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A Review on Parametric Study on Properties in Geopolymer Concrete by Using Industrial By Products

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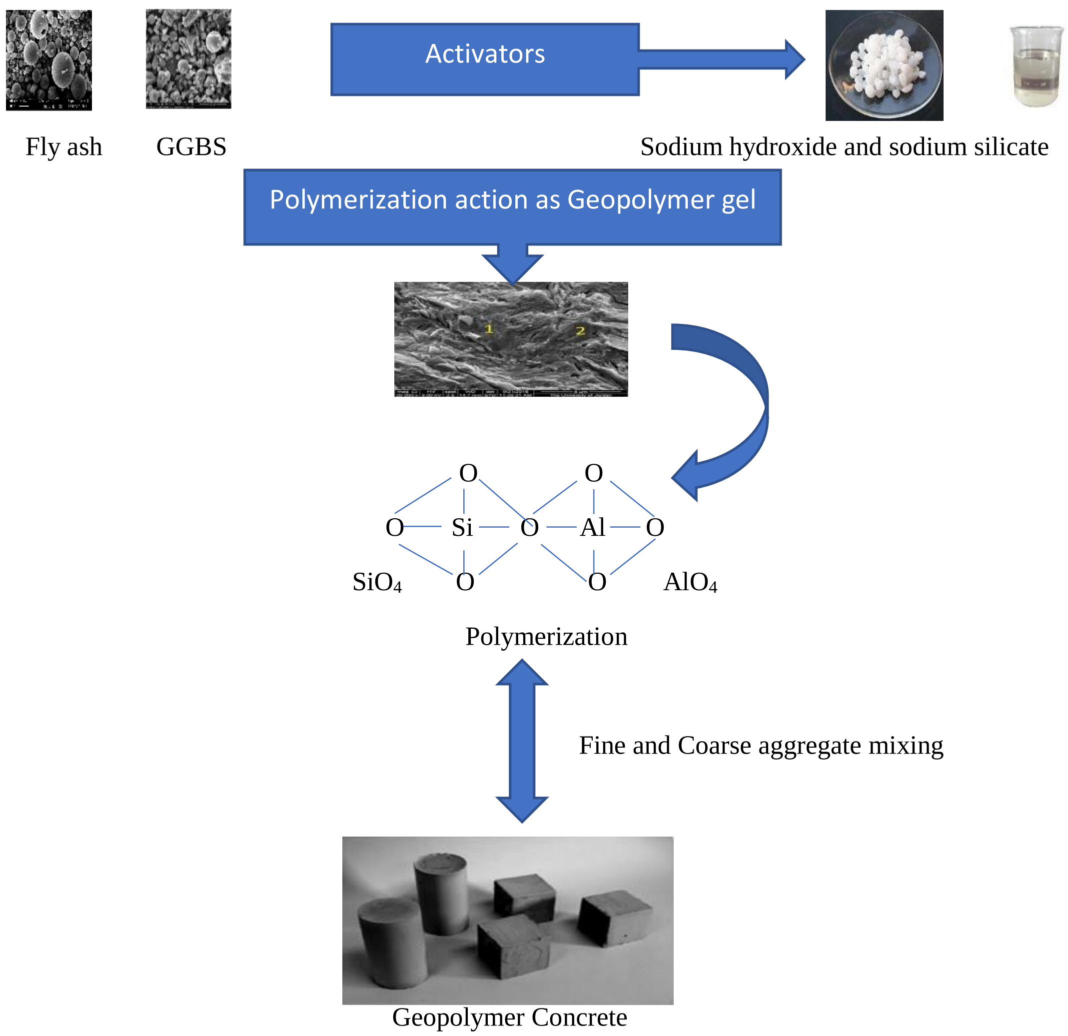
Representation of Graphical Abstract



Abstract

The term geopolymer is an amorphous structure invented by Davidovits in 1980. Geopolymer is a process of combining oligomers (small molecules) into a covalent bond structure. It forms an aluminium silicate structure where polymerization acts as a binding molecule and can achieve higher strength without the use of cement in concrete. Geopolymer concrete is widely used because of low CO2 emissions, which act as green concrete. This article criticizes the geopolymer concrete from various literature sources. Microstructural characterization, mechanical properties and durability in geopolymer concrete by the use of fresh and hardened by-products is studied from various sources. In this review, the molarity of activators in concrete is observed at different temperatures. Hence the future research, analyses the different curing conditions in geopolymer concrete that can make construction work easier in the field.

Keywords: Geopolymer, polymerization, microstructural characterization, mechanical properties, durability.

Introduction

Geopolymer concrete is an amorphous structure in which the binders are made from aluminium silicate sources. An alkaline liquid solution that is used to react with silicon (Si) and aluminium (Al) indicating that the source material is added to the concrete mixture using industrial products [83]. Thus, polymerization takes place in the chemical reaction of this concrete mixture by acting as a binding material. The source materials for aluminium-silicate should be increased in silicon (Si) and aluminium (Al). Replacement of industrial products in geopolymers should be unique in comparison with other aluminium silicate materials,(e.g. aluminosilicate gels, glasses, and zeolite) where the concentration of solids is higher than that of aluminosilicate gel or zeolite. Microstructural characterization is reviewed by scanning electron microscopy (SEM), X-ray diffraction (XRD), etc. The x-ray fluorescence (XRF) test application is reviewed to identify the oxide compositions. Industrial products such as fly ash, ground granulated blast furnace slag (GGBS), red mud, alccofine, metakaolin, etc. are chosen along a path that may resemble a higher strength where the polymerization acts and can achieve maximum durability in the concrete from the papers reviewed. The activators added to the concrete mixture may be sodium hydroxide and sodium silicate solution or potassium-based solutions. The molarity is to be noted from the sources for the increase in compressive strength. Naphthalene based superplasticizer is to be identified for ease of workability based on the review. [33].

Polymerization in geopolymer concrete

The polymerization reaction is explored as a non-crystalline structure which is a covalent bond and is similar to zeolite. As a result, the geopolymer concrete improves the mechanical properties of the application.

$$n\,(Si_2O_5,Al_2O_2) + 2nSiO_2 + 4nH_2O \longrightarrow n\,(OH)_3 - Si\text{-}O\text{-}\underset{\displaystyle (OH)_2}{\underset{|}{Al^{(-)}}}\text{-}O\text{-}Si\text{-}(OH)_3$$

(Geopolymer Precursor)

$$n\,(OH)_3 - Si\text{-}O\text{-}\underset{\displaystyle (OH)_2}{\underset{|}{Al^{(-)}}}\text{-}O\text{-}Si\text{-}(OH)_3 \longrightarrow (Na^+,K^+)\text{-}\,(\text{-}\underset{\displaystyle O}{\underset{|}{\overset{|}{Si}}}\text{-}O\text{-}\underset{\displaystyle O}{\underset{|}{\overset{|}{Al^{(-)}}}}\text{-}O\text{-}\underset{\displaystyle O}{\underset{|}{\overset{|}{Si}}}\text{-}O\text{-}) + 4nH_2O$$

(Geopolymer Backbone)

Fig. 1 .Geopolymerization binder reaction [83]

Microstructural characterization

The micro-characterization is examined by SEM (scanning electron microscopy) where the fine particle is measured and the voids are examined. Inorganic solid materials are scanned to produce a magnified image by emitting an electron beam into the sample. The XRD (x-ray diffraction) displays the chemical image in the sample. An X-ray fluorescence test (XRF) resembles the oxide composition of the sample in the geopolymer concrete. The binding material was tested by preparing samples of different proportions. The characterization of the specimen was studied by SEM, XRD and also by unconfined compressive force. The alkaline solution ratio was maintained at a rate of 1.75. As a result, the load deflection increased its strength in the geopolymer concrete [75].

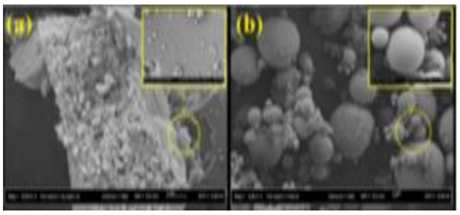
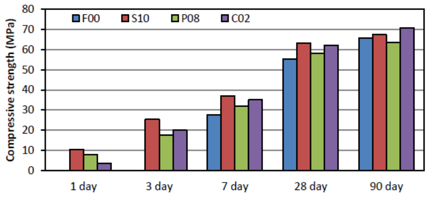


Fig. 2.Scanning electron micrograph of fly ash and ground granulated blast furnace slag [1]

Early age mechanical strength

The early age properties of fly ash based geopolymer concrete suitable for ambient curing were represented by the author, where the geopolymer concrete was cured at ambient temperatures of 23°C without any excess heat applied to the concrete specimen. Additives are added to the concrete mixture in a small quantity to study the high compressive strength and workability of a fly ash based geopolymer concrete with its binder content and the result was that the strength of the ambient curing temperature was increased by increasing the binder content by 10 % OPC for fly ash, thus increasing the compressive strength from 26 MPa to 58 MPa at 28 days of age. As a result, the author concluded that fly ash blended with slag, ordinary portland cement (OPC) can be used as an appropriate binder to obtain strength at ambient temperature. [5]. The effect of early strength and durability was described by the author by the addition of calcium aluminate to reduce the curing time. Various specimens were prepared for early strength and durability. Metakaolin was the industrial product used in this mixture of geopolymer concrete. The addition of calcium aluminate cement was found to be used as an accelerator for a mixture of up to 20%. This mix can be a good option for the pavement [21]. The properties of early age geopolymer concrete that can be cured in ambient curing have been analysed. Geopolymer concrete was prepared using fly ash, GGBS, OPC and calcium oxide in various proportions. As a result, the compressive strength was increased by a fly ash with 10% OPC at 28-day age strength. the author concluded that the binder content of small %ages of GGBS, OPC and calcium oxide when mixed separately with low calcium fly ash gave high strength at ambient curing [26].



Curing age (days)

Fig. 3. Compressive strength [5]

Bond and anchorage strength in geopolymer concrete

The bond strength was determined by the use of this class F fly ash geopolymer concrete for reinforced concrete, both deformed and smooth bars.85.2 % of fly ash and 14.2 % of GGBS were applied proportionately. The specimens were prepared and healed at 80°C as heat curing. After 48 hours, the bond strength was equal to that of conventional concrete. Thus, the conclusion shows that bond stress slip curves were similar to all other conventional concrete[24]. Carbon fibre reinforced polymer sheets (CFRP) were incorporated with a geopolymer based metakaolin. The specimens have been prepared in different proportions and have shown that geopolymer concrete based on metakaolin can be applied as an adhesive to CFRP, so that the concrete can be retrofitted.[44].

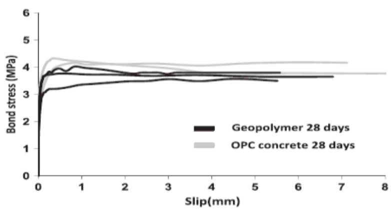


Fig. 4. Comparison of bond stress slip curves of geopolymer concrete and conventional concrete [24]

The strength of the anchorage bond with L- bend reinforcement beams based on geopolymer concrete was tested and also carried out analytically, the results were compared and analysed. Industrial products used in this geopolymer concrete are fly ash and GGBS oxide composites have been identified in the XRF(x-ray fluorescence) test. The activator of this mixture is sodium silicate and sodium hydroxide. The pull-out test was tested and analysed using the ANSYS software. As a result, the results show that the geopolymer L- bend bond has been more than 1.1 times higher than the plain bar in conventional concrete. Both in experimental and analytical, the result variation error was only 10%, so it is even suitable for small L- bend reinforced bar [76].

Mix design in geopolymer concrete

The design mix for geopolymer concrete was proposed by the author in the preparation of various specimens using fly ash and alccofine cured at different temperatures. The specimen was analysed using microstructures such as XRD and SEM. The design was proposed on the basis of the Indian standard (IS) code and concluded that the design was made using eco-friendly material and that design paper was intended for the required strength [19]. Fly ash and GGBS were used in geopolymer concrete, together with sand (M sand) and pond ash, to replace fine aggregates. Sodium hydroxide and sodium silicate are the activators of the mixture. The M 20 grade test mix was prepared and the mix design was examined in accordance with the IS code standards. The author followed the design of the Geopolymer Mix of Rangan. B.V. Thus, the GGBS material achieved a high strength of 20% of the fly ash material. [85].

Mechanical properties in utilization of industrial by products

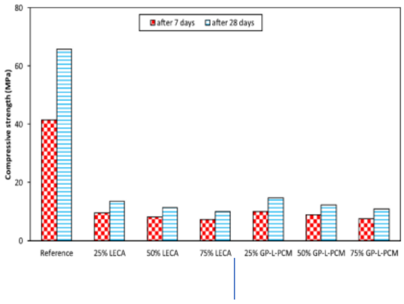
The author makes geopolymer concrete by using industrial products such as waste bottle glass, fly ash, GGBS, ceramic waste by knowing its density and specific gravity and experimenting with different molarities from 2 to 16 molarity (M) of alkaline solutions. It therefore concluded that the increase in molarity reduces the workability and compressive strength of 12 M sodium hydroxide as an alkaline solution, and also performed various microstructural characterizations in those proportions, confirming that the strong influence of sodium hydroxide solution gives high compressive strength. [1]. The author describes the parametric study of geopolymer concrete using class F fly ash as the main ingredient. Various ratios of alkaline solution to fly ash have been experimentally tested for its compressive strength at different curing times with its curing temperature, The naphthalene-based superplasticizer has also been used to reduce workability and has concluded that the compressive strength increases with increased molarity and only lowers the compressive strength when the superplasticizer is used. The compressor decreases with an increase in the water content ratio in the alkaline solution and increases the strength from 60^{o}C to 90^{o}C on the basis of the curing temperature. [2].

Residual materials such as argillaceous powder, calcareous powder, marble powder and fly ash with a mixture of epoxy resin and aggregate were used for the characterization of polymer concrete. Micro-characters were analysed by electron microscopy scanning. The experiment was conducted with a variety of prepared specimens to determine the compressive strength, tensile strength and flexural strength. The result was higher strength in calcareous powder. The additions of all other materials have increased the mechanical properties of geopolymer concrete. [13].

A low-calcium fly ash with nano-particles such as colloidal nano-silicate, multi-wall carbon nano-tube, titanium dioxide was used to analyse the effect of nano-particles on geopolymer concrete. Colloidal nano silica at 0.75 %, 3 %and 6 %were mixed with fly ash, while multiwall carbon nano tube at 0.02 %was prepared with Polycarboxylate ether at 2%. It was like a specimen. A further 1% titanium dioxide case has been added. The solution ratio was 0.25. Heat curing was maintained at 60^{o}C and therefore the compressive strength was obtained on average by the addition of titanium dioxide and the PH level was also the same for all cases in alkaline solutions. [14]. This paper described the use of a fly ash with glass fibre for a low carbon geopolymer building. The alkaline solution for the 0.43 ratio was adopted. Various proportions of the material are identified and tested. The glass fibre was added to the mixture from 0.1% to 0.5% of the weight of the concrete. The specimens were cured thermally at 90^{o}C. The conclusion of the author is that the compressive strength was achieved by 60 % at the curing age of 7 days. At room temperature, it was only possible to increase its compressive strength. The alkaline solution mix achieved a higher strength at 16 molarity solutions. The addition of 0.3 % of glass fibre gave the maximum strength when increased in concrete. There was a 16% increase in compressive strength compared to conventional concrete [16].

Software-based technology has been applied to geopolymer concrete using GGBS.117 mixtures have been produced and 351 specimens are made using GGBS-based geopolymer concrete. Parameters have been selected and given as inputs to be considered. Five main steps were taken to obtain the result of the GEP method. The fitness function was selected to obtain a fix value. Terminal select, the chromosomal architecture with the gene number was selected, the function was linked and the mixture was applied to pass through genetic operators. As a result, the data tested for GGBS based geopolymer concrete were collected and used in the database and, using empiric formulas, accurate results were obtained. [17]. In conventional concrete, a recycled aggregate of geopolymer concrete was used. The test for water absorption and bulk density was investigated. A higher loss was caused by Los Angeles abrasion testing in recycled geopolymer concrete aggregates than in conventional recycled aggregates. The result increased only by 12.9% when using recycled geopolymer aggregate and by 15.2% when using recycled geopolymer aggregate. [20].

Geopolymer concrete using industrial products such as fly ash, GGBS (Ground granulated blast furnace slag), HMNS (High magnesium nickel slag) have been analysed for its mechanical properties and micro-characteristics by applying different proportions of mixtures to geopolymer concrete. The micro-characters have been tested by SEM and XRD.Hence the author concludes that the mechanical properties were obtained at a mixing ratio of 70 % of fly ash, 20% of GGBS and 10% of HNMS and that the compressive strength was 55.6MPa and that the micrologic characterization at this ratio had crystalline phases[23].The properties in geopolymer concrete at both high and low strengths were investigated and evaluated, Compared to ordinary concrete by using materials such as Flyash, GGBS. The specimens were prepared and various tests were performed as a compressive strength test, tensile test, dry density, ultrasonic pulse velocity and workability test. The results show that the dry density and ultrasonic pulse were tested. The velocity was lower than OPC, but the SEM results were analysed, but there was a high compressive strength. The modulus of elasticity can be examined in the recommended equation[28]. The thermal and structural performance of geopolymer concrete was studied using a material coated with geopolymer expanded clay phase material added to the macrocapsules. The mixture of geopolymers and this mixture is compared to the lightweight expanded clay aggregate. The specimens were prepared to analyse the thermal and structural performance by conducting various tests, such as a thermal performance experiment, thereby recording the data and applying battery-powered heating. The conclusion was that The surface temperature of the slabs was reduced by 3.3°C by geopolymer concrete. The light weight of the expanded clay also reduced the compressive strength of the geopolymer concrete by 75%. [30].



Curing age (Days)

Fig. 5. Compressive strength of 7 day and 28-day age strength [30]

Red mud and fly ash, along with metakaolin, were the materials used as industrial products to find strength and microstructure in geopolymer concrete. The metakaolin was blended with red mud and fly ash. The microstructure was analysed by XRD and SEM and compared to experimental results. Therefore, the authors concluded that the higher concentration of alkaline solution used gives the higher strength [31]. Red mud and rice husk ash, both industrial products used as a composite geopolymer, are analysed with its microstructural characterisation and strength. The specimens were prepared in different proportions and concluded on the basis of the results that the high alkalinity solution of the mixture gives higher strength. [32].

GGBS and metakaolin-based geopolymer concrete have been used as the main material with 10 molar alkaline solutions for analysis of strength and micro-property. The micro-properties were analysed in FTIR, i.e. Fourier transform infrared spectroscopy, and the mixture was prepared in three different weight proportions for ambient curing. Thus, the conclusion of the author is that, as the %age of GGBS increases, the strength increases. The analysis of micro properties indicates the presence of bond characterization [34]. The characterization of geopolymer paste and concrete was analysed using a fly ash and GGBS material. Alkaline solutions have been used in various molarities. The specimens were prepared and healed in the ambient for up to 180 days. As a result, the higher alkaline concentration gave higher strength and thus the geopolymer concrete enhances the eco-friendly environment[35]. The recycled coarse crushed aggregate was combined with geopolymer concrete based on metakaolin and fly ash and is compared to the normal coarse aggregate. This is the Ingredients have been improved in strength, abrasion resistance, properties and acid resistance when mixed with the mixture. The recycled aggregate was well integrated with geopolymer concrete based on metakaolin to enhance its strength[38].

Metakaolin based geopolymer concrete was used for the analysis of its properties. Alkaline solution such as sodium silicate and sodium hydroxide ease used as an activator solution. The SEM test was carried out to determine the micro-property of the concrete. Various test specimens have been prepared and, as a result, the mixture has a high compressive strength when compared to conventional concrete. [40]. GGBS was incorporated with a fly ash based geopolymer concrete and its mechanical properties were predicted using an analytical equation for each and every proportion of the materials. For a 100%GGBS incorporated with no-Fly ash content, the predicted value is divided by the analytical formula method. (pt.) Is 0.0008(compressive strength(pc))-0.1494(pc)+9.1973(pc)-186.89. By the above analytical formula, the mechanical properties are obtained and compared to the experimental results. The conclusion is that as the content of the fly ash increases the compressive strength and the split tensile strength decreases. The gain rate is higher until the age of 7 days and then lowers and keeps constant. [41].

The author describes the short-term properties and also explains the creeping and shrinking properties of a fly ash based geopolymer concrete. The behaviour of property in the short term was similar to that of ordinary portland cement. Striking and shrinkage were analysed where the specimens were healed on the day of one year of age at the heat treatment. The results show that there was a higher resistance to sulphate attacks, an acid attack and a less creeping and dry shrinkage. [42]. The mechanical properties were analysed experimentally using the recycled coarse aggregate in GGBS and fly ash and its micro-characterisation was also analysed. The ratio of the water binder was used to extend the setting time. Thus, the combination of equal replacement of fly ash and GGBS gives high mechanical properties and also improves the workability of the concrete. [45]

Fresh concrete and hardened concrete properties have been experimentally analysed with 100 % recycled aggregates to improve concrete workability. GGBS and metakaolin were applied equally in the mixture, therefore the proportion mixture resulted in a 35 %increase in compressive strength compared to the normal gross aggregate. [46]. Physical and chemical properties of geopolymer concrete by fly ash and GGBS. Recycled aggregates have been used in various proportions from 0 %to 100 %to determine the workability, physical and mechanical properties of geopolymer concrete. The relationship between the stress strain curve, the modulus of elasticity, the poison ratio and its toughness has also been identified. Sodium hydroxide and sodium silicate are the two actuators used in the solution. The micro characters have been analysed. The binder ratio was therefore higher and lower in the recycled aggregate mix. [47].

Geopolymer concrete was produced by the industrial product, such as red mud and F-class ash, and the specimens were healed in heat curing. Thermogravity analysis was also carried out to determine the sintering in redmud. The compressive strength was normally obtained up to 600^{o}C and the compressive strength decreased by more than 600^{o}C and the strength was obtained in the first seven days of age. [48]. Mechanism of geopolymer in one part by testing red mud by leaching, x-ray photoelectron spectroscopy and nitrogen isothermal adsorption to determine the elements of sodium, aluminium, silica and iron. The results of the above test, presented by the author, show that when the red mud dissolves directly in water it releases high sodium, aluminium and silica elements, it improves the activity of aluminium silicate and silicon dioxide forming a geopolymer gel. When dissolved, silica smoke also produces geopolymer gel as an activator. For this mixture of geopolymer concrete, therefore, the long term may be necessary. [49].

Geopolymer concrete poles with the addition of fly ash are compared to conventional concrete poles. The specimens were prepared with an alkaline solution and the concrete poles are fixed to the field by following the heat-curing chamber. According to the author's findings, the transverse strength of the geopolymer concrete poles was high compared to the normal concrete poles and the deflection was also lower, but the failure load was higher in the geopolymer poles. [50]. High-performance concrete was produced using industrial products such as GGBS and glass fibre to enhance the strength of the concrete. Ordinary portal cement was used along with GGBS and glass fibre. Naphthalene based superplasticiser has been added to the mixture. The specimens were prepared for their performance at grade M 75 and resulted in a higher strength and GGBS acted as a filler for the concrete mix and the glass fibre enhanced the properties of the concrete. [54].

Ambient curing was done for industrial waste of geopolymer concrete such as GGBS and redmud. The PH of all materials was between 10 and 11. The specimens were made for compressive strength, split tensile and flexural, and therefore the strength-based conclusion is that the materials of fly ash and red mud should be sieved through a 45-micron sieve to achieve higher strength. [97]. Alccofine is the material used to add low calcium fly ash to increase compressive strength. The healing of the samples was done in both heat and ambient healing. A superplasticizer based on naphthalene was used in geopolymer concrete. The molarity of the alkaline solution was 16 molarity values for sodium hydroxide and sodium silicate ratios of 0.38.0.42 and 0.46. The microstructure was examined with XRD. The compressive strength can be achieved with a minimum requirement with the addition of Alccofine material and is therefore converted into a crystalline structure from an amorphous structure by X-ray diffraction to increase the strength. [98]. The alkaline activator-based fly ash and GGBS was used as a mixture in geopolymer concrete to determine the workability and its mechanical properties in geopolymer concrete. The alkaline ratio has been maintained between 0.35 and 0.4.

As a result, workability and set time decreased in addition to GGBS, but there was an increase in compressive strength. The 20 %to 30 %replacement at the activator ratio maintained at 0.4 at 10 molarity solution achieved optimum strength. [100].

Effect of activators-alkaline solutions in various molarity

The 20 %to 30 %replacement at the activator ratio maintained at 0.4 at the 10 molar solution achieved optimum strength. [3]. Fly ash based geopolymer concrete was used as the main material of the industrial product, This journal paper analyses the properties of a fly ash based geopolymer concrete by Fourier transforming ray diffraction method and also by scanning electron microscopy. The curing temperature remained constant at 60oC and the concentration of alkaline solutions varied from 4 M to 18 M in different molarity proportions. The specimens were prepared and also analysed from the above tests for their properties and therefore gave the optimum strength properties at a concentration of 12 M. [8].

The curing temperature remained constant at 60oC and the concentration of alkaline solutions varied from 4 M to 18 M in different molarity proportions. The specimens were prepared and also analysed from the above tests for their properties and therefore gave the optimum strength properties at a concentration of 12 M. The specimens were prepared and tested for their workability, initial and final setting of mortars and thus found that the high concentration of alkaline solutions gave higher workability and the time set was reduced by increasing the concentration Based on the test result , the author concluded that there was an interaction effect between one parameter and another based on the molarity of the parameter. The higher concentration of alkaline solutions resulted in lower compressive strength and achieved 75 %of the 28-day age strength at the third day strength. [9].

In order to find out the effect of high temperature in geopolymers, the fibre reinforced geopolymer composite was produced. Basalt, carbon, e-glass fibres were mixed in a geopolymer based on metakaolin. The result of the analysis was that the carbon fibre reinforced composite uses a protective layer of oxide which remains at high temperatures and does not destroy the strength of the material. [15]. A fly ash based geopolymer concrete was made to be tested with 1% addition of water where it improved the workability and the increase of the alkaline solution gave a negative impression on the properties of the concrete. Optimum molarity of the solution was achieved at 16 M and the ratio of fly ash to solution was 0.40. [22]. Geopolymer concrete by means of industrial products such as FA(fly ash), GGBS (Ground granulated blast furnace), HMNS(High magnesium nickel slag) were analysed for its mechanical properties and micro-characteristics by applying different proportions of mixtures in geopolymer concrete. The micro-characters were tested by SEM and XRD. Accordingly, the author concludes that the mechanical properties were obtained at a mixing ratio of 70 %of fly ash, 20 %of GGBS and 10 %of HNMS and that the compressive strength was 55.6 MPa and that the micro-logical characterization at this ratio had crystalline phases. [23]. Red mud, an industrial product of aluminium refineries, was used in geopolymer concrete. The strength and adsorption of metal ions led to improved adsorption, while the strength decreased, the red mud characterization was performed by SEM and XRD. The conclusion is that after purification of water, red mud can be used in geopolymer concrete to obtain strength. [25].

A high calcium fly ash as used in geopolymer concrete to find out the effects in alkaline solutions. The sodium silicate and sodium hydroxide solution was used an alkaline solutions in various molarities such as 8,10,12 and the ratio was between 1 and 2.5.The initial and final setting time was found out where it ranged between 105 as the maximum in initial setting and 115 to the maximum of final setting time. The curing was followed as a heat curing. The x-ray fluorescence test has also been done to find out the chemical composition. Hence the strength was obtained as high at 28-day age strength and the effects of alkaline solution based on the molarity property and higher concentration of sodium hydroxide gives low strength [27]. Alccofine was incorporated with fly ash to investigate the properties of geopolymer concrete. The specimens tested were prepared and healed in ambient healing. Microcharacters are analysed using SEM and XRD tests. High improvement in its properties occurred when the fly ash binder incorporated with high alccofine strength was obtained at 16 molarity of alkaline solution. The compactness of the structure was well collided with an increase in the molarity concentration of alkaline solution, which increases the strength but reduces the workability. [39]. Fly ash based geopolymer concrete was produced by the addition of activators such as sodium hydroxide and sodium silicate. The sample was prepared and the treatment was done in steam curing by wrapping it in a polythene foil. As a result , the author concluded that as the activator increases the workability and the strength increases by decreasing the water binding ratio, where the ratio was constant at 1:2.5. [91].

The molarity effect was examined in geopolymer concrete using the industrial product GGBS and metakaolin. The molarity was 8 molarity based on sodium hydroxide solution and sodium silicate as actuators. The conclusion is based on the fact that almost 90% of the strength is obtained at the early age of 7 days. The author therefore suggests that conventional concrete grades M 20 and M 30 may be replaced by GGBS and metakaolin. Also, Metakaolin with its full cement replacement gives high workability. [65]. The behaviour of alkaline solutions in different grades of fly ash and GGBS based geopolymer concrete was examined. Sample specimens were prepared in different grade proportions to determine the mechanical strength of the concrete. As a result, the compressive strength, the split tensile strength and the flexural strength were high when compared to ordinary cement concrete. [80].

Effect in the role of superplasticizer in geopolymer concrete

The effect of the superplasticizer was investigated in GGBS-based geopolymer concrete. In this investigation, 100% GGBS was applied to the alkaline solution of sodium silicate and sodium hydroxide. The water reducer superplasticizer was used in different ratios up to 6% and therefore the compressive force was applied to the maximum. As a result, the workability and strength properties have increased. Under ambient curing [33]. Fly ash, GGBS, glass powder was measured in different %ages in geopolymer concrete. The superplasticizer was used in a mixture of concrete and the superplasticizer was analysed in two phases. Fly ash and glass powder were mixed in different %ages from 0 to 20 %without the addition of a superplasticizer and the strength was obtained at 15 %. The next phase was the inclusion of GGBS and glass powder from 0 %to 20 %and the strength was obtained at 20 %and therefore the superplasticizer based on naphthalene was needed for geopolymer concrete. [99]. In this paper, a steam curing method was used to determine the effect of the curing temperature and also added polyvinyl alcohol fibre from 0 %followed to 1 %of the total volume mixture. Curing temperatures were 40,60 and 80^{o}C. The specimen test, such as the compressive strength test, the split tensile test, the direct tensile test and the porosity test, was performed to determine the optimum result. The result, however, concluded with a faster setting time due to the addition of polyvinyl fibre, but showed a lower density of geopolymer paste. The curing temperature at a rate of 80^{o}C increased the compressive strength while increasing the ductility in the tensile stress test as well as the porosity strength supported by its high compressive strength. Adding polyvinyl fibre to 0.6 %of increased the ductility of geopolymer paste [10]. In order to find out the effect of high temperature in geopolymers, a fibre reinforced geopolymer composite was made. Basalt, carbon, E-glass fibres were mixed in a geopolymer based on metakaolin. The result of the analysis was that the carbon fibre reinforced composite uses a protective layer of oxide, which remains even at high temperatures and does not interfere with the strength of the material. [15].

Geopolymer concrete was prepared using industrial products such as Flyash, GGBS. Silica smoke in different proportions, while alkaline solution indicators were used as a single solution instead of two alkaline solutions, sodium hydroxide, was the single activator used in this experimental setup.100% of GGBS was similar to micro cracks and High levels of reaction gels released and therefore concluded that the ambient cured specimen with 100% GGBS act as a binder when 10 molars of alkaline solution have been used to obtain sustainable concrete. [18]. Taguchi formula was applied in geopolymer concrete by incorporating the material GGBS.sodium silicate and sodium hydroxide, which was an alkaline solution at ratio 2.5 and a binder ratio of 0.35 followed at 14 molarity. The specimens were prepared in accordance with the above aspects. The partial replacement used in this mixture was fly ash, metakaolin, and silica fume. The setting time was increased in this geopolymer paste and the mixture of both GGBS and Flyash. Parameters were used in the taguchi's formula to obtain a mix ration in the ambient curing method to enhance compressive strength. [29]. The red mud was sintered up to 800^{o}C and analysed its micro structural properties. Thermogravity analysis was performed up to 1000^{o}C. Heat curing was carried out with the preparation of various specimens. The maximum strength was therefore achieved at 700^{o}C and the strength was 55 MPa. [36]. Pond fly ash was an industrial product used in geopolymer concrete. Alccofine was incorporated into the mixture to increase the compressive strength.14 The alkaline molarity solution was prepared for the mixture. For the analysis of the result in compressive strength, different temperature curing was done. Micro structures have also been analysed. Higher compressive strength was obtained during heat curing at a temperature of about 80^{o}C by the addition of Alccofine, thus enhancing the strength. The author also suggested that the results of compressive strength could be obtained by the Johnson mehl avrami Kolmogorov method. [43].

Geopolymer concrete using a fly ash material and GGBS has been used as industrial material by product. The proportion of the material was to vary by 75% and 25% of fly ash and GGBS. The alkaline solution used was sodium silicate and sodium hydroxide. The specimens were prepared for their strength, tensile, flexural and also for their beam and slab testing. The crack pattern was analysed and therefore concluded that the ambient curing compressive strength for grade M 20 was achieved with a greater improvement. The first crack pattern was observed at 46 kN and the results showed that geopolymer concrete was the best option for early gain strength. [53]. Temperature conditions for ash and GGBS-based geopolymer concrete have been followed and are compared to conventional concrete. The specimens were prepared and raised at 300 to 500oC for approximately 60 to 120 minutes. Thus, the conclusion was that the strength was increased in geopolymer concrete and that the elasticity modulus was lower in geopolymer concrete. [63]. Nano silica has been incorporated with fly ash to detect its effects, and GGBS is also incubated with the mixture. Various percentages of nano silica are added to the geopolymer mixture. The specimen was made and healed in ambient healing. Nano silica has increased its strength at 28-day age with 6% addition of nano silica [67]. Geopolymer concrete was produced using industrial products such as Fly ash, GGBS, Copper slag and agri products such as bagasse ash. The specimens were prepared and the healing was followed by both heat curing and ambient healing. The maximum strength of the ambient curing specimens was 25 % of bagasse ash and 75 % of GGBS [69].

Durability assessment

The alkaline solution of sodium hydroxide ratio to sodium silicate and mitoflash based geopolymer coating was used for pozzolan concrete by means of an industrial product such as volcanic mud by analysing its microstructural characterisation. Specimens were produced in cubes as well as in cylinders and the geopolymer coating paste was prepared in a 10-molar solution. The coating of the alkaline solution and the geopolymer coating were applied in two layers, such as horizontal and vertical, left to be cured at room temperature until the specimens were dried by applying the alkaline solution coating. The geopolymer coating was then applied and the specimens are kept for heat curing at 60^{o}C for 24 hours to ensure a polymerization reaction until the 7th day of curing. The specimens are then taken and soaked in 10% sulphuric acid solution, also in accordance with Darwin's theory of the wet-dry cycle process. The results showed an improvement in the durability of concrete with Geopolymer coating and a decrease in chloride ion penetration compared to conventional concrete. Thus, lowering the chloride ion penetration improves the durability of the ion. [6].

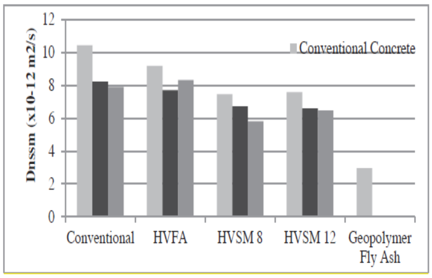


Fig. 6. Chloride penetration test

Geopolymer concrete specimens were prepared using industrial products such as fly ash, metakaolin and polypropylene fibre with activator solutions such as potassium silicate and potassium hydroxide. The specimen was prepared and healed at a normal temperature of 20^{o}C and at a constant humidity of 95%. The specimens were kept in normal room temperature for about 35 days to achieve strength. The specimens are then soaked in the solution. The conclusion was therefore that the geopolymer mortar had a good resistance to sodium chloride and sulfuric acid solutions. The compressive and tensile strength of the tap water produced a lower strength for the first 60-day age and a slow strength was regained[11]. Industrial products such as nano clay and flax fabric were used to prepare geopolymer composite with fly ash and found its micrologic characters by scanning electron microscope, x-ray diffraction test. The by-products were mixed in different proportions and the optimum strength was achieved at 2% nanoclay weight. Micro-characters indicate the degradation of the composite geopolymer by the use of the flax fabric and also find that Nano clay has increased the durability of the composite geopolymer. [12]. Rubber tyre fibres with class F fly ash were used as a material for geopolymer concrete with a naphthalene-based superplasticizer, the preparation of the specimen was carried out and various tests were carried out, and the discussion was as the tyre fibre increased the compressive strength decreased at all age day strength., but the tensile strength and flexural strength are increased by all ages. It is also possible to wear and tear at the maximum depth without rubber fibres, and therefore to apply this to heavy-duty floor tiles. [37].

The strength and stability characterization of geopolymer concrete using GGBS and red mud together with copper slag is analysed. Sodium hydroxide and sodium silicate are the two alkaline solutions used in mixtures. The Mix design was prepared on the basis of the test method. Testing and error method of blending banana fibre and steel fibre were also added. to find out its strength and stability. Approximately 2% of the fibre and 5% of the naphthalene-based superplasticizer were added to the mixture. The specimens were prepared and stored in a heat chamber at 50^{o}C for heat treatment for one day of age and then stored at room temperature for all ages. Durability test of the specimen was also carried out. Accordingly, the conclusion of the author is that the addition of fibre enhances the mechanical properties of the concrete. The use of copper slag provides a high resistance to concrete. Therefore, the mix performs a rich binder content [51]. In this fly ash and slag based geopolymer concrete, the durability study was examined in a freezing and thawing action comparing it to conventional concrete. The micro-characterization was examined by the SEM test. Samples such as prisms are prepared in two different mixtures and some cemented materials are added. The ultrasonic pulse velocity was carried out for its durability and concluded that the material results in a mechanical test load which results in a strain hardness before the microcrack appears. [52].

Recycled coarse aggregates have been partially replaced in geopolymer concrete by industrial products such as fly ash and GGBS. The specimens have been prepared and cured at ambient temperature. The results analyse that the recycled gross aggregate improves the properties of the concrete and reduces the minimum gaps. Durability is high and, as per the author, long-term durability to be considered [58]. Durability studies have been conducted for geopolymer concrete based on metakaolin and GGBS. Sodium silicate and sodium hydroxide were the two alkaline solutions used as actuators. Two different molarities such as 8 M and 10 M are prepared as different proportions. The author has identified that there is no change in the weight and compressive strength of the prepared specimens. The damage was not very serious depending on the concentration of acid because of its resistance when it was checked for durability. There is also damage due to the attack on sulphuric acid [59].

The strength and durability check were carried out for geopolymer concrete by incubating steel fibres with GGBS slag. The specimens were healed and the heat is healed. The test of compressive strength and durability for chloride penetration, corrosion testing, were also tested on the specimen. As a result, the steel fibres had increased concrete integrity and also had a low chloride permeability test.[60]. Low calcium fly ash based geopolymer concrete specimens were made to analyse the duality of the concrete using 12 molars of sodium silicate activators and sodium hydroxide as alkaline solutions with a binder ratio of 0.4. The compressive strength, tensile strength and flexural test were carried out. The specimens were heat-cured and the results found that the compressive strength was higher than that of the ambient curing specimen. As a result, the geopolymer concrete increases the durability of this low-calcium ash based geopolymer concrete [61]. Partial replacement of GGBS by conventional concrete in various %ages from 10 % to 50% by weight has been replaced. The self-compacting geopolymer concrete beam was prepared and analysed for its flexural resistance. The self-compacting concrete improves the mechanical properties and reduces the workability with the addition of GGBS. It also improves the ductility of self-compacting concrete. [71].

Corrosion activity was predicted for both conventional concrete with self-compacting concrete and geopolymer concrete using fly ash and GGBS, and samples were tested using an electrical resistance method by immersion in hydrochloride solutions, and samples were also immersed in magnesium sulphate solution. Thus, low mechanical properties may increase corrosion activity. [81]. GGBS and metakaolin are the two materials used and the materials are mixed in different %ages with 10 molar alkaline solutions to determine the strength and durability of the geopolymer concrete. The strength decreases as the metakaolin decreases. Durability achieved to the maximum when the specimens are immersed in chemical curing [84]. The asphalt concrete mixture was made and examined with marshal stability and the rubber crumbs mixed with the ultrasonic pulse velocity of the mixture were tested for the mixture and therefore the mixture modified with the addition of rubber crumbs and the %age of voids increased with the increase of the rubber crumbs and the elasticity increased with the increase of the rubber crumbs. [94].

Conclusion

On the basis of the above discussion, geopolymer concrete is an effective and affordable eco-concrete, where the industrial by-products are to be applied without dumping into the soil and the carbon emissions are also lower than conventional concrete. From the above literature survey, the effective material used in geopolymer concrete is fly ash and ground granulated blast furnace slag. Both industrial products such as fly ash and GGBS in different proportions can enhance the compressive strength and durability of ambient curing. The workability can be eased when the alkaline concentration increases. Future research can therefore enhance industrial products in geo-polymer concrete with an ambient curing condition.

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