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A Review On Development Of Flyash Based High Strength Geopolymer Concrete

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Abstract: *Geopolymer concrete is the latest development in the field of concrete technology and it is still developing. Geopolymers are inorganic, stable, hard and non-inflammable binder. The application of geopolymer binder are in fire resistance fiber composite, sealant industry, tooling aeronautics SPF aluminium, foundry equipment's, radioactive toxic waste, ceramic, bricks and other precast concrete. The current review is aims to put forward the development in geopolymer concrete for the production high strength geopolymer concrete having strength more than 90MPa. The development of high strength concrete is aimed to reduce structural member sizes and for economical construction in case of long span bridges and tall buildings. Also the use flyash in concrete to reduce green gas house emission into the atmosphere by reducing cement usage.*
Keywords: *Geopolymer concrete, high strength*

I. Introduction

The growing development in the field of construction due to urbanisation which leads to increased infrastructure, building and industrial development. To accomplish human requirement for economical construction high strength concrete is preferred. Cement is one of the most important material commonly used in every phase of construction. The increasing demand of cement production escalates manufacturing of cement. However for the production of one ton of cement releases approximately one ton of carbon dioxide (CO2) in to the atmosphere [1], which causes global warming. Around 7% of world greenhouse gas emission is attributed to cement production [2]. To reduce the use of cement into the concrete, use of mineral admixture were incorporated. Mineral admixtures are such as fly ash, silica fume, ground granulated blast furnace slag (ggbfs), rice husk ash and Metakaolin. Initially cement was replaced partially with mineral admixture and found useful results. Later the high volume fly ash was used for the production of concrete. The newer development in the field concrete technology is the concrete without Portland cement. French scientist Professor Davidovits in 1978 introduced a concrete which is produced by activating fly ash with alkaline solution without use of Portland cement. Davidovits named that concrete as a Geopolymer concrete. The geo means earth and polymer is small molecular chain of monomers. The Geopolymer concrete depend on thermally activated natural materials like Metakaolin or industrial by-product like fly ash, ggbfs, silica fume etc. to provide as a source of silicon (Si) and aluminium (Al). These Silicon and Aluminium is dissolved in an alkaline activating solution and subsequently polymerizes into molecular chains and become the binder [1].

II. Literature Review

The information related to fly ash based high strength geopolymer concrete from various sources i.e. journals, conference proceedings, books, codes etc. is collected. The review of literature is presented in subsequent sections. Professor Davidovits (1994) first studied about geopolymer concrete by using high alkali (K-Ca)-Poly (Sialate-siloxo) cement results from an inorganic polycondensation reaction, also called geopolymerisation. Yielding three dimensional zeolites frameworks. High tech geopolymer K ply (Sialate-siloxo) Binders ,weather used pure, with filler or reinforces are already finding application Geopolymer cement rapidly hardens rapidly at room temperature and provide compressive strength in the range of 20^0C, when tested in accordance with the standards applied to hydraulic binder mortars.[1]. The strength developed by AASC (alkali activated slag concrete) is reduced by lack of moist curing [2]. The test results shown that the compressive strength of geopolymer concrete does not vary with age, and curing the concrete specimens at higher temperature and longer curing period will result in higher compressive strength. Still, the commercially available Naphthalene-based super plasticizer progresses the workability of fresh geopolymer concrete. The start of curing of geopolymer concrete at elevated temperatures can be retarded at least 60 minutes without significant effect on the compressive strength. The test data also shown that the quantity of water in the concrete mix plays an important role [3]. The author studied about workability and strength of geopolymer mortar made from coarse lignite high calcium fly ash which was in the range of 110 ± 5%–135 ± 5% and was dependent on the ratio by mass of sodium silicate to NaOH and the concentration of NaOH. He obtained compressive strength was in the range of 10–65 MPa [6]. The researcher investigated by embedding Steel bars in an alkali-activated slag (AAS) concrete which was exposed (after curing for 28 days) to an accelerated carbonation test (3% CO2, 65% relative humidity (RH), and 25 _C temperature) and a laboratory environment (0.03% CO2, 65% RH, and 25 _C). Ordinary Portland cement (OPC) was also tested for relative purposes and exposed to alike experimental environments. The corrosion behavior of uncarbonated and carbonated AAS and OPC concretes was tested for different times, performing corrosion potential, linear polarization resistance, and electrochemical impedance spectroscopy measurements [8].The researchers conducted espriments on fly ash based geopolymer concrete by varying the types of curing namely ambient curing and hot curing. They use the ratio of alkaline liquid to fly ash as 0.4 for all the samples and the rest period kept as 5 days. For hot curing, they maintained temperature at 60^{o}C for 24 h in hot air oven. They perform test on compressive strength for each sample and they observed that there is an increase in compressive strength with the increase in age for ambient cured specimens and for hot cured samples the increase in compressive strength with age was very less as compared to that of specimens subjected to ambient curing. Their density of geopolymer concrete was around 2400 kg/m3 which is equivalent to that of conventional concrete [9].

Jamkar et al [21] studied the effect of fly ash fineness on workability and compressive strength of geopolymer concrete. Geopolymer concrete (GPC) was produced with different fineness of fly ashes with Blaine fineness of 542, 430, 367, 327 and 265 m^2/kg and activator solution of sodium silicate and sodium hydroxide (13 molar). The water to geopolymer binder ratio and solution to fly ash ratio was kept constant 0.35. The sodium silicate to sodium hydroxide ratio by mass was kept constant 1. The specimens were cured with varying time at about 90˚C. Authors found from their investigation that GPC in fresh state was cohesive, viscous and dark in colour. The mixes with unprocessed fly ash were relatively stiffer than processed fly ash. As the fly ash fineness will increase simultaneously, flow of GPC will also increase as measured by flow test. The strength of GPC will increase as the fineness of fly ash increases. Authors concluded that the rate of strength gain for unprocessed fly ash, UPF-II, was uniform from 4 to 24 hours of temperature curing. While the mix with UPF-I showed a uniform strength gain between 8 to 24 hours. The rate of strength gain for PF-I, PF-II and PF-III was higher during 4 to 8 hours of temperature curing there after it reduced. The mass density of GPC increased with the increasing fly ash fineness. The alkalinity of GPC was slightly affected by the fly ash fineness but it was similar to that of cement concrete.

Uma et al [26] carried out experimental investigation on the flexural response of reinforced geopolymer concrete (RGPC) beam. RGPC beam with different grades were produced under ambient curing. The reinforcement considered in the RGPC was about 0.87% and 1.75%. Total of eight number of specimen were cast by varying grade of concrete from M20 to M35. Simultaneously set of twelve cylinders were cast. These cylinders were tested to determine compressive strength, elastic modulus and Poisson’s ratio. After testing the specimens, they found that stress strain obtained for GPC was similar to OPCC. It was observed that the Poison’s ratio of GPC falls between 0.12 - 0.25. The values are nearly the same as in case of OPCC. They also developed finite element models using ANSYS 12.0 to comparative study of deformation characteristics of RGPC. They observed that the load deflection characteristics of RGPC beam using ANSYS 12.0 were found to be marginally lower compare to experimental test results. This was due to more stiffness of RGPC in ANSYS 12.0. Authors conclude that in order to get more accurate behavior, the tension reinforcement is to be precisely incorporated using discrete modeling technique.

The experimental work has been carried out by Anuar et al [22] to develop GPC incorporating with recycled concrete aggregate (RCA), waste paper sludge ash (WPSA) and alkaline liquid were used as a binder. The alkaline liquid that been used in geopolymerisation was the combination of sodium hydroxide and sodium silicate. Two different Molarity of sodium hydroxide was considered i.e. 8M and 14M. The compressive strength of the GPC specimen was tested at the age of 3, 7, 14, 21 and 28. The specimens were cured in ambient condition. Compressive strength results were plotted against ages of concrete specimens with two types NaOH molarity as discussed above. The author’s investigation revealed that higher concentration of NaOH solution higher compressive strength of GPC will produce by using RCA. GPC based on WPSA will set rapidly than GPC based on fly ash. It happen because of WPSA has high CaO content.

Patankar et al [28] investigated effects of sodium hydroxide (NaOH) on flow and strength of fly ash based geopolymer mortar. The effect of concentration of sodium hydroxide solution in terms of molarity on workability measured as flow and dry mass density after specified period of heating. Authors observed that the mix was more and more viscous and flow able with the increase in concentration of sodium hydroxide solution. Effect of duration and temperature curing on compressive strength of geopolymer mortar was observed by them that the rate of gain of strength reduces as the duration of heating increases specifically at higher temperature. After 12 hours of temperature curing, the rate of gain of strength is not much significant specifically at 90°C and 120°C but at heating temperature of 60°C, the rate of gain of strength was constantly increasing for all curing periods and with all higher concentrations. The effect of temperature on compressive strength of geopolymer mortar at various concentrations of sodium hydroxide for constant solution to fly ash ratio of 0.4 are tested 24 hours of heating in an oven at specified temperature with all other parameters held constant. Authors observed that the compressive strength increases with increase in temperature of oven heating. Rate of gain of strength was more between 40°C to 60°C temperature but the rate of gain of strength was reduced beyond 60°C as the temperature of heating increases up to 90°C or beyond that. The effect of concentration of sodium hydroxide solution in terms of molarity on compressive strength of geopolymer mortar was observed that the compressive strength increases with the increase in the concentration of sodium hydroxide solution. It was also observed by them that the higher concentration of sodium hydroxide requires higher temperature to achieve higher strength.

Semsi and Hasan [29] studied the effect of fly ash fineness on the compressive strength and splitting tensile strength of concretes. Author's experimental programme was based on three different types of fly ash fineness. Authors produced nine mixes by varying fineness and percentage of fly ash used to 5%, 10% and 15% by replacing cement. One reference mix was produced without incorporating fly ash. Hence, total ten mixes was produced. The specimens were cured in water at 20˚C. At the end of 7, 28, 56, 90, 120 and 180 days of curing the specimens were tested for compressive and splitting tensile strength. The test results of compressive and splitting tensile strength were plotted at different ages of curing. It was observed that the compressive and tensile strength of concrete increases as fineness of fly ash. But Authors investigation revealed that for better strength "Blaine fineness of fly ash" would be more than $385m^2/kg$.

Logan et al [30] carried comprehensive investigation on short term mechanical properties of high strength concrete (HSC). The main aim of their investigation was to improve predictive equations and to enhance the test data base for short term mechanical properties of HSC. Authors prepared three different mixes with target mean strength of 69, 97 and 124 MPa. The specimens were cured as described below,

1. 7 day moist curing
2. 1 day heat curing similar to that used in precast concrete plants for prestressed structural members.
3. Continual moist curing until the day of testing as per ASTM standard.

Authors test results revealed that the compressive strength for the first two concrete mixes exceeds their target values, whereas third batch failed to reach its target value. The effects of curing procedures on compressive strength were observed. The 7 day moist cured specimen showed the highest compressive strength at 28 days. The 1 day heat cured specimen showed strength gain at early age but weakened at later ages. The continual moist cured specimens exhibited a slightly lower strength. Authors expressed, this was due to low permeability of HSC.

III. Conclusion

Previous investigators have revealed that fineness of fly ash, fly ash content, type and quantity of activator solution, molarity of sodium hydroxide solution, type of source materials, blended source materials, various types of fine and coarse aggregates, water-to-geopolymer binder ratio, water to sodium oxide ratio, curing time and conditions, affect on properties of geopolymer concrete. However little information is available on the production of high strength geopolymer concrete and its properties in fresh and hardened state.

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