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REVIEW: AN OVERVIEW OF GEOPOLYMER CONCRETE

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Abstract-The world's most used construction material is concrete comprised of cement, aggregate, water, and added substances as it is seen as progressively flexible, tough, and dependable. Concrete is the second most useful material after water, which required huge amounts of Portland cement. The manufacturing procedure of Ordinary Portland Cement (OPC) emits a lot of CO2 which is very harmful to the environment. The amount of carbon emission is increasing day by day hence have to find an alternative of cement concrete. Geopolymer concrete is the best alternative of Portland cement which is manufactured by organic compound molecules. Fly Ash, is a measurable component of geopolymer concrete which is available in a lot of amounts. Fly ash is a waste by-product of thermal power plant its is easily accessible around world. Fly ash is rich in silica and alumina which when mix with alkaline activators makes and binding material knows as alumina silicate gel. This is the best alternative for construction material in place of Portland cement concrete. Geopolymer concrete a greener substitute for normal Portland concrete cement. This paper tells about the constituents of geopolymer concrete, its quality, and its applications.

Keywords: Geopolymer Concrete, Fly Ash, Strength, Applications.

1. INTRODUCTION

The name geopolymer was formed via a French Professor Davidovits in 1978 to symbolize a huge variety of substances characterized through networks of inorganic molecules (Geopolymer Institute 2010)1, 2 &three. The geopolymers rely upon thermally activated herbal materials like Meta kaolinite or business byproducts like fly ash or slag to offer a source of silicon (Si) and aluminum (Al). These Silicon and Aluminium is dissolved in an alkaline activating solution and eventually polymerizes into molecular chains and end up the binder.

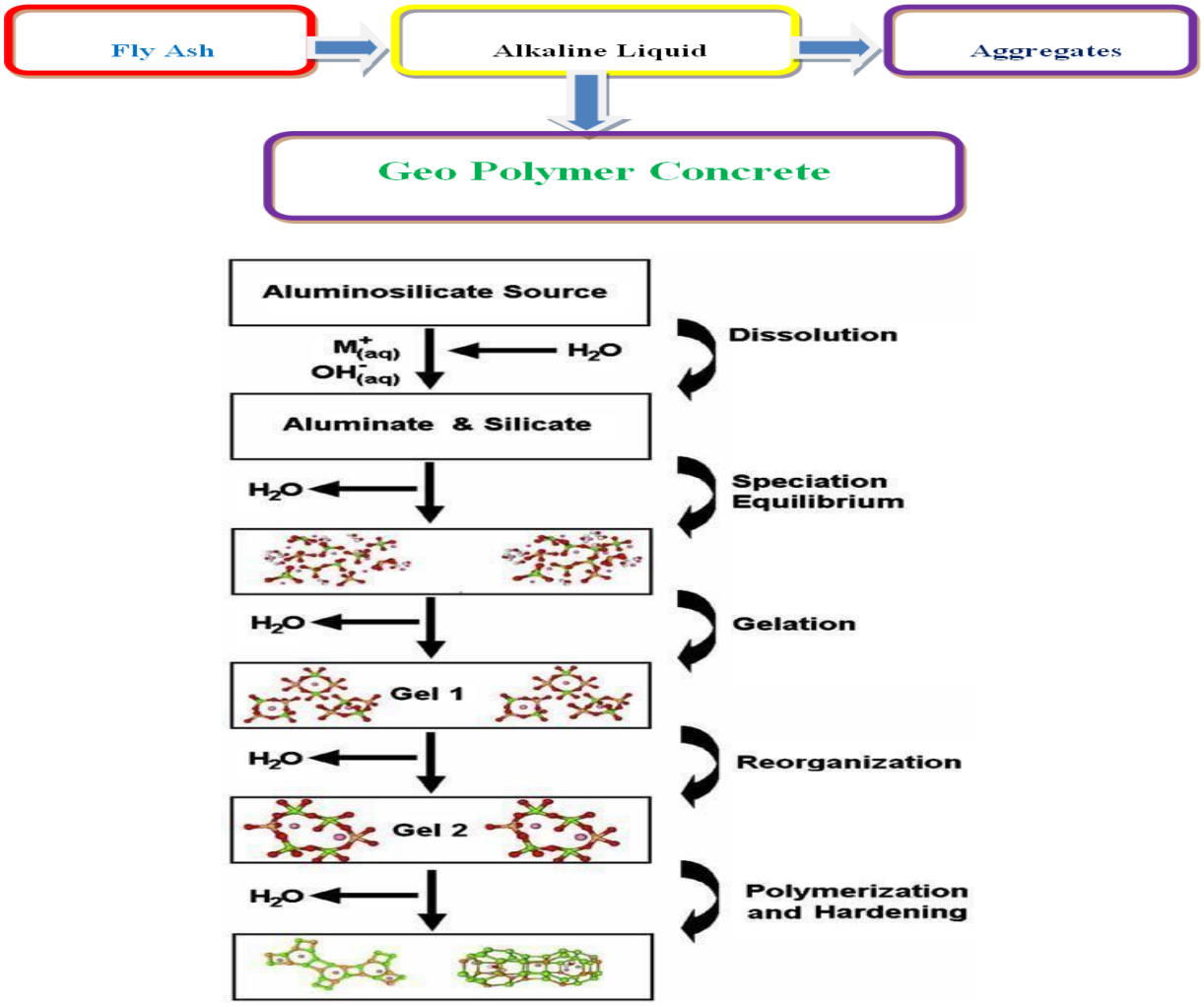

Fig. 1.1 Geopolymer Development Model

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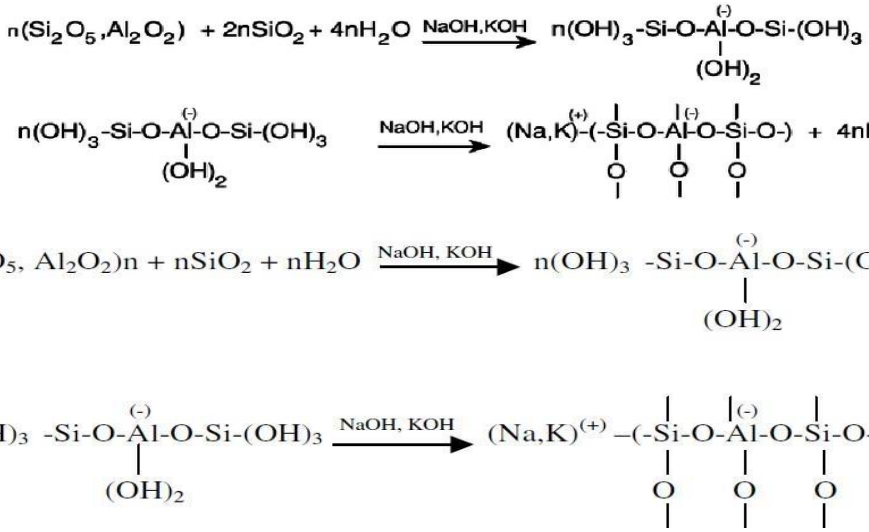
It is a brand new kind of binder produced by the reaction of aluminum silicate with alkali. In this binder, no Portland cement is worried. It is the most effective Al/Si fabric and alkali. It is an environmentally pleasant concrete, which could lessen CO2 emission, is the improvement of inorganic aluminum-silicate polymer, referred to as geopolymer, synthesized from substances of the geological origin or through the use of by-product materials consisting of Fly ash that is wealthy in silicon and aluminum(Saeed A, et al 2012, Phair J.W 2006, Cox P.M, et al 2000). According to Davidovits J. (1994), geopolymer is an alkali- poly (Sialate- Siloxo) binders attributable to the inorganic polycondensation response yielding 3- dimensional polymeric framework.
The polymerization by the alkaline can be shown as:



Geopolymers can be grouped in the family of inorganic binders, which are formed by the reaction of solid aluminum silicate with a high concentration of alkali or alkali Al-Si material produced from a water glass solution (Duxson P, et. al 2006, Hardjito D. et. al 2005). The source materials are either materials of geological origin which are rich in silicon and aluminum compounds or industrial waste products such as BFS, FA, S.F, Kaolin, Clay, etc. The alkalis used are sodium silicate (Na2SO3) and sodium hydroxide (NaOH). Geopolymer concrete is a brand new innovation in production in which Ordinary Portland cement (OPC) is definitely absent but is replaced with pozzolanas which have an abundance of Si and Al commonly found in Fly ash and other agro-waste materials.

2. IMPORTANCE OF GEOPOLYMER CONCRETE

Producing 1 tonne of cement required approximately 2 tonnes of raw substances (shale and limestone) and releases 0.87 tonnes of CO2, about 3 kg of Nitrogen Oxide (NOx), an air that comes out contribute to the level of smog and 0.4 kg of PM10 (particulate depend on a size 10 µm), airborne particles also being produced that is dangerous to the respiratory tract when inhaled. The worldwide emission of CO2 from all resources is generating about 23 billion tonnes in 12 months and the Portland cement production accounts for approximately 7% of total CO2 emissions. The Thermal Industry produces a waste called flyash that is dumped on earth, occupies larges regions. The wastewater from the Chemical Industries is discharged into the floor which contaminates floor water. By producing Geopolymer Concrete all the above-noted problems would get solved with the aid of rearranging them. Hence geopolymer concrete does now not consists of any a part of cement so no cement is needed for producing it. Therefore less manufacturing of cement which will bring about less emission of CO2 which is good for the environment. If geopolymer concrete is developed, more amount of thermal power plant wastes can be utilized in the construction field with the reduction in the usage of Portland cement which will also contribute to reducing global warming.
Cement production also needs a big amount of limestone which is visible depleting. On the opposite hand, there is a huge quantity of fly ash produced that is a by-product produced throughout the combustion of coal and big a part of it's far disposed inside the landfills which affect the groundwater in addition to surface sources of water. Hence it is of maximum significance to apply alternate pozzolan materials in an effort to utilize waste produced in addition to lower the destructive impact of on environment and additionally improve the performance of concrete.

3. CONSTITUENTS OF GEOPOLYMER CONCRETE

The following are the constituents of Geopolymer concrete

3.1 Fly Ash- Rich in Silica and Aluminum

It is a byproduct derived from the combustion of coal in thermal power plants with rich silica and alumina content when used in concrete will help reduce the adverse effect on the environment as a replacement of cement.
Fly ash is a by-product collected in the de-dusting of gases derived from the combustion of pulverized coal used in power plants. Fly ash is composed of fine particles, and its chemical composition is related to the different types and relative amounts of incombustible materials present in the coal. Fly ash particles are typically spherical, ranging in

diameter from less than 1 μm to no more than 150 μm (Malhotra, Concrete Construction Engineering Handbook, 2008).

3.2 Aggregates

Conventional fine and coarse aggregates of standard sizes are used in geopolymer concrete.

3.3 Alkaline Solutions

Sodium hydroxides and sodium silicates are used. These alkaline solutions on reacting with silica and alumina from source materials such as fly ash and aggregate will form binder material which imparts strength to concrete.
Alkaline activators are the important solution for the making of a geopolymer mix as it undergoes geopolymerization and offers binding assets by igniting the Al and Si inside the cementitious binder It mainly utilizes the high proportion of pH activators like the combination of sodium hydroxide or potassium hydroxide and sodium silicate or potassium silicate.
The Geopolymer Concrete Mix Was Prepared as Follows:

$$NaOH \text{ (in water)} + Na_2SiO_3 \Longrightarrow \text{Alkaline Liquid}$$

$$\left.\begin{array}{l}\text{Alkaline Liquid + Super plasticizer}\\ \text{+ Extra water + Aggregate + silica fume}\end{array}\right\} \Longrightarrow \text{Geopolymer Concrete}$$

4. PROPERTIES OF GEOPOLYMER CONCRETE

The various properties of Geopolymer concrete, based on Prof. B. Vijaya Rangan and Hardijito, are:

- Geopolymer concrete is an eco-friendly construction material and the best alternative to cement concrete. Use of geopolymer decreases the demand of Portland cement which is responsible for high CO2 emission
- The drying shrinkage is much less as compared to cement concrete. This makes it well proper for thick and closely constrained concrete structural participants.
- It has a low heat of hydration as in comparison with the cement concrete
- The fire resistance is good than OPC based concrete
- It has better protection to reinforcement steel from corrosion as compared to cement concrete
- This concrete found to possess very high acid resistance when tested under exposure to 2% and 10% sulphuric acids.

Different researchers have worked on the physical and chemical properties of geopolymers. Geopolymer was reported to have excellent mechanical and durability properties especially in the environment (Davidovits 1994, Sofi M, et., al 2007, Wallah S.E, et. al 2003). Some of these properties are stated below:

4.1 Compressive Strength

One of the major properties of Portland cement concrete is its high compressive strength which increases with age. However, the present construction requires a high early strength concrete so as to complete the project on schedule. Moreover, various studies conducted on geopolymer concrete showed high early strength. Aleem et. al 2012, reported that high and early strength was obtained in geopolymer concrete mix. They obtained average of 38 Mpa and 52 Mpa at 7 days and 28 days respectively. The strength of geopolymer concrete increases with increasing temperatures and morality of the mixtures.

4.2 Resistance to Acid Attack

Portland cement concrete is not resistant to acids. Most acid solutions will gradually or rapidly disintegrate Portland cement concrete depending on the concentration. Geopolymer concrete accomplished better in resistance to acid attack.
Rangan 2010 observed that the better performance of geopolymer concrete to acid attack is a result of the low calcium content of the component material.

5. APPLICATIONS

In the fast time period, there may be a big capacity for geopolymer concrete applications for bridges, consisting of precast structural factors and decks as well as structural retrofits the usage of geopolymer-fiber composites. Geopolymer technology is most superior in precast packages due to the relative ease in coping with sensitive substances. Geopolymer concrete can be used for the repair of pavements, bridge decks, retaining walls.

5.1 Economic Benefits of Geopolymer Concrete

Geopolymer concrete is estimated to be about cheaper than that of Portland cement concrete. In addition, the appropriate usage of fly ash earns approximately one carbon-credit which in terms of environmental aspect makes it more economical.
One tons of fly ash can manufacture approximately three cubic meters of high-quality fly ash based Geopolymer concrete. When it is utilized in infrastructure, the very drying shrinkage, the low creep, the excellent resistance offered

by geopolymer concrete has economic benefits.
It has more durability than the standard concrete and requires less repair, thus saves a huge amount of money to be spent on repair works and maintenance concrete-based infrastructure

6. LIMITATIONS

- Geopolymer concrete did not harden immediately at room temperature as in cement concrete.
- Geopolymer concrete doesn't set immediately it has a long setting time and takes minimum of 3 days to settle completely.

7. LITERATURE REVIEW

Prakash R. Voraa , Urmil V. Daveb The compressive strength of the geopolymer concrete does not change by the ratio of alkaline solutions to fly ash by mass. The ratio of sodium silicate to sodium hydroxide by mass has resulted into the higher compressive strength as compared to the ratio of for the geopolymer concrete. The geopolymer concrete compressive strength increases with increase of concentration in terms of molarities of sodium hydroxide. The geopolymer concrete compressive strength increases with increase in the curing time.
Raijiwala etal finded out that the geopolymer concrete compressive strength increased over controlled concrete by 1.5 times. The split tensile strength of geopolymer concrete also get increased over controlled concrete by 1.4 times and Flexural Strength of geopolymer concrete increased over controlled concrete by 1.6 times.
Koti Chiranjeevi, M.M. Vijayalakshmi, Praveenkumar T R Geo-polymer concrete using Nano silica has an high compressive strength and is suitable for structural applications.
“Rangan, B.V. et al stated that Geopolymer concrete is resistant to heat and resistant against various acid attacks, sulphate attack, & alkaliaggregate reaction. The Geopolymer concrete made up of fly ash is very prominent since it may cause flash setting which contains calcium plays a major role. These type of structures made up of geopolymer concrete can be adapted to marine environment.
Chanh et al proved that higher resistance is provided by means of fly ash-based geopolymer towards aggressive surroundings. As such, this pleasant of resistivity can be used to construct structures which can be uncovered to marine surroundings
D. Bondar etal noticed that thef geopolymer concrete strength decreased as the ratio of water to geopolymer solids by mass increased. Anuar etal revealed that the concentration (in term of molarity) of NaOH influenced the geopolymer concrete characterstic strength
Joseph Davidovits noticed that when fly ash and alkaline solution are mixed together they reacts with each other and formed a binding material. Hardijito & Rangan noticed that higher concentration of sodium hydroxide (molar) results in higher compressive strength and higher the ratio of sodium silicate-to-sodium hydroxide liquid ratio by mass, showed higher compressive strength of geopolymer concrete
J. Guru Jawahar et al. stated that the GGBS based Geopolymer concrete can achieve higher compressive strength as fly ash based Geopolymer concrete. They found a compressive strength of 57.6 Mpa after 28 days of curing.
Z. Chen et al. found that the geopolymer concrete gained maximum compressive strength of 32.8 MPa when GGBS & Sewage Sludge Ash (SSA) is being used in making of geopolymer concrete.
P.K Nath et al. found a significant increment of compressive strength of the geopolymer concrete when fly-ash is replaced by GGBS. They have experimented with four mix designs of GPC with GGBS in their research Viz.- S00 (0% GGBS), S10 (10% GGBS), S20 (20% GGBS) and S30 (30% GGB)
M.A.M. Ariffin et al. indicated that geopolymer concrete has superior durability performance compared to OPC concrete in the sulfuric acid environment
Joshi et al. found that the fly ash-based geopolymer concrete when the heat curing is done showed excellent resistance to chloride attack when exposed sodium chloride solution up to 90 days [28]. Sanni et al. confirmed improved resistance for chloride.
Sanni et al. confirmed change in resistance for chloride permeability and corrosion risk level at low rate through Rapid Chloride Penetration Test where maximum and minimum 1968 and 1548 coulombs for 28 days for M30 and M40 grade of Geopolymer concrete
K. Pasupathy et al. found that the low calcium fly ash based geopolymer concrete has less resistance against the saline environment as compared to the OPC concrete. They stated this may be due to the high porosity of the GPC than the OPC concrete which allowed the chloride ions to penetrate inside the concrete.
Khalid Bashir reported that there is an increase in compressive strength of geopolymer concrete when the ratio of alkaline liquid (Sodium silicate/Sodium Hydroxide) is increased.
Hardjito et al. also reported that increasing the alkaline liquid ratio from 0.4 to 2.5 with the same concentration of Sodium Hydroxide resulted in an increase in compressive strength.
B. Singh et al studied the topic “Geopolymer concrete The study included various parameters such as C-S-H effect, effect of admixtures, curing conditions, , geopolymer concrete fresh and hardened properties and durability. The study concluded that geopolymer concrete can be used as a construction material in several applications
“Rangan, B.V. et al stated that Geopolymer concrete is more resistant to heat, sulphate attack, water ingress & alkaliaggregate reaction. The role of calcium in Geopolymer concrete made up of fly ash is very prominent since it

may cause flash setting. Such structures with high durability can be adapted to marine environment.
"Wallah et al, explained that, fly-ash based geopolymer concrete which is heat cured, undergoes low creep and shows very little drying shrinkage as of about 100 micro strains at the end of one year. And it shows excellent resistance to sulphate attack [17].
Sathia et al., proved that when geopolymer is exposed to acid solution, only 0.5% of weight is lost when compared to normal concrete immersed in 3% sulphuric acid [7].
Aleem et al. stated that, the Geopolymer Concrete can be used in the precast industries it can be produced more in less time and the break during transportation can also be minimized. Geopolymer concrete should be effectively used for the beam column reinforced concrete structures and infrastructure works. As a result, fly ash will be effectively used and hence no landfills are required to dump the fly ash. [5].
Lokeshappa et al. stated that the rate of utilization of fly-ash in construction field is 38%, the region where the remaining portion of the fly ash is dumped pollutes the environment. So, it is important to carry out research and undertake development for studying the structural properties of fly ash and also to utilize the industrial wastes in the construction [11].

8. FUTURE SCOPE

As geopolymer concrete technology is a new one, there is a lot of scope to work on this topic. A lot of further research can be done on this topic by using by-products like rice husk ash, GGBS, pulverized fuel ash, etc .And also, investigation of Long term properties like durability, creep, drying shrinkage may also give the suitability of geopolymer concrete in the field. Different mixes and techniques can be used to increase the durability and other further properties of geopolymer concrete.

CONCLUSION

Geopolymer concrete is a more sustainable alternative to OPC concrete due to its both strength and use of waste byproducts and reduces the emission of Co2 in the manufacturing of cement which is good for the environment. Due to his high early strength, it can be used in precast works. Geopolymer concrete is more resistant to heat and corrosion its has more tensile and flexural strength as compared to ordinary cement concrete its is also a green concrete and does not harm the environment it has fast setting time its is the best alternative for cement concrete.
Geopolymer concrete can be used easily as an alternative to ordinary portland cement concrete its also satisfy all the conditions and can be used in all conditions that same of portland cement concrete. the geopolymer concrete shows high compressive strength than that of portland cement concrete and its get hardened like the normal portland cement concrete it can be easily mixed with low alkaline activating solutions and makes the concrete to prevent from various acid attacks and can be used under natural conditions. Geopolymer concrete can ne used for repairing pavements, retaining walls, pre cast members and for various rennovation works.

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