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Strength and permeation properties of self-compacting concrete containing fly ash and hooked steel fibres

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HIGHLIGHTS

- Paper presents properties of SCC containing hooked steel fibres.
- Steel fibres improved the strength properties of SCC.
- Permeability and porosity of SCC slightly increased with fibres.

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ABSTRACT

This paper presents properties of self-compacting concrete (SCC) made with class F fly ash and hooked steel fibres. The effect of steel fibres (0.5%, 1.0% and 1.5% by volume) on rheological (slump flow, V-funnel, L-box, U-box), strength (compressive strength, splitting tensile strength and flexural strength) and permeation properties (porosity, rapid chloride permeability, ultra sonic pulse velocity) of SCC specimens, were investigated.

The results indicated that the workability of SCC with 0.5% and 1.0% hooked steel fibres by volume, are found in range set by EFNARC and get reduced to some extent with increase in fibres volume fractions up to 1.5%. This led to decrease of other rheological characteristics prescribed by EFNARC and ACI 237 R. The enhancement in properties of SCC is because of augmentation in interfacial or bond strength of steel fibres and pore refinement by fly ash. In contrast, the improvement in properties of concrete like compressive strength from 34.6 to 38.5 N/mm^2, splitting tensile strength from 3.8 to 6.2 N/mm^2 and flexural strength from 5.5 to 8.2 N/mm^2 at 28 days was observed with increase in fibres content. SCC mixes with steel fibres exhibited very low range charge passing (100–1000 Coulomb) in rapid chloride ion penetrability, porosity increased from 9.3% to 9.9% and decrease in ultra sonic pulse velocity of about 17% at 28 days were observed with increase of steel fibre contents by volume in SCC mixes.

1. Introduction

Self-compacting concrete is relatively a topical advancement in the area of construction which is defined as remarkable deformability in the fresh condition and elevated segregation resistance. SCC flows underneath its own weight at the same time as left after uniform in composition and achieve complete compaction with no vibration. The employ of fine materials in SCC is needed such as fly ash to make certain the obligatory concrete properties. Self-compacting concrete (SCC) is a flowing mix which is appropriate designed for insertion by no vibration, in unusual conditions and as well in jam-packed reinforcement.

Literature research suggests that the substitution of usual concrete entirely or partly with steel fibres may advance the production practice. Consecutively to advance and expand the capability of SCC, its workability is maintained by the adding together of steel fibres, fly ash as supplementary cementitious material and superplasticizers. Grunewald and Walraven [1] emphasised that addition of steel fibres in the SCC may acquire help of widening the prospect of field use of SCC. Okama and Ouchi [2] concluded that to get the easier self-compatibility, aggregate contents can be kept invariable to with the adjustment of the water/cement fraction and the quantity of superplasticizer. In theory, a self-compacting or self-consolidating concrete be obliged to have a flexibility that permits self-compaction devoid of exterior energy, stay consistent in appearance in the placing process, pours effortlessly all the way through reinforcement and can be pumped longer distances because of its high fluidity [3].

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Fig. 1. Fly ash used in experiment.

Fig. 2. Hooked steel fibres.

Table 1
Chemical composition of ordinary Portland cement and fly ash.

Chemical composition (% by mass)	Ordinary Portland cement (43 Grade)	Fly ash (class F)
Silicon dioxide (SiO_2)	22.4	57.2
Aluminium oxide (Al_2O_3)	5.8	25.4
Ferrous oxide (FeO)	3.9	6.0
$SiO_2 + Al_2O_3 + FeO$	32.2	89.0
Magnesium oxide (MgO)	0.9	2.4
Calcium oxide (CaO)	55.8	1.1
Sodium oxide (Na_2O)	0.7	0.4
Potassium oxide (K_2O)	2.3	4.6
Sulphur trioxide (SO_3)	2.8	0.1
L.O.I	0.6	1.1

Corinaldesi and Moriconi [4] and El-Dieb [5] demonstrated that SCC with fibres, 10% by mass of cement, have enhanced the mechanical and durability properties of concrete because of its low porosity.

Siddique [6] has demonstrated to design and develop SCC with varying percentage of fly ash. Sahmaran and Yaman [7] concluded that the volumetric water-to-powder proportion technique is an innovative area to explore on the relations between strength and durability of the concrete. Studies by authors [8–10] have shown that cautious mix design is to be done while inserting steel fibres in it. The improvement of the fracture toughness is observed, considerably but they also affect negatively on the flow and segregation of fresh mixtures with the higher percentages of steel fibres in concrete mixes. Anastasiou et al. [8] concluded that steel fibres had negligible consequence on chloride ion penetration resistance. The matrix with 0.7% fibre content showed simply minor raise in chloride contents. Khurana and Saccone [10] suggests that the concrete made with fly ash lessens the claim of cement, fine fillers and necessity of fine aggregates for SCC.

Khaloo et al. [11] exhibited that there is less reduction in compressive strength for high-strength SCC as compared to medium-strength SCC and that may be due to more workability of high strength SCC, comparatively. With high percentage of steel fibres by volume in SCC, compressive strength decreases. Gencel et al. [12] reported increase (18–21%) in splitting tensile strength of fibre-reinforced concrete having different fibre volume fractions (0.2–0.8%), and maximum pulse velocity was observed in control mix, but the pulse velocity decreased with the incorporation of fibres in SCC mixes.

Studies have shown that the fibre geometry affects greatly not only hardened properties but also the fresh properties of SCC [7,9,14]. The orientations of fibres in concrete play a key function in shaping the ability of concrete. In RCC, the reinforcements are positioned in chosen places. But in fibre reinforced concrete (FRC), the fibres may be oriented randomly. Studies have shown that that dispersion, alignment, aspect ratio and volume fraction of fibres have important effects on rheological, mechanical and durability properties of SCC [13–15].

Though there is literature available on the use of steel fibres in SCC, but no work has been reported with hooked steel fibres in SCC. Therefore, in present investigation, research is designed for investigating the influences of hooked steel fibres in different volume contents (i.e. 0.5%, 1% and 1.5%) on rheological, strength and permeation properties of fibre reinforced SCC prepared with the addition of 10% fly ash.

2. Experimental plan

2.1. Materials used

2.1.1. Cement

Ordinary Portland cement (OPC) of 43 Grade (compressive strength 43 MPa at 28 days) Ultra Tech cement was used as a binder material in SCC. The chemical composition of cement is shown in Table 1. Test were performed as per BIS: 8112-1989 [16], and results are given in Table 2.

Table 2
Tests conducted on ordinary Portland cement (43 Grade).

Tests	Results obtained	Standard results as per IS: 8112-1989
Normal consistency (%)	26	–
Initial setting time (min)	155	Not less than 30
Final setting time (min)	220	Not be greater than 600
Fineness (m^2/kg)	283.4	Not less than 225
Specific gravity	3.15	–
Compressive strength (N/mm²)		
3 days	30.8	27
7 days	42.8	41
28 days	46.7	43