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Sustainable Subgrade Strengthening by Using Geopolymers in Black Cotton Soil

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ABSTRACT

The study explores the challenge posed by black cotton soils to civil and geotechnical engineers, particularly in the context of poor pavement performance and structural foundation damage. Soil stabilization techniques are crucial in addressing these issues, with geopolymers emerging as environmentally friendly alternatives. This research investigates the application of geopolymers to strengthen road subgrades, focusing on areas with unstable black cotton soil. Additionally, biological methods are explored to enhance the soil properties. Laboratory experiments and field trials are conducted to evaluate the effectiveness of geopolymers in improving subgrade stability. Various formulations are tested to determine the optimal mix, with results indicating that maximum strength is achieved after a 28-day curing period using 20% fly ash by weight of soil and a 10M solution. These findings signify a promising approach for sustainable subgrade strengthening in areas affected by black cotton soil instability.

INTRODUCTION

Soil is pivotal in construction, providing the groundwork for structural stability and integrity. Understanding its behaviour is paramount, as it influences design, construction, and long-term performance. Black cotton soil (BCS), prevalent in regions like India, poses challenges due to its high compressibility, swelling, and low bearing capacity. In road construction, the subgrade, the foundation upon which pavement is laid, plays a critical role. The properties of the subgrade, such as bearing capacity and moisture content, directly impact road infrastructure performance. Historically, soil stabilization methods have evolved from the early 20th century, with modern techniques focusing on chemical reactions to improve soil properties. Geopolymer stabilization, a form of biological soil stabilization, offers sustainable benefits by reducing carbon emissions, utilizing industrial by-products, and enhancing structural durability. By binding soil particles through a geopolymer matrix, this method holds promise for mitigating the challenges posed by black cotton soil, ensuring safer and more resilient infrastructure.

OBJECTIVES

1. To understand the mechanical properties of geopolymer treated black cotton soil and untreated soil.
2. To find the optimum dosage percentage of geopolymers for the maximum soil stabilisation (CBR & UCS) and also revealing the effect of alkaline activator on the strength of stabilized soil.

METHODOLOGY

PREPARATION OF ALKALINE ACTIVATOR:

The alkaline activator solution consisted of a 2:1 mixture of Na_2SiO_3 and NaOH. NaOH and Na_2SiO_3 solutions having concentration of 8M ,10M and 12M were prepared. NaOH and Na_2SiO_3 solutions were prepared 24h prior to use.

SAMPLE PREPARATION:

The required quantity of soil and fly ash at a percentage of 10%, 15%, 20% of weight of soil and mixed by hand for approximately 10 min. An appropriate quantity of the alkali solution using a preset molar ratio was added to the mixture and thoroughly stirred until a homogenous mixture was generated. The quantity of alkaline solution was estimated based on the optimum liquid content acquired during the standard proctor compaction test. Take 240g of black cotton soil and add the required moles of geopolymer (8M,10M and 12M) about optimum moisture content of the soil, add the required percentage of fly ash (10%,15% and 20%) by weight of soil taken and mix the soil, geopolymer and fly ash homogeneously for about 10min and prepare the UCS sample using UCS apparatus. Repeat the same procedure for every mole of geopolymer and percentage of fly ash. homogenize the soil samples to ensure uniformity. The specimens were extruded and cured at room temperature of 23 C. Geo-polymerization is can occur within this room temperature. Two specimens of each combination were prepared to ensure repeatability. The UCS of each specimen was measured after 3, 7, and 28 days. The specimens were extruded and cured at room temperature of 23 C. Geo-polymerization is can occur within this room temperature. Two specimens of each combination were prepared to ensure repeatability. The UCS of each specimen was measured after 3, 7, and 28 days.

RESULTS

Properties of black cotton soil

Parameters	**Value**
Liquid limit (%)	25
Plastic limit (%)	20
Optimum moisture content (%)	11.5
Maximum dry density (g/cc)	1.85
California Bearing Ratio (%)	2.14
Unconfined compressive strength (kg/cm^2)	1.41

The UCS values of the geopolymer-treated specimens improved with increasing FA proportion from 10%, 15% and 20%.The UCS value increased as the molarity of the activator increased from 8M to10M, but as the molarity of the activator increased further, the UCS value decreased.

The UCS value increased as the curing period is increased. For 3Days curing the highest value of UCS will came at 10M and 20 % of FA. AT 3Days, 7Days,28Days curing time the highest UCS value will came of a specimen contains 10M and 20 % of FA. The CBR values of the geopolymer-treated specimens improved with increasing FA proportion from 10%, 15% and 20%.Treated soil CBR 3.12% is high compared with the untreated soil CBR of 2%. Then the thickness of total pavement thickness is reduced. Treated subgrade is economical when compared with untreated subgrade.

CONCLUSION

The study investigates the sustainable strengthening potential of geopolymers in black cotton soil subgrades through various tests comparing untreated soil with treated samples mixed with geopolymers at different molarities and percentages of fly ash. Results from unconfined compressive strength (UCS) tests show a significant increase in soil strength with geopolymers, particularly at 8 and 10 moles, but a decrease at 12 moles suggests an optimal range. California Bearing Ratio (CBR) tests reveal varying trends, with samples treated with 10 moles of geopolymer and 20% fly ash showing the highest load-bearing capacity. Incorporating geopolymers and fly ash into black cotton soil demonstrates promise for subgrade applications, with fly ash showing potential as a supplementary stabilizer. Further research is needed to explore parameters like curing conditions and long-term performance, along with field-scale testing and economic assessments, to understand the feasibility and practicality of this sustainable strengthening technique.

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