine aggregates, coarse aggregates, cement and hairs is fully integrated with each other. In normal mix also, mixing of cement, fine aggregates and coarse aggregates was thoroughly done before water being poured in and after that water was added suitably and mixing was done again to make the concrete mixture uniformly wet and ready for placing. Then cast iron moulds were placed on the vibrating table and the fresh made concrete was being placed layer by layer in the moulds on the vibrating table. After placing two layers of concrete the vibrating table was switched on to offer uniform vibrations and then placing of concrete has been done continuously till the mould is completely full with concrete. The vibrating table has been used to compact the concrete mass effectively so as to reduce any chance of air bubbles void inside the concrete cube *(Figure 3).*

Figure 3 Compaction of concrete being done on the vibration table

After this the moulds were taken off from the vibrating table and were put inside the lab at a suitable place and left untouched for next 24 hours. And after exact 24 hours the moulds were opened and concrete cubes were taken out and straight away placed in the curing pond full with fresh and clean water for the curing period of 7, 14 and 28 days *(Figure4).* And after completion of this duration, the cubes were tested for the compressive strength in the compression testing machine for both types of concrete i.e Normal mix concrete cubes and Hair reinforced concrete cubes to carry out the comparison and analysis, to check how much the strength varies in accordance with the hair being used as a fibre reinforcement.

Figure 4 Cubes are being submerged in the curing pond for curing period of 7, 14 & 28 days

Materials Used

The ordinary Portland cement of 43 Grade is used with specific gravity 24 KN/m^2. The sand used for the experimental work was locally procured and confirmed to grading zone II. The sand was sieved first through 4.75mm sieve to remove any particles greater than 4.75mm and was then washed to remove dust. The coarse aggregates used in this experimental investigation are of 20mm (60%), 16mm (20%) and 12mm (20%) sizes, crushed angular in shape. The aggregates are made free from dust before being used in the concrete. Its specific gravity is 2.74 and the hairs used should be free from dust particles and any other matter, approximately uniform length of hairs should be mixed with the concrete mix and while mixing the hairs in concrete mix, equal distribution of hairs should be done over the concrete. Also water used in the work is conformed to IS: 456-2000 for mixing as well as curing of concrete specimens.

Compression Test

It is the most common test conducted on hardened concrete as it is an easy test to perform and also most of the desirable characteristic properties of concrete are qualitatively related to its compressive strength. The compression test is carried out on specimens cubical in shape of the size 150 × 150 × 150 mm. The load rate is taken as constant at 5.2 KN/mm^2 for each concrete cube tested. While applying load it is to be taken care of that load rate is neither too fast and not too slow, a moderate speed of load rate is maintained with the help of load rate lever so that the concrete cube which is being tested should give optimum resistance in order to get the accurate reading *(Figure 5).*

Figure 5 Compression Testing Machine

RESULTS AND DISCUSSIONS

The results are briefly tabulated and are shown in tables below, which shows the comparison of the compressive strength test performed on concrete cubes with the various mixes of concrete mixed with percentages of hair fibre by the weight of cement. We have done the comparison analysis of M20, M25 and M30 mix for the curing period of 7, 14 and 28 days.

Compressive strength analysis for curing period of 7 days

After the completion of the curing period of 7 days, cubes were tested under compressive testing machine. The load rate has been taken as 5.2 KN/mm^2 *(Table 1-3).*

Table 1 Compressive strength at 7 days curing period for M20 mix

S.No	Concrete mix	% Hair	Maximum load recorded (KN)	Compressive strength (N/mm^2)
1.	M20	0%	314.58	13.98
2.	M20	1%	321.34	14.28
3.	M20	1.5%	325.28	14.45
4.	M20	2%	331.83	14.74

Table 2 Compressive strength at 7 days curing period for M25 mix

S.No	Concrete mix	% Hair	Maximum load recorded (KN)	Compressive strength (N/mm^2)
1.	M25	0%	473.40	21.04
2.	M25	1%	481.38	21.39
3.	M25	1.5%	487.43	21.66
4.	M25	2%	493.09	21.91

Table 3 Compressive strength at 7 days curing period for M30 mix

S.No	Concrete mix	% Hair	Maximum load recorded (KN)	Compressive strength (N/mm^2)
1.	M30	0%	527.62	23.45
2.	M30	1%	543.60	24.16
3.	M30	1.5%	558.22	24.81
4.	M30	2%	579.15	25.74

Compressive strength analysis for curing period of 14 days

After the completion of the curing period of 14 days, cubes were tested under compressive testing machine. The load rate has been taken as 5.2 KN/mm^2 *(Table 4-6).*

Table 4 Compressive strength at 14 days curing period for M20 mix

S.No	Concrete mix	% Hair	Maximum load recorded (KN)	Compressive strength (N/mm^2)
1.	M20	0%	392.62	17.45
2.	M20	1%	394.19	17.51
3.	M20	1.5%	397.54	17.66
4.	M20	2%	402.83	17.90

Table 5 Compressive strength at 14 days curing period for M25 mix

S.No	Concrete mix	%Hair	Maximum load recorded (KN)	Compressive strength (N/mm^2)
1.	M25	0%	519.25	23.07
2.	M25	1%	524.93	23.33
3.	M25	1.5%	526.71	23.40
4.	M25	2%	531.69	23.63

Table 6 Compressive strength at 14 days curing period for M30 mix

S.No	Concrete mix	%Hair	Maximum load recorded (KN)	Compressive strength (N/mm^2)
1.	M30	0%	537.25	23.87
2.	M30	1%	549.61	24.42
3.	M30	1.5%	558.74	24.83
4.	M30	2%	571.29	25.39

Compressive strength analysis for curing period of 28 days

This curing period is the final period for strength analysis of concrete cubes of concrete mixes of M20, M25 and M30. The load rate has been taken as 5.2 KN/mm^2 *(Table 7-9).*

Table 7 Compressive strength at 28 days curing period for M20 mix

S.No	Concrete mix	% Hair	Maximum load recorded (KN)	Compressive strength (N/mm^2)
1.	M20	0%	480.33	21.34
2.	M20	1%	498.31	22.14
3.	M20	1.5%	515.88	22.92
4.	M20	2%	525.82	23.37

Table 8 Compressive strength at 28 days curing period for M25 mix

S.No	Concrete mix	%Hair	Maximum load recorded (KN)	Compressive strength (N/mm^2)
1.	M25	0%	568.31	25.25
2.	M25	1%	601.56	26.72
3.	M25	1.5%	616.80	27.41
4.	M25	2%	647.38	28.77

Table 9 Compressive strength at 28 days curing period for M30 mix

S.No	Concrete mix	%Hair	Maximum load recorded (KN)	Compressive strength (N/mm^2)
1.	M30	0%	687.6	30.56
2.	M30	1%	698.65	31.05
3.	M30	1.5%	722.44	32.10
4.	M30	2%	740.26	32.90

Compressive strength analysis with 8% hairs for the period of 14 days

We casted three more concrete cubes having 8% hairs by weight of cement for M20, M25 and M30 mix of concrete for the curing period of 14 days. We performed this operation because the research papers we've referred to had limited their work till maximum 5% hairs, so we opted for having new additional information in our project. The curing period of 14 days is taken due scarcity of time *(Table 10).*

Table 10 Compressive strength at 14 days curing period with 8% hairs addition

S.No	Concrete mix	% Hairs	Maximum load recorded (KN)	Compressive Strength (KN/mm^2)
1.	M20	0%	392.62	17.45
2.	M20	8%	422.8	18.79
3.	M25	0%	519.25	23.07
4.	M25	8%	532.60	23.67
5.	M30	0%	537.25	23.87
6.	M30	8%	547.6	24.33

RESULT ANALYSIS

- When M20 concrete with 1% hair is compared with the plain cement concrete for the curing duration of 7 days, it was found that there is an increase of 2.31% in compressive strength and with 1.5% hair it was found that there is an increase of 3.25% in compressive strength and with 2% hair there was an increase of 5.15% in compressive strength.
- When M25 concrete with 1% hair is compared with the plain cement concrete for the curing duration of 7 days, it was found that there is an increase of 1.63% in compressive strength and with 1.5% hair it was found that there is an increase of 2.86% in compressive strength and with 2% hair there was an increase of 3.97% in compressive strength.
- When M30 concrete with 1% hair is compared with the plain cement concrete for the curing duration of 7 days, it was found that there is an increase of 2.93% in compressive strength and with 1.5% hair it was found that there is an increase of 5.48% in compressive strength and with 2% hair there was an increase of 8.89% in compressive strength *(Figure 6).*

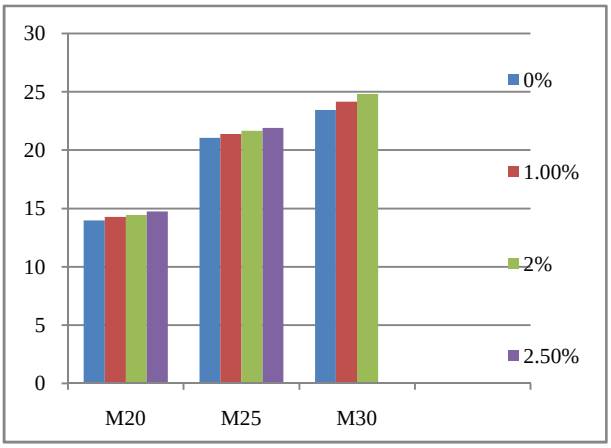

Figure 6 Graph showing increase in compressive strength for curing period of 7 days

- Again now when M20 concrete with 1% hair is compared with the plain cement concrete for the curing duration of 14 days, it was found that there is an increase of 0.34% in compressive strength and with 1.5% hair it was found that there is an increase of 1.19% in compressive strength and with 2% hair there was an increase of 2.51% in compressive strength and with 8% added hairs it is increased by 8.72% compared to PPC.
- Again now when M25 concrete with 1% hair is compared with the plain cement concrete for the curing duration of 14 days, it was found that there is an increase of 1.11% in compressive strength and with 1.5% hair it was found that there is an increase of 1.41% in compressive strength and with 2% hair there was an increase of 2.36% in compressive strength and with 8% added hairs it is increased by 2.53% compared to PPC.
- Again now when M30 concrete with 1% hair is compared with the plain cement concrete for the

curing duration of 14 days, it was found that there is an increase of 2.25% in compressive strength and with 1.5% hair it was found that there is an increase of 3.86% in compressive strength and with 2% hair there was an increase of 5.98% in compressive strength and with 8% added hairs it is increased by 1.89% compared to PPC *(Figure 7).*

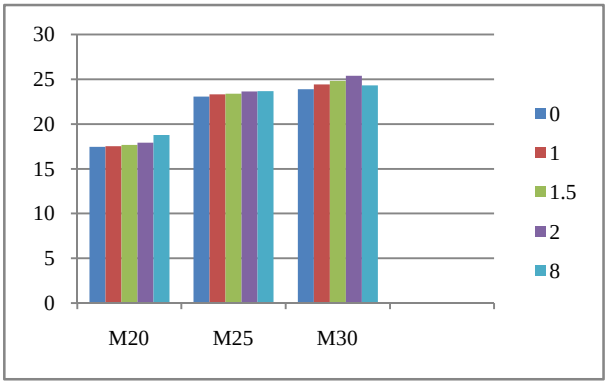

Figure 7 Graph showing increase in compressive strength for curing period of 7 days

- Now M20 concrete with 1% hair is compared with the plain cement concrete for the curing duration of 28 days, it was found that there is an increase of 3.61% in compressive strength and with 1.5% hair it was found that there is an increase of 6.89% in compressive strength and with 2% hair there was an increase of 8.68% in compressive strength.
- Now for M25 concrete with 1% hair is compared with the plain cement concrete for the curing duration of 28 days, it was found that there is an increase of 5.50% in compressive strength and with 1.5% hair it was found that there is an increase of 7.88% in compressive strength and with 2% hair there was an increase of 10.23% in compressive strength.
- Now M30 concrete with 1% hair is compared with the plain cement concrete for the curing duration of 28 days, it was found that there is an increase of 1.57% in compressive strength and with 1.5% hair it was found that there is an increase of 4.79% in compressive strength and with 2% hair there was an increase of 7.11% in compressive strength *(Figure 8).*

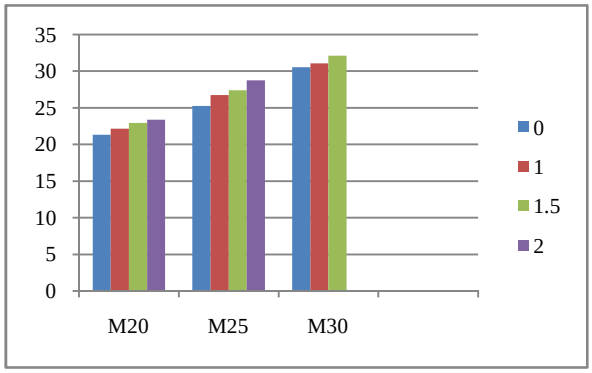

Figure 8 Graph showing increase in compressive strength for curing period of 28 days

So this is what we have analysed so far that using human hairs as a fibre reinforcement in concrete do increase its strength.

CONCLUSION

1. Crack formation and propagation are very much reduced showing that hair fibre reinforced concrete can have various applications in seismic resistant and crack resistant constructions, road pavement constructions etc *(Figure 9)*
2. It is well observed that the maximum increase is noticed in the addition of 2% hair fibre, by weight of concrete, in all the mixes.
3. Crack formation and propagation are very much reduced showing that FRC can have its applications in seismic resistant constructions.
4. The addition of human hairs to the concrete not only modifies various properties of concrete like compressive strength but also enhances the binding properties, micro cracking control and also increases spalling resistance.
5. Limitation of 10% addition of hairs by weight of cement in the concrete mixture as the incorporation of fibres was not workable and the concrete prepared was under segregation, so it was not possible to prepare a concrete cube with segregated concrete mixture.

Figure 9 Conventional cube has multiple cracks (Left) & Fibre reinforced cube has a single crack (Right)

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