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Cement free Green Concrete Material-The Geopolymer An Informative Overview.

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Abstract: *The conventional cement production is highly energy intensive and produces large amount of carbon dioxide which significantly contributing to the phenomenon of global warming. The production of cement also consumes significant amount of natural resources for the large scale production in order to meet the global infrastructure developments. Therefore a need to looking for an alternative binder to make environmental friendly concrete. The use of fly ash, a byproduct of thermal power plants for various engineering applications are well known. However to developed cement free concrete using 100% fly ash is an innovative approach towards the development of green concrete-The geopolymer. The present paper is aimed at providing a comprehensive review on the development of a geopolymer binder and showed a major thrust for wider applications of geopolymer binder towards a cost economic construction practice.*

Geopolymer is a type of inorganic polymer composite, under the class of alumino-silicate binding materials synthesized by thermal activation of solid alumino silicate base materials such as fly ash, metakaolin, GGBS etc., with an alkali metal hydroxide and sodium silicate solution.

The effect of parameters such as concentration of sodium hydroxide, alkali-flyash ratio with proper mix design for fly ash-sand-aggregates are important to understand for the development of geopolymer concrete of desired compressive strength. The other processing parameters such as curing time and curing temperature on development of compressive strength and microstructure of fly ash based geopolymer paste and mortar are equally need to monitored.

The geopolymer concrete is superior to convintial Cement concrete particularly with repect to high durability under aggressive environment and fire resistance property.

The mineralogical and microstructure studies on hardened geopolymer performed by means of Scanning electron microscope (SEM), X-ray diffraction (XRD), FT-IR and Differential Scanning Calorimeter (DSC) showed formation of a new amorphous alumino-silicate phase.

Keywords: *fly ash, geopolymer, alkaline activator, thermal curing, microstructure, compressive strength.*

1. Introduction

It is widely known that the production of Portland cement consumes considerable energy and at the same time contributes a large volume of CO_2 to the atmosphere which is one of cause of global warming. The production of one ton of cement emits approximately one ton of carbon dioxide to the atmosphere. However, Portland cement is still the main binder in concrete construction.

Fly ash, the finely divided residue that results from the combustion of ground or powdered coal in thermal power station is available abundantly all over the world. In India more than 100 million tons of fly ash is produced annually. Out of this, only 17 – 20% is utilized either in concrete or in stabilization of soil. Most of the fly ash is disposed off as a waste material that coves several hectors of valuable land. So, efforts are needed to make concrete more environmental friendly by using fly ash which helps in reduce global warming as well as fly ash disposal problem.

There are environmental benefits in reducing the use of Portland cement in concrete, and using a by-product material, such as fly ash as a substitute. With silicon and aluminium as the main constituents, fly ash has great potential as a cement replacing material in concrete. The concrete made with such industrial waste is eco-friendly and so it is called as “Green concrete”. Fly ash has been used as a pozzolanic material to enhance the physical, chemical and mechanical properties of cements and concretes. As the need for power increases, the volume of fly ash would increase. It is necessary and significant to use fly ash as material to produce concrete without Portland cement.

2. Geopolymer Concrete

A new material of construction based on pozzolanic property of fly ash that does not need the presence of Portland cement as a binder. Geopolymer is a type of amorphous alumino-silicate cementitious material. Geopolymer can be synthesized by polycondensation reaction of geopolymeric precursor, and alkali polysilicates. This was produced by the chemical reaction of aluminosilicate oxides (Si2O5, Al2O2) with alkali polysilicates yielding polymeric Si–O–Al bonds. Comparing to Portland cement, the production of geopolymers has a relative higher strength, excellent volume stability, better durability.

Davidovits introduced the term “geopolymer” in 1978 to represent the mineral polymers resulting from geochemistry . Geopolymers are a class of inorganic polymer formed by the reaction between the alkaline solution, silica and alumina present in source material. The hardened material has an amorphous 3-dimensional structure similar to that of an aluminosilicate glass. The most common activator is a mixture of water, sodium hydroxide and sodium silicate but other alkali metal systems or mixtures of different alkalis can be used. The influence of curing temperature, curing time and alkaline solution-to-fly ash ratio on the compressive strength are very well studded by researchers.

3. Mechanism

Higher proportion of silica (SiO_2) and or the sum of silica (SiO_2), alumina (Al_2O_3) and iron (Fe_2O_3) is needed to ensure that sufficient potential reactive glassy constituent is present in FA. When fly ash is activated in an acidic or basic environment, the effect of a high calcium concentration typically leads to the acceleration of the rate of reaction. In a pozzolanic reaction between fly ash and $Ca(OH)_2$ or calcium silicate phases in cement paste, the early reaction may be so rapid that it will be unsuitable for applications that require longer workability or setting time. Therefore, Class F fly ash is much preferred in cement and geopolymer applications due to the high content of amorphous aluminosilicate phases and greater workability.

Polymerization reaction is best observed in the presence of alkaline medium such as sodium hydroxide, or potassium hydroxide and the addition of silicates can be additional ionic composition with good bonding effects. The reactants in the chain reaction can be accelerated due to higher molar concentration of alkali ions; however, the increase in the concentration leads to rapid loss in consistency during mixing attributed to faster polymer reaction. The inclusion of sodium silicate in sodium hydroxide solution provides higher silicate content and due to which the gel formation is likely to provide faster polymerization. A similar reaction is observed in the case of potassium silicate added to potassium.

Polymerization takes place when reactive aluminosilicates are rapidly dissolved and free SiO_4 and AlO_4 tetrahedral units are released in solution. The tetrahedral units are alternatively linked to polymeric precursors by sharing oxygen atoms thus forming amorphous geopolymers. Positive ions Na+ that are present in framework cavities, balance the negative charge. (Fig.1)

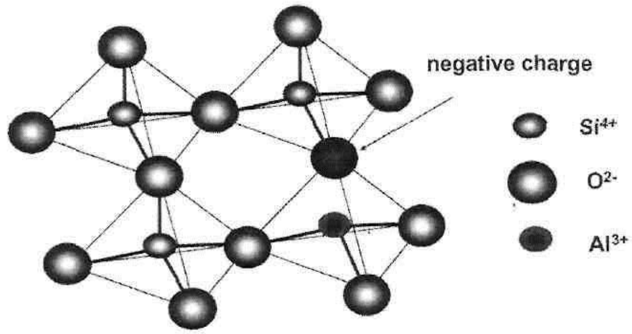


Fig.1 showing three dimensional network of Geopolymer

Fly ash mixed with alkali activators and sand and then the mixture is cured under certain temperature to carry out polymerization and condensation reactions which transformed the glassy constituent of the fly ash into well compacted cementitious material. (Fig.2, 3 & 4).

Fig. 2 & 3 Casting of Geopolymer cubes

Fig. 4 Heat Curing of Geopolymer Cubes

The most proposed mechanisms for the geopolymerisation include the following four stages.

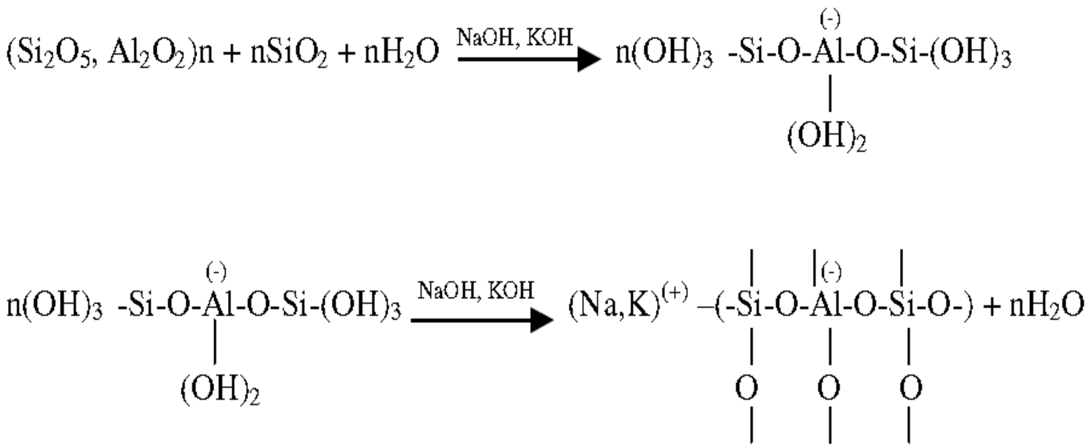
- Dissolution of Si and Al from the solid aluminosilicate materials in the strongly alkaline aqueous solution,
- Formation of oligomers species (geopolymers precursors) consisting of polymeric bonds of Si-O-Si and/or Si-O-Al type,
- Polycondensation of the oligomers to form a three-dimensional aluminosilicate framework geopolymeric framework)
- Bonding of the unreacted solid particles and filler materials into the geopolymeric framework and hardening of the wholesystem into a final solid polymeric structure

A geopolymer can take one of the three basic forms

Poly (sialate), which has [-Si-O-Al-O-] as the repeating unit.

Poly (sialate-siloxo), which has [-Si-O-Al-O-Si-O-] as the repeating unit.

Poly (sialate-disiloxo), which has [-Si-O-Al-O-Si-O-Si-O-] as the repeating unit.



(2-2)

The combination of sodium silicate (Na_2SiO_3) and NaOH solution was used as alkaline activators. The alkaline activator was prepared by mixing a sodium silicate and NaOH solution with a concentration of 10 M. The ratio of fly ash to alkaline activator (Na_2SiO_3/NaOH) ratio were fixed as 2.5 and applied for all samples. The fly ash was then mixed with the alkaline activator in the mixer. Sand is small aggregates in geopolymer mortar. Cubes were casted with taking sand –Fly ash ration fixed (50:50) keeping NaOH- concentration 10 M. The Mortar resulting from mixing the fly ash with sand and alkaline solution was poured in to metallic prismatic molds, (Cube Area 14.44 cm^2)which were later kept in an oven. The cubes were cured at different temperature for different time intervals in order to achieve optimum compressive strength after curing the specimens cubes were subjected to compressive strength and durability study under different aggressive chemical environment.

Characterization of Geopolymer:

The compressive strength of geopolymer cubes with UTM gives desired strength of 42 Mpa. (Fig. 5)

Fig.5 Shows compressive strength of Cube with UTM

The SEM, XRD and FT-IR study of geopolymer are presented in fig.6,7& 8

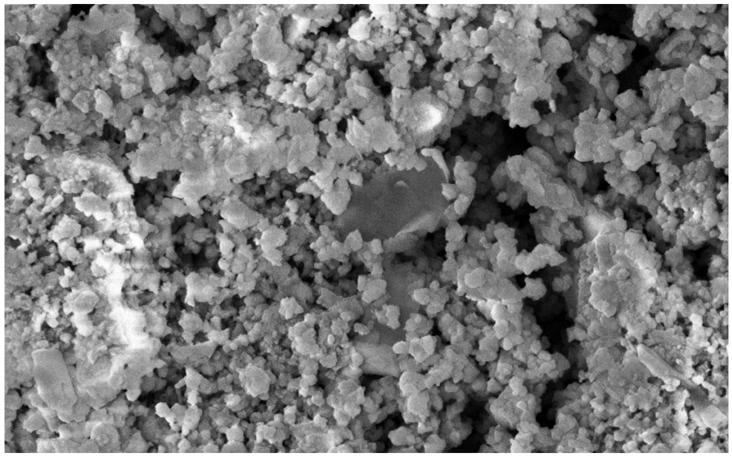


Fig.6 SEM of Geopolymer Phase

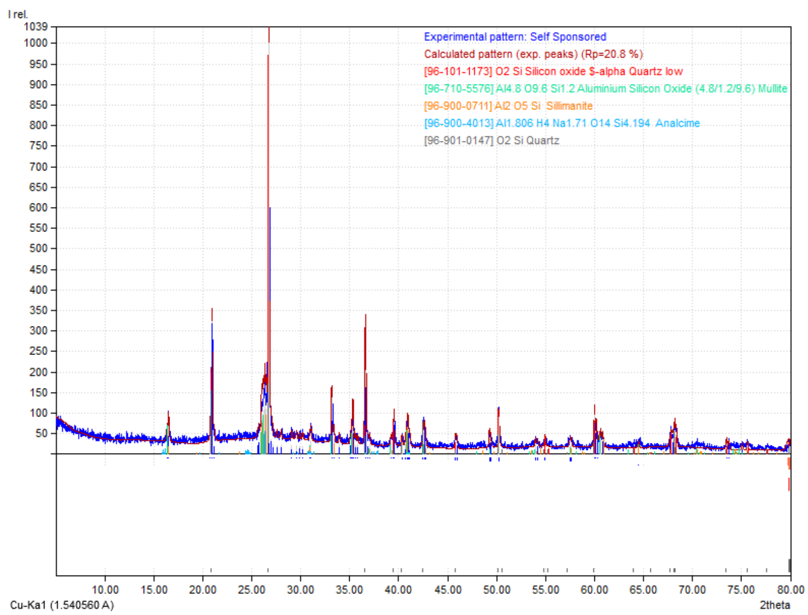


Fig.7 XRD of Geopolymer Cube

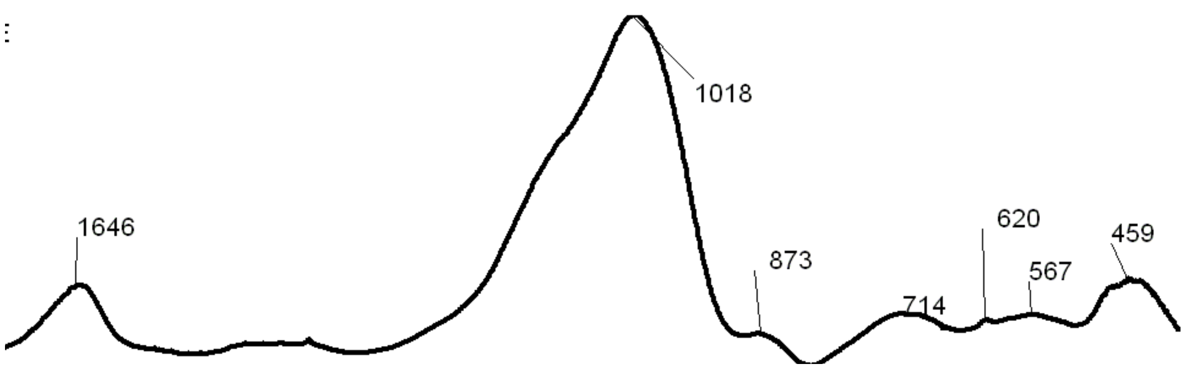


Fig.8- FT-IR graph of Geopolymeric Phase

Geoplolymer concrete has following advantages over OPC concrete

1. Excellent compressive strength

2. High Early strength.

3. Low Shrinkage

4. Durability under aggressive chemical environment

5. Resistance to acid and sulphate attacks.

6. Freeze-thaw resistance

7. Fire resistance property

8. Light weight

9. Corrosion resistance.

10. Toxic waste management

11. No danger of alkali-silica reaction

12.Under water abrasion resistance

4. Conclusion

Fly ash based Geopolymer concrete has excellent compressive strength and is suitable for structural applications. The durability study and mineralogical examination shows excellent utility of this green concrete for several site specific applications.

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