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Investigation on Geo-Polymer Concrete Block (GPCB) and Behaviour

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Abstract - *The increasing emphasis on energy conservation and environmental protection has led to investigation of alternatives to customary building material. Effort are urgently underway all over the world to develop environment friendly construction materials which makes minimum utility of natural resources and helps to reduce greenhouse gas emission. Geopolymer Concrete (GPC) is the name given to concrete where the binder is entirely replaced by an inorganic polymer formed between a strong alkaline solution and an aluminosilicate source. In this investigation, the study has gone through development of strength for various grades of geopolymer concrete for different curing conditions (ambient and oven curing). The trail mix has chosen for low calcium fly ashbased geopolymer concrete using mix design. The study has gone through, to change in concentration and curing condition on mechanical property such as compressive strength, tensile strength, flexural strength for only GPC Solid Block (GPCSB). The investigation conducted in this study of performance of the new concrete mix-proportion. The various characteristic of GPCSB used for high potential to be an alternative structural material. The study concludes that, investigation is environmental eco-friendly of mechanical properties.*

Key Words: GPCSB, Compressive Strength, Tensile Strength and Flexural Strength.

1. INTRODUCTION

The risk of climate change is careful to be one of the major environmental-tests for the society. The production of cement contributes to the emission of CO_2 through the decarbonization of limestone. Cement is one of the most vital building materials used worldwide for the production of concrete[1]. The cement industry is a major source of carbon emissions and deserves attention in the assessment of carbon emission- reduction options. Concrete is the most commonly used construction material in the world due to its high compressive strength, durability and availability. Fly ash is a residue from the combustion of coal which is widely available worldwide and leads to waste disposal proposal problems[2]. Recent research hasshown that it is possible to use 100% of fly ash as the binder in mortar by activating it with an alkali component, such as silicate salts and non silicate salts of weak acids. The world is facing the challenge of global warming and climate changes due to carbon dioxide (CO_2) greenhouse gases and increment of CO_2 concentration. According to current trends and development the industrial sector has a big challenge to maintain high quality of life while ensuring low energy consumptions and CO_2 emissions.

1.1 Low Calcium Fly Ash Based Geopolymer Concrete

In this research work, low calcium fly ash based geopolymer concreteis obtained from Ennore Power Station (EPS), Andhra Pradesh, India was used as the base material[3]. The source material such as fly ash, that is rich in silicon (Si) and aluminium (Al) are activated by alkaline liquid to produce the binder. The fly ash-based geopolymer paste binds the loose coarse aggregates, fine aggregates and other un-reacted materials with alkaline liquid that is a combination of sodium silicate and sodium hydroxide solutions to form the geopolymer paste that binds the aggregates and other non-reacted materials together to form the geopolymer concrete[4].

1.2 Objective of the Research

The main objective of the research is to conduct an extensive study on geopolymer concrete block. The sub objective includes the following:

1. To study the physical, mechanical and chemical property ofgeopolymer concrete block.

2. To study the Mechanical property of geopolymer concretehollow block[5].

2. EXPERIMENTAL PROGRAMME

2.1 Materials

- Fly ash
- Alkaline Activators
- Aggregates

Fly ash is a fine powder recovered from the gases of burning coal during the generation of electricity. These micron-sized earth elements consist primarily of silica, alumina and iron. Fly ash improves considerably the performance of binder paste and increases the bonding action with aggregate and reinforcement[6].

It increases the packing density of the cementitious system, thus creating a less permeable structure. Geopolymer concrete in this study was made from low calcium fly ash with a combination of sodium hydroxide (NaOH) and sodium silicate solution (Na_2SiO_3)[7].

Fly ash used in this study was low-calcium (ASTM Class F) dry flyash as shown in Table-1[8]. The chemical compositions of the fly ash from all batches as determined by X-Ray Fluorescence (XRF) analysis are given in Table-2.

Table -1: Collection of fly ash

Material	Class	Source
Fly ash	F	Thermal power station, Vijayawada, Andhra Pradesh, India.

Table -2: Report of tests of fly ash

S.No	Constituents	% Composition
1	Silica (as SiO_2)	48
2	Alumina (as Al_2O_3)	29
3	Ferric Oxide (as Fe_2O_3)	12.7
4	Calcium Oxide (as CaO)	1.76
5	Magnesium Oxide (MgO)	0.89

The alkaline liquid used was a combination of sodium silicate solution and sodium hydroxide solution[9]. The NaOH solids were dissolved in water to make the solution. The mass of NaOH solids in a solution depends on the concentration of the solution and is expressed in terms of Molar (M)[10].

In the absence of the usage of proper alternative aggregates becoming possible in the near future[20], the concrete industry globally will consume 8-12 billion tons annually of natural aggregates after the year 2015.

Table -3: Sieve analysis of fine aggregate

IS Sieve size	Mass Retained on Sieve (gm)	Cumulative Mass Retained (gm)	Cumulative % Mass Retained	Cumulative % Passing
4.75mm	-	-	-	-
2.36mm	70	70	3.5	96.5
1.18mm	98	168	8.4	91.6
600µ	985.5	1153.5	57.68	42.33
300µ	726.5	1880	94	6
150µ	95	1975	98.75	1.25
Pan	25	2000	100	0

Fig -1: Materials used in GPC

Fig -2: Dry Mixing of Materials

Fig -3: Fresh of GPC

Fig -4: Specimen after curing

Fig -5: Oven curing

2.2 Mix Proportion for GPC

The laboratory program conducted in this investigation focused on four basic mixes and these were designated with the molarity of NaOH[12]. The concentration of NaOH used in the experimentation was based on the review of previous research. The ratio of fly ash: sand: coarse aggregate was 1:1.1:2.6 with ratio of activator solution to fly ash as 0.4. The geopolymer concrete mixes were designated as GP1, GP2, GP3 and GP4 respectively. Table-4 shows the mix proportion for GPC[13].

Table -4: Mix Proportions for GPC for 1 m^3 of Concrete

Specimen	Designation of Mix	Aggregate C.A (kg)	Aggregate Sand (kg)	Fly ash (kg)	NaOH Solution Mass (kg)	NaOH Solution Molarity (M)	Sodium Silicate (kg)	Curing Condition
GPC Solid Block (150 x150 x 150mm)	GP1	1274	539	490	41	8M	103	30ºC and 60ºC
	GP2	1274	539	490	41	10M	103	30ºC and 60ºC
	GP3	1274	539	490	41	12M	103	30ºC and 60ºC
	GP4	1274	539	490	41	14M	103	30ºC and 60ºC

2.3 Mix Proportion for Geopolymer brick

The behaviour of unreinforced geopolymer brick masonry prism iscompared with clay brick masonry prism[11]. English bond un-reinforced Clay Brick Prism (CBP) and Geopolymer Brick Prism GBP (M1) and GBP (M2) of brick size 225 x 105 x 70 mm were cast using 10M and 12M NaOH concentration with prism dimension of 609 x 220 x 609 mm (h/t = 2.77) and 609 x 220 x 914 mm (h/t = 4.3). Table-5 shows the mix proportion for preparing GPC bricks.

Table -5: Mix Proportions for Geopolymer brick

Designation of Prism	Type of Brick	Mix Proportion of Brick	Mix Proportion of Fly ash : Binder)	Mix Proportion of mortar (Cement : Sand)
CBP	Clay Brick	Burnt Clay Moulded	-	01:04
GBP (M1)	Geopolymer Brick	1:3 (Fly ash: Quarry Dust)	01:00.5	01:04
GBP (M2)	Geopolymer Brick	1: 1.1: 2.6 (Fly ash: sand: Coarse Aggregate)	01:00.5	01:04

3. METHODOLOGY

The testing of concrete plays an important role in controlling and confirming the quality of cement concrete works[14]. Systematic testing of raw materials and fresh concrete are inseparable parts of any control programme for concrete. The main task is that when different materials are used in the concrete, careful steps are to be taken at every stage of work for different tests. The tests also have a deterring effect on those responsible for construction work. Tests are made by casting cubes or cylinder from the respective concrete[15]. It is to be noted that the standard compression test specimens give a measure of the potential strength of the concrete, not of the strength of the concrete in structure. In this study total experimentation consists of the following tests:

- Compressive Strength Test
- Split Tensile Strength Test
- Flexural Strength Test

3.1 Compressive Strength Test

Compressive strength of concrete is one of the most important and useful properties of concrete. In most structural applications concrete is implied primarily to resist compressive stress[16]. In this experimental investigation, both geopolymer concrete cubes and hollow blocks were used for testing compressive strength. The load at which the specimen ultimately fails is noted.

Fig -6: Compressive Strength Testing

3.2 Split Tensile Strength Test

The specimen fails due to tensile stresses developed in the specimen[17]. The tensile stress at which the failure occurs is termed the tensile strength of concrete.

Fig -7: Split Tensile Strength Test for cylinder

3.3 Flexural Strength Test

Flexural strength is a measurement that indicates the resistance of a material to deformation when placed under load. The beam specimens were 100 x 100 x 500 mm in cross-section[18]. Two legged vertical stirrups of 8 mm diameter at a spacing of 100 mm centre to centre were provided as shear reinforcement. The test specimen was mounted in a universal testing machine of 1000 KN capacity. The load was applied on two points from centre of the beam towards the support[19].

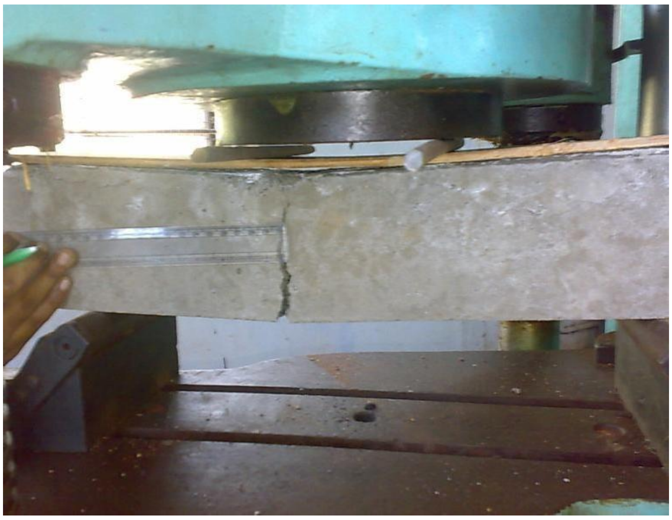

Fig -8: Flexural Strength Test

Table -6: Mix Proportions for Geopolymer brick

Material Properties	Shape	Dimensions of the Specimens (mm)
Compressive Strength	Cube	150 × 150 × 150
Flexural Strength	Prism	100 × 100 × 500
Split Tensile Strength	Cylinder	100× 150
Hollow block	Cube	100 x100 x 250 with one hollow of size 45 x 75 x 125

4. RESULTS AND DISCUSSION

Tests were conducted in various experimental setups to study the mechanical properties and chemical property of geopolymer concrete for various curing conditions in which fly ash was used as a replacement of cement. The behaviour of geopolymer brick masonry prism for varying height was compared with that of ordinary clay brick masonry prism.

Table -7: Compressive strength of GPC at 30°and 60°

Mix Designation	Molarity Of NaOH	Curing Condition	Compressive Strength (MPa) (Days)			Curing Condition	Compressive Strength (MPa) (Days)		
			7	14	28		7	14	28
GP1	8M	30°C	22.25	25.37	29.12	60°C	24.15	27.76	32.11
GP2	10M		27.22	30.14	31.12		28.12	30.43	33.36
GP3	12M		29.23	32.14	34.12		30.12	32.11	36.16
GP4	14M		30.45	34.22	36.24		32.45	34.12	37.12

Table -8: Flexural strength of GPC at 30°

Mix Designation	Molarity of NaOH	Curing Condition	Flexural Strength (MPa) (Days)		
			7	14	28
GP1	8M	30°C	1.25	1.5	2.32
GP2	10M	30°C	1.34	1.67	2.45
GP3	12M	30°C	1.67	2.53	3.25
GP4	14M	30°C	1.95	2.76	3.75

Table -9: Split tensile strength of GPC at 30° and 60°

Mix Designation	Molarity of NaOH	Curing Condition	Split Tensile Strength (MPa) (Days)			Curing Condition	Split Tensile Strength (MPa) (Days)		
			7	14	28		7	14	28
GP1	8M	30°C	1.2	1.76	2.23	60°C	1.05	2.34	2.98
GP2	10M		1.54	2.36	2.56		2.12	2.56	3.2
GP3	12M		1.98	2.65	2.95		2.78	2.65	3.68
GP4	14M		2.32	2.87	3.5		3.45	3.57	4.12

5. CONCLUSIONS

- Test procedures used in this study were based on available or modified procedures normally used for Portland cement concrete either from the available standards such as the Indian Standard or ASTM or from the previously published works in the areas within this study.
- Laboratory tests were conducted to find the characteristic mechanical properties such as compressive strength, Split tensile strength and flexural strength for GPC solid block for 7, 14 and 28 days of testing and for curing at room temperature and elevated temperature.
- Cube specimens of size 150 x 150 x 150 mm for measuring compressive strength, cylinder specimens of 100 mm diameter by 150 mm height for indirect splitting tensile strength and prism

specimens of 100 x100 x 500 mm for flexural strength were cast in the study.

- In order to study the water absorption and the resistance of fly ash based geopolymer concrete to sulphuric acid GPC cube specimen of 150 x 150 x 150 mm cured at 30°C and 60°C were tested. The test specimens were immersed in a 3% sulphuric acid for a period of exposure of 28 days. The sulphate resistance was evaluated based on the change in weight and change in compressive strength, split tensile strength and pH value of specimen after sulphate exposure.

- Compressive strength and split tensile strength increases with increase in concentration of NaOH from 8M to 14M. Increase in compressive strength was also observed with increase in curing time for GPC solid block.

- Maximum compressive strength achieved for GPC solid block for curing at 60°C was 37.12 MPa. The maximum value of split tensile strength for GPC solid block cured at 60°C was 4.12 MPa.

- Water absorption decreases with increase in concentration and curing time. The percentage of water absorption was found to decrease with increase in concentration of NaOH from GP1 to GP4.

- The bond between geopolymer concrete and steel reinforcementsneeds to be studied for the practical use of this material.

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