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Effect of Modified Geopolymer Self Compacting Concrete Using Rice Husk Ash

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Abstract

Self-Compacting Geopolymer Concrete (SCGC) in concrete construction is a revolutionary building material. As the name implies there is no requirement for compaction attempts to ensure complete compaction. It employs Supplementary Cementitious Materials (SCM) along with alkaline solutions such as sodium hydroxide, sodium silicate and super plasticizer which form a binder for the formation of framework and strength. In this paper, SCGC based on fly ash (FA) is replaced by varying Rice Husk Ash (RHA) percentages. The results revealed the production of self-compacting geopolymer concrete using RHA with potentially 60MPa high compressive strength, which can substitute traditional cement concrete and therefore minimize carbon emissions. Improved compressive and split tensile strength and modulus of elasticity with RHA incorporation of up to 5 percent were reported. Above the optimum 15 percent content, adverse effects were recorded by RHA incorporation. Regarding the ecological issues associated with RHA dumping, it will be necessary to utilize such an agricultural by-product. It is also useful to understand the use of RHA as concrete raw material because it can be used as renewable and multi-functional components. Ultimately, the mechanical reliability improvement provided in this study will help offer a strong basis for the production of dynamic filler materials for high strength concrete.

Keywords: *Self-Compacting Geopolymer Concrete, Supplementary Cementitious Materials, flyash, Rice Husk Ash.*

1. INTRODUCTION

In many industries, India is expanding. India's infrastructure within such industries is rising quite rapidly to meet the demands of many other industries. To reach the urbanization requirement, the building industry has changed extremely fast, thus increasing the use of cement concrete. To minimize conventional cement consumption, different findings are oriented on using supplementary cementitious materials like fly ash, silica fume (Mehta and Siddique, 2016). Indeed, the concept of geopolymer concrete is by far the most hopeful outcome of such research.Geopolymer concrete includes the manufacture of alumina and silica binders that can be extracted through minimal-cost components or industrial by-products, which can therefore also be called renewable geopolymer concrete. The durability performance of SCGC could increase through the introduction of SCMs in the cement mixture. SCMs are organic compounds otherwise by-products of the large factories those exhibits the properties of cement once complemented by means of water and cement. Also, employing the SCMs in concrete mixes makes it extra cost-effective, boosts strength, and the concrete's porousness is limited (Siddique, 2009). The SCMs varying cases consist of Fly Ash (FA), Ground Granulated Blast Furnace Slag (GGBFS), Rice Husk Ash (RHA), and Silica Fume (SF).

Rice husks make the tough-outer coatings of rice grains that are removed after the milling operation from the grains. Rice husk is a surplus product that is widely accessible across all grain-producing countries and comprises around 30-50% of organic carbon.The husks are separated from the whole grain during a traditional milling operation to expose raw brown rice that will produce white rice after further milling to eliminate the bran coating. Rice husk is hard to light up and is not easily incinerated with an open fire except if the air is blasted through the husk; burned rice husk ash is shown in figure 1. It also has a substantial energy content of 3410 kcal/kg on the scale. Hence it is a valuable choice of sustainable energy.

Figure 1: Rice Hush Ash (RHA)

It is a pozzolan constituent that is exceedingly responsive. It is acquired by exposing the rice husks to heat in a regulated condition to a degree under 700oC (Madandoust and. Ghavidel, 2013). It is viable for employing as SCMs as the developed product has an extreme concentration of amorphous silica. In recent years, many researches have been performed for employing RHA as a substitution for cement on the workability characteristics determination and also splitting tensile strength of RHA dependent SCGC. But, considerations regarding the mechanical properties particularly, compressive strength and elasticity modulus of SCGC that makes use of RHA subjected to varying curing stages were less exceptional. The present investigation is intended for the extensive analysis regarding the effect of RHA on the operational as well as workability characteristics concerning SCGC. For the accomplishment of the objective parameters such as cement substitution rates with RHA, age of the concrete, and water/binder proportions were taken into comprehensive practice.

2. LITERATURE REVIEW

The concrete constructions for some fieldwork involving geopolymer were employing FA in the form of alumina-silicate content. FA geo-polymerization necessitates elevated-temperature oven curing intervals between 60°C and 90°C, that mostly consumes a great deal of energy. Reasonable concrete curing enhances the geopolymer concrete's mechanical properties.(Guo et al., 2010) proposed that sustained curing may disintegrate the geopolymer mixture's granular structure contributing to a reduction in strength. (Rovnanik, 2010) stated that high temperatures create broad pores at an earlier age, thereby increasing the volume of pores and negatively impact the properties of geopolymer concrete.Anenhancement in geopolymer compressive strength was detected with a rise in curing temperature range of 60 to 70° C; moreover, compressive strength was decreased by a temperature above 70° C.

The RHA concentrations in the cement mix critically affect the workability performance of the concrete. (Ludwig and Le, 2016) examined the impact of superplasticizer as well as admixtures on the self-compacting and compressive properties of SCC and cement including RHA and fly ash. Subsequently curing for fifty-six days, the SCC’s compressive strength comprising 20% of FA and RHA remained approximately 130MPa. Utilizing a mixture of corresponding-weight portions of FA and RHA

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delivers great durability and Cl- diffusion tolerance with reduced super-plasticizer demand.

Curing seems to have a substantial effect on the properties of hardened concrete including durability strength, tightness of water, wear tolerance, the resilience of volume and ability to resist freezing and dissolving, creeping, chemical assault and thickness. Rice Husk Ash comprises a large proportion of silica, generally more than 80 percent, thereby rationalizing its usage in partial substitution for RHA to accomplish an acceptable ideal strength in concrete. RHA has been renowned for improving concrete strength and its capacity to endure intense coverage in regard to significant earnings in concrete costs by such replacements. (Ganesan et al., 2008). In binary and ternary blends with RHA, the pozzolanic activity was stated to be greater in amounts of 25% or more (Isaia et al., 2003).

3. PROPERTIES OF RICE HUSK ASH (RHA)

Unlike standard concrete, RHA may be used in conjunction alongside glass, steel and polyphenylene fibres to enhance the strength characteristics of perpetual concrete pavement constructed with 0.33 w / c ratio. In addition, RHA may afford large flexibility to the heated mix as that of mineral filler in hot mixed asphalt concrete (Sebnem et al., 2013).Data in tabulation 1, as well as 2 below, demonstrate the structural and synthetic characteristics of RHA concrete. The Compound content of the RHA changes for the results of the combustion.

Table 1: Compound Composition of RHA.

Compound Name	Proportions
SiO_2	91.73%
Al_2O_3	2.12%
Fe_2O_3	0.80%
CaO	1.27%
MgO	0.67%
Na_2O	0.14%
K_2O	0.76%
Others	0.89%
LOI	1.56%

RHA developed by regulated combustion is a porous product with large amorphous silica content. Two forms of residue, white RHA (WRHA) and black RHA (BRHA), were formed owing to the heat gradient amid the inside and external of the batch of rice husk. WRHA is a reasonable pure silica product, processed at a suitable temperature (500–700°C), whereas BRHA purity is quite lower attributable to strong carbon content. ASTM C618 sets out the pozzolan specifications for cement and concrete application. RHA has been graded to the form “N” pozzolan according to standards. (Salas et al., 2009) stated that, if treated, a definitearea of 274 thousand square meters per kg that could be ten folds those of SF as well as ordinary RHA may be obtained in RHA. The rice husk was processed at a density of 1 N for 24 hours by hydrochloric acid and afterward treated vigorously by water to create anunbiasedsolution. The huskmust again let to dry and scorched to ashes to that of 600°C in a muffle furnace for 3 hours.

Table 2: Physical Properties of RHA

Parameters	Range
Specific gravity	2.06–2.16
Specific surface (m2/kg)	240.0–376.8
Activity index of pozzolan (%)	81.25–88.90
Bulk density (Kg m3)	420.0–429.1
Median size of particle (µm)	5.0–7.41
Nitrogen adsorption	24.3–28.8

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(m2/kg)	
Surface area (cm2/g)	4091–5685

4. TEST ANALYSIS

4.1 Materials used

Fine, coarse and filler constitute the overall aggregate. The aggregate (fine) used is rinsed sand having a refinement modulus of 2.65, a specific gravity of 2.57, and water retention of 1.5%. The aggregate (Coarse) of average minimaldimensions of 12.4mm is used, with water retention and a specific gravity of 1.2 percent and 2.68. The recommended rice husks have been received through Namakkal District, Tamil Nadu. RHA was acquired by firing at an extremely elevated heat around 700°C and the level of temperature has been maintained at 10°C per minute. The ash collected is grey colour having an average element dimension of 24µm and a specific gravity of 2.2.

Table 3: Mix proportion

Mix ID	Coarse aggregate (kg m^{-3})	Fine aggregate (kg m^{-3})	RHA (kg m^{-3})	Water (litres)	SP (%)
M1	785	850	18 (5% RHA)	25	6
M2	785	850	36 (10% RHA)	25	6
M3	785	850	54 (15% RHA)	25	6
M4	785	850	72 (25% RHA)	25	6

The RHA surface area is considered to be 85m2/g. Since SCGC's standard mix design code is not available, guidelines for designing the different mixes are followed by the European Federation of Specialist Construction Chemicals and Concrete Systems (EFNARC).For all mixtures, a water cement ratio (W / C) of 0.5 was used. Table 3 shows the different mix proportion of specimens with varying percentages of RHA.

4.2 Casting and Curing

For about 10 minutes, dried components of RHA, the aggregates (coarse &fine) were combined with the pan mix. Cubes used in accordance with BS EN 12390 dimensional guidelines were 100 mm x 100 mm x 100 mm x 100 mm. During the trial mixtures, sufficient workability was not obtained; thus super plasticizer was applied to the mixture with the effective solution of the alkali. The molds have been greased so that the concrete can be easily removed once completely set. The samples have been cast and cured for 24 hours in an oven at 80°C as the trial mixture acquired maximum compressive strength values at such heating and immersed for 3, 7, 28, 56 and 90 days in water for curing. In order to prevent the loss of moisture, the de-molded samples are coated with cling film until the testing phase following heat curing.

5. PROPERTY EVALUATION TESTS

5.1 Fresh State Properties

The fresh state performance of the SCGC sample was evaluated in view of three qualities including filling, passing, and resistance to segregation. Using numerous techniques namely flow using slump, V-funnel, as well as L-box, these prarameters are evaluated. The slump flow test is conducted to determine SCGC's flow ability. The devices for this experiment consisted of conventional slump cone and untamped concrete were kept in the mold. The concrete was permitted to flow naturally. To estimate the percentages, the concrete diameter was calculated in two perpendicular locations. The results of the test showed strong filling ability and accuracy.The L-Box assessment is calibrated in order to consider the filling and passing capacity of SCPCs. The L-box device comprises of an L-shaped box with a straight and perpendicular portion parted by a compact door and in front of the door are mounted vertical reinforcement bars. The concrete was allowed to pass at the bottom of the box via the tightly spaced reinforced bars.Once the concrete staysfrom flowing, the blocking percentage was determined by calculating the concrete elevationon the edges of the straight and perpendicular sections. The V-Funnel Test has been employed primarily to test the filling capacity i.e. the flow capacity and to determine the segregation resistance of SCGC samples in which the device comprised of a V-shaped funnel. The concrete was employed without any compaction or tapping to fill the funnel entirely with it. After that, the trapdoor at the bottom was raised for letting the concrete to pour off by gravity. The periodengaged to flow via the orifice for all the concrete was registered as the flow time of the funnel.SCGC mandated a funnel flow time of 6 to 12 seconds. Table 4 summarizes the results achieved from the above tests.

Table 4: SCGC Fresh State Test Result (EFNARC)

Test method	Slump flow (mm)	V-funnel (sec)	L-box (H2/H1)
M1	674	11	0.91
M2	683	10.5	0.93
M3	693	7	0.95
M4	710	6.5	0.96

5.2 Mechanical Properties

In compliance with the BSI regulations, compressive tests were conducted. For SCC, that found to contain 5% RHA provide in Table 5, the highest compressive strength was achieved. From the data was observed that the compressive strength improves as the proportion of RHA rises with the replacement till 5 percent beyond that the compressive strength begins to decline, as per the findings. Substitutes of 5 as well as10 percent RHA allow the strength to improve simultaneously, but declines by replacing 15% and 20% RHA. Owing to the RHA's pozzolan content and filling capacity at the micro level there is a rise in the compressive strength. RHA interacts among the concrete by-product toprovide supplementary Calcium Silicate Hydrates (CSH). The additional CSH shrinks the porosity of concrete, thusenhancing the compressive strength of the concrete microstructure in the transition zone at the interface level and enhances the compressive strength of the cementmedium. The explanation for the reduction of compressive strength in the SCC samples is quite probably responsive with the slaked lime provided in the dried cement attributable to the rather large content of silica present. Significant portions of silica are therefore unable to react chemically (Chopra et al., 2015).

The substantial hardened characteristic of concrete that is essential for the layout of structural foundations is the split tensile strength. As can be observed, the strength of the splitting tensile rises with the percentage of RHA being replaced by up to 5 percent and then begins to fall. For SCC, which included 5% RHA, the maximum splitting tensile strength was obtained. When using 5 to 15 percent RHA, the split tensile strength increases, and by using 20 percent RHA split tensile strength decreases by relative to the SCC.

Table 5: SCGC Hardened State Test Result

Mix ID	Compressive strength (MPa)	Split tensile strength (MPa)	Modulus of elasticity (GPa)
M1(5% RHA)	59.6	3.70	31.95
M2(10% RHA)	56.7	3.68	31
M3(15% RHA)	51.2	3.62	29.76
M4(20% RHA)	47.4	2.93	27.98

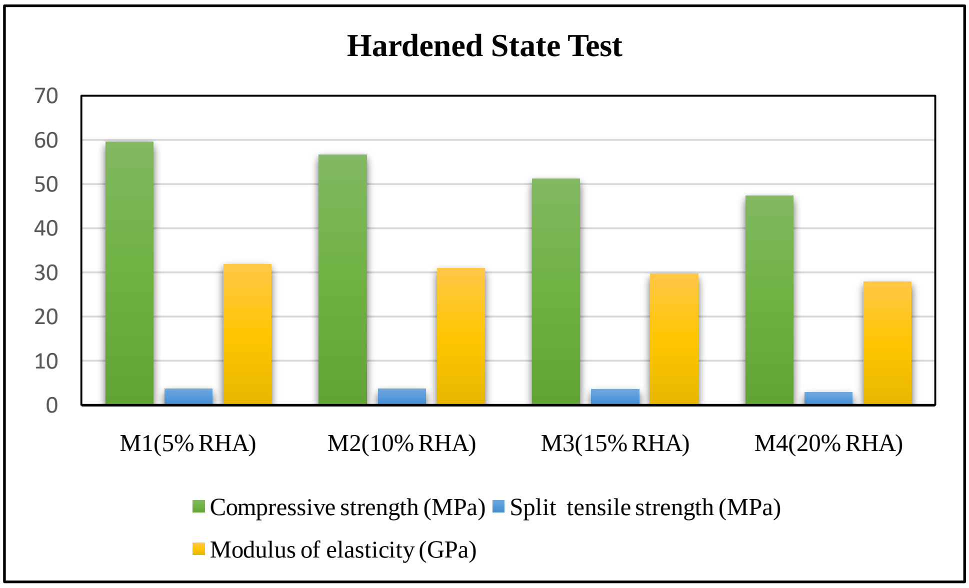

Figure 2: Compressive, Split tensile and Modulus of elasticity graph

Compared to compressive strength, eventually increased strength resulted primarily from exceedinglyresponsive RHA elementswhich combine with Ca (OH) $_2$to generate extra CSH, resulting in a more compact SCC microstructure. Modulus of elasticity increases after it begins to decrease with an improvement in RHA rate up to 5 percent. For SCC, which incorporated 5 percent RHA, the highest elasticity module was received. By adding 5 and 10 percent RHA, the modulus of elasticity increases throughout, and by introducing 15% and 20% RHA, the elasticity module declines in both. Comparative results of all the above mechanical properties are shown in figure 2.

Conclusion

In order to achieve the workability and hardened properties of SCC comprising RHA, an experiment analysis was carried out. Findings revealed that replacing RHA with fly ash-based SCGC decreases the characteristics of workability, and improved strength with increased binder content. Including RHA to the SCC also reduces the SCC's passing and filling capacity and therefore more superplasticizer should be employed to achieve acceptable workability. SCGC's development with RHA is practicable.It is indeed not alone cost-effective, yet further promotes the secure management of agricultural and industrial waste and hence preserves productive lands against degradation. Further, it reduces noise pollution due to SCGC's self-compacting property.

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