Research Paper

EFFECT OF ADDITION OF STEEL FIBERS ON STRENGTH AND DURABILITY OF HIGH PERFORMANCE CONCRETE

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ABSTRACT:
This paper presents an experimental investigation carried out to study the combined effect of addition of micro-silica and steel fibers on the strength and durability High performance concrete (HPC). A high performance concrete of M60 grade is considered and rapid chloride penetration tests were conducted to find the durability of HPC. Test results indicate that the addition of steel fibers to HPC increased strength and durability testing has also demonstrated the enhanced characteristics of HPC. Rapid chloride penetration results have ranged from extremely low to very low exhibits a high resistance to this form of environmental attack.

KEYWORDS High performance concrete, Silica fume, Steel fiber, Strength, Rapid chloride penetrability.

1. INTRODUCTION:

Concrete is the most widely used construction material in the world. One of the challenges facing civil engineers as we enter into the new century is the progress of our infrastructures. The highway capacity increases annually, and many infrastructures are approaching or have exceeded their useful service lives. High performance concrete (HPC) is a novel construction material with improved properties like higher strength, longer durability, higher constructability, etc than conventional concrete. The use of high-strength HPC in the construction of earthquake-resistant structures, long-span bridges, off-shore structures and other mega-structures will result in lighter sections, leading to cost-effective structures. Similarly, the use of HPC, having improved durability reduces life-cycle cost of structures. Because of these benefits, HPC has been used more widely in recent years for the construction of important concrete structures like nuclear power plants, viaducts, bridges, high-rise buildings, etc all over the world.

Steel fiber reinforced concrete (SFRC) is a composite material in which short discrete steel fibers are randomly distributed throughout the concrete mass. Extensive research work on SFRC has established that the addition of steel fibres to plain cement concrete (PCC) improves its strength, durability, toughness, ductility, post-cracking load resistance, etc. Owing to the favourable characteristics of SFRC, its use has steadily increased during the last two decades all over the world and its current fields of application includes airport and highway pavements, earthquake-resistant and explosion-resistant structures, mine and tunnel linings, bridge deck over lays, hydraulic structures, rock-slope stabilization, etc.

2. OBJECTIVE

Previous work on HPC indicated that several researchers studied the individual effect of addition of either micro-silica or steel fibers on the durability of normal concrete, no study has been conducted so far to investigate the combined effect of addition of micro-silica and steel fibers on the durability of HPC. Therefore, an attempt has been made to study the combined effect of addition of micro-silica and steel fibers on the durability of HPC.

3. EXPERIMENTAL PROGRAM

3.1 Materials

3.1.1Aggregates

i) Natural sand obtained from the local market is used as fine aggregate. The physical properties of fine aggregate like specific gravity, bulk density, gradation and fineness modulus were tested in accordance with IS : 2386.

ii) The crushed coarse aggregates of 20mm size obtained from the local crushing plants are used in the present investigation. The physical properties of coarse aggregate such as specific gravity, gradation, and fineness modulus are tested in concurrence with IS: 2386 as shown in Table 1.

TABLE 1: Physical properties of aggregates used in the mix

S.No.	Properties	Fine aggregate	Coarse aggregate
1	Fineness modulus	2.27	7.06
2	Specific gravity	2.43	2.64
3	Bulk density in loose state	1646kg/m^3	1564 kg/m^3

3.1.2 Cement:

53-Grade ordinary Portland cement is used. The physical properties and composition of major compounds are shown in Table2 and Table 3.

TABLE 2: Physical properties of Cement used in the mix

Properties	Specific gravity	Fineness	Initial setting time	Final setting time	Comp. strength (28 Days)	Soundness
Results	3.05	220 m^2/kg	112 min	112 min	54.5 N/mm^2	0.5 mm

TABLE 3: Chemical composition of the cement

Oxide composition	CaO	SiO_2	Al_2O_3	Fe_2O_3	SO_3	MgO
Percent	65.49	21.67	5.97	3.85	1.66	0.78

3.1.3 Water:

Water conforming to the requirement of water for concreting and curing as per IS: 456-2000.

3.1.4 Mineral Admixture:

Micro Silica “Corniche SF” brand Silica Fume with bulk density of 1.96kN/m^3 and specific surface area of 22,000 m^2/kg is used in the present work and % of micro silica is fixed based on trial mixes done by varying micro silica % from 0.0% to 10.0% at a constant increment of 2.5% by weight of cement. The optimum % of micro silica is found out to be 7.5%, so for the present research work the quantity of micro silica is fixed to 7.5%.

3.1.5 Chemical Admixture:

Super Plasticizer “Complast SP 430” complying to IS 9103: 1999 having a specific gravity of 1.220 to 1.225 is adopted. The optimum dosage of admixture was evaluated by slump cone test. Cement, micro silica and water are mixed in the given proportions and different percentage of super plasticizer is added. The consistency of the mix is measured by slump cone. Based on many trials the optimum quantity of super plasticizer required for desirable slump needed for making pumpable concrete is found to be 2.5% by weight of cement.

3.1.6 Steel Fiber

Dramix RC 80/60 BN Hooked End and Glued Non balling Steel fibres. Aspect ratio 80, Length 60 mm and dia 0.75 mm at and network of 276 Rm per Kg. Low carbon confirming to 10016-1-C9D. Tensile strength Rm Nom = 1225 N/mm^2 is used and quantity of steel fiber used is 25 kg/m^3 of HPC mix.

4. MIX DESIGN & TESTING OF HPC:

In this study, a HPC of M60 grade was considered. The mix design for the above grade of concrete was done using method proposed by Erntroy and Shacklock. Three types of locally available aggregates, viz. 10mm, 20mm coarse aggregates and fine sand in saturated surface dry condition were mixed together in the ratio 0.26:0.39:0.35 respectively. The mix proportion obtained was 1: 1.04: 2.1: 0.365 (cement: sand: coarse aggregate: water) and mix design details are shown in Table4. Using this proportion, standard concrete cubes of 150 mm size were casted for knowing compressive strength and standard cylindrical specimens of 150mm diameter & 300 mm length were casted to know tensile strength of HPC.

Table 4: Trial mix proportions for 1m^3 of HPC

Description	Trial mix
Mass of Cement – 53 Grade	487.89 Kg
Mass of Silica fume (7.5%)	36.59 Kg
Mass of water	191.6 Kg
Mass of Coarse aggregate (20mm &10 mm)	1104.4 Kg
Mass of Fine aggregate	545.4 Kg
Coarse aggregate (10mm): Coarse aggregate (20mm) :Sand	0.26:0.39: 0.35
Mass of Super plasticizer (2.25%)	10.98 Kg
Mass of Steel fibers	25 Kg

Table5: Compressive strength & Tensile strength of HPC

S.No	Description	With out Steel Fibers		With Steel Fibers	
		7 days	28 days	7 days	28 days
1	Compressive strength in N/mm^2	52.29	84.09	55.78	90.79
2	Tensile strength in N/mm^2	5.78	5.89	5.92	6.4

Table6: Permeability results of HPC using Rapid chloride permeability test

S.No	Description	With out Steel Fibers		With Steel Fibers	
		28days	90days	28 days	90days
1	Charge passed in coulombs	431	378	145	99
2	Remarks	Very low	Very low	Very low	Negligible

The durability of HPC in terms of its resistance to internal and external environmental attack is studied and these investigations included chloride ion penetration. Rapid chloride ion penetrability tests were completed on HPC specimens, an electrical current was recorded at 1 minute intervals over the 6 hour timeframe, resulting in the total coulombs passed value shown in Table 6, Fig-1&2. Four specimens were completed for each condition and specimens were tested at both 28 and 90 days.

Fig.-1. Running RCPT on 4 concrete specimens

Fig.-2. Concrete specimens under RCPT

7. Results and Discussions

Test results obtained for compressive strength, Tensile strength and Rapid chloride penetration (RCP) Test are presented in Table 5&6. The results reported are averages of six specimens. The individual variations are within ± !5% of the average and satisfies IS : 456-2000 requirements. It can be seen from Table 5 & 6 that the compressive strength and tensile strength of HPC is increased and chlorine penetration is decreased due to addition of micro silica and steel fibers because of filler effect, as the specific surface of micro-silica used in the present study is 22,000 m^2/kg. This value is about 100 times higher than the specific surface of cement. This clearly indicates that the particle size of micro-silica used is much smaller than the particle size of cement. As such, when micro-silica is added to plain concrete, it fills the voids present between the cement particles and also between the cement particles and the aggregates. It reduces the porosity which in turn reduces the permeability of the chlorine ions.

The durability test results show that the rapid chloride ion permeability is minimal when steel fibers were added to the HPC. Also, it is of note that the penetrability decreased significantly between 28 and 90 days.

CONCLUSIONS

The HPC studied in this research program has displayed an impressive set of material properties and the the conclusions are drawn as follows:

1. Addition of micro-silica to plain concrete up to 7.5% reduces HPC permeability, but further addition does not reduce the permeability. Addition of micro-silica beyond 10% makes the concrete harsh, dry and difficult to work.
2. Addition of steel fibers to plain concrete increased the compressive strength and tensile strength of concrete by 8% & 9% respectively.
3. Addition of steel fibers to HPC increased the resistance to chloride ion penetration.

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