ISSN:2348-2079

Volume-5 Issue-1

International Journal of Intellectual Advancements and Research in Engineering Computations

Experimental investigation of geopolymer concrete

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***Abstract*—This experimental study is intended to identify the mix ratios for different grades of Geopolymer Concrete by trial and error method.Geopolymer cement concretes (GPCC) are Inorganic polymer composites, A new Design procedure was formulated for Geopolymer Concrete which was relevant to Indian standard (IS 10262-2009). The applicability of existing Mix Design was examined with the Geopolymer Concrete. Two kinds of systems were considered in this study using 100% replacement of cement by ASTM class F flyash and 100% replacement of sand by M-sand. It was analyzed from the test result that the Indian standard mix design itself can be used for the Geopolymer Concrete with somemodification.**

***Index Terms*—GPCC , M-sand.**

I. INTRODUCTION

Geopolymers are inorganic polymeric materials with a chemical composition similar to zeolites but possessing an amorphous structure. Geopolymers may be seen as man-made rocks. They can be produced by reacting solid aluminosilicates with a highly concentrated aqueous alkali hydroxide or silicate solution. The chemistry andterminology of inorganic polymers was first discussed in detail by Davidovits. Since the first mention of the term 'geopolymer' by Davidovits, Geopolymers form three-dimensional disordered frameworks of the tecto-aluminosilicate type with the general empirical formula Mn[-(SiO2)z-AlO2]n.wH2O, in which n is the degree of polycondensation, and M is predominantly a monovalent cation (K+, Na+), although Ca2+ may replace twomonovalentcations in the structure.The present work is carried out in the framework of a project aims to produce the geopolymeric Mix procedure of different grade of geopolymer concrete matrices, stronger and denser equal to the cement concrete obtained by using Portland Cement binders, that can be used for the long term stabilization of inorganic toxic waste i.e. flyash. The particular work presented in this paper deals with a study investigating the Mix design.

OBJECTIVES:

- To provide better compressive strength
- The price of fly ash is low
- To make the structure fire proof, providing high thermal resistance
- Low permeability
- To support Eco-friendly structures

II.LITERATURE REVIEW:

DAVIDOVITS 1994, 1999

In 1978, Davidovits proposed that an alkaline liquid could be used to react with the silicon (Si) and the aluminum (Al) in a source material of geological origin or in by- product materials such as fly ash .The chemical reaction that takes place in this case is a polymerization process, Davidovits coined the term 'Geopolymer'.

VIJAYA RANGAN - 2005

The paper covers the materials and the mixture proportions, the manufacturing process, the fresh and hardened state characteristics, the influence of various parameters on the fresh and hardened state concrete. Combination of sodium silicate and sodium hydroxide has been widely used as the alkaline activator. Fly ash based geopolymer concrete has excellent compressive strength and is suitable for structural applications. The fly ash based geopolymer concrete also known as excellent sulfate attract. Several economic benefits of using fly ash based geopolymer concrete.

MOHD MUSTAFA AL BAKRI – 2011

This paper summarize the properties of fly ash based Geopolymer which make it better compared to normal concrete. The common materials used as alkaline solution in producing fly ash based geopolymerare sodium silicate and potassium hydroxide to produce the alkaline solution. The compressive strength increases with the increasing of fly ash fineness and thus reduction in porosity can be obtained. Fly ash-based Geopolymer is better than normal concrete in many aspects such as compressive strength, exposure to aggressive environment, workability and exposure to high temperature.

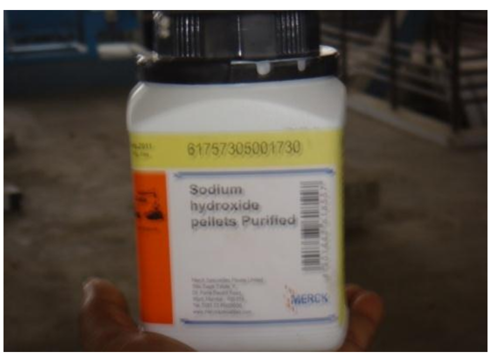
III.MATERIAL USED

Cementitious material used in this Experimental programme was low calcium Flyash (ASTM type F) [2]. The specific gravity Fly Ash was 2.3. The Specific gravity and Fineness modules for manufactured sand were 3.1 and 2.15 respectively. The chemical composition for cementitious material is shown in table 3. Locally available crushed granite stone aggregate of size 20 mm passing and retained in 10 mm, was used and the specific gravity and fineness modulus for the same are 2.6 and 6.4 as per IS: 2386- 1968 Part III. Both the Aggregates compiled with the requirements of IS: 383-1970.Specific gravity of NaoH and Na2Sio3
solutions were 1.47 and 1.6 respectively.

M-SAND

M-sand is crushed aggregates produced from hard granite stone which is cubically shaped with grounded edges, washed and graded with consistency to be used as a substitute of river sand. M-Sand is superior quality manufactured sand with international standards.

SODIUM HYDROXIDE:



Generally the sodium hydroxides are available in solid state by means of pellets and flakes. The cost of the sodium hydroxide is mainly varied according to the purity of the substance. Since our geopolymer concrete is homogenous material and its main process to activate the sodium silicate, so it is recommended to use the lowest cost i.e. up to 94% to 96% purity. In this investigation the sodium hydroxide pellets were used. Sodium hydroxide pellets are taken and dissolved in the water at the rate of 16 molar concentrations. It is strongly recommended that the sodium hydroxide solution must be prepared 24 hours prior to use and also if it exceeds 36 hours it terminate to semi solid liquid state. So the prepared solution should be used within this time.

SODIUM SILICATE:

Sodium silicate is also known as water glass or liquid glass, available in liquid (gel) form. In present investigation sodium silicate 2.0 (ratio between Na2O to SiO2) is used. 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.

ALKALINE LIQUID:

Generally alkaline liquids are prepared by mixing of the sodium hydroxide solution and sodium silicate at the room temperature. When the solution mixed together the both solution start to react i.e. (polymerisation takes place) it liberate large amount of heat so it is recommended to leave it for about 24 hours thus the alkaline liquid is get ready as binding agent.

MOLARITY CALCULATION:

The solids must be dissolved in water to make a solution with the required concentration. The concentration of Sodium hydroxide solution can vary in different Molar. The mass of NaOH solids in a solution varies depending on the concentration of the solution. For instance, NaOH solution with a concentration of 16 Molar consists of 16 x 40 = 640 grams of NaOH solids per litre of the water, were 40 is the molecular weight of NaOH. Note that the mass of water is the major component in both the alkaline solutions. The mass of NaOH solids was measured as 444 grams per kg of NaOH solution with a Concentration of 16 Molar. Similarly, the mass of NaOH solids per kg of the solution for other concentrations was measured as 10 Molar: 314 grams, 12 Molar: 361 grams, and 14 Molar: 404 grams.

IV.EXPERIMENTAL INVESTIGATION:

MIX PROPORTIONS:

The mix design in the case of geopolymer concrete is based on convenient concrete with some modification. In the case of conventional concrete the materials proportion can be found out of required strength using the code, but in the case of geopolymer concrete there is no design method or codalprovisions.The mass of combined aggregate may be taken between 75% of mass of the geopolymer concrete. The Alkaline liquid to fly ash ratio by mass values in the range of 0.45Ratio of Sodium hydroxide& Sodium Silicate by mass may be taken 2.5

Kg/M³						
Mix Grade	Sodium Silicate	Sodium Hydroxide Solution	Extra Water	Fly ash	Fine Aggregate (M Sand)	Coarse Aggregate
	kg/m³	kg/m³	ml	kg/m³	kg/m³	kg/m³
M20-M	168.00	67.20	12.60	420	710	1061
M25-M	217.85	87.14	15	500	621.85	928.50
M30-M	239.64	95.85	16.50	550	535.75	800.00
M35-M	274.28	109.71	12.80	640	434.81	773.08

(Table:1)

CURING

FIGURE 1: SPECIMENS UNDER AMBIENT CURING

FIGURE 2: HOT CURING OF SPECIMENS

After casting the specimens, they were kept in rest period for five days and then they were demoulded. The term 'Rest Period' was coined to indicate the time taken from the completion of casting of test specimens to the start of curing at an elevated temperature. This may be important in certain practical applications. For instance, when fly ash-based geopolymer concrete is used in precast concrete industry, there must be sufficient time available between casting of products and sending them to the curing chamber. At the end of the Rest Period, six test specimens were kept under ambient conditions for curing at room temperature as shown in Figure 1. Remaining six specimens were kept at 60°C in hot oven for 24 hrs and is shown inFig.2

V.RESULTS AND DISCUSSIONS:

DENSITY OF GEOPOLYMER CONCRETE:

Table 2 presents the density values in kg/m³ at 7 days and 28 days of curing. Density values ranges from 2251 to 2400 kg/m³. The density of geopolymer concrete was found approximately equivalent to that of conventional concrete. As the age of concrete increases, there is a slight increase in density as shown in Figure 3.Variation of density is not much significant with respect to age of concrete and type of curing.

Table 2: Density of Geopolymer Concrete

Type of Curing	Density of Sample (Kg/m³)			
	7 Days	Avg.	28 Days	Avg.
Ambient curing	2281.48 2311.11 2251.85	2281.48	2340.74 2370.37 2311.11	2340.74
Hot Oven Curing	2370.37 2311.11 2340.74	2340.74	2400.00 2311.11 2340.74	2350.62

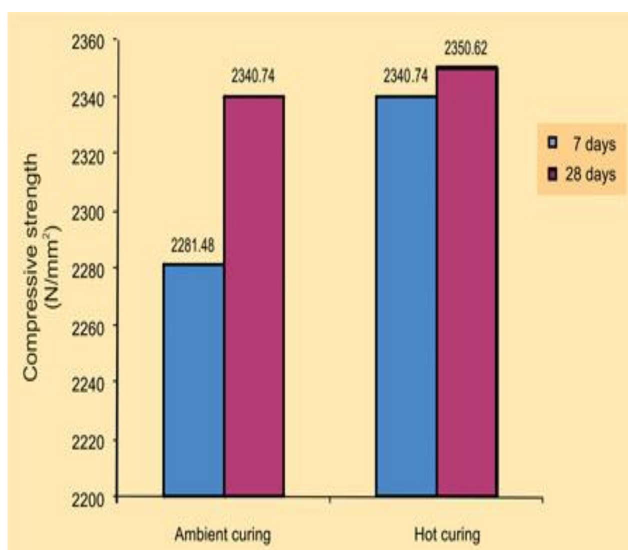


Figure 3: Variation of density with age of concrete

COMPRESSIVE STRENGTH:

The compressive strength at 7 and 28 days of curing is presented in Table 3. Figure 4 shows a graphical representation of variation of compressive strength for 7 days and 28 days of curing. Compressive strength of hot cured specimens are more than that of ambient cured specimens both in 7 and 28 days. 28 days compressive strength of hot cured specimens was 2 times more than that of ambient cured specimens. 7 days compressive strength of hot cured specimens was 7 times more than that of ambient cured specimens. In ambient Curing, the 28 days compressive strength is about 4.5 times 7 days compressive strength. In hot curing, the 28 days compressive strength is about 1.2 times 7 days compressive strength.

Table 3: Compressive Strength of Geopolymer Concrete

Type of Curing	Ultimate Load (N)		Compressive Strength (N/mm²)			
	7 Days	28 Days	7 Days	Avg.	28 Days	Avg.
Ambient Curing	9000	40400	3.92	3.89	17.614	17.693
	9200	39800	4.01		17.353	
	8550	41200	3.73		17.963	
Hot Oven Curing	67600	81000	29.47	28.31	35.316	33.223
	53000	69000	23.11		30.084	
	74200	78600	32.35		34.269	

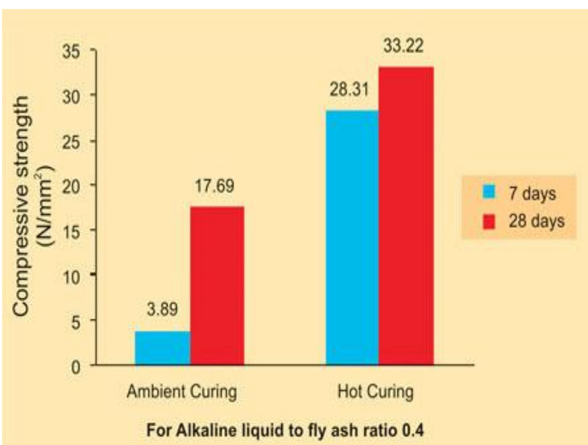


Figure 4: Variation of compressive strength with age of concrete

VI.CONCLUSION

With the generic information available on geopolymers, a rigorous trial-and-error method was adopted to develop a process of manufacturing fly ash-based geopolymer concrete following the technology currently used to manufacture Ordinary Portland Cement concrete. After some failures in the beginning, the trail-and-error method yielded successful results with regard to manufacture of low-calcium (ASTM Class F) fly ash based geopolymer concrete. Geopolymer concrete is an excellent alternative solution to the CO2 producing port land cement concrete. Low-calcium fly ash-based geopolymer concrete has excellent compressive strength within a day and is suitable for structural applications. The price of fly ash-based geopolymer concrete is estimated to be about 10 to30 percent cheaper than that of Portland cement concrete. In this study it is observed that Compressive strength results obtained for M-sand was nearly equal when compared to control concrete. Tensile strength of the river sand is high when compared to the M- Sand. Due to presence of sodium silicate as a sticky gel form in nature And also flyash is finer element it recommended to have 20% higher than of Mix design values. Due to presence of sodium silicate as a gel form it take delay in setting at ambient temperature. In order to overcome it recommended that heat curing is necessary, which also increase the compressive Strength. The temperature to be maintained is 60ºC for about 24hours to 48hours.

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