Influence of Silica Content on the Properties of Alkali Activated Cement

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Abstract

The influence of silicate content of alkali activator on the physical, mechanical and microstructure properties of paste phase of alkali activated cements (AC) were studied. The AC paste was produced by activating the Red Mud and ground granular blast furnace slag with a ratio of 25:75 (RM: GGBS) by using combination of sodium Hydroxide (SH) and Sodium Feldspar (SF) as alkali activators. The silicate content was varied from 0.2 to 1.2. Initially the test specimens were casted and cured at ambient temperature and tested for itscompressive strength at the age of 3, 7 and 28 days. It can be noticed that the compressive strength of test specimens were found to increase with increase in silicate content up to 0.8. The optimum value of compressive strength was found to be 44.52MPa corresponding to age of 28 days and silicate content of 0.8.Further, it can also be observed that the compressive strength of specimens increases with age. The variation of silicate content was found to have significant influence on porosity and water absorption properties. Micro structural and mineralogical characteristics were determined using SEM/EDAX and XRD analysis.

KeyWords: Alkali activated Cement (AC), Red Mud (RM), Ground Granular Blast Furnace Slag (GGBS), Sodium Hydroxide (SH), Sodium Feldspar (SF), Silicate ratio, Compressive strength, SEM and XRD

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Introduction

Manufacturing process of Ordinary Portland Cement (OPC) is one of the contributing factor to cause green house effect in the atmosphere. Approximately, 7% of world's total green house emission is through production process of OPC (1).Reduction in CO_2 emission could be achieved not only by varying the production process of cement, but also through developing the binders by using alternative materials. The binder; with combination of RM and GGBS could be considered as effective for production of resultant composites material, with properties better than OPC (2, 3).Ground Granular Blast Furnace Slag (GGBS) is a byproduct obtained during production of steel and pig iron and may be defined a non metallic product in molten state, rich in calcium silicates and other bases (ACI – 116R).

The quenching process of the molten slag is mainly responsible for production of various types of slag as per the practical requirements. The pozzolonic and physical properties of the slag is dependent on the quenching process of molten slag (5, 6).

Red Mud (RM) is a byproduct obtained through Bayer's process of extraction of Alumina from Bauxite ore.

The quantity of production ofRM is same as that of alumina from bauxite ore. Although the ratio percentage of RM output is mainly dependent on the type of bauxite used and methodology adopted for extraction process (7). Many research works has showcased the possibility of complete replacement of cement part in composites by slag material through alkali activation process (8, 9). The alkali activation process is a complex reaction where slag structure will initially breaks and produces the resultant product through polycondensation reaction (10).The properties of alkali ACs is generally dependent on altering the alkali and

silicate content in the alkali activated solution. The percentage of alkali content and silicate content of the mix proportion also depends on the mechanical, durability and microstructure properties of the alkali activated composites.A systematic understanding of the synthesizing factors of AC and their effect on macro and micro properties are essential.Hence the present experimental work focuses on the study on the effect of silicate content on the compressive strength, bulk density, apparent porosity, water absorption, micro structural and mineralogical properties are determined.

Materials Used

For the present experimental work; GGBS and RM were used as the binder materials. Table 1 and 2 represents the chemical composition of GGBS and RM respectively. Alkaline Activator used is the combination of Sodium Hydroxide (97% purity) andSodium Feldspar

Preparation of Test Specimens

The test specimens of alkali activated paste were produced by varying the silicate contentfrom 0.2 to 1.2 by keeping a constant value of alkali content as 8% with a constant water to slag ratio as 0.31.Alkali content of 8% was chosen in this study, as it was responsible to provide a better workability with early strength(12).The rate of hydration was increased with increase in the alkali concentration.(13).The detailed mix composition corresponding to its compressive strength is represented in table 1.

In order to produce AC paste specimens, the source materials and the activator solution were initially mixed with a desired proportion for the period of 5 minutes in a Hobart mixer to obtain a homogeneous paste. Initially, the mix in its fresh state was noticed to have better workability with high viscosity. Further, after determining the flow properties, the paste mixes was then transferred to the 50mm^3 moulds and were kept on vibrating table for 2 minutes to eliminate the entrapped air. The test specimens were demoulded after 24 hrs of casting the specimens. The specimens were tested for its compressive strength at the age of 3 days, 7 days and 28 days.

Table 1: Details of Mix proportion with compression test results

Specimen ID	Silicate Content	Compressive Strength (MPa)		
		3 days	7 days	28 days
AC 0.2	0.2	3.24	6.46	20.35
AC 0.4	0.4	6.62	11.23	26.49
AC 0.6	0.6	11.33	17.54	36.80
AC 0.8	0.8	15.52	22.49	44.52
AC 1.0	1.0	14.21	21.54	42.28
AC 1.2	1.2	13.56	20.24	39.51

Tests Carried out

Workability

Workability of the test specimens in the fresh state was determined by using mini flow table test apparatus. In this test the flow table, with modification, was raised and dropped for 15 times at a rate of 1 drop per sec. The workability of the test mix was calculated by measuring the diameter of the flow of paste mix in two perpendicular directions on the flow table after completing 15 drops. The average value of flow diameter is considered to be the workability of the given mix.

Bulk Density and Apparent Porosity

The apparent porosity and bulk density of the test specimens were determined at the age of 28 days with respect to Archimedes principle by using water as an immersion medium.

Water Absorption

In order to determine the water absorption of the test specimen, the specimens were oven dried at the temperature of 85^{o}C for the period of 24 hours and further its weight was measured (W_i).The test specimens were then immersed in water for 24 hours and corresponding weight was measured as saturated surface dry weight(W_f).

Micro structural and mineralogical Characterization

The mineralogical characteristics of the test specimens were analyzed by X Ray Diffraction technique (XRD) using Rigaku Miniflex X Ray Diffraction Machine with Cu- Kα radiation varying from 10^0 to 70^0 (2 θ) at a rate of 1^o per minute. The microstructure characterization was carried out through Scanning Electron Microscope analysis (SEM); correspondingly, the

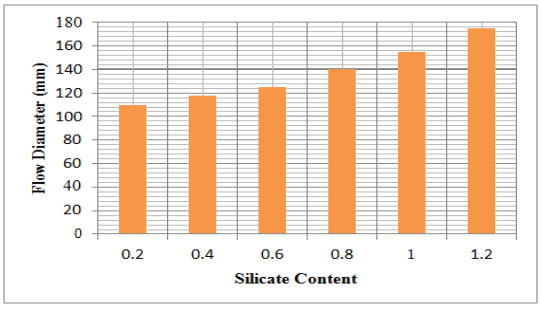
micrographs were recorded. Energy Dispersive X Ray Spectroscopy (EDAX) technique was used for quantitative analysis of the test specimens.

Results and Discussion

Workability:

Graph 1 represents the influence of variation of silicate content on workability of the given test specimens in its fresh state. The alkali content and water to slag ratio were maintained with a constant value of 8% and 0.33 respectively. It can be noticed that the flow diameter of the test specimens was found to increase with increase in the silicate content from 112 to 175 mm with respect to the silicate content ranging from 0.2 to 1.2 respectively.

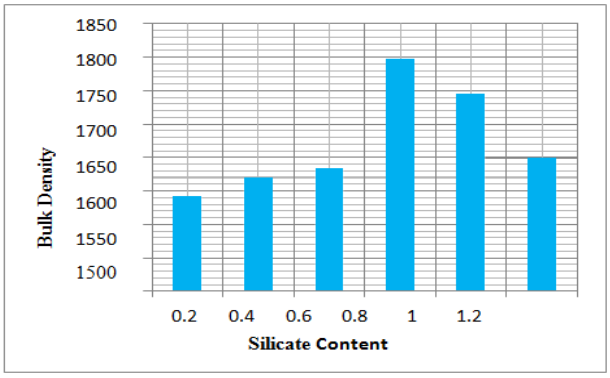
It can be noticed that the flow diameter was observed to be 140 mm, 155 mm and 175mm corresponding to the silicate content of 0.8,1 and 1.2 respectively. Higher the quantity of liquid alkaline solution ,water content in the reaction medium increases which results in large inter particle distance and consequently results in decrease in the friction between the particles , which results in increase in the flow diameter.



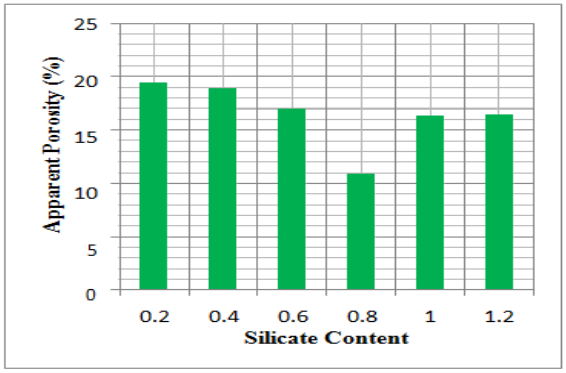
Graph 1: Variation of Silicate content Versus Flow diameter for AC specimens

Bulk Density, Apparent Porosity and Water Absorption

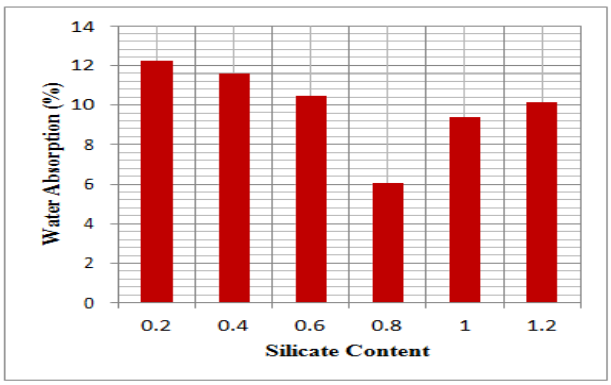
Graph 2, 3, 4 represents the variation of bulk density, apparent porosity and water absorption of the test specimens with respect to the variation of silicate content. The maximum and minimum value of bulk density was found to be 1758kg/m^3 and 1570 kg/m^3 corresponding to silicate content of 0.8 and 1.2 respectively. Apparent porosity and water absorption was found to decrease with variation of silica content from 0.2 to 0.6. Further, a rapid decrease of water absorption and apparent porosity was observed for silica content of 0.8, which correspond to the point of maximum bulk density resulting to a dense and homogeneous mix, responsible for optimum compressive strength. The test specimen possessing low silicate content varying from 0.2 to 0.6 had higher water absorption, indicating the presence of voids at a higher extent. With respect to the silicate content of 0.8 and 1, the water absorption was found to be 6.05 and 9.38% respectively. Presence of silicate content at a larger extent up to 0.8 results in denser and homogeneous microstructure.



Graph 2: Variation of Bulk Density with respect to Silicate Content



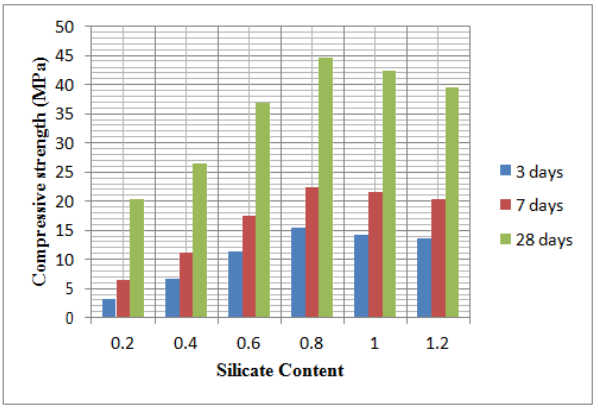
Graph 3: Variation of Apparent Porosity with respect to Silicate Content



Graph 4: Variation of water absorption with respect to Silicate Content

Compressive strength:

Graph 5 shows the variation of compressive strength of the test specimens at the age of 3 days, 7 days and 28 days with variation in silicate content ranging from 0.2 to 1.2 at a constant alkali content and water to slag ratio of 8% and 0.31 respectively. It can be observed that the compressive strength of the test specimens increases with increase in silicate content from 0.2 to 0.8 and the maximum (44.52 MPa) and minimum (20.35 MPa) compressive strength was obtained corresponding to the silicate content of 0.8 and 0.2 respectively. Graph 5 represents the variation of compressive strength with respect to the silicate content of the test specimens. Higher the silicate content, greater will be the compressive strength. This may be due to increase concentration of anions in the activator. The 7 day compressive strength for the test specimens was observed to be 31.74 , 42.39 , 47.66 , 50.52 , 50.95 , 51.23% of 28 days compressive strength of the specimens corresponding to the silicate content of 0.2,0.4,0.6,0.8,1 and 1.2 respectively. It can be noticed that the percentage of strength gain with respect to specimen age of 7 days was found to be increase with increase in the silicate content from 0.2 to 1.2. According to Wang et.al.; the silicate polymerization in sodium hydroxide based alkali activated paste contained the constant monomer, whereas the formation of dimer and trimer increases, but the polymer decreases under the duration ranging from 1day to7 days. Beyond the specimen age ranging from 7 days to 28 days, the quantity of formation of monomer and trimer decreases with increase in polymer quantity simultaneously. This shows the clear indication of the depolymerisation phenomenon for the period of 1 day to 7 days and polymerization phenomenon from 7 days to 28 days.



Graph 5: Variation of Compressive strength with respect to Silicate Content

Micro structure Characterization of Test Specimens by SEM and EDAX analysis.

Fig1 and 2 shows the SEM and EDAX analysis of the test specimens with variation of silicate content ranging from 0.2 to 1.2 respectively. The SEM images of the test specimens represent highly amorphous nature of the specimens with lower degree of crystallinity. Fig shows the micrograph and SEM images of AC 0.2, AC 0.4 and AC. This may be due to incomplete dissolution of alkaline solution and also partially due to dry shrinkage effect. Fig 2. represents the SEM image of AC 0.8 test specimen, which was quite dissimilar to other specimens because of its dense matrix with less micro cracks. This may be due to the fact that most of the slag grains were responsible for formation of CSH gel, in turn results in contribution of high strength of the test specimen. Beyond silica content of 0.8, the image shows the presence of the micro cracks with large pores.

This may presence of excess unreacted silica content leads to high porous and less dense microstructure.

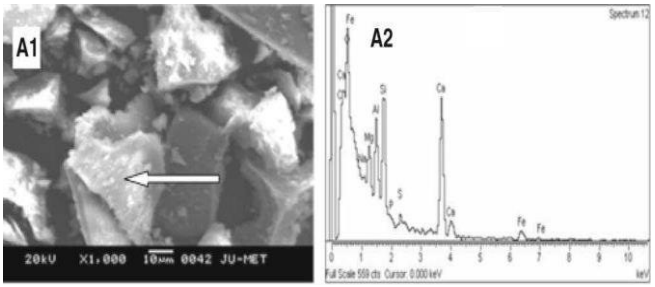


Fig 1 : SEM (A1) and EDAX (A2) of 25:75 (RM:GGBS) slag

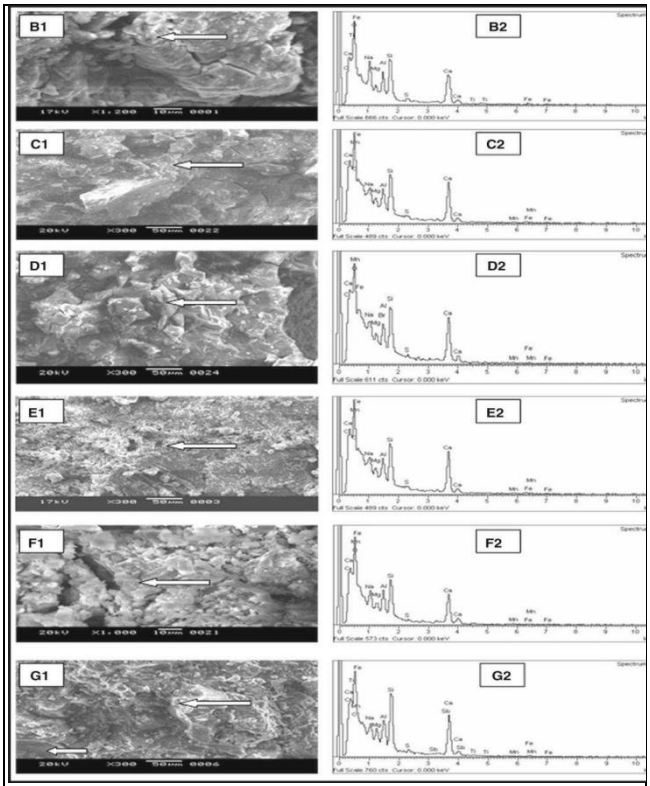


Fig 2: B1,C1, D1, E1, F1, G1 represents the SEM images and B2,C2, D2, E2, F2and G2 represents the EDAX images of AC 0.2,0.4,0.6,0.8,1.0 and 1.2 test specimens respectively

Observations and Conclusions

- Alkali activated slag based composite can be prepared by utilization of sodium hydroxide and sodium feldspar as alkali activator.
- The compressive strength of the test specimens is found to be increased with increase in silicate content from 0.2 to 0.8.
- The optimum value of 28 days compressive strength was found to be 44.52 MPa corresponding to the silicate content of 0.8.
- The dense matrix was observed with very less micro cracks and lower degree of porosity for the silicate content of 0.8.
- With increase in silica content up to 0.8, micro cracks were observed to be less with dense matrix; this is due to the reason that as the silica content increases, the quantity of unreacted grain particles decreases, which was a contributing factor for increase in compressive strength.
- As the silicate content increases beyond 0.8, the compressive strength was found to be decreased with wider cracks, less dense matrix and higher degree of porosity. This may be due to the presence of excess silica in the unreacted state.

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