International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2015): 78.96 | Impact Factor (2015): 6.391

A Review on Eco-Green Geopolymer Concrete

Sruthi.S[1], Dr. A. K. Priya[2]

[1]Assistant Professor, Department of Civil Engineering, CMS College of Engineering and Technology, Coimbatore

[2]Associate Professor, Department of Civil Engineering, KPR Institute of Engineering and Techhnology, Coimbatore.

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 alumino-silicate 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 by-product materials such as flyash,silicafume,slag,rice-huskash,redmud.Thechoice 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 Silica Reaction(ASR) 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 80^0C,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,after21 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 alkali activated Metakaolin-based geopolymer,liang 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 60^0C for

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 80^0C 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 60^0C 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 , M.I Abdul Aleem and P.D 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 60^0C 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 100^0C 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 GPC.Long term properties,S.E.Wallah 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

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 80^0C.[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 60^0C 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 75^0C 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 sulfate attacks.,Hasan sahan 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 Geopolymerfor sustainable concrete using flyash synthesized by high energy ball milling,A.M.Mustafa Al Bakri,H.Kamarudi, M.Bnhussain, J.Liyana 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 was more irregular.[28]Flyash based geopolymer 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 60^0C 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 65^0C 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 80^0C 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

temperature,10% replacement of foundary sand in hot curing at 60^0C 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 28th 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.

References

[1] Joseph Davidovits (1994),"Properties of Geopolymer Cements", Geopolymer Institute, First International Conference on Alkaline Cements and Concretes, (Pg.no:659-669)
[2] Kunal kupwade-patil and Erez Allouche, (2011), "Effect of Alkali Silica Reaction (ASR) in Geopolymer Concrete", World of Coal Ash (WOCA) conference, USA. (Pg.no:659-669)
[3] M.I.Abdul Aleem and P.D. Arumairaj, (2012), "Optimum mix for the Geopolymer Concrete", Indian Journal of science and technology. (Pg.no:659-669)
[4] Subhash.V.Patankar,Yuwaraj.M.Ghugal and sanjay.S.Jamkar,(2014) "Mix design of flyash based Geopolymer Concrete",Research Gate. (Pg.no:659-669)
[5] M.I.Abdul Aleem and P.D. Arumairaj, (2013), "Chemical formulation of Geopolymer Concrete with M-Sand, International Journal in Civil Engineering, Architecture & Design. (Pg.no:659-669)
[6] G.Habert, j.B.dEspinose de Lacaillere, N.Roussel, (2011) "An Environmental Evaluation of Geopolymer based Concrete production, Research gate, Journal of cleaner production. (Pg.no:1229-1238)
[7] "Abrasion resistance of Geopolymer concrete", Kolli Ramujee, M.Potharaju, (2014), Elsevier, 3rd International Conference on materials processing and characterization. (Pg.no:659-669)
[8] Nguyen Van Chanh, Bui Dang Van Tuan (2008), "Recent research Geopolymer Concrete", The 3rd ACF International Conference. (Pg.no:235-241)
[9] Liang Chen, Zaiqin wang, Yuanyi Wang and Jing Feng, (2016), "Preparation and properties of Alkali Activated metakaolin-based Geopolymer" Materials and Structural Department, Chandijang River Scientific Research Institute, Wuhan, China. (Pg.no:1 of12)
[10] Joseph Davidovitis, (1994), "Geopolymer: Man made Rock Geosynthesis and the resulting development of very Early High Strength Cement", Geopolymer Institute. (NAST's award) (Pg.no:091-139)
[11] Djwantoro Hardjito, Steenie.E.Wallah, Dody.M.J.Sumajouw and B.V.Rangan, (2017) "On the development of flyash based Geopolymer Concrete", ACI Materials Journal, Research Gate. (Pg.no:467-472)
[12] Andi Arham Adam, Harianto (2014), "The effect of temperature and duration of curing on the strength of flyash based Geopolymer Mortar", 2nd International Conference on Sustainable Civil Engineering Structures and Construction materials, Science Direct, Elsevier. (Pg.no:410-414)
[13] Gum Sung Ryu, Young Bok lee, Construction and Building Materials. (2016), "The Mechanical properties of Flyash based Geopolymer Concrete with Alkaline activators", (Pg.no:408-418)
[14] J.G.S.Van Jaarsveld and J.G.S.Van Deventer, (1997) "The Potential Use of Geopolymeric Materials to immobilize toxic metals", Minerals Engineering, vol 10, no.7 (Pg.no:01-10)
[15] S.E.wallah, B.V.Rangan, (2006),"Low Calcium flyash based Geopolymer Concrete: Long Term Properties", Research report, Curtin University, Australia, (Pg.no:01-99)
[16] Chamita Gunasekar, David.W.Law and Sujeeva Setunge, (2016), "Long term Engineering Properties of flyash Geopolymer Concrete", 4th International Conference on sustainable construction and technologies.
[17] L.Krishnan, S.Karthikeyan, S.Nathiya & K.Suganya, (2014), Geopolymer Concrete an Eco friendly construction material", International Journal of research in Engineering and technology, (Pg.no:164-167)
[18] Hanio Merinkline,S.Manjula Devi,Dr.C.Freeda Christy,(2013),"Fresh and Hardened properties of flyash based Geopolymer Concrete with Copper slag,International Journal of Engineering, Reseach and technology, (Pg.no:01-07).

[19] Joseph Davidovitis and M.davidivics, (1996),"Fire Resistance Geopolymer Composites", First International conference on Fiber composites in infrastructures, (Pg.no:972-981).
[20] Djwantoro Hardhito, Steenie.E.wallah and B.V.Rangan, (2004),"Factors influencing the compressive strength of flyash based Geopolymer Concrete", Civil Engineering Dimension, vol 6, No 2, (Pg.no:88-93).
[21] Gabor Mucsi, Janos Lakatos, Zoltan Molnar, Roland Szabo, (2014),"Development of geopolymer using Industrial Materials, the 9th International Conference"Environmental Engineering, (Pg.no:01-07).
[22] Part weiken,Mahyuddin Ramli,Cheah Chee Ban,(2015),"An overview on the influence of various factors on the properties of Geopolymer Concrete derived from Industrial by-products",Construction and Building materials,Elsevier,Research gate, (Pg.no:369-395).
[23] Sudipta Naskar, Arun Kumar Chakraborty, (2016),"Effect of Nano materials in Geopolymer Concrete", Science direct, Elsvier, 8, (Pg.no:273-275).
[24] Yagnesh Patel, Dr.Indrajit.N.patel, Mrs.Jagruti Shah, (2015),"Experimental Investigation on vcompressive strength and durability properties of Geopolymer concrete incorporating with Nano silica", Vol 6, issue5, (Pg.no:135-143).
[25] Xiaolu Guo, Huisheng shi, Warren.A.Dick, (2014),"Compressive strength and Microstructural characteristics of class C flyas Geopolymer", Cement and concrete composites, Elsevier, Reseach gate.
[26] Hasan sahan Arel,Blessen skariah Thomas,(2017),"The effects of Nano and micro particle additives on the durability and mechanical properties of moratrs exposed to internal and external sulfate attacks"Results in Physics,Elsevier, (Pg.no:843-851).
[27] A.M.Mustafa Al Bakri,H.Kamarudi,M.Bnhussain,J.Liyana & C.M.Ruzaidi,(2016),"Nano Geopolymer Concrete for sutainable Concrete using Flyash synthesized by High energy ball milling",Applied mechanics and Materials, vols 313-314,(Pg.no:169-173).
[28] A.M.Mustafa Al Bakri,H.Kamarudi,M.Bnhussain,Khairul Nizar Ismail,Zarina Yahya and Rafiza Abdul Razak,(2012),"Flyash based Geopolymer lightweight Concrete using Foaming Agent",International journal of Molecular Sciences, 13,(Pg.no:7186-7198).
[29] D.M.A.Huiskes, a.Keulen, Q.L.Yu, H.J.H.Brouwers, (2015),"Design and performance evaluation of ultra lightweight geopolymer concrete", Materials and Design, Elsevier, 89, (Pg.no:516-526).
[30] S.Usha,Deepa.G.Nair,Subha Vishnudas,(2016),"Feasibilty study of geopolymer binder Terracotta roof tile waste",Global colloquim in recent advancement and effectual researches in engineering,science and technology(RAEREST 2016),25, (Pg.no:186-193).
[31] J.S.Jayalakshmi, shri.N.G.Bhagavan, R.Kumutha, (2016),"Development of low strength and geopolymer concrete mix utilizing demolished aggregate", International journal of advanced research, vol 4, (Pg.no:1168-1179).
[32] Thamer Alomayri, (2017)"Effect of glass microfiber addition on the mechanical performances of flyash based geopolymer composites", Journal of Asian ceramics societies.
[33] Rekha devi,S.K.Sharma and Himmi Gupta,(2015),"Effect of different curing conditions on geopolymer concrete by partially replacing sand with foundary sand",Journal of today's ideas-tommorrows technologies,vol3,2, (Pg.no:123-128).
[34] M.Olivia & H.Nikraz, "Propertias of flyash geopolymer concrete in sea water Environment", Indian Journal of science.
[35] Nagarj.V.K, Puttaswamy.B.K, (2015),"A Study on wood ash based lye as alkaline activator in geopolymer concrete", International journal of innovative research in science, engineering and technology, vol4, issue 12, (Pg.no:12944-12951).
[36] Samuel demie,Muhd fadhil nuruddin,Nasir shafiq,(2012),"Effects of micro structure characteristics of interfacial transition zone on the compressive strength of self-compacting geopolymer concrete",Construction and building materials,41, (Pg.no:91-98).
[37] A.JoshuaDaniel,S.Sivakamasundari,D.Abhilash,(2016) "Comparative study on the behavior of geopolymer concrete with hybrid fibers under static cyclic loading",11th International symposium on plasticity and impact mechanics,Implast 2016,Science direct,Elsevier.
[38] Antonella petrillo, Raffaele cioffi, Claudio ferone, Francesco colangelo, Claudia borrelli, (2015),"Eco sustainable geopolymer concrete blocks production process", Sustainabilty of wellbeing, International forum (SWIF2015).8(Pg.no:408-418).
[39] Hamed Maraghechi,Iman fotovat Ahmadi and Siamak Motahari,(2011),"Effect of adding crumb tire rubber particles on the mechanical properties of DCPD modified sulfur polymer mortars",Journal Mechanics of materials and structures,vol6, (Pg.no:1283-1294).
[40] R.Rathan Raj,E.B.Perumal pillai,A.R.santhakumar,(2013),"Evaluation and mix design for ternary blended high strength concrete", chemical, Civil and mechanical engineering tracks of 3rd Nirma University International Conference(NUiCONE 2012), Elseveir,Sciverse Science direct(Pg.no: 65-74).
[41] M.L.Anoop Kumar,Dr.I.V.ramana Reddy,Dr.C.Sasidhar,P.Ramesh,D.Srinivasa murthy,(2013),"Feasibility of water containing metal ions as mixing water in cement mortar",International journal journal of emerging technology and advanced engineering,vol 3,issue 5(Pg.no:328-334).
[42] B.Kondraivendan, B.Bhattacharjee, (2015),"Flow behavior and strength for fly ash blended cement paste and mortar", International Journal of sustainable built environment, Elsevier.4, (Pg.no:270-277).
[43] Prof.M.R.Wakchaure and Mr.Prashant.A.Chavan, (2014),"Waste tyre crumb rubber particle as apartial replacement to fine aggregate in concrete", International journal of engineering research and technology, vol3, issue 6, (Pg.no:1206-1209).

[44] Prashant O Modani, M.R.Vyawahare, (2013), "Utilization of bagasse ash as a partial replacement of fine aggregate in concrete ", Chemical, Civil and mechanical engineering tracks of 3rd Nirma University International Conference on Engineering (NUiCONE 2012), 51(Pg.no:25-29).
[45] E.W.Gadzama,O.J.Ekele,V.E.Anametemfiok and A.U.Abubakar,(2015),"Effects of sugar factory wastewater as mixing water on the properties of normal strength concrete",International Journal of Science,Environment,Vol4,3, (Pg.no:813-825).
[46] Nitendra Palankar,A.U.Ravi Shankar,B.M.Mithun,(2015),"Studies on eco-friendly concrete incorporating industrial waste as aggregates",International Journal of Sustainable built Environment,vol4, (Pg.no:378-390).
[47] K.C.Panda and P.K.Bal,(2013),"Properties of self-compacting concrete using recycled coarse aggregate", Chemical,Civil and mechanical engineering tracks of 3rd Nirma University International Conference on Engineering (NUiCONE 2012),51, (Pg.no:159-164).
[48] Jiji Antony and Deepa.G.Nair, (2016),"Potential of construction and demolished wastes as pozzolana", Global colloquium in recent advancement and effectual researches in engineering, science and technology (RAEREST 2016), vol 25, (Pg.no:194-200).
[49] M.A.Iqbal,Abhishek Rajput,P.Bhargava,(2016),"Plain and reinforced concrete targets subjected to projectile impact,The 11th International symposium on plasticity and impact mechanics,(IMPLAST 2016),173, (Pg.no:138-144).
[50] Jyoti.S.Trivedi,Sandeep Nair,Chakradar Iyyunni,(2013),"Optimum Utilization of flyash for stabilization of sub grade soil using genetic algorithm", Chemical,Civil and mechanical engineering tracks of 3rd Nirma University International Conference on Engineering (NUiCONE 2012),51 (Pg.no:250-258).
[51] Prof.P.N.Balaguru, S.Kurtz and Jon Rudolph, (1997),"Geopolymer for repair and rehabilitation of reinforced concrete beams", Geopolymer Institute (Pg.no:01-05).
[52] Alan Richardson, Marcus Heather, (2013),"Improving the performance of concrete using 3D fibres", Non-Circuit branches of the 3rd Nirma University International Conference on Engineering (NUiCONE 2012), 51, (Pg.no:101-109).
[53] Cheah Chee Ban, Part Wei ken, Mahyuddin Ramli, (2017),"Mechanical and durability performance of novel self-activates geopolymer mortar", Sustainable civil engineering structures and construction materials, SCESCM 2016,171, (Pg.no:564-571).
[54]Vinodkumargupta,Prof.Akhilkhare,(2015),"Geopolymer concrete", SSRG,International Journal of Civil Engineering,vol2,Issue 4, (Pg.no:8-13).
[54] Siti Norsaffirah Zailan,Norsuria mahmed,Mohd Mustafa Al Bakri Abdullah,Andrei victor sandu,(2016),"Self cleaning geopolymer concrete",Materials Science and Engineering,133.
[55] Zeynab Embadi, Nilofar Asim, M.A.Yarmo & Roslinda Shamsudin, (2014),"Investigation of more Environmental friendly materials for passive cooling application based on geopolymer", ICESD 2014, (Pg.no:69-73).
[56] Kang Gao,Kae-long lin,De ying wang,Hau Shing shiu,Chao lung hwang and Ta wui,(2013),"Effects of Nano-SiO2 on setting time and compressive strength of Alkali activated metakaolin based geopolymer".The Open civil Engineering Journal,7, (Pg.no:84-92).
[57] S.Ridha, M.Akmalludin and S.S.Salehudin, (2016),"Microstructure investigation on Nano-Geopolymer cement cured under HPHT Conditions", ARPN journal of Engineering and applied sciences, vol11, 1, (Pg.no:144-149).
[58] H.Assaedi, F.U.A.Shikh, I.M.Low, (2015),"Charateristics of Nanosilica-Geopolymer nanocomposites and mixing effect", International Journal of chemical, Molecular, Nuclear, materials and metturgical Engineering, 9, (Pg.no:1471-1478).
[59] Joseph Davidovits and Michel Davidovics, (1991),"Geopolymer: Ultra-High temperature tooling material for the manufacture of advance composites", Geopolymer Institute, Vol2, (Pg.no:1939-1949).