

Determination of Fresh and Hardened State Properties of Self-Compacting Concrete Using GGBFS and RHA

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ABSTRACT: Concrete has made an innumerable variant changes in the field of construction. Over the last decade, one of the most outstanding advancements in concrete technology is Self-Compacting Concrete (SCC). SCC is a highly flowable type of concrete that spreads into the form without the need for mechanical vibration which is placed by means of its own weight. The importance of self-compacting concrete is that maintains all concrete's durability and characteristics, meeting expected performance requirements.

In certain instances, the addition of superplasticizers and viscosity modifier are added to the mix, reducing bleeding and segregation. Various studies had been carried out on SCC with different combinations of admixtures. However, no significant work has been done on the behavior of SCC using GGBFS and RHA as mineral admixtures.

This research is aimed to study the fresh and hardened state properties of SCC using GGBFS and RHA in three different grades of concrete mixes viz, M20, M40 and M60. Alongside, studies were also done on stress-strain behavior, flexural behavior and durability aspects were also investigated.

The study shown a good compatibility when GGBS and RHA are used in combination with chemical admixtures such as SP and VMA. Fresh and hardened state properties were found satisfactory at 30% GGBS in SCC.

KEY WORDS: Self Compacting Concrete, GGBFS, RHA, Strength properties of SCC.

I. INTRODUCTION

Self Compacting Concrete (SCC) can also be termed as self-levelling concrete, super workable concrete and self consolidating concrete. It is a high performance concrete which distinguishes itself with self-consolidation properties maintaining a good amount of flowability. As the name suggests, SCC does not require any vibration to achieve full compaction and this offers many advantages over conventional concrete.

The composition of SCC mix includes substantial proportion of fine-grained inorganic materials and this gives possibilities for utilization of mineral admixtures. The mix requires specialized and well-controlled placing methods in order to avoid segregation and bleeding. SCC can also be used in under water concreting works.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

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Vol. 7, Issue 6, June 2018

Earlier studies indicate that fresh and hardened state properties of SCC can be attained by using silica fume and fly ash as admixtures. There are no significant researches done on SCC using GGBFS and RHA. Therefore, the present study is aimed to study the strength properties of SCC using GGBFS and RHA for different grades of concrete.

II. OBJECTIVES AND METHODOLOGY

The objectives of this study are:

- i) Development of three different grades (M20, M40 and M60) of concrete.
- ii) Investigating the fresh and hardened state properties using GGBFS and RHA at varying proportions for the three grades of concrete.
- iii) Studying on stress-strain behavior and durability aspects.

The project is divided into two phases. In phase 1, three different grades of SCC mixes with GGBFS are prepared and fresh and hardened state properties are determined. In phase 2, the effect of RHA on SCC made with GGBFS is investigated.

III. BACKGROUND LITERATURE

[1] reviewed the study on Self Compacting Concrete (SCC) which can be made using numerous Admixtures and Fibers. This research studied the effect of compaction in conventional concrete as it is not easy to ensure the concrete to be compact fully by avoiding voids. To avoid these kind of factors, a new concrete, Self compacting concrete has evolved. SCC have the ability to flow by its own compaction around the reinforcement. It is suggested that freshly mixed SCC must possess the filling ability, passing ability and resistance to segregation without exceeding its limits. [10] examined SCC made of steel fibers as reinforcement in plain self compacting concrete.

[5] developed an experimental procedure for the design of SCC mixes. The test results for acceptance characteristics of self-compacting concrete such as slump flow; J-ring, V-funnel and L-Box are presented. Further, compressive strength at the ages of 7, 28, and 90 days was also determined.

[3] has studied the adoption of recycled glass waste as a partial replacement of fine aggregate in SCC and examined the fresh and hardened properties. Various proportions of recycled glass were used to replace fine aggregate. The results shown the slump value has increased with the increase of recycled glass. On the other hand, the compressive strength, splitting tensile strength, flexural strength and static modulus of elasticity of recycled glass (SCC) mixtures were decreased with the increase in the recycled glass content.

[12] investigated the optimum dosage of polypropylene and steel fibers in SCC and their implications on various fibers on the fresh and hardened properties was studied. Mechanical properties like compressive strength, flexural strength and impact strength of fiber reinforced self-compacting concrete was determined. The results concluded that the optimum dosage of steel and polypropylene fiber was 0.75% and 1.0% of the cement content, respectively.

[14] studied the fresh and hardened properties of SCC made with Metakaolin. Totally, fifteen mixes including different mix contents (0–20% by weight of cement) with three water/binder (w/b) ratios of 0.32, 0.38 and 0.45 were designed.

IV. EXPERIMENTAL PROGRAMME

Materials Used

Ordinary Portland Cement of 53 grade having specific gravity 2.91 is used. Coarse aggregates of 10mm angular size which are obtained from local quarry were used and tested for specific gravity and bulk density.

International Journal of Innovative Research in Science, Engineering and Technology

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Vol. 7, Issue 6, June 2018

The mixing process was carried out in a power operated concrete mixer. Fine aggregate, Cement and Filler material (GGBFS) were put in the concrete mixer first and mixed in the dry state. Later, superplasticizer is mixed with water and added to the material in the mixer. It was allowed to mix thoroughly and finally coarse aggregate was added to it, mixed till a mixture of uniform colour and consistency were achieved. Locally available river sand is used as a fine aggregate. Ground Granulated Blast Furnace Slag (GGBFS) was obtained from Penna Cement company, Hyderabad with properties confirming to IS 12089-1987. Rice Husk Ash (RHA) was obtained from local manufacturer. Glenium233 is used a superplasticizer and Glenium Stream 2 is used as a Viscosity Modifying Admixture. Acids like Na₂SO₄, H₂SO₄ and HCL were used for durability studies. Water used for mixing and curing is fresh potable water.

Mix Details

A SCC mix of three different grades, namely M20, M40 and M60 are prepared. In this research, the initial mix proportion was determined by [11] EFNARC. Different trail mixes were attempted for different grades of concrete. Table 1 shows the trail mix details of SCC for M20 grade of concrete.

Table 1: Trail mix details of SCC for M20 grade of concrete

Cement (Kg/m ³)	Coarse aggregate (Kg/m ³)	Fine aggregate (Kg/m ³)	Water (Kg/m ³)	Superplasticizer dosage
400	780	844	180	0.8 % by weight of cement

V. TESTING METHODS: PHASE 1- DETERMINATION OF FRESH AND HARDENED STATE PROPERTIES

Workability Tests

The workability tests done for ordinary conventional concrete mixes are not adequate for SCC as they are not sensitive to find the properties of SCC mix. Hence workability tests like Slump flow test and T50 cm test, V funnel test, L box test are carried out to determine the properties such as filling ability, passing ability and segregation resistance of freshly mixed SCC.

Specimen Preparation

After testing SCC for fresh properties, the mix is then placed and filled in molds of size 100x100x100mm and allowed to flow and settle by its own weight and excess concrete was removed with trowel. The specimens are left in the molds undisturbed for about 48 hours at room temperature and the molds were curing for 28days.

Hardened state properties

After the specimens were cured, their surfaces were wiped off and tested as per 516-1959.

Compression Test

Compression test was carried out on CTM on cubes of size 100x100x100mm. The load was applied at a uniform rate of 140kg/cm² per minute. The maximum load at which cubes are failed were noted down. The test was repeated for three cubes for all the grades of mixes and the average of the values is adopted. Table 2, table 3 and table 4 shows the compressive strengths of M20, M40 and M60 grades of SCC with varying proportions of GGBFS.

Table 2: Compressive strengths of SCC of M20 grade

Mix number	% of GGBFS replacement	Compressive strength (MPa)		
		3 days	7 days	28 days
A-1	0	13.61	19.34	27.51
A-2	10	9.38	16.29	29.45
A-3	15	10.47	18.85	30.89
A-4	20	10.19	19.3	31.58
A-5	25	11.21	19.48	32.43
A-6	30	12.86	22.16	35.13

International Journal of Innovative Research in Science, Engineering and Technology

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Table 3: Compressive strengths of SCC of M40 grade

Mix number	% of GGBFS replacement	Compressive strength (MPa)		
		3 days	7 days	28 days
B-1	0	18.20	30.5	43.3
B-2	10	14.07	27.01	45.31
B-3	15	14.9	27.78	45.88
B-4	20	15.83	28.16	46.11
B-5	25	15.99	28.36	47.05
B-6	30	16.08	30.77	51.91

Table 4: Compressive strengths of SCC of M60 grade

Mix number	% of GGBFS replacement	Compressive strength (MPa)		
		3 days	7 days	28 days
C-1	0	19.9	39.1	59.9
C-2	10	17.3	36.6	60
C-3	15	17.9	37.89	61.9
C-4	20	18.38	38.1	63.8
C-5	25	18.88	39.9	65.2
C-6	30	18.4	38.32	63.41

Optimum replacement of GGBFS for M20, M40 and M60 grades of SCC mixes are found to be at 30%, 30% and 25%. Further replacement in GGBFS, has lowered the compressive strength values.

Split Tension Test

The test was carried out by placing a cylindrical specimen of diameter 150mm and 300mm long horizontally between the loading surfaces of a compression testing machine and load was applied until the failure of the specimen. In order to reduce the magnitude of high compressive stress near the points of application of the load, narrow packing strips of suitable material such as ply wood are placed between the specimen and the loading platens of the testing machine. Table 5 shows the tensile strength variation of the three different grades of SCC mix.

Table 5: Splitting tensile strength at the end of 28 days for M20, M40 and M60 grade SCC

Grade of concrete	Mix number	% of GGBFS replacement	Tensile strength (MPa)
M20	A-1	0	2.11
	A-4	20	2.67
	A-5	25	2.88
	A-6	30	3.51
M40	B-1	0	3.09
	B-4	20	3.91
	B-5	25	4.05
	B-6	30	4.67
M60	C-1	0	4.22
	C-4	20	4.92
	C-5	25	5.86
	C-6	30	5.26

Optimum replacement of GGBFS for maximum tensile strength is found to at 30% for all the three grades of SCC mix.

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Flexure Test

The flexural strength of concrete is determined by subjecting a plain concrete beam to flexure under transverse loads. The specimens of size 100x100x500mm are cast and used for testing under two-point loading to determine the flexural strength. The load was applied gradually at a rate of 180kg/min for 100mm specimens and the maximum load at which failure occurred is noted. Table 6 shows the flexural strength variation for different proportions of GGBFS for three grades of SCC mixes.

Table 6: Flexural strengths for different proportions of GGBFS for three grades of SCC mixes.

Grade of concrete	Mix number	% of GGBFS replacement	Flexural strength (MPa)
M20	A-1	0	2.58
	A-4	20	2.89
	A-5	25	3.04
	A-6	30	3.82
M40	B-1	0	3.77
	B-4	20	4.12
	B-5	25	4.55
	B-6	30	4.98
M60	C-1	0	4.72
	C-4	20	5.15
	C-5	25	5.98
	C-6	30	5.75

Optimum replacement of GGBFS at which maximum flexural strength was obtained at 30% for M20 and M40 grades of SCC and for M60 grade SCC, it was observed that maximum flexural strength obtained at 25% replacement.

VI. PHASE 2: MIXES MADE WITH GGBFS AND RHA

Introduction

In phase 2, the mix proportion was designed based on EFNARC method, using GGBFS as a filler material. Rice Husk Ash (RHA) was used as a replacement for GGBFS without making any disturbances to the fresh and hardened state properties of SCC of three different mixes (M20, M40 and M60). This investigation is aimed to find the cementitious efficiency of GGBFS and RHA at varying replacement level. Table 7 shows the combined mix proportion of GGBFS and RHA.

Table 7: Mixes with GGBFS and RHA

S.No	GRAGDE	Cement (kg)	CA (kg)	FA (kg)	RHA (kg)	GGBFS (kg)	WATER (kg)	SP (%)
1	M20	280	780	844	3.60*	116.4	180	1.08
2	M40	350	800	800	4.50*	145.5	190	1.14
3	M60	450	660	810	30*	150	190	1.4

*GGBFS is replaced by 3% by weight with RHA

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Table 8 shows the final mix proportion taken for determination of fresh and hardened state properties.

Table 8: Final mix proportions

S.No	Mix	Mix code	Cement (kg)	CA (kg)	FA (kg)	GGBFS (%)	RHA (%)	Water (KG)	SP (%)	VMA (%)
1	M20	M2S	400	780	844	0	-	180	0.80	0.08
2	M20-GGBFS	M2SG	280	780	844	30	-	180	0.62	0.06
3	M20-GGBFS-RHA	M2SGR	280	780	844	97	3	180	1.08	0.11
4	M40	M4S	500	800	800	0	-	190	1	0.10
5	M40-GGBFS	M4SG	350	800	800	30	-	190	0.82	0.08
6	M40-GGBFS-RHA	M4SGR	350	800	800	97	3	190	1.14	0.114
7	M60	M6S	600	660	810	0	-	190	1	0.10
8	M60GGBFS-RHA	M6SGR	450	660	810	25	5	190	1.4	0.14

Fresh State Properties of SCC

The fresh state properties like slump cone test, V-funnel test and L-box test were done on the above eight different grades of mixes. Table 9 shows the fresh state properties of SCC made with GGBFS and combination of GGBFS and RHA.

Table 9: Fresh state properties of SCC

S.No	Mix code	Slump cone test		V funnel test		L box test
		Horizontal slump (mm)	T50 (sec)	Time for complete discharge	T ₅ (sec)	H ₂ /H ₁
1	M2S	760	3.08	6.21	8.03	0.98
2	M2SG	760	3.89	7.02	8.68	0.98
3	M2SGR	750	4.2	7.2	8.6	0.98
4	M4S	720	3.24	6.54	8.37	0.96
5	M4SG	720	3.8	6.78	8.25	0.98
6	M4SGR	760	4	5.9	8.35	0.98
7	M6S	715	4.28	7.01	8.56	0.86
8	M6SGR	720	3.24	6.54	8.37	0.96

Hardened State Properties

The specimens were cast in 100x100x100mm cubes and a cylindrical specimens of size 100mm diameter and 200mm height and cured for 28days. The specimens then tested for evaluation of hardened state properties like compressive strength, split tensile strength and modulus of rupture. Table 10 shows the hardened state properties of various mixes.

Table 10: Hardened state properties

S.No	Mix code	Compressive strength (MPa)	Split tensile strength (N/mm ²)	Modulus of rupture (N/mm ²)
1	M2S	34.15	3.11	3.58
2	M2SG	36.89	3.15	3.82
3	M2SGR	41.2	3.83	4.2
4	M4S	48.6	4.12	4.77
5	M4SG	52.67	4.67	4.98
6	M4SGR	58.25	4.72	5.4
7	M6S	63.97	5.22	5.72
8	M6SGR	68.51	5.86	5.99

International Journal of Innovative Research in Science, Engineering and Technology

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VII. CONCLUSIONS

1. By using mineral admixtures like GGBFS and RHA and also with suitable dosage of SP and VMA, acceptable properties in fresh and hardened state can be attained.
2. Studies indicate that there is a good compatibility between mineral combinations and chemical admixture such as SP and VMA when used in SCC.
3. The addition of RHA to GGBFS mixes has shown enhanced performance in terms of strength and durability in all grades of SCC. This is due to presence of reactive silica in GGBFS and RHA which offers good compatibility.
4. Optimum replacement of GGBFS for M20, M40 and M60 grades of SCC mixes are found to be at 30%, 30% and 25%. Further replacement in GGBFS, has lowered the compressive strength values.
5. Optimum replacement of GGBFS for maximum tensile strength is found to be at 30% for all the three grades of SCC mix.
6. Optimum replacement of GGBFS at which maximum flexural strength was obtained at 30% for M20 and M40 grades of SCC and for M60 grade SCC, it was observed that maximum flexural strength obtained at 25% replacement.
7. Highest hardened state properties were obtained for combinations of GGBFS and RHA for all the three grades of SCC mix.

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