International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-8 Issue-4, November 2019

Cementing Efficiency of Rice Husk Ash and Ground Granulated Blast Furnace Slag in M60 grade Self Compacting Concrete

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Abstract- This paper enumerates strength gain efficiency of Rice Husk Ash (Rha) and Ground Granulated Blast Furnace Slag (Gbbfs) blend in Self-Compacting Concrete (SCC). From the precious studies carried by the authors it was observed that optimal use of Rha+Ggbfs in low and medium strength concretes imparts initial strengths and also later strengths. In low and medium strength SCC mixes, Ggbfs replaces OPC optimally (30%) and Rha replaces Ggbfs optimally (3%) but in case of high strength SCC mixes, RHA replacing Ggbfs does not offer the required workability or strength so instead of replacing Ggbfs by certain amount, Rha is added to the SCC. It was found that GGBFS does not yield the required workability so RHA is added to GGBFS based SCC. So after various trial mixes it was found that 25% GGBFS by weight of OPC and 5% RHA by weight of GGHFS is added to OPC. It was observed that 5% RHA addition to OPC made with 25% Ggbfs gives desired workability and strength. Due to addition of GGBFS to SCC will enhance the later age compressive strength but early age compressive strength decreases while the desired workability is controlled using SP appropriately. In M60 GGBFS+RHA based SCC, the strength increase at 3 days is nearly 33% and the compressive strength at 28 days decreased by 10%. Similarly tensile strength in a GGBFS and RHA admixed SCC increases by around 27% in M60 grade.

Index words – Cementing efficiency factors, Rice husk ash, Ground granulated blast furnace slag, RHA, GGBFS

I. INTRODUCTION

SCC is a special type of concrete which can flow and compact by itself. To acquire such property the composition of the materials used should be adjusted in such a way that paste content is more for better fluidity and coarse aggregate content should be controlled so that flow is hindered and SP is used to control segregation.

Fines play a major role in SCC contributing for viscosity and workability. The major requirement of SCC is its capability to flow, pass and resist segregation. The Ggbfs is a combination of lime, silica, and alumina. Rha is made up of highly reactive silica due to its high fineness or high surface area and non-crystalline structure.

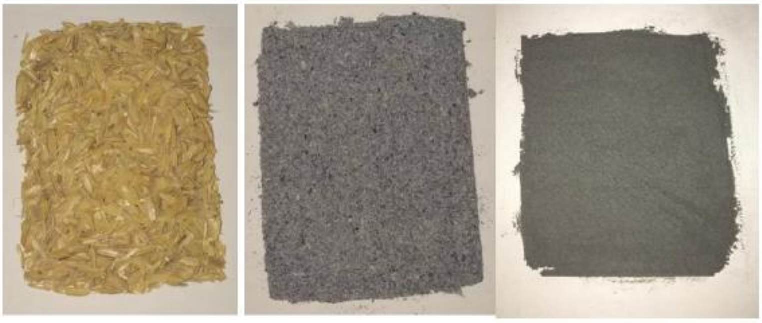

Fig 1: Preparation of Rha

Table 1- Characteristic SCC mix constituents (EFNARC 2005)

Manuscript published on November 30, 2019.
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Constituent	Typical range by mass (kg/m³)	Typical range by volume (litres/m³)
Powder	380 - 600	
Paste		300 - 380
Water	150 - 210	150 - 210
Coarse aggregate	750 - 1000	270 - 360
Fine aggregate (sand)	Content balances the volume of the other constituents, typically 48 – 55% of total aggregate weight.	
Water/Powder ratio by Vol		0.85 – 1.10

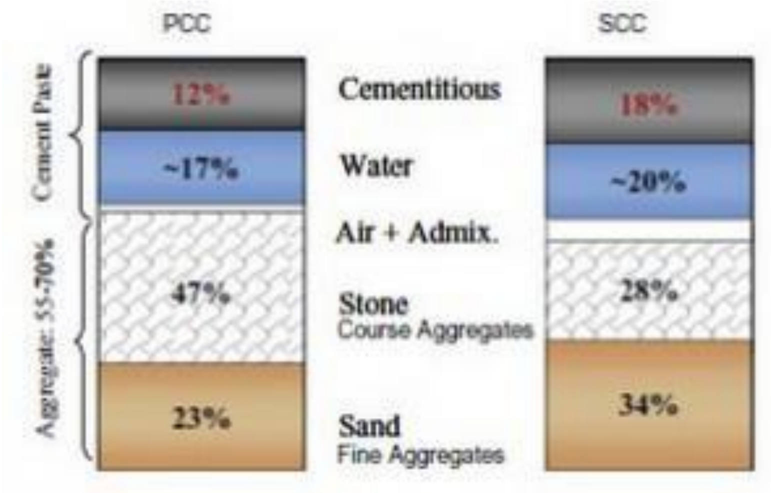

Fig 2 – SCC Components

II. METHODS to check SCC CHARECTERISTICS

The main purpose for tests on SCC is assess its flowabilty or deformable. The requirements for SCC is ability to fill, pass and resist segregation. One single method cannot characterize SCC so the combination of methods are adopted to access the self-compatibility and viscosity of SCC. To access the filling ability Slump flow, T_{50cm} Slump flow, V-funnel, Orimet etc tests are used. J ring, L Box, U Box and Fill Box tests are used to access passing ability of SCC. V-funnel at $T_{5minutes}$ and GTM screen stability tests are used to access the segregation resistance of SCC.

III. DESIGN OF SCC MIX

Local materials can be used in the design with appropriate corrections. Increase the powder content so that the paste content is increased and void content in aggregate is reduced, segregation is resisted by the use of viscosity enhancing agents. So by proper controlling the ingredients mix in SCC the requirements of SCC can be achieved. At present all SCC developers are adopting EFNARC guidelines since no standards are available. Researchers suggested various mix design methods based on several trial mixes. Most important mix designs are Nan-Su mix design method, EFNARC specifications etc.

IV. PROBLEM STATEMENT

In structures where there is dense reinforcement, the flow of concrete may be prohibited due to presence of coarse aggregate due to which concrete may not pass into congested reinforcement areas forming voids and leads to poor compaction. So in SCC, coarse aggregate size and quantity is reduced to facilitate smooth flow into closed reinforcement areas. The purpose of this project work is to evaluate the cementing efficiency in terms of strength of M60 grade ternary blended SCC made using GGBFS and RHA.

V. PROJECT SIGNIFICANCE

SCC can be developed using cement alone but usage of fly ash in SCC with the help of SP imparts similar performance as that of OPC only SCC. But rate of strength gain is effected when fly ash is used in high quantities in SCC. The early age strengths regain is very slow due to usage of fly ash while the later age strength gain is significant. This phenomena can be applicable to low and medium grade fly ash based SCC but it is not possible in high strength grade SCC because target strength in high strength fly ash concrete cannot be achieved with fly ash alone in SCC need some advocator to make fly ash active during early age. Similar is the case of GGBFS admixed in concrete instead of fly ash. GGBFS imparts later age strength to low and medium grade concretes but rate of gain of strength in early days is very low so RHA is added to GGBFS based SCC to boost the strength in early 3 and 7 days. So in the present work the strength efficiency of RHA and GGBS in SCC is evaluated to comprehend the role of pozzolanic behaviour of RHA and GGBS combination on the performance of SCC.

VI. OBJECTIVES

1. Appraise the compressive strength of M60 grade ternary blended SCC mix
2. Evaluate the influence of GGBFS and RHA blend on compressive strength of M60 grade SCC mixes
3. To estimate the strength efficiency factors of GGBFS and RHA based SCC mix at different ages of curing.

VII. LITERATURE REVIEW

The idea of SCC was coined by Okamura of Japan (1986). After which lots of research was reported and discussed below.

K Ozawa et al. (1989) studied the influence of 10-20% FA and 25-45% GGBFS on the properties of SCC as improving.

Badawe B.R and B.R Kumbhar (1997) found that concrete made with RHA has similar behaviour as that of concrete made with silica fume. Chemical resistance of H2SO4 of RHA based concrete is studied.

Rao M V S et al. (1999) studied the effect of 60% FA and 30% RHA replacement on the compressive strengths at 7 and 28 days and found to be improved by 44%. RHA improves early day strength and fly ask later age strength. Flexural strength of RHA based fly ash

Ganesh Babu K et al. (2000) appraised the efficiency of various admixtures or SCMs in concrete based on age and replacement percentage.

Nan - Su et al. (2001) suggested an innovative mix design practice for SCC, to make sure that the concrete attained the flowability, self-compacting capability and other anticipated SCC properties.

M V S Rao et al. (2004) investigated M40 to M80 grade concretes by considering 10% RHA as optimal percentage replaceement. They detected at higher RHA replacement percentages, the workability is significantly decreased so SP is required in high quantities.

Ravindra Krishna et al. (2005) studied the durability aspects of RHA based concrete through acid attack resistance and found that acid resistance increased by 80%.

Tahir Kibriya et al. (2006) accesses the characteristics of high strength grade RHA based SCC. Authors replaced 50% Portland cement with RHA and found to offer high resistance to sulphate and acidic environment with reduced permeability.

A Ahmadi et al. (2007) studied that RHA augment the micro and macro structure of the ITZ in SCC. Author reported that RHA of 20% replacement showed promising improvement in properties.

VIII. CEMENTING EFFICIENCY

In this paper strength efficiency of GGBFS+RHA blend in high grade (M60)SCC is expressed as efficiency factor “k”.

The Bolomey suggested an empirical formula to predict the strength of hardened concrete. That equation modified as

$$f_{ck} = a\,[(C+k*GR)/W] + 0.5$$

f_{ck} = estimated compressive strength (MPa.)

C =cement content (kg / m^3)

GR is the GGBFS+RHA mixture (kg/m^3)

W = water content in kg/m^3 and k represents efficiency factor.

IX. TEST RESULTS AND DISCUSSIONS

Table 2 presents the quantities of materials in blended SCC of M60 grade. Table 3 presents compressive strength of GGBFS admixed SCC at various percentage of replacement. Table 4 present compressive strengths of M60 grade blended concrete made with 25% GGBFS by weight of cement and 5% RHA by weight of powder of at all ages of concrete curing.

In M60 grade, the target strength at 28 days could not be achieved even after 25% GGBFS is admixed to concrete. So RHA is added to GGBFS based concrete. It was found that 5% RHA by weight of powder added to 25% GGBFS by weight of cement admixed concrete gives desired workability and compressive strength for M60 grade concrete.In M60 grade SCC replacement of cement or GGBFS by RHA does not give desired performance so after various trials it was decided that 5% RHA addition gives desired workability and strength. Due to addition of GGBFS to SCC will enhance the later age compressive strength but early age compressive strength decreases while the desired workability is controlled using SP appropriately. In M60 GGBFS based SCC, the strength reduction at 3 days is nearly 10% and the compressive strength at 28 days decreased by 11%. RHA is added as replacement of cement to improve the early age strength of SCC. In M60 GGBFS+RHA based SCC, the strength increase at 3 days is nearly 33% and the compressive strength at 28 days decreased by 10%. Similarly tensile strength of GGBFS and RHA admixed SCC increases by around 3 to 27% in M60 grade.

X. CEMENT EFFICIENCY FACTOR

Bolomey’s Coefficients (A) are figured from equation suggested by Bolomey. The strength efficiency factor ‘f’ of GGBFS in SCC for various replacement percentages at different ages can be assessed using strength and water/(cement+k*GGBFS) relation proposed by Bolomey.

Table 2 - Quantities of materials in blended SCC of M60 grade

Grade	Cement ‘c’ (kg)	Optimum % of replacement	GGBFS ‘g’ (kg)	RHA ‘r’ (kg) (%)	Water ‘w’ (kg)	Powder ‘p’ (p=c+g+r) (kg)	w/p ratio
M60	600	0% (GGBFS)	0	-	190	600	0.32
	450	25% (GGBFS)	150	-	190	600	
	450	(GGBFS+RHA)	150	30 Additive (5% bwp)	190	630	0.30

Table 3 -Compressive strength of GGBFS admixed SCC at various percentage of replacement.

% of GGBFS Replacement (of cement quantity)	Compressive strength (N/mm^2)		
	M60		
	3 d	7 d	28 d
0	21.90	43.03	65.97

10	18.39	32.23	54.92
15	18.19	41.49	55.79
20	19.44	33.87	58.20
25	19.68	34.43	59.22
30	17.96	31.97	54.69

d- days

Table 4-Compressive strength of M60 grade concrete made with various percentage of GGBFS by weight of cement and 5% RHA by weight of powder

% of GGBFS Replacement (of cement quantity)	RHA 5% added (of powder quantity) kg	Compressive Strength (N/mm^2) M60		
		3 d	7 d	28 d
0	0	21.90	43.03	65.97
10	30	18.95	40.44	66.03
15	30	19.75	41.68	68.16
20	30	20.22	41.93	69.39
25	30	20.78	43.97	72.07
30	30	20.26	42.63	70.39

Table 5 - Tensile strength of M60 blended SCC mixes

Designation	Tensile strength (N/mm^2) @ 28 days	
OPC based SCC mix	100% OPC M60 Grade SCC mix	3.89
GGBFS admixed SCC mix	Replacement percentage of GGBFS (of cement quantity) is 25% in M60 Grade SCC mix	4.02
GGBFS and RHA admixed SCC mix	Optimum replacement percentage of GGBFS and RHA Combination is 25% GGBFS (of cement quantity) and 5% RHA (of GGBFS quantity) in M60 Grade SCC mix	4.93

Table 6 - Calculations of Bolomey's Constants

Age	M60
3d	A=7.49
7d	A=14.74
28d	A=22.58

Table 7 - Evaluation of Strength Efficiency factor 'k' of GGBFS in SCC

Replacement % of GGBFS (bwc)	Cementing Efficiency Factor(k) M60		
	3 d	7 d	28 d
0	-	-	-
10	0.15	0.01	0.04
15	0.38	0.08	0.15
20	0.59	0.12	0.54
25	0.66	0.35	0.69
30	0.53	0.24	0.55
35	0.68	0.12	0.47

Table 8 -Evaluation of GGBFS and RHA combination Cementing or Strength Efficiency in M60 SCC mix

Optimum replacement percentage of GGBFS and RHA (bwc)	Cementing Efficiency Factor 'k' M60		
	3 d	7 d	28 d
30% Powder (25% GGBFS bwc + 5%RHA bwg as additive)	0.72	0.95	1.38

Retrieval Number: D8248118419/2019©BEIESP
DOI:10.35940/ijrte.D8248.118419
Journal Website: www.ijrte.org

Published By:
Blue Eyes Intelligence Engineering & Sciences Publication

Table 9- Cementing or Strength Efficiency factors of GGBFS and RHA in SCC

Pozzolan	Efficiency Factor 'k' (For optimum % replacement)								
	M20 Grade			M40 Grade			M60 Grade		
	3 d	7 d	28 d	3 d	7 d	28 d	3 d	7 d	28 d
GGBFS	0.81	1.27	1.89	0.72	1.21	1.64	0.53	0.24	0.55
GGBFS and RHA	1.08	1.28	2.30	0.77	1.27	2.00	0.72	0.95	1.38

Cementing or Strength Efficiency factor of admixture (called as supplementary cementing material (SCM)) indicates the amount of powder in kg replaces one kg of cement to achieve similar strength. For matching the performance of SCM with regard to concrete durability, the notion of strength or cementing efficiency factor is used. The strength or cementing efficiency factor (k-value) is expressed as the part of the pozzolan (Powder) in an SCM admixed or in additive concrete which can be considered as equivalent to OPC.

XI. CONCLUSIONS

Based on the result of this research the following conclusions can be drawn:

1. For M 60 grade SCC Mix the mandatory target strength was not attained at 25% GGBFS so 5% RHA was added instead of replacement of GGBFS while in M20 and M40. The calculations have shown that the Strength Efficiency factor 'k' at 3, 7 and 28 days were high at 25% GGBFS and 5% RHA addition (bwc).
2. The Strength Efficiency factor for M60 grade SCC 'k' was 0.72, 0.95 and 1.38 at 3, 7 and 28 days respectively at optimal 25% GGBFS replacement and 5% RHA as .additive.
3. Strength efficiency is more in GGBFS and RHA admixed SCC mixes than in GGBFS alone admixed SCC mixes.
4. Strength efficiency increased by 10% in high grade SCC mixes made with GGBFS and RHA when compared to OPC based SCC mixes.

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