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Experimental Study on Properties of Self Compacting Concrete with Rice Husk Ash and Fibre

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ABSTRACT

The present study aims to investigate the fresh, strength and durability properties of self-compacting concrete (SCC), with Rice Husk Ash as partial replacement of cement, incorporating steel fibres. For this purpose Rice Husk Ash from locally rice mills was used. A super plasticizer of Fosroc chemicals named 'STRUCTURO 100M' (an aqueous solution of carboxylic ether polymer) was used to increase the workability of concrete. The super plasticizer dosage was kept constant for all the SCC mixes. To make the SCC mix economical, cement was replaced with Rice Husk Ash (36% and 29%). The proportions of coarse as well as fine aggregates were kept constant for all mixes. Steel fibres (0-1.5 %) were incorporated in the mixes to improve the strength properties of SCC while satisfying the fresh properties of SCC. Slump flow (diameter and T_{500}) test, V-funnel (T_{10sec} and T_{5min}) test, L-box test and U-box test were carried out to obtain the fresh properties of SCC mixes i.e. filling ability, passing ability and segregation resistance. Strength properties of hardened concrete were investigated in terms of compressive strength, split tensile strength and flexural strength. Durability properties i.e. effect of chemical action on hardened concrete was investigated in terms of compressive strength. Tests results show that compressive, split tensile and flexural strengths increased with increase of fibre content with flexural strength being most affected with increase of fibre content upto 1.5%. All the mixes, satisfied most of the requirements of fresh properties as per EFNARC specifications, for SCC mix.

Keywords: SCC, RHA, Fly Ash, Steel Fibers.

I. INTRODUCTION

Self-compacting concrete (SCC) is an innovative concrete that does not require 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 engineering properties and durability as traditional vibrated concrete. SCC was developed in Japan by Okamura in late 1980's to be mainly used in highly congested reinforced concrete structures in seismic region. SCC offers a rapid rate of concrete placement, with faster construction times and ease of flow around congested reinforcement as compared to normal vibrated concrete. Steel fibres when incorporated in concrete, strengthens concrete and saves it from shrinkage or micro-cracks which generally leads to failure of concrete. Also, SCC gives better quality of concrete without the requirement of skilled labour. SCC consists of same components as the normal vibrated concrete. These components are cement, fine aggregate, coarse aggregate, water, additives and admixtures.

These components are so adjusted so that concrete flows under its own weight, passes through narrow openings of reinforcement and finally, completely fills the form work without segregation of coarse aggregates in absence of vibration. Also, it gives strength equivalent to NVC. In this way, flowability, passing ability and segregation resistance are essential properties of concrete to be considered as self-compacting concrete. However, the first two properties i.e. flow and passing ability are in opposition to the last one i.e. segregation resistance. So, SCC matrix should not only be sufficiently viscous to avoid segregation but also should have sufficient mobility to assure appropriate filling of form work. In this way, SCC in plastic state exhibits three basic characters, namely, flowability, self-levelling ability and resistance against segregation. The flowability of SCC is obtained by using proper admixture. Stability or resistance to segregation of plastic concrete is achieved by increasing the total fines content in concrete or by modifying viscosity.

Rice husk ash is produced by incinerating the husks of rice paddy. Rice husk is a by-product of rice milling industry. Controlled incineration of rice husks between 500^0C and 800^0C produces non-crystalline amorphous RHA (Mehta and Monteiro 1993, Malhotra 1993). RHA is whitish or gray in color. The particles of RHA occur in cellular structure with a very high surface fineness. They have 90% to 95% amorphous silica (Mehta 1992). Due to high silica content, RHA possesses excellent pozzolanic activity.

SCC have advantages over NC but still in hardened state it behave same as NC. So, SCC in hardened state have some limitations due to which fibres should be added to improve its properties. The durability of concrete when reinforced with conventional rebars is a major concern in aggressive environments. To address this problem, there have been efforts, in recent years, to develop alternatives to conventional rebars. Fibre reinforced concrete have shown better behaviour because of their inherent ability to stop or delay crack propagation. The main properties of FRSCC in tension, compression and shear are influenced by the type of fibre, volume fraction fibres, aspect ratio and orientation of fibre in the matrix. In SCC, increased risk of drying shrinkage is likely due to the rich powder content and lower coarse aggregate content. SCC has a heterogeneous structure and due to complex structure of concrete, internal stresses developed. These internal stresses result in micro-cracks developed in fresh or hardened state of concrete. Such micro-cracks exist at cement paste-aggregate interfaces within concrete even prior to any load or environmental effects. When SCC is exposed to external structural loads or environmental effects, concentration of tensile stresses causes the growth of micro-cracks in size and number; propagation of micro-cracks and eventual joining micro-cracks yield to large cracks and lead to failure of concrete. Steel fibres improve properties of SCC like shear resistance, ductility and cracks control.

Sample : In order to study the interaction of Steel fibres (hooked end) and rich hush ash with concrete under compression, flexure, split tension and impact, 21 cubes, 21 beams and 21 cylinders were casted respectively. The experimental program was divided into four groups. Each group consists of 6 cubes, 6 cylinders and 6 beams, of 15x15x15cm, 15(dia) x30cm and 15x15x50cm respectively.

- The first group SCC-I containing 36% of rich hush ash with replacement of cement and also having the steel fiber %age 0, 0.5, 1.0, 1.5
- The second group SCC-II containing 29% of rich hush ash with replacement of cement and also having the steel fiber %age 0, 0.5, 1.0, 1.5

METHODOLOGY

There are various methods available for mix design like LCPC, Japanese method etc. There is no standard procedure available for SCC mix design. However, different research agencies like EFNARC, PCI etc. made their own specifications for SCC workability characteristics.

'Japanese method' was initially used for mix design of SCC. This method is most useful in field application, is given in Appendix-I. The mix ratio used for study is 1:1.64:1.09. rice husk ash was added with 36% and 29% replacement by weight of cement and water-to-powder ratio used was 0.53 and 0.51 respectively. Mix composition used in study is given in Table 1. The various proportions were adjusted to satisfy most of the fresh properties, so that the mix could be designated as SCC and further maintains itself on addition of fibres.

Table 1. Composition of SCC Mix

Mix No.		C (kg/m^3)	RHA (kg/m^3)	FA (kg/m^3)	CA (kg/m^3)	SP (L/m^3)	Steel Fibre (%)	Steel Fibre (kg/m^3)	Water (L/m^3)	w/p ratio
SCC-I	M1	350	200	900	600	5.5	0	0	291.5	0.53
	M2	350	200	900	600	5.5	0.5	11.6	291.5	0.53
	M3	350	200	900	600	5.5	1.0	23.24	291.5	0.53
	M4	350	200	900	600	5.5	1.5	36.86	291.5	0.53
SCC-II	M5	390	160	900	600	6.0	0	0	280.5	0.51
	M6	390	160	900	600	6.0	0.5	11.6	280.5	0.51
	M7	390	160	900	600	6.0	1.0	23.24	280.5	0.51
	M8	390	160	900	600	6.0	1.5	36.86	280.5	0.51

C – Cement, RHA – Rice Husk Ash, FA – fine aggragates, CA – coarse aggregates, SP – super plasticizer

Materials : Cement : In the present study Ordinary Portland Cement (43 grade) conforming to IS: 8112 was used. The cement was tested in accordance to test methods specified in IS: 4031 and results obtained are shown in Table 2

Table 2 Test Results of Cement Sample

S.No.	Name of Test	Experimental value	Requirements as per IS: 8112-1989
1.	Normal Consistency (%)	28	-
2.	Specific gravity	3.15	3.15
3.	Initial setting time (min)	95	More than 30
4.	Final setting time (min)	215	Less than 600
5.	Fineness (%)	5	10
6.	Soundness (mm)	2.55	Less than 10
7.	Compressive strength (MPa)		
(i)	3 days	26.10	Greater than equal to 23
(ii)	7 days	36.69	Greater than equal to 33
(iii)	28 days	46.56	Greater than equal to 43

Rice Husk Ash : Rice Husk ash obtained from locally rice industries was used**.** The finer quality of rice husk ash is obtained from the Electro-static precipitators in the plant. The physical and chemical properties of fly ash are shown in Tables 3 and 4

Table 3 Physical properties of Rice Husk Ash

Physical Properties	Test Results
Color	Grey
Specific Gravity	2.16

Table 4 Chemical properties of Rice Husk Ash

Chemical properties	Percentage by weight
Calcium oxide(CaO)	1.25
Silica(SiO_2)	92.25
Alumina(Al_2O_3)	0.18
Iron oxide(Fe_2O_3)	0.43
Magnesium oxide(MgO)	4.89
Total sulphur(SO_3)	0.10
Loss of ignition	4.2

Super Plasticizer : Super plasticizer **STRUCTURO 100(M)** (Fosroc chemicals) was used as admixture. Structuro 100(M) combines the properties of water reduction and workability retention. Specifications of super plasticizer are shown in Table 5

Table 5 Specifications of Super plasticizer (Source : Fosroc Chemicals)

Particulars	Properties
Appearance	Light yellow
Basis	Aqueous solution of Carboxylic ether polymer
pH	6.5
Density	1.06 kg/litre
Chloride content	Nil to IS:456
Alkali content	Less than 1.5g Na_2O equivalent per litre of admixture
Optimum dosage	0.5 to 3.0 litres per 100kg of cementitious material

Aggregates: Aggregates constitute bulk of the major portion of concrete. The characteristics of aggregates affect the properties of HPC. Fine and coarse aggregates used in the present study were tested and results are tabulated below.

Fine aggregates: Locally available natural river sand was used as the fine aggregate. Its sieve analysis and physical properties are shown in Tables 6 and 7

Table 6 Sieve Analysis of Fine Aggregate

IS sieve size (mm)	% Passing
10.0	100
4.75	96.6
2.36	92.6
1.18	85.25
600 µ	77.15
300 µ	22.4
150 µ	5.65

Fineness modulus = 2.6 **Sand conforms to Grading Zone III as per IS: 383-1970.**

Table 7 Physical Properties of Fine Aggregate

Particulars	Observed Value
Specific gravity	2.67
Fineness modulus	2.20
Bulk density (loose), Kg/m³	1590
Bulk density (compacted), Kg/m³	1780

3.4.4.2 Coarse aggregates : Crushed stone aggregates conforming to IS: 383-1970 was used as coarse aggregate. The sieve analysis and physical properties are shown in Tables 8 and 9 respectively.

Table 8 Sieve Analysis of Coarse Aggregate

IS sieve size (mm)	% Passing
20	100
16	100
12.5	97.5
10	49.64
4.75	0.54
2.36	0.0

Fineness modulus = 6.52 **Coarse aggregate conforms to IS: 383-1970.**

Table 9 Physical properties of Coarse Aggregate

Particulars	Properties
Specific gravity	2.67
Fineness modulus	6.52
Bulk density(Loose),kg/m³	1460
Bulk density(compacted),kg/m³	1650
Maximum size, mm	12.5

3.4.5 Fibres: The various types of fibres like carbon, glass, synthetic, steel etc. can be used in reinforcing concrete. In this study, steel fibres were incorporated in concrete. Crimped Steel fibres were added in different proportions of 0, 1, 2, and 3 % by volume of concrete mass fig 3.1. Physical properties of steel fibres used are shown in Table 10.

Table 10 Physical Properties of Steel Fibres

Particulars	Properties
Shape	Cylindrical
Type	Crimped
Length, mm	20
Diameter, mm	0.4
Aspect Ratio	50

Mixing of Specimens : The mixing of concrete was done to have a homogeneous mixture of all ingredients in concrete. The hand mixing was done for the ingredients. Batching of concrete was done by weight and the mixing process was as given below:

1. Firstly, coarse aggregate was weighed and put in mixing pan.
2. Fine aggregate was added to the coarse aggregate.
3. Rice husk ash and cement were added to the aggregates. The mixture was thoroughly dry mixed so that the colour of the mixture was uniform and no concentration of any material was visible.
4. Steel fibres were added as per proportion or quantity recommended for the study.
5. The required quantity of superplasticizer was added to required quantity of water. To make solution, water was added and mixed thoroughly until uniform colored mixture was obtained.
6. The addition of rice hush ash to the mix required more time of mixing. After the mix starts flowing, the fresh properties were found. The mixing process was continued till the completion of all the tests.

RESULTS

Tests Results of Fresh Concrete

Filling ability

The ability of SCC to flow and fill completely all spaces within the formwork, under its own weight. In order to study filling ability following test are conducted.

1. Slump flow 2. T_{500} slump flow 3. V-funnel

Passing ability

The ability of SCC to flow through tight openings such as spaces between steel reinforcing bars without segregation or blocking. To study passing ability following tests are conducted.

1. L-box 2. U-box

Segregation resistance

The ability of SCC to remain homogeneous in composition during transport and placing. To study segregation resistance following test is conducted:

V-funnel at T_{5min}

Table 11 EFNARC specifications

Workability characteristics	Test methods	Recommended values
Filling ability	Slump flow	650-800 mm
	T_{500mm}	2-5 sec
Passing ability	V-funnel	6-12 sec
	L-box H_2/H_1	0.8-1.0
	U-box (H_2-H_1)	0-30 mm
	J-Ring	<10 mm
Segregation resistance	V-funnel at T_{5min}	6-15 sec

Tests Results of Hardened Concrete

Compression Strength Test Results :

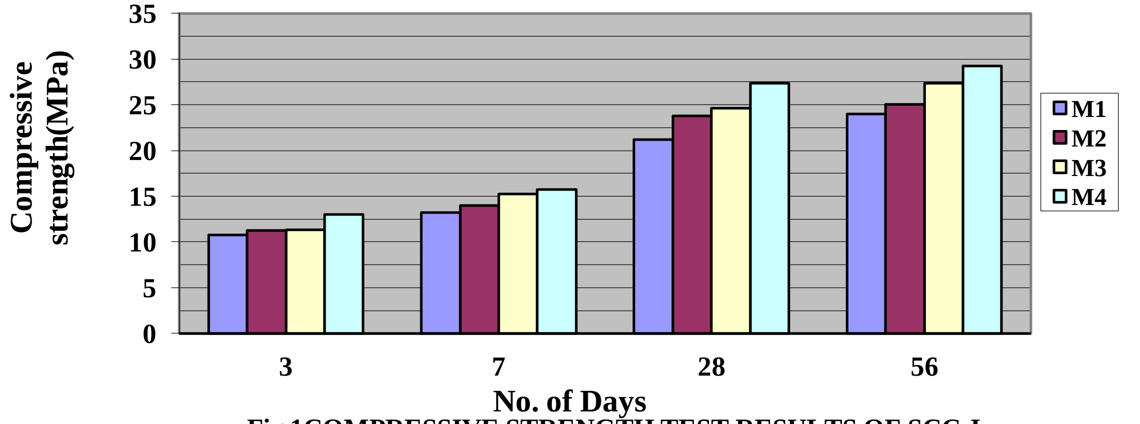

Fig 1COMPRESSIVE STRENGTH TEST RESULTS OF SCC-I

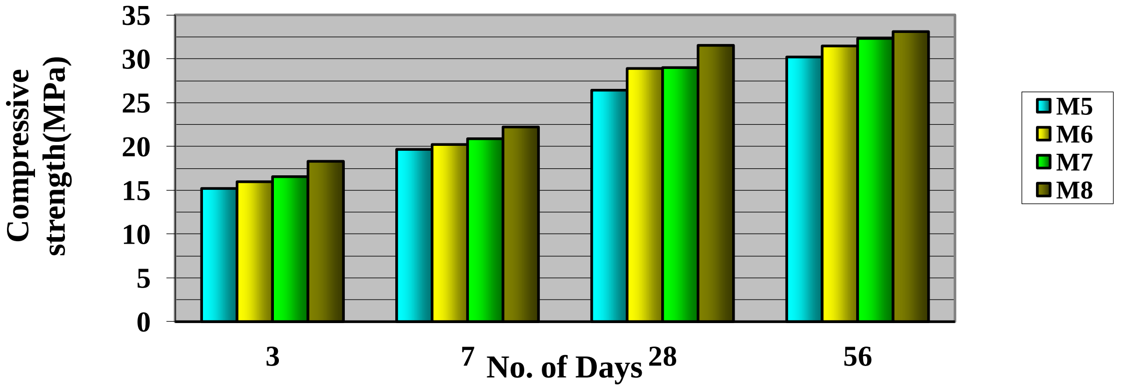

Fig 2COMPRESSIVE STRENGTH TEST RESULTS OF SCC-II

Split Tensile Strength Test.

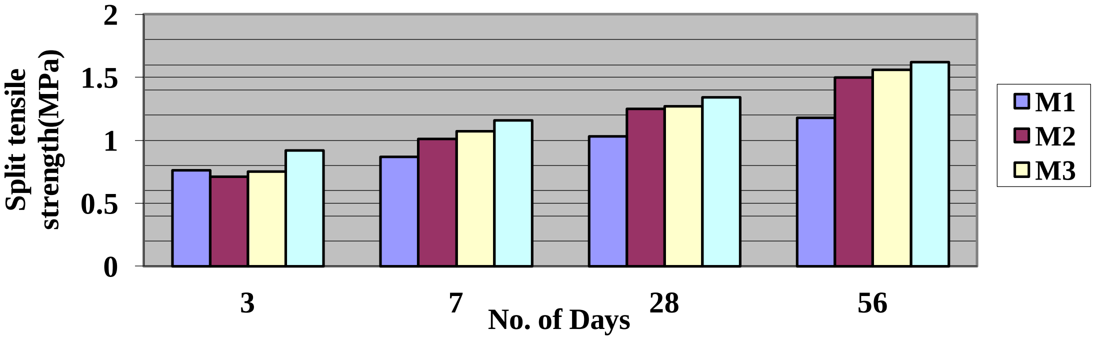

Fig 3 SPLIT-TENSILE STRENGTH RESULTS OF SCC-I

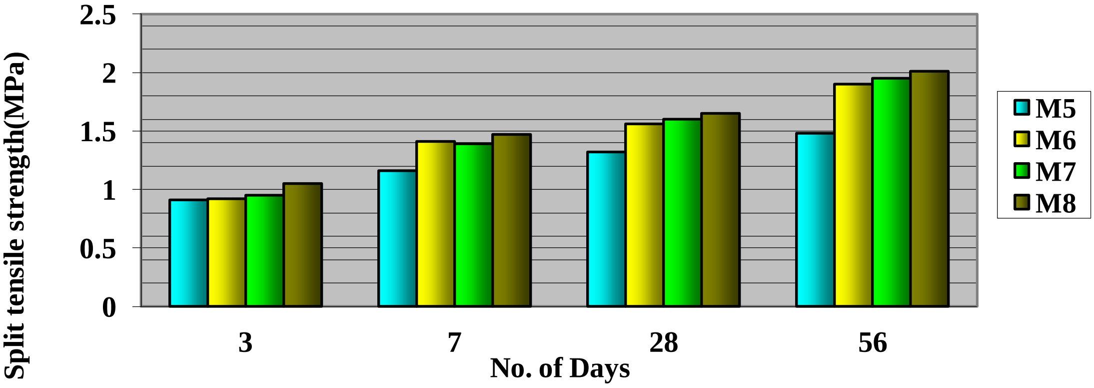

Fig 4 SPLIT-TENSILE STRENGTH RESULTS OF SCC-II

Flexural Strength Test Results

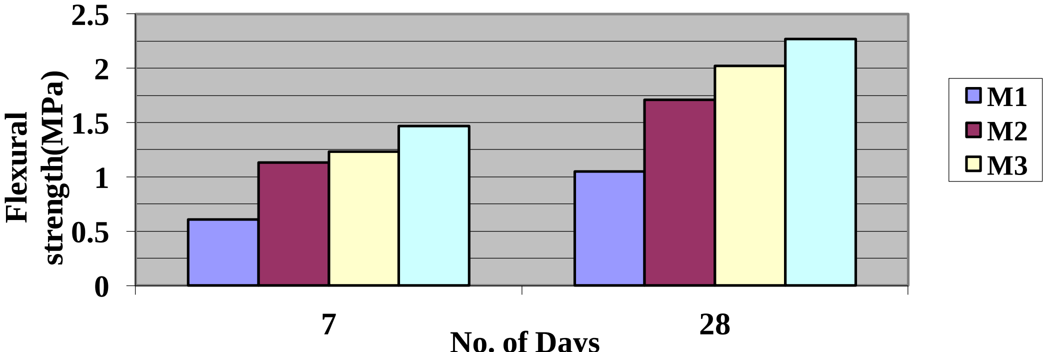

Fig 5 FLEXURAL STRENGTH TEST RESULTS OF SCC-I

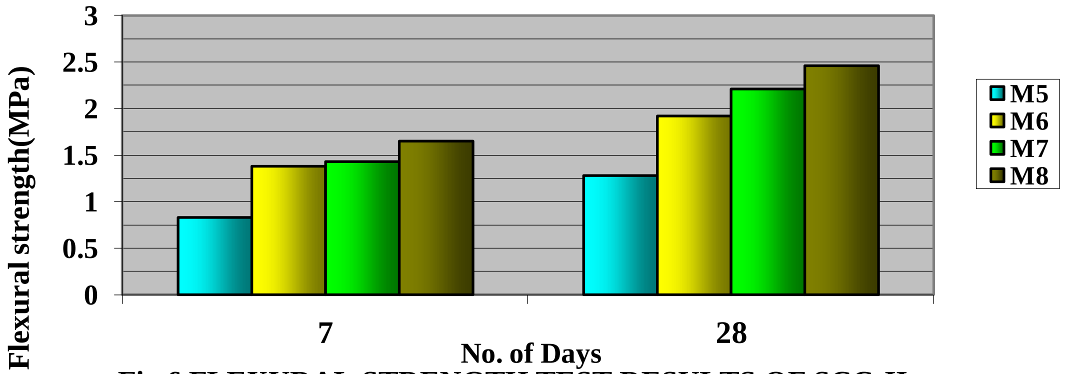

Fig 6 FLEXURAL STRENGTH TEST RESULTS OF SCC-II

CONCLUSIONS

1. The fresh properties of all SCC mixes satisfied the ranges specified by EFNARC except M_4 as shown in Table 4.1.
2. The 28-day compressive strength of SCC-I mixes with fibre content of 0.5%, 1% and 1.5%, were found to be increased by 12%, 16% and 29%, when compared to strength at 0% fibre content.
3. The 28-day compressive strength of SCC-II mixes with fibre content of 0.5%, 1% and 1.5%, were found to be increased by 9%, 9.7% and 19.4%, when compared to strength at 0% fibre content.
4. The 28-day split tensile strength of SCC-I mixes with fibre content of 0.5%, 1% and 1.5%, were found to be increased by 21%, 23% and 30%, when compared to strength at 0% fibre content.
5. The 28-day split tensile strength of SCC-II mixes with fibre content of 0.5%, 1% and 1.5%, were found to be increased by 18%, 21% and 25%, when compared to strength at 0% fibre content.
6. The 28-day flexural strength of SCC-I mixes with fibre content of 0.5%, 1% and 1.5%, were found to be increased by 63%, 92% and 115%, when compared to strength at 0% fibre content.
7. The 28-day flexural strength of SCC-II mixes with fibre content of 0.5%, 1% and 1.5%, were found to be increased by 50%, 72% and 92%, when compared to strength at 0% fibre content

SCOPE FOR FUTURE STUDY

1. Further study can be made by increasing the percentage of fibre content.
2. Different types of fibres like synthetic fibre, carbon fibres, or glass fibres may be used for future investigation.
3. Different types of waste materials like fly ash, silica fume, blast furnace also used for further studies.
4. In durability properties, SCC mixes containing fibres exposed to freezing and thawing cycles, can be investigated.
5. Further study can be done on SCC mixes containing fibres subjected to elevated temperatures.

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