Assessment of Properties of Green SCC with and without Novel Additive

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Abstract

Concrete is the most widely used construction material in civil engineering industry because of its proved structural strength and stability when made properly. The concrete industry is constantly trying to evolve to make concrete more sustainable replacing a part of full cement with additives and Supplementary Cementitious Materials (SCMs). Each tonne of cement production releases one tonne of CO_2 into the atmosphere and hence to greenhouse effect and global warming. A cost effective, alternative and innovative materials called novel additive is taken up for present study to reduce the cement consumption per m^3 of concrete/SCC without reduction in strength of required grade. In this project an effort is made replacing cement content of SCC partially with Fly Ash, Ground Granulated Blast Furnace Slag (GGBS) in combination of novel additive. The study focused at studying the properties of fresh SCC and hardened SCC. The design mix proportion of 1: 2.63: 1.86 with a W/B ratio of 0.36 is taken up and 4 different mixes with different combinations of varied percentage replacement materials with 2% by weight of cement of novel additive. The properties of green SCC showed that fresh properties get enhanced through usage of mineral admixtures including a novel additive and hence, the addition of mineral admixture improve the flowability or rheology of SCC mixes. The strength of SCC achieved is ranging from 32- 46 N/mm^2 for a cementitious content of 400 kg/m^3 , highest being with lowest cement content with novel additive.

Keywords: Rheology of SCC, Mineral Admixtures, Novel Additive, Sustainability

1. INTRODUCTION

Cement production is the third largest global source of man-made carbon dioxide emissions. Therefore, to make concrete more sustainable, one may choose one or more of the following approaches like Replacing cement in concrete with higher amounts of supplementary cementing materials (SCMs) than typical, replacing cement in concrete with combinations of SCMs that lead to synergic reactions boosting strength, producing leaner concrete with less cement per cubic meter using plasticizers and Making concrete with local aggregate susceptible to alkali silt. There are many other ways in which the cement content can be reduced. The present study is an effort to reduce the cement content of self-compacting concrete and examines the changes that take place in the rheology of the concrete.

2. LITERATURE SURVEY

The literature review clearly indicates that the Self-consolidating concrete has wider research scope and advantages regarding performance, strength, quality and durability, etc. Proper selection of materials, mix proportions based on various mix design methods, type of mineral and chemical admixtures, test methods and workability specifications are key concerns in the optimization and control testing of self-consolidating concrete. In most of the test data evaluated that the design methods developed to predict the characteristics of SCC is based on different mix proportions, materials and on experimental work. Various study show that the use of additive has a direct effect on its flowability and workability and various additives can be use depending upon their chemical and physical compositions and properties which can help in improving rheological properties of a self-consolidating concrete.

3. AIM AND SCOPE

To assess the properties of green Self consolidating concrete with and without novel additive and to check how it varies the rheological properties.

4. METHODOLOGY

The following methodology is adopted for the project work.

- Collection of samples of Materials – Cement, Cementitious materials such as Fly ash, GGBS and novel additives, Fine Aggregates and Coarse aggregates, water and Admixtures
- Physical and Chemical characterization of materials as per relevant codes of practice.
- Tabulation of properties of materials and designing mix proportion of SCC
- Conduction of trail mixes and fixing the design mix
- Assessment of properties of fresh SCC and Hardened SCC as per the scope.
- Tabulation of results of various tests, analysis of results and discussions on results
- Conclusions based on test results.
- Material Estimation for Mix Designation.

5. MATERIALS

The details of collection of samples of materials, physical and chemical characterization as per standard codal procedure, comparison with specifications, mix design procedure and design mix are provided in this part of the paper.

5.1 Cement

OPC 53 grade cement of having specific gravity of 3.15 conforming to IS 12269-1987 is used as the binding material. It is tested as per IS 1199 and IS 4031, is used as binder material in concrete.

Table 1 Physical Properties of Cement

Sl. No.	Material Properties tested as per	Cement (IS 12269-2013)	
		Test Results	Requirement
1	Fineness – residue on 90-micron sieve, percent (max)	7.446%	10% (max)
2	Soundness - by Le-Chattelier's apparatus	1.00 mm	10 mm (max)
3	Initial Setting Time	80.00 min	30 min (min)
4	Final Setting Time	485.00 min	600 min (max)
5	Compressive strength	53.66 N/mm^2	53 N/mm^2 (min)
6	Standard Consistency	31.5%	-
7	Specific Gravity	3.15	-

5.2 Fly Ash

Fly ash having specific gravity of 3.15 conforming to IS:3812 : is used as the binding material. It is tested as per IS:3812 : 2003, is used as binder material in concrete.

Table 2 Physical Properties of Fly Ash

Sl. No.	Test Conducted	Results	Requirements as per IS:3812 : 2003	
			I	II
1.	Specific Gravity	2.16	---	---
2.	Fineness – Specific surface in m^2/kg by Blaine's Air-Permeability method, (min).	410.0	320	200
3.	Lime reactivity – Average Compressive Strength in N/mm^2, (min).	4.6	4.5	--
4.	Soundness by Autoclave Test Expansion of Specimens, percent, (max)	0.025	0.8	0.8
5.	Residue on 45 micron sieve, percent, (max)	18.4	34	50

5.2 Aggregates

Nominal size of 20mm natural coarse aggregate and recycled coarse aggregate passing through 20mm and retained on12.5mm is used. Recycled fine aggregate that has passed through a 4.75mm sieve and has been retained on 1.5mm is used and assessed according to the relevant norms of practice.

Table 3 Physical Properties of NCA, M-Sand and RFA

SI. No.	Description	Natural Aggregate
A.		
1.	Specific Gravity	2.56
2.	Water Absorption / Moisture Content (%)	0.70
3.	Bulk Density (kg/m^3)	1550
4.	Percentage void in aggregate (%)	43.60
B.		
1.	Specific Gravity	2.61
2.	Water Absorption / Moisture Content (%)	2.04
3.	Bulk Density (kg/m^3)	1753
4.	Percentage void in aggregate (%)	39.31

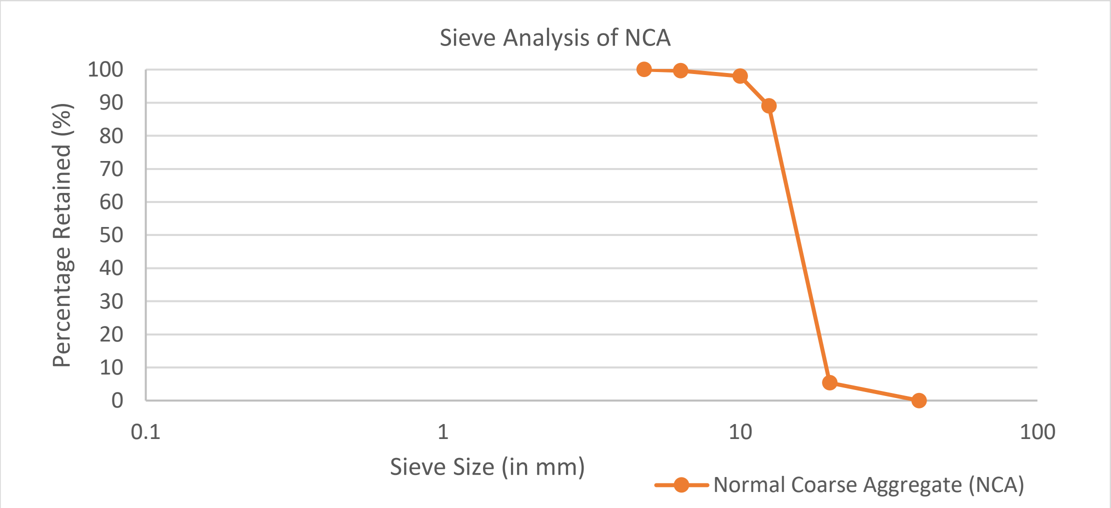

Fig 1 Gradation Curve - NCA

5.3 Admixtures

Melamine based superplasticizer with a market name B-8233 is used about 8-12mm of the cementitious material to reduce the water cement ratio as well as obtain high strength for higher grade of concrete. Similarly, 8% - 10% of GGBS and 30% Fly Ash and 5% of Novel additive are largely replaced with cement, M sand & natural coarse aggregate to improve concrete durability and strength.

5.4 GGBS and Novel Additive

GGBS and novel additive are brought from Ready mix Concrete plant, Bangalore.

The specific gravity of off-white colored GGBS is found to be 2.9 with a fineness of 350 kg/m^3 (BS 6699:1992). The loose bulk density is found to be 1200 kg/m^3. GGBS having Fineness by air permeability of 389 kg/m^3 is finer than cement but coarser than fly ash, specific gravity of 2.89, residue of 45% of 7.10% etc. The loss of ignition is found to be 0.32% and glass content of 90%.

Table 4 Chemical & Physical Properties of GGBS

Sl No	Characteristics	Test Results	Specifications As Per Is:16714:2018
A	**Chemical Requirements:**		
1	Manganese Oxide (MnO) %	0.32	5.5 Max
2	Magnesium Oxide (MgO) %	7.88	17.0 Max
3	Sulphide Sulphur (S) %	0.52	2.0 Max
4	Sulphate (as SO3) %	0.10	3.0 Max
5	Insoluble residue (I R) %	2.32	3.0 Max
6	Chloride Content (CI) %	0.004	0.1 Max
7	Glass Content %	96.8	85 Min
8	Gain on Ignition %	0.16	Not Specified
9	$\frac{CaO+MgO+1/3\ Al_2O_3}{SiO_2+2/3\ Al_2O_3}$	1.09	1.0 % (Min)
10	$\frac{CaO+MgO+\ Al_2O_3}{SiO_2}$	1.78	1.0 % (Min)
B	**Physical Requirements**		
1	Specific Gravity	2.84	Not Specified
2	Specific Surface Area (M²/Kg)	378	320 (Min)
3	Slag Activity		
	a) 7 Days	72.0	60 % (Min)
	b) 28 Days	91.0	75 % (Min)

6. MIX DESIGN PROCEDURE BY ABSOLUTE VOLUME METHOD

This particular mix is designed only with cement as primary cementitious material and later cement content is replaced with 30% fly ash and GGBS in from 50 kg to 200 kg/m^3.

i. Cementitious Content =400 kg/m^3
ii. Quantity of water 144 lit/m of SCC
iii. Coarse aggregate size=12.5 mm
iv. Water binder ratio 0.327

Therefore, the Mix proportion of mix for Cementitious content of 400 kg/m^3

Weigh Batching Mix Proportion – 1: 1.86: 2.63

Table 5 Material Estimation for Mix Designation

Mix No.	Mix Designation	Explanation
1	100CM	Mix with 100% cement
2	70CM	Mix with 70% cement, 30% Fly Ash
3	92C8G	Mix with 92% cement, 8% GGBS
4	90C10G	Mix with 90% cement, 10% GGBS
5	62C8G	Mix with 62% cement, 30% Fly Ash, 8% GGBS
6	2A60C8G	Mix with 60% cement, 30% Fly Ash, 8% GGBS, 2% Novel Additive
7	2A58C10G	Mix with 58% cement, 30% Fly Ash, 10% GGBS, 2% Novel Additive

Table 6 Material Estimation for Mix Designation

SI no	Mix designation	Cement %	Fly-ash %	GGBS %	Novel Additive %	Coarse Aggregate	M-Sand	RCA	RFA	W/C Ratio
1	100CM	100	-	-	-	100	100			0.36
2	70CM	70	30	-	-	100	100			0.36
3	92C8G	92	-	8	-	100	100			0.36
4	90C10G	90	-	10	-	100	100			0.36
5	62C8G	62	30	8	-	100	100			0.36
6	2A60C8G	60	30	8	2	100	100			0.36
7	2A58C10G	58	30	10	2			100	100	0.36

Table 7 Weigh Batching - Mix Proportion

Sl. No.	Mix Designation kg/m^3	Cement kg/m^3	Fly-Ash kg/m^3	GGBS kg/m^3	Novel Additive kg/m^3	Coarse Aggregate kg/m^3	M-Sand kg/m^3	RCA kg/m^3	RFA kg/m^3	W/C Ratio kg/m^3
1	100CM	400				743.90	1050.02			
2	70CM	280	120	32		743.90	1050.02			
3	92C8G	320	-	80	-	743.90	1050.02			
4	90C10G	360	-	100	-	743.90	1050.02			
5	62C8G	280	120	32		743.90	1050.02			
7	2A60C8G	280	120	24	8	743.90	1050.02			
8	2A58C10G	280	120	24	8			743.90	1050.02	

7. PROPERTIES OF GREEN CONCRETE

Green SCC has a high flowability and tends to have a high resistance to segregation and bleeding due to its high viscosity and self- compacting nature.

7.1 Test on freshly prepared concrete

After mixing of material the fresh concrete is subjected to slump test and V funnel test to know the flowability and workability of the self-consolidating concrete.

7.2 Casting

The specimen cast for different mix contains 21 cubes of 150mm* 150mm*150mm Compressive strength of concrete.

7.3 Curing of specimens

The specimen is air cured for 24 hours and demolded. The specimen after demolding is kept for curing for 28 days for performing Compressive Strength test. Flexural strength test and split tensile strength test are performed after 28 days of curing of specimen.

8. RESULTS AND DISCUSSION

8.1 Workability of concrete

Workability refers to a concrete's ease of placement and compacting without any segregation. The slump cone test is performed in accordance with the 2004 revision of IS: 1199-1959. Table 8 includes the procedure for concrete sampling and analysis as well as the results for the mixes' slump test & V-funnel time respectively.

Table 7 Workability of Concrete

Sl. No.	Mix Designation	Methods	Property	Unit mm	min	max	result
1	100CM	Slump	filling ability	sec	0	6	4.48
		V-Funnel	filling ability	sec	8	12	9.55
2	70CM	Slump	filling ability	sec	0	6	2.01
		V-Funnel	filling ability	sec	8	12	9.53
3	92C8G	Slump	filling ability	sec	0	6	4.02
		V-Funnel	filling ability	sec	8	12	8.43
4	90C10G	Slump	filling ability	sec	0	6	3.49
		V-Funnel	filling ability	sec	8	12	8.00
5	62C8G	Slump	filling ability	sec	0	6	3.28
		V-Funnel	filling ability	sec	8	12	11.05
6	2A60C8G	Slump	filling ability	sec	0	6	3.39
		V-Funnel	filling ability	sec	8	12	10.45
7	2A58C10G	Slump	filling ability	sec	0	6	2.25
		V-Funnel	filling ability	sec	8	12	9.29

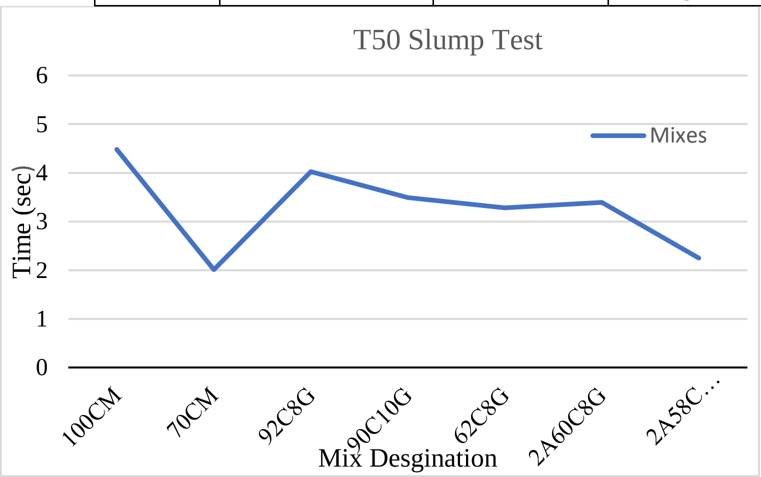

Fig. 2 Workability of Concrete

Results and Discussions

The slump test conducted to assess the flowability of mixes showed that the T50 slump measured in seconds ranged from 2sec. to 5 sec., highest being for control mix. Control mix has only cement as powder content. Other mixes have either fly ash, GGBS or novel additive as a partial powder content. Addition of mineral admixtures whose particle size is lesser than those of cement particles might have contributed to enhanced flow of mixes.

The mix with 30% fly ash showed the least value of T50 sec. This may be because of spherical shape of the particle of fly ash. Also mix with novel additive showed better flowability.

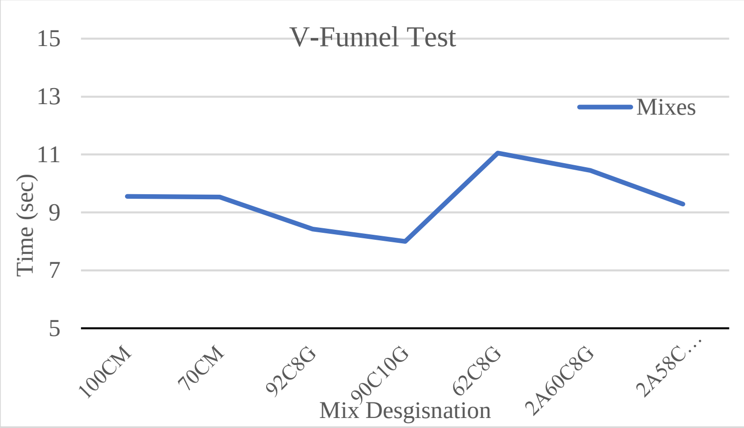

Fig. 3 Workability of Concrete

The rheology assessed through V Funnel test showed that the mixes of SCC have better flowability, fillability and segregation resistance. The mixes were cohesive with not much resistance to the follow allowing a V funnel time of 8 sec. to 11 sec. against the requirement of 6 – 14 sec. The variation in time of flow through V funnel is not much. This indicates that the good properties of green SCC may be achieved through usage of mineral admixtures including novel additive and hence, the addition of mineral admixture improve the flowability or rheology of SCC mixes.

8.2 Compressive Strength of Mixes

The compressive strength of different design mixes of SCC with cementitious content 400 kg/m^3 is determined as per the procedure of IS 516-1959 (reaff in 1999). The cube specimens of size 150*150*150 mm is used to determine compressive strength. Table 9 presents the results of compressive strength. The variation in strength for different curing regime i.e., 28 day strength.

Compressive Strength of SCC Table 9

Sl. No.	Mix Designation	Compressive Strength (f_{ck}) at Curing of 28days N/mm^2
1	100CM	46.67
2	70CM	29.68
3	92C8G	44.45
4	90C10G	45.78
5	62C8G	30.51
6	2A60C8G	31.27
7	2A58C10G	35.83

Results and Discussions

The 28-day compressive strength of mixes with 400kg/m^3 with only cement as binder showed 46.67N/mm^2. However, all other mixes showed lesser compressive strength values indicating that the fly ash or GGBS may not be of good quality. The results obtained do not match with the data as per the literature. Hence, selection of good quality material makes the mixes satisfy strength and other quality requirements. The mix with novel additive showed a strength of 31.27 and 35.83 N/mm^2.

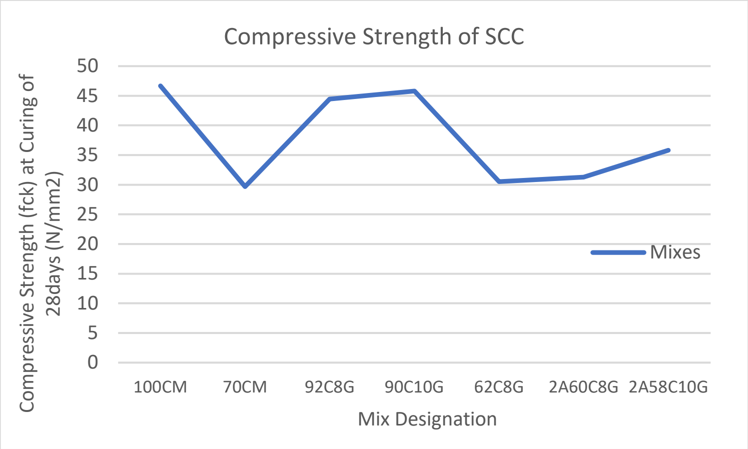

Fig. 4 Compressive Strength of SCC

CONCLUSION

From the discussions on test results of fresh SCC mixes with and without novel additive the following rational conclusions may be drawn.

1. The properties of green SCC as per the specifications may be achieved through usage of mineral admixtures including novel additive and hence, the addition of mineral admixture improve the flowability or rheology of SCC mixes.
2. The improved flowability may be because of spherical shape of the particle of fly ash. Also mix with novel additive showed better flowability.
3. The results of compressive strength obtained do not match with the data as per the literature. Hence, selection of good quality material makes the mixes satisfy strength and other quality requirements. Also, more trails may be needed to explore the effect of novel additive to SCC.

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