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High Strength Self Compacting Concrete with Blended Cement containing Agricultural Waste

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Abstract

Rice husk is an agricultural waste generated in massive quantitites from rice processing units worldwide. With no worthwhile use, it is a waste material which creates disposal problems. It's high silica content makes it suitable for use with cement. Very limited investigations on rice husk ash have suggested improved strength/durability however its performance in high strength SCC has not been investigated to-date. This experimental study aimed at evaluating the properties of high strength SCC made from blended cements using rice husk ash, Portland cement, natural aggregates and sand. Wide ranging investigations covering most aspects of mechanical behaviour and permeability were carried out for various mixes for compressive strengths of 60N/mm^2, 80N/mm^2 and 100N/mm^2. Compressive strengths of high strength SCC specimen with blended cements for 60N/mm^2, 80N/mm^2 and 100N/mm^2 were observed to be higher by about 4 to 9% than the control specimen, for concrete with 50% Portland cement blended with 50% rice husk ash. Higher elastic moduli and reduced permeabilities were observed along with better sulphate and acid resistance. Better strengths and improved durability of such high strength SCC make it a more acceptable material for major construction projects.

Keywords: Sustainable construction, Rice husk Ash, Self-Compacting Concrete, High Strength Concrete, Agricultural Waste

INTRODUCTION

SCC is a more recent material and was first developed in Japan in 1988 in order to achieve durable concrete structures by improving quality in the construction process. Research and development work into SCC in Europe began in the 1990s and now nearly all the countries in Europe and USA conduct some form of research and development in this material. Self-compacting concrete (SCC) is fresh concrete with superior flowability under maintained stability (i.e. no segregation), allowing self-compaction. The three properties that characterize a concrete as self-compacting are flowing ability - the ability to completely fill all areas and corners of the formwork into which it is placed, passing ability - the ability to pass through congested reinforcement without separation of the constituents or blocking, resistance to segregation - the ability to retain the coarse components of the mix in suspension in order to maintain a homogeneous material. Another advantage is that less skilled labor is required in order for it to be placed, finished and made good after casting. High powder contents are needed in SCC to increase the cohesiveness. Ground granulated blast furnace slag (GGBS), pulverized fuel ash (PFA), or an inert material such as limestone powder are most commonly used according to Goodier, Khayat and Collepardi [1,2,3]. Little research is available in high strength SCC. Similarly, limited investigations on rice husk ash blended with Portland cement and used for normal/high strength concretes have suggested improved strength/durability vide Loo, Kibriya [4 – 8]. However, its performance in high strength SCC has not been investigated to-date. Large quantities of rice husk produced in the rice growing regions pose disposal problems since it has no useful usage. Blending rice husk ash with cements and using it in high strength concretes in major construction projects is likely to reduce the costs thereby aiding cheaper construction with added life due to improved durability. Bulk use of rice husk ashes in blending cements can consume large quantities of this agricultural waste material thereby also solving its disposal problems.

RESEARCH SIGNIFICANCE

The significance of this research is to investigate the possible use of an abundantly available agricultural waste product i.e. rice husk in high strength SCC and to study its characteristics.

MIX DESIGN

In order to establish a procedure for mix design a linear projection of compressive strength versus w/c ratio from Design of Normal Concrete Mixes method was considered initially beyond the limiting w/c ratio of 0.3 as given by Teychenne [9]. An initial estimate of density was made and later adjusted in the light of values actually obtained. Three high strength concrete mixes for characteristic strengths of 60, 80 and 100N/mm^2 were designed using ordinary Portland cement blended with 50% rice husk ash, crushed natural calcareous limestone aggregates (maximum 20mm diameter) and medium grade sand. Control mix contained 100% Portland cement. Table 1 gives the details of mixes.

Table 1. Design of High Strength Self Compacting Concrete mixes.

Characteristic Strength N/mm^2	W/C Ratio	Cement kg	Sand kg	Water kg	Aggregate kg	Super Plasticizer	VMA %
60	0.36	465	515	168	1302	4 l/m^3	0.04
80	0.32	565	490	180	1214	7 l/m^3	0.044
100	0.28	678	450	190	1124	11 l/m^3	0.05

Table 2. Properties of High Strength Self Compacting Concrete.

W/C Ratio	Mixes	Cube Strength 7Days N/mm^2	Cube Strength 28Days N/mm^2	Cube Strength 42Days N/mm^2	Cylinder Strength N/mm^2	Flexural Strength N/mm^2
0.36	Control	54	63	66	53.5	6.4
	Blended SCC	56	70	74	58	7.3
0.32	Control	73	82	85	66	7.9
	Blended SCC	74	88	94	74	9
0.28	Control	92	103	106	86	9.8
	Blended SCC	91	108	114	90	11.4

DESCRIPTION OF TESTS

Three specimen each from three different batches were used in all tests. Specimen used for different tests were as follows: -

Compressive strength/density	150mm cubes, 150mm diameter, 300mm long cylinders.
Flexural strength	150x150x750mm beams.
Stress/strain behavior	150mm diameter, 300mm long cylinders.
Static modulus of elasticity	150mm diameter, 300mm long cylinders.
Dynamic modulus of elasticity	150x150x750mm beams.
Ultrasonic pulse velocity	150mm cubes.
Initial surface absorption	150mm cubes.
Sulphate and Chloride resistance	150mm cubes. (Immersed in 5% H_2SO_4 and 5% HCl solutions for 90 days and measuring weight loss)

All specimen were cured in water at 20^0 C for 42 days before testing.

DISCUSSION OF TEST RESULTS

The properties of the high strength concretes produced are summarized in Tables 2 and 3.

Compressive strength

Compressive strength tests on cubes at 7, 28 and 42 days showed that the rate of development of strength of SCC with blended cement containing 50% rice husk ash + 50% Portland cement was similar to that for control specimen. The compressive strengths of high strength SCC with blended cement containing rice husk ash and Portland cement was somewhat higher than the control specimen. It was observed that compressive strengths kept increasing, as it can be seen from 42-day strengths, as due to low w/c ratios, water is required from external sources for hydration of cement which keeps progressing with time [10]. High strength SCC with blended cement containing rice husk ash and Portland cement was observed to develop 80 to 85% of its 28-day characteristic strength in 7 days. The complete section of high strength SCC specimen including the aggregate and the paste, tends to reach failure simultaneously hence failure of cubes and cylinders tends to be sudden and explosive, typical of high strength concretes as mentioned by Navy [11]. Sudden failure is likely to cause damage or injury unless protective measures are taken. A loading rate of 0.15 to 0.2N/mm^2/s was observed to be safe enough as compared to 0.2 to 0.4N/mm^2 specified by BS1881: Part 116:1983.

Flexural strength

From the values given in Table 3, it can be seen that the flexural strength of high strength SCC with blended cement containing 50% rice husk ash + 50% Portland cement are observed to be higher by 8 to 10% as compared to control specimen. It is also a consequence of higher compressive strength and increased density of concrete with blended cement containing rice husk ash.

Table 3. Properties of high strength SCC.

W/C Ratio	Mixes	ISAT ml/m^2/s	Elastic Modulus N/mm^2	Dynamic Modulus N/mm^2	Pulse Velocity km/s
0.36	Control	0.23	36872	51378.2	4.79
	Blended SCC	0.16	38397	56615.8	5.21
0.32	Control	0.20	37198	54563.1	4.82
	Blended SCC	0.11	39461	59194.7	5.32
0.28	Control	0.17	38218	56684.7	4.84
	Blended SCC	0.10	40623	57954.8	5.40

Stress/strain behavior

Idealized stress/strain relationships in compression are shown in Figure 1. It was observed that the general form of the stress/strain characteristics of high strength SCC with blended cement containing 50% rice husk ash + 50% Portland cement were similar to that for control specimen. All the curves were observed to be virtually linear up to the point of failure, except for the initial small portion, typical of high strength concretes. Higher moduli of elasticity were observed for high strength SCC with blended cements containing rice husk ash and Portland cement as compared to similar concrete with Portland cement only.

Static modulus of elasticity

The average static modulus of elasticity for high strength SCC with blended cement containing 50% rice husk ash + 50% Portland cement was observed to be about 4 to 5% higher than the control specimen. Static modulus of elasticity was observed to be around 38000 to 40000 N/mm^2 for high strength SCC with blended cement containing rice husk ash and Portland cement as compared to 36800 to 38000 N/mm^2 for high strength concrete containing Portland cement only.

Dynamic modulus of elasticity

The average dynamic modulus of elasticity for concrete with blended cement containing 50% rice husk ash + 50% Portland cement was observed to be the higher by about 4% than the control. Table 3 gives the values of dynamic moduli of elasticity of various specimen.

Ultrasonic pulse velocity

The ultrasonic pulse velocities are given in Table 3. Average pulse velocity across high strength SCC with blended cement containing 50% rice husk ash + 50% Portland cement was observed to be 5.3 km/s as compared to an average velocity of 4.82 km/s for control mixes. Hence ultrasonic pulse velocity in the case of high strength SCC with blended cements containing rice husk ash and Portland cement was observed to be 10 to 12% higher than the control mixes. It is due to better quality, higher density and reduced voids in the high strength SCC with blended cements containing mixture of rice husk ash and Portland cement as compared to the control mixes.

Density of hardened concrete

The average saturated and oven-dried densities for high strength SCC with blended cement containing rice husk ash + Portland cement were 2578 and 2449kg/m^3 respectively, as compared to control mixes which were 2480 and 2461kg/m^3, respectively. Hence the saturated and dry densities of high strength SCC with blended cement containing rice husk ash and Portland cement are about 4% higher than the control mixes. It is due to better hydration and packing of finer materials in high strength SCC with blended cement containing rice husk ash and Portland cement. In the presence of higher content of cementitious material and the low w/c ratios, most of the unhydrated cementitious material acts as filler to densify the concrete, whilst the hydration process continues over longer duration.

Initial surface absorption (ISAT)

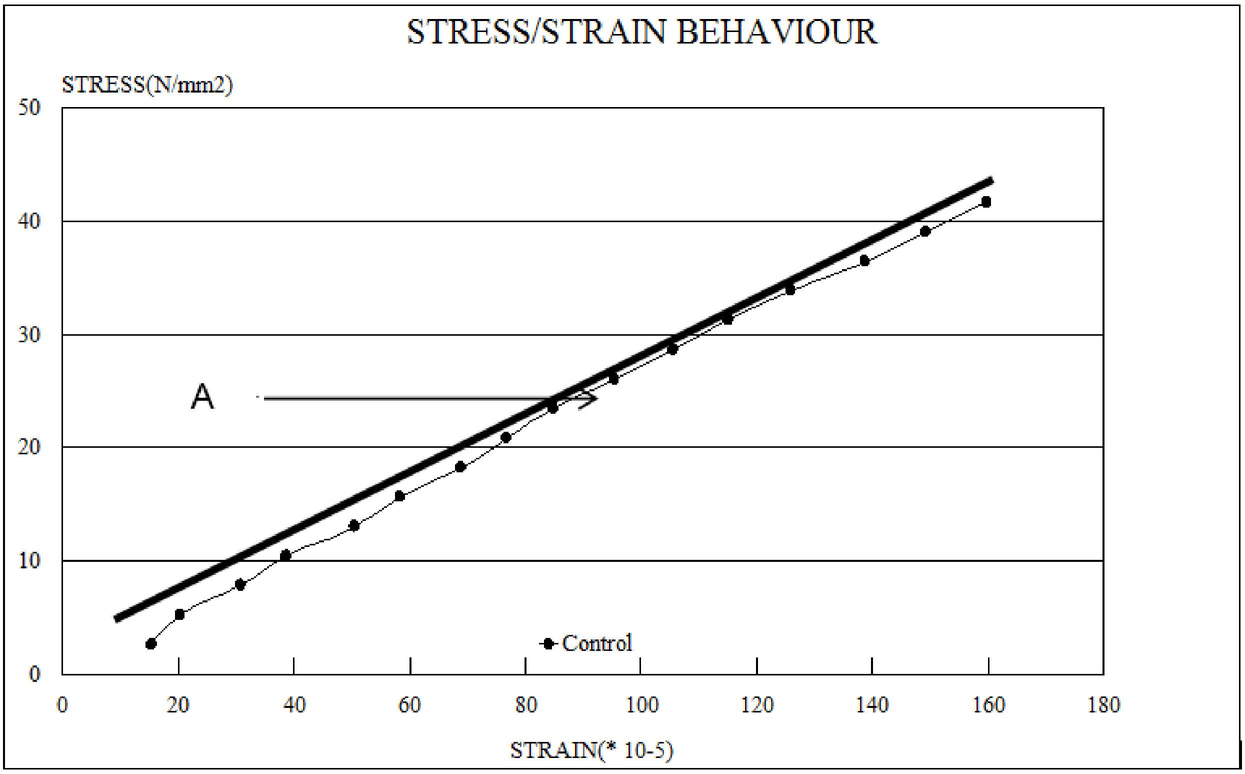
Results of ISAT are given in Table 3. Initial surface absorption for high strength SCC with blended cement containing 50% rice husk ash + 50% Portland cement was observed to be lower as compared to the control. The values are compared with the guidelines given by the Concrete Society Technical Report # 31 [10].

Sulphate and chloride resistance

For HCL solution, the weight loss for control was 8% as compared to 4% for high strength SCC with blended cement containing 50% replacement of cement with rice husk ash. Similarly, for H_2SO_4 solution, the weight loss for control was 6% as compared to 2% for 50% replacement of cement with rice husk ash. Therefore, the performance of high strength SCC with blended cements was two to three times better in acidic environment and three to four times better in sulphate environment as compared to concrete with ordinary Portland cement control mixes. It is mainly due to the negligible amounts of $Ca(OH)_2$ present in the products of hydration of blended cements, lower permeabilities and stable compounds formed due to secondary chemical actions by the silica content of the rice husk ashes.

Shrinkage.

Shrinkage of all specimen was observed to be similar for almost all specimen. No appreciable difference in shrinkage of specimen cast from high strength SCC with blended cements and control mixes were observed for 90 days.



Control – 100% Portland cement

A – High Strength SCC with blended cement

Figure 1. Idealized Stress – Strain Curves

CONCLUSIONS

High strength SCC mixes with blended cements containing 50% rice husk ashes can be designed for compressive strengths of 60N/mm^2, 80N/mm^2 and 100N/mm^2 like high strength concrete with ordinary Portland cement. High strength SCC specimen with blended cements developed satisfactory compressive strengths, 8 to 10% higher flexural strength, 2 to 4% higher static moduli of elasticity with values up to 40000N/mm^2, similarly higher values for dynamic moduli, about 10% higher pulse velocities, 4% higher density, very low permeabilities, similar shrinkage and two to three times improved sulphate and acid resistance as compared to control specimen. Better strengths and improved durability of such high strength SCC is likely to make it a more acceptable material for major construction projects. It will also help in consuming large volumes of agricultural wastes like rice husk ash thereby reducing its disposal problems along with resulting into cheaper cements with stronger and durable characteristics.

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