Journal of Research in Science, Technology, Engineering and Management (JoRSTEM)
ISSN: 2456-0197

Behaviour of Reinforced Soil Retaining Walls under Static Loads by Using Plaxis

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Abstract—***Nowadays Geosynthetics have been used as a routine reinforcement in earth structures such as reinforced soil retaining walls (mechanically stabilized earth (MSE) walls), column-supported embankments, soil slopes, and paved/unpaved roads. Reinforced soil structures are both economically and technically vary advantageous over their conventional counterparts, especially under poor soil conditions and when there are property line limitations. Various researchers have carried out extensive investigations into the mechanisms of reinforcement of the above-mentioned applications; especially the geosynthetic-soil interactions and they have subsequently considered them into design methods. This dissertation presents case studies and analyses of reinforced soil retaining walls were carried out. The behaviour of the walls under static loadings was investigated numerically with the aid of finite element program-Plaxis. The finite-element analyses provide relevant information on the mechanical behaviour of the wall that was otherwise difficult to obtain from the limit equilibrium based current design approaches. Practical implications of the findings of this study are highlighted along with the role of numerical modeling in the analysis and design of geosynthetic-reinforced retaining walls.***

Keywords-

I. INTRODUCTION

Reinforced soil retaining walls or reinforced earth walls (commonly grouped as Mechanically Stabilized Embankments – MSE) represent an innovative method of resolving familiar as well as unfamiliar and challenging problems. Reinforced earth is a composite material constructed with artificial reinforcing formed by interaction between frictional soil and reinforcing strips. The recent applications of reinforced earth structures are vast. MSE walls use metal strips, wire meshes or geosynthetics as reinforcement to retain soil mass. Since the advent of MSE walls using geosynthetics in 1970s, they are now constructed routinely as retaining wall structures for a variety of applications ranging from private properties to public facilities (Allen et al., 2002). Reinforced soil retaining wall have gained substantial acceptance as an alternative to conventional masonry and reinforced concrete cantilever retaining wall structures due to their simplicity, rapidity of construction, less site preparation and space requirement for construction operation. In addition to technical and performance advantages, another primary reason for the acceptance of reinforced earth retaining wall has been its inherent economy. Although comprehensive analytical and finite element studies of reinforced soil behaviour are necessary and important for a comprehensive analysis and design of reinforced soil structure, yet they are inevitably complicated by the fact that the precise geometry of the reinforcement and the elastic-plastic nature of the soil needs to be fully taken into account for optimum design of the reinforced earth wall. It is interesting to know that numerical modelling of reinforced earth retaining wall and other structures has been increasingly adopted in researches since in addition to their outstanding cost- and time-effectiveness.

Numerical modelling plays an important, sometime irreplaceable, role in promoting the research and practice. This research work employs the use of Plaxis version 8, a finite element program for modelling and analysis of the model in each of the cases considered.

1.1 Objectives and Scope of Study

This papers aims at performing a parametric analysis on the behaviour of reinforced soil retaining walls under static load. In order to achieve this aim, the followings objectives are set:

- To determine the influence of changes of the soil parameters in the geometry model on the performance of reinforced soil retaining walls.
- To determine the influence of changes in applied load on the performance of reinforced soil retaining walls.

In order to effectively determine the influence of geometry and mechanical properties of reinforced soil retaining walls, this research work will be divided into two different analytical cases with different case studies and these include:

- Numerical analysis of reinforced soil retaining wall for appropriate loads and geometry.
- Numerical analysis of reinforced soil retaining wall for appropriate geogrids stiffness selection.

II. METHOD OF ANALYSIS BY PLAXIS 2D

"Plaxis 2D version 8.2" is a finite element software program developed in the Netherlands for two dimensional analyses of geo-structures and geotechnical engineering problems. It includes from the most basic to the most advanced constitutive models for the simulation of the linear or non-linear, time-dependent and anisotropic behaviour of soil and/or rock. Plaxis is also equipped with features to deal with various aspects of complex structures and study the soil-structure interaction effect.

ISSN: 2456-0197

TABLE: SOIL DATA PARAMETERS

Mohr-Coulomb		1 Loose Sand	2 Dense Sand
Type		Drained	Drained
γ_{unsat}	[kN/m³]	16.5	18
γ_{sat}	[kN/m³]	18	20
k_x	[m/day]	1	1
k_y	[m/day]	1	1
E_{ref}	[kN/m²]	20000	65000
ν	[-]	0.25	0.3
c_{ref}	[kN/m²]	0	0
φ	[°]	34	40
ψ	[°]	0	10
$R_{inter.}$	[-]	0.67	0.8
Interface permeability		Neutral	Neutral

TABLE: BEAM AND GEOTEXTILE DATA PARAMETERS

No.	Identification	EA [kN/m]	EI [kNm²/m]	w [kN/m/m]	n [-]	Mp [kNm/m]	Np [kN/m]
1	Diaphragm wall	7.50E+06	1.00E+06	10	0	1.00E+15	1.00E+15
2	Footing	5.00E+06	8.50E+03	10	0	1.00E+15	1.00E+15

No.	Identification	EA [kN/m]	v [-]
1	Geogrid	2500	0

2.1. Numerical Analysis for Appropriate Load and Geometry & General Information on the Model

TABLE 2.1: UNITS

Type	Length	Force	Time
Unit	m	kN	Day

TABLE 2.2: MODEL DIMENSIONS

	Min.	Max
X	0	21
Y	0	11

TABLE 2.3: MODEL TYPE

Model	Plane Strain
Element	15 - Noded

2.2 Geotechnical Parameters and Design Methods

As described previously, the analyses will be performed on the wall different same soil as back fill and foundation material. The idea is to determine the behaviour of the wall under static loading and any variation(s) in the observed behaviour in each case and reported in terms of load vs. settlement curve.

2.3 The First Analysis

The Plaxis input model is shown in Figure 3.1 while the design sections for these different cases of models are shown in Figures 3.2 to 3.5. The design parameters for the different soil cases are shown in Table 3.4. The diaphragm wall and geogrids parameters are shown in Table 3.5 and 3.6 respectively. The model was prepared as retaining

wall proving support for a 4.5m width motor park.

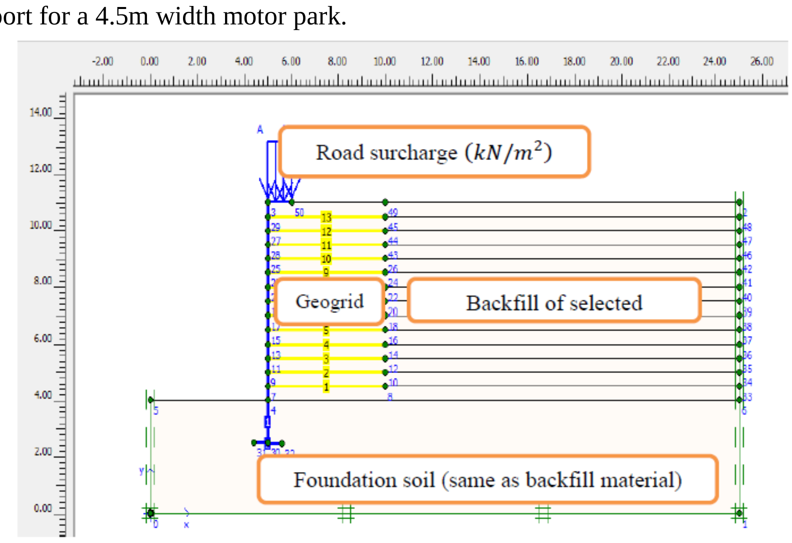

Figure 3.1: Plaxis Input Model

Figure 2.3: Plaxis Input Model

ISSN: 2456-0197

Model-1

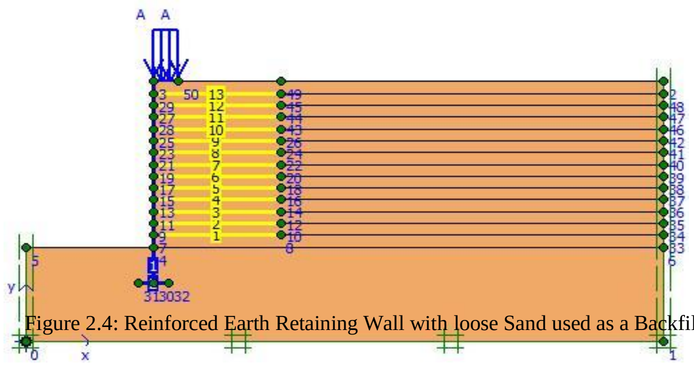

Figure 2.4: Reinforced Earth Retaining Wall with loose Sand used as a Backfill Material.

III. Results and Discussion

3.1 Numerical Analysis for Appropriate Load and Geometry:

Finite element analysis was carried out using commercial software PLAXIS version 8 for the four types of problems mentioned in the previous chapter. The results are compared and reported in this chapter. Behaviours of reinforced soil retaining walls under different conditions are investigated using PLAXIS version 8. Effect of the changes in the surcharged load (UDL) is shown through the relationship between load and deformation. The effect(s) of spacing of reinforcement on the soil is explained through the displacements developed. Effects of the geogrids length are also considered.

3.1.1 The First Analysis

This analysis was carried out like the case of Mr. Gaurav Singhai and the results obtained are essentially the same. For example, in the case of load-displacement variation of reinforced soil retaining wall for loose sand, the results obtained are shown below in Table 3.1 while the load-displacement curves from my analysis that obtained are shown in Figures 3.1, 3.2 and 3.3.

Model-2

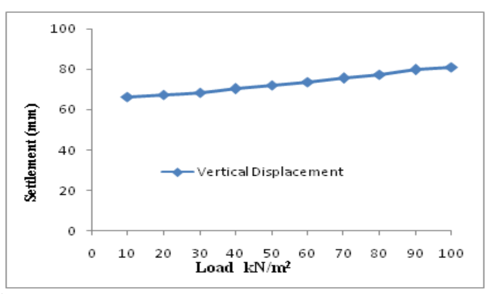

Figure 2.5: Reinforced Earth Retaining Wall with Dense Sand used as a Backfill Material.

Table 3.1: Displacements under Different Loadings for Loose Sand

Loads (kN/)	Horizontal displacement (mm)	Vertical displacement (mm)
10	26.66	66.34
20	28.56	67.42
30	30.10	68.23
40	31.68	70.11
50	33.21	71.93
60	34.67	73.66
70	36.15	75.41
80	37.78	77.32
90	39.67	79.60
100	40.60	80.82

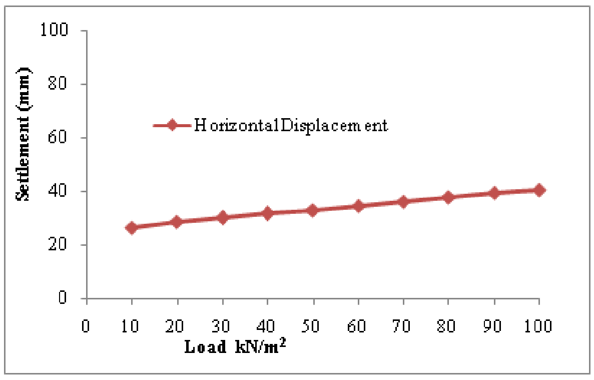

Figure 3.2: Load Displacement Relationship for Loose Sand (Horizontal Displacement).

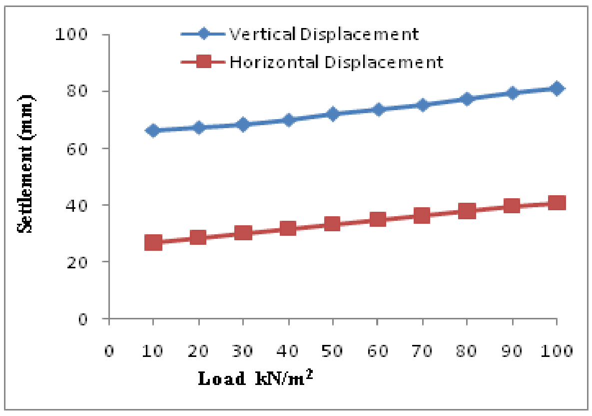

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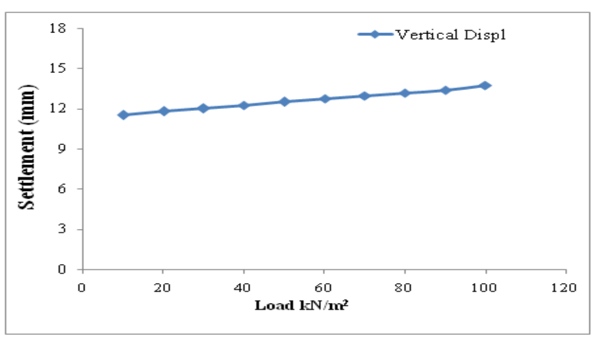
Figure 3.3: Comparison of Load Displacement Relationship for Loose Sand

In each case, the displacements of the soil increased steadily when the applied load is increased. Both horizontal and vertical displacements are almost the same in magnitude.

3.1.2 Load-Displacement Variation of Reinforced Soil Retaining Wall for Dense Sand.



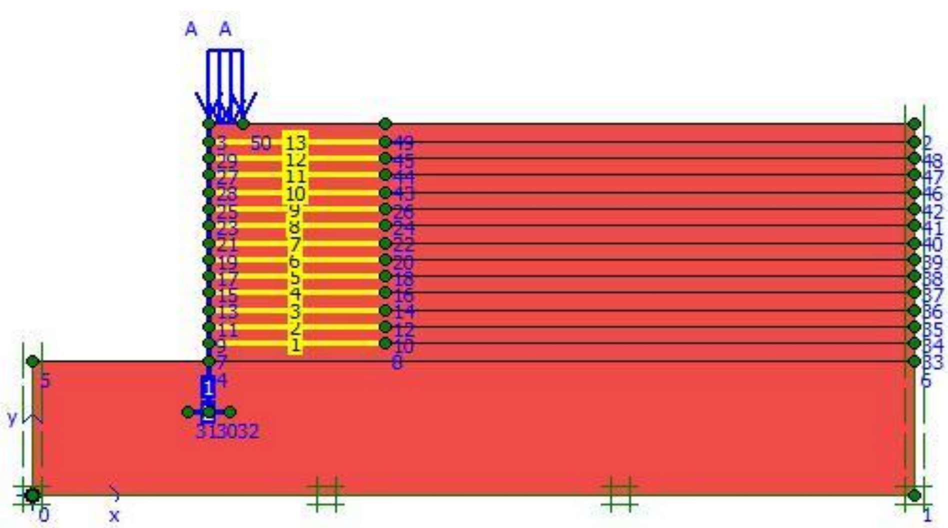


Figure 3.4: Load Displacement Relationship for Dense Sand (Vertical Displacement).

TABLE 3.2: DISPLACEMENTS UNDER DIFFERENT LOADINGS FOR DENSE SAND.

Loads (kN/m²)	Horizontal displacement (mm)	Vertical displacement (mm)
10	3.36	11.50
20	3.59	11.78
30	3.91	12.00
40	4.24	12.26
50	4.56	12.50
60	4.90	12.77
70	5.19	12.98
80	5.47	13.18
90	5.76	13.37
100	6.04	13.75

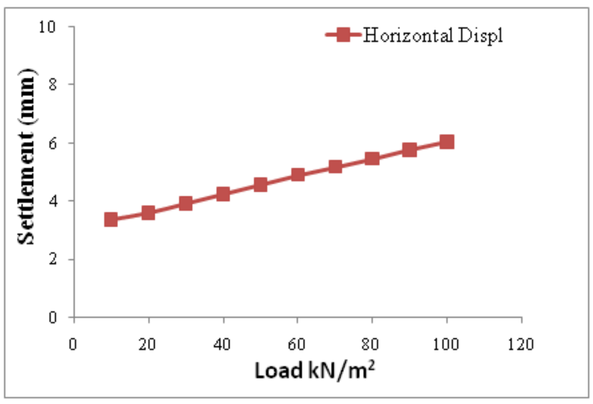


Figure 3.5: Load Displacement Relationship for Dense Sand (Horizontal Displacement).

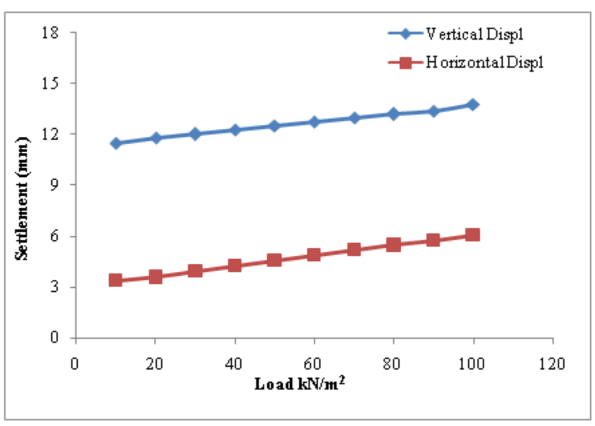


Figure 3.6: Comparison of Load Displacement Relationship for Dense Sand.

Remarks:

This Figure shows that with an increase of load there is a steady increase of both vertical and horizontal displacements. The rate of increment in both cases is approximately the same. However, the value of horizontal displacement is almost twice that of vertical displacement.

3.1.3. Comparison of Displacement for Different Soil Cases under the Same Arrangement of Geogrids Spacing 0.5m and Applied Load of 20 kN/m^2.

Table 3.3: Displacements for Different Soil Cases under Same Spacing of Geogrids and Same Applied Load.

S. No.	Type of Soil	Horizontal Displacement (mm)	Vertical Displacement (mm)
1	Loose Sand	28.56	67.42
2	Dense Sand	3.59	11.78

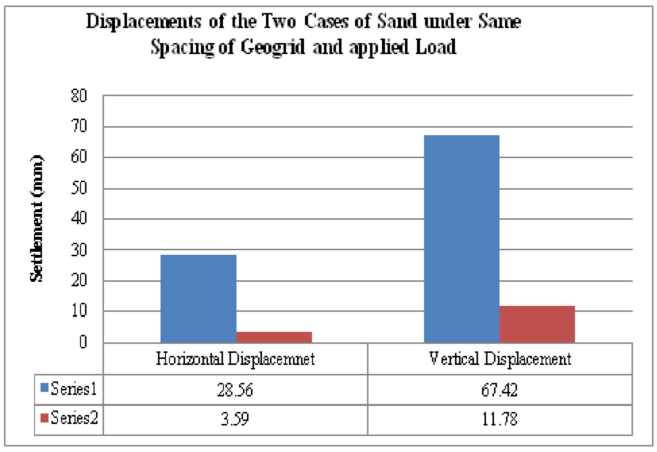


Figure 3.7: Displacements of the Two Cases of Sand under Same Spacing of Geogrids and applied Load.

Remarks:

This Figure shows that the horizontal displacement is generally higher than vertical displacement in dense sand and it is lesser in the case of loose sand. This result further corroborates the observed behaviour of loose sand with its vertical component of displacement higher than horizontal displacement.

IV. CONCLUSIONS

Following are the results obtained from static analyses carried out on the in this research work, the following concluding remarks can be made:

- The behaviour of the reinforced soil retaining wall is dependent on some factors which can positively or negatively influence the general performance of the wall. These factors include the value and dimension of the surcharge load (imposed load), length of the geogrid (s), stiffness of the geogrids, spacing of the geogrids among others.
- The behaviour of loose sand in terms of displacement is similar to that of while the responses of dense sand are compared.
- Loose and Dense sands showed higher degrees of instability as a backfill and foundation material in reinforced soil retaining wall.
- The exact degree of contribution of the soil reinforcement (geogrids) to the stability of the wall can be best determined by analysis.
- The behaviour of the wall in both soil conditions is similar.
- A state of equilibrium between the geogrids stiffness and the soil's angle of internal friction has to be reached for the reinforced wall to be stable, once this state of equilibrium is reached; an additional stiffness becomes unnecessary and uneconomical.

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