STUDY ON THE BEHAVIOUR OF FLY ASH BASED GEOPOLYMER CONCRETE

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ABSTRACT

"Geopolymer is new world for development concrete work ,in which cement is totally replaced by pozzolonic materials like fly ash and activated by highly alkaline solutions to act as a binder in the concrete mix". Mix design procedure is proposed on the basis of quantity and fineness of fly ash, quantity of water, grading of fine aggregate, fine to tottal aggregate ratio. Sodium silicate solution with **Na2O = 16.37%, SiO2 =34.35%, and H2O = 49.28% and sodium hydroxide solution** having 13M, 10M, 15M concentration were obtained throughout the experiment.Water to geopolymer binder ratio of 0.40, alkaline solution / fly ash ratio of 0.35 and sodium silicate / sodium hydroxide ratio of 2 by mass, made on cubes of 150mm measure compressive strength and workability of concrete. The temperature of oven heating is maintained at 60 degre C for 24 h duration , tested 7 days after heating.

Ordinary Portland cement is a major construction material for world. Cement manufacturing industry is one of the carbon dioxide emitting sources besides deforestation and burning of fossil fuels. The global warming is caused by the emission of greenhouse gases, such as CO2, to the atmosphere. Among the greenhouse gases is CO2 contributes about 65% of global warming. The cement industry contributes globally about 7% of greenhouse gas emission to the earth's atmosphere.

Global warming is a threatening issue now a days, cement industry also contributes to CO2 emissions. Construction materials to lessen the carbon emission. Concrete formed by organic and inorganic materials using alkaline solution , it also consumes waste materials product and naturals resources for the production of geopolymer concrete in order to meet global infrastructure developments.

Key words: geopolymer concrete, carbon emission, silicate solution, ambient curing, indusrial waste, agriculture waste.

The combine of (sodium silicate solution + sodium hydroxide solution) is used as alkaline solution for fly ash activation, Alkaline solution to fly ash ratio was varied as (0.45).The concentration of sodium hydroxide solution was maintained as 20M "Molars". The curing condition of geo polymer concrete was varied as ambient curing. The compressive strength, Flexural strength, Split Tensile Strength of the geopolymer concrete

was tested at various such as 3,7,14 and 28 days.

the test results was found that :

1-As the alkaline solution to fly ash ratio increases, the strength of geo polymer concrete also increases.

2-The strength of ambient cured concrete.

3-strength of concrete increases as the curing condition at various

Index Terms- Geopolymer concrete Mix design Fly ash alkaline solution Compressive strength.

1-INTRODUCTION

Concrete is the mostly used construction material that made by best foundations, architectural structures, bridges, roads, block walls, fences and poles. The production of one ton of Portland cement approximately 1 ton of CO2 into the atmosphere. Among the green house gases, CO2 'carbondioxide' contributes about 65% of global warming. The over all evaluated sharing of normal Portland concrete (OPC) generation to ozone harming substance discharges is assessed to be roughly 1.35 billion tons yearly or around 7% of the aggregate green house gas outflows to the earth' s atmosphere. However, the cement industry is extremely energy intensive. After aluminium , steel, the manufacturing of Portland cement is the great energy intensive process as it consumes 4GJ of energy per ton. After thermal power plants for the iron and steel sector, the Indian cement industry is the third largest user of coal in the country. The industry's capacity at the beginning of the year 2008-2009 was about 198 million tones. For housing, infrastructure and corporate capital expenditures the demand of cement in India is expected to grow at 10% annually. Considering an expected production & consumption growth of 9 to 10 %,

The formula of geopolymer was first introduced by Davidovits in 1978 to describe for mineral binders with chemical composition.This property similar to zeolites but with an amorphous microstructure. Unlike ordinary Portland cements, geopolymers do not form

Calcium silicate hydrates (Ca.SO3i.H2O) for matrix formation & strength, but utilize the poly condensation of silica , alumina precursors to attain structural strength. Two main component of geopolymers are source materials and alkaline liquids. The source materials on alumino silicate should be rich in silicon and aluminium . They could be by product materials like a "fly ash, silica fume, slag, rice-husk ash, red mud, etc". Geopolymers are also exclusive in comparison to other alumino silicate materials "e.g. alumino silicate gels, glasses, and zeolites" (Davidovits 1978).

The geopolymer technology may be decrease the total energy demand for producing concrete, lower the carbon dioxide (CO2) emission to the atmosphere caused by cement and aggregates industries by about 80%, thereby reducing the global warming. They possess the profits of rapid electricity gain, removal of water curing, proper mechanical and durability properties and can serve as eco-friendly and sustainable opportunity to ordinary Portland cement concretes (Thokchom et al., may 2006).

2-RAW MATERIAL

Raw materials must constitute a very large portion of Aluminum and Silica, inorganic non-metallic minerals and industrial waste, of which the main active ingredient is aluminum silicate. There are different kinds of raw materials that can be used to produce geopolymer cement like a "fly ash, red mud, metakaolin, natural pozzolan, blast steel slag, rice husk ash, and etc". In this review, the class F fly ash is used to form the geopolymer cement. Geopolymers possess different mechanical & thermal properties due to different raw materials, such as their variable chemical composition, particle size (fineness) and particle shape. Most of the latest research are discovered focusing on the mechanical & thermal properties of the fly ash based geopolymers. It is observed that a higher content of the glass phase will ensure a higher degree of geopolymerization, and thus resulting in a higher compressive strength.

1-Alkali-activators

For the alkali-activators, several choices are adopted. Alkali metal hydroxide (sodium hydroxide), carbonate, sulfate, phosphate, and fluoride (few studies) can be used as the activators

2-NaOH

Sodium hydroxide, also known as lye and caustic soda, is an inorganic compound.Higher NaOH dosages can result in a better workability, higher 3, 7, and 28- day strengths, and shorter demolding time. But too much (excessive) NaOH concentration would adversely affects the strength. The optimal NaOH content depends on other mixture constituents. The concentration of sodium hydroxide (NaOH) liquid measured in terms of Molarity (Mol/L) is better in the range of 8 to 20 M (Mol/L). To check which one influences the properties of the geopolymers more, the Na+ or the OH–, the study by Hardjito (2004) concluded that it is the OH– that influences the compressive strength of the geopolymers most

3-Na2SiO3

The higher ratio of the sodium silicate to the sodium hydroxide liquid by mass, the higher the compressive strength of the geopolymer concrete is. The reason maybe that Na2SiO3 improves the silicon (Si) / aluminium (Al) ratio and hence the compressive strength.

4-Si: Na

Some papers (Hardjito, and Rangan, 2005) mentioned about the increase of Na2O:Si2O3 decreases the compressive strength of geopolymer.

5-Si/Al Ratio

Silica and alumina are the primary precursors for the geopolymeric response, and the ratio of silicon (Si) and aluminium (Al) is the fundamental influence factor for the properties of geopolymer. The Silicon oxide (SiO2) to the aluminum oxide (Al2O3) or SiO2 : Al2O3 ratio by mass in the source material (fly ash) should preferably be in the range of 2.0 to 3.5 to make a good concrete (Si:Al by Mol is equal to 1.733 to 3.033).

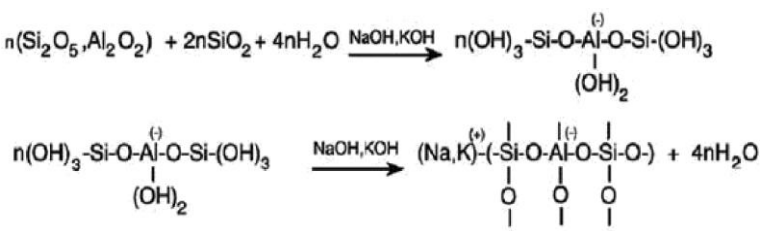
GEOPOLYME:-

In 1978, Davidovits recommended that binders could created by a polymeric reaction of alkaline liquids with the silicon and the aluminum in source materials of geological origin or by-product materials such as fly ash and rice husk ash. These binders were termed as geopolymers, because the chemical reaction that takes place in this case is a polymerization process. geopolymers are members of the family of inorganic polymers.

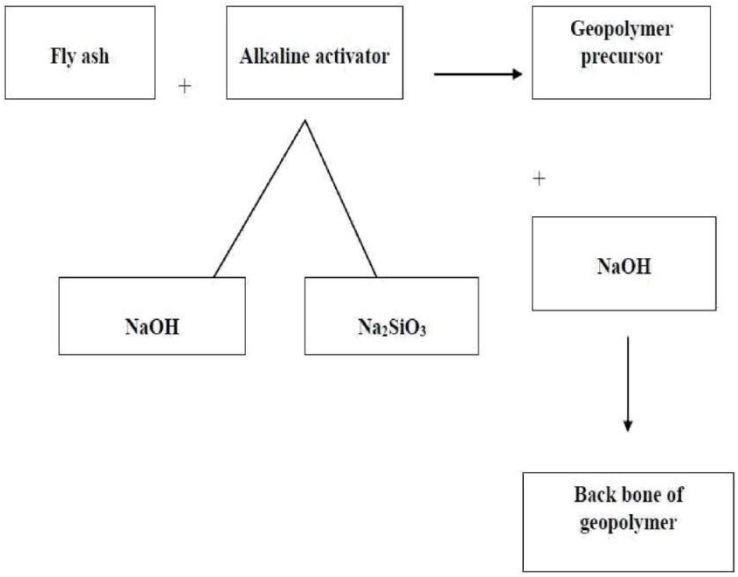
The chemical composition of the geopolymer material is similar to naturalzeolitic

materials, but the microstructure is amorphous instead of crystalline. The polymerization process involves a substantially fast chemical reaction under alkaline condition on Si

minerals, that results in a three dimensional polymeric chain and ring structure consisting of Si-O-Al-O bonds are formed. The schematic formation of geopolymer material can be described by the following equations (Ragan & Hardjito 2006)



Chemical Reaction Of Geopolymer



3-MATERIALS AND THEIR PROPERTIES

The physical and chemical properties

The different type materials use for making fly ash based geopolymer concrete specimens were low calcium fly ash, aggregates, alkaline liquids, extra water and metakolin.

1- Fly ASH

As according to ASTM C- 618, two major classes of fly ash are recognized.
These two classes are related to the type of coal burned and are designated
(a)Class F and (b) Class C in most of the current literature.
(a) Class F fly ash is normally generate by burning anthracite or bituminous coal while
(b) Class C fly ash is generally obtained by burning sub- bituminous or lignite coal. Two type ash discuss
Present Class F fly ash is collected in Vijayawada Thermal Power Station. Class F fly ashes with calcium oxide (CaO) content < 6%, designated as low calcium ashes, are not self hardening but generally exhibit pozzolanic properties.

2-Coarse aggregates

crushed granite stone aggregate of 10mm size was used as coarse aggregate, these is locally available. The coarse aggregate passing through 10mm and retaining 4.75mm was used for experimental work. The properties of coarse aggregates were determined as per IS: 2386- 1963

3-Fine aggregates

The locally available river sand, passing through 4.75 mm was used in this experimental work. The properties of fine aggregates were determined as per IS: 2386- 1963

4-Alkaline solution

A combination of sodium silicate solution (Na2Sio3) + sodium hydroxide solution (NaOH) was used as alkaline solution

Figure-Preparation of NaOH solution

5- Sodium hydroxide

The most common alkaline activator used in geopolymerisation is a combination of sodium hydroxide (NaOH) or potassium hydroxide (KOH) and sodium silicate (Na2Sio3) or potassium silicate (K2 SiO3). The type and concentration of alkali solution affect the dissolution of Pozzolanic material

6-Sodium silicate

Sodium silicate is the popular name for compounds with the formula Na2(SiO2)nO Concrete treated with a sodium silicate solution helps to significantly reduce amount porosity in most masonry products such as concrete. A chemical reaction occurs with the for Ca(OH)2 (portlandite) present in the concrete that permanently bi silicates with the surface, making them far more durable and water repellent .

FIGURE OF MATERIAL

Water Content of Mixture

In ordinary Portland cement (OPC) concrete, water in the mixture or admix chemically reacts with the cement to produce a paste that binds the aggregates In this parameter, the total mass of water + the mass of water contained in the sodium silicate solution, the mass of water in the sodium hydroxide solution, and the mass of extra water added to the mixture.

The mass of geopolymer solids + the mass of fly ash, the mass of sodium hydroxide solids, and the mass of solids in the sodium silicate solution. In this project work, the "water to flyash" ratio was fixed as 0.45 extra water, to find out the influence of other parameters on the strength of Geopolymer concrete.

➢ Metakaolin

Metakaolin (Pozzolanic materials) used in concrete as a binder replaced by cement. Metakaolin is a form of the clay mineral. The particle size of metakaolin is > cement particles, but not as fine as silica fume. 80% of fly ash and 20% metakaolin was used in this experiment work.

Figure- Metakaolin

The alkaline solution was then added to the dry materials and after that the mixing continued for further about 4 minutes to manufacture the fresh concrete. The fresh concrete could be handled up to 120 minutes or 2 hrs without any sign of setting and without any degradation in the compressive strength.

Figure- Mixing Of Geopolymer

4-EXPERIMENTS CONDUCTED

Workability Test

Workability is the property of freshly mixed concrete find that the ease with which it can be properly mixed, placed, consolidated and

finished without segregation. The workability of the fresh concrete was measured by means of the conventional slump test as per IS: 1199(1989).Before the fresh concrete was cast into moulds, the slump value of the fresh concrete was calculate using slump cone. In this project work, the slump value of the fresh concrete was maintained in the range of 30 to 40 mm.

Compressive Strength Test

The compressive strength test on hardened fly ash based geopolymer concrete was performed on standard compression testing machine of 3000kN Capacity, as per IS: 516-1959. Totally 27 number of cubical specimens of size 150mm x 150mm x 150mm was casted and tested for the compressive strength at the age of 3days, 7days and 28days. The compressive strength test was performed as shown in Figure 3.4. Each of the compressive strength test data corresponds to the mean value of thecompressive strength of three test concrete cubes.

Figure : Compressive strength on cube

Flexural Strength Test

The flexural strength test on hardened fly ash based geopolymer concrete was performed as per IS: 516-1959. Totally 27 number of Beams size 500mm×100mm×100mm casted and tested for the flexural strength at the age of 3days, 7days and 28days. The flexural strength test was performed as shown in Figure 3.5. Each of the compressive strength test data corresponds to the mean value of the flexural strength of three test concrete beams.

Figure : Flexural Strength test on Beams

Split Tensile Test

The split tensile test on hardened fly ash based geopolymer concrete was performed on standard compression testing machine of 3000kN Capacity, as per IS: 5816: 1999. Totally 27 number of cylindrical moulds of size 150mm diameter and 300mm height casted and tested for the flexural strength at the age of 3days, 7days and 28days. The split tensile test was performed as shown in Figure 3.6. Each of the compressive strength test data corresponds to the mean value of the flexural strength of three test concrete cylinders.

Figure : Split tensile test

5-CONCLUSIONS:-

Based on the test results, the following conclusions are drawn:

The Na2SiO3 to NaoH by mass equal to 1:2.5 has resulted into the higher strength as compared to the ratio of 1:2 and 1:3 for the geopolymer concrete.

Compressive strength of concrete increases 30% for 7days, flexural strength of concrete increases 40% for 7 days and split tensile strength 50% for 7 days when compared to 3 days strength.

Compressive strength of concrete increases 42% for 28 days, flexural strength of concrete increases 45% for 28 days and split tensile strength 60% for 28 days when compared to 7 days strength.

The fly ash can be used to produce geo polymeric binder phase which can bind the aggregate systems consisting of fine and coarse aggregate to form geo polymer concrete. Therefore these concrete can be considered as eco-friendly material Compressive, flexural and split tensile strengths are increases with the Higher the ratio of sodium silicate -to-sodium hydroxide ratio by mass.

The workability of the geopolymer concrete in fresh state increases with the increase of extra water added to the mix.

Geopolymer concrete tend to show no significant physical change in its properties at normal operating room temperature which is observed in case of normal variety. The complete setting of Geopolymer concrete specimens will take upto 72 hours without any reminisces on the surface on which it is hardened.

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