DURABILITY STUDIES ON GEOPOLYMER CONCRETE USING GROUND GRANULATED BLAST FURNACE SLAG (GGBS)

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Abstract - *Today concrete usage to the world is second to the water. The demand of concrete is increasing day-by-day and cement is used for satisfying the need of development of infrastructure facilities. An important ingredient in the conventional concrete is the portland cement. Enormous amount of cement is utilized in construction industries worldwide. During the cement manufacturing, large amount of greenhouse gases like carbon-di-oxide (co2) is liberated in the atmosphere which pollutes the environment. Approximately 1ton of co2 is liberated during the manufacturing process of every 1ton of opc. This pollution could be prevented only by restricting the production and usage of cement. Geopolymer concrete is an alternative material for the conventional concrete which completely eliminates the usage of cement and made by using aluminate and silicate bearing materials with a caustic activator. The advantages of geopolymer concrete include higher compressive and tensile strength, resistance to heat and cold, low creep and shrinkage and chemical resistance. This study deals with the investigation on the durability studies of geopolymer concrete using ggbs (ground granulated blast furnace slag).*

***Key Words*: GGBS, La-hypercrete, sodium hydroxide, sodium silicate.**

1.INTRODUCTION

The term 'geopolymer' was first introduced by Davidovits in 1978 to describe a family of mineral binders with chemical composition similar to zeolites but with an amorphous microstructure. Unlike ordinary Portland/pozzolanic cements, geopolymers do not form calcium- silicate-hydrates (CSHs) for matrix formation and strength, but utilizes the polycondensation of silica and alumina precursors to attain structural strength. Two main constituents of geopolymers are: source materials and alkaline liquids. The source materials on alumino-silicate should be rich in silicon (Si) and aluminum (Al). They could be by-product materials such as fly ash, silica fume, slag, rice-husk ash, red mud, etc. Geopolymers are also unique in comparison to other aluminosilicate materials (e.g. aluminosilicate gels, glasses, and zeolites). The concentration of solids in geopolymerisation is higher than in aluminosilicate gel or zeolite synthesis. The use of this concrete helps to reduce the stock of wastes and also reduces carbon emission by reducing Portland cement demand.

1.1 .History of geopolymer concrete

Theory the majority of the earth's crust is made up of Si-Al compounds. Davidovits proposed in 1978 that a single aluminium and silicon containing compound which is geological in nature could react in polymerization process with an alkaline solution. The binder which was created is termed as "geopolymers" but nowadays the majority of aluminosilicate sources are by-products from organic combustion like flyash from coal burning. The inorganic polymers have crystalline microstructure. Some researches says that ancient "Roman cement" is a geopolymer cement, but this material is chemically unlike alkali activated geopolymer cements because it is made using lime and forms calcium-silicate-hydrates, which is much closer to Portland cement from a chemical standpoint.

1.2 Need for study

1. To find an alternative for the ordinary Portland cement.
2. To reduce CO2 emission and produce eco-friendly concrete.

2. OBJECTIVES

- To determine the Acid resistance (acid attack) test of geopolymer concrete using GGBS.
- To determine the Sorptivity test of geopolymer concrete using GGBS.
- To determine the Water absorption test of geopolymer concrete using GGBS.

3. METHODOLOGY

➢ Preparation of alkali activated solution:

- 12 Molarity of sodium hydroxide solution is prepared before 24 hours of casting geopolymer concrete. For this 480gms of NaoH is mixed in 1litre of distilled water. (1 Molarity = 40 gms, therefore, 12 Molarity = 12 x 40 =480 gms).

- Sodium hydroxide and sodium silicate are mixed in the ratio of 1: 2.5 (based on literature reviews).

- **Casting of specimens:**
  - The specimens for various tests are casted and demoulded and cured in room temperature till the day of testing.

4.MATERIALS

4.1. Fine aggregate

River sand was used here in this investigation. The sand was first sieved in 2.26 mm sieve to remove particles greater than 2.36mm and then was washed to remove the dust. The specific gravity of 2.652 and fineness modules of 3.45 was found.

4.2. Coarse aggregate

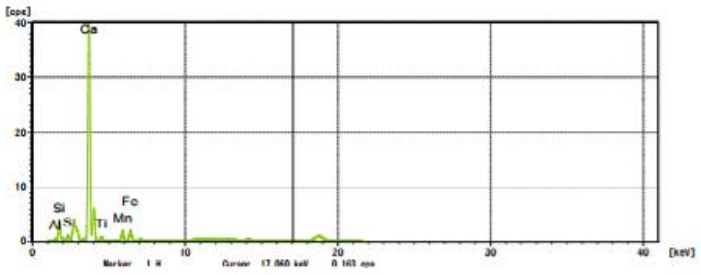
Locally available coarse aggregate size which is passed through 12.5mm sieve and retained in 10mm sieve was used in the work. The specific gravity of 2.652 and fineness modules of 7.01 was found.

4.3. Ground granulated blast furnace (GGBS)

GGBS is a waste material generated from the iron or slag industries which is a white powdered substance.

4.3.1.X-ray- fluorescence (XRF) test

- Xrf is the emission of characteristics "secondary or fluorescent" x-rays from a material that has been excited by bombarding with high-energy x-rays or gamma rays. This test was done in Central ElectroChemical Research Institute (CECRI), Karakudi, Tamilnadu.



Live Time : 80 s Processing Time : P2
XGT Dia. : 100 /m X-ray tube vol. : 50 kV
Current : 1.000 mA
X-ray Filter : Nonexistence Cell : Nonexistence

Quant. Corr. : Standard-less

Elem.	Line	Mass [%]	2sigma [%]	Atomic [%]	Intensity [cps/mA]	Formula	Mass [%]	Molecule [%]
13 Al	K	5.804	0.408	5.158	8.36	Al2O3	10.968	6.659
14 Si	K	13.991	0.375	11.942	46.17	SiO2	29.929	30.835
16 S	K	0.972	0.073	0.727	12.81	SO3	2.427	1.877
20 Ca	K	37.441	0.541	22.398	634.51	CaO	52.388	57.833
22 Ti	K	0.898	0.074	0.450	11.95	TiO2	1.498	1.161
25 Mn	K	1.079	0.062	0.471	31.43	MnO2	1.707	1.216
26 Fe	K	0.758	0.040	0.325	28.46	Fe2O3	1.084	0.470
8 O		39.057	0.613	58.529				

- From the results, we can say that calcium (Ca) is more in GGBS when compared to other oxide elements.

4.4. Activator solution

4.4.1. Sodium hydroxide solution

Procedure

Take 1000ml glass beaker and clean it properly. Now put 480gms of sodium hydroxide(pellets) in the beaker. Then pour 1000ml (1 liter) of distilled water to the glass beaker. Using the stirrer, continuously stir the salt in the water until it gets dissolved in water. During stirring more amount of heat will be released.


FIG 1: Sodium hydroxide salt and sodium hydroxide solution after preparation

4.4.2. Sodium silicate solution

White powder readily soluble in water which significantly reduces porosity.

4.4.3. La-hypercrete [S 25 (HTS code 38244090)]

It is a super-plasticizer. La – hypercrete is a high range water reducing admixture (HRWRA). 1% of weight of ggbs is the weight of la-hypercrete used in the concrete. To reduce the workability, it is used.

FIG 2 La-hypercrete

5. EXPERIMENTAL WORK

5.1. Acid resistance test (Sulphate attack)

In this method, the percentage of loss of weight was calculated before and after immersing the concrete cubes in 1% sulphuric acid diluted in distilled water.

5.1.1. Requirements

- Concrete cube of size 70mm x 70mm.
- 1% Sulphuric acid diluted in distilled water.
- Weighing machine.
- Compression testing machine.

FIG 3 Concrete cube of size 70mm x 70mm and 1% Sulphuric acid diluted in distilled water.

5.1.2. Procedure

Totally six cubes of size 70mm x 70mm were casted and weighed. Three cubes were cured in room temperature and three cubes were immersed in 1% Sulphuric acid diluted in distilled water. Both are cured for 28 days and after 28 days they were weighted initially. Then the cubes were tested in the universal testing machine to find its compressive strength.

FIG 4 Concrete cubes before and after testing in compression machine

5.1.3. Acid attack test result

Cube no	Average compressive strength of concrete after 28 days of normal room curing (N/mm2)	Average compressive strength of concrete after 28 days of acid curing (N/mm2)
1.	17.605	5.451
2.	24.187	11.983
3.	16.094	3.601

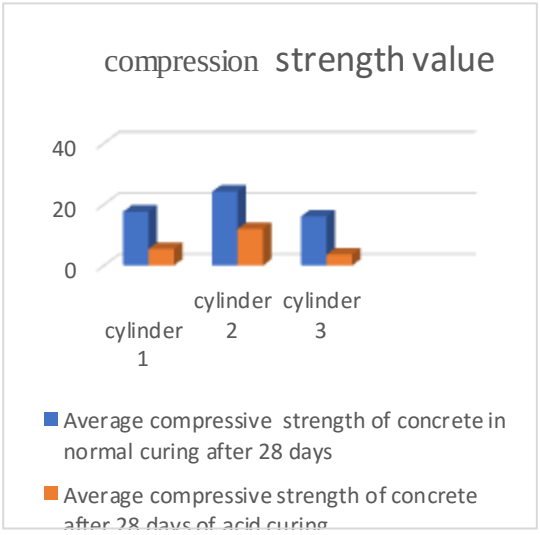


Chart 1

5.2. Water absorption test

5.2.1. Requirements

- Cylinder of size 50 mm diameter x 100 mm height.
- Weighing machine.
- Water bath.
- Oven.

FIG 5 Cylinder of size 100mm diameter x 50mm height, Water bath.

5.2.2. Procedure

After 28days of curing the concrete cylinders were oven dried for 24hours at 110 degrees Celsius and again weighed. The weight was noted as dry weight(W1) of the cylinder. Now the concrete cylinder was kept in water bath at 90 degrees Celsius for 3.5 hours. After that they are weighed as the wet weight (W2) of the cylinder.

% weight absorption = [(W2-W1)/W1] x 100

Where,

W1 = oven dry weight of cylinder in grams.
W2 =wet weight of cylinder in grams after 3.5 hours.

FIG 6 Concrete specimens on water bath and specimens while weighing

5.2.3. water absorption test result

Cylinder no	Weight of oven dried specimens in grams (W1)	Weight of wet specimens in grams (W2)	Weight absorption (%)
1	0.561	0.562	1.815
2	0.582	0.580	1.533
3	0.618	0.618	1.410

5.3. Sorptivity test

The measurement of capillary rise absorption rate on reasonably homogeneous material is known as Sorptivity.

5.3.1. Requirements

- Cylinder of size 50 mm diameter x 100 mm height.
- Weighing machine.

FIG 7 Cylinder of size 100mm diameter x 50mm height.

5.3.2. Procedure [as per ASTM C1585-13(2008)]

The cured cylinder specimens were weighed initially. Then the specimens were kept in the tray where the water 5mm in it. Only the bottom surface is set free to allow the water to pass through it and the other surface were sealed with non-absorbent coating. The quantity of water absorbed in time of 30minutes was measured. The surface water was wiped off with the tissue paper before weighing. The weight was measured at 1,3,5,7,10,15,20,25,30 mints of immersion.

Sorptivity, **S** (in mm) = $\mathbf{I\sqrt{T}}$
cumulative filtration at time, $\mathbf{I = \Delta w / Ad}$
change in weight, **w = W2-W1**

where,

W1 = oven dry weight of the cylinder (in grams)
W2 = weight of cylinder after 30minutes capillary suction of water (in grams)
A = surface area of the specimen through which water penetrated
d = density of water.

Table 1 Acceptance limits for durability indexes

Acceptance criteria		OPI (log scale)	Sorptivity (mm/h)
Laboratory concrete		>10	<6
As-built structures	Full acceptance	>9.4	<9
	Conditional acceptance	9.0 to 9.4	9 to 12
	Remedial acceptance	8.75 to 9.0	12 to 15
	Rejection	<8.75	>15

5.3.3. Sorptivity test result

Cylinder no	Area of the specimen (mm2)	Sorptivity value (10^-5 mm/hr)
1.	1963.495	11.157

FIG 8 Sorptivity test setup and weighing of specimens

6.RESULTS, DISCUSSION AND CONCLUSION

6.1. RAPIDCHLORIDE PENETRATION TEST (RCPT)

- The chloride ion penetration in the geopolymer concrete is in **moderate range** since the coulombs values are 2534.4 and 2703.6

6.2. ACID RESISTANCE TEST

- Average compressive strength of concrete after 28 days of normal room temperature curing was higher when compared with average compressive strength of concrete after 28 days of acid curing.
- The strength in the acid immersed concrete was decreased by more than 50% when compared with normally cured concrete.

6.2. WATER ABSORPTION TEST

- The water absorption is found to be 1.815%, 1.53% and 1.410% on 28 days of curing and it is found to be less.

6.2. SORPTIVITY TEST

- The Sorptivity value is found to be 2.789, 5.578 and 8.368 on 28 days of curing and it seems to be less and within the full acceptance limit.

From the above said experimental studies and the obtained results, it can be concluded that the geo polymer concrete performs well under durability studies.

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