Experimental study Durability characteristics of Self Compacting Concrete mixes containing Silica Fume and Rice Husk Ash

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***Abstract*—Concrete is a mixture of cement, sand, gravel and water which dries hard and strong and is used as a material for building. Concrete has to be heavily vibrated for flow into very intricate forms or forms that have a lot of reinforcing bars. Hence to overcome these defects the self-compacting concrete is used. Self-compacting concrete is a flowing concrete mixture that is able to consolidate under its own weight. The self-compacting concrete flows easily at suitable speed into formwork without blocking through the reinforcement without being heavily vibrated. This project deals with the self- compacting concrete where the cement is partially replaced with fly-ash and silica fume. Similarly, there is increase in the fresh properties (workability) and decrease in the hardened properties (split-tensile strength and compressive strength) for replacement of fly ash. Self-compacting concrete (SCC) is a type of concrete that can flow under its own weight and completely fill the form work, without vibration effect, and at the same time cohesive enough to be handled without bleeding. SCC usually requires a large content of binder and chemical admixtures. This work outlines the preliminary results of a research project aimed at producing and comparing SCCs incorporating Fly ash (FA) and Rice husk ash (RHA)as supplementary cementing materials in terms of their properties like compressive strength, split tensile strength and flexural strength.**

***IndexTerms*—SCC and Fresh concrete flow, Self-compacting concrete, Fly ash, Rice husk ash, Compressive strength, Flexural strength, Split tensile strength.**

I. INTRODUCTION

Self-Compacting Concrete (SCC) was developed in Japan during the later part of the 1980's to be mainly used for highly congested reinforced structures in seismic regions. Recently, this concrete has gained wide use in many countries for different applications and structural configurations. The use of SCC has many advantages, such as: reducing the construction time and labour cost, eliminating the need for vibration, reducing the noise pollution, and also improving the filling capacity of highly congested structural members.

SCC consists of the same components as conventionally vibrated concrete, which are cement, aggregates and water, with the addition of chemical and mineral admixtures in different proportions .The first point to be considered when designing SCC is to restrict the volume of the coarse aggregate so as to avoid the possibility of blockage on passing through spaces between steel bars. This reduction necessitates the use of a higher volume of cement which increases the cost besides resulting in temperature rise. So cement should be replaced by high volume of mineral admixture like fly ash or rice husk ash.

Fly ash (FA) is a beneficial mineral admixture for concrete. Research shows that adding FA to normal concrete, as a partial replacement of cement (less than 35 %), will benefit both the fresh and hardened states. In the fresh state, the fly ash improves workability. This is due to the smooth, spherical shape of the fly ash particle. The tiny spheres act as a form of ball bearing that aids the flow of the concrete. In the hardened state, fly ash contributes in a number of ways, including strength and durability [1, 2].

Rice husk ash (RHA) has been used as a highly reactive pozzolanic material to improve the microstructure of the interfacial transition zone between the cement paste and the aggregate in SCC. Research shows that the utilization of rice husk ash in SCC mix produced desired results, reduced cost, and also provided an environment friendly disposal of the otherwise agro-industry waste product [3, 4].

For concrete to be self-compacting it should have filling ability, passing ability and resistance against segregation. Self-compact ability is obtained by limiting the coarse aggregate content and using lower water– powder ratio together with the addition of super plasticizers.

RECENT INNOVATIONS IN SELF COMPACTING CONCRETE

1. SCC with different types of admixtures and super-plasticizers.
2. SCC using fibers.
3. SCC incorporating filler additives.
4. SCC containing fly ash, slag & silica fume.
5. SCC using recycled concrete aggregate.

6. SCC containing plastic waste.
7. SCC containing tyre rubber waste.

II. EXPERIMENTAL PROGRAMME

II.1. Materials:

Cement: All types of cement complying with Indian standards are suitable for SCC. The cement used in this experiment is the 43 grade Ordinary Portland Cement [5].

III. Table 1: Test results on cement

Test		Test Results
Normal consistency		30%
Specific gravity		3.15
28-days Compressive Strength (MPa)		45.79
Setting Time (minutes)	Initial	62
	Final	190

Fly ash (FA): FA is a by-product obtained from burning pulverized coal in electric power generating plants. The FA used in the present work had a specific gravity of 2.23, and a normal consistency of 45%.
Rice husk ash (RHA): RHA is produced by incinerating the husk of rice paddy. Rice husk is a by-product of rice milling industry. The RHA used in the present work had a specific gravity of2.13, and a normal consistency is 26%.
Aggregates: The fine aggregate(sand) can be finer than normal, as the material <150micron may help increase cohesion, there by resisting segregation. River sand was used as fine aggregate, and crushed stone with a maximum size of 12mm was used as coarse aggregate [6]. Table 2 shows the test results on aggregates.

Table 2: Test results on aggregates

Test	Test Results	
	Coarse Aggregate	Fine Aggregate
Bulk Density (kg/m^3)	1404	1500
Specific gravity	2.65	2.64

Super plasticizer (SP): This is a chemical compound used to increase the workability of the mix without adding more water.The super plasticizer used in this work is Cera Hyper plasticizer HRW 40.
Water: Potable water was used for mixing and curing.

II.2. The Mix Proportioning:

The process of mixture proportioning is one of the important tasks in achieving SCC properties. So far a mix design procedure to get the proportion of the ingredients in the SCC is not standardized. No method specifies the grade of concrete in SCC, except the Nan Su et al. method [7]. In this work, mix designing was carried out for M25 grade concrete, and the procedure is based on the method proposed by Nan Su et al. This method was preferred as it has the advantage of considering the strength of the SCC mix. Unlike other proportioning methods like the Okamura and EFNARC methods, it gives an indication of the target strength that will be obtained after 28days of curing. The water to powder ratio was varied so as to obtain SCC mixes of various strengths. The principal consideration of the proposed method is to fill the paste of binders into voids of the coarse aggregate piled loosely. The strength of SCC is provided by the aggregate binding by the paste at hardened state, while the workability aspect of SCC is provided by the binding paste at fresh state. Therefore, the amount of coarse and fine aggregates, binders, mixing water and SP will be the main factors influencing the properties of SCC[8]. The quantities of the SCC ingredients obtained are listed in Table 3.

Table 3: Quantities of SCC ingredients in kg/m^3

Mix	Cement	FA	RHA	Coarse aggregate	Fine aggregate	Water	SP
FA based SCC	200	301.4	-	743	961	216.2	9
RHA based SCC	200	-	331.3	743	961	166.4	9.6

II.3. Tests conducted:

II.3.1 Fresh concrete tests: Once a satisfactory mix is arrived at, it is tested in the lab for properties like flowing ability, passing ability and blockage using Slump cone, L-Box, U-Box and V-funnel apparatus. The slump flow test is used to assess the horizontal free flow of SCC in the absence of obstructions, and it indicates the resistance to segregation, and filling ability of concrete. On lifting the slump cone filled with concrete the average diameter of spread of the concrete is measured. Also T50 time is taken in seconds from the instant the cone is lifted to the instant when the horizontal diameter of the flow reaches 500mm.

The flow ability of the fresh concrete can be tested with the V-funnel test, whereby the flow time is measured. The funnel is filled with about 12 liters of concrete and the time taken for it to flow through the apparatus is measured. Shorter flow time indicates greater flow ability.

L-box test assesses filling and passing ability of SCC, and serious lack of stability (segregation) 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, i.e. ratio of the height of the concrete at the end of the horizontal section (H_2) to height of concrete at beginning of horizontal section (H_1) is determined.

U-box test is used to measure the filling and passing ability of SCC. The apparatus consists of a U shape vessel that is divided by a middle wall into two compartments. The U-box test indicates the degree of compactability in terms of filling height i.e. H_1-H_2, the difference of height of concrete attained in the two compartments of U-box.

The mixes are checked for the SCC Acceptance Criteria laid down by the European Federation of Specialist Construction Chemicals and Concrete Systems (EFNARC) [9] listed in Table 4.

II.3.2 Hardened Concrete Tests: The tests on hardened concrete include compressive strength (cube size: 150mm side), split tensile strength (cylinder size: length 300mm and diameter 150mm), and flexural strength (prism size: 100x100x500mm) each for 7 days, 14 days and 28 days of curing [10] [11].

III. RESULTS AND DISCUSSIONS

III.1 Fresh concrete test results:

The results of slump flow, L-Box, U-Box, V-funnel tests are given in Table 4

Table 4. Test results of fresh SCC mixes

Test	Unit	Range(as per EFNARC)	Test Results		Remarks
			FA based SCC	RHA based SCC	
Slump flow	mm	650-800	740	710	Acceptable
\T50 slump flow	sec	2-5	4	2.5	Acceptable
L- box (H2/H1)	-	0.8-1.0	0.9	0.86	Acceptable
U- box (H1- H2)	mm	0-30	25	21	Acceptable
V- funnel	sec	6-12	11	9	Acceptable

Both the fresh SCC mixes were tested for filling ability (slump flow by Abrams cone, and V- Funnel) and passing ability (L-box, U-box). All the test results satisfied the acceptance criteria for rheological properties of SCC as laid down by EFNARC, as seen from Table 4.

III.2 Hardened concrete test results:

Table 6: Tests results on Hardened SCC specimens

Strength (in MPa)		FA based SCC	RHA based SCC
Compressive strength	7 days	13.69	11.28
	14 days	19.55	12.95
	28 days	21.80	14.10
Split tensile Strength	7 days	0.85	0.74
	14 days	1.14	0.89
	28 days	1.29	1.14
Flexural Strength	7 days	2.54	2.27
	14 days	3.66	3.25
	28 days	4.84	3.77

The hardened properties like compressive strength, split tensile strength and flexural strength were checked and found that not all the test results were satisfactory. Fig. 1 through Fig. 3 show the graphical representation of the strengths against the age at loading for the different mixes. The low strength of RHA based SCC may possibly be due to the high amount of RHA (62.35%), and the low strength of FA based SCC may possibly be due to the high amount of FA (60.11%) in the mixes.

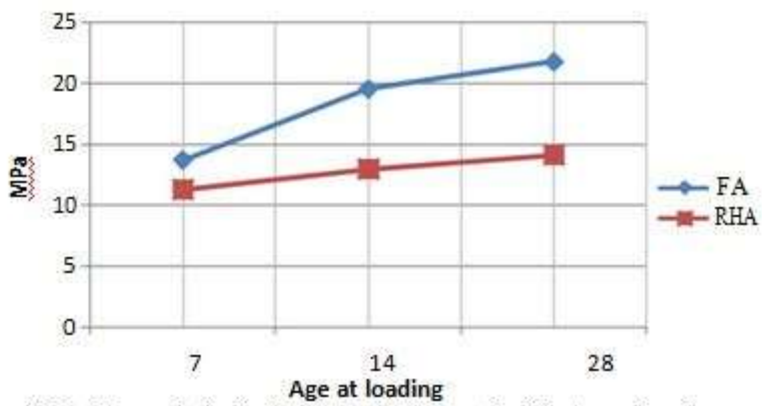

Fig 1. The variation in Compressive Strength with Age at loading

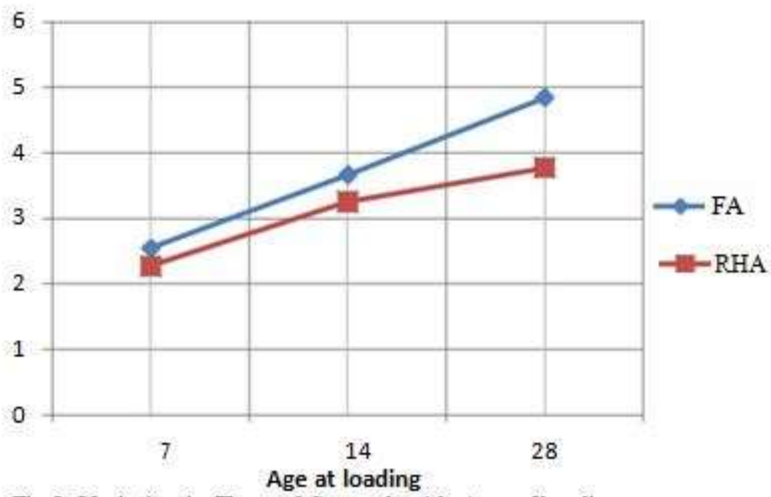

Fig 2. Variation in Flexural Strength with Age of loading

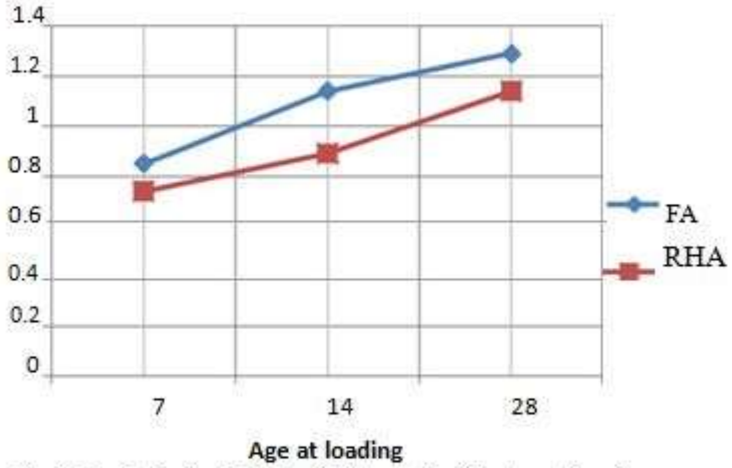

Fig 3. Variation in Split Tensile Strength with Age of loading

IV. CONCLUSIONS

It is evident from the experimental results that the compressive strength decreases with the increase in percentage of fly ash and increases with the increase in percentage of silica fume. The SCC mixes containing fly ash, and that containing rice husk ash as filler materials were tested for their fresh properties as per EFNARC guidelines. Both SCC mixes have satisfied all the acceptance criteria laid down by EFNARC.

The hardened properties like compressive strength, split tensile strength and flexural strength were checked and found that not all the test results were satisfactory. But a comparative study of the test results shows that SCC containing FA has better compressive strength, split tensile strength and flexural strength than SCC containing RHA.

Past research has shown that the optimum level of cement replacement with RHA for normal concrete is 30% [12]. The low strength of rice husk ash based SCC may be due to the high amount of rice husk ash (62.35% of total powder). Also, the optimum level of cement replacement with fly ash for normal concrete is 35% [2].The low strength of fly ash based SCC is possibly due to the high amount of fly ash (60.11% of total powder).

It is also observed from the results that the calculated cement content (200kg/m3) as per the Nan Su et al. method was not adequate to give the required strength to the mix. The quantity of cement content calculated was possibly not sufficient to bind all the ingredients in the mix. As a consequence, more trials with higher percentage of cement are required to attain the target strength.

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