International Journal of ChemTech Research
CODEN (USA): IJCRGG ISSN: 0974-4290
Vol.8, No.4, pp 1735-1741, 2015

Effect of Slag Content and Alkaline Concentration on the Moisture Absorption Characteristics of Geopolymer Concrete

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Abstract: Concrete is one of the extensively used construction material and cement is the major ingredient in it. Cement manufacturing process involves the liberation of high amount of carbon dioxide to the atmosphere. This green house gas emission is challenging to the earth's climatic pattern. So, the need of a material to use in place of cement is an immediate requirement. Geopolymer concrete is an innovative material which essentially consists of a cementitious material that has high content of alumina and silica and an alkaline activator solution, mixture of sodium hydroxide and sodium silicate. In this paper, the effect of slag content, sodium hydroxide concentration and alkaline ratio on water absorption, sorptivity has been studied. The result infers that the increase in the alkaline nature of the geopolymer mixes reduces the moisture absorption characteristics of geopolymer concrete.
Keywords: Geopolymer; slag; alkaline ratio; water absorption; sorptivity.

Introduction

Cement industry is one of the major sectors in utilizing the industrial energy excessively and emits CO_2 to the atmosphere[1-2]. Due to the increasing demand for the cement usage in construction industry, huge amount of cement is to be manufactured as it is the major ingredient in the concrete production, which may leads to increase in environmental pollution[2]. In this regard cement has to be partially or fully replaced by industrial by-products such as fly ash[3-4], slag[5], rice husk ash (RHA)[6]. Alkali activated concrete or geopolymer concrete needs a source material which has high content of alumina and silica and an activator solution to activate the polymerization reaction to form CSH gel. The liquid part of the geopolymer concrete is a mixture of alkali silicate and alkali hydroxide which has to be optimum such that it helps in the gelation and oligomers formation. Among the different curing methods available, ambient and heat curing are commonly applied for geopolymer specimens. Curing method has no significant effect as these two types of curing give 28th day compressive strength which has only marginal variation[7]. Pore structure is an important concern related to durability of the concrete. Durable concrete which is having less water absorption are observed to have low liquid/binder, high aggregate/solids and low alkaline/fly ash[4]. High alkaline solution content also increases water absorption[3-4]. Sorptivity and water absorption are parameters which are inversely proportional to durability[9]

Materials and Methodology

Materials

Ground Granulated Blast Furnace (Ggbfs)

Ground Granulated Blast Furnace (GGBFS), the binder material is obtained from JSW Steel Limited, Salem. The specific gravity of the slag is 2.53. The mean particle size of slag is 29µm. GGBFS has high content of CaO which has straight effects on strength[1]. Slag has dense packing of molecules and the strong microstructure of interfacial aggregate/binder transition zone provides better durability properties to it[8]. The chemical composition of slag obtained using XRF is given in table 1.

Table 1 Chemical Composition of GGBFS

Oxide	**CaO**	**SiO_2**	**Al_2O_3**	**MgO**	**SO_3**	**Fe_2O_3**	**Na_2O**	**K_2O**
GGBFS	36.77	30.97	17.41	9.01	1.82	1.03	0.69	0.46

Alkaline Activator Solution

Alkaline activator solution which is mainly a mixture of alkali hydroxide and alkali silicate, essentially sodium or potassium[10-11] is used for activating the geopolymerization reaction and in current study sodium hydroxide with 99.51% purity and sodium silicate (SiO_2 – 28%, Solids – 35 to 40% and Mg_2O – 9%) have been used.

Aggregates

Graded river sand is used as fine aggregate which is having fineness modulus of 2.79 and specific gravity of 2.63. Crushed granite stone aggregate is used as coarse aggregate with a maximum size of 20 mm with fineness modulus of 7.27 and specific gravity of 2.75.

Methodology

Sodium hydroxide flakes were mixed with distilled water for specified molarity. NaOH solution is mixed with Na_2SiO_3 solution to obtain the desired alkaline ratio. In the present study, saturated water absorption and sorptivity characteristics of geopolymer concrete specimens are studied by varying the slag content as 400 & 450 kg/m^3, molarity of NaOH as 12M & 14M and alkaline ratios of 1.5, 2.0 & 2.5. The various mixes obtained are given in table 2.

Table 2. Mix Variables

Mix No.	**Slag content (kg/m^3)**	**NaOH concentration (moles)**	**Alkaline Ratio**
M01	400	12	1.5
M02	400	12	2.0
M03	400	12	2.5
M04	400	14	1.5
M05	400	14	2.0
M06	400	14	2.5
M07	450	12	1.5
M08	450	12	2.0
M09	450	12	2.5
M10	450	14	1.5
M11	450	14	2.0
M12	450	14	2.5

100mm cube specimens were prepared for water absorption and 100mm diameter x 50mm height cylindrical samples were casted for sorptivity test. 28 days of ambient curing is done for the prepared specimens. The quantity arrived for various mixes are tabulated in table 3.

Table 3 Quantities of Materials used

Mix No.	Slag (kg/m^3)	Fine Aggregate (kg/m^3)	Coarse Aggregate (kg/m^3)	Sodium Silicate Solution (kg/m^3)	Sodium Hydroxide Solution (kg/m^3)
M01	400	432	1376	120.00	80.00
M02	400	432	1376	133.33	66.67
M03	400	432	1376	142.86	57.14
M04	400	432	1376	120.00	80.00
M05	400	432	1376	133.33	66.67
M06	400	432	1376	142.86	57.14
M07	450	486	1548	135.00	90.00
M08	450	486	1548	150.00	75.00
M09	450	486	1548	160.71	64.29
M10	450	486	1548	135.00	90.00
M11	450	486	1548	150.00	75.00
M12	450	486	1548	160.71	64.29

Saturated water absorption test[12-13] was carried out as per ASTM C642-06, in which the specimens were kept in oven for 100°C for 24h in order to remove the free moisture content. The weight of the samples and their dimensions were taken at regular intervals until the percentage reduction in the weight was observed to be less than 0.5. The specimens are then immersed in water completely to obtain the saturated weight. Sorptivity test[12-13] was carried out as per ASTM C1585-13 in which the samples were kept inside the oven at 50°C for 3 days. The lateral surface and base of the specimens were sealed in order to prevent the intrusion of water. The specimens were placed in a pan containing water over the supports in order to maintain the water level of 1 to 3 mm above the top of the supporting device. The weight of the samples was taken at regular intervals.

Results and Discussion

The geopolymer mixes shows high alkaline in nature which has a significant role in the polymerization reaction to occur and the relatively high pH and high Na content are helpful in maintaining the pore solution chemistry required for good stability of the geopolymer samples. The alkalinity values of the geopolymer mixes were found to be in the range of 9.9-11.3 which is in agreement with Hanio et al [18]. Saturated Water Absorption (SWA) and Apparent Volume of Permeable Voids (AVPV) results obtained for various mixes are tabulated in table 4. Time Vs Absorption plots were drawn for each mixes and it is observed that similar trend is shown by all mixes. Time Vs Absorption plot of various mixes are shown in figure 1.

Effect of Binder Content

For geopolymer mixes, the binder content has a strong influence on water absorption characteristics. Water absorption of geopolymer concrete is much lower than the comparable traditional concrete mixes because of the presence of refined and closed[14-16] porosity which arrest the way of water to enter inside. It can be observed from the results, that the water absorption values of the geopolymer mixes decreases with the increase in the binder content. This shows that the water absorbing characteristics of geopolymer mixes is similar to the cement concrete mixes. Due to the fine particle size of slag, the packing of geopolymer mixes are good. The AVPV (Apparent Volume of Permeable Voids) values ranges between 0.11% and 9.63% (less than 12%), which infers that the mixes are classified as “good”. Capillary absorption co-efficient which is also known as sorptivity, the slope of the absorption curve [17] is very less compared to OPC mixes. For less binder content the radius of pores will be high so that tight packing will not be there which leads to high porosity, whereas increase in binder content fills the pore spaces inside the structure.

Table 4 SWA and AVPV Results

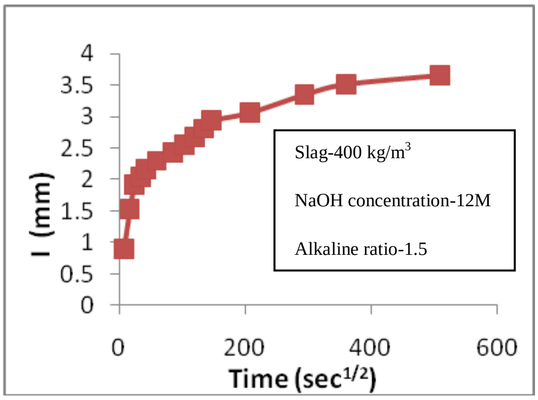
Mix No.	Dry Density (kg/m³)	Saturated Density (kg/m³)	Saturated Water Absorption (%)	Apparent Volume of Permeable Voids (%)
M01	2235.16	2450.31	4.81	9.63
M02	2261.98	2376.55	4.69	5.06
M03	2099.79	2244.68	4.30	4.92
M04	2326.02	2328.68	4.57	0.11
M05	2165.69	2217.05	4.50	2.37
M06	2313.65	2257.34	4.39	4.14
M07	2201.89	2284.46	3.78	3.75
M08	2472.96	2575.08	3.76	4.13
M09	2254.82	2396.25	3.69	6.27
M10	2275.05	2302.45	3.70	1.20
M11	2544	2233.01	3.66	2.90
M12	2408.32	2424.33	3.58	0.66

Effect of NaOH concentration

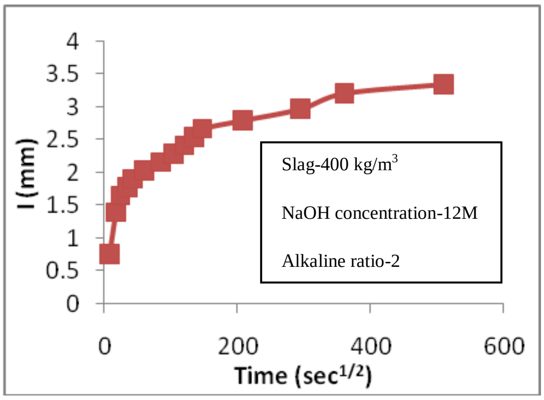
The sodium hydroxide concentration does not have significant influence on the water absorbing characteristics of geopolymer concrete as the reduction in the water absorption values found to be less than 5% when the NaOH concentration increases from 12M to 14M. No such variation has been observed in the sorptivity results, which infers that the NaOH concentration shows no influence on the sorption behavior of geopolymer concrete.

Effect of Alkaline Ratio

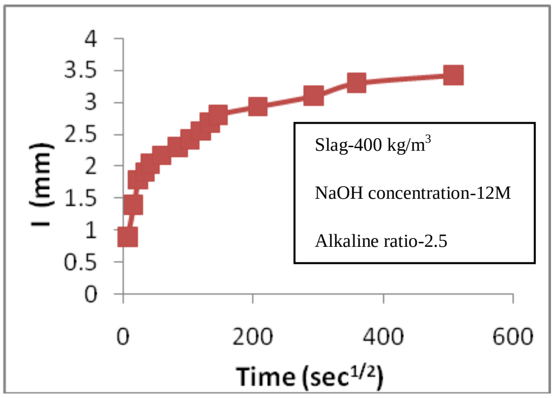
The change in the alkaline ratio does not show significant change in the water absorption characteristics of geopolymer with a slag content of 400kg/m^3. This behavior is in contrast when the slag content was increased to 450kg/m^3. The amount of absorption has found to reduce with the increase in the alkaline ratio, this shows that the alkaline ratio also plays a vital role in the moisture absorbing characteristics of geopolymer concrete.



(a)



(b)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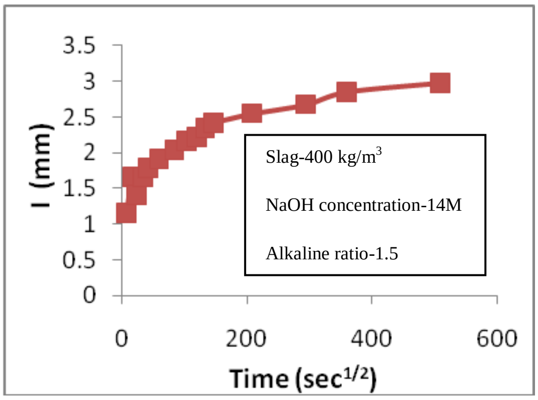
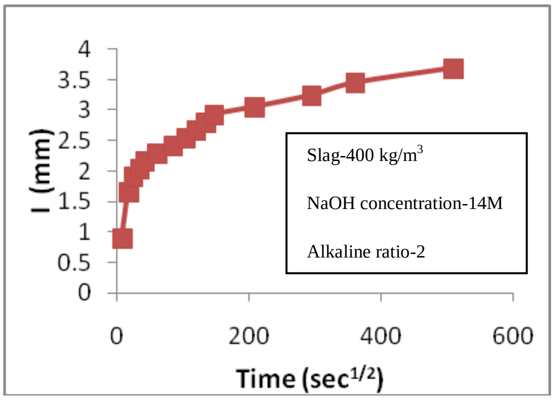
Time (sec$^{1/2}$)
Slag-400 kg/m^3
NaOH concentration-12M
Alkaline ratio-2.5

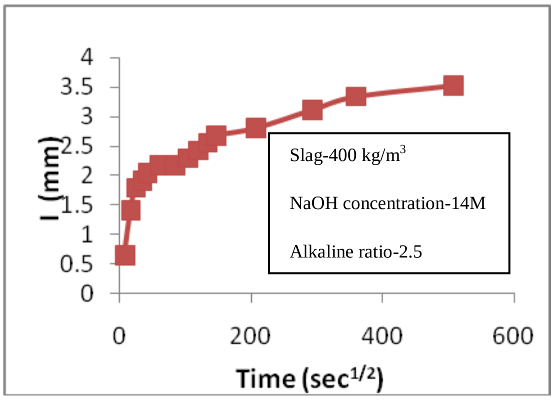
(c)


I (mm)
Time (sec$^{1/2}$)
Slag-400 kg/m^3
NaOH concentration-14M
Alkaline ratio-1.5

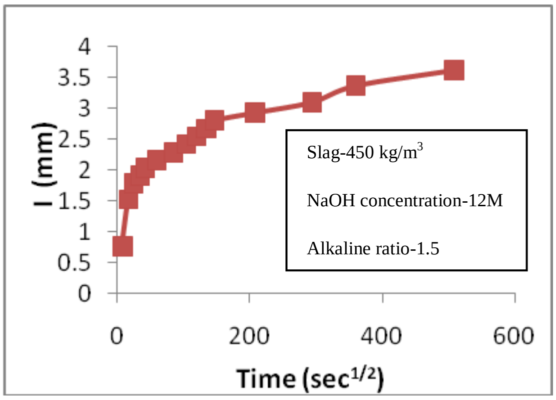
(d)


I (mm)
Time (sec$^{1/2}$)
Slag-400 kg/m^3
NaOH concentration-14M
Alkaline ratio-2

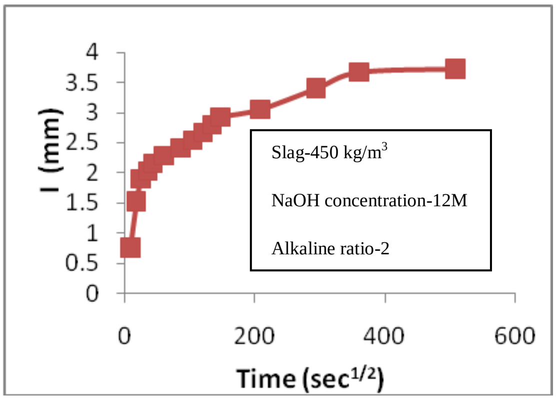
(e)


I (mm)
Time (sec$^{1/2}$)
Slag-400 kg/m^3
NaOH concentration-14M
Alkaline ratio-2.5

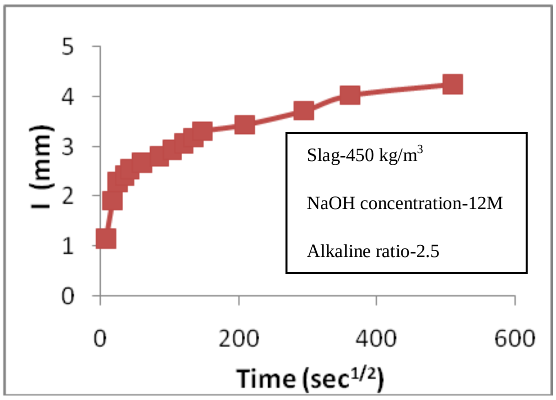
(f)


I (mm)
Time (sec$^{1/2}$)
Slag-450 kg/m^3
NaOH concentration-12M
Alkaline ratio-1.5

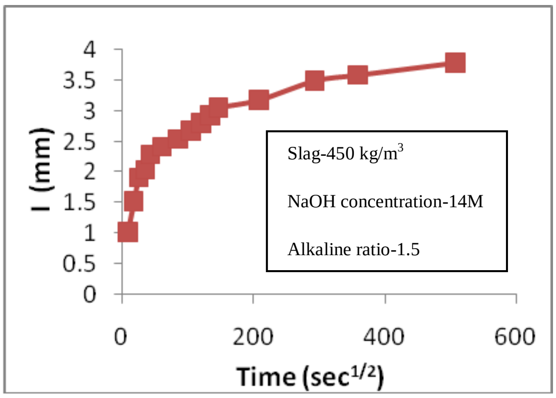
(g)


I (mm)
Time (sec$^{1/2}$)
Slag-450 kg/m^3
NaOH concentration-12M
Alkaline ratio-2

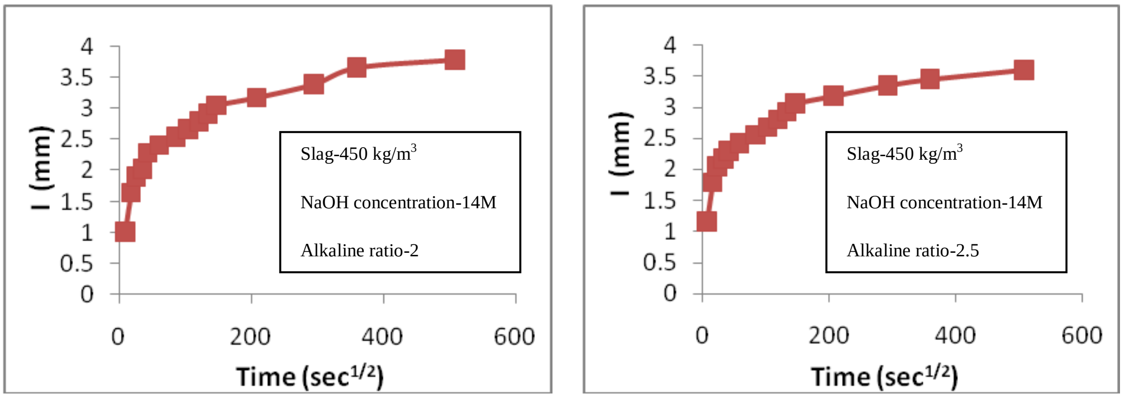
(h)


I (mm)
Time (sec$^{1/2}$)
Slag-450 kg/m^3
NaOH concentration-12M
Alkaline ratio-2.5

(i)


I (mm)
Time (sec$^{1/2}$)
Slag-450 kg/m^3
NaOH concentration-14M
Alkaline ratio-1.5

(j)



(k) **(l)**

Figure 1. Sorptivity plots for various mixes

Conclusions

Based on the experimental investigations conducted, the following conclusions were made:

- Geopolymer concrete can play as a best substitute for cement concrete, thereby reduces the CO_2 emission to the atmosphere.
- Geopolymer mixes are highly alkaline in nature which helps in maintaining the pore solution chemistry and results in high early strength.
- Binder content is having a strong influence on both water absorption and sorptivity characteristics. Slag which is used as binder for geopolymer mixes has good packing of molecules which reduce the permeability characteristics. The % absorption reduces with the increase in the slag content, which shows similar behavior with that of cement concrete.
- The percentage reduction in absorption increases with the increase in the alkaline ratio and sodium hydroxide concentration

Acknowledgement

The authors acknowledge the Vice Chancellor, SASTRA University, Thanjavur, India for providing the facilities to carry out the work and the encouragement in completing this work.

References

1. Moruf Olalekan Yusuf, Megat Azmi Megat Johari, Zainal Arifin Ahmad, Mohammad Maslehuddin, Evolution of alkaline activated ground blast furnace slag–ultrafine palm oil fuel ash based concrete, *Materials and Design*, 2014, 55, 387-393.
2. M.B. Ali, R. Saidur, M.S. Hossain, A review on emission analysis in cement industries, *Renewable and Sustainable Energy Reviews*, 2011, 15(5), 2252-2261.
3. Suresh Thokchom, Partha Ghosh, Somnath Ghosh, Effect of water absorption, porosity and sorptivity on durability of geopolymer mortars, *ARPN Journal of Engineering and Applied Sciences*, 2009, 4(7), 28-32.
4. Monita Olivia, Hamid R, Nikraz, Strength and water penetrability of fly ash geopolymer concrete, *ARPN Journal of Engineering and Applied Sciences*, 2011, 6(7), 70-78.
5. Susan A. Bernal, Ruby Mejía de Gutiérrez, Alba L. Pedraza, John L. Provis, Erich D. Rodriguez, Silvio Delvasto, Effect of binder content on the performance of alkali-activated slag concretes, Cement and Concrete Research, 2011, 41, 1-8.

6. Ramadhansyah Putra Jaya, Badorul Hisham Abu Bakar, Megat Azmi Megat Johari, Mohd Haziman Wan Ibrahim, Strength and permeability properties of concrete containing rice husk ash with different grinding time, *Central European Journal of Engineering*, 2011, 1(1), 103-112.
7. Mark Reed, Weena Lokuge, Warna Karunasena, Fibre-reinforced geopolymer concrete with ambient curing for in situ applications, *Materials and Science*, 2014, 49(12), 4297–4304.
8. Darshan.S.Shah, Jayeshkumar Pitroda, An Experimental Study on Durability And Water Absorption Properties of Pervious Concrete, *International Journal of Research in Engineering and Technolog*y, 2014, 3(3), 439-444.
9. S. Pavía, E. Condren, Study of the Durability of OPC versus GGBS Concrete on Exposure to Silage Effluent, *Journal of Materials in Civil Engineering*, 2008, 20(4), 313-320.
10. V. Bhikshma, M. Koti Reddy, T Srinivas Rao, An experimental investigation on properties of geopolymer concrete (no cement concrete), *Asian journal of civil engineering (building and housing)*, 2012, 13(6), 841-853.
11. A. Palomo, M.W. Grutzeck, M.T. Blanco, Alkali-activated fly ashes A cement for the future, *Cement and Concrete Research*, 29, 1323–1329.
12. Rushabh A. Shah, Jayeshkumar Pitroda, Effect of Water Absorption and Sorptivity on Durability of Pozzocrete Mortar, *International Journal of Emerging Science and Engineering*, 2013, 1(5), 73-77.
13. Susan A. Bernal, Ruby Mejía de Gutiérrez, John L. Provis, Engineering and durability properties of concretes based on alkali-activated granulated blast furnace slag/metakaolin blends, *Construction and Building Materials*, 2012, 33, 99-108.
14. F. Collins, J.G. Sanjayan, Effect of pore size distribution on drying shrinking of alkali-activated slag concrete, *Cement Concrete Research*, 2000, 30 (9), 1401–1406.
15. R. Wassermann, A. Katz, A. Bentur, *Minimum cement content requirements: a must or a myth?* Materials Structures, 2009, 42 (7), 973–982.
16. Folagbade, Samuel Olufemi, Effect of Fly Ash And Silica Fume on The Sorptivity of Concrete, International Journal of Engineering Science and Technology, 2012, 4(9), 4238-4246.
17. G.Fagerlund, On the capillarity of concrete, *Nordic Concrete Research*, 1982, 1, 6.1-6.20.
18. H.Hanio Merinkline, S.Manjula Devi, Dr.C.Freeda Christy, Fresh And Hardened Properties Of Fly Ash Based Geopolymer Concrete With Copper Slag, *International Journal of Engineering Research & Technology*, 2013, 2(3), 1-7.

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