International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 7 (2018) pp. 81-84

Rice Husk Ash as a Potential Source Material for Geopolymer Concrete: A Review

Shaswat Kumar Das
Under Graduate Student, Department of Civil Engineering,
Government College of Engineering, Keonjhar, Odisha-758002, India

Jyotirmoy Mishra
PhD Research Scholar, Department of Civil Engineering,
VSSUT, Burla, Sambalpur, Odisha-768018, India

Syed Mohammed Mustakim
Senior Technical Officer, Environment & Sustainability Department,
CSIR-IMMT, Bhubaneswar, Odisha-751013, India

Abstract

Concrete is the most versatile, durable and reliable construction material on the planet. But sustainability becomes the major concern as the conventional concrete is not eco-friendly due the large carbon footprint of Ordinary Portland Cement (OPC) industries. Efforts are needed to develop an eco-friendly material with minimal environmental damage. A concrete with complete replacement of OPC by pozzolanic materials like fly-ash, Rice Husk Ash (RHA), Ground Granulated Blast-furnace Slag (GGBS) etc. having a polymeric binder is called Geopolymer concrete (GPC). In Geopolymer concrete, most of the research work has been focused on fly ash based binders. However, the RHA has the potential to be used as a source material in Geopolymer concrete as the RHA is a pozzolanic material containing about 85-90% of silicon dioxide (SiO2). This paper briefly reviews the work carried out by various researchers & scientists on RHA based Geopolymer concrete as well as focuses on sustainable utilization and potential benefits of using RHA in the field of Geopolymer concrete.

Keywords: Rice Husk Ash, Geopolymer, Pozzolanic material, Ground granulated blast furnace slag.

Introduction

In every man-made structure, from roads to skyscrapers and bridges to dams, concrete is used as the major constituent of all. Concrete is second only to water in terms of its use by mankind [Hanson, 1995]. Cement is the most essential ingredient of the concrete which binds all the aggregates together in the matrix but cement is both energy & resource intensive material. The production of one metric ton of the OPC requires 4GJ of energy, and also emits about one metric ton of carbon dioxide into the atmosphere [1]. The cement industries nearly contribute 7% of total CO_2 emitted annually [2]. Therefore nowadays extensive research work is going on Geopolymer concrete as a full replacement of cement in concrete by various pozzolanic materials such as- fly-ash, GGBS, Metakaolin etc.

Rice Husk Ash (RHA) is the by-product of rice milling industries which is left after the production of biomass energy from the husk (rice hull). Generally, the RHA is burnt in the boiler at a controlled temperature by means of direct combustion or gasification which produces heat energy. This heat energy is used to process the paddy at the mill. After this process, a non-biodegradable residue product is formed which is rich in silicon dioxide called Rice Husk Ash. For every 1000 kg of paddy, about 55 kg of RHA is left as residue [3]. India is the second largest producer of rice around the globe, about 120 million tons of RHA is annually produced worldwide which becomes a severe environmental threat from last few decades.

When the Rice husk is burnt at a controlled temperature it has high SiO_2 content and most of it is in the amorphous form [3]. Due to occurrence of the abundant silica content, it shows pozzolanic behaviour so it can be used as a source -material in Geopolymer concrete.

Properties of RHA

Physical Properties

The RHA (pulverized) is a very fine and porous material having a particle size range of 5-75 micron [4]. Physical properties of RHA as referred by some researchers is given below in table -1.

Table 1: Physical Properties

Physical Properties	Mehta et al.	Nagrale et al.
Mean particle size	----	63.8 μm
Specific gravity	2.06	2.11
Fineness Passing 45 μm	99%	98%

The physical properties of RHA largely depend on burning conditions. Particularly, the period and temperature of burning affect the microstructure and characteristics of RHA (Nagataki 1994). Hwang & Chandra (1997) suggested that burning rice husk at temperatures below 700°C produces amorphous silica which has a high surface area as shown in Table-2.

Table-2: Rice husk ash properties produced from different burning conditions (Hwang & Chandra 1997)

Burning Temperature	Hold Time	Furnace Environment	Properties Of Rice Husk Ash	
			Silica Form	Surface-Area (m^2/g)
500-600° C	1 min	Moderately Oxidizing	Amorphous	122
	30 min			97
	2hr			76
700-800° C	15 min -1hr			100
	>1hr	Highly Oxidizing	Partially crystalline	6-10
>800° C	>1hr		Crystalline	<5

Chemical Properties

The RHA contains a large amount of amorphous silica which actually comes from the husk which is consist of 50% cellulose, 25-30% lignin, and 15-20% silica [5]. After oxidization process of Rice husk, the RHA is formed which nearly contains 85-90% of silica. Test of the chemical composition of RHA is generally done by XRF. The test result by different authors is given below in the table-3.

Table-3: the chemical composition of RHA (by % of Wt.) (LOI*-Loss on Ignition)

Constituents	SiO_2	AL_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	K_2O	LOI*
H.Than le et al	86.81	.50	.87	1.04	.85	----	.69	3.16	4.6
H.ChaoLung et al.	91.00	.35	.41	----	.81	1.2	.08	3.21	8.5
R.Zerbino et al.	95.04	.30	.44	1.25	.45	.01	.09	1.04	.51

RHA based Geopolymer concrete

Joseph Davidovits coined the term "Geo-polymer" in 1978 to describe a family of mineral binders that possess a chemical composition similar to zeolites while exhibiting an amorphous microstructure. In contrast to OPC, principal binders in Geopolymer concrete are not calcium-silicate-hydrates (CSHs). Instead, the role of the binder is assumed by an aluminosilicate polymeric gel, formed by tetrahedrally bonded silicon and aluminium with oxygen atoms shared in between [7]. Two important constituents of Geopolymer concrete are source materials and alkaline liquids. The source material must be rich in silicon (Si) or aluminium (Al) or both of it. These could be either natural minerals like kaolinite, clays etc. or by-products like fly ash, Rice husk ash (RHA), blast furnace slag, silica fume etc.

In Geopolymer concrete, most of the research work has been focused on fly ash based binders. However, the RHA has the potential to be used as a source material in Geopolymer concrete.

Mix designs

As there is no practicing code available for mix design of Geopolymer concrete, the mix design is done in trend similar way as Portland cement concrete. The coarse and fine aggregate occupy 75-80 % of total mass of the Geopolymer concrete like OPC concrete [15]. Except for the aggregates, there are two major ingredients of Geopolymer concrete namely the source material and alkaline liquids.

The choice of source material depends upon the researcher and the purpose of the research. The RHA can be used alone for making Geopolymer concrete as well as it can be used in addition with other materials like fly ash, GGBS, calcine sludge etc. as a source material for GPC production.

The alkaline liquid which is used for polymerization is a mixture of sodium silicate & sodium hydroxide or potassium silicate & potassium hydroxide. The sodium based alkaline solution is widely used for its better performance and availability. The alkaline solution is prepared before few hours of use to reduce the heating effect of sodium hydroxide dissolution in the mixture. The sodium silicate is commercially available in the market with a wide verity of grades. The A53 is generally used for Geopolymer concrete which has an approximate ratio of 2 between SiO_2 & Na_2O (i.e-SiO2= 29.4%, Na2O=14.7% and water=55.9%) [15]. Sodium hydroxide is available commercially in the form of pellet or flake with purity 97-98% [15]. The sodium hydroxide solids are dissolved in the pure water in a range of 8-14 molarity.

YunYongKim et al. prepared the Geopolymer concrete specimens with RHA & sand of ratio 1:2. They used sodium hydroxide of concertation 7, 8, 9 and 10 molar and the sodium silicate to sodium hydroxide ratio was 2.5% by mass [13].

Ekkasit Nimwinya et al. used water treated sludge (WTS) and RHA to prepare Geopolymer concrete. They used calcined WTS and RHA with various proportion as 100:0, 85:15, 70:30, 60:40 & 50:50 respectively. They used the sodium silicate solution with a proportion of 8.0% Na_2O & 27.0% SiO_2 and the sodium hydroxide of 8 molars [14].

Workability

The workability of the fresh Geopolymer concrete decreases when the fly ash is replaced by rice husk ash. At the 25% and 30% replacement of fly ash with rice husk ash has very low workability. Some chemical admixtures should be used to enhance the workability of the fresh concrete [11].

Ridho Bayuaji et.al added table sugar with the rice husk ash-fly ash based Geopolymer concrete in a doge of 10.5 kg per cubic meter of concrete to reduce the setting time. Nevertheless, more is the setting time concrete will be workable for a longer period [16].

Though there is numerous research has been done on RHA based Geopolymer concrete, but the workability part has not been touched till now. It’s the most fundamental property of the concrete after strength, without proper knowledge of workability a concrete can’t be commercialized. Hence there is an urge of extensive research on the workability of RHA based Geopolymer concrete.

Curing period, temperature and method

Heat curing, ambient temperature curing and shade curing are the methods of curing adopted in Geopolymer concrete. The heat curing is best suited for precast industries but it becomes a limitation to the application of Geopolymer concrete in in-situ castings [17, 18]. In the heat curing process the Geopolymer concrete is placed in the oven after casting for a period of 24 hours in a temperature of 60-80℃, then the specimens are demoulded and cured in normal room temperature for 7, 14 and 24 days.

Ambient temperature curing and shade curing have its own advantages as both are energy efficient and can be adopted everywhere. In order to facilitate the ambient temperature curing some amount of calcium-rich source material can be added to the mix [15].

Strength Properties:

Prasanna Venkatesan Ramani et al. (2015) stated the RHA can be used as a source material in Geopolymer concrete in addition to ground granulated blast furnace slag (GGBS). They also reported the addition of RHA beyond 10% had a retarding effect on the compressive strength. At up to 20% replacement, the target strength was surpassed and compressive strength as high as 51 MPa was reached at 28 days. The split tensile and flexural strengths showed a trend similar to that of compressive strength with respect to the RHA proportion [8].

D.R Dara and A.C Bhogayata (2015) stated that by addition of rice husk ash in Geopolymer concrete, the compressive strength increased up to 25% and then after starts decreasing up to 40%. The percentages of replacement of rice husk ash were increases from 0% to 25%, the compressive strength was increased from 2.24% to 1.78% in which maximum increase was observed at 25% as 5.40% compared to normal concrete test result [6].

Mohamed Usman and Senthil Pandian stated that the compressive strength of the fly-ash based Geopolymer concrete gradually decreased with the increment of RHA percentage. It is observed that 10% replacement of fly ash by RHA decreases 10.2% of compressive strength than the normal Geopolymer concrete [11].

Durability studies

Corrosion Resistance

The incorporation of RHA in Geopolymer concrete increases its corrosion resistance. The corrosion initiation period was 34 days for the 10 % RHA and 36 days for the 20 % RHA, while it was only 23 days for the control specimen. It is possible that the fine RHA particles account for greater dissolution of silica and alumina ions and a stronger passive layer formation [8].

Sulfate Resistance

Geopolymer concrete has more sulfate resistance than controlled concrete. The sulfate resistance of Geopolymer concrete improves in order to increase in RHA percentage in the matrix [12].

YunYongKim et.al showed that the Geopolymer mortar made up off rice husk ash has a great sulfate resistance as compared to the controlled concrete due to the absence of calcium hydroxide ($Ca(OH)_2$) [13].

Conclusions

Considering all the research work done by various researchers and scientists the following conclusions may be drawn-

1. The RHA activity is governed by its amorphous silica content and surface area which largely depends on the burning condition.
2. As RHA is a pozzolanic material it can be used alone for making Geopolymer concrete as well as it can be used in addition with other materials like fly ash, GGBS, calcine sludge etc.
3. The addition of RHA in Geopolymer concrete enhances both its compressive and tensile strength.
4. The RHA based Geopolymer concrete has more resistance against both chloride and sulfate attack.
5. Though the workability of Geopolymer concrete reduces with increasing percentage of RHA it can be achieved by adding super-plasticizers and other retarders like table sugar.

By observing all the above literature and experimental work done by various eminent researchers worldwide, we can confidently establish that the Rice Husk Ash has the true potential to be used in Geopolymer concrete as a source material.

Acknowledgements

The authors wish to gratefully acknowledge the support of Prof.Dr. Trilochan Sahu and Asst. Prof. Alok Patel of Govt. College of Engineering, Keonjhar, Odisha, India. The authors also acknowledge the scientific and technical assistance of CSIR-IMMT, Bhubaneswar, Odisha, India.

References

[1] Mehta, P.K.,Reducing the Environmental Impact of concrete, ACI Concerete International, 23 (10),pp.61-66,2001
[2] McCaffrey, R., “Climate Change and the Cement Industry”, Global Cement and Lime Magazine (Environmental Special Issue), 2002, pp. 15-19.
[3] Mehta, P.K., “Rice husk ash – a unique supplementary cementing material”, Proceedings of the CANMET/ACI International Symposium on Advances in Concrete Technology, V.M. Malhotra, ed., Athens, Greece,1992,pp-407-430.
[4] Mehta, P.K., Method for Producing a Blended Cementitious Composition, United States Patent, No. US 6451104 B2,2002.
[5] Analysis Of Chemical Composition Of Rice Husk Used As Absorber Plates Sea Water Into Clean Water Humayatul Ummah1, Dadang A.Suriamihardja, Mary Selintung3 and Abdul Wahid Wahab4, VOL. 10, NO. 14, AUGUST, 2015.
[6] Experimental Study of RHA-FA based Geopolymer Composites D. R. Dara1 A. C. Bhogayata2, Vol. 3, Issue 04, 2015 | ISSN (online): 2321-0613
[7] Davidovits, J, “Soft Mineralogy and Geopolymers”,Proceedings of the of Geopolymer 88 International Conference, the Université de Technologie,Compiègne, France, 1988.
[8] Prasanna Venkatesan Ramani, Pazhani Kandukalpatti Chinnaraj Geopolymer concrete with ground granulated blast furnace slag and black rice husk ash, DOI: 10.14256/JCE.1208,2015.
[9] Harish Kizhakkumodom et al.,Effect of griding of low carbon-RHA on the microstructure performance of blended cement concrete /Cement & Concrete Composites 55 (2015) 348-363.
[10] James J and Subba Rao M, 1986 Reactivity of rice husk ash *Cement and Concrete Research* 16 296-302
[11] Mohamed Usman and Senthil Pandian, Study on Fly Ash and Rice Husk Ash Based Geopolymer Concrete with Steel Fibre, Civil Engineering Systems and Sustainable Innovations ISBN: 978-93-83083-78-7.
[12] Resistance of Geopolymer concrete against sodium sulfate (Na2So4) Solution, by Shamsul Bashir and Sunil Saharan, IJERT,vol.6 Issue 11 November, 2017
[13] YunYongKim, Byung-JaeLee et al. Strength and Durability Performance of Alkali-Activated Rice Husk -Ash Geopolymer Mortar, Volume 2014, Article ID 209584, Scientific World Journal.
[14] Ekkasit Nimwiny et al. A sustainable calcined water treatment sludge and rice husk ash Geopolymer, Journal of cleaner production 119(2016) 118-134.
[15] B. Vijaya Rangan, Geopolymer concrete for environmental protection, SPECIAL ISSUE - Future Concrete, The Indian Concrete Journal, April, 2014
[16] Ridho Bayuaji et al., Mechanical Properties of MIRHA-Fly Ash Geopolymer Concrete, Materials Science Forum Vol. 803 (2015) pp 49-57 © (2015) Trans Tech Publications,
[17] P. Nath and P.K Sarker,Geopolymer concrete for ambient curing condition https://www.researchgate.net/publication/266222256
[18] P. Nath, P.K Sarker, Effect of GGBFS on setting, workability and early strength properties of fly ash geopolymer concrete cured in ambient condition, Construction and Building Materials 66:163–171, September 2014.