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Geopolymer Composite: Enhancing the Structural Strength and Sustainability

Shreya Mahalle¹, Devanand Rathod², Suraj Waghamare³, Sakshi Pole⁴, Rupesh Kumbhare⁵,
Tushar Rathod⁶, Prof. S. S. Pawar⁷

U.G Student, Civil Engineering, Department of Civil Engineering, J.D.I.E.T., Yavatmal, Maharashtra, India¹⁻⁶

Assistant Professor, Department of Civil Engineering, J.D.I.E.T., Yavatmal, Maharashtra, India⁷

ABSTRACT: Geopolymer concrete is an innovative and sustainable alternative to traditional Portland cement concrete. The use of geopolymer concrete has gained prominence in the construction industry due to its potential for reduced environmental impact and enhanced material performance. In this research we focused on partially substituting brick and concrete slag and alkaline activators in the GPC mixture. The purpose of the study is to reduce green-house gases by using Brick slag and concrete slag which are the by-products of the construction and demolition industry, hold the potential to reduce waste and minimize the demand for traditional aggregates. Sodium silicate and sodium hydroxide are alkaline activators in geo-polymerization, facilitating the formation of a highly durable and environmentally friendly construction material. This examination researches the comprehensive analysis of the mechanical properties, durability, and environmental sustainability of GPC at testing durations of 7 days, 14 days, 21 days, and 28 days. The study explores various proportions of brick slag and concrete slag, ranging from 10% to 40%, in the GPC mixture. In reference with the research, this study underscores the significance of geopolymer concrete as an innovative solution for sustainable construction, showcasing its compatibility with brick slag and concrete slag as partial substitutes. The findings underscore here aim to promote the wider adoption of geopolymer concrete within the construction industry and emphasize its role in reducing the environmental impact.

KEYWORDS:- geopolymer concrete, concrete and brick slag, alkaline activators, fly ash, compressive strength.

I. INTRODUCTION

1.1 General

Concrete is a material that is frequently used in building. The primary ingredient used to make concrete is Portland cement. More CO₂ is released into the atmosphere by the cement industry because one ton of Portland cement is produced. Many efforts have been made to reduce the amount of Portland cement used in concrete by finding substitutes such as fly ash, silica fume, brick slag, and concrete slag. It has also been suggested that an alkaline liquid be used to react with silicon (Si) and aluminum (Al) to produce binders. Because the resulting chemical reaction involves a polymerization process, the Geopolymer technology exhibits great promise for usage in the concrete industry as an alternative to Portland cement as a binder. Numerous studies suggest that fly ash can be used as a raw material to create geopolymer. This aluminum-silicate cementitious compound has excellent mechanical qualities, including strong compressive strength and temperature stability. Structural reinforcement is added into the molds or beds before the concrete is cast, compacted, and cured. Enhancing the structural strength of geopolymer concrete involves optimizing the mix design, curing process, and material selection. Carefully select the type and proportions of raw materials, including fly ash, slag or other aluminosilicate sources. A well-balanced mix design with the right ratio of activators (alkaline solutions) is crucial for achieving higher compressive and flexural strengths. Use high-quality raw materials with suitable chemical compositions and particle sizes. Ensure the aluminosilicate source is rich in reactive components to promote geo-polymerization. Choose high-quality aggregates with good bonding properties to the geopolymer matrix. Properly selected aggregates can help achieve stronger interfacial bonds. The properties of geopolymer concrete are tested and analyzed regularly to identify areas requiring improvement. Adjust mix composition and curing conditions based on test results. Ongoing research and development may lead to innovations that further improve the strength of the structure.

Concrete slag

Concrete slag, often referred to as slag concrete or slag cement, is a type of concrete that incorporates slag as a partial replacement for Portland cement. Slag is a by-product of the iron and steel manufacturing process and is often used in construction to enhance the properties of concrete.



Fig (1) Concrete slag

Brick slag

Slag bricks are a type of construction brick that incorporates slag as a raw material. Slag is a byproduct of various industrial processes, including metal smelting and steel production. When processed and mixed with other materials, slag can be used to make bricks.



Fig (2) Brick slag

Fly ash

Fly ash is a fine dust that is a byproduct of burning coal in a power plant. It is collected from flue gases using electrostatic precipitators or other particle filtration equipment. Fly ash is a useful product with a variety of uses, especially in homes and businesses.



Fig (3) Fly ash

1.2 OBJECTIVES

To determine the ideal blend proportion of brick slag or concrete slag with other Cementitious materials to achieve the desired performance and sustainability characteristics in GPC.

To evaluate the compressive strength, flexural strength, and durability properties of GPC containing brick slag or concrete slag to ensure it meets or exceeds relevant Industry standards.

Investigate the use of curing-enhancing admixtures to ensure proper curing of GPC Precast members, resulting in increased strength development and durability.

To study and conduct tests for enhancing the compressive strength, flexural strength, and durability properties of GPC, by using partial substitute of materials ensuring that it meets or exceeds the performance requirements for various precast applications.

1.3 NEED OF STUDY

Geopolymer concrete is an innovative and environmental-friendly alternative to traditional Portland cement-based concrete. It is gaining popularity due to several compelling advantages and needs in the construction industry. Geopolymer concrete has up to 90% greater thermal insulating qualities than OPC concretes while emitting much less CO₂. Greater heat and fire resistance. Giving 'waste' items, which are frequently disposed of in landfills, a useful use. Geopolymer concrete helps in reducing the depletion of natural resources, as it can be made from industrial waste materials like fly ash, slag, and other aluminosilicate sources. This not only conserves resources but also diverts waste from landfills, contributing to a more sustainable construction industry.

1.3 Scope of Work

The scope for enhancing the structural strength and sustainability of geopolymer composites is offers numerous opportunities for research, development, and practical application. The results highlighted here are intended to encourage the widespread use of geopolymer concrete in the building sector and highlight its contribution to lowering environmental impact

II. LITERATURE REVIEW

2.1 Compressive strength of eco-friendly geopolymer concrete.

Amir Ali Shahmansouri ,(2021): This research experimentally substituting ground granulated glass furnace slag (GGBS) with silica fume (SM) and natural zeolite (NZ) in the GPC activated by sodium hydroxide (NaOH) solution with different and sodium silicate solution on the compressive strength. The results is shown in this research increasing the NaoH concentration reduce the concrete strength and while adding the SF and NZ to the concrete yielding an improvement in the compressive strength. More effective parameters in a wider range of variation could be considere for future research. Although the proposed ANN model could accurately predict the compressive strength of GPC hybridization of ANN with some metaheuristic algorithm such as lion optimisation algorithm , social engineering optimizer and red deer algorithm could further increase the accuracy of prediction of future work .

2.2 Durability characteristics of steel fibre reinforced geopolymer concrete:

N. Ganesan , (2015): In summary, the study suggests that GPC, especially when reinforced with steel fibers, possesses favorable durability characteristics, making it a promising alternative to conventional concrete in various applications. The study compared the durability characteristics of plain and fiber-reinforced geopolymer concrete (GPC) with conventional concrete (CC) in various aspects including water absorption, porosity, sorptivity, abrasion resistance, resistance to chemical attack, alternate wetting and drying, and chloride ion penetrability.

2.3 Fracture behaviour of heat cured fly ash based geopolymer concrete

Prabir K. Sarker, (2018): In this study highlights that geopolymer concrete exhibits unique fracture behavior characterized by increased toughness and a higher threshold for crack initiation, primarily due to its superior bond and tensile strengths and a denser interfacial transition zone when compared to OPC concrete. Fracture energy in GPC is similar to OPC, increasing with compressive strength. GPC required higher stress for crack formation, indicated by a higher critical stress intensity factor compared to OPC. This difference was attributed to GPC's higher bond and tensile strengths, resulting in a smoother fracture plane and more brittle failure due to a denser interfacial transition zone.

2.4 Life cycle assessment of geopolymer concrete

Daniel A. Salas, (2018): The production of sodium hydroxide is the most relevant life cycle process regarding the environmental performance of geopolymer concrete, as it is a man raw material in the production of sodium silicate as well other items such as concrete mixing facilities, curing process. Due to the high environmental burden related to electricity use within the life cycle of sodium hydroxide, the share of renewable energy in the mix considered for the life cycle assessment influences overall results. The source of hydroxide influences greatly the overall environmental

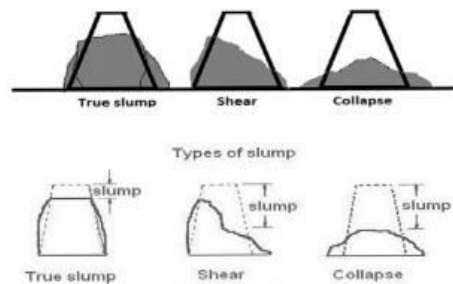
impacts, due to both, the energy mix and type of sodium chloride used for its production. The characterization of local sodium hydroxide, produced with solar salt, entails lower environmental impacts than average European sodium hydroxide, produced with solution mining and rock mining salt.

2.5 Parametric Studies on Compressive Strength of Geopolymer Concrete

Prakash R. Voraa , (2017): The ratio of alkaline liquid to fly ash, by mass does not affect the compressive strength of the geopolymer concrete .The compressive strength of the geopolymer concrete increases with increase in the curing time. However, the increase in strength beyond 24 hours is not much significant. 1 day rest period increases the compressive strength of the geopolymer concrete as compared to that for the concrete.

2.6 Properties of pervious geopolymer concrete using recycled aggregates

Vanchai Sata , (2013): This paper discusses the use of recycled aggregate from crushed structural concrete(RC) and crushed clay bricks(RB) as coarse aggregates in making pervious geopolymer (PGC) concrete with high-calcium fly ash. The compressive strengths of PGCs containing (RC) and (RB) were lower than those with natural aggregates (NA), but they fell within typical strength ranges. Overall, the results suggest that using RC and RB as recycled coarse aggregates with a high-calcium fly ash geopolymer binder is feasible for making pervious concrete with acceptable properties.



III. METHODOLOGY

During our research, we study various literature on this topic. After reading all the literature, I decided on a few materials, tested them and added them to the geopolymer concrete. These materials include fly ash, brick slag, concrete slag and binders such as sodium hydroxide and sodium silicate, which act as alkaline activators. Once you have identified the ingredients, you need to learn how to calculate mixing ratios. To fully compact concrete, a higher water to cement ratio may be required than theoretical. In other words, one of the functions of water is to lubricate the concrete so that it is properly compressed into place. An alkaline binder ratio is assumed. Estimate the amounts of Na_2SiO_3 and NaOH based on the proportion of alkaline binder. Perform the molarity calculations needed to estimate the amounts of water and NaOH floc. An hour before preparing geopolymer concrete, an alkaline solution should be prepared and mixed with the calculated amount of water. The formwork must be oiled before pouring the required amount of geopolymer concrete. Fly ash and aggregate were dry mixed with alkaline liquid (NaOH and sodium silicate solution) using a mechanical mixer, and then the wet mixing process was started and continued for 1 minute. It was reminiscent of the process of mixing regular concrete. Geopolymer concrete samples were demolded at 1 day of age and then air cured until 28 days of age. Compression testing and design testing are performed. After testing the sample, the sample analysis results are analyzed and comparative analysis is performed.



Fig.(4) Slum Test

Fig.(5) Compression Test

IV. DESIRED OUTCOMES

1. **Strength and Durability:** Geopolymer concrete is expected to have high compressive strength and durability, similar to or better than traditional Portland cement concrete.
2. **Environmental Benefits:** Geopolymer concrete should offer significant environmental advantages by producing lower carbon emissions and reducing the demand for traditional cement, which is a major source of greenhouse gases.
3. **Reduced Curing Time:** Geopolymer concrete may have shorter curing times, allowing for faster construction and reduced project durations.
4. **Cost-effectiveness:** It should be cost-competitive or even more economical than conventional concrete, considering its materials and production processes.
5. **Fire Resistance:** Geopolymer concrete may be designed to have enhanced fire resistance, making it suitable for fireproof structures.
6. **Sustainability:** Geopolymer concrete should contribute to sustainable construction by reducing carbon emissions, conserving natural resources, and minimizing waste.
7. **Applicability:** The desired outcome is that geopolymer concrete can be used in a wide range of construction applications, from buildings and bridges to roads and infrastructure, without compromising performance.



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