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AN EXPERIMENTAL STUDY ON FLEXURAL AND ELASTIC BEHAVIOUR OF FLYASH BASED GEOPOLYMER CONCRETE WITH GGBS

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ABSTRACT

Ordinary Portland cement concrete is one of the most widely used construction materials being used in infrastructure development throughout the world.cement is the main ingredient in the production of concrete. carbondioxide and green house gases are produced from industries during the production of cement. The production of cement emits for about equal amount ofcarbondioxide. It also produces global warming. In order to reduce the usage of cement, supplementary cementing materials like fly ash and GGBS and instead of water, Alkali solution have been introduced in the name of Geopolymer concrete. Geopolymer concrete is an inorganic polymer composite.In this paper an attempt is made to study flexural and elastic properties ofgeopolymer concrete replacing with GGBS in 5 different percentages as (100% , 0%), (90% ,10%), (80% , 20%), (70% , 30%), (60% , 40%). Sodium silicate (103kg/m^3) and sodium hydroxide of 8 molarity (41kg/m^3) solutions were used as alkaline activators in all different mixes. The investigations were carried for the Compressive test, Tensile test, Flexural strength test, Modulus of Elasticity, Poisson's ratio on the concrete specimens. The specimens were cured at ambient temperature and tested at 7th and 28th days.

Introduction

Concreteis one of the most widely used construction material.Production of Portland cement is currently exceeding 2.6 billion tons per year worldwide and growing at 5 percent annually. Portland cement production is a major contributor to carbon-di-oxide emissions as an estimated five to eight percent of all human-generated atmospheric carbon-di-oxide worldwide comes from the concrete industry. 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. The amount of the carbon dioxide released during the manufacture of Ordinary Portland Cement is approximately one ton for every ton of Ordinary Portland Cement produced.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%.

New supplementary cementitious materials and pozzolanas such as ground blast furnace slag, metakaolin, fly ash, and silica fume are being increasingly used as additives along with new varieties of superplasticizers. These have helped in producing very efficient high-performance concretes.

Geopolymer Concrete

In this work, fly ash-based geopolymer is used as the binder, instead of Portland or any other hydraulic cement paste, to produce concrete. The fly ash-based geopolymer paste binds the loose coarse aggregates, fine aggregates and other un-reacted materials together to form the geopolymer concrete, with or without the presence of admixtures. The manufacture of geopolymer concrete is carried out using the usual concrete technology methods. The

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silicon and the aluminium in the low calcium (ASTM Class F) fly ash are activated by a combination of sodium hydroxide and sodium silicate solutions to form the geopolymer paste that binds the aggregates and other un-reacted materials.

Origin

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. The term ''geopolymers'' was first introduced to the world by Davidovitsof France resulting in a new field of research and technology. 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.

Constituents of Geo-polymer Concrete

Ingredients required for creation of geopolymer binders are:

- Geopolymeric source materials (GSMs) such as fly ash, GGBS.
- Aggregate system consisting of fine and coarse aggregates
- Alkaline Activator Solution

Geopolymerization

Geopolymerization is the process of polymerizing silica alumina containing minerals using alkali solvents. The addition of sodium silicate is to enhances the process of Geopolymerisation.

Necessity of Geopolymer Concrete

Construction is one of the fast growing fields worldwide. As per the present world statistics, every year around 260, 00, 00,000 tons of cement is required. This quantity will be increased by 25% within a span of next 10 years. Since the limestone is the main source material for the OPC an acute shortage of limestone may come after 25 to 50 years. More over while producing one ton of cement, approximately one ton of Co2 will be emitted to the atmosphere, which is a major threat for the environment. In addition to the above huge quantity of energy is also required for the production of cement. Hence it's essential to find alternative binder.

Objectives

- To make a concrete without using cement and water (i.e. Geopolymer concrete).
- To study the different flexural and elastic 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.

Materials

Fly ash

Fly ash is a crucial ingredient in the creation of geopolymer concrete due to its role in the geopolymerization process. Fly ash is a powdery pozzolan. Fly ash is the main byproduct created from the combustion of coal in coal-fired power plants.

Table 1.Chemical composition

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

Table 2. Properties of Fly ash

SNo.	*Property*	*Value*
1	Specific Gravity	2.44
2	Fineness	227.8 g/m^2
3	Fineness Modulus	5
4	Density	1029.7 Kg/m^3

Ground Granulated Blast Furnace Slag

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.

Table 3.Properties of GGBS

S No.	*Property*	*Value*
1	Specific Gravity	2.58

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2	Fineness	202.7 g/m^2
3	Fineness Modulus	7
4	Density	2067.06 Kg/m^3

Table 4.chemical composition

Chemical constitution	Cement (%)	GGBS (%)
CaO	65	40
SiO_2	20	35
Al_2o_3	5	10
MgO	2	8

Fine aggregate

The fine aggregate used in the project was locally supplied and conformed to grading zone II as per IS: 383:1970.

Table 5.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

Coarse aggregate

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

Table 6.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

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

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 in water.

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.

Superplasitcizer

Addition of superplasticizer to stiff concrete mix reduces its water reducing efficiency. In this investigation, a superplasticizer CONPLAST SP 430 complies with BIS : 9103-1999 and BS : 5075 part 3 and ASTM C 494 has been used.

Preparation of Alkaline Activator Solution

The mixture of sodium silicate solution and sodium hydroxide solution forms 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. Sodium hydroxide pellets have to be distilled in water and then mixed with sodium silicate solution.

Geo-polymer mix design value

The design compressive strength is taken as 45MPa

Constituents	Density (kg/m^3)
Coarse aggregate	1294
Fine aggregate	554
Fly ash	408
Sodium silicate	103
Sodium hydroxide	41
Super plasticizer	6.12

Casting and Curing of test specimens

Each specimen was casted in 3layers and each layer received 25 strokes of compaction by standard compaction rod for concrete. After 24 hours the specimens were demoulded and placed into ambient curing till age of testing to be done.

Testing of specimen

Compressive Strength test

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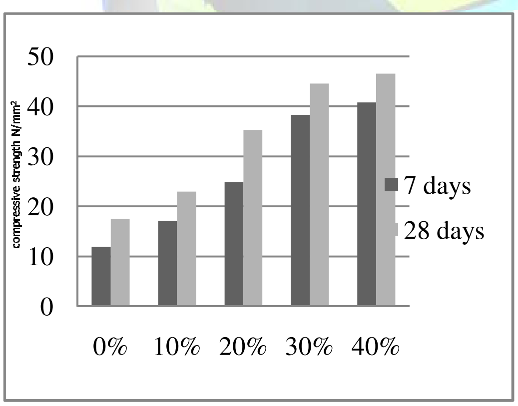
All the cubes were tested under drying condition, after drying the surface of the specimens containing no moisture in it. Using compression testing machine of 200Tonnes capacity as per IS: 516-1959 code. From the test results, it was observed that the maximum compressive strength was obtained for mix with 30% GGBS and 70% flyash.

Table 7.compressive test results

MIX ID	*FLYASH (%)*	*GGBS (%)*	*Compressive strength N/mm²*	
			7th Day	28th Day
M1	100	-	11.88	17.55
M2	90	10	17.09	22.97
M3	80	20	24.85	35.32
M4	70	30	38.33	44.58
M5	60	40	40.77	46.55
CM	-	-	26.67	37.85



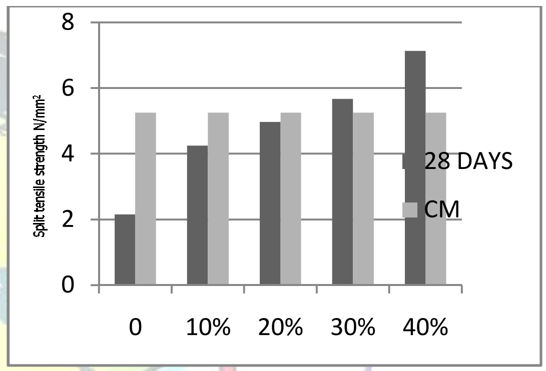
Bar chart of compressive strength

Split Tensile Strength test

As per IS 516-1959 the split tensile strength of specimen were calculated.It was observed that the maximum split tensile strength was obtained for mix M2 with 30 % GGBS and 70% flyash

Table 8.split tensile test results

MIX ID	*Binder (%)*		*Split tensile strength (N/mm²)*
	FLYASH	*GGBS*	*28th Day*
M1	100	-	2.15
M2	90	10	4.25
M3	80	20	4.97
M4	70	30	5.67
M5	60	40	7.13
CM	-	-	5.25



Bar chart of split tensile strength

Flexural Strength test

As per IS 516-1959, the flexural strength has been calculated using the formula

$$f_b = \frac{Pl}{bd^2}$$

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 9.flexural strength results

MIX ID	*Binder (%)*		*Flexural strength (N/mm²)*
	FLYASH	*GGBS*	*28th Day*
M1	100	-	3.16
M2	90	10	4.47
M3	80	20	5.28
M4	70	30	6.10
M5	60	40	6.97
CM1	-	-	5.65

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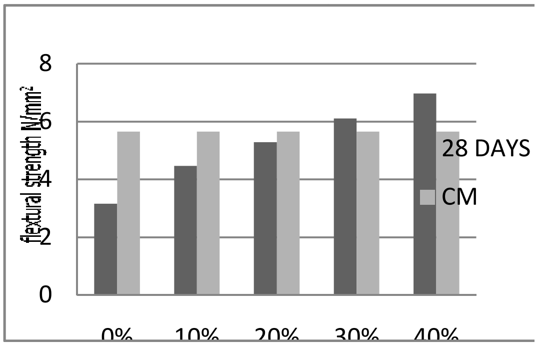

Bar chart of Flexural strength

Elastic Properties

Modulus of Elasticity

Young`s modulus is a measure of the stiffness of an elastic isotropic material. It is defined as the ratio of the stress along an axis over the strain along that axis in the range of stress in which Hooke`s Law.Modulus of elasticity is determined by subjecting a cube or cylinder specimen to uniaxial compression and measuring the deflections by means of LVDT's connected with dial gauges fixed between certain gauge lengths. The average value of modulus of elasticity determined by means of an extensometer as per IS 516 -1959.

Modulus of Elasticity = stress/strain.

Table 9.modulus of elasticity results

MIX ID	*Binder (%)*		*Modulus of Elasticity (GPa)*
	FLYASH	*GGBS*	*28th Day*
M1	100	-	27.33
M2	90	10	30.73
M3	80	20	32.54
M4	70	30	33.76
M5	60	40	35.68

Poisson`s Ratio

Poisson`s ratio is the negative ratio of transverse to axial strain when the material is compressed in one direction.it usually tends to expand in the other two directions perpendicular to the direction of compression. This phenomenon is called Poisson effect. The Poisson ratio is the fraction of expansion by the fraction of compression, for small values of these changes.

Poisson`s ratio = lateral strain/linear strain (Or) 1/m.

Table 10.poisson's ratio results

MIX ID	*Binder (%)*		*Poisson's ratio*
	FLYASH	*GGBS*	*28th Day*
M1	100	-	0.26
M2	90	10	0.24
M3	80	20	0.23
M4	70	30	0.22
M5	60	40	0.19

Conclusion

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

- The optimum replacement level of fly ash by GGBS in GPC has been 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.
- From the test results, it was observed that the maximum strength was obtained for mix with 30% GGBS and 70% flyash.
- The present studies indicate that as strength of concrete increases there is decrease in the average value of Poisson's ratio.
- The Modulus of elasticity values increases with increase in compressive strength of geopolymer concrete.
- The obtained elastic properties values are in pair with the values developed for ordinary Portland cement concrete.

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