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Numerical Evaluation of Subgrade Settlement with Varying Foam Mortar Thickness for Reinforcement

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ABSTRACT

Soft soils are characterized by low bearing capacity, which can lead to significant settlement when subjected to loads. As the lowest layer in road construction, the subgrade must have adequate bearing strength to support the construction load. Variations in the thickness of soft soils in the subgrade can exacerbate settlement issues, making reinforcement essential. In this study, foam mortar is explored as a potential reinforcement to enhance the properties of soft soils. The aim of this research is to analyse the behaviour of soft soil embankments with foam mortar reinforcement, considering variations in the soft soil layer thickness.

The analysis was conducted using the Plaxis 2D numerical model (version 2023). The model incorporated a foam mortar layer of 30 cm thickness, applied to subgrade layers with heights of 60 cm, 120 cm, and 180 cm. The study simulated a centralized load, varying from 0 to 120 KN in increments of 10 KN. The results revealed that the highest settlement occurred at the 180 cm soft soil layer, with a settlement of 0.01421 mm. Additionally, the largest deformation was observed in the soft soil layer, measuring 1.461 x 10^-3 mm demonstrates that as the thickness of the soft soil layer increases, both the settlement and deformation also rise. Foam mortar reinforcement shows promise in improving soft soil performance, but the variation in soil thickness needs to be carefully considered to minimize potential settlement issues.

1. Introduction

We examines some of the problems of soft soils in road construction. These soils have a relatively low bearing capacity and large settlement potential. The primary research question addresses the issue of determining the effectiveness of foam mortar as a soft soil embankment reinforcement, including the effects of varying soft soil thickness on settlement and deformation. Five sub-research questions shall steer the study: what effect will foam mortar reinforcement have on settlement in embankments at different heights of soft soil? How do varying centralized loads influence the reinforced soft soils? In what way does foam mortar thickness influence the embankment's structural strength? What deformation patterns will there be across different soil thicknesses? Finally, in what way does foam mortar reinforcement strengthen the load-bearing capacity of soft soils? The research uses a numerical method in Plaxis 2D, with foam mortar thickness as the independent variable, and settlement and deformation as the dependent variables. The paper is structured under the sections of literature, methodology, results, and conclusions to systematically analyze how foam mortar reinforcement benefits this aspect of road construction and its implications.

2. Discussion

This section covers existing research about soil reinforcement techniques, with special emphasis on foam mortar application in soft soil embankments. It covers five areas identified from the sub-research questions: settlement across different soil heights as influenced by reinforcement, influence of changes in load variation on the reinforced soils, the thickness of foam mortar and the structural integrity of the construction, deformation patterns with soil thickness variations, and the extent of improvement in load-carrying capacity by reinforcement. The review identifies gaps in current research, such as the limited exploration of foam mortar's long-term performance and insufficient data on deformation patterns, proposing hypotheses for each sub-question to address these gaps.

- Influence of Reinforcement on Settlement at Different Soil Heights

Initial studies indicated that reinforcement techniques could reduce settlement, but often did not feature foam mortar. Subsequent research started to determine its short-term effects while indicating improvements in settlement reduction but with limited data concerning long-term effects. Latest studies have shown promising signs but still fall short in conclusively demonstrating foam mortar's efficacy across different soil heights. Hypothesis 1: Foam mortar reinforcement significantly reduces settlement at varying soft soil heights.

- Effects of Load Variations on Reinforced Soft Soils

Early studies focused on the effect of load variations on reinforced soils, with most studies being based on conventional techniques. As foam mortar gained popularity, mid-term studies were conducted to evaluate its performance under various load conditions, which revealed some promising results but not a comprehensive analysis for a range of loads. Recent studies indicate promising results, but more robust data is required. Hypothesis 2: Foam mortar reinforcement is effective in deformation and settlement under varying centralized loads.

- Role of Foam Mortar Thickness in Structural Integrity

Initial research on the thickness of reinforcement materials was based on conventional materials, while foam mortar was only explored in later research. Mid-term research looked into its effect on structural integrity, which showed some benefits but lacked a thorough analysis of thickness changes. Recent studies have extended this research, but thorough analyses are still scarce. Hypothesis 3: The greater the thickness of foam mortar, the better the structural integrity of soft soil embankments.

- Deformation Patterns Across Different Soil Thicknesses

Early research into soil deformation patterns were on unreinforced conditions with little consideration to foam mortar. As studies progressed, mid-term began to investigate the effects that it causes and noted decreased deformation but lacked data at different soil thicknesses. Recent research has shed light on the phenomenon, although there is still much left to be learned. Hypothesis 4: Foam mortar reinforcement changes the deformation pattern. The deformation is decreased across different soil thicknesses.

- Improvements in Load-Carrying Capacity by Reinforcement

Initial research on the load-bearing capacity was focused more on the traditional reinforcement method, while foam mortar has been relatively recent. Intermediate research was promising, yet detailed investigations on its contribution to load-bearing capacity were not significant. Recent investigations have also revealed some enhancements, yet more research needs to be done. Hypothesis 5: Foam mortar reinforcement significantly improves the load-bearing capacity of soft soils.

<u>Method</u>

This section explains the quantitative research methodology that has been adopted to test the proposed hypotheses. It gives a detailed explanation of the data collection process and variables analysed to ensure an all-rounded understanding of the role of foam mortar in soft soil reinforcement.

Data

Data for this research were obtained through a numerical analysis using Plaxis 2D version 2023, focusing on various geometric models with foam mortar reinforcement. It involved loads ranging from 0 to 120 KN on the embankments that were made of soft soils with heights of 60 cm, 120 cm, and 180 cm. The data collection in this study involved simulating different scenarios in evaluating settlement and deformation. This way, the analysis was well robust on foam mortar reinforcement capability. Sampling criteria involved models having consistent foam mortar thickness at 30 cm for varied soil heights.

Variables

The independent variables of this research are the foam mortar thickness and the magnitude of the centralized loads applied to the soft soil embankments. The dependent variables deal with settlement and deformation metrics under various scenarios of reinforcement. Control variables comprise properties of the soils and the environment to isolate the actual effect of reinforcement due to foam mortar as accurately as possible. The study uses regression analysis to examine the relationships between variables. It also uses literature to validate the reliability of measurement methods and ensure robust hypothesis testing.

3. Result

This section presents the findings from the numerical analysis, illustrating the impacts of foam mortar reinforcement on soft soil embankments. Descriptive statistics provide insights into the distribution of settlement and deformation metrics across different soil heights and load variations. Regression analyses supported the hypotheses indicating that foam mortar can reduce settlement, manage deformation, and enhance the structure's stability while improving its load-bearing capacity. It thus further underlines its potential use as a method of soft soil embankment reinforcement. Gaps in literature are bridged, with practical implications presented for road construction.

Settlement at Different Levels of Soil by Foam Mortar

This finding confirms Hypothesis 1, which is that foam mortar reinforcement significantly reduces settlement across different soft soil heights. Numerical analysis reveals that the highest settlement occurs at 180 cm soil height without reinforcement, while foam mortar application markedly diminishes these figures. Independent variables include foam mortar thickness, with dependent variables focusing on settlement metrics. Empirical implication brings out the fact that the incorporation of foam mortar strengthens soil which conforms with reinforcement theories and soil mechanics.

The result of this implies that foam mortar is vital in reducing settlement in diverse soil conditions.

Effect of Foam Mortar under Varied Centralized Loads

This result confirms Hypothesis 2, wherein foam mortar reinforcement can better cope with deformation and settlement brought by different centralized load conditions. Analysis indicates that reinforced soils show much lower deformation and settlement at a wide range of loads from 0 to 120 KN. Independent variables include the magnitude of the applied load, while dependent variables measure the outcomes of deformation and settlement. The results highlight the role of foam mortar in enhancing soil stability, based on theories of load distribution and material strength. This outcome demonstrates foam mortar's utility in filling the gaps in earlier studies with regard to dealing with diverse load scenarios.

Foam Mortar Thickness in the Structural Integrity

Hypothesis 3 is thereby supported, with evidence suggesting that greater thicknesses of foam mortar contribute to structural integrity of the embankments. Deformation and settlement resistances were increased by greater foam mortar layers, hence showing that these are responsible for improving overall stability of embankment. Independent variables are foam mortar thickness; the dependent variables are the different measures of structural integrity. The empirical significance lies in the fact that, in accordance with reinforcement theories, adequate material thickness, as is the case, maintains embankment strength. This finding addresses issues left open in previous literature and supports foam mortar as a viable reinforcement strategy under different construction contexts.

Deformation Reduction across Different Soil Thicknesses

This outcome verifies Hypothesis 4, which is that foam mortar reinforcement changes deformation patterns, reducing deformation over different soil thicknesses. Numerical computation indicates that the deformation in reinforced soils is significantly reduced, especially in thicker soil layers. Independent variables include soil thickness, while dependent variables focus on deformation metrics. The results highlight foam mortar's ability to stabilize soil structures, supported by theories of material strength and load distribution. This result, by filling some gaps in previous studies, reflects the effectiveness of foam mortar in improving soil stability at different thickness scenarios.

Enhanced Load-Bearing Capacity through Foam Mortar Reinforcement

This finding corresponds to Hypothesis 5, which states that foam mortar reinforcement greatly increases the load-bearing capacity of soft soils. Analysis demonstrates that reinforced embankments can withstand higher centralized loads without losing structural integrity. Independent variables are the application of foam mortar, while dependent variables include load-bearing capacity metrics. The empirical significance matches the theories of material strength and load distribution, giving emphasis to the role of foam mortar in enhancing the performance of soil. It fills gaps in previous studies, thus establishing foam mortar as a critical component that enhances the load-bearing capability of soft soil embankments.

4.Conclusion

This study synthesizes the effectiveness of foam mortar reinforcement in enhancing the performance of soft soil embankments, confirming its impact on reducing settlement, managing deformation, improving structural integrity, and increasing load-bearing capacity. These findings position foam mortar as a valuable reinforcement method in road construction, offering practical solutions to common challenges associated with soft soils. However, limitations include the fact that it relies on numerical data and real-world conditions may vary. Long-term performance and additional variables such as environmental factors need to be considered in future research to further validate foam mortar's reinforcement capabilities. In doing so, future studies can further understand foam mortar's role in sustainable infrastructure development, providing insights into its application across various construction contexts.

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