Study of Mechanical Properties of Fly Ash Based Geopolymer Concrete

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Abstract – *Cement manufacture is the second most carbon dioxide emitting source while the first being by motor vehicles. The increased demand of cement leads to the increased production of cement and emission of greenhouse gases and need for alternative methods for eco-friendly binder producton.*

In this project, the mechanical properties of fly ash based geopolymer concrete is tested and compared with the Indian Standard values provided in the Indian Standard Codes and evaluated for the adequacy to be used as a replacement binder for cement

Key Words: Geopolymer concrete, Cement, Comparison, Fly ash, Heat curing

1.INTRODUCTION

Cement manufacturing industry is the India's second highest payer of Central Excise and major contributor of to GDP. As the recent decade faced a lot of constructions happening throughout India, the demand for cement has increased. Also the development in the electrical and electronic technology in the past decade and increase of population resulted in need for increased electricity production. Since India most relies on thermal power plants for the production of electricity, the production of thermal power plant waste (Fly ash) increased and the problem of disposal of this waste material is also arisen.

Geopolymer concrete is a concrete made from the polymeric reaction between a binder material which is rich in alumina-silicates and alkaline liquids. The reaction is a non-heat emitting one in which the alumina-silicates combines with the alkaline liquids and forms a three dimensional polymeric chain. The reaction a product so efficient that the strength carrying capacity and durability of the concrete is more than the Ordinary Portland Cement concrete.

There are two major limitations regarding using geopolymer concrete as a construction material which are delayed setting time and need for heat curing. These limitations can be overcome by adding calculated proportion of cement into the geopolymer mix making a Geopolymer Composite concrete

The present paperwork aims to study the mechanical properties exhibited by geopolymer concrete and to compare with the standard values stipulated in Indian Standard Codes and evaluate the adequacy of using geopolymer concrete as a replacement for OPC concrete.

2. MATERIALS USED

The materials used for the preparation of geopolymer concrete is fly ash, fine aggregate, coarse aggregate, alkaline liquids and distilled water. Fly ash was obtained from thermal power plants via local Ready Mix Concrete plants. Fine aggregate used was M-sand obtained from local suppliers having fineness modulus of 4.66 and specific gravity of 2.65. Coarse aggregate used was crushed granite obtained from local suppliers and having specific gravity of 2.68 and fineness modulus of 2.95. Distilled water was used to mix geopolymer concrete. Properties of fly ash given in table-1.

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%

2.1 Alkaline Solution

Geopolymer is a product of polymerization reaction happening between fly ash and alkaline solutions having silicates and hydroxide. Silicate and hydroxide of both sodium or potassium can be used. For convenience here, used sodium hydroxide solution of molarity 13M and sodium silicate solution having SiO_2 concentration of about 34.35% is used

2.2 Preparation of Alkaline Solution

Commercial grade sodium hydroxide pellets were purchased from local suppliers and calculated amount of pellets for 13M solution is added to distilled water and mixed thoroughly one

day before casting. Sodium silicate was purchased from local suppliers in liquid form in required concentration.

2.3 Mix Proportioning

Since there are no dedicated code provisions for the mix design of geopolymer concrete, approximate mix design was done based on journals obtained from international research sites. The mix proportion used is given in table-2 below

Table – 2: Mix proportion

Ingredient	Proportion
Fly ash	1
Alkaline solution	0.35
Fine aggregate	2.09
Coarse aggregate	3.89
Water	0.19
Additional water	0.09

2.4 Casting and Curing

In this experiment, mixing is done by mixer machines. Firstly, the dry mixtures which contains fly ash, fine and coarse aggregates are mixed for 4 to 5 minutes and then the alkaline solutions and water is added and mixed for about 10 minutes for proper homogenous mixture. Moulds are prepared and fresh concrete is poured and compacted in three layers. Finished moulds are kept in air for 24 hours to harden and then kept in an oven at 60^0 for 24 hours for curing. After heat curing, the specimen is kept in the oven itself for next 24 hours to cool down and then kept in atmosphere for next 7 days before testing.

3. TEST RESULTS

Geopolymer concrete cubes were cast and tested in Compressive testing machine for compressive strength. Geopolymer concrete cylinders were tested in compressive testing machine for Compressive strength, Splitting tensile strength and Modulus of elasticity test. All the specimens were casted for M20 mix concrete and tested after 7-day curing period. The results obtained from the afore mentioned test is tabulated in the below given table-3. It was found that the test specimens exhibit increased properties at 7-day than that stipulated in IS codes at 28-day. The mixing, casting, testing geopolymer concrete specimen are show in figures

Table-3: Comparison of results

Properties	Geopolymer Concrete	Cement Concrete Values
Workability	23.67 mm	65 mm
Compressive Strength (Cube)	26.8 N/mm^2	20 N/mm^2
Compressive Strength (Cylinder)	26.16 N/mm^2	20 N/mm^2
Splitting Tensile Strength	3.68 N/mm^2	3.13 N/mm^2
Modulus of Elasticity	2.58*10^4 N/mm^2	2.23*10^4 N/mm^2

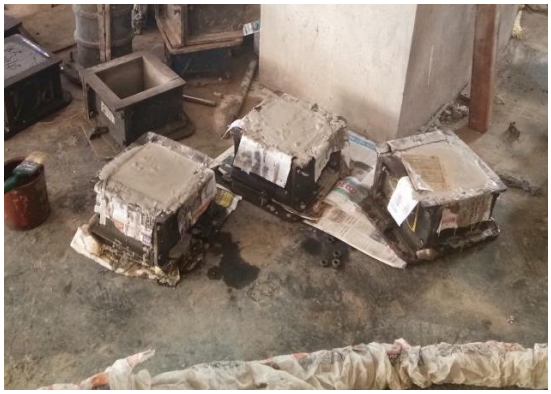

Fig-1: Casting of Geopolymer concrete cubes

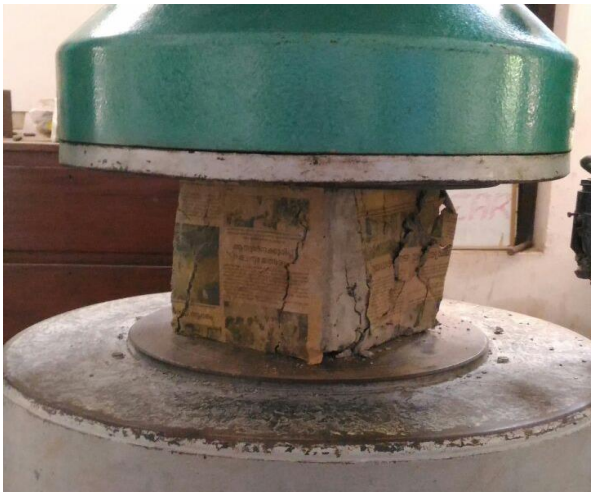

Fig-2: Testing of Geopolymer concrete cubes

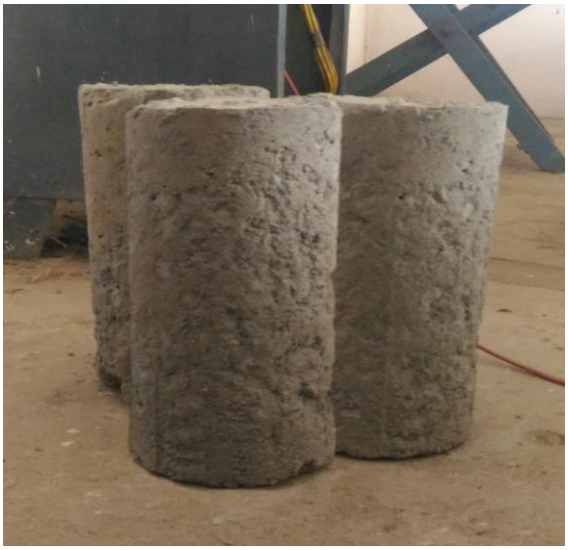

Fig-3: Geopolymer concrete cylinder specimens

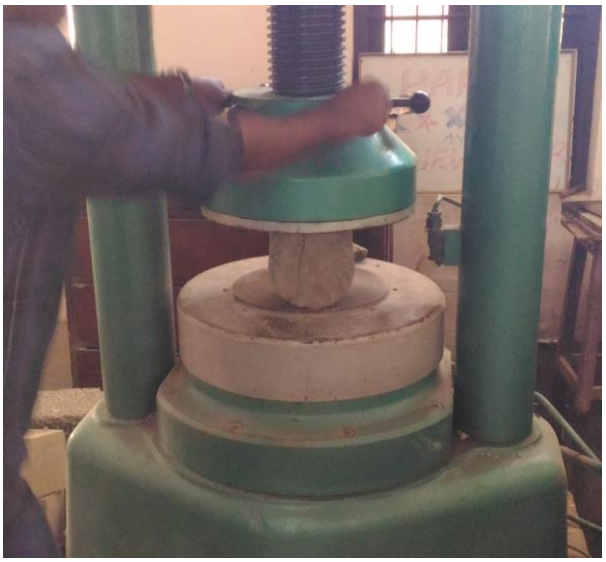

Fig-4: Splitting tensile strength test

4. CONCLUSIONS

Based on the results which are obtained from this experimental investigation, the following conclusions are drawn

- Geopolymer concrete exhibited its characteristic parameters higher than cement concrete.
- The concrete exhibited higher rate strength gain than conventional cement concrete
- The decreased workability can be adjusted by adding additional calculated amount of water into the mix.
- The necessity of heat curing is the major drawback which can be rectified by adding conventional cement
- Geopolymer concrete is a viable replacement for cement concrete reducing both the amount of carbon dioxide emitted by cement manufacturing plans and the piling amount of thermal power plant waste

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