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Analyzing Strength Characteristics of Self Compacting Concrete by using Hair Fibre as a Partial Replacement of Cement

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Abstract: In a field of construction, eco-friendly, cost and time are the three key factors which every civil engineer have to satisfies, For that purpose we use human hair which is going as a waste in our experimental study and determining the positive effect in the properties of concrete as fibre reinforced concrete. Annually 40 tones of hair is available throughout the world causing problems in degradation, by using hair as a fragmentary replacement of cement in concrete can reduce environmental problems. Though hair is a typical bio-degradable matter available in abundance at cheaper cost so that we can also reduce some cement content and cost factor. On the other hand a new technology named self-compacting concrete which is developed by the skilled work man ship is used. Using SCC can shorten the time and decrease the cost of building process. SCC has good elastic property in fresh state and have high resistance to segregation, it can spread under gravity due to its self weight without any vibration or compaction. The incorporation of randomly distributed hair fibre in SCC enhances its tensile property (i.e. human hair is strong in tension), and effective in delaying micro cracks and also hope combination of these two made a new technology views saving environment and making a construction with ease come reducing cost and saving the time of project. Experiments were conducted on concrete cubes of standard sizes ($0.15m^3$) with addition of different proportions of human hair fibres (i.e. 0%, 0.25%, 0.5%, 0.75%, and 1%) by weight of cement. In this work, fly ash is used as mineral admixture and PCE based super plasticizer as chemical admixture for achieving fluidity nature. For each percentage of hair fibre added in concrete, the 7 days, 14 days and 28 days compressive strength of cubes are obtained by crushing in compression testing machine.

Index Choice: Self compacting concrete; Fibre reinforced concrete; Human air fibre; Fly ash; Compression testing

I. INTRODUCTION

I. General: over the last decade a rapid growth in concrete construction has enhanced concrete productivity and improved working environment. The addition of fibers in SCC has a great affect on its productivity in practice. Through the elimination of compaction process, requirement of using SCC and reduction of micro cracks by using fibre reinforced concrete has widely improved the productivity of SCC. The working environment has enriched through elimination of vibration induced damages and there by reduced noise, and improved safety.

Self-compacting concrete is also called self-consolidating concrete or self-leveling or vibration free concrete. The idea of SCC was first initiated by Hazime okamura in 1986, but the first prototype was manufactured in Japan during year 1988 by Ozawa due to lack of skilled work men. FRC is defined as composite material containing a mixture of cement mortar or concrete and small, well defined and uniformly dispersed suitable fibres.

FRC is made of different fibres such as steel fibres, natural fibres, glass fibres and synthetic fibres etc,. FRC consists of a fibre which is a small piece of reinforcement material possessing certain characteristic properties; these may changes with varying concrete, fibre materials, geometric, distribution, orientation, densities mixing and compaction techniques of concrete, shape and size of the aggregates.

These fibres help to arrest the propagation of cracks, thus improving the tensile strength of concrete and substantially increase its mechanical properties. By the addition of Super plasticizers, water cement ratio can be reduced. Decrease in water cement ratio substantially enhances the compressive strength of SCC.

Hair is a typical bio-degradable matter available in abundance at very low cost causing environmental problems. Because of a typical bio-degradable nature of the hair they can only be disposed in an economical way by consigning them to land fill and such they are relatively environmentally unfriendly. Therefore this hair fibre is to be effectively utilized in an economical and environmentally friendly way, in this context incorporation of hair fibre as admixture in concrete. Concrete is weak in tension and hence remedial measures must be taken to overcome this deficiency. A way of overcoming this is, by introducing hair fibres which has tensile strength and readily available in large quantities in concrete.

There are lot of saloon, beauty parlors, temples and manicure centers springing up in almost all the shopping complexes throughout the country and huge waste materials coming from the centers are the used synthetic hair. Therefore this work deals with reuse of the synthetic hair fibre in concrete production so as to reduce the waste so that reducing the environmental problems and simultaneously improving the strength of the concrete.

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Thermal insulation makes its suitable for reinforcing material. Hair entangles the mortar and prevents it from spalling.

II. MATERIALS & MIX DESIGN

1.Materials to be used

In this project materials like cement, fly ash, river sand, coarse aggregates, super plasticizers, water and hair fibres are used in this study. The description of each of the material is mentioned in the following sections. The aim of this study is to evaluate the effect of the hair fibres on strength and durability characteristics of SCC. The test results of the materials used in this work were obtained according to respective IS codes.

2.Cement

The prior engineering purpose of cement is to produce mortar and concrete for binding of aggregates to form a construction that is durable under normal environmental conditions. In this exp; cement OPC 53 grade specified by IS 12269-2013 is used.

Property	Results
Specific gravity	3.15
Fineness	98%
Consistency	30%
Initial setting time	30 minutes (minimum)
Final setting time	600 minutes (minimum)
Compressive strength (7 days)	37 N/mm^2
Compressive strength (28 days)	53 N/mm^2

Table 1: Physical properties of cement

Name	Composition (%)
Calcium oxide (lime)	61.3
Silicon dioxide (silica)	20.1
Aluminum oxide (alumina)	4.51
Ferrous and ferric oxides	0.51
Magnesium oxide (magnesia)	1.0
Sulphur trioxide (sulphuric anhydrite)	3.0
Alkaline oxides (alkalis)	1.1
C_2S, C_3S, C_3A, C_4AF	24-26, 48-52, 7-8, 11-20

Table 2: Chemical Properties of cement

3.Mineral Admixtures

Mineral admixtures such as glass fibre, fly ash, quartzite, silica fume and stone powder is used to enhance the viscous nature of SCC and ground blast furnace slag. Size should be less than 0.1 mm or the particle size of fly ash varies from less than 1ppm to more than 100ppm with the typical particle size measuring less than 20ppm. While their specific surface area should be lie in between 300-500m^2. Small particle size may cause alkali silica reaction. In addition some nano materials such as mono-silica are also introduced in SCC to increase the viscosity. Fine particles of size about lesser than 0.125mm should be used.

Fly ash is one of the popularly known and extensively used byproduct in the construction field which resembles to Portland cement. It is an inorganic and non combustible finely powdered residue obtained from the emitted gases of industrial furnace. All most all the fly ash particles are solid spheres and the rest are hollow. It is also act as one of the types of mineral admixture in the production of SCC not only provides economical benefits but also reduces the heat of hydration and also improves rheological properties, reduce thermally developed cracking of concrete due to depletion of heat of hydration as a whole and enhance short term and long term properties concrete. The collected fly ash for this work is from Thermal power plant at Vijayawada. In this work fly ash as mineral admixture in SCC by considering properties as per, EN 450, IS 3812-1981.

Property	Results
Color	Grey
Specific gravity	1.91
Density	0.965gm/cc
Fineness	70%

Table 3: Physical properties of fly ash

Name	Composition (%)
SIO_2	52.14
Al_2O_3	25.88
Fe_2O_3	3.14
TiO_2	1.51
CaO	0.34
NaO_2	1.19
K_2O	1.22
SO_3	0.53
P_2O_5	1.65
MgO	1.13

Table 4: Chemical Properties of fly ash

4.Fine Aggregates

Sand is a naturally occurring granular form of quartz obtained as end product of weathering of rocks, naturally available along the river beds. The physical, chemical and engineering properties of sand are commonly influenced by the local conditions. Locally available sand in the form of natural pit sand by source was used as fine aggregate. The sand which is passing through 4.75mm sieve is taken as fine aggregate in this experiment according to IS 2386- 1963.

Property	Results
Zone	2
Type	River sand
Size	All sizes passed on 4.75mm sieve
Fineness	97.29%
Specific gravity	2.6
Apparent specific gravity	2.67
Water absorption	1.01%
Bulk density (compact state)	1.70g/cc
Bulk density (loose state)	1.60g/cc

Table 5: Physical properties of fine aggregates

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5.Coarse Aggregates

Aggregate is a composition of one or more than one mineral naturally formed under or over the earth surface by means of natural process such as volcanic activity and rock cycle. Aggregates are extensively used in drainage and base materials compared to soil due to high hydraulic conductivity.

As per IS 2386-1963, coarse aggregates are broadly classified into two categories. They are coarse aggregate (gravel) which can be of almost rock type usually in between 60mm and 4.75mm and coarse aggregate (grit) which usually ranges between 4.75mm-12.5mm. The crushed aggregate of size 12 mm are used in the experiment and consider properties as per EN 12620

Property	**Results**
Type	Crushed
Fineness	93.86%
Size	12mm
Specific gravity	2.93
Apparent Specific gravity	2.94
Water absorption	0.20%
Bulk density (compact state)	1.69g/cc
Bulk density (loose state)	1.47g/cc

Table 6: Physical properties of coarse aggregates

6.Super Plasticizers

Super-plasticizers are low molecular-weight; water soluble polymers designed to achieve high amounts of water reduction in concrete mixtures in order to attain a desired slump and also decrease the water cement ratio to increase the strength. They also can be used without water reduction to produce concretes with very high slumps, in the range of 150-250mm. Flowing concretes are those with high workability of more than 190mm. To impart necessary workability to concrete, high range water reducers such as Super-plasticizers are used. Due to the liquefying property of Super-plasticizers, they reduce plastic viscosity of concrete, disperse cement particles in concrete mix and enhance flow ability of the mix.

Fig.1: Mixing of plasticizer in water

7.Water

Water is an essential ingredient of concrete constituents which provides a bonding medium in concrete in the form of paste by mixing with cement. In practice potable water is used for concrete production. Water with PH value 6-8 is acceptable but the best coarse to find out whether a particular source of water is suitable for concrete or not. If the compressive strength is up to 90% the source is acceptable according to IS 456- 2000. We take our surrounding tap water of PH- 7.4

8.Hair Fibre

Hair is collected in saloons and in beauty parlors. Color: combination of white and black Water absorption: 45% (Note: We consider water absorption based on reviews Dhansh Anderson and T. Naveen Kumar). Amounts, size and other properties of hair should be consider according to ASTM 820/106, ASTMC116/95, EN 14889)

Fig.2: Hair fibre

Fig.3: Water absorption test for Cleaning of hair

Cleaning of hair should be done to remove any oil contents and chemicals for not showing any impact on the properties of concrete. We cleaned hair by using acetone (CH3COCH3).

Property	**Results**
Molarity	58.08g/mol
Purity	99%
Density	0.789g/cc
Water	0.30%
Residue	0.00%

Table.7: Properties of Acetone

Fig.4: Cleaning of hair with acetone

9.Mix Design

To present the properties of SCC (passing ability, filling ability, segregation resistance) in its plastic state and strength characteristics in its hardened state.

Material	**Traditional concrete mix**	**Self compaction concrete mix**
Fines	12%	18%
Sand	24%	34%
Coarse aggregate	46%	28%
Water	18%	20%
Admixture	Trace	0.01%

Table 8: Comparison of traditional concrete mix and self compacting concrete mixes

After obtaining satisfactory SCC conventional mix, the mix which is taken into consideration for all other mixes which are 0.25%, 0.5%, 0.75%, 1%, replacement in cement with hair fibre.

Conventional SCC Mix Compositions

Material	Quantity
Cement	430kg/m3
Fly ash	120kg/m^3
Water powder ratio	0.5
Water content	220kg/m^3
Fine aggregate	978kg/m^3
Coarse aggregate	588kg/m^3
Super plasticizer	3.14% in water content =6.90kg/m^3

Table 9: Quantity of materials in kg/m^3

Material	Quantity
Cement	8.6 kg
Fly ash	2.4 kg
Water content	4.45 kg
Fine aggregate	19.79 kg
Coarse aggregate	11.90 kg
Super plasticizer	3.14% in water content =140 ml

Table 10: Quantity of materials for 6 cubes in Kgs

Name of material	Hair Percentage Replacements				
	0%	0.25 %	0.5%	0.75 %	1%
Hair(kg)	0	0.022	0.043	0.064	0.086
Cement (kg)	8.6	8.578	8.557	8.836	8.514
Fly ash (kg)	2.4	2.4	2.4	2.4	2.4
Sand (kg)	19.5	19.56	19.56	19.56	19.56
Aggregate (kg)	11.7	11.76	11.76	11.76	11.76
Water (lt)	4.4	4.4	4.4	4.4	4.4
Super plasticizer(ml)	140	140	140	140	140

Table 11: Hair replaced mix compositions

III. RESULTS DISCUSSION

In this experimental study we performed the tests, when self compacting concrete is in fresh state and the concrete is in hardened state. In fresh state, concrete has fluidity nature having high deformability. We measure the fluidity by workability tests and test whether hair fibre reinforced concrete is suitable or satisfying the SCC properties.

Tests on Fresh Concrete or Workability Tests

The workability property of SCC is also known as self-compacting ability and segregation resistance. Self compacting ability is nothing but filling ability, passing ability and the segregation resistance of the concrete which are also known as properties of concrete in fresh state.

Fig.5: **Preparation of concrete mix with addition of Hair fibre**

Fig.6: **Preparation of concrete mix with addition of Hair fibre**

IV. EXPERIMENTAL RESULTS

1.Fresh State SCC Results

Name of the test	Percentage replacement of hair					Acceptance criteria
	0 %	0.25 %	0.05 %	0.75 %	1 %	
Slump cone test (mm)	720	700	680	650	620	650-800
T_{50cm} slump(sec)	3	4	5	5	6	2-5
J ring (sec)	3	5	8	10	14	0-10
V funnel (sec)	8	10	12	13	16	8-12
L box (mm)	0.9	0.85	0.8	0.79	0.73	0.8-1.0
U box (mm)	0	1	3	5	8	0-30

Table 11: Fresh state SCC test results for conventional and hair replaced SCC mixes

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Compressive Strength Test Results

Sl. No	Percentage replacement of hair	COMPRESSIVE STRENGTH		
		7 days strength (MPa)	14 days strength (MPa)	28 days strength (MPa)
1	0%	33.67	38.44	44
2	0.25%	34.18	40.77	46.48
3	0.50%	38.1	43.6	50.17
4	0.75%	28.3	33.45	37.11
5	1%	25.69	27.28	35.15

Table 12: Cube Compressive strength results after 7 days, 14 days and 28 days for both Conventional and hair replaced SCC mixes

Graphical Variation of Results

Workability Test Results graphical Variations

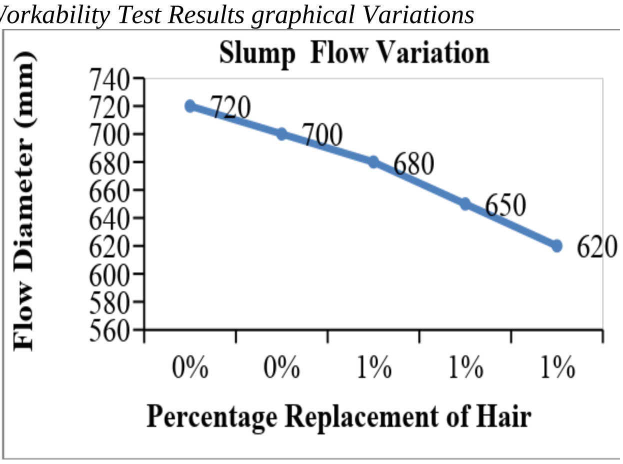

Fig.7: Slump flow variations for conventional and hair replaced SCC mixes

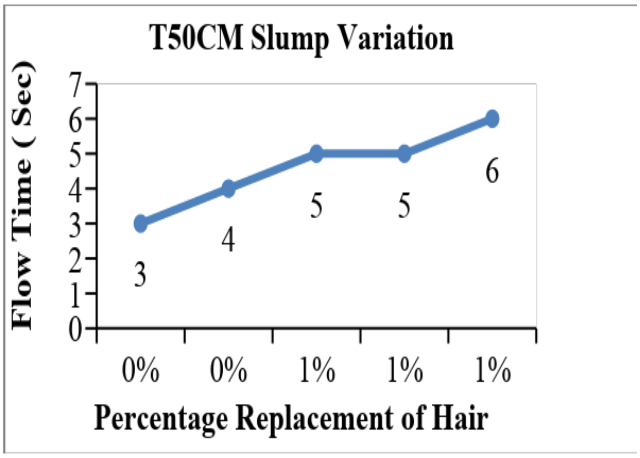

Fig.8: T$_{50CM}$Slump flow variations for both conventional and hair replaced SCC mixes

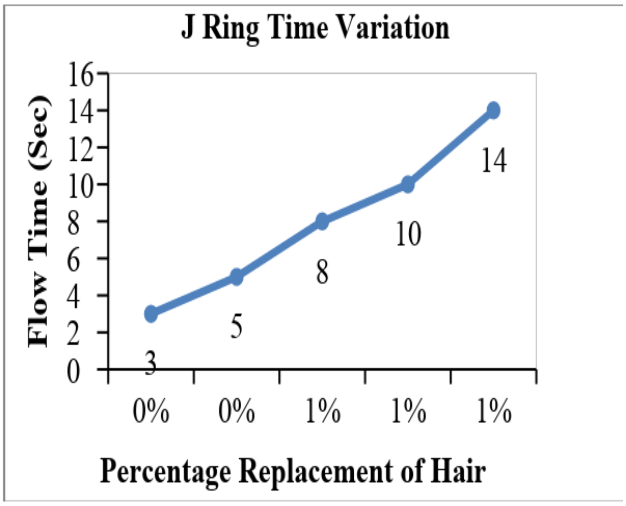

Fig.9: J ring test variations for both conventional and hair replaced SCC mixes

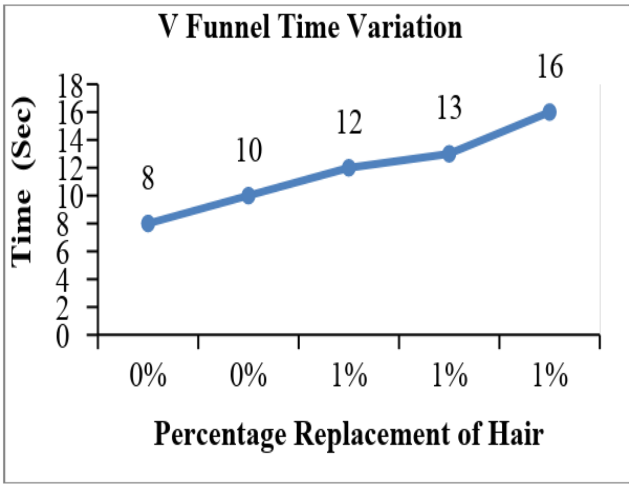

Fig.10: V funnel time variations for both conventional and hair replaced SCC mixes

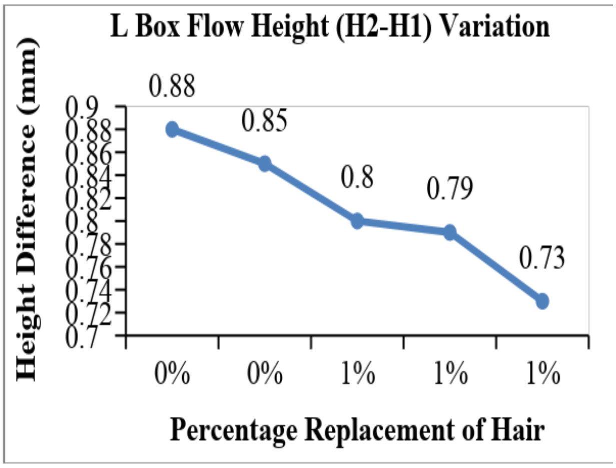

Fig.11: L box flow height variations for both conventional and hair replaced SCC mixes

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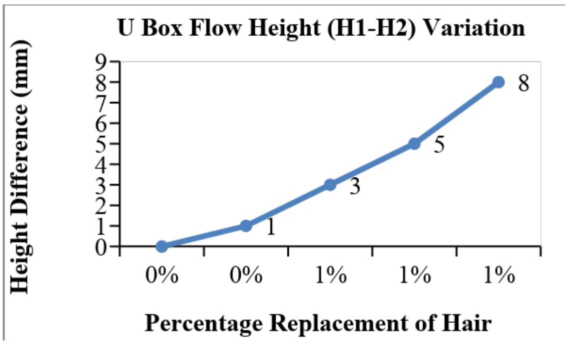

Fig.12: U box test variations for both conventional and hair replaced SCC mixes

Compressive Strength Test Graphical Variations

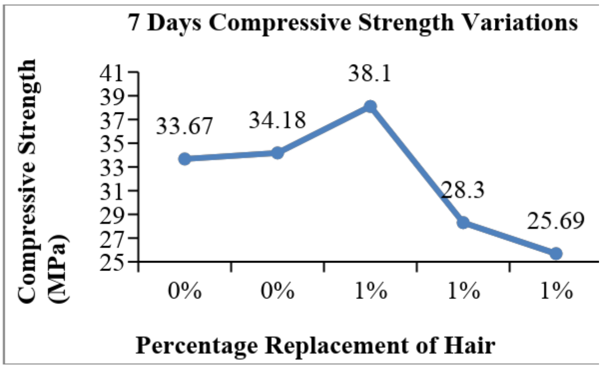

Fig.13: Cube compressive strength variations of 7 days curing for both conventional and hair replaced SCC mixes

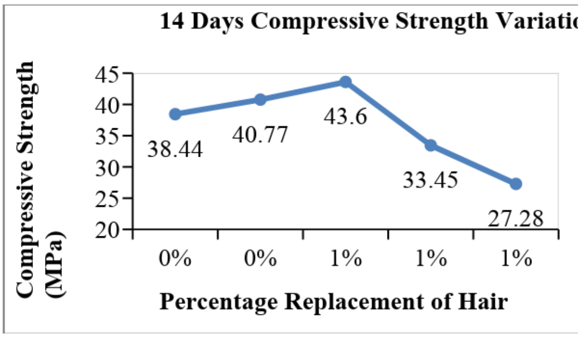

Fig.14: Cube compressive strength variations of 14 days curing for both conventional and hair replaced SCC mixes

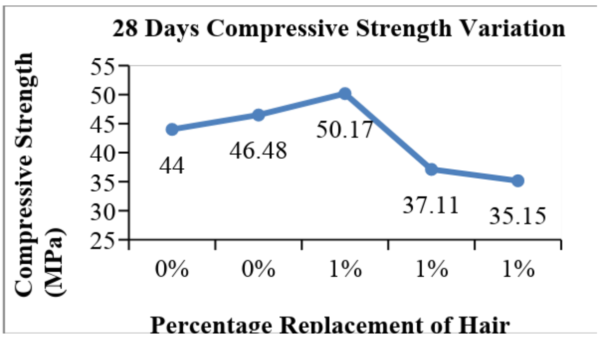

Fig.15: Cube compressive strength variations of 28 days curing for both conventional and hair replaced SCC mixes

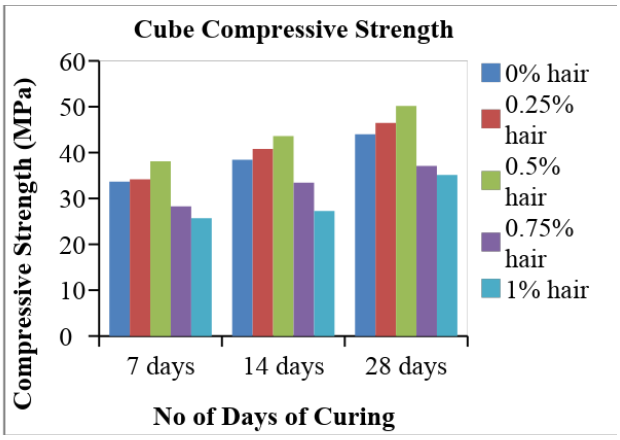

Fig.16: Comparison of conventional mixes with hair replaced concrete mixes for 7 days, 14 days and 28 days.

V. CONCLUSION

In this work, it is observed that there is remarkable increment in properties of self compacting concrete and compressive strength according to the percentages of hair fibres by weight in cement comparing to the conventional self compaction concrete.

1. Slump flow is decreasing with increase in fibre content (as per Fig.7). We replace 0.25%, 0.5%, 0.75%, 1% of fibre content in SCC mix, for 0.25%, 0.5% and 0.75% hair fibre mixes, slump flow is within limits of SCC and for 1% hair fibre mix, time exceeds the limit of SCC(as per table 11).
2. T_{50CM} slump is increasing with increase in fibre content (as per Fig.8). For 0.25%, 0.5% and 0.75% hair fibre mixes, time for 50cm slump is within limits of SCC and for 1% hair fibre mix; time exceeds the limit of SCC(as per table.11).
3. J ring time is increasing with increase in fibre content (as per Fig.9). For 0.25%, 0.5% and 0.75% hair fibre mixes, time for J ring is within limits of SCC and for 1% hair fibre mix; time exceeds the limit of SCC(as per table 11).
4. V funnel time is increasing with increase in fibre content (as per Fig.10). For 0.25%, 0.5% and 0.75% hair fibre mixes, V funnel time is within limits of SCC and for 1% hair fibre mix, time exceeds the limit of SCC(as per table.11).
5. Blocking ratio in L box is decreasing with increase in fibre content (as per Fig.11). For 0.25%, 0.5% hair fibre mixes, blocking ratio in L box is within limits of SCC and for 0.75%, 1% hair fibre mix, blocking ratio exceeds the limit of SCC (as per table.11).
6. Blocking ratio in U box is decreasing with increase in fibre content (as per Fig.12). For 0.25%, 0.5% hair fibre mixes, blocking ratio in U box is within limits of SCC and for 0.75%, 1% hair fibre mix, blocking ratio exceeds the limit of SCC (as per table.11).

When we replaced human hair in certain percentages 0.25%, 0.5%, 0.75%, 1% in conventional SCC mix, we observed that Compressive strength increasing with increase in hair fibre content, at certain percentage of hair fibres strength gradually decreases.

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Up to 0.5% hair mixes there is increase in compressive strength and after 0.5% hair mixes compressive strength gradually decreases, with increase in fibre content(as per Figures.13, 14, 15).

It is well observed that maximum increase of strength is noticed in the addition of 0.5% hair fibre by weight in cement (as per table.12). Comparing to conventional concrete compressive strength is increased to 14.02% after 28 days curing at 0.5% (as per Fig.15).

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