Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 10, October : 2023

PARAMETRIC STUDY ON GGBS BASED GEOPOLYMER CONCRETE: A REVIEW

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Abstract
The major problem the world is facing today is the environmental pollution. In the construction industry mainly the production of Portland cement will causes the emission of pollutants results in environmental pollution. We can reduce the pollution effect on environment, by increasing the usage of industrial by-products in our construction industry. Geopolymer concrete is such a one and in the present study, to produce the geopolymer concrete the Portland cement is fully replaced with GGBS (Ground granulated blast furnace slag) and alkaline liquids are used for the binding of materials. The alkaline liquids used in this study for the polymerization are the solutions of Sodium-hydroxide (NaOH) and sodium silicate (Na_2Sio_3). This study investigates the use of GGBS (ground granulated blast furnace slag) in 100% replacements by mass in cement. Harden concrete properties like compressive strength, Spilt tensile, flexural strength of concrete are be determined for Geopolymer concrete and Normal concrete. Finally the test results were compared from the test results, it has been observed that the geopolymer concrete possess better result than the normal concrete.

Keywords: GGBS, Geopolymer Concrete, Alkaline Liquid, Compressive Strength. Spilt Tensile Strength, Flexural Strength.

I. Introduction

Many emerging nations' economies depend heavily on the construction sector, which also serves as the backbone of their development. However, cement, a conventional binding material, used widely in construction because of its high-embodied energy and CO_2 emissions, hinders the achievement of the UN Sustainable Development Goals (SDGs). The huge manufacturing and usage of ordinary Portland Cement (OPC) has a negative influence on the environment, and 5– 7% of global CO_2 emissions are attributable to its massive production. Recent advancements have assisted in providing an imperative sustainable solution by partially utilizing industrial wastes such as fly ash, GGBS, silica fume, and rice husk ash in place of cement and minimizing the embodied energy and CO_2 emissions. Partial replacement by the optimum amount of these industrial wastes in concrete has been reported to enhance the mechanical properties such as flexural, compressive, and tensile strength, and limit the chloride ion penetration with time. Utilizing these industrial wastes has also been reported in substantial cost savings together with benefits to the environment.

As compared to conventional cement-based concrete, observations of better physical and durability properties obtained by partially replacing OPC with fly ash, GGBS, and silica fume are reported. However, replacing cement completely by these materials is incongruous due to the economic cost and changes in mechanical behaviour. Providentially, Davidovits' description of the inorganic aluminosilicate polymers known as geopolymers has offered a feasible option for their complete replacement. These inorganic aluminosilicate polymers are generally industrial waste such as GGBS, fly ash, etc., which, when activated by alkali, are realized into geopolymers binders. Hence, these industrial by-products can be realized as useful construction materials. The concrete, thus obtained, is called geopolymers concrete. Geopolymer concrete has shown to exhibit better physical and durability properties than OPC-based conventional concrete. The enhancement is attributed to the denser hydration product as compared to cement paste. The geopolymer binder also exhibits better binding characteristics, which results in a considerably stronger interfacial Transition Zone (ITZ) and microstructure. Geopolymer concrete has proved to be a viable alternative to Portland cement-based concrete because of the reduction in the embodied energy and carbon footprint. Literature study reveals a lesser impact of geopolymers concrete on the environment as compared to concrete with higher amounts of cement. This environmental impact of the geopolymer concrete was assessed by determining the Environmental Impact Factor (P) through a Life Cycle Assessment (LCA). Thus, geopolymer concrete resonates with the UN Sustainable Development Goals related to energy, climate, and infrastructure.

Optimization of a geopolymer concrete mix incorporated with a combination of GGBS, fly ash, and silica fume have also taken place. Scarce literature is available regarding the implementation of the Taguchi method for only GGBS-based geopolymer concrete and that too reinforced with fiber material. The Taguchi method is also implemented to optimize the compressive strength of geopolymer concrete with palm oil fuel ash. Steel fiber-incorporated GGBS-based geopolymer concrete has been optimized by the Taguchi method for better spilt tensile strength. The use of the Taguchi method to determine the optimum process parameters for GGBS-based geopolymer concrete reinforced with polypropylene fibers appears to be undocumented in the literature.

In this study, an analysis of the results of the combined usage of different levels of GGBS, polypropylene fibers, and alkali ratio ($NaOH:Na_2SiO_3$) to further improve the fresh state property, viz., workability and hardened state properties, and compressive and flexural strengths of the GGBS-based geopolymer concrete incorporated with polypropylene fibers, was made. By using Taguchi's method, this study also intends to determine the optimum levels of the three factors: the alkali ratio ($NaOH: Na_2SiO_3$), the percentage of GGBS, and the percentage of polypropylene fibers. Three levels were adopted for each factor, based on the above literature review. Experiments were conducted on nine mixes to investigate optimum levels of each factor or process parameter for the responses, namely, workability, and compressive and flexural strengths. Significant factors and their ranks were also derived by using Taguchi's method. ANOVA was also performed on the data to find the factor parameter with least and most significant influence on the responses and optimum levels of each factor, and the results of Taguchi's method and ANOVA were compared.

Geopolymer concrete is produced by the alkali activation of fly ash or ground granulated slag combining with aggregates. The progress in the field of geopolymer concrete up to present time has been the fruit of an empirical approach, rather than the fundamental and scientific one. And because of empirical approach, the results from different studies cannot be related to one another. Geopolymers are a group of inorganic polymer produced by the result of reaction between an alkaline solution and an aluminosilicate as a source. The microstructure of hardened geopolymer material has an amorphous, three-dimensional structure similar to that of an aluminosilicate glass. However unlike a glass, these hardened geopolymer materials are produced at low temperature and as a result can integrate an aggregate skeleton and a reinforcing system, if required, during the forming process. The reactants needed to form a geopolymer are an alkali hydroxide, alkali silicate solution and an aluminosilicate fine binder. The binder needs to have a significant proportion of silicon and aluminium ions held in amorphous phases. Commonly used binders include class-F fly ash, ground granulated slag and metakaolin, but any fine amorphous aluminosilicate material can be used . All types of concrete fail under compression when tested . But compression strength itself is not the property of concrete to explain the performance of concrete. Concrete failure will always develop in weakest part of one of these three phases namely: aggregate zone, transition zone and hydrated cement paste. Thus, in order to increase the compressive strength of concrete, great care must be taken to strengthen all these three phases. It also depends on the microstructural features of concrete which govern the other properties like strength, elastic modulus and durability.

Geopolymerization mechanism - Similar to conventional organic polymerization, this process involves forming monomers in solution, then activating them to polymerize to form a solid polymer. This geopolymerisation process involves three separate but interrelated stages Dissolution-During initial mixing the alkaline solution dissolves silicon and aluminium ions from the amorphous phases of the binder like fly ash or GGBS. Condensation- In this solution, neighbouring silicon or aluminium hydroxide. molecules undergo a condensation reaction where adjacent hydroxyl ions from these nearest molecules condense to form an oxygen bond connecting these molecules, and a free molecule of water. Polymerisation-Monomers and other silicon and aluminium hydroxide molecules condense to form rigid chains or nets of oxygen bonded tetrahedral with application of mild temperatures or even at ambient temperatures. All the three process of geopolymerisation.

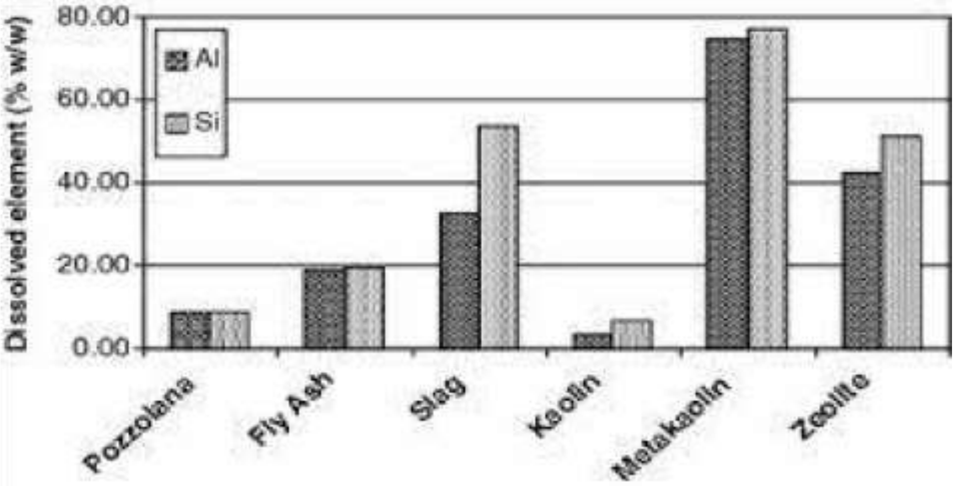

Figure 1: Binding Elements Of GGBS

Binding Solution: Alkaline Solution Binding solution used in Geopolymerization process is an alkaline solution comprising of mixture of NaOH and Na2SiO3 in varying proportions. As explained in the mechanism this alkaline solution dissolves the binder to get alumina-silicate products which have the cementing property. According to Peterman the activation of the selected pozzolanic material is the most significant factor in producing a mechanically-sound cementations material via the Geopolymerization process.

The initial mechanism of reaction is driven by the ability of the alkaline solution to dissolve the pozzolanic material and release reactive silicon and aluminium into solution. The activators prompt the precipitation and crystallization of the siliceous and aluminous species present in the solution. OH- acts as a catalyst for reactivity, and the metal cation serves to form a structural element and balance negative framework carried by the tetrahedral aluminum Palomo. concluded that the type of alkaline liquid as a precursor plays an important role in the polymerisation process. Reactions occur at a high rate when the alkaline liquid contains soluble silicate of sodium or potassium, in comparison with the use of only alkaline hydroxides. Xu and Van Deventer confirmed that the addition of sodium silicate solution (Na_2SiO_3) to the sodium hydroxide (NaOH) solution as the alkaline liquid improved the reaction between the source material and the solution. The most common alkaline liquid used in geopolymerisation is a combination of sodium hydroxide (NaOH) or potassium hydroxide (KOH) and sodium silicate or potassium silicate. Furthermore, after a study of the geopolymerisation of natural Al-Si minerals by Hardjito et al. and Panagiotopoulou et al. found that generally the NaOH solution caused a higher extent of dissolution of minerals than the KOH solution. Hence in the present work NaOH and Na_2SiO_3 are used as binding solution. The activator solution was prepared one day prior to its use in specimen casting. Admixtures Various superplasticizers can be used to substantially improve the workability of fresh concrete without increasing the amount of water and hence reducing the risk of segregation. In order to improve the workability of fresh concrete, Raijiwala and Patil used high-range water-reducing naphthalene based superplasticizer with the dosage from 0.6-2.0% of the weight of fly ash . used polycarboxylate ether based high performance superplasticizers in the concrete.

Aggregates It may be noted that any concrete requires fine aggregates and coarse aggregates so that a packing of these two inert filler materials creates minimum space for binder paste in the concrete mix and this is required from economic point of view also since binder portion is generally the most expensive in any concrete mix. Locally available crushed sand and crushed granite coarse aggregates are used at the saturated surface dry condition for geopolymer concrete mixes. Mixing of Geopolymer Concrete According to Nuruddin . mixing process can be divided into two stages, dry mix and wet mix. Initially coarse aggregate, fine aggregate and GGBS will be mixed together in rotating pan mixer for 3 to 5 minutes. The alkaline solution is prepared by mixing sodium hydroxide solution with sodium silicate solution one day before making the geopolymer concrete to get the desired alkaline solution. The liquid part of the mixture, i.e., the alkaline solution, extra water and the superplasticizer, should be premixed thoroughly and then added to the dry mixture. The wet mixing can be done for 1.5 to 3 minutes. The process of mixing is depicted.

Fresh geopolymer concrete is then hand mixed to ensure the mixture homogeneity. The aluminosilicate gel is highly viscous and mixing agitation can easily encapsulate air into the matrix. Mechanical vibration of the formed molds serves to reduce this potential and greatly improves the overall strength of the hardened geopolymer concrete. Curing of Geopolymer Concrete Curing is a main important process for both strength and durability of geopolymer concrete. Geopolymer concrete needs to be cured in a high temperature to accelerate a reaction of geopolymerisation. Duration, temperature and type of curing have been investigated by various researchers like Olivia and Nikraz . and Mustafa et al. Curing process of geopolymer concrete can be achieved by: oven curing (30-90 °C), hot gunny curing (33-38 ºC), ambient curing (27-32ºC), and external exposure curing (39-44 ºC). Special curing techniques like steam curing at temperature of 600C for 24 hours followed by air curing in a control environment with a temperature of 23-2 0C until testing can also be followed. There is an increase in compressive strength with the increase in age for ambient cured specimens. According to Vijai et al. the increase in compressive strength with age is very less as compared to that of specimens subjected to ambient curing for hot cured samples. The rate of increase in strength will be rapid up to 24 hours of curing time; beyond 24 hours, the gain in strength is only moderate. Therefore, heatcuring time need not be more than 24 hours in practical applications. Heat-curing can be achieved by either steam-curing or dry-curing.

According to Rangan [19], 25-35°C range of temperature can be provided by the ambient curing conditions in tropical Int. J. Adv. Sci. Eng. Vol.5 No.1 879-885 (2018) 882 E-ISSN: 2349 5359; P-ISSN: 2454-9967 Shabarish V Patil et al., International Journal of Advanced Science and Engineering www.mahendrapublications.com climates. So, in the present study the adopted curing regime is only restricted to ambient curing. As there are no standard codes established for the mix design of geopolymer concrete in any part of the world, so for the mix design process is carried on basis of some of the following thumb rules like density of concrete as 2400kg/m3, quantity of total aggregates as 80% of the total constituents, coarse aggregate content as 70-75% of total aggregates.

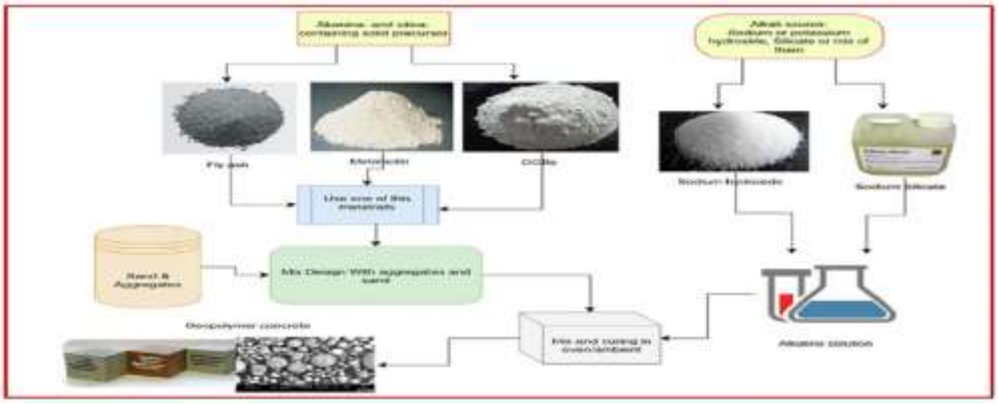

Figure 1.2:- Flow Chart

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Ground-Granulated Blast-Furnace Slag (GGBS)

GGBS is a principal byproduct produced by steel and iron productions. The furnace is typically run at a temperature of 1500 degrees Celsius. The blast furnace is supplied with a carefully regulated combination of limestone, iron ore and coke. When limestone, iron ore and coke are melted together in a blast furnace, iron and slag are created in the molten state. When the slag from the blast furnace is molten, it is swiftly cooled with strong water jets, which transform it into GGBS, a fine, granular and glassy substance. depicts the GGBS manufacturing process.

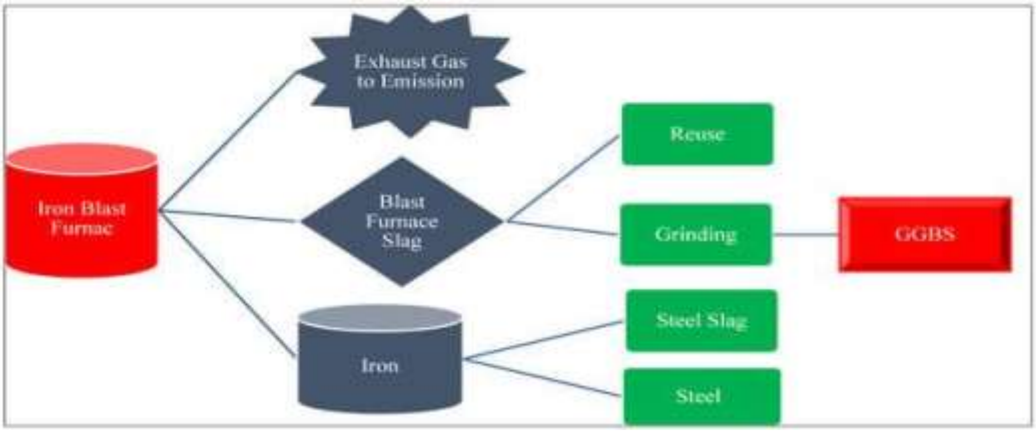

Figure 1.3 - Manufacturing Process of GGBS

II. Literature

Krishna Rao and D. Rupesh Kumar (2023) presents the details of materials used for the production of geopolymer concrete and method of parametric optimization, strength and durability properties of geopolymer concrete. Initially the materials will be selected and the study the properties of fine aggregate, coarse aggregate, chemical composition of fly ash, ground granulated blast furnace slag (GGBS), alkaline activators (NaOH, Na_2SiO_3) and super plasticizer will be assessed.

Kiran Kumar Poloju and Kota Srinivasu (2021) found that geo-polymer concrete shows better strength performance compared to OPC concrete. Strength properties of geopolymer concrete increase with use of lesser alkaline activator. i.e. 1.5 ratio compared to 2.5. The impact of molarity of NaOH on workability and SS/SH ratio which directly affect strength of concrete is discussed. The increase of GGBS and decrease of SS/SH ration affect strength properties of geo polymer concrete.

Ganesan Nagalingam and Ramesh Babu Chokkalingam (2020) proves that GGBS based Geopolymer concrete performs well in strength tests. This study also reveals strengths go up with age of concrete. It also proves GGBS and flyash based geopolymer concrete are the best alternatives for conventional concrete.

I.

Mehme eren gulsan et al. (2019) discussed the work on effect of nano-silica and steel fiber on the fresh and hardened state performance of self compacting geopolymer concretes. They have investigated that incorporation of nano-silica (0%,1%,2%) and steel fiber (0%,0.5%,1%) affected the fresh state properties. A combined utilization of them improved bond strength and flexural performance of the self compacting geopolymer concrete. In addition, the effect of nano-silica was found to be dominant on fresh state properties and compressive strength, while the effect of steel fiber was found to be superior on flexural performance and bonding strength.

Patel and Niraj Shah.(2018) described the work on effect of temperature curing and ambient curing on mechanical properties of Self Compacting Geopolymer Concrete.They have the effect of percentage (0, 5, 15 and 25%) replacement of Rice Husk Ash on the properties of Self Compacting Geopolymer Concrete. The optimum percentage replacement of Rice Husk Ash with Ground

Granulated Blast Furnace Slag is 5% at ambient curing and 15% at 70 °C temperature curing. The higher strength is obtained at 70 °C temperature curing than at ambient.

Patel and Niraj Shah (2018) evaluated the effect of Fresh and Mechanical properties of Self Compacting Geopolymer Concrete. The Self-compacting Geopolymer concrete was developed using Ground Granulated Blast Furnace Slag as the primary binder and Ground Granulated Blast Furnace Slag was replaced with 5%, 15% and 25% of Rice Husk Ash. Self compacting geopolymer concrete blended with 100% Fly Ash failed to achieve the required strength at 3, 7 and 28 days at ambient temperature due to incomplete geopolymerization process without heat. The compressive strength, split tensile strength, and flexural strength of self compacting geopolymer concrete is improved up to 5% replacement of Rice Husk Ash with compared to control mix at all ages.

Saad Al-Rawi and Nildem Tayşia (2018) discussed the work on impact of Steel Fiber and Ground Granulated Blast Furnaces slag content on the fresh and hardened properties of fly ash based Self-Compacting Geopolymer Concrete. Two series of self-compacting geopolymer concrete were formulated with a constant binder content of 450 kg/m3 and at an alkaline-to-binder (a/b) ratio of 0.50. Fly ash was substituted with Ground Granulated Blast Furnace Slag with the replacement levels being 0%, 25%, 50%, 75%, and 100% by weight in each Self-compacting Geopolymer concrete series. The increasing the amount of Ground Granulated Blast Furnace Slag on the mixes had a negative effect on the fresh properties. In addition, using of Ground Granulated Blast Furnace Slag in the mixes of SCGC significantly improved the compressive strength.

Anusha and Dheekshith (2017) The studies on Compressive strength of Geopolymer concrete made with replacing cement by Ground Granulated Blast furnace Slag(GGBS) shows decrease at lesser percentages of replacement of 10% and 15%. A slight increase in strength is observed with 20% replacement of cement with GGBS. A significant increase in compressive strength is observed when 25% of cement is replaced with GGBS. Comparison of the strengths of conventional concrete and Geopolymer concrete shows that even though geopolymer concrete cannot be treated as equivalent to concrete with ordinary Portland cement, presence of some percentage of GGBS up to 25% can yield the required strength. As GGBS is available almost free of cost, replacing cement with GGBS will definitely reduce the cost of producing concrete. This will also reduce the burden of disposal of GGBS produced at the steel plants. The use of eco-friendly GGBS as a replacement to cement shall also reduce the effects of CO_2 emission on the environment during the production of cement.

Suresh.G.Patil and Manojkumar(2017) reported in his paper to study effects of several factors on th.e properties of fly ash based geopolymer concrete on the compressive strength and alsi the cost comparison with the normal concrete. The test results indicated that the highest compressive strength 54Mpa was observed for 16M of NaOH, ratio of NaOH to Na_2Sio_3 2.5 and alkaline liquid to fly ash ratio of 0.35, lowest compressive strength of 27Mpa was observed for 8M of NaOH ratio of NaOH to Na2Sio3 is 1 and alkaline liquid to fly ash ratio of 0.40.

Matghew Sudhakar and Natarajan (2017) presented the increase of GGBS content, Compressive Strength is gradually increases. In this Coal Ash and GGBS Combination is taken along with 15M Alkaline Solution and total replacement of about 30% is taken into consideration and Higher Compressive Strength up to 57Mpa is achieved .However the cost of GGBS added Geopolymer is 7% Higher than OPC but when we Consider Strength aspect, it is almost 3 times than OPC at 7 days.

Ganapati Naidu.etl (2017) presented in this paper to study strength properties of geopolymer concrete using low calcium fly ash replacing with slag in 5 different percentages. Higher concentrations of GGBS result in higher compressive strength of geopolymer concrete 90% of compressive strength was achieved in 14 days.

J.Srinivas1, B.Prakash (2016) GGBS blended FA based GPC mixes attained enhanced mechanical properties at ambient room temperature curing itself without the need of heat curing as in the case of only FA based GPC mixes. The increase in GGBS replacement in GPC mixes enhanced the mechanical properties at ambient room temperature curing at all ages. Keeping in view of savings in natural resources, sustainability, environment, production cost, maintenance cost and all 7 other GPC properties, it can be recommended as an innovative construction material for the use of constructions.

P. Ukesh Praveenet al. (2016) GGBS blended FA based GPC mixes attained enhanced mechanical properties at ambient room temperature curing itself without the need of heat curing as in the case of only FA based GPC mixes. The replacement of sand with slag and quarry dust in GPC mixes enhanced the mechanical properties at ambient room temperature curing at all ages. Keeping in view of savings in natural resources, sustainability, environment, production cost, maintenance cost and all other GPC properties, it can be recommended as an innovative construction material for the use of constructions.

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P Abhilash, C. Sashidhar and I.V.Ramana Reddy (2016) explained about the GGBS blended FA based GPC mixes attained enhanced mechanical properties at ambient room temperature curing itself without the need of heat curing as in the case of only FA based GPC mixes. Fly ash based GPC mixes have attained comparable values of mechanical properties at ambient room temperature curing at all ages to normal Strength. Keeping in view of savings in natural resources, sustainability, environment, production cost, maintenance cost and all other GPC properties, it can be recommended as an innovative construction material at low cost for the use of constructions. Though 100% Fly ash exhibited decrease in strength, it maintains the strength. The cost is also low compared to the 50% GGBSand 50% Fly ash.

Sashidhar (2016) conducted research on GGBS blended FA based GPC mixes attained enhanced mechanical properties at ambient room temperature curing itself without the need of heat curing as in the case of only FA based GPC mixes. The replacement of sand with slag and quarry dust in GPC mixes enhanced the mechanical properties at ambient room temperature curing at all ages. Keeping in view of savings in natural resources, sustainability, environment, production cost, maintenance cost and all other GPC properties, it can be recommended as an innovative construction material for the use of constructions.

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GPC properties, it can be recommended as an innovative construction material for the use of constructions.

Prasanna Venkatesan and Pazhani (2015) examined the strength and durability properties of Geopolymer concrete prepared using Ground Granulated Blast Furnace Slag and Black Rice Husk Ash. Black Rice Husk Ash was replaced with Ground Granulated Blast Furnace Slag at various proportions such as 10%, 20% and 30%. In addition of Black Rice Husk Ash beyond 10% had a retarding effect on the compressive strength. Although upto 20% replacement,the target compressive strength was surpassed and strength was reached at 28 days.

Ammar Motorwala (2013) conducted the experimental study in which he thoroughly studies about the structural behaviour of fresh fly ash using geopolymer the main objective of his study was to find the parameters and various concentrations of alkaline solutions that totally contribute the strength especially the compressive strength. He also concluded the fact that strength is completely depended on the molarity. He did curing under sunlight and found the compressive strength to be 17N/mm2. He also concluded the fact that flash is bit expensive and hence it was used in limited quantity. Instead of it, geopolymer concrete is taken in order. He concluded the fact that geopolymer concrete will be a revolutionary product in constructional field The compressive strength of the material formed by using geopolymer and GGBS increases as more the Geopolymer more will be the strength. Addition of Fly ash more than 3% will be will deteriorate the structure. Acid resistance of structure made from Geopolymer is high as compared to Ordinary Portland cement.

Memon et al. (2013) conducted experiments by varying the concentration of sodium hydroxide from 8 M to 14 M. Test methods such as Slump, flow; V-Funnel, L-box and J Ring were used to assess the workability characteristics of SCGC. The test specimens were cured at 70°C for a period of 48 hours and then kept in room temperature until the day of testing. Compressive strength test was carried out at the ages of 1, 3, 7 and 28 days. Test results indicate that concentration variation of sodium hydroxide had least effect on the fresh properties of SCGC. With the increase in sodium hydroxide concentration, the workability of fresh concrete was slightly reduced; however, the corresponding compressive strength was increased. Concrete samples with sodium hydroxide concentration of 12 M produced maximum compressive strength.

Voraa and Dave (2013) cast 20 geopolymer concrete mixes to evaluate the effect of various parameters affecting its compressive strength in order to enhance its overall performance. Various parameters i.e. ratio of alkaline liquid to fly ash, concentration of sodium hydroxide, ratio of sodium silicate to sodium hydroxide, curing time, curing temperature, dosage of superplasticiser, rest period and additional water content in the mix have been investigated. The test results show that compressive strength increases with increase in the curing time, curing temperature, rest period, concentration of sodium hydroxide solution and decreases with increase in the ratio of water to geopolymer solids by mass 10 and admixture dosage respectively. The addition of naphthalene based superplasticiser improves the workability of fresh geopolymer concrete. It was further observed that the water content in the geopolymer concrete mix plays significant role in achieving the desired compressive strength.

Lohani (2012) conducted the experimental study using fly ash with 0.5% carbon content. He made the specimen of M20 and M25 grade concrete. As an environmental concerned researcher, he conducted a comparative study of ordinary Portland cement with geopolymer concrete. In his study, he made shocking revelations about the environmental concerns of various pollution-related parameters. In his study, he clearly figured out the way that industries are causing way too much of pollution which is not only causing damage but harming the environment in the most decent way. In his study only he concluded the fact that 7 cement only is causing 9.78% of the world's pollution. He sated the fact that indeed the pollution content is very low but still can be very harmful in the upcoming future. With his comparative study, he concluded the fact that geopolymer is of great fire resistance as compared to geopolymer concrete. Also, he stated the fact that geopolymer is far better than ordinary Portland cement in terms of compressive strength. The most important aspect that he figured out that the geopolymer are cost-efficient, i.e. the cost of building reduced if we use geopolymer concrete. It is not only cost effective but also durable as compared to the structures which are made up of OPC. He also claimed that Geopolymer concrete is corrosion free.

Fareed Ahmed Memon et al. (2012) investigated the effect of superplasticizer and amount of extra water on strength and workability properties of Fly ash-based Self compacting geopolymer concrete. The experiments were conducted by varying the amount of extra water (10% to 20%) and dosage of superplasticizer (3% to 7%). The increase in amount of extra water and superplasticizer, the workability was improved. However, the addition of water beyond 15% resulted in bleeding, segregation and decreased the compressive strength of the concrete.

Patankar and Jamkar (2012 found that the compressive strength decreases with increases in replacement of cement by fly ash. Up to 40% replacement of cement, initial strength is less but strength at 60 days of curing is more or less similar to that of conventional concrete at 28 days of curing. Beyond 40% replacement of cement, workability and strength has been reduced and setting time increased. Beyond 60% replacement of cement, increases the water 11 demand, difficulty in mixing, more time required for demoulding of cubes and rate of gain of strength is observed.

Satish Kumar et al. (2012) found that the density of geopolymer concrete composite was found approximately equivalent to that of conventional concrete. In geopolymer concrete composite there is increase in compressive strength, flexural 7 strength, and split tensile strength up to fiber percentage of 0.02% by volume of concrete with respect to geopolymer concrete.The factors that influence the early age compressive strength of geopolymer concrete such as molarities of sodium hydroxide are presented by Bhosale and Shinde (2012). The mechanism of activation of fly ash with alkaline solution is also described. Alkaline activator was used as sodium hydroxide and sodium silicate solution. The comparison of ratio Na_2SiO_3 and NaOH at the values 0.39 and 2.5 were studied test were conducted to check mechanical properties of geopolymer concrete such as compressive strength, split tensile strength, flexural strength, rebound hammer test, acid resistant test for ambient temperature and oven dry temperature. From test result it was observed that compressive strength was more for oven dry temperature as compare to ambient temperature. Also it was observed that compressive strength increases as increase in molarities of sodium hydroxide.

Patankar et al. (2012) study about the changes the quantity of water in mixture without disturbing the mix proportion and tested the mechanical properties of fresh concrete and hard concrete. It is observed that the flow of geopolymer concrete increases with increase in waterto-geopolymer binder ratio by maintaining other parameters constant. Means higher ratio gives segregated mixture while lower ratio gives viscous and dry mixture. Also it is observed that compressive strength of geopolymer concrete decreases as ratio of water-to-geopolymer binder increases. And it is reported that the suitable range of water-to-geopolymer binder ratio was in between 0.24 to 0.35. By reducing the mean particle size of the fly ashes from 30 µm to below 10 µm, substantial improvement in the flow and strength properties of mortars and concrete are achieved by Chaterjee but the enhancement of properties corresponding to further reduction of fly ash particle size to even 3-5 µm is either incommensurate or inconsistent.

Fareed Ahmed et al. (2011) have studied the compressive strength and workability characteristics of low-calcium fly ash based self compacting geopolymer concrete. They have studied effect of extra water, curing time and curing temperature of self compacting geopolymer concrete. The addition of extra water improved the workability characteristics of concrete mixtures. Concrete specimens cured at 70°C produced the highest compressive strength as compared to specimens cured at 60°C, 80°C and 90°C.

Fareed Ahmed Memon et al. (2011) investigated the effect of curing conditions on the compressive strength of self-compacting geopolymer concrete. The experiments were conducted by varying the curing time and curing temperature in the range of 24-96 hours and 60-90°C respectively. Concrete specimens cured at 70°C produced the highest compressive strength and increase in compressive strength with the increase in curing time.

Muhd Fadhil Nuruddin et al. (2011) described the work on Effect of mix composition on workability and compressive strength of self-compacting geopolymer concrete. The premixing of alkaline solution, super plasticizer, and extra water before being added to the dry mix of concrete has successfully improved the workability and strength. In 48 h and 70 °C of heat curing, 12% addition of extra water to the mixture with water-to-geopolymer solids ratio of 0.33 could improve concrete compressive strength.

Fadhil Nuruddin et al. (2011) have studied the effects of super plasticizer and molarity of sodium hydroxide alkaline solution on the workability, microstructure and compressive strength of self compacting geopolymer concrete The parameters studied were super plasticizer dosage and molarity of NaOH solution. An increase in strength and a decrease in workability of these concrete samples were examined with the increase in molarity of NaOH solution from 8M to 14M. NaOH Concentration of 12M and super plasticizer dosage of 6% produced satisfactory performance.

Raijiwala (2011) discussed with the process of making geopolymers from thermal power plants using fly ash. He briefly discussed the various properties of geopolymers using fly ash and GGBS. He was into the fact that geopolymers are completely resistant from chemical attacks. Also in his studies, he concludes the fact the geopolymer concrete has higher compressive strength by the addition of fly ash. He concluded the fact by doing the experiment in which two specimens was taken and cured and heated at 25 and 60 degree Celsius in the oven. With these specimen, he studied the geopolymer's characteristics such as compressive strength, curing temperature, the effect of wet mixing time, the slump of concrete, the effect of superplasticizer, etc. He gave the conclusions that compressive strength is increased by 1.5 times and split tensile strength. His paper completely dealt with the fact that geopolymer shows various kinds of properties which is the need of the hour to design more substitutional materials which can replace cement to some extent helping in the eco-friendly environment.The compressive strength and split tensile strength of geopolymer concrete decrease with increasing FA content in the mix irrespective of curing periods. For a given proportion of a mix, the compressive strength and split tensile strength increase with age. The compressive strength and split tensile strength of geopolymer concrete is maximum for the FA0-GGBS100 irrespective of curing period. The rate of gain in compressive strength and split tensile strength of geopolymer concrete is very fast at 7 days curing period and the rate gets reduces with age. Geopolymer concrete can be recommended as an innovative construction material for the use of the use of construction.

III. Methodology

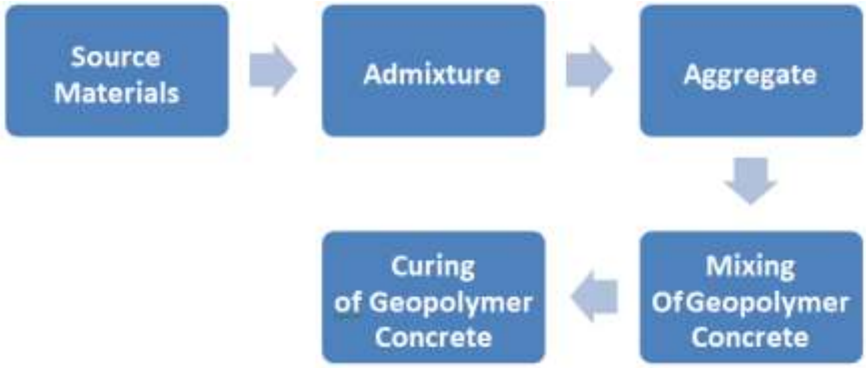

Figure 3.1 – Preparation of Geopolymer Concrete

3.1 Source Materials

The materials used for making geopolymer concrete specimens are alkaline liquids, aggregates, water, and low-calcium fly ash.

3.1.1 Alkaline Liquid: Generally alkaline liquids were prepared by mixing the sodium hydroxide solution and sodium silicate at room temperature. When the solution is mixed both solutions start to react, it is recommended to use it in the next 36 hours.

3.1.2 Sodium Silicate: The advantages of sodium silicate adhesives include their ability to expand and make contact; a controllable index adjustment across broad ranges; and the formation of a rigid layer that is a strong, permanent seal resistant to tearing, bugs (i.e., pests) and moderately resistant to heat and water. They are used for paper, wood, metal, sheet metal and other materials, except plastic.

3.1.3 Sodium Hydroxide: The sodium hydroxide used was in the flakes form with 99% purity.

Table3.1: Chemical ingredients of sodium hydroxide

Chemical ingredients	Per cent
Carbonate	2%
Chloride	0.01%
Sulfate	0.05%
Potassium	0.1%
Silicate	0.05%
Zinc	0.02%
Iron	0.002%

3.1.4 Aggregates: For this Project work, locally available aggregates, comprising 20 mm and 14 mm coarse aggregates, in dry surface conditions were used. Locally available river sand was used as fine aggregates.

3.1.5 Water: The water used for the preparation of the solutions was mineral water. Water was used only for the preparation of sodium hydroxide solution.

3.1.6 GGBS: The GGBS was obtained from quenching molten iron slag from a blast furnace in water or stream, to produce a glassy, granular product that is then dried and ground into a fine powder.

3.2 Mixture Proportion: The development and manufacture of geopolymer concrete took place at Curtin University when the present work was undertaken. Some results of that study which had already been published by several authors were referred. Based on that study, mixture proportions were formulated. For preparing the following mixture proportion IS 456 was used.

Table No. 3.2 Mixture Proportion for 8 Molarity of NaOH for one Specimen

Materials	Quantity
GGBS	1.5 kg
Fine Aggregate(Sand)	2.25kg
Coarse aggregate	4.5 kg
Sodium silicate solution	450 ml
Sodium Hydroxide Solution	167 ml
Potable water	520 ml

3.2 Curing :

Curing of concrete must begin as soon as possible after placement and finishing and must continue for a reasonable period as per the relevant standards, for the concrete to achieve its desired strength and durability. Uniform temperature should also be maintained throughout the concrete depth to avoid thermal shrinkage cracks. Also, protective measures to control moisture loss from the concrete surface are essential to prevent plastic shrinkage cracks.

IV. Conclusions

The conclusions based on the limited observations from the state of art on properties of fresh properties of GGBS based concrete are:

1. Mechanical properties such as compressive strength, split tensile strength and flexural strength shows increasing trend with the decrease of metakaolin.
2. Mix with GGBS seems to have good compressive, split and flexural strengths, this may be due to increase in alkaline reaction between GGBS particles.
3. Nearly 90% of total strength of GPC is achieved within the age of 7days.
4. Then increase in strength of GPC between 7days and 28days appeared to be high when compared with 3days and 7days.It shows that even after 7days geopolymer reaction is taking place but at a higher rate.

References

[1] B. Sarath Chandra Kumar, and K. Ramesh. "Analytical Study on Flexural Behavior of Reinforced Geopolymer Concrete Beams by ANSYS." IOP Conference Series: Materials Science and Engineering. Vol. 455, Issue 1, 2018.
[2] B. Sarath Chandra Kumar, K. Ramesh and P. Poluraju. "An Experimental Investigation on Flexural Behavior of GGBS and Metakaolin Based Geopolymer Concrete," ARPN Journal of Engineering and Applied Sciences, Vol. 12, Issue 7, 2017, pp. 2052-2062.
[3] Annapurna, Ravande Kishore, A Study on the microstructure of GGBS and Fly Ash based Geopolymer concrete, Seventh international conference on Recent Engineering And
[4] Technology (ICRET 2017), Hyderabad, April 7, 2017
[5] Mary Sowjanya, Annapurna, Ravande Kishore, Grade designation of Fly Ash and GGBS based Geopolymer concrete, 1st National Conference on Advances of Construction Engineering for Sustainability, ITS, Hyderabad, October 6, 2017
[6] D. Sravanthi, B. Sarath Chandra Kumar, Y. Himath Kumar (2019), "Experimental Study on GGBS based on Geopolymer Concrete", Proceedings.

[7] G. Srinivasa Rao and B. Sarath Chandra Kumar (2019), "Experimental Investigation of GGBS based Geopolymer Concrete with Steel Fibers", International Journal of Recent Technology and Engineering (IJRTE), (ISSN 2277-3878), Volume 07, Issue 6C2, pp. 49–55.
[8] N. Sai Kiran, Y. Himath Kumar and B. Sarath Chandra Kumar (2019), "Experimental Investigation on Reinforced Geopolymer Concrete Slabs", International Journal of Recent Technology and Engineering (IJRTE), (ISSN 2277-3878), Volume 07, Issue 6C2, pp. 248–254.
[9] M. Ratna Srinivas, Y. Himath Kumar and B. Sarath Chandra Kumar (2019), "Studies on Flexural Behavior of Geopolymer Concrete Beams with GGBS", International Journal of Recent Technology and Engineering (IJRTE), (ISSN 2277-3878), Volume 07, Issue 6C2, pp. 199–205.
[10] G. Kranthi Kumar and B. Sarath Chandra Kumar (2019), "Study on Structural Behavior of RC Sandwich Deep Beam", International Journal of Recent Technology and Engineering (IJRTE), (ISSN 2277-3878), Volume 07, Issue 6C2, pp. 73–78.
[11] Ch. Sravan Kumar Reddy, B. Sarath Chandra Kumar and SS. Asadi (2019), "Utilization of Low Density Polyethylene Waste in the Manufacturing of Paver Brick", International Journal of Recent Technology and Engineering (IJRTE), (ISSN 2277-3878), Volume 07, Issue 6C2, pp. 62–67.
[12] Sujit Kumar, Puru Deep Gautam, B. Sarath Chandra Kumar (2019), "Effect of Alkali Activator Ratio on Mechanical Properties of GGBS based Geopolymer Concrete", International Journal of Innovative Technology and Exploring Engineering (IJITEE), (ISSN 2278-3075), Volume 08, Issue 12, pp. 947–952.
[13] I. Jaffery, Y. Himath Kumar and B. Sarath Chandra Kumar (2017),"Study on Strength And Durability Parameters of Geopolymer Concrete with GGBS For 12M and 14M Alkali Activators", ARPN Journal of Engineering and Applied Sciences, (ISSN 2321-1814), Volume 12, Issue 04, February 2017, pp. 1202-1212.
[14] S. Sai Sandeep, Sk. Kalesha,Y. Himath Kumar and B. Sarath Chandra Kumar (2017), "Effect of Molarity on Compressive Strength of Geopolymer Mortar with GGBS and Metakaoline". International Journal of Civil Engineering and Technology, (ISSN 0976-6308), Volume 08, Issue 04, pp. 935-944.
[15] K. Nagendra Reddy, K. Surya Narayana, J. Damodhar Reddy, B. Sarath Chandra Kumar and Y. Himath Kumar (2017), "Effect of Sodium Hydroxide and Sodium Silicate Solution on Compressive Strength of Metakaolin and GGBS Geopolymer", International Journal of Civil Engineering and Technology, (ISSN 0976-6308), Volume 08, Issue 04, pp. 1905-1917.
[16] B. Sarath Chandra Kumar, K. Ramesh and P. Poluraju (2017), "An Experimental Investigation on Flexural Behavior of GGBS and Metakaolin based Geopolymer Concrete", ARPN Journal of Engineering and Applied Sciences, (ISSN 2321-1814), Volume 12, Issue 07, pp. 2052-2062.
[17] G. Adisekhar and B. Sarath Chandra Kumar (2017), "Effect on Flexural Strength of Reinforced Geopolymer Concrete Beams by using GGBS, Metakaolin and Alkaline Solution", International Journal of Civil Engineering and Technology, (ISSN 0976-6308), Volume 08, Issue 05, pp. 175–188.
[18] B. Sarath Chandra Kumar and K. Ramesh (2017), "Flexural Behaviour of Reinforced Geopolymer Concrete Beams with GGBS and Metakaolin", Global Journal of Engineering Science and Researches, (ISSN 2348-8034), Volume 4, Issue 10, October 2017, pp. 119-128.
[19] B. Sarath Chandra Kumar, Sadasivan Karuppusamy, K. Ramesh (2019), (2019), "Correlation between Compressive Strength and Split Tensile Strength of GGBS and MK Based Geopolymer Concrete using Regression Analysis", Journal of Mechanics of Continua and Mathematical Sciences, (ISSN 0973-8975), Volume 14, Issue 1, pp. 21-36.