

A Review on Environmental Protection of Geopolymer Concrete

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Abstract: *The development of Geopolymer concrete technology in recent years reaches the highest development due to its lower global warming potential and as it is a viable solution for conventional concrete replacement. In this respect, the geopolymer technology proposed by Davidovits (1978) is one of the revolutionary developments resulting in a low-cost and ecological substitute for Portland cement. Geopolymers have the potential to replace the traditional OPC based concrete as the geopolymer binders are highly sensitive and durable. Geopolymer Concrete can obtain its higher strength economically by using the industrial wastes. Recycling of such wastes and using them in construction materials appears to be viable solution to prove for an environmental impact. In this paper, the development of Geopolymer technology by using industrial waste in Oven and ambient curing will be reviewed from the present study required for our future needs*

Keywords: Geopolymer technology, Higher Strength Environmental Impact, Industrial waste.

1. Introduction

The production of cement is increasing about 3% approximately every year and thus this production consumes a huge amount of energy which affects the Global. Thus a new technology based on the environmental impact is developing a low emission of CO₂ requiring an alternate source for Cement industry. Geopolymer is a type of amorphous aluminosilicate cementitious material that can be formed at roomed temperature by using industrial waste or by-products as source materials as similar to that of OPC. Geopolymer binders may be made from a variety of aluminosilicate sources. 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. He also stated that a metakaoline based geopolymer with potassium containing alkaline activator showed a double the compressive strength of geopolymer mix with sodium alkaline activating solution. There are two main constituents of geopolymer, namely the source materials and the alkaline liquids. The source materials for geopolymers based on aluminosilicate should be rich in silicon (Si) and aluminium (Al). These could be the by-product 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. This study will review the Nano composites, fibres, glass powders etc., to incorporate with Geopolymer Concrete and thus to study the future needs of the source materials to give a higher strength and durability compared to OPC.

2. Literature Survey

Geopolymer Concrete- Environmental Protection: [1] B.Vijaya Rangan, "Geopolymer Concrete for Environmental protection", The Indian Concrete Journal (2014) investigated on a large scale reinforced geopolymer concrete members and concluded that that Geopolymer Concrete offers environmental protection by means of up cycling a low calcium fly ash/by products and resulted in an excellent compressive strength which is suitable for its structural applications and also showed an excellent resistance to sulphate attack and fire.[2] Herbert Sinduja, J, Sakthieswaran, N, ShinyBrintha, G, " Geopolymer Concrete with different Additives", International Journal of Engineering Research (2015) reviewed on the geopolymer binders that the increase in aluminium leads to the products of low strengths accompanied by micro structures with increased Na-Al-Si grains rather than amorphous Na-Al-Si containing geopolymers. At the temperature higher than 800C the strength of all tests is not found to increase and thus considering an optimum temperature within 800C. An addition of 6 % of Nano Silica shows an appreciable improvement in Compressive, Flexural and tensile strength and also reviewed that the modified polycarboxylate based SP was the most efficient type which increased the relative slump of the paste up to 45 % with reference to the paste without using any SP and thus useful for developing eco-friendly concrete in all aspects.[3] Sonal.P.Thakkar, Darpan. J. Bhorwani, Rajesh Ambaliya, "Geopolymer Concrete using different source Materials", International Journal of Emerging Technology and Advanced Engineering (2014), has presented the various combination of flyash and GGBFS to achieve compressive strength at the grade of M25 by both Oven and ambient curing and hence studied that Oven curing is more than ambient curing in its strength at 7 and 28 days of the test result in various mixing combinations and hence resulted at 28 day strength in ambient curing at the ratio of 50:50 of Fly ash and GGBS.[4] Tarun R Naik and Rakesh Kumar, " Geopolymer concrete for sustainable developments: Opportunities, limitations and future needs", University of Wisconsin, USA, represent that water to

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geopolymer solid ratio governs most of the properties of GPC. The dry or steam curing requirements has restricted its application to precast concrete products. Thus considerable research work is needed for the production of versatile, Eco friendly, cost effective and low carbon footprint geopolymer cement which could be easily mixed and hardened.[41] Nicoletta Toniolo, Aldo.R. Boccaccini, "Fly ash Geopolymer containing added silicate waste", Elsevier-Ceramics International, (2017), The synthesis of Geopolymers using biomass ashes, redmud, recycled glass and heavy metals containing wastes is a potential way to dispose and reuse such wastes which to be recycled.[42] Eslam Gomaa, Simon Sargon, et al., "Fresh properties and compressive strength of high calcium alkali activated fly ash mortars", Journal of King saud University-Engineering Sciences, (2017) This paper presents the fresh properties and thus the workability has increased. [43] Prakash.R.Vora, Urmil.V.Dave, "Parametric Studies on Compressive Strength of Geopolymer Concrete", Procedia Engineering-Elsevier NUICONE-(2012) The addition of Naphthalene based superplasticizer improves the workability of fresh Geopolymer Concrete and thus the water content mix plays significant role in achieving the desired compressive strength.[44] Rudolf hela, Denisa Orsakova, "The Mechanical Activation of FlyAsh", Science Direct, Procedia Engineering (2013), In this paper the mechanical activation is done by sieving the flyash than grinding which is a cost effective.[45] Andi Arham Adam, Horianto, "The Effect of temperature and duration of Curing on the strength of flyash based geopolymer concrete, 2nd International Conference on sustainable Civil Engineering Structures and Construction Materials(2014), The effect of temperature has been found when the compressive strength is increased at 120^oC at 20 hours.[46] Natasa marjanovic, Miroslav Komljenovic, Zvezdana Bascarevic, Violeta Nikolic", Comparison of two alkali activated systems: Mechanically activated flyash and flyash blast furnace slag blends", 7th Scientific technical conference Material Problems in Civil engineering (MATBUD 2015)", Here the alkali systems represents the best routes for Geopolymer Technology development and can be related to the binding gel of the composition: Ca/Si~0.40 and Al/Si~0.20. [48] A.Wilkinson, D.Woodward, et al., "A state of the art review into the use of Geopolymer cement for road applications "Taylor & Francis Group, London, Hindawi Corporation, (2015), Thus in order to use for road applications the standard specification and its material sare required as it is suitable for a low CO2 emission to the environment.

Effect of Ambient Curing Geopolymer

[5] P.Vinodhini, S.Kumaravel, P.Girija, "Effect of ambient curing in geopolymer concrete", International Journal of applied Engineering Research, (2015) resulted that the compressive strength of ambient cured concrete increases as the age of concrete increases due to the increase of the compact gel in geopolymer concrete.[6] P.Nath, P.K.Sarker, "Geopolymer Concrete for ambient curing condition", research Gate Publication (2015), studied about the condition of ambient curing in geopolymer concrete and hence resulted the higher compressive strength by adding slag of 30% of the total binder and thus decreases the compressive strength more than that of 30% slag.

Thus based on the effect of ambient curing the compressive strength increases up to a certain percentage only and decreases more than the limitation. Different source materials may be applied to reach the higher percentage in ambient curing.[30] Smitasingh, Rahul das Biswas, Aswath.M.U, "Experimental study on Redmud based geopolymer concrete with Flyash & GGBS in ambient temperature curing", International Journal of advances in mechanical and Civil Engineering(2016) The redmud has been suggested for a cost effective geopolymer concrete which becomes a potential sources materials along with Flyash & GGBS in ambient curing temperature.[34] Partha Sarathi Deb, Pradip Nath and Prabir Kumar sarker, "Properties of flyash and slag blended Geopolymer Concrete cured at ambient temperature", Conference Paper, Research Gate (2013) Here there is an increase in workability up to 20% of the total binder and thus increased in compressive strength. When compared with OPC The Geopolymer concrete has shown less sorptivity and permeable void at 28th day.[35] Pradip nath, Prabir Kumar Sarker, Vijaya.B.Rangan, "Early age properties of low calcium flyash Geopolymer Concrete suitable for ambient curing "Science Direct, Procedia Engineering (2015), The compressive strength increased with increase of the binder content for flyash with 10% OPC. Thus the results showed that the flyash geopolymers blended with small percentages of GGBS, OPC can be a suitable binder for low to moderate strength concrete production at ambient curing condition.[36] Arie Wardhono, David.W.Law, Anthony Strano, "The strength of alkali-activated slag/Fly ash mortar blends at ambient temperature", The 5th International Conference of Euro Asia Civil Engineering Forum, Science Direct, (2015), The reduction of our environmental impact over the production of CO2 emission is done by replacing the OPC with slag and flyash and could provide a best solution in ambient curing.[37] B.H.Shinde, K.N.Kadam, "Properties of flyash based Geopolymer Mortar with ambient curing", International Journal of Engineering Research, (2016) The Geopolymer mortars with 8% lime gives the maximum strength than that of the other mixes, Hence the Geopolymer mortar with OPC gives better results as compared to geopolymer with lime.[38] Partha Sarathi deb, Pradip Nath and Prabir Kumar sarker, "Properties of flyash and slag blended Geopolymer Concrete cured at ambient temperature", New developments in Structural Engineering and Construction, (2013), The Geopolymer concrete cured in the laboratory ambient condition gained its strength with 20% of the total binder. The incorporation of slag in the binder of Geopolymer Concrete reduced the sorption and VPV in comparison to the total mixture.

Effect of fiber in Geopolymer Concrete:

[7] Januarti Jaya Ekaputri, Subaer Junaedi, Wijaya, "Effect of curing temperature and fiber on metakaolin based geopolymer", Sustainable Civil Engineering structures and construction materials, (2016) presents the addition of PVA fibers in metakaolin based geopolymer and concluded that 0.6% of PVA is recommended for a metakaolin based geopolymer where extending more percentage causes compacting problem to the fresh mixture.[8] A.Natali, S.Manzi, M.C.Bignozzi, "Novel fiber reinforced composite materials based on sustainable geopolymer matrix", International Conference on green buildings and sustainable

cities (2011), The carbon fibers are applied in metakaolin based geopolymer concrete and thus resulted that all the selected fibres were found to have good adhesion property. Geopolymer added with PVC and carbon fibers exhibited the best energy absorption capacity, achieving an enhanced ductility in the first crack load.[9]Behzad Nematollahi, Jay Sanjayan, Jessie Xia Hui Chai, "Properties of fresh and hardened glass fibre reinforced flyash based geopolymer concrete", (2014) evaluated the effect of glass fiber addition on the properties of fresh and hardened geopolymer concrete and resulted that there is a decrease in workability but increase in density, compressive strength and Flexural strength in an Heat curing fly ash based geopolymer concrete. The increase in compressive and flexural strengths were 34% for GPC mix containing 1.25% of glass fibres.[10] Navid Ranjbar, Mehdi Mehrali, Arash Behnia, Alireza javadi Porsari, Mohammed Mehrali, U.Johnson Alengaram, Mohd Zamin Jumaat, "A Comprehensive study of the Polypropylene fiber reinforced fly ash based geopolymer" PLOS ONE journal(2016) results in the reduction of shrinkage in 3% wt of PPF and enhances the energy absorption of the composites. The workability is reduced by increasing the percentage of PPF but the toughness or energy absorption of the material was improved.[11] K.Siddharth, D.Dinakar, V.Suresh, C.Balaji, M.Dinesh Kumar, "Strength studies on silica fume based geopolymer mortar with coir fibre", International Research journal of Engineering and Technology, (2016) evaluated that the silica fume based geopolymer 7.5% enhanced the overall property and increased the durability nature by addition of 0.75% of coir fibre and beyond the percentage it reduces the working texture.[12]K.Arunagiri, P.Elanchezhiyan, V.Marimuthu, G.Arun kumar and P.Rajeshwaran, "Mechanical Properties of Basalt Fibre based Geopolymer Concrete", International Journal of Science, engineering and Technology, (2017), obtained a strength in addition of 2% of basalt fiber in various mix proportions which acts as a crack arrestors and prevent sudden failure of structures.[13] H.Teja Kiran Kumar, K.Prasanthi, "Experimental study on coir fibre reinforced flyash based geopolymer concrete with 12M molar activator", International Journal of civil Engineering and Technology(2017) applied the coir fibre in various ratios to resist the micro cracks and thus found an optimum percentage of coir fibre as 2.25% increase in strength whereas beyond the percentage the strength decreases.[15]Shanthini.D, Grija.S, Abinaya.S, Devaki.R, "Fibre reinforced geopolymer concrete", International Journal of Civil Engineering and Technology(2016) evaluated and reviewed about the alkaline solutions and properties of fibre reinforced geopolymer concrete as the constituents of the fibre used is polypropylene fibre which can be applied for infrastructure works in different molar ratios of alkaline solutions .[50]A.Talib, M.Y.Khan, A.Baqi, M.K.Vakil, "Effects of polypropylene fibre on strength of Geopolymer Concrete, Research gate conference paper (2016), analyzed that there is increase in compressive strength for about 30% and 50% in its tensile strength with the addition of polypropylene fibre and also has the reduction of 80% in carbon emissions compared to OPC.[32]Thangaraj Sathanandam, Paul.O.Awoyera, Venkudusamy Vijayan, Karupannan Sathishkumar, "Low carbon building: Experimental insight on the use of flyash

and glass fibre for making Geopolymer concrete", (2017) The thermally cured concrete specimens achieved 60% of its total compressive strength at early age with the addition of glass fibre of 0.3%.[47]Mohamed Usman.M.K, Senthil Pandian.M"Study on Flyash and Rice Husk Ash based Geopolymer Concrete with Steel Fiber "Civil Engineering systems and sustainable Innovations, The study reveals that 10% replacements of Flyash with Rice husk ash are suitable for the production of Geopolymer Concrete, The workability of fresh concrete decreases but can enhance by adding chemical admixture.

Effect of Glass Powder in Geopolymer Binder:

[16]Mostafa Vafaei, Ali Allahverdi, "High Strength Geopolymer binder based waste glass powder", Science Direct, Advanced Powder Technology, (2017) and this study has proved the feasibility reuse of waste glass powder to produce high strength geopolymer binder with are placement level of 24% increases the compressive strength of the geopolymer mortar about 6 times.[17]Dr.I.R.Mithanthaya, Dr.N.Bhavanishankar Rao, "Effect of glass powder and GGBS on strength of flyash based geopolymer concrete", International Journal of Engineering Trends and Technology, (2015) identified that the replacement of 10% of flyash by glass powder and 15% of GGBS increases the strength of concrete and thus the water absorption is found to be constant at this mixture and thus it is economical when compared to OPC.[18]Nimisha Sasindran.C, Vidya Jose, "Effect of Glass powder on geopolymer concrete", International journal of scientific & Engineering Research(2017), signified that there is increase in workability of geopolymer concrete with the addition of glass powder and also increase in its compressive strength for about 15% replacement.

Effect of Nano Composites in Geopolymer Concrete:

[19]Rama .k.Layek, Arun .K.Nandi, "A Review on Synthesis and properties of polymer functionalized graphene", Elsevier-Polymer (2013) has reviewed the properties of polymer by graphene, a nano composite, the functionalization of graphene has an immense scope for the development of new and improved strategies. [20]Jeffrey. R. Potts, Daniel.R.Dreyer, Christopher.W.Bielawski, Rodney. S. Ruoff, "Graphene based polymer Nano composites", Polymer Journal(2010), represented one of the most technological development to emerge from the interface of graphene based materials and polymer materials.[21] Mathialagan Sumesh, U.Johnson Alengaram, Mohd Zamin Jumaat, Kim Hung Mo, "Incorporation of nano materials in cement composite and geopolymer based paste and mortar, Elsevier-Construction and building materials, (2017) concluded that the incorporation of nano materials in partially replaced cement composite and geopolymer has significant potential to be used an effective building material in Civil Engineering field application. The modified polycarboxylate based superplasticizer was found better among different types on the workability and strength.[22] Dimitrios. G. papageorgiou, Ian. A. Kinloch, Robert. J. Young, " Graphene/Elastomer nanocomposites", Elsevier Carbon Journal, (2015), the incorporation of graphene matrixes has been showed to lead to a significant enhancement in the mechanical, thermal and barrier properties and thus concluded that the use of graphene in

specified class of material can overcome some disadvantages of elastomers and can produce a high quality elastomeric nanocomposites.[23] H.Assaedi, F.U.A.Shaikh, I.M.Low, "Effect of Nano clay on durability and mechanical properties of flax fabric reinforced geopolymer composites".Journal of Asian ceramic societies (2017)The results showed that the incorporation of Nanoclay has appositive impact on the physical properties, mechanical performance and durability of flax fabric reinforced geopolymer composites and based on the observation the nanoclay has great potential in improving the durability of flax fabric reinforced geopolymer nanocomposites during ages.[24]Xuqiang Ji, Yuanhong Xu, Wenling Zhang, Liang Cui, Jingquan Liu, "Review of functionalization, structure and properties of graphene/polymer composite fibers", Elsevier Journal, (2016) the graphene enhanced fibers can be used in reinforcement of rubber and plastic, reinforcement of cement and thus will promote many industry development and step into a new energy and material world.[25] P.Noorunnisa Khanam, M.A.AL maadeed, M.Quederni, Eileen Harkin Jones, Beatriz mayoral, Andrew Hamilton, Dan sun, "Melt processing and properties of linear low density polyethylene graphene Nano platelet composites" Elsevier Vacuum, (2016) the addition of graphene Nano platelets increased the viscosity of the polymer, which will lead to higher processing power requirements and thus the thermal conductivity has been improved significantly. [14] N.L.N.Kiran Kumar, Dr.K.V.S Gopala Krishna sastry "Effects of nano silica on the strengths of Geopolymer Concrete cured at Ambient Temperature", International Journal of Civil Engineering and Technology, (2017) The strength has obtained with Flyash based GPC with Nanosilica at 28th day and has a considerable improvement. Hence it is observed that the addition of 6% of nano silica in GGBS blended flyash GPC cured at ambient temperature improves compressive strength, tensile strength and flexural strength.[26] Sandeep.N. Tripathi, G.S.Srinivasa Rao, Ajith.B.MAthur and Rakshvir Jasra, "Polyolefin/Graphene Nanocomposites Review "Royal Society of Chemistry, (2017)It has been expected that the addition of graphene Nano sheets to polymer matrices could act as an excellent reinforcement but has to be fully realized.[27]Vivek Dhand, Kyond yop rhee, Hyung Ju Kim and Dong Ho Jung, "A Comprehensive review of graphene Nanocomposites", Hindawi Publishing corporation, Journal of nano materials, (2013)The graphene nanocomposites shows a promising growth in technology and thus it is best in future reinforcement.[28]Saturi Baco, Sazmal.E.Arshad, Saafie sallah, Afishah Alias and Fouziah MD Yassin, "Preparation and characterization of carbon Nanofibres/Metakaolin geopolymer based Nanocomposite"International Journal of Science Environment, (2015) The crystallinity has been improved with temperatue with an addition of 1% of carbon nano fibers.[29]Mahoud.M.Hassaan, Hisham.M.Khater, Medhat.S.El Mahllawy, Abdeen.M.El Nagar, "production of Geopolymer composites enhanced by NAnokaolin material", Journal of advanced ceramics, (2015) The enhancement of mechanical and microstructural properties with nanokaolin addition upto 3% is realized while futhur increase results in lower strength, hence an addition of nano kaolin provides enhancement in geopolymer microstructure.[31]Sudipta Naskar, Arun kumar Chakraborty, "Effect of Nano Materials in geopolymer concrete"Science direct, Perspectives in

science(2016)from the study it is concluded that nano silica and titanium di-oxide can be added to the geopolymer and can have better results in different ratios.[33] Hisham. M. Khater, "Effect of Nano silica on micro structure formation of low cost geopolymer binder", Nano composites Journal Taylor & Francis group, (2016) The addition of Nano silica enhances the mechanical and microstructural charateristics of Geopolymer.

Effect of Sugarcane Bagasse and other source materials in Geopolymer Concrete

[39]Biruk Hailu and Abebe Dinku"Application of Sugarcane Bagasse ash as a partial cement replacement material", Journal of Ethiopian Engineers and Architects, (2012)The test indicates that the replacement of bagasse ash upto 10% resulted in better compressive strength.[40]Vinicus.N.Castaldelli, Jorge.L.Akasaki et al., "Use of slag/Sugar cane Bagasse ash blends in the production of alkali activated materials", Materials(2013)The bagasse ash presented a high percentage of crystallized material and a high proportion of organic matter and could be applied as an alternative approach to OPC.[49]Ramin Hosseini Kupaei, U.Johnson Alengaram and Mohd Zamin jumaat, "The Effect of different parameter on the development of compressive strength of oil palm shell Geopolymer Concrete", Hindawi Publishing Corporation, The scientific world journal (2014), Different parameters where used based on this Oil palm shell in various ratios and thus found that the compressive strength is high at 65^oC at 2 days of curing period.

3. Conclusion

Hence this review gives a view on various source materials in Geopolymer Concrete and is as follows:

Geopolymer Concrete is the best technology in one of new trends to have a green environment and a safe life cycle. It produces a low carbon footprint in our daily life cycle. The Geopolymer mixed with fibre gives a higher strength upto certain percentage of addition compared to OPC.Thus future research should meet the higher strength in ambient curing for a highly structured building ecologically.The effect of Nano Composites in geopolymer is taking a huge part in our new technology.The effect of Sugarcane bagasse ash and Oil palm likewise various source materials should be analyzed and experimented highly which we can apply it and be used for it in our daily life to reduce the CO2 emission and lead a Green Eco World.

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