REVIEW ON THE STUDY OF FLY ASH BASED GEOPOLYMER CONCRETE

Vishnu Ramesh[1], Annie Joy[2]

[1] PG student, Civil Engineering, Toc H Institute of Science and Technology, Kerala, India
[2] Assistant Professor, Civil Engineering, Toc H Institute of Science and Technology, Kerala, India

ABSTRACT

Large amount of carbon-dioxide emission takes place due to the increase in the production of cement. This results into greenhouse effect. In order to overcome this problem, many researchers have done experiments to find out optimum strength of concrete by replacing cement with fly ash and when it combine with alkaline solution which is known as a Geopolymer concrete. Self Compacting Geopolymer Concrete (SCGC) is a type of concreting execution and it does not require compaction. It is made by complete elimination of ordinary Portland cement content. SCGC needs more amount of fine aggregate than coarse aggregate compared to control mix. Geopolymer concrete were synthesized from fly ash, activated by combination of alkaline solution(sodium hydroxide and sodium silicate or potassium hydroxide and potassium silicate).

Keyword: - *Self compacting geopolymer concrete, Fly ash*

1. INTRODUCTION

Geopolymer binders are a type of inorganic polymer that can be formed by using industrial waste or by-products as source materials to form a binder that looks like and performs a similar function to Ordinary Portland Cement. Geopolymer binder can be used in applications to fully replace OPC with environmental and technical benefits. Geopolymer binder is made from alumina and silicon, and not from calcium and silicon. The sources of aluminium which is present in nature are not as carbonates. When aluminium made active for use as geopolymer binder, it do not release vast quantities of CO_2. The temperature during curing is very important and depending upon the source materials and activating solution; heat often must be applied to facilitate polymerization. Geopolymer binders differ from Portland cement in their setting mechanism which depends on polymerization rather than hydration. As a result geopolymers can achieve their significant maximum strength within 3 to 5 days, depending on the curing effort applied. Self-compacting concrete (SCC) is a flowing concrete mixture that is able to consolidate under its own weight. SCC is of high fluid nature. This fluid nature makes it suitable for placing in difficult conditions and in sections with congested reinforcement. Use of SCC can also help minimize hearing-related damages on the worksite. Such damages are induced by vibration of concrete. Reduction in time required to place large sections is another advantage of SCC. Self compacting geopolymer concrete is the combination of both self compacting concrete and geopolymer concrete

2. LITERATURE REVIEW

Different studies were done in the field of geopolymer concrete and some of them are listed below. Researchers found that geopolymer concrete is an effective replacement to conventional concrete using ordinary Portland cement.

Jamdade P.K et.al (2014)[1] promoted the use of industrial waste fly ash as the replacement for cement. Researchers done experiments on curing time, curing temperature of geopolymer concrete. The compressive strength rises from 12 hrs to 24 hrs at 60°c. The compressive strength is considerably achieved but for the polymerization the temperature is not sufficient. The study shows that, for polymerisation the temperature 90°c is quite sufficient. Geopolymer concrete gives more strength than normal concrete in minimum period of curing. Geopolymer concrete has larger compressive strength with higher curing temperature. Increase in the curing temperature beyond 60° c did not increase the compressive strength substantially. As the curing time is increased, it will improve the polymerization and increase the compressive strength.

Krishnan L et.al (2014)[2] conducted studies and concluded that the geopolymer technology is suitable for application in concrete industry as an alternative binder to the Portland cement. Geopolymer binder is prepared using fly ash and GGBS(ground granulated blast furnace slag) with alkaline liquids sodium hydroxide and sodium silicate. A 12 Molarity solution was taken to prepare the mix. The objective of this research work was to produce a carbon dioxide emission free cementious material. Geopolymer concrete is such a material that avoids such harmful effects. The emission of carbon dioxide during the production of ordinary Portland cement is very much high. The production of one ton of Portland cement emits approximately one ton of CO_2 into the atmosphere.

Ali A. Aliabdo et.al (2016)[3] used an innovative industrial waste fly ash as a replacement of cement and the effect of little addition of cement with fly ash are described in this work. Objective of the study is to find out the compressive strength, split tensile strength characteristics of fly ash based geopolymer and also with some addition of cement. This paper also intends to find out the alkaline solution resting time, curing period and curing temperature on fly ash based geopolymer concrete. The study results show that, generally adding cement improves all fly ash based geopolymer properties but it does not improve workability. The increase of fly ash content improves geopolymer concrete properties. Using 30 min resting solution has a significant effect on geopolymer properties compared with using 24 h resting solution.

Hardijito et.al (2008)[4] observed that higher concentration of sodium hydroxide resulted higher compressive strength. Higher compressive strength of geopolymer concrete is also shown when the ratio of sodium silicate-to-sodium hydroxide liquid ratio by mass is higher. There is an increase in compressive strength with the increase in curing temperature in the range of 30 to 90 °C. Longer curing time also increased the compressive strength.

Rashida A jhumarwala et.al (2013)[5] conducted an experimental investigation on Self compacting geopolymer concrete (SCGC). SCGC were synthesized from low calcium fly ash and it is activated by combination of sodium hydroxide and sodium silicate solution. Incorporation of super plasticizer is done for self-compatibility. In this study it is observed that maximum compressive strength of SCGC is achieved at higher temperature cured concrete. It is also observed that, as molarity increases the strength goes on decreasing.

Sashidhar C et.al (2015)[6] conducted study on Fresh and Strength Properties of Self compacting Geopolymer Concrete Using Manufactured Sand. In this study, SCGC mixes were manufactured using class F fly ash and ground granulated blast furnace slag (GGBS) with proportion of 50:50 and with 100% manufactured sand (MS). This investigation is mainly focused on the fresh and compressive strength properties of SCGC. It is done by varying the molarity of sodium hydroxide. During all curing periods at ambient temperature, the contribution of GGBS helps the SCGC mixes to attain significant compressive strength development.

Ushaa T G et.al (2015)[7] investigated the performance of self compacting geopolymer concrete containing different mineral admixtures. In this study, fly ash was replaced by different mineral admixtures. The use of such materials reduces the cost of self compacting geopolymer concrete. It occurs especially if the mineral admixtures used are waste or industrial by-product. From the study it was found that all the self compacting geopolymer concrete mixes had a satisfactory performance in the fresh state. Good workability is found for blast furnace slag series compared to silica fume series among the mineral admixtures considered.

Shankar.H.Sanni et.al (2013)[8] conducted experimental investigation on the variation of alkaline solution on mechanical properties of geopolymer concrete based on fly ash. The grades chosen for the investigation were M-30, M-40, M-50, M-60 and the mixes were designed for 8 molarity. The alkaline solution used for the study was the combination of sodium silicate and sodium hydroxide solution and the varying ratio taken are 2, 2.50, 3 and 3.50. The test specimens were 150x150x150 mm cubes and 100x200 mm cylinders. Specimens were heat-cured at 60°C in an oven. The freshly prepared geopolymer mixes were cohesive. Increase in the ratio of alkaline solution increases the workability. The strength of geopolymer concrete can be improved by decreasing the water/binding and also aggregate/binding ratios. The curing period improves the polymerization process resulting in higher compressive strength. The obtained compressive strength is in the range of 20.64 – 60 N/mm^2 and split tensile strength is in the range of 3 – 4.9 N/mm^2. The optimum dosage for alkaline solution can be considered as 2.5 and because for this ratio, the strength is maximum for GPC specimens of any grade in compression and tension.

Faiz uddin ahmed sheikh (2016)[9] in his paper, presents mechanical and durability properties of geopolymer concrete that contains recycled coarse aggregate (RCA). The RCA is collected from local construction and demolition (C&D) waste in Perth, Australia. The RCA is used as a partial replacement of natural coarse aggregate (NCA) in geopolymer concrete. Replacement at 15%, 30% and 50% by weight which is corresponding to series two, three and four, respectively, whereas the geopolymer concrete containing 100% NCA is control and is considered as the first series. The effects of RCA on the measured mechanical and durability properties of geopolymer concrete follow similar trend in cement concrete. Observations are done in very good correlations of compressive strength with volume of permeable voids and water absorption of geopolymer concrete containing RCA, whereas the correlation between the compressive strength and the sorptivity is not that strong. This paper presents preliminary study on the effect of recycled coarse aggregates (RCA) mainly on the mechanical and durability properties of fly ash based geopolymer concrete. The mechanical properties are measured at 7 days and 28 days whereas the durability properties are measured at 28 days.

Sabina kramar et.al (2015)[10] in her study, deals with the mechanical and microstructural characterization of geopolymers synthesized from locally available fly ash. Sodium silicate solution is used for activating low calcium fly ash. Characterization of samples were done by means of flexural and compressive tests, X-ray powder diffraction (XRD), Fourier transform infrared (FTIR) spectroscopy and scanning electron microscopy (SEM). Mercury intrusion porosimetry and gas sorption were used to identify porosity and pore size distributions. The compressive strength of the geopolymers, which is in the range of 1.6 to 53.3 N/mm^2, is strongly related to the water content and also with the SiO_2 / Na_2O mass ratio of an alkali activator. The compressive strength significantly increased with decrease in the water content and also with the increased silicon concentration used for the synthesis of geopolymers.

Emad Benhelal et.al(2013)[11] investigated that cement industry has been always among the largest CO_2 emission sources. Almost 5-7% of global CO_2 emissions are caused by cement plants, while 900 kg of CO_2 is emitted to the atmosphere for the production of one ton of cement. In this particular work, discussions have been done on global strategies and potentials toward mitigation of CO_2 emissions in cement plant and the most promising approaches have been introduced. More over the barriers against worldwide deployment of such strategies are identified and comprehensively described. Detail review have been done in three strategies of CO_2 reduction including energy saving, carbon separation and storage as well as utilizing alternative materials. The significant industrial CO_2 emissions released impose an immeasurable impact on the environment. Its atmospheric concentration was substantially enlarged over the past decades from 1.1% per year for 1990-1999, to 3.5% per year for 2000-2007 and eventually reached to 394.35 ppm in May 2011. With the increase in the CO_2 emissions to the environment for the past decades that contribute to the global warming phenomenon, more research was done to overcome this problem. Beside that these emissions strictly forced governments around the world to discuss promising approaches toward emission control and mitigation that could be applied by all industries that facing the same CO_2 emission problem especially for the cement industry. Cement plant has been always among industries which generate plenty of CO_2 aside from other sectors such as electricity and heat generation sector and transportation sector. In addition to CO_2 generation due to fossil fuels combustion in the cement production, carbon dioxide is also produced as by-product during decomposition reactions. Moreover in conventional plants various near optimal design and operation lead to extra and undesired emissions of CO_2 into the environment. Therefore, this analysis was done with objectives to clearly review all the factors that need to be taken into consideration in implementing the strategic approaches on reducing the CO_2 emission to the environment by the cement industries.

Daniel L Y(2010)[12] in his paper, presents a study on geopolymers and geopolymer/aggregate composites made with class F flyash. Samples were heated up to 800° C to evaluate strength loss due to thermal damage. There is 53% of strength increase for geopolymer after temperature exposure. The tests show that the aggregates steadily expanded with temperature with an expansion of about 1.5–2.5% at 800°C. Correspondingly, the geopolymer matrix undergoes contraction of about 1% between 200°C and 300°C and also a further contraction of 0.6% between 700°C and 800°C. This apparent incompatibility is concluded to be the cause of the observed strength loss. 15 different geopolymer combinations and four different aggregates are presented in this study.

3. RESULTS AND DISCUSSION

Geopolymer concrete achieves strength early than conventional concrete. This happens because of the curing method applied. Oven curing or high temperature curing enhances the early strength attainment. Geopolymer concrete shows optimum compressive strength mainly at sodium silicate to sodium hydroxide ratio of 2.5. Figure 1 show compressive strength obtained for different grades. Temperature plays a significant part in strength achievement. Figure 2 shows the 28 day compressive strength of geopolymer concrete at various temperatures. Variation in alkali to binder ratio, curing time also has very much importance in strength.

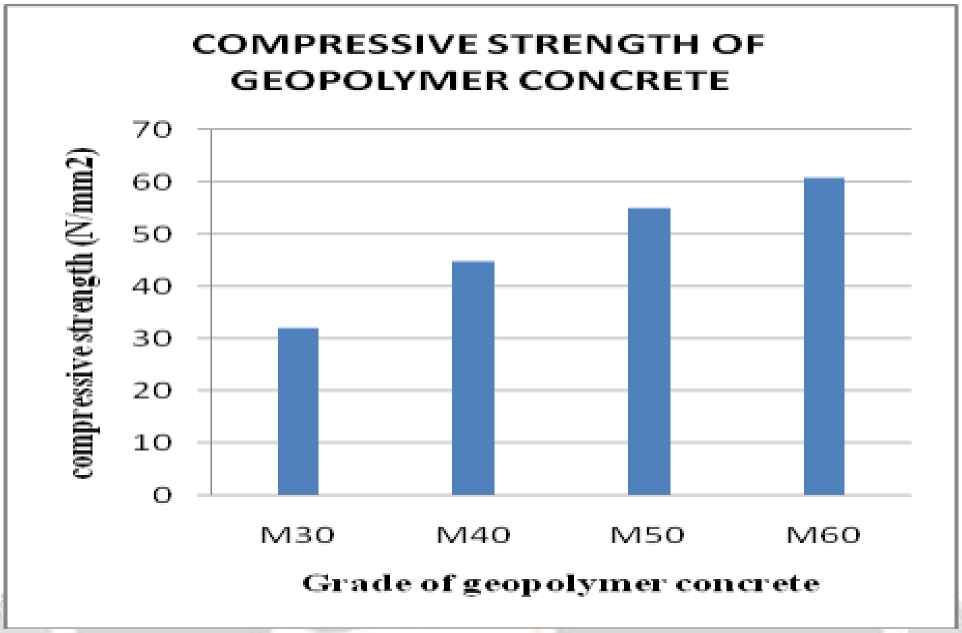

Chart-1: 28 day compressive strength of geopolymer concrete with sodium silicate to sodium hydroxide ratio of 2.5

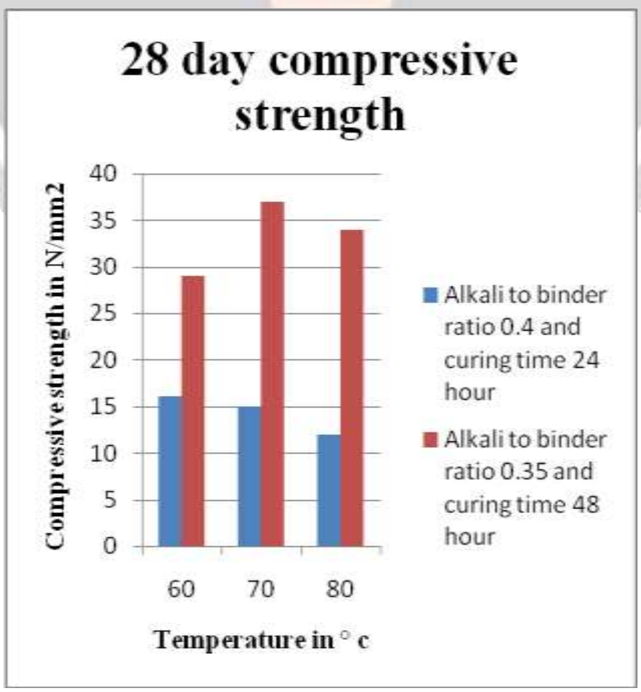

Chart- 1: Effect of temperature on compressive strength of concrete

4. CONCLUSIONS

Compressive strength of Geopolymer concrete is sufficient enough to be used in construction activities. Main consideration should be given to the curing process. It means proper oven curing leads to good strength properties, otherwise the strength attainment may consume time. This Geopolymer concrete technology proves to be a good alternative to cement and thus it reduces or eliminates the harmful effects caused by cement. Large emission of CO_2 can be eliminated. At the same time fly ash is a byproduct which is largely available can be effectively utilized for construction. Other factors needed to be considered are Sodium silicate to sodium hydroxide ratio or potassium silicate to potassium hydroxide ratio, Molarity of Sodium hydroxide or potassium hydroxide (according to alkali used), Alkali to binder ratio, Curing temperature and curing period.

5. REFERENCES

[1]. Prof. Jamdade P.K, Prof. Kawade U.R, (2014), Evaluate Strength of Geopolymer Concrete by Using Oven Curing, *IOSR Journal of Mechanical and Civil Engineering*. 11, 63-66

[2]. Krishnan L, Karthikeyan S, Nathiya S, Suganya K, (2014) Geopolymer concrete an eco-friendly construction material, *International Journal of Research in Engineering and Technology*,3, 164-167

[3]. Ali A. Aliabdo, Abd Elmoaty M, Abd Elmoaty, Hazem A. Salem, (2016) Effect of cement addition, solution resting time and curing characteristics on fly ash based geopolymer concrete performance, *Journal of Construction and Building Materials*, 123, 581-593

[4]. Djwantoro Hardjito, Chua Chung Cheak, Carrie Ho Lee Ing (2008) Strength and Setting Times of Low Calcium Fly Ash-based Geopolymer Mortar, *Modern applied science*,2, 3-11

[5]. Rashida A Jhumarwala, Rao P.S, Patel T.N (2013) Experimental Investigation on Self Compacting Geopolymer Concrete (SCGC), *Paripex - Indian Journal Of Research*, 3, 173-175

[6]. Sashidhar C, Guru Jawahar J, Neelima C, Pavan Kumar D (2015) Fresh and Strength Properties of Self compacting Geopolymer Concrete Using Manufactured Sand, *International Journal of ChemTech Research*,8, 183-190.

[7]. Usha T G, Anuradha R, Venkatasubramani G S (2015) Performance of self compacting geopolymer concrete containing different mineral admixtures, *Indian journal of engineering and material sciences*, 22, 473-481

[8]. Shankar H. Sanni, Khadiranaikar R.B (2013) Performance of alkaline solutions on grades of geopolymer concrete, *International Journal of Research in Engineering and Technology*, 366-371

[9]. Faiz Uddin Ahmed Shaikh (2016) Mechanical and durability properties of fly ash geopolymer concrete containing recycled coarse aggregates, *International Journal of Sustainable Built Environment*.

[10]. Sabina Kramar, Vilma Ducman (2015) Mechanical And Microstructural Characterization of Geopolymer Synthesized From Low Calcium Fly Ash, *Chemical Industry & Chemical Engineering Quarterly*,21, 13-22

[11]. Emad Benhelal, Gholamreza Zahedi, Ezzatollah Shamsaei, Alireza Bahadori (2013) Global strategies and potentials to curb CO2 emissions in cement industry, *Journal of Cleaner Production*,142-161

[12]. Daniel L.Y. Kong, Jay G. Sanjayan (2010) Effect of elevated temperatures on geopolymer paste, mortar and concrete, *Cement and Concrete Research*,40, 334-339