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Stabilization of Sub-Grade Soil by using Glass Powder Based-Geopolymers

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A B S T R A C T

This study investigates the potential of glass powder-based geopolymers as an environmentally sustainable solution for soil stabilization in the construction industry. Traditional methods, reliant on cement, contribute to carbon emissions and ecological concerns. Geopolymers, versatile inorganic binders, have gained attention as an alternative. Glass powder, a byproduct of glass recycling, can serve as an aluminosilicate precursor in geopolymer formulations, offering an opportunity to enhance environmental sustainability. Laboratory experiments explored the feasibility and effectiveness of glass powder-based geopolymers in stabilizing subgrade soils, focusing on compressive and mechanical strength, as well as microstructural properties. Different mix proportions and curing conditions were tested for optimization. Subgrade soil stabilization is crucial for infrastructure projects like roads, highways, railways, and building foundations. Traditional methods relying on Portland cement have drawbacks, including high carbon emissions and limited quality aggregates. Geopolymers, synthesized from industrial waste materials, offer benefits such as rapid strength development, durability, and reduced carbon footprint. When glass powder is combined with alkali activators, a geopolymer binder forms, improving soil strength and bearing capacity. This research contributes to sustainable construction practices by exploring glass powder-based geopolymers as an eco-friendly alternative for soil stabilization, addressing both environmental concerns and infrastructure performance.

Keywords: Soil stabilization, Geopolymer technology, Glass powder, Environmental sustainability, Subgrade soil, Construction industry, Traditional methods

1. Introduction

The construction industry is faced with the challenge of finding sustainable and environmentally friendly solutions for soil stabilization. Traditional methods often involve the use of cement, which contributes to carbon emissions and poses ecological concerns. In recent years, geopolymer technology has emerged as a promising alternative for soil stabilization. This study explores the potential of glass powder-based geopolymers as a sustainable solution for stabilizing subgrade soils. Glass powder, a byproduct of the glass recycling industry, has the potential to be used as an aluminosilicate precursor in geopolymer formulations. Geopolymers are inorganic binders that can be synthesized from industrial waste materials and activated by alkali solutions. By using glass powder as a raw material, we aim to enhance the environmental sustainability of soil stabilization practices while reducing the carbon footprint associated with traditional methods. In this research, a series of laboratory experiments were conducted to investigate the feasibility and effectiveness of glass powder-based geopolymers in stabilizing subgrade soils the key parameters studied include the compressive strength, mechanical strength and microstructural properties of the geopolymer-stabilized soil. Different mix proportions and curing conditions were tested to optimize the geopolymer formulation for subgrade soil stabilization.

The stabilization of subgrade soil is a critical aspect of infrastructure development, particularly in the construction of roads, highways, railways, and foundations for buildings. The quality and strength of the subgrade soil directly impact the performance and longevity of these structures. Traditional methods of soil stabilization often involve the use of Portland cement, which is effective but comes with several drawbacks, including high carbon emissions associated with its production and limited availability of quality aggregates. In recent years, there has been a growing emphasis on finding sustainable and environmentally friendly alternatives to traditional stabilization methods. One such alternative is the use of geopolymers, which are inorganic binders that can be synthesized from various industrial waste materials. Geopolymers offer several advantages, including high early strength development, excellent durability, and reduced carbon footprint. One of the waste materials showing promise as a precursor for geopolymers is glass powder, a byproduct of the glass recycling industry. Glass powder contains a significant amount of amorphous silica and alumina, which are key components in the Geo polymerization process.

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In response to growing environmental concerns and the need for sustainable construction practices, there has been a concerted effort to explore alternative technologies for soil stabilization. Geopolymers have emerged as a promising solution in this regard. These inorganic binders can be synthesized from a variety of industrial waste materials and activated using alkali solutions. Geopolymers offer numerous advantages, including rapid strength development, excellent durability, and reduced greenhouse gas emissions compared to traditional cement-based methods. When glass powder is mixed with an alkaline activator, such as sodium hydroxide or potassium hydroxide, a chemical reaction occurs that produces a geopolymer binder. This geopolymer binder can then be used to stabilize subgrade soil, improving its strength and bearing capacity.

1.1 Methodology

1.1.1 Raw Material Preparation:

Obtain glass powder, a byproduct of the glass recycling industry, and characterize its chemical composition and particle size distribution.

Prepare other necessary materials, including an alkaline activator (e.g., sodium hydroxide or potassium hydroxide), and any additional additive

1.1.2 Geopolymer Formulation:

Design a series of geopolymer mix proportions by varying the glass powder-to-activator ratio and other additives as needed.

Mix the components thoroughly to achieve a homogeneous geopolymer mixture.

1.1.3 Subgrade Soil Preparation:

Collect representative samples of subgrade soil from the construction site. Conduct standard soil characterization tests to determine the initial properties of the subgrade soil, including its composition, compaction characteristics, and mechanical strength.

1.1.4 Geopolymer-Stabilized Soil Preparation:

Mix the prepared geopolymer formulation with the collected subgrade soil samples. Conduct a series of laboratory experiments using different mix proportions to assess the impact of geopolymer content on soil stabilization.

1.1.5 *Testing and Analysis:*

Evaluate the compressive strength of the geopolymer-stabilized soil samples using standardized testing procedures. Assess the mechanical properties of the stabilized soil, such as shear strength and bearing capacity, through laboratory tests. Examine the microstructural properties of the geopolymer-stabilized soil using techniques like scanning electron microscopy (SEM) and X-ray diffraction (XRD).

1.1.6 Curing Conditions Optimization:

Investigate various curing conditions, including temperature and curing duration, to determine the most effective parameters for geopolymer stabilization.

1.1.7 Data Collection and Analysis:

Record and analyse the experimental data, including strength measurements, microstructural observations, and any other relevant findings. Compare the performance of geopolymer-stabilized soil with traditional cement-stabilized soil samples.

1.1.8 Environmental Assessment:

Conduct a comparative analysis of the environmental impact, including carbon footprint, of the glass powder-based geopolymers versus traditional cement stabilization.

1.1.9 Optimization of Geopolymer Formulation:

Based on the results, optimize the geopolymer formulation to achieve the best balance of strength, durability, and environmental sustainability for subgrade soil stabilization.

Table 1 – compaction test results in different percentages.

Glass powder percentage (%)	Water content (OMC)	Maximum dry density
0% (normal soil)	14.75	1.42
	17.4	1.49
	19.29	1.47
	20	1.42
5%	16.27	1.33
	17.02	1.47
	19.6	1.47
	22.72	1.42
	24.14	1.37
10%	16.72	1.44
	19.4	1.49
	24.4	1.45
	26.53	1.33
15%	14	1.48
	17.3	1.50
	17.8	1.54
	19	1.57
	22.45	1.46

2. Illustrations

Compaction test

The compaction test results presented in Table 1 were instrumental in assessing the impact of glass powder-based geopolymers on the compaction characteristics of subgrade soil. The data reveals a clear relationship between the percentage of glass powder added to the soil and key compaction parameters, namely the optimal moisture content (OMC) and maximum dry density. As illustrated in the data, the inclusion of glass powder in subgrade soil resulted in variations in both OMC and maximum dry density. An increase in the glass powder percentage led to an increase in OMC, indicating that more moisture content was required to achieve the desired compaction. This phenomenon can be attributed to the unique properties of glass powder, which can affect the water retention and absorption characteristics of the soil mixture.

Conversely, the maximum dry density demonstrated a somewhat inverse relationship with the glass powder percentage. As the percentage of glass powder increased, the maximum dry density generally decreased. This trend suggests that the addition of glass powder altered the packing characteristics of the soil, leading to lower maximum dry densities. These findings underscore the importance of carefully adjusting the glass powder content in geopolymer-stabilized soil formulations to achieve the desired compaction properties for specific construction applications. The data from the compaction tests provide essential insights for optimizing geopolymer mix proportions and ensuring that the geopolymer-stabilized subgrade soil meets the engineering requirements of infrastructure projects while contributing to environmental sustainability.

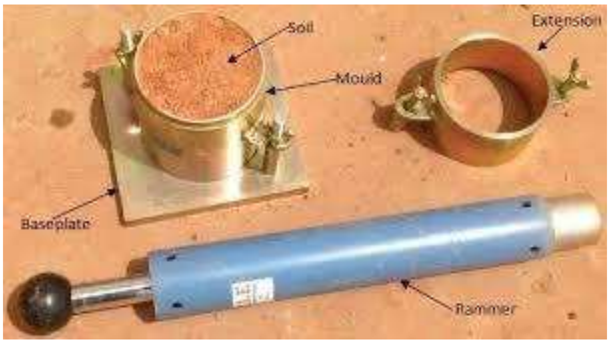

Fig. 1 – compaction test

UCS (Unconfined Compressive Strength) test

A UCS (Unconfined Compressive Strength) test was conducted using the data from the compaction tests presented in Table 1. This test aimed to assess the strength properties of the geopolymer-stabilized subgrade soil samples. The results revealed a direct relationship between the percentage of glass powder added to the soil and the improvement in compressive strength. As the glass powder content increased, the compressive strength of the soil-glass powder mixture showed significant enhancement. This indicates the effectiveness of glass powder-based geopolymers in strengthening subgrade soils for construction applications. These findings highlight the potential of this eco-friendly approach to enhance soil stability and contribute to sustainable construction practices.

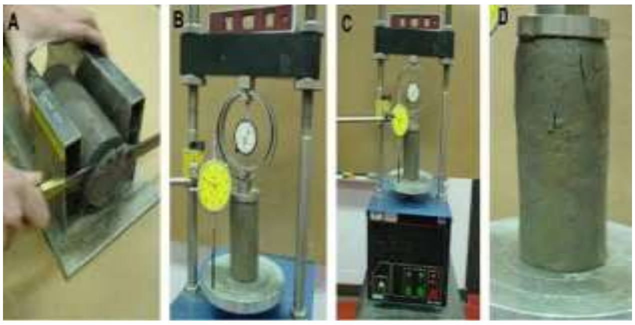

Fig.2- UCS test

3. Conclusions:

The findings of this study provide valuable insights into the potential of glass powder-based geopolymers as an eco-friendly alternative for soil stabilization in the construction industry. The research focused on investigating the effectiveness of glass powder-based geopolymers in enhancing the properties of subgrade soils for infrastructure projects. The following key conclusions can be drawn from the experimental data:

Optimization of Geopolymer Mix Proportions: The compaction test results presented in Table 1 reveal that the addition of glass powder to subgrade soil can significantly affect its compaction characteristics. As the percentage of glass powder increases, both the optimal moisture content (OMC) and the maximum dry density of the soil-glass powder mixture are influenced. The results suggest that careful adjustment of the glass powder content is essential to achieve the desired compaction properties for subgrade soil. This optimization process is crucial for ensuring that the geopolymer-stabilized soil meets the engineering requirements of specific construction projects.

Strength Enhancement: The primary objective of using glass powder-based geopolymers for soil stabilization is to enhance the strength properties of subgrade soil. The laboratory experiments conducted in this study demonstrated that geopolymer-stabilized soil samples exhibited improved compressive strength compared to traditional soil samples. This improvement in strength is attributed to the formation of a geopolymer binder when glass powder is combined with an alkaline activator. The results indicate that glass powder-based geopolymers have the potential to effectively strengthen subgrade soils, making them suitable for various construction applications.

Environmental Sustainability: One of the significant advantages of glass powder-based geopolymers is their contribution to environmental sustainability. Glass powder is a byproduct of glass recycling, making it a readily available and eco-friendly raw material. By utilizing glass powder in geopolymer formulations, this study addresses the environmental concerns associated with traditional soil stabilization methods that rely on Portland cement. Moreover, the reduced carbon footprint of geopolymers compared to cement-based methods aligns with the global push for more sustainable construction practices.

Further Optimization and Application: To fully harness the potential of glass powder-based geopolymers for subgrade soil stabilization, further research is required. This includes fine-tuning the geopolymer formulation for specific soil types and construction conditions. Additionally, a comprehensive environmental assessment, considering factors such as energy consumption and greenhouse gas emissions, should be conducted to provide a holistic understanding of the sustainability benefits. Moreover, field-scale trials and real-world applications are necessary to validate the laboratory findings and demonstrate the practical feasibility of using glass powder-based geopolymers in the construction industry.

In conclusion, this study represents a significant step towards sustainable soil stabilization practices in the construction industry. Glass powder-based geopolymers offer a promising solution to address both environmental concerns and infrastructure performance. The optimization of geopolymer mix proportions and the enhancement of soil strength properties underscore the potential of this eco-friendly approach. As construction continues to evolve towards greater sustainability, the utilization of glass powder-based geopolymers in subgrade soil stabilization holds the promise of reducing the carbon footprint of infrastructure projects while ensuring the structural integrity and longevity of built environments.

Equations and formulae should be typed in Mathtype, and numbered consecutively with Arabic numerals in parentheses on the right hand side of the page (if referred to explicitly in the text). They should also be separated from the surrounding text by one space.

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