Geo Polymer Concrete

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***ABSTRACT** - The cement industry is the India's second highest payer of Central Excise and Major contributor to GDP. With infrastructure development growing and the housing sector booming, the demand for cement is also bound to increase. However, the cement industry is extremely energy intensive. Concrete is the world's most versatile, durable and reliable construction material.Geo polymer concrete is an innovative construction material which shall be produced by the chemical action of inorganic molecules. Geo polymer results from the reaction of a source material that is rich in silica and alumina with alkaline liquid. It is essentially cement free concrete.Research is shifting from the chemistry domain to engineering applications and commercial production of geopolymer concrete. Geopolymer concrete/mortar is the new development in the field of building constructions in which cement is totally replaced by pozzolanic material like fly ash and activated by alkaline solution. This paper presented the effect of concentration of sodium hydroxide, temperature, and duration of oven heating on compressive strength of fly ash-based geopolymer mortar. Sodium silicate solution containing Na O of 16.45%, SiO of 34.35%, and H O of 49.20% and sodium hydroxide solution of 2.91, 5.60, 8.10, 11.01, 13. and 15.08. Moles concentrations were used as alkaline activators. Geopolymer mortar mixes were prepared by considering solution-to-fly ash ratio of 0.35, 0.40, and 0.45. The temperature of oven curing was maintained at 40, 60, and 120°C each for a heating period of 24 hours and tested for compressive strength at the age of 3 or 7 days as test period after specified degree of heating. Test results show that the workability and compressive strength both increase with increase in concentration of sodium hydroxide solution for all solution-to-fly ash ratios. Degree of heating also plays vital role in accelerating the strength; however there is no large change in compressive strength beyond test period of three days after specified period of oven heating.*

***KEYWORDS** - Geopolymer Concrete, Fly Ash, Strength, Curing, Applications.*

I. INTRODUCTION

Geopolymer materials characterize an innovative technology that is producing considerable interest in the manufacture industry, mainly in light of the ongoing emphasis on sustainability. In contrast to Portland cement, most geopolymer systems rely on nominally processed natural materials or industrial byproducts to offer the binding agents. Subsequently Portland cement is accountable for upward of 85 percent of the energy and 90 percent of thecarbon dioxide attributed to a typical ready-mixed concrete, the probable energy and carbon dioxide savings over the use of geopolymers can be considerable. Subsequently, there is growing interest in geopolymer applications in transportation infrastructure. While geopolymer technology is deliberated new technology has ancient roots and has been postulated as the structure material used in the construction of the pyramids at Giza as well as in other ancient construction. More-over, alkali-activated slag cement is a type of geopolymer that has been in use since the mid-20th century.

Geopolymer Concrete –an advanced material that is categorized by long chains or networks of inorganic moleculesis a potential substitute to conventional Portland cement concrete for use in transportation substructure construction. It trusts on nominally processed natural materials or industrial byproducts to expressively reduce its carbon footprint, while also being very resistant to many of the durability issues that can plague conservative concrete. Though, the development of this material is still in its infancy, and a number of developments are still needed.

The term geopolymer was first coined and invented by Davidovits which was acquired from fly ash as a result of geo-polymerization reaction. This was created by the chemical reaction of alum inosilicate oxides (Si2O5, Al2O2) with alkali polysilicates yielding polymeric Si–O–Al bonds. The geopolymerization process comprises three isolated processes and during initial mixing, the alkaline solution dissolves silicon and aluminum ions in the raw material that is fly ash, slag, silica fume, bentonite, etc. It is also understood that the silicon or aluminum hydroxide molecules undergo a concentration reaction where adjacent hydroxyl ions from these near neighbors condense to form an oxygen bond linking the water molecule and it is seen that each oxygen bond is molded as a result of a condensation reaction and thereby bonds the neighboring Si or Al tetrahedra.

Chemical Structures of Polysialates - Three types of polysialates present in Geopolymers, namely polysialates (-Si-O-Al-O), polysiloxo sialates (-Si-O-Al-O-Si-O)and poly-disiloxosialates (-Si-O-Al-O-Si-O)as depicted in Figure 1.

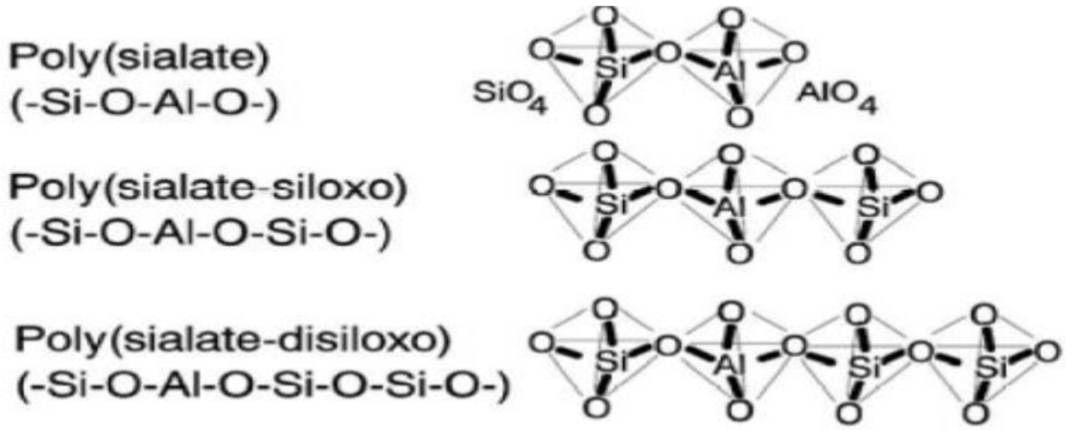

Fig 1.Chemical Structures of Polysialates

II. LITERATURE SURVEY

S. No	Authors	Year	Test conducted	Observations
1	Goretta et al.	2004	Compressive strength.	The response was attributed to material loss by propagation of both lateral and radial cracks and presence of micro cracks and aggregates in the matrix.
2	Bakharev	2005	Compressive strength. FTIR, XRD, and SEM.	An increase of temperature of heat treatment caused a decrease of Si/Al ratios in aluminosilicate gel, and long curing at room temperature narrowed the range of distribution of the Si/Al ratios.
3	Bakharev	2005	Compressive strength.	Fly ash activated by sodium silicate, 6 h heat curing is more beneficial than 24 h heat. Fly ash activated by sodium hydroxide had more stable strength properties.
4	Fernández-Jiménez et al.	2005	Compressive strength.	The particle size distribution and the mineral composition of the starting fly ash, the type and concentration of the activator, and so forth.
5	Duxson et al.	2005	Compressive strength.	This demonstrates that the characteristics of geopolymers can be tailored for applications with requirements for specific microstructural, chemical, mechanical, and thermal properties.
6	Bakharev	2006	Compressive strength, shrinkage measurements, XRD, and SEM.	Geopolymer materials prepared using class F fly ash and sodium and potassium silicate show high shrinkage as well as large changes in compressive strength with increasing fired temperature in the range 800–1200°C.
7	Škvára et al.	2006	Compressive strength.	The hardness of geopolymer is approximately twice higher than for OPC that could indicate less deformability and higher brittleness.
8	Chindaprasirt et al.	2007	Compressive strength.	The samples with a high strength were obtained using the delay time after molding and before subjecting the sample to heat of 1 h with heat

				curing in the oven at 75°C of not less than two days.
9	Kong and Sanjayan	2008	Compressive strength	The strength declined with inclusion of geopolymer/aggregate composites. While aggregates undergo expansion at elevated temperatures, the geopolymer matrix experienced contraction.
10	Temuujin et al.	2009	Compressive strength.	Addition of the calcium compounds CaO and Ca(OH)2 improves mechanical properties and cured at ambient temperature. Calcium compound addition reduces mechanical properties cured at elevated temperatures.
11	Kumar et al.	2010	Compressive strength. FTIR, XRD, and SEM.	Combined effect of particle size and change in reactivity due to mechanical activation altered the geo polymerization reaction. The improvement in physical properties is related to the intrinsic structure developed due to enhanced geopolymerisation.
12	Wongpa et al.	2010	Compressive strength.	Paste content and the aggregate content P/Aggregate of 0.34 and Si/Al of 0.63 showed the highest compressive strength.
13	Jämstorp et al.	2010	Compressive strength.	Samples with pore sizes of about 40 nm, exhibited a satisfying initial release of 60–80% of the API content within 10 h and nearly all within 24 h, as well as fairly high compression strengths of 50–60 MPa.
14	Elimbi et al.	2011	Setting time, linear shrinkage, compressive strength, XRD, and SEM.	Above 700°C, there is an increase of setting time. The compressive strength increases when the calcination temperature of kaolinite clays is between 500 and 700°C but drops above 700°C.
15	Somna et al.	2011	Compressive strength.	Sodium hydroxide-activated ground fly ash cured at room temperature can be produced with reasonable strength. Ground fine fly ash can be used as a source material for making geopolymer cured at ambient temperature.

III. COMPOSITION OF GEOPOLYMER CEMENT CONCRETE MIXES

The Geopolymer concrete was prepared using Fly Ash, Manufacturing Sand, Coarseaggregates, Sodium Hydroxide andSodium Silicate.

3.1 Fly Ash:Fly ash is a byproduct of electricity producing plant using coal as fuel.It is aparticularly fine ash formed from the inorganic mechanisms of the coal that remains after combustion of the carbonaceous part of the coal. Fly ash comprise particles of silica, alumina, oxides of iron, calcium, magnesium and toxic heavy metals like lead, arsenic, cobalt, and copper.Fly ash can be separated into two types according to the calcium content. The ash containing less than 10% CaO iscalled low-calcium fly ash (Class F) and the ash typically containing 15% to 30% of CaO is called high-calcium fly ash (Class C).The Fly Ash of class F which has rich in Silica and Aluminum was obtained from Thermal Power Station, Mettur, Tamil Nadu, India, whose nature of appearance was observed using SEM Analysis and the image is presented in Figure 2.

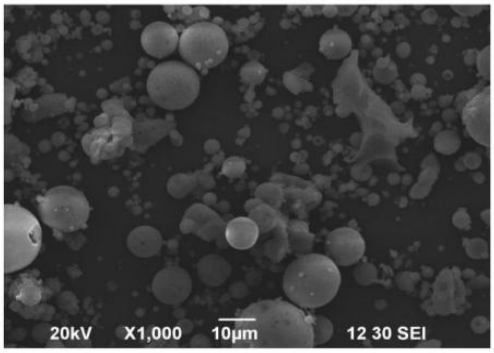

Fig 2. SEM Image of Fly Ash

3.2 Manufacturing Sand: M-Sand is nothing but disturbing of hard stone aggregates to the size of natural sand. The finest particles are detached by washing with water. The M-sand was analyzed using SEM, XRD and EDX.

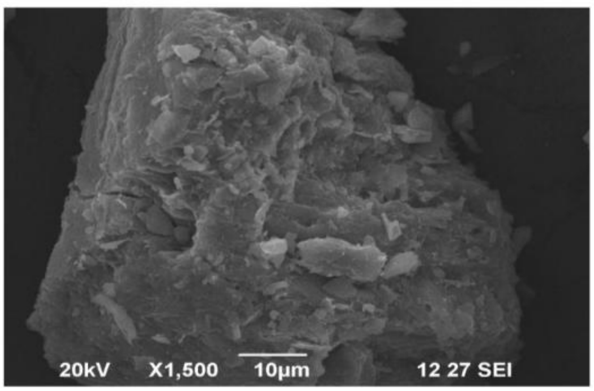

Fig 3. M-Sand

3.3Coarse Aggregates: Coarse aggregates are gained by pulverizing of hard rock stones. Commercial grade of 20 mm size coarse aggregates were collected from M/S Techno Max, Coimbatore, Tamil Nadu, South India and were used as such.

3.4 Sodium Hydroxide Solution: Analytical gradeSodium Hydroxide (NaOH) was obtained from Sigma Aldrich, Bangalore. A solution of molarity 10 was prepared in distilled water and used.

3.5 Sodium Silicate SolutionSodium Silicate (Na_2SiO_3) solution of grade A53containing 29.4% SiO_2, 14.7 % Na_2O and 55.9 % of water was procured from Sigma Aldrich, Bangalore and used as such.

3.6 Mix Design:Abest mix of Flyash, Fine Aggregate& Coarse Aggregate in the ratio of 1:1.5:3.3 as found by Aleem et al.is auxiliary with a solution of suitable composition of NaOH & Na_2SiO_3combined together as commended by Davidovits.The exact quantities of materials for 1m^{3}arepresented in Table-1.

Table 1.Quantity of Materials for 1m^{3}of Geopolymer Concrete

S.No	**MATERIALS**	**Kg/ m^3**
1	Fly ash (Class F)	408.00
2	Fine sand	612.00
3	Coarse aggregate (20mm in size)	1346.40
4	Sodium silicate solution	103.00
5	Sodium hydroxide solution(10 Molar)	41.00

APPLICATIONS: Geopolymer concrete applications is used for bridges such as precast structural elements and decks as well as structural retrofits using geopolymer-fiber composites. Geopolymer technology is most innovative in formed applications due to the qualified ease in handling sensitive materials and the need for a measured high-temperature curing environment mandatory for many current geopolymer. Other potential near-term applications are precast pavers & slabs for paving, bricks and precast pipes.

LIMITATIONS:
The followings are the limitations,

- Fetching the base material fly ash to the required location
- High cost for the alkaline solution
- Protection risk supplementary with the high alkalinity of the activating solution.
- Practical problems in applying Steam curing / high temperature curing process Considerable research is ongoing to develop geopolymer systems that address these technical hurdles.

IV.CONCLUSION

Geopolymer concrete has outstanding properties as discussed earlier so it can be very useful for rehabilitation and retrofitting works. It can also be used in road works because of its very early attainment of strength. The financial benefits and involvement of geopolymer concrete to maintainable development have also been outlined.As because the geopolymer concrete is a whole new concept of structural concrete with a new technology and since no Indian Standards are available so a detailed study on the chemistry behind the polymerization is desired. So a new method can be there rather than the conservative mixing procedure which is obtained for the mixing of geopolymer concrete.

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