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Compressive Strength Testing of Steel Fiber Reinforced Concrete in Different Curing Regimes

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***Abstract*- The potential use of Steel Fiber Reinforced Concrete (SFRC) is to improve the structural strength and reduce steel reinforcements requirements. Here blast furnace slag (GGBS) has been used as a supplementary material along with the cement. It helps in increasing the durability and strength of the concrete. This study mainly deals with the compressive strength of high strength concrete reinforced with metallic (steel) fibres based upon different curing methods like normal curing, steam curing and hot air oven curing. Addition of HRWR¶ super plasticizer as it allows the reduction of the water to cement ratio as well as production of high performance concrete. The study mainly emphasis upon the best combination of aggregates, steel fibres and also best curing methods. The investigation results suggests that the mix SF 13 having CA 40% & Mortar 60% with the addition of 60 mm steel fibre by 60% and 35 mm steel fibre by 40% has shown the maximum value in different curing methods.**

Keywords - Steel Fiber Reinforced Concrete; Ground Granulated Blast Furnace Slag; High Range Water Reducers; Compressive strength; steel fibres; super plasticizer.

I. INTRODUCTION

Fibre reinforced concrete (FRC) may be defined as a composite material made with Portland cement, aggregate, and incorporating discrete discontinuous fibres. We incorporate such fibres as plain, unreinforced concrete may be a brittle material, with a low tensile strength and a low strain capability. The role of non-uniformly distributed discontinuous steel fibres is bridging the cracks that develops and this successively provides ductility. There are alternative ways that could increase the strength of concrete. The important contribution of the fibres is to extend the toughness of the concrete (defined as some function of the area under the load v/s deflection curve) beneath any kind of loading. The fibres tend to increase the strain at peak load, and provide a wonderful deal of energy that's absorbed in post-peak portion of the load v/s deflection model curve.

The fibre reinforcement act effectively as rigid inclusions among the concrete matrix, when they are within the kind of short separate fibers**.** Physically, they be regarded as a direct and thus have the same order of magnitude as aggregate inclusions; steel fibre reinforcement cannot therefore replacement of longitudinal reinforcement in reinforced and pre-stressed structural members. However, due to the inherent material properties of fibre concrete, the presence of fibres among the body of the concrete or the provision of a tensile skin of fibre concrete are typically expected to boost the resistance of conventionally reinforced structural members to cracking, deflection and different utility conditions.

- Discrete reinforcements in concrete provides homogeneity and hence improved mechanical properties in compression and flexural tension.
- In this project a series of concrete mixes were tested with the different dosage of steel fibres.
- Addition of Steel fibers are expected to provide better performance for the cement-based composites.
- Addition of GGBS helps in attaining a higher ultimate strength than concrete made with Portland cement.
- Addition of HRWR plasticizer is done so as to reduce the content of water and increase the workability of concrete.

II. BACKGROUND

Concrete is one of the most resourceful and environmental friendly building materials. It can be cast to fit any structural shape from a cylindrical water storage tank to a rectangular beam, slabs and column in a high-rise building. It is readily available in at relatively low cost and can be transported to sites. Concrete is strong under compression but weak in tension. As such, a form of reinforcement is needed. The most common type of concrete reinforcement is a steel bar.

Some of the advantages to use concrete are high compressive strength, decreased maintenance, good fire resistance, increase in water resistance, and long servicing life. While some disadvantages to use concrete are poor tensile strength, formwork demand and comparatively low strength per unit weight.

It is now well established that one of the important properties of steel fibre reinforced concrete (SFRC) is its superior resistance to cracking and crack propagation. Because of this, ability of concrete to fibre composites possess enhanced extensibility, arrest cracks and tensile strength or lastingness, at each initially crack and at ultimate, specifically beneath flexural loading and the fibres to hold the matrix along, even when the cracking of concrete occurs extensively. Finally the result is reached that remarkable post cracking ductility is imparted in fibre reinforced concrete which is not seen in ordinary concrete. This transformation which changes brittle concrete to a ductile form of concrete would substantially increase the energy absorption characteristics of the fibre composite and its ability to withstand repeatedly applied shock or impact loading.

III. EXPERIMENTAL STUDY

The details of materials used in the present experimental investigation are as follows:

A. Cement

Ordinary Portland cement (OPC) of grade 53 having 28 days compressive strength of 47.9 MPa was used in our study. The specific gravity of cement was found to be 3.11.

B. Fine aggregates

River sand obtained from locally available source passing through 4.75mm IS sieve was used with fineness modulus of 2.49 and specific gravity of 2.67.

C. Coarse aggregates

Machine crushed well graded angular blue granite stone with 12.5 mm maximum size was used. The fineness modulus and specific gravity was found to be 6.9 and 2.73 respectively

D. Steel fibres

Hooked end Steel fibres of length 60mm and 35mm each having aspect(l/d) ratio 120 and 70 respectively were used. The specific gravity of steel fibres was 7.9.

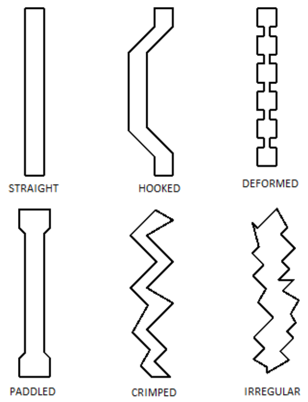

Figure1: Shapes of steel fibres available in market:-

For our research we have used the following type of fiber as shown in Table 1 :
Steel fibre – 4% of the volume fraction of mortar

Table1: Dimensions of Steel Fiber Used

Property of fibre	**Steel**	
Appearance	**Hooked**	
Length(L)	**60mm**	**35mm**
Aspect Ratio(L/d ratio)	**120**	**70**

E. Chemical admixture (HRWR)

A polycarboxylate ether based super-plasticizer condensate was used with specific gravity of 1.16.

F. Ground Granulated Blast Furnace Slag(GGBS)

Ground granulated blast furnace slag was used along with cement to act as a binder.

G. Casting of specimen

The binder(Cement + GGBS), fine aggregate and course aggregate were mixed first in a pan type concrete mixer of capacity 40 Kg for a period of 3 minutes, and then a high range water reducer of dosage of 1.0 % of the volume of binder was added to the concrete mix to achieve the desired consistency. Steel fibres(4% of the volume of the mortar)were then added into the pan mixer and the mixing was continued for 2 minutes. Steel fibres of 60mm and 35mm of varying proportions were used. This mix was then transferred to and casted in steel cube moulds of standard size 100 X 100 X 100 mm and were compacted on a table vibrator. The surface finishing was done very carefully to obtain a uniform smooth surface.

Table2: Mix Proportions

MIX ID	CA:MORTAR	SF.RATIO (60mm:40mm)
SF1	60:40	Only 60mm
SF2	50:50	Only 60mm
SF3	40:60	Only 60mm
SF4	60:40	Only 35mm
SF5	50:50	Only 35mm
SF6	40:60	Only 35mm
SF7	60:40	60:40
SF8	60:40	50:50
SF9	60:40	40:60
SF10	50:50	60:40
SF11	50:50	50:50
SF12	50:50	40:60
SF13	40:60	60:40
SF14	40:60	50:50
SF15	40:60	40:60

H. Curing Condition

In this research study, different types of curing regime were adopted for all specimens. Steel fibre concrete after remolding was cured under wet, hot air and steam condition. The specimen were wet, hot air and steam cured separately for each mix proportions for 28 days, whereas for hot air oven curing, the specimen were kept in hot water bath for 2 hour after remolding and then oven cured for 28 days. The Tests were performed at 28 day for all curing condition.
Accelerated hardening is any methodology by that high early age strength is achieved in concrete. These techniques square measure particularly helpful within the manufacture business,

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Table3: Specification Of Materials Used

MixID	CA	FA	Binder		SF(4%of V_m)		Plasticizer	Water
	(Kg)	(Kg)	Cement(kg)	GGBS(kg)	(Kg)		(ml)	(ml)
SF1	4.32	2.1	0.39	0.39	0.114		7.8	234
SF2	3.6	2.61	0.48	0.48	0.141		9.6	288
SF3	2.88	3.18	0.57	0.57	0.171		11.4	342
SF4	4.32	2.1	0.39	0.39	0.114		7.8	234
SF5	3.6	2.61	0.48	0.48	0.141		9.6	288
SF6	2.88	3.18	0.57	0.57	0.171		11.4	342
					60mmSF	35mm SF		
SF7	4.32	2.1	0.39	0.39	0.066	0.045	7.8	234
SF8	4.32	2.1	0.39	0.39	0.057	0.057	7.8	234
SF9	4.32	2.1	0.39	0.39	0.045	0.066	7.8	234
					60mmSF	35mm SF		
SF10	3.6	2.61	0.48	0.48	0.084	0.057	9.6	288
SF11	3.6	2.61	0.48	0.48	0.069	0.069	9.6	288
SF12	3.6	2.61	0.48	0.48	0.057	0.084	9.6	288
					60mmSF	35mm SF		
SF13	2.88	3.18	0.57	0.57	0.105	0.069	11.4	342
SF14	2.88	3.18	0.57	0.57	0.084	0.084	11.4	342
SF15	2.88	3.18	0.57	0.57	0.069	0.105	11.4	342

*V_m=Volume of Mortar

whereby high early age strength permits the removal of the formwork inside twenty four hours, thereby reducing the cycle
time, leading to cost-saving edges. The foremost unremarkably adopted hardening techniques square measure steam hardening, hot air kitchen appliance hardening, heat water hardening, boiling water hardening and autoclaving
A typical hardening cycle involves a preheating stage, called the "delay period" starting from two to five hours; heating at the speed of twenty-two °C/hour or forty four °C/hour till a most temperature of 50−82 °C is achieved; then maintaining at the most temperature, and at last the cooling amount. the full cycle ought to ideally not exceed eighteen hours.

Steam activity is advantageous wherever early strength gain in concrete is vital or wherever further heat is needed to accomplish association, as in atmospheric condition. Two strategies of steam curing used: steam at atm pressure (for closed cast-in-place structures and enormous precast concrete units) and aggressive steam in autoclaves (for small factory-made units). Solely steam at gas pressure is going to be mentioned here a typical steam-curing cycle consists of:

1. decreasing the temperature over a period.
2. holding the utmost temperature constant over a period,
3. initial delay before steaming, and
4. increasing the temperature over period.

I. Initial and final setting time

The amount between addition of water and starting of action (loss of consistency) is thought as initial setting time. The water-cement quantitative relation of zero.3 is constant for the all combine proportions. The depth of penetration of the needle for initial setting time is once paste stiffens sufficiently for needle to a degree 5±1 millimeter from all-time low, initial set is alleged to own taken place. Final setting time is that the time taken for the initiation of hardening method.

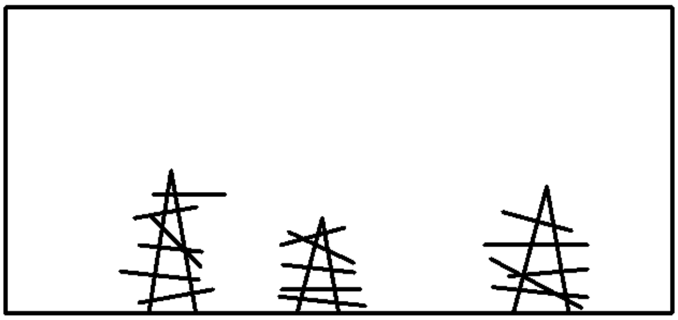
J. Compressive Strength

The compressive strength of cubes 100 X 100 X 100 mm was performed on the compression testing machine of 2000kN loading capacity. The specimen of all mixes was tested after 28day and results were carefully noted.

K. Bridging Action

The resistance to pullout of steel fibres (dowel action) is important for efficiency. Pullout strength of steel fibres significantly improves the post cracking Tensile strength of concrete. As an SFRC beam or other structural Element is loaded, steel fibres bridge the cracks, as shown in figure. Such Bridging action provides the SFRC specimen with greater ultimate tensile Strength and, more importantly, larger toughness and better energy absorption. An important benefit of this fibre behavior is material damage tolerance. The fibres play an important role in confining the materials.

Figure 2: Bridging Action Behavior



L. Workability of Concrete

An addition of fibres in concrete reduces its workability. Further the workability of SFRC is affected by fibre aspect ratio and volume fraction as well the workability of plain concrete as fibre content increases, workability decreases. Most researchers limit V_f to 2.0% and l/d to 100 to avoid unworkable mixes. In addition, some researchers have restricted the fibre reinforcement index $[V_f*(l/d)]$ to 1.5 for identical reason. To beat the workability issues associated with SFRC, modification of concrete mix design is usually recommended. Such modifications will embrace the employment of additives. What is acceptable workability obviously depends on the nature of the application and method of placement.

IV. EXPERIMENTAL DETAILS AND CALCULATIONS

A. Mix Details

In this study, a total of 15 different combinations of concrete mixture proportions were prepared. Each combination consists of 3 specimens for three different curing methods. A total of 45 cubes were casted for the study as shown in Table 2. The various aggregates proportion are given below:

Coarse aggregate to mortar ratio = 60% - 40%, 50% - 50%, 40% - 60% to the mass of concrete.

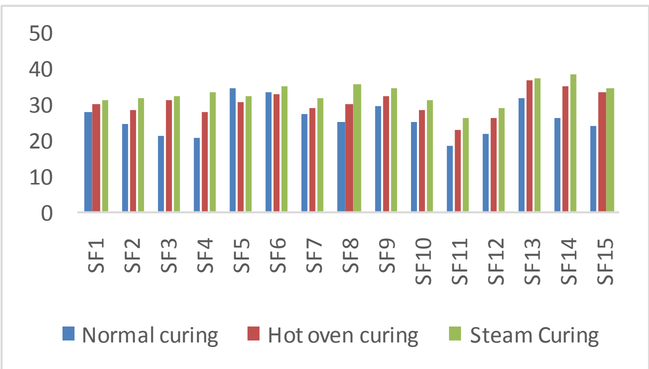
Mortar: Binder to Fine aggregate = 1:2.68 to the mass of mortar.

Water content = 0.3% to the volume of binder.

Chemical admixture (HRWR) = 1% to volume of binder

Steel fibre = 4% to the volume fraction of mortar as shown in Table 3.

Figure 3: Bar Graph Comparing Compressive Strengths



V. RESULTS

- For various steel fibre concrete cubes casted in our study in different curing regimens, the compressive strength after 7 days is shown in Table 4 and corresponding bar graph comparing results for different curing regimes is shown in Figure 3.
- The mix SF 13 having CA 40% & Mortar 60% with the addition of 60 mm steel fibre by 60% and 35 mm steel fibre by 40% has shown the maximum value in different curing methods.
- Similar values were observed in the mix SF14 in which CA 40% & Mortar 60% and Fiber is 50% both of 60mm and 35 mm.

Mix ID	Normal curing(N/mm^2)	Hot oven curing(N/mm^2)	Steam Curing(N/mm^2)
SF1	27.9	30.6	31.7
SF2	24.9	28.6	32
SF3	21.5	31.4	32.8
SF4	20.7	27.9	33.9
SF5	34.7	30.7	32.5
SF6	33.7	32.9	35.4
SF7	27.3	29.2	32.3
SF8	25.2	30.1	35.9
SF9	29.5	32.5	34.7
SF10	25.2	28.7	31.5
SF11	18.6	23.3	26.2
SF12	21.7	26.4	29.4
SF13	32.2	36.8	37.9
SF14	26.5	35.6	38.9
SF15	24.3	33.9	35

Table 4: Compressive Strength after 7 days

VI. CONCLUSION

- The effect of steel fiber addition in different concrete mixes were studied.
- The variation in the compressive strength of different steel fibre reinforced concrete were experimented.
- Replacing cement by 50% slag has shown an increase in compressive strength according to curing method.
- This implies the addition of slag can be accelerated by steam curing and hot air oven curing than the normal curing.
- Correspondingly varying the fibre with different aspect ratio and the combination of steel fibre with different lengths shown a significant variation in the compressive strength.
- This can be concluded that the replacement of cement with slag can give a comparatively higher value by accelerated curing & also the effect of different dosages of fibre will influence the compressive strength.

VII. RESEARCH SIGNIFICANCE

The present study shows the important findings on compressive strength gain and the type of curing regime to be adopted for SRFC. Also the improvements in concrete have been done by addition of GGBS and HRWR plasticizer. A quantitative analysis of the compressive strength for various steel fibre reinforced concrete mixture proportions were investigated.

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