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Study on Slag-Rice Husk Ash based Alkali Activated Concrete

D. Das[1,*], S.M.Laskar[2], B. Hussain[3]

[1] Department of Civil Engineering, Jorhat Engineering College, Jorhat-785007,India
[2]Department of Civil Engineering, National Institute of Technology Mizoram, Aizawl-796012,India
[3]Department of Civil Engineering, Jorhat Engineering College, Jorhat-785007, India

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Abstract

Alkali activated binder is an innovative material and a potential alternate to conventional Portland cement for use in construction applications. Alkali activated binder is prepared using industrial or agro based by-products such as ground granulated blast furnace slag, fly-ash, rice husk ash, etc. This paper presents the processes and tests involved in evaluation of the strength and workability of slag-rice husk ash based alkali activated concrete. Raw rich hush ash was collected from various sources, ground and tested to attain suitable fineness and use in preparation of the concrete. Blast furnace slagand rice husk ash were incorporated in various percentages to prepare the alkali activated concrete. Results from the tests were compared with that of conventional Portland concrete. The fineness of rice husk as well as the amount played significant role in altering the properties of alkali activated concrete. Porousness of rice husk ash lowers the workability and compressive strength.

Keywords: Ground granulated blast furnace slag, Rice husk ash, Portland cement concrete, Workability, Strength

1. Introduction

Concrete is extensively used globally as primary construction material. Portland cement (PC) is the major constituent of conventional Portland cement concrete. Globally, the consumption of Portland cementsand hence its production is increasing day by day. However, the production and use of Portland cement leads to emission of carbon dioxide in huge quantity which accounts for7% of greenhouse gas emission annually. The production of one ton of cement emits one ton of CO_2 in the atmosphere [1]. The process used in manufacturing of Portland cement releases about 13500 million tons of green-house gas annually [2] lead to generation of waste products which if remain unattended lead to human health and environmental hazards. This concern about the consequence of waste generation and disposal has led to investigation of various waste utilization methods. To fulfil the commitment regarding sustainable development, concrete of tomorrow not only needs to be eco-friendly but it should also be durable. In recent years awareness on the quantity and diversity of hazardous solid waste generation and degradation of the air quality with its impact on humanhealth and natural environment has increased. The various industrial processes. In this context,alternate materials which are sustainable in nature are introduced into concrete. They have good binding properties with aggregates and possesslong chain structures which help in developing long range network structure of bonding. Rice husk is an organic waste and it produced large quantities inmany parts of world including Assam, India as most of theagricultural land in Assam is rice paddy field. Rice husk arethe hard protective coverings of rice. It is a major by-product of the rice milling industry. Rice husk ash (RHA) is the waste ash of rice husk.The characteristics of the ash dependents on composition of rice husks, burning temperature and burning time. To keep the silica content in amorphous state the burning temperature for preparing the RHA must be kept in controlled condition.

The ash obtained from uncontrolled burning conditions contains significant amounts of cristobalite and tridymite which are nonreactive silica minerals. RHA is a very fine material with average particle size ranged from 5 to 10μ[3] RHA is composed mostly of silica in amorphous from(85-90%) and it has highly micro-porous structure which is suitable to replace cement through its pozzolanic reaction.The fineness of rice husk ash affects the properties of the mixes. RHA is extremely sensitive with fineness changes[4]. It is basically finer and less reactive compared to Portland cement but it can disperse in the mixture and create numerous quantities of nucleation sites for precipitation of calcium hydroxide which can refer as pozzolanic reaction. The form of silica produced and reactivity of RHA is dependent on the conditions of incineration. It is found that rice husk burned at temperature

*Corresponding author. Tel: +919957564092; E-mail address: dasdebasish014@gmail.com

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500ºc and 600ºc contains pure amorphous silica and without crystalline silica formed.

Blast furnace slag (BFS) based alkali activate concrete is a suitable alternate to the conventional Portland cement concrete. Rigorous study has been carried out to evaluate the behavior of slag-based alkali activate systems in terms of workability, strength, durability, etc. [5-8]. Alkali activatedsystems (AAS) differ from Portland cementsystems (PCS) in terms of the reaction pathway in order to attain structural integrity.PCS depends upon the presence of C-S-H for matrix formation and strength whereas AAS utilizes raw materials such as BFS, RHA, fly-ash(FA), etc. Use ofBFSin concrete enhances the compressive strength. The strength enhancement also depends on the alkali content. Curing temperature also imparts positive effect in the strength in cement in early ages of reaction [9]. Few researchers have appliedAASas concrete repairing agent. AASexhibit better repairing characteristics than Portland cement-basedagents. With the addition of steel slag significant improvementin the abrasion resistance of AAS can be attained[10].Increase in the replacement level of BFSenhance the flexural and compressive strength. The increase sodium content for alkali activation increases the strength [11]. Researchers found that alkali metal silicates and hydroxides to be the most suitable as alkali activator. Since alkali silicates are more expensive than hydroxides, so hydroxides can be considered as most suitable. Moreover, it was observed that sodium hydroxide activated AAS can attain higher strength compared to sodium silicate activated AAS when cured at ambient temperature [12]. From the study of past works, it is noted that scanty amount of works related on slag-rice husk based AAS have been conducted. Extensive research related to behavior of AAS prepared using BFS and RHA is yet to be undertaken to arrive at suitable conclusions regarding behavior of AAS. Therefore, an attempt has been made to investigate the properties of BFS-RHA based alkali activated concrete (AAC). This paper presents the results from the laboratory investigation on the fresh and hardened state AAC.

2. Experimental program

2.1 Materials

In this study locally available BFS, RHA, fine aggregates and coarse aggregates are used to prepare AAC. In Table 1 the typical properties of RHA are shown.

In this study sodium hydroxide (NaOH) is used as alkali activator. NaOH pellets having 97-98% purity is used to prepare the alkali activator solution. Required concentration is prepared by mixing the pellets with distilled water one day before casting.

Table-1. Chemical composition of rice husk ash[13]

Chemical composition	Rice Husk Ash
SiO_2	93.0
Al_2O_3	0.17
Fe_2O_3	0.35
$SiO_2+Al_2O_3+Fe_2O_3$	93.5
SO_3	0.11
CaO	0.91
MgO	0.42
Na_2O	0.63
K_2O	2.82
LOI	4.70

Table-2. Fineness of RHA with time

Grinding time of RHA min	Fineness(m^2/kg)
0	50
15	310
30	800

Locally available coarse aggregate is used in this study of water absorption 1.5%[14] and specific gravity of 2.61[15]. The sizes of aggregates are size of 20mm. Locally available fine aggregates are used in this study of zone II. The avg. water absorption and avg. specific gravity are 0.8% [15]and 2.68[15] respectively.

RHA is obtained as by-product from agro-based biomass industry. The RHA collected from source are ground to very fine particle size in the Los Angeles Abrasion Testing Machine for 15 and 30 min in two different sets. Toevaluate the suitable fineness of RHA that produces concrete with satisfactory performance, a preliminary study is conducted by replacing cement by RHA ground for various time periods in control mix (CM1) by the 15% weight of cement. The Blaine fineness apparatus was used for measuring the fineness of RHA.

2.2. Mix Proportions

The mix proportioning for control mix (CM1) was done with specified target strength. IS 10262-2009 was followed for the purpose. For this, four mixes were prepared with 15 % weight of cement with their grinding time. Where FM0 stands for 0 % rice husk, FM1 represents raw RHA of 15% weight of cement; and FM2 andFM3 are 15% weight of cement with 15min and 30 mingrinding respectively.

Mix proportion of BFS-RHA based AAC is presented in Table 4. Alkali activator solution/total binder agent (a/b) ratio was kept constant as 0.65 throughout the study. RHA content was increases by 10%, 20% and 30% of total binder content. Here BFS and/or RHA are termed as total binder. The quantity of coarse aggregate and fine aggregates are kept constant throughout the study. The concentration of NaOH solution was fixed as 10 molar (M).

Table-3. Mix proportions for CM1 [17]

Mix	Cement (kg)	RHA 15% wt of cement(kg)	RHAGrinding Time	FA (kg)	CA (kg)	Water(ml)	Extra water(ml)
FM0	3.07	0	0	5.38	8.56	1538	171
FM1	2.61	0.46	0	5.38	8.56	1538	171
FM2	2.61	0.46	15	5.38	8.56	1538	171
FM3	2.61	0.46	30	5.38	8.56	1538	171

Table-4. Mix quantities for different mixes [17]

Ingredients	Mix			
(kg/m^3)	M0	M1	M2	M3
GGBS	328	295.2	262.4	229.6
Coarse Aggregate	1134	1134	1134	1134
Fine Aggregate	710	710	710	710
RHA	0	32.8	65.6	98.4
NaOH	213.2	213.2	213.2	213.2
Alkali/Binder Ratio	0.65	0.65	0.65	0.65

Table-5. Mix proportion for CM2 [17]

Ingredients	Quantity (kg/m^3)
Cement	389
CA	1134
FA	710
Water	155.57
w/c ratio	0.40

Themix proportion for controlled mix (CM2) was carried out with the specified target strength. Details of mix proportioning are given in Appendix A. IS: 10262-2009 was followed for the purpose. In Table 5, the detail quantity for controlled mix specimen is given.

After completing the mix proportioning, computation of the total amount of each material required for casting six cubes for each mix is done.

The calculated amount of each material is collected from their respective sources.After the collection of materials, the following procedure is followed to prepare the specimens. For FM0 dry mixing of PC, CA and FA is performed for 10 minutes. Calculated amount of water is added into the dry sample in threetime-intervals and the sample is thoroughly mixed throughout the time interval.

For FM1 dry mixing of cement, CA, FA and RHA (raw) is performed for 10 minutes. For FM2 dry mixing of cement, CA, FA and RHA (15 min ground) is performed for 10 minutes and also for FM3 Mix dry mixing of cement, CA, FA and RHA (30 min ground) is performed for 10 minutes.

AAC and PCC were prepared as per the Indian Standard Codes. Hand mixing of the ingredients was done. Each type of concrete prepared was put into standard moulds and compaction was done using the concrete vibration table. The specimens were taken out from the mould after 24 hours and immersed into the curing tank

After proper mixing of the sample, slump test is performed. A thoroughly cleaned slump cone having bottom diameter 20cm, top diameter 10 cm and height 30 cm is used. A steel tamping rod of 16mm diameter and 60 cm height is used for ramming. The ramming is done by giving 25 blows in three layers while pouring the concrete in the slump cone. The slump value is noted.

The mixes is then poured into the mould and are properly compacted in three layers by using a steel tamping rod. The mould is then placed in a concrete vibration table till the mix gets uniformly filled into the mould. The mould is kept for 24 hours. After 24 hours the specimens are removed from the mould and kept in water for curing. The compressive strengths of 3 specimens are computed on 7^{th} day and of the remaining 3 specimens on 28^{th} day.

4. Experimental Results

4.1 Test for suitability of Rice Husk Ash

4.1.1 Workability Test

Concrete slump test is carried out to check the uniform quality of concrete during construction. Generally concrete slump value is used to find the workability which indicates water cement ratio but there are various other factors including properties of material that effects the concrete slump value that are mixing methods, dosages of admixtures, air content present in concrete etc. The referred code is IS: 1199-1959 for conducting this test.

Table-6: Slump value for CM1 [16]

Mix	Slump value (mm)
FM0	120
FM1	80
FM2	105
FM3	117

The slump value of controlled mix is 120. It is observed that when raw RHA with no-ground has been used then the slump value reduces due to the amorphous nature of the crystal as a result of which it absorbs more amount of water and very less amount of water is present for mobility and as a result the workability is very low. But when it is ground, crystals are no longer amorphous, the water absorbing property of the crystal reduces, as a result more amount of water is available for wetting of the particle surface thus the workability is high in M-2 in compared to M-1.

4.1.2 Compressive Strength Test

Compressive strength test is a mechanical test measuring the maximum amount of compressive load a material or a structure can carry on its surface without crack or deflection. Compressive strength of concrete depends upon many factors such as water cement ratio, quality of concrete material, quality control during production of concrete etc. These specimens are tested by compression testing machine after 7 and 28 days of curing. 100 mmcube mould was used for PCC.

Table-7. Compressive Strength for CM1 [18]

Mix	Compressive strength MPa	
	7 days	28 days
FM0	20.5	26.5
FM1	6.63	7.36
FM2	20.93	27.53
FM3	19.86	25.93

The above results show that the compressive strength value of M1 and M3 are less than the value of M2. It is due to the fact that the available water in FM1 and FM3 mixing and hydration is less because of high absorption of water by RHA. Whereas the result of FM2 mix is quite satisfactory because it has enough water for hydration. So, the fineness of RHA plays an important role in strength on concrete. That’s why for further work the RHA of 15 min grinding is used

4.2 Test for slag-rice husk ash alkali activated concrete

4.2.1 Workability Test

Concrete slump test carried out for checking the consistency of fresh concrete before its use. This test can also be used as an indicator for improperly mixed batch.

Table-8. Slump value for GPC [16]

Mix	Slump value (mm)
M0	70
M1	87
M2	62
M3	48

Due to addition of rice husk ash the workability of the concrete mix slightly improved as a result of enhanced workability. Increasing the rice husk ash content, the workability monotonously reduced. This reduction in workability observed due to the fact that the added rice husk ash absorbed high amount of water from the matrix due to the porousness of its particle.

4.2.2 Compressive Strength Test

Compressive strength test is a mechanical test measuring the maximum amount of compressive load a material or a structure can carry on its surface without crack or deflection. For cube test, generally two types of specimens are used either (100 x100 x100) mm or (150 x 150x 150) mm.The results from the compressive strength test for all mixes of geopolymer concrete are presented below

Table-9. Compressive Strength for GPC [18]

Mix	Compressive strength (MPa)	
	7 days	28 days
M0	4.46	24.6
M1	12	27.33
M2	9.6	25.4
M3	9.2	24.23

In this work rice husk ash is increases by 10%, 20% and 30% and their corresponding strength shown in table 4.1. Due to addition of rice husk ash the workability of the concrete mix slightly improved as a result of enhanced workability. Homogenous matrix was formed due to the compaction of concrete into the mould and therefore M1exhibited higher compressive strength than M0.

However, increasing the rice husk ash content, the workability monotonously reduced. This reduction in workability observed due to the fact that the added rice husk ash absorbed high amount of water from the matrix due to the porousness of its particle, as a result complete the lack of workability eventually lead to formation of geopolymer matrix of non-homogenous nature and low strength. The porosity of RHA if can be reduced then it is possible that the resulting concrete mix may show higher strength.

4.3 Tests for Control Mix 2

4.3.1 Workability Test

Concrete slump test is carried out for control mix 2. This test is carried out for checking the quality of concrete during construction.

Table-10. Slump value for CM2 [16]

Mix	Slump Value(mm)
CM 2	20

4.3.2 Compressive Strength Test

This test is carried out to measure the compressive load that the material or structure can carry on its surface without cracking.

Table-11. Compressive strength for CM2 [18]

Mix	Compressive Strength (MPa)	
	7 days	28 days
CM2	17.89	27.53

From the results obtained from controlled mix it can observed that the compressive strength is quite similar with the strength of GPC.

5. Conclusion

This paper presents the processes and tests involved in evaluation of the strength and workability of slag-rice husk ash based alkali activated concrete. From the test results, work it can be concluded that the grinding of RHA improves the property of RHA based concrete to when added in controlled amount. The fineness of RHA plays a significant role in the physical properties of concrete i.e. when RHA is finer, the strength decreases. RHA and GGBS have the potential to replace the PC in conventional concrete.

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Disclosures

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References

1. Malhotra. Making concrete greener with fly-ash. Concrete International, 1999, vol-21
2. Malhotra. Sustainable development and concrete technology. Concrete International,2002,vol-24
3. Aprianti E, Shafigh P, Bahri S, Farahani J.N. Supplementary cementitious materials origin from agricultural waste-A review.Construction and Building Materials 74 (2015)176-187
4. AntiohosS.K.,Papadakis V.G.,Tsimas S. Rice Husk ash(RHA) effectiveness in cement and concrete as a function of reactive silica and fineness. Cement and Concrete Research61-62(2014) 20-27

5. Brough,A.R. and Atkinson A. Sodium silicate-based alkali activated slag mortars: Part I. Strength hydration and microstructure. Cement and Concrete research,2002,32(6),865-879

6. Kim, Y. J., Kim, S. C., and Kim Y. T. Corrosion resistance and hydration heat of concrete containing ground granulated blast furnace slag.KSCE J. Civ. Eng.2003, 7(4), 399-404.

7. Gorhan, G., and Kurklu, G. The influence of the NaOH solution on the properties of the fly ash-based geopolymer mortar cured at different temperatures.Composites: Part B,2014, vol- 58, 371-377.

8. Singh Gaurav, Das Souvilk, Ahmed Abdullahi Abdulaziz,Saha Showmen, Karmakar Somnath. Study of Granulated Blast Furnace Slag as Fine aggregates in Concrete for sustainable infrastructure. Procedia- Social and Behaviour Sciences 195(2015) 2272-2279

9. Puertas F., Ramirez Martinez, Alonso S., Vazquez. Alkali-activated fly ash/slag cement Strength behaviour and hydration products.Cement and Concrete Research 30(2000) 1625-1632

10. Shunguang Hu, Hongxi Wang, Gaozhan Zhang, Qingjun Ding. Bonding and abrasion resistance of geopolymeric repair material made with steel slag. Cement &Concrete Composities 30(2008) 239-244

11. Cengiz Duran Atis, CahitBilim .Wet and dry compressive strength of concretecontaining ground granulated blast-furnace slag. Building and Environment 42(2007)3060-3065

12. Altan, E., and Erdogan, S. T. Alkali activation of a slag at ambient and elevated temperatures.Cement& Concrete Composition.2012, 34, 131-139

13. Jongpradist P, Homtragoon W, Sukkarak R, Kongkitkul W, Jamsawang P. Efficiency of Rice Husk Ash as Cementitious Mateial in High-Strength Cement-Admixed Clay. Hindawi, Advances in Civil Engineering, vol. 2018, Article ID 8346319

14. IS:383-1970 “Specification for Coarse and Fine aggregate from natural sources for concrete” Bureau of Indian Standards.

15. IS: 2386 Part III-1963 Method of test for aggregates for concrete, Bureau of Indian Standard

16. IS: 1199- 1959 Method of sampling and analysis of concrete, Bureau of Indian Standard

17. IS:10262-2009 Specification for concrete mix proportioning, Bureau of Indian Standard

18. IS: 516-1959 Methods of test for strength of concrete, Bureau of Indian Standard