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Effect of Polypropylene Fibres on Strength and Plastic Shrinkage of High Volume Fly Ash Self Compacting Concrete

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Abstract

Objectives: The present paper aims to test the influence of polypropylene fibre on plastic shrinkage and compressive strength of High Volume Fly Ash Self-Compacting Concrete (HVFA_SCC). **Methods/Statistical Analysis:** Six 150mm cubes and a slab of dimension 560mm×365mm×114mm were casted each for five mixes of HVFA_SCC with and without polypropylene fibres. The cementitious material (600 kg/m3) and water to powder ratio (0.325) were kept constant. The self-compacting concrete mixes had a cement replacement of 30%, 40%, 50%, 60%, and 70% of class F fly ash. The dosage of polypropylene fibres was 0.1% of total volume of concrete.**Findings:** Experimentationson these mixes were made to attain the fresh properties of concreteon viscosity, stability, filling and passing abilities. The compressive strength and plastic shrinkage properties were determined. Slump flow values on the mix blends were in the range of 650mm - 800mm and flow times were ranging from 2 to 4 sec. The HVFA_SCC mixes with polypropylene fibres had developed the twenty-eight days compressive strengths ranging from 24.0 MPa to 46.0 MPa. Addition of polypropylene fibres in high volume fly ash self-compacting concrete had not shown any significant effect on the strength parameters but it had improved concrete resistance to plastic shrinkage by reducing sedimentation and bleeding due to increase in cohesion of mix. The control on bleed water resists the migration of the cementitious fines and the sand to the surface. The PFSCC60 has attained a twenty-eight days Compressive strength of 30 MPa. **Applications/Improvements:** PFSCC60 has consumed only 40% cement by weight of the cementitious material proves to be economical and by reducing the emission of greenhouse gases found to be ecofriendly.

Keywords: Compressive Strength, High Volume Fly Ash Self-Compacting Concrete (HVFA_SCC), Plastic Shrinkage, Polypropylene Fibre

1. Introduction

Concrete is one of the largest manufactured material in the world and accounts for more than six billion metric ton annually, the quality and the performance of concrete plays vital role in most of infrastructures including residential, commercial, industrial, dams, power plants and transportation system. Being a construction material the consumption of Portland cement is directly proportional to the demand for

concrete. Manufacture of Portland cement generates enormous amount of carbon dioxide, and thus causing global warming. Many researches are in progress to control the use of Portland cement and to address the global warming issues.

Reaction of cement with water is an exothermic, during course of reaction of tricalcium silicate and dicalcium silicate with water, calcium silicate hydrate and calcium hydroxide are formed. Calcium silicate hydrate is the most important product responsible for The concrete strength. The lack of durability of concrete is due to presence of calcium hydroxide. It reacts with sulphur present in soil or water to form calcium sulphate which further reacts with tricalcium aluminates and causes deterioration of concrete, which is known as sulphate attack[1].

In mass concreting or in large scale construction and

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Table 1. Mix proportions of self-compacting concrete

Mix Designation	Cement (Kg/m^3)	Fly ash (Kg/m^3)	Fine Aggregate (Kg/m^3)	Coarse Aggregate (Kg/m^3)	Water (Kg/m^3)	Super Plasticizer (Kg/m^3)	w/p ratio	Poly propylene fiber (Kg/m^3)
SCC30	420	180	780	700	195	7.5	0.325	
SCC40	360	240	763	700	195	7.5	0.325	
SCC50	300	300	745	700	195	7.5	0.325	
SCC60	240	360	727	700	195	7.5	0.325	
SCC70	180	420	710	700	195	7.5	0.325	
PFSCC30	420	180	780	700	195	7.5	0.325	0.91
PFSCC40	360	240	763	700	195	7.5	0.325	0.91
PFSCC50	300	300	745	700	195	7.5	0.325	0.91
PFSCC60	240	360	727	700	195	7.5	0.325	0.91
PFSCC70	180	420	710	700	195	7.5	0.325	0.91

in sections with congested reinforcement it is difficult to place concrete and achieve proper compaction, large number of skilled workmanship is required to overcome the problem lead to development of self-compacting concrete[2]. Flowing under its own weight self-compacting concrete is able to fill the formwork completely, in the presence of dense reinforcement too, without any external vibration, while maintaining homogeneity, to achieve this is the need to add mineral admixtures and use proper super plasticizers to increase flow ability and reduce bleeding of concrete[3].

Use of mineral admixture is one of the most effective and viable solution universally adopted to address sustainability issues in the construction industry. By replacing cement with certain amount of fly ash in concrete, it not only increases the flow ability and cohesion of concrete but also increases the strength, reacting with calcium hydroxide and form calcium silicate hydrate, so as to increase the durability of concrete. Since fly ash is finer than fine aggregate it reduces percentage of voids in concrete. Fly ash is one of the residues generated by combustion of coal in thermal power stations and cement is the main source of greenhouse gasses during its production consuming most of precious natural resources. The substitution of cement with fly ash addresses environmental problems and helps to achieve self-compacting ability in concrete and increases durability of concrete[3–8].

Normal concrete has little resistance to cracking with limited ductility, low impact and abrasion resistance. Fibres are incorporated to improve concrete resistance to plastic shrinkage, improve durability, reduce permeability and sedimentation, increase cohesion of mix and reduce bleeding[9–13].

Due to high cement content, self-compacting concrete may show more creep and shrinkage properties than ordinary concrete mix. Previous studies had shown incorporation of fly ash and fibers increased its durability and mechanical properties, but less was the focus on creep and shrinkage properties. Hence the main objective of this study is to incorporate polypropylene fibers in high volume fly ash self-compacting concrete to assess the effect on plastic shrinkage.

2. Experimental Program

The experimental program consists of batching the SCC mixes with 30%, 40%, 50%, 60%and 70% substitution of cement by fly ash,

- on the incorporation of 0.1% polypropylene fibres as volume fraction of the mix

and

- without the incorporation of polypropylene fibres.

Mix proportions of self-compacting concrete are shown in Table 1.

2.1 Materials

The fresh and hardened properties of HVFA_SCC are reliant on the properties of ingredients. Tests were conducted on the materials to determine their characteristics.

- The cement used in the present study was 43 grade ordinary Portland cement.
- Conforming to IS: 383-1970 graded coarse aggregate of nominal size 20mm and natural fine aggregate of size 4.75mm and below were used. Specific gravity values of coarse and fine aggregates were 2.71 and 2.6 respectively.
- Mineral admixture used in this study was class F fly ash procured from RTPS Raichur and chemical admixture used is Master Rheo built 1125 manufactured by BASF India Limited.
- Polypropylene fibers were used in this study, polypropylene fibres were brought from Pune, and fibres used were fine polypropylene monofilaments. The fibre is available on three different sizes viz., 6mm, 12mm and 24 mm. In the present investigation 12mm length fibres were considered.

2.2 Test Procedure

SCC shall possess some fresh concrete properties like filling ability, passing ability, flowing ability. Guidelines are given by EFNARC to test these properties in concrete; a mix satisfying these properties is called as self-compacting concrete. These test procedures are briefly described below.

- Filling ability of concrete is tested by conducting slump flow test on fresh concrete, the two parameters being measured are flow time (T50) and
- flow spread. The former indicates deformation rate with in a marked flow distance and latter indicates free unrestricted deformability.
- The flow ability of fresh concrete can be measured by V- funnel test by noting the flow time. First about twelve liters of concrete is filled in the funnel followed by noting down the flow time (in seconds). If the flow time is shorter, it indicates greater flow ability.
- Being suitable for laboratory and site use L- Box test is a widely used test for assessing passing ability and filling ability of SCC. The lack of stability (segregation) can be detected visually by the commencement of test. First the vertical section of the L- Box is filled up with concrete. After that the doorway is lifted to let the concrete to flow till the end. The ratio of the height at the end (H2) to height of the concrete at the beginning of horizontal section (H1) is obtained. It indicates the degree to which the passage of concrete through the bars was limited or the passing ability of concrete.
- Filling ability and passing ability of SCC were measured by conducting U- Box test. Middle wall of the apparatus divides it into two compartments. Filling heights i.e., (h1-h2) indicate degree of compactability the difference is being attained in two compartments of U- Box.
- Cube specimens of 150mm×150mm×150mm were casted and tested under compression testing machine of 2000 KN capacity as per IS 516:1959.
- A box (size 560mm × 365mm × 114mm) with 3 stress raisers is used to measure the plastic shrinkage. Immediately after casting the slab specimens are transferred to open atmosphere along with the mould after 5 hours the shrinkage parameters such as length of crack, width of the crack, total area of crack is noted down on a plastic sheet. After 24 hours of casting similar observations are made. The specimens are demoulded at this stage and transferred to curing tank. After 28 days of curing, again shrinkage parameters are noted on same plastic sheet. Width of the crack is measured with optical comparator which had a measuring capacity of 0.1 mm. The length and area cracks are calculated using auto cad.

3. Results and Discussions

3.1 Fresh Concrete Tests

Fresh property tests on concrete indicated above are conducted on all mixes and their results are tabulated in Table 2. Fresh concrete tests conducted on all mixes are within the range as per EFNARC guidelines, though we can observe that filling ability, passing ability and flowing ability of mixes have been reduced minutely after incorporating polypropylene fibers in high volume fly ash self-compacting concrete.

3.2 Compression Test

Figures 1, 2 shows the compressive strengths for HVFA_SCC mixes at different curing ages. There are no significant changes in the compressive strengths after incorporating polypropylene fibers in self-compacting concrete on all ages, strength decreased with increase in fly ash content for HVFA_SCC mixes.

Table 2. Fresh concrete properties of mixes

Mix designation	Slump flow (mm)	T500 (sec)	V-funnel (sec)	V-funnel T5 (sec)	L-Box	U-Box (mm)
SCC30	700	3	8	11	0.87	20
SCC 40	700	3	9	12	0.835	24
SCC50	740	3	8	11	0.86	22
SCC60	760	3	7	11	0.9	15
SCC70	800	3	7	9	0.89	17
PFSCC 30	675	3	9	12	0.79	30
PFSCC40	650	3	9	12	0.8	20
PFSCC 50	720	3	8	12	0.825	28.25
PFSCC 60	715	3	8	11	0.83	23.34
PFSCC 70	785	3	7	10	0.839	15

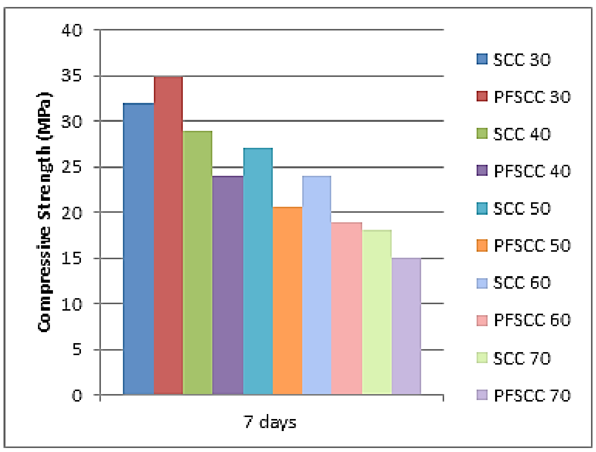

Figure 1. 7 days compressive strength of SCC mixes.

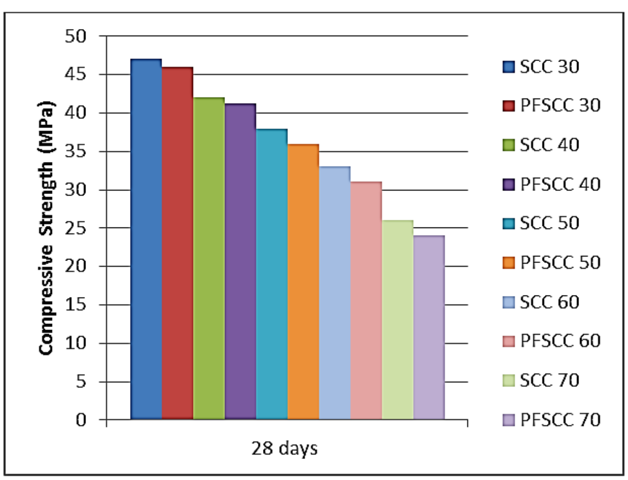

Figure 2. 28 days compressive strength of SCC mixes.

3.3 Plastic Shrinkage

Figures 3–12 and Table 3 proves that addition of polypropylene fibres into the SCC mix has minimized plastic shrinkage cracks. Crack lengths were in the range of 221 to 2258 mm at 1 day. SCC70 and PFSCC30, PFSCC40, PFSCC50, PFSCC70 mixes did not show any 1day cracks. Crack width and number of cracks of all mixes were ranged from 0.1 to 1mm and 5 to 64 respectively. Additional cracks occurred on the 28th day were also noted.

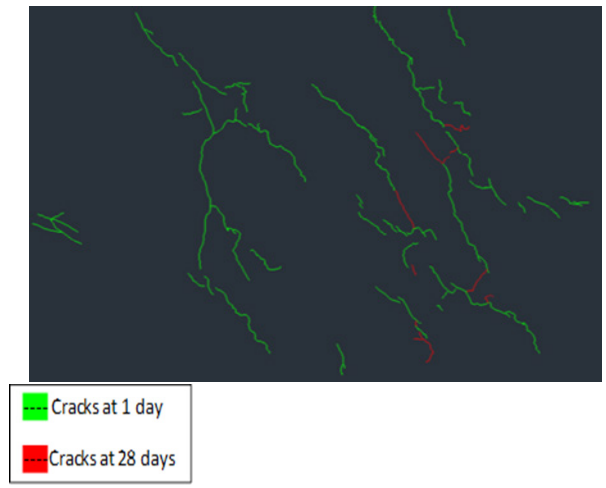

Figure 3. Auto CAD image of Shrinkage cracks – SCC30 mix.

Figure 4. Auto CAD image of Shrinkage cracks – PFSCC30 mix.

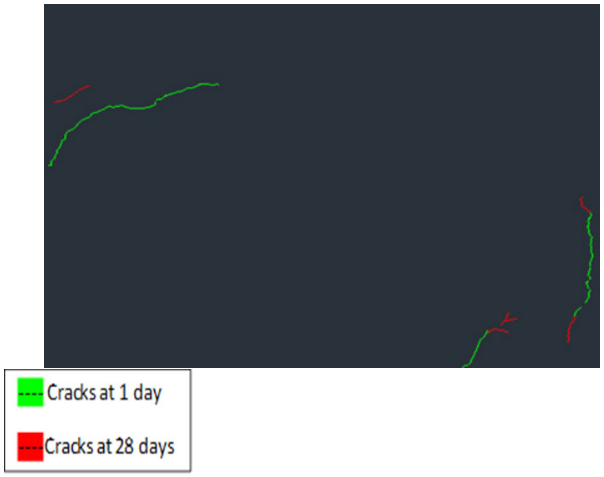

Figure 5. Auto CAD image of Shrinkage cracks – SCC40 mix.

Figure 6. Auto CAD image of Shrinkage cracks – SCC40 mix.

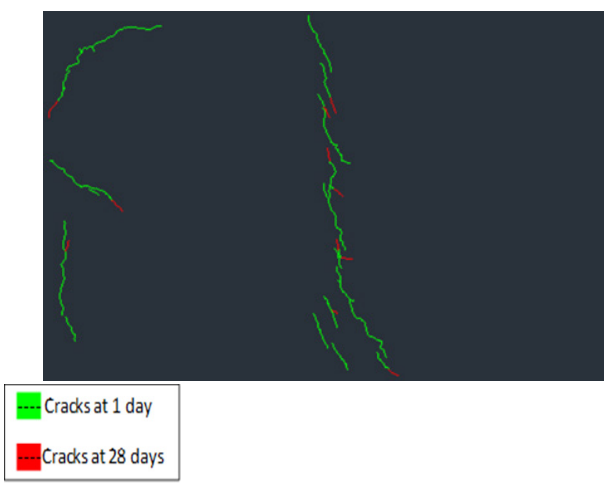

Figure 7. Auto CAD image of Shrinkage cracks – SCC50 mix

Figure 8. Auto CAD image of Shrinkage cracks – PFSCC50 mix

Figure 9. Auto CAD image of Shrinkage cracks – SCC60 mix.

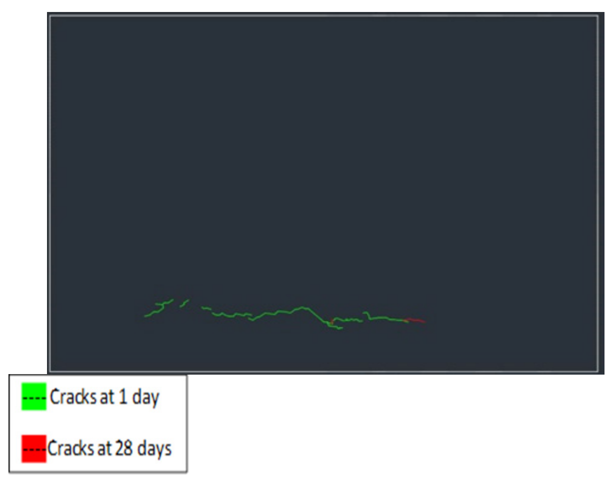

Figure 10. Auto CAD image of Shrinkage cracks – PFSCC60 mix.

Figure 11. Auto CAD image of Shrinkage cracks – SCC70 mix

Figure 12. Auto CAD image of Shrinkage cracks – PFSCC70 mix.

4. Conclusions

From laboratory test outcomes on the properties of compressive strength and plastic shrinkage of HVFA_SCC with 0.1% polypropylene fibres by volume fraction of the mix, replacing cement by 30%, 40%, 50%, 60% and 70% with fly ash, the following conclusions are drawn:

1. Addition of polypropylene fibers to HVFA_SCC has not shown any significant effect on compressive strength of high volume fly ash self-compacting concrete.
2. As percentage cement replacement of fly ash was increased from 30% to 70%, strength of HVFA_SCC has decreased; PFSCC70 has shown 28 days strength of 24Mpa.
3. Plastic shrinkage results prove that polypropylene fibres form bridge between micro cracks and hence they resist the propagation and enlargement of cracks.

Table 3. Details of plastic shrinkage cracks of SCC

Mix designation	Total crack length (mm)		Crack width range (mm)		Number of cracks	
	1 Day	28 Days	1 Day	28 Days	1 Day	28 Days
SCC 30	2258	238	0.1 to 0.6	0.1 to 0.8	64	11
PFSCC 30	Nil	Nil	Nil	Nil	Nil	Nil
SCC 40	397	149	0.1 to 0.6	0.1 to 0.7	8	6
PFSCC 40	Nil	Nil	Nil	Nil	Nil	Nil
SCC 50	961.7	137.68	0.1 to 0.8	0.1 to 1	30	11
PFSCC 50	Nil	Nil	Nil	Nil	Nil	Nil
SCC 60	221.45	58.38	0.1 to 0.4	0.1 to 0.5	13	5
PFSCC 60	314.47	27	0.1 to 0.3	0.1 to 0.3	11	2
SCC 70	Nil	Nil	Nil	Nil	Nil	Nil
PFSCC 70	Nil	Nil	Nil	Nil	Nil	Nil

5. References

1. Shetty MS. Concrete technology theory and practice. 6th edn. S. Chand & Company Ltd; 2012.
2. Okamura H, Ouchi M. Self-compacting concrete, development, present use and future. Proceedings of the 1st International Symposium on Self-Compacting Concrete, Stockholm; 1999. p. 3–14.
3. Khatib JM. Performance of self-compacting concrete containing fly ash. Construction and Building Materials. 2007; 22:1963–71.
4. Craeye B, De Schutter G, Desmet B, Vantomme J, Heirman G, Vandewalle L, Cizer O, Aggoun S, Kadri EH. Effect of mineral filler type on autogenous shrinkage of self-compacting concrete. Cement and Concrete Research. 2010; 40:908–13.
5. Bouzoubaa N, Lachemi M. Self-compacting concrete incorporating high volumes of class F fly ash Preliminary results. Cement and Concrete Research. 2001; 31:413–20.
6. Sukumar B, Nagamani K, Raghavan RS. Evaluation of strength at early ages of self-compacting concrete with high volume fly ash. Construction and Building Materials. 2008; 22(7), 1394–401.
7. Huang C-H, Lin S-K, Chang C-S, Chen H-J. Mix propor-

tions and mechanical properties of concrete containing very high-volume of Class F fly ash. Construction and Building Materials. 46:71–8.

8. Patel I, Modhera CD. Study effect of polyster fibers on flexural strength and abrasion resistance of high volume fly ash concrete with class F-fly ash. Indian Journal of Advanced Civil Engineering. 2014; 4(2):101–10.
9. Karahan O, Atis CD. The durability properties of polypropylene fiber reinforced fly ash concrete. Materials and Design. 2010; 32:1044–9.
10. Zhang P, Li QF. Effect of polypropylene fiber on durability of concrete composite containing fly ash and silica fume. Composites: Part B. 2013; 45:1587–94.
11. Alhozaimy M, Soroushiad P, Mirzac F. Mechanical properties of polypropylene fiber reinforced concrete and effect of pozzolanic materials. Cement and Concrete Composites. 1995; 18:85–92.
12. Enfedaque AA, Galvez JC, Canovas MF, Osorio IR. Polyolefin fiber-reinforced concrete enhanced with steel-hooked fibers in low proportions. Materials and Design. 60:57–65.
13. Sadhu RS, Singh J, Dhanoa JS. Effect of air cooled blast furnance slag and polypropylene fiber on mechanical properties of concrete. International Journal of Civil, Structural, Environmental and Infrastructure Engineering Research and Development. 2015; 5:45–56.