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A Review on - Study of Fly Ash based Geopolymer Concrete

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Abstract: *The basic purpose of any research is to obtain environmental friendly product. As we know that concrete is the world's most versatile, durable and reliable construction material in Civil Engineering. After water concrete is most consumed material which required huge amount of Portland cement. Ordinary Portland cement is major generator of carbon dioxide, which is harmful to atmosphere and it contributes 5 to 7 % of total green house gas emission. It also consume large amount of energy. Hence it is essential to find alternative to cement.*

Hence we came up with the new technology in concrete, which we called Geo-polymer concrete. Geo-polymer concrete that is zero cement concrete has potential to reduce carbon emission and lead to sustainable development and growth of concrete industry. The main objective of this project is to study important structural properties of concrete like Compressive strength and flexural strength of hardened concrete to determine the tensile and compressive strength of concrete.

This project will provide a momentum to the running wheels of the construction industry and will minimize the effects of global warming to save the environment. Our project will discuss in detail the manufacturing processes of Geo-polymer concrete and also its successful application.

Keywords: *Carbon Emission; Polymers; Durability; High Strength; Eco-friendly ;Global warming.*

I. INTRODUCTION

After wood, concrete is widely used in all over .Ordinary Portland cement is conventionally used for production of concrete as primary binder. The environmental issues are arises while production of OPC. While manufacturing of OPC the amount of carbon dioxide released due to calcinations of lime stone and combustion of fossil fuel is one ton for every ton of OPC. Amount of energy required to produce OPC is next to aluminum and steel .On the other side, the abundance and availability of fly ash worldwide create opportunity to utilize this by-product of burning coal, as partial replacement or as performance enhancer for OPC. Fly ash in itself does not possess the binding properties, except for the high calcium or ASTM Class C fly ash. However, in the presence of water and in ambient temperature, fly ash reacts with the calcium hydroxide during the hydration process of OPC to form the calcium silicate hydrate(C-S-H) gel. This pozzolanic action happens when fly ash is added to OPC as a partial replacement or as an admixture. The development and application of high-volume fly ash concrete, which enabled the replacement of OPC up to 60-65% by mass (Malhotra 2002; Malhotra and Mehta 2002), can be regarded as a landmark in this attempt.

In another scheme, pozzolans such as blast furnace slag and fly ash may be activated using alkaline liquids to form a binder and hence totally replace the use of OPC in concrete. In this scheme, the alkalinity of the activator can be low to mild or high. In the first case, with low to medium alkalinity of the activator, the main contents to be activated are silicon and calcium in the by-product material such as blast furnace slag. The main binder produced is a C-S-H gel, as the result of a hydration process. In the later case, the main constituents to be activated with high alkaline solution are mostly the silicon and the aluminum present in the by-product material such as low calcium (ASTM Class F) fly ash (Palomo, Grutzeck et al. 1999).

A. Geopolymers

Polymer is a class of materials made from large molecules that are composed of a large number of repeating units (monomers). The molecular structure of the unit that makes up the large molecules controls the properties of the material. The non- crystalline or amorphous state is the state when the regularity of atomic packing is completely absent. The most familiar kind of an amorphous solid is glass (Young, Mindness et al. 1998). Geopolymers are a member of the family of inorganic polymers, and are a chain structures formed on a backbone of Al and Si ions. The chemical composition of this geopolymer material is similar to natural zeolitic materials, but they have amorphous microstructure instead of crystalline (Palomo, Grutzeck et al. 1999; Xu and van Deventer 2000). The polymerisation process involves a substantially fast chemical reaction under highly alkaline condition on Si-Al minerals, that results in a three- dimensional polymeric chain and ring structure consisting of Si-O-Al-O bonds, as follows (Davidovits 1999): $M_n [-(SiO_2)_x -(AlO_2)_n] \cdot xH_2O$ (2-1)

Where: M = the alkaline element or cation such as potassium, sodium or calcium; the symbol – indicates the presence of a bond, n is the degree of polycondensation or polymerisation; z is 1, 2, 3, or higher, up to 32.

The schematic formation of geopolymer material can be shown as described by Equations (2-2) and (2-3) (van Jaarsveld, van Deventer et al. 1997; Davidovits 1999). These formations indicate that all materials containing mostly Silicon (Si) and Aluminium (Al) can be processed to make the geopolymer material

B. Fly ash-based geopolymer concrete

In this work, fly ash-based geopolymer is used as the binder, instead of Portland or any other hydraulic cement paste, to produce concrete. The fly ash-based geopolymer paste binds the loose coarse aggregates, fine aggregates and other un-reacted materials together to form the geopolymer concrete, with or without the presence of admixtures. The manufacture of geopolymer concrete is carried out using the usual concrete technology methods. As in the OPC concrete, the aggregates occupy the largest volume, i.e. about 75-80 % by mass, in geopolymer concrete. The silicon and the aluminium in the low calcium (ASTM Class F) fly ash are activated by a combination of sodium hydroxide and sodium silicate solutions to form the geopolymer paste that binds the aggregates and other un-reacted materials.

C. The Use Of Fly Ash In Concrete

One of the efforts to produce more environmentally friendly concrete is to reduce the use of OPC by partially replacing the amount of cement in concrete with by-products materials such as fly ash. As a cement replacement, fly ash plays the role of an artificial pozzolan, where its silicon dioxide content reacts with the calcium hydroxide from the cement hydration process to form the calcium silicate hydrate (C-S-H) gel.

The spherical shape of fly ash often helps to improve the workability of the fresh concrete, while its small particle size also plays as filler of voids in the concrete, hence to produce dense and durable concrete. Generally, the effective amount of cement that can be replaced by fly ash is not more than 30% (Neville 2000).

An important achievement in the use of fly ash in concrete is the development of high volume fly ash (HVFA) concrete that successfully replaces the use of OPC in concrete up to 60% and yet possesses excellent mechanical properties with enhanced durability performance. HVFA concrete has been proved to be more durable and resource-efficient than the OPC concrete (Malhotra 2002). The HVFA technology has been put into practice, for example the construction of roads in India, which implemented 50% OPC replacement by the fly ash (Desai 2004).

Activation of fly ash with alkaline solutions enables this by-product material to be a cement-like construction material. In this case, concrete binder can be produced without using any OPC; in other words, the role of OPC can be totally replaced by the activated fly ash. Palomo et al (1999) described two different models of the activation of fly ash or other by-product materials. For the first model, the silicon and the calcium in the material is activated by a low to mild concentration of alkaline solution. The main product of the reaction is believed to be a calcium silicate hydrate (C-S-H) that results from the hydration process. On the contrary, the material used in the second model contains mostly silicon and aluminum, and is activated by a highly alkaline solution. The chemical process in this case is polymerization.

A well known example of the first model is the activation of blast furnace slag, that has a long history in the former Soviet Union, Scandinavia and Eastern Europe (Roy 1999).

On the other hand, studies on the second model are limited (Palomo, Grutzecket al. 1999). Many aspects of the material characteristics and reaction mechanisms are still not clear. For the second model, Davidovits (1999) coined the term Geopolymer in 1978 to describe the alkali activated material from geological origin or by-product materials such as fly ash and rice husk ash. Davidovits (1994) also revealed the fact that very few scientific literatures on geopolymer material available was caused by the patent oriented schemes of research works. Only from the late 1990s scientific information were becoming available in the published literature.

D. Constituents Of Geopolymer Concrete

The following are the constituents of Geopolymer concrete:

- 1) Fly Ash- rich in Silica and Aluminum
- 2) Sodium Hydroxide or Potassium Hydroxide
- 3) Sodium Silicate or Potassium Silicate

E. Properties Of Geopolymer Concrete

The superior properties of Geopolymer concrete, based on Prof. B. Vijaya Rangan and Hardijito, are

- 1) Sets at room temperature
- 2) Non toxic, bleed free
- 3) Long working life before stiffening
- 4) Impermeable
- 5) Higher resistance to heat and resist all inorganic solvents
- 6) Higher compressive strength

Compressive strength of Geopolymer concrete is very high compared to the ordinary Portland cement concrete. Geopolymer concrete also showed very high early strength. The compressive strength of Geopolymer concrete is about 1.5 times more than that of the compressive strength with the ordinary Portland cement concrete, for the same mix. Similarly the Geopolymer Concrete showed good workability as of the ordinary Portland Cement Concrete.

F. Applications

In the short term, there is large potential for geopolymer concrete applications for bridges, such as precast structural elements and decks as well as structural retrofits using geopolymer-fiber composites. Geopolymer technology is most advanced in precast applications due to the relative ease in handling sensitive materials (e.g., high-alkali activating solutions) and the need for a controlled high-temperature curing environment required for many current geopolymer. Other potential near-term applications are precast pavers & slabs for paving, bricks and precast pipes.

To date, the exact mechanism of setting and hardening of the geopolymer material is not clear, as well as its reaction kinetics. However, most proposed mechanism consist of the following (Davidovits 1999; Xu and van Deventer 2000):

- 1) Dissolution of Si and Al atoms from the source material through the action of hydroxide ions.
- 2) Transportation or orientation or condensation of precursor ions into monomers.
- 3) Setting or poly condensation/polymerization of monomers into polymeric structures.

However, these three steps can overlap with each other and occur almost simultaneously, thus making it difficult to isolate and examine each of them separately (Palomo, Grutzeck et al. 1999).

A geopolymer can take one of the three basic forms (Davidovits 1999), i.e:

- a) Poly(sialate), which has $[-Si-O-Al-O-]$ as the repeating unit.
- b) Poly(sialate-siloxo), which has $[-Si-O-Al-O-Si-O-]$ as the repeating unit.
- c) Poly(sialate-disiloxo), which has $[-Si-O-Al-O-Si-O-Si-O-]$ as the repeating unit.

Sialate is an abbreviation of silicon-oxo-aluminate. Davidovits (1999) proposed the possible applications of the geopolymer material depending on the molar ratio of Si to Al,

II. DISCUSSION & CONCLUSION

Joseph Davidovits found that Flyash reacted with alkaline solution and formed a binding material. Hardijito & Rangan observed that higher concentration of sodium hydroxide (molar) resulted higher compressive strength and higher the ratio of sodium silicate-to-sodium hydroxide liquid ratio by mass, showed higher compressive strength of geopolymer concrete. They also found that the increased in curing temperature in the range of 30 to 90 °C increased the compressive strength of geopolymer concrete and longer curing time also increased the compressive strength.

They handled the geopolymer concrete up to 120 minutes without any sign of setting and without any degradation in the compressive strength, resulted very little drying shrinkage and low creep.

Suresh Thokchom et al reported that the Geopolymer mortar specimens manufactured from fly ash with alkaline activators were structurally intact and did not show any recognizable change in colour after 18 weeks exposure in 10% sulfuric acid solution and the Geopolymer Concrete was high resistance against sulfuric acid. D. Bondar et al indicated that the strength of geopolymer concrete decreased as the ratio of water to geopolymer solids by mass increased.

Anuar et al revealed that the concentration (in term of molarity) of NaOH influenced the strength characteristic of geopolymer concrete. S. Vaidya et al examined that uniform temperature was developed throughout the mass and Elastic Modulus and Poisson's ratio were within the acceptable limits.

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