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Study On The Durability Properties Of SCC Partially Replaced With Agricultural And Industrial Waste.

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ABSTRACT

This study aims to investigate the durability properties (porosity and chloride ion penetration) of self Compacting Concrete (SCC) partially replaced with Copper (Cu) slag and Rice Husk Ash (RHA). Copper slag was used as partial replacement for fine aggregate. Cu slag was replaced at constant level of 10% and 20 % of weight of Sand. Concrete mixes were produced by replacing cement with RHA at 1%, 2%, and 3% of weight of cement. Fresh concrete properties namely the slump flow, workability, passing and filling ability of SCC were studied and reported in previous publication. This study presents the durability properties of SCC with RHA and Cu slag at the age of 56 days. All the mixes were less porous as compared to the control mix at all ages and showed "low range" to "very low range" chloride penetration.

Keywords: SCC, agriculture, induastrial waste, rice husk ash, copper slag

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INTRODUCTION

Increasing concern for environmental protection, energy conservation with minimal impact on economy have been motivating researchers to look for other alternatives of cement in the concrete industry. Studies have shown that waste materials can be successfully used in all kinds of existing and future concrete structures, by replacing cement sometimes up to 70%. They provide environmentally safe, stable, and more durable and low cost construction materials [1–3].In recent years, many researchers have established that the use of pozzolanic materials like blast furnace slag, silica fume, metakaolin (MK), fly ash (FA) and rice husk ash (RHA) etc. can, not only improve the various properties of concrete, but also can contribute to economy in construction costs [4]. Lot of research work has been carried out to use industrial and agricultural waste as substitute for cement, fine aggregate and coarse aggregate. Many slags have cementitious or pozzolanic properties which trigger the researchers to use it in cement or concrete.

Copper slag is a by-product obtained during the matte smelting and refining of copper [5-8]. Large amount of copper slag are generated as waste worldwide during the copper smelting process. The world copper production is currently about 14.98 million tons and it is estimated that for every ton of copper produced, about 2.2tons of copper slag is generated as a waste [9]. Current options of management of this slag are using waste slag as a cement replacement material, fine aggregate replacement material and coarse aggregate replacement material [10-16] in concrete depends upon the properties of the material.

Rice husk, obtained from rice processing mills when properly burnt at temperature lower than 700°C generates rice husk ash (RHA) containing reactive amorphous silica content [17,18]. The silica content in RHA is approximately 90% and is most suited for use as a pozzolan to improve the microstructure of the interfacial transition zone (ITZ) between the cement paste and the aggregate in SCC. The use of RHA in concrete as SCM is a sustainable environmental solution; it saves energy and natural resources by reducing cement consumption and CO2 generation [19], and its utilisation generally improves the properties of the blended cement concrete [17,20].

Self-compacting concrete 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. Self-compacting involves the use of limited aggregate content, low water to binder (w/b) ratio, and use of super plasticisers [21]. Highly fluid nature of SCC makes it easy to be poured in places where human access is difficult. Workability and mechanical properties of cu slag replaced SCC was studied, in which cu slag was replaced at the range of 20-40 % of cement [22]. The effect of different mineral additions on the rheology and compressive strength of SCC was studied [23-26].

Many researchers have been studied on using copper slag and RHA, in the production of normal and high strength concrete, not much research have been carried out on SCC with slag and RHA replacement. In this present work SCC mix was prepared with 10 and 20 % fine aggregate replaced with cu slag, and cement replaced with RHA in the range of 1-3%. The durability properties of SCC mix with slag, RHA were studied and reported.

MATERIALS

OPC of grade 53 was used in this study. River sand with a specific gravity of 2.66 and fineness modulus of 2.91 was used as the main fine aggregate for this study and copper slag as replacement material. Coarse aggregate consist of 16 mm well graded gravel stones. Copper slag used in this work was brought from Sterlite Industries Ltd, Tuticorin, Tamil Nadu, India Rice husk, obtained from rice processing mills when properly burnt at temperature lower than 700°C generates rice husk ash (RHA) containing reactive amorphous silica content. The silica content in RHA is approximately 90% and is most suited for use as a Pozzolan to improve the microstructure of the interfacial transition zone (ITZ) between the cement paste and the aggregate in SCC. The RHA with particle size of 150 µmm was used as a partial replacement of cement in the SCC mixes. Super plastizer BASEF master glenium SKY 8233 was used in the SCC mix. It is a chemical admixture based on poly carboxylic ether. The mix proportion for control SCC mix (M-50) without replacement of cement and fine aggregate is 1:1.69:1.86:0.33:0.45. Physical and chemical properties of cement, fine aggregate, coarse aggregate, copper slag, RHA and super plastizer are given in Table 1and Table 2.

Table 1: Physical Properties of Ingredients used in SCC

Physical properties	Cement	FA	CA	Cu slag	RHA
Specific gravity (g/cm^3)	3.15	2.77	2.69	3.59	2.11
Percentage of voids	-	-	-	34	-
Water absorption %	-	1.06	0.4	0.4	-
Moisture content %	-	2.4	0.25	0.13	-
Fineness modulus	-	3.18	3.46	3.28	-
Bulk density (Kg/m^3)	950	1500	1450	1900	-
Fineness	2 %	-	-	-	-

Table 2: Chemical Properties of cement, Cu slag, RHA

Chemical Properties	Cement	Cu slag	RHA
SiO_2	21.8	25.84	94
Fe_2O_3	3.8	68.29	0.37
Al_2O_3	4.8	0.22	1.2
CaO	68.3	0.15	2.93
Na_2O	0.21	0.58	-
K_2O	0.46	0.28	0.5
Mn_2O_3	0.9	0.22	-
TiO_2	0.25	0.41	-
SO_3	2.2	0.11	0.3
CuO	-	1.2	-
Loss on Ignition	2	6.59	5.81
Insoluble residue	0.4	14.88	-

EXPERIMENTAL INVESTIGATION

Mix design

Totally 9 mix designs were investigated. Each mixture was made with water cement ratio of 0. 5. Preliminary studies have been done in concrete cubes without copper slag (Control Mix) and in the next study fine aggregate was replaced with copper slag at 10 and 20 % of weight of Sand. In the next stage RHA was used as partial replacement for cement and the effect of RHA on the strength of copper slag SCC were studied. The mix proportion of cement: Fine Aggregate (FA): Coarse Aggregate (CA): Fly Ash: Super plasticizer (SP) adopted was 1:1.69:1.86:1.64:3.6.

Specimen details

For casting, the entire test specimen were cleaned and oiled properly. These were securely tightened to correct dimensions before casting. The casting of specimens was in accordance

With IS: 516 (1959). After casting, the specimens were allowed to remain in iron moulds for first 24 h at room temperature (27 ± 2 °C). After that these were de moulded and placed in the water tank at room temperature for curing. The specimens were tested after 7, 28 and 56 d of curing period. The specimen ID for each mix is given in Table 3

SCC fresh concrete test

SCC has special characteristics compared to other concretes. The parameters for each of these characteristics are independent of each other, so many test are done to measure the pasty phase characteristics of SCC. Based on the results of the pasty phase test we can measure the stability and workability of SCC. Also the stability can be compared with different grade of concrete at the end of the experiment. A concrete is said to be SCC based on its workability characteristics at its fresh state. In order to comply with the characteristics of SCC at its fresh state, concrete should possess some basic quality such as filling ability, passing ability and segregation resistance. Typical range of values for the workability properties of the fresh SCC according to codel provision is given in Table 4

Table 3: Specimen ID and Replacement details

Specimen Details	Cement (%)	FA (%)	Cu slag (%)	RHA (%)
SCC (M50)	100	100	-	-
$C10_S0_{RHA}$	100	90	10	-
$C10_S1_{RHA}$	99	90	10	1
$C10_S2_{RHA}$	98	90	10	2
$C10_S3_{RHA}$	97	90	10	3
$C20_S0_{RHA}$	100	80	20	-
$C20_S1_{RHA}$	99	80	20	1
$C20_S2_{RHA}$	98	80	20	2
$C20_S3_{RHA}$	97	80	20	3

Table 4: Acceptance limit for SCC as per codal provision (EFNARC)

Method	Unit	Typical range	
		Min	max
Slump flow test (filling ability)	mm	650	800
T_{50} cm Slump flow (filling ability)	sec	2	5
V-funnel test (filling ability)	sec	6	12
J-ring (passing Ability)	mm	0	10
L-Box (passing Ability)	(H_2/H_1)	0.8	1
U-Box (passing Ability)	H_2-H_1	0	30

SCC Durability test

The investigated durability properties are porosity and rapid chloride permeability. For both the test 100 × 200 mm cylinders were cast and sliced to 100 × 50mm cylinders. Both these tests were performed according to ASTM C 642 (2006) and ASTM C 1202 (2010), respectively for curing period of 56 days.

RESULTS AND DISCUSSION

Pasty phase test [26]

The fresh concrete properties (i.e.) the pasty phase test values of SCC with two different percentage of copper slag replacement and different level of RHA replacement were presented in Table 5. All the SCC exhibited satisfactory slump flow in the range of 500-800 mm. All the fresh concrete properties were in good agreement with the codal values listed in Table 6. Workability was found to be low for SCC with maximum percentage of RHA replacement i.e $C20_S$ 3_{RHA}. Therefore the workability decreases with the increase in RHA content.

Table 5: Fresh concrete properties of SCC replaced with Cu slag and RHA [26]

Specimen ID	Slump Flow Test		V-Funnel test (sec)	J-Ring (sec)	L-Box	U-Box	Remark
	Slump (mm)	T_{50} slump (sec)					
SCC	680	2	1.6	4	0.12	0	satisfied
$C10_S0_{RHA}$	720	2.6	1.9	5	0.15	0.5	satisfied

C10$_{S}$1$_{RHA}$	715	2.5	1.7	6	0.18	7	satisfied
C10$_{S}$2$_{RHA}$	688	3.6	1.5	7	0.29	16.5	satisfied
C10$_{S}$3$_{RHA}$	580	4.5	1.3	8	0.37	Blocking	-
C20$_{S}$0$_{RHA}$	670	8	1.6	7	0.19	0.1	satisfied
C20$_{S}$1$_{RHA}$	700	4.4	2.4	8	0.17	0	satisfied
C20$_{S}$2$_{RHA}$	682	2.7	1.5	8	0.16	1	satisfied
C20$_{S}$3$_{RHA}$	590	2.9	1.8	10	0.3	Blocking	-

Table 6: Rapid Chloride ion Penetration Test at 56 days curing

Mix ID	Charge passing in coulombs	Chloride permeability rating as per code (ASTM C1202-97)
SCC (Control Mix)	2900	Moderate
C10$_{S}$0$_{RHA}$	2400	Moderate
C10$_{S}$1$_{RHA}$	2000	low
C10$_{S}$2$_{RHA}$	1200	low
C10$_{S}$3$_{RHA}$	1000	Very low
C20$_{S}$0$_{RHA}$	2600	Moderate
C20$_{S}$1$_{RHA}$	2100	low
C20$_{S}$2$_{RHA}$	1250	low
C20$_{S}$3$_{RHA}$	950	Very low

The other pasty phase test namely the L-box, V-funnel, U-box, J-ring test values indicate that the all nine concrete mixes with different percentage of cu slag and RHA replacement satisfies the minimum requirement of self compacting concrete. It has better passing and filling ability compared to control mix [26].

Durability test

Rapid chloride penetration test

The 56-day test results for the resistance to penetration of chloride ions into concrete, measured in terms of the electric charge passed through the specimens in coulombs for different SCC mixes with rice husk ash and control mix are shown in Fig. 1. From the results it was found that as the replacement level of RHA increased, the charge passed decreased. Therefore blended mixes have lower ion penetration than unblended SCC. The chloride ion permeability values fall in the range of very low (100-1000 coulombs) category. It can also be seen that from the graph that as cement replacement by RHA increases, the charge passed decreases. According to present investigation the permeability class ranged from "moderate" for Control Mix to "very low" for 3% RHA (C20$_{S}$3$_{RHA}$).

Table 7: Porosity at different curing age

Mix ID	Porosity (%)
SCC (Control Mix)	14
C10$_{S}$0$_{RHA}$	13
C10$_{S}$1$_{RHA}$	12.5
C10$_{S}$2$_{RHA}$	11
C10$_{S}$3$_{RHA}$	9.5
C20$_{S}$0$_{RHA}$	12.9
C20$_{S}$1$_{RHA}$	11.5

C20S2RHA	10
C20S3RHA	9.5

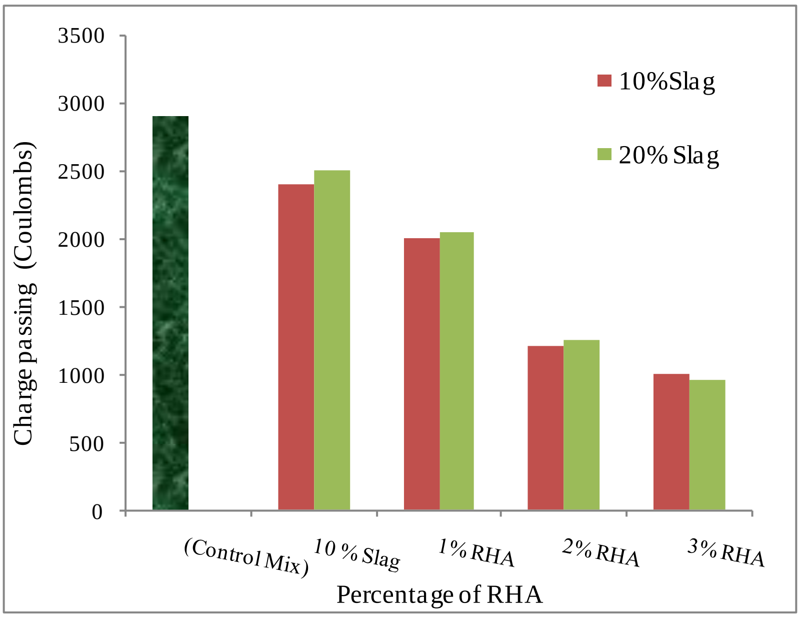

Figure 1: RCPT at 56 days curing

Porosity Test

Porosity is an important factor as it directly affects the durability of the SCC. The results indicate that the porosity decreased with increases in curing time. The main reason behind this is due to the additional or increased rate of hydration and/or pozzolanic reactions. There is more formation of C-S-H gel as a product of pozzolanic reaction between calcium hydroxide and silica. This gel fills the voids and increases the density of concrete. The results of porosity of SCC concrete mixes are shown in Fig. 2. Lowest porosity is achieved by mix 3% RHA (C20S3RHA).

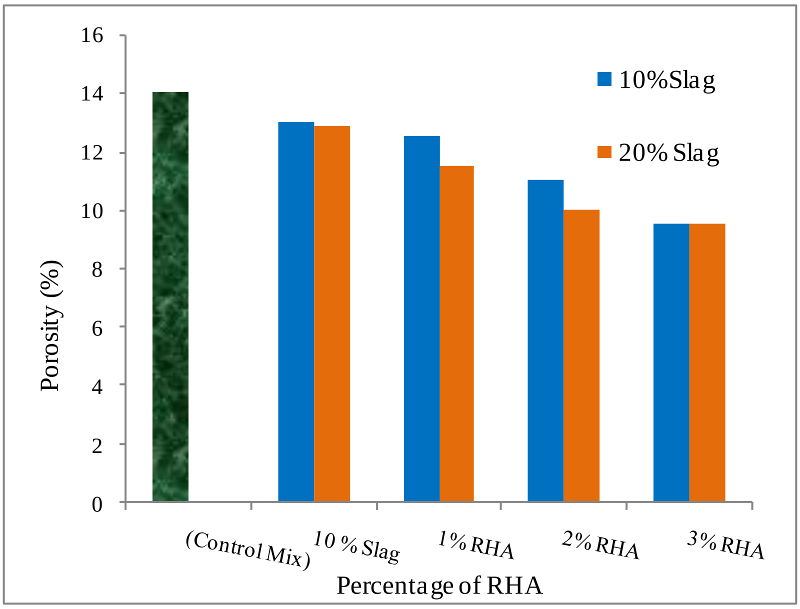

Figure 2: Compressive strength of 20 % cu slag SCC with different percentage of Nano silica

CONCLUSION

Replacement of cement by RHA as a supplementary cementitious material, has positive effect on Cu slag replaced self-compacting concrete. Fresh properties results showed that workability decrease with increase in amount of RHA. From the result of RCPT it can be observed that, as the replacement level of RHA increased, the charge passed decreased. Therefore blended mixes have lower ion penetration than unblended SCC. The chloride ion permeability values fall in the range of very low (100-1000 coulombs) category. The porosity of the cu slag mix reduces with the addition of RHA. As the percentage of Ash increases the porosity decreases which is an important factor for the durability properties of concrete. Thus supplementary cementious material enhances the property of SCC.

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