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Effect of Sodium Hydroxide Concentration and Alkaline Ratio on the Compressive Strength of Slag Based Geopolymer Concrete

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Abstract: Concrete is the widely used building material and cement is the main constituent in the manufacturing of concrete. With the intention of overcoming the environmental issues of cement, an effort has been made to find a substitute for cement by using industrial by-products such as flyash and slag which are rich in Silicon (Si) and Aluminium (Al) content to react with an alkaline solution, which is a mixture of Sodium hydroxide (NaOH) and Sodium Silicate (Na_2SiO_3) to form a paste, which are termed as Geopolymers. In this regard, an experimental investigation has been made to study the variation in the Compressive Strength of slag based Geopolymer concrete by varying the concentration of Sodium hydroxide as 10, 12, 14M and the ratio of alkaline solution (SiO_3^{2-} / OH^-) as 1.0, 1.5, 2.0. The compressive strength of the mixes was determined for their 3, 7, 14 and 28 days curing for studying there variation at different age of curing. The test results show that the compressive strength of the Geopolymer mixes increases with the increase in the NaOH concentration and alkaline ratio.
Keywords: Geopolymer, Slag, Alkaline Solution, Compressive strength, Sodium hydroxide, Sodium silicate.

Introduction

Cement is the major ingredient in the production of concrete. In the manufacturing of cement, equivalent amount of CO_2 is emitted to the atmosphere[1]. The cement industry contributes 7% of the total CO_2 emission[2] and this will increase rapidly due to the increase in the cement production. China is the largest manufacturer of cement and produces around half of the global production[3]. The manufacturing process involves burning of coal, fuel oils and petroleum coke for producing energy. But in recent years, natural gas and alternative fuels are used for energy production in the manufacture of cement globally[4]. Due to these environmental issues, attempts been carried out to minimize the use of cement in concrete[5]. In order to minimize the use of Cement as a binder, an alternative source materials of geological origin which are rich in Silicon (Si) and Aluminium (Al) content or an industrial by-product such as Flyash and Rice Husk Ash to react with an alkaline solution[6] and the chemical reaction formed is of polymerization process, which are termed as Geopolymers. A wide research took place in Alkali Activated Slag as a substitute binder for cement concrete[7-10]. Most well-known alkaline solution employed in the geopolymer technology is the mixture of sodium hydroxide with sodium silicate or potassium hydroxide with potassium silicate[11-12]. The curing temperature is a major factor influencing the development of strength and can be achieved at above ambient curing temperature. The increase in the curing temperature decreases the setting time of concrete and can attain 70% of its desired strength within 3-4 Hrs due to the rapid polymerization reaction[13-15] and found that there was no such significant increase in the strength after 28 days[6]. Geopolymer concrete based on Metakaolin possesses high strength with ordinary portland cement concrete and increase in the thermal conductivity[16]. The fineness of flyash plays a vital role in the strength and carbonation of concrete, which shows increase in fineness improves the strength of

Geopolymer concrete[17]. The complete replacement of flyash in flyash based Geopolymer concrete with slag shows excellent compressive strength results[18].

Materials and Methodology

Ground Granulated Blast Furnace Slag (GGBS)

Ordinary Portland Cement (OPC) of 53 Grade confirming to IS12269 with a specific gravity of 3.15 was taken for the controlled specimens. Ground Granulated Blast Furnace Slag (GGBS), a derivative of iron with a specific gravity of 2.90 has been taken for Geopolymer Concrete. The chemical composition obtained from XRF for OPC and GPC is given in the **table 1.**

Table 1. Chemical composition of OPC and GPC

Oxide	**CaO**	**SiO_2**	**Al_2O_3**	**MgO**	**SO_3**	**Fe_2O_3**	**Na_2O**	**K_2O**
OPC	63.12	24.52	6.88	2.16	1.43	0.51	0.44	0.63
GGBS	36.77	30.97	17.41	9.01	1.82	1.03	0.69	0.46

Aggregates

Crushed granite stone aggregates of 16 mm maximum size available in the vicinity were taken with a specific gravity of 2.62 and fineness modulus of 2.93. Local river sand in saturated surface dry condition was used as fine aggregate of specific gravity 2.75 and fineness modulus 3.39.

Alkaline Activated Solution (AAS)

GGBS requires an Alkaline Activator Solution (AAS) to form Geopolymerization reaction. The activator solution used here is a mixture of Sodium Hydroxide (99.51% NaoH by mass) and Sodium Silicate Solution (SiO_2 – 28%, Solids – 35 to 40% and Mg_2O – 9%) which is used as a catalyst liquid.

Superplasticizer

The Geopolymer concrete has the ability to set quickly with low workability. In order to overcome this issue, chemical admixture (Glenium B233) was added. It is of light brown colour liquid with less than 0.2% of chloride ion content and has a relative density of 1.08 at 25^oC as prescribed by the Manufacturer.

Experimental Investigations

In order to overcome the high evolution of heat during the preparation of NaOH solution, this has been prepared a day before the casting. Then the Na_2SiO_3 solution was mixed the NaOH solution for the required ratio of AAS. In order to achieve the required workability of GPC, chemical admixture in the form of Superplasticizer (Glenium B233) was added to the AAS. Glenium was available in the form of Light Brown Liquid with pH of 6. Excess water has been restricted which may leads to the development of pores, which could be the cause of reduction in the strength and durability of GPC.

The Geopolymer mixes were prepared by taking Sodium Hydroxide solution with concentration of 8M, 10M, 12M and 14M. The ratio of alkaline solution was varied as 1.0, 1.5 and 2.0 and varying the liquid binder ratio to get an acceptable workability of concrete. The detailed mix proportioning is listed in table 2. The mixtures were casted in 100mm size cube specimens and vibrated using table vibration technique. The curing of the specimens was done at ambient temperature condition as there is no significant increase in the strength at elevated temperature.

Table 2. Mix Proportioning of Geopolymer Concrete

	Slag	**Fine Aggregate**	**Coarse Aggregate**	**Alkaline Solution**
kg/m^3	356.36	467.12	1284.29	160.36
Mix Ratio	1	1.31	3.60	0.45

Results and Discussions

Effect of Age of Curing

The workability of the mixes was determined using Slump cone test and their corresponding cube compressive strengths were determined using Compression Testing Machine of 3000kN capacity. The 3, 7, 14 and 28 days cube compressive strength were found out in order to determine the variation in the strength due to the age of curing. The effect of age of curing on the alkaline ratio for different concentration of NaOH solution is shown in figures 1-4.

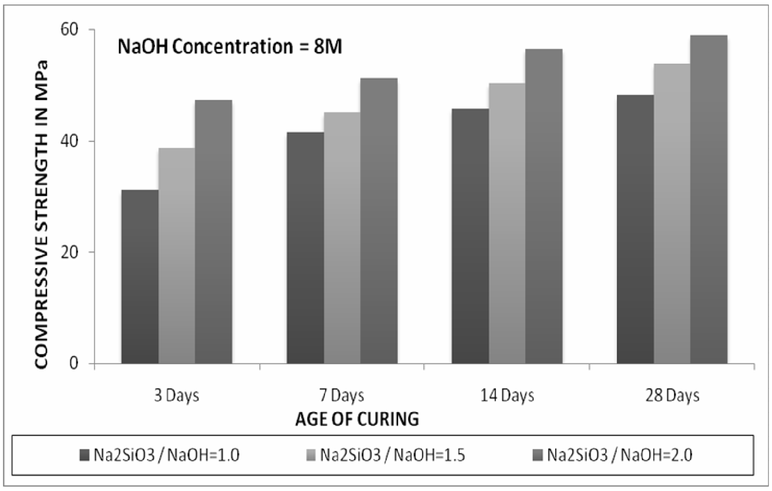

Figure 1. Effect of Alkaline ratio and curing on Compressive Strength for 8M NaOH solution

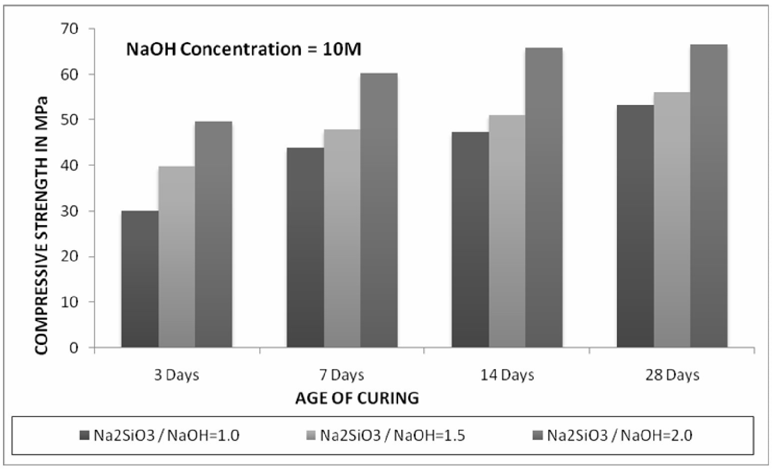

Figure 2. Effect of Alkaline ratio and curing on Compressive Strength for 10M NaOH solution

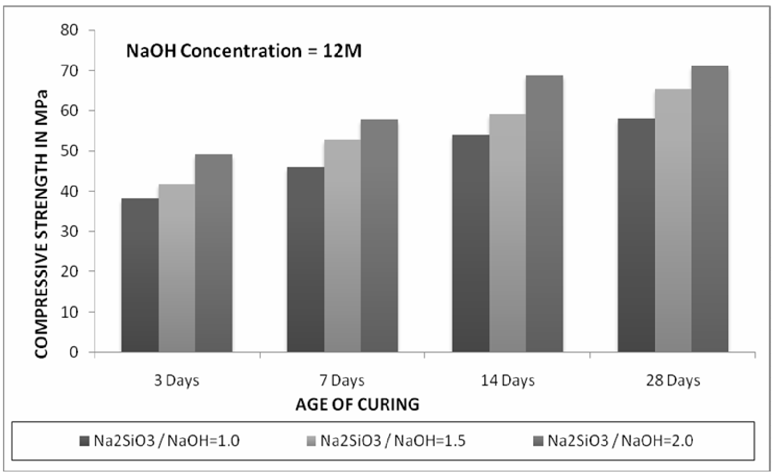

Figure 3. Effect of Alkaline ratio and curing on Compressive Strength for 12M NaOH solution

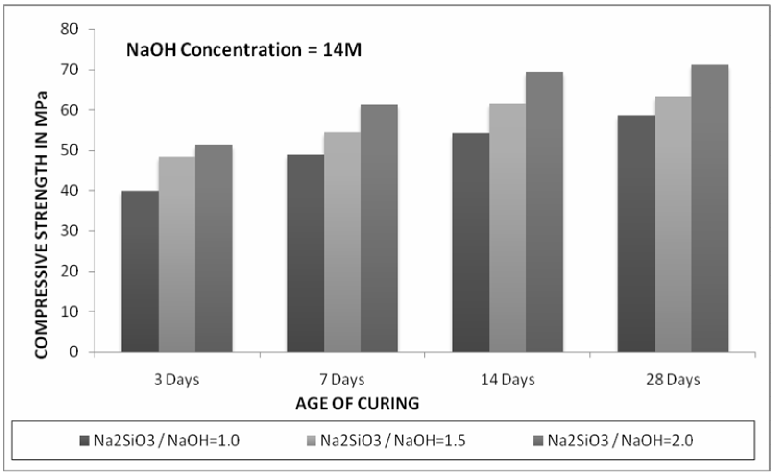

Figure 4. Effect of Alkaline ratio and curing on Compressive Strength for 14M NaOH solution

From the above results, it has been observed that the 3 day strength of the Geopolymer mixes attains higher strength of around 70% of the characteristic strength and found to be increase with the increase in the ratio of the alkaline solution. More than 95% of the strength was attained after 14 days of curing, which infers that the Geopolymer mixes has the ability to attain higher early strength compared with the mixes prepared with OPC.

Effect of NaOH Concentration and Alkaline ratio

The results infer that the strength of the Geopolymer mixes increases with the increase in the concentration of NaOH solution. The mixes with 12M NaOH solution attains more than 20% of the strength for concrete with 8M NaOH solution and there was no such significant increase in the strength for 14M NaOH solution.

Conclusions

From the test results, the following conclusions were made:

1. The use of Portland cement has been completely eliminated; thereby reduce the emission of CO_2 to the atmosphere which results in the reduction of Green House Gases.
2. The mixing time has a major responsibility in the workability of concrete and it decreases with the increase in the mixing time. It also has been found that the slump value increases with the increase in the slag content.
3. The use of Chemical admixture (Glenium B233) does not show any significant increase in the strength of the concrete and there found to be increase in the workability of concrete.
4. The curing has been done under ambient temperature conditions, so as to check the suitability of the Geopolymer concrete in practical applications.
5. Geopolymer Concrete shows superior results in compressive strength compared with the Ordinary Portland Cement Concrete.
6. The compressive strength of the Geopolymer mixes increases significantly with the increase in the NaOH concentration and found be more than 20% than the results obtained for the mix with 8M NaOH solution and there is no such significant increase for the mix with 14M NaOH solution.
7. The compressive strength of the Geopolymer mixes increases with the increase in the alkaline ratio and the result with an alkaline ratio of 2 were found to be in the range of 21% to 25% than that of the mix with the alkaline ratio of 1.0.

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References

1. Davidovits J., High-Alkali Cements for 21st century Concretes in Concrete Technology, Past, Present and Future, Proceedings of V.Mohan Malhotra Symposium, ACI SP-144., 1994, 383-397.
2. Deja J, Uliasz-Bochenczyk A, Mokrzycki E., CO_2 emissions from Polish cement industry, International Journal of Green house gas control., 2010, 4(4), 583-588.
3. Hanle L, Jayaraman K, Smith J., CO_2 emission profile of the US cement industry.y, 2004.
4. Jacott M, Comunes F., Energy use in the cement industry in North America: Emissions, Waste generation and pollution control., 2003, 1990-2001.
5. Malhotra V.M., Making Concrete greener with flyash, ACI Concrete International., 1999, 21, 61-66.
6. Davidovits J., Soft Mineralurgy and Geopolymers, Proceedings of Geopolymer 88 International Conference, France., 1988.
7. Puertas F, Martnez-Ramirez S, Alonso S and Vazquez T. Alkali Activated Flyash/Slag Cements: Strength Behaviour and Hydration Products, Cement and Concrete Research., 2000, 30(10), 1625-1632.
8. Brough AR 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.
9. Al-Otaibi S. Durability of Concrete incorporating GGBS activated by Water-Glass, Construction and Building Materials., 2008, 22(10), 2059-2067.
10. Escalante-Garcia JI, Espinoza-Perez L, Gorokhovsky A and Gomez-Zamorano LY. Coarse Blast Furnace Slag as a Cementitious Material, Comparative study as a partial replacement of Portland Cement and as an Alkali Activated Cement, Construction and Building Materials., 2009, 23(7), 2511-2517.
11. Davidovits J, Chemistry of Geopolymeric Systems, Terminology, Geopolymer 99 International Conference, France., 1999.
12. Barbosa VFF, MacKenzie KJD and Thaumaturgo, Synthesis and Characterisation of Materials based on Inorganic Polymers of Alumina and Silica: Sodium Polysialate Polymers, International Journal of Inorganic Materials., 2000, 2(4), 309-317.
13. Barbosa V.F.F., MacKenzie K.J.D., Thermal Behaviour of inorganic Geopolymers and Composites derived from Sodium Polysialate, Mater. Res. Bull., 2003, 319-331.
14. Rowles M., O'Connor B., Chemical Optimization of the Compressive Strength of Aluminosilicate Geopolymers Synthesized by Sodium Silicate Activation of Metakaolinite, J. Mater. Chem., 2003, 1161-1165.
15. Chanh N.V., Trung B.D., Tuan D.V., Recent research in Geopolymer Concrete, the 3rd ACF International Conference., 2008.
16. Martin-Lopez C, Reyes Araiza L, Manzano-Ramirez A, Rubio Avalos J.C, Perez-Bueno J.J, Muniz-Villareal M.S, Ventura-Ramos E, Vorobiev Y, Synthesis and characterization of a concrete based on metakaolin Geopolymer, Inorganic Materials., 2009, 45(12), 1429-1432.
17. Das B.B., Pandey S.P., Influence of fineness of flyash on the carbonation and electrical conductivity of concrete, Journal of Materials in Civil Engineering., 2011, 1365-1368.
18. Parthiban K, Saravanarajamohan K, Shobana S, Anchal Bhaskar A. Effect of replacement of slag on the mechanical properties of flyash based Geopolymer Concrete. International Journal of Engineering and Technology., 2013, 5(3), 2555-2559.

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