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Study on Alkali-Activated Concrete Containing High Volume GGBS with 30% Cement in Ambient Condition

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ABSTRACT:- The current research aims to investigate alkali-activated ground granulated blast furnace slag was partially replaced with OPC by 30% by weight. The workability and mechanical properties of alkali-activated concrete were studied. All results of alkali activated slag concrete were compared to control concrete on plain GGBS. The ground granulated blast furnace slag is activated with different concentrations of sodium hydroxide and sodium silicate activating solutions. The activated slag pastes are cured at 23 ± 2°C for 28 days in sealed plastic containers, the resulting hardened alkali activated pastes are impregnated with epoxy and then polished. The results indicated that the workability decreased as the slag content increased.
Keywords:- GGBS; Alkali-activators.

I. INTRODUCTION

One possible alternative is the use of alkali-activated binder using industrial by products containing silicate materials. The most common industrial by-products used as binder materials are ground granulated blast furnace slag (GGBS). GGBS has been widely used as a cement replacement material due to its latent hydraulic properties.

GGBS is a latent hydraulic material which can react directly with water, but requires an alkali activator in concrete. This is the Ca $(OH)_2$ released from the hydration of Portland cement.

Thus, when used with Portland cement, GGBS will not start to react until some Portland cement hydration has taken place. This delay causes the blended cements to develop strength more slowly at early ages compared to the normal Portland cement.

It is widely known that the production of Portland cement consumes considerable energy and at the same time contributes a large volume of CO_2 to the atmosphere. However, Portland cement is still the main binder in concrete construction prompting a search for more environmentally friendly materials.

Recent research has shown that it is possible to use 100% slag as the binder in concrete by activating them with an alkali component, such as; caustic alkalis, silicate salts, and non silicate salts of weak acids (Bakharev, Sanjayan, & Cheng, 1999; Talling & Brandstetr, 1989). There are two models of alkali activation. Activation by low to mild alkali of a material containing primarily silicate and calcium will produce calcium silicate hydrate gel (C-S-H), similar to that formed in Portland cements, but with a lower ratio (Brough & Btkinson, 2002; Deja, 2002). The second mechanism involves the activation of material containing primarily silicate and aluminates using a highly alkaline solution. This reaction will form an inorganic binder through a polymerization process (Barbosa, Mackenzie, & Sindhunata, 2006; Xu, 2002). The term "geopolymeric" is used to characterize this type of reaction from the previous one, and accordingly, the name geo-polymer has been adopted for this type of binder (Davidovits, 1994). The geo-polymeric reaction differentiates geo-polymer from other types of alkali activated materials (such as; alkali activated HVGGBS) since the product is a polymer rather than C-S-H gel.

1.1 Objectives of present study

The aim of the research is to evaluate the properties and suitability of alkali activated HVGGBS as an alternative to the use of ordinary Portland cement (OPC) in the production of concrete.

The individual objectives will include;

1) Evaluation of the strength development of alkali activated HVGGBS concrete in comparison with conventional concrete (OPC)
2) Optimization of the mix design for alkali activated HVGGBS concrete
3) Evaluation of the performance of alkali activated HVGGBS concrete with respect to the strength properties

The study builds on and contributes to the development of new environmentally friendly binders in concrete. Although there are numerous studies that assess the suitability of alkali activated HVGGBS to replace OPC as a binder in concrete, many of these studies have focused on the strength properties

II. EXPERIMENTAL METHODS

2.1 Material

GGBS

Ground granulated blast furnace slag is off-white in color and substantially lighter than Portland cement. GGBS is obtained by quenching molten iron blast furnace slag immediately in water or stream, to produce a glassy granular product that is then dried and ground into a fine powder. It is an excellent binder to produce high performance cement and concrete. The table shows the chemical composition and physical composition of GGBS.

As by-products of the metallurgical industry, the chemical composition, structure and properties of GGBS vary depending on the source, i.e. iron blast-furnace slag are hydraulic while nickel and copper slag have only pozzolanic properties due to the lack of lime and therefore they need to react with lime before become hydraulic (Regourd, 1986)

Table 1: Typical Physical Properties of GGBS

Sl. No.	Colour	Off-white
1.	Specific gravity	2.9
2.	Bulk density	1200kg/m^3
3.	Fineness	>350m^2/kg

3.1.5 Alkaline activators

The alkaline activator used in this study was a sodium silicate based solution which means that the alkaline activator contained sodium silicate and sodium hydroxide. The sodium hydroxide solution (NaOH) was prepared in a fume cabinet by dissolving sodium hydroxide pellets in de-ionized water at least 1 day prior to mixing**.**

The alkaline solution used is a combination of Sodium silicate and Sodium hydroxide solution. The source materials exhibit better zeolitic properties with Sodium hydroxide solution rather than with Potassium hydroxide solution. The addition of Sodium Silicate solution to Sodium hydroxide solution enhances the reaction rate between source material and alkaline solution. The Sodium hydroxide with 97-98% purity is in the pellets or flakes form. These pellets were mixed with water to get the required molarity of the Sodium hydroxide solution, and it varies between 8 morality (8M) to 16molarity (16M). NaOH solution with a concentration of 8M consists of 320 grams of NaOH solids per liter of the solution.

That is, $8 \times 40 = 320$ grams

Where, 40 is the molecular weight of NaOH and 8 is the molarities of the solution. In this solution the mass of NaOH solids was measured to be 262 grams. In the total weight of 320 grams of NaOH solids which will consume during the reaction and reduced to 262 grams

The properties of the sodium silicate (Na_2SiO_3) supplied are shown in Table 8

Table 2: Chemical and physical properties of liquid sodium silicate

Sl.No.	Product name	D^{TM}
1.	Wt. Ratio Sio_2/Na_2O	2.00
2.	% Na_2O	14.7
3.	% SiO_2	29.4
4.	Density @20^{0}C g/cm^3	1.53
5.	pH	12.8
6.	Viscosity Centipoises	400
7.	Characteristics	Clear to opalescent liquid

Table 3: Details of Alkali-activated concrete mixtures for M$_{30}$

Sl. No.	Mix designation	D1	D2	D3	D4
1.	GGBS content Kg/m^3	359.10	359.10	359.10	359.10
2.	OPC content Kg/m^3	153.90	153.90	153.90	153.90
3.	Fine aggregate Kg/m^3	538.65	538.65	538.65	538.65
4.	Coarse aggregate Kg/m^3	1231.2	1231.2	1231.2	1231.2
5.	$\frac{Activator\ solution}{HVGGBS}$	0.35	0.35	0.35	0.35

6.	Molarity [M]	8M	12M	8M	12M
7.	$Na_2SiO_3/NaOH$	0.4	0.4	0.25	2.5
8.	NaOH, Kg/m^3	27.36	41.04	10.94	16.42
9.	$Na_2SiO_3 Kg/m^3$	10.94	16.42	27.36	41.04
10.	Super plasticizer Kg/m^3	7.695	7.695	7.695	7.695

2.2 Mixture proportions

The activator was prepared by mixing sodium silicate and sodium hydroxide is 0.4 and 2.5 left until the temperature of the solution got down to the room temperature. The ratios of GGBS slag: fine aggregate: coarse aggregate were taken as 1:1.05:2.40. The mixing proportions details are shown in table 3.

2.3 Casting, Curing and Testing

Cementitious materials and aggregate were mixed in a pan mixer for 5 minutes, and then the liquid component of the material was added and mixed for extra 5 minutes. Just after mixing, the slump of fresh concrete was determined in accordance with ASTM C173. Then the mixture was cast into 15 x 15 x 15 cm moulds, cylinders of 15 cm diameter and 30 cm height moulds and prisms of 10 x 10 x 50 cm, in three layers. Each layer was vibrated for 15 seconds using vibrating table immediately after casting.

The compressive strength of cube specimens was measured in triplicate after ages of 7, 14 and 28 days. The testing machine employed for this test complies. The splitting tensile strength was determined using cylinder specimens according to ASTM C 496 at ages of 28 days. The flexural strength tests were carried out on the prisms of 10 x 10 x 50 cm at ages of 28 days using simple beam with two points loading.

III. RESULTS & DISCUSSIONS

3.1 Fresh Properties:

The alkali-activated concrete gives good workability. The degree of workability decreased as the replacement of with slag increased. They used constant w/b ratio of 0.5 and sand to binder of 3. They reported that the GGBS mortars had lower workability that CVC mortars.

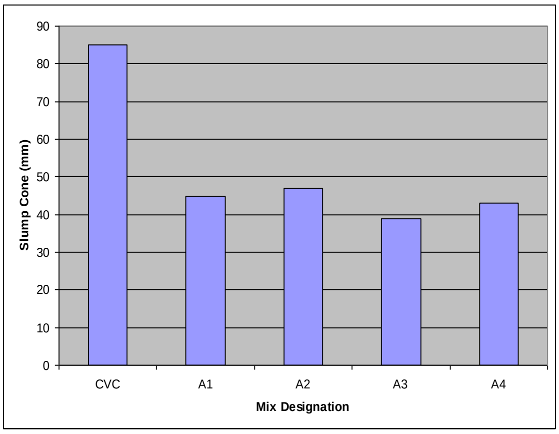

Figure 1: Slump Values for Various HVGGBSC Mixes

3.2 Mechanical Strength Development:

The compressive strength, splitting tensile strength and flexural strength development at different ages of different concrete mixtures are studied. The compressive, splitting and flexural strengths of concretes increased with increasing hydration time. The obtained results indicate that this type of concrete reaches good compressive strength at early ages. Replacing GGBS with slag led to increasing strength. Figure 2 illustrates that as the amount of slag increased in concrete matrix as the gain in strength obtained. However, after 7, 14 and 28 days of hydration, the compressive strength were 14.34, 17.56 & 28.05 respectively fig. 3 shows the splitting tensile strength of different mixtures. Apparently, similar findings of splitting strengths were found as compressive strengths. The splitting tensile strength of HVGGBS concretes blended with slag is still higher than those of plain CVC concrete. Figure 4 illustrates the flexural strength results. However, it is known that there is a relationship between the flexural strength and compressive strength of concrete, such that the higher the compressive strength the higher the flexural strength of concrete. The flexural strengths of concretes were dependant on the amount of slag. As the amount of slag increased as the flexure strength increased.

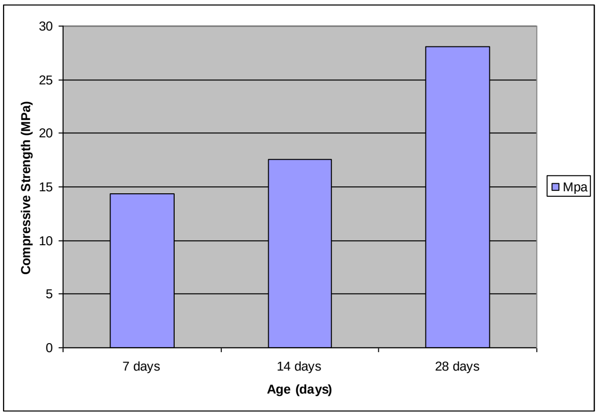

Fig. 2: Compressive strength developments of different concrete mixtures

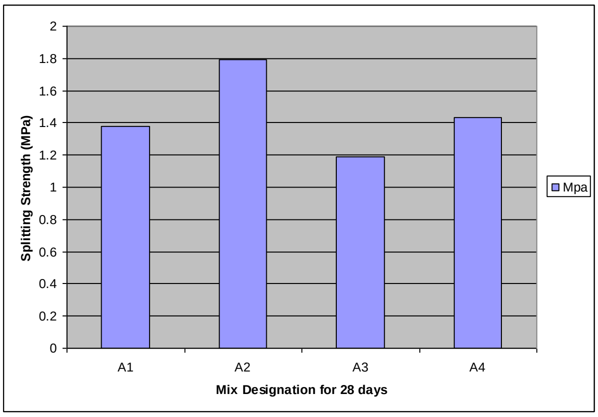

Fig. 3: Splitting tensile strength developments of different concrete mixtures

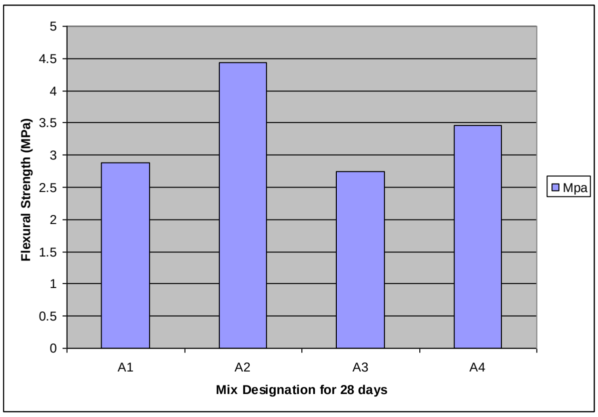

Fig. 4: Flexural strength developments of different concrete mixtures

IV. CONCLUSION

- HVGGBS Concrete can be produced even @ ambient temperature in the range of 20°C -35°C by using alkali activator solution.
- The HVGGBS Concrete gains strength over a long period.
- The Strength gained by HVGGBS concrete is less & the setting time is more compare to OPC.
- The early age strength of HVGGBS concrete depends on the temperature as the temperature increases the strength also increases.
- As the concentration of sodium hydroxide & the ratio of sodium silicate to sodium hydroxide increases the strength of HVGGBS Concrete increases.
- From structural point of view, GGBS replacement enhances lower heat of hydration, higher durability and higher resistance to sulphate and chloride attack when compared with normal ordinary concrete.
- After 28 days the strength gained by HVGGBS Concrete is 80%-90% of OPC and the strength goes on increasing with time.
- The Split Tensile strength gained by HVGGBS Concrete after 28days is about 7% of the compressive strength.
- The Flexural Strength gained by HVGGBS Concrete is 40% of Split Tensile strength.

V. SCOPE FOR FURTHER STUDIES

The further study can be done based on the following parameters

- By changing the percentage of GGBS & OPC by 60%-40% & so on the further work can be carried out.
- By changing the ratio of activator solution the further work can be carried out.
- By changing the Molarity of sodium hydroxide the further work can be carried out
- By increasing the initial curing temperature the further work can be carried out.

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