

Study of Parameter on Geopolymer Concrete

Mr. Arya Bhujbal

Dept. of Civil Engineering Sinhgad
Academy of Engineering,
Kondhwa
Pune, Maharashtra, India

aryabhujbal11@gmail.com

Mr. Sumit Thakur

Dept. of Civil Engineering Sinhgad
Academy of Engineering,
Kondhwa
Pune, Maharashtra, India

sumitthakur.sae@sinhgad.edu

Mr. Pruthviraj Gaikwad

Dept. of Civil Engineering Sinhgad
Academy of Engineering, Kondhwa
Pune, Maharashtra, India

pruthvigaikwad048@gmail.com

ABSTRACT

The Geopolymer concrete (GPC) is an innovative and eco-friendly construction material that uses industrial by-products such as **Fly Ash**, **Ground Granulated Blast Furnace Slag (GGBS)**, and **Metakaolin** as binders instead of Ordinary Portland Cement (OPC). The alkaline activators used, such as **Sodium Hydroxide (NaOH)** and **Sodium Silicate (Na₂SiO₃)**, form a polymeric chain structure that provides excellent strength and durability.

KEYWORDS

Sodium Hydroxide, Sodium Silicate, Geopolymer Concrete.

INTRODUCTION

Concrete is one of the most widely used construction materials in the world. It is second only to water as the most consumed substance on Earth. However, the production of ordinary Portland cement (OPC), the main binding component in conventional concrete, is responsible for nearly **8% of global CO₂ emissions**. For every ton of cement produced, approximately **0.9 to 1 ton of CO₂** is released into the atmosphere. With the rapid pace of infrastructure development and urbanization, the demand for cement continues to rise, thereby contributing significantly to global warming and environmental degradation.

In this context, researchers and engineers have been seeking sustainable and eco-friendly alternatives to OPC-based concrete. One such promising material is **Geopolymer Concrete (GPC)**. The term *geopolymer* was first introduced by **Joseph Davidovits in 1978**, referring to inorganic polymers formed by the reaction between aluminosilicate materials and alkaline solutions. These polymers possess a three-dimensional framework of Si-O-Al bonds, which provide strength, stability, and durability comparable to or better than traditional cementitious materials.

Geopolymer concrete is produced by activating aluminosilicate-rich industrial by-products such as **fly ash**, **Ground Granulated Blast Furnace Slag (GGBS)**, and **metakaolin** using alkaline solutions such as **Sodium Hydroxide (NaOH)** and **Sodium Silicate (Na₂SiO₃)**. The process involves *dissolution*, *reorientation*, and *polycondensation* of silicate and aluminate species into a hardened binder. This reaction eliminates the need for Portland cement entirely, making GPC an environmentally sustainable alternative.

The concept of geopolymers was first introduced by **Professor Joseph Davidovits**, a French materials scientist, in the **late 1970s**. He coined the term "*geopolymer*" to describe a new class of inorganic polymeric materials produced by the chemical activation of alumina-silicate compounds using alkaline solutions.

Davidovits conducted pioneering research at the **Institute Geopolymer, France**, and demonstrated that fly ash, slag, and metakaolin could undergo polymerization reactions when mixed with alkaline activators to form strong, cement-like binders. He also proposed that ancient civilizations, such as the Egyptians, might have used natural geopolymers to construct massive stone structures.

Ordinary Portland Cement production releases large amounts of CO₂ and consumes huge quantities of natural resources. Geopolymer concrete, by replacing cement with industrial by-products, can reduce CO₂ emissions by up to 80%, contributing to sustainable development.

Since the 1980s, significant progress has been made in the development of geopolymer concrete. Researchers such as **Rangan**, **Hardjito**, and **Van Jaarsveld** carried out extensive experimental studies on the mechanical and durability properties of fly ash and GGBS-based geopolymers. Today, GPC is considered one of the most sustainable materials for structural and non-structural applications, as it effectively converts industrial waste into a valuable construction resource.

LITERATURE REVIEW

1. Vemundla Ramesh, Dr.Koniki Shrikanth (2020) -- "Mechanical Properties & Mix Design Of Geopolymer Concrete" (EDP SCIENCES)

Geo-polymer concrete (GPC) is a most viable solution to cement as the raw materials depleting down the years and, many countries have started imposing carbon taxes. After a review for the literature reveals that there is no proper mix design procedure developed yet. GPC has better mechanical properties when compared to normal concrete. Curing conditions, setting times, workability, alkaline solution to binder ratios, molarity of alkaline solution, Na₂SiO₃/NaOH and SiO₂/Al₂O₃ ratios play an important role to develop GPC. This paper presents an overview of Geopolymerization process, mechanical properties and mix design of GPC. Proper mix design of geopolymer concrete can produce desired mechanical properties for ambient curing condition and geopolymer concrete can consider as

eco-friendly construction material. This paper deals with study of advancement in mix design and mechanical properties of geopolymer concrete.

2. Oke O. L.,Ayein I.S. (2019) – “Effects of Source Materials on Mechanical Properties of Geopolymer Concrete”(American Journal Of Engineering Research)

This work aims at studying the effects of source materials on the mechanical properties of geopolymer concrete. Three source materials were used which were Rice Husk Ash (RHA), Saw Dust Ash (SDA) and Cow Dung Ash (CDA) and the amount of Alumina and Silica oxides in them were determined to be RHA (81.28%), SDA (72%) and CDA (71.2%). They were used with Alkaline solution in ratio 0.4 to produce binding medium for other constituents. The Alkaline solution was a combination of Sodium Silicate and Sodium

Hydroxide in ratio 2.5. Compressive and Flexural strengths of geopolymer concrete produced with RHA, SDA and CDA were determined after heat curing for 24 hours, 48 hours and 72 hours at temperature of 100°C. Both compressive and flexural strengths increased as the curing age increased. RHA-geopolymer concrete gave the highest compressive and flexural strengths followed by SDA and CDA in that order.

KEY WORDS: source, materials, geopolymer, concrete, compressive, flexural, strength

Based on the experimental work on GPC using ultra-fine GGBFS, the following conclusion were made:

3. Vijayasathy Rathanasalam, Jayabalan Perumalsami, Karthikeyan Jayakumar (2020) - “Mechanical Properties Of a Geopolymer Concrete/Ultrafine Material Based Composite” (Materials)

- The strength properties of GPC based on UFGGBFS and fly ash were found to be improved.

- At ambient temperature, the GPC strength was determined after 7 d and 28 d of curing; in addition to polymerization, hydration played an important role in the strength improvement.

- 14-M GPC showed the best performance with respect to the flexural, compressive and tensile strength when compared to 10 M, 12 M.

- The 15-% addition of UFGGBFS showed good strength for all the molarity values when compared to the other amounts.

- The increase in the amount of UFGGBFS improved the interfacial transition zone of GPC. The water absorption of GPC decreased with an increase in the UFGGBFS amount.

- Using crushed-stone sand and UFGGBFS is environment friendly and hence, the mixture can be used as an innovative material.

MATERIAL

1. Ground Granulated Blast Furnace Slag (GGBS)

GGBS improves the long-term strength and durability of concrete structures. It helps reduce the heat of hydration, making it suitable for mass concrete works. Its use also lowers CO₂ emissions, contributing to sustainable construction.

GGBS concrete resists chemical attacks, especially from sulfates and chlorides.



2. Fly ash

Fly Ash is a fine powder generated as a by-product from burning pulverized coal in power plants. It contains silica and alumina, which react with lime to form cementitious compounds. Used as a partial replacement for cement, it improves workability and reduces permeability. Fly Ash enhances the long-term strength and durability of concrete. It helps minimize environmental waste and reduces cement consumption. Concrete with Fly Ash shows better resistance to chemical attack and thermal cracking.

3. Metakaolin

1. Metakaolin is a calcined form of kaolin clay produced by heating it to around 700–800°C. It is a highly reactive pozzolanic material used to replace part of cement in concrete. Metakaolin refines the pore structure, reducing permeability and improving strength. It increases resistance to sulfate and chloride penetration, enhancing durability. The material also improves the appearance and color of concrete surfaces.



Its use contributes to producing high-performance and eco-friendly concrete.

4. Conplast

Conplast is a range of chemical admixtures developed by Fosroc for concrete and mortar. These admixtures include plasticizers, superplasticizers, retarders, and accelerators. Conplast improves workability and reduces water content without compromising strength. It helps in achieving higher early and ultimate strengths in concrete. The admixtures enhance durability by reducing permeability and shrinkage. Conplast products are widely used for quality control and



performance optimization in construction.

RESULT

Following are the final mix design of gpc.

1. Water content 148 kg.
2. Cement content 412 kg.
3. Coarse Aggregate 1318.59 kg.

4. Fine aggregate 451.825 kg.
5. Chemical admixture 0.0036 m³
6. w/c ratio 0.36

CONCLUSION

From the experimental and analytical results, it is concluded that geopolymer concrete is a sustainable, high-strength, and durable alternative to OPC concrete. Using fly ash and GGBS reduces CO₂ emissions and effectively utilizes industrial waste. GPC shows higher compressive, tensile, and flexural strength along with better durability and lower shrinkage. Hence, geopolymer concrete can be effectively used in precast structures, pavements, and structural applications demanding sustainability and performance.

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