A Review on Geo-polymer Concrete

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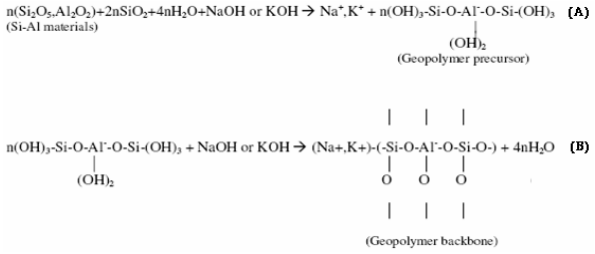
Abstract

Concrete is the most important product now-a-days for any type of construction because of its versatility, durability and reliability. Conventional concrete generally the combination of ordinary Portland cement, fine aggregate, coarse aggregate and water with a specific water/cement ratio but in the case of Geo-polymer concrete it utilizes binding materials as fly-ash and alkali solution. As because the production of ordinary cement generates a huge amount of CO_2 (1 ton Ordinary Portland cement = 1 ton CO_2) to reduce the amount of CO_2 generation, a new way is geo-polymer which uses mainly fly-ash which a byproduct of coal obtained from the thermal power plant in a huge quantity. It's an excellent construction material for the construction of concrete. This paper gives a review on different partial replacement of the binder i.e. fly-ash with different materials like glass powder, GGBS to its strength and potential application.

1. Introduction

Geo-polymer are inorganic polymer materials with a chemical composition similar to zeolites but possessing an amorphous structure. Geo-polymerization is the process of polymerizing silica and alumina containing minerals using alkali solvents. Discovered by Joseph Davidovits in France, geo-polymer cements are likely similar to materials used in antiquity. Although cements are the most common application of geo-polymerization, a range of refractory and structural products have been produced. The products of geo-polymerization are called poly-silicates. The vast majority of minerals on the earth's surface exist as alumino-silicate crystals (for example: clays, feldspars, quartz). By dissolving these and then allowing them to re-condense, materials with longer range crystalline structure than its components may be formed.

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.



A little quantity of water is added to the mix and curing was done room temperature and also by elevated temperature (60^0C to 90^0C) because the temperature during curing is very much important for the generation of its strength. With the temperature the polymerization process will go on

which will help the strength of the concrete to increase.

The necessity of Geo-polymer concrete , the constituents, Physical Properties, Its Application and Limitations are discussed below.

2. Advantages of Geo-polymer Concrete

Now-a-days construction is in a boost and any type of conventional construction is done by cement concrete where the cement which is used is Ordinary Portland Cement or Portland Slag Cement (a type of OPC). The process of OPC creates a large quantity of CO_2, it is seen that 1 ton of OPC production creates 1 ton of CO_2 which enhances the results of Green House effect and also pollute our environment in a great measure. This OPC can only be made from the limestone but with the increase in the demand of cement the quantity of lime stone will get reduce in the next 30-40 years.

The main work of cement in cement concrete is as a binder, but according to IS-10262 the strength of cement is also used in the total strength of cement concrete.

So, seeing all this measure we can say the cement can easily be replaced by a product named Fly-ash with Ground Granulated Blast Furnace Slag (GGBS) or by Glass powder. All the above mentioned product are waste materials which can easily be find out. Fly-ash a by-product of thermal plant with a composition almost similar to OPC, GGBS a waste product of Power plant can be a partial replacement of Fly-ash and Glass are generally used waste or broken glass powder. This process can also help in not to dump the waste material from the plant and to use them to produce concrete and to reduce the emission of CO_2 due to production of cement.

3. Constituents of Geo-polymer Concrete

Geo-polymer is generally a mix of binder and alkali solution with fine aggregate and coarse aggregate. Where the role of binder plays by mainly Fly-ash, but with a replacement of some percentage of fly-ash with GGBS shows a good result. Where the alkali solution is the mix of Sodium Hydroxide or Potassium Hydroxide and Sodium Silicate or Potassium Silicate to a different ratio.

Geo-polymer is mainly a result of formation of zeolites in a geological formation. Where zeolites are crystalline structure of molecules containing aluminum, silicon, oxygen in a frame with the cation of water and other materials on their pore (Behzad and Majidi). Geo-polymers are amorphous semi-crystalline and crystalline structure of Al-Si particle (Davidovits,1991).

A geo-polymer can be described as a low calcium alkali activated alumino silicate cement where the structure is comprised of predominantly Si-O-Al and Si-O-Si bonds arranged in a solid X-ray amorphous alumino-silicate network[1]. The chemistry of geo-polymers are often be same to that of the zeolite as because they have the same chemical compositions[2&3].

The main components of the alkali solution are:-

3.1 Sodium Hydroxide

Physically Sodium Hydroxide looks like flakes or pellets which is almost white in colour. In normal market it is available with different purity content. It cost also vary with the purity of the substance. Since our geo-polymer concrete is homogeneous in nature and the material is also homogeneous and its main work is to activate the sodium silicate, so it is recommended to use a purity level of 94% to 96% i.e. a low cost sodium hydroxide.

3.2 Sodium Silicate

Physically it looks like a gel like liquid, which is also known as water glass or liquid glass. Its the main thing in the alkali solution. Because of different % of Na_2O the strength of geo-polymer concrete varies. With 8% Na_2O in sodium silicate gives a much more good result i.e. almost 45 MPa.[4] with a curing temperature of 45^0C.

4. Physical Characteristics of Geo-polymer Concrete

The main interesting characteristics of geo-polymer concrete according to Prof. B.V.Rangan and Hardijito[5] are

1. It can set at room temperature without any elevated temperature.
2. Its highly resistant to chemical action, its non-toxic and bleeding free.
3. has a higher compressive strength of about 1.5 times than a normal OPC concrete mix.
4. Its impermeable also.

5. It shows a higher resistance to sulphate attack after full immersion for 15 weeks in different % of magnesium sulphate solution.
6. Geo-polymer mortar shows a higher resistance to sulphuric acid solution.

In accordance to the above points S.P.Ahirrao and S.V.Deodhar also seen that with some proportions of glass powder or glass granules with the fly-ash content in the mix of geo-polymer increases its compressive strength, flexural strength, tensile strength, bond strength, mass density and also resistance to sulphate and chemical attack. Increases the compressive strength to a minimum of 1.5 times that of conventional OPC concrete.

5. Applications of GPC

It can be highly used in any kind of structural construction work due to its high early strength and high compressive strength than the conventional OPC concrete. It can be used in any kind of rehabilitation works, road repair works due its high early strength gain. Fly-ash based geo-polymer bricks are also highly appreciated now-a-days because it uses waste materials like fly ash. 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 60^0 to 90^0C for 24hrs during 24 to 48 hrs of casting.

6. Discussion of Results

According to Joseph Davidovits it was found that fly-ash mixed with alkali solution makes a polymeric chain which acts as a binder. Then B.V.Rangan and Hardijito found that 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 ration gives a high strength and also with the increase in curing temperature from 30^0C to 90^0C gives a high strength during the period of 24hrs to 48 hrs of the casting i.e. the 2nd day of casting.

6.1 Compressive Strength

It has seen that with the application of GGBS in geo-polymer concrete which is some replacement of fly-ash shows a good results in the compressive strength in ambient temperature. it shows a result a almost 55 MPa[8] after 28 days full room temperature curing. Upto a replacement of 30%[8] of fly-ash with GGBS shows this result. Other than this replacement shows a lower result.

6.2 Fineness of Fly-ash

For different fineness of fly-ash different test results are noted from which it is seen that the maximum strength is generated for that kind of fly-ash which fineness is $542m^2/kg$[9]. It shows a good strength with continuous heating for the period of general period of heat curing i.e. 24 hours.

Till date in most of the cases of geo-polymer it is seen that the geo-polymer concrete is cured by heat curing with a temperature ranging between 60^0 C to 90^0 C but some results are also obtained with a highly elevated temperature ranging from 100^0 C to 1000^0C also. But the result of heat curing between temperature 60^0C to 100^0C gives a good result.

Most of the experiment of Geo-polymer concrete is done by the conventional process of mixing of normal cement concrete. But this two things are fully different because of its material used and strength generation techniques. In cement concrete the strength is generated by hydration process of cement and water after addition of addition of water to it but the strength generation of geo-polymer concrete is due its polymerization with is obtained after the addition of fly-ash which is rich in silicon and aluminum to alkali solution. Thus forming a chain of monomer to polymer the strength is generated. With the increase in curing temperature the polymerization takes place which gains the strength of the concrete.

With the addition of slag the curing temperature of geo-polymer concrete get reduce and it can be cured at room temperature. With different concentration of Sodium Hydroxide (NaOH) solution different test results are obtained. It is seen that with a increase in the molarity content of NaOH the strength increases.

7. Conclusions

From the above discussion following conclusions can be drawn:-

With the addition of GGBS upto a % of 30% gives a good result in compressive strength under room temperature curing.

More fineness of fly-ash gives more compressive strength, so with the increase in fineness the

strength of geo-polymer concrete also increase as because it gets more surface area and more amount of Si-Al bond for polymerization.

With a higher silicate modulus (Na_2O/SiO_2) the strength of the geo-polymer concrete get increased.

Its generates a high early strength with reference to that of the normal cement concrete which helps in repair type of works for roads, buildings etc.

Even at ambient temperature fly-ash based geo-polymer activated with NaOH gives rise in compressive strength in the presence of calcium based additive like GGBS.

As the geo-polymer is a whole new concept of structural concrete than the conventional cement concrete so there should be a new concept of designing it. As there is no mix-design code is available or any type of Standards are available so it needs a very important review on the results which had came out upto till date work done all over the world.

The process which are followed for the geo-polymer experiments are almost as that of cement concrete, but this two things are fully different so there should be a little bit similarity between the test pattern or mixing pattern but the full thing of geo-polymer concrete should be investigated in details because cement concrete generates strength through hydration process when water is added to cement but geo-polymer generates strength through polymerization process when a base material which is rich in Silicon and Aluminum is added with some alkaline solution to make a bind in concrete.

8. **References**

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