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COMPARATIVE STUDY ON PROPERTIES OF GGBS BASED GEOPOLYMER CONCRETE WITH PLAIN CEMENT CONCRETE

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ABSTRACT

The major problem the world is facing today is the environmental pollution. In the construction industry mainly the production of Portland cement will causes the emission of pollutants results in environmental pollution. We can reduce the pollution effect on environment, by increasing the usage of industrial by-products in our construction industry. The demand of concrete is increasing day by day and Cement is used for satisfying the need of development of infrastructure facilities, 1 ton cement production generates 1 ton CO_2, which adversely affect the environment. In order to reduce the use of OPC and CO_2 generation, the new generation concrete has been developed such as GEOPOLYMER CONCRETE. In the present study, to produce the geo-polymer concrete the Portland cement is fully replaced with Ground Granulated Blast Furnace Slag (GGBS) and Alkaline Liquids (AL) are used for the binding of materials. GGBS is considered as a more eco-friendly alternative to Ordinary Portland Cement (OPC). The alkaline liquids used in this study for the polymerization are the solutions of Sodium Hydroxide (NaOH) and Sodium Silicate (Na_2Sio_3). Different molarities of sodium hydroxide solution are taken to prepare different mixes. Mix design is done as per IS 10262 and based on density of concrete, and the compressive strength is calculated for each of the mix.

Key words: Granulated Blast Furnace Slag (GGBS), Geopolymer concrete, Sodium Hydroxide (NaOH) and Sodium Silicate (Na_2Sio_3)

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INTRODUCTION

Concrete is the second most used material in the world after water. Ordinary Portland cement has been used traditionally as a binding material for preparation of concrete. But this rapid production of ordinary Portland cement creates two big environmental problems for which we have to find out civil engineering solutions. 1 tone of carbon dioxide is estimated to be released to the atmosphere when 1 ton of ordinary Portland cement is manufactured. Also the emission by cement manufacturing process contributes 7% to the global carbon dioxide emission. In India about 2,069,738 thousands of metric tons of CO2 is emitted in the year of 2010. The cement industry contributes about 5% of total global carbon dioxide emissions. The cement is manufactured by using the raw materials such as lime stone, clay and other minerals. Quarrying of these raw materials is also causes environmental degradation. To produce 1 ton of cement, about 1.6 tons of raw materials are required and the time taken to form the lime stone is much longer than the rate at which humans use it. On the other side the demand of concrete is increasing day by day for its ease of preparing and fabricating in all sorts of convenient shapes. So to overcome this problem, the concrete to be used should be environmental friendly. To produce environmental friendly concrete, we have to replace the cement with the industrial by products such as fly-ash, GGBS (Ground granulated blast furnace slag) etc. In this respect, the new technology "geo-polymer concrete" is a promising technique.

The term geopolymer was first coined by Davidovits in 1978 to represent a broad range of materials characterized by chains or networks of inorganic molecules. Geopolymers are chains or networks of mineral molecules linked with co-valent bonds. Geopolymer is produced by a polymeric reaction of alkaline liquid with source material of geological origin or by product material such as GGBS. Geo-polymers have the chemical composition similar to Zeolites but they can be formed an amorphous structure. For the binding of materials the silica and alumina present in the source material are induced by alkaline activators.. This combination increases the rate of reaction. Blast furnace slag is a by-product of iron manufacturing industry. Iron ore, coke and limestone are fed into the furnace, and the resulting molten slag Floats above the molten iron at a temperature of about 1500oC to 1600oC. The molten slag has a composition of 30% to 40% silicon dioxide (SiO2) and approximately 40% CaO, which is close to the chemical composition of Portland cement. After the molten iron is tapped off, the remaining molten slag, which mainly consists of siliceous and aluminous residues, is then rapidly water- quenched, resulting in the formation of a glassy granulate. This glassy granulate is dried and ground to the required size which is known as ground granulated blast furnace slag (GGBS). The production of GGBS requires little additional energy compared with the energy required for the production of Portland cement. The replacement of Portland cement with GGBS will lead to a significant reduction of carbon dioxide gas emission. GGBS is therefore an environmentally friendly construction material.

MATERIALS AND METHODS

Materials used for PPC

- Cement
- Aggregates
- Water

Materials used for the GPC

The materials used for preparing GGBS based geopolymer concrete specimens are,

- Ground Granulated Blast Furnace Slag (GGBS)
- Sodium hydroxide flakes

- Sodium silicate solution
- Fine aggregate
- Course aggregate

Ground Granulated Blast Furnace Slag (GGBS)

Ground granulated blast furnace slag (GGBS) is a by-product of the steel industry. Blast furnace slag is defined as “the non-metallic product consisting essentially calcium silicates and other bases that is developed in molten condition simultaneously with iron in a blast furnace”. In production of iron, blast furnaces are loaded with iron ore, fluxing agents, and coke. When the iron ore, which is made up of iron oxides, silica and alumina comes together with the fluxing agents, molten slag and iron are produced. The molten slag goes through the particulars process depending on what type of slag it will become. Air cooled slag has rough finish and larger surface area when compared to aggregates of that volume which allows it to bind well with the Portland cements as well as asphalt mixtures.

Fig 1: Ground Granulated Blast Furnace Slag

Sodium hydroxide

Generally the sodium hydroxides with purity of 98% available in solid from by means of flakes were used for the present investigation. The mass of water is the major component in both the alkaline solutions. In order to improve the workability extra water has been added to the mixture. In the present investigation sodium hydroxide flakes were obtained from the Sai chemicals a local dealer

Fig 2: Sodium Hydroxide Flakes

Sodium silicate solution

Sodium silicate also known as water glass or liquid glass, available in liquid (gel) form. Sodium silicate solution is commercially available in different grades. The sodium silicate solution with Sio = 32.68%, Na2O =15.63% water =51.69% by mass, has been used for the present study. As per the manufacture, silicates were supplied to the detergent company and textile industry as bonding agent. Same sodium silicate is used for the making of geopolymer concrete. In the present investigation sodium silicate solutions was purchased from local market.

Fig 3: Sodium Silicate Solution

PREPARATION OF TEST SPECIMENS

Preparations of the alkaline solutions

The sodium hydroxide flakes were dissolved in water to make the solutions. The concentrations of the NaOH solutions depends on molarity 12M, 14M and 16M. The sodium silicate solutions was added to this NaOH solution and this mixture of alkaline liquid was prepared one day prior the casting of the specimens as this confirmed to have the better. The alkaline liquid was used after 24 hours and within 36hrs. On day of casting of specimens, the alkaline liquid was mixed to binder and aggregate with water added (if necessary) in order achieve better workability.

Mixing, casting and curing of GPC

For mixing conventional method used for making normal concrete was adapted to prepare geopolymer concrete. The solids constituents that is GGBS and aggregates mixed in dry form for 3-4 min. at the end of mixing, the liquid component of the geopolymer concrete mixture, i.e., combination of the alkaline solutions with extra water added to the solids and the mixing continued for another 3-4 min. the fresh GGBS based geopolymer was grey in colour and shiny in appearance.

The fresh concrete was poured into the moulds in three layers immediately after mixing and compacted by hand compaction by giving 25 strokes for each layer. After casting the test specimens were covered with HDPE (high Density polythelyne) sheet, to minimize the water evaporation during the test period of 24 hrs at room temperature.

Fig 4: Fresh GGBS based Geopolymer Concrete

Fig 5: Specimens covered with HDPE Sheet

Compressive Strength Test

Compression test s the most significant common test conducted on hardened concrete. Because most of the desirable characteristic properties of concrete are qualitatively related to its compressive strength. The compression test is conducted on compression testing machine according to IS: 516-1959[5]. The test specimen cubical in shape used for this test was 150mm X 150mm X 150mm in size. The rate of loading was maintained at 140 kg /sq cm/min. This test was carried out on the different combination of binders and alkaline solution as tabulated in appendix A and calculation ere made using the following equation.

$$\text{Compressive Strength} = \frac{Load\ at\ failure}{cross\ sectioanal\ area}\ \text{MPa}$$

RESULTS AND DISCUSSION

The compressive strength test values for different types of mixes are tabulated below:

For Pain Cement Concrete

Specimen no	Load (KN)	Compressive strength (MPa)
1	696	30.93
2	803	35.69
3	927	41.20
4	933	41.97
5	644	28.62

Table 1: Compressive Strength Values for Plain Cement Concrete

The effects of various salient parameters on the compressive strength of geopolymer concrete are discussed. The parameters considered are,

- Compressive strength v/s Binder
- Compressive strength v/s mass of NaOH flakes
- Compressive strength v/s Mass of Na_2Sio_3 solution

Compressive strength v/s Binder

The different binder quantities added in the mixture for 12M, 14M and 16M NaOH solutions and study on compressive strength were made. It is observed from the figure 6 that the compressive strength of geopolymer concrete is more than 7.0 kg binder rather than 6.0 kg binder (calculated for 5 cubes) for alkaline liquid to binder ratio of 0.4. This result shows that higher or lower quantity of binder, yields lower value of compressive strength. Similarly higher or lower ratio of alkaline liquid to binder ratio also yields lower value of compressive strength. A similar trend is same for different molarities of NaOH solution.

This effect is due to reaction with the alumina-silicates present in the industrial waste and the alkaline activators added in the optimum quantity shown above.

It is observed that higher value of compressive strength is shown in 12M solution instead 14M and 16M solutions. This also prevails that higher molarity in NaOH does not help in achieving the compressive strength. However better results are shown in 12M solutions compared to higher molarity NaOH solutions.

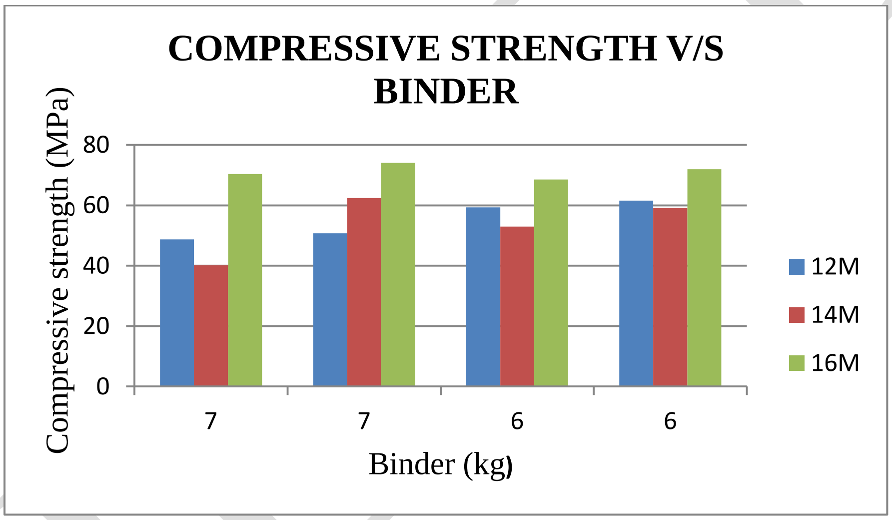

Fig 6: Effect on Compressive Strength by Binder

Compressive Strength v/s Mass of NaOH Flakes

The results of compressive strength v/s mass of NaOH flakes are plotted in the figure 7

The result shows that, decrease in NaOH flakes increases the compressive strength of geopolymer concrete. However the maximum value occurs for alkaline liquid to binder ratio of 0.4. The reason for decrease of compressive strength is due to increase of Na_2O in the geopolymer concrete.

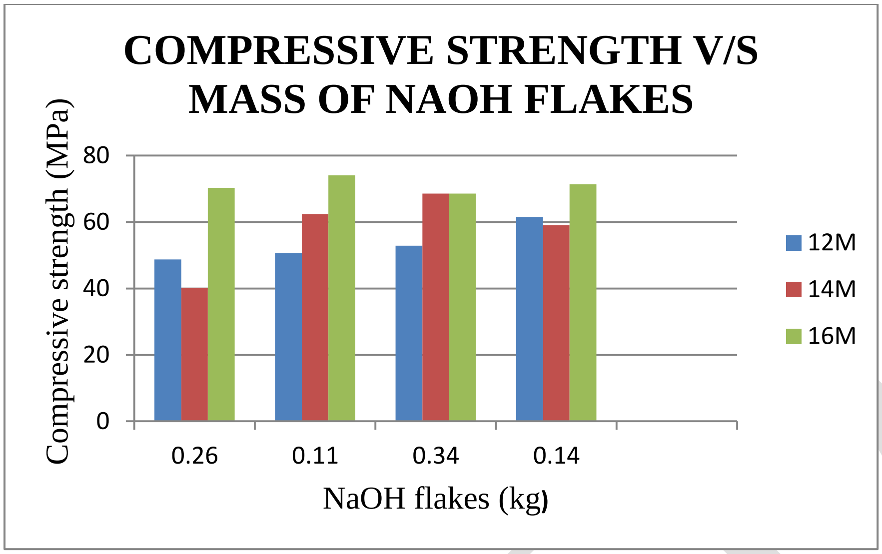

Fig 7: Effect on Compressive Strength by Mass of NaOH flakes

Compressive strength v/s Mass of Na_2Sio_3 solution

The results of compressive strength v/s mass of sodium silicate solution are plotted in figure 8. It is observed from the graph that, the increase of sodium silicate solution increases the compressive strength for all the molarities of NaOH solution. The increase in compressive strength is obtained for the alkaline liquid to binder ratio of 0.4. The reason for increase in compressive strength is due to increase in a silicate which forms body of the geopolymer concrete with proper bond.

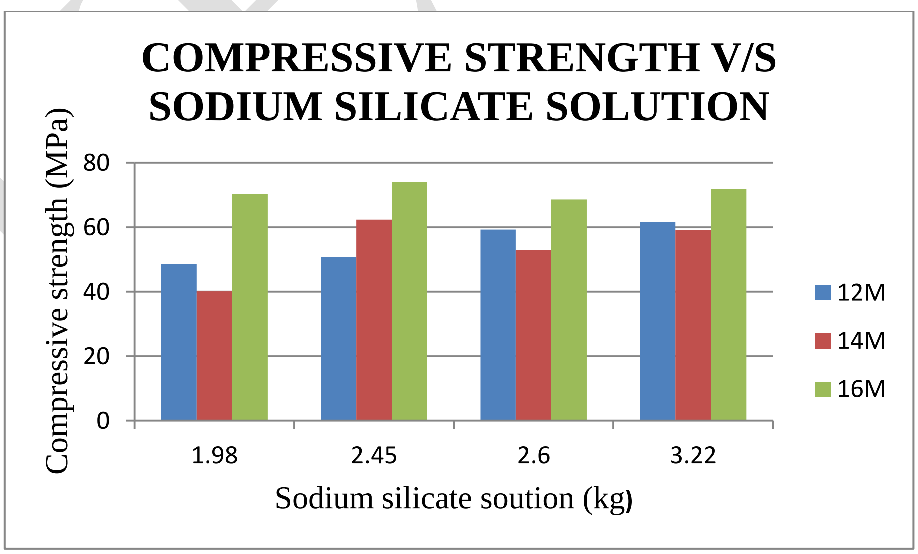

Fig 8: Effect on Compressive Strength by Mass of Na_2Sio_3 Soution

CONCLUSION

Based on the present experimental investigations the following conclusions are drawn.

- Higher concentration of sodium hydroxide in the solution results in lower compressive strength of GGBS based geopolymer concrete.
- The compressive strength increases with the increased concentration of sodium silicate solution, up to certain ratio.
- As water binder ratio increases the compressive strength of GGBS based geopolymer concrete decreases.
- GGBS based geopolymer concrete can be effectively utilized as an alternative material for OPC concrete, subjected to the other functional requirements and limitations of temperature curing

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