Modification of Properties of Geo-Polymer Concrete at Ambient Temperature Using RHA

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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. In the present study the Ground Granulated Blast Furnace Slag (GGBFS) & Rice Husk Ash (RHA) materials are used in the replacement of Portland cement and alkaline liquids are used for the binding of materials. Many researchers have been carried out for determination of percentage combination of GGBFS and RHA. In this study, combination of GGBFS and RHA is taken as 90% GGBFS and 10% RHA [1] and effect of Sodium Hydroxide Molarity & ratio of Na2SiO3/NaOH are checked. The alkaline liquid is the mixture of Sodium Hydroxide (NaOH) and Sodium Silicate (Na2SiO3). Various Na2SiO3/NaOH ratios are taken as 2 and 3. Various molarities of Sodium Hydroxide (NaOH) are taken as 10M, 12M, and 14M. The cube specimens and cylindrical specimens will be casted and Compressive strength test and split tensile strength test are conducted. Test results show that geo-polymer concrete with 12M NaOH and ratio of 3 Na2SiO3/NaOH produced maximum compressive strength. As per results Geo-polymer concrete can be developed at ambient temperature using GGBFS and RHA.

Key words: Alkaline Solution, Ambient Curing Temperature, Sodium Hydroxide, Sodium Silicate, RHA

I. INTRODUCTION

Now-a-days common Portland Cement (OPC) is having a major role in the construction family. Concrete for a building has most likely been based on a usual Portland Cement (OPC) binder [2]. The Ordinary Portland Cement (OPC) is one of the main ingredients used for the production of concrete and has no alternative in the civil construction industry. Unfortunately, production of cement involves emission of large amounts of carbon-dioxide gas into the atmosphere, a major contributor for green house effect and the global warming; hence it is inevitable either to search for another material. [3] The search for any such material, which can be used as an alternative or as a supplementary for cement should lead to global sustainable development and lowest possible environmental impact. Fly ash, Ground Granulated Blast furnace Slag, Rice husk ash, High Reactive Metakaolin, silica fume are some of the pozzolanic materials which can be used in concrete as replacement of cement.[4] Out of this GGBFS and RHA were selected for present work as 90% GGBFS and 10% RHA [1]. The Rice Husk Ash is an agro-industrial waste generated in the rice milling industry. It is obtained by burning rice husk in incinerator. The ash obtained as a result of this combustion process has a high content of unburnt carbon [5]. Hence the use of RHA as a building material is very limited; even though it has high silica content of about 87-97 % [6].Alkaline solution is needed for binding the aggregates to binder material. The most common alkaline liquid used in geo-polymerisation is a combination of sodium hydroxide (NaOH) or potassium hydroxide (KOH) and sodium silicate or potassium silicate. [7] One of the important things about RHA is due to high specific area of the RHA, the super plasticizer is needed for desirable workability, and also the amount of extra water is increased for desirable workability. [8] In geo-polymer concrete extra water is added to the concrete only for workability and easiness in placing the concrete, on the other hand, in Portland cement, water is necessary for the hydration of cement.

A. Origin of Term 'Geo-polymer'

The term ''Geo-polymer'' was first introduced to the world by Davidovits of France resulting in a new field of research and technology. Geo-polymer also known as 'Inorganic Polymer' has emerged as a 'Green' binder with wide potentials for manufacturing sustainable materials for environmental, refractory and construction applications. [9]

B. Why 'Geo-polymer Concrete?'

- Reduces the demand of OPC and hence reduces CO2 emission.
- Utilise waste materials from industries such as fly ash, silica-fume, GGBFS and RHA.
- Protect water bodies from contamination due to fly ash, GGBFS, RHA & other by products disposal.
- Conserve acres of land that would have been used for coal combustion products disposal.
- Produce a more durable infrastructure.

C. Objectives

- To develop sustainable concrete using industrial & agriculture waste materials by 100% replacement of cement.
- To develop geo-polymer concrete at ambient temperature using waste material such as GGBFS & RHA.
- To find the optimum ratio of sodium silicate to sodium hydroxide and optimum molarity of sodium hydroxide using combination of GGBFS and RHA.

II. MATERIALS

Various materials used in this study are Fine Aggregate, Coarse Aggregate (10mm Grit, 20 mm Kapachi), Ground Granulated Blast Furnace Slag & Rice husk Ash as binder material, Alkaline Liquid consist of Sodium Silicate and Sodium Hydroxide and Super Plasticizer for improving workability.

A. Aggregates

Both the coarse and fine aggregate will be collected from locally available at Ahmadabad, Gujarat. A good quality, well graded coarse aggregate of size 20 mm (Kapachi) and10 mm (Grit) will be used in the preparation of all test specimens.

B. Ground Granulated Blast Furnace Slag

GGBS has been used in construction industry for years as replacement of ordinary Portland cement when molten iron slag is quenched in steam or water, a glassy product is obtained. It is then dried and made into powder. [10] GGBFS used for this study is obtained from Guru Corporation Memnagar, Ahmedabad.

C. Rice Husk Ash (RHA)

The RHA is also obtained from Guru Corporation Memnagar, Ahmedabad. It was finely ground in a ball-mill for 30 minutes and passed through a 75µ Sieve.

The chemical properties of GGBFS and RHA are given in table-1.

Property	GGBFS	RHA
Sio_2	31.25%	93.96%
Al_2O_3	14.06%	0.56%
Fe_2O_3	2.80%	0.43%
CaO	33.75%	0.55%
MgO	7.03%	0.4%
Specific Gravity	2.61	2.14
Fineness	cm^2/gm	$5673 cm^2/gm$

Table 1: Chemical compositions of GGBFS & RHA

D. Alkaline Liquid

Alkaline solution plays most important role in geo-polymerization process. The alkaline liquid is a combination of sodium silicate solution and sodium hydroxide solution or potassium hydroxide. The sodium silicate (Na2SiO3) solution will be purchased from a local supplier. From the market survey it is found that two types of sodium silicate (Na2SiO3) is locally available which is generally used for the various industries. The chemical composition of such sodium silicate (Na2SiO3) is given in Table-2.

Sr. No.	Constituents	Composition	Type 1	Type 2
1	Sodium Oxide	(Na_2O)	14.46	8.5
2	Silicate Oxide	(SiO_2)	32.53	28.49
3	Water	(H_2O)	53	63

Table 2: Chemical Compositions of Sodium Silicate (Na2SiO3)

Fig. 1: Sodium Silicate Solution & Sodium Hydroxide in flake form

Commercial grade sodium hydroxide (NaOH) in flakes form with 97%-98% purity is available from a local supplier. The NaOH solids are dissolved in water to make the sodium hydroxide solution. The mass of NaOH solids in a solution can be varied depending on the concentration of the solution expressed in terms of molar, M. For instance, NaOH solution with a concentration of 8M consist of 8x40 = 320 grams of NaOH solids (in flake form) per litre of the solution, where 40 is the molecular weight of NaOH. [11] In this experimental work sodium hydroxide would be used in three different concentrations such as, 10M, 12M, and 14M.

E. Super Plasticizer

1% Polycarboxylic Eather based high range superplasticizing admixture is added to achieve high workability without segregation or bleeding.

III. METHODOLOGY

The mix proportions were taken as given in Table-3. As there are no code provisions for the mix design of geo-polymer concrete, the density of geo-polymer concrete was assumed as 2400 Kg/m3 and other calculations were done based on the density of concrete [12]. The combined total volume occupied by the coarse and fine aggregates was assumed to be 75%. The alkaline liquid to binder ratio was taken as 0.40. Some researchers determine percentage combination of GGBFS and RHA from that, combination of GGBFS and RHA is taken as 90% GGBFS and 10% RHA by mass. Various NaOH to Na2SiO3 ratio is taken as 2 and 3. Various molarities of Sodium Hydroxide (NaOH) are taken as 10M, 12M, and 14M.

Mix No.	Na2SiO3 / NaOH Ratio	Molarity	Binder (GGBFS + RHA) (kg)	NaOH Solution (NaOH Solid + Water) (kg)	Na2SiO3 solution (kg)	Coarse Aggregate (kg)		Fine Aggregate. (kg)
						20mm (Kapachi)	10mm (Grit)	
1	2	10M	37.03 + 4.15	1.57 + 4.92	11.97	43.20	77.76	36.54
2		12M	37.03 + 4.15	1.78 + 3.71	11.97	43.20	77.76	36.54
3		14M	37.03 + 4.15	1.97 + 2.94	11.97	43.20	77.76	36.54
4	3	10M	37.03 + 4.15	1.57 + 4.92	11.97	43.20	77.76	36.54
5		12M	37.03 + 4.15	1.78 + 3.71	11.97	43.20	77.76	36.54
6		14M	37.03 + 4.15	1.97 + 2.94	11.97	43.20	77.76	36.54

Table 3: Mix proportions of geo-polymer concrete

The normal mixing procedure was adopted. First, the fine aggregate, coarse aggregate and GGBS &RHA were mixed in dry condition for 3-4 minutes and then the alkaline solution which is a combination of Sodium hydroxide and Sodium silicate solution with super plasticizer was added to the dry mix. Then some extra water about 20% by weight of the binder was added to improve the workability. The mixing was continued for about 6-8 minutes. After the mixing, the concrete was placed in cube moulds of size 150mm×150mm×150mm by giving proper compaction. The specimens were then cured under room temperature till the time of testing. The cubes were then tested at 3, 7 and 28 days from the day of casting.

A. Slump Test

Initially numerous trial batches are casted for one slump volume, to achieve workability. In slump test fresh concrete was filled in slump cone in four layers, the each layer of concrete was compacted 25 times with the help of steel rod 0.6m long and16mm in diameter. Slump value achieved was 75 mm.

Fig. 2: Slump Test

B. Compression test

Compression test was conducted on a 2000KN capacity compression testing machine. The load was applied uniformly until the failure of the specimen occurs. The specimen was placed horizontally between the loading surfaces of the compression testing machine and the load was applied without shock until the failure of the specimen occurred.

Fig. 3: Fresh Geo-polymer concrete

IV. RESULTS & DISCUSSION

Six mixes were prepared to study the effect of Sodium Hydroxide Molarity and Na2SiO3 to NaOH ratio on compressive strength and tensile strength.

A. Effect of Molarity of Sodium Hydroxide on Compressive Strength

Sodium Hydroxide is essential to activate the alumino-silicate source material to develop geo-polymer concrete. It plays an important role in dissolution process and in bonding of solid particles. The increase in molarity of activating solution increases the solubility of alumino-silicate materials. With higher Sodium Hydroxide molarity, production of reactive bond increases which further increases the compressive strength of geo-polymer concrete. This is due to the faster dissolution of alumina and silica from source material into the solution, thereby aiding the formation of larger amounts of alumino-silicate polymeric gel which accelerate the geo-polymerization [13]. It was observed that increasing trend in compressive strength of geo-polymer specimen as Sodium Hydroxide molarity increases from 10 M to 12M. After 12M it decreased with further increase in Sodium Hydroxide molarity i.e. in 14M. At 14M more hydroxide ions precipitate in alumina-silicate gel at very early age of geopolymerization and hence delayed next reaction process resulting in lower strength [14]. The results of compressive strength of Geo-polymer concrete mixes activated by different molarity are as shown in Figure 4.

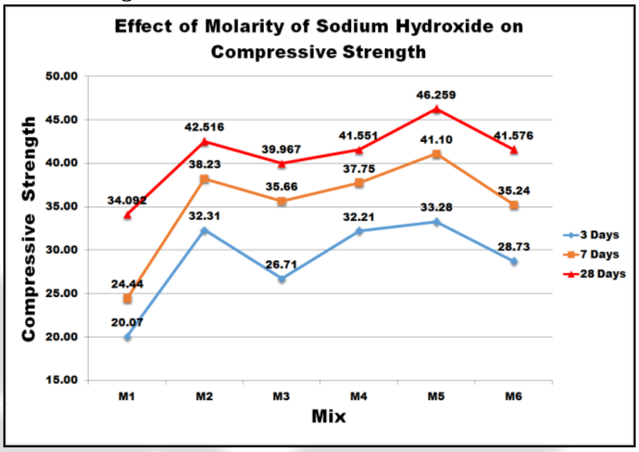

Fig. 4: Effect of Molarity of Sodium Hydroxide on Compressive Strength

B. Effect of Molarity of Sodium Hydroxide on Tensile Strength

It was observed increase in split tensile strength with increase in the Molarity of Sodium Hydroxide with the same trend as compressive strength up to 12M after that tensile strength decreased. The results of split cylinder tensile strength test are shown in figure 5.

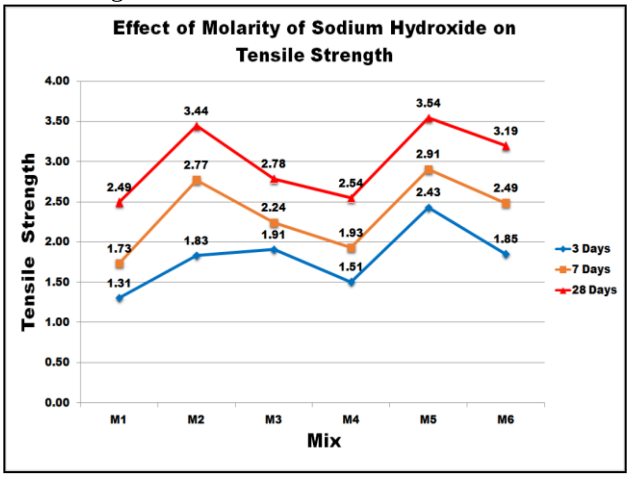

Fig. 4: Effect of Molarity of Sodium Hydroxide on Tensile Strength

C. Effect of Na_2SiO_3/NaOH ratio on Compressive Strength

The Na_2SiO_3/NaOH ratio of 3 contributed to high compressive strength. From figure 5 it is clear that ratio of Na_2SiO_3/NaOH contributed major role in compressive strength of geo-polymer concrete.

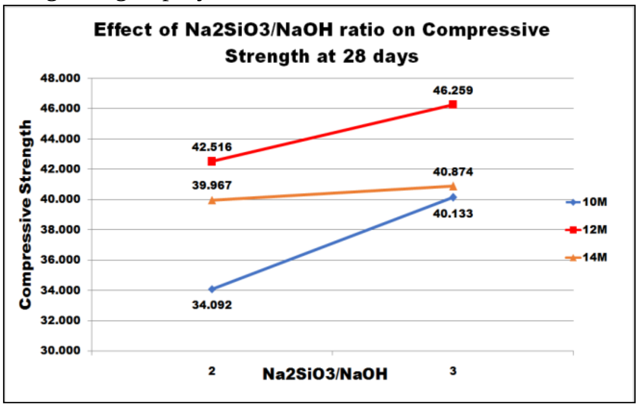

Fig. 5: Effect of Na_2SiO_3/NaOH ratio on Compressive Strength

D. Effect of Na_2SiO_3/NaOH ratio on Tensile Strength

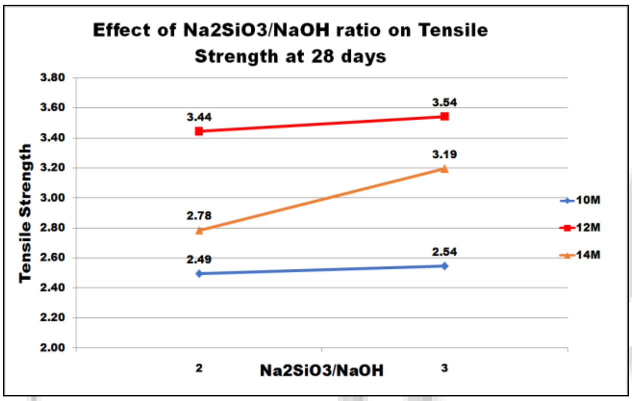

Fig. 6: Effect of Na2SiO3/NaOH ratio on Tensile Strength

V. CONCLUSION

- As the Sodium Hydroxide molarity increases from 10M to 12M, it was observed increase in compressive strength of geo-polymer concrete mixes and decrease in 14M,
- The mix with 12M Sodium Hydroxide molarity gives highest compressive as well as tensile strength, After 12M compressive strength & tensile strength are decreased due to excess hydroxide ion concentration which lowers the rate of geo-polymer formation,
- The mix with Na2SiO3/NaOH ratio of 3 contributed to high compressive strength,
- It is possible to produce geo-polymer 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 temperature using GGBFS and RHA as sole binder, and
- 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.

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REFERENCES

[1] Prasanna Venkatesan Ramani, Pazhani Kandukalpatti Chinnaraj, Gradevinar 8/2015 DOI: 10.14256/JCE.1208.2015
[2] L. K. Turner and F. G. Collins, Construction Building Material Vol. 43, PP.125–130, 2013
[3] Supraja, M. Kanta Rao, International Journal of Electronics, Communication & Soft Computing Science and Engineering, ISSN: 2277-9477, Volume 2, Issue 2
[4] B. N. Sangeetha, International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181, IJERTV4IS120515,Vol.4 Issue 12, December-2015
[5] Krishnarao. R. V., Subrahmanyam. J., Jagadish Kumar. T., Journal of the European Ceramic Society, 21, PP.99-104, 2001.
[6] Lanning, F. C.: Silicon in rice, J. Agric. Food. Chem., 11, PP. 435-437.
[7] Davidovits J. Geo-polymer Chemistry and Applications, 2nd Ed., Institute of Geo-polymer, 2008. PP. 1-585.
[8] Mrs. A.Shalini, G.Gurunarayanan, R.Arun kumar, V.Jaya prakash, S.Sakthivel, IJIRST International Journal for Innovative Research in Science & Technology, Volume 2, Issue 12, May 2016, ISSN (online): 2349-6010.
[9] K. M. Chetan, K. C. Sachin, B. B. Gopal, IJSRD - International Journal for Scientific Research & Development| Vol. 5, Issue 02, 2017 | ISSN (online): 2321-0613
[10] Divya Bhavana Tadepalli, Madhavi Etaveni, Syed Eashan Adil, International Journal of Engineering Research and General Science Volume 4, Issue 2, March-April, 2016, ISSN 2091-2730
[11] Ravi Kumar R, Sridhar R, IJRET: International Journal of Research in Engineering and Technology eISSN: 2319-1163 pISSN: 2321-7308
[12] Hardjito, D. and Rangan, B. V. (2005), Research Report GC1, Faculty of Engineering, Curtin University of Technology.
[13] Memon FA, Nuruddin MF, Shafiq N., International Journal of Minerals, Metallurgy and Materials. 2013; 20(2):205−13.
[14] Yamini J. Patel and Niraj Shah, Indian Journal of Science and Technology, Vol 11(1), DOI:10.17485/IJST/2018/v11i1/117698,January 2018