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Long Term Durability and Characteristic of Geopolymer Concrete

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ABSTRACT

It is estimated that more than 63, 00, 000 scrap-tires weighing more than 70, 00, 00 tones are produced in India. This waste being non-biodegradable poses severe fire, environmental and health risks. Concrete is one of the most popular construction materials. Due to this fact, the construction industry is always trying to increase its uses and applications and improving its properties, while reducing cost. In general, concrete has low tensile strength, low ductility, and low energy absorption. Concrete also tends to shrink and crack during the hardening and curing process. These limitations are constantly being tested with hopes of improvement by the introduction of new admixtures and aggregates used in the mix. Hence, it is inevitable to find an alternative material to the existing most expensive, most resource consuming Portland cement. Geopolymer concrete is an innovative construction material which produced by the chemical action of inorganic molecules. Fly Ash, a by-product of coal obtained from the thermal power plant is used as bonding agent. Fly ash is rich in silica and alumina reacted with alkaline solution produced aluminosilicate gel that acted as the binding material for the concrete. It is an excellent alternative construction material to the existing plain cement concrete. Geopolymer concrete shall be produced without consuming of ordinary Portland cement. This paper briefly reviews the constituents of geopolymer concrete, its durability.

Keywords**--** Geopolymer Concrete, Fly Ash, Strength, Curing, Applications

I. INTRODUCTION

The geopolymer was formed by a French Professor Davidovits in 1978. It represents a broad range of materials characterized by networks of inorganic molecules (Geopolymer Institute 2010)1, 2 &3. The geopolymer involves on thermally activated natural materials like Meta kaolinite or industrial combination with fly ash or slag to provide a source of aluminum (Al) and silicon (Si). These Silicon and Aluminum is dissolved in an alkaline activating solution and made molecular chains to become the binder. The ultimate structure of the geopolymer depends on the ratio of Si to Al (Si:Al), with the materials most use in transportation infrastructure typically having an Si:Al between 2 and 3.5 5 &6 . The reaction of Fly Ash with an aqueous solution containing Sodium Hydroxide and Sodium Silicate in their mass ratio which gives material with three dimensional polymeric chain and ring structure consisting of Si-O-Al-O bonds7. The formation of geopolymer material can be shown in Equations (A) and (B).

$n(Si_2O_5, Al_2O_2) + 2nSiO_2 + 4nH_2O + NaOH$ or $KOH \rightarrow Na^+, K^+ + n(OH)_3 -Si - O - Al^- - O -Si-(OH)_3$

$\downarrow$

OH_2

(Geo-polymer Precursor)

O OO

| | |

$n(OH)_3 - Si - O - Al^- - O - Si - (OH_3) + NaOH$ or KOH
$\rightarrow (Na^+, K^+) - (- Si - O - Al^- - O - Si - O -) + 4n\ H_2O$

| | |

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The chemical reaction of Geopolymer concrete represent without water and instead water is expelled during curing and subsequent drying. This is different to the hydration reactions that occur when Portland cement is mixed with water, gives produce of primary hydration products calcium silicate hydrate and calcium hydroxide. This difference made impact on the mechanical and chemical properties of the geopolymer concrete. It render more resistant to heat, water ingress, alkali–aggregate reactivity, and other types of chemical attack 3&5. In the case of geopolymer made from fly ash, the role of calcium in these systems is very important, because its presence can result in flash setting and therefore must be carefully

controlled 5. The source material is mixed with an activating solution that provides the alkalinity (sodium hydroxide or potassium hydroxide are often used) needed to liberate the Si and Al and possibly with an additional source of silica (sodium silicate is most commonly used). The temperature during curing is very important, and depending upon the source materials and activating solution, heat often must be applied to facilitate polymerization, although some systems have been developed that are designed to be cured at room temperature 2&3. The necessity of Geopolymer Concrete, the Constituents, Properties and applications and limitation are discussed in detail in this paper
.

II. APPLICATIONS

Geopolymer concrete is used in bridges such as precast structural elements and decks. It is also used in handling sensitive materials. These concrete need high temperature environment. This type of concrete is also used in precast pavers and precast pipes.

III. LIMITATIONS

The base material fly ash to the required location. High cost for the alkaline solution. Safety risk is needed with the high alkalinity of the addition of solution. Difficulty in applying high temperature curing process will occur.

IV. ANALYSIS

4.1ANALYSIS OF HARD CONCRETE

4.1.1CARBONATION TEST ON CONCRETE USING A PHENOLPHTHALEIN INDICATOR

Procedure Concrete bears a strong alkali at the time when it is manufactured (pH=12~13), which is due to the creation of large amounts of Ca(OH)2 and such remains in concrete when the cement mineral in concrete reacts with water resulting in an aqueous solution. Such Ca (OH) 2 does not contribute to strength development, but forms passive protective oxide film, which plays an important role for corrosion prevention of the steel rebar inside the concrete [3]. In this process the concrete is neutralized is conducted in such a manner that light acid carbon gas in the air (approx. 0.035%) infiltrates through capillary pores on concrete surface and contacts the pore solution in the concrete where Ca (OH) 2 is dissolved and in turn changes into stable calcium carbonate and water. In which, the reaction product is created but the calcium carbonate is deposited on the pore wall inside concrete causing the concrete tissue to increase in density, while water evaporate or is used in the chemical reaction continuously. Especially, when concrete is sufficiently wet and the water existing in the concrete pores flow out to the surface from the inside, calcium carbonate or alkali carbonates, that is, NaCO3, KCO3, etc. emerge outwardly together and which are then deposited little by little continuously on concrete surface and gives efflorescence in the shape of white water flow. Calcium carbonate deposited on the pore wall inside concrete bears neutrality and depending on the degree where the Ca (OH) 2 is changed into calcium carbonate and pH is changed from a strong alkali to neutral gradually from the surface where carbon gas and water infiltrates easily. Through such process of neutralization, concrete neutralization accelerates in concrete with a high water-cement ratio creating large pores and low waterproofing properties from the aspect of concrete quality, and also in the high-concentration carbon gas and proper humidity (50~75%) from the environmental aspect. When the humidity is overly high, such blocks the internal pores of concrete that is the path for carbon gas to flow in rather affecting the neutralization. The neutralization occurs at a rapid speed in the environment where dry and wet conditions repeatedly occur. Concrete carbonation phenomenon creates an environment that corrodes the steel rebar in the concrete. In such environment, corrosion may occur through the onslaught of chloride ions although a passive protective oxide film is formed [4]. As discussed above, steel rebar can corrode through a decrease of the pH of the concrete close to the steel rebar. Pourbaix[5] said that passive protective oxide film on the surface of steel rebar in concrete begins to corrode at the degree of pH at 10.4 or less. A pH level at 10.4 or less of the concrete that has strong alkali content means that water and oxygen has already sufficiently flowed owing to carbonation [6]in concrete. When carbonation is in progress up to the depth of the steel rebar, the steel rebar can be anticipated to result to a corrosive environment. Parrott recommends that the supply of moisture and oxygen is an important element to corrosion by neutralization, and therefore neutralization occurs however no corrosion does at a relative humidity of less than to 60%. Steel rust appears in such a manner that the original volume expands to 2.5 to 7 times resulting in cracking inside concrete, which causes severe durability degradation of a structure such as bond strength, degradation, reduction in the cross sections of the steel rebar, etc. For such reason, it is important to determine the carbonation from the aspect of durability.

4.1.2 ACID RESISTANCE

Acid resistance was tested on 15×15×15 cm size cube specimens made of geopolymer concrete. The cube were weighed and immersed in 5% solution of sulphuric acid and 5% solution of phosphoric acid for 30 and 60 days respectively. Then the cubes were taken out from the acid solutions and the surfaces of specimens were cleaned and the weighted and the average loss of weight and were calculated.

4.1.3 SULPHATE RESISTANCE

The sulphate attack testing procedure was conducted on 150×150×150 mm size cube of geopolymer concrete and the cubes were cured in 5% sodium sulphate solution and 5% magnesium sulphate solution for 30 and 60 days respectively. The degree of sulphate attack was evaluated by measuring the weight losses of the cubes at 30 and 60 days respectively.

For comparison purpose, these tests were also performed on same grade of OPC concrete. But for this test on OPC concrete the specimen cubes were first cured for 28 days and then sulphate resistance test was performed with the same procedure as mentioned above.

V. RESULT AND DISCUSSION

5.1 CARBONATION TEST

The figure given below shows the concrete using geopolymer are carbonated by turns the color as pink.

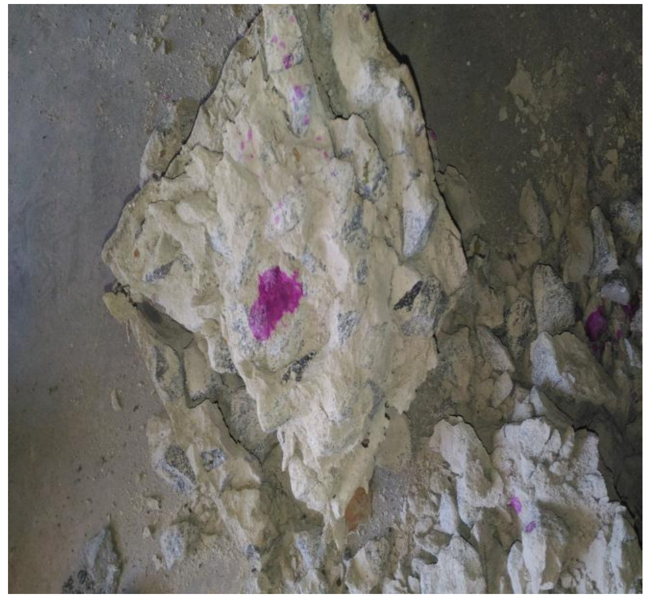
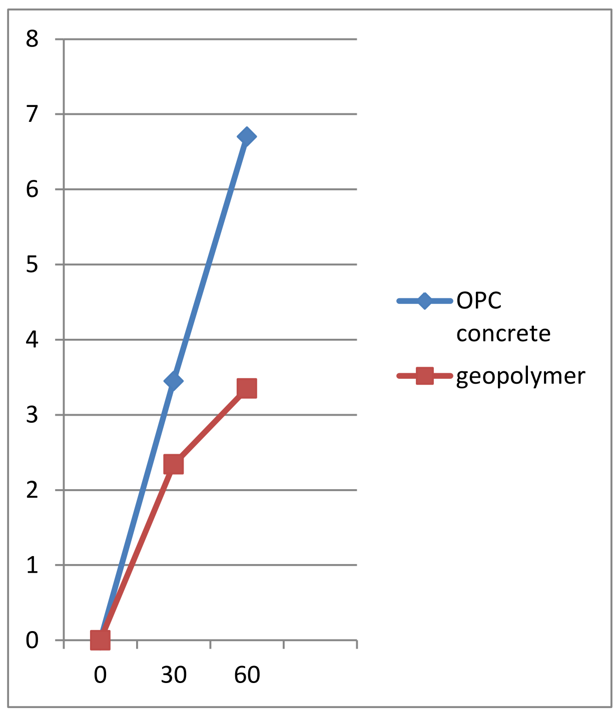


Fig 5.1- Carbonation test on concrete

5.2 ACID ATTACK TEST

No. of Days	OPC concrete (%)	Geopolymer concrete (%)
0	0	0
30	3.45	2.34
60	6.70	3.35

Table 5.1: Weight loss in percentage due to 5% solution of H2SO4

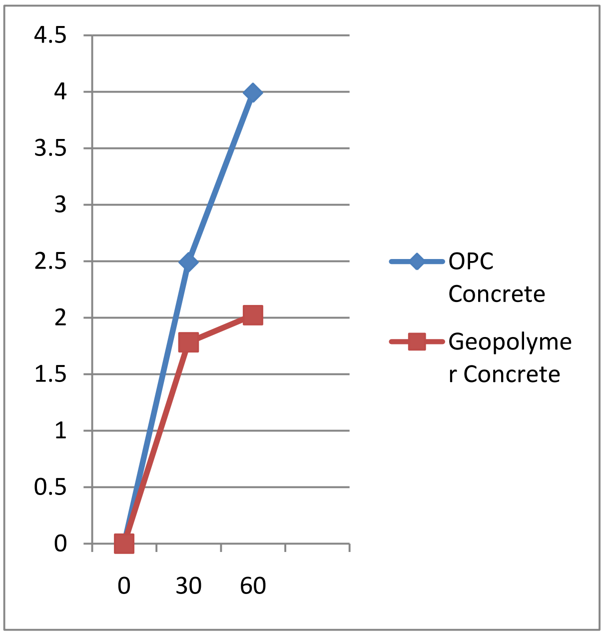


Graph 5.1: Comparison of weight loss of OPC concrete and geopolymer concrete on acid.

5.3 SULPHATE RESISTANCE TEST

No. of Days	OPC concrete (%)	Geopolymer concrete (%)
0	0	0
30	2.49	1.78
60	3.99	2.02

Table 5.1: Weight loss in percentage due to 5% solution of H3PO4



Graph 5.2: Comparison of weight loss of OPC concrete and geopolymer concrete on sulphate acid

VI. CONCLUSION

Geo-polymers were used in structural work, road construction, aero-space materials, transportation, metallurgy mining etc. Durability of the concrete can be obtained using Geo-polymer. The chemical waste like sodium hydroxide and sodium silicates are collected by the government to reuse as Geo-polymer concrete. So it reduced the cost of construction materials and also helps to recycle chemical wastes. Better in durability strength can be obtained by curing at 1200^{o}C. The major disadvantage of ambient cured reduced the weight of concrete and so sunlight is used in tropical countries for curing. Geo polymer concrete should be cured under sunlight for 90 days to get better stability. But there will be no loss in the weight of concrete. The water content using in concrete is very low due to fly ash in the concrete. So that super-plasticizers were mainly used to get better workability in concrete.

REFERENCE

[1] Abhishek Bisarya et al., [1] said that the most research worked gave higher the strength lesser the workability and vice versa. Hence there is need of the day to investigate the remedies of the problem of workability in Geopolymer Concrete.

[2] Ammar Motorwala et al., [2] analyzed that increased in the compressive strength with increased in the molarity was seen.

[3] Anuar K.A et al., [3] proved that the higher concentration of sodium hydroxide (NaOH) solution increased the higher compressive strength of geopolymer concrete will produced and also the higher concentration of NaOH will made the good bonding between aggregate and paste of the concrete.

[4] Bennet Jose Mathew et al., [4] said that the curing at elevated and ambient temperature will form fly ash-GGBS based concrete of comparable strengths. Geopolymer concrete can be prepared at comparable cost with OPC based concrete provided transportation system for raw materials is well established.

[5] Bharat Bhushan Jindal et al., [5] determined that the Geopolymer concrete show high early compressive strength on heat curing which made it suitable for useful in pre casting industry and the compressive strength at 7 days equivalent or higher than the ordinary Portland cement in 28 days.

[6] Douglas et al., [6] used Geopolymer Concrete in waste stabilization. Geopolymer Concrete immobilized chemical toxins and reduced leach ate level concentrations.

[7] Jaydeep .S et al., [7] recommended that the compared to hot air oven curing and curing by direct sun light, oven cured specimens gave the higher compressive strength but sun light curing is convenient for practical conditions. He also said that the compression strength is increased by increasing of molarities of sodium hydroxide.

[8] Mohd Mustafa Al Bakri et al., [8] proved that the fly ash-based geopolymer was better than normal concrete in compressive strength, exposure to aggressive environment, workability and exposure to high temperature.

[9] Monique Tohoué Tognonvi et al., [9] said that the tubes of Geopolymer reinforced with sand show good resistance when they are subjected to acid, neutral or humid environment. The mechanical properties of those materials are not changed after durability tests. The presence of soluble species on the surface which would be hydroxide or carbonate potassium due to the increase of

the pH value is found using SEM observation. The presence of potassium ions in the solution evidenced par ICP-AES analysis. The surface of samples appears not to be attacked which shows the stability of these materials.

[10] Prof.More Pratap Kishanrao [10] proved that the mixture of fly ash and ground granulated blast furnace slag in equal proportions is used as binding material in complete replacement of conventional Portland cement to prepare geopolymer concrete mixes.

[11] Muhd Fadhil Nuruddin et al.,[11] said that cast in-situ application in Geopoymer concrete is a viable one.

[12] Raijiwala et al., [12] determined that the Compressive strength of GPC increased over controlled concrete by 1.5 times (M-25 achieves M-45), Split Tensile Strength of GPC increased over controlled concrete by 1.45 times and Flexural Strength of GPC increased over controlled concrete by 1.6 times.

[13] Shankar H. Sanni et al., [13] recommended that the compressive strength loss for the specimens exposed in sulphuric acid were in the range of 10 to 40% in normal concrete and it was about 7 to 23% in Geopolymer. The Geopolymer concrete and normal mixes indicated minor changes in weight and strength when the specimens were exposed to sulphuric acid and magnesium sulphate.

[14] Tejas Ostwal et al., [14] analyzed that the strength achieved by Geopolymer blocks is 4MPa which is equal to the strength of cement concrete block of compression 23kN/m3. The average water absorption percentage of GPC block is found to be 1.40 %. The cost of one block is estimated to be 50.62. Even though the costs of GPC blocks are higher as compared to traditional cement concrete block, it is recommended to use in place of cement concrete blocks and burnt brick, since GPC blocks are ecofriendly in nature.

[15] Vignesh.P et al., [15] said that the Water absorption property is lesser than the nominal concrete and achieved strength in a short time.