Parameters Affecting Alkali Activated Concrete with Fly Ash and Rice Husk Ash

Prof. Sonal Thakkar[1], Jay Patel [2], Eesh Kumar Taneja[3], Gulam Jilani[4]

[1](Assistant Professor, Civil Engineering Department, Institute of Technology, Nirma University, Ahmedabad, Gujarat, India)
[2,3,4](M.tech & B. Tech Student, Civil Engineering Department, Institute of Technology, Nirma University, Ahmedabad, Gujarat, India)

Abstract: **Cement production is highly energy intensive and involves large amount of energy for production and releases large release of carbon dioxide. Alkali activated concrete is a concrete produces which is produced using rice husk ash and fly ash combination. Sodium based alkaline activators were used. As both materials rice husk ash and fly ash are available in abundance and are used for landfill conversion of these into useful product is sustainable and environmental friendly. Effect of parameters affecting mix design like molarity, alkaline ratio and ratio of alkaline ratio to cementitious material are evaluated.**

Keywords- **Alkali activated concrete, Fly ash, Rice husk ash, alkaline ratio, molarity**

Table1- Nomenclature

RHA	Rice husk ash
FA	Fly Ash
AAC	Alkali activated concrete

I. INTRODUCTION

It is a well known fact that cement is most widely used material in the construction material [1]. Production of cement is highly energy intensive process and consumes lot of energy. Besides this, it is not environmentally sustainable as production of one ton of cement produces equivalent amount of carbon dioxide in atmosphere. Globally it is assumed that by 2025 the cement industry will be emitting CO_2 at the rate of 3.5 billion tones/year, more or less equal to total emission made by "transport and energy sector" of today's Europe [2,3]. It is believed that Portland cement has contributed immensely in development of building technology and material science fields and has led to faster development of economic growth. For sustainable development, cement industry and faces important challenges of reduction of particulate matter and emission levels [4]. It is important to find substitute of cement concrete and hence one of the alternative is alkali activated concrete. Geopolymer concrete as proposed by Davidovits in 1988, offers a good alternative and lot of research potential. Geopolymer concrete uses waste materials like fly ash which is available throughout the world in abundance and hence it reduces the CO_2 emission to atmosphere by about 80% [5]. There are many technologies envisaged for replacement of cement as building material, one of which is alkali activated concrete or geopolymer concrete. Alkali activated concrete uses waste materials like fly ash, slag, RHA, which are reacted with alkali reagents to form a stable compound.

In the country like India where power is produced by burning coal, fly ash the waste product of power station is available in abundance. It is used marginally to replace cement, but is still used as landfill disposal. According to government estimate, generation of fly ash is expected to reach about 225 million tons by 2017. Government of India, along with Department of science and technology and various other departments is trying to increase the utilization of fly ash. It's utilization is increased from 45 million tons in 2005 to 73.13 million tonne in 2010-2012, which is roughly 50% of its generation. Government desires to achieve 100% utilization in coming years [6].

India being a agricultural country, rice husk ash constitutes 20% of the 500 million tons of paddy produced in the world. 75% organic volatile matter and balance 25% of the weight of this husk is converted into ash during the burning process known as rice husk ash. Rice husk ash contains very high amount of silica content and is found to be amorphous in nature. The amorphous silica contained in RHA can react with cementitious binders to perform pozzolanic activity [7].

Since rice husk ash and fly ash both are in abundance its effective utilization as building material will lead to sustainable development. In alkali activation, reaction shown in figure 1 takes place. Alkali activation generally takes place with source material rich in alumina and silica reacting with alkaline solution consisting of sodium or potassium hydroxide with sodium or potassium silicate [8].

$$n(Si_2O_5, Al_2O_2) + 2nSiO_2 + 4nH_2O + NaOH/KOH \rightarrow Na^+, K^+ + n(OH)_3\text{-Si-O-Al}^{-}\text{-O-Si-}(OH)_3$$

(Si-Al materials)
Geopolymer precursor

$$n(OH)_3\text{-Si-O-}\underset{(OH)_2}{\underset{|}{\overset{-}{\text{Al}}}}\text{-O-Si-}(OH)_3 + NaOH/KOH \rightarrow$$

$$(Na^{+}, K^{+})\text{-}(\text{-}Si\text{-}O\text{-}\underset{(OH)_2}{Al^{-}}\text{-}O\text{-}Si\text{-}O\text{-}) + 4nH_2O$$

Fig1- Polymerization process

II. RESEARCH SIGNIFICANCE

Present investigation aims to utilize rice husk ash which is a waste product effectively into useful building material. Gujarat produces lot of rice from which rice husk ash is produced but it is not used due to improper burning of husk and this leads to poor quality of husk. Concrete with alkali activation of M 25 grade using fly ash and rice husk ash was attempted and parameters affecting the alkali activation was found.

III. LITERATURE REVIEW

Ambily et. al [9] used combination of slag and rice husk ash. Rice husk ash was in form of micronized biomass silica and sodium hydroxide and sodium silicate were used as alkaline activator. Variation of micronized biomass silica was done from 0% upto 30% and various properties of fresh concrete like slump, density and compressive strength were tested and evaluated. It was found that 10% replacement gave higher compressive strength.

Nuruddin et. al. [10] conducted studies on compressive strength and bond strength of fly ash and rice husk ash based geopolymer concrete. Rice husk ash was microwave incinerated.. They observed that under temperature curing due to incorporation of RHA the strength increased as refinement of pore structure occurred.

Bernal. et. al. [11] studied mechanical and structural changes induced by high temperature exposure of paste made from rice husk ash and silica fume combined with slag. They found that paste samples had strength more than 50 MPa and retained the same strength upto 600 °C.

IV. EXPERIMENTAL PROGRAM

Material used in the investigation were fly ash and rice husk ash.

4.1 Material specification

Source Materials:

Fly ash of class F was used in the investigation. Fly ash was obtained from Ukai Thermal Power Plant. GGBFS was obtained from JSW cement plant and is given in Table 2, while RHA was obtained from local industry is given in Table 3.

Table 2- Properties of fly ash

			Fly Ash	
Sr. No.	Particulars	Unit	Test Results	Specification (IS:3812:2003)
1	Colour	-	Light Grey	-
2	Specific Surface area	m^2 / kg	416.36	320 min.
3	Loss of Ignition	%	1.05	5.0 max.
4	SiO_2 + $Al2O_3$ + Fe_2O_3	%	93.02	70 min.
5	SiO_2	%	61.40	35 min.
6	CaO	%	5	7.0 max.
7	SO_3	%	0.56	3.0 max.
8	Na_2O	%	0.62	1.5 max.
9	Reactive Silica	%	34.36	20 min.
10	Total Chlorides	%	0.03	0.05 max.
11	Moisture	%	0.10	2.0 max.
12	Passing on 45 Micron sieve (Wet sieving)	%	91.86	66 min.
13	Retention on 45 Micron sieve (Wet sieving)	%	8.14	34 max.
14	Pozzolanic Activity Index	%	82.44	80 min.

Table 3- Properties of rice husk ash

Sr. No.	Characteristics	Test Results	Requirement as per IS standard-12089-1987
1	Color	Dim gray	-
2	Specific surface area (m^2/ kg)	293	275 (min)
3	Loss on Ignition (%)	4.51	3 (max)
4	SiO_2 (%)	89.84	-
5	Al_2O_3+Fe_2O_3 (%)	2.45	-
6	Specific Gravity	2.23	-

Alkaline Solutions:

Sodium Hydroxide was obtained in form of flakes with 98% purity and was dissolved in tap water depending on the concentration of solution, expressed in terms of Molarity (M). For making 12 M solution, 12 * 40 = 480 grams of sodium hydroxide flakes were dissolved in water. Sodium silicate was in liquid form with 15.5 % of Na_2O, 35.4% of SiO_2 and 45.9% of water. Sodium silicate had ratio of SiO_2/Na_2O as 2.23 and specific gravity of 1.58.

Super Plasticizer:

Naphthalene based superplasticizer was used for increasing the workability of geopolymer concrete.

Aggregates:

Coarse aggregates of 20 mm and 10 mm were used which were locally available and had specific gravity of 2.7 while fine aggregates was in form of sand confirming to Zone II.

4.2 Preparation of Concrete

The solution of sodium hydroxide and sodium silicate were used as alkaline solutions in the present investigation. Commercial grade sodium hydroxide in pellets form and sodium silicate solution were used which was dissolved to form alkaline solution and it was prepared one day prior to casting of concrete

As there are no code provisions for the mix design of alkali activated concrete, the density of alkali activated concrete was assumed as 2400 Kg/m^3. The rest of the calculations was done by considering the density of concrete. The total volume occupied by fine and coarse aggregate is adopted as 75%.The conventional method used in the making of normal concrete is adopted to prepare geopolymer concrete [12].

In order to achieve equivalent compressive strength of M25 grade of alkali activated concrete for fly ash and rice husk ash, various permutation and combination were done by keeping the above parameters constant and varying the alkaline solution to cementitious material ratio, molarity of sodium hydroxide and sodium silicate to sodium hydroxide solution ratio with different trial mixes.

Different Proportion of RHA was mixed with FA but it was found that increase in RHA percentage led to decrease in strength and hence RHA percentage was restricted to 5% along with FA. Rice Husk Ash is produced mainly be cooling suddenly and unevenly and hence reactivity of RHA is very less. Table 4 shows initial parameters to be taken for mix design.

Table 4- Mix proportion of AAC with RHA

Density of concrete	2400 kg/m^3
RHA	21.4 kg/m^3
FA	407.14 kg/m^3
Coarse aggregate	
20 mm	702 kg/m^3
10mm	468 kg/m^3
Fine aggregate	630 kg/m^3
Rest period	24 hrs
Curing temperature	60°C
Admixture	1.5%
Water	42.85 kg/m^3

Quantity of fly ash and rice husk ash as per mix proportion was measured and allowed to dry mix. After that dry mixing, solution and admixture was added and wet mix was carried out. Oven curing is more preferable in alkali activated concrete. In this investigation, temperature was kept at 60°C. Cubes were kept for 24 hours in oven after 1 day of rest period.

4.3 Parameters affecting mix design of AAC

This paper evaluates effect of different parameters on compressive strength

4.3.1 Effect of Alkaline Ratio to Cementitious Material

Amount of alkaline ratio to cementitious material decides, amount of cementitious material that will give required strength . Figure 2 shows that for 10 M solution as the alkaline ration to cementitious ratio increases from 0.3 to 0.4 and as alkaline ratio increases from 1.5 to 2.5 compressive strength increases.

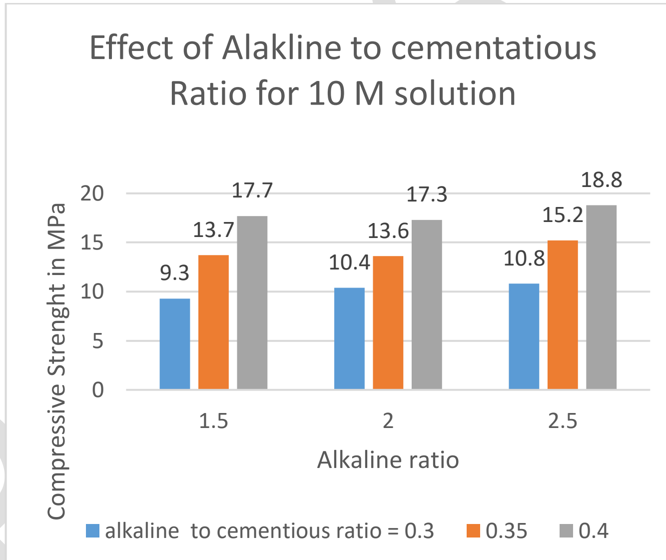

Figure 2: Compressive Strength for 10 M solution

For 12 M solution as the alkaline to cementitious material increases from 0.3 to 0.4, there is increase in compressive strength of alkali activated concrete as shown in Figure 3.

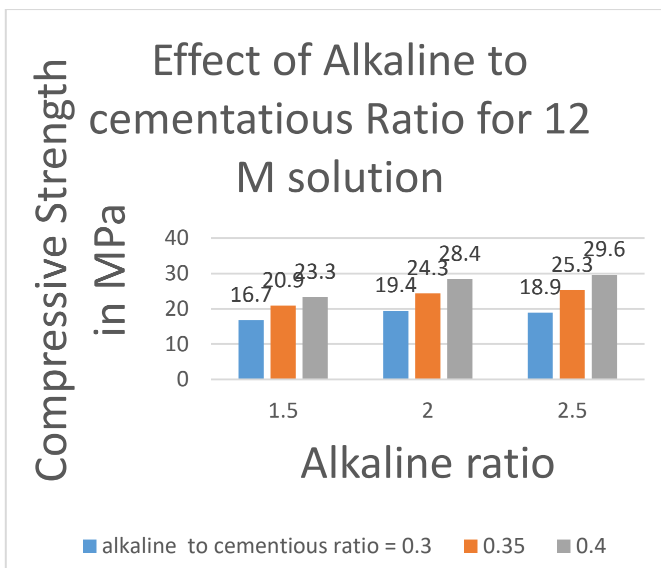

Figure 3: Compressive strength of AAC for 12 M solution.

4.3.2 Effect of Molarity:

Molarity of mix is important parameter. Higher molarity indicates more use of sodium hydroxide. Optimum use should be made to have economy in mix design and strength. As shown in figure 4 as molarity of solution increase, i.e. amount of sodium hydroxide increases compressive strength increases. Figure 4 is for alkaline ratio to cementitious ratio of 0.3.

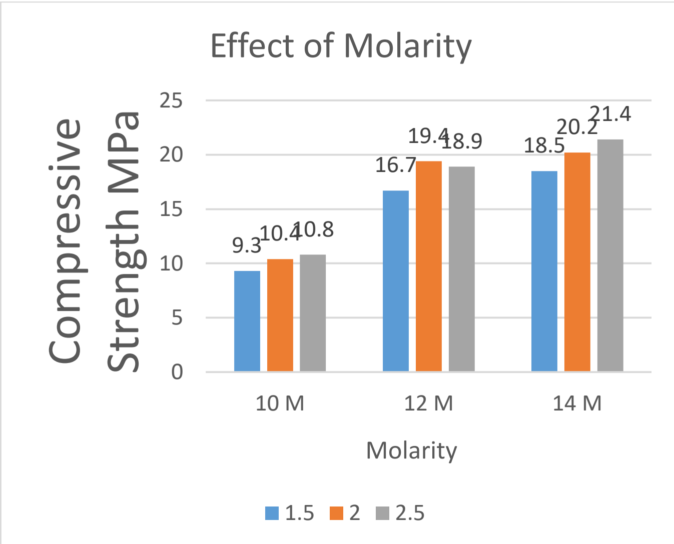

Figure 4: Compressive strength of AAC for different Molarity.

4.3.3 Effect of Alkaline Ratio:

Ratio of Sodium Silicate to Sodium Hydroxide is called alkaline ratio. It will decide amount of alkaline material to be taken in mix design. As shown in figure 5 as alkaline ratio increases from 1.5 to 2.5, there is increase in compressive strength.

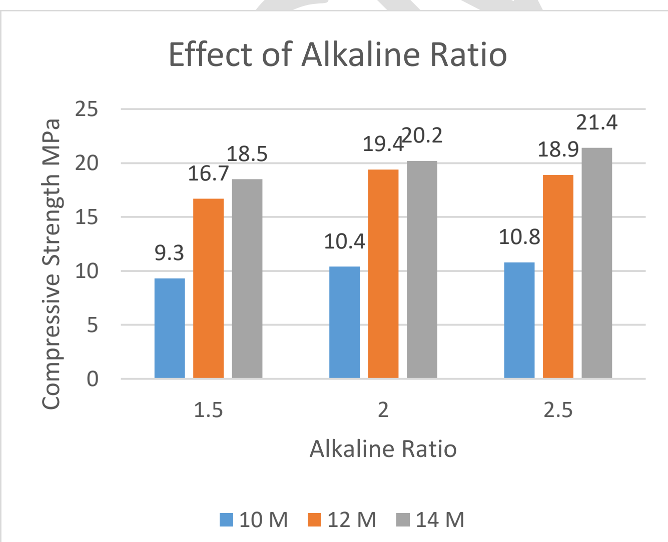

Figure 5: Comparative results of AAC with different

V. CONCLUSION

This concrete will be sustainable as it will it will help in solving the problem of industrial waste and also will help in converting rice husk ash into a useful product. Present investigation shows parameters that effect compressive strength of alkali activated concrete. It also shows increase in compressive strength with increase in molarity but optimum strength can be obtained at 12 M solution. Also optimum alkaline ratio is 2 with alkaline ratio is 0.4 at which optimum strength is obtained. Rice husk ash and fly ash combination can be used to produce concrete which can be used for non-structural work.

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REFERENCES

[1]. Caijun Shi, A. Fernández Jiménez, Angel Palomo " New cements for the 21st century: The pursuit of an alternative to Portland cement ", Cement and Concrete Research 41(2011) Page 750-763.
[2]. Aïtcin, P.C. 'Cements of yesterday and today; Concrete of tomorrow,' Cement and Concrete Research, 30, 2000, 1349
[3]. Malhotra, V. M. "Introduction: Sustainable Development and Concrete Technology." ACI Concrete International 24(7): 22., 2002.
[4]. Scrivener, K.L. & Kirkpatrick, R. J. 'Innovation in use and research on cementitious material,' Cement Concrete Research, 38 (2), 2008, 128.
[5]. Davidovits, J. " High-alkali Cements for 21st Century Concretes. Concrete Technology: Past, Present and Future." ACI,Detroit, USA. SP 144-19: 383- 397.,1994.
[6]. High volume fly ash concrete technology technology: Fly ash status summary report in India prepared by Confederation of Indian Industry and HVFAC.
[7]. Young Kim Yun, Byung-jae Lee, Saraswathy Velu and Kwon Seung-Jun, "Strength and Durability Performance of Alkali activated rice husk geopolymer mortar," The scientific world Journal, Hindawi Publishing Corporation, Vol 2014.
[8]. Davidovits, J. (1999). Chemistry of Geopolymeric Systems, Terminology. Geopolymer '99 International Conference, France.
[9]. Ambily P.S., Ravisankar K, Umarani C and Kumar S.S, " Influence of Micronised Biomass Silica on Workability and Strength of Alkali Activated Slag Concrete," Journal of Scientific and Industrial Research, Vol. 74, Feb. 2015, page 98-101.
[10]. Kusbiantoro Andri , Nuruddin M. F. , Shafiq N., Qazi S. A.,"The effect of microwave incinerated rice husk ash on the compressive and bond strength of fly ash based geopolymer concrete," Construction and Building Materials, 36 (2012) 695–703.
[11]. Bernal S.A, Rodríguez E.D., Mejía de Gutiérrez R., Provis J.L. , "Performance at high temperature of alkali-activated slag pastes produced with silica fume and rice husk ash based activators", Materiales de Construcción , Vol. 65, Issue 318, April–June 2015.
[12]. Hardjito D. and Rangan B. V. "Development and properties of low calcium fly ash based Geopolymer concrete." Research Report GC 3, Faculty of Engineering, Curtin University of Technology, 2006.