Strength Of Geopolymer Concrete By Using Mineral Admixtures: A Review

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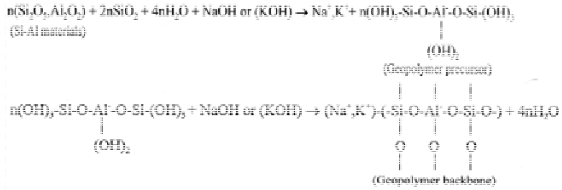
Abstract— *Utilization of waste materials has been encouraged in construction field for the production of cement and concrete because it contributes to reducing the consumption of natural raw materials as resource and also reducing emission of greenhouse gases. All of these conditions have led researchers to look into alternative materials with high compressive strength that are also cheap and more environmentally friendly to use as building materials . Geopolymer is a promising alternative binding material to OPC which is a major contributor on the release of CO2 that causes global warming. Geopolymer has been proven to be environmental friendly and low energy consumptive material. It contains flyash, alkaline solution as binding material. Mineral admixtures are added to increase the strength and polymerization process. In this paper it concludes the strength and properties of geopolymer mixtures containing different mineral admixtures like GGBS, slag, rice husk, flyash, bentonite, alccofine, etc.*

Keywords— ***Geopolymer concrete, Mineral admixtures, GGBS, slag, rice husk, flyash, bentonite, alccofine***

I. Introduction

A. GEOPOLYMER

Portland cement concrete industry has full-fledged universally in recent years.The demand for concrete as a construction material has enlarged due to enhance of infrastructure. However , production of Portland cement concrete generates problems such as carbon di oxide emission, global warming. Geopolymers are inorganic polymeric binding materials, developed by Joseph Davidovits in1970.Geopolymer is a type of amorphous alumino silicate cementations material that shows the ideal properties of rock forming minerals. Davidovits proposed that an alkaline liquid could be used to react with silicon and the aluminum in a source material of geological origin. Flyash geopolymers have been prepared as geopolymer pastes, mortar and the concretes. The source materials and the alkaline liquids are the two main constituents of geopolymer. The natural minerals that are rich in silicon and aluminium are the source materials for geopolymers. The alkaline liquid are from soluble alkali metals that are sodium or potassium based. The most common alkaline liquid used in geopolymerisation is a combination of sodium hydroxide and sodium silicate. When fly ash is introduce to concrete that hold portland cement, the mixture widens strength through a series of hydration reactions through which calcium silicate hydrate forms. Contact between portland cement grains and water initiates the reactions. Unlike portland cement hydration, geopolymerization may be described as a three-phase process that is commence by contact between an aluminosilicate material (such as fly ash) and an activate solution. These phases include dissolution, reorientation,and hardening process. Geopolymerization involves a diverse chemical reaction between aluminosilicate oxides and alkali silicate solutions at highly alkaline conditions and mild temperatures elastic three dimensional amorphous to semi-crystalline polymeric and ring structure, which dwell of Si–O–Al and Si–O–Si bonds.



The reaction path point out that Si-Al materials might become raw material for geopolymers. For the finest reaction, alkali activator (alkali solution and sodium silicate) and the favorable environment for retort are requisite. The main factors distressing geopolymerization are type and nature of raw materials, alkaline activators and curing conditions. Longer curing time improves the polymerisation process resulting in high compressive strength.Geopolymer cement concrete needs heat to gain strength

B. CONSTITUENTS OF GEOPOLYMER MIXTURES:

a. *Fly ash:* Fly ash is an industrial waste normally used to replace Portland cement for making mortar. Geopolymer is usually made of fly ash activated with alkaline solution at low temperature and it is sometimes called alkali-activated flyash. Low calcium flyash is used for flyash based geopolymer mixtures.:

b. *Aggregates:* Fine and coarse aggregates are used in Geopolymer mixtures. Maximum size of fine aggregates used are less than 4.75 mm . It constitutes 75-80 % of the mass of GPC and the aggregate are in saturated surface dry condition. .

c. *Alkaline solution:* Alkaline solution comprises mixture of sodium hydroxide solution and sodium silicate solution at room temperature. Sodium hydroxide is available in flakes with purity of 97%- 98% purity. According to essential concentration sodium hydroxide is dissolved in water to make solution.It liberates large amount of heat so it is recommended to leave it for about 24 hours. Sodium silicate, (Na_2SiO_3), known as water glass or liquid glass, is commercially available in liquid form.

d. *superplasticizer:*To advance the workability of fresh concrete, high-range water-reducing naphthalene based super plasticizer was added to the mixture. The dosage of super plasticizer also has an effect on the compressive strength of the concrete.

e. *Water*:Portable water is used for mixing. The water content in Geopolymer concrete is the combined water present in the alkaline solution.

C. Effect of curing:

Curing plays an important role in strength of geopolymer .Strength of geopolymer concrete mainly depends on the temperature of curing and corresponding curing hours. The parameters such as curing time and curing temperature significantly affect the compressive strength of the hardened geopolymer concrete. As the curing temperature increases, the setting time of concrete decreases . During curing process, the geopolymer concrete experience polymerization process. Due to the increasing of temperature, polymerization become more rapid and the concrete can gain 70% of its strength within 3 to 4 hours of curing .

D. Advantages

- Cutting the world's carbon
- The cost of fly ash is stumpy
- High compressive strength
- Fire resistant
- stumpy permeability
- Eco friendly
- Excellent properties within both acid and salt environments.

E. Applications

The wide applications for bridges, such as precast structural elements and decks as well as structural retrofits using geopolymer-fiber composites. Geopolymer technology is most advanced in precast applications due relative ease in handling sensitive materials (e.g., high-alkali activating solutions) and the necessitate for a controlled high-temperature curing environment essential for many current geopolymer systems. To date, none of these potential applications has advanced beyond the development stage, but the durability attributes of geopolymers make them attractive for use in high-cost, severe-enviroment applications such as bridges. Other potential near-term applications are precast pavers and slabs for paving

F. Limitations

Even though several geopolymer systems have been projected ,most are complicated to work with and necessitate great care in their fabrication. In addition, there is a safety risk related with the high alkalinity of the activating solution, and high alkalinity also have need of more processing, ensuing in increased energy utilization and greenhouse gas generation. Additionally, the polymerization reaction is very sensitive to temperatureand usually have need of the geopolymer concrete be cured at elevated temperature under a strictly controlled temperature system . In many respects, these facts may bound the practical use of geopolymer concrete in the shipping infrastructure to precast application. Significant research is in progress to develop geopolymer systems that address these technical hurdle, create a low personified energy, low carbon dioxide binder that has alike property to portland cement. Additionally current research is focusing on the growth of user-friendly geopolymers that do not require the use of highly caustic activating solutions.

- geopolymer concrete requires special handling needs and is extremely difficult to create. It requires the use of chemicals, such as sodium hydroxide, that can be harmful to humans.
- While the idea of geopolymer concrete seems ultimate and could be the best thing to come along since Portland concrete, there are still too many unsound issues that can basis major hiccups in the mixing and application process of the concrete.

II. LITERATURE SURVEY

Mr. Bennet Jose Mathew *et.al,* intended to studyStrength, Economic and Sustainability Characteristics of Coal Ash –GGBS Based Geopolymer Concrete. A combination of 15 molar sodium hydroxide and sodium silicate in the ratio of 2.33 was used. M55 grade OPC concrete (CM). Fly ash - GGBS and bottom ash - GGBS based geopolymer concrete mixes are manufactured separately. in addition mixes were set by replacing fly ash with bottom ash in 10%, 20% and 30% replacement levels (by weight). 100mm cube specimens of each geopolymer concrete mix are cured at elevated temperature at 60oC for 6 hours and then at 100oC for 3 hours. Another set of specimens of each mixes are cured by air curing for 28 days. OPC based concrete is cured in both elevated and ambient temperature by respective standard practices. The strength of concrete specimens and effect of replacement on the strength of fly ash–GGBS based geopolymer concrete is discussed along with cost and environmental impact analysis.It is observed that Curing at elevated and ambient temperature will form fly ash-GGBS based concrete of comparable strengths.Bottom ash –GGBS based geopolymer concrete gives very low strength possibly due to large particle size. Geopolymer concrete can be prepared at comparable cost with OPC based concrete provided transportation system for raw materials is well traditional. The embodied energy of fly ash- GGBS based geopolymer concrete is 40 % less than that of OPC based concrete. Sodium hydroxide (39%) and sodium silicate (49%) together contributes a lion's share to in material form energy of geopolymer concrete while in OPC cement contributes nearly 94% of the total embodied energy.

RohitZende *et.al,* studied On Fly Ash and GGBS Based Geopolymer Concrete under Ambient Curing Condition.Fly ash is replaced by GGBS in proportions of 25%, 50% and 75% to enhance various properties of concrete. The mix design is carried out for 11M and 13M concentration of sodium hydroxide. Alkaline activator solution ratio of 2.5 and alkaline liquid to fly ash ratio 0.40 is selected for this investigation. The specimen of size 150x150x150mm cubes, 150x300mm cylinders and 500x100x100mm prisms were casted and the specimens of geo-polymer concrete are cured at ambient temperature for 7days and 28 days. The cured specimens were then tested for compressive strength, split tensile strength and flexural strength respectively. Cement can be replaced by using fly ash, GGBS in the preparation of geopolymer. It helps in reducing carbon dioxide emission. It is observed that increase in GGBS content reduces the setting time and increases the degree of workability. The increase in slag content in the geopolymer concrete, increases in compressive strength, split tensile strength and flexural Strength. Nearly 80% of the strength is achieved in 7days at ambient curing. Maximum strength is obtained at slag replacement of 75% and the strength is increased as molarity increases.

Prasanna Venkatesan Ramani *et.al,* experimentally studied on the strength and durability properties of geopolymer concrete prepared using the ground granulated blast furnace slag and black ricehusk ash. The geopolymer concrete was initially prepared with ground granulated blast furnace slag as the primary binder instead of cement,and then blast furnace slag was replaced with black rice husk ash. The GGBS was kept as the base material in which the Black Rice Husk Ash was added in different percentages, and its effects on the compressive, flexural and tensile strengths, and durability properties, like Rapid chloridepermeability and resistance to accelerated corrosion, were studied. The strength results show that an optimum proportion of BRHA that can be used in geopolymer concrete is 20 %,considering the target strength of 30 MPa. It can be seen from the durability studies that the geopolymer concrete performed remarkably well with regard to chloride penetration and corrosion resistance for up to 20 % BRHA replacement.These results are very important for the development of such innovative concretes, in which the use of OPC is completely omitted. It promotes the utilization of alternate materials like GGBS and BRHA for binder production. Since these materialsare essentially industrial by-products, it also means a solution. It is possible to produce geopolymer concrete of substantial strength and durability using GGBS and BRHA to their disposal problem.

V. Supraja *et.al,* experimentally studied on Geo-Polymer concrete incorporating GGBS. Different molarities of sodium hydroxide solution i.e. 3M, 5M, and 7M and 9M are taken to prepare different mixes .Thecube specimens are in use of size 100mm x 100mm x 100mm.Two different curing conditions are carried that is oven curing at 500^0c and curing directly by placing the specimens to direct sunlight. The geo-polymer concrete specimens are tested for their compressive strength .For oven curing, the cubes are placed inan oven at 600 c for an hour. Then the cubes are demouldedand kept in oven at 500^0 C for 3 days and 7 days. For the sun light curing, the cubes are demoulded after 1 day of casting and they are placed in the direct sun light for 3 days and 7 days. From results, it is observed that the compressive strength is increased with the increase in the molarity of sodium hydroxide. After 3 days of curing the increase in the compressive strength is not significant. oven cured specimens gives the higher compressive strength but sun light curing is convenient for practical conditions.

A. Allahverdi *et.al,* investigated the geopolymerization of construction waste materials with different alkali-activators based on combinations of $Na_2SiO_3$and NaOH. Waste brick and concrete were used as rawmaterials. The proportion of the waste concrete waslimited to the maximum amount of 60% (byweight), The sodium oxide contents of the designed geopolymer cement mixes were attuned at threedifferent levels of 6, 7, and 8% (by weight of dry binder). The water-to-dry binder ratios (W/DBratios) were adjusted at four different values of 0.26, 0.27, 0.28 and 0.30, for an approximately the same consistency. Laboratory techniques of Fourier Transform Infrared Spectroscopy (FTIR) and Scanning Electron Microscopy (SEM) were utilized for studying molecular and microstructure of the materials. Results obtained for 28-day compressivestrength confirm that waste brick is more suitablethan waste concrete for geopolymerizationreactions.The maximum achievable 28-day compressivestrength is 40 MPa for system comprising of only waste brick and containing 8% Na_2O by weight of dry binder.

Shankar H. Sanni, ***et.al,*** investigated on performance of geopolymer concrete subjected to severe environmental conditions. The grades choosen for the investigation were M-30, M-40, M-50 and M-60, the mixes were intended for molarity of 8M and 12M. The alkaline solution used with the ratio of 2.50 and 3.50.The test specimens were size of 150x150x150 mm cubes, 100x200 mm cylinders heat-cured at 60°C in oven. Durability of specimens were assessed by immersing GPC specimens in 10% sulphuric acid and 10% magnesium sulphate solutions individually, at times monitoring surface corrosion and depth of dealkalization, changes in weight and strength over a phase of 15, 30 and 45 days. The results revealed fly ash based GPC specimens prepared with different alkali content showed varying degree of corrosion when showing to sulphuric acid. Specimens received white deposits on the surfaces for the duration of contact to magnesium sulphate solution which gradually more distorted from soft and flaky shape to hard and rounded shape. GPC and PPCC mixes showed minor changes in weight and strength when the specimens were showing to sulphuric acid and magnesium sulphate. GPC do not have Portland cement, they can be considered as less energy intensive, since Portland cement is highly intensive energy material next only to Steel and Aluminium. GPC utilises the industrial waste for producing the binding material in concrete, hence it can be considered as eco-friendly material.

Bharat Bhushan Jindal ***et.al,*** carried out research on fly ash based geopolymer concretes with different percentages of alccofine and cured at ambient as well as heat environment in an electric oven at 90°C and the effects of percentage of alccofine, curing temperature, a period of curing, fly ash content, was studied on compressive strength as well as workability of geopolymer concrete. . The concentration of NaOH solution was 16 M so as to achieve better compressive strength . 2% Naphthalene Sulphonate based superplasticizer was used to improve the workability of fresh geopolymer mix.The mix design of geopolymer concretes with fly ash was done in reference tothe proposed design mix for the different proportion of fly ash. Similar to that of conventional concrete, coarse and fine aggregates were taken approximately 75-77% by mass of the entire mixture Higher W/GPS ratio improves the workability but reduces the compressive strength. Therefore, a fixed W/GPS ratio of 0.27 was used toachieve higher compressive strength. Alkaline liquid to fly ash (AL/FA) ratio was kept 0.38, 0.42 and 0.46 respectively for mix designated fly ash content 350 kg, 370 kg and 400 kg per meter cubic of geopolymer mix. GPC mixes with different amount of Alccofine 1203 (0%, 5%, and 10%) were also made to analyze its effect on workability and compressive strength of geopolymer concrete. Based on the results it is concluded that Unprocessed fly ash doesn't gain any desirable mechanical properties.The presence of alccofine produces better workable concrete with processed and unprocessed fly ash geopolymer concrete.Minimum required compressive strength for general construction purpose can be achieved with alccofine even at room temperature. The increase in compressive strength is significant at 900C in the presence ofalccofine and perhaps provides an opportunity for the most economical and sustainable way to achieve higher compressive strength. XRD study points out that on the addition of alccofine, amorphous material changes into the crystalline material which is responsible for the improved compressive strength of GPC.

PradipNath. Prabir Kumar sarker ***et.al,*** aimed to achieve fly ash-based geopolymers suitable for curing without elevated heat (21 - 23°c). Geopolymer concrete and mortar mixtures were proportioned with different mix variables which include the amount of GGBFS in replacement of fly ash, as 10%, 20% and 30% of total binder respectively. Varying ratio of sodium silicate to sodium hydroxide (SS/SH) as 1.5 and 2.0 respectively.Slump and flow test was conducted immediately after mixing. Compressive strength test was conducted at 3, 7, 28 and 56 days. The test was conducted in a temperature of 21–23°c. Adding of GGBFS in the fly ash based geopolymer mixture reduces the workability and setting time, Slump of concrete and flow of mortar decreased with the enhance of slag. Fly ash based geopolymer modified with GGBFS is found to be a suitable binder for low to moderate strength concrete production at ambient curing condition, as it eliminates the necessity of heat curing. Among the mixtures of this study, the mixtures having 10% slag, 40% alkaline activator and SS/SH ratio 1.5–2.5 with no extra water can be considered as the optimum mixture for reasonable compressive strength in ambient curing condition.

Shweta Mane ***et.al,*** studied on the effect of elevated temperatures on geopolymer mortar and concrete for different types of coarse and fine aggregates, also they are compared with the OPC concrete of M20 grade. Coarse aggregates used for concrete specimens are basalt and granite aggregates while natural river sand and crushed sand are used as fine aggregates for mortar specimens. OPC and Geopolymer specimens were tested for compressive strength .After that the specimens were subjected to elevated temperatures 40ºC, 100ºC, 200ºC geopolymer mortar has better compressive strength (81% more for natural sand and 89% more for crushed sand) than the general OPC mortar. The fly ash-based Geopolymer concrete shows good fire resistance and shows less reduction in compressive strength than the general OPC concrete, without causing spalling. In both the cases, OPC and GPC concrete, granite aggregates show more (5.63% more) strength than the basalt aggregates. For mortar, crushed sand show better performance (10.49% more strength) than the natural river sand. Geopolymer produces a substance that is comparable to or better than traditional cements. Low-calcium fly ash-based geopolymer concrete offers several economic benefits over Portland cement concrete as the cost of one ton of fly ash is only a small fraction of the cost of one ton of Portland cement., 300ºC, 400ºC and 500ºC. Fly ash based geopolymer concrete has excellent compressive strength (68% more for basalt aggregates and 67% more for granite aggregates) than the general OPC concrete and is suitable for structural applications.

Mohammed Haloob Al-Majidi *et.al,* experimentally investigated on the mechanical and micro structural properties of geopolymer concrete mixes using fly ash and GGBS .Fly ash based Geopolymer concrete requires high temperature curing treatment in order to develop early strength properties which is considered as a limitation for cast in place concrete applications. Fresh geopolymer mortar properties were examined through workability, and setting time, mechanical performance and physical and chemical characteristics of hardened mortar were evaluated by compressive strength tests, direct tensile tests, flexural strength tests, SEM-EDS, porosity, and FTIR analysis and thermal heating. From results, it is revealed that increasing in GGBS content in the flyash based geopolymer mortar decreases the workability and increases the setting time and hardening in fresh geopolymer mortar. In hardened geopolymer mortar increasing in GGBS increases the compressive strength and reduces porosity. Geopolymer mixes with increased GGBS content had considerably improved flexural and direct tensile strength, without any heat curing treatment which makes the proposed method suitable for in situ applications.

III. CONCLUSION

From the past research studies, it can be sequel that:

1. Geopolymer concrete can be prepared at comparable cost with OPC based concrete provided transportation system for raw materials is well traditional.
2. Increase in GGBS content reduces the setting time and increases the degree of workability. The increase in slag content in the geopolymer concrete, increases in compressive strength, split tensile strength and flexural Strength
3. As the molarity increases, Strength is also increased. Different mineral admixtures like GGBS, slag, rice husk, bentonite, alccofine can be partially replaced for flyash.
4. Oven cured specimens gives the higher compressive strength but sun light curing is convenient for practical conditions.
5. GPC utilises the industrial waste for producing the binding material in concrete, hence it can be considered as eco-friendly material.

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