Strength and Durability Studies of Flyash and Potassium Feldspar Powder based Geo-Polymer Concrete

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***Abstract* - Geopolymer concrete is another option now-a-days to use instead of Ordinary Portland Cement concrete, as geo-polymer concrete is ecofriendly concrete because it does not produce carbon during its production. In Geo-polymer concrete various minerals and admixtures can be used according to design and availability of minerals. In this paper Potassium Feldspar powder is going to be used along with flyash. Potassium Feldspar powder (PFP) is used as raw material in ceramic and glass industries. Potassium Feldspar powder has high silica and alumina content and can be used as one of the source materials to develop Geopolymer concrete. The study will focus on combine effect of PFP and fly ash in Geopolymer concrete. In this study the PFP is replaced with flyash in ratio of 10%, 20% and 30% to develop Geopolymer concrete. The experimental study measured the mechanical and durability properties of Geopolymer concrete and optimum percentage of PFP to get strength of M35. In the results, it is observed that the 7 and 28 days compressive strength of the specimen increases in the 14M solution and 16M solution desired strength M35 is achieved while the strength decreases in 12M solution for 20% replacement. The replacement of PFP up to 20% in recommended for 14M and 16M solution.**

***Index Terms* - Geopolymer Concrete, Flyash, Alkaline Solutions, Cementless Concrete, Compressive Strength, Split Tensile Strength, Durability studies**

1.INTRODUCTION

Many eco-friendly technologies are developed for effective management of resources and in the context of increased awareness regarding the ill effects of the overexploitation of natural resources. Cement is conventionally used as the primary binder to produce concrete and the environmental problems associated with the production of cement are also very well known. The amount of the carbon dioxide released during the manufacturing process of cement due to the calcination of limestone and combustion of fossil fuel is in the order of one ton for every ton of cement produced. Due to its low cost and easy availability, OPC is extensively used in India. Concrete can be cast in almost any desired shape and once hardened it becomes a load-bearing element.

On the other hand, due to all such reasons, it is needed to be replaced by non-producing CO2 materials such as fly ash and various supplementary materials. As such, Geopolymer concrete has been introduced to reduce this type of problem. Fly ash is easily available to replace totally manufactured cement and make a concrete-like material. It is a superb elective development material to the current plain concrete cement. Geopolymer is a type of amorphous aluminosilicate cementitious material that exhibits the ideal properties of rock-forming minerals, i.e. hardness, chemical stability and longevity. Geo-polymerization involves a heterogeneous chemical reaction between solid aluminosilicate oxides and alkali solutions at highly alkaline conditions and mild temperatures yielding three dimensional amorphous to semi-crystalline polymeric and ring structures, which consist of Si–O–Al and Si–O–Si bonds. Geopolymer concrete is made by a process of the two-part mix. Firstly, consisting of an alkaline solution (soluble silicate) and secondly, solid aluminosilicate materials. These soluble silicates and aluminosilicates give a better Geopolymerisation. The water in a Geopolymer blend assumes no job in the synthetic response; It just gives the usefulness to the combination during control. Geopolymer exists to the gathering of solid and strong cementations materials that solidify at temperatures beneath 100°C.

2.HISTORY OF GEO- POLYMER CONCRETE

Davidovits has proposed that some of the major pyramids, rather than being blocks of solid limestone, but are made of Geo-polymers, which are cast in their final positions in the structure. He additionally thinks about that Roman concrete and the little ancient rarities were recently thought to be stone material, of the Tiahuanaco civilization which was made utilizing information on Geopolymer strategies. Nonetheless, on the grounds that Roman concrete structures calcium-silicate-hydrates, and requires limestone as a reactant, it is more like Portland concrete than antacid initiated "Geopolymer concrete, for example, Pyrament concrete of LoneStar. Geopolymer binders and Geopolymer cement are generally formed by the reaction of an alumina-silicate powder with an alkaline silicate solution at roughly ambient conditions. Geopolymer cement can also be made from natural sources of materials, such as fly ash from coal. Most studies on Geopolymer types of cement have been carried out using natural or industrial waste sources of metakaolin and other alumina-silicates. Modern and innovative applications depend on more extensive and refined siliceous crude materials. Most of the Earth's covering is comprised of Si-Al mixes.

2.1 Types of Concrete

There are many types of concrete, designed to suit the performance needed for the specific purpose. Following are types of concrete.

1. High strength concrete.
2. Ordinary Portland cement concrete.
3. Rapid hardening concrete.
4. Self-compacting concrete.
5. Asphalt concrete.
6. Glass concrete
7. Polymer concrete
8. Geo-polymer concrete

2.2 Geo Polymer Concrete

In 1978 Daidovits given name Geopolymer to materials that are portrayed by inorganic atoms. Geopolymer cement concrete is made from the utilization of waste materials such as fly ash and ground granulated blast furnace slag (GGBS). Flyash is the side-effect produced from the warm force plant and ground grind impact heater slag is created as waste material in steel plant. As both fly ash and ground granulated blast furnace slag (GGBS) is waste in nature so the use of these materials in the construction purpose leads to the drop in cost of the Geopolymer concrete. The use of this concrete helps to use the wastes in a most appropriate way and it also reduces carbon emission by reducing Portland cement demand. The main constituents of Geo-polymer concrete are silica and aluminum which are provided by thermally activated natural materials or as industrial byproducts. The Geopolymer concrete is also known alkali-activated cement or inorganic polymer cement.

Since Portland cement is responsible for upward of 90 percent of the carbon dioxide Geopolymer concrete is a better option in most of the cases. The reaction occurs between flyash with alkaline solutions which are Sodium Hydroxide and Sodium Silicate in their mass ratio. This results in a material with a three-dimensional polymeric chain of Si-O-Al-O bonds. In the Geopolymer concrete the alkaline solutions leaches out the aluminosilicates from the raw materials and form a gel which provides a binder and due to which the concrete gets harden. The process of Geopolymerisation occurs normally at ambient and slightly elevated temperature depending on the properties of the source material.

3.PROPOSED MODEL

For the development of Geopolymer concrete first of all, Sodium hydroxide is weighted as needed in casting purpose. The molarity of Sodium hydroxide taken must be selected as per need i.e. 12M, 14M and 16M. For all these molars there are different proportions of Sodium hydroxide mixed with water to make a particular molar solution. While making a solution of Sodium hydroxide one must be very careful as it will heat the water while mixing which can be very harmful if proper care is not taken. Stir the solution until it cools down and then can be taken for the use. Then take out the required amount of Sodium silicate in a plastic bucket. Mix the Sodium hydroxide and Sodium silicate solution properly in a bucket. Weight the required amount of Fly Ash, Fine aggregate, and Coarse aggregate. Take out the required amount of super plasticizer as needed according to the mix design. Geopolymer concrete is plastic enough on its own that we can neglect this.

3.1MIXING PROCESS:

- Properly oil the machine and the moulds so that the concrete would not get stuck in them and can be easily removed.

- Put the measured coarse aggregate, fine aggregate and fly ash in the machine and properly mix them until it is uniformly mixed.
- Pour the Sodium hydroxide and Sodium silicate solution in the mixture along with the super plasticizer and again mix them for few minutes until it is uniformly mixed.
- While mixing, extra water should be added to the concrete mixture.
- Fill the molds with the concrete applying proper compaction such that no voids should be remained in the mould.
- Now put the molds in oven for curing for 24 hours at 60^{o} c.

Figure: Pan Mixture Machine

3.2 Test Procedure

3.2.1 Workability Test

- Functionality is characterized as the property of solid which is deciding the measure of valuable inside work important to create full compaction.
- A workable concrete is important to produce a dense concrete with high strength and durability.
- The factor affecting workability is w/c ratio, mix proportion, size, shape, texture and grading of aggregate and use of admixture.
- Concrete is said to be workable when it is easily placed and compacted homogeneously means without bleeding and segregation.
- If the concrete is not workable then it needs more work or effort to be compacted on place, also it creates honeycombs.

3.3 Compressive Strength Test

It is the limit of a material or structure to withstand loads having a tendency to lessen size. Test for compressive strength is completed either on block or chamber. Different standard codes suggest solid chamber or solid 3D Square as the standard example for the test.

For 3D shape test, three kinds of examples either 3D squares of 15cm X 15cm X 15cm or 10cm X 10cm x 10cm relying on the size of total are utilized. For the greater part of the works cubical moulds of size, 15 cm x 15cm x 15cm are regularly utilized.

Figure: Compressive Test

This concrete is poured in the mould and tempered properly so that it does not have any voids. After 24 hours of oven curing these moulds are removed and test specimens are put aside for 7/28 days. The top surface of these examples should be made even and smooth. This is done by putting paste and spreading smoothly on the whole area of the specimen.

These examples are tried by pressure testing machine following 7 days restoring or 28 days relieving. The load should be applied gradually at the rate of 5.2 kN per second till the Specimens fails. Burden at the disappointment separated by region of example invigorates the compressive of cement.

3.4 Result & Discussion

7 and 28 days Comparison of Compressive strength:

The Figure shows the 7 days compressive strength of Geopolymer concrete for Mix-1 and Mix-2. From both the Mix's created for the Geopolymer concrete Mix-2 had shown better results as compared to Mix-1

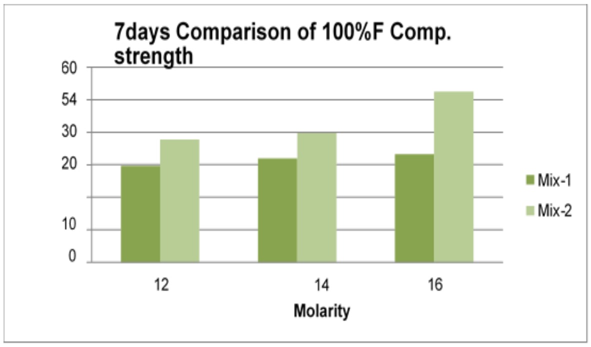

Figure: 7 days comparison of compressive strength

The Figure shows the 28 days compressive strength of Geopolymer concrete for Mix-1 and Mix-2. From both the Mix's created for the Geopolymer concrete Mix-2 had shown better results as compared to Mix-1

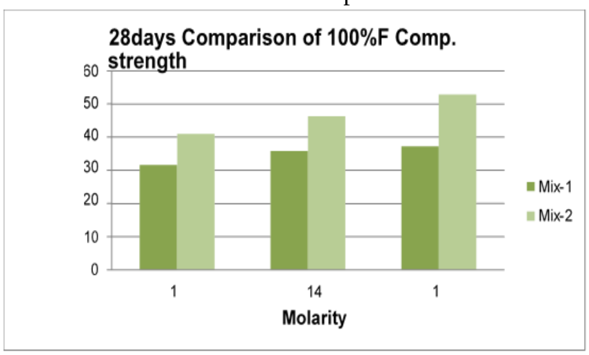

Figure: 28 days Comparison of 100%F Comp. Strength

7 and 28 days comparison of compressive strength replaced with 10%, 20% and 30% PFP:

The figures below show the comparison of compressive strengths for 10%, 20% and 30% PFP replacements.

The results of 7 days 10%, 20% and 30% PFP replacement comparison shows in Figure. There is a significant decrement in the compressive strength especially for 12M and 16M solution in 30% PFP replacement.

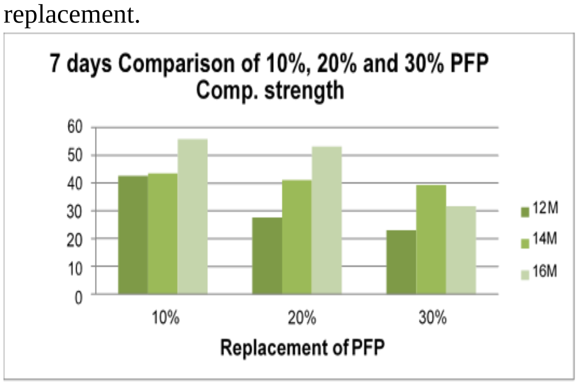

Figure: 7 days Comparison of 10%, 20% and 30% PFP Comp. strength

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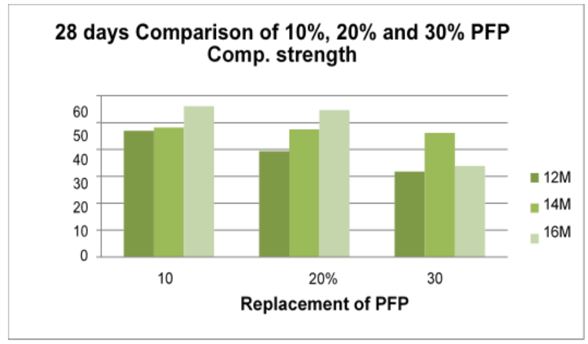

Figure: 28 days Comparison of 10%, 20% and 30% PFP Comp. strength

3.5 MIX DESIGN

There are no standard guidelines to develop mix design of Geopolymer concrete. The mix design was carried out using previous research work and trial and error method. Sample calculation for mix design of Flyash based M35 Geopolymer concretes shown below.

1. Characteristic compressive strength of Geopolymer Concrete (fck) = 35MPa.
2. Type of curing: Oven curing at 60 °C for 24 h
3. Workability in terms of flow: 25–50 % (Degree of workability—Medium)
4. Fly ash
   a. Fineness in terms of specific surface: 430m2/kg
   b. Specific gravity of flyash = 2.3
5. Alkaline solutions (Na2SiO3 and NaOH)
   a. Molarity of Sodium hydroxide: 12, 14, 16 M
   b. Specific gravity of Sodium Hydroxide = 1.47
   c. Specific gravity of Sodium Silicate = 1.6
6. Coarse aggregate
   a. Type: Crushed/angular
   b. Maximum size of aggregate: 20 mm
   c. Specific gravity of coarse aggregate = 2.6
7. Fine aggregate
   a. Sand conforming = zone III
   b. Specific gravity of fine aggregate = 3.1
8. Design Step:

Step 1: Selection of fly ash to the compressive ratio: The amount of flyash required for M35 grade =600 Kg/m3 is derived from the below Figure

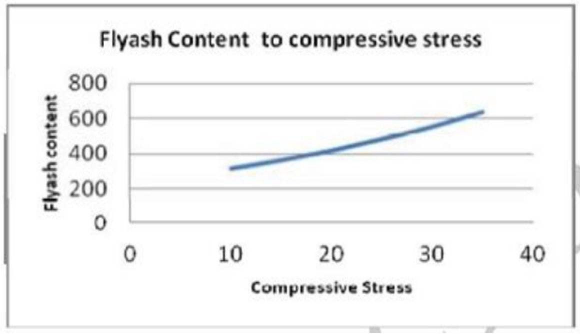

Figure: Flyash to Compressive stress Ratio

Step 2: Selection of alkaline liquid ratio: The ratio between Sodium hydroxide to sodium silicate is 1:2.5. The amount of alkaline liquid required according to the compressive stress is from the Figure

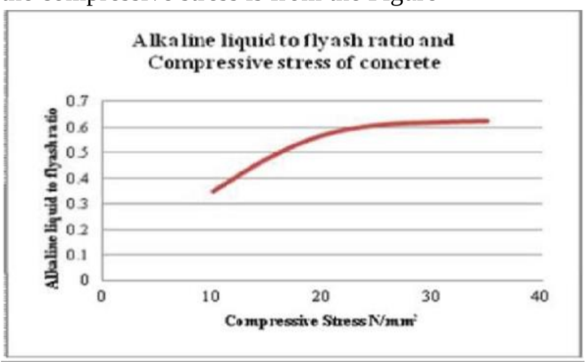

Figure: Alkaline Liquid Ratios

Step 3: Selection of water content: The maximum water content to add extra is 0.06 Water to flyash ratio the minimum water content to be added extra is 0.02 water to flyash ratio According to workability extra water can be added this is due to flyash is arrived from various plant which have different properties in absorption of water in order to match extra water is added. Amount of water add extra 0.02 to water flyash ratio = 0.03x600 = 18kg/m3

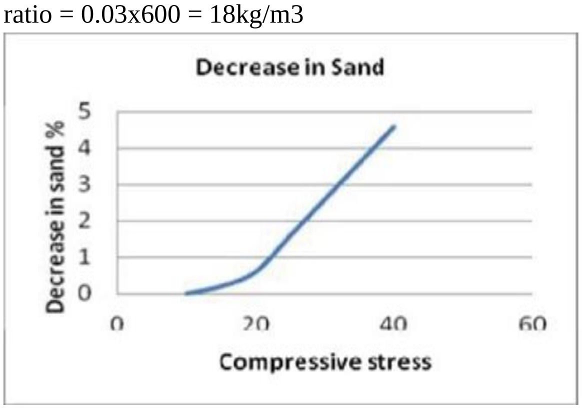

Figure: Adjustment of values in sand content percentage

Table: Estimation of Air Content

Nominal Maximum size of aggregate in mm	Entrapped air as percentage of volume of concrete
10	3 %
20	2 %

Determination of aggregate content from the table, for the specified maximum size of aggregate of 10 mm, the amount of entrapped air in the wet concrete is 3 %. Taking this into account and applying the following equations:

$V= [SO/S_{so}+S/S_s+F/S_f+1/P\times F_a/SF_a] \times 1/1000$ and

$V= [SO/S_{so}+S/S_s+F/S_f+1/ (1- P)\times F_a/SF_a]\times 1/1000$

Where, V = Absolute volume of fresh concrete, which is equal to gross volume minus the volume of entrapped air.

S = Sodium Silicate Solution (kg) per m^3 of concrete.

SO = Sodium Hydroxide Solution (kg) per m^3 of concrete F = Weight of Flyash (kg) per of m^3 of concrete

S_f = Specific gravity of Flyash

P = Ratio of fine aggregate to total aggregate by absolute volume

F_a C_a= Total masses of fine aggregate and coarse aggregate (kg) per m^3 of concrete respectively

SF_a, SC_a= Specific gravity of saturated surface dry fine aggregate and coarse aggregate, respectively.

S_s=Specific gravity of Sodium Silicate solution.

S_{so}= Specific gravity of Sodium hydroxide solution

Fine aggregate content:

Consider volume of Gpc $1m^{3.}$

But entrapped air in Gpc =2%

Absolute volume of fresh concrete=1-2/100= 0.98 m^3

$V = \{(105/1.47) +(266/1.6) +(600/2.3) +(1/ (0.35) +(F_a/2.6)\} \times (1/1000)$

F_a = 433 kg

Coarse aggregate content:

$V = \{(105/1.47) +(266/1.6) +(600/2.3) +(1/ (1-0.35) +(C_a/2.8)\} \times (1/1000)$ C_a=876.45 kg

4. CONCLUSION

From both the Mix's created for the 100% flyash based Geopolymer concrete, Mix-2 had shown better results as compared to Mix-1. The desired target mean strength had been achieved in Mix-2 as a result Mix-2 had been finalized for the future work purpose.

The test results show that as the replacement with 20% PFP increases the compressive strength and Split tensile strength for 14M and 16M solutions, replacement above 20% PFP for same molarity decreases both compressive and split tensile strength.

In 10% replacement specimens the compressive strength and split tensile strength of 12M, 14M and 16M solution increased by 15%, 10% and 10% respectively.

In specimens with 20% PFP replacement, the compressive strength and split tensile strength of the 14M and 16M solution increases about 3%, while the compressive strength and split tensile strength of 12M solution specimen decreases about 3%.

Form the results; it is also observed that, the molarity has significant effect on the compressive strength and split tensile strength for all three solutions of 12M, 14M and 16M. The strength increases as molarity increases.

In the replacement of 30% PFP, the compressive strength of 12M and 16M solution specimen decreased about 22% and 33% respectively, and the split tensile strength decreased by 26% and 25% respectively. Whereas the compressive strength and split tensile strength of 14M solution specimen remains almost same.

5. FUTURE SCOPE

- Utilization of Geo- Polymer reduces pollution.
- It is Cost effective.
- It uses less quantity of water, so it can be more effective.
- It is also a light weight.

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