Effect of Acid Attack on Rice Husk Ash-Filtered Sand Self-Compacting Concrete

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ABSTRACT-This paper deals with the effect of rice husk ash and filtered sand on the durability property acid attack. In this study M_{70} grade concrete with rice husk ash, filtered sand and superplasticizer were used. Cement and sand was replaced at the levels of 5%, 10%, 15%, 20% and 25%, 50%, 75%, 100% respectively. From the test results, it was observed that rice husk ash SCC and rice husk ash filtered sand SCC has shown better performance than conventional concrete.

KEYWORDS

Fresh Properties, Durability properties, Self-Compacting Concrete (SCC), Rice Husk Ash (RHA), Filtered Sand (FS), Acid Resistance, Hydrochloric Acid (Hcl).

INTRODUCTION

Concrete is a widely used construction material for various types of structures due to structural stability and strength. All the materials required producing such huge quantities of concrete come from the earth's crust. Thus, it deflects its resources every year creating ecological strains. On the other hand, human activities on earth produce solid wastes in considerable quantities of over 2500/MT per year, including industrial wastes, agricultural wastes and wastes from rural and urban societies. Recent technological development has shown that these materials are valuable as inorganic and organic resources and can produce various useful products. Amongst the solid wastes, the most prominent ones are fly ash, blast furnace slag, rice husk ash, silica fume and demolished construction materials.

From the middle of 20th century, there had been an increase in the consumption of mineral admixtures by the cement and concrete industries. This increasing demand for cement and concrete is met by partial cement replacement. Substantial energy and cost savings can result when industrial by-products are used as a partial replacement for the energy intense Portland cement. The use of by-products is an environmental–friendly method of disposal of large quantities of materials that would otherwise pollute land, water and air. The current cement production rate of the world, which is approximately 1.2 billion tones/year, is expected to grow exponentially to about 2 billion tones/year by 2015. Most of the increase in demand will be met by the use of supplementary cementing materials.
Prior to 1970, RHA was usually produced by uncontrolled combustion and the ash so produced was crystalline and possessed poor pozzolanic properties. In 1973, Mehta published the first of several papers describing the effect of pyro processing parameters on the pozzolanic reactivity of RHA. Based on his research, Pitt designed a fluidized bed furnace for controlled burning of rice husks. By burning the rice husks under a controlled temperature and atmosphere, a highly reactive RHA was obtained. The utilization of RHA as a pozzolanic material in cement and concrete provides several advantages, such as improved strength and durability properties, reduced materials cost due to cement savings and environmental benefits related to the disposal of waste materials.

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. 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. Production generally involves screening and possible washing. Separating into discrete fractions, recombining and blending may be necessary.

Therefore the utilization of Rice Husk Ash (RHA) & Filtered Sand (FS) in concrete for the replacement of cement & sand, environmentally and economically advantageous. In the present study Portland cement and sand was replaced by RHA and FS at various percentages to study strength and durability property acid attack.

EXPERIMENTAL PROGRAMME

MATERIALS USED

Cement: ordinary Portland cement of 53 grade confirming to IS: 12269-1987 was used for the present experimental investigation. The cement was tested as per the Indian standards IS: 4031-1988. The test results are given in Table 1.

Sl.No	PROPERTIES	Obtained Values	Requirement as per IS -12269
1	Fineness	2.59	Not more than 10%
2	Soundness	1.00 mm	Not more than 10 mm
3	1.Initial Setting Time	71.00 min	Not less than 30 min
	2. Final Setting Time	438.00 min	Not more than 600 min
4	Compressive strength	53.36 N/mm²	Not less than 53 N/mm²
5	Standard Consistency	31%	
6	Specific Gravity	3.12	

Table 1: Physical Properties of Cement

Fine Aggregates: Natural river sand as per IS: 383-1987 was used. The physical properties and sieve analysis of fine aggregate are presented in Table 2.

Sl.No	Properties	Results
1	Fineness Modulus	2.855
2	Specific Gravity	2.62
3	Water Absorption	1.0%
4	Zone	II

Table 2: Physical Properties of Fine Aggregates (Natural Sand)

Filtered Sand IS: 383-1987 was used. The physical properties obtained on conducting sieve analysis and specific gravity tests for Filter Sand and for different replacement levels of sand by Filter Sand is presented in Table 3. The amount of silt content in sand to be used in concrete should be less than 5% according to codal provisions (IS 383). If the amount of silt content is higher than 5% affects the strength of concrete. Hence the amount of silt content in the present filtered sand is investigated by using Hydrometer test (Table 4).

Sl. No	Fine Aggregate	Specific Gravity	Fineness Modulus	Zone
Fine Aggregate (NS+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

Table 3: Test Results of Fine Aggregates (Natural sand & Filtered sand)

% of Filter Sand	% of Silt	% of Clay	% of Finer Sand
25	14.3	39.19	46.51
50	28.8	38.29	32.91
75	42.5	32.10	25.40
100	49.87	24.87	25.26

Table 4: Hydrometer Test Results

Coarse Aggregates: Crushed Granite jelly of size 12.5mm down confirming to IS: 383-1987 was used (Table 5).

Sl. No	Particulars of the test	Results
1.	Fineness modulus	6.54
2.	Specific Gravity	2.65

Table 5: Physical characteristics of Coarse Aggregates (12.5 mm down size)

Rice Husk Ash: The rice husk ash obtained from Maddur (Mandya dist.).RHA used for investigation have tested in the Civil Aid and the chemical characteristics are given in Table 6.

Sl.No	Test Conducted	Results	Requirements as per IS:3812:2003	
			Siliceous Pulverized Fuel Ash	Calcareous Pulverized Fuel Ash
1	Silicon Dioxide(Sio_2)+Aluminum oxide($Al_2 0_3$)+iron oxide $Fe_2 o_3$),Percentage by mass(min)	98.92%	70%	50%
2	Silicon dioxide(Sio_2),Percentage by mass(min)	94.08%	35%	25%
3	Magnesium oxide(Mgo),percent by mass,(max)	0.18%	5%	5%
4	Total Sulphur as sulphur trioxide(Sio_3),Percentage by mass(max)	0.29%	3%	3%
5	Calcium oxide percentage by mass,(Cao)	0.28%	5%	5%

Table 6: Chemical characteristics of Rice Husk Ash

Superplasticizer: Polycarboxylic ether based super plasticizer Glenium 6100 has been used in present research work.

MIX PROPORTIONING

For the present investigation, High strength self-compacting concrete of grade $M_{70}$was aimed. To achieve this grade of concrete, OKAMURA (JAPANESE) METHOD of mix design was used.

Note: [C.SCC - Conventional Self Compacting Concrete with only Cement & Natural Sand without RHA & FS].
The mix proportions obtained for C.SCC of M_{70} grade is 1:1.12:1.17 is been replaced by RHA & FS in place of cement & natural sand by different percentages, which is tabulated in Table 7.

Note: C.SCC-Conventional Concrete (0%RHA, 0%FS);
A Series-5% RHA; B Series-10% RHA; C Series-15% RHA; D Series-20% RHA;
A_o A_1 A_2 A_3 A_4 – 5% RHA, (100%NS+0%FS, 75%NS+25%FS, 50%NS+50%FS, 25%NS+75%FS, 0%NS+100%FS);
B_o B_1 B_2 B_3 B_4 – 10% RHA, (100%NS+0%FS, 75%NS+25%FS, 50%NS+50%FS, 25%NS+75%FS, 0%NS+100%FS);
C_o C_1 C_2 C_3 C_4 – 15% RHA, (100%NS+0%FS, 75%NS+25%FS, 50%NS+50%FS, 25%NS+75%FS, 0%NS+100%FS);
D_o D_1 D_2 D_3 D_4 – 20% RHA, (100%NS+0%FS, 75%NS+25%FS, 50%NS+50%FS, 25%NS+75%FS, 0%NS+100%FS).

Mix	Cement		RHA		NS		FS		CA		Water	SP	
	% age	Wt in Kgs	% age	Wt in Kgs	% age	Wt in Kgs	% age	Wt in Kgs	% age	Wt in Kgs	Water in Ltrs	% age	SP in ml
[illegible]	100	649.0	0	0	100	726.6	0	0	100	759.5	208.0	0.8	5192
A_0	95	616.5	5	32.4	100	726.6	0	0	100	759.5	208.0	0.8	5192
A_1	95	616.5	5	32.4	75	545.0	25	181.6	100	759.5	208.0	0.8	5192
A_2	95	616.5	5	32.4	50	363.3	50	363.3	100	759.5	208.0	0.8	5192
A_3	95	616.5	5	32.4	25	181.6	75	545.01	100	759.5	208.0	0.8	5192
A_4	95	616.5	5	32.4	0	0	100	726.6	100	759.5	208.0	0.8	5192
B_0	90	584.1	10	64.9	100	726.6	0	0	100	759.5	208.0	0.8	5192
B_1	90	584.1	10	64.9	75	545.0	25	181.6	100	759.5	208.0	0.8	5192
B_2	90	584.1	10	64.9	50	363.3	50	363.3	100	759.5	208.0	0.8	5192
B_3	90	584.1	10	64.9	25	181.6	75	545.0	100	759.5	208.0	0.8	5192
B_4	90	584.1	10	64.9	0	0	100	726.6	100	759.5	208.0	0.8	5192
C_0	85	551.6	15	97.3	100	726.6	0	0	100	759.5	208.0	0.8	5192
C_1	85	551.6	15	97.3	75	545.0	25	181.6	100	759.5	208.0	0.8	5192
C_2	85	551.6	15	97.3	50	363.3	50	363.3	100	759.5	208.0	0.8	5192
C_3	85	551.6	15	97.3	25	181.6	75	545.0	100	759.5	208.0	0.8	5192
C_4	85	551.6	15	97.3	0	0	100	726.6	100	759.5	208.0	0.8	5192
D_0	80	519.2	20	129.8	100	726.6	0	0	100	759.5	208.0	0.8	5192
D_1	80	519.2	20	129.8	75	545.0	25	181.6	100	759.5	208.0	0.8	5192
D_2	80	519.2	20	129.8	50	363.3	50	363.3	100	759.5	208.0	0.8	5192
D_3	80	519.2	20	129.8	25	181.6	75	545.0	100	759.5	208.0	0.8	5192
D_4	80	519.2	20	129.8	0	0	100	726.6	100	759.5	208.0	0.8	5192

Table 7: Mix proportions of RHA-FS SCC and Conventional SCC per m^3 by weight

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 IS: 456-2000.

1. Slump flow: Minimum 600mm.
2. Sufficient amount of fines (<12.5mm) preferably in the range of 400kg/m^3 to 600kg/m^3.This can be achieved by having sand content more than 38% and using mineral admixture to the order 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 like slump flow test, L-box test and V-funnel test as recommended by EFNARC for determining properties of SCC in fresh state. Most of Indian researchers are following these guidelines to determine the rheological properties of SCC mixes.

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 test of the 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.

TESTS CONDUCTED

Acid Attack Test:

A total number of 126 cubes of size of 100 mm were casted and stored in a place at a temperature of 27°C±2°C for 24 hours and then the demoulded specimens were water cured for 28 and 56 days. After curing, the specimens were taken out and allowed to dry for one day. Weights of the cubes were taken. For acid attack, 5% dilute hydrochloric acid (Hcl) with PH value of about 2 was used. After that, cubes were immersed in the above said acid water for a period of 28 days.

The concentration of the solution was maintained throughout this period. After 28 days, the specimens were taken from the acid water. The surfaces of the cubes were cleaned, weights of the specimens were registered and then they were tested in the compression testing machine of 2000kN capacity under a uniform rate of loading of 140 kg/cm^2/min. The loss in compressive strength of the concrete cubes without RHA and the improvement of resistance of resistance of acid attack of RHA along with FS concrete cubes were analyzed.

RESULTS AND DISCUSSIONS

The slump flow characteristics, V-funnel & L-box of the mixtures satisfies the EFNARC requirement. Slump flow decreases with increase in RHA content along with FS. The RHA indicates the increase in the viscosity of concrete. The blocking ratio in L-box test were as per requirement of SCC mixes as laid down by EFNARC guidelines. The results are presented in Table 8.

Sl.No	Designation	Slump Values, mm	EFNARC Values	T_{500}, Slump	EFNARC Values	V-Funnel, Sec	EFNARC Values	H2/H1 Ratio	EFNARC Values
1	C.SCC	768	650-800 mm	2.95	2-5 Secs	8.54	6-12 Secs	0.95	0.8-1.0
2	A0	760		3.18		8.72		0.84	
3	A1	743		3.23		9.12		0.81	
4	A2	725		3.29		9.16		0.92	
5	A3	708		3.68		9.34		0.87	
6	A4	694		4.05		9.51		0.81	
7	B0	690		3.32		9.36		0.88	
8	B1	683		3.41		9.52		0.87	
9	B2	680		3.62		9.48		0.89	
10	B3	676		3.91		9.56		0.87	
11	B4	672		3.98		9.66		0.86	
12	C0	686		3.94		9.32		0.90	
13	C1	681		4.01		9.50		0.86	
14	C2	673		4.17		9.52		0.92	
15	C3	670		4.23		9.60		0.90	
16	C4	661		4.47		9.88		0.90	
17	D0	680		4.17		10.09		0.92	
18	D1	672		4.36		10.26		0.90	
19	D2	666		4.64		10.36		0.93	
20	D3	658		4.92		10.44		0.92	
21	D4	653		5.12		10.83		0.86	

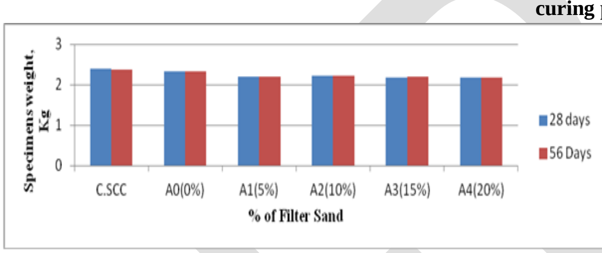
Table 8: Test results of Fresh concrete

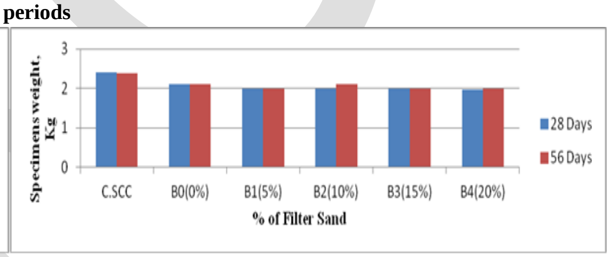
The fresh concrete properties compared to EFNARC specifications, the slump obtained from RHA-FS SCC is between 768 mm to 653mm. The V-Funnel time obtained from RHA-FS SCC is between 2.95 sec to 5.12 sec. The H_2/H_1 ratio obtained from RHA–FS SCC is between 0.945 to 0.862.The fresh concrete properties of RHA-FS SCC obtained are within the EFNARC specifications.

Compressive Strength:

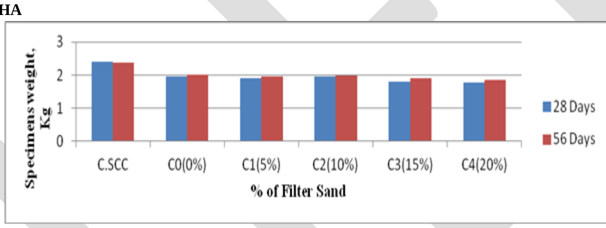
Sl. No	Concrete	Percentage Replacement of		Designation	Weight of C.SCC specimens and RHA-FS SCC specimens, Kg		Ratio of weight of RHA-FS SCC with respect to C.SCC	
		RHA	FS		28 Days	56 Days	28 Days	56 Days
1	C.SCC	0%	0%	C.SCC	2.380	2.400	1.000	1.000
2	RHA-FS SCC (with 5% RHA & different levels of FS)	5%	0%	A_0	2.320	2.340	0.975	0.975
3		5%	25%	A_1	2.200	2.210	0.924	0.921
4		5%	50%	A_2	2.220	2.230	0.933	0.929
5		5%	75%	A_3	2.180	2.190	0.916	0.913
6		5%	100%	A_4	2.170	2.180	0.912	0.908
7	RHA-FS SCC (with 10% RHA & different levels of FS)	10%	0%	B_0	2.100	2.110	0.882	0.879
8		10%	25%	B_1	1.990	2.000	0.836	0.833
9		10%	50%	B_2	2.000	2.100	0.840	0.875
10		10%	75%	B_3	1.980	1.990	0.832	0.829
11		10%	100%	B_4	1.970	1.980	0.828	0.825
12	RHA-FS SCC (with 15% RHA & different levels of FS)	15%	0%	C_0	1.960	2.000	0.824	0.833
13		15%	25%	C_1	1.900	1.950	0.798	0.813
14		15%	50%	C_2	1.950	1.990	0.819	0.829
15		15%	75%	C_3	1.800	1.900	0.756	0.792
16		15%	100%	C_4	1.780	1.860	0.748	0.775
17	RHA-FS SCC (with 20% RHA & different levels of FS)	20%	0%	D_0	1.890	1.990	0.794	0.829
18		20%	25%	D_1	1.700	1.900	0.714	0.792
19		20%	50%	D_2	1.800	1.920	0.756	0.800
20		20%	75%	D_3	1.690	1.840	0.710	0.767
21		20%	100%	D_4	1.600	1.800	0.672	0.750

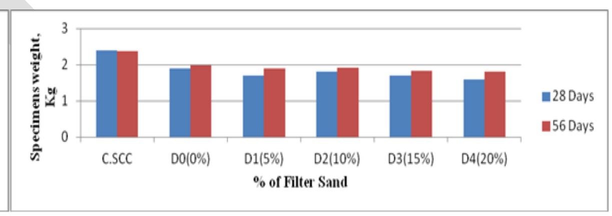
Table 9: Weight of Conventional SCC mix (C.SCC) & RHA-FS SCC with different replacement levels of RHA and FS specimens with respect to different curing periods





5% RHA10% RHA





15% RHA20% RHA

Fig 1: Comparison of specimen's weight of conventional SCC mix (C.SCC) & RHA-FS SCC of different replacement levels of RHA and FS for curing periods of 28 and 56 days

From above Table and Fig following observations are made:

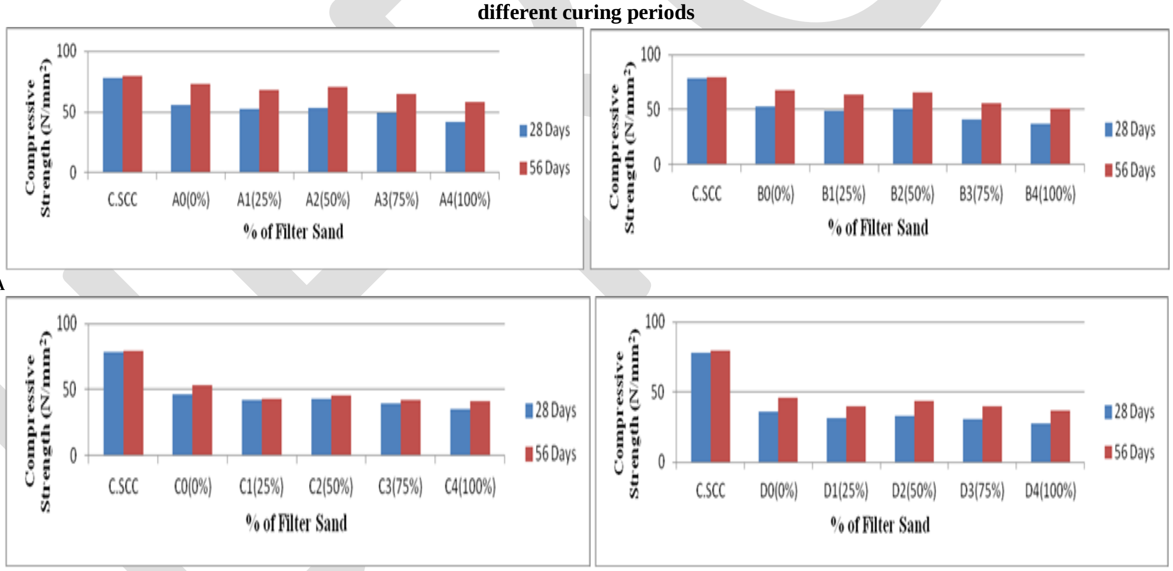
The partial replacement of cement by RHA alone in C.SCC (RHA-FS SCC) reduces the weight of C.SCC, with increase in percentage of RHA the reduction in weight also increases. The weight of RHA-FS SCC with RHA of 5%, 10%, 15% and 20% and FS of 0% (A_0, B_0, C_0 and D_0) is 2.34, 2.11, 2.00 and 1.99 kgs respectively, whereas weight of C.SCC is 2.4 kg.

In addition to the replacement of cement by RHA, the natural sand partially replaced by FS in SCC (A_1, A_2, A_3, A_4 series), reduces the weight of RHA-FS SCC specimen further, for a typical case of RHA-FS SCC with 10% RHA and FS of 25%, 50%, 75% and 100% (B_1, B_2, B_3, B_4 series) the weights are 2.00, 2.10, 1.99 and 1.98 kgs respectively, whereas the weight of RHA-FS SCC of B_0 (10% RHA and 0% FS) is of 2.11 kg.

Hence from the above observations the replacement of cement and natural sand by RHA and FS respectively in SCC (RHA-FS SCC) reduces the weight of SCC in comparison to C.SCC.

Sl. no	Concrete	Percentage Replacement of		Designation	Comp Strength of C.SCC specimens and RHA-FS SCC specimens, N/mm^2		Ratio of Comp Strength of RHA-FS SCC with respect to C.SCC	
		RHA	FS		28 Days	56 Days	28 Days	56 Days
1	C.SCC	0%	0%	C.SCC	78.12	79.69	1.000	1.000
2	RHA-FS SCC (with 5% RHA & different levels of FS)	5%	0%	A_0	55.90	73.18	0.716	0.918
3		5%	25%	A_1	52.65	68.44	0.674	0.859
4		5%	50%	A_2	53.33	70.81	0.683	0.889
5		5%	75%	A_3	49.48	64.88	0.633	0.814
6		5%	100%	A_4	42.07	58.36	0.539	0.732
7	RHA-FS SCC (with 10% RHA & different levels of FS)	10%	0%	B_0	52.44	67.54	0.671	0.848
8		10%	25%	B_1	49.18	63.40	0.630	0.796
9		10%	50%	B_2	50.66	65.77	0.648	0.825
10		10%	75%	B_3	40.88	55.99	0.523	0.703
11		10%	100%	B_4	37.03	50.36	0.474	0.632
12	RHA-FS SCC (with 15% RHA & different levels of FS)	15%	0%	C_0	46.20	53.77	0.591	0.675
13		15%	25%	C_1	41.77	44.00	0.535	0.552
14		15%	50%	C_2	42.96	45.92	0.550	0.576
15		15%	75%	C_3	39.10	43.35	0.501	0.544
16		15%	100%	C_4	35.55	42.07	0.455	0.528
17	RHA-FS SCC (with 20% RHA & different levels of FS)	20%	0%	D_0	35.84	45.75	0.459	0.574
18		20%	25%	D_1	31.55	43.84	0.404	0.550
19		20%	50%	D_2	32.73	45.48	0.419	0.571
20		20%	75%	D_3	30.51	43.10	0.391	0.541
21		20%	100%	D_4	27.99	37.03	0.358	0.465

Table 10: 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



5% RHA10% RHA

15% RHA20% RHA

Fig 2: Comparison of Compressive strength of conventional SCC mix (C.SCC) & RHA-FS SCC of different replacement levels of RHA and FS for curing periods of 28 and 56 days

From Table and Fig the following observations are made:

The SCC with RHA attains significant strength only after 28 days of curing unlike Conventional Self Compacting Concrete (0% RHA, 0% FS) which attains its strength at 28 days of curing.

The compressive strength of RHA-FS SCC for different replacement level of FS from 0% to 100% with 5%, 10%, 15% and 20% of RHA varies between 73.18 N/mm^2 to 58.36 N/mm^2; 67.54 N/mm^2 to 50.36 N/mm^2; 53.77 N/mm^2 to 42.07 N/mm^2 and 45.75 N/mm^2 to 37.03 N/mm^2 respectively. Whereas compressive strength of Conventional SCC is 79.69N/mm^2.

The compressive strength of RHA-FS SCC of A-series SCC i.e. 5% RHA and FS of 0%, 25%, 50%, 75% and 100% are 73.18 N/mm^2, 68.44 N/mm^2, 70.81 N/mm^2, 64.88 N/mm^2 and 58.36 N/mm^2. Similar variations are observed for RHA of 10%, 15% and 20% i.e. B, C and D-series.

The RHA-FS SCC with replacement of 5%, 10%, 15% & 20% of RHA and replacement of FS of 50% (A_2, B_2, C_2 & D_2) the compressive strength compared to 0% FS (A_0, B_0, C_0 & D_0) reduces, it reduces by 3.24%, 2.62%, 14.60% & 0.60% respectively. And when compared to 25% of FS (A_3, B_3, C_3 & D_3) the compressive strength increases, it increases by 3.47%, 3.74%, 9.34% & 3.75% respectively.

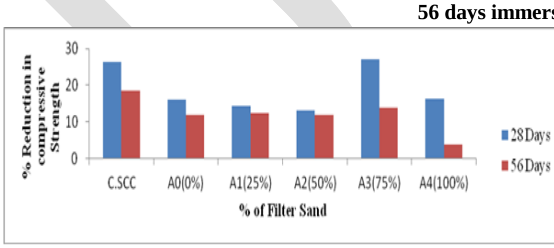
The replacement of sand by FS in RHA-FS SCC influences in reduction of the compressive strength. However the replacement level of FS of 50% (A_2, B_2, C_2 & D_2) gives higher strength when compared to other replacement levels of FS.

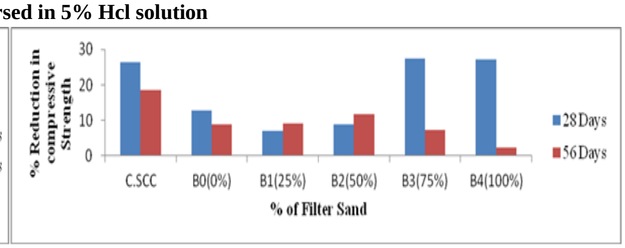
Hence from the above observations replacement of cement partially by RHA reduces the compressive strength compared to C.SCC. The compressive strength of RHA-FS SCC is reduced further when natural sand is replaced partially by FS.

Acid Resistance:

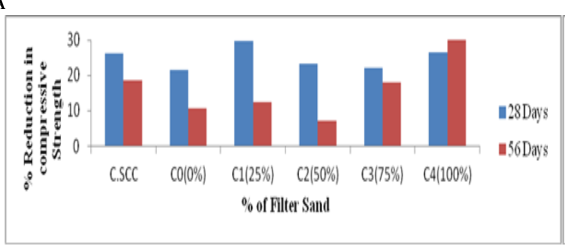
Sl. no	Concrete type	Compressive strength of specimens before immersion in Hcl soln 'N/mm^2'		Compressive strength of specimens after immersion in Hcl soln 'N/mm^2'		% Reduction in Compressive strength after immersion in Hcl soln		Ratio of % change in strength wrt C.SCC	
		28 Days	56 Days	28 Days	56 Days	28 Days	56 Days	28 Days	56 Days
1	C.SCC	78.12	79.69	61.86	67.18	26.29	18.62	1.00	1.00
2	A_0	55.90	73.18	48.12	65.42	16.17	11.86	0.62	0.64
3	A_1	52.65	68.44	46.00	60.88	14.46	12.42	0.55	0.67
4	A_2	53.33	70.81	47.12	63.20	13.18	12.04	0.50	0.65
5	A_3	49.48	64.88	38.90	57.00	27.20	13.82	1.03	0.74
6	A_4	42.07	58.36	36.18	56.18	16.28	3.88	0.62	0.21
7	B_0	52.44	67.54	46.50	62.00	12.77	8.94	0.49	0.48
8	B_1	49.18	63.40	45.90	58.12	7.15	9.08	0.27	0.49
9	B_2	50.66	65.77	46.48	58.86	8.99	11.74	0.34	0.63
10	B_3	40.88	55.99	32.10	52.18	27.35	7.30	1.04	0.39
11	B_4	37.03	50.36	29.14	49.16	27.08	2.44	1.03	0.13
12	C_0	46.20	53.77	38.00	48.61	21.58	10.62	0.82	0.57
13	C_1	41.77	44.00	32.18	39.11	29.80	12.50	1.13	0.67
14	C_2	42.96	45.92	34.85	42.86	23.27	7.14	0.89	0.38
15	C_3	39.10	43.35	32.00	36.72	22.19	18.06	0.84	0.97
16	C_4	35.55	42.07	28.10	32.10	26.51	31.06	1.01	1.67
17	D_0	35.84	45.75	30.00	45.16	19.47	1.31	0.74	0.07
18	D_1	31.55	43.84	27.40	39.10	15.15	12.12	0.58	0.65
19	D_2	32.73	45.48	28.98	40.00	9.17	13.70	0.35	0.74
20	D_3	30.51	43.10	25.35	34.18	20.36	26.10	0.77	1.40
21	D_4	27.99	37.03	21.18	30.10	32.15	23.02	1.22	1.24

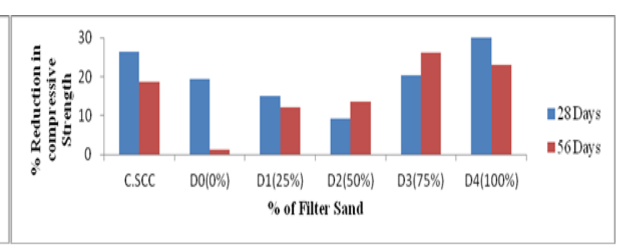
Table 11: The Compressive strengths of C.SCC and RHA-FS SCC specimens of different replacement levels of RHA and FS cured for 28 days and 56 days immersed in 5% Hcl solution





5% RHA10% RHA





15% RHA20% RHA

Fig 3: Percentage reduction in compressive strength of specimens immersed in 5% Hcl solution cured for 28 days and 56 days

From Table following observations are made on strength loss of SCC immersed in 5% Hcl solution.

Both C.SCC and RHA-FS SCC specimens when immersed in acid for 28 days, suffered loss in compressive strength.

The strength loss of C.SCC is 26.29% & 18.62% for 28 and 56 days water cured specimens immersed in acid for 28 days respectively. Similarly the loss in strength of RHA-FS SCC with different levels of RHA and FS are lesser in 56 days water cured specimens.

All RHA-FS SCC specimens with different levels of RHA and FS showed almost lower degree of loss in strength compared to that of C.SCC specimens at both 28 and 56 days water curing period, when immersed in 5% Hcl solution.

It is found that the % loss in strength of RHA-FS SCC as RHA replacement level increases from 5%-20% (A_0, B_0, C_0 and D_0) goes on decreasing. The % losses in strength are 11.86%, 8.94%, 10.62% and 1.31%.

It is seen that the % loss in strength of RHA-FS SCC specimens (A_0, B_0, C_0 and D_0) showed lesser values as compared to C.SCC of 18.62%. Increase in % replacement level of RHA increases the acid resistance.

It is found that with the partial replacement of FS from 25%-100% the % reduction in strength increases marginally than that of 0% replacement level of FS. However the C and D series with RHA of 15% and 20% and FS varying between 25%-100% the % reduction in the strength increases drastically, which shows that the RHA-FS SCC with RHA upto 10% and with different replacement levels of FS (25% to 100%) has better acid resistance compared to the other proportions of RHA and FS. The % reductions of A_1-A_4, B_1-B_4, C_1-C_4 and D_1-D_4 are 12.42-3.88%, 9.08-2.44%, 12.50-31.06% and 12.12-23.02% respectively.

From all the observations, it can be seen that the resistance to acid attack of RHA-FS SCC specimens is higher than that of C.SCC specimens and resistance goes on increasing as RHA and filter sand replacement level increases, except C and D series.

CONCLUSIONS

Fresh properties:

RHA contributes in the reduction of agricultural waste that is the main cause of environmental problems in agricultural countries. On the other hand, it is an approach to improve the quality of concrete without using costly additives such as silica fume, GGBFS etc.

Due to the presence of RHA in SCC along with FS, the required strength of SCC is obtained to actual values, after 56 days of curing unlike normal concrete which attains the strength at 28days.

The presence of RHA reduces the slump, with the increase in quantity of RHA in SCCs the reduction in slump also increases. The addition of FS along with RHA further reduces the slump. For D_4-Mix (20% RHA+100% FS) the slump reduced frrom768 mm (Conventional SCC mix) to 653 mm.

The T_{500} time increases with the increase in percentage of RHA. The presence of FS further increases the T_{500} time i.e., 2.95 sec to 5.12 sec.

The increase of RHA affects the consistency of flow of SCC. The presence of FS along with RHA, add to the increase in reduction of consistency of flow.

The V Funnel time increases with the increase in percentage of RHA. The presence of FS further increases the V Funnel time.

Durability properties:

The RHA-FS SCC when immersed in 5% Hcl solution (acid) the weight gets reduced, with increase in replacement levels of both RHA and filter sand in SCC the percentage weight loss also goes on increasing. However the % loss in weight is lesser than C.SCC.

The RHA-FS SCC with replacement level of RHA upto 10% shows better acid resistance with all % replacement level of FS (upto 100%). RHA-FS SCC with replacement level of RHA 15% and 20% shows better acid resistance with FS upto 50%. Hence the resistance to acid attack of RHA-FS SCC specimens is higher than that of C.SCC specimens and resistance goes on increasing as RHA and filter sand replacement level increases, except C_3, C_4 and D_3, D_4 specimens.

The RHA-FS SCC with only replacement of cement by RHA (upto 20%) and without the replacement of natural sand by filter sand increases the chemical resistance against acid attack, with replacement of natural sand by filter sand along with replacement of cement by RHA the durability factors becomes vice versa.

Hence the RHA-FS SCC with replacement of cement by RHA is more durable than the RHA-FS SCC with replacement of natural sand by filter sand.

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