International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 3 Issue 2, February - 2014

Geopolymer Concrete - A Brief Review

Dr. S. G Patil
Professor in Civil Engineering
Poojya Doddappa Appa College of Engg.
Gulbarga, Karnataka, INDIA

Ram Panth
Research Scholar & Asst. Professor
Guru Nanak Dev Engineering College
Bidar, Karnataka, INDIA

Abstract - Large quantities of Portland cement is one of the major generator of carbon dioxide, into the atmosphere causing environmental problems and In addition to that large amount of embodied energy also being consumed for the cement production and also consumes huge amount of the natural resources i.e. limestone and fossils fuel but also produces almost 0.9t of CO2 for 1t cement clinker production. Also world cement production generates 2.8 billion ton man-made greenhouse gas annually on the other side abundant availability of fly ash worldwide creates opportunity to utilize (by – product of burning coal, regarded as a waste material) as substitute for OPC to manufacture concrete solving the disposal problem and substitute to concrete by an eco friendly and sustainable material similar to conventional concrete. Geopolymer or inorganic alumino-silicates polymer is synthesized from predominantly silicon and aluminum materials of geological origin or by product materials, such as fly ash with alkaline liquids such as a combination of Sodium Silicate and Sodium Hydroxide . The chemical composition of geopolymer is similar to that of zeolite, but amorphous in microstructure. Flyash-based geopolymer binders show excellent short and long-term mechanical characteristics and similar or even better to conventional concrete and geopolymers are much superior to aggressive environment and fire than conventional concrete.

KeyWords: OPC, flyash, slag, alkaline liquid, geopolymer concrete; strength, durability.

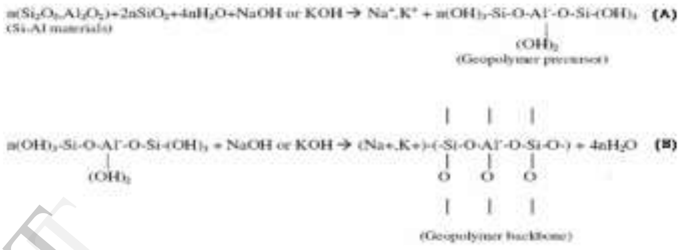
1. INTRODUCTION

The term geopolymer was introduced by Davidovits to represent the mineral polymers resulting from geochemistry. The polymerization process involves a chemical reaction under highly alkaline conditions on Al-Si minerals, yielding polymeric Si-O-Al-O bonds, as described by[1]

$$Mn [– (Si – O2) z – Al – O] n. wH2O \quad (2)$$

Where M is the alkaline element, the symbol – indicates the presence of a Bond, z is 1,2, or 3, and n is the degree of polymerization. Exact mechanism by which geopolymer setting and hardening occur is not yet clear and is under research.

The reaction of fly-ash with an aqueous solution contains NaOH and Na_2SiO_3 in their mass ratio, results in a material with 3D polymeric chain and ring structure consisting of Si-O-Al-O bonds. The schematic formation of geo-polymer material can be shown as described by Equation A and B and the end product of this process is an amorphous polymeric material.



Geopolymer concrete is a type of concrete which does not utilize any Portland cement in its production but, the binder is produced by the reaction of an alkaline liquid with a source material that is rich in silica and alumina.

2. CONSTITUENT MATERIALS OF GEOPOLYMER CONCRETE

Geopolymeric source materials (GSMs) are rich in silica and alumina, which could be natural minerals (such as kaolinite, clays, etc) or industrial by-products (such as fly ash, silica fume, slag, rice-husk ash etc). - Alkaline Activator Solution (AAS) based on alkali metals (commonly Sodium or Potassium) based. The most common AAS is a combination of alkali hydroxide
(NaOH, KOH) and alkali silicate (Sodium or potassium silicate) minerals containing reactive oxides of silicon and aluminium can be activated by suitably formulated highly alkaline liquid to obtain inorganic polymeric binding material [Sindhunata, 2006]. The following are the constituents for ambient curing, if slag is not used than high temperature curing is required. [Rajamane, 2009a]:

-Fly ash,
- Ground Granulated Blast Furnace Slag (GGBS),
- Fine aggregates (in the form of river sand),
- Coarse aggregates (in the form of crushed granite stone),
- Alkaline Activator Solution (combination of solutions of alkali silicates and hydroxides, besides distilled water)

A. Basic mixture proportions

No standard mix design approaches are yet available for GPCs. Djwantoro Hardjito, et al (2004), showed that the geopolymer paste binds the coarse aggregates, fine aggregates and other un-reacted materials together to form the GPC, and usual concrete technology methods to produce GPC mixes can be often employed Mixture proportions are characterized by an alkaline liquid to fly ash by mass of 0.35 and aggregate to total mass proportion of approximately 75% with the nominal strengths.
GPC Mix Design.

Djwantoro Hardjito, et al (2004), showed that the geopolymer paste binds the coarse aggregates, fine aggregates and other un-reacted materials together to form the GPC, and Usual concrete technology methods to produce GPC mixes can be often employed. As in the Portland cement concrete, the aggregates occupy the largest volume, (about 75-80 % by mass) in GPCs. The silicon and the aluminium in the fly ash are activated by a combination of sodium hydroxide and sodium silicate.

3. FRESH GEOPOLYMER CONCRETE

Fresh geopolymer concrete has been reported to be highly viscous and cohesive with low workability fresh geopolymer concrete became stiff in a short time, thus implying a short initial setting time. To improve the workability of mortar, superplasticiser or extra water can be added. However, the use of superplasticiser had an adverse effect on the strength of geopolymer. As such, extra water gives higher strength than addition of superplasticiser.

A. Curing
Curing temperature is an important factor for the strength point of view of geo-polymer concrete, the main polymerization process or the chemical reaction of Geopolymer concrete takes place with the temperature imposed to it during the curing, Generally the curing which is done for geopolymer is hot steam curing or normal hot curing in oven with in a temperature of 600C-900C for 24 hours, Beyond 600C it doesn't affect the polymerization process and beyond 24-48 hrs of curing is insignificant for strength development, Ambient temperature curing is effective if the fly ash content is partially replaced by calcium based additive like GGBS. (Ground Granulated Blast Furnace Slag), slag upto 30% of total binder is sufficient for 28 days ambient temperature curing.

B. Density
The density of the geopolymer concrete was 2360 ±60 kg/m3.

4. HARDENED GEOPOLYMER CONCRETE

A. Compressive strength

Significant factors affecting the compressive strength are the curing temperature, curing time, and the type of alkaline activator. Longer curing time and higher curing temperature increased the compressive strength, although the increase in strength may not be significant for curing at more than 60^{o}C and curing for periods longer than 48 hours , As the H_2O-to-Na_2O molar ratio increased the compressive strength of geopolymer concrete decreased, the compressive strength decreased when the water-to geopolymer solids ratio by mass increased, (total mass of water in the mixture is the sum of water contained in the sodium silicate solution, the mass of water in the sodium hydroxide solution, and the mass of extra water, if any, added to the mixture. The mass of geopolymer solids in the mixture is the sum of the mass of fly ash, the mass of sodium hydroxide flakes, and the mass of solids in sodium silicate solution) Application of GGBS in geo-polymer concrete which is some replacement of fly-ash shows a good result in the compressive strength in ambient temperature, 55 MPa after 28 days full room temperature curing. Upto a replacement of 30% of fly-ash with GGBS shows this result. Other than this replacement shows a lower result. With the application of GGBS with geo-polymer to a certain percentage (25%) of fly-ash doesn't need high temperature for curing during the early period of casting and gain same or maybe high strength then the geo-polymer cured at high temperature almost of 60 to 90^{O}C for 24hrs during 24 to 48 hrs of casting. Use , behavior and effect of fibers on geopolymer concrete is similar to Portland cement concrete . Light weight are also achieved in geopolymers and the behavior is similar to conventional light weight concrete [3]. Modulus of Elasticity of geopolymer concrete is slightly less than conventional concrete.

5. FACTORS AFFECTING STRENGTH OF GEOPOLYMERS

A. Molarity
Molarity of NaOH solution plays a vital role in the strength of geopolymer concrete with a higher concentration of NaOH solution a higher compresht sive strength can be achieved, A satisfactory result was obtained at a molarity of 16M beyond which the test results fall down. From 8M to 16M[20] there was a rise in the Compressive strength for all mixes

B. Sodium silicate to Sodium hydroxide ratio
A ratio of 2.5 gives a higher compressive strength further stated that geopolymer with a ratio of 1.5 gives the optimum result which was 48Mpa. A ratio of 2.5 gives a result of 71MPa [21].

C. Water to geopolymer solids ratio.
In this parameter the total mass of water is the sum of the mass of water contained in the sodium silicate solution, the mass of the water use in the making of the sodium hydroxide solution and the mass of extra water, if any, present in the mixture. The mass of geopolymer solids is the sum of the mass of fly ash, the mass of sodium hydroxide solids used to make the sodium hydroxide solution and the mass of solids in the sodium silicate solution i.e. the mass of Na_2O & SiO_2. A ratio of 0.17 to 0.18 provides a good result and above 0.18 the results decrease continuously [2].

D. Fly ash and alkaline activator ratio.

Higher fly ash content with a higher alkaline activator content gives a high compressive strength and vice versa, geopolymer with a ratio of 1.4 to 2.3 provides a high compressive strength.

E. Rest Period:

Rest period is time between casting and curing and is of 3 hour to 2 days, Inclusion of a 24 hour period before curing, or rest day, increased the compressive strength of geopolymer concrete.

6. REINFORCED GPCS

Parameters that effect structural geopolymer concrete are similar to that of ordinary concrete and therefore IS 456:2000 can be applied conservatively .Load carrying capacity of geopolymer beams and slabs are slightly higher than normal concrete at similar concrete strengths and the behavior of geopolymer flexural members are similar as well. The load capacity and behavior of geopolymer columns are similar to the conventional concrete. The bond strength of geopolymers is significantly higher than that of conventional concrete.

7. LONG TERM PROPERTIES

The creep and shrinkage of geopolymers are substantially lower than conventional Portland concrete. Drying shrinkage strains of fly ash-based Geopolymer concretes were found to be insignificant. The ratio of creep strain to- elastic strain (called creep factor) reached a value of 0.30 in approximately 6 weeks after loading on the 7th day with a sustained stress of 40% of the compressive strength.

8. DURABILITY OF GEOPOLYMER CONCRETE

It shows a higher resistance to sulphate attack after full immersion for 15 weeks in different % of magnesium sulphate solution in terms of weight loss and compressive strength as compared conventional concrete. The performance of geopolymer materials when exposed to acid solutions was superior to ordinary Portland cement concrete. Bakharev [5] investigated the durability of geopolymer materials manufactured using class F fly ash and alkaline activators when exposed to a sulphate environment. The material prepared using sodium hydroxide had the best performance, which was attributed to its stable cross-linked aluminosilicate polymer structure. The effect of corrosion resistance was studied by Miranda et al [7] utilized activated flyash mortars in construction industry which performed well and also reducing corrosion of reinforcing steel in flyash concrete. Geopolymer materials do not generate any dangerous alkali-aggregate reaction, even in the presence of high alkali content.

9. CONCLUDING REMARKS

Geopolymer concrete shows significant potential to be a material for the future, because it is not only environmentally friendly but also possesses excellent mechanical properties, both in short term and long term and durability. Basic mixture proportions characterized by 75% aggregate to total mass, alkaline liquid to fly ash of 0.35 (analogous to water to cement ratio) and elevated temperature curing results in a high strength geopolymer concrete. Ambient curing of geopolymer has been trialed and further mixture trials with ambient curing are presently being researched. Works on reinforced GPC are not many and however, the existing test results shows that structural behavior of GPCs and CCs are essential and similar in nature, except that sometime at the same strength level, GPCs may tend to have lower modulus of elasticity. Contrastingly, GP composites have performed better than P-C composites in durability related tests such as Sulphate, acid and corrosion resistance. This is mainly due to polymeric nature of GP matrix without presence of free Lime. Fly-ash based geo-polymer mixed with alkali solution shows a high result with a higher ratio of sodium silicate to sodium hydroxide mix. With the increase in the ratio gives a high strength and also with the increase in curing temperature from 30 deg C to 90 deg C gives a high strength during the period of 24hrs to 48 hrs of the casting i.e. the 2nd day of casting. Further research is needed to understand the science behind geopolymer technology like microstructure, rheology of fresh concrete and a large data base of various characteristics of geopolymer concrete should be collected in order to prepare design tools and codes/standards for this new material. The economic benefits and contributions of geopolymer concrete to sustainable development are evident.

REFERENCES

1. Davidovits, J. 1991 “Geopolymers: inorganic geopolymeric new materials” Journal of Thermal Analysis, 37, pp. 1633-1656.
2. A.Palomo, M.W.Grutzeck and M.T.Blanco, (1999), “Alkali-activated fly ash as cement for the future Cement Concrete”, 29, 1323-1329.
3. D. Hardjito, S. Wallah, M. Sumajouw and V. B. Rangan, (2004), on the “Development of fly ash-based geopolymer concrete”, ACI Materials Journal .s 101, 467-472.
4 Siddiqui KS 2007, “Strength and durability of low –calcium fly-ash based geopolymer concrete”, final year Honours dissertation, The University of Western Australia, Perth.
5 D. Hardijito, (2005), “Studies of fly ash-based geopolymer concrete”. PhD Thesis, Curtin university of Technology, Perth, Australia.
6 Anuar K.A, Ridzuan A.R.M., Ismail S., Universiti Teknologi MARA 40450 Shah Alam, Selangor, Malaysia, “Strength Characteristic of Geopolymer Concrete” - International Journal of Civil & Environmental Engineering, Vol: 11 No: 01 February 2011.
7 Hardjito, D. and Rangan, B. V. 2005 “Development and Properties of Low Calcium Fly Ash Based Geopolymer Concrete”, Research Report GC1, Faculty of Engineering, Curtin University of Technology
8 M.I. Abdul Aleem, P.D.Arumairaj, (2012), “Geo-polymer Concrete” - A Review, IJESET, 1, *2*, pp: 118-122.