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Development and Properties of Low-Calcium Fly Ash-Based Geo polymer Concrete

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Abstract: The main objective of this current study is to develop a cement free concrete material because of the green house effect during the manufacture of cement. It is reported that every one tonne production of cement emits one tonne carbon dioxide which causes global warming and in broad sense disturbs the entire ecological system. It results the promotion of geopolymer concrete where silica and alumina will bind together with alkaline solution during the process of polymerization. The researchers taken greater initiatives in geopolymer concrete there is no specific study related to the mix design because of commercialization and patenting. Hence the authors interested in identifying specific mix design using trial proportion of low calcium fly ash and alkaline solutions (sodium silicate and sodium hydroxide). This investigation deals suggested that pozzolans such as blast furnace slag might be activated using alkaline liquids to form a binder and hence totally replace the use of OPC in concrete. In this scheme, the main contents to be activated are silicon and calcium in the blast furnace slag. The main binder produced is a C-S-H gel, as the result of the hydration process.

INTRODUCTION

Concrete is the second most consumed material after water and is the basis for the urban development. It can be roughly estimated that 30 billion tonnes of concrete are manufactured globally each year. Concrete is generally made from cement, fine aggregate (sand), coarse aggregate (stone and gravel) and water. It is estimated that the production of cement is reported by 150 countries and reached 3.7 billion tonnes in 2012. The Demand for cement in India totalled 154 million metric tons in 2007, representing the second largest market in the world behind China. The production of cement is in critical conditions due to high amount of carbon dioxide gas released to the atmosphere. The trading of carbon dioxide (CO2) emissions is a critical factor the cement industries, as the greenhouse effect created by the emissions is considered to produce an increase in the global temperature that may result in climate changes. Hence the researchers intended to identify a new material which has not even required cement as a binder material to control global warming in broad sense. This research is one such attempt to produce green concrete using industrial by product such as low calcium (class F) fly ash, contains high silica and alumina which is activated by alkaline solution to produce binder known in the name of geopolymer concrete. In 1978, Davidovits (1999) proposed that binders could be produced by a polymeric reaction of alkaline liquids with the silicon and the aluminium in source materials of geological origin or by-product materials such as fly ash and rice husk ash. He termed these binders as geopolymers. Palomo et al (1999) eighty one test cubes of 150x150x150mm of low-calcium fly ash-based geopolymer concrete were cast to study the effect of various parameters on compressive strength of low-calcium fly ash-based geopolymer concrete.

LITERATURE SURVEY

Chandan Kumar et al (2014) says Geopolymer is a class of alumina silicate binding materials synthesized by thermal activation of solid aluminosilicate base materials such as fly ash, metakaolin, GGBS etc., with an alkali metal hydroxide and silicate solution. These binders are currently attracting widespread attention due to their potential utilization as a high performance, environmental friendly and sustainable alternative to Portland cement India being the largest coal fly-ash producer in the world produces abundant by product from thermal With five different trial mixes with different molarity of NaOH (8M, power plant known as coal fuel ash Based on the mixture design process 10M, 12M and 14M) and super plasticizer combinations under the curing temperature of 60°C. The fresh and hardened properties have been studied. Bhosale and Shinde (2012) using fly ash and alkaline activator with geopolymerization process.

The factors that influence the early age compressive strength such as molarities of sodium hydroxide (NaOH) have been studied. Sodium hydroxide and sodium silicate solution were used as an alkaline activator. These studies the comprises the comparison of the ratios of Na2SiO3 and NaOH at the values 0.39 and 2.51. The geopolymer paste samples were cured at 60°C for 1 day and kept at room temperature until the testing days. The compressive strength tested at 7 and 28 days. The result showed that the geopolymer paste with NaOH concentration, compressive strength increase with molarities increases. It was also found that at ratio of 2.5 of Na2SiO3 and NaOH the compressive strength was greater as compared to 0.39 and compressive strength is more for oven drying as compared to specimen left in ambient temperature.

Dave and Sahu (2012) observed in study three series of geopolymer concrete specimens composing 8M concentration of sodium hydroxide (NaOH) was adopted and 9 cube specimens were prepared. After casting, the specimens were kept in rest period for five days and then they were demoulded. The specimens were wrapped by plastic sheet to prevent loss of moisture and placed in an oven. The test specimens were cured at 60°C in an oven and at ambient condition. The curing time varied from 24hours to 168hours (7days). The result showed that the strength of geopolymer concrete after 24hours was not superior and after 7days the compressive strength of geopolymer concrete was moderate. Another important observation was that the 7days compressive strength of hot cures specimens was about 3 times more than that of ambient cured specimens. Increases porosity in case of geopolymer pastes. Incorporation of silica fume enhances the compressive strength of mortar specimens whereas it causes a significant drop for the paste specimens. This could be due to the notable variations of porosity between the specimens prepared with or without silica fume. Water absorption values were found directly related to total porosity of specimens. For paste specimens, water absorption gradually increases with introduction of silica fume into mix. In contrast, mortar specimens showed a decreasing trend in water absorption with increasing silica fume content. The Si/Al weight ratios showed a decreasing trend with addition of silica fume for geopolymer mortars. This could be reason for improved porosity resulting in lesser water absorption and higher compressive strength.

D.HARDJITO et al (2005) observed evaluated the effect of several factors on the properties of fly ash based geopolymer concrete, especially the compressive strength. The test variables included with the age of concrete, curing present study is combination of sodium hydroxide (NaOH) and sodium silicate (Na Sio) with ratio 2.5. A grade chosen for the investigation was M40.The mixes were designed for molarity of 12M, 14M and 16M. The test results have shown that compressive strength increases with increase in molarity.

DEBABRATA DUTTA et al. (2006) **f**ollowing results were made on the basis of experimental investigation. Addition of silica fume to fly ash based geopolymer mortar specimens improves the total porosity. However, it MARIA et al. (2014) critically analyzed the economic and environmental benefits of geopolymer concrete and address the financial and environmental issuesassociated with the production and use of Portland cement. Geopolymer concrete products also known to possess far better durability and strength properties than Portland cement concrete. These properties were investigated time, curing temperature, quantity of super plasticizer, the rest period extensively in laboratory to verify and confirmthe superior prior to curing and the water content in the mix. The test result shows that the compressive strength of geopolymer concrete does not vary durability and strength properties. Laboratory tests were with the age of concrete, Longer curing time improves the conducted on compressive strength, split tensile strength and polymerization process resulting in higher compressive strength approximately up to 75hours, commercially available Naphthalene flexural test for specimens with combination of different based super plasticizer improved the workability of the fresh concrete molarity (8M,10M,12M,14M,16M). It was found that but had very little effect on the compressive strength up to about two percent of this admixture to the mass of fly ash, beyond this value there is some degration of the compressive strength and increase in the curing temperature increases the concrete compressive strength up to 75°C.The results of a study on fly ash-based geopolymer concrete. The test parameters covered certain aspects of manufacture of geopolymer concrete. The paper also reports the stress-strain behaviour of the concrete with compressive strength in the range of 40 to 65 MPa. Tests were carried out on 100mmx200mm cylindrical geopolymer concrete specimens. Test results show that a good agreement exists between the measured stress-strain relations of fly ash- based geopolymer concrete and those predicted by a model developed originally for Portland cement concrete. Longer mixing time yielded lower slump of fresh concrete, and higher compressive strength and higher density of hardened concrete. This suggests that the extended mixing time resulted in better polymerisation process, and hence enhanced properties of hardened concrete. The term 'rest period' is used to indicate the time taken from the end of casting to start of curing at an elevated temperature. The compressive strength of specimens increased with a rest period of one day or more after casting. The extent of strength gain is significant, in the range of 20 to 50 percent compared to the compressive strength of specimens with no rest period.

U.R.KAWADE et al (2010) says concrete use around the world is second only to water. The production of ordinary Portland cement contributes 5-7% of total green house gas emission. It also consumes large amount energy .Hence it is essential to nd alternative to cement. Fly ash is a byproduct of coal obtained from thermal power plant. It is also rich in silica and alumina. In this paper, y ash is used to produce a geopolymer concrete. Geopolymer is a material resulting from the reaction of a source material that is rich in silica and alumina with alkaline solution. Geopolymer concrete is totally cement free concrete. In geopolymer, y ash act as binder and alkaline solution act as an activator. Fly ash and alkaline activator undergo geopolymerization process to produce alumino silicate gel.

Alkaline solution used for compressive strength of GPC specimens with 12M is 1.25 times more than that of GPC with other molarities after 28 days of hot curing split tensile strength with 12M was 1.18 times more than other molaritieswhile flexural strength with 12M is 1.058 times more. It was also reported that geopolymer technology does not only contribute to the reduction of green house gas emissions but alsoreduces disposal costs of industrial waste and geopolymer technology encourages recyclingof waste and finally it will be an important step towards sustainable concrete industry.

H.Mohd Mustafa al Bakri et al (2010) observed the thermal stability of the geopolymer materials prepared with sodium containing activators was rather low and significant changes in the microstructure occurred. At 800°C, the strength of the concrete was reduced due to the increase in the average pore size where amorphous structures were replaced by the crystalline Na-feldspars. The reverse situation was observed when potassium silicate was used as activators because it can remain mostly amorphous up to 1200°C. After firing these materials, it reduced average pore size and improved compressive strength of geopolymer. Fly ash based geopolymer prepared using class F fly ash with sodium and potassium silicate show high shrinkage as well as large changes in compressive strength with increasing fired temperature in the range 800 to 1200°C.

PALOMO et al (1999) studied the geopolymerisation of low- calcium (ASTM Class F) fly ash (molar Si/Al=1.81) using four different solutions with the solution-to-fly ash ratio by mass of 0.25 to 0.30. The molar SiO_2/K_2O or SiO_2/Na_2O of the solutions was in the range of 0.63 to 1.23. The specimens were 10x10x60 mm in size. The best compressive strength obtained was more than 60 MPa for mixtures that used a combination of sodium hydroxide and sodium silicate solution, after curing the specimens for 24 hours at 65°C.

PROPERTIES OF MATERIALS

FLY ASH

Fly ash is a byproduct material generated from Mettur thermal Power station. Presently the annual production of fly ash in India is about 112 million tones and is expected to cross 225 million tons by the year 2017. When pulverized coal is burnt to generate heat the residue contains 80% Fly Ash and 20% bottom ash. If not managed properly Fly Ash disposal in sea/rivers/ponds can cause damage to aquatic life also. Slurry disposal lagoons/settling tanks can become breeding grounds for mosquitoes and bacteria. It can also contaminate the underground water resources with traces of toxic metals present in Fly Ash. In developed countries more than 80% fly ash is used in various fields where in India very less percentages in various segments the chemical compositions of the fly ash from all batches, as determined by X-Ray Fluorescence (XRF). Fly ash contained a very low percentage of carbon as indicated by the low Loss on Ignition (LOI) values.

Table 4.1 Chemical Properties of Fly Ash

S.No	Material	Specific Gravity
1	Silica	59.60
2	Alumina	26.45
3	Iron oxide	6.61
4	Calcium oxide	1.2
5	Magnesium oxide	0.77
6	Sulphur tri oxide	0.58
7	Titanium oxide	1.45
8	Loss of ignition	1.70

Table 4.2 Properties of Fine aggregate

S.No.	Name of the Test Material	Value
1.	Specific Gravity	2.66
2.	Fineness Modulus	2.70
3	Water Absorption	2.3%
4	Bulk Density	1624 Kg/m^3

FINE AGGREGATE

The sand used for experimental program was locally procured and conforming to zone II. The sand was first sieved through 4.75 mm sieve to remove any particles greater than 4.75 mm. The fine aggregate were tested as per Indian Standard Specification IS: 383 – 1970. The physical and mechanical properties of the sand used are shown in table compared with opc.

COARSE AGGREGATE

Aggregates typically constitute 70 – 80 % weight of Concrete; hence, aggregate types and sizes play an essential role in modifying the concrete properties. The maximum size of aggregate is generally limited to 20 mm. Aggregate of size 10 mm is desirable for structure having congested reinforcement. Well graded cubical or rounded aggregates are desirable. Aggregates should be of uniform quality with respect to shape and grading. The maximum 15 mm size was selected to reduce difficulties of producing, mixing and placing concretes and to prevent segregation of aggregates in fresh concretes. In my work aggregates of size 12.5 and down has been used.

WATER

Water is the most important and least expensive ingredient of concrete. It acts as lubricant for fine and coarse aggregate and acts chemically with cement to form binding paste. The quantity water should be sufficient for hydration and suitable for workability. Normal portable water is used for mixing of concrete. Locally available potable water confirming to standard specified in IS: 456-2000 is used.

ALKALINE SOLUTION

A combination of sodium silicate solution and sodium hydroxide solution were chosen as the alkaline liquid. Sodium hydroxide in pellets form with 97% purity and sodium silicate solution of 0.1N were used. The sodium hydroxide (NaOH) solution was prepared by dissolving the pellets in distilled water. Preparation of NaOH solution resulted in emission of heat of 60°C. The mass of NaOH solids in a solution varied in the current study as 8, 12 & 14 Molarities

S.No	Content	Value
1	pH	14
2	Specific gravity	2.1
3	Boiling point	145°C
4	Molecular weight	40

Fig **4.1** MIXING AND CURING

It was found that the fresh fly ash- based geopolymer concrete was dark in colour (due to the dark colour of the fly ash), and was cohesive. The amount of water in the mixture played an important role on the behaviour of fresh concrete. When the mixing time was long, mixtures with high water content bled and segregation of aggregates and the paste occurred. This phenomenon was usually followed by low compressive strength of hardened concrete. Mix sodium hydroxide solution and sodium silicate solution together at least one day prior to adding the liquid to the dry materials. Mix all dry materials in the pan mixer for about three minutes. Add the liquid componentof the mixture at the end of dry mixing, and continue the wet mixing for another four minutes.

Table 4.5 Properties of Sodium Silicate (Na2O SiO2)

S.No	Content	Value
1	Na_2O	15.9
2	SiO2	31.4
3	Specific gravity	1.6
4	Molecular weight	184

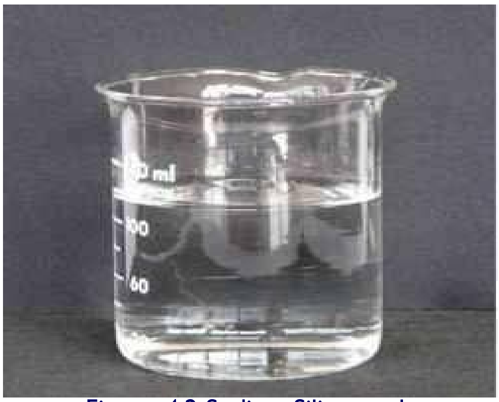

Figure: 4.2 Sodium Silicate gel

Geopolymer concrete specimens should be wrapped during curing at elevated temperatures in a dry environment (in the oven) to prevent excessive evaporation. Unlike the small geopolymer paste specimens, who can easily be wrapped by placing a lid on the mould, a suitable method was needed for large size geopolymer concrete specimens. Extensive trials revealed wrapping of concrete specimens by using vacuum bagging film is effective for temperatures up to 100ºC for several days of curing. To tighten the film to the concrete moulds, a quick lock seal or a twist tie wire was utilized. The later was used in all further experimental work due to its simplicity and economics. Preliminary tests also revealed that fly ash-based geopolymer concrete did not harden immediately at room temperature. When the room temperature was less than 30oC, the hardening did not occur at least for 24 hours. Also, the handling time is a more appropriate parameter for fly ash- based geopolymer concrete.

CONCLUSIONS

From the specific surface area results the ashes (ESP flyash and pond flyash) having more specific area than the cement this will leads to form strong gel while adding water. The formation of this gel leads to reduce the segregation of aggregate. The cube compressive strength of ESP flyash replaced concrete is higher than the controlled concrete and pond flyash replaced concrete is higher than the control concrete up to 6% replacement. The water demand of concrete containing fly-ash increases with increasing amount of fly ash. The increase is primarily due to the high surface area of the fly ash. The ultimate load resisting capacity of Pond fly ash replaced R.C beams are higher than the controlled R.C beams up to 6% replacement is 10.97% and ESP flyash replaced R.C beams are higher than the controlled R.C beam is 24.76%. Hence from this study it can be recommended the cement may be replacement by pond flyash is increasing 7.21% and 10.97 % for 4%, 6% replacement level respectively and ESP fly ash increasing 8.93%, 15.98%, 24.76 for 4%, 6%, 8% ESP fly-ash replacement. From the results obtained it may be concluded that the ESP fly-ash Pond flyash replacement of cement shows a higher value in all appreciable characteristics than the controlled specimens.

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