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State of Art- Investigation of method of curing on geopolymer concrete

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Abstracts: *In India, fly ash is produced annually more than 100 million tons. The geopolymer is a material where the cement is totally replaced by pozzolanic material like fly ash. In geopolymer concrete for polymerization of geopolymer concrete needs heat, so at the time of curing most of the researchers provide oven heat curing but on site it is not possible to cure concrete by oven, so there is need to work on methods of curing for geopolymer concrete.*
Key Words*: Geopolymer concrete, Types of curing, fly ash.*

I. Introduction

Geopolymer is a new invention in the world of concrete in which cement is totally replaced by pozzolanic material that is rich in silica and alumina like fly ash and activated by alkaline liquids to act as a binder in the concrete. (Subhash V. Patankar,2013). The demand of concrete is increasing day by day for satisfying the need of development of infrastructure facilities. It is well established fact that the production of OPC not only consumes significant amount of natural resources and energy but also releases substantial quantity of carbon dioxide to the atmosphere. Therefore, it is essential to find alternatives to make the concrete environment friendly. (Prakash R. Vora,2013).

Cement industries releases CO2 in the atmosphere, which is one of cause of global warming. Also, in Most of the fly ash is disposed off as a waste material that coves several hectors of valuable land. So, efforts are needed to make concrete more environmental friendly by using fly ash which helps in reduce global warming as well as fly ash disposal problem. (Satpute Manesh B,2012). Thermal Power Plant are the two major issues concern with the environmental pollution and human health. Both these issue can be solve partially by utilizing fly ash in concrete by partial or full replacement of cement. Geopolymer concrete is a new cementitious material which is produced by chemically activation of fly ash with highly alkaline solutions like sodium hydroxide and sodium silicate. Subhash V. Patankar,et al. (2012)

II. Research Review

Subhash V. Patankar(2014) has presented the effect of quantity of water, temperature duration of heating on compressive strength of fly ash based geopolymer concrete. Sodium silicate solution containing Na2O of 16.45%, SiO2 of 34.35% and H2O of 49.20% and sodium hydroxide solution with concentration of 13 Mole were used as alkaline activators. Geopolymer concrete mixes were prepared by maintaining solution to fly ash ratio of 0.35. Workability was measure by flow table apparatus. Geopolymer concrete cubes of 150 mm side were cast. The temperature of curing was varied as 40 60, 90, and 1200C 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. Test results show that the quantity of water plays important role in balancing workability but contribute nothing towards strength. While higher temperature requires less duration of heating to achieve desired strength and vice versa. It is also observed that the rest period of 3 days is sufficient after heating at and above 900C temperature.

Satpute Manesh B, et al (2012), have studied of effect of duration and temperature curing on compressive strength of fly ash based of geopolymer concrete. Geopolymer concrete is manufactured by cement fully replacing with processed low calcium fly ash which is chemically activated by alkaline solutions like sodium silicate and sodium hydroxide. Cubes of size 150mm X 150mm X 150mm were made at solution to fly ash ratio of 0.35 with 16 Mole concentrated sodium hydroxide solution. The specimens were cured in oven at 60^0C, 90^0C and 120^0C for 6, 12, 16, 20 and 24 hour's duration. Test results show that the compressive strength increases with increase in duration and temperature of oven curing.

S.S.Jamkar et al,(2013) have highlighted on the effect of fly ash fineness on the compressive strength of geopolymer concrete. Geopolymer concrete was produced by activating fly ash with a highly alkaline solution of sodium silicate containing 16.45% Na_2O, 34.35% SiO_2 and 49.20% H_2O and 13 molar sodium hydroxide solution. Concrete cubes of 150 mm were cast using five samples of fly ash with different Blaine fineness and solution to fly ash ratio of 0.35. The specimens were cured in an oven for 4, 8, 12, 16, 20 and 24 hours at 90^oC. The compressive strength results show that the fly ash fineness plays a vital role in the activation of geopolymer concrete. An increase in the fineness increased both workability and compressive strength. It was also observed that finer particles resulted in increasing the rate of reaction needing less heating time to achieve a given strength.

R. Anuradha, et al. (2011), have studied to identify the mix ratios for different grades of Geopolymer Concrete by trial and error method. A new Design procedure was formulated for Geopolymer Concrete which was relevant to Indian standard (IS 10262-2009). The applicability of existing Mix Design was examined with the Geopolymer Concrete. Two kinds of systems were considered in this study using 100% replacement of cement by ASTM class F flyash and 100% replacement of sand by M-sand. It was analyzed from the test result that the Indian standard mix design itself can be used for the Geopolymer Concrete with some modification.

Subhash V. Patankar, (2013) has investigation on study the effect of grading of fine aggregate (sand) on the flow and compressive strength of fly ash based geopolymer concrete. Sodium silicate solution with Na_2O = 16.37%, SiO_2 = 34.35% and H_2O = 49.28% by mass was maintained constant. Moreover, the concentration of sodium hydroxide solution was maintained at 13 moles and solution (Na_2 SiO_3+NaOH)-to-fly ash ratio was maintained at 0.35. Workability of geopolymer concrete was measured by flow test. Cubes of 150 mm size were cast and cured in oven at 900C for 6 hours to measure compressive strength at the age of 3days. Test results indicated that geopolymer concrete is more workable with grading of sand confirming to zone-I. However, compressive strength of geopolymer concrete remained nearly the same for all the grading of fine aggregate.

N A Lloyd, (2010) have been carried the results from the reaction of a source material that is rich in silica and alumina with alkaline liquid. A summary of the extensive studies conducted on fly ash-based geopolymer concrete is presented. Test data are used to identify the effects of salient factors that influence the properties of the geopolymer concrete and to propose a simple method for the design of geopolymer concrete mixtures. Test data of various short-term and long-term properties of the geopolymer concrete and the results of the tests conducted on large-scale reinforced geopolymer concrete members show that geopolymer concrete is well-suited to manufacture precast concrete products that can be used in infrastructure developments. The paper also includes brief details of some recent applications of geopolymer concrete.

Atteshamuddin S. Sayyad, et al. (2013), has analysed the impact of steel fibres and low calcium fly ash on the compressive, flexural, split-tensile, and bond strengths of hardened GPCC. Geopolymer concrete mixes were prepared using low calcium fly ash and activated by alkaline solutions (NaOH and Na_2SiO_3) with solution to fly ash ratio of 0.35. Crimped steel fibres having aspect ratio of 50 with volume fraction of 0.0% to 0.5% at an interval of 0.1% by mass of normal geopolymer concrete are used.

Subhash V. Patankar,et al.(2012), have worked on the effect of solution-to-fly ash ratio at different quantities of fly ash used as source material in the development of geopolymer concrete. Cubes of size 150 mm were cast at solution-to-fly ash ratios of 0.25, 0.30, 0.35,0.40, 0.45 and 0.50 after measuring the flow of geopolymer concrete using 300, 400, 500, and 600Kg/m3quantities of fly ash. The entire specimens were cured in oven for duration of 6 hours under the constant temperature of 90^0C. Test results have shown that the flow and compressive strength increases with increase in solution-to-fly ash ratio at same quantity of fly ash. But the mix was more and more viscous at higher solution-to-fly ask ratio. Quantity of fly ask also plays major role in the production of geopolymer concrete. Increases in the quantity of fly ash in the mix showed increase in both workability and compressive strength.

D. Hardjito, et al,(2004), has presented the effect of mixture composition on the compressive strength of fly ash-based geopolymer concrete. Test results show that water to sodium oxide (H_2O-to-Na_2O) molar ratio and the water-to-geopolymer solids ratio by mass influence the compressive strength of fly ash-based geopolymer concrete. The compressive strength decreases when these ratios increase. However, the sodium oxide-to-silicon oxide (Na_2O-to-SiO_2) molar ratio of the geopolymer mixture does not have any significant effect on the compressive strength within the range of 0.095 and of 0.120 of this ratio.

Subhash V. Patankar et al, (2013) has been carried out to study the effect of water-to-geopolymer binder ratio on workability in terms of flow and compressive strength tested after heat curing in oven at 90^0C for 8 hours duration. Activated liquid to fly ash ratio of 0.35 by mass was maintained constant on the basis of past research. Sodium silicate solution with Na_2O = 16.37%, SiO_2 = 34.35% and H_2O = 49.28% and 13 mole concentrated sodium hydroxide solution were used as alkaline activators. Test results show that the flow of geopolymer concrete increases with increase in the water-to-geopolymer binder ratio. But the compressive strength decreases with increase in water-to-geopolymer binder ratio similar to water/cement ratio in cement concrete.

Prakash Vora,(2012)has worked on mechanical properties of the processed fly ash based geopolymer concrete. Geopolymers are a type of inorganic polymer formed at certain temperature by using industrial waste or by products as source materials to form a solid binder that looks like & performs a similar function to ordinary Portland cement. Normally for geopolymer concrete class F fly ash of thermal power station is used. In the present investigation Class F Processed fly ash from Dirk India Private Limited was used. The effect of good quality processed fly ash on the mechanical properties like Compressive strength, Split Tensile strength & Flexural strength of geopolymer concrete was investigated & compared with ordinary Portland cement concrete properties. The results indicated that the geoplymer concrete gives good results for various mechanical properties as compared to control concrete. Complete replacement of OPC by fly ash has brought at par or superior performance of geoploymer concrete as compared to that for the control concrete depicts importance of geopolymer concrete for Civil Engineering applications.

N A Lloyd, (2013) has obtained Geopolymer results from the reaction of a source material that is rich in silica and alumina with alkaline liquid. It is essentially cement free concrete. This material is being studied extensively and shows promise as a greener substitute for ordinary Portland cement concrete in some applications. Research is shifting from the chemistry domain to engineering applications and commercial production of geopolymer concrete. It has been found that geopolymer concrete has good engineering properties with a reduced global warming potential resulting from the total replacement of ordinary Portland cement. The research undertaken at Curtin University of Technology has included studies on geopolymer concrete mix design, structural behavior and durability. This paper presents the results from studies on mix design development to enhance workability and strength of geopolymer concrete. The influence of factors such as, curing temperature and régime, aggregate shape, strengths, moisture content, preparation and grading, on workability and strength are presented. The paper also includes brief details of some recent applications of geopolymer concrete.

Claudio Ferone et al. (2011) has studied on coal fly ash has been used in polycondensation processes aimed at the production of geopolymer–based low temperature ceramic bricks. The ash has been employed both “as received” and after drying, showing favorable reactivity in any case. Different curing conditions with a variable period at 60 °C have been tested. Samples obtained have been characterized by measuring Unconfined Compressive Strength (UCS) and by SEM observations. Good strength values have been obtained with the systems tested. Furthermore, it has been found that mechanical performance increases as the time during which samples are kept at 60 °C increases.

Prakash R. Vora et al (2013) have described the experimental work conducted by casting 20 geopolymer concrete mixes to evaluate the effect of various parameters affecting its the compressive strength in order to enhance its overall performance. Various parameters i.e. ratio of alkaline liquid to fly ash, concentration of sodium hydroxide, ratio of sodium silicate to sodium hydroxide, curing time, curing temperature, dosage of super plasticiser, rest period and additional water content in the mix have been investigated. The test results show that compressive strength increases with increase in the curing time, curing temperature, rest period, concentration of sodium hydroxide solution and decreases with increase in the ratio of water to geopolymer solids by mass & admixture dosage, respectively. The addition of naphthalene based superplasticiser improves the workability of fresh geopolymer concrete. It was further observed that the water content in the geopolymer concrete mix plays significant role in achieving the desired compressive strength.

Benny Joseph, (2012) has presented the summary of study carried out to understand the influence of aggregate content on the engineering properties of geopolymer concrete. Influence of other parameters on engineering properties of geopolymer concrete such as curing temperature, period of curing, ratio of sodium silicate to sodium hydroxide, ratio of alkali to fly ash and molarity of sodium hydroxide are also discussed in this paper. Based on the study carried out, it could be concluded that a geopolymer concrete with proper proportioning of total aggregate content and ratio of fine aggregate to total aggregate, along with the optimum values of other parameters, can have better engineering properties than the corresponding properties of ordinary cement concrete.

E. Arioz(2012) have studied the effects of curing conditions on physical and mechanical properties and on the microstructure of geopolymer pastes were investigated. F class fly ash was activated by 12M sodium hydroxide and sodium silicate solutions. Geopolymer pastes were cured at 40°C, 80°C and 120°C for 6, 15 and 24 hours respectively. The samples were tested for compressive strength at the ages of 7, 28 and 90 days and the effect of aging was also investigated. After 28 days of curing, the samples were crushed and were extracted using leaching tests. USEPA TCLP (toxicity characteristic leaching procedure) method was applied for leaching tests. Inductively Coupled Plasma-Optical Emission Spectroscopy was used to determine the content of leach solution. For 28-days samples, microstructure of the samples were observed by X-ray diffractometry(XRD), Scanning Electron Microscope(SEM)/Energy Dispersive X-Ray(EDX) Spectrometer, and Fourier Transform Infrared Spectroscopy(FTIR) techniques. The results showed that the curing temperature and time are important parameters affecting the mechanical properties and microstructure of geopolymers.

Kunal Kupwade-Patil, (2013), The author studied reports the findings of an experimental investigation for alkali silica reaction (ASR) between reactive aggregates and the geopolymer matrix. Specimens were prepared using one Class C and two Class F fly ash stockpiles.

Aleksandra Radlinsha,et al. (2013) have been studied the micro structural (as determined by quantitative X-ray diffraction, scanning electron microscopy, and energy dispersive spectroscopy techniques) and material properties of alkali-activated fly ash concrete were evaluated to verify the material's performance and structural viability. Results show that the heat-cured products of reaction of fly ash in an aqueous alkaline solution form a concrete binder with adequate design properties and promising durability aspects

P.M.Vijaysankar, et al. (2013), have obtained the behavior of Fly ash based Geopolymer Concrete Solid Blocks and its Durability, the size of the block were adopted was 200mm x 200mm x 400mm. The brick were cast with fly ash to river sand, M-sand and eco-sand (silica sand) with the ratio of 1:2.5 by weight. Sodium hydroxide and Sodium silicate solution were used as the alkaline activators. The binder solution consists of a combination of NaOH and Na2SiO3 solution in the ratio of 1:2.5. The optimum water/ binder ratio of 0.416 was selected as per available literature. The water/binder ratio is the ratio of solution (NaOH, Na2SiO3 and water) to fly ash. Totally 60 blocks were casted in this study under ambient curing. The blocks were cast with different types of sand with river sand, M-sand and eco-sand (silica sand). The experimental results obtained were compared with locally available Cement Solid Blocks.

Sourav Kr. Das, et al. (2014),have worked on high mechanical properties combined with substantial chemical resistance (magnesium or sulphate attack), low shrinkage and creep and environment friendly nature (very less amount of CO2 production in comparison with OPC), it is a novel construction material for future. Till date it was seen that the strength of geo-polymer concrete mostly depends on the molarities of the alkaline liquid (NaOH or KOH) and ratios of SiO2and Na2O, H2O and Na2O, Si and Al, water to geopolymer solids by mass in the total alkaline solution. It was seen that geo-polymer concrete made of fully Fly-ash or partial replacement by GGBS results with 80% reduction in CO2 emission compared to OPC, although the alkaline solution to some extent pollutes the environment.

Subhash V. Patankar,et al.(2013) have studied on Geopolymer concrete/mortar is the new development the field of building constructions in which cement is totally replaced by pozzolanic material like fly ash and activated by alkaline solution. This paper presented the effect of concentration of sodium hydroxide, temperature, duration of oven heating on compressive strength of fly ash based geopolymer mortar. Sodium silicate solution containing Na2O of 16.45%, SiO2 of 34.35% and H2O of 49.20% and sodium hydroxide solution of 2.91, 5.60, 8.10, 11.01, 13.11 and 15.08 Moles concentrations were used as alkaline activators. Geopolymer mortar mixes were prepared by considering solution-to-fly ash ratio of 0.35, 0.40 and 0.45. The temperature of oven curing was maintained at 40, 60, 90, and 1200C each for heating period of 24 hours and tested for compressive strength at the age of 3 days as test period after specified degree of heating. Test results show that the workability and compressive strength both increases with increase in concentration of sodium hydroxide solution for all solution-to-fly ash ratios. Degree of heating also plays vital role in accelerating the strength however there is no large change in compressive strength beyond test period of three days after specified period of oven heating.

III. Conclusion

In this research review paper methods of curing of geopolymer concrete is discussed in brief. Oven heat curing of geopolymer concrete has been attempted by various researchers. but for curing of geopolymer concrete is quit difficult on site by using oven, so there is scope to work on types of curing which makes geopolymer concrete cure easily. Most of researcher used only oven heat curing for geopolymer concrete. They studied only for different curing temperature in oven curing, but only few researcher work on steam, membrane curing and no one work on accelerated curing, as well as comparison on steam, accelerated, membrane, natural and oven curing. So there is scope on method of curing of geopolymer concrete. Most of researchers work on compressive strength only, so there is scope to study the mechanical properties like short term as well as long term property of geopolymer concrete. Also researchers studied for different curing time like 6,12,18,24 hours and also for different curing temperature but few researchers worked on different rest period, so there is scope for work.

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