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Study on Strength and Durability of High Performance Steel Fibre Reinforced Concrete

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ABSTRACT: In the present world for the construction of special structure advanced concrete composites which posses superior properties like high compressive and tensile strength , impact and heat resistance and superior durability is needed .With the development of high grade cement and availability of proper mineral admixture and chemical admixture it has been made possible to manufacture concrete with these properties. An attempt has been made in this study to investigate the role and contribution of silica fume as mineral admixture and steel fiber on the strength and durability of high performance concrete.
KEYWORDS: HPC(High Performance Concrete),CRM(Cement Replacement Materials),SFRC(Steel Fiber Reinforced Concrete),HPFRC(High Performance Fiber Reinforced Concrete), HPSFRC (high-performance steel fiber reinforced concrete)

I. INTRODUCTION

High-performance concrete (HPC) is concrete that has been designed to be more durable and, if necessary, stronger than conventional concrete. HPC mixtures are composed of essentially the same materials as conventional concrete mixtures, but the proportions are designed, or engineered, to provide the strength and durability needed . In this silica fumes as a mineral admixture and steel fiber is used to investigates it's effect on HPC . The use of silica fume as a mineral admixture is a convenient way of improving the engineering properties of cement-based materials. The increased use of mineral admixtures as cement replacement materials (CRM) in concrete could reduce the green house gas emissions into the environment. To increase the fracture resistance of cementitious materials, fibers are frequently added, thus forming a composite material. Steel fiber reinforced concrete (SFRC) is increasingly used day by day as a structural material due to the enhanced mechanical properties. Steel fiber reinforced concrete has gained acceptance for a variety of applications, namely, industrial floors, bridge decks, hydraulic and marine structures, precast elements, tunnel linings, nuclear vessels, blast resistance and many more. In this we use High performance fiber reinforced concrete (HPFRC) as it is a high-performance concrete reinforced with short steel fibers of specific geometry and shape, having high compressive strength, high tensile strength, high energy absorption capacity (toughness), high impermeability, corrosion resistance and abrasion resistance.

II. METHODOLOGY

In this chapter, characteristics of various materials chosen and used, details of experimental program to study the effect of silica fume and crimped steel fibers on different characteristics of concrete with salient details of instrumentation used has been presented. The methodology adopted for the entire study is shown in the form of a flow diagram figure 1.

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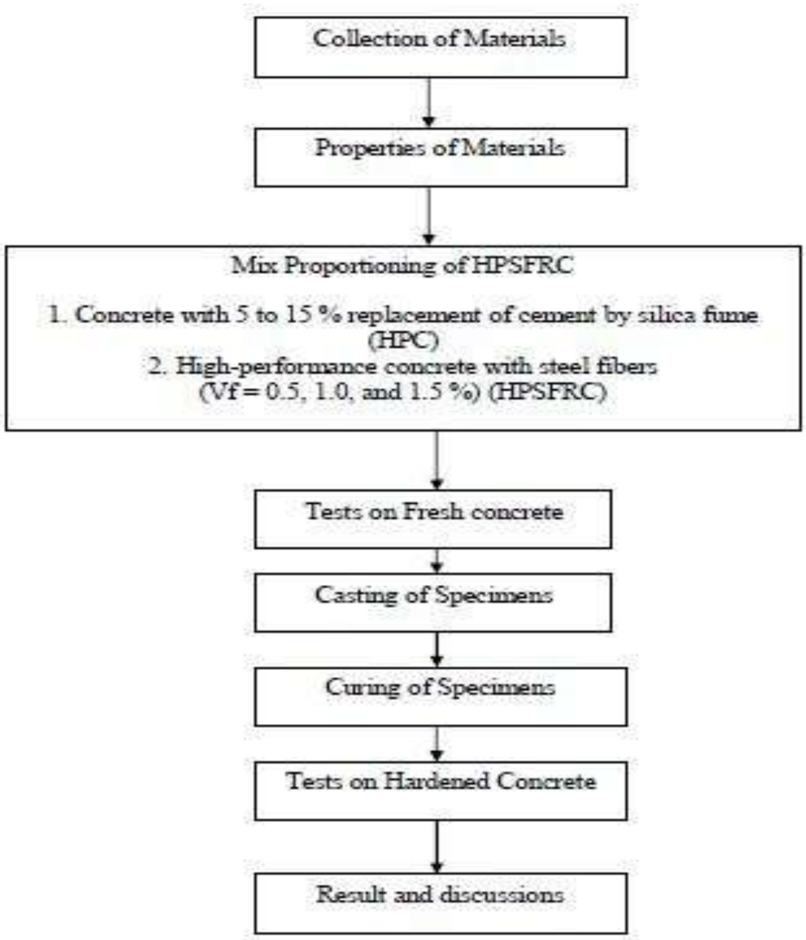

Fig 1 Methodology of the Study

Materials used in this investigation is-

- Cement- Ordinary Portland cement (OPC) - 53 grade, having 7-day and 28- day compressive strengths of 37.6 MPa and 54.5 MPa respectively, satisfying the requirements of IS: 12269-1987 was used. Physical and chemical properties of OPC are given in Tables

CaO	SiO_2	AlO_3	Fe_2O_3	MgO	K_2O	SO_3	P_2O_5	LOI	LSF
64.26	21.07	5.54	5.16	0.86	0.37	0.72	0.33	1.54	0.925

Table 1 Chemical composition of OPC-53 grade(in percentage)

Parameter	Value
Normal consistency (%)	29
Specific gravity, Gc	3.15
B.E.T. Fineness (m2/kg)	245
Initial /Final setting time (minutes)	43/365
Soundness by Le-Chatelier expansion (mm)	3
7-day compressive strength (MPa)	37.6
14-day compressive strength (MPa)	42.4
28-day compressive strength (MPa)	54.5

Table 2 Physical properties of OPC-53 grade

- Silica fume (SF) (in a powder form to achieve high-strength) also called as micro silica, was used. The chemical analysis of silica fume (Grade 920-D) are given in table below

Component	Result	ASTM C1240-99	AASHTO M307-90	Canadian std. Association1986
Silicon dioxide, SiO2	88.7 %	85%(min.)	85% (min.)	85% (min.)
Moisture content	0.7 %	3% (max.)	3% (max.)	3% (max.)
Loss of Ignition at 975oC	1.8 %	6% (max.)	7% (max.)	6% (max.)
Carbon	0.9 %	-	-	-
Fineness (by residue on 45 micron)	2 %	10%(max.)	10% (max.)	10% (max.)

Table 3 Chemical Analysis of silica fumes

- Locally available river sand passing through 4.75 mm IS sieve, conforming to grading zone-II of IS: 383-1970 was used as fine aggregate.
- Crushed blue granite stone of maximum size 12.5 mm, conforming to IS: 383-1970, was used as coarse aggregate.
- Water is an important ingredient of concrete as it is necessary for the hydration of cement to form the stable cement paste for making sufficient bonding with aggregates. Clean potable water available locally was used.
- A commercially available superplasticizer (SP) of sulphonated naphthalene formaldehyde (SNF) type conforming to IS: 9103-1999 and ASTM Type F (ASTM C 494) was used as the HRWR admixture. Water content in superplasticizer was estimated as 30%.
- Steel fibers conforming to ASTM A820-01 have been used, are crimped fibers of diameter = 0.45 mm, length = 36 mm and having aspect ratio of 80. The mechanical properties of the fibers are given in Table 4 .Figure 2 shows the crimped steel fibers used as reinforcement in the HPSFRC mixes.

Sl. No	Geometry and properties	Value
1	Fiber diameter, d (mm)	0.45
2	Fiber length, l (mm)	36
3	Aspect ratio, l/d	80
4	Ultimate tensile strength, fu (MPa)	910
5	Young's modulus, Ef (GPa)	200
6	Number of fibers per kg.	22410

Table 4 Mechanical properties of fiber

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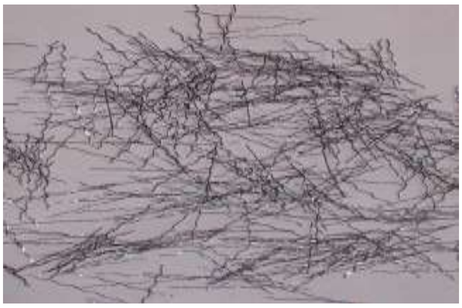

Fig 2 Crimped Steel Fiber

Now after arranging all the materials different specimen containing different composition is prepared. Mixtures were proportioned using guidelines and specifications given in ACI 211.4R-1999, guidelines of ACI 544.3R-1993 and salient specifications of IS: 10262-1982, as applicable for the chosen strength range, as no specific methodology is available for the mix proportioning of high-performance / steel fiber reinforced concretes. For each water-to-cementitious materials (w/cm) ratio, three silica fume concrete mixes with SF/cm ratios of 0.05, 0.1 and 0.15 (SF replacement at 5%, 10%, and 15% respectively), and nine fibrous concrete mixes with fiber volume fractions (Vf) of 0.5%, 1.0% and 1.5% (39, 78 and 117.5 kg/m3) were considered. The amount of the dosage of superplasticizer of sulphonated naphthalene formaldehyde (SNF) condensate dosage range of 1.75 to 2.75% by weight of cementitious materials.

Sl. No.	Mix designation	w/cm	C (kg)	FA (kg)	CA (kg)	SF (kg)	W (kg)	SP (%)	Vf (%)
1	FC1-0	0.4	416			22			
2	FC2-0	0.4	394.2	691	1088	43.8	175	1.75	0
3	FC3-0	0.4	372.2			65.8			
4	FC1-0.5	0.4	416			22			
5	FC2-0.5	0.4	394.2	687	1079	43.8	175	1.75	0.5
6	FC3-0.5	0.4	372.2			65.8			
7	FC1-1	0.4	416			22			
8	FC2-1	0.4	394.2	682	1071	43.8	175	1.75	1
9	FC3-1	0.4	372.2			65.8			
10	FC1-1.5	0.4	416			22			
11	FC2-1.5	0.4	394.2	678	1062	43.8	175	1.75	1.5
12	FC3-1.5	0.4	372.2			65.8			

Table 5 Mixed proportions for HPSFRC (Data for 1 cubic meter)

After Casting all the specimens various tests was performed likeslump test , compaction factor test, compressive strength, tensile strength etc. adopting American Society for Testing Materials (ASTM) standards and Bureau of Indian Standards (BIS), and ACI Committee 544 recommendations.

III. CONCLUSION

Based on the experimental investigations carried out on the high-performance steel fiber reinforced concrete (HPSFRC) at water-cement (w/cm) ratios of 0.40, the conclusions drawn are presented.

- In the fiber reinforced concrete mixes with steel fibres and somewhat high dosages of super plasticizers are necessary to maintain workability at medium level.
- The silica fume replacement at 10% and 15% of OPC shows higher improvement in compressive strength compared to concrete with 5% silica fume replacement of OPC.
- Addition of steel fibers in silica fume concrete has shown moderate improvement in strength. At fiber volume fraction, Vf = 1.5%, the improvement in strength is marginal compared to 1% fiber volume fraction of concrete.
- Due to increase of fiber volume fraction from 0% to 1.5% in HPC, cube strength increased in

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the range of 1.5% - 13% and post-peak load response has considerably improved

- It is observed from the test results that there is a significant improvement in splitting tensile strength due to increase in fiber content from 0 to 1.5% (RI = 0 to 3.88) for all the mixes and the variation is 16.4-55.9%.
- An increase in strength of 55.9% for 1.5% fiber content (RI = 3.88) and 45.4% for 1% fiber content (RI = 2.58) of concrete was obtained revealing that tensile strength of fiber reinforced concrete has improved considerably
- Water absorption of HPSFRC mixes reduce as the w/cm ratio reduces and with increasing supplementary cementing materials (SCM) in the mix.
- HPSFRCs exhibit better performance against the attack of sulphuric acid and sea water.

It is clear from the above discussions that the additions of mineral admixtures, along with the fibres are giving higher compressive strength as well as tensile strength compared to the conventional concrete. However, silica fume concrete gives better result. However consultation of expert must be taken before its application.

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