Estimation of Ground Granulated Blast Furnace Slag and Rice Husk Ash Cementing Efficiency in Low and Medium Grade Self-Compacting Concretes

G Mounika, V Srinivasa Reddy, M V Seshagiri Rao, M Swaroopa Rani

Abstract - Ternary blended Self Compacting Concrete (SCC) made with rice husk ash (RHA) and GGBFS (ground granulated blast furnace slag) has developed as a substitute to normal concrete. It has advantages such as less cement usage, energy usage, cost and for other ecological and socio-economic benefits. The current work quantifies the 3, 7 and 28-days cementitious efficiency for various percentages of RHA and GGBFS combination in SCC. The usage of GGBFS in M20 and M40 SCC reduces workability but increases compressive and tensile strength when compared with OPC based SCC. The optimum GGBFS is found to be 30% for low and medium strength levels of SCC. For M20 and M40, 30% GGBFS reduces workability slightly but still within desired limits. So after various trial mixes it was found that 27% GGBFS by weight of OPC and 3% RHA by weight of GGBFS quantity can be admixed to OPC SCC to achieve similar strength and workability and also better rate of strength regain in early days of hardening. In M20 and M40 grades of SCC, 3% RHA by weight of GGBFS quantity is replaced. 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. This is true for all grades of GGBFS based SCC. In M20 GGBFS based SCC, the strength gain at 3 days is nearly 9% but the compressive strength at 28 days increased by 31%. In M40, GGBFS based SCC, the strength gain at 3 days is nearly 14% but the compressive strength at 28 days increased by 21%. RHA is added as replacement of cement to improve the early age strength of SCC. RHA addition to concrete as cement replacement may help to improve strength marginally but impacts the workability drastically so SP should be used controllably to attain the desired workability. In M20 GGBFS+RHA based SCC, the compressive strength enhancement at 3 days is 21% and the compressive strength at 28 days increased by 46%. In M40, GGBFS+RHA based SCC, the compressive strength enhancement at 3 days is 20% and at 28 days increased by 34%. Similarly tensile strength in all grades of GGBFS and RHA admixed SCC increases by around 15 to 34% in M20 grade and 9 to 36% in M40 grade SCC mix. So it can be concluded that RHA and GGBS combination principally yields early strength which is not possible in SCC mixes primary made with fly ash.

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

I. INTRODUCTION

Hajime Okamura is considered to be the first person to present the idea of concrete consolidates by itself.

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This type of special concrete called self-compacting concrete (SCC) has enhanced performance and various This concrete is supposed to have ability to flow and don't require any form of compaction as adopted in conventional concrete. social-economic benefits. The composition of SCC mix majorly consists of powder and fine aggregates and uses mineral and chemical admixtures. This concrete is highly workable, self-consolidating and highly flowable. Self-consolidating concrete mainly consists of high contents of cement paste and has issues with segregation, shrinkage and heat generation. So use of admixtures such as Water Reducers and Viscosity modifiers are used in SCC to control the rheology of concrete. There is no standard code available in India for SCC. In SCC, fines are the major game changer and is resposible for fluidity and SP is responsible for viscosity and workability. SCC should process filling ability, passing ability and segregation resistance. In order to attain the above properties SCC should contain high amount of fillers such as fly ash along with the use of chemical admixtures. The materials used in producing SCC are Cement (10% of total mix volume), Fine aggregate, Coarse aggregate (less than 50% of total aggregate ratio), Water, Mineral and Chemical admixtures. From durability point of view, the cement content should not be more than 500 kg/m^3 and if the cement content is less than 350 kg/m^3 the usage of fillers or pozzolans is advisable. Cement and filler together forms powder material. Powder in SCC prevents segregation of aggregates and improves workability. Usage of powders in SCC alters the microstructure of SCC by improving the density of particle packing and easy viscosity and friction between particles.

II. EFNARC PROVISIONS

1. Water/powder ratio by volume is taken as 0.85 to 1.10. Water content is restricted to 210 litre/m^3.
2. Total powder content – minimum 380 and maximum 600 kg per meter cubic.
3. Coarse aggregate -about 45-50 % of total aggregate weight. Fine aggregate content is used more.
4. VMA is used to control the variations of the sand grading and the moisture content of the aggregates.

III. DESIGN OF SCC MIX

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.

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. OBJECTIVES OF THE PRESENT STUDY

1. Study the influence of GGBFS on compressive strength of M20, M40 and M60 grade SCC mixes
2. Study the influence of GGBFS and RHA on compressive strength of M20, M40 and M60 grade SCC mixes
3. To evaluate the strength efficiency factors for 3, 7 and 28 days of GGBFS and RHA based SCC mixes.

V. CEMENTING EFFICIENCY

The influence of GGBFS and RHA mixture is based on the age of the concrete and the percentage of replacement. RHA develops the micro-structure of the ITZ. In this paper cementing efficiency of GGBFS+RHA blend in low (M20) and medium (M40) grades of SCC is conveyed as efficiency factor "k". It was found that optimum replacement level of GGBFS in cement concrete is 30% and 25% for low (M20) and medium (M40) grades of SCC. 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.

The rate of pozzolanic reaction (PR) and cement hydration (CH) governs the value of k. If the strength attained by the blended concrete is same as that of concrete made with only cement then k is equal to one indicates that the total powder contents are same in both types of concrete otherwise if k less than one, for similar strengths total powder content in blended concrete is less than cement content in conventional concrete signifying that the pozzolanic reaction would be slower than cement hydration so the conventional concrete will attain more strength than blended concrete. The GGBFS based concrete has k is less than one at early age and would reach unity at later age. If k greater than one means pozzolanic reaction occurs along with hydration of cement and strength attained by blended concrete is higher than reference concrete for same water-cement ratio. GGBFS + RHA based SCC has 'k' more than one at 3 and 7 days and therefore the strengths of GGBFS + RHA based SCC is higher. The contribution of GGBFS and RHA may be expressed in terms of efficiency factor, k. For compressive strength of concrete, k is in the range of 0.7 to 1.8, which means that in a conventional concrete, 1 kg of GGBFS may replace 0.7 to 1.8 kg of cement to attain the similar compressive strength for same water cement ratio.

VI. EXPERIMENTAL TEST RESULTS

The following tables present experimental results of various tests conducted. Table 1 presents the quantities of materials in blended concretes of various grades. Table 2 shows Compressive strength of GGBFS admixed SCC at various percentage of replacement,

Table 1- Quantities of materials in blended concretes of various grades

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
M20	400	0% (GGBFS)	0	-	180	400	0.45
	280	30% (GGBFS)	120	-	180	400	
	280	30% (GGBFS+RHA)	116.4	3.6 (Admixed) (3% of optimum GGBFS)	180	400	
M40	500	0% (GGBFS)	0	-	190	500	0.38
	350	30% (GGBFS)	150	-	190	500	
	350	30% (GGBFS+RHA)	145.5	4.5 Admixed (3% of optimum GGBFS)	190	500	

Table 2 -Compressive strength of GGBFS admixed SCC at various percentage of replacement.

% of GGBFS Replacement (of cement quantity)	Compressive strength (N/mm^2)					
	M20			M40		
	3 d*	7 d*	28 d*	3 d*	7 d*	28 d*
0	15.58	22.47	30.97	20.04	33.06	47.95
10	10.81	19.71	33.59	15.48	29.77	49.84
15	11.81	20.44	35.18	16.45	30.68	50.49
20	12.00	20.93	36.14	16.92	30.93	50.78
25	12.33	21.93	36.67	17.26	31.17	52.68
30	14.15	24.34	40.58	17.72	34.93	57.94
35	12.91	23.46	39.22	16.86	32.79	54.00

*d- days

Table 3 - Compressive strength of optimally blended GGBFS and RHA based concrete of low and medium grade

Optimum GGBFS and RHA Combination % of replacement	Compressive strength (N/mm^2)					
	M20			M40		
	3 d	7 d	28 d	3 d	7 d	28 d
30% (Total Powder) (3% RHA replaced by weight of GGBFS)	17.73	27.42	45.32	23.88	38.75	64.08

In M20 and M40 grade concretes, cement replaced with 30% GGBFS improves the compressive strength at 28 days. This improvement is observed till 30% replacement after which the compressive strength slows decreases. After various trial mixes, desired target strength is obtained when 3% or RHA by weight of GGBFS (27% GGBFS and 3% RHA) is added to concrete. Blending 27% GGBFS and 3% RHA to concrete not only improves 28 day compressive strength but also increase 3 and 7 days strength and attains required workability. Table provides compressive strengths of GGBFS and RHA blended concrete of M20 and M40 grades at all ages of concrete curing. The usage of GGBFS in M20 and M40 SCC reduces workability but increases compressive and tensile strength when compared with OPC based SCC. The optimum GGBFS is found to be 30% for low and medium strength levels of SCC. For M20 and M40, 30% GGBFS reduces workability slightly but still within desired limits. So after various trial mixes it was found that 27% GGBFS by weight of OPC and 3% RHA by weight of GGBFS quantity is admixed to OPC SCC. This 27% GGBFS+3% RHA combination produces essential workability and Strength in case of M20 and M40 grade SCC mixes. 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. This is true for all grades of GGBFS based SCC. In M20 GGBFS based SCC, the strength gain at 3 days is nearly 9% but the compressive strength at 28 days increased by 31%. In M40 GGBFS based SCC, the strength gain at 3 days is nearly 14% but the compressive strength at 28 days increased by 21%. 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. RHA addition to concrete as cement replacement may help to improve strength marginally but impacts the workability drastically so SP should be used controllably to attain the desired workability. This is principally true for M20 and M40 grade SCC mixes. So 5% RHA is added to cement instead of replacement along with 25% of GGBFS. In M20 GGBFS+RHA based SCC, the strength enhancement at 3 days is 21% and the compressive strength at 28 days increased by 46%. In M40 GGBFS+RHA based SCC, the strength reduction at 3 days is 20% and the compressive strength at 28 days increased by 34%. Similarly tensile strength in all grades of GGBFS and RHA admixed SCC increases by around 15 to 34% in M20 grade and 9 to 36% in M40 grade. In M20 and M40 grade concretes, cement replaced with 30% GGBFS improves the compressive strength at 28 days. This improvement is observed till 30% replacement after which the compressive strength slows decreases. After various trial mixes, desired target strength is obtained when 3% or RHA by weight of GGBFS (27% GGBFS and 3% RHA) is added to concrete. Blending 27% GGBFS and 3% RHA to concrete not only improves 28 day compressive strength but also increase 3 and 7 days strength and attains required workability. Table 4 provides split tensile strengths of GGBFS and RHA blended concrete of M20 and M40 grades at all ages of concrete curing.

Table 4 – Split-tensile strength of optimally blended GGBFS and RHA based concrete of low and medium grade

Designation		M20	M40
Mix1	-		
	Tensile strength (N/mm^2) @ 28 days	2.33	2.76
Mix2	% of GGBFS Replacement (of cement quantity)	30%	30%
	Tensile strength (N/mm^2) @ 28 days	2.68	2.97
Mix 3	Optimum GGBFS and RHA Combination % of replacement	27% GGBFS (of cement quantity) and 3% RHA (of GGBFS quantity)	27% GGBFS (of cement quantity) and 3% RHA (of GGBFS quantity)
	Tensile strength (N/mm^2) @ 28 days	3.12	3.76

VII. ASSESSMENT OF CEMENT EFFICIENCY FACTOR

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. Bolomey’s Constants (A) are calculated 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 5- Calculations of Bolomey's Constants

Age	M20	M40
3d	A=8.23	A=8.57
7d	A=11.88	A=14.15
28d	A=16.37	A=20.48

Table 6 - Evaluation of Strength Efficiency factor 'k' of GGBFS in SCC

Replacement % of GGBFS (bwc)	Cementing Efficiency Factor(k)					
	M20			M40		
	3 d	7 d	28 d	3 d	7 d	28 d
0	-	-	-	-	-	-
10	0.16	0.26	1.74	0.12	0.19	1.27
15	0.25	0.56	1.79	0.24	0.63	1.29
20	0.33	0.78	1.84	0.39	0.78	1.30
25	0.38	0.98	1.86	0.58	0.85	1.46
30	0.81	1.27	1.89	0.72	1.21	1.64
35	0.66	1.16	1.67	0.66	1.03	1.43

Table 7- Evaluation of GGBFS and RHA combination Strength Efficiency in M20 and M40 SCC mixes

Optimum GGBFS and RHA Combination % of replacement (bwc)	Efficiency Factor 'k'					
	M20 Grade			M40 Grade		
	3 d	7 d	28 d	3 d	7 d	28 d
30% Powder (27% GGBFS and 3% RHA)	1.08	1.28	2.30	0.77	1.27	2.00

Table 8-Cementing or Strength Efficiency factors of GGBFS and RHA in SCC

Pozzolan	Efficiency Factor 'k' (For optimum % replacement)					
	M20 Grade			M40 Grade		
	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
GGBFS and RHA	1.08	1.28	2.30	0.77	1.27	2.00

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.

VIII. DISCUSSIONS

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.

IX. CONCLUSIONS

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

1. Strength efficiency factor of M20 grade SCC mix made with optimum 30% GGBFS are 0.81, 1.27 and 1.89 at 3, 7 and 28 days respectively.
2. Strength efficiency factor for M20 grade SCC 'k' was 1.08, 1.29 and 2.30 at 3, 7 and 28 days respectively at optimal 27% GGBFS bwc and 3% RHA bwg combination. The compressive strength of 28 days increased by 32%.
3. For M 40 grade SCC Mix made with optimum 30% GGBFS the evaluations have shown that the strength efficiency factor are 0.72, 1.21 and 1.64 at 3, 7 and 28 days respectively.
4. Strength efficiency factor for M40 grade SCC 'k' was 0.77, 1.27 and 2.00 at 3, 7 and 28 days respectively at optimal 27 % GGBFS and 3% RHA combined mixture.
5. Strength efficiency is more in GGBFS and RHA admixed SCC mixes than in GGBFS alone admixed SCC mixes.
6. Strength efficiency increased by 30% in lower grade, 20% in medium grade and 10% in high grade SCC mixes made with GGBFS and RHA when compared to OPC based SCC mixes.

REFERENCES

1. K Ganesh Babu and V Sree Rama Kumar , Efficiency of GGBS in Concrete , Science Direct –Cement and Concrete Research (2000),pp-1031-1036
2. V Srinivasa Reddy, M V Seshagiri Rao, S Shrihari," Appraisal of Processing Techniques for Recycled Aggregates in Concrete", International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249 – 8958, Volume-8 Issue-6, August 2019, Retrieval Number F8407088619/2019©BEIESP, DOI: 10.35940/ijeat.F8407.088619, pp.1661-1665
3. K Ganesh Babu and G S N Rao and P V S Prakash, Efficiency of pozzolans in cement composites, Concrete 2000(1993),pp. 497-509 Dundee
4. K Ganesh Babu and G S N Rao, Efficiency of fly ash in concrete, Cement Concrete Composites (1993),pp. 223-229
5. Shrihari, S and Seshagiri Rao, M V and Reddy, V Srinivasa, Evaluation of Cementing Efficiency in Quaternary Blended Self-Compacting Concrete (March 2019). International Journal of Civil Engineering and Technology 10(3), 2019, pp. 83–90. Available at SSRN: https://ssrn.com/abstract=3453705
6. C. Chandana Priya, M. V. Seshagiri Rao and V. Srinivasa Reddy, "Studies On Durability Properties Of High Strength Self-Compacting Concrete –A Review", International Journal of Civil Engineering & Technology (IJCIET) - SCOPUS indexed, Volume 9, Issue 11, (November 2018), pp. 2218–2225, Article ID: IJCIET_09_11_219, ISSN Print: 0976 – 6308, ISSN Online: 0976 – 6316, (SCOPUS indexed)

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