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Paper Authors

K. Shyam Sundar Murty[1*], B.V.Shiva Kumar[2], M.Durga Prasad[3***]**

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COMPARISON OF COMPRESSIVE BEHAVIOUR OF HEAT CURED GEOPOLYMER CONCRETE AND STEAM CURED GEOPOLYMER CONCRETE

K. Shyam Sundar Murty[1*], B.V.Shiva Kumar[2], M.Durga Prasad[3***]**
[1, 2 ,3] Department of Civil Engineering, Wellfare Engineering College, Visakhapatnam, A.P.,India.
[*] shyam.civil27@gmail.com, [**] shivakumar.bandaru@gmail.com, *** medisettydurgaprasad@gmail.com

ABSTRACT: Concrete is the most widely used man-made construction material. In the present work, an attempt has been made to establish mix proportions for Geopolymer Concrete and to study the effect of molarity of NaOH solution, Alkaline to GGBS ratio and ratio of Sodium Silicate to Sodium Hydroxide on compressive strength of Geopolymer concrete. A mix design for M20 grade Conventional Concrete has been carried out as per the code IS 10262: 2009 and the same was adopted for Geopolymer Concrete with replacement of cement by Ground Granulated Blast Furnace Slag and compressive strength of Geopolymer Concrete with that of Conventional Concrete at the age of 28 days has been compared. A total of 6 mixes have been developed with three varying parameters. In these mixes, alkaline solution having Sodium hydroxide of varied molarity 8M, 12M and 16M has been adopted the ratios of Sodium Silicate to Sodium Hydroxide(Na_2SiO_3/NaOH) are maintained at 1.0 and 2.33 with alkaline to GGBS ratio 0.3. These alkaline solutions were prepared 24 hours in advance to the casting process. The conventional method of mixing, compacting and moulding has been followed for the production of the Geopolymer concrete.

Cubes of dimension 150 mm x150 mm x150 mm have been cast using the cast iron moulds conforming to IS 10086: 1982. The specimens were left in air for 24 hours. The cubes were subjected to heat curing at a temperature of 60°C. Three cubes of each mix were taken out from the oven carefully after 4 hours of heating and the same procedure was repeated for the same number of cubes after 6 hours and 8 hours of heating. The same number of cubes of each mix were cast separately and kept in steam curing at 100°C. The compressive strengths of heat cured Geopolymer Concrete at durations of 4 hours, 6 hours, 8 hours and 24 hours heating at the age of 28 days is compared with that of steam cured concrete. It is observed that the specimens which are subjected to steam curing and heat curing for a duration of 24 hours have high compressive strength.

Keywords: Geopolymer concrete, Steam Curing, Heat Curing, Ground Granulated Blast Furnace Slag, Compressive Strength, Sodium Silicate, Sodium Hydroxide

INTRODUCTION

The civil engineering construction is progressing massively day by day leading to the increase in demand for the cement production. Concrete is the most widely used man-made construction material from ages. It is obtained by mixing cement, aggregates and water in required proportion. As the demand for concrete as a construction material increases, so also the demand for Portland cement. It is estimated that the production of cement increased from about 1.5 billion metric tons in 1995 to 4.3 billion metric tons in 2010.

On the other hand, the climate change due to global warming and environmental protection has become major concerns caused by the emission of green house gases, such as carbon dioxide, to the atmosphere by human activities. Among the green house gases, CO_2 contributes about 65% of global warming. The cement industry is held responsible for some of the CO_2 emissions, because the production of one tonne of Portland cement emits approximately one tonne of CO_2 in the atmosphere. The environment must be protected by preventing the dumping of waste or by- product materials in uncontrolled manners. The Geopolymer technology shows considerable promise for application in concrete industry as an alternative to Cement technology. In terms of global warming, the geopolymer concrete significantly reduce the CO_2 emission to the atmosphere caused by the cement industries. Davidovits (1988: 1994) proposed that an alkaline liquid could be used to react with the Silicon(Si) and Aluminium(Al) in the by-product pozzolanicmaterials such as Fly ash(pulverized fuel ash), Ground Granulated Blast Furnace Slag(GGBS), Silica fume, Rice husk ash and Metakaoline. Since, the chemical reaction that takes place in this case is a polymerization process, he coined the term geopolymer to represent these binders.

Ground Granulated Blast FurnaceSlag (GGBS or GGBFS) is obtained by quenching molten iron slag (a by-product of iron and steel-making) from a blastfurnace in water or steam, to produce glassy, granular product that is then dried and ground into a fine powder. The main components of blast furnace slag are CaO (30-50%), (28-38%) SiO_2, Al_2O_3 (8-24%) and MgO (1-18%).

The sodium hydroxides with purity 98% available in solid forms by means of flakes were used for the present investigation. The mass of water is the major component in both the alkaline solutions.

Sodium silicate is also known as water glass or liquid glass, available in liquid (gel) form. The sodium silicate solution is commercially available in different grades.

MATERIALS USED IN THE EXPERIMENT

Cement

The cement used for the investigation was Ordinary Portland Cement (OPC) of grade 53 with brand conforming to IS: 455-1989. The cement is fresh and is of uniform colour and consistency. It is free from lumps and foreign matter. The cement procured was tested for physical properties in accordance with IS:12269-1987.

Ground Granulated Blast Furnace Slag (GGBS)

Ground Granulated Blast Furnace Slag is used as a completed replacement of cement in the manufacture of Geopolymer Concrete. In the present investigation, GGBS was obtained from a local dealer. It was tested as per BS:6699 with 70% GGBS and 30% OPC53 grade. The sand used in the tests, ambient conditions and methods of tests are as per IS 4031 and IS 4032.

Aggregates

Aggregates can be classified on the basis of the size as coarse aggregate and fine aggregate.

Coarse Aggregate

Coarse aggregates are used for making concrete. The aggregate fractions from 80mm to 4.75mm are termed as coarse aggregate.In this experimental programme aggregateof sizes 20mm and 10mm are used. It is free from impurities such as dust, clay particles and organic matter. The coarse aggregate is tested for various properties according to IS: 2386-1963.

Fine Aggregate

The aggregate fractions from 4.75mm to 150 microns are termed as fine aggregates. The locally available river sand is used as fine aggregate. The sand is free from clay,silt and organic properties according to IS:2386-1963.

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The sand is confirmed to Zone III as per IS:383-1970.

Sodium Hydroxide

Generally the sodium hydroxides with purity 98% available in solid forms 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 a local dealer. The following are the results given by the supplier based on an analysis made on sodium hydroxide flakes.

Sodium Silicate Solution

Sodium silicate is also known as water glass or liquid glass, available in liquid (gel) form. The sodium silicate solution is commercially available in different grades.

EXPERIMENTAL SETUP

The method adopted to obtain the design mix for M20 grade concrete is done according to IS:10262-2009. Compressive strength test has been conducted on cube of size 150 mm x 150 mm x 150mm.

Cement: Fine Aggregate: Coarse Aggregate: Water =1:2.21:3.89:0.5

PREPARATIONS OF TESTING SPECIMENS

Mixing of Conventional Concrete

All the materials were mixed using pan mixer with a maximum capacity of 80litres. The materials were fed into the mixer in the order of coarse aggregates (20mm and 10mm sizes), fine aggregates, OPC and sand. The materials were mixed dry for 1.5min. Subsequently three-quarters of the water is added and the remaining water, while mixing continued for a further 6 min in order to obtain a homogenous mixture. Upon discharging from the mixer, the slump cone test was conducted on the fresh concrete for the mixture. Then the fresh concrete was placed into the steel cube moulds and allowed to compact without any vibration. Finally, surface finishing was done carefully to obtain a uniform smooth surface.

Mixing of Geopolymer Concrete

Initial Preparations

The sodium hydroxide crystals were dissolved in water to make the solution.The concentration of NaOH solution depends on the Molarity 8M, 12M and16M.The sodium silicate solution was added to this NaOH solution and this mixture of alkaline liquid was prepared one day prior to the casting of the specimens as this is confirmed to have the better results. The alkaline liquid was used after 24 h and within 36 h. On the day of casting of the specimens, the alkaline liquid was mixed to sodium silicate solution 1hour prior to mixing.

Casting of the Specimens

For mixing, conventional method used for making normal concrete was adopted to prepare Geopolymer Concrete.The solid constituents viz. GGBS and aggregates were mixed in dry form for about 3-4 minutes.At the end of this mixing,the liquid component of the Geopolymer Concrete mixturei.e., combination of the alkaline solution with extra water was added to the solids and the mixing continued for another 3-4 minutes.The fresh GGBS based Geopolymer Concrete was grey in color and shiny in appearance. The green mix was cohesive.The workability of the fresh concrete was measured by means of the conventional slump test. Then the fresh concrete was placed into the steel cube moulds and allowed to compact on a vibrating table for 30seconds. Finally, surface finishing was done carefully to obtain a uniform smooth surface. A total of 6 mixes(9 cubes per mix) of

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Alkaline/ GGBS ratio 0.3 are prepared with different NaOH molarities 8M, 12M and 16M and different Na_2SiO_3/ NaOH ratios (1 and 2.33) were casted in the above manner.

Compaction of GPC cubes on vibrating table

CURING OF THE SPECIMENS

The specimen cubes of standard size 150mmx150mmx150mm (length x breadth x depth) were casted for Compressive strengthand tested for 28 days.

The following specimens were casted for hardened concrete tests.

Number of Geopolymer Concrete cubes for Compressive strength = 72 samples

After casting, the specimens are dried in air for 24hours and thensubjected to heat curing at a temperature of 60°C. After 4hours of heating, 3 cubes from each mix are taken out carefully from the oven and are allowed to cool and left in air. The similar procedure is carried out after 6 hours and 8 hours of heating.

Furnace used for heat curing

As per IS 9013:1978after casting the concrete specimens, they were tested as per IS 516-1959

Steamcuring tank

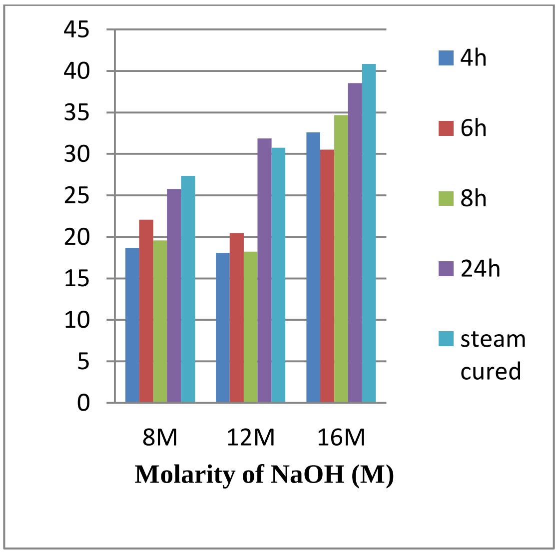
TESTS CONDUCTED ON CONCRETE

Compressive strength

Concrete specimen cubes are used to determine compressive strength of concrete and were tested as per IS 516-1959.

RESULTS

1.Variation of Compressive strength of GPCatAlkaline/GGBS=0.3, Na_2SiO_3/NaOH=2.33 at durations of 4,6,8 and 24 hours of heat curing and steamcuring shown in the following graph.



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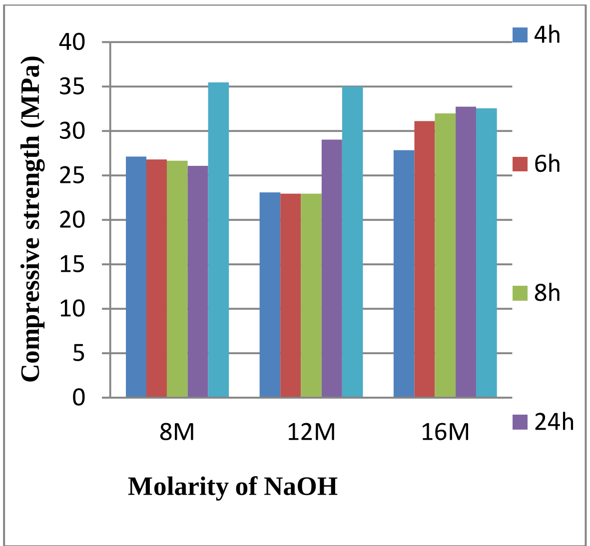
GPC at Alkaline/GGBS=0.3, $Na_2SiO_3/NaOH$=1 at durations of 4,6,8 and 24 hours of heat curing and steamcuring is shown in the following graph.



CONCLUSIONS

In the present work, an attempt has been made to establish mix proportions for Geopolymer Concrete and to study the effect of molarity of NaOH (8M, 12M and 16M) solution, Alkaline/GGBS ratio (0.3) and ratio of sodium silicate to sodium hydroxide (1 and 2.33) on compressive strength of Geopolymer Concrete.

a. For GPC subjected to heat curing for the durations of 4,6,8 and 24 hours at 60°C and accelerated curing(steam curing) at 100°C with $Na_2SiO_3/NaOH$=1.0 and Alkaline/GGBS=0.3, the compressive strength is high for the specimens subjected to accelerated curing(steam curing) by boiling water method for 8M and 12M NaOH solutions whereas the compressive strength for 16M NaOH solution is high for the specimens subjected to heat curing at 24 hours at 60°C

b. For GPC subjected to heat curing for the durations of 4,6,8 and 24 hours at 60°C with $Na_2SiO_3/NaOH$=1.0 and Alkaline/GGBS=0.3, the compressive strength is high for the specimens of 16M NaOH for all the durations.

c. For GPC subjected to heat curing for the durations of 4,6,8 and 24 hours at 60°C and accelerated curing(steam curing) at 100°C with $Na_2SiO_3/NaOH$ = 2.33 and Alkaline/GGBS=0.3, the compressive strength is high for the specimens subjected to accelerated curing(steam curing) for 8M and 16M NaOH solutions whereas the compressive strength for 12M NaOH solution is high for the specimens subjected to heat curing at 24 hours at 60°C.

d. For GPC subjected to heat curing for the durations of 4,6,8 and 24 hours at 60°C with $Na_2SiO_3/NaOH$=2.33 and Alkaline/GGBS=0.3, the compressive strength is high for the specimens of 16M NaOH solution for the all the durations.

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