

Review on Effects of Different Parameters on Behavior of Geopolymer Concrete

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ABSTRACT: Portland cement concrete industry has grown universally in recent years. The demand for concrete as a construction material has increased due to an increase of infrastructure. However, Portland cement concrete generates problems such as durability and carbon dioxide emission. There are many ways to reduce environmental pollution (carbon dioxide) caused by the production of Portland cement and by the increasing of waste material. Around 120 million tons of fly ash get assembled every year at the thermal power stations in India. It becomes a serious problem due to the inadequacy of land disposal. Cement is totally replaced by the pozzolanic material that is rich in Silicon, and Aluminium like fly ash referred to as “Geopolymer concrete” which is a contemporary material. Geopolymer concrete was actually manufactured by reusing and recycling of industrial solid wastes and by-products. Fly Ash, a byproduct of coal obtained from the thermal power plant is plenty available worldwide. Fly ash is used as ingredients in concrete which enhance the properties of concrete and utilization of fly ash is helpful for consumption. This paper presents a brief history and review of geopolymer technology with the aim of introducing the technology and the vast categories of materials that may be synthesized by alkali activation of aluminosilicates.

KEYWORDS: Fly Ash, Carbon Dioxide, Alkaline Activator, Geopolymer Concrete, Strength, And Durability.

I. INTRODUCTION

In the context of increased awareness regarding the ill effects of the over-exploitation of natural resources, eco-friendly technologies are to be developed for effective management of these resources. Concrete usage around the world is second only to water. Cement is conventionally used as the primary binder to produce concrete. The environmental problems associated with the production of cement are well known. The amount of the carbon dioxide released during the manufacture of cement due to the calcination of limestone and combustion of fossil fuel is in the order of one ton for every ton of cement produced. Hence, it is imminent to find an alternative material to the existing most expensive most resource consuming Portland cement. OPC is extensively used in India due to its low cost and easy availability. Concrete can be cast in almost any desired shape, and once hardened, can become a structural (load bearing) element. On the other hand, it also affects environment. Also, there are much negative influences of OPC. For example emissions of airborne pollution in the form of gases, noise, dust, and vibration when operating machinery and during blasting in quarries, devouring of large quantities of fuel during manufacture and release of CO₂ from the raw materials during manufacture. Due to all such reasons, it is needed to be replaced by non-producing CO₂ materials such as fly ash and various supplementary materials. As such, geopolymer concrete has been introduced to reduce this problem. Fly ash is plentifully available to replace totally manufactured cement and make concrete like material. It is an excellent alternative construction material to the existing plain cement concrete. Geopolymer concrete shall be manufactured without using any amount of ordinary Portland cement. The advancement of geopolymer concrete is an important step towards the production of environmentally friendly concrete. Geopolymer is a type of amorphous aluminosilicate cementitious material that exhibits the ideal properties of rock-forming minerals, i.e., hardness, chemical stability, and longevity. Geopolymerization involves a heterogeneous chemical reaction between solid aluminosilicate oxides and alkali metal silicate solutions at highly alkaline conditions and mild

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temperatures yielding three-dimensional amorphous to semi-crystalline polymeric and ring structures, which consist of Si–O–Al, and Si–O–Si bonds.

II. OBJECTIVE

The main target of this study to analyze the different parameters to affect the geopolymer concrete properties like as durability and strength.

III. LITERATURE REVIEW

Gaurav Nagalia, Yeonho Park, Ali Abolmaali, and Pranesh Aswath examines the role of alkali hydroxide and its concentration on the microstructure and compression strength of fly ash based geopolymer concrete. Geopolymer is an innovative ceramic material, composed of long chains and networks of inorganic molecules, that is used as an alternative to conventional portland cement for civil infrastructure applications. In this study, aluminosilicate geopolymers with different alkaline solutions [NaOH, KOH, Ba(OH)₂, and LiOH] were prepared by mixing Class C (9.42% CaO) and Class F-fly ash (1.29% CaO). The samples were cured under different experimental conditions and then tested for compressive strength. X-ray diffraction (XRD) and scanning electron microscopy/energy dispersive spectroscopy (SEM/EDS) have been used to identify the new phases formed in the geopolymeric matrix. The results revealed that microstructural properties of fly ash particles and calcium content have a significant effect on the setting time and the compressive strength of geopolymer concrete, and the structure of the formed Geopolymer is typically glass like. The early polymerization of geopolymer concrete is dependent on the concentration of the sodium hydroxide solution (NaOH). The exclusive use of NaOH showed the highest compressive strength when compared with other combinations of alkali hydroxides.

D. V. Reddy, Jean-Baptiste Edouard and Khaled Sobhan use the supplementary cementitious materials as partial replacements of the cement in concrete will play a significant role in the environmental control of greenhouse effects and global temperature reduction. The development of geopolymer concrete (GPC), in which all of the portland cement is replaced with fly ash (in combination with sodium hydroxide and sodium silicate solutions), offers a promising alternative to ordinary Portland cement concrete. This paper evaluates the durability characteristics of low-calcium fly ash-based geopolymer concrete that was subjected to a corrosive marine environment. A series of GPC beams, which contained fly ash with 8- and 14-M concentrations of NaOH and SiO₂=Na₂O solutions, respectively, and were centrally reinforced with a 13-mm rebar, were tested for accelerated corrosion exposure with wet and dry cycling in artificial seawater and an induced current. A sudden rise in the current intensity that is attributable to specimen cracking was indicative of durability. The test results indicated the excellent resistance of the geopolymer concrete to chloride attack, with a longer time to corrosion cracking relative to ordinary portland cement concrete.

Cheah Chee Ban, Part Wei Ken and Mahyuddin Raml introduces a novel Geopolymer system based on hybridization between high calcium wood ash (HCWA) and pulverized fuel ash (PFA), which use a low percentage of alkaline activator (5% of binder weight), ambient temperature curing, and a pressurized forming method for the fabrication of load-bearing masonry unit. The elimination of alkali hydroxide was made possible by the Arcanite mineral (approximately 12%), which is inherently present in HCWA. The HCWA-PFA geopolymer mortar blocks with various sodium silicate content (0–5%) and curing regime (water and moist curing) were assessed in terms of mechanical (compressive, flexural, and UPV) and durability performance (water absorption, total porosity, and intrinsic air permeability) over a curing period of up to 90 days. The addition of Na₂SiO₃ was found to enhance the early strength development of HCWA-PFA mortar blocks. Moreover, the mortar blocks exhibited continuous strength growth over a prolonged curing period. Moist-cured samples consistently outperformed their water-cured counterpart in every aspect. All of the fabricated HCWAPFA geopolymer mortar blocks are classified as normal-weight, solid, load-bearing masonry unit.

Partha Sarathi Deb and Prabir Kumar Sarker presents the effects of ultrafine fly ash on setting time, Strength, and porosity of geopolymer paste specimens cured at 20°C. The addition of ultrafine fly ash reduced

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setting time and improved compressive strength of geopolymers based on fly ash only or fly ash blended with 15% ground granulated blast-furnace slag (GGBFS) or 10% ordinary portland cement (OPC). With the addition of ultrafine fly ash, a reduction in porosity was observed by the mercury intrusion porosimetry (MIP), and a denser microstructure was observed by the scanning electron microscope (SEM) photographs. Thus, for room temperature curing conditions, a control on the setting time and improvements in strength and porosity of geopolymers could be achieved by varying the percentage of ultrafine fly ash.

Kunal Kupwade-Patil, and Erez N. Allouche 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. Geopolymer concrete (GPC) specimens made from Class F FA exhibited lower diffusion coefficients, chloride contents, and porosity compared with their GPC Class C FA and OPC counterparts. Overall, GPC specimens displayed limited signs of leaching and corrosion product formation, whereas OPC specimens exhibited the formation of multiple corrosion products along with significant leaching.

Zhen Liu, C. S. Cai, Hui Peng and Fenghong Fan Aiming to solve the problems caused by the construction and demolition waste and the depletion of natural aggregates, in the present study, both the coarse recycled aggregates and the fine recycled aggregates are used to produce new green concrete with a fly ash based geopolymer. The mechanical study shows that the reduction rates of the compressive strength, Young's modulus, and the Poisson's ratio of the geopolymeric recycled aggregate concrete (GRAC) specimens increase with the increase of the water/cement (w/c) ratio. The Young's modulus is much more vulnerable to the increase of the w/c ratio than the compressive strength. These significant changes to the GRAC samples could be attributable to the deteriorated properties rendered to the geopolymer by the increase of the w/c ratio. When the minimum ratio of w/c is applied, the fly ash-based geopolymer renders better mechanical properties to the concrete specimens than the ordinary portland cement. With the aid of scanning electron microscopy and nanoindentation, there is no interfacial transition zone well developed between the old cement paste and the new geopolymer/cement paste.

William Gustavo Valencia Saavedra, Daniela Eugenia Angulo, and Ruby Mejía de Gutiérrez evaluated the performance of geopolymer concretes based on a binary mixture of fly ash (FA) with blast furnace slag (GBFS) in an 80=20 ratio and activated with a mixture of sodium silicate and sodium hydroxide. FA/GBFS and Portland cement (OPC) concretes were immersed in 5% by weight sodium sulfate and magnesium sulfate solutions. Volumetric expansion and mechanical resistance loss were measured, and the reaction products were characterized by X-ray diffraction and scanning electron microscopy. The highest levels of deterioration were found in the probes exposed to MgSO₄, indicating the higher aggressiveness of this solution. After aging for 360 days in MgSO₄, the FA/ GBFS concrete expanded by 0.04% and decreased its mechanical resistance by 33%, compared to 0.08 and 48%, respectively, for similarly treated OPC concretes. However, the same exposure to Na₂SO₄ increased the observed FA/GBFS resistance while reducing the mechanical resistance of OPC by 30%. This relates to their respective expansion percentages of 0.0068 and 0.412% and the presence of expansive ettringite in the OPC concretes.

Chaicharn Chotetanorm, Prinya Chindaprasirt, Vanchai Sata, Sumrerng Rukzon and Apha Sathonsaowaphak investigated the resistance to sulfate attack, compressive strength, sorptivity, and pore size of high-calcium bottom ash geopolymer mortars. Ground lignite bottom ashes (BAs) with median particle sizes of 16, 25, and 32 μm were used. NaOH, sodium silicate and temperature curing were used to activate the geopolymerization. Results showed that relatively high strengths of 40.0–54.5 Mpa were obtained for the high-calcium bottom ash geopolymer mortars. The use of fine BA improved the strength and resistance to sulfate attack of mortars. The good performances were attributable to the high degree of reaction of fine BA and the associated low amount of large pores (0.05–100 μm) compared with those of coarse BA. The incorporation of water improved the workability of mixes, and the compressive strength, sorptivity, and resistance to sulfate attack decreased due to the increase in large pores.

P. Chindaprasirt, T. Chareerat, S. Hatanaka and T. Cao Investigated the synthesis of high-strength Geopolymer using fine high-calcium fly ash. The effect of fineness of fly ash on the setting time of geopolymer

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(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 6, June 2017

paste, workability, strength development, and drying shrinkage of geopolymer mortars made from classified fine high-calcium fly ash was investigated. Air-classified fly ash with three different finenesses coarse original fly ash (CFA), medium-fineness fly ash (MFA), and fine fly ash (FFA)—from the Mae Moh Power Station was used for this study. The heat-cured geopolymers were activated with sodium hydroxide (NaOH) and sodium silicate. A small amount of water was incorporated for workability. The results indicate that the setting time of paste decreases with an increase in fly-ash fineness. The flow, strength, and drying-shrinkage characteristics of mortars were improved using fine fly ash. Geopolymer mortars with high 28-day compressive strength of 86.0 MPa were obtained.

Kunal Kupwade-Patil, and Erez N. Allouche This study reports the findings of an experimental investigation for alkali silica reaction (ASR) between reactive aggregates and the geopolymer matrix. Specimens were prepared using one Class C and two Class F fly ash stockpiles. Mechanical testing included potential reactivity of the aggregates via length change and compression test measurements, as per ASTM standards. Results suggest that the extent of ASR reaction due to the presence of reactive aggregates in fly ash-based geopolymer concretes is substantially lower than in the case of ordinary portland cement-based concrete, and well below the ASTM specified threshold. Furthermore, geopolymer concrete specimens appeared to undergo a densification process in the presence of alkali solutions, resulting in reduced permeability and increased mechanical strength. Utilizing ASR-vulnerable aggregates in the production of geopolymer concrete products could contribute to the economic appeal and sustainability of geopolymer binders in regions that suffer from the insufficient local supply of high-quality aggregates.

O. Sanusi, B. Tempest, V. O. Ogunro and J. Gergely investigation the effect of replacing some percentage of natural coarse aggregate with recycled concrete aggregate (RCA) in geopolymer concrete synthesis. The study focuses on the compressive strength and release of elements from the Geopolymer concrete samples. The toxicity characteristic leaching procedure (TCLP) was used to determine the release of potentially hazardous heavy metals (PHHMs) and other constituents of potential concern (COPCs) from the geopolymer concrete and also to identify if the material should be categorized as either hazardous or nonhazardous. It was found that replacing virgin aggregates with RCA had a small impact on the compressive strength of the concrete, reducing it by a maximum of 34%. As measured by toxicity characteristics leaching procedure (TCLP), the release of As was reduced by adding RCA. The leached concentrations of the elements, Ba, Cd, Cr, and Pb, were found to be below TCLP regulatory limits.

Pattanapong Topark-Ngarm, Prinya Chindaprasirt, and Vanchai Sata investigated setting time, strength and bond of high-calcium fly ash geopolymer concrete. The high-calcium fly ash was from Mae Moh power plant in northern Thailand. Both sodium silicate solution and sodium hydroxide solution were used as alkali activators in every mix. Sodium hydroxide solution with 10 M, 15 M, and 20 M concentrations, sodium silicate to sodium hydroxide ratios of 1.0 and 2.0, alkaline liquid to fly ash ratio of 0.5 and two curing regimes viz., heat curing at 60 ± 2°C for 24 h and room temperature curing at 23 ± 2°C were used. The results indicated that fresh geopolymer concrete had the short setting time of 28–58 min due to the presence of high calcium content of fly ash. In general, strengths and modulus of elasticity increased with the increase in NaOH concentration. For compressive strength, the optimum Na₂O content was around 12% of fly ash. The high-strength geopolymer concrete with a 28-day compressive strength of 54.4 Mpa was obtained for mix with 15M NaOH. The moduli of elasticity of geopolymer concrete were related to the compressive strengths and comparable to those of Portland cement concrete. The tensile splitting strength and bond strength were also related to the compressive strength and the values were higher than those of portland cement concrete. In particular, the bond strengths were significantly higher than those given by the current design code.

Weibo Ren, Jinyu Xu, and Erlei Bai studied the residual behaviors of the alkali-activated fly ash–slag geopolymer concrete (FSGC) under different heating temperatures and cooling regimes. Changes in weight, compressive strength and ultrasonic pulse velocity were firstly investigated. Then the wavelet packet technique was adopted to further analyze the measured ultrasonic signals in frequency domain. Finally, the microstructures were investigated by scanning electron microscopy. The results indicate that an increase in temperature makes the weight, compressive strength, and ultrasonic pulse velocity value of FSGC decrease, especially under extreme heat conditions. The deterioration of specimens cooled by watering is more obvious than that of

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Website: www.ijirset.com

Vol. 6, Issue 6, June 2017

specimens cooled naturally. Based on the experimental results, it can be concluded that the critical temperature for FSGC is 600°C, but this temperature may change with the contents of fly ash and slag. Also, with the increase of temperature and specimen damage, the higher frequency components of the signal attenuate steadily and signal energy stored in lower frequency bands increases. A wavelet packet energy spectrum-based index is sensitive to thermal damage, which can be used as a supplementary indicator to assess the damage degree of the heated FSGC. After high-temperature exposure, FSGC undergoes distinct morphological destruction as confirmed by the developments of microcracks and the damaged aluminosilicate gel matrix.

Patimapon Sukmak, Pre De Silva, Suksun Horpibulsuk and Prinya Chindaprasirt examines the short-term resistance ability of two different cementitious systems prepared using silty clay as a major component of five wt% sodium sulfate and five wt% magnesium sulfate solutions. The two cementitious systems are clay-Portland cement and clay-high calcium fly ash (FA) geopolymer. The 28-day strength of the clay-FA geopolymer is up to 1.2 times higher than that of clay-cement. The results show that the physical performance of clay-FA geopolymer, when exposed to sulfate solution, is better than that of clay-cement. While the geopolymer phase is prominent in the clay-FA geopolymer system, gypsum, and ettringite phases are present in both systems, especially in the clay-cement system. The strength reduction in clay-cement with duration of sulfate exposure is caused by the formation of ettringite and crystallization of gypsum (observed by scanning electron microscope and X-ray diffraction) as well as the decalcification of CSH phases. There is no major change in the microstructure and pH of clay-FA geopolymer when exposed to sulfate solutions, and hence the strength reduction is insignificant. The exposure to magnesium sulfate solution causes more degradation in both clay-FA geopolymer and clay-cement system than the exposure to sodium sulfate because the CSH phases react with magnesium sulfate solution to form ettringite. The disappearance of CSH phases in both systems is observed by XRD analysis. Overall, clay-FA geopolymer shows better resistance to sulfate attack than clay-cement. The clay-FA geopolymer can be considered as a green construction and building material in sulfate-rich areas.

Muhammad Aamer Rafique Bhutta, Warid M. Hussin, Mohd Azreen and Mahmood Mohd Tahir investigated the performance of geopolymer concrete prepared using blended ash of pulverized fuel ash and palm oil fuel ash from agroindustrial waste along with alkaline activators when exposed to a 5% sodium sulphate solution for up to 18 months. Ordinary portland cement (OPC) concrete was also prepared as the control concrete. The main parameters studied were the evaluation of mass change, compressive strength, products of degradation, and microstructural changes. The deterioration was examined using X-ray diffraction (XRD), a Fourier transform infrared spectroscopy (FTIR), a thermogravimetry analyzer (TGA), and a field emission scanning electron microscope (FESEM). The results of geopolymer and OPC concretes were compared and discussed. The compressive strength of geopolymer concrete, when exposed to a 5% sodium sulfate solution for more than one year, was superior to that of OPC concrete. These materials could be used for making sulphate-resistant concretes, attributable to a more stable cross-linked aluminosilicate polymer structure formed in the geopolymer concrete.

Farhad Aslani examine the relationships are proven for normal and high-strength GCs at elevated temperatures to establish efficient modeling and specify the fire-performance criteria for concrete structures. They are developed for unconfined GC specimens that consist of compressive strength, modulus of elasticity, flexural strength, thermal strain, prestressed thermal strain, and the compressive stress-strain relationships at elevated temperatures. The proposed relationships at elevated temperature are compared with experimental results and available OPC relationships. These results are used to establish more accurate and general compressive stress-strain relationships.

IV. CONCLUSION

From the literature review, the critical reviews are as follows:

- Geopolymer concrete use as an alternative to Portland cement and it reduce CO₂ emission in the world so it can be said that it helps to the nature that's why geopolymer concrete represents a "Green concrete" and also as an "eco-friendly concrete."

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Website: www.ijirset.com

Vol. 6, Issue 6, June 2017

- The experimental works prove that geopolymer concrete with moderate to moderately high strength can be developed at very low concentration of alkaline activator and ambient air curing.
- Use of fly ash in combination with slag is found to be more reactive and the strength gained is more.
- Specialized curing regimes such as steam curing, hot air curing are required only when accelerated strength gain is required. When design strength is required at 28 days normal curing is sufficient.
- Higher the fineness of fly ash gives a higher compressive strength because of more surface area with a more Si-Al bond of polymerization.
- Generally heat cured geopolymer concrete gives higher strength but it can be obtained at ambient temperature by replacing fly ash content by GGBFS.
- Fly ash based geopolymer is better than normal concrete in many aspects such as compressive strength, exposure to aggressive environment workability and exposure to high temperature.

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