Mix Design and Environmental Benefits of Geopolymer Concrete

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Abstract: **In this study we carry out a detailed environmental evaluation of geopolymer concrete production using the Life Cycle Assessment methodology. The literature shows that the production of most standard types of geopolymer concrete has a slightly lower impact on global warming than standard Ordinary Portland Cement (OPC) concrete. Whilst our results confirm this they also show that the production of geopolymer concrete has a higher environmental impact regarding other impact categories than global warming. This is due to the heavy effects of the production of the sodium silicate solution. Geopolymer concrete made from fly ashes or granulated blast furnace slags based require less of the sodium silicate solution in order to be activated. They therefore have a lower environmental impact than geopolymer concrete made from pure metakaolin. However, when the production of fly ashes and granulated blast furnace slags is taken into account during the life cycle assessment (using either an economic or a mass allocation procedure), it appears that geopolymer concrete has a similar impact on global warming than standard concrete. This study highlights that future research and development in the field of geopolymer concrete technology should focus on two potential solutions. First of all the use of industrial waste that is not recyclable within other industries and secondly on the production of geopolymer concrete using a mix of blast furnace slag and activated clays. Furthermore geopolymer concrete production would gain from using waste material with a suitable Si/Al molar ratio in order to minimise the amount of sodium silicate solution used. Finally, by taking into account mix-design technology, which has already been developed for OPC concrete, the amount of binder required to produce a geopolymer concrete could be reduced.**

Key Words: **Geopolymer Concrete, Sodium, Silicate, Sodium Hydroxide, Fly ash, Ground granular blast furnace slag, Compressive strength, Split Tensile strength, Flexural strength, and Temperature effect.**

I. INTRODUCTION

The search for environmentally friendly construction materials is imperative, as the world is facing serious problems due to environmental degradation. There is a significant expectation on the industry to reduce carbon dioxide (CO2) emissions to the atmosphere. In view of this, one of the efforts to produce environmentally friendly concrete is to reduce the usage of Portland cement by using by-product materials, such as fly ash. It is known that production of one ton of Portland cement accounts for about one ton of carbon dioxide released to the atmosphere, as the result of de-carbonation of limestone in the kiln during manufacturing of cement. A significant advance in the usage of fly ash in concrete is the development of high volume fly ash (HVFA) concrete, which partially replaces the use of Portland cement in concrete(up to 60%), while maintaining excellent mechanical properties with enhanced durability performance. Another development is geopolymer, i.e. inorganic Alumino-silicates polymer synthesized from minerals of geological origin or by- products materials, such as fly ash, rice husk ash etc., that are rich in silicon (Si) and aluminum (Al). Fly ash is abundantly available worldwide, and efforts to utilize it in concrete production are of significant interest to the concrete technologists and industry. GGBS (Ground Granulated Blast Slag) is a waste material generated in iron or slag industries have significant impact on Strength and Durability of Geopolymer Concrete. This paper gives a brief review of the development of geopolymer concrete. The factors that affect the production of geopolymer concrete such as source minerals, workability, curing time, and curing temperature are discussed in the paper. The potential use of geopolymer concrete and the future challenges are also mentioned.

II. LITERATURE REVIEW

Several authors have reported the use of GGBS in Geopolymer Concrete for various civil engineering applications Abdul Aleem M.I and Arumairaj (2012) made an attempt to find out an optimum mix for the Geo-polymer concrete and they have casted concrete cubes of size 150 x 150 x 150 mm and cured under Steam curing for 24 hours based on the compressive strength. The optimum mix is Fly ash: Fine aggregate: Coarse aggregate (1:1.5:3.3) with a solution (NaOH & Na2SiO3 combined together) to fly ash ratio of 0.35. High and early strength was obtained in the Geo-polymer concrete mix. Abdul Aleem M.I and Arumairaj P.D (2012) conducted a review surveying on Geopolymer concrete. It was presented that due to the high early strength Geopolymer Concrete shall be effectively used in the precast industries, so that huge production is possible in short duration and the breakage during transportation shall also be minimized. They revealed the characteristics of geopolymer concrete and informed that Geopolymer Concrete can be used in place of ordinary Portland cement concrete. Balaguru. P (1997) conducted a study on the usage of Geopolymer concrete for Repair and rehabilitation of reinforced concrete Beams. The primary objective of the investigation was to determine whether Geopolymer can be used that not for repair of concrete. They concluded that Geopolymer concrete can be successfully used to bond carbon fabrics to reinforced concrete beams. Bhikshma et al. (2010), investigated the flexural behavior of high strength manufactured sand concrete. The researchers observed that Workability of the M50 grade manufactured sand concrete observed to be 30% less compared to the conventional concrete, the compressive strength of M50 grade concrete with varying percentages of (0%, 25%, 50%, 75%,and 100%) manufactured concrete improved the strengths by 6.89%, 10.76%, 17.24%, 20.68%,respectively and the load carrying capacity and Moment carrying capacity of the RC beams of manufactured sand concrete obtained 3 to 12% higher when compared to conventional concrete. GANAPATHI NAIDU.P et al (2012) presented out a Study on strength properties of Geopolymer concrete with addition of GGBS. In this paper an attempt was made to study the strength properties of Geopolymer concrete using Low calcium fly ash replacing with slag in 5 different percentages. They obtained Compressive strength of geopolymer concrete increases with increase in percentage of replacement of fly ash with GGBS was up to 28.57% of replacement of fly ash by GGBS, the setting was normal and fast setting was observed. They concluded maximum of 25% loss in compressive strength was observed when geopolymer exposed to a temperature of 500□C for two hours.

Joseph Davidovits (1994) carried out a Properties of Geopolymer cements. This paper focused on Geopolymer concrete has excellent properties and is well-suited to manufacture precast concrete products that are needed in rehabilitation and retrofitting of structures after a disaster. The concluded by introduced low – CO_2 geopolymeric cements, not only for environmental uses, but also in construction, civil engineering would reduce CO_2 emission caused by the cement and concrete industries by 80%. Leopoldo franco et al (2000) carried out a research on concrete strength and durability of prototype tetrapod and compared the results of field and laboratory tests. This paper presented in order to investigate the material properties after a long-term exposure at sea. There was little or no degradation had taken place after 16 to 24 years period at sea. LIoyd N.A and B.V Rangan (2010) conducted experiments on geopolymer concrete with fly ash. They conclude that Geopolymer concrete has excellent properties and is well-suited to manufacture precast concrete products that are needed in rehabilitation and retrofitting of structures after a disaster. Current research is focusing on the durability of Geopolymer in aggressive soil conditions and marine environments. Lyon E et al (1996) studies the Fire Response of Geopolymer structural composites. They study the use of Geopolymer composites in infrastructure and transportation applications. They revealed that Geopolymer composites are non – combustible structural materials which are suitable for infrastructure applications where a high degree of fire resistance is needed at low to moderate cost. Also it was interred that load bearing capability during fire exposure, where temperatures reach several hundred degrees centigrade, will be significantly higher than organic resin composites. Madheswaran C.K et.al (2013) studied the variation of strength for different grades of geo polymer concrete by varying the molarities of sodium hydroxide. Different molarities of NaOH (3M, 5M, and 7M) were taken to prepare different mixes and cured in the ambient temperature. GPC mix formulations with compressive strength ranging from 15 to 52 MPa had been developed. The specimens were tested for their compressive strength at the age of 7 and 28 days. The compressive strength of GPC increased with increasing concentration of NaOH. Mahesh Patel et al. (2013), studied the Strength of High Performance Concrete with GGBS and Crusher Sand by replacing the fine aggregates by crusher sand and cement by CGBS. It was concluded that the 20% replacement of find aggregates by crusher sand was optimum, based on the Compressive strength and Split Tensile strength. Mohemed aquib javeed et al (2015) a carried out Studies to find out the optimum level of sustainable Geopolymer concrete with combination of manufactured sand and pond ash as a fine aggregate material replacing conventional natural river sand and using ambient curing for its strength development. It was confirmed that 60% of m-sand and 40% of pond ash as a replacement to natural sand was optimum amount in order to get a favorable strength. Muhd Fadhil Nuruddin et al (2011) carried out Compressive Strength and Interfacial Transition Zone Characteristics of Geopolymer Concrete with different cast in – situ curing conditions. They concluded that compressive strength of geopolymer concrete was much affected by the curing conditions. Therefore proper curing method was important to obtain acceptable strength of geopolymer concrete structures. Shankar H Sanni & Khadiranaikar (2012) studied the durability characteristics of Geopolymer concrete and compared with PPCC specimens. The GPC and PPCC specimens were soaked in 10% sulphuric acid solution after 7 days of casting. The specimens were kept fully immersed in this solution, having four times the volume of specimens for the duration of 45 days. The effect of that solution on the GPC and PPCC specimen were regularly monitored through visual inspection, measurement of weight change and strength were tested. It was concluded that the compressive strength loss for the specimens exposed in sulphuric acid was in the range of 10 to 40% in PPCC, whereas it was about 7 to 23% in GPC. Sumajouw D.M.J et al (2006) Studies the behavior of Fly ash based Geopolymer concrete: Study of slender reinforced columns. To present the results of experimental study and analysis on the behavior and the strength of reinforced Geopolymer concrete slender columns. The heat-cured low-calcium fly ash-based geopolymer concrete reinforced columns had excellent potential for applications in the precast industry. Vijai et al (2010) conducted tests on Geopolymer concrete cubes, cylinders and prism specimens by using fly ash and aggregates and also using the ordinary Portland cement along with the fly ash and aggregates. It was inferred that the density of GPC ranges from 2336 to 2413 kg/m^3 and density of GPCC ranges from 2356 to 2424 kg/m^3. They also reported that Geopolymer Concrete has two limitations such as delay in setting time and necessity of heat curing to gain strength. Vijaya Rangan et al (2006) studied the behavior of fly ash-based Geopolymer concrete and informed that the geopolymer concrete had an excellent compressive strength and is suitable for the structural applications. The elastic properties of the hardened concrete, as well as the behaviour and strength of the reinforced structural members were similar to those of Portland cement concrete. Therefore, the design provisions present in the current standards and codes can be used to design the reinforced fly ash-based geopolymer concrete structural members. Vijaya Rangan B (2004) carried out a study on the durability of geopolymer concrete for environmental protection. This paper describes the results of the tests conducted on large – scale reinforced Geopolymer concrete member and illustrates the application of Geopolymer concrete in the construction industries. An excellent resistance to sulphate attack and fire, good acid resistance, undergoes low creep were noted on the benefits of using Geopolymer concrete. Yogendra O. Patil et al (2013) carried out an experimental study using GGBS as partial replacement of OPC in cement concrete Experiment were made to study the compressive and flexural strength of concrete containing various % of GGBS at the age of 7, 28 and 90 days. They concluded that Increase in % of GGBS result in decrease in strength of concrete. The Optimum replacement of OPC by GGBS was 20%.

III. DISCUSSION

Based on various researchers, it is observed that Geopolymer Concrete made up of Fly ash and Alkaline Solution Provides, a new era In the Construction Industry. Sodium Silicate (Na_2SiO_3) and Sodium Hydroxide (NaOH) when reacts with fly ash generates Geopolymerization Process and which is responsible for the Strength generation. Geopolymer Concrete Requires Oven Curing of 600C to 1000C for 24 to 96 Hours. GGBS makes significant impact on the strength of Geopolymer concrete.

IV. CONCLUSIONS

Based upon above literature review it could be concluded that all researchers have put their efforts to show the effect of GGBS on Geopolymer Concrete. However it should be noted that with the variation in the parameters such as Na_2SiO_3/ NaOH Ratio, Molarity of NaOH, Curing temperature, Curing time makes the Variation in the Strength. Replacement of Fly ash by GGBS increases the Strength gradually without Oven curing provision. A lack of information on some aspects of geopolymerisation has become apparent and the research community should focus on these gaps. Despite the current status and wide acceptance of Portland cement, the desirable properties of Geopolymers, their environmental benefits and the strong academic and commercial R&D activity suggest that Geopolymer technology is poised for significant progress in the near future.

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