GEOPOLYMER CONCRETE AN ECO-FRIENDLY CONSTRUCTION MATERIAL

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Abstract

The objective of this research work was to produce a carbon dioxide emission free cementious material. The geopolymer concrete is such a vital and promising one. In this present study the main limitations of fly ash based geopolymer concrete are slow setting of concrete at ambient temperature and the necessity of heat curing are eliminated by addition of Ground Granulated Blast Furnace Slag (GGBS) powder which shows considerable gain in strength. The Alkaline liquids used in this study for the polymerization process are the solutions of sodium hydroxide (NaoH) and sodium silicate (Na_2Sio_3). A 12 Molarity solution was taken to prepare the mix. The cube compressive strength was calculated for 12M solution for different mix Id i.e. $F_{90}G_{10}$, $F_{80}G_{20}$, $F_{70}G_{30}$, and $F_{60}G_{40}$ (Where F and G are, respectively, Fly Ash and GGBS and the numerical value indicates the percentage of replacement of cement by fly ash and GGBS).The cube specimens are taken of size 100 mm x 100 mm x 100 mm. Ambient curing of concrete at room temperature was adopted. In total 36 cubes were cast for different mix Id and the cube specimens are tested for their compressive strength at age of 1 day, 7 days and 28 days respectively. The result shows that geopolymer concrete cubes gains strength within 24 hours without water curing at ambient temperature. Also the strength of geopolymer concrete was increased with increase in percentage of GGBS in a mix. It was observed that the mix Id $F_{60}G_{40}$ gave maximum compressive strength of 80.50 N/mm^2. Also the splitting tensile strength and flexural strength for the mix $F_{60}G_{40}$ was done. Thus the geopolymer concrete is considered to be an environmentally pollution free construction material.

Keywords: *Geopolymer concrete, Fly ash, GGBS, Ambient curing*

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1. INTRODUCTION

The major problem that the world is facing today is the environmental pollution. In the construction industry mainly the production of ordinary Portland cement (OPC) will cause the emission of pollutants which results in environmental pollution. The emission of carbon dioxide during the production of ordinary Portland cement is tremendous because the production of one ton of Portland cement emits approximately one ton of CO_2 into the atmosphere [1]

The geopolymer technology shows considerable promise for application in concrete industry as a alternative binder to the Portland cement [2] In terms of global warming, the geopolymer concrete significantly reduce the CO_2 emission to the atmosphere caused by the cement industries [3] Davidovits (1988; 1994) proposed that an alkaline liquid could be used to react with the Silicon (Si) and Aluminum (Al) in a source material of geological origin or in by product materials such as fly ash and GGBS to produce binders. Because the chemical reaction that takes place in this case is a polymerization process, he coined the term geopolymer to represent these binders [4]

The geopolymer concrete has two limitations such as the delay in setting time and the necessity of heat curing to gain strength. These two limitations of geopolymer concrete mix was eliminated by replacing 10% of fly ash by OPC on mass basis with alkaline liquids resulted in Geopolymer Concrete Composite (GPCC mix) [5]

The present paper work is aims to study the compressive strength characteristics of geopolymer concrete using fly ash and GGBS which are producing at ambient temperature conditions without water curing. Also aims to eliminate the necessity of heat curing of concrete.

2. MATERIALS USED

Fly ash was taken from thermal power plant, Mettur, Salem, Tamil Nadu. GGBS slag was obtained from Mangalore suppliers, Karnataka. The properties of fly ash and GGBS are given in table 1. and 2. Locally available river sand having fineness modulus of 2.73 and a specific gravity 2.67 was used. Crushed granite coarsed aggregate of 20 mm maximum size having a fineness modulus of 6.94 and specific gravity of 2.81 was used. Distilled water was used in a concrete mix. Super plasticizer CONPLAST SP 430 was used for workability.

Table -1: Properties of fly ash

Parameters	Experimental value (%)	Requirements as per IS 3812-2003
Silica	64.11	SiO_2 >35%

Aluminium oxide	18.58	Total - >70%
Iron oxide	4.32	
Calcium oxide	1.21	-
Sodium oxide	0.21	<1.5%
Potassium oxide	1.02	
Magnesium oxide	0.24	<5%
Loss of ignition	0.64	<12%

Table -2: Properties of GGBS

Parameters	**Experimental value (%)**	**Requirementas per IS 12089 – 1987**
Silica	32.78	
Calcium oxide	34.8	(CaO + MgO + Al_2O_3) / SiO_2 1.94>1
Magnesium oxide	8.0	
Aluminium oxide	20.8	
Iron oxide	1.10	
Loss of ignition	0.62	

2.1 Alkaline Solutions

The solution of sodium hydroxide and sodium silicate are used as alkaline solutions in the present study. Commercial grade sodium hydroxide in pellets form and sodium silicate solution are used.

2.2 Preparation of Alkaline Solutions

In this research work the compressive strength of Geopolymer concrete is examined for the mixes of 12 Molarity of sodium hydroxide. The molecular weight of sodium hydroxide is 40. To prepare 12 Molarity of solution 480 g of sodium hydroxide flakes are weighed and they can be dissolved in distilled water to form 1 litre solution. Volumetric flask of 1 liter capacity is taken, sodium hydroxide flakes are added slowly to distilled water to prepare 1liter solution.

2.3 Mix Proportions

As there are no code provisions for the mix design of geopolymer concrete, the density of geo-polymer concrete is assumed as 2400 $Kg/m^{3.}$ The rest of the calculations are done by considering the density of concrete. The total volume occupied by fine and coarse aggregate is adopted as 77%. The alkaline liquid to fly ash and GGBS ratio is kept as 0.4. The ratio of sodium hydroxide to sodium silicate is kept as 2.5.The conventional method used in the making of normal concrete is adopted to prepare geopolymer concrete.

2.4 Casting and Curing

Firstly, the fine aggregate, coarse aggregate, fly ash and GGBS are mixed in dry condition for 3-4minutes and then the alkaline solution which is a combination of Sodium hydroxide solution and Sodium silicate solution with super-plasticizer is added to the drymix. Water is taken as 10 % of the cementious material (fly ash and GGBS). The super plasticizer is taken as 3% of the cementious material. The mixing is done for about 6- 8 mins for proper bonding of all the materials. After the mixing is done, cubes are casted by giving proper compaction in three layers.

Table-3: Material requirements for 1 m^3

Fly ash+ GGBS	**Sodium hydroxide**	**Sodium silicate**	**Fine Agg.**	**Coarse Agg.**
394.30 kg / m^3	45.14 kg / m^3	112.86 kg / m^3	555.0 kg / m^3	1293.00 kg / m^3
Distilled water: 10% of the total cementious material				
Super plasticizer: 3 % of the total cementious material				

3. TEST RESULTS

The cubes are tested in compressive testing machine (100 Tonne capacity) to determine their compressive strength at the age of 1 day, 7 days and 28 days of curing. The results have shown that the mix combination of F_{60} G_{40} gave maximum strength compare to the rest.The splitting tensile strength and flexural strength for the mix combination of F_{60} G_{40} was done. The results are shown in table 4 and table 5 respectively. It was found that as the age of the concrete increases the compressive strength of geopolymer concrete is enhanced at ambient temperature without water curing. The mixing, casting, testing and failure modes of geopolymer concrete specimen are shown in figure 1,2,3,4,5,6,7and 8 respectively.

Table-4: Avg.Cube compressive strength results

Mix Id	**Compressive strength (N/mm^2)**		
	1 day	**7 days**	**28 days**
F_{90} G_{10}	4.40	24.00	30.50
F_{80} G_{20}	9.12	32.32	54.00
F_{70} G_{30}	12.94	42.06	67.00
F_{60} G_{40}	15.03	57.05	80.50

Table-5: Splitting tensile Strength and Flexural Strength results

Splitting Tensile Strength 2P/πdl (N/mm^2)	**Flexural Strength Pl/bd^2 (N/mm^2)**
8.25	17.25
8.30	18.35
8.50	18.25
Average. 8.35	Average 17.95


Fig-1: Casting of Geopolymer concrete


Fig-2: Placing of Geopolymer concrete


Fig-3: Testing of Geopolymer concrete Cube


Fig-4: Failure mode of Geopolymer concrete cube


Fig-5: Testing of Geopolymer concrete Prism

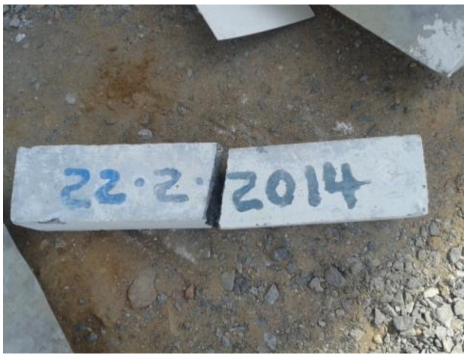

Fig-6: Failure mode of Geopolymer concrete cylinder


Fig-7: Testing of Geopolymer concrete Cylinder

Fig-8: Failure mode of Geopolymer concrete Prism

4. CONCLUSIONS

Based on the results obtained in the experimental investigation, the following conclusions are drawn.

- The geopolymer concrete gained strength within 24 hours at ambient temperature without water curing.
- The necessity of heat curing of concrete was eliminated by incorporating GGBS and fly ash in a concrete mix.
- The strength of geopolymer concrete was increased with increase in percentage of GGBS in a mix.
- It was observed that the mix Id $F_{60}G_{40}$ gave maximum compressive strength of 80.50N/mm^2.

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