Effect of Rice Husk Ash on Fresh and Hardened Properties of Self Compacting Concrete

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Abstract

Self-compacting concrete (SCC) is one of the High Performance Concrete with excellent strength and durability properties. However, its mix proportioning and testing methods for flow characteristics are different from those of the ordinary concrete. SCC has high powder content and a super plasticizer for enabling flow while keeping coarse aggregate in a viscous suspension. The powder is usually cement and a filler material. In this paper an attempt has been made to study fresh and hardened properties of self compacting concrete using Rice Husk Ash as partial replacement of cement in different percentages in addition to filler. Modified Nan-su method has been used for design mix as the study was carried out for medium strength of concrete.

Key Words: Rice Husk Ash (RHA), Self Compacting Concrete, Strength, Durability, Modified Nan-su Method.

1. Introduction

Self-compacting concrete (SCC) is an innovative concrete that does not requires vibration for placing and compaction. It is able to flow under its own weight, completely filling formwork and achieving full compaction, even in the presence of congested reinforcement. The hardened concrete is dense, homogeneous and has the same mechanical properties and durability as traditional vibrated concrete. Popularity of using self-compacting concrete (SCC) in concrete construction is increased in many countries, since SCC is effectively applied for improving durability of structures while reducing the need of skilled workers at the construction site.

Self-compacting concrete (SCC) offers various advantages in the construction process due to its improved quality, and productivity. SCC has higher powder content and a lower coarse aggregate volume ratio as compared to normally vibrate concrete (NVC) in order to ensure SCC's filling ability, passing ability and segregation resistance. If Only cement is used in SCC, then it become costly, susceptible to be attacked and produces much thermal crack. It is therefore necessary to replace some of the cement by addition of filler to achieve an economical and durable concrete.

Now days, the ecological trend aims at limiting the use of natural raw materials in the Field of building materials and hence there is an increased interest in the use of alternative materials (waste) from various industrial activities, which presents significant advantages in economic, energetic and environmental terms.

In this paper Rice Husk Ash is used as a mineral admixture. Rice husk is an agricultural residue obtained from the outer covering of rice grains during milling process. It constitutes 20% of the 500 million tons of paddy produced in the world. Initially rice husk was converted into ash by open heap village burning method at a temperature, ranging from 300°C to 450°C. When the husk was converted to ash by uncontrolled burning below 500°C the ignition was not completed and considerable amount of unburned carbon was found in the resulting ash. Carbon content in excess of 30% was expected to have an adverse effect upon the pozzolanic activity of RHA. The ash produced by controlled burning of the rice husk between 550°C and 700°C incinerating temperature for 1 hr, transforms the silica content of the ash into amorphous phase. The reactivity of amorphous silica is directly proportional to the specific surface area of ash. The ash so produced is pulverized or ground to required fineness and mixed with cement to produce blended cement. About 600 million tons per year of rice paddy was produced all over the world out of which an estimated 120 million tons in year 2010-2011 was grown in INDIA. Rice husk is the outer covering of the rice grain that is removed as a result of milling process on rice kernel. Huge amounts of RHA obtained after burning of rice husk, probably has no use at all and getting rid of it is also a problem.

2. Literature Review

Shazim Ali Memon et al [1] conducted a study of substantiate the feasibility of developing low cost SCC using RHA. Test has been carried out on fresh and hardened properties of SCC using RHA as compared to control concrete. The compressive strengths developed by the SCC mixes with RHA were comparable to the control concrete. Cost analysis showed that the cost of ingredients of specific SCC mix is 42.47% less than that of control concrete.

K. Ganesana et al [2] investigated Rice husk ash blended cement with respect to assessment of optimal level of replacement for strength and Permeability properties of concrete. The properties of concrete investigated include compressive strength, splitting tensile strength, water absorption, sorptivity, total charge-passed derived from rapid chloride permeability test (RCPT) and rate of chloride ion penetration in terms of diffusion coefficient. This particular RHA consists of 87% of silica, mainly in amorphous form and has an average specific surface area of 36.47 m^2/g. Test results obtained that up to 30% of RHA could be advantageously blended with cement without adversely affecting the strength and permeability properties of concrete.

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S. Kanakambara Rao [3] conducted a review on Experimental Behavior of Self Compaction Concrete blended with Rice Husk Ash. He studied on experimental behavior of SCC with RHA as a partial replacement of cement. RHA has been used as a highly reactive pozzolanic material to improve the microstructure of the interfacial transition zone (ITZ) between the cement paste and the aggregate in self-compacting concrete. The basic objective of the study is to understand the rheological and strength characteristics of the self-compaction mixes with different compositions of RHA. Different replacements percentages of RHA with cement and different water cementitious material ratio are determined for both normal concrete and SCC.

Annahita Ansari performed (4) carried out the experimental work using Rice husk ash in concrete; addition to improving mechanical properties of concrete could act to reduce fuel consumption and co amount in the production of concrete. Also with using in the Northern indigenous construction of Iran and other rice producer countries help environment health with regard to sustainable transportation.

M.A.Ahmadi et al (5) studied the Mechanical properties up to 180 days of self compacting and ordinary concretes with rice-husk ash (RHA), from a rice paddy milling industry in Rasht (Iran). Two different replacement percentages of cement by RHA, 10%, and 20%, and two different water/cementitious material ratios (0.40 and 0.35), were used for both of self compacting and normal concrete specimens. The results are compared with those of the self compacting concrete without RHA, with compressive, flexural strength and modulus of elasticity. It is concluded that RHA provides a positive effect on the Mechanical properties at age after 60 days. Base of the result self compacting concrete specimens have higher value than normal concrete specimens in all test except modulus of elasticity. Also specimens with 20% replacement of cement by RHA have the best performance.

Vilas V. Kirjinni & Shrishail B. Anadinn.[6] They emphasized on the mixture proportion which is one of the important parameter in the self compacting concrete. They have used modified Nan-su method and obtained mix design in normal grades with different mineral admixtures & the compressive strength and flow properties of SCC were also studied.

Vilas V. Karjinni, Shrishail B.Anadinni, Dada S. Patil et al. [7] Presented a comparative evaluations of fresh and hardened properties of SCC using different mineral admixture with Nan-su and Modified Nan-su mix design method.

On the basis of above studies, many researchers have reported the use of powder as mineral admixtures in SCC. An extensive work involving the study of performance of RHA individually in SCC as a powder or filler and as a partial replacement of cement qualitatively and quantitatively has not been reported, considering the conservation of cement, natural resource is to be used as a mineral admixture in SCC, the proposed investigation is needed.

3. Research Significance

Self-compacting concrete (SCC) has recently been one of the most important developments in the concrete technology. For a newly developing material like Self compacting concrete, studies on durability is of paramount importance for instilling confidence among the engineers and builders. The literature indicates that some studies are available on the SCC with different mineral admixture as powder content (filler), but comprehensive studies involving use of RHA individually in SCC as a powder or filler and as a partial replacement of cement qualitatively and quantitatively has not been reported. Hence, considering the gap in the existing literature, an attempt has been made to study the effect of mineral admixture (RHA) on the fresh and hardened properties of self compacting concrete. This involves compressive strength, flexural strength, split tensile strength and water absorption test.

4. Materials

4.1 Cement

In this experimental study, Ordinary Portland Cement conforming to IS: 8112-1989 [12] was used. The physical and mechanical properties of the cement used are shown in Table 4.1.

Physical Property	Results
Fineness (retained on 90-µm) sieve)	8%
Normal Consistency	28%
Vicat initial setting time(minutes)	75
Vicat final setting time (minutes)	215
Specific gravity	3.15
Compressive strength at 7-days (Mpa)	20.6
Compressive strength at 28-days (Mpa)	51.2

Table 4.1: Properties of cement

4.2 Aggregates

Locally available natural sand with 4.75 mm maximum size was used as fine aggregate, having specific gravity, fineness modulus and unit weight as given in Table 4.2 and crushed stone with 16mm maximum size having specific gravity, fineness modulus and unit weight as given in Table 4.2 was used as coarse aggregate.

Table 4.2: Physical properties of coarse and fine aggregates

Property	Fine Aggregate	Coarse Aggregate
Specific Gravity	2.66	2.95
Fineness Modulus	3.1	7.69
Surface Texture	Smooth	--
Particle Shape	Rounded	Angular
Crushing Value	---	17.40
Impact Value	---	12.50

4.3 Rice Husk Ash (RHA)

Rice husk is an agricultural residue obtained from the outer covering of rice grains during milling process. The ash produced by controlled burning of the rice husk between 550°C and 700°C incinerating temperature. For this work RHA was obtained from Manikaji Metachem Private Limited at Murtizapur.

Table 4.3 Physical properties of RHA.

Physical Properties	Results
Colour	Grey (Blackish)
Specific Gravity	1.64

4.4 Super Plasticizer (SP)

The High range water reducing super plasticizer increases the workability of self compacting concrete mixes. High range water reducing superplasticizer was used. The admixture MASTERGLENIUM SKY-8276 (BASF) was used as a superplasticizer. It was used to provide necessary workability.

Table 4.4: Physical Properties of Super plasticizer

Physical Properties	Results
Density	1.2 kg / l
Colour	Gray

5. Mix Proportioning

The mix proportion was done based on the Modified Nan-Su method. The mix design was carried out for M30 normal grade of self compacting concrete with RHA as partial replacement of cement with a fraction of 0%, 10%, 20% &30%

Table 5.0: Quantities of Materials for 1m^{3}of SCC mixes.

Mix	Cement (kg/m^3)	RHA (Filler) (kg/m^3)	RHA as Cement Replacement (kg/m^3)	Total Powder Content (kg/m^3)	Fine Aggregate (kg/m^3)	Coarse Aggregate (kg/m^3)	W/P (0.40) (kg/m^3)	SP (1.9 %) (kg/m^3)
Mix-0	382	104	0.00	486	710	612	195	9.234
Mix-1	343.8	104	38.2	486	710	612	195	9.234
Mix-2	305.6	104	76.4	486	710	612	195	9.234
Mix-3	267.2	260	114.8	642	710	612	232	5.136

Mix-0:- 0% Replacement of Cement with RHA.
Mix-1:- 10% Replacement of Cement with RHA.
Mix-2:- 20% Replacement of Cement with RHA.
Mix-3:- 30% Replacement of Cement with RHA.

5.1 Self Compactability Tests on SCC mixes

Various tests were conducted on the trial mixes to check the quality control test for SCC are performed to ensure that the requirement of Filling ability, Passing ability and flow ability are as required.

Table 5.1: Requirement of Fresh SCC

Method	Properties	Range of values
Flow value	Filling ability	650-800mm
V-funnel	Viscosity	6-12 sec
L-box	Passing ability	0.8 - 1.0

6. Result and Discussion

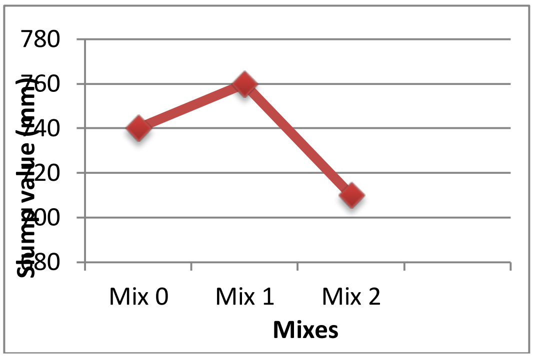
6.1 Fresh properties SCC

6.1.1 Rice Husk Ash (RHA)

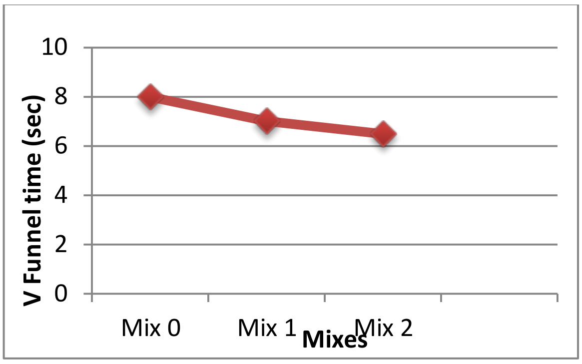
Table 6.1.1 shows results of fresh state properties of SCC with 0%, 10%, & 20% and 30% replacement of cement by RHA. Here, replacement of 30% cement by RHA did not satisfy the requirement of fresh state properties of SCC as per EFNARC, European Guidelines for SCC **(10).** The Slump flow values increased from 740-760 for 0% to 10% replacement of cement but got decreased for 20% replacement of cement by RHA. V-funnel values decreased with the increase in replacement of cement by RHA. & L-box test values decreased with the increase in replacement of cement by RHA. Hence up to 20% replacement of cement can be allowed to satisfy the requirement of fresh state properties of SCC. Since water content and dosages of superplasticizer were kept constant for all the mixes. Graph 6.1.1 shows variation in slump flow values with respect to different mixes. Graph 6.1.3 shows variation in V-funnel values with respect to different mixes. Graph 6.1.2 shows variation in L-box values with respect to different mixes.

Table 6.1.1 Test results for self-compactibility

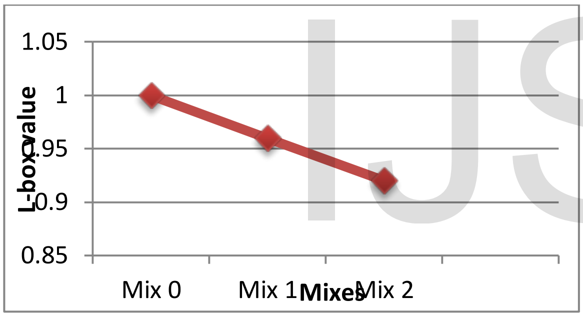
Types	**Mix 0**	**Mix 1**	**Mix 2**	**Recommended Values (2,3)**
Slump Flow Test	740	760	710	650-800
V-Funnel Test	8	7	6.5	6 - 12
L-Box Test	1	0.96	0.92	0.8 - 1



Graph 6.1.1: Slump Flow Value with RHA



Graph 6.1.2: V-funnel Value with RHA



Graph 6.1.3: L-Box Value with RHA

RHA was used to replace the cement content by three various percentages (10, 20 and 30 %). The partial replacement with RHA was carried out for M30 grades of concrete. To fulfil the requirement of SCC in fresh state and evaluate flow characteristic using slump cone, V-funnel, & L-box tests and to fix dosage of superplasticizer (HRWRA) as per EFNARC [8] guidelines and fix the dosage of water /powder ratio was needed. The test results are presented in the table VII.

Table 6.1.2: Fresh properties SCC

Test	**Mix-0**	**Mix-1**	**Mix-2**
Slump Flow Test	780m	710 mm	670 mm
V-Funnel Test	6.65 Sec	6.60 Sec	6.76 Sec
L-Box	1.00	0.89	0.88

6.2 Hardened Properties of SCC

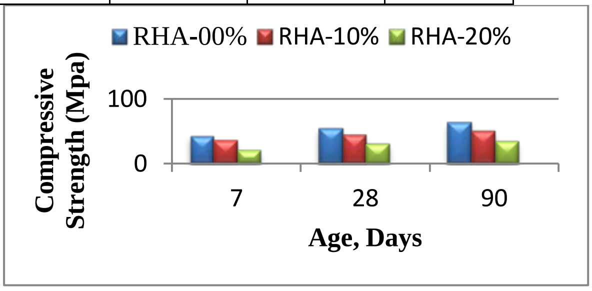
All the mixes were tested for various hardened properties like compressive strength, flexural strength & Split Tensile Strength and water absorption test as per Indian Standards.

6.3 Cube compressive strength

Standard cubes of 100 mm X 100mm X 100mm size were prepared for 7 days, 28 days and 90 days compressive strength. The compressive strength of three cubes with its average value is reported in Table 6.3. Table shows that with the increase in replacement of cement with RHA the compressive strength decreased at all ages of test. For 0%, 10%, and 20% replacement of cement with RHA better results were obtained and for replacement of 20% cement with RHA target strength for M: 30 grade of SCC was obtained. The Compressive strengths for Mix-2 obtained were 21 N/mm^2, 31.5 N/mm^2 and 36.22 N/mm^2 at 7 days, 28 days and 90 days respectively. The compressive strength of M: 30 grade of SCC was monitored up to 90-day showed an increase of 13 to 14 %, over its 28-day strength. Graph 6.3 shows the variation of compressive strength with age for different mixes.

Table 6.3: Results of Compressive strengths of SCC (N/mm^2)

Mix	7 days	28 days	90 days
Mix-0	44	56	64.4
Mix-1	37	45	51.75
Mix-2	**21**	**31.5**	**36.22**



6.3: Variation of compressive strength with age

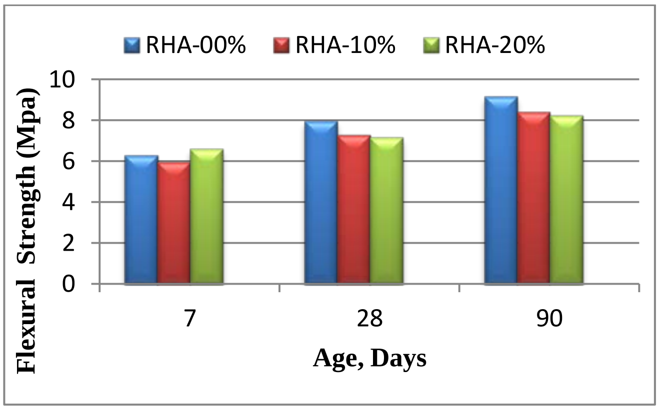
Mix-0:- 0% Replacement of Cement with RHA.

Mix-1:- 10% Replacement of Cement with RHA.

Mix-2:- 20% Replacement of Cement with RHA.

6.4 Flexural strength

Standard prisms of 150 mm x 150 mm x 700 mm size were cast for 7 days, 28 days and 90 days flexural strength test. The flexural strength of three prisms with its average value is reported in Table 6.4. Table shows that with the increase in replacement of cement with RHA the flexural strength decreased at all ages of test. For 0%, 10%, and 20% replacement of cement with RHA better results were obtained and for replacement of 20% cement with RHA target strength for M: 30 grade of SCC was obtained. The flexural strengths for Mix-2 obtained were 6.6 N/mm^2, 9.9 N/mm^2 and 11.38 N/mm^2 at 7 days, 28 days and 90 days respectively. The flexural strength of M: 30 grade of SCC monitored up to 90-day showed an increase of 13 to 14%, over its 28-day strength. Flexural strength was much better than target strength for M: 30 grade of Concrete. Graph 6.4 shows the variation of flexural strength with age for different mixes.



Graph 6.4: Variation of flexural strength with age

Table 6.4: Results of Flexural strengths of SCC (N/mm^2)

Mix	7 days	28 days	90 days
Mix-0	6.3	7.98	9.177
Mix-1	6	7.32	8.418
Mix-2	6.6	7.17	8.25

6.5 Split tensile strength

Standard cylinders of 150 mm diameter and 300 mm length were cast for 7 days, 28 days and 90 days split tensile strength test. The split tensile strength of three cylinders with its average value is reported in Table 6.5. Table shows that the increase in replacement of cement with RHA the split tensile strength decreased at all ages of test. 0%, 10%, and 20% replacement of cement with RHA obtained better results and replacement of 20% cement with RHA obtained target strength for

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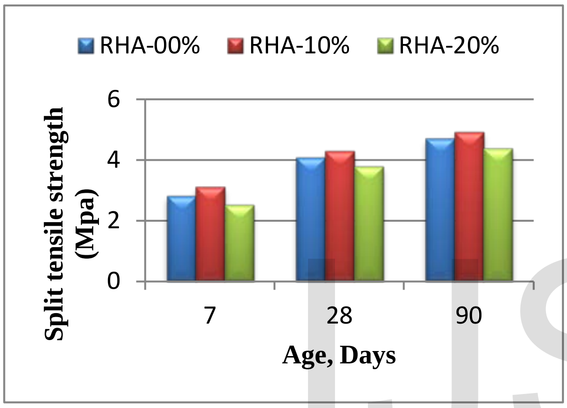
M: 30 grade of SCC. The split tensile strengths for Mix-2 obtained were 2.54 N/mm^2, 3.81 N/mm^2 and 4.381 N/mm^2 at 7 days, 28 days and 90 days respectively. The split tensile strength of M: 30 grade of SCC monitored up to 90-day showed an increase of 13 to 14 %, over its 28-day strength. Tensile strength was much better than target strength for M: 30 grade of Concrete. Graph 6.5 shows the variation of split tensile strength with age for different mixes.

Table 6.5: Results of Split tensile strength of SCC (N/mm^2)

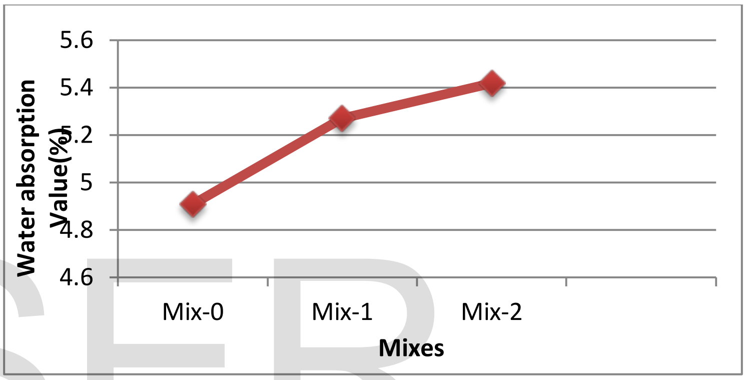
Mix	7 days	28 days	90 days
Mix-0	2.83	4.1	4.71
Mix-1	3.113	4.3	4.95
Mix-2	**2.54**	**3.81**	**4.381**

Table No. 6.6 Water absorption values

Mix	Water absorption value
Mix-0	4.91 %
Mix-1	5.27 %
Mix-2	5.42 %



Graph 6.5: Variation of split tensile strength with age



Graph 6.6: Variation of Water absorption values with mixes

6.6 Water absorption Test

The water absorption of SCC with RHA was determined by immersing standard cube specimens in water. After 48 hours, the average percentage weight difference of the cubes is represented as water absorption of SCC in Table No. 6.6. With the increase of replacement of cement by RHA the water absorption were was gradually increase in less percentage. Graph 6.6 shows variation in water absorption with different mixes. The water absorption is obtained within permissible limit.

7. Conclusions

On the basis of experimental investigations carried out, it is concluded that,

i. RHA can be used in large quantities in SCC and cement content can be reduced to as low as 305.6 kg/m^3 for M: 30 grade of SCC.

ii. Required compressive strength, flexural strength and split tensile strength, flowability and adequate self compactibility were obtained.

iii. The slump flow value was obtained within the acceptable value up to replacement of 20% cement by RHA.

iv. The V-funnel & L-box Test showed acceptable value up to replacement of 20% cement by RHA.

v. Hence, as per the requirements of fresh state properties of SCC the Addition of 20% RHA can be allowed.

vi. The SCC mixes with replacement of 20% cement by RHA gave optimum results.

vii. Flexural and Split tensile strength was much better than target strength for M: 30 grade of Concrete.

viii. RHA being pozzolanic materials shown much better performance after 90 days curing as compared with the same at 28days.

ix. It was observed that the water absorption within acceptable limit. Hence the concrete will be impermeable.

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