# A Review on Eco-Green Geopolymer Concrete

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Abstract: Concrete is the most widely used building material in the world because of its versatile application. The essential ingredient of concrete is Portland cement, which is not considered an environmentally friendly material. The production of Portland cement not only uses up a considerable amount of energy but also emits a substantial amount of CO2. The production and use of alternative materials, such as geopolymer, represents a great opportunity to ensure greater sustainability in the construction sector. In order to reduce the environmental impact due to cement production, it is necessary to develop a new type of binder. In this respect, the geopolymer technology proposed by Davidovits (1978) is one of the revolutionary developments resulting in a low-cost and greener substitute for Portland cement. Geopolymer concrete is an innovative binder material and is produced by totally replacing Portland cement. It is an excellent alternative construction material to the existing plain cement concrete. In the present age the waste generated from industries is the huge concern for the environment, health, and cause for land filling. Recycling of such wastes and using them in construction materials appears to be viable solution not only to the pollution problem but also an economical option in construction. In this paper, the approach for development of new construction material in geopolymer concrete using industrial waste to provide a potential sustainable source will be reviewed from the present study.

Keywords: Sustainability, Geopolymer, Recycling, Industrial waste

## 1. Introduction

Construction sector is responsible for relevant environmental impacts and one of its most crucial points is the use of concrete. Concrete is the most widely used construction material in the world and its production causes high levels of carbon dioxide (CO2) in the atmosphere.

Ordinary Portland cement (OPC) has traditionally been used as binder material in concrete and its production involves approximately 7% of global anthropogenic CO2 emissions Geopolymer is a type of amorphous aluminosilicate cementitious material. Geopolymer binders may be made from a variety of alumino-silicate sources. The engineering aspects of geopolymer concrete as later described in this document relate to geopolymeric materials based primarily on low calcium (or Class F) fly ashes. Geopolymers incorporating significant quantities of calcium rich materials such as slag, for instance, may have different properties to those based on low calcium fly ash alone.

Davidovits (1988; 1994) proposed that an alkaline liquid could be used to react with the silicon (Si) and the aluminium (Al) in a source material of geological origin or in by-product materials such as fly ash and rice husk ash to produce binders. Because the chemical reaction that takes place in this case is a polymerization process, he coined the term'Geopolymer' to represent these binders. There are two main constituents of geopolymer, namely the source materials and the alkaline liquids. The source materials for geopolymers based on aluminasilicate should be rich in silicon (Si) and aluminium (Al). These could be the byproduct materials such as flyash, silicafume, slag, ricehuskash, redmud. The choice of the source materials for making geopolymers depends on factors such as availability, cost, type of application, and specific demand of the end users. The alkaline liquids are from soluble alkali metals that are usually Sodium or Potassium based. The most common alkaline liquid used in geopolymerization is a combination of sodium hydroxide (NaOH) or potassium hydroxide (KOH) and sodium silicate or potassium silicate.

# 2. Literature Survey

#### **Properties and effects of Geopolymer Concrete**

[1] Properties of Geopolymer Cements, Joseph Davidovits, Geopolymer Institute. (1994). Joseph Davidovits investigated that the behavior of geopolymeric cementsis similar to that of zeolites and feldspathoids, they immobilize hazardous materials within the geopolymeric matrix, and act as a binder to convert semi-solid wastes into adhesive soilds.Their unique properties which include high early strength, low shrinkage, freeze-thaw resistance , sulphate resitance and corrosion resistance for long term containment in surface disposal facilities.[2] Effect of Alkali Reaction(ASR) Silica in Geopolymer Concrete,Kunal Kupwade-Patil and Erez Allouche(2011), explains about the effect of ASR in Geopolymer Concrete which occurs due to chemical reaction between hydroxyl ions.Various test samples were taken under Scanning Electron Microscopy (SEM), X-Ray diffraction (XRD) and Fourier Transform Infra-Red Spectroscopy (FTIR) done by using three aggregates, i.e Limestone, Sandstone and Quartz) by Class F Fly ash immersed in 1Molarity NaoH in 80°C, by comparing Ordinary Portland Concrete, where Ordinary Portland Concrete exceeded 6 times greater expansion then Geopolymer Concrete after 34 days of Exposure and the leaching effect was high in Ordinary Portland Concrete, after 21 days, and also the strength increseases from 20 Mpa to 90Mpa in GPC. Therefore Flyash based Geopolymer Concrete is significantly less vulnerable to ASR compared to OPC.[9,42]Preparation and Properties of geopolymer, liang Metakaolin-based alkali activated chen, zaiiquin wang, yuang wang and jing feng(2016). This paper details about the metkaolin particles by various tests such as XRD,FTIR and HMGB.Different curing conditions were taken and found that the results are best at  $60^{\circ}$ C for

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168 hours that activates a thermal conductivity of 0.37 w/mk and compressive strength is of 50 Mpa.[13,49]The Mechanical properties of flyash based GPC with alkaline activators, Gum sung ryu, young bok lee et al (2013), It has examined the performance of strength based on the properties through various tests and based on these tests the mechanism strength has high compressive strength and is suitable for prescast concrete structures.[16]Long term engineering properties of flyash based GPC, Chamila gunasekar, David. W. Law & SujeevSetunge, The one year compressive strength has been observed with various test performances and found a best engineering property on GPC other than OPC.[18]Fresh and Hardened properties of flyash based GPC with Copper Slag, HAnio, Manjula Devi,Freeda cristy(2013)The research has been examined by adding Flyash along with Copper slag thus obtained a higher strength by using copper slag one of the industrial material.[34]Properties of flyash GPC in seawater environment, M.Olivia, H.Nikraz, The properties of flyash GPC is subjected to continuous immersion of 3.5% NaCl solution and accelerated wetting & drying at 80°C and 24 hours cycle in NaCl solution and thus reached the target strength higher than 55Mpa and found no reduction in strength for GPC.

#### Design Mix and its Chemical formulation

[3, 60]Optimum Mix for the Geopolymer Concrete, M.I Abdul Aleem and P.D Arumairaj(2012). The Optimum mix for Geopolymer Concrete by Indian Standards is given by the author. The ratio of trial mixes are given on Fly ash: Fine Aggregates: Coarse Aggregates in different mix ratio and found that the ratio 1:1.5:3.30 gives high strength with the ratio of flyash to water as 0.35 in steam curing at  $60^{\circ}$ C using auto clave steam curing. The alkaline solution used is Sodium Hydroxide and Sodium silicate combination. Thus Geopolymer Concrete did not attain any strength at room temperature or by water curing as per his previous studies.[4]Mix design of flyash based geopolymer concrete,Subash.v.Patankar,Yuwaraj.m.Ghugal & sanjay Jamkar (2014). The mix design has been given by the author modified the guidelines from Anuradha Et.al.The design steps has been given in various ratios based on Fly ash by Indian standard Codes with various Mix ratios such as M20,M30,M35 and M40 which has been experimentally practiced for its workability, Degree, Wet Density and Compressive strength.[5,50] Chemical formulation of GPC with M-Sand Abdul Aleem and P.D M.I • Arumairaj, S. Vairam (2013). The Natural sand is totally replaced with M-Sand with flyash as the binder content, Various tests such as XRD, SEM have been analyzed. After mixing of the composition, it has been found that the spherical particles of silicate in flyash is completely changed to irregular clusters and found a new chemical formulation ALBITE having formula (NaAlSi3O8)5, which was done in PXRD pattern of GPC.Hence the Original content 8.34% of flyash and 1.74 % in Msand was not available in GPC-ALBITE (Dissolution of CO2). Thus new Compound Polysilicate is formed which has very high Compressive strength.

## An Environmental Evaluation

[6]An environmental evaluation of geopolymer based concrete, G.Habert, J.b.D Espinose de Lacaillere, N.roussel.

This paper gives a review about the recent research trends on GPC with its environmental impact which is due to heavy effects of the production of sodium silicate solution. The materials and methods were given in three main stages, Functional Unit, Inventory Phase covers and life cycle inventory. Thus the GPC has lower impact on global warming than the standard OPC.[7]Abrasion resistance of geopolymer concrete, Kolli Ramujee, M.Potharaju (2014), The Abrasion resistance of GPC has been done by using the grade M20 as G20. The materials used are Fly ash, Fine aggregates as river sand and Coarse aggregates as crushed granites with the alkaline solution as Sodium Hydroxide and Sodium Silicate using 8 Molarity. The test procedure has been done by Swirling action of agitation paddle and concluded that the decrease in water content and increase in the concentration of NaoH hardens the concrete, The depth of wear in GPC was smaller than OPC and hence GPC has better abrasion resistance.[8]Recent Research Geopolymer Concrete, Nguyen Van Chanh, Bui Dang Trung, Dang Van Tuan, University of Technology, Hemcity, Vietnam (2008). This paper explains about GPC with its SEM result of microstructure. The curing is at  $60^{\circ}$ C for two Hours and boiled in water about four hours.Sea water can be used for blending of GPC when the temperature increases, the compressive strength increases.[10]Man made geosynthesis and resulting development, Joseph davidovits, (1994). His research explains about all inorganic polymers provide heat resistance application on fire resisitant wood chip board has been done and thus the organic resin was created. The geopolymeric binders are done through X-Ray diffraction and MAS-NMR spectroscopy and thus found the invention of very early high strength cement. Thus geopolymers are manufactured and they do not require extreme high temperature kilns, with large expenditure of fuel. [11] Development of fly ash based geopolymer concrete, Djwantoro Hardjito, Steenie.E.wallah, Dody. M. J. Sumajoun & B.Vijaya Rangan.(2017). In this research Fly ash based geopolymer concrete is examined and concluded that the flyash based geopolymer is suitable for the manufacture of precast concrete structures which produce a green environment.[12] The effect of temperature and duration of curing ,Andi arham adam,Horianto(2014),The author explains with an experimental procedure with the flyash based geopolymer and based on the temperature the curing period reaches to the high compressive strength of 100<sup>°</sup>C at 20 hours.[14]The potential use of geopolymeric materials to immobilize toxic metals,JGS Van Jaors veld & JSJ Van Deventer (1997), The author is clear about the properties of geopolymer and its application on waste materials such as flyash, with contaminated soil, mine tailings and building waste which contains large amount of silica and alumina used as reagent in geopolymerisation reactions. Thus by utilizing the waste materials and their reactive properties, it is possible to create various geopolymeric matrices.[15,54]Low calcium fly ash based properties,S.E.Wallah GPC.Long term and B.V Rangan,(2006), The experimental study on low calcium flyash based GPC for its long term properties has been examined and the test procedure were taken for creep,dry shrinkage, sulfate resistance and sulfuric acid resistance and thus the curing is done by ambient curing ,hot oven curing and steam curing and thus the hot oven curing gave best results and thus as the result increases, the strength

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increases.[17]GPC an eco friendly construction material, L.Krishnan, S.Karthikeyan, S.Nathiya and K.Suganya (2014) This paper has been explained about the GPC based on geopolymer of flyash and ground granulated blast furnace slag applied in different ratios and thus has achieved in 60:40 ratio of Flyash:GGBS for 12M alkaline solution done by ambient curing and found best result.[19]Fire resistance geopolymer composites, J, Davidovits (1996), The fire response of potassium alumino silicate matrix carbon fiber composite was measured and being evaluated and found the Flame Propagation Index as the ratio of Peak Haet rebeers rate (kN/m) to the time to ignition(s) and thus the carbon reinforced potassium aluminisilicate resin geopolymer are non combustible structures materials suitable for infrastructure application which is fabricated at 80°C.[20]Factors influencing the compressive strength of flyash based GPC, Djwantro Hardito, Steenie. E.Wallah.Dady, M. J Sumajano and B.V.Rangan.(2004)The Various test variables include the age of concrete, curing time, temperature, Quantity of super plasticizer rest period for curing and water content for mix. The compressive strength of GPC does not vary with the age of concrete and thus the longer curing time improves the polymerization process resulting in high compressive strength.

# Development of Geopolymer using industrial waste materials

[21]The development of GPC using Industrial Material, (2014) The development of geoplymer of flyash based geopolymer withredmud added and the results shows that it may be commericialized by manufacturing and thus concluded by the author that the mechanical activation by ball mill increases in material fineness, the grinding fineness improved compressive strength and thus the addition of red mud tailored the compressive strength.[22]The influence of various factors on the properties of GPC derived from industrial by-products,PArtwei-ken,Mehyddin remli(2014). The author has reviewed the various industrial by-products used for GPC and resulted that Red mud and Rice Husk ash has higher concentration of NaoH and decrease in compressive strength of Geopolymer.[23,59]Effect of Nano Material in GPC, Sudipta Naskar, Arun Kumar Chakraborty (2016), The Paper presents the effect of Nano materials in GPC, used Collodial Nano Silica and Muliwall Carbon Nano Tube with Titanium dioxide and found that Nano silica and also titanium di oxidecan be added with flyash to get satisfactory amount with compressive strength.[24] Experimental Investigation on compressive strength and durability properties of GPC incorporating with Nano silica, Yagnesh patel, Dr. Indrajith. N. Patel (2015) The author describes the application of Nano Silica in GPC using Heat curing at  $60^{\circ}$ C for 24 hours and thus the result showed that the increase in percentage of Nano silica increase the compressive strength. Thus Nano Silica showed a impact on compressive strength and durability properties of GPC and thus theaddition of Nano silica can enhance the properties of GPC.[25]Compressive strength and microstructural charateristics of class C flyash geopolymer, Xiaolu, Huisheng shi, Warren.A.Dick (2009).This research gives the compressive strength and micro-structural charateristics of class C flyash geopolymer and hence a high compressive strength of 63.4Mpa was concluded by curing at  $75^{\circ}$ C for 8 hours and thus is beneficial for resource conservation and environment protection.[26]The effects of Nano and micro particle additives on the durability and mechanical properties of mortars exposed to internal and external sahan sulfate attacks.,Hasan arcl,Blessen skariah Thomas,(2017). The research finds the highest compressive strength was observed with 4% nano silica replacement wheares the highest flexural strtength was observed with 13% of micro silica replacement. Thus the nano and micro silica particles were more effective against the internal and external sulfate attacks than other minerals.[27,58,59]Nano sustainable concrete Geopolymerfor using flvash synthesized by high energy ball milling, A.M.Mustafa Al Bakri,H.Kamarudi, M.Bnhussain, J.Livana and C.M.Ruzaidi,(2016).The development of nano geopolymer for sustainable concrete by high energy ball milling requires to produce nano geopolymer paste and thus achieved a high compressive strength in Nano GPC. The surface structure was more uneven spherical in shape-milled particles which more irregular.[28]Flyash based geopolymer was lightweight concrete using foaming agent, Mohd Mustafa Al Bakri Abdullah Et al(2012). This research by using an foaming agent as light weight concrete with curing at  $60^{\circ}$ C found a very high strength and its strength reached to the maximum of 18.2 Mpa at 28 days.[29] Design and performance evaluation of ultra light weight GPC, D.M.A Huisken, Q.L.Yu.HJH. Brouwers (2015), The development of sustainable Ultra light weight GPC for both thermal and load bearing purposes. Hence it is achieved by applying waste glass. The materials used were 70% F.A and 30% GGBS.The effect on compressive strength of concrete is negligible. [30]Feasibility study of geopolymer binder from terracotta roof tile waste, S.Usha, Deepa.G.Nair, Suba Vishnudas,(2016)The feasibility of geopolymer binder from terracotta roof tile waste was investigated by different parameters and was powdered to 75micrometer using ball mill analyzed ny SEM and found that the compressive strength decreases when the molarity increases more than 11M and thus the optimized condition is in the ratio of alkaline solution of 0.8 and a curing of  $65^{\circ}C$  at 24 hours.[31]Development of low strength and GPC mix utilizing demolished aggregate, J.S.Jayalakshmi, Shri.N.G.Bhagavan & R.Kumutha, (2016), The demolished aggregate were utilized in GPC and found that the slump value increases with increases in demolished aggregate, but the compressiveband split tensile strength decreases with respect to demolished aggregate.[32]Effect of glass microfiber addition on the mechanical performances of flyash based GPC, Thamar Alomayri, (2017) The various amount of glass microfibers were introduced and thus result shows that the appropriate addition of glass microfibers can improve the mechanical properties of GP composites. The glass fibre was added first to flyash at the dosages of 1%,2% and 3% by weight cured at 80°C for 24 hours covered in plastic film. Thus the glass microfiber can enhance the post cracking response of geopolymer composites and thus its properties have given greater strength.[33]Effect of different curing conditions on GPC by partially replacing sand with foundary sand, Rekha devi,S.K.Sharma & Himmi Gupta(2015),This research has been used flyash, foundary sand, Coarse aggregate and alkaline solution as per Indian standards and found that the strength increases with the increase in curing the

Volume 6 Issue 9, September 2017 <u>www.ijsr.net</u> Licensed Under Creative Commons Attribution CC BY temperature, 10% replacement of foundary sand in hot curing at  $60^{\circ}$ C for 24 hours. 30% replacement of foundary sand in ambient curing. Thus the strength increases with curing time.

[35]A study on wood ash based lye as alkaline activator in GPC,Nagaraj.V.K,Puttaswamy.B.K,This article represents as GGBS used as filler and lye leached from waste wood ashon mixing with distilled water for 3 days. The specimen are subjected to ambient curing rather to check stability of GGBS and Lye based GPC. The 28<sup>th</sup> day strength showed greater compressive strength and it can be used as an alternative foe concrete.[36,53,55] Effects of micro structure characteristics of interfacial transition zone on the compressive strength of self-compacting geopolymer concrete gives the higher strength in geoplymer concrete.[37] Comparative study on the behavior of geopolymer concrete with hybrid fibers under static cyclic loading has been explained by resulting in heavy compressive strength.[38] Eco sustainable geopolymer concrete blocks production process has been produced and concluded that these applications may be used for future trends.[39,43]Effect of adding crumb tire rubber particles on the mechanical properties of DCPD modified sulfur polymer mortars and has best strength in mechanical properties but lower strength in its compressive strength.[41,45] Feasibility of water containing metal ions as mixing water in cement mortar and found that the water containing metal ions can be used by testing as an alkaline solution.

Thus the industrial waste materials such as Flyash, GGBS,[44]Bagasse ash,[46,47,48,56]Demolished coarse aggregate,red mud,tyre waste,[52] 3D fibres etc., are the main sources for a green environment which can be used as an alternative for concrete.

# 3. Conclusion

Hence from the study of the literatures, the Geopolymer Concrete will play an important role in the future which is to be investigated and applied to our life cycle to save and produce a green environment. Economically and the future study might be done by the ambient curing applied to heavy structures with the natural alkaline solution and prove the strength of the natural sources.

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