Enhancing Trench Stability:
AGeogrid Reinforcement Approach

1. introduction

Soils, a ubiquitous material in construction, face challenges from erosion caused by wind and rain, jeopardizing the stability of earthen roofs [1]. Without geogrid reinforcement, roof maintenance becomes costly [2]. Erosion in rocky formations raises structural compromise concerns and the risk of loose rock detachment due to weathering

3.conclusions

In conclusion, this research has delved into the critical realm of trench stabilization through the implementation of geogrids, employing static analysis as the primary methodology. The comprehensive investigation, conducted using the finite element numerical method, has yielded invaluable insights into the challenges and dynamics inherent in trench construction

2. Results and discussion

The analytical stages in this research encompass the following: in each stage, a layer of trench soil with a thickness of 80 cm is introduced, and the geogrid element is activated in conjunction with the construction of the facing wall. Upon the completion of layer implementation across 10 phases, a subsequent phase is initiated utilizing the "Phi-ɛreduction" calculation type

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Result and discussion

depicts contours representing the horizontal and vertical configurations of the trench for a width of 13 meters.

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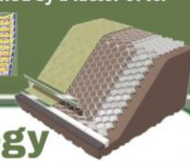

4. methodology

In this study, a simulated trench environment was established, comprising an earthen area measuring 8×35 meters. A segment of this area, spanning 20 meters in width and 8 meters in height, was designated as a stable earthen zone with robust materials located behind the trench

Soil type	γ (kN/m3)	E (MPa)	ν	c (kPa)	φ(°)	ψ (°)	R_{inter}
Embankment (behind the trench)	21	2000	0.3	2000	30	0	1
Trench	18	25	0.3	1	34	4	1

Table 2. The specifications of geogrid reinforcement.

	Material type	EA (KPa)	T_y (KN/m)
Geogrid	Elastoplastic	1000	200

methodology

Table1 and Table2

the properties of soil materials used in this study

the specifications of geogrid

Enhancing Trench Stability: A Geogrid Reinforcement Approach

Authors:

Abstract

This paper investigates trench stabilization using geogrid reinforcement, employing static analysis via the finite element numerical method through PLAXIS 2D. Focusing on the challenges associated with soil instability in construction projects, particularly earthen roofs and rocky formations, theis study emphasizes the potential for structural compromise and fragmentation due to erosion and weathering. Geogrid polymer networks, strategically integrated with soil and stone, emerge as a preventive measure against such disasters. Notable advancements in geogrid-related research are surveyed, establishing the context for this study. The methodology encompasses a simulated trench environment, systematically reinforced with a geogrid in 10 layers, within an 8×35-meter earthen area. The properties of soil materials and geogrid specifications are detailed, while standard boundary conditions emulate real-world scenarios. Fine meshing ensures result accuracy, and trench width reduction analysis reveals a crucial correlation between diminished dimensions, augmented displacement, and a decreased safety factor. The results highlight a heightened instability within the trench as it undergoes dimensional changes. The decrease in trench length directly correlates with a reduction in the safety factor, underscoring the risk of compromised structural integrity. Reducing the length of the trench from 15 meters to 14 meters is associated with an approximate 1% increase in displacement, concurrently accompanied by a 9% decrease in volume. This insight emphasizes the need for meticulous trench dimension considerations in construction practices. The findings contribute to the geotechnical engineering

field, prompting a re-evaluation of design methodologies and offering empirical evidence for the development of robust guidelines in trenching projects.

Keywords: Trench Stabilization; Geogrid Reinforcement, Finite Element Numerical Analysis; Soil Stability

1. Introduction

Soils, a ubiquitous material in construction, face challenges from erosion caused by wind and rain, jeopardizing the stability of earthen roofs [1]. Without geogrid reinforcement, roof maintenance becomes costly [2]. Erosion in rocky formations raises structural compromise concerns and the risk of loose rock detachment due to weathering [2-3]. To address these challenges, the application of geogrid polymer networks proves instrumental [4]. These networks, formed by interconnecting polymer strips, serve as a preventive measure against disasters or structural damage in various constructions, including roads, bridges, and buildings [5]. The design of geogrids incorporates strategically positioned empty spaces between the polymer strips, facilitating their integration with soil, stone, and other geotechnical materials. This integration enhances the composite material's resistance, making geogrids a valuable asset [5].

In recent years, there has been a notable surge in studies focusing on geogrids and trench-related research. Abdelouhab et al. studied earthen wall behavior, exploring numerical analyses with various strip reinforcements, including metal and synthetic polymers of different hardness [6]. Zhou et al. investigated the interaction between sand particles and geogrid during tensile testing, analyzing sand displacement around the geogrid's transverse element through digital camera analysis [7]. Bhowmik et al. developed a device for inclined pullout tests on geosynthetics, focusing on geogrids, and explored interactions with different anchor types, offering insights into geosynthetic stability on slopes in landfill covers [8]. Bildik and Laman conducted laboratory experiments examining the impact of single and multiple layers of geogrids on bearing capacity and stress behavior. Parameters such as geogrid depth, vertical spacing, and layer number provided insights into soil-structure-pipe interaction and stress distribution [9]. Abdi et al. investigated the "Pegged Geogrid" (PG) system in large-scale pull-out tests, revealing improved soil passive resistance without bolting or welding. Evaluation of peg parameters in sandy and gravely soils highlighted the significant impact of peg inclusion on pull-out resistance and strain distribution along the geogrid [10]. Al-Haddad et al. emphasized the importance of protecting buried pipelines, exploring geosynthetic reinforcements to mitigate stress, with geogrid identified as a prevalent material in 38% of cases, addressing high costs and environmental concerns [11].

This research delves into the investigation of trench stabilization through the utilization of geogrid, employing static analysis as the methodology. The essential analyses were carried out using the finite element numerical method through PLAXIS 2D to comprehensively address the stabilization challenges inherent in trench construction.

2. Methodology

2.1. Geometry and materials

In this study, a simulated trench environment was established, comprising an earthen area measuring 8×35 meters. A segment of this area, spanning 20 meters in width and 8 meters in height, was designated as a stable earthen zone with robust materials located behind the trench. Positioned at a distance of 15 meters, the subsequent phase involved the introduction of a trench reinforced with geogrid within the same soil environment. The reinforcement of the geogrid in the trench was executed systematically, employing a layer-by-layer approach consisting of 10 layers. At each step, an 80 cm thick layer of sandy soil with a low bearing capacity was implemented and subsequently reinforced with geogrid. The trench walls were constructed using concrete pieces with a thickness of 20 cm and exhibited low resistance characteristics. The properties of soil materials and geogrid reinforcement specifications are outlined in Table 1 and Table 2, respectively.

Table 1. The properties of soil materials used in this study.

Soil type	γ (kN/m3)	Ė (MPa)	ν̇	ċ (kPa)	φ'(°)	Ψ (°)	$\boldsymbol{R}_{inter}$
Embankment (behind the trench)	21	2000	0.3	2000	30	0	1
Trench	18	25	0.3	1	34	4	1

Table 2. The specifications of geogrid reinforcement.

	Material type	EA (KPa)	T_y (KN/m)
Geogrid	Elastoplastic	1000	200

2.2. Boundary and initial condition

The boundary conditions of the models are designed to emulate real-world conditions accurately. Specifically, the left side of the model is constrained from horizontal movement, simulating the typical stability of the natural terrain. However, vertical movement is permitted, accounting for potential ground settlement. In contrast, the right border, corresponding to the trench location, is configured to allow both horizontal and vertical movement. The lower border imposes restrictions on vertical displacement but permits horizontal movement. These boundary conditions, known as standard boundary conditions [12], align with common scenarios encountered in various problems. Following the application of standard boundaries, the right border is subsequently released based on the displacement of the trench wall. In problem-solving, the program discretizes the domain into small elements, commonly referred to as a mesh, and solves the problem within each individual element before aggregating the results to characterize the entire model [13]. The choice of mesh size is a critical consideration, as larger mesh sizes contribute to shorter solution times at the expense of result accuracy. Conversely, smaller mesh sizes lead to increased solution time but enhance result precision. In this study, very fine meshes were employed to ensure a higher degree of accuracy in the obtained results. During the meshing process, it is advisable to prioritize clusters within sensitive areas where concentration is more pronounced. Fig. 1 illustrates the meshing of the model representing the soil environment and geogrid.

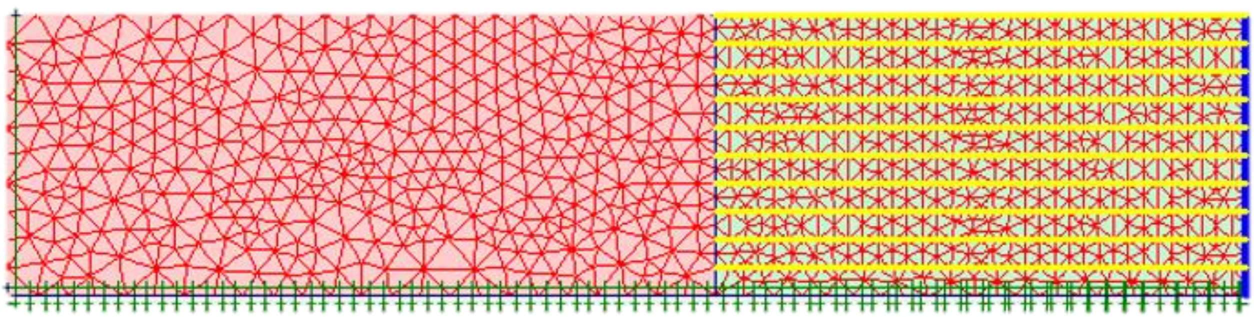

Fig. 1. The meshing of the model used in this study. Very fine mesh was set to represent the soil environment and geogrid.

When establishing the finite element drawing and meshing model's geometry, it is imperative to define the initial stress state and overall condition. The initial conditions comprise two distinct aspects: firstly, the establishment of initial water pressure, and secondly, the specification of the initial geometry's general configuration to generate the initial effective stress field [14]. The initial weight stress should be configured to reflect a state devoid of any new activities or trench creation. This research investigates the impact of diminishing the width of the trench on both stability and displacements. To achieve this objective, the width of the trench is systematically reduced. Fig. 2 depicts trenches with widths of 10, 8, and 5 meters, respectively.

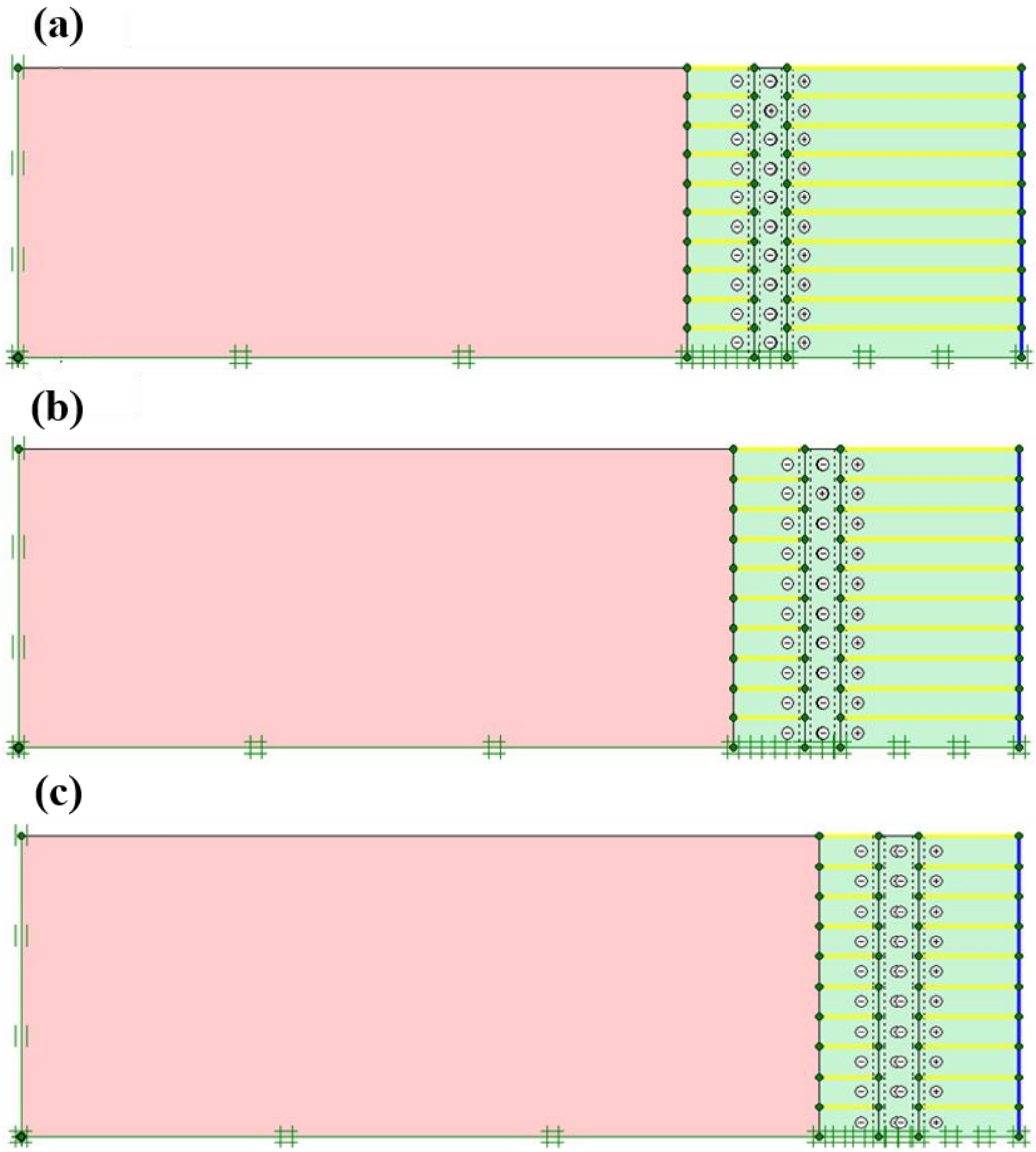

Fig. 2. The geometry and dimensions of the trenches employed in this research are presented for **(a)** 10 meters, **(b)** 8 meters, and **(c)** 5 meters.

3. Results and Discussion

The analytical stages in this research encompass the following: in each stage, a layer of trench soil with a thickness of 80 cm is introduced, and the geogrid element is activated in conjunction with the construction of the facing wall. Upon the completion of layer implementation across 10 phases, a subsequent phase is initiated utilizing the "Phi-c-reduction" calculation type [15]. This phase is designed to assess stability and derive the confidence factor of excavation. Fig. 3 illustrates the deformed mesh during the final phase of geogrid implementation, magnified by a factor of 10.

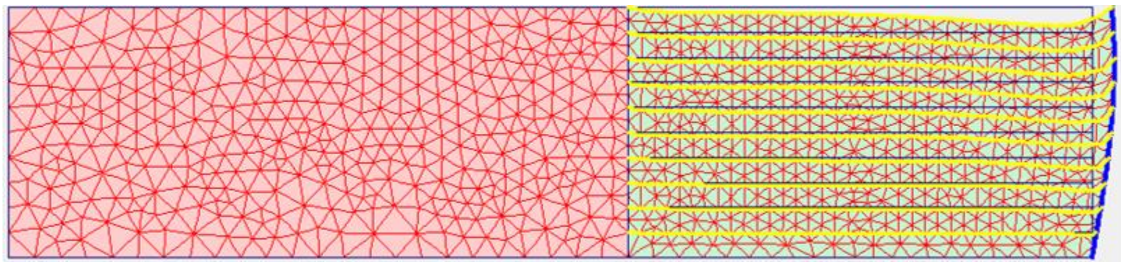

Fig. 3. Deformed mesh depicting displacement in a 13-meter-wide trench.

Additionally, Fig. 4 depicts contours representing the horizontal and vertical configurations of the trench for a width of 13 meters.

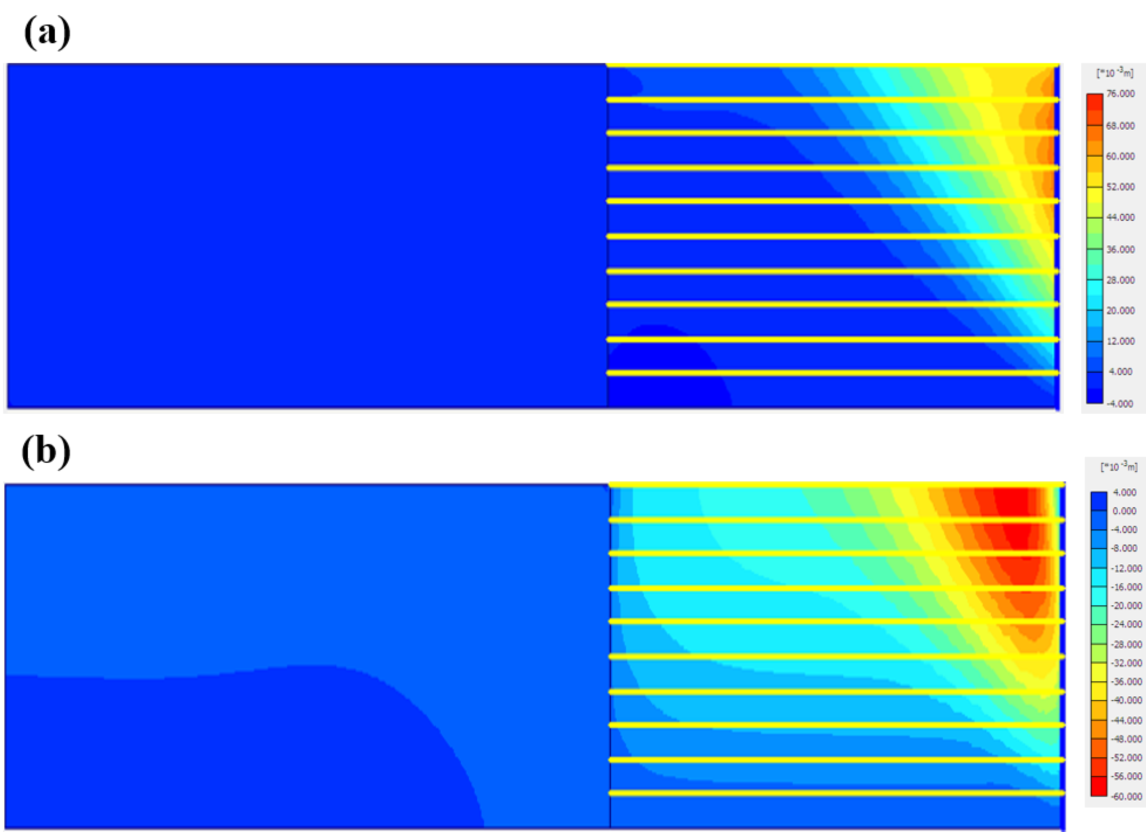

Fig. 4. Visualization of the model variations during the conclusive analysis phase of the 13-meter-wide trench, depicted as **(a)** horizontal displacement and **(b)** vertical displacement.

This study focuses on the investigation of trench stability. Initially, a trench length of 15 meters was considered and systematically reduced to assess the impact on stability. Two key parameters, namely the change in location and trench safety factor, were utilized to gauge stability. The initial phase of the modeling entails an examination of the alterations applied to the trench, with a subsequent evaluation of its stability. Thus, initially, a trench with a length of 15 meters was considered without reinforcement, resulting in an unstable state. Subsequently, the same length of trench was reinforced with geogrid, achieving stability. The trench length was then gradually reduced, maintaining stability until reaching a length of 13 meters, at which point the trench became unstable. Throughout these scenarios, the distance between geogrids was maintained at 0.8 meters. The obtained results indicate factor of stability (FOS) of 2.9665 and 2.7123 for trench lengths of 15 and 14 meters, respectively. Additionally, the displacements observed for these trenches are 0.08002 and 0.08041, respectively. In essence, the reduction of trench length from 15 meters to 14 meters resulted in an approximately 1% increase in displacement, accompanied by a 9% decrease in the FOS. In Fig. 5, the variations in location and FOS of the trench are depicted for different trench lengths.

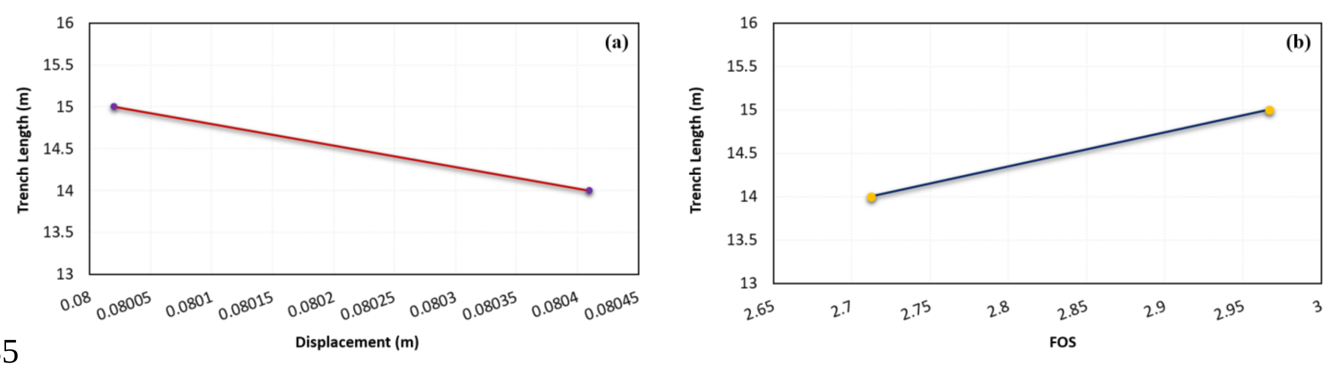

Fig. 5. Displacement and FOS changes of trench. Graph **(a)** illustrates the variation in location, while **(b)** depicts the change in reliability coefficient concerning different trench lengths.

The observed correlation between the reduction in trench length and an augmented displacement is a crucial finding in the context of soil and geotechnical science. This relationship suggests a heightened level of instability within the trench as it undergoes dimensional changes. The diminishing trench length appears to be directly linked to a decrease in the safety factor, indicating a concerning escalation in trench instability. These results underscore the complex interplay between trench dimensions, displacement, and overall stability. The concurrent increase in displacement and decrease in safety factor implies that alterations in trench geometry may exacerbate soil mechanics, leading to compromised structural integrity. This insight is particularly significant for engineering and construction practices, highlighting the need for careful consideration of trench dimensions to mitigate potential instability risks. Furthermore, these findings prompt a reevaluation of existing design and excavation methodologies to enhance safety measures in trenching operations. The observed trends provide valuable empirical evidence that can inform future geotechnical assessments and contribute to the development of more robust guidelines for trenching projects.

4. Conclusions

In conclusion, this research has delved into the critical realm of trench stabilization through the implementation of geogrids, employing static analysis as the primary methodology. The comprehensive investigation, conducted using the finite element numerical method, has yielded invaluable insights into the challenges and dynamics inherent in trench construction. The study has demonstrated a notable correlation between the reduction in trench length and an augmented displacement, signaling heightened instability within the trench as it undergoes dimensional changes. The parallel decrease in safety factor further underscores the escalating risk of trench instability with diminishing dimensions. These findings emphasize the intricate interplay between trench geometry, displacement, and overall stability, providing crucial implications for engineering and construction practices. The observed trends and empirical evidence offer a foundation for reevaluating existing design and excavation methodologies. It is evident that careful consideration of trench dimensions is paramount to mitigating potential instability risks and ensuring the long-term structural integrity of excavated structures. As this study contributes to the growing body of knowledge in geotechnical science, it opens avenues for the development of more robust guidelines and practices in trenching projects. In the future, addressing the limitations of this study and exploring further aspects of trench stabilization, such as different soil types and geogrid configurations, will enrich our understanding and contribute to the continuous improvement of geotechnical engineering practices.

5. References

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