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AN EVALUATION OF GEOPOLYMER CONCRETE

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ABSTRACT

The most adaptable, long-lasting, and trustworthy building material in the world is concrete. Concrete, the most ubiquitous substance after water, required massive amounts of Portland Cement. In terms of atmospheric carbon dioxide pollution, the manufacture of ordinary Portland cement is second only to the vehicle. The manufacturing of cement also required a substantial quantity of energy. Therefore, it is necessary to discover a substitute for the current most costly and resource-intensive Portland Cement. An revolutionary building material, geopolymer concrete is made by combining inorganic molecules via chemical reactions. Worldwide, there is an abundance of fly ash, a by-product of coal produced by thermal power plants. The concrete's binder, an aluminosilicate gel, was created when flyash—which is high in silica and alumina—reacted with an alkaline solution. As a substitute for the standard plain cement concrete, it works well in building projects. The production of geopolymer concrete must not include the use of regular Portland cement in any way. Geopolymer concrete, its strength, and its uses are summarized in this article.

KEYWORDS: Geopolymer Concrete, Fly Ash, Strength, Curing, Applications.

I. INTRODUCTION

In 1978, a French professor named Davidovits came up with the term "geopolymer" to describe a wide variety of materials that include networks of inorganic molecules (Geopolymer Institute 2010)1, 2 & 3. The geopolymers get their silicon (Si) and aluminum (Al) from thermally activated natural minerals such Meta kaolinite or from industrial waste items like slag or fly ash. The binder is made of molecular chains formed when silicon and aluminum are dissolved in an alkaline activating solution. A three-dimensional polymeric chain and ring structure are produced by a chemical reaction that takes place on silicon-aluminum minerals under alkaline circumstances, according to Professor B. Vijaya Rangan (2008) of Curtin University in Australia. 4 The ratio of silicon to aluminum (Si:Al) is a key factor in determining the final structure of geopolymers. Materials with a Si:Al ratio of 2 to 3.5 are usually evaluated for usage in transportation infrastructure.

The reaction of Fly Ash with an aqueous solution containing Sodium Hydroxide and Sodium Silicate in their mass ratio, results in a material with three dimensional polymeric chain and ring structure consisting of Si-O-Al-O bonds[7].

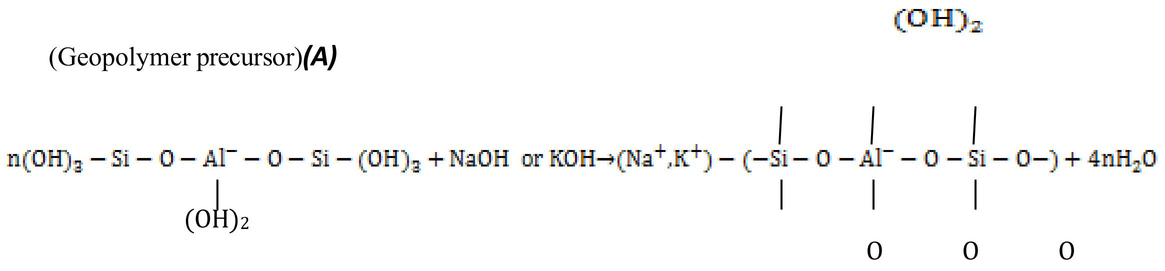
The schematic formation of geopolymer material can be shown as described by Equations (A) and (B)

$$n(Si_2O_5,Al_2O_2)+2nSiO_2+4nH_2O+NaOH \text{ or } KOH \rightarrow Na^+,K^+ + n(OH)_3-Si-O-Al^- -O-Si-(OH)_3$$

(Si-Al materials)

$\downarrow$

(Geopolymer precursor)***(A)***



$$n(OH)_3-\underset{\textstyle (OH)_2}{Si-O-Al^-}-O-Si-(OH)_3+NaOH \text{ or } KOH \rightarrow (Na^+,K^+)-(-\overset{|}{\underset{|}{Si}}-O-\overset{(OH)_2}{\underset{\textstyle O}{\overset{|}{\underset{|}{Al^-}}}}-O-\overset{|}{\underset{|}{Si}}-O-)+4nH_2O \quad (B)$$

(Geopolymer backbone)

Water is not involved in the chemical reaction of Geopolymer concrete and instead water is expelled during curing and subsequent drying. This is in contrast to the hydration reactions that occur when Portland cement is mixed with water, which produce the primary hydration products calcium silicate hydrate and calcium hydroxide. This difference has a significant impact on the mechanical and chemical properties of the resulting geopolymer concrete, and also renders it more resistant to heat, water ingress, alkali–aggregate reactivity, and other types of chemical attack [3&5].

In the case of geopolymers made from fly ash, the role of calcium in these systems is very important, because its presence can result in flash setting and therefore must be carefully controlled [5]. The source material is mixed with an activating solution that provides the alkalinity (sodium hydroxide or potassium hydroxide are often used) needed to liberate the Si and Al and possibly with an additional source of silica (sodium silicate is most commonly used).

The temperature during curing is very important, and depending upon the source materials and ac- tivating solution, heat often must be applied to facilitate polymerization, although some systems have been developed that are designed to be cured at room temperature [2&3].

The necessity of Geopolymer Concrete, the Constituents, Properties, Applications and Limitations are discussed in detail in this paper.

II. NECESSITY OF GEOPOLYMER CONCRETE

A rapidly expanding industry on a global scale is construction. Current global data indicate a yearly need of around 260,00,00,000 metric tons of cement. Within the next decade, this amount will rise by 25%. There may be a severe scarcity of limestone in 25 to 50 years since it is the primary ingredient in regular Portland cement. Also, a tonne of carbon dioxide is released into the air during cement production, which is a big problem for the environment. Cement manufacture also requires an enormous amount of energy, on top of everything else. Therefore, finding a different binder is of the utmost importance. Air pollution from carbon dioxide gas was a byproduct of cement manufacturing. Flyash, a byproduct of the thermal industry that is essentially just dumped on the ground, takes up a lot of space. Chemical companies' effluent seeps into the earth, tainting groundwater sources. The production of geopolymer concrete will reorganize all of the aforementioned problems.Geopolymer concrete is made from thermal industry waste fly ash and chemical refinery waste water.

Geopolymer concrete eliminates the need for cement, which means less cement manufacturing and less carbon dioxide emissions, which means less air pollution.

III. CONSTITUENTS OF GEOPOLYMER CONCRETE

The following are the constituents of Geopolymer concrete

- Fly Ash- rich in Silica and Aluminium
- Sodium Hydroxide or Potassium Hydroxide
- Sodium Silicate or Potassium Silicate

IV. PROPERTIES OF GEOPOLYMER CONCRETE

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

- sets at room temperature
- non toxic, bleed free
- long working life before stiffening
- impermeable
- higher resistance to heat and resist all inorganic solvents
- 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.

V. APPLICATIONS

Precast structural components and decks made of geopolymer concrete, as well as structural retrofits using geopolymer-fiber composites, hold great promise for the near future of bridge construction. Because many modern geopolymers demand a regulated high-temperature curing environment and because handling delicate components (such as high-alkali activating solutions) is relatively easy, geopolymer technology has progressed to its most refined form in precast applications. Pavers and slabs made of precast concrete, bricks, and precast pipes are some more possible uses in the near future.

VI. LIMITATIONS

The followings are the limitations

- Bringing the base material fly ash to the required location
- High cost for the alkaline solution
- Safety risk associated with the high alkalinity of the activating solution.
- Practical difficulties in applying Steam curing / high temperature curing process

Considerable research is ongoing to develop geopolymer systems that address these technical hurdles.

VII. RESULTS & DISCUSSION

After reacting with an alkaline solution, Joseph Davidovits discovered that flyash could be used as a binding agent. The compressive strength of geopolymer concrete was shown to be stronger at larger ratios of sodium silicate to sodium hydroxide by mass, and at higher concentrations of sodium hydroxide (in molar terms), according to Hardijito and Rangan. Additionally, they discovered that geopolymer concrete's compressive strength was enhanced by increasing the curing temperature between 30 and 90 °C and by extending the curing time. The geopolymer concrete exhibited little drying shrinkage and creep after being handled for 120 minutes; moreover, it showed no signs of setting or deterioration in compressive strength. Geopolymer mortar specimens made from fly ash with alkaline activators remained structurally sound and colorless after 18 weeks in a 10% sulfuric acid solution, according to Suresh Thokchom et al., and Geopolymer Concrete exhibited excellent resistance to sulfuric acid. The strength of geopolymer concrete was shown to decrease with increasing water to eopolymer particles by mass ratio, according to D. Bondar et al. Anuar et al. found that the strength characteristic of geopolymer concrete was affected by the content (in terms of olarity) of NaOH. According to the research of S. Vaidya et al., the mass's temperature was uniformly distributed, and the elastic modulus and Poisson's ratio were both within the permissible range. The compressive strength of GPC was 1.5 times higher than that of controlled concrete (M-25 becomes M-45), the split tensile strength was 1.45 times higher, and the flexural strength was 1.6 times higher, according to Raijiwala et al. Hey Muhd The feasibility of cast-in-situ use in Geopoymer concrete was suggested by Fadhil Nuruddin et al. Geopolymer concrete was used by Douglas et al. to stabilize trash effectively. Chemical pollutants were trapped and leachate concentrations were decreased by using geopolymer concrete.

VIII. RELATED WORKS

Due of the high demand for natural sand, quarry dust will partly substitute for the fine aggregate. Due to its high silica content, quarry dust has the potential to enhance the compressive strength of geopolymer concrete when used in part as a substitute for it. The properties will be examined using Sodium Hydroxide solutions of varying concentrations (8M, 10M, 12M, 14M, and 16M). Likewise, several curing processes will also be investigated. For the various molar ratios of sodium hydroxide solutions, it is necessary to investigate curing methods such as hot air, steam, sun, and ambient.In order to investigate the potential of Geopolymer Concrete as an alternative to traditional concrete, various structural components such as Plain Cement Concrete Beams, Reinforced Concrete Beams, Reinforced Concrete Columns, and Reinforced Beam Column joints will be cast and evaluated under the aforementioned sodium hydroxide solution concentrations and curing conditions. We will study the properties of geopolymer concrete and suggest using it instead of regular Portland cement concrete based on the test findings.

IX. CONCLUSION

Conditions that are appropriate for regular portland cement concrete may also be employed with user-friendly geopolymer concrete. All of the ingredients in Geopolymer Concrete need to be easily combined with an activating solution that is reasonably low in alkali and have a decent curing time when left out in the open air. The mixing and hardening processes for the manufacturing of flexible, inexpensive geopolymer concrete are quite similar to those for portland cement. Repairs and rehabilitation projects are to make use of geopolymer concrete. The precast industries may make good use of Geopolymer Concrete's excellent early strength, which allows for massive production in a short amount of time with little breaking during transit. For reinforced concrete structures, Geopolymer Concrete is an excellent choice for the beam-column connection. The infrastructure works will also make use of geopolymer concrete. Also, there's no need to dump the flyash in landfills since it will be put to good use. If the government takes the appropriate measures, it may minimize the cost of the alkaline solutions needed for geopolymer concrete by recovering sodium hydroxide and sodium silicate solution from chemical industry waste.

REFERENCES

(1) "Pyramids of Egypt Made of Man- Made Stone, Myth or Fact?" by J. Davidovits (1984). Archaeometry Symposium 1984. Smithsonian Institution, Washington, DC. Source: Davidovits (2008). The Chemistry and Applications of Geopolymers. French Institute of Geopolitical Studies, Saint-Quentin.
The Geopolymer Institute published a report in 2010 ("3"). Geopolymers: What Are They? Hello there. French Institute of Geopolitics, Saint-Quentin. Available onlineathttp://www.geopolymer.org/science/introduction as of January 29, 2010.

In their 2004 article "On the Development of Fly Ash-Based Geopolymer Concrete," Hardjito, Wallah, Sumajouw, and Rangan discuss the use of fly ash in concrete. Vol. 101, no. 6, ACI Materials Journal.
[5] "Low-Calcium, Fly-Ash-Based Geopolymer Concrete." Rangan, B. V. Handbook of Engineering for Concrete Constructions. Boca Raton, Florida: Taylor & Francis Group, 2008.
In 2009, Lloyd and V. Rangan published a paper [6]. "Geopolymer Concrete—An Eco-Friendly Alternative to Cement?" 10th Annual ACI International Conference on New Developments in Concrete Technology and Sustainability Issues, ACI Special Publication SP-261. The American Concrete Institute is located in Farmington Hills, Michigan.

At the 2008 Third ACF International Conference (ACF/VCA), researchers Nguyen Van Chanh Bui and Dang Van Tuan presented their findings on geopolymer concrete [7].
[8] in the ARPN Journal of Engineering and Applied Sciences, volume 4, issue 1, February 2009, by Suresh Thokchom, Partha Ghosh, and Somnath Ghos - Resistance of Fly Ash based Geopolymer Mortars in Sulfuric Acid.
The following is a reference to a paper presented at the Second International Conference on Engineering Properties of Alkali Activated Natural Pozzolan Concrete in June 2010 by D. Bondar, C. J. Lynsdale, N. B. Milestone, N. Hassani, and A. A. Ramezanianpour: University of Wisconsin, Madison, Wisconsin.
The authors of the cited work are Anuar K.A., Ridzuan A.R.M., and Ismail S. from Universiti Teknologi MARA in Shah Alam, Selangor, Malaysia (10). Geopolymer Concrete's Strength Parameters - International Journal of Civil and Environmental Engineering, Volume 11, Issue 1, February 2011, Pages 1–11.
In their 2011 paper for the World Coal Ash Conference, S. Vaidya et al. evaluated self-curing geopolymer concrete for mass pour applications experimentally.
Geopolymer concrete: a material for the future, by D.B. Raijiwala and H. S. Patil, published in the March 2011 issue of the Journal of Engineering Research and Studies.
In a 2011 study published in the World Academy of Science, Engineering, and Technology, Muhd Fadhil Nuruddin, Andri Kusbiantoro, Sobia Qazi, and Nasir Shafiq examined the compressive strength and interfacial transition zone of geopolymer concrete subjected to varying in-situ curing conditions [13]. The use of geopolymer technology for waste stabilization was discussed by Douglas C. Comrie, John H. Paterson, and Douglas J.

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