

Making Geopolymer with the Help of Blended Mixture and Heat Curing: A Review

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ABSTRACT

However, the result is reversed in absence of water glass. Other authors ^[12] noticed that prolonged exposure of alkali-activated slag in higher curing temperature gradually lowers the strength with time though initially it tends to the strength-gaining. Again it has been observed that the solubility of slag is increased with curing temperature ^[46]. But, other authors consider that the drop in strength is resulted from the development of new hydrated product which creates barrier around the slag grains and makes obstacle towards further hydration ^[117]. According to some studies ^[118], the generation of unreacted material is emphasized with raised curing temperature. Some researchers ^[84] observed the successive drop in compressive strength with prolonged heat curing. Sanjayan et. al. ^[23, 24] investigated on slag activated with water glass (powder) under heat curing. Some authors ^[102] also spotted to the requirement of the separation of the toughened samples in a manner to resist evaporation of water. Higher strength in compare to non-isolated water and air curing was observed for the same with isolation. Criado ^[2]

REVIEW OF EXISTING LITERATURE

Past literature were reviewed with the aim to collect specific information on the research area to identify the drawbacks indicated in the earlier chapters and also to develop a pathway to resolve drawbacks to have a high performance fly ash based geopolymer. Testing methods are also reviewed to understand their shortcomings and to develop a better one to appreciate the performance of the product in a more scientific way. Literature in this regard is very limited. Literature on the experience of using supplementary materials were collected. Most of the available literatures on geopolymer with supplements dealt with mostly strength. But literature on the synthesizing parameters like optimization of curing temperature, curing duration, alkali concentration,

possibility of water curing etc. is limited. Comparative analysis in view of pore morphology, microstructure and durability study on blended geopolymer is very limited. Review aimed at to stretch the research from single phase composites to multiphase primarily, by blending supplementary materials with fly ash to develop new geopolymer and its parametric trend. Lot of works have been done on geopolymer from MK-Fly ash-based geopolymers and MK-rock-forming minerals ^{[4], [5], [53], [129], [137]}. It is well known that strength and durability of geopolymeric binders is better compared to conventional cement binders in general ^{[71], [125]}. The polymeric reaction product and their proportion should be monitored to satisfy some important properties e.g. durability, porosity, strength and stability which are expected from a high performance binder. A concept of blended geopolymer for the betterment in connection with improved structural performance may be drawn in a manner to compensate the major drawbacks of fly ash based geopolymer. In this chapter a review on previous studies mainly related to blended geopolymer and their properties have been done. Again, considering the structural stability as the prime concern, the review has been also focused towards the study related to the basic chemistry of activators, reactivity of precursors with the variation of base materials, methodology concerning curing types and profile, phase generation or transformation or deterioration of activated product with time in ambient and aggressive exposure. The entire review is divided into four sections (i) Instability of Geopolymer with Aging (ii) Reactivity of precursors with variation of Base material and Alkali (iii) Parametric

Instability of Geopolymer with Aging

Carsten Kuenzel. et.al. (2012) ^[146] focused on the instability of geopolymer over time. Drying shrinkage is observed at normal environment with low moisture for geopolymer pastes prepared from metakaolin. This research tried to correlate the impact of mixing composition like water content, silica alumina ratio,

sodium to aluminium ratio, sodium ions and potassium ions on drying shrinkage at normal temperature. The study suggested the reduction of gel contraction and successive drying shrinkage with the possible reduction in structural water content. The study reveals the consequence of the whole quantity of cations, density of ionic charge, the relative measures and permanencies of cation, presence of aluminate combines in the mixing on shrinkage with aging. It is quite enough to understand that the existence of excessive water in the polymeric product which ascends by means of improper control on mixing parameters, choice of alkali and lack of chemical understanding, may bring the instability of geopolymer with time.

REACTIVITY OF PRECURSORS WITH VARIATION OF BASE MATERIAL AND ALKALI

Van Jaarsveld. et.al. (2002) ^[131] examined that the fundamental research on geopolymerization process is under demand, due to extreme exposure of the marketable application. In fact, differential reactivity of base material affects the final characteristics of the material indeed. Apropos the same it matters a lot on the typical level of synthesis. These pragmatic deviations in measureable characteristics take place owing to the inadequate suspension of those waste solids. Several parameter including water to solid ratio, percentage ash of kaolinite, category of silicate involved, keep considerable influence on the ultimate characteristics of the product. The specific work exhibits that two important elements basically control the performance of the developed geopolymer. One is the thermal account of the base material and the second one is the curing profile. Again the investigation suggests to consider these major elements before scheming this product for particular tender. Also an inter-relationship exists amid the numerous parameters which influence developed structure and characteristics of geopolymers. The clay content lies a great impact on the hardened characteristics. The clay gets abided into the formation but some portion of the clay may not react in the same manner which creates inconvenience like water retaining nature. Heatcuring at higher magnitude and intensity may bring in humid environment exhibits cracking. Whereas, the same under moderate intensity of heat curing appears with better compound. Present research has revealed that cautious attention on the mixing procedure, heat curing

profile, environmental moisture content is required for manufacturing geopolymer composite to meet categorical needs.

J G S Jaarsveld. et.al. (2003) ^[78] proposed in this research work that not every waste material is dissolved

in alkali solution. Because of that the author mentioned that original structure of some waste particles remain intact and contribute to either quicken or toughen those developed frameworks. In this research, distinctive parameters like dissolution behavior, reactivity, mechanical performances through XRD and FTIR techniques. Author recognized the degree of crystallinity of the geopolymer is the prime influencing parameter for strength perspective. Again, the presence of calcium in fly ash and its role towards strength development has been found out. The extent of particle, calcium contamination, metals in alkaline medium and base material category directly influence initial synthesis and the final product.

M N Qureshi. et.al. (2013) ^[94] first time introduced blast furnace slag as a base material activated by the term flow diameter in a manner to evaluate workability and setting times were maintained. The typical parameters like liquid to solid ratio, alkaline medium, amount of silicate solvent, basematerial to activating solution, and silicate solvent to metal hydroxide. Again, the typical characteristic like consistency, setting behaviour were broadly investigated. Research outcome shows, consistency and setting behaviour of activated GGBS depend mainly on the feature of the activating solvent indeed. In this research, the verification of the potentiality of blast furnace slag as source material was exercised.

H Djwanto. et.al. (2006) ^[49] reported several vital research not only on the progress, behaviour, production, but also on the uses of Low-C Fly Ash Geopolymer. Above all, the cement is deliberated to be the most significant part in the conventional concrete. Understanding the issue of greenhouse gases and its negative impacts like its high energy and natural resources consumption, a new alternative infrastructure development constituent was targeted. Author again concentrated on the generation of vast quantity of fly ash which may be beneficially used in this purpose throughout the world; very few fly ashes are efficiently recycled indeed. Basically this fly ash can be assumed as the prime constituent of the new vista.

Xiaolu Guo. et.al. (2010) ^[136] organized geopolymers from fly ash (CFA) comprising calcium more than 25% in presence sodium hydroxide and sodium silicate solution as activator. Maximum compressive strength was obtained for molar ratio of 1.5 and Na₂O 10 wt. % of CFA. . Those samples a regime of 23⁰C for 28 days. At 1036 and 1400 cm⁻¹ the main peak was attributed associated with asymmetric stretching of Al–O/Si–O bonds in FTIR spectroscopy. bending band was observed

at The polymeric structure was associated with (C–S–H) gel mutually (predicted from SEM and EDAX) due to the existence of higher calcium.

Xu H. et.al. (2000) ^[137] anticipated that the chemical composition of geopolymer is almost same like zeolites. But these particles possess a complete amorphous characteristic. As per author mutual polymerization of the species of alumina and silicate was formed by this process. This product was actually originated by dissolving source material comprising of silicon and aluminium high value of pH. It only occurred with the presence of alkali silicate solvent. The research includes the investigation on geopolymerization from fifteen natural Al-Si minerals in a way to govern the consequence of mineral characteristics on the strength of developed geopolymer. Again the research output defines maximum dissolution of alkali solution for framework silicates in compare to chain, sheet and ring structures. The author suggests KOH instead of NaOH in maximum cases out of the fifteen minerals. The research appropriately correlates the ion pair mechanism with the mineral dissolution as well as the geopolymerization. The research on the other hand, exhibited the several source of materials which can be potentially used in the purpose of geo-synthesis.

Catherine A. Rees. et.al. (2008) ^[20] mainly focused on the growth of the seeding of geopolymer mixture with higher superficial extent of alumina particles. Conspicuous variation in kinetics of reaction along with the developed structure was observed. At the early stages, the development of face isolated gels due to the seed surface nucleation was happen. These phenomena exclude the initiation time before the establishment of polymeric gel, generally spotted through the activation of hydroxide. Despite the development of few sections with very higher silica gel inside the arrangement, the characteristics of leading polymeric gel part remain almost unaltered. Lengthy heat exposure exhibits the development of zeolite part generated from both of the seeded and unseeded medium.

Hua Xu. et.al. (2003) ^[51] studied on the consequence of metallic cations organized in alkali- feldspars on the development of water phase in geopolymers through typical experiments like Si MAS NMR EDAX, SEM practices. Again the author introduces tests like ICP, PAS-FT-IR etc. in the same connection. The suspension of alkali-feldspars was originated to be repressed in a concentrated alkaline solution. As per DSC results it was investigated that the presence of potassium in the water phase, may be resulted from potassium hydroxide solvent or sometime from dissolved K-

feldspar. The Si-MAS-NMR analysis was done to find out polymerizing movement among silicate and aluminosilicate species driven in the occurrence of potassium certainly. Author investigated through microstructure study like SEM and EDAX. The study confirmed highest synthesizing and strengthening of polymer from the alkali-feldspar-kaolinit (AFK) grounds with sodium to potassium choices for the value of 3.5 up to 85.6. The research correspondingly expressed that greater dissolving affinity with the engrossment of potassium may give rise to the strength of the product amalgamated as of activation of the AFK matrices.

B A Latella. et.al. (2008) ^[10] responsible the total porosity as a limiting parameter to control the structure in connection with physical and microstructural properties. In this research four typical types of geopolymer having equal composition (like ratio of sodium and aluminium, ratio of silicon and aluminium as 1 and 2 respectively) were monitored in respect to mechanical performance considering typical combination of precursor. The combinations were like sodium aluminate, colloidal solvent of SiO₂, Ludox; sodium hydroxide, fumed silica, MK; Ludox, sodium hydroxide, metakaolin; commercial sodium silicate, metakaolin. The same trend was followed for fracture toughness and modulus of elasticity. The author differentiated the change in mechanical properties like toughness and modulus of elasticity for paste and mortar sample.

J L Provis. et.al. (2005) ^[76] found a major constituent of the geopolymer binder phase is consisted of nanometer-sized crystalline structures. This structure was closed to The remaining aluminosilicate material accumulated these nano-crystallites abide with the amorphous. Existence of the unreacted particles were observed within the developed s. By the degree of crystalline ordering, the physicochemical properties of the developed geopolymer was significantly influenced. These was subjected to the primary . The research found that using of more alkali silicate emphasize the crystalline structure more in the polymer product in compare to that, activated with alkali

hydroxide only. In fact, the rapid nucleation of species in presence of soluble silicates was the basic cause behind. In the evaluation of geopolymerization, calorimetric data were possibly of great significance. But some contradictory outcomes were also found there in this work. Again the conflict was suitable resolved by collaborating data in connection with mechanical analysis, phase identification of the matrix. Author pointed out the proper identification was possibly the best

way to correlate the chemical composition of the source material and the reacted product. To conclude that higher knowledge of chemistry might be applied again for the better understanding of geopolymer, to elevate the performance of the product.

workability of mixes was improved by the incorporation of water but its affect the porosity a lot.

J Temuujin. et.al. (2009) [68] introduced the power driven or mechanical activation of ash and its impact on the features of the geopolymers developed at ambient heat exposure. Essentially this process influenced by grain size and morphological stand point. The author indicates towards the fact that the harden property of polymeric compound were reduced along with the introduction of free water in the reaction mix. For raw and routinely activated samples, strength under room temperature curing was found 16 (2) MPa and 45 (8) MPa, respectively. This procedure was performed in a typical methodology where milling agent to powder ratio was controlled as 10:1. This activation was proved efficient to improve the size and shape of the grains in connection with better reactive potentiality without allowing major alteration in mineral arrangement. Around 80% increment was observed for the fly ash activated by this technology rather than ordinary one. The key role to increase the strength of polymeric product was endorsed through this methodology by minimizing the grain size and modifying the morphological extent. There by this methodology directly emphasize the higher rate of suspension or reactivity by tuning the size of grains or particles through mechanical process of activation.

PARAMETRIC STUDY ON THE PERFORMANCE OF NON-BLENDED GEOPOLYMER

Khale D. et.al. (2007) [33] addressed geopolymerization as a broad scope of research for utilizing solid waste products. Khale D. et.al briefly elaborated various factors which influence the mechanism of geopolymerization and development of geopolymer. The impact of various parameters like starting materials, alkali activators, super-plasticizers, , Silicate- Aluminium ratio, liquid-solid ratio have been briefly described. Again the author has focused on few important terms in connection with geopolymerization like calcination, relative humidity. Immobilization of toxic metal by geopolymer along with micro-structural characterization are worked out in this research. The author depicted geopolymerization as embryonic tool for the operation of several waste disposal.

Pre De Silva. et.al. (2008) [104] explored on the progress of typical phases and its growth at micro level in set of

geopolymers. He also enquired into several parameters such as silicon oxide, aluminate, sodium oxide and water at alkali response of metakaolin. Here, the author investigated on the possessions and impacts of cure duration on strength and others physical properties. The distinguishing molar ratios of the typical mix of geopolymers were governed

as silicon-aluminium ratio and aluminium-sodium ratio separately. The makings were tested from time to time by XRD, SEM practices. With the prolonged curing exposure (40⁰C for 28 weeks), amorphous Na–Al–Si parts (generated at initial age), was converted to semi-crystalline parts. The primary silicon oxide, aluminate, sodium oxide substances in mixes were seemed as the important criteria of prevailing the phase transformation. It was also noticed in few mixtures that well-amplified zeolite parts include chabazite, faujasite, zeoliteA & P. Compressive strength development undertook several deviations resulting of corresponding phase changes with elongated curing. Essentially, after prolonged curing, crystalline phases which were developed by mixture development provide low strengths.

P Rovnanik (2010) [109] observed the metakaolin-based geopolymer properties which are not directly resulted by the use of primary source material metakaolin and its constituent. It is also subjected to specific surface area, configuration and comparative extent of activator. It is also hinged upon the primary level of circumstances. The author also explained the upshot of the curing intensity and duration (varied from 10 to 80⁰C) on the typical physical performance and its correlation in micro level. It is resulted though the handling mix at raised heat curing which speeds up the strengths improvement. It was examined that mechanical performance were declined after 28 days of heat exposure. Whereas, mixes which was preserved at moderate or room temperature performed well enough. Impact of raising in curing temperature on geopolymer was tested in micro structurally including MIP. An inclination towards higher value of pore size and volume was observed parallel to the increment of curing intensity, which was again confirmed through mechanical enactment.

N V Chanh (2008) [21] observed that geopolymer is an aluminosilicate amorphous solid which may be amalgamated from the poly-condensation response of geopolymeric predecessor and polysilicates induced from silicate solution. The resources, mix complex, micro level induction and factors influencing characteristics of geopolymer were represented. Investigation on the applicability of fly ash as the primary home of silicon and aluminium was considered. Best result was obtained

at a curing temperature range of 60°C to 90°C. The strength value at this level was found appreciable. Also, higher strength of the product was emphasized through the longer curing duration one to four days. Nonetheless, the rise in strength after 2 days was not noteworthy indeed. Through the rise of additional water in the combination, slump value of the fresh geopolymer was observed to be increased. The strength value of heat-cured geopolymer is not highly dependent on age (study on strength

was confined for a short period). Even composite exhibits good resistance in acidic and saline exposure.

R N Thakur. et.al. (2009) [106] experimented on the growth of macro and microstructure of geopolymer with or without introducing sand. It was organized by thermal activation of fly ash in alkaline medium. Author again studied on the chief amalgamation factors like (Na₂O/Al₂O₃), (SiO₂/Al₂O₃), water to ash ratio, percentage of sand, heat curing profile and its impact on the change of the typical characteristics at micro and macro level. The compressive strength was optimized at a curing regime of 85°C for 2 days. Establishment of a novel amorphous aluminosilicate part, which affects the improvement of the strength was found out through typical micro level analysis like (SEM), (XRD). The study results that alkali metal, silicon and water level of mixture has a noteworthy impact on the hardened properties. Author found that water in mixture plays a significant role throughout several stages like suspension, poly-condensation and toughening of geopolymerisation. Again, research depicts the strength under compression is improved along the reduction of the presence of external water in the mix. The research was inclined towards the optimization of strength considering heat curing profile including the temperature regime and time extent. As per the researcher, hotness crosses stimulation blockade and enriches the rate of dissolving of the source material. Raising strength was visualized with the application of heat influx in the system. Here amorphous phase with partly water phases was observed under high resolution microscopy. The existence like aluminosilicate part (s) like hydroxysodalite, herschelite etc. was confirmed through mineralogical studying equipment, such as X-ray diffractometer. The investigation ensures 1:1 ash to sand ratio is best for having good strength indeed. In certain industrial applications, the geopolymer binders are considered as future eco-friendly alternative to Portland cement.

T Bakharev. et.al. (2005) [123] examined on the durability of geopolymer materials when exposed to 5% solutions of sulfuric and acetic acids. In this

investigation, a class F fly ash (FA) and alkaline activators were used. The change in weight, compressive strength and microstructural changes were considered as the key parameters in this study. When exposed to acid solutions, the durability of geopolymer components was higher to OPC (Ordinary Portland cement) paste. In selected), conspicuous dilapidation of strength was detected. This study revealed that the degradation was associated with

curing displayed finest presentation. It exhibited sustainable cross-linked aluminosilicate polymer structure formed.

X J Song. et.al. (2005) [119] anticipated that the earlier issue was unresolved unless a long- standing study under sulfuric acid corrosion is observed based, the investigational data was based on specimens exposed to 10% sulfuric acid solutions up to eight weeks. The author stated that) based geopolymer concrete was cured for 24 hours under alternate temperature (23°C and 70°C) at the initial stage. 28 days' compressive strength of 50-mm cubes lied from 53MPa to 62MPa that was also being pointed out in this study. Samples were examined at 7, 28, and 56 days with the exposure in a 10% sulfuric acid carrying considering a relation between acid volume to specimen surface area of 8 ml/cm². Confirming ASTM C267 tests, the weight loss, residual compressive strength, and the residual alkalinity were controlled here. The test confirms minimum weight loss (less than 3wt. %), for geopolymer concrete under sulfuric acid. Geopolymer cubes were intact enough to take considerable load further. In compare to PC concretes, AAFG binders exhibited much lower mass change. Moreover, in such low pH environments, steel reinforcement cannot be used properly. Therefore, either alternate reinforcement needs to be used or the permeability of geopolymer materials has to be considerably amended. To conclude, author recommended essentially the high purity siliceous aggregates in this investigation.

S Thokchom. et.al. (2009) [115] correlated durability with apparent porosity and sorptivity for mortar specimens. By activating a Class F fly ash with a mixture of NaOH and Na₂SiO₃, geopolymer mortar specimens were manufactured. This mixture of NaOH and Na₂SiO₃ was consisted of Na₂O immersion of geopolymer mortar specimens, Nitric acid solution was used and the evaluation was performed to predict durability. This was executed Higher apparent porosity and water sorptivity were found for specimens containing lesser Na₂O. In Nitric acid solution, even after 24 weeks, substantial

compressive strength was retained by the performance of geopolymer mortars in Nitric acid is influenced by porosity and sorptivity of geopolymer mortar specimens.

PARAMETRIC STUDY ON THE PERFORMANCE OF BLENDED GEOPOLYMER

Geopolymer Blended with Supplementary Calcium compound

J Temuujin. et.al. (2009) [67] minutely observed the impact of calcium supplements on the characteristics of geopolymer prepared from ash. In this present research, Calcium supplements was replaced to ash from 1 to 3 wt. (%). Again, the research was focused to the development of polymer structure at heat & ambient curing (20°C to 70°C). This research briefly indicates that calcium supplements is highly beneficial towards the enhancement of typical characteristics at green and harden condition. For Calcium Oxide and Calcium Hydroxide as supplements in weight 3% within the mix of fly ash geopolymer inaugurate better strength characteristics. The author indicates calcium hydroxide as a beneficial additive than calcium oxide. In this experimental program it was resulted that addition of Calcium compound developed secondary input as generation of CSH and others hydrates associated with Alumina, Silicon and Calcium. In the same way, increment of suspension of ashes comprising silica in activator along with higher poly-condensation reactivity was observed. Again the author suggested that the sudden drop or degradation of the characteristics of polymer exposed in raising temperature might be due to the inadequate formation of 3D network. The efflorescence made on the geopolymer synthesized from collie ash was confirmed as hydrate comprising Na and P, as decided from mineral analysis.

C K Yip. et.al. (2005) [18] introduced to evaluate the consequence of GGBFS on the characteristic of polymer composites prepared from metakaolin at micro and macro standard. The author also found The author confirmed that this phenomenon is dependent on the feature of alkali and base to supplements ratio by weight. Again, the research conveys that the appearance of hydrate and polymeric gel mutually is mainly possible under lower alkaline medium. Mutual existence of dual phases was absent unless considerable calcium supplements is available at the primary level. The author suggests, CSH may fill the internal hollow spaces of the porous polymeric file. The particular process interconnect the deviation amongst elements which in fact results in improved strength phenomena. It was also found that moderate amount of calcium dissolvable

calcium from GGBFS participates in the development of CSH at low alkalinity. The author again mentioned that the precipitation of

Calcium Hydroxide is enhanced in presence of excessive metal hydroxide in the mixing system. The author concludes that the mutual development of CSH and polymeric binder brings the structural homogeneity with compact bonding and a strengthen feature.

H M Khater. et.al. (2012) [50] examined the impact In this program a product of alkaline activation of aluminosilicate wastes collected process. This wastes were considered as coarse aggregates. and demolished walls comprising cement binder. The aggregates were passed through sieve size of 90 micron. The aggregate was prepared by mixing demolished walls and concrete waste as 6:4 (weight percent). Lime content was incorporated 0wt. % –25wt. %. Two distinct curing procedure like ambient temperature curing at (23°C) in tap water and under a mild temperature were accomplished. On each specimen mix, drying treatment at 80°C for 24 hours was performed. This act was executed to refine the mechanical properties of dried and wet samples. were rectified by the addition of the calcium compound through rise of hydrated lime up to 10wt. % which were subjected to water curing. In contrary, at 40°C. In the presence of calcium hydroxide, aluminosilicate wastes produce more aluminosilicate geopolymer using as 3:3wt. %. accelerated both mechanical and microstructural properties, respectively. Finally, the author concluded that alkaline activation of aluminosilicate wastes served as an aid to generate valuable constituents. In the building industry, these materials may be applied for further investigation.

K Wang. et.al. (2004) [82] made and investigation on fly ash binder from cement kiln dust and several parameters controlling its characteristics. The research exhibited good performance of fly ash binder with cement kiln dust as supplements by 50 wt. %. The concentration of alkali hydroxide was maintained as 2 wt. % to 5 wt. %. The curing temperature was controlled as 24, 38 and 50°C. The gravimetric analysis er in this research. The XRD defined ettringite as a long term (observed for 100 days) stable system which was the prime product of CKD-FA binders with hydration. Curing temperature has favourable effect on strength development rather than hydroxide.

A Palomo. et.al. (2004) [4] characterized the reaction products developed during alkaline activation by means of MASNMR. The research is mainly focused to find out the role of curing profile actually. The initial

development of tecto-silicates as an amorphous product diverted into two consecutive phases. The study deals with the Si/Al ratio of zeolite precursor attained at 85°C reaches at 1.86 from 0.95 with curing duration of 5 hrs. to 7 days. The mechanical, chemical, micro-structural properties of prepared products were discussed intensity and duration of temperature. Prolonged curing time with high temperature emphasize the formation of continuous alumino-silicate matrix that heightens mechanical behavior of the molded product.

S Alonso. et.al. (2001) ^[111] projected metakaolin as another reactive source of silica which is able to form cementitious product which better physical characteristics. The interesting findings is that the developed product in presence of calcium hydroxide is similar to that in absence of calcium hydroxide with high alkali medium. The product was identified as sodium alumino silicate. was also distinguished in this study. The research work again stated that salient, concentration of alkali, content of etc. controlled the rate of polymer formation. Although the temperature accelerates its formation, with the rise of the activator concentration, delayed polymer formation was found to be increased in activator concentration. Again the study shows that the ratio of metakaolin to Ca(OH)₂ made no impact on the rate of aluminosilicate formation.

C K Yip. et.al. (2003) ^[16] proved the existence of geopolymeric and CSH gel within a single product. Morphology and elemental composition of the two phases were checked by scanning electron microscopy. The SEM results showed the consistency of elemental composition. Still, CSH gel formulated in this system possessed a considerably lower Ca/Si ratio rather than that usually formed with the hydration of OPC. Few calcium precipitates were there of CSH and geopolymeric gels, respectively. Such recommendation was there that the properties such as size, elemental composition etc. of the calcium precipitates held on to the key which reformulate a new trend of concrete to improve durability. A brief view on the consequence of slag on the typical properties of alkali activated metakaolin was elaborated.

Z Li. et.al. (2007) ^[139] made a considerable inspection on the progression of the strength of FA-based geopolymer subjected to low level temperature of heat curing. Slag as supplement was incorporated up to 4 wt. % into fly ash-based geopolymer. Combination of 10 wt. % metakaolin and 90 wt. % fly ash showed improved compressive strength. Compressive strength of 53.1 MPa and 70.4 MPa were achieved when cured at 30 and 70°C respectively for 14 days. The author pointed out the

improvement in structural strength by introducing XRD, FTIR, XPS, and MIP. At curing temperature of 70°C, the rise in strength was about 15 MPa. The geopolymers showed diffuse hump under XRD at about 20–35° 2θ max, Cu K.

Variation of temperature (30°C and 70°C) did not have significant effect on compressive strength for geopolymer with 4wt. % of slag as supplements. The study revealed that incorporation of slag as supplements help to make the system more amorphous. Thus, a chances of the presence of new amorphous phase CSH is highlighted in this study. The test results showed that slag addition increases the compressive strength significantly. The change in MIP pattern suggests that higher curing temperature (70°C) emphasizes the development of finer pores. The abridged pores have significant contribution to the strength characteristics.

CAST-IN-SITU GEOPOLYMER

Hu Mingyu. et.al. (2009) ^[57] investigated on the synthesis of geopolymer at ambient temperature. For this purpose, author introduced fly ash and bentonite as base material and supplementary material. A combination of NaOH and CaO was used. Reactivity of metakaolin was found better in compare to fly ash. This low reactivity is basically responsible for the poor rate of reaction at ambient temperature at the time of geopolymerization. In this research methodology the supplementary material was introduced in a way to have better rate of geopolymerization which enhance the properties of fly ash based geopolymer as well. This research explored the differential nature between fly ash and geopolymer made by the same. The comparison was carried out through X-ray spectra. The spectra were almost similar for every case except the pics of CaCO₃. From the result the author indicated that geopolymerization reaction did not allow the formation of new crystalline phases indeed. Secondary electron image proves the existence of zeolite in the matrix. Again, some unreacted fly ash particles were visualised even after sixty days of curing in ambient temperature. Some networked outcome was also observed microscopically at the top surface of fly ash particles which was arbitrarily dispersed. Due to the presence of these products over fly ash the structure exhibited lesser porosity. The author found bentonite as the prime cause behind this phenomenon. The durability exposure tests observed the better performance for the geopolymer comprising zeolites. Lower weight loss was observed after sixty days of emersion in magnesium sulfate. At the end of the research the author suggested that geopolymer comprising zeolite was much intact under aggressive environment and exhibited no fracture as confirmed by short term (two months) sulfate

exposure.

GEOPOLYMER BLENDED WITH SUPPLEMENTARY SILICA COMPOUND

Prud'homme. et.al. (2010) ^[36]. Dehydroxylated kaolinite and alkaline hydroxide pellets solution (dissolved in potassium silicate) were used to prepare the materials. After that, the constituents were transmitted to a polyethylene mold sealed with a top. Then the materials were employed to oven at 70°C for 24 hours. FTIR-ATR spectroscopy studied that a polycondensation reaction was used in the formation of the amorphous solid for all thermal measurement having a 0.22 W m⁻¹ K⁻¹ value.

Again, TGA-MS experiments confirmed that there was a synthesization of. For the applications in building materials, this substance had potentiality as an insulating material.

OBJECTIVES OF THE PRESENT RESEARCH

The objective of the present research is to develop blended geopolymer by eliminating the major drawbacks discussed in earlier chapters. There are three major aspects. Firstly, the investigation on the optimal parameters of activator prior mixing and its impact on non-blended fly ash. Secondly, the effect of supplementary material on the properties of geopolymer at green and hardened state. Thirdly, to develop water cured blended geopolymer as a cast-in-situ product. Finally, the resolved aspects will be useful to align in a way to compensate the major drawbacks of Alkali activated fly ash based geopolymer. The study is aimed to develop a new stable blended geopolymer in connection with physical, mechanical, microstructural performance in ambient and aggressive environment.

The scope of studies comprised of (i) optimization of temperature level of activator solution prior mixing. (ii) incorporation of combination of oxides in activator solution (iii) supplementation of external calcium based material (lime stone dust, silica fumes and blast furnace slag) in fly ash geopolymer. (iv) parallel study on alkali activated fly ash blended with calcium subjected to water curing (v) Silica fume blending with flyash to compensatethe role of sodium silicate. (vi) new approach to assess workability and durability. For all the studies physical, mechanical, microstructural and mineralogical studies were made separately to appreciate the non-blended and blended geopolymer characteristics clearly. Considering the major aspects, the entire research can divided into three parts.

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