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Strength Parameters of Self Compacting Concrete With Partial Replacement of Cement by Rice Husk Ash and Natural Sand by Filtered Sand

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Abstract - This paper presents an experimental study on the strength parameters of SCC with Rice Husk Ash (RHA) and filtered sand (FS) as a partial replacement for cement and sand respectively in SCC of M70 grade, termed as RHA-FS SCC. The cement has been replaced by RHA in four different levels of 5%, 10%, 15% & 20%, and FS in four different levels of 25%, 50%, 75% & 100%. Strength parameters of Compressive strength, split tensile strength and flexural strengths of RHA-FS SCC are tested for 28 days & 56 days curing periods. Strength parameters of RHA-FS SCC are compared with Conventional SCC; it is found that SCC with Filtered Sand (FS) for the replacement of sand in proportion of 50:50 along with Rice Husk Ash (5%, 10%, 15% & 20%) had more strength than the other proportions of FS & RHA.

Keyword: Conventional Self compacting concrete(C-SCC), Filtered Sand (FS), High Range Water Reducing Agent (HRWR), Natural Sand (NS), Rice Husk Ash (RHA), Rice Husk Ash-Filtered Sand-Self Compacting Concrete(RHA-FS-SCC), Self Compacting Concrete (SCC), Viscosity Modifying Agent (VMA)

1. INTRODUCTION

ONE major challenge facing the civil engineering community is to execute projects in harmony with nature using the concept of sustainable development. This calls for use of high performance environment-friendly and economical construction materials. In the context of concrete, this is the most predominant building material. Concrete is a composite material which is made of filler and a binder. However, there is a limit to the fluid behaviour of normal fresh concrete. Thorough compaction, using vibration, is normally essential for achieving workability. Inadequate compaction of concrete results in large number of voids, affecting performance and long term durability of structures. Self-compacting concrete (SCC) provides a solution to these problems. Concrete that is capable of compaction under its own weight and can occupy all the spaces in the forms, which self-levels, does not segregate and does not entrap air is termed as self-compacting concrete (SCC).

The main components of concrete are cement, sand & coarse aggregate. The production of cement adds pollution to the environment is a well-known fact to civil engineers.

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River sand which is used as fine aggregate is becoming very scarce, sand mining is discouraged to save the rivers of our country. Because of these environmental and economic reasons it requires thinking about the use of industrial wastes as alternative materials in concrete production, which not only reduce the cost of production of concrete but also controls the pollution relatively.

Rice plant is one of the plants that absorbs silica from the soil and assimilates it into its structure during the growth (Smith et al., 1986). Rice husk is the outer covering of the grain of rice plant with a high concentration of silica, generally more than 80-85%

Surface soils from tank beds, agricultural fields and village common lands have been excavated and washed to produce a kind of artificial sand in order to meet the enormous demand known as filtered sand. Only source materials with suitable strength, durability and shape characteristics should be considered.

Therefore the utilization of Rice Husk Ash (RHA) & Filtered Sand (FS) in concrete for the replacement of cement & sand is environmentally and economically advantageous.

This paper analyses the effect of Rice Husk Ash (RHA) & Filtered Sand (FS), in SCC by partial replacement of cement and sand on compressive strength, split tensile strength and flexural strength of SCC.

2. TESTING OF SCC

It is important to mention that none of the test methods for SCC have yet been standardized and included in Indian Standard Code for the present. The following are some of the features of SCC mentioned in Indian standard code IS456-2000.

1. Slump flow: minimum 600mm.

2. Sufficient amount of fines (<12.5mm) preferably in the range of 400kg/m3 to 600kg/m3.This can be achieved by having sand content more than 38% and using mineral admixture to the order

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of 25% to 50% by mass of cementitious materials.

3. Use of high range water reducing (HRWR) admixture and viscosity modifying agent {VMA) in appropriate dosages are permitted.

European guidelines for testing, covers number of parameters ranging from material selection, mixture design and testing methods liked slump flow test, L-box test and V-funnel test as recommended by EFNARC3 for determining properties of SCC in fresh state. Most of Indian researchers are following these guidelines to determine the rheological properties of SCC mixes.

3. TESTING METHODS OF SCC

Different methods have been developed to characterize the rheological properties of SCC. No single method has been found until date, which characterizes all the relevant workability aspects. Each mix has been tested by more than one test method for the different workability parameters. Following are the tests recommended by European guidelines.

A. **Slump flow test-** The slump flow test is used to assess the horizontal flow of SCC in the absence of obstructions. The test also indicates resistance to segregation. On lifting the slump cone, filled with concrete the average diameter of spread of the concrete is measured. It indicates the filling ability of the concrete.

B. V-funnel test- The flowability of the test fresh concrete can be tested with the V-funnel test, where by the flow time is measured. The funnel is filled with about 22kgs of concrete and the time taken for it to flow through the apparatus is measured. Shorter flow time indicate greater flowability.

C. L-Box test- This is a widely used test, suitable for laboratory and site use. It accesses filling and passing ability of SCC and serious lack of suitability can be detected visually. The vertical section of the L-box is filled with concrete, and then the gate is lifted to let the concrete flow into the horizontal section. Blocking ratio,it indicates passing ability of concrete or the dosage to which the passage of concrete through the bars is restricted.

4. MATERIALS

The materials used in this investigation are:

Cement: OPC Birla Super 53 grade cement with specific gravity of 3.12.

Fine aggregate:

i) Natural sand (NS): River sand from Malavalli taluk, Mandya district, Karnataka state. Its physical properties are: Fineness Modulus -2.855, Specific Gravity-2.62, Water absorption-1.0% and conforms to Zone-II as per IS specifications.

ii) Filtered sand (FS): Filtered Sand obtained from Harohalli (Ramanagar), Karnataka state. This is an extracted sand from the agricultural soil which consists of silt content more than the IS specification, this will affect the strength of concrete. The amount of silt content in the present filtered sand is investigated by using Hydrometer test as described in IS: 2720(part 4) -1985. The silt content of FS for 100%, 75%, 50% and 25% by weight of Natural sand are of 49.87%, 42.5%, 28.8% and 14.3% respectively. The physical properties for different replacement levels of NS by FS are presented in Table 1.

TABLE 1
PHYSICAL PROPERTIES OF NATURAL SAND & FILTERED SAND

Sl. No	Fine Aggregate	Specific Gravity	Fineness Modulus	Grade
	Fine Aggregate (RS+FS)			
1	100% sand + 0% FS	2.62	2.855	Zone II
2	75% sand + 25% FS	2.61	3.76	Zone II
3	50% sand + 50% FS	2.19	3.51	Zone II
4	25% sand + 75% FS	2.22	3.42	Zone II
5	0% sand+ 100% FS	2.46	3.40	Zone II

Rice Husk Ash (RHA): Rice husk ash was collected from the rice mill from Maddur (Mandya dist, Karnataka state). The chemical properties of Rice husk ash tested from CIVIL AID are tabulated in Table 2. It is found that the presence of SiO2 is higher than 90%, it is highly silicious in nature.

TABLE 2
CHEMICAL CHARACTERISTICS OF RHA

Test Conducted	Result	Requirements as per IS:3812:2003	
		Siliceous Pulverized Fuelash	**Calcareous Pulverized Fuel Ash**
Silicon Dioxide(Sio_2) +Aluminum oxide(Al_20_3) +iron oxide Fe_2o_3), Percentage by mass(min)	98.92%	70%	50%
Silicon dioxide(Sio_2), Percentage by mass(min)	94.08%	35%	25%
Magnesium oxide(Mgo), percent by mass,(max)	0.18%	5%	5%
Total Sulphur as sulphur trioxide(Sio_3),Percentage by mass(max)	0.29%	3%	3%
Calcium oxide percentage by mass,(Cao)	0.28%	5%	5%

Coarse aggregate: The granite metal jelly of 12.5mm down size with fineness modulus -6.54 and specific gravity-2.65.

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Admixture: Glenium 6100 has been used to maintain the workability of the concrete without increasing the water cement ratio. The dosage of superplasticizer was fixed based on the Marsh Cone method and the dosage is restricted to 0.8% of the cementations content.

5. EXPERIMENTAL WORK

In this experimental work, a total of 378 numbers of concrete specimens were casted. The specimens considered in this study consisted of 126numbers of 150mm size cubes for compressive strength test, 126 numbers of 150mm dia and 300mm long cylinders for split tensile test and 126 numbers of 100mmx100mmx500mm for flexural test. The mix design of concrete to achieve high strength SCC of grade M70 was done according to OKAMURA (Japanese) METHOD[7,8] . The water cement ratio of 0.32 was kept constant.

Based on the quantities of ingredients of the mixes , the quantities of RHA has been partially replaced in proportion of 5%, 10%, 15% and 20% and FS by 25%, 50%, 75% and 100% by weight of cement and sand respectively. The ingredients were thoroughly mixed in mixer machine by adding 0.8 % of the admixture till uniform consistency was achieved and the concrete was tested for the workability as per EFNARC guidelines, slump test, V-funnel test & L-box tests are being carried out to determine the properties of SCC in fresh state. Then the concrete was poured into the moulds without any compaction or vibration, allowing the concrete to get self compacted. The top surface was finished by means of trowel. The specimens were removed from the mould after 24 hrs and cured for 28days and 56days. The test for compressive , split tensile and flexural strengths were conducted using 2000kN compression testing machine on both 28days and 56 days cured specimens , as per IS specification.

The concrete with partial replacement of cement and sand by RHA and FS has been termed as RHA-FS-SCC and the concrete without RHA or FS has been termed as C-SCC. The properties of RHA-FS-SCC of fresh state and hardened state were compared with the properties of C-SCC.

6. RESULTS AND DISCUSSIONS

The results of workability tests and strength tests are shown in table 3 and 4. Comparison of compressive strength of RHA-FS-SCC of different percentages of RHA and FS with C-SCC are presented in Fig.1. The comparison of typical split tensile strength and flexural strength of RHA-FS-SCC of 5% RHA with C-SCC are shown in Fig. 2a & 2b respectively.

Workability

Workability test for SCC can be broadly split into three categories: Filling ability test, passing ability test and segregation resistant test. Each test i.e slump flow test, T-500time test, V-tunnel test and L-box tests fits into one or more of these categories.

Slump Flow Test: The flowability has been measured by using slump cone test. The slump value reduced with the increases in the percentage of RHA. The slump value of RHA-FS-SCC with 0% FS and different levels of RHA of 5%, 10%, 15% &20% compared to C-SCC of 768mm reduced to 760mm, 690mm, 686mm & 680mm respectively. The addition of FS along with RHA further reduced the slump. For a typical 5% RHA and FS varying from 0 to 100% the slump value varied from 768mm to 694mm (Table 3). However, the slump values are within the EFNARC guidelines of 800mm to 650mm.

T-500time: It is an indication of rate of spread of concrete. Lower time indicates greater flowability. T-500time increased with the increase in percentage of RHA & FS(Table 3). The T-500time for 5 to 20% RHA along with different levels of FS are within the EFNARC guidelines (EFNARC guideline- 2sec to 5sec).

V-Funnel Test: It is used to assess the viscosity and filling ability of SCC. If SCC shows segregation then the flow time increases significantly. According to EFNARC values the flow of V-Funnel test should be between 8 & 12sec. The flow time of RHA-FS-SCC with different levels of RHA and FS varies between 8.54 to 10.83sec which are within the EFNARC values(Table 3), though the flow time of RHA-FS-SCC compared to C-SCC are higher.

Passing Ability: This test is conducted to assess the flow of concrete and also the extent to which the concrete is subjected to blocking by the reinforcement. According to EFNARC an acceptable H2/H ratio should be between 0.8 to 1. The H2/H1 ratio of RHA-FS-SCC with different levels of RHA and FS varies between 0.84 to 0.925. Which are within the EFNARC values (Table 3). The H2/H1 ratio of C-SCC is 0.945.

Hardened Properties

The SCC with RHA starts attaining its significant strength (Compressive, Split tensile & Flexural strength) only after 28days unlike C-SCC(Table 4 and fig1 & 2).

Compressive Strength: The partial replacement of cement by RHA reduced the compressive strength of RHA-FS-SCC, for 5%, 10%, 15% &20% RHA with 0% FS compared to C-SCC the compressive strength reduced by 8.17%, 15.24%, 32.52% & 42.59% respectively(Table 4). Further reduction in compressive strength was observed with the partial replacement of natural sand by FS (Fig1). For replacement of 5%,10%,15% & 20% RHA with replacement of 50% FS the compressive strength was higher than the other replacement levels of FS(25%,75% & 100%)(Fig2). The compressive strength of A2 to D2 mixes of RHA-FS SCC (50% FS with 5%, 10%, 15% & 20% of RHA) were higher by 3.35% to 3.60% compared to A1 to D1 Mixes (25% of FS) of RHA-FS SCC. The compressive strength of RHA-FS SCC with replacement levels of 20% RHA & 100% FS (D4 Mix) was 46.46% of C.SCC.

Split Tensile Strength and Flexural Strength: The variations of split tensile and flexural strengths of RHA-FS-SCC with different levels of RHA & FS were similar to the variations of compressive strength (Table 4 and Fig 2a & 2b).

International Journal Of Scientific & Engineering Research, Volume 4, Issue 5, May 2013
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TABLE 3
TEST RESULTS OF FRESH CONCRETE

Concrete	**Percentage replacement of**		**Designation**	**Water Binder Ratio**	**Slump Values in (spread dia) mm**	**T_{500} sec**	**V Funnel Values in sec**	**L Box H_2/H_1 Ratio**
	RHA	**FS**						
Conventional SCC	0%	0%	C.SCC	0.32	2.95	8.54	0 .945	768
RHA-FS SCC (5% RHA)	5%	0%	A_0	0.32	3.18	8.72	0.84	760
	5%	25%	A_1	0.32	3.23	9.12	0.812	743
	5%	50%	A_2	0.32	3.39	9.16	0.92	725
	5%	75%	A_3	0.32	3.68	9.34	0.868	708
	5%	100%	A_4	0.32	4.05	9.51	0.811	694
RHA-FS SCC (10% RHA)	10%	0%	B_0	0.32	3.32	9.36	0.875	690
	10%	25%	B_1	0.32	3.41	9.52	0.865	683
	10%	50%	B_2	0.32	3.62	9.48	0.888	680
	10%	75%	B_3	0.32	3.91	9.56	0.87	676
	10%	100%	B_4	0.32	3.98	9.66	0.855	672
RHA-FS SCC (15% RHA)	15%	0%	C_0	0.32	3.94	9.32	0.9	686
	15%	25%	C_1	0.32	4.01	9.50	0.86	681
	15%	50%	C_2	0.32	4.17	9.52	0.918	673
	15%	75%	C_3	0.32	4.23	9.60	0.896	670
	15%	100%	C_4	0.32	4.47	9.88	0.898	661
RHA-FS SCC 20% RHA)	20%	0%	D_0	0.32	4.17	10.09	0.921	680
	20%	25%	D_1	0.32	4.36	10.26	0.904	672
	20%	50%	D_2	0.32	4.64	10.36	0.925	666
	20%	75%	D_3	0.32	4.92	10.44	0.915	658
	20%	100%	D_4	0.32	5.12	10.83	0.862	653

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TABLE 4

Strengths of Conventional SCC mix (CSCC) &RHA-FS SCC with different replacement levels of RHA and FS with respect to 28days and 56days of curing periods

Concrete	Percentage Replacement of		Designation	Compressive strength N/mm^2		Split Tensile Strength N/mm^2		Flexural strength N/mm^2	
	RHA	FS		28days	56 days	28days	56 days	28days	56 days
C.SCC	0%	0%	C.SCC	78.12	79.69	8.12	8.77	14.43	16.80
RHA&FS SCC(with 5% RHA)	5%	0%	A0	55.90	73.18	5.89	6.61	11.93	15.60
	5%	25%	A1	52.65	68.44	4.97	5.82	10.86	13.13
	5%	50%	A2	53.33	70.81	5.28	6.08	11.40	14.53
	5%	75%	A3	49.48	64.88	4.70	4.88	7.73	11.46
	5%	100%	A4	42.07	58.36	3.86	4.76	6.46	9.00
RHA&FS SCC(with 10% RHA)	10%	0%	B0	52.44	67.54	4.64	5.77	10.13	12.40
	10%	25%	B1	49.18	63.40	3.76	4.95	8.13	10.00
	10%	50%	B2	50.66	65.77	4.32	5.37	9.13	11.00
	10%	75%	B3	40.88	55.99	3.55	4.19	7.47	8.40
	10%	100%	B4	37.03	50.36	3.11	3.93	6.06	7.20
RHA&FS SCC(with15 % RHA)	15%	0%	C0	46.20	53.77	3.98	4.35	7.20	7.21
	15%	25%	C1	41.77	42.00	3.27	3.46	5.73	5.80
	15%	50%	C2	42.96	45.92	3.67	4.12	5.93	6.60
	15%	75%	C3	39.10	43.35	2.68	3.07	5.26	5.26
	15%	100%	C4	35.55	42.07	2.43	2.73	4.33	4.54
RHA&FS SCC(with 20% RHA)	20%	0%	D0	35.84	45.75	2.99	3.84	5.46	6.53
	20%	25%	D1	31.55	43.84	2.42	3.01	4.47	4.66
	20%	50%	D2	32.73	45.48	2.77	3.46	4.86	5.27
	20%	75%	D3	30.51	43.10	1.81	2.52	4.13	4.36
	20%	100%	D4	27.99	37.03	1.52	2.33	3.33	3.60

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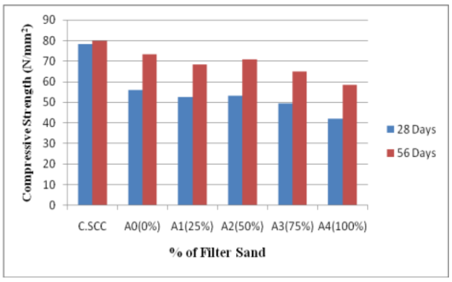

Fig. a: 5% RHA

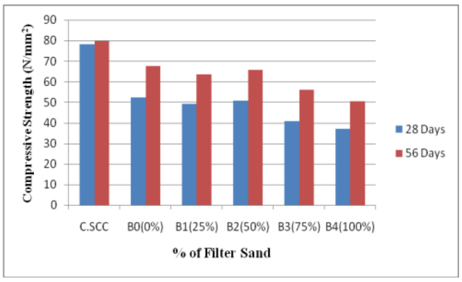

Fig. b: 10% RHA

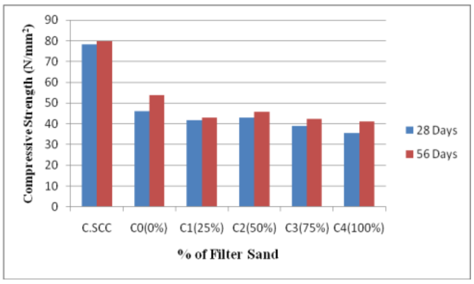

Fig. c: 15% RHA

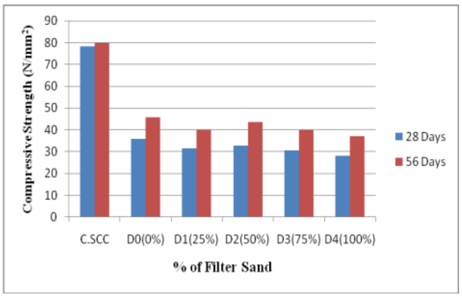

Fig. d: 20% RHA

Fig. 1 Comparison of Compressive strength of conventional SCC mix (C.SCC) &RHA-FS SCC with different replacement levels of RHA and FS with respect to different curing periods

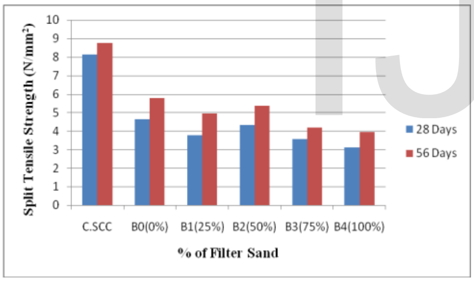

Fig. a: 5% RHA

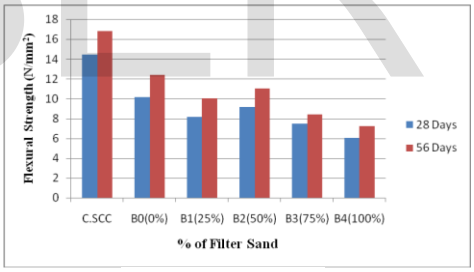

Fig. b: 5% RHA

Fig. 2 Comparison of Split tensile and flexural strength of conventional SCC mix (C.SCC) &RHA-FS SCC for a replacement of 10% RHA with different replacement levels of FS for curing periods of 28 days and 56 days

6. CONCLUSIONS

Based on the experimentation, following conclusions are drawn:

1) Presence of RHA in SCC along with FS the required strength of SCC was obtained after 56 days of curing.The presence of RHA reduced the slump, with the increase in quantity of RHA in SCCs the reduction in slump also increased. The addition of FS along with RHA further reduced the slump

2) The increase of RHA affected the consistency of flow of SCC. The presence of FS along with RHA further reduced the consistency of flow.

3) In RHA-FS SCC the replacement of FS in any percentage (i.e.25%, 50%, 75% & 100%) influenced in reduction of strength of hardened properties of concrete (compressive strength, split tensile strength & flexural strength).This may be due to the presence of silt content in the FS

4) Of the all percentage replacement of FS in RHA-FS SCC the 50% proportions with any percentage of RHA (5%, 10%, 15% & 20%) has higher strength (compressive strength, split tensile strength & flexural strength) than all other proportions of FS.

5) 5% RHA to 20% RHA with 0% FS achieves the strength of M 65 grade to M 35 grade. Whereas for 5% RHA to 20% RHA with 100% FS achieves the strength M 50 grade to M 30.However for 5% RHA to 20% RHA with 50% FS achieves the strength M 60 grade to M 40 grade.

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