
ENHANCING STABILITY AND PERFORMANCE OF MECHANICALLY STABILIZED EARTH RETAINING WALLS THROUGH GEO-GRID INTEGRATION AND TIEBACK ANCHORS

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ABSTRACT

Mechanically stabilised earth (MSE) retaining walls are essential infrastructure elements that provide stability to slopes and support different civil engineering constructions. Nevertheless, the stability and performance of these buildings might be compromised over time due to problems such as heightened loading demands, environmental conditions, and soil qualities. This research aims to improve the stability and performance of MSE retaining walls by using geogrid reinforcement and tieback anchors.

Geogrid reinforcement included into MSE retaining walls enhances tensile strength, facilitating contact between the soil and the structure, hence enhancing overall stability. In addition, tieback anchors provide horizontal support, diffusing forces and reducing wall deformation. This work examines the combined impact of geogrid reinforcement and tieback anchors on the performance of MSE retaining walls via an extensive investigation of current literature, laboratory experiments, and numerical analysis.

The main goals are to analyse the effects of geogrid location, spacing, and material qualities on the stability of the wall, evaluate how well tieback anchors can withstand lateral earth pressure, and optimise the combination of these strategies to improve overall performance. The laboratory studies will use physical modelling to replicate real-world settings, while numerical modelling will provide valuable insights into the long-term behaviour and performance of the system under different loading scenarios.

The project will provide useful information about the design, construction, and maintenance of MSE retaining walls that include geogrid reinforcement and tieback anchors. These integrated solutions provide sustainable and cost-effective methods for managing slope stability and sustaining important infrastructure in civil engineering projects by improving stability, reducing deformation, and boosting load-bearing capacity.

Key Words: (MSE) Retaining Walls, Stability Enhancement, Geogrid Integration, Tieback Anchors, Slope Stability

1. INTRODUCTION

Mechanically stabilised earth (MSE) retaining walls are essential components in civil engineering, providing vital reinforcement for infrastructure projects on a global scale. Nevertheless, the stability and performance of these buildings are often compromised over time due to problems such as soil instability, environmental variables, and fluctuating loading conditions. In order to overcome these difficulties, the combination of geogrid reinforcement with tieback anchors has emerged as a viable method to improve the stability and effectiveness of MSE retaining walls. MSE retaining walls are often used for its efficacy, economical nature, and adaptability in offering soil retention and slope stabilisation. These buildings are crucial for bolstering transit infrastructure, facilitating economic activities, and implementing environmental protection measures. Nevertheless, with the rising demands for infrastructure and changing environmental circumstances, there is an increasing need to enhance the resilience and efficiency of MSE retaining walls in order to guarantee their long-term performance and safety.

Geogrid reinforcement is the process of integrating strong polymer or metallic grids into the soil of MSE retaining walls. Geogrids function as tensile reinforcements, augmenting the interaction between soil and structures, strengthening the ability of the soil to bear weight, and decreasing the sideways pressure exerted by the earth. Geogrid integration may greatly improve the stability and performance of MSE retaining walls by distributing loads more effectively and reducing deformation. Tieback anchors are essential for providing lateral support to MSE retaining walls, in addition to geogrid reinforcement. These anchors are placed below the wall construction and anchored in stable soil or rock formations to withstand the pulling pressures caused by the soil or additional weights on the wall. Tieback anchors apply stress on the wall to efficiently resist lateral earth forces, resulting in less wall deformation and improved overall stability.

The combination of geogrid reinforcement with tieback anchors provides a mutually beneficial solution to tackle the many difficulties encountered by MSE retaining walls. Through the integration of these technologies, engineers have the capacity to augment stability, boost performance in the face of fluctuating loading circumstances, and prolong the

lifespan of MSE structures. This integration enhances the durability of MSE retaining walls and provides sustainable solutions for solving slope stability, erosion management, and earth retention concerns in civil engineering projects. The objective of this research is to examine the efficacy of using geogrid integration and tieback anchors in improving the stability and performance of MSE retaining walls. The research aims to provide useful insights into the design, building, and maintenance of robust MSE structures by thorough analysis, laboratory testing, and numerical modelling. The knowledge acquired from this study will provide valuable information for engineering practices, contribute to the progress of sustainable infrastructure development, and guarantee the safety and effectiveness of essential infrastructure systems.



There are various sorts of retaining walls, and we'll go through a few of them here.

Gravity Retaining Wall The weight of these walls is intended for resistance to horizontal forces from the ground. Earthquake loads, lateral pressure from the earth pushing on the bottom confront, and upward pressures caused by the wall's load are the main factors acting on such kinds of walls. Additional variables, such as vehicular burdens, have to be taken into account if the criteria are satisfied. It is usual practice to calculate lateral pressure on the earth using the famous Coulomb equation.

Cantilever Retaining Wall – These concrete-built walls employ the technique of leverage principle in their construction. These possess a considerably thinner stalk and rely heavily on the load of the backfill soil to prevent slipping and overturn. remarkably typical style of earth- retaining construction is a cantilevered retaining wall. Two distinct ground surface elevations are maintained using ground sloping and ground restraining systems. Cantilever walls have an L-shaped or reversed T-shaped foundation and are made of reinforced concrete. The foundation receives all vertical pressure behind the wall, protecting it from falling due to lateral displacement from the very same soil mass. Since construction requires space behind the walls, they are not well suited to facilitating slopes until temporary support is provided during construction.

Counterfort Retaining Wall - These types of walls resist all lateral loads by flexing action rather than mass. As a consequence, such walls have a huge foot structure, a upright stalk wired by bar, and thin transversal slabs called Counter strength Supporting it at even intermissions. The slab is designed for high tensile stresses stress since it is designed to be put inside the area in which the soil mass must always be maintained. A cantilever wall with a greater stem necessitates a large base, hence Counterfort walls are designed with transverse support to overcome this limitation. Because a big base is required for a cantilever wall with a large stem, Counterfort walls are constructed with transverse supports to overcome these limitations. The wing walls protrude upward from the heels of the footing into the stem of counterfort cantilevered retaining walls. The stems between counterforts are narrower (than cantilevered walls) and extends horizontally between the counterfort walls like a beam.

Gabion or Crib Wall - A gabion wall has wire material cages which hold stones or rubble together. Steel barrels are packed with stone or debris in crib walls, which are a sort of gabion wall. Stacking timber grillages and filling the interior with earth or rubble is another alternative. Also popular are precast concrete crib walls.

GEOGRID

Geogrid can be defined as a geosynthetic material mainly made up of polymeric material. Example – Polyethylene, polyvinyl alcohol polypropylene etc. It is a very useful reinforcing material now a days.

Geogrid is generally fabricating by 3 ways: extrusion, knitting or welding. The coarse or fine substance that is put on top of the geogrids combines with it. The apertures interlocking with the struts (level straps/bars) to limit the overlying coarse/soil substantial owing to the rigorousness and forte of the struts. The aggregates are held in place by the geogrids' interlocking. It is easier than traditional approaches to achieve mechanical stabilization of any ground work.

Functions of Geogrid

Its flexible and dynamic nature, makes it a appropriate choice for retaining walls, enabling them to become more robust and earthquake-resistant.

The construction costs are found to be much cheaper when geogrids were used instead of standard concrete retaining walls.

Advantages of Geogrid

The usage of geogrids allows for more cost-effective construction.

It is harmless to the environment.

Geogrids make members more resilient since they protect them from environmental threats.

It helps to keep the soil from collapsing.

Because the placement techniques are straightforward, geogrids ensure ease of construction.

Tie Anchor

A tie back anchor is generally used in soil or rock. It helps to carry and transmit the applied tension load into the earth. It is kind of a holding system widely used in conjunction with other retaining structures.

The tieback's bond length must reach outside the soil's possible critical slip surface. Otherwise, the tieback will not be able to prevent the ground material within the failure surface from collapsing.

2. OBJECTIVES

The objectives of this research are:-

- Assess the efficacy of geogrid reinforcement in improving the stability of MSE retaining walls.
- Evaluate the influence of tieback anchors on mitigating horizontal soil forces and minimising wall displacement.
- Examine the combined impact of incorporating geogrid integration and tieback anchors on the performance of Mechanically Stabilised Earth (MSE) walls.
- Calculate the most effective positioning and distance between geogrids to provide the highest level of stability and ability to handle heavy loads.
- Examine the strength and effectiveness over time of Mechanically Stabilised Earth (MSE) walls that use geogrids and tieback anchors.
- Assess the effectiveness of geogrid reinforcement and tieback anchors in enhancing the performance of MSE walls under different loading circumstances.
- Determine the key parameters that impact the efficiency of geogrid integration and tieback anchors in maintaining the stability of MSE walls.
- Create design standards for incorporating geogrid reinforcement and tieback anchors into Mechanically Stabilised Earth (MSE) retaining walls.
- Conduct a study to determine the cost-effectiveness of using geogrids and tieback anchors in comparison to traditional designs of mechanically stabilised earth (MSE) walls.
- Offer suggestions for enhancing the stability and efficiency of MSE retaining walls by including geogrid integration and tieback anchors.

3. LITERATURE REVIEW

The succeeding segments of this thesis review and provide information on the scientific literature on MSE barriers on soil weakness.

Yang et al. (2009) conducted a monitoring study on the main line of the Gan (Zhou)-Long (Yan) railway during the construction of a cast-in-situ geogrid-reinforced earth retaining wall. A reinforcing retaining wall's vertical base stresses turned out to not be uniform throughout its entire length, having an upper limit in the centre and a value that is lowest at the ends. The highest horizontal movement of a wall face throughout construction is contained inside a section of the bottom wall, and the greatest lateral pressures of the wall facing are maintained inside a section of the upper wall post construction.

The results of parametric studies on Geosynthetic Reinforced Multitiered Retaining Walls were presented by Leshchinsky et al. in 2004. He performed his research using two different kinds of examinations, one of which was centred around equilibrium limits (EL), and the subsequent one centred on continuum mechanics (CM). Limiting equilibria examination, if performed properly, generated virtually identical security variables in multitiered MSE walls for breakdown as the research that utilised continuum mechanics in the instance of stability of slopes. It was stated that

a tensile strength might be determined using equilibrium limit theory. The requirement for the tensile strength of reinforcements grew together with the rise in height of a multitiered retention walls. When compared to excellent grade fill, poor quality infill needs higher tension strength and a longer reinforcement.

Hossains et al. (2012) led a learning on an MSE (Mechanically Stabilized Earth) barrier situated on SH-342 in Texas (Lancaster). The objective of the study was to investigate the reasons behind the uncontrolled movement of the wall. Extensive fieldwork and laboratory testing were carried out to analyze the factors contributing to the wall's motion. The field examination comprised earth uninteresting and RI to assess the subsurface conditions. Resistivity Imaging was particularly cast-off to recognize areas with hovering aquatic regions inside the backfilling region. Through the study, several factors were identified that contributed to the extreme crusade of the MSE barrier. One significant factor found was the presence of a significant amount of fines in the backfill material. The inclusion of fines increased the likelihood of excessive movement in the MSE wall.

Additionally, the poor drainage capabilities of the backfilling of soil added further strain on the barrier. The infiltration of water into the backfill material resulted in the formation of water zones, which significantly contributed to the movement of the wall.

In summary, Hossain et al.'s (2012) study on the MSE wall in Lancaster, Texas, identified several factors contributing to the uncontrolled movement of the wall. These factors included the presence of forfeits in the backfilling, bad drainage capabilities, and the formation of water zones due to water infiltration. The learning highlights the position of suitable design and building performs to mitigate such issues and ensure the stability of MSE walls.

To investigate the impact of soil and reinforcing constraints on the performance of reinforcing foundations, parametric methods were employed. The study aimed to understand how variations in these parameters affected the behavior of the reinforced foundations. Using finite element analysis, the researchers prophesied the distortion actions of both reinforced and unreinforced foundations when exposed to normal fault movement. Through their analysis, they identified two key reinforcing mechanisms: shear rupture interception effects and tensioned membrane. In summary, Chiang et al. (2021) utilized finite element simulations to examine the efficiency and strengthening machineries of GRS footing under typical culpability measure. They compared computational and experimental results, investigated the effect of soil and reinforcing constraints, and predicted the deformation behavior of strengthened and unreinforced foundations. The study highlighted the important role of shear rupture interception effects and tensioned membrane in reinforcing GRS foundations.

Linhares et al. (2021) investigated the effectiveness of GRS walls through experimental and numerical approaches, considering the effect of surcharge width under working stress conditions. Their findings highlighted the significance of the maximum surcharge width in influencing the loads on the reinforcement. The numerical analysis further emphasized the role of backfill compaction in predicting building movements and enhancing the act of the strengthened soil wall by minimizing post-construction motions.

Guler et al. (2007) examined the failure process of reinforced soil segmented walls with extendable reinforcements using a numerical analysis availing the finite element method. The findings of three experimental test full-scale constructions earlier reported in the literature were then compared to the numerical method. The failing plane of a GRS-retaining wall approaches a straight sliding type, which originates from the structure's toe with a quite low slope.

Fonseca et al.(2014) analyzed assumptions from numerical analysis to measurements in an instrumented geogrid reinforced soil construction on a foundation soil which is collapsed, where recycled construction and demolition wastes (RCD) were employed as backfill. The porous collapsible foundation soil was evaluated by means of reinforcing strains, horizontal and vertical earth pressures, wall face displacements, settlements, and horizontal displacements. It was showed from both the field measurements as well as the numerical predictions that in geosynthetic retaining wall RCD waste could be an useful backfill material in the place of general conservative materials.

Xiao et al. (2015) studied a number of model retaining walls. The effects of various parameters of the strip foundations on the GRS walls was analyzed. The offset distance, the width of the strip footing on the GRS wall, the size of geogrid, and the relationship between geogrid and concretewall facing were incorporated. To detect prospective failure surfaces appearing in the walls, In the backfill a narrow pigmented sand layers were put.

It was also found that the contour of the sideways movement of the wall aspect was affected by offset distance of footing. The failure surface began at the footing's one-side edge. The mechanical connection tests revealed three potential slip surfaces exists. Two-part wedge method provided by Spencer had factor of safety lesser than Bishop's slip round surface technique, as specified by the limit equilibrium studies.

Song et al. (2018) used the FEM software plaxis to research the disappointment process of a GRS wall numerically. The failure mechanism was investigated based on the investigation of the construction layer and the impact of strength of soil, strength of geocell, and location of geocell. As per the findings, the slope was curvy and went through the bottommost of the wall and connected with the wall.

Sadat et al. (2018) looked into the performance of an MSE barrier and the impact of different parameters on its efficiency when the wall face stabilized with respect to the reinforcement zone. The research was supported with the use of a numerical method that was tested using triaxial testing and then MSE wall tests. Differential settlement would generate considerable lateral and vertical displacements, and an elevation in active earth pressure and geotextiles reinforced strain, according to the numerical calculations. The highest horizontal displacement happened around 1.0 m above the toe.

4. METHODOLOGY

This research examines the analysis of a retaining wall that is reinforced with geogrid using the Plaxis 2D programme. Subsequently, the soil stability is assessed by analysing the tie anchor in conjunction with the given information. Plaxis is a programme that uses finite element analysis. This programme has been specifically designed and used in the fields of geotechnical and structural engineering to examine various aspects such as stability, deformation, and ground water flow.

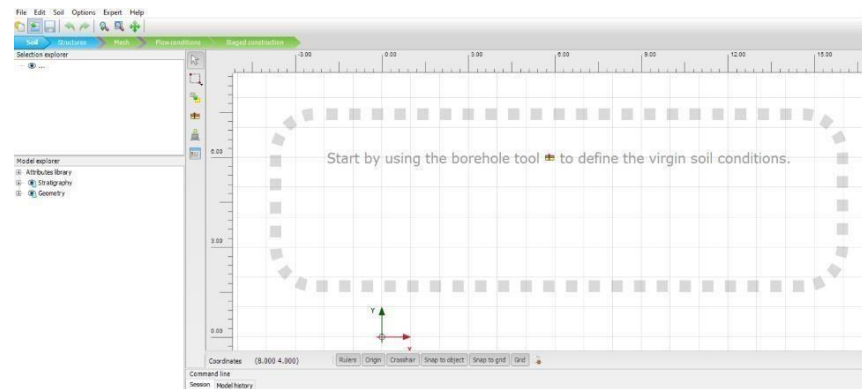


Figure.1 Basic Layout of Plaxis 2D

The research uses Plaxis software version v20. A total of 45 test models have been scrutinised and evaluated. In order to simulate the flat strain behaviour of soil clusters, a set of 15 node components were used.

FINITE ELEMENT RETAINING WALL MODEL

All the models were made in Plaxis software. The height of the wall varies from 4m and 5m. The standard geometry of the retaining wall of height 4m is shown in the figure.

FINITE ELEMENT MATERIAL PROPERTIES

Mohr's Coulomb's models Typically, these particular models need five input restrictions. The parameters in question include the moduli of elasticity, Poisson's ratios, angle of repose, cohesiveness, and dilatancy angles. The present research focus on exploring the permanence of walls using the Mohr Coulomb model, without taking into account the water table. The load is 20 kilonewtons (kN). It is constant. The Mohr-Coulomb failure condition is used to describe the behaviour of a material under stress. The MC model represents a substance that is linearly elastic and completely plastic. The specific properties of this model may be found in the table.

12m

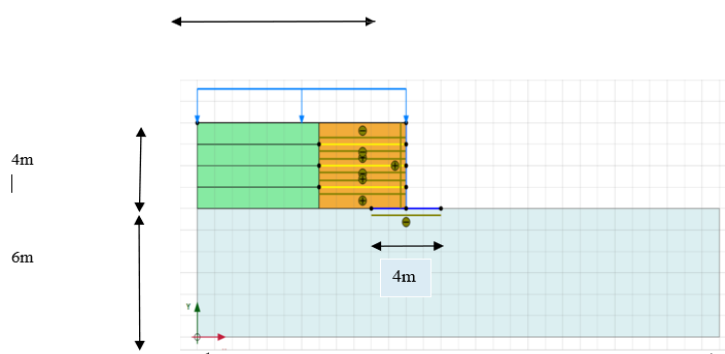


Figure 3.2 Geometry of MSE wall 30m

Table 3.1 Finite Element Material Properties (Kibria et al. 2014; Kong et al. 2013)

Material	Mass Density $\gamma_{unsaturated}$ (kg/m ³)	$\gamma_{saturated}$ (kg/m)	Elastic Modulus E (kN/m ²)	Cohesion (kN/m ²)	Internal Angle of Friction ϕ (°)	Angle of Dilation ψ (°)
Geogridsoil	19	20	30,000	1	34	-
BackfillSoil	19	20	12,500	1	34	4
FoundSoil	16	16	5500	8.45	27	0

Table 3.2 Finite Element Plate Properties (Kibria et al. 2014; Kong et al. 2013)

Material	Flexural Rigidity EI (kN m ² /m)	Normal Rigidity EA (kN/m)	Weight W (kN/m/m)
Foundation block	370000	18000000	0.15
Concretefacing	1100	5000000	38

Table 3.3 Finite Element tie anchor properties (Muhammed et. al. 2017)

Material	Flexural Rigidity EI (kN m ² /m)	γ (kN/m ³)	Dia (m)	Normal Rigidity EA (kN/m)
Grout body	2500000	24.90	0.0250	-
Anchor	-	-	-	200000

5. METHODS

A research was done to evaluate methods for enhancing the stability of the retaining wall. Here, we have measured the heights of the wall at three distinct points, namely 4 metres, 5 metres, and 6 metres. Geogrids also exhibit differences in their characteristics, in addition to their different heights. Initially, the rigidity of the geogrid was compared, followed by the subsequent alteration of the vertical spacing of the geogrid. The investigations were conducted using a finite element model created in the Plaxis 2D programme. Tie anchors, sometimes referred to as effective supports, help minimise the deflection of retaining structures. When we combine it with geogrids, we additionally verify the outcome here. The behaviour of geogrids was studied by combining node-to-node anchor with the geogrid and investigating it.

Mechanism Of Geogrid- The geogrid achieves its intended reinforcing effect via a range of approaches.

Lateral Confinement- Through its interconnection with the earth, it limits the horizontal flow of bulk materials and offers lateral confinement. It enhances the stiffness, enabling a greater amount of weight to be exerted while maintaining the same level of deformation. It decreases the amount of vertical pressure applied to the underlying soil and increases the amount of horizontal pressure.

increase of load distribution angle- Geogrid is used to distribute the load at a wider angle under the rails, which decreases the pressure on the subgrade. As a result, settlements and deformations are reduced.

Tension Member Effect- A loading capacity is created, which is an upward vertical force and helps to sustain the imposed load, reducing the stress on the soil.

6. RESULTS AND CONCLUSIONS

The thesis examines the stability and performance of mechanically stabilised earth (MSE) retaining walls by integrating geogrids and tieback anchors. It presents important findings that highlight the effectiveness of these integrated techniques in improving the stability and performance of MSE structures. The study shows that combining geogrid reinforcement with tieback anchors significantly enhances the stability, load-bearing capacity, and resistance to deformation of MSE retaining walls.

The combination of geogrids with tieback anchors leads to a reduction in lateral earth pressures, a decrease in wall deflection, and an enhancement in resilience under different loading circumstances. Additionally, the research identifies the most successful design criteria and offers technical instructions for the actual use of these methodologies. It emphasises their cost-effectiveness and long-term sustainability in infrastructure projects. In summary, the findings provide significant knowledge for the field of geotechnical engineering, aiding in the creation of secure, long-lasting, and environmentally-friendly MSE retaining wall solutions for essential infrastructure requirements.

7. CONCLUSIONS

After investigating the problem following conclusions can be drawn The use of geogrids is an exceptional method for enhancing the stability of retaining structures. The factor of safety of a retaining wall improves as the vertical space between geogrids is decreased. Increasing the rigidity of the geogrid minimises both vertical and horizontal deflection. As the geogrid's stiffness rises, the factor of safety likewise increases, hence enhancing the stability of the retaining wall. The use of a tie anchor in conjunction with a geogrid enhances the lateral deflection compared to using the geogrid alone. While the factor of safety does rise, the variance is not significant when the stiffness of the geogrid is increased.

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