A REVIEW OF GEOPOLYMER CEMENT AS PRECURSOR IN THE DEVELOPMENT OF 'GREEN CONCRETE'

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ABSTRACT-The increasing demand for green concrete has been spurred by demand for high quality concrete products, desire of nations to reduce green-house gas emission, need for conservation of natural resources and limited landfill spaces. Geopolymer concrete (GPC) are preferred because they generate 70–80% less carbon dioxide with remarkably lesser greenhouse gas emissions than ordinary Portland cement. Geo-Polymer is an inorganic alumina-silicate polymer synthesized from predominantly silicon (Si) and aluminum (Al) materials of geological origin or by-product materials such as Fly Ash, GGBS, silica fume etc., GPC has high strength, with good resistance to chloride penetration, acid attack. This paper briefly reviews the constituents of GPC, its strength, advantages, and limitations. The test results demonstrate the excellent potential of GPC to be a material of choice for the future.

KEYWORDS: **Green Concrete, precursor, Water Glass, Elevated and ambient temperature.**

1. INTRODUCTION

The term 'geopolymer' was first introduced by Davidovits in 1978 to describe a family of mineral binders with chemical composition similar to zeolites but with an amorphous microstructure. Geopolymer cement concretes (GPCC) are inorganic polymer composites, which are prospective concretes with the potential to form a substantial element of an environmentally sustainable construction by replacing/ supplementing the conventional concretes .These are commonly formed by alkali activation of industrial aluminosilicate waste materials such as FA and GGBS, etc., and have a very small greenhouse footprint when compared to traditional concretes. N. P. Rajamane, M.C. Nataraja et.al (2011) said that, Unlike ordinary Portland/pozzolanic cements, geopolymers do not form calcium- silicate-hydrates (CSHs) for matrix formation and strength, but utilise the polycondensation of silica and alumina precursors to attain structural strength. The polymerization process involves a substantially fast chemical reaction under alkaline conditions on Si-Al minerals, resulting in a three-dimensional polymeric chain and ring structure consisting of Si-O-Al-O bonds(Jeffrey C. Petermann and Athar Saeed,2010).There are two main constituents of geopolymers, namely the source materials and the alkaline liquids. The source materials for geopolymers based on alumina-silicate should be rich in silicon (Si) and aluminium (Al) B. VijayaRangan (2008).The schematic formation of geopolymer material can be shown as described by Equations (1) and (2) (Davidovits, 1994; van Jaarsveld et al., 1997).Heat-curing of low-calcium fly ash-based GPC is generally recommended. Heat-curing substantially assists the chemical reaction that occurs in the geopolymer paste.(B. VijayaRangan 2008).Heat curing process requires special arrangements which is energy-consuming and may not be feasible to apply in cast-in-situ concreting. Therefore, development of geopolymer mixtures suitable for curing at normal temperature will widen its application. This paper presents a study on low calcium fly ash based GPC cured in ambient temperature without additional heat. Small amount of additives were added with fly ash to accelerate the early-age reaction (PradipNath et.al,). Green concrete (GC) offers numerous environmental, technical benefits and economic benefits such as high strength, increased durability, improved workability and pumpability, reduced permeability, controlled bleeding, superior resistance to acid attack, and reduction of plastic shrinkage cracking. These characteristics pro-motes faster concrete production, reduction of curing waiting time, reduction of construction costs, early project completion, reduction of maintenance costs and increased service life of construction projects.(K.M. Liew et.al)(2017).

2. OBJECTIVE

The production of Ordinary Portland Cement (OPC) concrete produces a large amount of carbon dioxide CO2. It is reported that, the production of OPC is responsible for around 6% of all man-made global carbon emissions. In general, the choice of geopolymer as a binder is increasing due to its low or no CO2 emission and also to enhance better mechanical properties, and its long-term durability of GPC.

3. COMMON WASTE MATERIALS USED AS SUPPLEMENTARY CEMENTING MATERIALS (SCM) IN GPC

SCM are widely used as pozzolanic materials (create extra strength by pozzolanic reaction) in high-strength concrete, reduce permeability and improve the durability of the concrete. The waste materials utilized in GC can be grouped into three categories namely agricultural, industrial and municipal wastes are as depicted in Table. 1.In order to utilize their pozzolanic properties in green concrete, the waste materials are often activated through physical or chemical means or their combination (K.M. Liew et.al)(2017).

Table. 1. Categories of Wastes utilized in GPC

S.NO	TYPES OF WASTE	PRECURSOR
01	Agricultural	Rice husk ash, Palm oil fuel ash, Bagasse ash, Wood waste ash, Bamboo Leaf ash, Corn cob ash.
02	Industrial	fly ash, slag, silica fume, metabolic, alcidine 1203.Red Mud
03	Municipal	Glass, Plastic, Paper.

4. CONSTITUENTS OF GEOPOLYMER CONCRETE

GPC is a one type of green concrete which is developed using precursor materials like Fly Ash, GGBS and Fine aggregate and Coarse aggregate and alkaline activator water glass cured at elevated or ambient temperature.

FLY ASH

It is the best raw material for preparation of geopolymers due to the minimal water content and finer particle size. Fly ash-based geopolymerisation has only become the subject of intense research interest within the past decade , however there are currently a number of well-established academic and industrial research centers worldwide that are investing significantly in developments in this field.(Peter Duxson et.al)(2007).

GGBS

Ground-granulated blast furnace slag (GGBFS) is also a byproduct material of iron and steel production, which is obtained by quenching molten iron slag from a blast furnace in water or steam. After quenching, granular product used to be dried and ground into a fine powder and the process produce a glassy type of material.

FINE AGGREGATE AND COARSE AGGREGATE

Fine and coarse aggregates used by the concrete industry are suitable to manufacture GPC. Natural river sand obtained from the local sources. Crushed stone aggregates as coarse aggregates were used. The aggregates were tested as per Indian standards.

WATER GLASSES :(sodium hydroxide (NaOH) + sodium silicate (Na_2SiO_3))

The synthesis of the geopolymer paste specimens was produced by mixing loess and fly ash with sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3).The solutions were prepared by mixing sodium hydroxide in pellets form in sodium silicate solution and water.

SUPER-PLASTICIZER

Naphthalene based super-plasticizer is useful to increase the workability and strength of GPC prepared using industrial wastes**.**

5. LITERATURE REVIEW

João Claudio Bassan de Moraes et.al,(2018) revealed an interesting valorization of the sugar cane straw ash (SCSA) as an additional precursor in blast-furnace slag (BFS)-based Alkali-activated binders (AABs),in view of the improvement of mechanical properties and the reduction in the consumption of BFS in AABs.. With the increase of the sodium concentration in the activator, more crystalline phases were produced.

Peter Duxson et,al,(2007) reported that inorganic polymers ("geopolymers") as an element of the push for a sustainable concrete industry and much smaller CO2 footprint than traditional Portland cements, and display very good strength and chemical resistance properties as well as a variety of other potentially valuable characteristics.

J. Temuujin et.al,(2009) reviewed the effect of mechanical activation of fly ash on the properties of geopolymer cured at ambient temperature. Mechanical activation of the fly ash results in particle size and morphology changes with concomitant increase in reactivity with alkaline liquid. Addition of free water in the reaction mix decreases mechanical properties of the geopolymer samples. After 28 days, compressive strength of the room temperature cured samples was 16 (2) MPa and 45 (8) MPa for unmilled and mechanically activated fly ash based samples, respectively.

Pattanapong Topark-Ngarm et.al,(2014) made a strengths and modulus of elasticity increased with the increase in NaOH concentration. For compressive strength, the optimum Na_2O content was around 12% of fly ash. The high-strength geopolymer concrete (GPC) with 28-day compressive strength of 54.4 MPa was obtained for mix with 15M NaOH. The modulii of elasticity of GPC were related to the compressive strengths and comparable to those of portland cement concrete. The tensile splitting strength and bond strength were also related to the compressive strength and the values were higher than those of portland cement concrete.

Zhen Liu, S.M et.al,(2016) concluded that construction and demolition waste and the depletion of natural aggregates, in the present study, both the coarse recycled aggregates and the fine recycled aggregates are used to produce new green concrete with a fly ash–based geopolymer. The mechanical study shows that the reduction rates of the compressive strength, Young's modulus, and the Poisson's ratio of the geopolymeric recycled aggregate concrete (GRAC) specimens increase with the increase of the water/cement (w/c) ratio. The Young's modulus is much more vulnerable to the increase of the w/c ratio than the compressive strength.

Mithanthaya I.R et.al,(2017) concluded from their studies that the use of major industrial wastes such as fly ash, glass powder and GGBS is found to be feasible in the production of new sustainable green construction material of reasonably good strength. It has also been observed that use of naphthalene-based super plasticizer improves the fresh and hardened behavior of GPC. Finally concluded that the results indicated that replacement of fly ash by various percentages of the GGBS resulted in increase of the compressive strength, split tensile strength of the fly ash based GPC up to 15% and thereafter there is a decrease in the strength values.

Ankur Mehta and Rafat Siddique (2017) conducted Strength, permeability and micro-structural characteristics of low-calcium fly ash based geopolymers. They concluded that the mechanical properties of fly ash based geopolymers found to be improved with the inclusion of OPC at different levels as fly ash replacement. Compressive strength and split tensile strength of the specimens attained maximum values with 20% OPC.

Vinita Vishwakarma and D. Ramachandran (2017) reviewed Green Concrete mix using solid waste and nanoparticles as alternatives. They concluded that the solid waste which are generated from agricultural, industries and bio-waste that can reduce the usage of cement in concrete structures. It has been suggested that these waste materials as a substitute to be added in concrete structures as admixture to get the better workability, strength and durability. Utilize the nanoparticles to make Green Concrete and achieve the high performance concrete by reducing the usage of natural resources and green house emission gas (CO2).

Eslam Gomaa et.al, (2017) carried out Fresh properties and compressive strength of high calcium alkali activated fly ash mortar. Two different sources of class C fly ash, with different chemical compositions were used to prepare alkali-activated mortar mixtures. Four different sodium silicate to sodium hydroxide (SS/SH) ratios of 0.5, 1.0, 1.5, and 2.5 were used as alkaline activators with a constant sodium hydroxide concentration of 10 M.

Pradip Nath and Prabir Kumar Sarker (2016) have conducted a flexural strength and elastic modulus of ambient-cured blended low-calcium fly ash geopolymer concrete. Geopolymer concretes were produced using low calcium fly ash with a small percentage of additive such as ground granulated blast furnace slag (GGBFS), ordinary Portland cement (OPC) or hydrated lime to enhance early age properties. Samples were cured in room environment (18–23 ^{0}C and 70 ± 10% relative humidity) until tested. Finally revealed that Modulus of elasticity of ambient cured GPC tend to be lower than that of OPC concrete of similar grade. Prediction of elastic modulus by Standards and empirical equations for OPC concrete were found not conservative for GPC.

William Gustavo Valencia Saavedra and Ruby Mejía de Gutiérrez (2017) carried out the Performance of geopolymer concrete composed of fly ash after exposure to elevated temperatures. Alkaline activated concretes based on a mixture of fly ash (FA) and blast furnace slag (GBFS), as well as FA and Portland cement (OPC), both at a ratio of 80:20, were exposed to temperatures between 25^{0}C and 1100^{0}C. The results showed that the activated concretes have better performance than the reference ones (100% OPC). At temperatures of 1100 ^{0}C, the residual strengths of the FA/GBFS and FA/OPC concretes are 15 and 5.5 MPa, respectively, unlike the OPC concrete that lost 100% of its strength.

Jean-Baptiste Mawulé Dassekpo et.al, (2017) have studied Synthesis reaction and compressive strength behavior of loess-fly ash based geopolymers concrete. The test results showed Compressive strengths of up to 18.46 MPa and 12.29 MPa, can be obtained from the mix design respectively for fly ash-based geopolymer paste and loess-based geopolymer paste at 7 days curing time. The addition of loess and fly ash of up to 50% reduces suitably the compressive strength.

6. ADVANTAGES:

- Better compressive strength than that of ordinary concrete.
- Very Low Creep and Shrinkage.
- It is Resistant to Heat and Cold.
- It has a very strong chemical resistance. Acids, toxic waste and salt water will not have an effect on geopolymer concrete. Corrosion is not likely to occur with this concrete as it is with traditional Portland concrete.
- It shall be used in repairs and rehabilitation works.
- Fire proof i.e; higher resistance to heat.
- Low permeability.
- Eco-friendly

7. LIMITATIONS

- Difficult to Create – geopolymer concrete requires special handling needs and is extremely difficult to create. It requires the use of chemicals, such as sodium hydroxide, that can be harmful to humans.
- Pre-Mix Only – geopolymer concrete is sold only as a pre-cast or pre-mix material due to the dangers associated with creating it.
- Geopolymer concrete did not harden immediately at room temperature as in conventional concrete.
- Geopolymer concrete specimens took a minimum of 3 day for complete setting without leaving a nail impression on the hardened surface.

8. CONCLUSION

The following summarizes notable characteristics of geopolymerization;

The premise of geopolymerization is a fairly new idea, and commercial implementation is in its infancy. However, this new technology shows great potential for application in conventional construction as well as for construction in harsh and demanding environments such as high temperature applications and locations subject to chemical attack. The pozzolanic materials required for alkali-activation are readily-available on a global level, and the cost-to-benefit ratio for the utilization of industrial waste is exceptional in relation to traditional cementitious products used in the industry today.

As a product known for its ability to sustain the environment while maintaining durability and structural integrity under severe conditions, geopolymer concretes are being proven as a worthy substitute for traditional methods of cementitious production and field application.

The government can make necessary steps to extract sodium hydroxide and sodium silicate solution from the waste materials of chemical industries, so that the cost of alkaline solutions required for the geopolymer concrete shall be reduced.

9. REFERENCE

[01] N. P. Rajamane, M.C. Nataraja and N. Lakshmanan, An introduction to geopolymer concrete, Indian Concrete Journal, (2011), 1-4.

[02] Jeffrey C. Petermann and Athar Saeed, Alkali-Activated Geopolymers: A Literature Review, Air Force Research Laboratory Materials and Manufacturing Directorate, (2010), 1-91.

[03] B. Vijaya Rangan, Fly Ash-Based Geopolymer Concrete, Curtin University of Technology (2008) .

[04] K.M. Liew , A.O. Sojobi L.W. Zhang , Green concrete: Prospects and challenges , Construction and Building Materials 156 (2017) 1063–1095, DOI:10.1016/j.conbuildmat.2017.09.008.

[05] Peter Duxson, John L. Provis, Grant C. Lukey, Jannie S.J. van Deventer, The role of inorganic polymer technology in the development of ‘green concrete’, Cement and Concrete Research 37 (2007) 1590–1597,DOI:10.1016/j.cemconres.2007.08.018.

[06] João Claudio Bassan de Moraes, Mauro Mitsuuchi Tashima, Optimum Use of Sugar Cane Straw Ash in Alkali-Activated Binders Based on Blast Furnace Slag, American Society of Civil Engineers.(2018),DOI: 10.1061/(ASCE)MT.1943-5533.0002261.

[07] J. Temuujin, R.P.Williams, A. van Riessen, Effect of mechanical activation of fly ash on the properties of geopolymer cured at ambient temperature, Journal of Materials Processing Technology 209 (2009) 5276–5280, DOI:10.1016/j.jmatprotec.2009.03.016.

[08] Pattanapong Topark-Ngarm, Prinya Chindaprasirt, and Vanchai Sata, Setting Time, Strength, and Bond of High-Calcium Fly Ash Geopolymer Concrete, Journal of Materials in Civil Engineering,(2014) ISSN 0899-1561,DOI:10.1061/(ASCE)MT.1943-5533.0001157.

[09] Zhen Liu, C. S. Cai, Hui Peng, and Fenghong Fan, Experimental Study of the Geopolymeric Recycled Aggregate Concrete, Journal of Materials in Civil Engineering,(2016) ISSN 0899-1561,DOI: 10.1061/(ASCE)MT.1943-5533.0001584.

[10] Mithanthaya I.R, Shriram Marathe , N B S Rao, Veena Bhat, Influence of superplasticizer on the properties of geopolymer concrete using industrial wastes, International Conference on Recent Trends in Engineering and Material Sciences 4 (2017) 9803–9806.

[11] Mandeep Kaur, Jaspal Singh and Manpreet Kaur, Synthesis of Fly ash based Geopolymer Mortar considering different concentrations and combinations of Alkaline Activator Solution, Ceramics International (2017), DOI: 10.1016/j.ceramint.2017.10.071.

[12] Ankur Mehta and Rafat Siddique, Strength, permeability and micro-structural characteristics of low-calcium fly ash based geopolymers, Construction and Building Materials 141 (2017) 325–334, DOI:10.1016/j.conbuildmat.2017.03.031.

[13] Vinita Vishwakarma and D. Ramachandran, Green Concrete mix using solid waste and nanoparticles as alternatives – A review, Construction and Building Materials 162 (2018) 96–103, DOI:10.1016/j.conbuildmat.2017.11.174.

[14] Eslam Gomaa, Simon Sargon, Cedric Kashosi, Mohamed ElGawady, Fresh properties and compressive strength of high calcium alkali activated fly ash mortar, Journal of King Saud University – Engineering Sciences (2017), DOI:10.1016/j.jksues.2017.06.001.

[15] Pradip Nath and Prabir Kumar Sarker, Flexural strength and elastic modulus of ambient-cured blended low-calcium fly ash geopolymer concrete, Construction and Building Materials (2016), DOI:10.1016/j.conbuildmat.2016.11.034.

[16] William Gustavo Valencia Saavedra and Ruby Mejía de Gutiérrez, Performance of geopolymer concrete composed of fly ash after exposure to elevated temperatures, Constructionand Building Materials 154 (2017) 229–235,DOI:10.1016/j.conbuildmat.2017.07.208.

[17] Jean-Baptiste Mawulé Dassekpo, Xiaoxiong Zha and iapeng Zhan, Synthesis reaction and compressive strength behavior of loess-fly ash based geopolymers for the development of sustainable green materials, Construction and Building Materials 141 (2017) 491–500, DOI:10.1016/j.conbuildmat.2017.03.034.

[18] Arumairaj P.D and Abdul Aleem M.I, An experimental study on different curing methods of Geopolymer Concrete made with Fly Ash and Manufactured Sand, Archieve Des Sciences Journal (2013), 556-571.