Self-Compacting Concrete with Super Absorbent Polymers as Internal Curing Agent

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Abstract

As water is becoming a meager material day-by-day, there is an urgent need to investigate in saving of water for making concrete and curing. Curing of concrete is maintaining satisfactory moisture content in concrete during its early stages in order to develop the desired strength and durability properties. The concept of self-compacting and internal curing is to eliminate the compaction for concrete also maintaining sufficient moisture content in concrete for curing purpose. So, an attempt has been made to develop self-compacting self-curing concrete (SCSCC) by using Super Absorbent Polymers (SAP) as self-curing also called internal curing agents. The effect of variation in strength parameters such as Compressive strength, Splitting tensile strength, modulus of rupture and Modulus of elasticity were studied for different dosage of self-curing agent (0%, 0.1%, 0.3%, 0.5%, 0.7% weight of cement) and from the experimental investigation it is manifest that addition of 0.3% SAP was achieved desirable properties.
Keywords: Internal curing, Super Absorbent Polymers, SCC, Strength

I. Introduction

Self-compacting concrete (SCC) represents one of the most outstanding advance in concrete technology during the last decade. Self-compacting concrete was first developed in Japan around the year 1980 [1],[2]. The growing use of concrete in special architectural configurations and closely spaced reinforcing bars have made it very important to produce concrete that ensures proper filling ability, passing ability, segregation resistance, good structural performance and adequate durability [3],[4]. Concrete is a mixture of cement, aggregates and water with or without suitable admixtures. To attain desirable strength and other properties, curing is necessary [5]. Curing is the process of controlling the rate and degree of moisture loss from concrete during cement hydration. It may be either after it has been placed in position or during the manufacture of concrete products, thereby providing sufficient time for the hydration of the cement to occur. Since the hydration of cement does take time days and even weeks rather than hours curing must be undertaken for a reasonable period of time. The need for adequate curing of concrete cannot be overemphasized because curing has a strong influence on the properties of hardened concrete; proper curing will increase strength, durability, water tightness, abrasion resistance, volume stability, and resistance to freezing and thawing effect. Proper moisture conditions are critical because water is necessary for the hydration of cementations materials. The concept of self-curing is to reduce the water evaporation from concrete and hence increase the water retention capacity of the concrete compared to ordinary concrete. Scarcity of potable water increases day by day. The use of self-curing agent is very important from the point view that water resources are getting valuable every day. Moreover requirement of water for concreting is also high. Concrete of $1m^3$ requires $3m^3$ of water for construction, most of which is needed for curing purpose only [6].

Self-curing or internal curing is a technique that can be used to provide additional moisture in concrete for more effective hydration of cement and reduced self-desiccation. There are two major methods available for internal curing of concrete. The first method uses saturated porous lightweight aggregate (LWA) in order to supply an internal source of water, which can replace the water consumed by chemical shrinkage during cement hydration [7],[8]. The second method uses poly-ethylene glycol (PEG) or SAP which reduces the evaporation of water from the surface of concrete and also helps in water retention [9].

II. MATERIALS AND METHODS

53 Grade Ordinary Portland cement conforming to IS: 12269 – 1987 [10] was used for the study. The specific gravity of cement is 3.15. Class 'F' fly ash having specific gravity of 2.27 as obtained from Mettur thermal power plant was used as a mineral admixture. Locally available fine aggregate (river sand) having specific gravity of 2.68 conforming to grading zone-III was used as natural fine aggregate. Natural crushed coarse aggregate of maximum 12 mm size and specific gravity 2.72 was used in this study. Mixing water is required in accordance with the quality standards of drinking water. The Glenium B233 (polycarboxylate ether based) superplastcizer was also used to attain good workability in SCC.

A. Super Absorbent Polymers (SAP)

SAPs are a group of polymeric materials that have the ability to absorb a considerable amount of liquid from the surroundings and to retain the liquid within their structure without dissolving. SAPs are primarily used for absorbing water and aqueous solutions; about 95% of the SAP world production is used as a urine absorber in disposable diapers. SAPs can be produced with water absorption of up to 5000 times their own weight. In this present study the SAP is used as internal curing agent in SCC in a form of gel like shown in Fig.1.

Fig. 1: Super absorbent polymers

B. Mix Design for SCC

SCC mix design was done as per the guidelines prescribed by EFNARC, Okamura H and his associates [11,[12]. The total powder content to 579.7 kg/m^3 (cements + fly ash). Coarse aggregate content is fixed at 50% by volume (774.20 kg/m^3) of concrete and fine aggregate content at 45% (838.61 kg/m^3) by mortar volume. The W/P ratio is kept at 0.33 by weight, with air content 2%. Super plasticizer dosage is fixed at 0.7% of cementitious materials. The SAP is added in different dosages (0%, 0.1%, 0.3%, 0.5% and 0.7%) by the weight of cement. Before concrete mixing SAP was immersed in water for 15min. So that, it absorb and hold water. This absorbed water is effectively used for curing purposes.

C. Testing methods

The fresh concrete properties of SCC such as filling ability, passing ability and segregation resistance test were measured for all the mixes in order to ensure the self compactabilty. Slump flow, T_{50cm} slump flow and 'V' funnel test were conducted to measure filling ability of fresh concrete. Also, passing ability and segregation resistance tests such as 'J' ring, 'U' box, and 'L' box were carried out as per EFNARC guidelines. Totally 30 cubes of 150 mm size for compressive strength, 30 cylinders of 150 mm x 300 mm for split tensile strength, 30 prisms of 500 mm x 100 mm x 100 mm for modulus of rupture and 30 cylinders of 150 mm x 300 mm for modulus of elasticity were cast to measure the properties of hardened concrete. The SCC mix without SAP as denoted as Control mix (CM). The specimens were tested for compressive strength (Fig.2), split tensile strength (Fig.3), flexural strength (Fig.4) and modulus of elasticity according to IS: 516:1959 [13] at the age of 7 and 28 days. Three specimens were tested for each mix at different properties of hardened concrete.

Fig. 2: Compressive strength

Fig. 3: Split tensile strength

Fig. 4: Modulus of rupture

III. RESULTS AND DISCUSSIONS

A. Fresh SCSCC Properties

The limitations of workability for SCC as per EFNARC are shown in Table 1. The fresh concrete properties of SCC made with SAP are furnished in Table 2. It is evident from the results that Control mix, 0.1% SAP, 0.3% SAP, 0.5% SAP mixes is in conformity with EFNARC. The 0.7% mix satisfies the slump flow, but it does not satisfy all other workability tests. This is due to the amount of internal water (absorbed water) held in SAP is more. So it affects the rheological characteristics of the SCC.

Table – 1
Limitations of workability for SCC as per EFNARC

S.No	Test method	Unit	Typical range of minimum value	Typical range of maximum value
1.	Slump flow	mm	650	800
2.	T_{50cm} Slump flow	sec	2	5
3.	'J' ring	mm	0	10
4.	'V' funnel	sec	6	12
5.	'U' box	mm	0	30
6.	'L' box	H2/ H1	0.8	1

Table - 2
Fresh concrete workability properties of SCSCC

S.No	Mix Id	Slump flow (mm)	T_{50cm} Slump flow (sec)	'J' Ring (mm)	'V' Funnel (sec)	'U' Box (H2-H1) mm	'L' Box (H2/H1)
1.	CM (0% SAP)	685	4.3	8.1	8.5	24	0.95
2.	0.1% SAP	677	4.5	8.3	9.1	26	0.93
3.	0.3% SAP	668	4.7	8.5	9.7	28	0.91
4.	0.5% SAP	656	5.0	9.3	10.5	30	0.86
5.	0.7% SAP	625	5.5	10.2	12.5	33	0.77

B. Hardened SCSCC Properties

The properties of hardened concrete such as compressive strength, split tensile strength, and flexural strength were shown in Table.3. From the hardened concrete test results we noticed that the addition SAP up to 0.3% showed significant results.

Table - 3
Hardened concrete properties of SCSCC

S.No	Mix id	Compressive strength (MPa)		Spilt tensile strength (MPa)		Modulus of Rupture (MPa)		Modulus of Elasticity (GPa)	
		7 days	28days	7days	28days	7days	28days	7days	28days
1.	CM (0% SAP)	22.80	30.24	2.33	3.15	3.50	4.15	21.87	26.49
2.	0.1% SAP	25.14	34.95	2.61	3.88	3.81	4.73	24.07	28.45
3.	0.3% SAP	28.60	41.92	2.92	4.21	4.23	5.59	24.83	31.37
4.	0.5% SAP	26.09	32.06	2.75	3.26	3.87	4.51	21.53	27.23
5.	0.7% SAP	24.15	30.91	2.42	3.18	3.65	4.25	23.41	26.67

Compared to the control mix (CM) the 0.3% SAP mix increased about 20.2% at the age of 7 days, 27.8% at the age of 28 days compressive strength (Fig.5). Similarly, 20.2% at the age of 7 days, 25.1% at the age of 28 days in split tensile strength {Fig.6). Likewise, 17.2% at the age of 7 days, 25.75% at the age of 28 days in modulus of rupture (Fig.7). Also, 11.92% at the age of 7 days, 15.55% at the age of 28 days in modulus of elasticity (Fig.8).

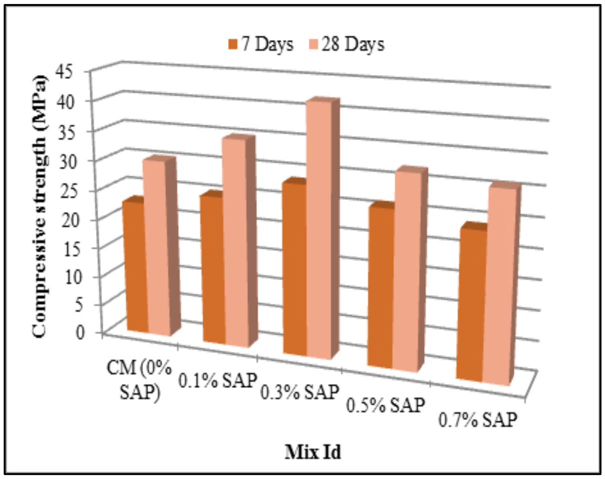

Fig. 5: Compressive strength

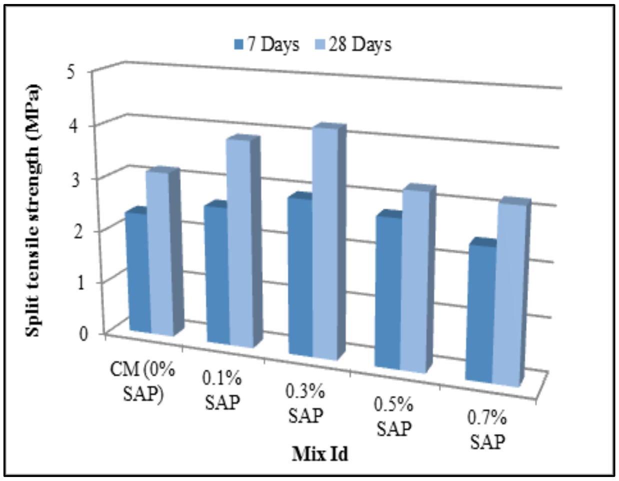

Fig. 6: Split tensile strength

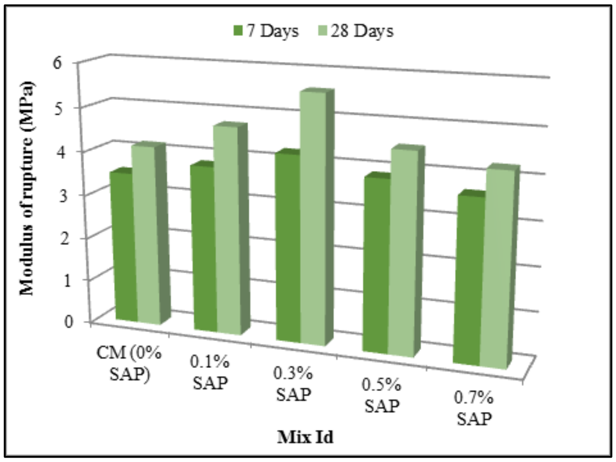

Fig. 7: Modulus of Rupture (flexural strength)

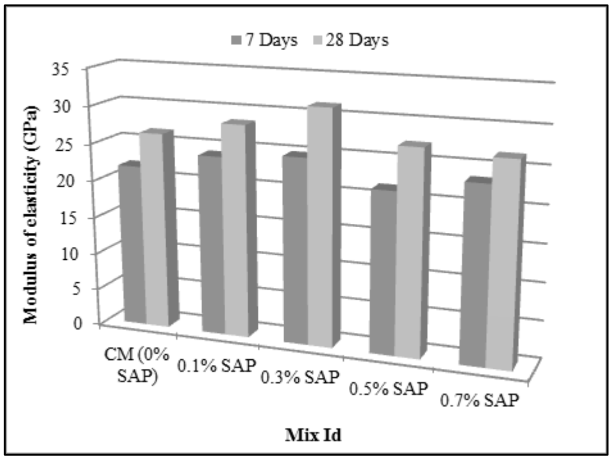

Fig. 8: Modulus of elasticity

IV. Conclusion

The mix combinations of SCSCC with SAP and CM satisfied the fresh workability concrete properties up to 0.5% as per recommended guide lines given in EFNARC standards. The compressive strength, split tensile strength, modulus of rupture and modulus of elasticity values are remarkably increased up to 0.3% after that it slightly decreased. So, the optimum percentage of addition of SAP in SCC for internal curing is 0.3%. This extends the hydration and thereby increases the strength of concrete. Therefore, self-compacting self-curing concrete with SAP is recommended for field application where curing is difficult and water scarcity areas.

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