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Performance Evaluation of Self-Compacting Concrete Using Rice Husk Ash and Ground Granulated Blast Furnace Slag as Sustainable Cement Replacements

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Abstract: *Unlike the ordinary concrete Self-Compacting Concrete (SCC) has the capacity to flow under gravity without the use of an external vibrator. It has low yield stress, high deformity and relative viscosity, and good filling capacity and hence very tough and strong. In contrast to conventional concrete, the SCC needs other mix ratios and hydraulic flows test procedures. It fills complicated formworks and reinforced areas without segregating or forming loose holes, and thus it is a popular material used in present-day constructions, although it requires more binder material and chemical additives most of the times. This paper investigates how Rice Husk Ash (RHA) can be used as a partial cement replacement and Ground Granulated Blast Furnace Slag (GGBS) used as an expansive additive in SCC. Application of these mineral admixtures is done with the hope of reducing the cost of production and heat of hydration. Research is based on constant level of RHA content 15-20 per cent, and variable GGBS contents of 5, 10, 15, and 20 per cent. The factors which also may have a significant effect when working with constant water to binder ratios, fixed superplasticizer mass, and constant aggregate masses.The results of tests show that RHA and GGBS have a significant effect on the fresh-state properties of SCC, and they do not reach the critical values. The characteristics of strength will be constant until 30 percent of the binder is replaced but will start to drop after 40 percent. The results indicate that combination of RHA and GGBS could perform efficiently in green and high-performance SCC without generating weakness.*

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I. Introduction

The contrast between Self-Compacting Concrete (SCC) and the conventional concrete lies in that it flows under its own weight requiring no vibration. It has low stress on yield, high deformity, moderate viscosity, and optimal filling capacity, therefore, very durable and strong. In contrast to standard concrete, the proportions of the mix and the flow tests should be different in SCC. The possibility of filling complex formworks and reinforcement area without any form of segregation and voids make it an attractive construction material in this generation, although it may require significant proportion of binder content and chemical admixtures.This paper examines the possibility of mixing Participation of Rice Husk Ash (RHA) as a cement substitute Ground Granulated Blast Furnace Slag (GGBS) as expansive additive in SCC. Such mineral admixtures are utilized to cut down costs of production and also to reduce heat of hydration. The study measures constant RHA content of 15-20 percent and a variable GGBS content of 5%, 10%, 15 and 20 percent. Among the key parameters, constant water-to-binder ratios, fixed superplasticizer, and all at constant aggregate proportions must be pointed out.Test data reveal that RHA and GGBS have a significant effect on the fresh-state properties of SCC, being on the acceptable level. Incorporation of strength is stable at a replacement of binder below 30 but a reduction starts being observed above 40. It is noted in the findings that it is possible to incorporate RHA and GGBS in sustainable, high-performance SCC without losing strength.

1.2 History of SCC

In 1983, the construction industry experienced a surge of global interest due to the increasing demand for large-scale infrastructure projects such as nuclear power plants, tunnels, dams, and high-rise buildings. These projects required significant financial investment, labor, and time. Japan emerged as a leading nation in addressing these challenges, placing strong emphasis on the quality of concrete materials used in construction. A major concern in Japan was maintaining the strength and durability of concrete while facing a decline in skilled labor availability, prompting innovations in construction materials and methods. The buildings ought to be firm and dense and as such they will require good workers to perform compaction. A continuous decline in the number of skilled professionals within the construction sector led to a noticeable slowdown in infrastructure development. This issue was effectively addressed through the innovation of a new type of concrete that could be placed without the need for extensive labor, reducing both construction time and costs. This advanced concrete—known for its high durability and compressive strength—proved to be a significant breakthrough. Once Japan began implementing Self-Compacting Concrete (SCC) in its projects, many other countries soon followed, making SCC a widely adopted material in major construction ventures due to its performance benefits and ease of application.

1.3 Motive of SCC

The social problem which burst forth during formulation of the purpose of Self-Compacting Concrete had to do with the stability of solid structure, which appeared in Japan in 1983 since the quality of development work has been worsening in Japan due to the diminishing number of skilled labourer in the development business. Concrete was a reaction greater than one of the materials made use of in the attainment of good structures devoid of the trend of progress work to replace solid substances, and was simply through use of and creation of its own weight so like concreted a barbed bar slot. Self-Compacting Concrete consists of mixture of a wide range of pieces of normally vibrated conventional solids e.g. bond bits, total bits, water, embedded items and mixtures.

1.4 Global Development of SCC.

As SCC became a transformative material in the construction sector, researchers and engineers worldwide intensified their studies on its behavior and potential. From the United States to Europe—including nations like France, the UK, Germany, and Sweden—numerous publications and technical studies were produced, underscoring SCC's superiority in terms of durability and workability. By 2002, its advantages over traditional concrete were widely recognized. In India, significant efforts were made both in laboratories and on construction sites to implement SCC. In Delhi, early innovations emerged through collaborative work involving companies like L&T and MBT on metro projects. Major organizations such as the Nuclear Power Corporation, Gammon India, and Hindustan Construction Company conducted large-scale trials. The Structural Engineering Research Centre (SERC) in Chennai played a pivotal role in Indian SCC research. For instance, the Delhi Metro expansion utilized SCC extensively for vaults, tunnel linings, and precast segments. Despite these efforts, the development and adoption of SCC in India remains limited, with few evaluations aligned with European SCC guidelines in recent years (Sood et al., 2009).

1.5 Application of RHA

RHA is a green product that does not produce emissions that amount to greenhouse gases. Numerous alternatives on ways of disposing them by commercial exploitation of this RHA are in the process of consideration. Super-pozzolan RHA is a very good one. A mixture of this super-pozzolan was made in order to produce various concrete mixes. Specialty cements and concrete mixtures are highly in demand of fine amorphous silica. This product finds numerous uses and green concrete is one of them.

1.6 Use of GGBS

GGBS is used as filler material and is by-product of pig iron manufacturing process. The production of it involves melting of iron-bearing minerals and limestone flux under high temperatures of about 1500 o C in a blast furnace. The water hose burns down the liquid slag fast and produces a shiny glossy granular product that is referred to as the granulated impact heater slag. Granulated or palletized hydrated slag forms hydrates that cannot be distinguished with hydrates of Portland bond, i.e. C-S-H and AF1 phases. their slow response to water compared to Portland concrete allows them to be used in a variety of ways through activation: artificially, by proximity to lime and sulphate activators (or high temperatures), or by pounding. Granulated heater impact slag is pounded to give the extremely pozzolanic slag. The alternative to Slag in concrete is other pozzolanic materials such as Fly fiery debris and silica smoulder which can replace a truly huge proportion of concrete in concrete. Overall, GGBS have greater content of CaO than other forms of pozzolanas. In India, liquid iron slag present in heater is quenched in water resulting in production of GGBS that becomes glistening, grained product that is converted to fine dust.

1.7 GGBS Applications

It makes long-life concrete structures with ordinary portland cement and/or pozzolanic material. Due to its better concrete durability, GGBS has found large application in Europe, and routinely finds increasing application in U.S. To increase the life span of structures to 50 to 100 years. Such slag cements like PBFC and HSBFC are produced by GGBS, also GGBS in ready-mixed durable concrete is produced upto 30 to 70%. The damage of ASR can be minimized by ensuring that GGBS enhances the resistance to chloride penetration thereby inhibiting the risk of corrosion in the reinforcing structures.

II. EXPERIMENTAL INVESTIGAITON

The motive of this investigate and compare the qualities of SCC formed when cement is replaced with a mixture of RHA and GGBS. In this work, research base on experiments conduct in labor, the paper which has already published and reading material from books.

III. Material Used

Cement It having binding property that hardens and sets in construction and can bond other materials. The most common varieties of cement are used in masonry mortar and concrete structure, Mixture of cement and aggregate that forms a strong building material.

3.2.2 Test on coarse aggregate

Sieve analysis of course aggregate

Weight of sample tested=3.454Kg

Table 3.2 Observation for coarse aggregate test

IS sieve size in mm	WT. of CA retained	% wt. retained	Cumulative percentage of total wt. retained	% passing	Desirable value according to Is 383
20	61	1.73	1.73	98.27	85-100
16	1438	42.63	43.36	55.64	0
12.5	1405	40.64	85	15	0
10	467	12.54	97.54	2.46	0-20
4.75	84	2.46	100	0	0-5
Pan	0	0	0	0	0

Water absorption of CA

The WA of CA used is 0.48%

Sp. gravity of C.A.

The sp. gravity of C.A. used is 2.56

Table 3.3 Observation for F.A. Sieving

Sieve size	Weight of fine aggregate retained (gm)	Percentage retained	Cumulative percentage retained	Percentage passing	Permissible percentage according to Is 383
10	0.0	0.0	0.0	100	100
4.75	0.0	0.0	0.0	100	90-100
2.36	0.0	0.0	0.0	100	75-100
1.18	764	76.4	76.4	23.6	55-90
600	160	16	92.4	7.6	35-59
300	24	2.4	94.8	5.2	8-30
150	50	5	99.8	0.2	0-10
Pan	2	0.2	100	0	

The fine aggregate being used is of Zone 2.

Water

For mixing and curing purpose water used.

Alternate materials

Rice Husk Ash

RHA is produced by incinerating the husk of rice paddy.RHA used, was from Rudhiana cement plant.

Table 3.4: Physical properties of RHA

Property	Result
Specific gravity	2.74
Consistency	28%
Colour	Black

Ground Granulated Blast Furnace Slag (GGBS)

GGBS is a non-metallic powder made up of calcium silicates and aluminates, among other things. The molten slag is quickly chilled in water, resulting in a glassy sand-like substance. The GGBS comes from ASTRAA CHEMICALS, and its physical parameters are as follows

Table 3.5: Physical properties of GGBS

Property	Result	
Specific gravity	3.02	
Consistency	32.5%	
Colour	Dull white	

Superplasticizer

Is a chemical substance that is used to increase workability without adding more water. The SP utilised in this work is Fosroc Chemicals (India) Pvt.ltd's Auramix 400.

3.3 Mix Design/proportioning

It can be classified as Self-compacting if it has the following characteristics

- Filling ability
- Passing ability
- Segregation resistance

To achieve that, one the most aspect which should be done careful is mix design. EFNARC provide the guidelines for development of SCC.

However, assuming a broad supply from ready-mixed concrete facilities, they have presented a simple mix-proportioning technique. The C.A. and F.A. contents are predetermined, allowing for simple self-compactability by adjusting the wate and plasticizer dosage.

In this work try and error mix was used to find desirable value for fresh properties and hardened properties. The purpose was to design SCC-mix of high strength M45 grade. The design begins with 450 kg/m3 cement, a water cement ratio of 0.4, and a binder content of 1% SP. Table shows the good outcome values that have been used. For fresh properties are in acceptable limited from EFNARC and are discussed in next point.

Table 3.6 : Mix Design

Mix	Cement	C.A.	F.A.	W/B	SP	RHA	GGBS
SCC 0%	530	750	916	0.41	1%	0	0
SCC(20%RHA+5%GGBS)	397.5	750	916	0.41	1%	106	26.5
SCC(20%RHA+10%GGBS)	371	750	916	0.41	1%	106	53
SCC(20%RHA+20%GGBS)	318	750	916	0.41	1%	106	106
SCC(15%RHA+15%GGBS)	371	750	916	0.41	1%	79.5	79.5

The specimens were casted from every mix proportion Table 4, for testing (Hardened) Compressive strength, Flexure and Split tensile strengthening respectively, result are shown and discussed in next point.

Research Methodology

The main characteristics of SCC are the properties in the fresh state. The ability to flowing under its own wt. without vibrating, to flowing through badly blocked reinforcement under its own wt. and to maintain homogeneity without segregation are all factors considered in the mix design. IS 456:2000 specifies a degree of workability, whereas SCC is more workable.

- Passing ability
- Filling ability
- Segregation resistance
- Four tests done for this project to ensure that the design mix could be utilised to generate specimens for testing toughened characteristics.
- Testing freshen concrete
- Slump test
- V-Funnel test
- L-Box test
- U-Box test

Following the completion of fresh property tests, similar specimen used for casting, with cubes, beams, and cylinders serving as specimens for hardened property testing.

IV. RESULTS AND DISCUSSIONS ON FRESH CONCRETE PROPERTIES

SCC is type of concrete which need large paste volume in order to achieve both high strength and self compacting properties. From all round performance points of view, the use of a large aabinder paste volume is undesirable as it would lead to high heat of hydration, greater shrinkage and creep. In order to get good workability and avoid this heat of hydration different trial mix were tested and value which is used was discussed in Chap 3, SP is used to enhance workability without increasing water. The results are showing in *table 4.1*

Table 4.1: Result for different fresh concrete properties test

Mix	Slump Flow (mm)	V-Funnel Time (Sec)	L-Box(H2/H1)	U-Box (H2-H1)
SCC 0%	718	11	0.96	25
SCC(20%RHA+5%GGBS)	692	10	0.92	24
SCC(20%RHA+10%GGBS)	690	10	0.93	24
SCC(20%RHA+20%GGBS)	681	10	0.89	23
SCC(15%RHA+15%GGBS)	661	9	0.875	23

Compressive strength

When it comes to talk about concrete structure, first things comes in mind is compressive strength. Concrete are very strong in compression, to design concrete which will used in construction that can resist compressive stresses. When a plain concrete member is subjected to compression, the failure of the member takes place, in its vertical plane along the diagonal. SCC is one of type concrete which most efficiency and has high strength compare to normal concrete, in this work M45 grade concrete is designed. Admixture RHA and GGBS are used as replacement to enhance fresh and hardened properties, in this work 20%RHA is fixed and added along with 5%, 10%, 20% of GGBS for three different mix and for more investigation 15%RHA and 15%GGBS was used as another mix to check the range strength will be maximum. The result are showing in *Table 4.2*

Table 4.2: Compressive strength test results for various SCC mixes

Property	*Mix*	*Curing Period*		
		7 days	*28 days*	*56 days*
Compressive strength	SCC 0%	*35.13*	*50.5*	*56.1*
	SCC(20%RHA+5%GGBS)	*36.2*	*51.6*	*57*
	SCC(20%RHA+10%GGBS)	*36.8*	*52.7*	*57.5*
	SCC(20%RHA+20%GGBS)	*35.6*	*52.1*	*54.8*
	SCC(15%RHA+15%GGBS)	*37.8*	*53.60*	*59.1*

It may be noted from *Table 4.2* and also Fig 4.1 that the 28-days compressive strength when cement replaced by 15%RHA and 15%GGBS is 53.6 MPa, which is about 16.04% more than the design strength. For 28-days when there is no replacement of cement strength is 50.5, which is about 10.89% more than the design strength. From 10.89% to 16.04%, Compressive Strength increased 5.15%.

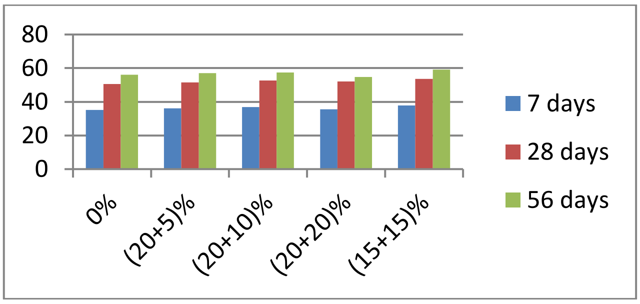

Figure 4.1: Compressive strength of SCC mixes at various ages

Split tensile strength

The split tensile strength of all the mixes was determined at the ages 7 days, 28 days and 56 days when additional percentages of RHA along with GGBS in concrete mix. The split tensile strength results of individual concrete mix are also shown graphically. The maximum values of split tensile strength of concrete is when combination of 15%RHA and 15%GGBS are used as replacement while minimum values is when combination of 20%RHA and 20%GGBS are used as replacement of cement.

Table 4.3: Split tensile strength test results for various SCC mixes

Property	Mix	Curing Period		
		7 days	28 days	56 days
	SCC 0%	3.29	3.45	3.97
Split tensile	SCC(20%RHA+5%GGBS)	3.5	3.67	4.2

	SCC(20%RHA+10%GGBS)	3.61	3.7	4.4
	SCC(20%RHA+20%GGBS)	3.49	3.5	4.17
	SCC(15%RHA+15%GGBS)	3.72	3.85	4.8

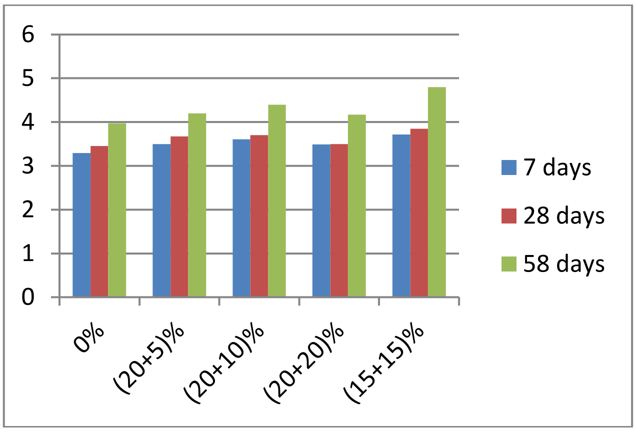

Figure 4.3: Split tensile strength of SCC mixes at various ages

It may be noted from *Table 4.3* and also Fig.4.3 that the 28-days Split Tensile strength when cement replaced by 15%RHA and 15%GGBS is 3.85 MPa, while up 15%RHA and 15%GGBS the split tensile strength was increasing significantly.

Flexure strength

The flexural strength of all the mixes was determined at the ages 7 days, 28 days and 56 days when additional percentages of RHA along with GGBS in concrete mix. Flexural strength results of individual concrete mix are also shown graphically. The maximum values of flexural strength of concrete is when combination of 15%RHA and 15%GGBS are used as replacement while minimum values is when combination of 20%RHA and 20%GGBS are used as replacement of cement.

Table 4.4: flexural strength test results for various SCC mixes Property

Property	Mix	Curing Period		
		7 days	28 days	56 days
Flexural strength	SCC 0%	9.34	9.47	11
	SCC(20%RHA+5%GGBS)	9.5	9.61	11.8
	SCC(20%RHA+10%GGBS)	9.58	9.65	12.3
	SCC(20%RHA+20%GGBS)	9.48	9.5	10.87
	SCC(15%RHA+15%GGBS)	9.68	9.83	12.93

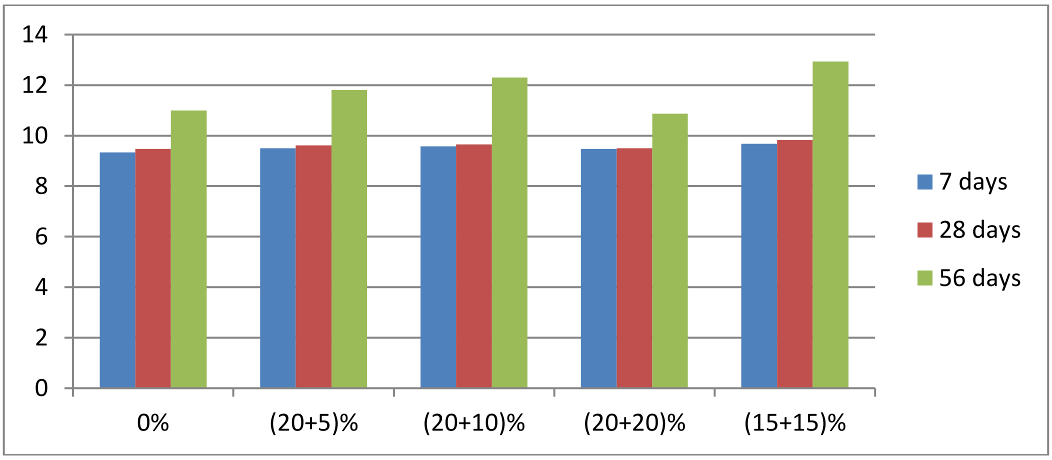

Figure 4.5: Flexural strength of SCC mixes at various ages

It may be noted from *Table 4.4* and also Fig 4.5 that the 28-days Flexural strength when cement replaced by 15%RHA and 15%GGBS is 9.83 MPa, and it is increasing significantly, while when cement replaced by 20%RHA and 20%GGBS, Flexural strength start decrease.

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