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Geopolymer Concrete by using fly ash and GGBS as a Replacement of Cement

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Abstract: *Concrete has occupied an important place in construction industry in the past few decades and it is used widely in all types of constructions ranging from small buildings to large infrastructural dams or reservoirs. Cement is major ingredient of concrete. The cost of cement is increasing day by day due to its limited availability and large demand. At the same time the global warming is increasing day by day. Manufacturing of cement also releases carbon dioxide. In the present study an attempt been made on concrete and also an experimental investigation on the concrete using by replacing cement with FLYASH and GGBS to decrease the usage of cement as well as emission of concrete.Experimental studies were performed on plain cement concrete and replacement of cement with Fly ash is done. In this study the concrete mix were prepared by using flyash,sodium silicate, sodium hydroxide. A comparative analysis has been carried out for concrete to the Geopolymer concrete in relation to their compressive strength, split tension strength, acid resistance and water absorption. The concrete made with fly ash performed well in terms of compressive strength, split tension strength acid resistance and water absorption showed higher performance at the age of 7,14,28 days than conventional concrete. And also two different types of acid attack is done to determine the and compressive strength both on conventional concrete and geo polymeric concrete.*

Keywords: *Acid Attack, Bond Strength, Compressive strength, Flexural strength, GPC, Split Tensile strength.*

I. Introduction

Concrete is one of the most widely used construction materials; it is usually associated with Portland cement as the main component for making concrete. The demand for concrete as a construction material is on the increase On the other hand, the climate change due to global warming, one of the greatest environmental issues has become a major concern during the last decade. The global warming is caused by the emission of greenhouse gases, such as CO_2, to the atmosphere by human activities. Among the greenhouse gases, CO_2 contributes about 65% of global warming. The cement industry is responsible for about 6% of all CO_2 emissions, because the production of one ton of Portland cement emits approximately one ton of CO_2 into the atmosphere.Although the use of Portland cement is still unavoidable until the foreseeable future, many efforts are being made in order to reduce the use of Portland cement in concrete. These efforts include the utilisation 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 this respect, the geopolymer technology shows considerable promise for application in concrete industry as an alternative binder to the Portland cement. In terms of reducing the global warming, the geopolymer technology could reduce the CO_2 emission to the atmosphere caused by cement and aggregates industries by about 80%Heat-cured low-calcium fly ash-based geopolymer concrete has excellent compressive strength, suffers very little drying shrinkage and low creep, excellent resistance to sulfate attack, and good acid resistance. It can be used in many infrastructure applications. One ton of low-calcium fly ash can be utilised to produce about 2.5 cubic metres of high quality geopolymer concrete, and the bulk price of chemicals needed to manufacture this concrete is cheaper than the bulk price of one ton of Portland cement. Given the fact that fly ash is considered as a waste material, the low-calcium fly ash-based geopolymer concrete is, therefore, cheaper than the Portland cement concrete. The special properties of geopolymer concrete can further enhance the economic benefits. Moreover, reduction of one ton of carbon dioxideThe main objective of this paper is to examine the physical properties of coarse aggregate, fine aggregate and cement. Investigate the mechanical properties of concrete by complete replacement of fly ash in concrete mix then find their mechanical properties and determine the special mechanical properties using acid attack and bond strength on conventional concrete and geo polymeric concrete Among the waste or by-product materials, fly ash and slag are the most potential source of geopolymers. Several studies have been reported related to the use of these source materials. Cheng and Chiu (2003) reported the study of making fire-resistant geopolymer using granulated blast furnace slag combined with metakaolinite. The combination of potassium hydroxide and sodium silicate was used as alkaline liquids.

Van Jaarsveld et. al., (1997; 1999) identified the potential use of waste materials such as fly ash, contaminated soil, mine tailings and building waste to immobilise toxic metals. Palomo et. al., (1999) reported the study of fly ash-based geopolymers. They used combinations of sodium hydroxide with sodium silicate and potassium hydroxide with potassium silicate as alkaline liquids. It was found that the type of alkaline liquid is a significant factor affecting the mechanical strength, and that the combination of sodium silicate and sodium hydroxide gave the highest compressive strength. an Jaarsveld et. al. (2003) reported that the particle size, calcium content, alkali metal content, amorphous content, and morphology and origin of the fly ash affected the properties of geopolymers. It was also revealed that the calcium content in fly ash played a significant role in strength development and final compressive strength as the higher the calcium content resulted in faster strength development and higher compressive strength. However, in order to obtain the optimal binding properties of the material, fly ash as a source material should have low calcium content and other characteristics such as unburned material lower than 5%, Fe2O3 content not higher than 10%, 40-50% of reactive silica content, 80-90% particles with size lower than 45 µm and high content of vitreous phase (Fernández-Jiménez & Palomo, 2003). Gourley (2003) also stated that the presence of calcium in fly ash in significant quantities could interfere with the polymerisation setting rate and alters the microstructure. Therefore, it appears that the use of Low Calcium (ASTM Class F) fly ash is more preferable than High Calcium (ASTM Class C) fly ash as a source material to make geopolymers.

II. Experimental Study

2.1 Material Used

1) GGBS

Ground granulated blast furnace slag is used as main replacement for cement in this geopolymer concrete
Specific gravity test should be conducted before mixing
The specific gravity of GGBS was 2.92

FLYASH

It was a waste product hich was formed by industries and from other sources
The specific gravity of fly ash is 2.133

2) Fine Aggregate

This material which passes through BIS test sieve number 4 (4.75mm) is called as fine aggregate usually natural sand is used as a fine aggregate at places where natural sand is not available crushed stone is used as fine aggregates.

- Specific gravity of fine aggregate is 2.415
- Sieve Analysis was conducted to the fine aggregate which shows the sand belong to zone III as per IS: 383-1917.
- Water absorption for fine aggregate is 1%
- Fineness modulus for fine aggregate is 2.47

3) Coarse Aggregate

The material which is retained on BIS test sieve number greater than 4.75mm size of aggregate is termed as coarse aggregate. The broken stone is generally used as a stone aggregate. The nature of work decides the maximum size of the coarse aggregate. Locally available coarse aggregate having the maximum size of 20mm was used.

Specific Gravity Of Aggregates

Size	Specific gravity
20mm	2.64
10mm	2.57

- Average impact value of aggregate sample = 21.43%
- Average abrasion value of aggregate sample =15.82%
- Average crushing value of aggregate sample = 19.81%.

4 Alkaline Liquid

The alkaline liquid used was a combination of sodium silicate solution and sodium hydroxide solution. The sodium silicate solution (Na_2O= 13.7%, SiO_2=29.4%, and water=55.9% by mass) was purchased from a local supplier in bulk. The sodium hydroxide (NaOH) in flakes or pellets from with 97%-98% purity was also purchased from a local supplier in bulk. The NaOH solids were dissolved in water to make the solution.

5. Super Plasticiser

In order to improve the workability of fresh concrete, high-range water-reducing naphthalene based super plasticiser was added to the mixture

2.2 Mix Design

Extensive study on the development and the manufacture of low-calcium fly ash based geopolymer concrete research was already been reported in several publications (Hardjito et. al., 2002a; Hardjito et. al., 2003, 2004a, 2004b, 2005a, 2005b; Rangan et. al., 2005a, 2005b). Complete details of that study are available in a Research Report by Hardjito and Rangan (2005). Based on that study, two different mixture proportions were formulated for making concrete specimens.

The mixture proportions per m^3 for GPC are

MATERIAL	WEIGHT Kg/m^3
20mm coarse aggregate	776
10mm coarse aggregate	517
Fine aggregate	554
Fly ash	102.2
GGBS	306.7
Sodium silicate	102
Sodium hydroxide	41
Super plasticizer	20
Extra water	55

III. Test And Results

3.1 Experimental Test

3.1.1 Compressive strength

The compressive strength of a material is that value of uni-axial compressive stress reached when the material fails completely. The cubes are then tested between the loading surfaces of the compressive testing machine of capacity 2000KN in such a way that the smooth surface directly receives the load and it is applies until the failure of the load. The compressive strength is determined by the ratio of failure load to the cross sectional area of the specimen.

$$f_c = \frac{failure\ load}{cross\ sectioal\ area}$$

Fig.3 Testing of Cube Specimens

3.1.2 Split tensile strength

The resistance of a material to a force tending to tear it apart, measured as the maximum tension the material can withstand without tearing. Tested by keeping the cylindrical specimen in the compressive testing machine and is continued until failure of the specimen occurs.

Splitting Tensile Strength shall be calculated by using the formula:

$$\boldsymbol{f_{ct} = \frac{2P}{\pi ld}}$$

P = maximum load in Newtons applied to the specimen,

L = length of the specimen in mm,

D = cross sectional dimension of the specimen in mm.

Testing of Cylindrical Specimens

3.1.3 Flexural Strength

The flexural strength may be expressed as the modulus of rupture f_b, which, if "a" equals the distance between the line of fracture and the nearer support, measured on the centre line of tensile side of the specimen, shall be calculated to the nearest 0.5kg/sq.cm as follows:

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

Where

b=measured width in cm of the specimen

d=measured depth in cm of the specimen.

l= length in cm of the span in which the specimen was supported and

p=maximum load in kg applied to the specimen.

Testing of Prism Specimens

3.1.4 Durability Tests

- Acid Exposure

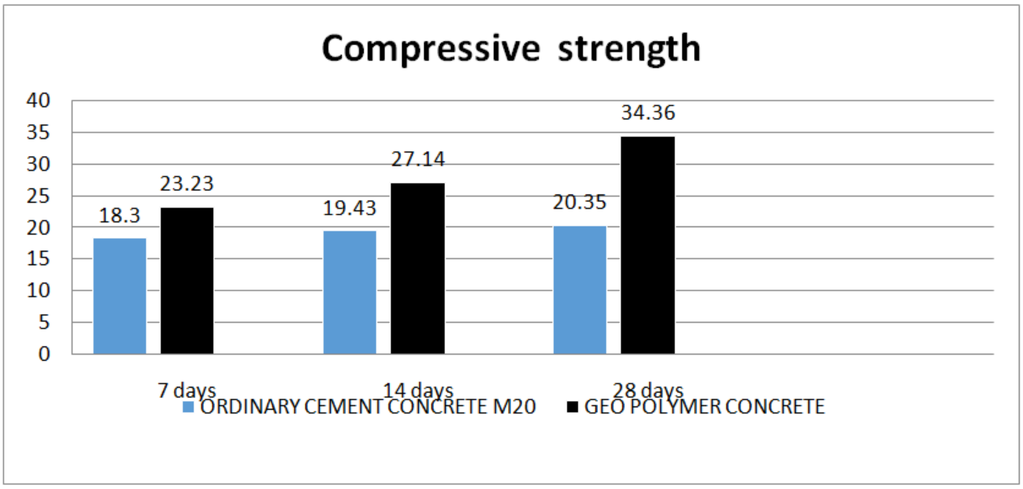
Hydrochloric acid (HCL) of 1% concentration was considered to be representative of aggressive sewer environments and 1% Hydrochloric acid (HCL) solution has been used in many laboratory tests to investigate the acid resistance of concretes for sewer structures. Concrete cube 15 × 15 × 15 cm samples were immersed in 1% Hydrochloric acid solution over 28, 60 and 90 days and the samples were regularly investigated by visual inspection of surface deterioration, measuring mass change and testing load bearing capacity in compression.

Specimens of Acid Exposure

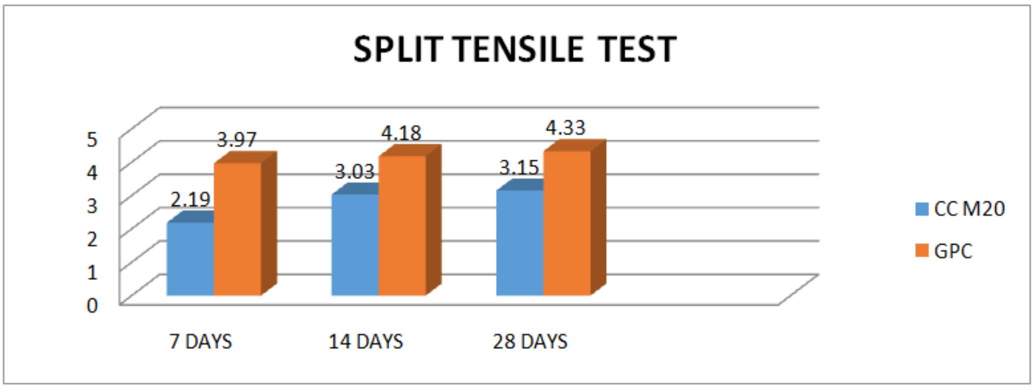
- Sulphate Exposure

In this study, Sodium sulphate,Na_2SO_4 1% by mass of water solution is prepared .The compressive strength of cube specimens with dimensions of 15 × 15 × 15 cm which were prepared by the substitution of quartzite by coarse aggregate by weight were determined after the specimens were kept in 1% Na_2SO_4 Sulphate solution. Then, the specimens were placed into sulphate solution and kept there for 28, 60 and 90 days. The specimens were removed from sulphate solution after 28, 60 and 90 days, and then, the compressive strength and mass losses of the specimens were determined. *Water absorption tests*Water absorption test was done for measuring the amount of water absorbed by a cube or a cylindrical specimen. And the percentage of water absorbed Concrete samples were prepared and cured in the laboratory, and are tested, to evaluate the concrete fresh and harden properties like compressive strength, Split tensile strength, flexural strength requirements, Durability Test. The different tests were conducted in the laboratories as shown in below.

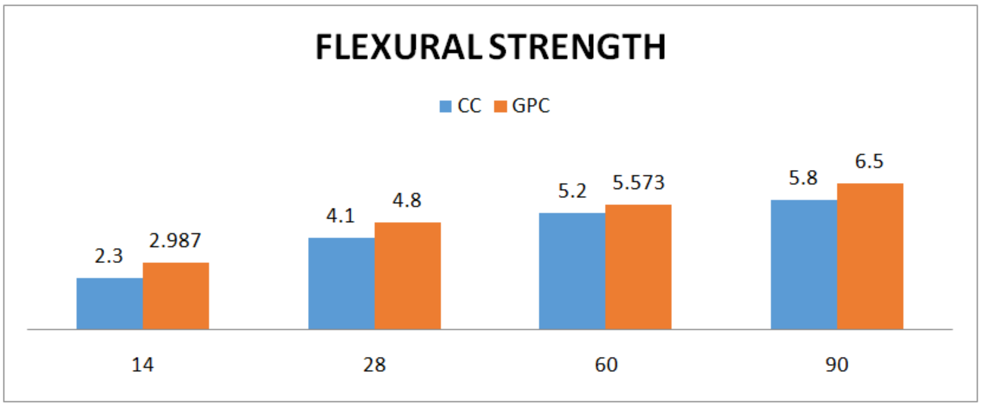
3.2 Mechanical Characteristics of GPC in Concrete
3.2.1 Compressive Strength of GPC in Cube Specimens (N/mm^2)



***2)* Split Tensile Strength of GPC in Cylinder Specimens :N/mm**

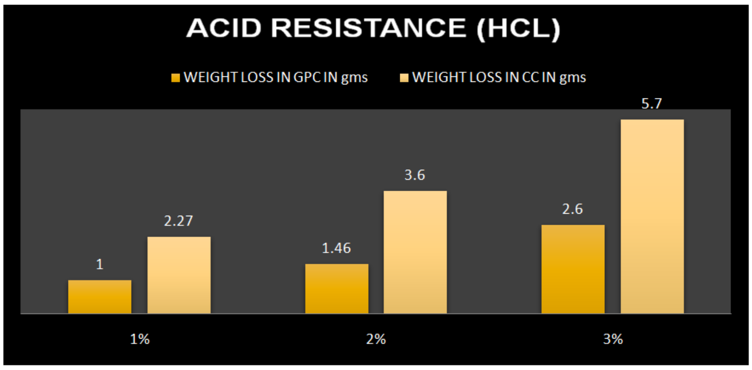


***3)* Flexural Strength of GPC in Prism Specimens:N/mm**

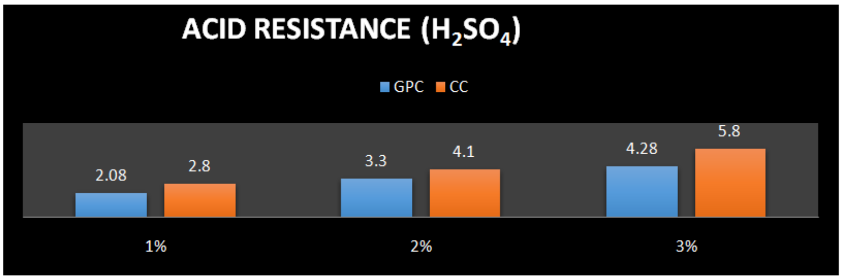


3.3 Acid Attack on Concrete

1) Compressive Strength of GPC in Cube Specimens with HCL:

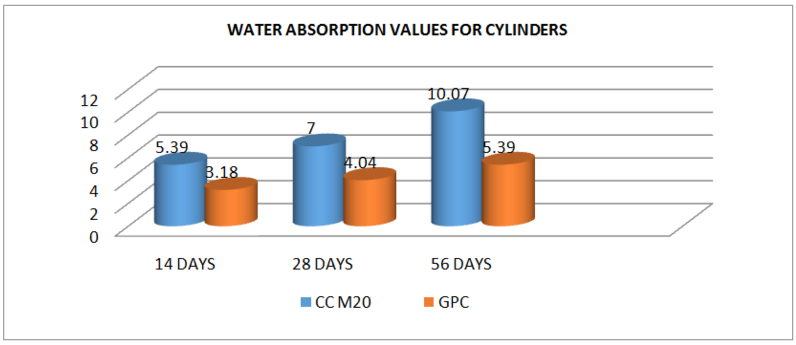


2) Compressive Strength of GPC in Cube Specimens with H_2SO_4

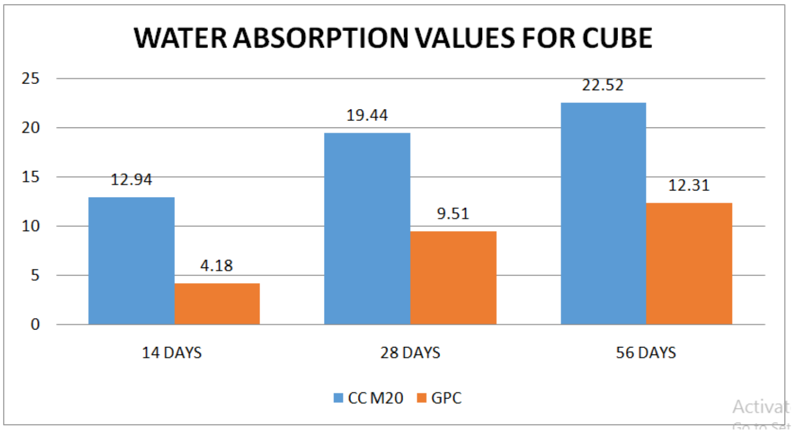


3.4 Water Absorption

Water absorption for cylindrical specimen



Water absorption for cube



IV. Conclusion

1. It is observed that the concrete slump values are equal to the values of cc of M20 grade
2. It is observed that the compressive strength of the GPC was 5 N/mm^2 more when it is compared with conventional concrete at 7 days .which was 33% more then cc
3. It is observed that the compressive strength of the GPC was 14N/mm^2 more when it is compared with conventional concrete at 28 days. Which was 50% more than ordinary cc
4. It is observed that split tensile strength of GPC was 1.72N more when it is compared with conventional concrete at 7 days.
5. It is observed that the Split tensile strength of GPC 1.12N more when it is compared with conventional concrete at 28 days.
6. It is observed that flexural strength of the GPC was 0.6% more when it is compared with conventional concrete at 28days.
7. It is observed that the flexural strength of GPC was 0.7% when it is compared with conventional concrete at 90 days.
8. During 1%HCL acid attack on GPC the compressive strength was 1.27% when it is compared with conventional concrete at 28 days.
9. During 3%HCL acid attack on GPC the compressive strength was 3.1% when it is compared with conventional concrete at 28 days.
10. During 1%H_2SO_4 acid attack on GPC the compressive strength was 0.7% more when it is compared with conventional concrete at 28 days.
11. During 3%H_2SO_4 acid attack on GPC the compressive strength was 3.5% more when it is compared with conventional concrete at 28 days.
12. It is observed that the WATER absorption of GPC cylindrical specimen was 5% less when compared with conventional concrete at 28 days.
13. It is observed that the WATER absorption of GPC cubical specimen was 10% less when compared with conventional concrete at 28 days.

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