NUMERICAL MODELLING OF GEOSYNTHETIC REINFORCED RETAINING WALL

A DISSERTATION
SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE AWARD OF THE DEGREE
OF

MASTER OF TECHNOLOGY
IN
GEOTECHNICAL ENGINEERING

Submitted by:
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MAY, 2023

CANDIDATE'S DECLARATION

I, Nikhil Gautam (2K21/GTE/10) of M. Tech (Geotechnical Engineering), hereby declare that the Project Report entitled " NUMERICAL MODELLING OF GEOSYNTHETIC REINFORCED RETAINING WALL", which is submitted by me to the Department of Civil Engineering, Delhi Technological University, Delhi is submitted in partialfulfillment of the requirement for the award of the degree of Master of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any Degree, Diploma Associateship, Fellowship or other similar titleor recognition.

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CERTIFICATE

I hereby certify that the Project Report entitled “NUMERICAL MODELLING OF GEOSYNTHETIC REINFORCED RETAINING WALL ", which is submitted by Nikhil Gautam (2K21/GTE/10) of M. Tech (Geotechnical Engineering), Delhi Technological University, Delhi submitted in partial fulfilment of the requirement for the award of Master of Technology, is a record of the project work carried out by the student undermy supervision. To the best of my knowledge, this work has not been submitted in part or full for any Degree or Diploma to this University or elsewhere.

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ABSTRACT

Mechanically stabilized earth (MSE) retaining wall is a distinctive structure which is used extensively in the recent days. Generally, there are various types of soil reinforcement can be used in mechanically stabilized earth retaining wall. Steel strip, welded steel grid, wire mesh, geotextiles, and geotextile sheets are examples of modern soil-reinforcing elements. The adoptionof a facing system minimizes soil erosion between reinforcing parts and enables for the safe construction of steep slopes and steep walls. Since the early 1970s, geosynthetic materials are produced and then used as reinforcement material in soil retaining structures. Geosynthetics have been increasingly popular in reinforced soil constructions, and they currently account for a considerable percentage of reinforced soil industry. Technological advances in the polymer sector have been regularly comprised into new geosynthetic products, improving the qualities of geosynthetic materials used in geotechnical applications. Geotextile is one of the main products of geosynthetic materials. Reinforced soil walls are composite structures made up of reinforcement and compacted backfill. The present study focuses on the behaviour of geotextile in Mechanically Stabilized retaining wall. The horizontal deflection, vertical deflection and influence of spacing of geotextile are studied. The geotextiles are applied into varying height of wall too. The stability of this composite system is imparted by the friction between the reinforcement and backfill and tension in the reinforcement. They have been proven to be a sustainable and cost-effective alternative for the conventional masonry and concrete retaining walls. The length of geotextile and the surcharge load are taken constant and comparison has been drawn between with and without geotextile structure. Significant improvement of stability of structure is shown after application of geotextile. The combination of geotextile and soil effectively enhances the overall stability of the retaining wall structure.

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LIST OF SYMBOLS, ABBREVIATIONS AND NOMENCLATURE

	Description
MSE	Mechanically stabilized earth wall
m	meter
mm	millimeter
GRS	Geosynthetic reinforced soil wall
kN	Kilo newton
FEM	Finite element modeling
E	Elastic modulus
γ_{unsat}	Mass density
γ_{sat}	Saturated unit weight
EI	Flexural rigidity
W	weight
EA	Normal rigidity
φ	Internal angle of friction
ψ	Angle of dilation
s	second
g	gram
FS	Factor of safety
Z	Height from ground level
No’s.	numbers
γ	Unit weight of soil
δ	Shearing resistance angle
H	height
k_a	Coefficient of active earth pressure
C_a	Adhesion between geotextile and soil
σ_h	Lateral pressure
S_v	Spacing between geotextile

CHAPTER 1

INTRODUCTION

Composite constructions comprised of reinforcement and backfill that has been compacted are called reinforced soil walls. The tension in the reinforcement as well as the friction between the reinforcement and the backfill contribute to the stability of this composite structure. They have shown to be a viable and affordable replacement for traditional masonry and concrete retaining walls. A construction called a mechanically stabilised earth (MSE) retaining wall is made up of soil reinforcing elements installed on a wall facing and compressed fill materials in varying thicknesses. What gives the wall construction its stability is the friction and strain interaction between the fill material and soil reinforcing element. Reinforcements are added to levels of the backfill soil during the construction of an MSE wall, and this reinforced material resists the earth pressure brought on by the retained material by utilising the relative movement between the reinforcement and soil.

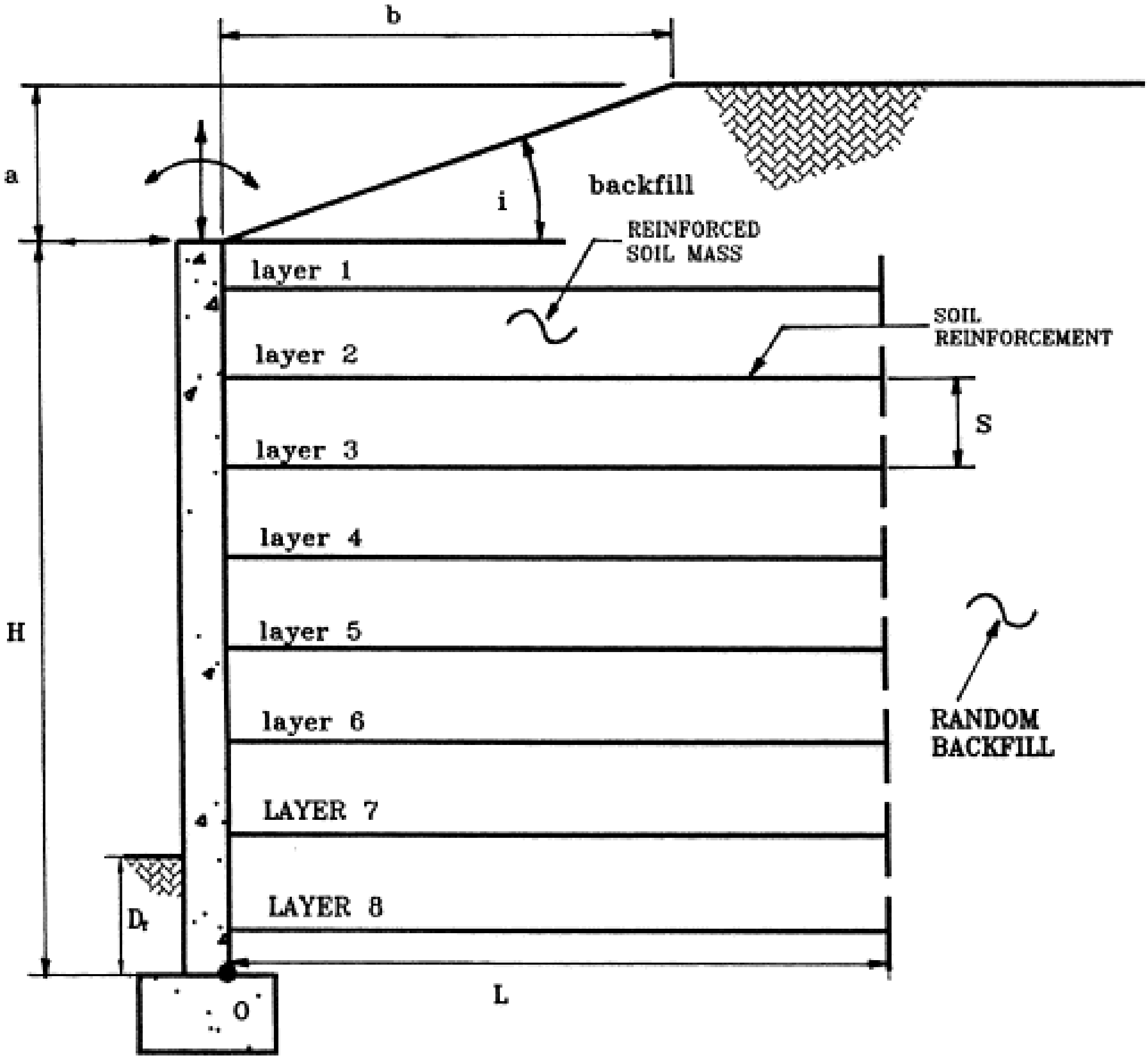


Fig. 1.1 shows retaining wall with reinforcement (chen et al. 2000)

There are many different types of retaining walls, but only a few of them are covered here.

- **Gravity Retaining Wall** - A gravity retaining wall is a structure built to withstand horizontal ground forces only through the force of gravity. Seismic loads, lateral earth pressure pressing on the bottom face, and vertical forces from the wall's weight are the main factors acting on these kinds of walls. Other forces, such as vehicle loads, must be taken into account if they are satisfied. It is usual practise to calculate lateral earth pressure using the Coulomb equation.
- **Cantilever Retaining Wall** –Concrete cantilever retaining walls maintain themselves by using leverage. These have a noticeably smaller stem, and the weight of the soil backfill is essentially what keeps them upright.The most typical style of earth-retaining structure is a cantilever retaining wall. Behind the wall, the foundation is under complete vertical pressure, which prevents it from collapsing owing to lateral displacement from the same soil mass. They are not well adapted to facilitating slopes until temporary support is provided during building since construction requires room behind the walls.
- **Counterfort Retaining Wall** - Rather than using mass to withstand lateral loads, these sorts of walls bend to do so. Such walls therefore have a massive foot structure, a vertical stem reinforced with bar, and thin transverse slabs known as Counterfort. providing it with frequent support. The slab is made to withstand high tensile stresses because it is intended to be installed inside a space where the soil mass must constantly be preserved. To get around this restriction, Counterfort walls are designed with transverse support. A cantilever wall with a larger stem requires a larger base. In order to get over these restrictions, Counterfort walls are built with transverse supports since a broad base is needed for a cantilever wall with a large stem. From the footing's heels up into the stem of the counterfort cantilevered retaining walls, the wing walls project. As opposed to cantilevered walls, the stems between counterforts are thinner and stretch horizontally between the counterfort walls like a beam.
- **Gabion or Crib Wall** - A gabion wall has cages made of wire material that hold stones or other debris together. Crib walls, a type of gabion wall, are constructed using steel barrels that are filled with stone or rubble. Another option is to stack wooden grillages and fill the interior with dirt or debris. Precast concrete crib walls are also common.

- **Reinforced Earth Retaining Wall** – This type of wall is built and engineered to hold soil laterally and to withstand lateral pressure. The walls frequently occur in terrain with unfavourable slopes because they connect soils between two distinct altitudes. These barriers are a cost-effective alternative for public transit, railroad, and road networks. These are also utilised to address other challenging design issues such a shortage of space and extremely tall constructions.

1.1 GEOTEXTILE

Geotextiles are polymer fabrics used in a variety of civil engineering applications, including the building of highways, drains, harbour works, breakwaters, and land reclamation. The creation of fibres, filaments, slit films (tapes), or yarns, followed by the transformation of these constituent elements into a fabric, is the traditional method for creating geotextiles. Wet, dry, and melt extrusion processes are used to create the filaments. For the production of synthetic fiber-based geotextiles, melt extrusion is frequently employed using polymers like polyester and polypropylene. Webbing, mats, and nets are examples of special geotextiles that, despite having a similar look to classic geotextiles, are not the direct byproducts of textile technology. Classic geotextiles are made of textile industry products like woven, knitted, nonwoven fabrics, etc. The interlocking of the geotextiles keeps the aggregates in place.

1.1.1 Functions of Geotextile

Geotextile were discovered to be far less expensive to construct than traditional concrete retaining walls because of their flexibility and dynamic character, which allows retaining walls to become more resilient and non – corrosive in nature.

1.1.2 Advantages of Geotextile

- **Cost-effectiveness:** Geotextiles can contribute to cost savings in retaining wall construction. By using geotextiles, there may be a reduced need for expensive materials such as traditional backfill, thereby lowering overall project costs.
- **Environmental friendliness:** Geotextiles are generally considered environmentally friendly. They are often made from synthetic materials that are resistant to degradation, which can extend their lifespan and reduce the need for frequent replacements. Additionally, geotextiles can help with soil erosion control, promoting sustainable construction practices.

- **Enhanced resilience:** Geotextiles can improve the resilience of retaining wall structures by acting as a protective layer. They provide a barrier between the soil and the structural components, shielding them from potential damage caused by external factors such as water infiltration or chemical exposure.
- **Soil stabilization:** Geotextiles help to prevent soil collapse behind retaining walls. They function by providing reinforcement and stabilization to the soil mass, distributing the lateral forces exerted by the retained soil. This can significantly reduce the risk of wall failure and ensure long-term stability.
- **Ease of construction:** Geotextiles are relatively easy to install, which can simplify the construction process. They can be quickly placed and secured during the wall assembly, resulting in time savings and increased efficiency.

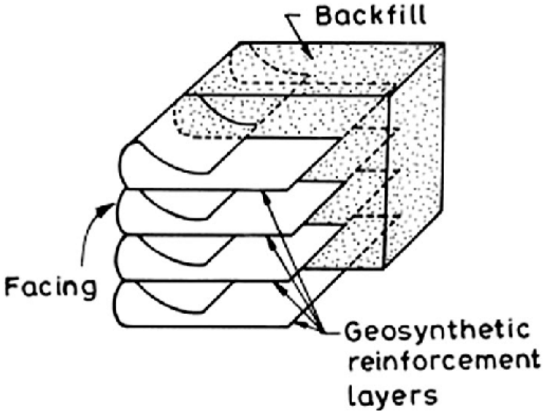


Figure 1.2 Diagram of a GRS retaining wall (Cheng et al., 2006)

1.1.3 Drainage cell

Drainage Cells are impervious to soil-borne germs and pollutants and are primarily comprised of recycled polypropylene. Landscapers can utilise established plants in roof gardens, which need soil with a depth of water retention, thanks to Nero cellular shadow and an efficient drainage profile.

Thermal expansion in concrete during hot summer days might result in cracks in the waterproofing. Because of their distinctive design and void characteristics, drainage cell systems allow this heat to escape, lowering the likelihood of cracking and extending the life of the structure.

1.1.4 PROCESSING OF GEOTEXTILE

The geotextile's desired reinforcing effect is achieved by a variety of techniques.

- **FILAMENTS:** Wet, dry, and melt extrusion processes are used to create the filaments. For the production of synthetic fiber-based geotextiles, melt extrusion is frequently employed using polymers like polyester and polypropylene.

- **SHORT (STAPLE) FIBRES:** The filaments are cut into short, 2 to 10 cm-long fibres that are referred to as staple fibres. Then, a yarn is created by twisting these staple fibres together.
- **SLIT FILMS:** Using slit dies that are then cut using cutting-edge blades, the films are created by a melt extrusion process. These films can be further fibrillated, creating a fibrillated yarn, which is a collection of fibrous strands.

1.2 OBJECTIVES

The objectives of the present study are as follows -

- To analyse the impact of vertical spacing of geotextile reinforcement on the stability of retaining wall.
- To find out the best combination amongst varying spacing with respect to different lap length of geotextile in mechanically stabilized earth (MSE) retaining wall model.

CHAPTER 2

LITERATURE REVIEW

The literatures on mechanically stabilized earth (MSE) walls on weak soil are reviewed and presented in the following paragraphs -

Manohara et al. (2021) investigated how the performance of the geosynthetic reinforced soil walls was affected by the width and position of surcharge loads. The finite element programme PLAXIS 2D is used to analyse numerical simulations of a geosynthetic reinforced soil wall. In order to take the water table at deeper depths into consideration, a very fine mesh was used for the analysis. A multi-stage building simulation was used to conduct the plastic analysis.

Krishna et al. (2016) investigated the experiments on models of reinforced soil retaining walls subjected to horizontal base shaking. In these testing, a single degree of freedom shake table with computer control and hydraulic drive is employed. The test wall is 750 mm x 500 mm in plan and 600 mm deep. It is built as a laminar box. It has been seen and studied how the reinforced retaining walls respond to changes in the acceleration, frequency, and surcharge loading.

Abazi et al. (2015) numerically analyzed a 9 m tall reinforced soil retaining wall in a platform embankment employing software to stimulate the behaviour of its various components. A number of software programmes, including tensar soil, slide, and plaxis 2D, were analysed the design. The outcomes demonstrated that the wall satisfies both static and seismic requirements.

Kong et al. (2021) investigated performance of curved and straight sections which are reinforced with different length of reinforcements. They measured lengths of 1, 3, 5, and 7 metres. A numerical analysis in three dimensions was carried out. The length of reinforcements was changed while keeping the height of the wall constant, which had a divergent impact on the behaviour of the wall. Curved sections were discovered to require more reinforcement than straight sections. Applying the reinforcement lengths separately is recommended. Therefore, it is more economical to utilise different lengths of reinforcement for the curved and straight areas rather than using the same length for both.

Chiang et al. (2021) reported a number of finite element simulations to examine the efficiency and reinforcing mechanisms of geosynthetic reinforced soil (GRS) foundation due to normal fault movement. For model validation, the computational and experimental findings for reinforced and unreinforced foundations were first compared. Using parametric approaches, the effect of soil and reinforcing parameters on the performance of reinforced foundations was examined. Finite element analysis was used to estimate the deformation behaviour of reinforced and unreinforced foundations exposed to normal fault movement. The shear rupture interception effects and tensioned membrane were the two main reinforcing mechanisms identified in this study.

Linhares et al. (2021) used experimental studies and numerical simulations to explore the effectiveness of geosynthetic reinforced soil (GRS) walls based on the effect of surcharge width under working stress conditions. In the lab, experiments with wrapped-face walls and blocks were carried out. Various facing types and surcharge widths were taken into consideration when examining the four various types of geosynthetic reinforced soil walls. The two-dimensional computer programme PLAXIS was used to create the numerical model of GRS walls. The reinforcement loads may be impacted by maximum surcharge width, according to the results of the physical and numerical testing. The numerical analysis showed that backfill compaction predicted building movements and raised reinforcement loads, causing a sort of compressive stress in the reinforced soil wall and reducing 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 results of three experimental test full-scale buildings whose findings had previously been published in the literature were then contrasted with those of the numerical method. A GRS-retaining wall's failing plane resembles a straight sliding type and originates from the structure's toe with a very slight slope.

Hatami et al. (2001) investigated the structural behavior of reinforced soil wall systems with different reinforcement types using a computational technique which is a non-uniform reinforcement. To simulate wall models, a finite difference approach was utilized, which included the building the wall in steps and the installation of reinforcement in the wall periodic intervals of vertical spacing, followed by a sloped surcharge. A finite difference approach was used to simulate wall models, which involved building the wall in stages and installing reinforcement in the wall at regular vertical intervals, followed by a slanted surcharge. In all non-uniform reinforcement walls, the lateral earth pressure coefficient and the horizontal wall movement behind the facing are obviously dependent on the stiffness value of the wall's reinforcing layers at various heights. A formula is suggested for calculating the maximum reinforcement load in walls with specific backfill types, non-uniform reinforced wrapping faces, like those examined in this paper, and reinforcing configurations.

Reddy et al. (2015) studied reinforced soil retaining walls with rock flour and sand as fill materials are used and their relative economy is assessed over the conventional retaining walls. The silty sand backfill is designed for having a consistent load of twenty kN / m^2 of backfill of four to ten m of height. It was found that saving of 35 to 40 % can be done by using rock flour in reinforced soil material.

Bathurst et al. (2013) studied a number of model retaining walls and explains the lessons learnt, the impact of construction activities on wall performance, and the limits of both systems for estimating connection loads. To characterise the backfill soil qualities and geogrid stiffness properties, as well as to calibrate strain gauge readings, an intensive materials testing programme was carried out.

Wong et al. (2009) used the FEM software plaxis to study the failure process of a GRS wall numerically. The effects of factors like backfill soil, length, spacing, stiffness, and creep of the reinforcement were observed. After simulating the construction sequence, a 10-year creep analysis was performed on each model wall.

Yang et al. (2012) examined a reinforced retaining wall for two years of six m high while construction and afterconstruction with aim of identifying the behavior of the structure where lime treated soil was used under working-stress conditions. The geotextile reinforcement also assisted in maintaining the integrity of the embankment while the soil which was treated with lime absorbed almost the entire load due to gravity. Under the influence of gravity force, backfill predominantly exhibited elastic deformation. Construction-related backfill compaction played a significant role in lateral earth pressure and reinforcement deformation at the back of the face, which gradually decreased as backfill strength and facing displacement rose.

Bilgin et al. (2009) looked into the controlling failure mode when evaluating the minimum required reinforcement length, as well as the possibility of lowering the prescribed minimum reinforcement lengths. Investigated was the effect of different design factors on the minimal length of reinforcement required and the manner of failure of reinforced retaining walls. The results show that, depending on the characteristics of a particular wall, both external and internal failure modes can be deciding factors in determining the minimal length of reinforcement needed. The results of parametric trials are reported in this paper, including the impact of several variables on the minimum necessary reinforcement length and ruling failure criterion.

Wang et al. (2019) studied horizontal displacement of the wall face, vertical and horizontal soil stresses, and geotextile strains in the geotextile reinforced soil retaining wall. To comprehend the structural behaviour of geotextile reinforced retaining walls under static loads with a deformation buffer zone, model experiments and numerical simulations were employed. Geotextile reinforced soil retaining walls with deformation buffer zones had less lateral displacement. The face plate of the geotextile-reinforced soil retaining wall experienced an increase in horizontal soil pressure. Along the length of the reinforcement, the horizontal and vertical soil pressures displayed a nonlinear pattern with a decreasing value towards the face panel. The largest cumulative strain measured for the geotextile was 0.45 percent, and the peak tension was close to 29.12 percent of the ultimate tensile strength.

Rowe et al. (2001) studied a geosynthetic reinforced retaining wall which was analyzed by finite element method. For this scenario, the angle of friction among backfill and wall side facing was estimated to be around 30 and 45°. A very compressible and weak foundation layer, as compared to a rigid foundation, can significantly increase deflections at the face and bottom of wall, strain in the reinforcement layers and vertical stresses at the wall's toe are comparatively at a lesser extent. The only factor was the plane stress that was unchanged by the stiffness of the foundation.

Chen et al. (2013) examined the efficiency and sustainability of a geocell-reinforced retaining structures using a numerical model in this research. A built-in model that included the Mohr-Coulomb yield criterion for the nonlinear elastic stress strain relation was employed for the investigation. Indicators of satisfactory agreement in the validation of the numerical model include corresponding results in potential slip surfaces and evaluating critical loads under which the wall is on the edge of failure. Similar comparisons may be concluded among the stimulated models and analytical observations for the lateral deformations of walls. In Rankine's active state, the lateral earth pressures behind back of the wall surface were significantly higher than the plane stress, than those against below reinforced section stayed near to the earth pressures at rest.

Holtz et al. (2017) reviewed evolution of a geosynthetic reinforced soil slopes and wall. The soil-geosynthetic interaction behaviour must be directly investigated in this case; otherwise, the interaction parameters are simply guidelines. The Unit Cell Device is the only instrument capable of doing this for planar strain. Geosynthetics are a significantly more effective reinforcement material than steel since the strength of both the geosynthetic and the sand are used roughly equally. Contrary to geosynthetic reinforcement, creep of GRS structures is not an issue at working stresses. The geosynthetic releases when the loading stops, causing GRS to deform.

Latha et al. (2006) investigated the benefits on the efficiency of earth embankments through laboratory model experiments using geocell, built on deficient foundation soil and suggested a straightforward approach for designing geocell-supported embankments. A strategy based on slope stability was recommended for the first construction of embankments supported by geocells, replacing the layer with a surface soil that had characteristics similar to those found in the study. The empirical method is congruent with the experimental prototype embankments' stability analyses and corresponding measured surcharge capacities.

On the basis of literature reviewed, following research gaps are observed –

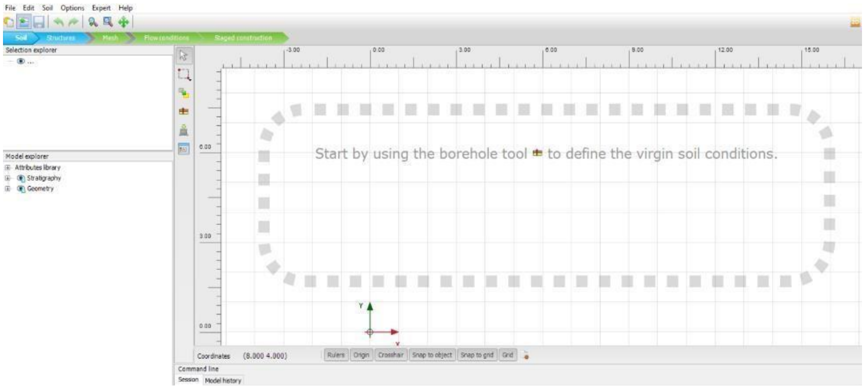
1. Since geotextile is an emerging field, none of these studies provide data about their behavior in unsaturated condition and about their effectiveness in reinforced wall.
2. There are still wall failures due to excessive deformation and also due to the collapse of structure.

An attempt has been made to work in this direction in order to fill the observed research gap. The study on numerical modelling on retaining wall on many aspects is described in the following chapters, keeping the aims in mind.

CHAPTER 3

MATERIALS AND METHODOLOGY

In this study, Plaxis 2D software is used to analyse a retaining wall reinforced with geotextile. The analysis involves an eight-phase simulation. The first phase begins when the foundation is being built, and the following phases begin as the weight is applied with varied spacings. A finite element programme is called Plaxis. This software has been developed and is incredibly useful in geotechnical and structural engineering to examine various stability, deformation, ground water flow, etc.



Start by using the borehole tool to define the virgin soil conditions.

Figure 3.1 Basic Layout of Plaxis 2D

Plaxis software version v20 is used in the study. For simulating the soil clusters plane strain model of 15 node elements were used.

3.1 MSE RETAINING WALL MODEL

Each model is stimulated in Plaxis 2D software. The wall is four m high. The surcharge applied on the retaining wall is 100 kN/m^2. The constant of the Mohr coulomb model, which describes the plastic volumetric strain is called dilatancy angle. The standard geometry of the retaining wall is shown in the figure 3.3.

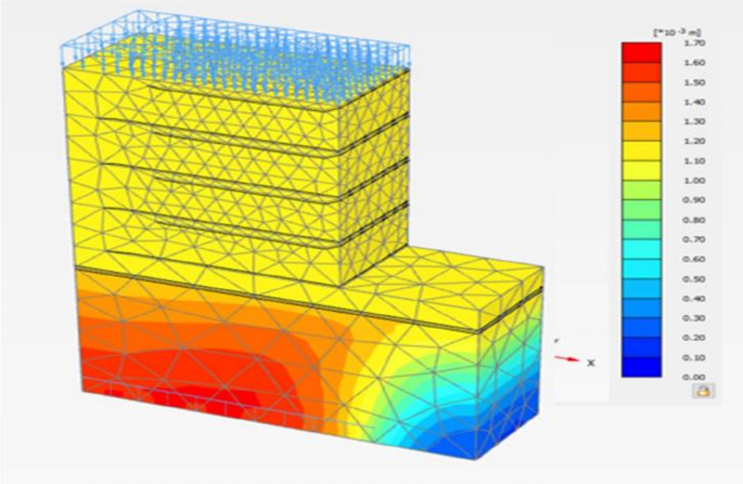


Fig. 3.2 Displacement Response of Geotextile reinforced retaining wall (Ripon et al 2021)

3.2 FINITE ELEMENT MATERIAL PROPERTIES

This specific model generally requires five input parameters. They are elastic modulus, Poisson’s ratio, friction angle, cohesion and dilatancy angle. The properties of soils are shown in Table 3.1. Length of the geotextile taken is 5m, using the mohr coulomb criterion, the model is depicted as a linearly elastic material; the characteristics for this model are stated in table 3.2 and table 3.3.

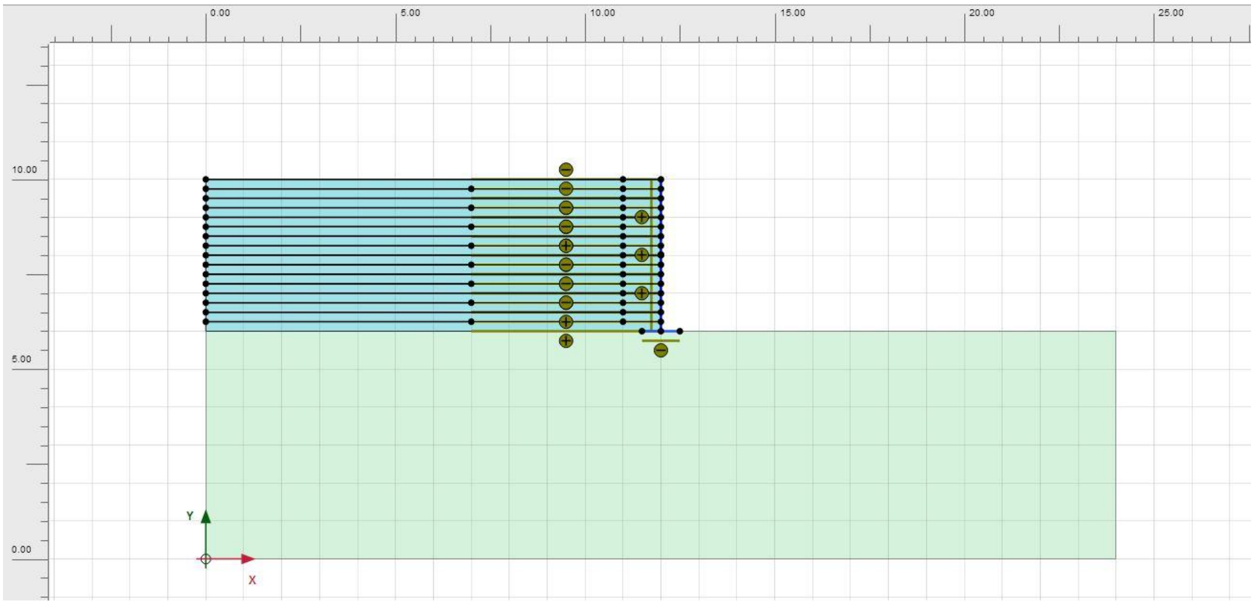


Fig. 3.3 Geometry of retaining wall with geotextile reinforcement

Table 3.1 Finite element material properties (Kibria et al. 2014; Kong et al. 2013)

Material	Mass density γ_{unsat} (kg/m^3)	γ_{sat} (kg/m)	Elastic modulus E (kN/m^2)	Cohesion (kN/m^2)	Internal angle of friction φ (°)	Angle of dilation ψ(°)
Backfill Soil	19	20	12500	1	34	4
Found Soil	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
Concrete facing	11000	5000000	38

3.3 METHODOLOGY

The study has been conducted to investigate improvement of the stability of the retaining wall. So here we have taken height of the wall which is 4m. The wall considered in the present study is reinforced with geotextile reinforcement. The spacing between the layers of geotextile are taken as 0.5m , 0.67m and 0.80m, subsequently for further models and the plate length 0.5m and thickness of the plate provided is 0.15m. The backfill soil and the foundation soil used properties are shown in table 3.1 and table 3.2, respectively. The length of geotextile taken is 5m. Multi Phase Simulation is carried out in the analysis like in first phase construction of the foundation is done and likewise construction of the remaining phases are done before and after the application of the uniform surcharge load acting on the top of the wall.

Table 3.3 Properties of non woven geotextile (ASTM D5199)

Properties	Value
Concentration (g/m^2)	198
Opacity (mm)	1.75
Apparent Opening dimension (mm)	0.10
Permittivity (s^{-1})	1.95
Cross-plane permeability (m/s)	3.5 x 10^{-3}
Ultimate tensile strength (KN/m)	9.28

General information on the model for appropriate load and geometry

Table 3.4 Model dimension

	Min	**Max**
X	0	24
Y	0	12

Table 3.5 Model type

Model	**Plane Strain**
Element	15- Noded

CHAPTER 4

RESULTS AND DISCUSSION

The stability of the retaining wall was initially assessed without the use of any geotextile reinforcement and with the different location of the geotextile reinforcement, the vertical spacing changes. After the application of geotextile reinforcement, simulations were carried out by modifying the height of the wall and adjusting the vertical spacing of the geotextile. Overall lateral and vertical wall deflections, as well as displacements, were analysed and processed. Figure 4.1 to Figure 4.13 give lateral and vertical deflection pictures of 2D models with geotextiles. Mesh which is a network that constitutes of cells and points were obtained by the plaxis 2D software.

4.1 CASE 1: WITHOUT GEOTEXTILE REINFORCEMENT

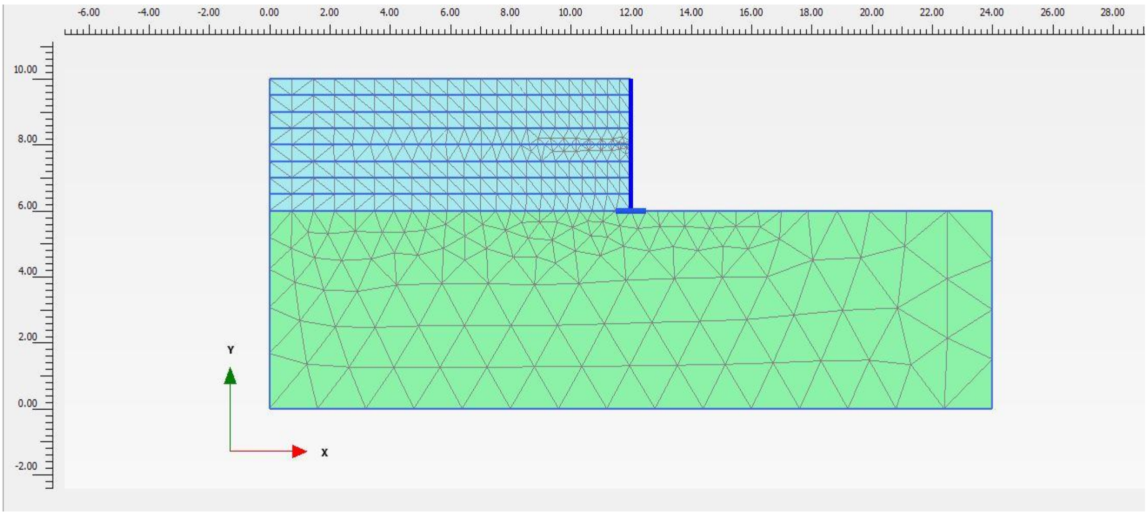
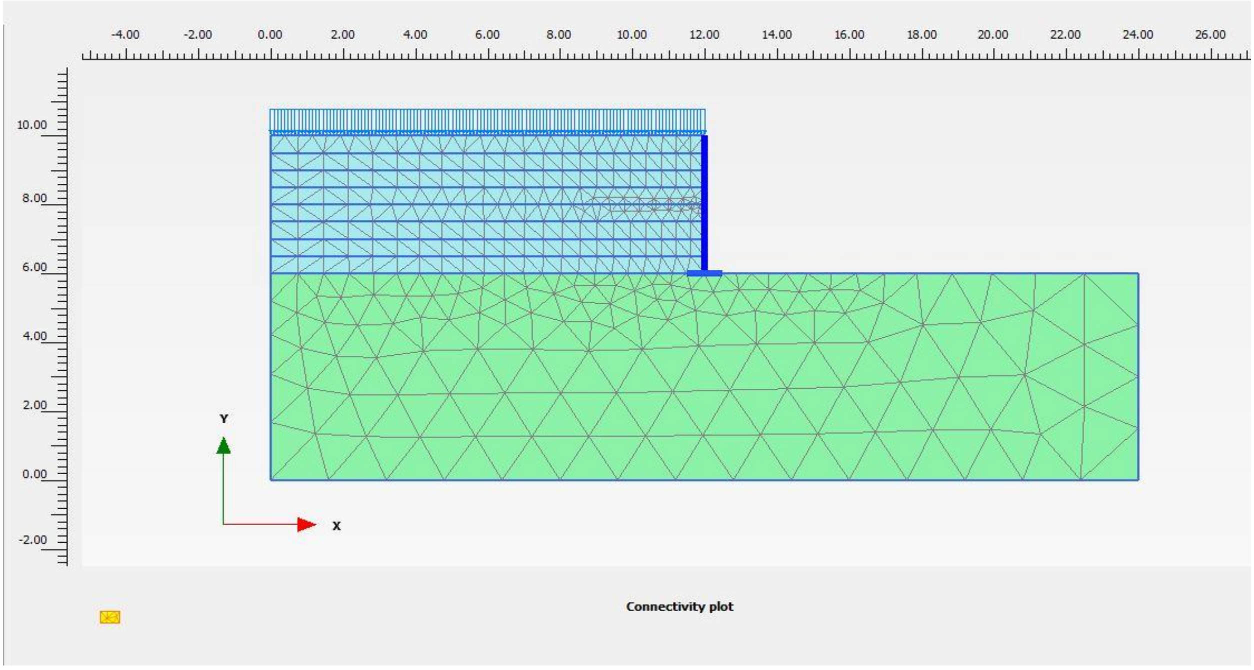
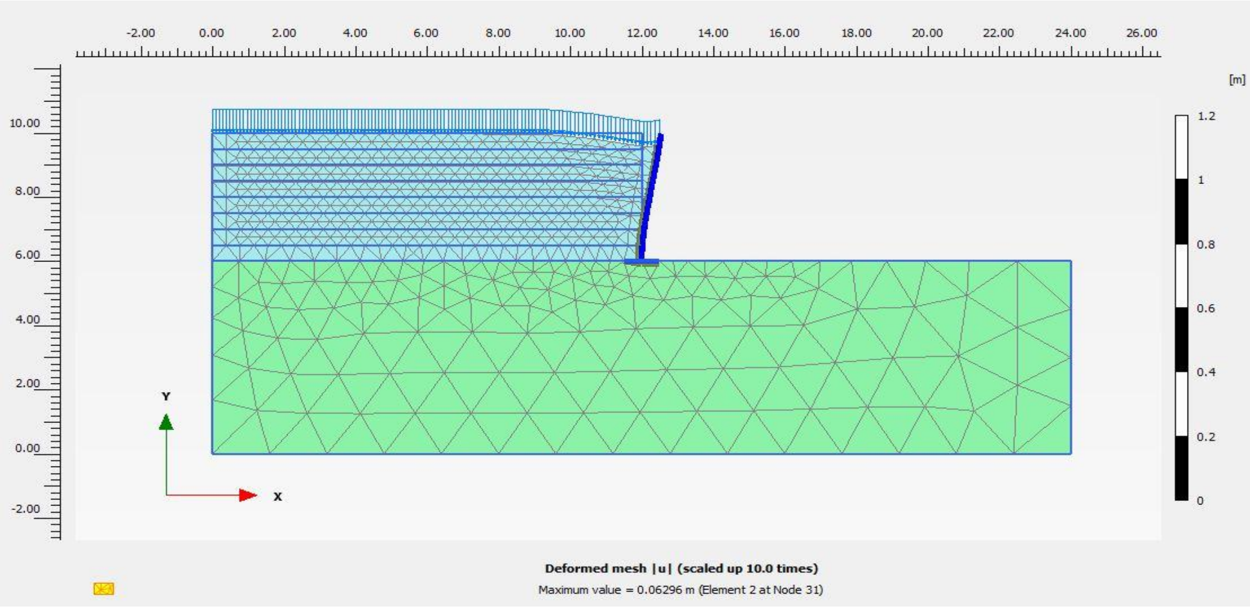


Fig. 4.1 Mesh analysis of 4m high retaining wall of compacted backfill soil with no geotextile reinforcement and no loading



Connectivity plot

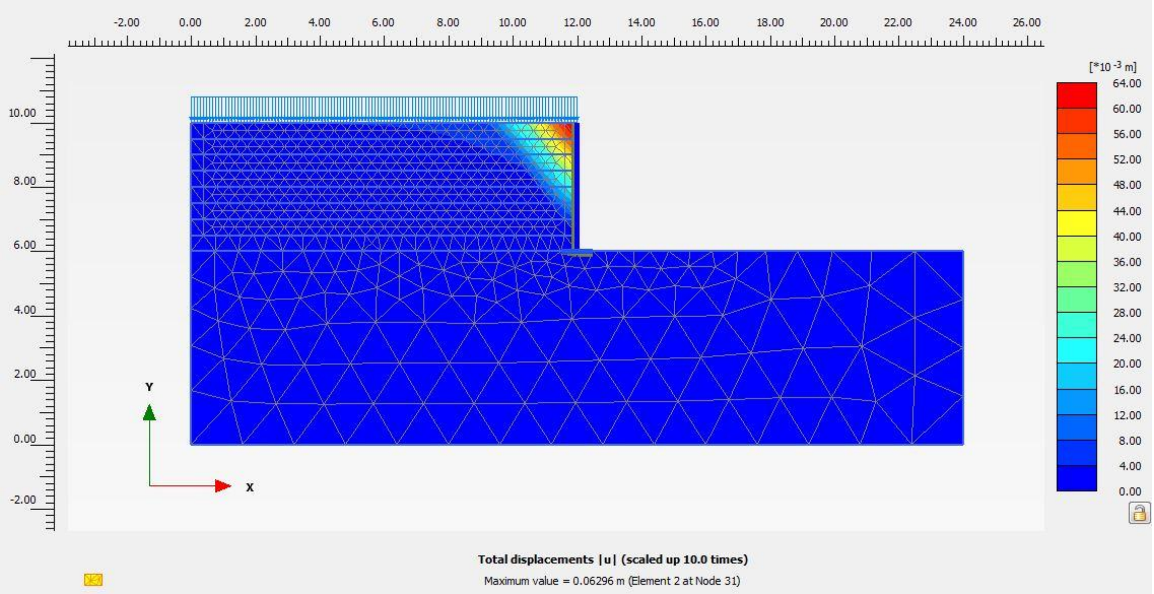
Fig. 4.2 Mesh analysis of 4m high retaining wall of compacted backfill soil with no geotextile reinforcement with uniform loading



Deformed mesh |u| (scaled up 10.0 times)

Maximum value = 0.06296 m (Element 2 at Node 31)

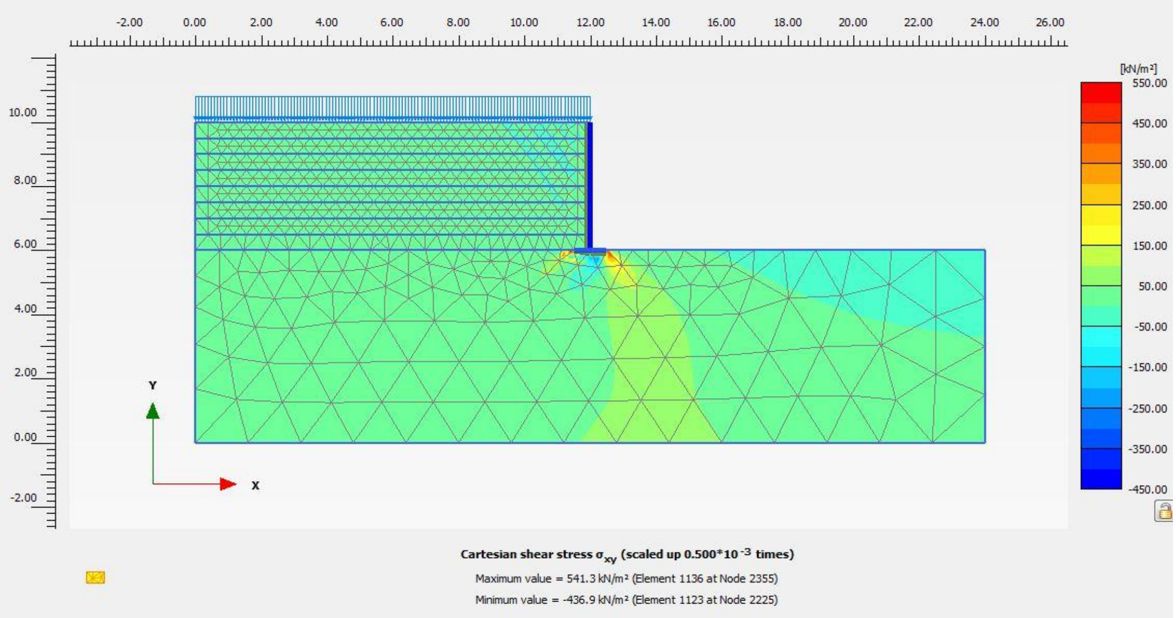
Fig. 4.3 Deformed mesh of 4m high retaining wall of compacted backfill soil with no geotextile reinforcement



Total displacements |u| (scaled up 10.0 times)

Maximum value = 0.06296 m (Element 2 at Node 31)

Fig. 4.4 Total displacement of 4m high retaining wall of compacted backfill soil with no geotextile reinforcement



Cartesian shear stress σ_{xy} (scaled up 0.500*10^{-3} times)

Maximum value = 541.3 kN/m² (Element 1136 at Node 2355)

Minimum value = -436.9 kN/m² (Element 1123 at Node 2225)

Fig. 4.5 Cartesian shear stress of 4m high retaining wall of compacted backfill soil with no geotextile reinforcement

4.2 CASE 2: WITH DIFFERENT VERTICAL SPACING BETWEEN GEOTEXTILE REINFORCEMENT

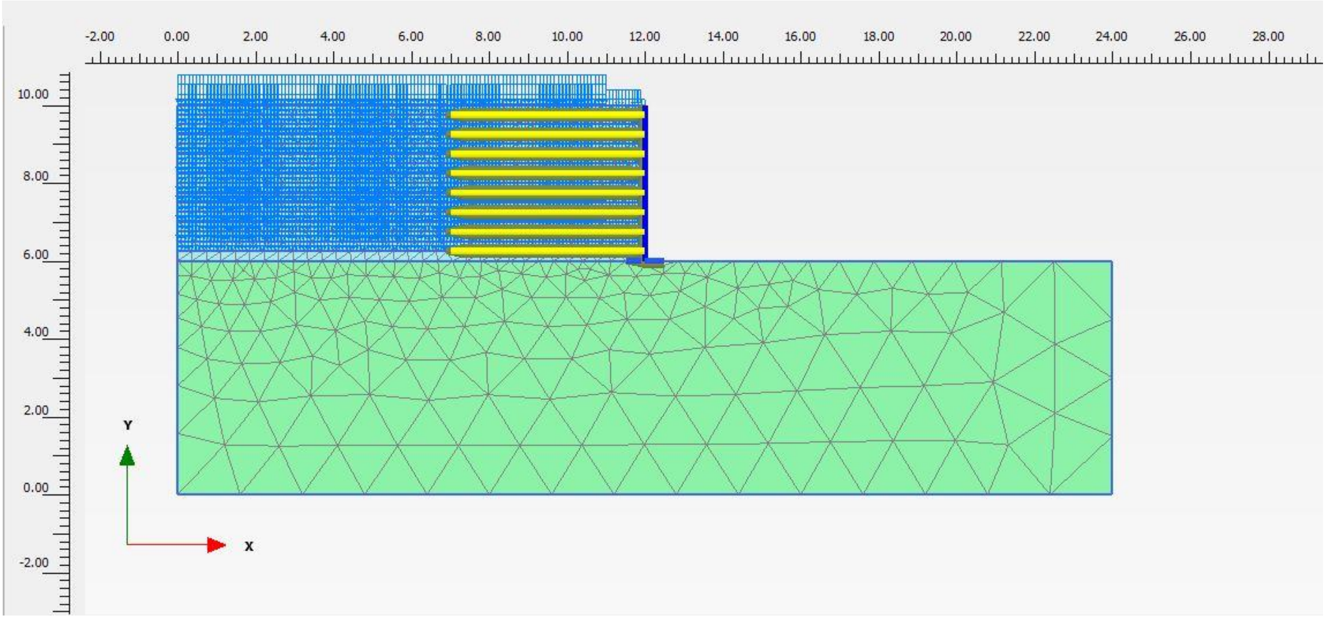
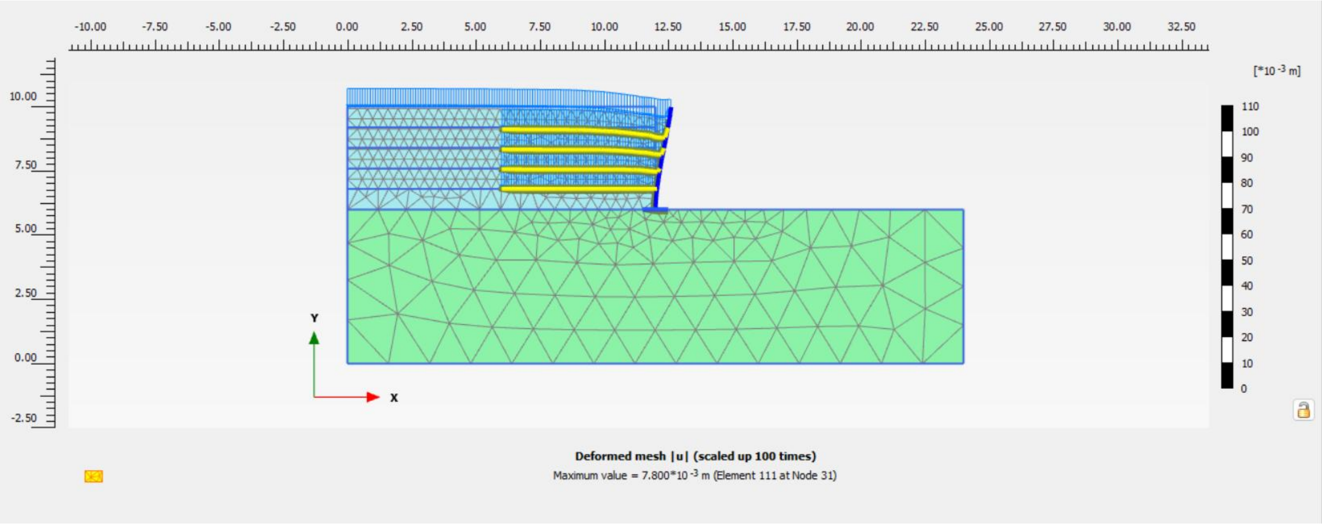
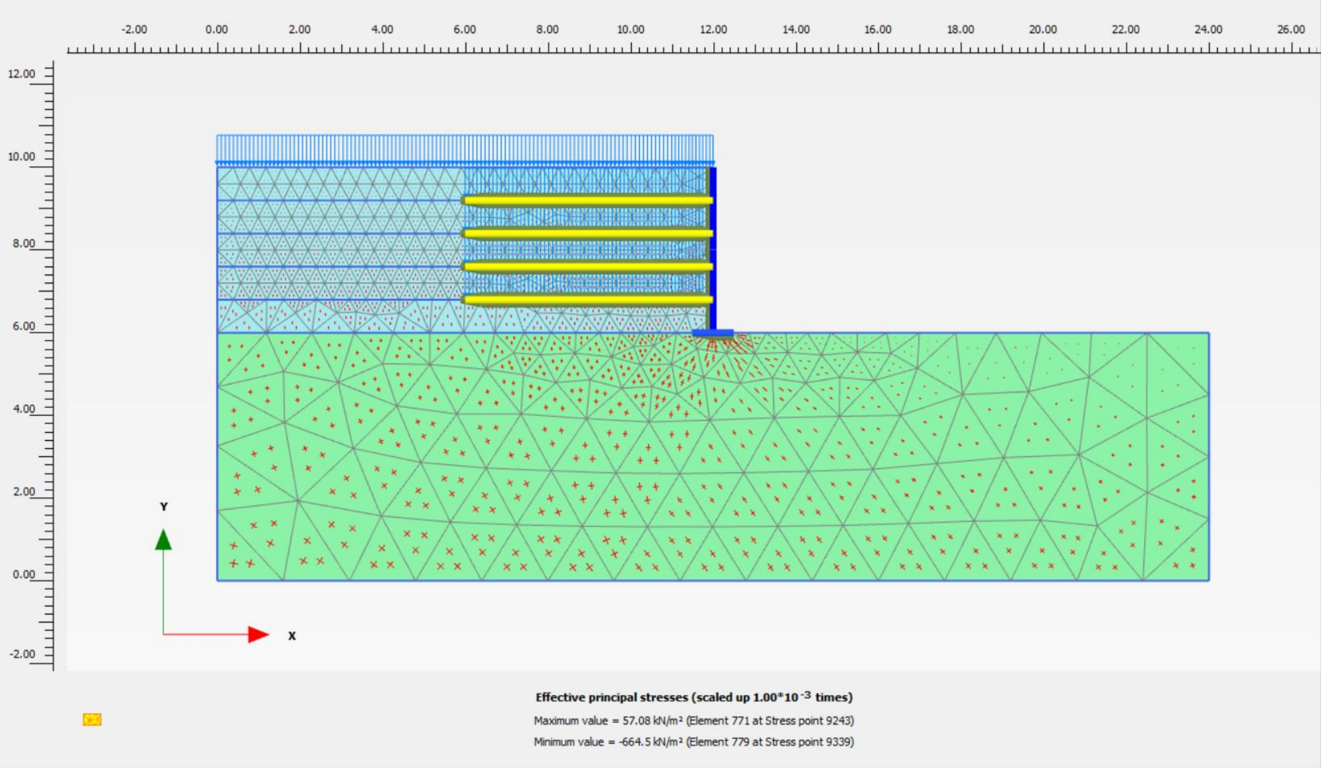


Fig. 4.6 Mesh of 4m high retaining wall with 50 cm vertical spacing between geosynthetic reinforcement



Deformed mesh |u| (scaled up 100 times)
Maximum value = $7.800*10^{-3}$ m (Element 111 at Node 31)

Fig. 4.7 Deformed mesh of 4m high retaining wall with 80 cm vertical spacing between geosynthetic reinforcement

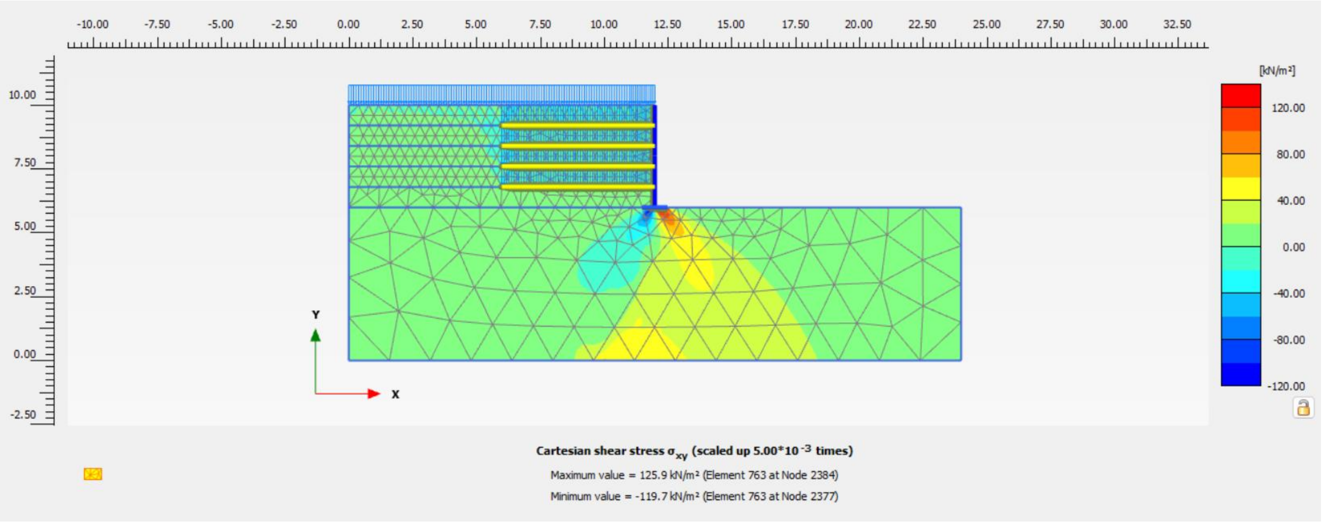


Effective principal stresses (scaled up 1.00*10 $^{-3}$ times)

Maximum value = 57.08 kN/m² (Element 771 at Stress point 9243)

Minimum value = -664.5 kN/m² (Element 779 at Stress point 9339)

Fig. 4.8 Effective principal stresses of retaining wall of 4m height with 80 cm vertical spacing between geosynthetic reinforcement

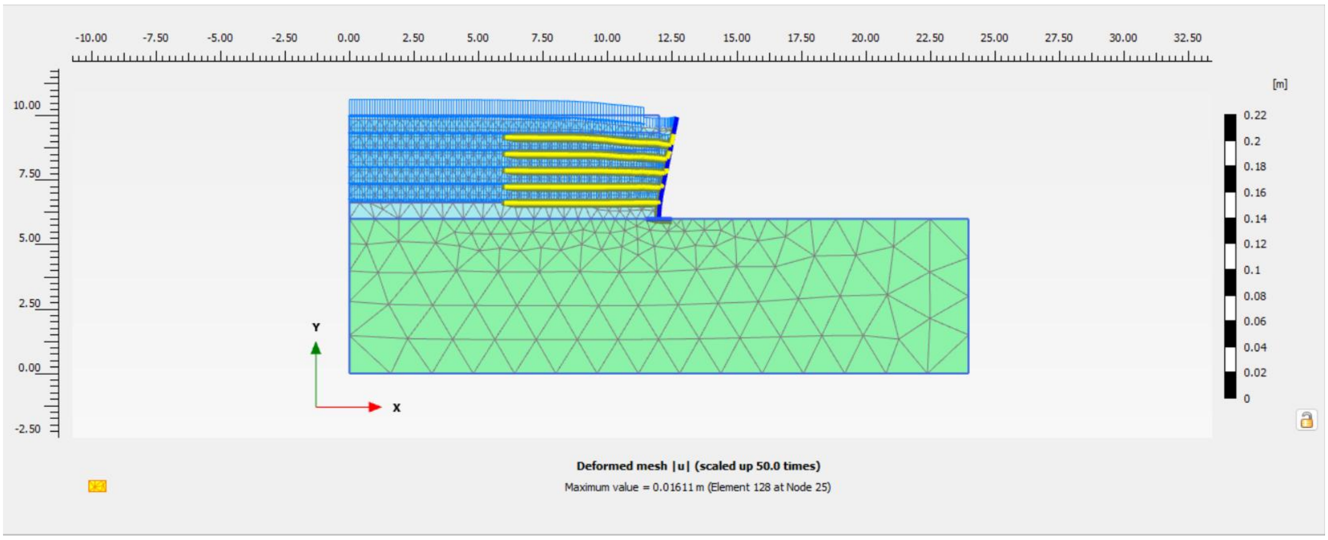


Cartesian shear stress σ_{xy} (scaled up 5.00*10 $^{-3}$ times)

Maximum value = 125.9 kN/m² (Element 763 at Node 2384)

Minimum value = -119.7 kN/m² (Element 763 at Node 2377)

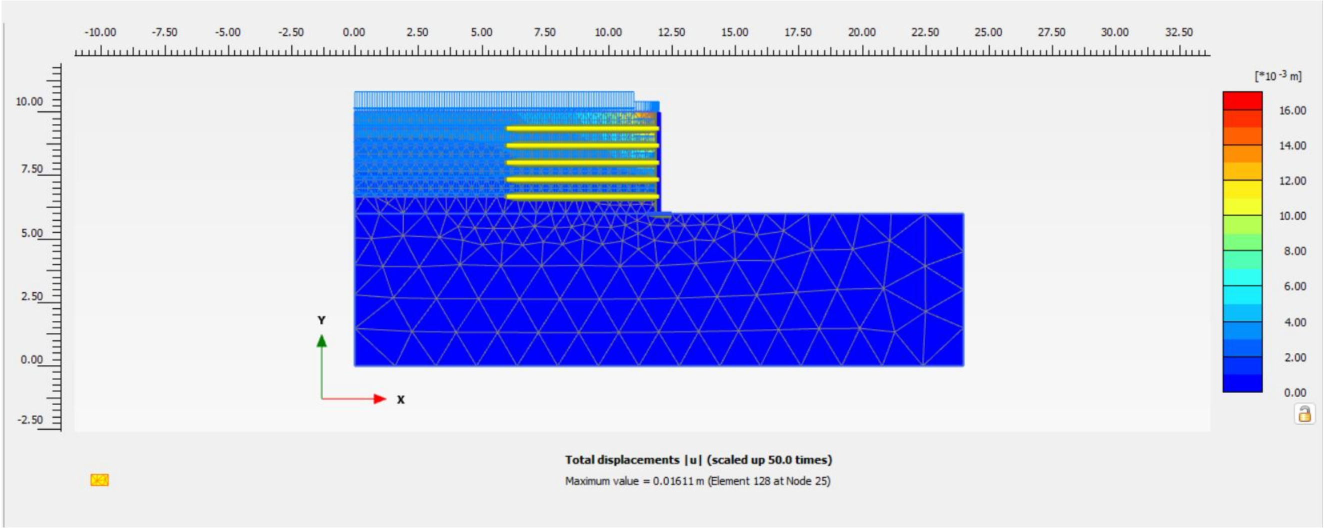
Fig. 4.9 Cartesian shear stress of retaining wall of 4m height with 80 cm vertical spacing between geosynthetic reinforcement



Deformed mesh |u| (scaled up 50.0 times)

Maximum value = 0.01611 m (Element 128 at Node 25)

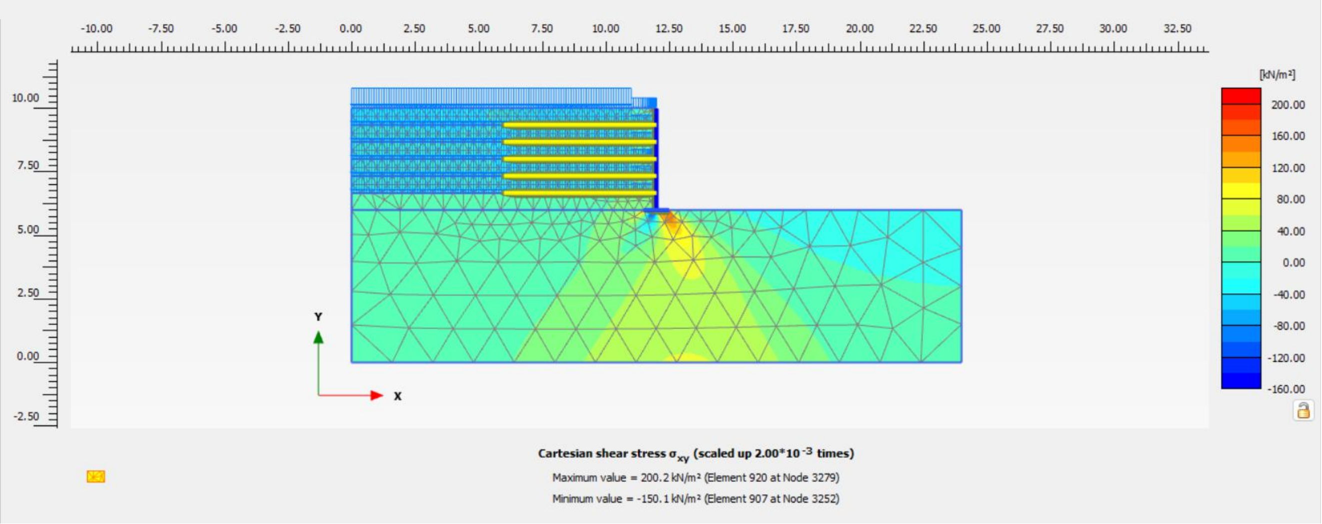
Fig. 4.10 Deformed mesh of 4 m high retaining wall with 67 cm vertical spacing between Geosynthetic reinforcement



Total displacements |u| (scaled up 50.0 times)

Maximum value = 0.01611 m (Element 128 at Node 25)

Fig. 4.11 Total Displacement of 4 m high retaining wall with 67 cm vertical spacing between Geosynthetic reinforcement

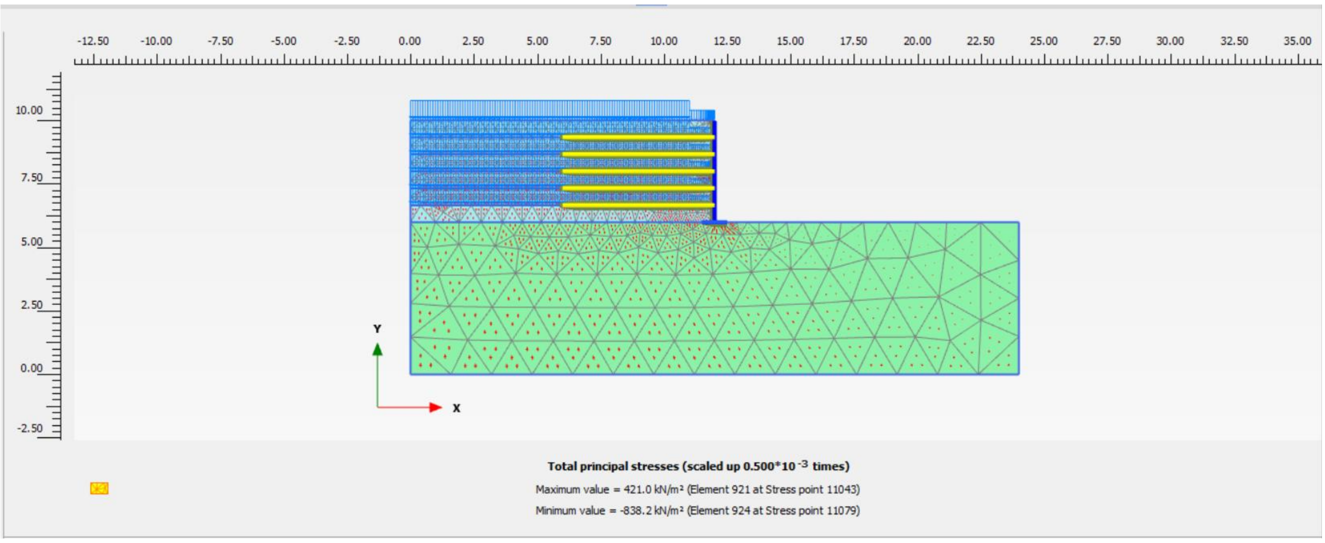


Cartesian shear stress σ_{xy} (scaled up $2.00*10^{-3}$ times)

Maximum value = 200.2 kN/m² (Element 920 at Node 3279)

Minimum value = -150.1 kN/m² (Element 907 at Node 3252)

Fig. 4.12 Shear stresses in retaining wall of 4 m height with 67 cm vertical spacing between geosynthetic reinforcement



Total principal stresses (scaled up $0.500*10^{-3}$ times)

Maximum value = 421.0 kN/m² (Element 921 at Stress point 11043)

Minimum value = -838.2 kN/m² (Element 924 at Stress point 11079)

Fig. 4.13 Total principal stresses in retaining wall of 4 m height with 67 cm vertical spacing between geosynthetic reinforcement

4.3 CALCULATION OF OVERLAP LENGTH

The L*o* is the required overlap length which is calculated as per the formula given below by (Koerner, Robert M., 1933- Designing with geosynthetics)

$$L_o = \frac{S_V \sigma_h FS}{4(C_a + \gamma Z \tan \delta)} \qquad (1)$$

Where, S_v is spacing,
σ_h = lateral pressure,
FS = factor of safety,

C_a = Adhesion between geotextile and soil,
γ = density of soil,
Z = height from ground level,
δ = shearing resistance angle among soil and layer of geotextile.

By putting we get the value of overlap length to be L_o = 0.375m, but minimum length should be 1m as per the provison provided in Designing with geosynthetics by Koerner, Robert M., 1933.

Table 4.1 Different combinations of geotextile layering

Layer (No's.)	Spacing (m)	Lap Length (m)	Surcharge (kN/m^2)
5	0.80	1	100
6	0.67	1	100
8	0.50	1	100

Table 4.2 Total displacement and shear stress values of retaining wall models with different spacing

Spacing (m)	Layers (No's.)	Total displacement (m)	Cartesian shear stress max value (KN/m^2)	Cartesian shear stress min value (KN/m^2)
0.50	8	0.06296	541.3	-436.9
0.67	6	0.01611	200.2	-150.1
80	5	0.0078	125.9	-119.7

The observations taken from the table and model are studied and it is found that the Model 3 which is having 5 no. of layers is among the best suitable combination with lap length of 1 m which is uniform among all the rest models. Less displacement of wall means that the wall is having higher stability and chances of failure are less as compared to the other models. In all models, the overall displacement of the retaining wall and the various forces acting on it are depicted as seen in figures 2, 4. These results are essential to the design of the retaining wall. In the plaxis output shown in figure 4.8, active earth pressure acting on retaining walls is represented as effective normal stresses. The maximum bending moment occurs at the middle height of the retaining wall, as shown in figure 4.10. Therefore, it is necessary to build retaining wall designs to handle a significant amount of bending moment in the middle height zone, whereas bending moment near the top and bottom of the wall must be minimised. The above can further be summarized in the following points given below:

- Compared to other types of reinforcement, including metallic strips or geogrids, using geotextiles as reinforcement in soil-retaining walls may have advantages. These include speedy building, economic savings, and ease of use.
- A thorough material characterization programme combined with consistent monitoring of fully constructed model could help us better understand how geotextile-reinforced soil structures behave.
- To strengthen foundation soil and decrease differential settlement, high stiffness geotextiles may be employed. One such instance is the reinforcement of the tank pad foundation using woven geotextile at the Panipat Refinery in India (Dutta and Kumar, 2004).

4.4 DUBROVA'S REDISTRIBUTION OF PRESSURE

According to Dubrova theory, also known as the Dubrova's method is a theory related to earth pressure on retaining structures. The Dubrova theory provides a method to estimate active earth pressure on retaining walls. It is an extension of the classical Rankine theory ad considers the effects of soil dilatancy and wall deformation.

The key principle of the Dubrova theory is that the active earth pressure depends not only on the friction angle of the soil but also on the dilation angle. The dilation angle represents the tendency of the soil to dilate or spread apart under pressure.

According to the Dubrova theory, the force against the wall at any depth z is given by:

$$P_a = \frac{\gamma}{2\cos\delta'}\left(\frac{z}{\frac{1}{\cos\varphi}+(\tan\varphi^2+\tan\varphi\tan\delta')^{0.5}}\right)^2 \qquad (2)$$

Where:

P_a is the active earth pressure,

γ is the unit weight of the soil,

z is the height of the retaining wall from the surface and

φ is the internal friction angle

δ' is the external friction angle between wall and soil

The calculation of K_a in the Dubrova theory takes into account the friction angle, dilation angle, wall roughness, and wall flexibility. The theory assumes a linear distribution of earth pressure with depth and neglects other factors like groundwater effects or soil cohesion. Based on the Dubrova's method of redistribution of pressure, an improved calculation method of active earth pressure for gravity retaining wall with backfill soil rotating can be put forward, which considers the influence of wall displacement.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE STUDY

- Using FEM software, an attempt is made to investigate the behaviour of a 4-meter-long Geotextile-reinforced MSE wall. The best model is determined by comparing the wall deformation of each model to one another.
- Using geotextile in soil retaining walls as an additional reinforcement has potential advantages over using geogrids or metallic sheets as reinforcement. A variety of spacing and overlap length combinations are used to put the geotextile in the wall. A few benefits are rapid construction, ease of use, and significant cost reductions.
- A thorough material characterisation project and systematic evaluation of complete constructions should help us understand how geotextile reinforced soil structures behave.
- Increased stiffness reinforcing foundation soil with geotextile can increase bearing capacity and decrease differential settlement.

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