Compative Study on Acid Resistance of Geopolymer Concrete to Conventional Concrete

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Abstract

Growth of Environmental pollution is a serious issue to be addressed in the global scenario. Among the Major industries contributing to the Pollution, a Cement industry contributes to around 5% of Carbon dioxide emissions globally. Hence there is a need to use substitute material for cement which reduces this impact on Environment. Geopolymer concrete is made utilizing binder materials like Flyash, Silica fume, rice husk ash, GGBS, Metakaolin etc., and Alkali Activator solutions. This paper deals with the study on chemical resistance of Geopolymer concrete when compared to conventional concrete. Sulphuric acid is chosen for attack in this study since it can cause both acid and sulphuric attack on concrete matrix. The test results of present study compares the resistance offered by ordinary Portland cement concrete and geo-polymer concrete.

Keywords: Geopolymer, Flyash, Acid resistance, Sulphuric acid.

I. INTRODUCTION

Among the several vital properties of hardened concrete, Durability plays a major role as it influences the life of structures. Reaction and resistance of concrete to the aggressive environment quantifies durability of hardened concrete. Durability of hardened concrete can be characterized as its capacity to resist Chemical attack, weathering action, wear and tear while retaining its designed engineering properties. Chemical attack on concrete can be explained under acid attack, Chloride attack, Alkali aggregate reaction, Sulphate attack, carbonation etc., Sulphur attack can occur due to association between concrete and sewage water or sea water or Ground water containing sulphates. Soil contains Sulphates in many forms mainly as magnesium sulphate, calcium sulphate, Ammonium sulphate, Potassium sulphate and Sodium sulphate. Generally sulphates present in solid form does not cause any significant damage to concrete but when present in dissolved form reacts with hydration products of concrete. Calcium sulphate causes unsubstantial deterioration due its low soluble nature while magnesium sulphate causes greater deterioration by reaction with calcium hydroxide and hydrated calcium aluminates. This reaction causes deterioration of cement paste volume in the concrete matrix and converts concrete in to granulated and powdered mass.

Even though Ordinary Portland Cement is the broadly utilized component in construction industry, its resistance to Chemical attacks is a noteworthy concern. In the recent studies binders of Geopolymer concrete has been found to be more effectively resisting the chemical attack apart from environmental friendliness. Geopolymer concrete is made utilizing binder materials like Flyash, Silica fume, rice husk ash, GGBS, Metakaolin etc., and Alkali Activator solutions. Generally either Sodium Hydroxide, Sodium silicate solutions or Potassium hydroxide , Potassium silicate solutions can be used as Alkali activator Solutions. In this study Flyash based Geopolymer concrete is made using Sodium hydroxide and Sodium silicate solutions. Coal based thermal power plants produce Flyash. It is a powdered residue originating from oxidization of powdered coal. Amorphous silica in flyash triggers the Pozzolanic activity. Geo-polymer concretes have alumina-silicates as binder and they generally do not have free lime. Therefore their resistance to acids can be estimated to be superior to the Portland cement based concrete.

II. MATERIAL CHARACTERISTICS

Tests on materials used for preparation of conventional concrete and Geopolymer concrete are conducted in order to find the material properties.

(a) Cement: Ordinary Portland Cement (OPC) of 53 grade is used for preparation of conventional concrete of M30 grade. Specific gravity of cement is tested and found to be 3.15 using Density bottle method. Different properties of cement are tested and the results are discussed in Table 1.

Table 1 Properties of OPC 53 grade cement

S.No	Material property	Test result	Specifications (IS 12269:2013)
1	Specific gravity	3.15	3.0-3.2
2	Soundness using Le chatelier's method	4	Should be less than 10mm
3	Normal consistency	33%	—

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S.No	Material property	Test result	Specifications (IS 12269:2013)
4	Initial setting time	30 min	Should not be greater than 30min
5	Final setting time	560 min	Should not be greater than 600min
6	Percentage of cement retained on sieve no.9	5%	Should not be greater than 10%

(b) Coarse aggregate: Durability against chemical attack of a concrete depends not only upon the cement characteristics but also on the properties of Aggregate. Specific gravity of the Coarse aggregate is found as 2.67 using density basket apparatus. Coarse aggregate size used for casting of both conventional and Geopolymer concrete is 20mm.

(c) Fine aggregate: Locally available sand passing through 4.75mm IS sieve is used for casting. Specific gravity of sand is found as 2.67 using Pycnometer bottle method. The zone of sand is confirmed to be Zone III sand in accordance with IS 383-1970.

(d) Flyash: Fly ash is generally available as Class C and Class F type. Active compounds in addition to calcium alumina-silicate glass that may be present in Class C fly ash are free lime, an hydrate, tricalcium aluminate, calcium sulfo-aluminate, and rarely, calcium silicates. Low calcium (Class F) fly ash characteristically contain a large proportion of silicate glass of high silica content plus crystalline phases of low reactivity. Hence as Class F flyash contains low or no free lime content it is selected as binder in this study. Composition of flyash used in this study is discussed in Table 2.

Table 2 Composition of Class F Flyash

Constituent	Composition/Percentage
Cao	0.72-3.6
SiO_2	49-67
Al_2O_3	16-28
Fe_2O_3	4-10
MgO	0.32-2.6
SO_3	0.1-1.9

(e) Alkali Activator Solutions: Alkaline environment is essential for the initiation of geopolymer binder reaction. Sodium hydroxide solution in combination with Sodium silicate solution or Potassium hydroxide solution in combination with Potassium silicate solution are generally used as Alkali Activator Solutions.

Sodium hydroxide solution: Sodium hydroxide is available in the form of pellets, flakes, sticks or chips and in solutions of different concentrations and purities. Sodium hydroxide solution in combination with Sodium silicate solution is most commonly used because Sodium hydroxide is abundantly available at low cost.

Sodium Silicate solution: The preparation of sodium meta silicate is done for 33.3% concentration by mixing Sodium meta silicate powder in water.

III. EXPERIMENTAL STUDY

Mix design: The grade of concrete used in this study is M 30. Conventional concrete mix design is adopted according to IS 456:2000. Mix proportions of Geopolymer concrete used in this study are presented in table 3.

Table 3 Mix proportion of Geopolymer Concrete

Ingredients of Geo-polymer concrete	Quantity (Kg/m^3)
Fly ash	405
NaOH	70.88
Na_2SiO_3	70.88
sand	683.13
Coarse aggregate	1268.66
Total water	108.35
Extra water	29.46

Mixing and Casting: The preparation of sodium hydroxide solution is done for 13 M by mixing 520grams of sodium hydroxide pellets in 1 litre of distilled water. The preparation of sodium hydroxide solution is an exothermic in nature. The preparation of sodium silicate solution is done by mixing 590 grams of sodium meta silicate powder in 1litre of water. 97% purity of sodium meta silicate powder is used. Alkali Activator solutions are prepared 24 hours prior to mixing of Geopolymer Concrete.

Weigh Batching is adopted for accounting the materials. Concrete mixer machine is used for mixing the materials. Flyash, Coarse aggregate and Fine aggregate are thoroughly mixed in dry state. After attaining a homogenous dry mixture alkali activator solutions and free water content are added. A decent mixing is carried out before placing the fresh Geopolymer Concrete mix in moulds. Conventional concrete is mixed and cast according to IS 10262:2009. Cube specimen moulds of size 150x150x150mm and Cylinder specimens of diameter 300mm and height 150mm are used for casting the specimens. A Thin layer of grease or waxing agent is applied to the mould for easy demoulding of specimens.

Fig. 1 Casting of Geopolymer specimens

The specimens are demoulded after 24hours of cast. Conventional concrete specimens are Water cured for 28 days. Geopolymer concrete specimens oven cured for 24 hours at 60^0C.

Fig. 2 Demoulded concrete specimens

After 24 hours of oven curing the specimens are air cured for 28 days and tested for compressive and Split tensile strengths.

Fig. 3 Testing of Concrete Specimens

Concentrated sulphuric acid (98% and density of 1.84 g/cc) was used to prepare the diluted sulphuric acid of 10%concentration.Conventional concrete and Geopolymer Specimens are immersed in Sulphuric acid after 28 days for a week period and tested for the compressive and split tensile strength.

Fig. 4 Concrete specimens immersed in Sulphuric acid

IV. RESULTS

Conventional concrete cubes are removed from curing tank before 4-5 hours of testing and surface dry condition is ensured. Cubes and Cylinder specimens are placed in Compression Testing Machine and tested. Compressive strength Results are presented in table 4.

Table 4 Cube strength of conventional concrete specimens before and after Acid attack

Cube	Cube Strength (N/mm^2)	Cube Strength after immersion in acid (N/mm^2)
C1	30.22	19.55
C2	30.22	20
C3	30.67	20.44
C4	31.11	20.88
C5	31.11	20.88
C6	30.22	20
C7	30.67	20.88
C8	31.11	20.88
C9	30.67	21.33
C10	30.67	21.77

Table 5 Split Tensile strength of conventional concrete specimens before and after Acid attack

Cylinder	Cylinder strength(N/mm^2)	Cylinder Strength after immersion in acid (N/mm^2)
CY1	3.8	2.26
CY2	3.53	2.12
CY3	3.39	2.41

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Geopolymer Concrete Cubes has lost their texture and appearance, revealing the aggregates in them after exposing to the acid environment.

Table 6 Cube strength of Geopolymer concrete specimens before and after Acid attack

Cube	Cube Strength(N/mm^2)	Cube Strength after immersion in acid (N/mm^2)
GC1	30.67	22.22
GC2	30.22	21.33
GC3	31.11	22.22
GC4	31.56	22.22
GC5	31.11	21.78
GC6	30.67	22.22
GC7	31.11	22.22
GC8	31.11	21.78
GC9	31.11	21.33
GC10	31.11	22.22

Table 7 Split Tensile strength of Geopolymer concrete specimens before and after Acid attack

Cylinder	Cylinder strength(N/mm^2)	Cylinder Strength after immersion in acid (N/mm^2)
GCY1	3.54	2.83
GCY2	3.54	2.69
GCY3	3.68	2.97

Comparision of Conventional concrete and Geopolymer concrete specimens are graphically presented below.

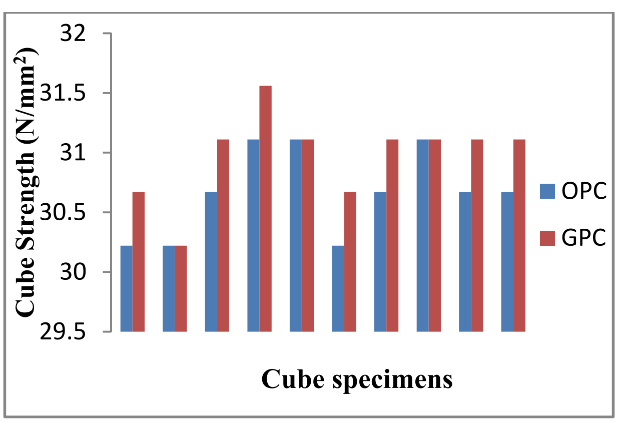

Fig. 5 Compressive Strength Comparison of cubes before Acid attack

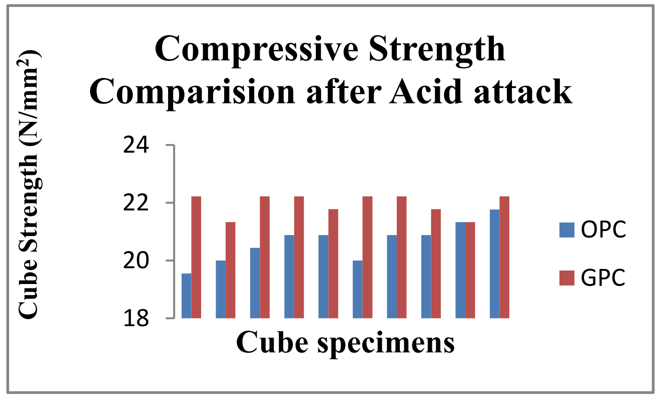

Fig. 6 Compressive Strength Comparison of cubes after Acid attack

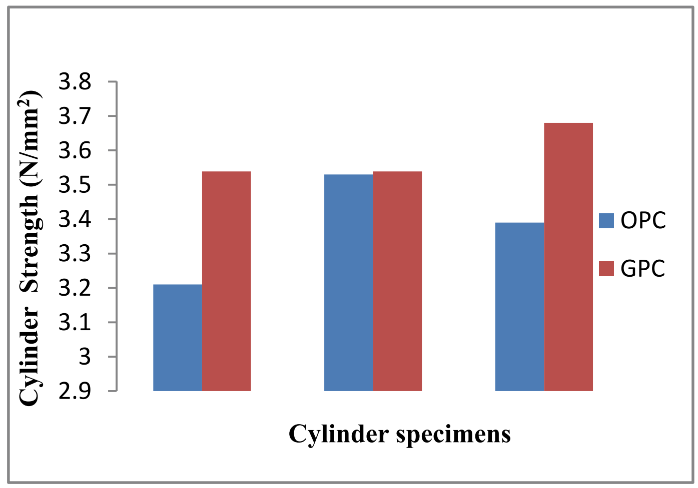

Fig. 7 Split tensile Strength Comparison of cubes Before Acid attack

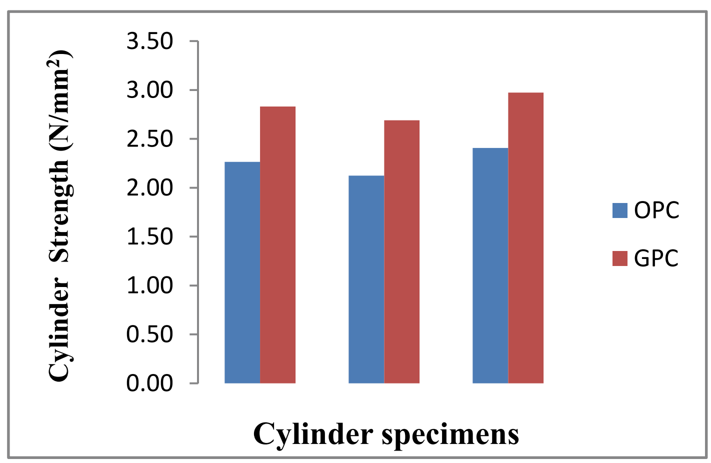

Fig. 8 Split tensile Strength Comparison of cubes after Acid attack

V. CONCLUSIONS

The average of 28days compression test of GPCs were in the range of 30.2 to 31.11 MPa. The corresponding values for OPCCs were 29.33 to 30.67 MPa

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respectively. It may be noted that this strength levels are quite adequate when compared with the minimum structural grade recommended in IS456-2000 for extreme exposure condition.

GPC specimens has maintained their shapes without any signs of severe external deteriorations but the GPCs had strength losses of 28.49% which is quite considerable. OPC concrete specimens had almost lost their shape with many locations of severe externally visual deteriorations; the strength losses were very high i.e; 35%. The OPC concrete specimens has exposed coarse aggregates, the surfaces were rough and whitish in color. Expansive chemical reaction should have happened in the Conventional Concrete specimens since a perceptible increase in the diameter of the specimens was noticed. These specimens could be considered as having reached their ultimate level of integrity. In contrast the GPC specimens were intact even though significant strength losses have occurred. From the above results, it is clear that GPC mixes have comparatively high resistance to Sulphuric acid attack. This can be ascribed to the fact that the Geopolymer Concrete do not have free lime content in its components and Geopolymer themselves are not easily attacked by the acids. Conventional concrete do contain free lime content in its components and are easily attacked by the acids.

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