International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 5.22 (SJIF-2017), e-ISSN: 2455-2585
Volume 4, Issue 12, December-2018

REVIEW ON MECHANICAL PROPERTIES OF GEOPOLYMER MORTAR REINFORCED WITH NATURAL FIBRE

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Abstract—Now a days, the major goals of latest investigations are to minimize greenhouse gas emission and reduce the energy required for production of materials in construction industries. The manufacturing process of ordinary Portland cement emits greenhouse gases. Geopolymer binder is an eco-friendly material, good alternative to ordinary Portland cement. In this study, geopolymer mortar contains fly ash, natural fibres, fine aggregates and activator solutions. The activator solutions are combination of sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3). The purpose of this study is to briefly review the activator solution and mechanical properties of fibre reinforced geopolymer mortar.

Keywords—Geo-polymer, Natural fibre, Fly ash, Activator solution, Compressive strength,

I. INTRODUCTION

The importance of sustainable development and environmental safety has lead to examination of alternatives to conventional building materials. Among the goals of these examinations are to minimize greenhouse gas emission and reduce the energy required for production of materials. Currently, cement is the main material for construction industry. The manufacturing process of Portland cement requires large amount of energy and produces a large volume of carbon dioxide (CO_2) to the atmosphere. It is examined that one ton of CO_2 is released into the atmosphere, for one ton of cement manufactured. The manufacturing process of cement involves very high temperatures ranges 1400–1500°C, the destruction of nature to extract raw materials, and the release of greenhouse gases such as CO_2 and NOx. Accordingly, the need arise for further examination into binding products with decreased environmental impacts and with increased economic benefits.
Easily available economical by-products such as fly ash and blast furnace slag have been adopted to fulfill these requirements. It was noted that the total amount of low-calcium fly ash produced annually by the year 2017 will be about 180 Million Tonne in India, providing a way to meet growing demand. The reclaimed use of this low-calcium fly ash in construction will reduce the cost of disposal and also overall cost of concrete manufacture reduces.

In 1978, J. Davidovits generate cement formed by the polymerization of alkaline activator liquid with the Si and Al present in fly ash. Si and Al are available in source materials of earthly basis or consequent materials such as low-calcium fly ash, husk ash, GGB (ground granulated blast) furnace slag and waste paper fly ash. From last two decades, ordinary cement has been replaced by low-calcium fly-ash. The binder paste is made from low-calcium fly ash and alkaline liquids.

A. GEOPOLYMER

The term “geopolymer” is generally used to describe the amorphous to crystalline reaction products from the synthesis of alkali alumino-silicates with alkali hydroxide/alkali silicate solution. Geopolymeric gels and composites are also commonly referred to as low-temperature alumina-silicate glass, alkali-activated cement, geo-cement, alkali-bonded ceramic, inorganic polymer concrete, and hydroceramic. Geopolymer is a type of amorphous alumino silicate cementitious material that exhibits the ideal properties of rock forming minerals, i.e., hardness, chemical stability and longevity. The polymerization process involves a substantially fast chemical reaction under alkaline conditions on Si-Al minerals, resulting in a three-dimensional polymeric chain and ring structure consisting of Si-O-Al-O bonds.

B. FLY ASH BASED GEOPLYMER MORTAR

In this study, ordinary Portland cement is completely eliminated and low-calcium fly ash based geopolymer is used as the binder. ASTM class F fly ash is low-calcium based fly ash generally used in geoploymer binder. The manufacture of geopolymer mortar is carried out using the usual method followed in cement mortar. The silica and alumina present in class F fly ash react with activator solution. The activator solution is a combination of sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3) solutions to form the geopolymer paste instead of water that binds the aggregates and other un-reacted materials.

C. FLY ASH

Mostly available fly ash is a low-calcium based by-product obtained from the burning of anthracite and bituminous coal. Fly ash considered one of the most important source materials to produce geopolymer cements. Generally, low-calcium based fly ash is an acidic material containing oxides such as Al_2O_3, $SiO_2$and Fe_2O_3 provides a potential for alkali reactions. Most of the fly ashes obtained from the burning of coal are made up of a heterogeneous mix of Al_2SiO_5 (aluminosilicate) and SiO_2 (silica glasses) plus small amounts of crystalline materials including quartz, magnetite, hematite and mullite.

D. CLASSIFICATION OF FLY ASH

- **Low-calcium fly ash Class F**: - The ignition of solid, aged anthracite and bituminous coal generally produce Class F low-calcium fly ash. This low-calcium fly ash is pozzolanic in nature, and also contains CaO (lime) less than 7%. Adding an alkaline activator solution such as NaOH and Na_2SiO_3 (water glass) to Class F fly ash can produce a geo-cement**.**
- **Low-calcium fly ash Class C**: - Low-calcium fly ash manufactured from the ignition of fresh lignite or sub-bituminous coal. In addition to possessing pozzolanic features, it also has some self-binding properties. Class C fly ash stiffens and gets strengthen with time, in the presence of water. Class C fly ash typically contains lime (CaO) greater than 20%. Due to self-cementing character, Class C fly ash does not require an alkaline activator solution.

E. FINE AGGREGATE

River sand or fine aggregate is used in this investigation. Fine aggregate generally includes the particles that all passes through 4.75mm sieve and retain on 0.075mm sieve. According to its grading, IS specifications classify the fine aggregate into four types as fine aggregate of grading Zone-I to grading Zone-IV. The fine aggregates become progressively finer from grading Zone-I to grading Zone-IV. The sieve analysis helps to find out the zone of sand, size of aggregate and to find out particle size distribution of sand used. The fine aggregate (sand) is made saturated surface dry (SSD) before using in geopolymer mix to avoid water absorption from activator solution.

F. NATURAL FIBRE

Natural Fibres are fibres that are produced by plants, animals and geological processes. Bast fibers are collected from the outer cell layers of the plant's stem. In this study, we shall use Shel which is an example of Bast fibres. Shel is generally obtained from a multipurpose tree called Bhimal (Biul or Beuhal). Common occurrence of Bhimal is in North India upto an altitude of 2000m. Bhimal (Grewia Optiva scientific name) is a moderate sized tree which can grow up to 45 feet and 4.5 feet in girth. Besides fruits, fuel wood and fodder the tree also yield very useful jute like fibre called Shel.

G. ACTIVATOR SOLUTION

Mainly the combination of NaOH (sodium hydroxide) or KOH (potassium hydroxide) and Na_2SO_3 (sodium silicate) or K_2SO_3 (potassium silicate) is used to make alkaline solution for polymerization. When the alkaline solution contains soluble silicate, either sodium silicate or potassium silicate reactions occur at a high rate, compared to the use of only alkaline hydroxides. Addition of Na_2SO_3 (sodium silicate) solution to the NaOH (sodium hydroxide) solution as the alkaline solution in different SS/SH ratio 1.5 to 2.5 further increase the reaction between solution and source material. The alkaline activator is produced by mixing both the solutions together. NaOH (Sodium hydroxide) pellets are dissolved in tap water in different concentrations from 8M to 16M. There after an unspecified amount of heat is released due to the mixing Na_2SO_3 with NaOH solution. Therefore it is prepared 24 hours prior to use.

H. PROPERTIES OF GEOPOLYMER MORTAR

- Bleeding free and good adhesion
- Higher stability and durability
- Longer working period before its stiffening
- Lower permeability and lower shrinkage
- Greater resistance to heat and also resist all inorganic solvents
- High compressive strength
- Highly resistant against freezing and thawing

II. RELATED WORKS

Davidovits Joseph, Environmentally Driven Geopolymer Cement Applications (2002) in this paper attempt is made to study environmentally driven geopolymer applications based on the implementation of (K,Ca)-Poly(sialate-siloxo) / (K,Ca)-Poly(sialate-disiloxo) cements. In industrialized countries (Western countries) emphasis is laid on toxic waste (heavy metals) and radioactive waste safe containment. On the opposite, in emerging countries, the applications relate to sustainable development, essentially geopolymeric cements with very low CO_2 emission. The production of 1 tonne of geopolymeric cement generates 0.180 tonnes ofCO_2, from combustion carbon-fuel, compared to 1 tonne of CO_2 for Portland cement. Geopolymeric cement generates six times less CO_2 during manufacture than Portland cement. Immobilization technologies with geopolymeric materials have three goals**.** First one is to seal the hazardous materials into an impermeable monolith. This prevents the direct contact of potential leachates, like ground water and percolating rain. Geopolymeric cements do not rely on lime and are not dissolved by acidic solutions. Portland based cements (plain and slag mixtureed) are destroyed in acidic environment.

Hardjito Djwantoro *et.al.* (2004) in this paper efforts were made to develop environmentally friendly construction materials. To reduce greenhouse gas emissions, fly ash based geopolymer concrete was developed. In geopolymer concrete, low-calcium fly ash was chemically activated by a high-alkaline solution to form a paste that binds the loose coarse and fine aggregates together. In this paper the dry fly ash obtained from the silos at a local power station was used as the base material. The geopolymer paste binds the loose coarse aggregates, fine aggregates and other unreacted materials together to form the geopolymer concrete. The manufacture of geopolymer concrete is carried out using the usual concrete technology methods.
Higher curing temperature resulted in larger compressive strength, even though an increase in the curing temperature beyond 60°C did not increase the compressive strength substantially. To evaluate the resistance of geopolymer concrete to sulphate attack, specimens were soaked in a 5% sodium sulphate (Na_2SO_4) solution for different periods of time. The author concluded that higher concentration (in terms of molar) of sodium hydroxide solution results in a higher compressive strength. Higher the ratio of sodium silicate-to-sodium hydroxide liquid ratio by mass, higher is the compressive strength. Longer curing time, in the range of 6 to 96 h (4 days), produces larger compressive strength of geopolymer concrete. The fresh geopolymer concrete is easily handled up to 120 min without any sign of setting and without any degradation in the compressive strength. The resistance of geopolymer concrete against sodium sulphate is excellent.

Wallah Edward Steenie (2009) in this paper attempt is made to study the drying shrinkage of heat-cured fly ash-based geopolymer concrete. In geopolymer concrete, low-calcium fly ash, alkaline solution and aggregates were used. Fly ash-based geopolymer concrete is manufactured without using Portland cement. In addition, it also utilizes waste or by-product material that makes it more environmentally friendly. As a relatively new material, extensive studies are still needed to explore this type of concrete as a construction material. One area that needs to be studied is its shrinkage behaviour, which is an important long-term property of concrete. Shrinkage is the decrease in volume of concrete with time. Unlike creep, shrinkage is independent of the external factors to the concrete. There are some types of shrinkage in the concrete which should be distinguished - plastic shrinkage, chemical shrinkage, thermal shrinkage and drying shrinkage. The aggregates play a significant role in affecting the shrinkage of concrete. This is related to the restraining effect of the aggregate on shrinkage. The higher aggregate content results in smaller shrinkage and also concrete with aggregates of higher modulus or rougher surfaces is more resistance to the shrinkage process. The author concluded that the heat-cured fly ash-based geopolymer concrete undergoes very low drying shrinkage.

Yellaiah P., Sharma K. Sanjay, Rao Gunneshwara T.D. (June 2014) in this research paper, the influence of various parameters on the consistency and setting times of low-calcium fly ash based geopolymer cement under varied heat curing temperature were investigated. The consistency of geopolymer cement does not show any variation when mixed with different combinations of alkaline activator solution; whereas the setting times were observed to be dependent on concentration of NaOH solution, ratio of alkaline liquid and variation in temperature. The test results revealed that the normal consistency of geopolymer paste is found to be at 28% of alkaline activator solution for all the selected mixtures. Wherein, increase in concentration of NaOH solution increases setting times; increase in alkaline liquid ratio decreases setting times up to certain limits viz; increase in alkaline liquid ratio from 1.5 to 2.0 decreases setting times; further increase in alkaline liquid ratio from 2.0 to 2.5 increases setting times.

Sofi Yasir and Gull Iftekar (2015) this paper intended to study the properties of fly ash based Geopolymer concrete. M20 grade GPC can be formed by adopting nominal mix of 1:1.5:3 (fly ash: fine aggregates: coarse aggregates) by varying alkaline liquid to fly ash ratio from 0.3 to 0.45. The compressive strength, tensile strength and flexural strength tests were conducted on geopolymer concrete and parameters that affect it are analyzed and proved experimentally. The durability properties like permeability and acid attack are also studied. From the test results, it was concluded that geopolymer concrete possesses good compressive strength and offers good durability characteristics. With the increase of alkaline liquid to fly ash ratio strength decreases and alkaline liquid to fly ash ratio less than 0.3 is very stiff.

III. CONCLUSIONS

The ends drawn from related works above speaks to that the geopolymer in auxiliary applications has lead to the aggregate end of bond from solid, which eventually progresses toward becoming "Green cement". In activator arrangement, sodium silicate to sodium hydroxide proportion observed to be ideal between SS/SH proportion 1.5 to 2.5. Also, as the concentration of NaOH increases 8M, 10M, 12M up to 14M strength properties increases and further decreases. It also concluded that as the fineness of fly ash increases compressive strength of geopolymer increases. High strength geopolymer mortar will be produced by making use of GGBS and stone dust. The strength properties of low-calcium fly ash based mortar are superior to other traditional mortars. It likewise inferred that when the extent of filaments in mixture builds the workability of mixture diminishes.

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