Suitability of GGBFS & RHA (Combined) as Source Material in Geopolymer Concrete – A Review

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Abstract

Pollution is the most important aspect on which we have to think about. Cement being the most important material in the concrete causes the environmental pollution in its production. To overcome this problem use of various by-products should be done, like Flyash, GGBFS, RHA, Silica Fume, etc. Therefore, an attempt has been made to study the suitability of Ground Granulated Blast Furnace Slag (GGBFS) & Rice Husk Ash (RHA) materials as replacement of Portland cement. GGBS is obtained from blast furnace slag, a by-product from the manufacture of iron & RHA is the agricultural waste produced from rice husk mill. In many countries there is big need to reduce cost of construction due to highly increase in demand. So by using these waste products there is decrease in consumption of cement which decreases the cost and also these materials are easily available for people. Research has shown that the replacement of cement with Supplementary Cementing Materials improves the mechanical properties of concrete. In this paper the suitability of GGBFS & RHA as source material i.e. binder will be checked.

Keywords: Alkaline Solution, Ambient Curing Temperature, CO_2 Emission, GGBFS, RHA

I. Introduction

The Civil Engineering construction is increasing massively day by day with the increase in demand for the cement production. One ton production of cement emits about one ton of Carbon dioxide into the atmosphere, including for burning of the fuel fossils and for process of production using raw materials [1]. This enormous liberation of carbon dioxide from the cement industries is one of the major issues for the cause of ecological imbalance, resulting in green-house effect. This emission of carbon dioxide into the atmosphere is minimized by using the waste materials. One of the industrial by product generated from the Steel Plants, called as Ground Granulated Blast Furnace Slag (GGBFS). Ground-granulated blast-furnace slag (GGBFS) is obtained by quenching molten iron slag from a blast furnace in water or steam, to produce a glassy, granular product that is then dried and ground into a fine powder. [2] Adding GGBFS with the Sodium Hydroxide Solution and Sodium Silicate Solution, (together called as alkaline activators), which forms a good bond between the GGBFS and other body forming inert aggregates (Coarse and Fine Aggregates).

Another agricultural waste material can be used in geopolymer concrete is known as RHA (Rice Husk Ash). During milling of paddy about 78% of weight is received as rice, broken rice and bran. Rest 22% of the weight is received as husk. This husk is used as fuel in the rice mills to generate steam for the parboiling process. This husk contains about 75% organic volatile matter and the balance 25% of the weight of this husk is converted into ash during the firing process, is known as rice husk ash RHA [3]. This RHA in turn contains around 85% to 90% amorphous silica. So far every 1000 kgs of paddy milled, about 220 kgs (22%) of husk is produced, and when this husk is burnt in the boilers, about 55 kgs (25%) of RHA is generated.

II. Objectives

The main aim of this review paper is to investigate the potential use of commercially available industrial waste ground granulated blast furnace slag (GGBFS) and rice husk ash (RHA) as a sustainable construction material for producing geo-polymer concrete.

This paper is based on the comprehensive review of available literature on sustainable construction materials, GGBFS and RHA. The review is not arranged chronologically but on the priority basis of the literature for the proposed work and covered categories of geo-polymer concrete with various cementetious materials.

III. Literature review

N A Lloyd et al [4], presented brief details of fly ash-based geo-polymer concrete. A simple method to design geo-polymer concrete mixtures has been described and illustrated by an example. N A Lloyd used fly ash as binder in the replacement of cement. The price of one ton of fly ash is only a small fraction of the price of one ton of Portland cement. Therefore, after allowing for the price of alkaline liquids needed to the make the geo-polymer concrete, the price of fly ash-based geo-polymer concrete is estimated to be about 10 to 30 percent cheaper than that of Portland cement concrete. Geo polymer concrete has excellent properties and is well-suited to manufacture precast concrete products that are needed in rehabilitation and retrofitting of structures after a disaster. The economic benefits and contributions of geo-polymer concrete to sustainable development have also outlined.

V. Supraja et al [5], studied about geo-polymer concrete, in which Portland cement is fully replaced with GGBS (Ground granulated blast furnace slag) and alkaline liquids as binding agents. The alkaline liquid used is the solution of Sodium hydroxide (NaOH) and sodium silicate (Na2Sio3). Different molarities of sodium hydroxide solution i.e. 3M, 5M, and 7M and 9M are taken to prepare different mixes. And the compressive strength is calculated for each of the mix. The cube specimens are taken of size 100mm x 100mm x 100mm. Two different curing are carried i.e. oven curing at 500c and curing directly by placing the specimens to direct sunlight. The geo-polymer concrete specimens are tested for their compressive strength at the age of 3 and 7 days. The result shows that there is no significant increase in the strength of oven cured specimens after 3 days of oven curing and the strength of geo-polymer concrete is increasing with the increase of the molarity of sodium hydroxide.

Prasanna Venkatesan Ramani et al [6], reported that when GGBS was replaced with BRHA by 10%, 20% and 30%, and NaOH and Na2SiO3 solutions added to the mix, the compressive strength of geo-polymer concrete was improved. Prasanna Venkatesan Ramani observed that replacement of 10% of RHA in 100% GGBS geo-polymer gave higher compressive strength and tensile strength. Up to 20% replacement of GGBS with RHA strength is greater than target strength even though there was retarding effect with increase in percentage of BRHA. But 30% replacement did not give high strength and durability. So it was concluded that use of higher percentages of RHA is not required.

P. Nath et al [7], concluded that with the increase of alkaline activator solution in the mix from 35% to 45% of total binder, the setting time increased and compressive strength decreased. Slump of fresh concrete also increased with the increase of alkaline solution in the mixture. Also the alkaline activator solution with SS/SH ratio of 2.5 achieved lesser slump and setting time than those with 1.5 and 2. Compressive strength variation of concretes was not significant due to variation of SS/SH ratio in the mix.

Sonali K Gapalliwar et al [8], observed the effect of replacement of cement by GGBS and RHA and natural sand by quarry sand. GGBS replacement values were about 10%, 20% and 30%.while the percentages of replacement of GGBS and RHA was (25%+5%), (22.5+7.5%) and (20%+10%).the super plasticizer used was AC-PLAST-BV M4 PLASTICIZER which is a high range water reducing agent. a slump value of 60mm was maintained for all mixtures. the replacement level of (22.5%+7.5%) gives good increase in compressive strength, while the rest of the mixtures of GGBS with RHA gives lower strength compared to the controlled mixture.

Ravi Prasad et al [9], showed good increase in compressive strength when cement was replaced with RHA. Concrete containing GGBS was subjected to high temperatures.

Rajat Siddique et al [10], observed compressive strength of Geo-polymer concrete with super plasticizer SNP (sulphonated naphthalene polymer) with a dosage of 1.1% by weight of cement was added to reduce the use of water in concrete. No significant deterioration of mechanical properties of concrete was seen between temperatures of 270C to 1000C. At 3500C reduction in tensile and compressive strength is less than 40% of initial value. 20% of GGBS can be suitable for construction of nuclear structures.

Surya Veera Vasudeva Rao et al [11], studied on the performance of RHA at elevated temperatures. Super plasticizer used was SP430A2 to obtain a workable mix. Slump value of 75mm was maintained in all mixes. 5% to 10% replacement of RHA with cement doesn't change the strength but workability decreases with increase in RHA. So 10ml, 12ml, 14ml, 16ml super plasticizer was added for replacement level of RHA of 5%, 10%, 15%, and 20% respectively. Compressive strength increases till 1000C to 1500C then decreases up to 7000C. 15% replacement is found to be optimal as the residual compressive strength at various temperatures in the range of 1000C to 7000C shows similar strength to that of concrete without RHA. 10% replacement with RHA shows good performance for both 7 days and 28 days when compared to normal concrete.

G Hassan Abood et al [12], studied on properties of RHA and its use as cement replacement material. In this paper test was conducted on specimens of RHA of 3 different grades. They were ground for 180 min, 270 min and 360 min. they maintained the slump value in between 200mm and 240mm, so the workability of concrete was found to be good. The Compressive strength for 1day, 3days, 7days and 28 days were investigated. The 28days strength has increased from 39.6MPA to 50.2MPA for 10% RHA ground for 270 min, i.e. 30% of strength was increased compared to control mix. The replacement of 15% RHA increased the compressive strength by 5%. The use of 20% replacement mix did not give any increase in compressive strength so further replacement of RHA in concrete is not desirable and should be avoided.

Shakir Mahboob et al [13], studied on the effect of various curing times of oven cured geo-polymers, samples cure in ambient temperature, the performance implication of different ratios of ground granulated blast furnace slag and fly ash, use of impact compaction GGBS. They concluded that GGBFS is higher in compressive strength and lower in flexural strength, combined microwave and oven heating can reduce the curing time and increase material strength. Study also gave the reasons why geo-polymers can be weekend which are, white and matrix damage due to leaching, unreacted material, uneven curing during heat treatment, poor Si:Al ratio, non uniform particle composition.

Ganapati Naidu et al [14], studied on properties of concrete containing ground granulated blast furnace slag. Higher concentrations of G.G.B.S (Slag) result in higher compressive strength of geopolymer concrete. Mixing of G.G.B.S was tested up to 28.57%, beyond that immediate setting was observed. There is no necessity of exposing geopolymer concrete to higher temperature to attain maximum strength if minimum 9% of flyash is replaced by GGBS. Compressive strength of geopolymer concrete is increase with increase in percentage replacement of flyash with GGBS. Flyash was replaced by GGBS up to 28.57%, beyond that fast setting was observed. 90% of compressive strength was achieved in 14 days. The average density of geopolymer concrete was equal to that of OPC concrete.

Mrs. A. Shalini et al [15], studied on the performance of rice husk ash in geo-polymer concrete. Workability of RHA concrete has been found to decrease with increase in RHA replacement. Concrete requires approximate increase in water cement ratio due to increase in percentage of RHA because RHA is highly porous material. RHA provides excellent thermal insulation.

K.Madhu et al [16], studied on partial replacement of cement with RHA and metakaolin. M30 mix grade concrete was used with RHA in proportion of 0%, 5%, 10%, 15% and 20%. By adding critical mix and replacing the cement by rice husk ash fine, it is found that by increasing the percentage of RHA workability decreases due to increase in water absorption and strength decreases gradually.

Smita Singh et al [17], studied on use of alternate and low cost construction material Rice Husk Ash(RHA) as cementing material in concrete in the proportion of 0%, 5%, 10%, 15% and 20% of cement by weight. Average maximum compressive strength achieved for 14 days was 22.22 for 5% of RHA. Moreover, with the use of RHA, the weight of concrete reduces and making it lighter.

Ravi Kumar R. and Sridhar R et al [18], they carried out experimental investigation on properties of GGBS based geo-polymer concrete for high volume traffic. An attempt has been made to establish the mix proportion to geo-polymer concrete, to study the engineering properties of geo-polymer concrete and to prove that the new alternate material is eco-friendly. The mix combinations of alkaline solutions are achieved by adding sodium hydroxide solution of varied molarity 12M, 14M and 16M, with the sodium silicate solution maintaining a ratio of 2.5, 5.0 and 7.5 with alkaline liquid to binder ratio as 0.3, 0.4 and 0.5

B. Sarath Chandra Kumar et al [19], studied on durability of GGBS and metakaolin based geo-polymer concrete. The alkaline liquids used in this study for polymerization process are the solution of sodium hydroxide and sodium silicate. The cube specimens are taken of size 150mm×150mm×150mm. The test data indicates that on exposure to 5% sodium sulphate, sulphuric acid and sodium chloride, the losses in weight, and strength of geo-polymer concrete are significantly much less than those for cement concrete. Thus the geo-polymer concrete is considered to be an environmentally pollution free construction material.

T. Ravi Prasad et al [20)], studied on enhancement of fiber concrete by using GGBS and RHA. The effect on compressive strength of concrete for different proportion of GGBS and RHA for high performance concrete was studied to find the optimum proportion.

IV. Conclusions

- It is possible to produce Geopolymer Concrete of significant strength using GGBFS and RHA. It promotes the utilization of waste materials like GGBFS and RHA for concrete production. Since these materials are by-products (Industrial & Agricultural), it's also reduces disposal problem,
- It is feasible to develop geo-polymer concrete at ambient tempera¬ture using GGBFS and RHA as sole binder,
- Use of GGBFS and RHA to develop geo-polymer concrete indirectly reduces the emission of green house gas CO2 in the atmosphere released from the cement industries,
- Up to 30% RHA replacement is recommended. Higher replacement will not give any further increase in strength,
- 90% GGBFS and 10% RHA gives optimum strength, so this percentage combination is ideal situation for this concrete,
- With the increase in the percentage of RHA, workability of design mix decreases due to increase in water absorption and also strength is decreases gradually,
- Geopolymer concrete is estimated to cost 20 to 30% cheaper than cement based concrete, so it develops more sustainable and durable structure than ordinary Portland Cement Concrete.
- Use of GGBS decreases the loss of mass and gives good resistance to sulphate attack and Use of RHA increases the compressive strength of concrete under sulphate attack. So the concrete can be used in nuclear structures or as refractory concrete. As it shows good resistance to sulphate attack, it can be used in marine structures.

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