**Australian Journal of Basic and Applied Sciences**, 9(27) August 2015, Pages: 457-464

ISSN:1991-8178

**Australian Journal of Basic and Applied Sciences**

Journal home page: www.ajbasweb.com

# Durability of Alkali Activated Concrete – A Review

[1]R. Gopalakrishnan and [2]K. Chinna Raju

*[1]Asst.Professor, Department of Civil Engineering, Sri Venkateswara College of Engineering,Sriperumbudur-602117*
*[2]Associate Professor, Division of Structural Engineering, Anna University, Chennai.*

**ARTICLE INFO**

***Article history:***
*Received 23 June 2015*
*Accepted 25 August 2015*
*Available online 2 September 2015*

***Keywords:***
*Durability, Sulfate, Acid, Thermal effects*

**ABSTRACT**

Concrete is the most commonly used construction material. Customarily, concrete is produced by using Ordinary Portland Cement as a binder a highly energy intensive product which causes pollution to the environment due to the emission of carbon dioxide. Attempts to reduce the use of Portland cement in concrete are receiving much attention due to the environment related. Geopolymer concrete is a new material that does not need the presence of Portland cement as a binder. Geopolymer is an inorganic alumina-hydroxide polymer which is synthesized from predominantly silicon and aluminium materials of geological origin or by product materials such as fly ash, granulated blast furnace slag or rice husk ash, etc. Research in the field and publications in this field of geopolymer binders, states that this new material is highly potential to replace an alternative to Portland cement. The Durability of these materials is better than OPC which is the main advantage as such it can be replaced. This paper presents a review of the literature about the durability of alkali-activated binders. In this paper the durability properties such as resistant to acid, resistance to sulphate, resistance to high temperature and fire has been discussed.



**To Cite This Article:** R. Gopalakrishnan and [2]K. Chinna Raju., Durability of Alkali Activated Concrete – A Review. ***Aust. J. Basic & Appl. Sci.,*** *9(27): 457-464, 2015*

## INTRODUCTION

The annual production of 4 GT Ordinary Portland cement is the dominant binder of the construction industry (Juenger, M., Winnerfeld, J. Provis, 2011). The production of one tonne of OPC generates 0.55 tonnes of chemical Carbon dioxide and requires an additional 0.39 tonnes of Carbon dioxide in fuel emissions for baking and grinding, accounting for a total of 0.94 tonnes of carbon dioxide (Gartner, E., 2004). It is also reported (Damtoft, J., *et al*., 2008) that the cement industry emitted in 2000, an average of 0.87 kg of carbon dioxide for every kg of cement produced. As a result the cement industry contributes about 7% of the total worldwide $Co_2$ emission.( Ali, M., *et al*., 2011)

The projections for the global demand of Portland cement show that in the next 40 years it will have a twofold increase, reaching 8 GT/year (Taylor, M., D. Gielen, 2006). Research works (Pacheco-Torgal, F., J. Gomes, 2008; Pacheco-Torgal, F., J. Gomes, 2008; Li, C., H. Sun, L. Li, 2010) carried out so far in the development of alkali-activated cements showed that much has already been investigated and also that an environmental friendly alternative to Portland cement is rising. Davidovits *et al* (1990) was the first researcher to address the carbon dioxide emissions of these binders stating that they generate just 0.184 tonnes of carbon dioxide per ton of binder. Duxson *et al* (2007) does not confirm these numbers stated that although carbon dioxide emissions generated during the production of sodium oxide is very high, still the production of alkali activated binders is associated to a level of carbon dioxide emissions lower than the emissions generated in the production of OPC. This paper reviews the various durability properties of the alkali-activated concrete of the various investigators.

### *II. Review On Acid Attack:*

Bakharev.*et al* (2004) investigated durability of Geo polymer concrete using class F fly ash and alkaline activators exposed to 5% solution of acetic and sulfuric acid by immersing the samples for the period of 150 days in which the parameters they studied were an evolution of weight, compressive strength, products of degradation and micros structural changes. The samples activated by sodium hydroxide, weight losses in acetic and sulfuric acid solutions were 0.45% and 1.96%. The samples activated by sodium silicate which has 3.83% weight gain in the acetic acid solution and 2.56% weight loss in the sulfuric acid solution. The samples activated with sodium hydroxide and potassium

**Corresponding Author:** R. Gopalakrishnan, Asst.Professor, Department of Civil Engineering, Sri Venkateswara College of Engineering,Sriperumbudur-602117
E-mail: gopalakrishnan@svce.ac.in.

hydroxide was in good in acetic acid with 1.15% weight loss, but very poor in sulfuric acid with 12.43%.The most significant weight change in both acetic and sulfuric acid was in OPC and OPC+ FA samples, which has weight losses in acetic acid solution of 10% and 5.47% respectively. In sulfuric acid, both OPC and OPC + FA samples has weight gain. OPC samples gained more than 40% and severely deteriorated, while OPC + FA samples gained more than 40% and severely deteriorated, while OPC + FA samples gained 19.15% and exhibited severely deteriorated in the surface. In an acidic environment, high performance materials deteriorate with the formation of fissures in amorphous matrix, with low performance goes polymers deteriorate through crystallization of Zeolites and formation of fragile grainy structures. More crystalline Geo polymer material prepared with sodium hydroxide, which was the best performance as it is more stable in the aggressive environment of sulfuric acid and acetic acid solutions than amorphous geo polymers prepared with the sodium silicate activator.

Song *et al*., (Song, X.J., 2005) reported that sulfuric acid corrosion in concrete sewer pipes, has not been satisfactorily investigated. Geo polymer binders are found to be reported as acid resistant and are promising as a alternative binder for sewer pipe manufacturing works. In his paper he presented an experimental data on the durability of fly ash based Geo polymer concrete when exposed to 10% sulfuric acid solution for 8 weeks using class F fly ash. The compressive strength of 50 mm cubes at an age of 28 days ranged from 53 Mpa to 62 MPa. With the fixed ratio of acid volume to specimen surface area of 8 ml/sq.cm, samples were tested at 7, 28 and 56 days. The results confirmed that Geo polymer concrete is highly resistant to sulfuric acid in terms of a very low mass loss of less than 3%. Moreover, Geo polymer cubes were structurally intact and still had enough load carrying capacity even though the entire section had been neutralized by sulfuric acid.

Temuujin. *et al*., (2012) in his investigation carried out Acid and alkaline resistance of Geo polymer to Calcining the 0̊ to 600̊ c and compared with the class F fly ash based geo polymer paste. He states that the calcinations of fly ash based geopolymer at 600̊ c resulted in a decrease of amorphous component from 63.4 to 61.6 weight%. But the solubility of Al, Si, and Fe ions in 14M NaOH and 18% HCL later 5 day immersion decreased from 1.3 to 16 fold in comparison to as prepared geopolymer samples. Calcination of the geopolymer samples also resulted in a 30 % reduction in compressive strength. Acid and alkaline resistance of the calcined geopolymer increases due to the partial crystallization of the surface of amorphous constituents in the Geo polymer and the behavior of the Geo polymers can also be improved by regulating the amount of quartz impurity and level of iron oxides in the fly ash thus assisting the geopolymer calcinations process.

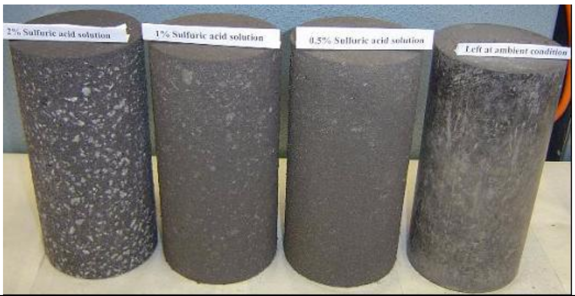
Suresh Thokchom *et al* (2009**)** carried out an investigation by immersing of geo polymer samples with a percentage $Na_2O$ ranged from 5% to 8% of fly ash in 10% Sulfuric acid solution up to a period of 18 weeks and evaluated its resistance in terms of visual appearance, residual alkalinity, changes in weight and compressive strength. Visual inspection of Geo polymer mortar samples did not reveal any remarkable change in color and remained structurally intact though the exposed surface turned slightly softer. He had concluded that after exposure in the acid solution for 18 weeks, the geopolymer samples almost lost its alkalinity and showed very low weight loss in the range from 0.41% to 1.23% of initial weight. Loss of weight was found higher for specimen with the highest percent of $Na_2O$ Compressive strength loss at the end of the test was 52% for specimen with 5% $Na_2O$ and 28% for specimens with 8% $Na_2O$ which indicated that geo polymers are highly resistant to sulfuric acid.

B.V. Rangan *et al* (2005**)** in his experimental investigation against sulfuric acid resistance, performed the study of heat cured low calcium fly ash based geo polymer concrete for the period of one year by immersing samples for a concentration of 2%, 1% and 0.5%. He observed that the visual appearance of the specimens after exposure to sulfuric acid resistance showed that acid attack slightly damaged the surface of the specimens. The damage to the surface of the specimens increased as the concentration of the acid solution increased and the maximum loss of test specimens of about 3% after one year of exposure is relatively small compared to that of Portland cement concrete.

Kannapiran *et al* (2011; 2012) in his investigation against sulfuric acid resistance performed the study of immersing the concrete cube specimens using 14M in 5% sulfuric acid solution for the period of 4 weeks. He observed that there is no sign of surface erosion, cracking or spalling of the specimens.OPC specimens exposed to sulfuric acid undergoes on the surface.The severity of the damage and the distortion of the shape of the specimens shall be depending on the concentration of the solution and in increase in period of exposure.The degradation due to sulfuric acid attack on compressive strength is about is 6.9% in GPC 30 and 4.3% in GPC 50 and 21% reduction in M30 grade OPC and 19% in M50 grade OPC.

Kannapiran *et al* (2012) in his another investigation conducted a study against sulfuric acid resistance and chloride resistance for the flexure behavior of beams by immersing concrete beams for the period of 180 days by immersing the specimens for a 10% concentration of sulfuric acid and hydrochloric acid.He observed that there is a very little erosion, 3.26% and 1% weight loss, 10.64% and 4.47% decrease in ultimate moment for specimens exposed to chloride and acid attacks respectively. SEM micro graphs showed changes in the microstructure of binder phase after exposure to aggressive solutions, which appeared to be milder. The micro structural analysis in the EDAX reports that no CSH gel was performed on concrete, even though the fly ash had a considerable amount of calcium in them.

Vanchai Sata *et al* (2012) in his experimental investigation against sulfuric acid resistance performed the study of soaking the mortar cube specimens in 3% sulfuric acid solution for the period of 120 days. In order to study the resistance of lignite Bottom ash geopolymer mortars on sulfuric acid attack and to compare the results to cement mortar, three Portland cement mortar (PC -100% OPC, PFA40- OPC60 + FA40, PFBA40- OPC60 +BA40) and three geopolymer mortars GFBA- Fine ash, GMBA- Medium ash, GCBA- Coarse ash was used. The compressive strength of cement mortars increased with the curing age in accordance with the strength development of Portland cement. The strength development of geo polymer mortars increased at a lower rate compared to those of Portland cement mortars. This was due to the fact that the heat curing increased the early age compressive strength. For the cement based mortars, against the sulfuric acid resistance, their weight losses due to primarily on the reaction between calcium hydroxide presented in the specimen and the acid, which can induce tensile stress, resulting in cracking and scaling of the mortar. Among the cement mortar specimens, the PFA40, PBA40 mortars exhibited higher acid resistance than that of PC mortar. After 120 days of immersion in sulfuric acid solution, the weight loss of PFA40 and PBA40 mortars was 91.8% and 77.2%, respectively, while that of PC mortar was 95.7%. Compared to the cement based mortars, the weight losses of all geo polymer mortars were much lower. After 120 days of immersion GFBA, GMBA, GCBA mortars had lost only 3.6%, 1.7% and 1.4% of their weights. The geo polymer mortars had a low weight loss under acid attack due to lower water absorption of these binders, and also to their low calcium contents compared to those of cement based mortars. The better performance of the geopolymer mortars in the sulfuric solution due to the more stable cross-linked aluminosilicate polymer structure as compared to the normal Portland cement hydration structure.




| | | | |
|---|---|---|---|
| 2% sulfuric acid solution | 1% sulfuric acid solution | 0.5% sulfuric acid solution | Left in ambient condition |

**Fig. 1:** Visual Appearance of Heat-cured Geopolymer Concrete after One Year Exposure in Sulfuric Acid Solution (Wallah and Rangan, 2006)

**Fig. 2:** Appearance of concrete specimens exposed in 10% sulphuric acid –Left Control Concrete for 28 days, right-Alkali activated concrete for 56 days (XJ Song)

***III. Review of Sulfate Attack:***

Bakharev (19**)** conducted an experimental investigation for the study of Geo polymer materials using class F fly ash and alkali activators exposed to sulfate environment. In his study three tests were conducted to determine the resistance of Geo polymer materials, which involved immersion for a period of 5 months into 5% solution of sodium sulfate and magnesium sulfate and a solution of a combination of 5% sodium sulfate and magnesium sulfate. The change in weight, compressive strength, degradation was studied.

In the sodium sulfate solution, significant fluctuations of strength occurred with strength reduction 18% in the FASS (fly ash, sodium silicate with 8M) and 65% in the materials prepared with a mixture of sodium hydroxide and potassium hydroxide activators FAK (8M) while 4% strength increase was measured in specimens activated by sodium hydroxide FA(8M). In the magnesium sulfate solution, 12% and 35% strength was an increase was measured in FA and FAK specimens, respectively, and 24% strength decline was measured in the FASS samples. The least changes in Geo polymer specimens were found in the solution of 5% sodium sulfate + 5% magnesium sulfate. The most significant fluctuations of strength and micro structural changes took place in 5% solution of sodium sulfate and magnesium sulfate. In the solution of sodium sulfate, migration of alkalies from geopolymer specimens into the solution was observed. Diffusion of alkali ions into the solution caused significant stresses and the formation of deep vertical cracks in the specimens prepared a mixture of sodium and potassium hydroxides. Magnesium sulfate solution, in addition to migration of alkalies from geopolymers into the solution, there was also the diffusion of Mg and CA in the surface layer of Geo polymers, which improved their strength. Specimens prepared with sodium hydroxide were more stable in sulfate solutions than specimens prepared using sodium silicate or a mixture of sodium and potassium hydroxide solutions.

B.V. Rangan *et al* (2005) in his experimental investigation against sulfate resistance, performed the study of heat cured, low calcium fly ash based geo polymer concrete for the period of one year by immersing samples for a concentration of 5%. The sulfate resistance was evaluated based on the change in mass, change in length and change in compressive strength of the specimens after sulfate exposure.

Test results showed that heat cured, low calcium fly ash based Geo polymer concrete has an excellent resistance to sulfate attack. There was no damage to the surface of the test specimens after exposure to sodium sulfate solutions up to one year. It can be seen that the visual appearance of the test specimens after soaking in sodium sulfate solution up to one year revealed that there was no change in the appearance of the specimens compared to the condition before they exposed. There was no sign of surface erosion, cracking or spalling on the specimens. There was no significant changes in mass and the compressive strength of test specimens after various periods of exposure up to one year.The change in length was extremely small and less than 0.015%.Low calcium fly ash- geo polymer concrete undergoes a different mechanism to that of Portland cement concrete and the geopolymerisation products are also different from hydration products. As there is no gypsum or ettrigite formation in the main products of geopolymerisation, there is no mechanism of sulfate attack in heat cured low calcium fly ash based geopolymer concrete.

Kannapiran *et al* (2011) in his investigation against Sulfate resistance performed the study of immersing the concrete cube specimens prepared by 14M in 5% Sodium sulfate solution for the period of 4 weeks. It can be seen that visual appearance of the test specimens after soaking in sodium sulfate solution up to 4 weeks revealed that there is no change in the appearance of the specimens compared to the condition before they are exposed. The test data reveal that sodium sulfate solution causes very little reduction in compressive strength in geopolymer concrete specimens than OPC counterparts. There is slight decrease in the mass of specimens due to the erosion by the exposed liquid. The decrease in mass of specimens soaked in sodium sulfate solution is approximately 1.6% after 4 weeks of exposure. In the case of OPC specimens soaked in sulfate solution, the decrease in mass is about 3.5%.

N.P. Rajamane *et al* (2012) in his investigation against sulfate resistance by submerging the Test specimens of typical GBCs (GGBS based, with fly ash contents of 25% percent GPC1 and 50% percent GPC2) and PPCC (Portland Pozzolana cement concrete) in 5% Sodium sulfate and 5% Magnesium support for 90 days. Against the sodium sulfate solution, at the end of 30 days, there were minor changes in the weight in the range of -0.4% to 1.1%, but there was a noticeable strength loss of about 12.2% in PPCC whereas the strength loss in GPC specimens was almost negligible. The actual values being 1.8% for GPC1 and 4.4% for GPC2. At the end of 90 days of exposure, there was noticeable weight losses in both concretes, very low values and the specimens has maintained their integrity with very minor distress seen on the surface when examined visually. The mixes GPC1 and GPC2 had strength losses of about 29% and 19%, but the PPCC recorded a higher strength loss of about 39% thereby providing the superiority of GPCs. With regard to Magnesium sulfate attack the mixes GPC1, GPC2 and PPCC had percent strength losses of about 6.5%, 10.2% and 9.1% after 30 days of exposure and these values increase to 15.8%, 21.3% and 19.3% at the end of 90 days of exposure. Thus, there is no clear distinction between the GPC and PPCC mixes in respect of the resistance attack by the magnesium sulfate solution. However, GPC1 containing 25% fly ash and 75%GGBS seems to lose marginally less strength than both GPC2 containing higher amount of fly ash and PPCC.

Chaicharn *et al* (2012) in his experimental investigation studied the performance of against sulphate attack for the Ground lignite bottom ashes with the particle sizes of 16, 25 and 32 micro strains.

Mortar bars were used for the test of sulfate resistance and they were immersed in 10% sodium sulfate solution after the age of 7 days and were tested for sulfate induced expansion and weight change until 360 days of immersing them. The expansion of mortar bars was found to depend on the fineness of the bottom ash and water content of the mixture. The expansions of specimens which contained extra water (B) were significantly higher than those of mixture without water (A). After immersion of 360 days, the expansions of B specimens were between 215-325 micro strains, whereas those of series A war between 80-160 micro strains. The mix with the extra water content with larger amount of larger pores exhibited high expansion and low strength. For the effect of fineness of Bottom ash, the expansions were lower with the use of fine Bottom ash.

Vanchai Sata *et al* (2012) in his experimental investigation against sulfate resistance performed the study of soaking the mortar bar specimens in 5% sodium sulfate solution for the period of 240 days. In order to study the resistance of lignite Bottom ash geopolymer mortars on sulfate attack and to compare the results to cement mortar, three Portland cement mortar (PC -100% OPC, PFA40- OPC60 + FA40, PFBA40- OPC60 +BA40) and three geopolymer mortars GFBA- Fine ash, GMBA- Medium ash, GCBA- Coarse ash were used. In case of the geo polymer mortars, the BA geopolymer mortars gave excellent resistance to sodium sulfate attack. After exposure to 5% Sodium sulfate solution for 360 days, the length changes of Geo polymer mortars were only 65-121 microstrain, while those of the PFA40 and PFBA40 mortars were 595 and 648 microstrain, respectively. The PC exhibited highest expansion of 7600 microstrain. The main geopolymerization products were different from Portland cement hydration products and were less susceptible to sulfate attack compared to normal cement hydrated product.

***Review On Elevated Temperature (Thermal Behaviour):***

Balaguru (1997) in his experimental work measured the fire response of geopolymer matrix and he compared the results with organic matrix composites being used for transportation, military and infrastructure applications. It was found that geopolymer composites did not ignite burn, or release any smoke even after extended heat exposure. The geopolymer composite retained sixty percentage of its flexural strength after a simulated fire exposure. It had been reported that geopolymer composites could be used to strengthen concrete structures and geopolymer coating could protect the transportation infrastructures. The performance of geopolymers was better in comparing to organic polymers in terms of fire resistance.

Pan and sanjayan (2010) in their experimental investigation studied the stress- strain behavior of geopolymer kept at elevated temperatures with the aim to study the fire resistance of geopolymer. They have found that the strength of geopolymers increased with temperature. They concluded that there was a significant contraction while the temperature was 200° C to 290° C. But, they had noticed the sudden expansion when the range of temperature was 380° to 520° C.

Daniel and sanjayan (2010) presented after an extensive work on the effect of elevated temperature on Geopolymer paste , mortar and concrete using Australian fly ashes. Different parameters have been examined such as specimen size, aggregate size and aggregate type and superplasticizer type. The study resulted that the influence of specimen size is more when compare to the aggregate size in the thermal behavior at elevated temperature at 800° C. Aggregate size greater than 10 mm resulted in good strength performances in both ambient and elevated temperatures.

Deventer (2007) done the fundamental experimental work into the geopolymerisaion process to find ourt relationship between compositon and temperature of the final chemical and physical properties of geopolymeric products from arrived from waste materials. From the analysis of different studies they found out that the differences in reactivity of source materials used during the synthesis of waste based geopolymers, significantly affects the final properties of the geopolymeric material. Finally he concluded that water content, the flyash Vs kaolinte ratio as well as the type of metal silicate usdd has a substantial effect on the final properties of the geopolymer.

In particular they showed that the thermal history of the source material such as kaolinte as well as the curing regime for the geopolymer are important factors that must be taken in to consideration when a designing a geopolymer product for a specific application.

Bakharev (Bakharev, T., 2005) reported a after a full detailed research work on the study of thermal stability of properties firing to around 800°- 1200° c of materials prepared using Class F fly ash geopolymer using potassium and sodium as activatiors. Compressive strength and shrinkage measurements were found in the studies. The materials were prepared in the water binder ratio as 0.09- 0.35 using compaction pressures up to 10 MPa and curing temperatures 80° to 100° C. In compare to sodium and potassium silicate, potassium silicate as activator was better in compressive strength on heating and deterioration was started at 1000° c.Compaction at 1-10 Mpa were reduced shrinkage on firing all materials.Geopolymer materials prepared using class F fly ash and alakaline activatiors showed higher shrinkage as well as change in compressive strength with increasing fire temperatire in the range of 800° -

1200° c. Thus the materials are found unsuitable for refractory applications.

***Review On Chloride Attack:***

Susan A.Bernal (Susan, A., Bernal, 2012) in his experimental investigation studied the engineering properties of alkali activated slag / metakaolin blends the resistance against chloride attack. The higher concentration, compressive strength at an early age are enhanced by the inclusion of metakaolin in the binder. Increased metakaolin contents and higher concentration results in most of the cases to reduced water sorptivity and lower chloride permeability. The correlation between the RCPT and a directly measured chloride diffusion is weak, revealing the limitations of RCPT when applied to alkali-activated concretes. He concluded that all durability parameters fall within the range of highly durable concretes, assuming that the correlations developed for Conventional Portland cement concretes also holds good for alkali-activated concretes.

NP Rajamane (Rajamane, N.P., 2011) in his experimental investigation evaluated the chloride permeability using RCPT method of testing by comparing the GPC and PPC concrete. The test results indicated that GPC rated 'Low' to very low rating and PPC were rated very low and concluded that both the mixes are very similar in respect of chloride penetration as indicated by their RCPT values as it can be considered as acceptable structural concrete for reinforced concrete constructions.

DV Reddy (Reddy, D.V., 2012) in his experimental investigation evaluated the durability characteristics of low calcium fly ash-based geopolymer Structural concrete subjected to corrosive marine environment. A series of GPC beams, containing fly ash with 8M and 14M concentrations of NaOH and SiO2/Na2O solutions, and centrally reinforced with 13 mm rebar, were tested for accelerated corrosion exposure, with wet and dry cycling in artificial seawater, and induced current.The durability was monitored by indication of sudden rise in the current intensity due to specimen cracking. The test results indicated excellent resistance of the geopolymer concrete to chloride attack, with longer time to corrosion cracking, compared to OPC. By analyzing and comparing the behavior and properties of both types of concrete (GPC and OPC), it was observed that GPC is more homogeneous and well-bonded to the aggregate (failure surfaces through the aggregate), compared to OPC. Consequently, corrosion-based better crack resistance and long-term durability are obtained with GPC.

Kunal Kupwade-Patil (2012;2012) in his experimental investigation studied the durability of steel reinforced concrete specimens made from three alkali-activated fly ash (FA) stockpiles and Ordinary Portland cement (OPC) in cyclic wet-dry chloride environment was evaluated over a period of 12 months. Testing methods included electrochemical methods, chloride diffusion and contents analysis, chemical and mechanical analyses, and visual examination.GPC (Geopolymer Concrete) specimens made from Class 'F' FA exhibited lower diffusion coefficients, chloride contents, and porosity compared to their GPC Class 'C' FA and OPC counterparts. Overall, GPC specimens displayed limited signs of leaching and corrosion product formation, while OPC specimens exhibited the formation of multiple corrosion products along with significant leaching. Based on the results finally he concluded that GPC concrete might serve as an effective substitute for OPC in reinforced concrete structures located in marine environments or subjected to prolonged exposure to deicing salts or brackish water.

In another experimental investigation, he studied the alkali silica reaction (ASR) between reactive aggregates and the geopolymer matrix. Specimens were prepared using two Class F and one Class C fly ash stockpiles. Mechanical testing included potential reactivity of aggregate via length change and compression test measurement as per ASTM standards. Results suggest that the extent of ASR reaction due to the presence of reactive aggregates in fly ash-based geo polymer concretes is substantially lower than in the case of OPC based concrete, and well below the ASTM specified threshold. Furthermore, geo polymer concrete specimens appeared to undergo a densification process in the presence of alkali solution, resulting in reduced permeability and increased mechanical strength. Utilizing ASR-vulnerable aggregates in the production of geo polymer concrete products could contribute to the economic appeal and sustainability of geo polymer binders in regions that suffer from insufficient local supply of high quality aggregates.

J.Wongpa (2010) in his research work produced the Inorganic polymer concrete(IPC) with fly ash(FA) and rice husk-bark ash(RHBA) with different mixtures varying the Sio2/ Al2O3 ratios. He found that S/A ratio is the major parameter controlling the compressive strength, modulus of elasticity, water permeability of IPCs.Paste/ Agg ratio also affects the above properties of IPCs in the same direction of S/A ratio, however with low influence. Higher S/A ratios and higher Paste/ agg. Ratios result in lower compressive strength and higher water permeability.In addition he concluded that the compressive strength has an influence on the modulus of elasticity of IPCs. The square root of compressive strength linearly affects the elastic modulus of IPCs as same as that of Portland cement concrete but in the slope of that relation of IPCs is lower than that of conventional concrete by about three times.

Monita Olivia (2011**)** in his experimental work studied the strength development, water absorption, and water permeability of low calcium fly ash geopolymer concrete with variations in water/ binder ratio, aggregate/ binder ratio and alkaline/ fly ash ratio.The results indicated that strength of fly ash geopolymer concrete was increased by reducing the water/binder ratio and aggregate/ binder ratio and the water absorption of low calcium fly ash geopolymer was improved by decreasing the water/ binder ratio, increasing the fly ash content, and using a well graded concrete and he concluded that a good quality of low calcium fly ash geopolymer concrete can be produced with appropriate parameters and mix design.

Anurag Mishra (2008) in his experimental investigation studied the effect of concentration of NaOH fly ash geopolymer concrete and curing time (heat curing to 100 c).Results indicated that there was an increase in compressive strength with increase in NaOH concentration. Strength was also increased with increase in curing time, although the increase in compressive strength after 48hrs curing time was not much higher. The water absorption test indicated that percentage water absorption of cubes decreased with increase in NaOH and curing time.

### *Conclusion:*

The literature review about the durability of alkali-activated binders shows that New research work is needed on the use of sodic wastes to replace sodium silicate in order to reduce the cost of these materials.

The new binders present higher chemical resistance, however it seems that depends on the low content of soluble calcium compounds than it is from their low permeability.

In acid attack the strength and weight loss of the geopolymer concrete was very low in compare to the conventional concrete prepared using OPC and sodium silicate activator performs well compare to potassium hydroxide.

The evolution of products after geopolymerization is different from the conventional concrete as such it is less susceptible than the concrete in the sulphate attack.

Contrary to standard OPC binders alkali-activated binders show a high stability to high temperatures which depends on the silicon/ aluminium ratio. The experimental investigation shows that the behaviour of alkali-activated binders show that these materials are specially recommended for works with a fire risk in tall buildings and tunnelling works.

## REFERENCES

Ali, M., R. Saidur, M. Hossain, 2011. A review on emission analysis in cement industries. Renewable sus. Energy rev., pp: 2252-61.

Anurag Mishra, 2008. Effect of Concentration of Alkaline liquid and curing time on strength and water absorption of Geopolymer Concrete, ARPN Journal of Engineering and Applied Sciences, pp: 14-18.

Bakharev, T., 2004. Durability of geopolymer materials in sodium and magnesium sulfate solutions, Cement and Concrete Research, pp: 1233-46.

Bakharev, T., 2004. Resistance of geopolymer materials to acid attack, Cement and Concrete Research, pp: 658-70.

Bakharev, T., 2005. Geopolymeric materials prepared using class F fly ash and elevated temperature curing, Cement and concrete research, pp: 1224-32.

Balaguru, P., S. Kurtz, 1997. Geopolymer for repair and rehabilitation of reinforced concrete beams, Geopolymer institute report.

Chaicharn Chotetanorm, Prinya Chindaprasirt, 2012. High Calcium bottom ash geopolymer:Sorptivity, pore size and resistance to sodium sulphate attack, Journal of Materials in Civil Engineering, pp: 1943.

Damtoft, J., J. Lukasik, D. Herfort, D. Sorrentino, 2008. Sustainable development and climate change initiatives, Cement Concrete research, pp: 115-127.

Daniel, L.Y., G. SAnjayan, 2010. Effect of elevated temperatures on geopolymer paste, mortar and concrete, Cement and concrete Research, pp: 334-39.

Davidovitis, J., D.C. Comrie, J.H. Peterson, 1990. Geopolymeric concretes for environmental protection. ACI concrete international, pp: 30-40.

Duxon, P., J. Provis, G. Lucky, J. Van Deventer, 2007. The role of inorganic polymer technology in the development of Green Concrete. Cement Concrete Research, pp: 1590-7.

Gartner, E., 2004. industrially interesting approaches to low cements, Cement Concrete research, pp: 1489-98.

Habert, G., 2011. An environmental evaluation of geopolymer based concrete production: reviewing current research trends, Journal of cleaner production, pp: 1229-38.

Juenger, M., Winnerfeld, J. Provis, 2011. Advances in alternative cementitious binders, cement concrete research, P1232-43.

Kannapiran, Sujantha, Nagan, 2011. Durability study on alumina-silicate concrete , synthesized using anthracite coal fly ash, Journal of Structural Engineering, pp: 94-100.

Kannapiran, Sujatha, Nagan, 2012. Resistance of reinforced geopolymer concrete beams to acid and chloride migration, Asian journal of civil engineering, pp: 225-38.

Kunal Kupwade-Patil, 2012. Examination of Chloride Induced Corrosion in Reinforced Geopolymer Concretes, Journal of Materials in Civil Engineering.

Kunal Kupwade-Patil, 2012. Impact of Alkali Silica Reaction on Fly ash Geopolymer Concrete, Journal of materials in Civil Engineering.

Li, C., H. Sun, L. Li, 2010. A review: the comparison between alkali-activated slag and metakaolin cements. Cement Concrete research, pp: 1341-9.

Lucky, G.C., 2007. Van Deventer, Physical evolution of Na-geopolymer derived from metakaolin up to 1000 c, Journal of materials science, pp: 3044-54.

Monita Olivia, 2011. Strength and water penetrability of fly ash Geopolymer Concrete, ARPN Journal of Engineering and applied sciences, pp: 70-77.

Pacheco-Torgal, F., J. Gomes, 2008. Jalali said. A review part II, About materials and binders manufacture. Construction build master, pp: 1315-22.

Pacheco-Torgal, F., J. Gomes, 2008. Jalali said. Alkali-activated binders, A review part I, Terminology reaction, mechanisms and hydration products, Construction building materials, pp: 13050-14.

Pacheco-Torgal, F., Z. Abdollahnejad, 2011. Durability of alkali-activated binders: A clear advantage over Portland cement or an unproven Issue., Construction and building materials, pp: 400-05.

Rajamane, N.P., 2011. Rapid Chloride permeability test on geopolymer and Portland cement concretes, The Indian Concrete Journal, pp: 21-25.

Rajamane, N.P., M.C. Nataraja, 2012. sulfate resistance and eco-friendliness of geopolymer concretes, Indian Concrete Journal, pp: 13-22.

Rangan, B.V., 2005. Fly ash-Based Geopolymer Concrete, A Research Report.

Reddy, D.V., 2012. Durability of fly ash-based geopolymer structural concrete in the marine environment, Journal of materials in Civil Engineering.

Song, X.J., 2005. Durability of fly ash based Geopolymer concrete against sulphuric acid attack, International conference on durability of building materials and components.

Suresh Thokchom, Partha Ghosh and Somnath Ghosh, 2009. Resistance of fly ash based geopolymer mortars in sulfuric acid, ARPN Journal of engineering and Applied sciences, pp: 65-70.

Susan, A., Bernal, 2012. Engineering and durability properties of concretes based on alkali-activated granulated blast furnace slag/ metakaolin blends, Construction and Building Materials, pp: 99-108.

Taylor, M., D. Gielen, 2006. Energy efficiency and Carbon dioxide emissions from the global cement industry. Int. Energy agency.

Temuujin, J., A. Minjigmaa, 2012. Resistance of lignite bottom ash geopolymer mortar to sulfate and sulfuric acid attack, Cement and Concrete Composites, pp: 700-08.

Vanchai data, Prinya Chindaprasirt, 2012. Resistance of lignite bottom ash geopolymer mortar to support the ad sulfuric acid attack, Cement and Concrete Composites, pp: 700-08.

Wongpa, J., 2010. Compressive Strength, modulus of elasticity, and water permeability of inorganic polymer concrete, Materials and Design, pp: 4748-54.

Zhu Pan and Sanjayan G, Stress, 2010. Strain behavior and abrupt loss of stiffness of geopolymer at elevated temperatures, Cement and Concrete composites, p: 1-7.