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Review Article

STUDY OF GEOPOLYMER CONCRETE UNDER DIFFERENT CURING CONDITION - A REVIEW

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ABSTRACT

Usage of concrete around the world is second only to water. Portland Pozzolana Cement (PPC) is conventionally used as the primary binder to produce concrete. The amount of carbon dioxide released during the manufacture of PPC due to the calcinations of lime stone and combustion of fossil fuel is in the order of 700 kg for every ton of PPC produced. In addition, the extent of energy requires to produce PPC is only next to steel and aluminum. In other hand, the abundant availability of fly ash worldwide creates opportunity to utilize (by – product of burning coal, regarded as a waste material) as substitute for PPC to manufacture concrete. Binders could be produced by polymeric reaction of alkali liquids with the silicon and the aluminum in the source materials such as fly ash and rice husk ash and these binders are termed as Geo-polymer. In the Geo-polymer Concrete, fly ash and aggregates are mixed with alkaline liquids such as a combination of Sodium Silicate and Sodium Hydroxide. United Nation's Intergovernmental panel on Climate Change (IPCC) prepared a report on global warming during April 2008 which enlists various methods of reduction of CO2 emissions into atmosphere. As per that report, unmindful pumping of CO2 into the atmosphere is the main culprit for the climate change. A Large volume of fly ash is being produced by thermal power stations and part of the fly ash produced is used in concrete industry, low laying area fill, roads and embankment, brick manufacturing etc. Further use of fly ash as a value added material as in the case of geopolymer concrete, reduces the consumption of cement. The Reduction of cement usage will reduce the production of cement which in turn cut the CO2 emissions. Many researchers have worked on the development of geopolymer cement and concrete for the past ten years. Ttime has come for the review of progress made in the field of development of geopolymer concrete.

INTRODUCTION

PPC is extensively used in all over world due to its low cost and easy availability. Concrete can be cast in almost any desired shape, and once hardened, can become a structural (load bearing) element, other hand it also affects environment, also there are many negative influence of OPC. As example emissions of airborne pollution in the form of gases, noise, dust, and vibration when operating machinery and during blasting in quarries, devouring of large quantities of fuel during manufacture and release of CO2 from the raw materials during manufacture. From the 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 problem. Coal fly ash is plentifully available to replace totally manufactured cement and make a concrete like material. It is an excellent alternative construction material to the existing plain cement concrete, Geopolymer concrete shall be manufactured without using any amount of ordinary Portland cement, Advancement of geopolymer concrete is an important step towards the production of environmentally friendly concrete.

Fig 1 *Worldwide production & utilisation of Fly-ash*

Name of Country	Production (million tons)	Utilization (million tons)
Australia	59	<25
China	>150	52
Germany	78	40
India	>132	48
Japan	55	29
Russia	102	32
South Africa	78	57.9
Spain	58	26
UK	60	34

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Geopolymer type concrete is a type of amorphous alumino silicate cementitious material that exhibits the ideal properties of rock forming minerals, i.e., hardness, chemical stability and longevity[1].

Geopolymer Theory

Geo-polymerization is a geo-synthesis–a reaction that chemically integrates minerals. Exposure of alumino-silicate materials such as fly ash, blast furnace slag, or thermally activated Substances to high-alkaline environments (hydroxides, silicates) gives rise to the formation of a geopolymer. Geopolymers are characterized by a two- to three-dimensional Si-O-Al structure.

All these materials represent a new order of cementitious products able to provide ceramic and zeolitic properties not normally present in traditional cement materials, schematic formation of polycondensation material by alkali into poly (sialatesiloxo) can be shown as described by equations (1) and (2). The last term in equation (2) signifies that water is released during the chemical reaction that occurs in the formation of geopolymers. Water is expelled from the mixture during the curing process leaves behind discontinuous nano pores in the matrix. Which provide prosperity to the accomplishment of geopolymers. The water in a geopolymer mixture plays negligible role in the chemical reaction that takes place, it merely provides the workability to the mixture during manipulation.

It is in resemblance to the chemical reaction of water in a Portland cement concrete mixture during the hydration process, Geopolymers exist to the group of strong and durable cementitious materials that harden at temperatures below 100°C[2].

n(Si2O5, Al2O2) + 2nSiO2 + 4nH2O +NaOH/KOH
(Si-Al materials) |
|
Na+, K+ + n(OH)3-Si-O-Al--O-Si-(OH)3
|
(OH)2
(Geopolymer precursor) -----------------[1]

n(OH)3-Si-O-Al--O-Si-(OH)3 + NaOH/KOH
| |
(OH)2 |
(Na+, K+)-(-Si-O-Al--O-Si-O-) + 4nH2O
| | |
O O O
(Geopolymer Backbone) -------------------[2]

Geopolymer Development

Geopolymer cements concrete develop through a series of several distinct reaction processes from initial pozzolanic activation to final microstructure development. Benefits of using pozzolans as a matrix binder for agglomeration is that they tend to be economical, environmentally-friendly, more absorbent of liquids and produce a highly durable product. All Major processes are dissolution of the alumino silicate species withina highly basic, alkaline environment, polymerization of the dissolved minerals into short-lived structural gel, precipitation of formed hydration products similar to natural zeolites and final hardening of the matrix by excess water exclusion and the growth of crystalline structures. Figure 2 illustrates the overall polymerization process in alkali-activated geopolymers[3].

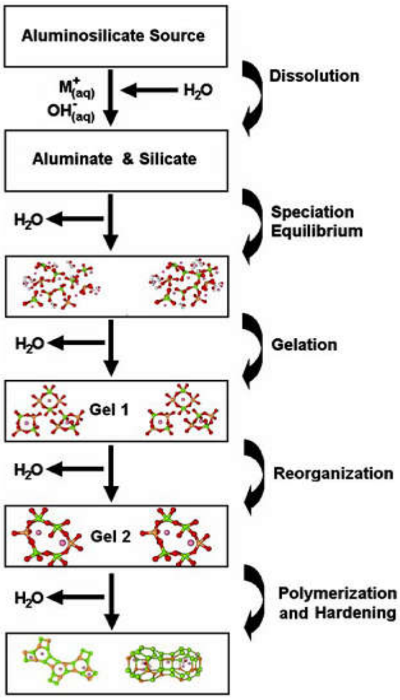

Fig 2 ***Geopolymer Development***

Advanteges of GPC

Depend on the synthesis conditions (including nature of start materials), geopolymer concrete can be made to achieve the following advantages:

1. High early compressive strength gain
2. Good abrasion resistance
3. Rapid controllable setting and hardening
4. High level of resistance to a range of different acids.
5. High surface definition that replicates mould patterns
6. It's impermeable like normal OPC concrete
7. Bleeding free.

LITERATURE

D.Hardjito and B.V.Rangan (2005)[1] describe the development the mixture proportion amnd the short term properties of low calcium fly ash based geopolymer concrete. Subsequent reported the long term properties and the behaviour and the strength of reinforced geopolymer concrete.

Olivia *et al* (2008)[2] have investigated on the water penetrability of low calcium fly ash geopolymer concrete. The conclusion drawn is that fly ash geopolymer concrete exhibits low water absorption and sorptivity, Low water/binder ratio and a better grading are recommended in order to reduce the capillary porosity and the overall porosity of geopolymer concrete.

P. Chinddaprasirt *et. al*. (2011)[3] presented the study of synthesis of high strength geopolymer using fine high calcium fly sh. The effect of fineness of flyash on the setting time of geopolymer paste, workability, strength development and drying shrinkage of geopolymer mortars mde from classified fine high calcium fly ash was investigated.

Harbert Sinduj *et.al*. (2011)[4] aimed to determine the optimum value of the alkaline activator/ fly ash ratio. The effect of the oxide molar ratios of SiO2/Al2O3, water content of the water glass content were studied for each Alkaline activator/flyash ratio. Result reveled that the alkaline activator/flyash ration 0.40 has the optimum amount of alkaline liquid, which shows the highest rate of geopolymeriztion compared to other ratios.

Alloucher *et al*. (2011)[5] studied the self-curing properties of geopolymer concrete. The study shows that the temperature generated is dependent upon the amount of concrete mixed. The strength of GPC was found to increase with curing period. The modulus of elasticity and Poisson‟s ratio corresponding to 28 days‟ curing were found to be within acceptable range for typical concrete used in a structural application, Mustfa *et al*. (2012) based on the experimental work concluded that the Na2SiO3/NaOH ratios and NaOH molarities the compressive strength of the fly ash based geopolymer concrete. The Na2SiO3/NaOH ratio of 2.5 contributed to the high compressive strength of 55Mpa. The highest NaOH molarity did not necessarily give the highest compressive strength. The geopolymer with 12-14 M NaOH showed excellent results including a high compressive strength of up to 94 MPa corresponding to 7 days‟ curing.

Raijiwala *et al* (2011)[6] they reported the progress of the research on making geopolymer concrete using the thermal power plant fly ash Gujarat, India. The project aims at making and studying the different properties of geopolymer concrete using this fly ash and the other ingredients locally available in Gujarat. Potassium Hydroxide and sodium Hydroxide solution were used as alkali activators in different mix proportions. Effects of various salient parameters on the compressive strength of low-calcium fly ash-based geopolymer concrete are discussed by considering the ratio of alkaline solution to fly ash (by mass) 0.35 constant. The specimens were cured at two different temperature 25°C and 60°C for 24 hours in the oven. The main parameters studied were the compressive strength, curing temperature, effect of wet-mixing time, influence of handling time on compressive strength, effect of super plasticizer on compressive strength, effect of super plasticizer on slump of concrete, effect of water-to-geopolymer solids ratio by mass on compressive strength, stress-strain relation of geopolymer concrete in compression. Experimental results indicate that the compressive strength of GPC increased over controlled concrete by 1.5-1.6 times and split tensile strength of GPC increased over controlled concrete by 1.45 times. The flexural strength of GPC increased over controlled concrete by 1.6 times. For pull out test GPC increases over controlled concrete by 1.5 times.

Prakash R. Vora *et.al*. (2012)[7] they has been investigated the various parameters like ratios of alkaline liquid to fly ash, concentration of sodium hydroxide, curing time, curing temperature, dosage of super plasticizer. The result shows that compressive strength increases with increases in curing time, curing temperature, rest period.

Shankar H. Sanni (2012)[8] they examined the performance of geopolymer concrete under several environmental condition. Durability of specimens were assessed by immersing GPC specimens in 10% sulphuric acid and 10% magnesium sulphate solutions separately, periodically monitoring surface deterioration and depth of dealkalization, changes in weight and strength over a period of 10, 20 and 30 days, The test results indicate that the heat-cured fly ash-based geopolymer concrete has an excellent resistance to acid and sulphate attack when compared to conventional concrete. Thus the production of geopolymers have a relative higher strength, excellent volume stability and better durability.

Ammar Motorwala *et al* (2013)[9] they have conducted an experimental study that involves the observation of structural behaviour of fresh fly ash-based geo-polymer concrete. The main objective of this study was to find the effect of varied concentrations of alkaline solutions on the strength characteristics of the concrete. The test conducted, yielded certain important findings such as increase in the compressive strength with increase in the molarity. Curing under normal sunlight yielded strength of 15 N/mm2 and curing when done by wrapping with plastic bag showed better compressive strength as it preserves the moisture. For the rate analysis carried, fly ash based concrete is more expensive than cement concrete and hence not economical, However, in the broader picture considering carbon credit, waste disposal and limited availability of non-renewable resources, geopolymer concrete is sure to play major role in construction industry.

Rajamane *et al* (2013)[10] have reported the overview of 'geopolymeric cement concrete' based on extensive works carried out and published information. The GPCs may be either self curing or high temperature curing, with compressive strength ranging from 25 to 70 MPa. Look at the properties of GPC's with reference to stress-strain curves, bond strength, corrosion and sulphate resistance, thermal conductivity and expansion coefficient, electrical resistance ultrasonic pulse velocity, flexure and shear behaviour indicates that the industrial waste based GPC's can possess satisfactory strength and durability related characteristics depending upon their formulations.

Subhash V. Patankar *et.al*.(2014)[11] studied the effect of quantity of water, temperature duration of heating on compressive strength of fly ash based geopolymer concrete.Na2Sio3 solution containing Na2O of 16.42%, SiO2 of 34.32% and H2O of 49.22% and sodium hydroxidesolution with concentration of 14 Molar were used in geopolymer concrete as alkaline activators. Geopolymer concrete mixes were prepared with 0.35 solutions to processed fly ash ratio. Workability was measure by flowtable apparatus. Geopolymer concrete cubes of 150 mm X 150 mm X 150 mm were cast. The temperature ofcuring was varied as 400C, 600°C, 900°C, and 1200°C for each period of 8, 12 and 24 hours of oven heating and tested after a rest period of 1, 2, 3, 7 and 28 days after demoulding the concrete cube. Test results show that the quantity of water plays important role in balancing workability but not affect on strength, while higher temperature requires less duration of heating to achieve desired strength and vice versa. Author says that the rest period of 3 days is sufficient after heating at and above 900°C temperature.

R. Vijay Ranjan (2014)[12] they conducted an extensive studies on fly ash based geopolymer concrete are presented in this paper, salient factors that influence the properties of the concrete in the fresh and hardened states are identified. The test data of various short term and long term properties of the geopolymer concrete are then presented. The paper describes the result of the application of the test conducted on large scale reinforced geopolymer concrete members and illustrate the application of the geopolymer concrete in the construction industry. Recent application of geopolymer concrete in precast construction construction and the economic merits of the geopolymer concrete are also include.

Gupta (2015)[13] they studied the effect of concentration of sodium hydroxide, temperature, and duration of oven heating on compressive strength of fly ash based geopolymer mortar. All Geopolymer mortar mixes were prepared by considering alkaline liquid-to-fly ash ratio of 0.35, 0.40, and 0.45. The temperature of oven curing was maintained at 40, 60, and 120°C each for a heating period of 24 hours and tested for compressive strength at the age of 3 or 7 days as test period after specified degree of heating. All results shown that the workability and compressive strength both increase with increase in concentration of sodium hydroxide solution for all solution-to-fly ash ratios.

Ganesn Lavanya *et.al*.(2015)[14] they presents an investigation into the durability of geopolymer concrete prepared using high calcium fly ash along with alkaline activators when exposed to 2% solution uf sulfuric acid and 5% magnesium sulphate for upto 40 days. The durability was also assessed by measuring wter absorption and sorptivity. OPC concrete was also prepared s control concrete. The alkaline solution used for study is the combination of sodium hydroxide and sodium silicate with the ratio of 2.60. The molarity of the sodium hydroxide was fixed as 12.

M. Talha Junaid *et.al*. (2015)[15] they present a systematic approach for selecting mix proportion for alkali activated fly ash geopolymer concrete. The proposed mix design process is developed for low calcium fly ash activated using sodium silicate and sodium hydroxide as activator solution. In this paper the key factors that characteristics of mix are identified. The ratio of alkaline liquid water is identified to be most closely linked to the strength of GPC mix.

J.Thaariniet *et.al*.(2016)[16] they discussed the cost of producing 1 m³ of GPC and OPC are calculated based on the market rates of the ingredients required and compared for socioeconomic feasibility. Totally Based on the cost calculations, it was seen that the cost of production of OPC concrete is higher than the cost of production of GPC for higher grades. For the M30 grade GPC concrete the cost of production is marginally higher than OPC concrete of the same grade.

CONCLUSION

Based on the above literature review work in this study, the following conclusions are found

Effect of Curing Hour and Curing Temperature: the Cuing hour and curing temperature is very significant parameter of geopolymer concrete because it is very important for polymerization process. For longer curing time and curing hours is improved the polymerisation process resulting in development of higher compressive strength, The curing temperature at 90ºC showed better compressive strength than 80ºC and 100ºC. Furthermore 90ºC-12 hour curing produced maximum strength when compared with 90ºC-24 hours curing. Beyond this optimum temperature, increase in the curing temperature and curing hours reduced the compressive strength of geopolymer concrete specimens[5].

It should be noted that, most of the geopolymer concrete tested so far was either heat cured or steam cured at higher temperature than ambient. While such concrete can be precast easily, it is not always practicable in cast-in-situ applications due to delayed setting and slow strength development in ambient condition. It is necessary to investigate the mechanical properties of geopolymer concrete suitable for ambient curing condition. Fly ash can be replaced partially with ground granulated blast furnace slag, PPC and calcium hydroxide to enhance the chemical composition facilitating alkaline reaction. Effect of various additives and total binder content was investigated on the early age properties of geopolymer concrete.

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