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AN EXPERIMENTAL INVESTIGATION ON STRENGTH PARAMETERS OF FLYASH BASED GEOPOLYMER CONCRETE WITH GGBS

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Abstract— *Concrete is the most abundant manmade material in the world. One of the main ingredients in a normal concrete mixture is Portland cement. However, the production of cement is responsible for* ***approximately 5% of the world's carbon dioxide*** *emissions. In order to create a more sustainable world, engineers and scientists must develop and put into use a green building material. Geopolymer concrete is also much more durable that ordinary concrete due to its resistance to corrosion. It is also much stronger than ordinary concrete. Geopolymer concrete is a revolutionary sustainable building material that will pave the way for green building. In this paper an attempt is made to study strength properties of geopolymer concrete using low calcium fly ash replacing with slag in 5 different percentages. Sodium silicate (103 kg/m3) and sodium hydroxide of 8 molarity (41kg/m3) solutions were used as alkaline solution in all 5 different mixes. The investigations are to be carried for the Compressive strength, Split tensile strength, Flexural strength test on the concrete specimens. Hopefully one day in the near future geopolymer concrete will replace ordinary Portland cement as the most abundant man-made material on earth.*

Keywords— Origin of term Geopolymer, fly ash, ggbs, alkaline liquid, design mix proportion, preparation of alkaline solutions, ambient curing, strength parameters, geopolmer concrete

1.INTRODUCTION

1.1 General

Concrete is one of the most widely used construction material. Portland cement production is a major contributor to carbon-di-oxide emissions. The global warming is caused by the emission of greenhouse gases, such as carbon-di-oxide, to the atmosphere by human activities.Among the greenhouse gases, carbon-di-oxide contributes about 65% of global warming. Many efforts are being made in order to reduce the use of Portland cement in concrete. These efforts include the utilization of supplementary cementing materials such as fly ash, silica fume, granulated blast furnace slag, rice-husk ash and metakaolin, and finding alternative binders to Portland cement. In terms of reducing the global warming, the geo-polymer technology could reduce the carbon-di-oxide emission to the atmosphere caused by Cement about 80%. In this project ,the effort was made to study the strength parameters of geo-polymer concrete.

1.2 Origin Of Term 'Geopolymer'

The term "Geopolymer" was first introduced to the world by Davidovits of France resulting in a new field of research and technology. Geopolymer also known as 'inorganic polymer', has emerged as a 'green' binder with wide potentials for manufacturing sustainable materials for environmental, refractory and construction applications.

Geopolymer concrete (gpc) :

Ingredients required for creation of geopolymer binders are:

- Geopolymer source materials such as fly ash, ggbs, metakaolin, rice husk ash, etc
- Aggregate system consisting of fine and coarse aggregate
- Alkaline Activator Solution

1.3 Properties Of Geo-Polymer Concrete

Geopolymer are inorganic binders, which are identified by the following basic properties,

Compressive strength depends on curing time and curing temperature. As the curing time and temperature increases, the compressive strength increases.

Resistance to corrosion, since no limestone is used as a material, Geopolymer cement has excellent properties within both acid and salt environments. It is especially suitable for tough environmental conditions.

Geopolymer specimens are possessing better **durability and thermal stability** characteristics.

1.4 Salient Features Of Geo-Polymer Concrete

- Geopolymer concrete reduced CO_2 emissions of geopolymer cements make them a good alternative to ordinary Portland cement.

- The mechanical behavior of Geo-polymer concrete is higher than nominal concrete mix.
- Durability property of Geo-polymer concrete is higher than the nominal concrete mix.
- Geo-polymer Concrete is Eco-Friendly.
- Water absorption property is lesser than the nominal concrete.

1.5. Need For The Study

- To find an alternative for the ordinary Portland cement.
- To reduce CO_2 emission and produce eco-friendly concrete.
- To develop a cost efficient product.
- To provide high strength concrete than ordinary Portland concrete.

1.6. Objectives:

- To make a concrete without using cement (i.e. Geopolymer concrete).
- To study the different strength properties of geo-polymer concrete with percentage replacement of GGBS.
- To evaluate the optimum mix proportion of Geo-polymer concrete with fly ash replaced in various percentage by GGBS.
- To compare the cost variation of geo-polymer concrete with normal concrete.

2. REVIEW OF LITERATURE

2.1 General

In this chapter study of geo-polymer concrete and the application of are discussed using following research articles are presented.

2.2 Geo-Polymers

In 1978, Davidovits et al proposed that an alkaline liquid could be used to react with the silicon (Si) and the aluminium (Al) in a source material of geological origin or in by- product materials such as fly ash and GGBS to produce binders.

2.3 Literatures On Geopolymer:

Ganapati Naidu. P, A.S.S.N.Prasad reported in this paper that an attempt is made to study strength properties of geopolymer concrete using low calcium fly ash replacing with slag in 5 different percentages. Higher concentrations of G.G.B.S (Slag) result in higher compressive strength of geopolymer concrete.90% of compressive strength was achieved in 14 days.

Supraja .V, M. KantaRao presented a study of geopolymer concrete, the portland cement is fully replaced with GGBS and alkaline liquids (sodium hydroxide and sodium silicate) are used for the binding of materials. Different molarities of sodium hydroxide solutions i.e. 3M, 5M, 7M and 9M are considered. The strength of geopolymer increases with increase of molarity of sodium hydroxide.

SundarKumar, S.Vasugi summarized the development of low concentration alkali activator geopolymer concrete mixes and the results of tests conducted to determine the mechanical properties such has compressive

Parthiban.K, K.Saravanarajamohan presented the influence of the various proportions of GGBS (0-100%) on Fly Ash based GPC; the effect of the amount of Alkaline Activated Solution (AAS) in the mixture of GPC on their compressive strength is studied under ambient temperature conditions.

Gokulram.H, R.Anuradha presented the results of an experimental investigation and compare on the mechanical properties of different binder composition (100% replacement of cement by ASTM class F Fly ash (FA) and ground granulated blast furnace slag (GGBS)) of Geopolymer Concrete Composites (GPCC). The study analyses of polypropylene fibre on the mechanical properties of hardened GPCC.

Palaniappan. A,S.Vasantha discussed the results of an experimental investigation and compare on the mechanical properties of different binder composition (17 TO 20 % replacement of cement by ground granulated blast furnace slag (GGBS)) of Geopolymer Concrete Composites (GPCC). The test results show that GGBS concrete shown increase in compressive strength of 13.82% as compared with conventional concrete.

Prof.Pratap,Krishnan concluded the experimental investigation FLY ASH and BLAST FURNACE SLAG are used in equal proportion (50% each).The geopolymer concrete gains about 60-70% of the total compressive strength within 7days.

3. MATERIALS

3.1 General

In this chapter varies materials and method of conducting the test was discussed in detail and detailed methodology of the work was presented.

3.2 Materials Used

- Fly ash
- Ground granulated blast furnace slag (GGBS)
- Chemicals
  - -Sodium hydroxide
  - -Sodium silicate
- Superplasticizer
- Aggregates
  - -Fine aggregate
  - - Coarse aggregate

3.2.1 Fly Ash

Fly ash is one of the most abundant materials on the Earth. It is also a crucial ingredient in the creation of geopolymer concrete due to its role in the geopolymerization process. A pozzolan is a material that exhibits cementitious properties when combined with calcium hydroxide. Fly ash is the main by product created from the combustion of coal in coal-fired power plants. There are two “classes” of fly ash, Class F and Class C. Each class of fly ash has its own unique properties.The chemical composition of fly ash are shown in the table 1

Table 1.Chemical Composition Of Fly Ash

OXIDES	PERCENTAGE
Sio_2	52.0
Al_2O_3	33.9
Fe_2O_3	4.0
CaO	1.2
K_2O	0.83
Na_2O	0.27
MgO	0.81
SO_3	0.28
LOI	6.23
SiO_2/Al_2O_3	1.5

3.2.2 Ground Granulated Blast Furnace Slag

Ground granulated blast furnace slag comprises mainly of calcium oxide, silicon di-oxide, aluminium oxide, magnesium oxide. It has the same main chemical constituents as ordinary portland cement but in different proportions.And the addition of G.G.B.S in Geo-Polymer Concrete increases the strength of the concrete and also curing of Geo-Polymer concrete at room temperature is possible.

Chemical Composition

The chemical composition of the ordinary Portland cement and the chemical composition of GGBS is compared and discussed below in Table2.

Table 2 .Chemical composition of ggbs

Chemical constitution	Cement (%)	GGBS (%)
Calcium oxide (CaO)	65	40
Silicon di-oxide (SiO_2)	20	35
Aluminum oxide(Al_2o_3)	5	10
Magnesium oxide(MgO)	2	8

3.2.3Alkaline Liquid

A combination of alkaline silicate solution and alkaline hydroxide solution was chosen as the alkaline liquid. Sodium-based solutions were chosen because they were cheaper than Potassium-based solutions.

3.2.4 Chemicals

In this project chemicals are the very important constituents. Sodium Silicate and Sodium Hydroxide liquid are obtained commercially from local suppliers in Salem.

3.2.4.1 Sodium Hydroxide

The sodium hydroxide solids were of a laboratory grade in pellets form with 99% purity, obtained from local suppliers. The sodium hydroxide (NaOH) solution was prepared by dissolving the pellets (a small, rounded, compressed mass of a substance of sodium hydroxide)in water. The mass of sodium hydroxide solids in a solution varied depending on the concentration of the solution expressed in terms of molar, M. For instance, sodium hydroxide solution with a concentration of 8M consisted of 8x40 = 320 grams of sodium hydroxide solids (in pellet form) per liter of the solution, where 40 is the molecular weight of sodium hydroxide.

3.2.4.2 Sodium Silicate

Sodium silicate solution (water glass) obtained from local suppliers was used. The chemical composition of the sodium silicate solution was Na_2O=8%, SiO_2=28%, and water 64% by mass. The mixture of sodium silicate solution and sodium hydroxide solution forms the alkaline liquid.

3.2.5. Mechanical action Of Superplasticizer

Superplasticizers are water reducers which are capable of reducing water contents by about 30 percent. However it is to be noted that full efficiency of superplasticizer can be got only when it is added to a mix that has an initial slump of 20 to 30mm. Addition of superplasticizer to stiff concrete mix reduces its water reducing efficiency. Depending on the solid content of the mixture, a dosage of 1 to 3 percent by weight of cement is advisable. In this present investigation, a superplasticizer namely CONPLAST SP 430 has been used for obtaining workable concrete at low w/c ratio. CONPLAST SP 430 is based upon NSF condensates used for this study.The mechanism consists of very large molecules (colloidal size) which dissolve in water to produce ions with high negative charge (anions).

3.2.6 Aggregates

The aggregates are the main components of the concrete which greatly varies the strength, density and other properties of the concrete. Different types of aggregates used are discussed below.

3.2.6.1 Fine Aggregate

The fine aggregate used in the project was locally supplied and conformed to grading zone II as per IS: 383:1970. It was first sieved through 4.75mm sieve to remove any particles greater than 4.75mm. Properties of the fine aggregate are tabulated below in Table 3.

Table 3. Properties of fine aggregates

S.No	Characteristics	Values
1.	Type	Uncrushed (natural)
2.	Specific gravity	2.54
3.	Bulk Density	1668 kg/m^3
4.	Fineness modulus	2.76
5.	Grading zone	Zone II

3.2.6.2 Coarse Aggregate

Locally available coarse aggregate having the maximum size of (10 - 20mm) were used in this project. Properties of the coarse aggregate are tabulated in Table 4.

Table 4 . Properties of Coarse aggregates

S.No	Characteristics	Values
1.	Type	Crushed
2.	Specific gravity	2.6
3.	Bulk Density	1765 kg/m^3
4.	Fineness modulus	6.45
5.	Maximum size	20mm

4.METHODOLOGY

The methodology explains about the step by step procedure that is going to be done in the project. The methodology is explained in the following figure.

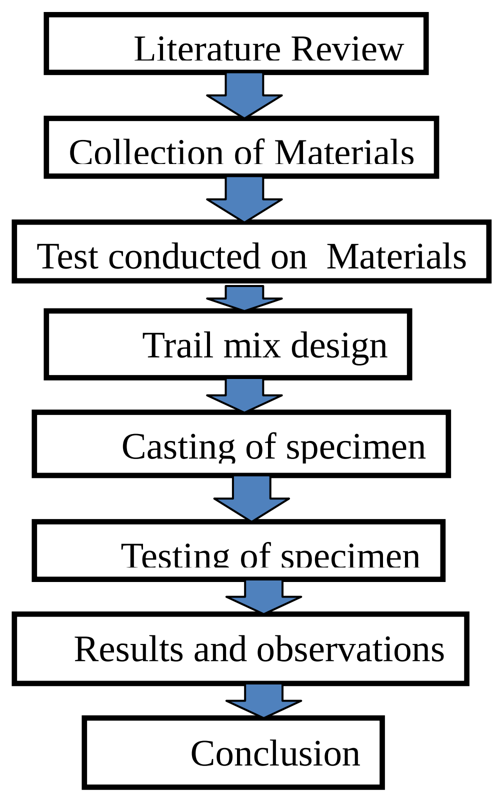

Fig -1: Methodology Of Geopolymer Concrete

5.MIX PROPORTION AND EXPERIMENTAL INVESTIGATION

5.1 Introduction

In this chapter mix design of Geo-polymer concrete and the experimental investigation carried out on the test specimen to study the strength related properties of geo-polymer concrete was discussed in detail.The experimental test for strength properties of concrete are compressive strength, split tensile strength, Flexural strength test of concrete. Based on the test procedure given in IS 516-1959 code tests were conducted on specimens.

5.2 Mix Proportion For Geo-Polymer Concrete

Most of the reported works on geo-polymer material to date were related to the properties of geo-polymer paste or mortar, measured by using small size specimens. In addition, the complete details of the mixture compositions of the geo-polymer paste were not reported.Palomo et al (1999) studied the geo-polymerization of low-calcium ASTM Class F fly ash (molar Si/Al=1.81) using four different solutions with the solution-to-fly ash ratio by mass of 0.25 to 0.40. The molar SiO_2/K_2O or SiO_2/Na_2O of the solutions was in the range of 0.63 to 1.23.

5.3 Preparation Of Alkaline Activator Solution

The mixture of sodium silicate solution and sodium hydroxide solution forms the alkaline liquid.A combination of alkaline silicate solution and alkaline hydroxide solution was chosen as the alkaline liquid. sodium-based solutions were chosen because they were cheaper than potassium-based solutions. The Alkali activator solution has to be prepared 24 hours advance before use. The Sodium hydroxide is available in small flakes and Sodium Silicate in crystal forms depending on the required solution of different morality has to be prepared.

5.4 Design Of Geo-Polymer Concrete

Some of the trials carried out indicated that the workability and strength characteristics of such mixes were not satisfactory. Such a thing is possible because GPC involves more constituents in its binder (GGBS,flyash, Sodium silicate, Sodium hydroxide and water), whose interactions and final structure and chemical composition are strongly dependent on the source of the material and their production process. Therefore the formulation of the GPC mixture was done by trial and error basis. Numerous trial mixes were cast and tested for compressive strength at the end of 28 days. The ratio of AAS to binder solids and the composition of binder solids (GGBS & flyash) Table 5 shows the various mix proportions of Geo-polymer concrete.The primary objective or performing the trial and error procedure was to obtain a good cohesive mix with satisfactory workability.

Table 5. Proportion Of Adding Cementitious Materials For PreparationOf Geopolymer Concrete

MIX ID	BINDER (%)	
	FLYASH	GGBS
M1	100	-
M2	90	10
M3	80	20
M4	70	30
M5	60	40

5.5 Geo-Polymer Mix Design

A sample of mix design was shown that the aggregates occupy the largest volume,(about 75-80% by mass) in GPCs. The silicon and the aluminum in the fly ash are activated by a combination of sodium hydroxide and sodium silicate.

Mix Proportions Value

CONSITUENTS	DENSITY (KG/M^3)
Coarse aggregate	1294
Fine aggregate	554
Fly ash	408
Sodium silicate	103
Sodium hydroxide	41
Super plasticizer	6.12

6.RESULTS & DISCUSSIONS

The various strength test that are to be done listed as below.

- Compressive strength
- Split tensile strength
- Flexural strength

Test Specimens

The test specimens for compressive strength test were made of cubes having a size of 150mm x 150mm x 150mm cast iron steel moulds were used. For each mix proportion three numbers of cubes were cast and tested at the age of 7 days and 28 days. The test specimens for split tensile strength test were made of cylinders having a size of

100mm diameter and 300mm high cast iron moulds were used. For each mix proportion three numbers of cylinders were cast and tested at 28 days. The test specimens for Flexural strength test were made of prism having a size of 500mm x 100mm x 100mm cast iron steel moulds were used. For each mix proportion three numbers of prisms were cast and tested at the age of 28 days. Table 6 shows the Details of test specimen

Table 6. Details of Test Specimen

S.NO	NAME OF TEST	SIZE OF SPECIMEN (mm)	No. OF SPECIMEN
1	Compressive Strength	150 x 150 x 150	36
2	Split tensile test	150 x 300	18
3	Flexural strength test	500 x 100 x 100	18
Total			72

6.1 Compressive Strength Test

The variation of compressive strength at the age of 7th and 28th days with optimum percentage of GGBS and flyash were given below in Table6.1 From the test results, it was observed that the maximum compressive strength was obtained for mix M2 with 30% GGBS and 70% flyash.

Table 6.1 Compressive Strength results

MIX ID	FLYASH (%)	GGBS (%)	Compressive strength N/mm²	
			7th Day	28th Day
M1	100	-	12.88	16.30
M2	90	10	18.67	21.11
M3	80	20	26.85	34.32
M4	70	30	37.33	42.48
M5	60	40	42.77	45.55
C M	-	-	25.06	36.84

6.2 Split Tensile Strength

The variation of split tensile strength at the age of 28th days with optimum percentage of GGBS and Flyash were given below.It was observed that the maximum split tensile strength was obtained for mix M2 with 30 % GGBS and 70% flyash.

Table 6.2. Split TensileStrength

MIX ID	Binder (%)		Split tensile strength (N/mm²)
	FLYASH	GGBS	28th Day
M1	100	-	1.92
M2	90	10	3.15
M3	80	20	3.91
M4	70	30	4.37
M5	60	40	5.94
C M	-	-	4.20

6.3 Flexural Strength

The results of flexural strength of concrete at the age of 28 days are presented in Table6.3. The variations in flexural strength at the age of 28 days with different percentage of GGBS and Flyash were plotted .From the test results, it was observed that when the percentage of GGBS increases, the flexural strength of concrete also increases. On the contrary, the strength decreases when the percentage of flyash increases.

Table 6.3 . Flexural strength values

MIX ID	Binder (%)		Flexural strength (N/mm²)
		GGBS	28th Day
M1	100	-	2.40
M2	90	10	3.58
M3	80	20	4.16
M4	70	30	4.68
M5	60	40	5.97
CM1	-	-	4.45

Suggestions For Future Work

- Studies can be made on its durability property and to improve its workability characteristics.

- Fiber reinforced Geopolymer composites may be considered a solution to improve flexural strength and fracture toughness.
- Since there is demand for natural sand, the fine aggregate shall be replaced partially by quarry dust.
- Different structural elements like Geopolymer Concrete Beam, Reinforced Geopolymer Concrete Beam, Reinforced Geopolymer Concrete Columns, Reinforced Beam Column joints shall be cast for the above mentioned concentrations of Sodium Hydroxide solution and curing conditions and tested.

7.CONCLUSION

Based on the experimental investigation the following conclusions are listed below:

The optimum replacement level of fly ash by GGBS in GPC will be carried out. Water absorption property is lesser than the nominal concrete. Achieving strength in a short time i.e. 70% of the compressive strength in first 4 hours of setting. Determines the different strength properties of geo-polymer concrete with percentage replacement of GGBS.

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- IS 10262:2009; Mix design of concrete.
- IS 456:2000; Plain and Reinforced concrete code of Practice.
- IS 383:1970; Specification for coarse and fine aggregates from natural sources for concrete
- IS 516: 1959; Methods of tests for Strength of concrete

BIOGRAPHIES

Vignesh. P is a PG scholar in the field of Department of Structural Engineering , Paavai Engineering College , India. . Holding a bachelors degree in paavai Engineering college, affiliated to Anna University Chennai, in the year 2013. My current research is undertaken on An Eperimental investigation on strength parameters of flyash based geopolymer concrete with ggbs. He has published many papers on various International conferences.

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