Geopolymer Concrete – A Look Over

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Abstract - ***Geopolymer technology mainly aims in total replacement of Portland cement. Geopolymer concrete is gaining its popularity globally as a construction material. This technology was coined by Professor Joseph Davidovits. Geopolymers mainly uses alkaline activators such as silicates of potassium or sodium and hydroxides of potassium or sodium along with industrial by-products like ground granulated blast furnace slag (GGBS), fly ash etc. The alkaline activator liquid used in geopolymer concrete undergoes geopolymerization and then reacts with by-products of industries and produces binding property and binds the aggregates. In this study fresh property, hardened property, durability properties and microstructure studies of different mineral admixture based geopolymer concretes are discussed based on different curing conditions and molarity.***

Key Words: *Total replacement of Portland cement, alkaline activators, industrial by-products, geopolymerization.*

1. INTRODUCTION

The demand for cement as material of construction is rapidly increasing day to day. Cement manufacturing industry mainly emits carbon di-oxide (CO2), this greenhouse gas causes global warming in the atmosphere. Cement manufacturing industries emits about 7-8% of greenhouse gas into atmosphere. Hence to arrest various environmental pollution caused by cement industries various researches have been conducted in replacing cement, like including waste materials and by-products of industries as supplementary cementitious materials such as rice husk ash, saw dust, metakaolin, silica fume, ground granulated blast furnace slag (GGBS), fly ash etc.

Geopolymer concrete is a special concrete which completely replaces the use of Portland cement. Thus CO2 emission by cement manufacturing industries can be reduced by implementing geopolymer concrete. Chemical composition of geopolymer is same as zeolite and its nature of structure is amorphous. The alumina and silica present in industrial by-products reacts with alkaline liquid and produces binding property. Alkaline liquid used in geopolymerization is combination of sodium hydroxide (NaOH) or potassium hydroxide (KOH) and sodium silicate (Na2Sio3) or potassium silicate (K2Sio3) is most common. This combination of alkaline liquid accelerates the rate of reaction.

2. NECESSITY OF GEOPOLYMER CONCRETE

Cement manufacturing industries produces 3×109 tons of cement per year and this production will be soon increased to 25% within 10 years. It is seen that one ton CO2 is released into the atmosphere during manufacturing of one ton of cement. Consumption of energy is high during manufacturing of cement. The main ingredient of OPC is lime stone and it is visualized that shortage of limestone will occur within 50 years.

Ground granulated blast furnace slag (GGBS) is a by-product obtained during manufacturing of wrought iron or pig iron and Fly ash is residue generated by coal combustion which are drive out of the boilers, these industrial by-products requires large area for dumping and when dumped in large areas the minute particles are carried by wind, this may cause various ill effects on people leaving close to landfill area hence to eliminate ill effects on people and to reduce the landfill, these by-product can be used to produce geopolymer concrete instead of leaving it as dead material.

Hence in order to reduce the above ill effects and environmental hazards geopolymer concrete becomes a necessary material of construction.

3. MATERIALS REQUIRED FOR GEOPOLYMER CONCRETE

- *Cementitious binder.*

Various industrial by-products and naturally available materials can be used to produce geopolymer concrete. Commonly used cementitious binders are fly ash, GGBS, metakaolin, rice husk ash, etc.

- *Alkaline activators.*

Alkaline activators are the important ingredient of geopolymer mix, it undergoes geopolymerization and gives binding property by igniting the Al and Si present in the cementitious binder. It mainly uses high pH activators like combination of sodium hydroxide or potassium hydroxide and sodium silicate or potassium silicate.

- *Aggregates.*

Aggregates used to produce geopolymer concrete should be chosen and tested as per IS standards.

4. LITERATURE REVIEW

V.Supraja, M.Kanta Rao carried out experimental study on geopolymer concrete by incorporating only GGBS. In this study sodium hydroxide and sodium silicate were used as alkaline activators and different molarities of sodium hydroxide were prepared i.e.; 3M, 5M, 7M, 9M. In this work 100 × 100 × 100 mm cubes were casted and these specimens were subjected to two different types of curing (oven curing at 500C and sunlight curing). The casted and cured specimens were then tested for compression at 3 days and 7 days. It was observed that oven cured specimens had no significant increase in strength after 3 days, but oven cured specimens gad high strength when compared to sunlight cured specimens. It was observed that strength of geopolymer concrete increased with increase in molarity of sodium hydroxide solution.

Ganapati Naidu. P, A.S.S.N Prasad, S. Adiseshu, P.V.V. Satayanarayana studied the strength properties of geopolymer concrete by using low calcium fly ash (Class F) and replacing it with GGBS in five different percentages. Sodium hydroxide of 8M with sodium silicate was used as alkaline activators. In this test compression test, split tensile test and flexural strength were studied at 3 days, 7 days, 14 days and 28 days. The test specimens were cured under ambient conditions and also oven cured at 500^{0}C for 2 hours, after 2 hours the oven cured samples were kept foe sun drying. Mineralogical analysis was carried out by using XRD, SEM and EDS. The compression strength was high for geopolymer concrete specimens having maximum replacement of fly ash with GGBS. It was observed that there was 25% loss in compression strength for specimens exposed to oven curing at 500^{0}C for 2 hours. The 14 days compression strength was 90% of its 28 days. The density of geopolymer concrete was found to be same as conventional concrete.

U.R. Kawade, P.A. Salunkhe, S.D. Kurhade investigated compression strength of low calcium fly ash (Class F) by keeping constant alkaline activator ratio of 2.5 and mix was designed for different molarities of 12M, 14M, 16M. In this investigation specimens were cured at 60^{0}C for 24 hours and later kept for ambient curing. Compression test was carried at 7 days and 28 days. The strength of specimens increased when molarity was increased. It was observed that compression strength at 7 days was 80-85% of its 28 days.

Shankar H. Sanni, R.B.Khadiranaikar presented experimental investigation on mechanical properties of fly ash based geopolymer concrete by varying alkaline activator ratios of 2, 2.5, 3, 3.5 and molarity of 8M was set as constant. The different grades preferred for this work were M30, M40, M50, M60. The test specimens used were 150 × 150 × 150 mm cubes and 100 × 200mm cylinders heat cured at 60^{0}C in oven. It was observed that the mix was cohesive and workability increased with increase in alkaline activator ratio. Workable flow of geopolymer concrete was found to vary from 58-145 mm. alkaline activator ratio of 2.5 was taken as optimum as it had high compression strength and split tensile strength.

Raijiwala D.B, Patil H.S. Sankalp dealt with different properties of Class F fly ash geopolymer concrete. Combination of potassium hydroxide and sodium hydroxide of equal percentages along with sodium silicate were used as alkaline activators. Various tests like compression test, split tensile test, flexural test, pullout test and durability tests were studied at 1 day, 7 days, 14days, 28days. Curing was carried at 60^{0}C, 80^{0}C, 100^{0}C in oven by wrapping the specimens with polythene covers for 24 hours and later kept for ambient curing. Durability test was conducted by immersing the cube specimens in 3.5% NaCl solution and 5% $MgSo_4$ solution. The loss in weight was weighed at 1 day, 7 days, 14 days, 28 days, 56 days. The strength properties mainly depend on alkaline activator to cementitious binder (fly ash) ratio, molarity, alkaline activator ratio and curing temperature.

M.F. Nuruddin, A.Kusbiantoro, S. Qazi, M.S. Darmawan, N.A. Husin conducted research by using fly ash and microwave incinerated rice husk ash (MIRHA), fly ash was replaced by MIRHA in percentages of 3, 5, 7. Different curing such as hot gunny curing, ambient curing and external exposure curing was practiced. Sodium hydroxide of 8M concentration and sodium silicate were used to prepare test specimens for compression test and microstructure properties at 3 days, 7 days, 28 days, and 56 days. External exposed specimens had high strength when compared to other two types of curing. Scanning electron microscopy also showed better improvement in interfacial transition zone for external exposure samples.

Prof. More Pratap Kishanrao used equal proportions of fly ash and GGBS to prepare geopolymer concrete specimens. Depending on trials a satisfactory mix design having a good workability and strength was proposed. In this work 100 ×100 × 100 mm cube specimens were tested for compressive strength at 7 days and 28 days. Specimens were cured in oven in varying temperatures form 100^{0}C-500^{0}C. It was observed that 7 days strength was found to be 60-70% of 28 days strength. Loss of weight of specimens were noticed when temperature was varied from 250^{0}C-500^{0}C. Geopolymer concrete mixes were found to have high viscosity and cohesiveness with low slumps and initial was more than 30 minutes and final setting time was within 600 minutes.

BapugoudaPatil, Veerendra Kumar, Dr.H. Narendra prepared geopolymer samples by implementing fly ash, GGBS and pond ash in different proportions. In this research study river sand was replaced by M-sand, as its properties are same as river sand. Specimens were casted and cured under ambient conditions for compressive strength test and durability tests. Compressive strength test was carries at 7 days, 14 days, and 28 days. It was noticed that the 7 days strength was 70-80% of 28 days strength. Durability tests such as saturated water absorption test, fire resistance test, acid resistance test, chloride and sulphate resistance tests were carried out. In acid resistance test, the deterioration of specimens was low when immersed in HCl solution. In chloride and sulphate resistance test, the specimens gained weight when immersed in NaCl solution and $MgSO_4$ solution respectively. In fire resistance test, combination of fly ash and GGBS based specimens showed good resistance at 300^0C and 600^0C in both water and air cooling, but pond ash based specimens showed low resistance. In 28 days saturated water absorption test, it was observed that specimens had good resistance as they were less porous. Thus we can say geopolymers have a relative high strength, excellent volume stability and a better durability.

5. IMPORTANT PARAMETERS

- *Molarity*

The strength of geopolymer concrete mainly depends on molarity It describes the concentration of hydroxide solution. Increase in molarity increases the strength of geopolymer concrete. It is expressed in terms of moles (M).

- *Alkaline activator to cementitious binder ratio*

This ratio determines the cementitious binder content in geopolymer mix. Decrease in this ratio increases the cementitious binder content and simultaneously increases both strength and workability.

- *Alkaline activator ratio*

It is the ratio of sodium silicate to sodium hydroxide. This ratio varies the activator content in geopolymer mix. Increase in this ratio increases the silicate content in the mix and increases the workability of the mix and decreases the strength.

- *Water to geopolymer solids ratio*

This ratio is same as water to cement ratio in conventional concrete. It is the ratio of all liquid content to all solid content present in the geopolymer mix. Increase in this ratio increases the workability of mix meanwhile it reduces the strength.

6. ADVANTAGES AND DISADVANTAGES

Advantages

- Eco friendly.
- Better compressive strength.
- Low permeability.
- High resistance to abrasion, acid and salt attack.
- Fire proof.

Disadvantages

- Uneconomical, due to high cost of alkaline activators.
- Alkaline activator like hydroxides of potassium and sodium causes ill effects on users.
- Accelerated curing like oven curing, steam curing, etc is very hard to achieve in situ conditions.

7. CONCLUSION

- With the elimination of Portland cement the carbon dioxide emission by cement manufacturing industries can be reduced.
- The industrial by–product can be effectively used to produce geopolymer concrete.
- For any geopolymer concrete mix the workability increases with increase in alkaline activator ratio.
- The mechanical strength properties increase with decrease in alkaline activator to cementitious binder ratio.
- The 7 days strength of geopolymer concrete is 70-80% of its 28 days strength.
- Increase in molarity increases mechanical and durability properties of geopolymer concrete.
- Geopolymer concrete has excellent durability properties.
- Average density of geopolymer concrete is same as conventional concrete.
- As per scanning electron microscopy geopolymer concrete has a better microstructure as there is improvement in interfacial transition zone.
- GGBS based geopolymer concrete has a better compressive strength, resistance to high

temperature, exposure to aggressive environment and is suitable for structural applications.

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