Performance analysis of self compacting concrete without super plasticizer

Ravichandran Subbarayalu¹ · A. M. Vasumathi² · P. Kalai Selvi³

Received: 18 January 2017 / Accepted: 9 August 2017 / Published online: 19 August 2017
© Springer International Publishing AG 2017

Abstract The use of self compacting concrete (SCC) in civil engineering works has become an attractive option which produces confident cohesive concrete. This paper reviewed the feasibility of preparing a SCC without using super-plasticizer but with only mineral admixtures that are available locally, with the coarse aggregate size of with 20 mm well graded aggregates which is entirely a different way of preparation of SCC. The enhancement aspects were tested and ascertained with the EFNARC guidelines. The hardened properties of SCC were tested and compared with control concrete of M₂₅ grade. In the preliminary investigation, mechanical properties of the SCC which have been prepared by the above said method were tested by its unique testing methodologies. Based on the test results, in the second phase, the flexural behavior of the SCC specimens, using beam specimens were tested for its load carrying capacity by loading frame. In both the phases of investigation, the results revealed that this type of SCC will be promising and effective combination to that of the traditional type of SCC prepared by Glenium product and also cost effective.

Keywords Self compacting concrete · Particle size distribution · Workability · Mineral admixtures · Glenium · EFNARC · Flexural behavior

1 Introduction

Self compacting concrete (SCC) can be defined as a fresh concrete which possesses superior flow ability under maintained stability (i.e., no segregation), thus allowing self-compaction, that is material consolidation without addition of energy. Venkataram Pai et al. [1] experimentally analyzed the development of self compacting concrete with various mineral admixtures. The required compaction properties were achieved by adding super-plasticizers and mineral admixtures such as fly ash, rice husk ash, silica fume, etc. Comparison of these SCC mixes in terms of their Compressive, Split Tensile, and Flexural strengths were analyzed. The effect of fly ash on fresh and hardened properties of self compacting concrete were analyzed by Shriram [2]. Heat of hydration, setting time and compressive strength of SCC were studied experimentally and the effect of super plasticizer (SP) on type of the properties of the fly ash blended cement were investigated by Tkaczewska [3]. Fouad Khairallah [4] have investigated the mechanical behavior of confined self compacting reinforced concrete circular columns under concentric loading. The SCC mix contained with ground granulated blast furnace slag (GGBS) exhibited greater strength because of the high pozzalonic activity of GGBS. Yousaf et al. [5] investigated the performance of 3rd generation locally available chemical admixtures in the production of self compacting concrete (SCC). The fundamental rheological properties and stability of SCC in fresh state were found out with locally available chemical admixtures related to

---

✉ Ravichandran Subbarayalu
ravic0306@gmail.com

A. M. Vasumathi
amvasu2006@gmail.com

P. Kalai Selvi
selvikalai902@gmail.com

¹ Madurai Institute of Engineering and Technology,
Pottapalayam, India

² Velammal College of Engineering and Technology,
Viraganoor, Madurai, India

³ KLN College of Information Technology, Pottapalayam,
India

ACI [6], EFNARC [7] Poulson [8] specifications. The performance of various laboratory trials were compared with two types of admixtures belonged to sulphonated naphthalene formaldehyde (SNF) and poly carboxylic ether (PCE)s families. Silica fume Chenab sand were used as coarse aggregate, marble crush of 8 mm down was used as coarse aggregates. Mechanical properties of the materials were found out. Testing was carried out as per ASTM [9] test methods. It revealed that 3rd generation admixtures performed much better than those of first and second generation. The mechanical properties of self-compacted fiber concrete with steel and polypropylene fibers were investigated by Kamal [10]. Paja, [11] investigated the flexural properties of SCC with several straight and hooked end steel fibers of ratios varied from 0, 1.0, 1.5%. The bending tests were carried out on 550 mm beams with 150×150 mm cross section. The bottom side of each specimen was notched with 25 mm depth using 2 mm diamond saw. The three-point bending tests were conducted on servo-controlled electro hydraulic machine. The tests were performed until the beam reached the 5 mm deflection. The deflection of the two opposite sides of the specimen was measured in the center of the specimen by LVDT sensor placed on the steel frame. Flexural behavior of steel fibre reinforced self-compacting concrete (SFR-SCC), tests according to RILEM TC 162-TDF [12] and EN 14651 [13] were performed. Swernalatha [14] investigated the properties of utilization of flyash and pond ash in self compacting concrete and segregation and possibility under dense reinforcement. Suryadi [15] experimentally investigated the chemical admixture's influence on the performance of self compacting concrete. Three different chemical admixtures were used in the research. Fly ash was used and the micro structure of the concrete was modified. The reduction of water-cement powder ratio decreased the porosity and increased the performance of hardening concrete. The higher use of chemical admixture increased the compressive strength of SCC. Mithra et al. [16] investigated the flexural properties of SCC prepared with GGBS and super plasticizer. $100 \times 100 \times 2000$ mm size specimens with HYSD bars were used as beams and tested for flexural behavior. GGBS with 0, 30, 40 and 50% with water powder ratio varied from 0.35 to 0.4 along with the dosage of super plasticizer as 2.2% by weight of cement was used in the study. Properties of self compacting concrete using recycled coarse aggregate (RCA) have been analyzed by Bal [17]. Gaywala [18] presented the progress of the research on different hardened properties of SCC. Ordinary portland cement (OPC), low calcium fly ash were used as binder materials, crushed stones of size 12.5 mm downed and retained at 10 mm were used in equal weight proportion as coarse aggregate. Glenium sky 784 was used as high performance plasticizer with 1.0–1.5% dosage level

of binder (cement + fly ash). Fly ash content was varied by 15, 25, 35, 45 and 55%. Flexural strength test was carried out on $10 \times 10 \times 50$ cm specimens and compared with control specimens of ordinary cement concrete (OCC), by two point loading pull out strength test carried out on cubes and the local bond strength was determined with a 12 mm diameter bar at the centre of cube specimens. Upadhyay et al. [19] discussed the testing and mix design of SCC with various materials. The mechanical properties of SCC reinforced with polypropylene fibres was investigated by Gencel et al. [20]. This experimental investigation aimed and prepared a SCC with only mineral admixtures with the coarse aggregate size 20 mm well graded and tested its standard according to the EFNARC [7] guide lines. Proportions have been made by trial and error methods based on the control mixture prepared as per IS 456-2000 [21] specifications and on the compatibility of materials. The materials were chosen, which are easily available locally. The properties of the aggregates were tested according to IS 383-1970 [22] standards.

2 Materials and methods

2.1 Materials

2.1.1 Aggregates

Well graded Coarse aggregates passing through 20 mm sieve and retained at 16 mm sieve size was used in this experimental study and the self Compacting Concrete properties were tested (Tables 1, 2).

2.1.2 Lime stone powder

A high quality lime stone powder generally permits a reduction in water content of a concrete mixture, without

Table 1 Fines modulus of aggregates

Material	Fines modulus (number)
Fine aggregate	4.269
Coarse aggregate	5.370

Table 2 Physical properties of materials

Material	Specific gravity (number)
Cement	3.02
Lime	2.17
Fly ash	2.37
Fine aggregate	2.85
Coarse aggregate	2.84

loss of workability. Lime stone powder obtained from India Cement Limited, Tirunelveli was used in this study (Table 2).

2.1.3 Fly ash

Generally fly ash is used as filling material. In this investigation Class-A Fly ash from Thermal Power Station (Tuticorin) has been used as binder material replacing cement by certain proportions (Table 2).

2.1.4 Cement

Ordinary Portland Cement (53 grade) Dalmia cement conforming to IS 12269 [23] was used. Various laboratory tests were conducted on cement and the properties were determined as per IS 4031 [24] standards. The results conformed to the Indian Standard recommendations (Table 2).

2.1.5 River sand

River sand confirming Zone-IV was used in this experimental study (Tables 1, 2).

2.1.6 Steel

Thermo mechanically treated (TMT) bars confirming IS 1786:2000 [25] standards of 12 mm diameter were used for main reinforcement and 6 mm diameter mild steel rods were used for stirrups (Table 3).

3 Specimen preparations

Mix design for control concrete: M₂₅ As per IS 10262-2009 [26] was adopted. Mix proportions: 1:2.175:3.237.

3.1 Control concrete specimens

Specimens were prepared as cubes and cylinders for M₂₅ grade concrete for control concrete (CC) specimens (Table 4).

3.1.1 Self compacting concrete preparations

Self-compact ability can be largely affected by the characteristics of materials and mix proportions. In this experimental study, three types of Self-compacting concrete mixture proportions were adopted. The mortar or the paste in the self compacting concrete requires high viscosity and deformability, thereby the water-powder ratio has been adopted as 0.50 (as per EFNARC guide lines) constantly. After several trial mixes, due to its water absorbing characteristics lime powder content was fixed as 5% of the total powder content for all the mix proportions. Self-compacting concrete (SCC) specimens were prepared for the three types such as SCC-1, SCC-2 and SCC-3 (Tables 4, 5).

4 Testing program

Workability test for control specimen was carried out by means of Slump cone method for three w/c ratios 0.5, 0.55 and 0.6 likely, out of which 0.55 arrived as optimum. Mechanical properties of SCC were carried out by standard

Table 3 Mechanical properties of steel

Sl. no.	Parameter	As per 1786:2008 specifications
1.	Grade of steel	Fe 500
2.	Yield stress (N/mm ²)	500
3.	Ultimate tensile strength (N/mm ²)	545
4.	Elongation (%)	12

Table 4 Specimen preparations

Sl. no.	Category	Specimen	Numbers	Description
1.	Control concrete-CC	Cubes	9	Cured and tested at the age of 3,7 and 28 days
		Cylinders	3	Cured and tested at the age of 28 days
2.	Self- compacting concrete- SCC-1	Cubes	9	Cured and tested at the age of 3,7 and 28 days
		Cylinders	3	Cured and tested at the age of 28 days
3.	Self- compacting concrete- SCC-2	Cubes	9	Cured and tested at the age of 3,7 and 28 days
		Cylinders	3	Cured and tested at the age of 28 days
4.	Self- compacting concrete- SCC-3	Cubes	9	Cured and tested at the age of 3,7 and 28 days
		Cylinders	3	Cured and tested at the age of 28 days

Table 5 Specimen proportions

Specimen	SCC 1		SCC2		SCC3	
Powder content						
Cement	18%	70%	18%	60%	18%	50%
Flyash		25%		35%		45%
Fine aggregate	45%		50%		52%	
Coarse Aggregate (20 mm)	30%		20%		15%	
Lime	5%		5%		5%	
Water/powder ratio	0.5		0.5		0.5	

methods according to EFNARC guidelines (Table 6). Specimens were prepared by cubes of size 150 mm × 150 mm × 150 mm and the compressive strength at the age of 3, 7 and 28 days strength were tested in compression testing machine (CTM) of 1000 kN capacity (Table 7). Cylinders of size 150 mm diameter and 300 mm height were casted and tested for split tensile strength at the age of 28 days (Table 8).

5 Flexural strength testing program

Based on the test results obtained through phase-1 investigation, flexural behavior of the self compacting concrete (SCC) have been aimed and tested off with beam specimens of size 150 × 150 × 750 mm (Table 9) for all combinations. Since the earlier strength of the SCC combinations were less than to that of CC, in about 50% average strength, flexural strength of the SCC combinations were tested at 7 and 28 days respectively, which exposed moderate strength that suits to the structural applications. The beams were casted as per the clause 26.5.1.1 of IS: 456-2000 [21] with four numbers of 12 mm diameter thermo mechanically treated (TMT) bars as main reinforcement and 6 mm diameter of mild steel rods for stirrups. Control specimens were casted for M₂₅ grade concrete and SCC specimens for SCC-1, SCC-2 and SCC-3 combinations (Table 9).

The mix proportion were designed as per IS 10262-2009 [22] for M₂₅ grade concrete and for SCC combinations.

Table 6 Mechanical properties of SCC

Sl. no.	Types of SCC	Testing methods				
		Passing ability		Filling ability		Segregation resistance
		L-box (0.80–1.0 mm) H2/H1	J-ring (0.00–10.0 mm)	Slump flow (650–850 mm)	V-funnel (8–12 s)	
EFNARC acceptance criteria						
1.	SCC-1	1	2	800	6	0
2.	SCC-2	1	4	750	8	0
3.	SCC-3	0.95	7	710	9	2

Table 7 Average compressive strength of cubes at the age of 3, 7 and 28 days

Sl. no.	Specimens	Compressive strength in N/mm ²		
		3 days	7 days	28 days
1.	Control	17.98	27.62	42.22
2.	SCC-1	9.70	18.30	37.04
3.	SCC-2	8.08	16.22	34
4.	SCC-3	7.24	12.13	29.82

- SCC-1 powder content 18%, cement 70%, flyash 25%.
- SCC-2 powder content 18%, cement 60%, flyash 35%.
- SCC-3 powder content 18%, cement 50%, flyash 45%.

The beam specimens were prepared and cured under water for 7 and 28 days. The flexural strength was tested on 7 and 28 days.

5.1 Testing methodology

The cured specimens were tested under load frame instrument. The beam specimens were tested for midpoint loading and their deflections were observed with linear variable differential transformer (LVDT) attached to the specimens. The readings were recorded in a data logger attached to the load frame instrument (Tables 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19). Gradual loading has been imposed on the specimens through a load cell 1000 Tons capacity until failure (Figs. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11). The flexural strength (σ_b) was determined by using the fundamental bending equation formula, Bending stress = $\sigma_b = \frac{3WL}{4bd^2}$ where W is the load in Tons, I is the moment of inertia, b is the width of beam (150 mm), d is the depth of beam (150 mm).

6 Results and discussions

The mechanical properties of SCC combinations showed a unique behaviour, such that, the compressive strength of SCC-1 was more than (37.04 N/mm²) to that of SCC-2 (34 N/mm²), whereas the split tensile strength results

Table 8 Average split tensile strength of cylinders at the age of 28 days

Specimen	Loads $P \times 10^3$ (N)	Diameter of specimen D (mm)	Length of specimen L (mm)	Tensile strength = $2P/\pi DL$ (N/mm ²)
Control	133.33	150	300	1.88
SCC-1	43.33			0.61
SCC-2	70.00			0.99
SCC-3	76.67			1.08

Table 9 Specimen preparations

Sl. no	Category	Specimen	Numbers	Description	Reinforcement details	
					Main rod	Stirrups
1.	Control concrete CC	Beams	6	Cured and tested at the age of 7 and 28 days	4–12 mm diameter TMT rods	6 mm diameter mild steel at 150 mm c/c
2.	Self- compacting concrete- SCC-1	Beams	6	Cured and tested at the age of 7 and 28 days	4–12 mm diameter TMT rods	6 mm diameter mild steel at 150 mm c/c
3.	Self- Compacting Concrete- SCC-2	Beams	6	Cured and tested at the age of 7 and 28 days	4–12 mm diameter TMT rods	6 mm diameter mild steel at 150 mm c/c
4.	Self- Compacting Concrete- SCC-3	Beams	6	Cured and tested at the age of 7 and 28 days	4–12 mm diameter TMT rods	6 mm diameter mild steel at 150 mm c/c

Table 10 Seven days flexural strength results for control specimens

CC1			CC1.2			CC1.3		
Load in (Tons)	Deflection in (mm)	Flexural strength N/mm ²	Load in (Tons)	Deflection in (mm)	Flexural strength (N/mm ²)	Load in (Tons)	Deflection in (mm)	Flexural strength (N/mm ²)
0	0	0	0	0	0	0	0	0
1.0	0.3	6.250	1.0	0.30	6.250	1.0	0.34	6.25
2.0	0.3	12.500	2.4	0.36	15.000	2.0	0.35	12.50
3.3	0.3	20.625	3.7	0.36	23.130	3.5	0.38	21.875
4.2	0.3	26.625	4.4	0.37	27.500	4.9	0.42	30.625
5.9	1.5	26.250	5.9	1.52	36.875	5.5	1.59	34.375
7.2	2.9	36.875	7.6	2.96	47.500	6.8	2.57	42.500
6.4	2.3	45.000	6.8	2.39	42.500	5.7	2.89	35.625
4.9	2.9	40.000	5.3	2.73	33.125	4.8	3.3	30.000
4.0	3.1	30.630	4.8	2.97	30.000	4.0	4.1	25.000

Table 11 Seven days flexural strength results for SCC1 specimens

SCC1			SCC1.2			SCC1.3		
Load in (Tons)	Deflection in (mm)	Flexural strength (N/mm ²)	Load in (Tons)	Deflection in (mm)	Flexural strength (N/mm ²)	Load in (Tons)	Deflection in (mm)	Flexural strength (N/mm ²)
0	0	0	0	0	0	0	0	0
1.2	0.1	7.500	1.3	0.1	8.125	1.1	0.2	6.875
1.9	1.1	11.875	2.4	1.2	15.000	1.8	0.3	11.250
2.8	1.6	17.500	2.7	1.5	16.875	2.2	1.3	13.750
3.5	1.5	21.875	3.4	1.5	21.250	2.9	1.5	18.125
4.7	1.8	29.375	4.9	1.9	30.625	3.6	2.4	22.500
5.9	2.7	36.875	6.2	2.8	38.750	4.8	2.8	30.000
5.1	2.0	31.875	5.4	2.0	33.750	5.7	2.9	35.625
4.3	1.9	26.875	4.6	1.8	28.750	4.4	1.9	27.500
4.0	2.2	25.000	3.3	2.5	20.625	3.0	3.0	18.750

Table 12 Seven days flexural strength results for SCC2 specimens

SCC2			SCC2.2			SCC2.3		
Load in (Tons)	Deflection in (mm)	Flexural strength (N/mm ²)	Load in (Tons)	Deflection in (mm)	Flexural strength (N/mm ²)	Load in (Tons)	Deflection in (mm)	Flexural strength (N/mm ²)
0	0	0	0	0	0	0	0	0
2	1.1	12.500	1.7	1.2	10.625	1.95	1.2	12.188
2.2	1.6	13.750	2.4	1.7	15.000	2.3	1.4	14.375
3.2	2.0	20.000	2.9	2.1	18.125	2.9	1.7	18.125
3.9	2.5	24.375	3.6	2.8	22.500	3.5	2.4	21.875
4.6	2.7	28.750	4.4	2.9	27.500	4.4	3.1	27.500
3.6	3.4	22.500	3.7	3.2	23.125	4.1	3.3	25.625
2.7	3.7	16.875	2.9	3.5	18.125	3.6	3.5	22.500
2	4.1	12.500	2.3	3.9	14.375	2.7	3.8	16.875
2.1	5.0	13.125	2	4.3	12.500	2.2	4.1	13.750

Table 13 Seven days flexural strength results for SCC3 specimens

SCC3			SCC3.2			SCC3.3		
Load in (Tons)	Deflection in (mm)	Flexural strength (N/mm ²)	Load in (Tons)	Deflection in (mm)	Flexural strength (N/mm ²)	Load in (Tons)	Deflection in (mm)	Flexural strength (N/mm ²)
0	0	0	0	0	0	0	0	0
2	1.1	12.500	2.4	1.3	15.000	1.7	1.4	10.625
2.2	1.6	13.750	2.9	1.9	18.125	2.2	1.7	13.750
3.2	2.0	20.000	3.4	2.7	21.250	2.9	2.1	18.125
3.9	2.5	24.375	4.2	3.6	26.250	3.4	2.7	21.250
3.7	3.3	23.130	4.7	3.9	29.375	4.8	3.6	30.000
3.4	3.4	21.250	5.1	4.3	31.875	4.9	3.6	30.625
4.1	4.3	25.625	4.8	4.4	30.000	5.2	4.1	32.500
5.0	4.7	31.250	3.7	3.7	23.130	4.7	3.9	29.375
4.6	4.2	28.750	3.1	2.8	19.375	3.7	3.4	23.130

Table 14 Maximum 7 days flexural strength results—comparison

CC1.2			SCC1.2			SCC2.3			SCC3.3		
Load in (Tons)	Deflection in (mm)	Flexural strength (N/mm ²)	Deflection in (mm)	Flexural strength (N/mm ²)	Flexural strength (N/mm ²)	Load in (Tons)	Deflection in (mm)	Flexural strength (N/mm ²)	Load in (Tons)	Deflection in (mm)	Flexural strength (N/mm ²)
0	0	0	0	0	0	0	0	0	0	0	0
1.0	0.30	6.250	1.3	0.1	8.125	1.95	1.2	12.188	1.7	1.4	10.625
2.4	0.36	15.000	2.4	1.2	15.000	2.3	1.4	14.375	2.2	1.7	13.750
3.7	0.36	23.130	2.7	1.5	16.875	2.9	1.7	18.125	2.9	2.1	18.125
4.4	0.37	27.500	3.4	1.5	21.250	3.5	2.4	21.875	3.4	2.7	21.250
5.9	1.52	36.875	4.9	1.9	30.625	4.4	3.1	27.500	4.8	3.6	30.000
7.6	2.96	47.500	6.2	2.8	38.750	4.1	3.3	25.625	4.9	3.6	30.625
6.8	2.39	42.500	5.4	2.0	33.750	3.6	3.5	22.500	5.2	4.1	32.500
5.3	2.73	33.125	4.6	1.8	28.750	2.7	3.8	16.875	4.7	3.9	29.375
4.8	2.97	30.000	3.3	2.5	20.625	2.2	4.1	13.750	3.7	3.4	23.130

Table 15 Twenty eight days flexural strength results for control specimens

CC1			CC1.2			CC1.3		
Load in (Tons)	Deflection in (mm)	Flexural strength (N/mm ²)	Load in (Tons)	Deflection in (mm)	Flexural strength (N/mm ²)	Load in (Tons)	Deflection in (mm)	Flexural strength (N/mm ²)
0	0	0	0	0	0	0	0	0
2.9	0.3	18.125	2.7	0.3	22.500	3.2	0.4	20.000
4.1	0.3	25.625	3.9	0.4	24.375	4.4	0.5	27.500
5.8	0.3	36.250	4.7	0.4	29.375	6.1	0.5	38.125
6.7	0.3	41.875	5.6	0.9	35.000	8.0	1.7	50.000
7.9	1.5	49.375	6.5	1.4	40.625	9.4	3.2	58.750
9.7	2.9	60.625	7.8	1.5	48.750	8.6	2.7	53.750
6.4	2.3	40.000	8.9	2.7	55.625	7.6	1.5	47.500
4.9	2.9	30.625	9.1	3.1	56.875	6.3	1.3	39.375
4.0	3.1	25.000	7.6	2.7	47.500	4.2	2.9	26.250

Table 16 Twenty eight days flexural strength results for SCC1 specimens

SCC1			SCC1.2			SCC1.3		
Load in (Tons)	Deflection in (mm)	Flexural strength (N/mm ²)	Load in (Tons)	Deflection in (mm)	Flexural strength (N/mm ²)	Load in (Tons)	Deflection in (mm)	Flexural strength (N/mm ²)
0	0	0	0	0	0	0	0	0
2.4	0.1	15.000	2.2	0.1	13.750	2.0	0.2	12.500
3.4	1.1	21.250	2.9	1.3	18.125	2.9	1.3	18.125
4.8	1.6	30.000	4.7	1.8	29.375	3.8	1.5	23.750
5.3	1.5	33.125	5.6	1.8	35.000	4.9	1.9	30.625
6.8	1.3	42.500	7.1	2.3	44.375	6.4	2.5	40.000
8.1	2.7	50.625	8.3	2.9	51.875	8.1	2.8	50.625
5.1	2.0	31.875	6.1	1.9	38.125	9.3	3.7	58.125
4.3	1.9	26.875	3.9	1.6	24.375	7.2	2.9	45.000
3.8	2.2	23.750	2.7	2.4	22.500	5.1	2.6	31.875

Table 17 Twenty eight days flexural strength results for SCC2specimens

SCC2			SCC2.2			SCC2.3		
Load in (Tons)	Deflection in (mm)	Flexural strength (N/mm ²)	Load in (Tons)	Deflection in (mm)	Flexural strength (N/mm ²)	Load in (Tons)	Deflection in (mm)	Flexural strength (N/mm ²)
0	0	0	0	0	0	0	0	0
2.1	1.1	13.125	2.0	1.0	12.500	2.3	1.0	14.375
3.3	1.6	20.625	2.9	1.3	18.125	3.4	1.7	21.250
4.2	2.0	26.250	3.7	1.9	23.130	4.6	2.2	28.750
5.1	2.5	31.875	4.8	2.7	30.000	5.4	3.0	33.750
6.4	2.7	40.000	6.1	2.7	38.125	6.7	3.3	41.875
7.5	3.4	46.875	7.8	3.6	48.750	7.8	4.1	48.750
5.2	3.7	32.500	6.2	3.5	38.750	5.2	3.4	32.500
4.0	4.1	25.000	5.1	4.2	31.875	4.3	3.9	26.875
3.8	5.0	23.750	3.6	4.9	22.500	2.9	4.3	18.125

Table 18 Twenty eight days flexural strength results for SCC3specimens

SCC3			SCC3.2			SCC3.3		
Load in (Tons)	Deflection in (mm)	Flexural strength (N/mm ²)	Load in (Tons)	Deflection in (mm)	Flexural strength (N/mm ²)	Load in (Tons)	Deflection in (mm)	Flexural strength (N/mm ²)
0	0	0	0	0	0	0	0	0
2.0	1.1	12.500	2.6	1.0	16.250	2.0	1.2	12.500
3.1	1.6	19.375	3.9	1.4	24.375	2.9	1.6	18.125
3.9	2.0	24.375	4.8	1.9	30.000	3.4	2.0	21.250
4.6	2.5	28.750	5.9	2.7	36.875	4.7	2.7	29.375
5.8	2.7	36.250	6.8	3.3	42.500	6.0	3.1	37.500
6.4	3.4	40.000	7.5	3.9	46.875	7.2	3.9	45.000
5.4	3.7	33.750	5.6	3.4	35.000	6.3	3.9	39.375
4.1	4.1	25.625	3.9	4.2	24.375	5.2	4.0	32.500
3.8	5.0	23.750	2.8	4.9	17.500	4.4	4.7	27.500

Table 19 Maximum 28 days flexural strength results—comparison

CC1.2			SCC1.3			SCC2.2			SCC3.3		
Load in (Tons)	Deflection in (mm)	Flexural strength (N/mm ²)	Deflection in (mm)	Flexural strength (N/mm ²)	Flexural strength (N/mm ²)	Load in (Tons)	Deflection in (mm)	Flexural strength (N/mm ²)	Load in (Tons)	Deflection in (mm)	Flexural strength (N/mm ²)
0	0	0	0	0	0	0	0	0	0	0	0
2.7	0.3	22.500	2.0	0.2	12.500	2.0	1.0	12.500	2.0	1.2	12.500
3.9	0.4	24.375	2.9	1.3	18.125	2.9	1.3	18.125	2.9	1.6	18.125
4.7	0.4	29.375	3.8	1.5	23.750	3.7	1.9	23.130	3.4	2.0	21.250
5.6	0.9	35.000	4.9	1.9	30.625	4.8	2.7	30.000	4.7	2.7	29.375
6.5	1.4	40.625	6.4	2.5	40.000	6.1	2.7	38.125	6.0	3.1	37.500
7.8	1.5	48.750	8.1	2.8	50.625	7.8	3.6	48.750	7.2	3.9	45.000
8.9	2.7	55.625	9.3	3.7	58.125	6.2	3.5	38.750	6.3	3.9	39.375
9.1	3.1	56.875	7.2	2.9	45.000	5.1	4.2	31.875	5.2	4.0	32.500
7.6	2.7	47.500	5.1	2.6	31.875	3.6	4.9	22.500	4.4	4.7	27.500

Fig. 1 Testing of beam specimen

obtained, exhibited a different manner of tensile strength (SCC-1 = 0.61 N/mm²) which is less than that of SCC-2 (0.99 N/mm²). It was perceived that proportion of coarse aggregate in the combinations influenced the strength properties. In the beginning, all the specimens showed a gradual and almost uniform deflection in terms of loading pattern. The maximum flexural strength at the age of 7 days

Fig. 2 Load vs deflection—control specimens comparison

(Table 14) was tabulated according to the ultimate loading values attained by the specimens from their respective combinations. The incorporation of steel reinforcement in the specimens was that to analyze the compatibility of SCC for structural applications. The failure crack appeared seemed to be shear pattern by its location. The test results revealed that among the SCC combinations, SCC1.2

Fig. 3 Load vs deflection—SCC1 specimens comparison

Fig. 4 Load vs deflection—SCC2 specimens' comparison

Fig. 5 Load vs deflection—SCC3 specimens comparison

Fig. 6 Bending stress vs bending strain—specimens comparison @ 7 days

specimen had showed a progressive result compared to that of control specimen, such that the ultimate load achieved for CC1.2 was 7.6 Tons to that of 6.2 Tons of SCC1.2 specimen. The flexural strength increment of CC1.2 was of 125% increase to that of SCC1.2 as a whole comparatively to the rest of other combinations. At the age of 28 days, the flexural strength results indicated a similar behavior to CC1.2 and SCC1.3 rather than SCC1.2. Moreover the

Fig. 7 Load vs deflection—Control specimens comparison

Fig. 8 Load vs deflection—SCC1 specimens' comparison

Fig. 9 Load vs deflection—SCC2 specimens comparison

Fig. 10 Load vs deflection—SCC3 specimens comparison

Fig. 11 Bending stress vs bending strain—specimens comparison @ 28 days

flexural strength of SCC1.3 specimen achieved a value of 58 N/mm^2 (9.3 T) to that of 57.00 N/mm^2 (9.1T) for CC1.2 specimen, respectively. The ductility characteristics of control concrete were seemed to be better than that of SCC due to the addition of lime in SCC combinations which adversely affect the bonding strength. It was perceived that the performance of self-compacting concrete showed a positive effect in terms of load carrying in the long run. Hence forth the test results revealed that the SCC concrete prepared with non-rational method by using large size coarse aggregates such as 20 mm well graded and with only mineral admixtures proved efficient and effective for structural applications.

7 Conclusion

This research work focused on the utilization of SCC that was prepared, without super-plasticizer usually played a vital ingredient in the preparation of SCC universally. The mechanical properties of SCC combinations were modified by the various proportions of fly ash which basically holds good bonding property. The flexural strength results showed that the SCC combinations which were prepared by the above methodology was fool proof to be used in structural applications, there by the cost of preparation of SCC and consequences that developed due to the incorporation of super-plasticizer could also be minimized.

Compliance with ethical standards

Conflict of statement This is hereby stated that the research paper to be submitted is a unique investigation and purely of my own thesis work.

References

- Venkataram Pai BH, Nandy M, Krishnamoorthy A, Sarkar PK (2014) Experimental study on self compacting concrete containing industrial by-products. *Eur Sci J* 10, no. 12 ISSN 1857-7881 (Print) e—ISSN 1857-7431
- Mahure SH (2014) Effect of Fly Ash on fresh and hardened properties of self compacting concrete, ISSN: 2277-9655. *Impact Factor* 1:852
- Tkaczewska E (2014) Effect of the super plasticizer type on the properties of the fly ash blended cement. *Constr Build Mater* 70:388–393
- Khairallah F (2013) Mechanical behavior of confined self-compacting reinforced concrete circular columns under concentric axial loading. *Ain Shams Eng J* 4:641–649. doi:10.1016/j.asej.2013.01.009
- Yousaf M, Siddiqi ZA, Sharif B, Khan AH (2013) Performance of 3rd generation locally available chemical admixtures in the production of SCC. *Pak J Eng Appl Sci* 12:9–20
- American Concrete Institute (2005) ACI committee 318: building code requirements for structural concrete. American Concrete Institute, Farmington Hills
- EFNARC specifications and guide lines for self-compacting concrete ISBN 0953973344 “EFNARC” pp 1–32 (2002)
- Rilem TC (2002) 162-TDF. Test and design methods for steel fibre reinforced concrete, final recommendations. *Mater Struct* 35 (9):579–582
- ASTM C 1018. Standard test methods for flexural toughness and first crack strength of fiber reinforced concrete (using beam with third point loading). *ASTM* 2002(4):637–44
- Kamal MM, Safan MA, Etman ZA, Kasem BM (2013) Mechanical properties of self-compacted fiber concrete mixes. *HBRC J* 10(1):25–34
- M. Paja, k^a, T. Ponikiewski^b “Flexural behavior of self-compacting concrete reinforced with different types of steel fibers” *Construction and Building Materials* 27, pp 297–408 (2013) <http://dx.doi.org/10.1016/j.conbuildmat.2013.05.072>
- Barros JAO, Antunes JAB (2003) Experimental characterization of the flexural behaviour of steel fibre reinforced concrete according to RILEM TC 162-TDF recommendations. In: Schutgen B, Vandewalle L (eds) *Proceedings of the RILEM TC 162-TDF workshop*, pp 77–89
- EN 14651:2005 + A1:2007(E). Test method for metallic fibre concrete—measuring the flexural tensile strength [limit of proportionality (LOP), residual] CEN European Committee-439 for Standardization 440
- Swernalatha S, Vidhya K (2013) Utilization of fly ash and pond ash in self compacting concrete. *Int J Res Dev* 2(5):1672–1680
- Suryadi A, Qomariah, Sarosa RM (2012) Investigation of the chemical admixture influence on the performance of self compacting concrete. Part-I *Nat Appl Sci* 3(3):11–16
- Mithra M, Ramanathan P, Muthupriya P, Venkatasubramani R (2012) Flexural behavior of reinforced self compacting concrete containing GGBFS” ISSN: 2277-3754. *Int J Eng Innov Technol* 1 (4):124–129
- Bal PK (2012) Properties of self compacting concrete using recycled coarse aggregate. *Procedia Eng* 51:159–164
- Gaywala NR, Raijiwala DB (2011) Self- compacting concrete: a concrete of next decade. *Composites* 120–158
- Upadhyay H, Shah P, George E (2011) Testing and mix design method of self-compacting concrete. In: *National conference on recent trends in engineering and technology*. pp 1–4
- Gencil O, Ozel C, Brostow W, Martı́nez-Barrera G (2011) Mechanical properties of self-compacting concrete reinforced with polypropylene fibres. *Mater Res* 15:216–225. doi:10.1179/143307511X13018917925900
- Indian Standard PLAIN AND REINFORCED CONCRETE CODE OF PRACTICE (Fourth Revision) “IS 456:2000” pp 1–100 BIS 2000
- Indian Standard SPECIFICATION FOR COARSE AND FINE AGGREGATES FROM NATURAL SOURCES FOR CONCRETE (second revision) “IS 383:1970”(Reaffirmed 1997) Copyright 1971
- Indian Standard ORDINARY PORTLAND CEMENT, 53 GRADE—SPECIFICATIONS “IS 12269:2013” pp 1–10, BIS 2013
- Indian Standard METHODS OF PHYSICAL TESTS FOR HYDRAULIC CEMENT (PART 1–15) “IS 4031: 1991” pp 1–8 BIS 1991
- Indian Standard HIGH DEFORMED STEEL BARS AND WIRES FOR CONCRETE REINFORCEMENT (fourth revision) “IS 1786:2008” pp 1–22 BIS 2008
- Indian Standard CONCRETE MIX PROPORTIONING—Guide lines (First Revision) “IS 10262:2009 pp 1–18 @ BIS 2009