International Journal of Electronics, Communication & Soft Computing Science and Engineering
ISSN: 2277-9477, Volume 2, Issue 2

Experimental study on Geo-Polymer concrete incorporating GGBS

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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. Geo-polymer concrete is such a one and in the present study, to produce the geo-polymer concrete the Portland cement is fully replaced with GGBS (Ground granulated blast furnace slag) and alkaline liquids are used for the binding of materials. 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 i.e. 3M, 5M, and 7M and 9M are taken to prepare different mixes. And the compressive strength is calculated for each of the mix. The cube specimens are taken of size 100mm x 100mm x 100mm. Two different curing are carried i.e. oven curing at 50^0c and curing directly by placing the specimens to direct sunlight. The geo-polymer concrete specimens are tested for their compressive strength at the age of 3 and 7 days. The result shows that there is no significant increase in the strength of oven cured specimens after 3 days of oven curing and the strength of geo-polymer concrete is increasing with the increase of the molarity of sodium hydroxide.**

***Key words*: Geo-polymer, GGBS, Alkaline solutions, curing, compressive strength**

I. INTRODUCTION

Environmental pollution is the biggest menace to the human race on this planet today. It means adding impurity to environment. It has a severe effect on the ecosystem. There are many reasons which cause pollution. In our construction industry, cement is the main ingredient/ material for the concrete production. But the production of cement means the production of pollution because of the emission of CO_2 during its production. There are two different sources of CO_2 emission during cement production. Combustion of fossil fuels to operate the rotary kiln is the largest source and other one is the chemical process of calcining limestone into lime in the cement kiln also produces CO_2.[1] In India about 2,069,738 thousands of metric tons of CO_2 is emitted in the year of 2010. The cement industry contributes about 5% of total global carbon dioxide emissions. [2, 3] And also, 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. [Geo-polymer institute][6]. 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. [4]. The most common alkaline liquid used in the geo-polymerization is the combination of Sodium hydroxide/ Potassium hydroxide and Sodium silicate/ Potassium silicate. This combination increases the rate of reaction. Among 15 Alumino-silicate minerals, all the Al-Si minerals are more soluble in NaOH solution than in KoH solution [5]. Ground granulated blast furnace slag (GGBS) is a by-product from the blast-furnaces used to make iron. During the process, slag was formed and it is then dried and ground to a fine powder.

II. MATERIALS

Slag is taken from Vizag steel plant in Andhra Pradesh and it is then grinded to get fine powder form of GGBS. The properties of GGBS are given in Table. I and the chemical Moduli for this material is

CaO+MgO+SiO2	78.26
(CaO+MgO)/ SiO2	1.18
CaO/SiO2	1.02

Table.I: Properties of GGBS

Particulars	Test results
Fineness(m2/kg)	387
Initial setting time (min)	170
Loss on ignition(% mass)	0.03
Magnesia content (% mass)	8.97
Sulphide sulphur (% mass)	0.42
Manganese content (% mass)	1.02
Chloride content (% mass)	0.018

A. Aggregates

Coarse aggregates of sizes 12mm and 20mm and fine aggregate taken from a local supplier are used in the present study and they have the properties as given in Table.II

Table.II Properties of Aggregates

Property	Coarse Aggregate		Sand
	20mm	12mm	
Fineness Modulus	8.14	8.14	3.45
Specific gravity	2.87	2.83	2.6
Bulk Density	1533.33 kg/m3	1517 kg/m3	1254.24 kg/m3
Percentage of voids	45.24%	47.14%	51.76%

B. Alkaline solutions

The solutions of Sodium hydroxide and Sodium Silicate are used as alkaline solutions in the present study. Commercial grade Sodium Hydroxide in flakes form (97%-100% purity) and Sodium silicate solution having 7.5%-8.5% of Na_2O and 25% -28% and water of 67.5%-63.5% are used in the present study.

III. METHODOLOGY

C. Preparation of Alkaline solutions

In this paper the compressive strength of geo-polymer concrete is examined for the mixes of varying molarities of Sodium hydroxide (3M, 5M, and 7M and 9M). The molecular weight of sodium hydroxide is 40. To prepare 3M i.e. 3 molar sodium hydroxide solution, 120g of sodium hydroxide flakes are weighed and they can be dissolved in distilled water to form 1 liter solution. For this, volumetric flask of 1 liter capacity is taken, sodium hydroxide flakes are added slowly to distilled water to prepare 1liter solution. The weights to be added to get required molarity are given in Table.III.

Table.III: Weights of NaOH flakes

Required Molarity	Weight in g. of Sodium hydroxide flakes
3M	120
5M	200
7M	280
9M	360

D. Mixing, Casting and Curing

The mix proportions were as given in Table.IV. As there are no code provisions for the mix design of geo-polymer concrete, the density of geo-polymer concrete is assumed as 2440 Kg/m^3. The Other calculations are done by considering the density of concrete. The total volume occupied by the aggregates (Coarse and fine aggregates) is assumed to be 65%. The alkaline liquid to GGBS ratio is taken as 0.30. The quantities of all ingredients are kept constant as given in table-IV except the molarity of NaOH is changed in the each mix. The conventional method used in the making of normal concrete is adopted to prepare geo-polymer concrete. First, the fine aggregate, coarse aggregate and GGBS are mixed in dry condition for 3-4 minutes and then the alkaline solution which is a combination of Sodium hydroxide solution and Sodium silicate solution with super-plasticizer is added to the dry mix. The mixing is done about 6-8 minutes for proper bonding of all the materials. After the mixing, the cubes are casted by giving proper compaction. The sizes of the cubes used are of size 100mmX100mmX100mm. For the curing geo-polymer concrete cubes, two methods are used, one by placing the cubes in hot air oven and by placing the cubes in direct sun-light. For oven curing, the cubes are placed in an oven at 60^0 c for an hour. Then the cubes are demoulded and kept in oven at 50^0 c for 3 days and 7 days. For the sun light curing, the cubes are demoulded after 1 day of casting and they are placed in the direct sun light for 3 days and 7 days.

Table.IV: Mixing proportions of geo-polymer concrete

Ingredients in (kg/m3)		Different mixes			
		G1	G2	G3	G4
GGBS		670	670	670	670
Fine Aggregate		600	600	600	600
Coarse Aggregate	20 mm	320	320	320	320
	12 mm	650	650	650	650
Sodium silicate solution		120	120	120	120
Sodium hydroxide solution		80 (3M)	80 (5M)	80 (7M)	80 (9M)
Super-Plasticizer		5	5	5	5

IV. Results

The cubes are tested in compressive testing machine to determine their compressive strength at the age of 3 days and 7 days of curing. The following figures from 1-4 are showing the compressive strength increment with molarity of NaOH. (3M, 5M, 7M and 9M) for the specimens which were cured by hot air oven and by direct sun light at the age of 3 days and 7 days.

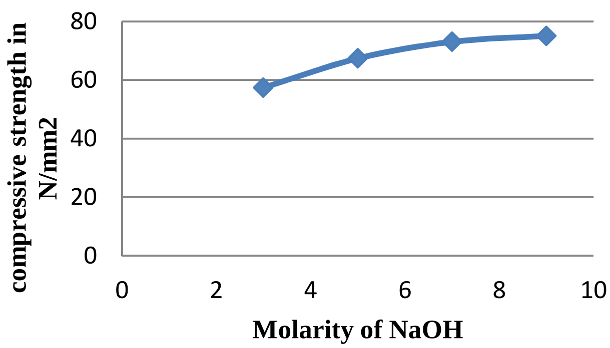

Fig.1 Compressive strength at the age of 3 days of oven cured specimens

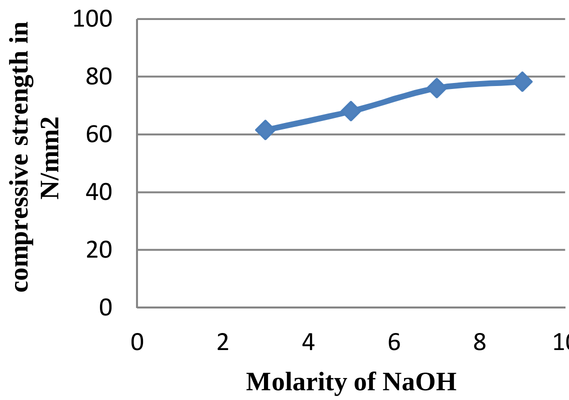

Fig.2 Compressive strength at the age of 7 days of oven cured specimens

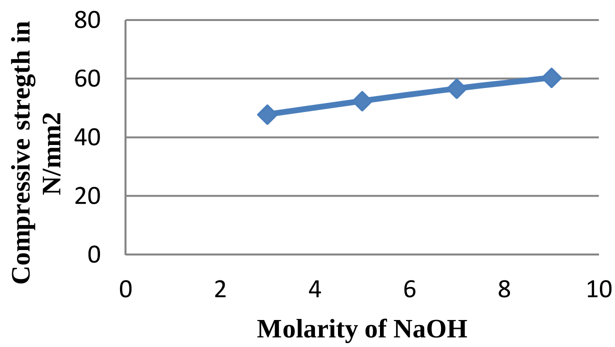

Fig.3 Compressive strength at the age of 3 days of sun light cured specimens

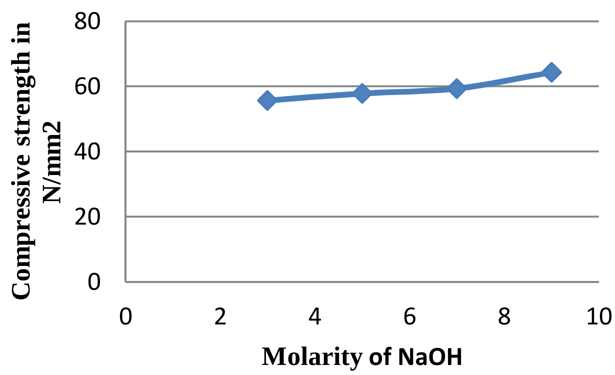

Fig.4 Compressive strength at the age of 7 days of sun light cured specimens

The variation in the compressive strengths of specimens which are cured by hot air oven and by direct sun light at the age of 3days and 7 days and also the variation by curing time are shown in below figures.

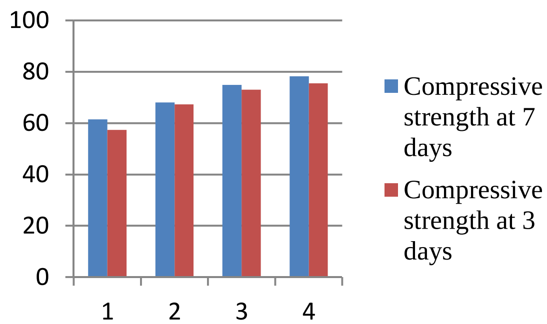

Fig.5 Variation in the compressive strength of oven cured specimens at the age of 3 days and 7 days.

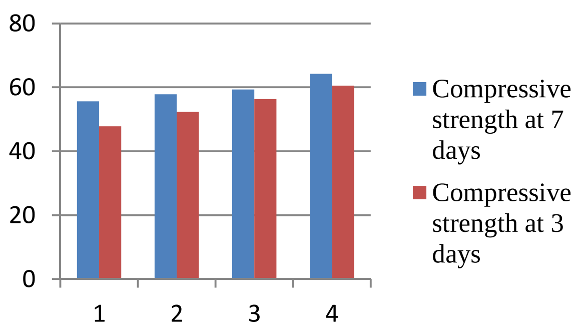

Fig.6 Variation in the compressive strength of sun-light cured specimens at the age of 3 days and 7 days.

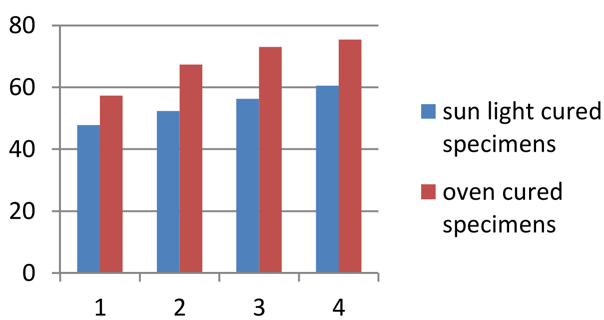

Fig.7 Variation in the compressive strength at 3 days between specimens of oven cured and direct sun light

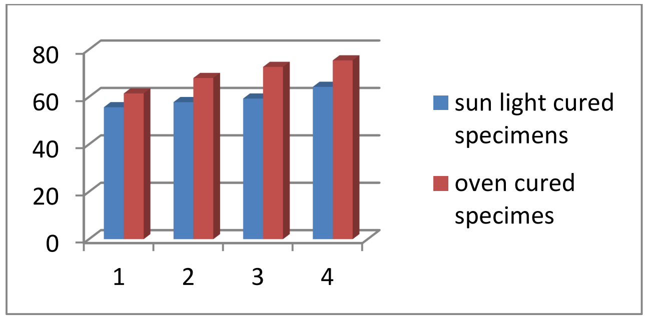

Fig.8 Variation in the compressive strength at 7 days between specimens of oven cured and direct sun light

E. Discussions

- We observed that the compressive strength is increased with the increase in the molarity of sodium hydroxide.
- After 3 days of curing the increase in the compressive strength is not significant.
- Compared to hot air oven curing and curing by direct sun light, oven cured specimens gives the higher compressive strength but sun light curing is convenient for practical conditions.

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