Geopolymer concrete: A way of sustainable construction

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Abstract: **Geopolymer concrete is an eco-friendly, economical, cementless, and durable concrete. By the comprehensive survey of the literature; Geopolymer concrete is sustainable development for the construction industry. Geopolymer concrete reduces the carbon footprints by the using industrial solid waste material like as Flyash and blast furnace slag as a binding material. Around one ton of carbon dioxide (CO_2) emission for the production of the one ton of cement. In geopolymer concrete, we use the waste material like as flyash and slag as a binding material. Moreover, that binding material activating by the alkaline solution (sodium hydroxide and sodium silicate). Around 120 million tonnes of Flyash and 12 million tonnes of slag produced annually at the thermal power station and Steel Plant respectively in India. Presently in India, due to Limited modes of practices of utilisation use amount of slag and flyash dumped in lands of each production unit and engaging in valuable agricultural land and grave pollution to the whole environment. Hence, Geopolymer concrete is a perfect alternative to Portland cement concrete.**

Keywords: **Fly ash, Slag, Geopolymer concrete, Alkaline activator, Portland cement.**

I. INTRODUCTION

Concrete is the world's most reliable, durable, versatile construction material. After to water, Concrete is the user most material which required large quantities of Portland cement. Portland cement production is the second to the automobile as the dominant generator of Co_2, which polluted production. So, required to find an alternative material to the existing most expensive most resource consuming Portland cement. Geopolymer concrete is an innovative material which is produced by the chemical action of inorganic molecules. Geopolymer concrete a way to the sustainable development of concrete Industries. Geopolymer concrete made by the industrial solid waste like as flyash or slag, an alkaline solution, aggregate, sand, water and superplasticiser. Industrial solid waste like as slag and flyash used as a binding material and alkaline solution used for the activating the industrial solid waste for geopolymerization. The industrial solid waste contains silica and Alumina; geopolymer concrete reduces the carbon footprints due to reducing the use of Portland cement. In 1 ton production of cement produces the one ton of CO_2 in the atmosphere. Around 7 to 8% of CO_2 produced by the cement production in the world. CO_2 is a Greenhouse gas that increases the temperature of the earth. In the development of countries increase the development of the infrastructure that is built by the concrete. So, production of concrete increases day by day due to increase in the demand for infrastructure. Around 120 million tons of flyash produces from the thermal power plant and 12 million tons of slag generated from a steel plant in India. Many valuable cultivated land used for the disposal of the slag and flyash. Industrial solid waste polluted the soil and the underground of that area. By the use of industrial solid waste, we did the double profit work one by the use of waste to prevent the land from the disposal or dumping and second by the generating the concrete.

II. GEOPOLYMER CONCRETE

Geopolymer concrete is a new kind of concrete which uses different chemistry to that found in Portland cement concrete. Davidovits (1991) firstly introduce the word 'Geopolymer' to sketch an alternative cementitious material which has ceramic-like properties. As opposed to OPC, the manufacture of geopolymer does not consume high levels of energy. A geopolymer concrete is made of the amorphous alumino-Silicate materials such as flyash and slag with alkali based Chemicals such as sodium silicate and sodium hydroxide. Geopolymer concrete does not need to OPC to work. Geopolymer is inorganic polymers that have been phased attracting world attention to potentially Revolution material. Similar to nature zeolite minerals, geopolymer is a class of 3 dimensionally networked alumino-silicate materials. A wide range of natural aluminium- silica minerals such as flyash and slag could serve as potential source material for the synthesis of geopolymers.

Geopolymer is a type of amorphous aluminosilicate cementitious material that exhibits the ideal property of Rock-forming minerals due to hardness, chemical stability and longevity. Geopolymerization involves a heterogeneous chemical reaction between solid(binder powder) and Aluminium silicate oxide and alkali metals silicate solution at highly alkaline conditions and mild temperature yielding three-dimensional amorphous to semicrystalline polymeric and ring structure which consists of Si-O-Al and Si-O-Si bonds. the systematic formation of polycondensation material by alkali into poly(sialate-siloxo) can be shown as described by the equation

$n(Si_2O_5\ ,\ Al_2O_2) + nH_2O + nSi_2$
(NaOH, KOH)

$\downarrow$

$n\ (OH)_3 – Si\ -O-Al(OH)_2 – O-\ Si(OH)_3\ -$
(NaOH, KOH)

$\downarrow$

(Na^+, K^+)-(Si-O-Al-O-Si-O-) + nH_2O

III. LITERATURE REVIEW

Patimapon Sukman et al. examine the short-term resistant ability of two different cementitious system prepared using silty clay as a significant component of five wt.% sodium sulphate and 5wt.% magnesium sulphate solution. The cementitious system is clay Portland cement and clay high calcium flyash geopolymer concrete. Moreover, concluded that the exposure to magnesium sulphate causes more degradation than sodium sulphate in both clays flyash geopolymer and clay cement system. The 28 days strength of clay fly ash geopolymer is up to 1.2 times higher than the clay cement.

Weibo Ren et al. Study the residual behaviours of alkali-activated flyash slag geopolymer concrete under different heating temperature and cooling regimes. Analysis the change in weight, compressive strength, UPV test, wavelet test, and microstructure of concrete. Compressive strength, UPV of FSDC decrease due to increase in temperature especially under extreme heat condition. The specimen cooled by watering is most degradable than the specimen cooled naturally.

Mohammad Amer Rafique Bhutta et al. Examine the performance of geopolymer concrete prepared using pulverised fuel(PFA) and palm oil fuel ash from Agro-Industrial waste along with alkaline Activator. Analysis the mass changes, compressive strength, mineralogical property, microstructural changes by exposed to 5% magnesium sulphate solution for up to 18 months. The resulted that OPC concrete shows mass decrease up to 20% compared to 4% decreased for blended fuel ash geopolymer concrete. The Portland cement concrete was more susceptible to attack by 5% sodium sulphate solution compared to Blended fuel ash geopolymer concrete. The performance of geopolymer concrete in 5% sodium sulphate solution was more stable due to cross-linked aluminosilicate polymer structure as compared to normal portland cement C-S-H structure.

William Gustavo et al. Examine the performance of geopolymer concrete based on a binary mixture of flyash and ground granulated blast furnace slag(GGBFS) in 80/20 ratio and activated with a mixture of sodium silicate and sodium hydroxide. Analysis the durability of FA/GGBFS and OPC concrete by immersed in 5 wt % sodium sulphate and magnesium sulphate solution. Check the volumetric expansion, mineralogical characteristics, microstructural changes and compressive strength of concrete. Moreover, found that the loss of compressive strength in FA/GGBFS system was 33% for 360 days of magnesium sulphate exposure and 48% of the Portland cement concrete. The expansion of FA/GGBFS concrete and OPC concrete were .041 and 0.086 respectively for magnesium sulphate exposure. The expansion of FA/GGBFS concrete and OPC concrete is 0.0068% and 0.412% respectively in sodium sulphate solution.

Farhad Aslani investigated the relation for normal and high strength geopolymer concrete at elevated temperature. Moreover, to establish the efficient Modelling and specify the fire performance criteria of concrete structures. Analyse the compressive strength, flexure strength, thermal strain and modulus of elasticity of concrete. He proposed the free thermal strain relationship for unstressed and prestressed geopolymer concrete at a higher temperature. He proposed the relationship between the compressive strength, elastic modulus and flexure strength of unstressed geopolymer concrete with different geopolymer resins composition geopolymeric Binder type and aggregate type at elevated temperature. Moreover, the results are in good reasonable agreement with the experimental results.

Paulo H.R. Bourges et al. Studied that to improve the geopolymer formulation by the development of micro concrete. He investigated the three parameters one) the Andreasen packing factor q= .21, .235, and .26 which are alter particle size distribution of aggregate, 2) solution to solid rate 1.3,1.4, and 1.5, 3) type of aggregate either glass or quartz. Moreover, concluded that geopolymer concrete made with Quartz present better properties than made with glass aggregate. To make self-compacting mix uses the intermediate Andreasen factor q= 2.235 and solution to the solid ratio are 1.4.

DV Reddy et al. Evaluates the durability characteristics of low calcium fly ash based geopolymer concrete that was subjected to a corrosive Marine environment. Test the geopolymer concrete beams which contained flyash with 8M and 14M concentration of sodium hydroxide and sodium silicate solution. Moreover, conclude that the strength increases between 7 to 28 days are 15% for 8M concentration and 7% for 14M concentration geopolymer concrete and 33% increases of OPC concrete. The splitting tensile strength was also consistently higher for geopolymer concrete comparative to OPC concrete. The electrical resistivity of geopolymer concrete was not significantly affected, and reduced cracking implies a permeability reduction.

Partha Sarathi Deb et al. Studied the effect of ultrafine flyash on setting time, strength and porosity of geopolymer paste and specimen cured at 20^0C made with 15% GGBFS or 10% OPC. Analyse setting time, compressive strength, mineralogical properties, and microstructure of concrete. They improve the density of microstructure by using ultra-fine flyash that reduced the porosity and increase compressive strength. They found that the maximum compressive strength at 10% ultra-fine flyash mix with flyash only geopolymer and 5% ultrafine flyash for GGBFS or OPC blended geopolymer. Using of ultrafine flyash reduce d setting time of flyash geopolymer paste.

Chaicharn Chotetanorm et al. Studied that resistance to sulphate attack, compressive strength, sorptivity, and pore size of high calcium bottom ash in geopolymer mortar. They used the ground lignite bottom ash with medium particle sizes of 16, 25 and 32 micrometres in a mortar. They use sodium hydroxide and sodium silicate and temperature curing to activate the geopolymerization. Moreover, concluded that the fine bottom Ash gives the high compressive strength, low rate of sorptivity and low expansion in a mortar, When subjected to 10% sodium sulphate solution for 360 days.

Pattanopong Topark Ngarm et al. Investigated the strength, setting time, and bond of high calcium fly ash based geopolymer concrete. They use Sodium Hydroxide with 10M, 15M, and 20M concentration, sodium Syndicate to Sodium Hydroxide ratio of 1, 2, alkali liquid flyash ratio of 0.5 and two curing regimes heat curing at 60+2^{0}C for 24 hours and room temperature curing at 23+2^{0}C.were used. Moreover, concluding that high-calcium flyash suitable for producing high strength geopolymer concrete with high Bond strength between concrete and rebar. The optimum sodium oxide content was approximately 12% by weight of flyash, and optimum strength of 54.4MPa was obtained with the 15M sodium hydroxide. Bond strength of high calcium geopolymer concrete was slightly higher than low calcium fly ash based geopolymer concrete.

ST Erdogan studied the strength development of mixture containing only ground perlite as their powder(Binder) activated with sodium hydroxide(NaOH) and sodium silicate solution at room temperature or using oven dry curing. XRD, FTIR, and NMR analysis indicate that when cured at 100^{0}C sodium hydroxide solution activated mixture undergoes more geopolymerization then we activated mixture. Activator gave high strength mixture 40-50MPa when samples cured in a dry oven at 100^{0}C when both activator have used the contribution of WC to strength development is Greater.

P. Chindraprasirt et al. Studied the synthesis of high strength geopolymer using fine high calcium fly ash. Analyse the effect of fineness of flash on the setting time of geopolymer paste workability, strength development and dry shrinkage geopolymer mortar made from classified fine high calcium fly ash. To find the optimum point of delay time, Curing temperature and duration of curing at high temperature. Moreover, found that the optimum parameter for fine flyash activated with sodium silicate solution and sodium hydroxide ten molar solution at 1:1 mass ratio was 1 hour for delay time and 3-day heat curing at 75^{0}C. The high calcium fly ash based geopolymer mortar continue to gain strength when kept in a normal atmospheric condition after the initial heating curing period.

Gaurav Nagalia et al. Investigated the role of alkali hydroxide and its concentration on the microstructure and compressive strength of fly ash based geopolymer concrete. Geopolymer concrete with different alkaline solutions[NaOH, KOH, $Ba(OH)_2$ LiOH] was prepared by mixing Class C (9.42% CaO), and class f fly ash (1.29% CaO). Moreover, concluded that the higher concentration of CaO in flyash provide higher strength in the finished geopolymer concrete. Sodium Hydroxide was the only one that resulted in mechanical strength that is comparable to Portland cement concrete.

Kunal Kupwade Patil et al. Investigated the alkali-silica reaction between reactive aggregates and geopolymer Matrix. The specimen was prepared by using Class C and class f flyash stockpiles. OPC concrete exhibited higher average expansion by a factor of six compared to geopolymer concrete specimens. alkali-silica reaction product was formed on Portland cement concrete specimen on the geopolymer concrete specimen made with Class C flyash. Fly ash-based geopolymer concrete is significantly less vulnerable to ASR than Portland cement based concrete. Elevated temperature results in reinitiation of the geopolymerization process of unreacted flyash particles leading to lower porosity and higher strength.

Kunal Kupwade Patil et al. Investigated the durability of Steel reinforced concrete specimen made from the alkali-activated flyash stockpiles and OPC in cyclic wet-dry chloride environment was evaluated over a period of 12 months. Analyse the chloride diffusion, corrosion potential and rates Pore structure and chloride content, microstructure and chemical analysis of the specimen. Moreover, concluded that geopolymer concrete specimen exhibit lower average diffusion, coefficients, chloride content and porosity compared with their Portland cement counterparts. Geopolymer concrete specimen made from class f flyash exhibited significantly higher resistance to chloride-induced corrosion compared to OPC as well as class f fly ash concrete.

Biruk Hailu Tekle et al. Investigated the bond property between sand coated GFRP bars a corrosive resistant substituent to a Steel bar and flyash based geopolymer concrete. They analyse the bond failure mode, bond relationship curve, effect of embedment length, the effect of compressive strength and bar diameter. Moreover, concluded that the bond performance of Sand coated GFRP reinforced geopolymer concrete is better than the Portland cement concrete. The pull out load increases with increasing amendment length, but the average Bond strength decreases. The residual Bond stress is caused by the friction resistance between the concrete and sand coating of GFRP bars. Load increases the bond stress in the vicinity of free end increases because of the redistribution of bond stress along the amendment length.

M. Albitar et al. Investigated the behaviour of reinforced concrete at all load level and understanding of the bond between the reinforcement and concrete is required. The bond between the concrete and the reinforcement control the formation of cracks widening and stiffening at the serviceability limit. Analyse the pullout test, accelerated corrosion method, sorptivity and water absorption test, frictional strength, maximum slip and corrosion induced cracking. Moreover, concluded that corrosion of reinforcement not only reduce the strength but also lead to deterioration of the bond which can cause increased deflection, reduced strength and ultimate failure. A new model of geopolymer concrete with new corroded enforcement was proposed.

O. Sanusi et al. Investigated the effect of replacing some percent(%) of natural coarse aggregate with recycled aggregate in geopolymer concrete synthesis. In this study focus on the compressive strength and release of elements from the geopolymer concrete sample. Moreover, concluded that use of recycled aggregate in geopolymer concrete affect both the compressive strength and leaching of the elements. The compressive strength was reduced for recycled aggregate addition with rates UP to approximately 30% but then slightly increased for more magnificent addition. Mixes with less than 30% recycled coarse aggregate released at a level higher than the screening limit. Incremental addition of recycled coarse aggregate leads to a reduction of as leaching. TCLP testing indicated that most of the COPC were not leached at a level above the EPA soil screening levels or the TCLP regulatory threshold.

Ginghis Maranan et al. Investigator job on the performance of sand coated GFRP bars of a parameter such as a bar diameter 12.7mm, 15.9mm and 19 mm and the embedment length (5, 10 and 15 diameters of bars). The test of the direct pullout test of GFRP bars into geopolymer concrete with a compressive strength of 33Mpa. Moreover, concluded that the specimen with a longer embedment length failed because of concrete splitting whereas the specimen with a shorter embedment length failed because of the bar pull out. Specimen failed because of bar diameter cause the peak average bond stress to decrease. The increase in the embedment length results in lower average Bond stress because of the different type failure.

Zhen Liu et al. Investigated the problems caused by the construction and demolition waste and the depletion of natural aggregate in the present. Both the course recycled aggregate and the fine recycled aggregate are used to produce new green concrete with fly ash based geopolymer concrete. moreover, concluded that the compressive strength, young modulus, and poisons ratio decrease with the increase of water content and w/c ratio for the geopolymer recycled aggregate concrete specimens. young modulus is more vulnerable to the change of w/c ratio than compressive strength. SEM and Nanoindentation Technologies so there is no interfacial transition between the old cement paste. The fly ash based geopolymer is capable rendering a lower w/c ratio for the production of recycled aggregate concrete than Portland cement while even producing a higher compressive strength.

Cheah Chee Ban et al. Investigated a new geopolymer system based on hybridisation between high calcium wood ash and pulverised fuel as which uses as a low % of Alkaline activator (5% of binder wt.), ambient temperature curing and pressurised forming a method for the fabrication of load-bearing masonry unit. the removal of alkali Hydroxide was made possible by the arcanite minerals (approximately 12%) which are inherently present in HCWA. moreover, concluded that the early strength development is due to primarily by the formation of N-A-S-H and K-A-S-H geopolymeric gel. Meanwhile, the long-term strength development is caused by the formation of (Ca, K)-A-S-H geopolymeric gel and secondary C-S-H gels.

IV. CONCLUSION

Based on the discussion, it is concluded that geopolymer concrete has excellent potential to use as a construction material in several applications. Geopolymer concrete is a perfect alternative to Portland cement concrete. In a comprehensive survey of papers, we found that the geopolymer concrete has excellent physical and mechanical properties as compared to Portland cement concrete. Geopolymer concrete durability is higher as compared to the Portland cement. Geopolymer concrete highly resistive to sulphate attack, acid attack, alkali-silica reaction. Geopolymer concrete indirectly reduces the carbon footprints by the usage of industrial solid wastes and reduce the usage of portland cement. Because in the production of portland cement high amount of carbon dioxide generated. So, geopolymer concrete is a way of sustainable developments.

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