Evaluation of the Behavior of Geo-Synthetic Reinforced Soil Wall with Improved Soil as Backfill

D.V.SivaSankara Reddy, Ch.Gopal Reddy, M.Jugal Kishore, K.Kowshik

Abstract*: By using PLAXIS 8.6 a model had been developed to analyse the behaviour of Geo-synthetic reinforced soil retaining wall constructed with a segmental concrete blocks. The models are used for observing various parameters such as displacement of wall, stress generated along face of wall with respect to height of wall and base conditions. The study describes PLAXIS 8.6 programme utilization in prediction of weak spots or point of failures in a Reinforced wall and helps in avoiding such conditions and also makes the weak soil utilization in construction of such walls with some limitations.

Keywords: GRS wall; nonlinear elastic-plastic model; PLAXIS 8.6; Backfill.

I. INTRODUCTION

Mechanically stabilized earth prepared by the provision of artificial reinforcing. It can be effectively used for stability aspects and controls the earth pressure variations in retaining walls, bridge abutments, seawalls, and dikes. Although, The MSE have been used throughout history by using basic principles of MSE. In preparation of MSE utilization of reinforcing elements can vary, but includes steel and geosynthetics. The present geo-reinforced soil wall or GRS wall are the extended and advanced method of the MSE.

Even though limit equilibrium methods (LEM) are capable of analyzing a soil retaining wall's overall stability, they do not have the capability to model the wall's deformation behaviour. The forces calculated by limit equilibrium methods do not present the working forces since the theories are based on the extreme failure conditions. On the other hand, finite element methods (FEM) can provide perspicacity into the deformation behaviour and assess the overall performance of soil retaining walls under various conditions (geometry, soil properties, and reinforcement's properties). Soil materials are heterogeneous; their response is strongly affected by factors such as: grain size, mineralogy, structure, pore water pressure, and initial stress state etc. Finite element models require additional soil parameters, such as Young's modulus and Poisson's ratio that are not considered in LEM, for describing the stress-strain relationship of soils. A series of constitutive models have been developed for the characterization of stress-strain behaviour before and after failure of soil materials. The most common constitutive model used in soil mechanics is the Mohr-Coulomb model, also named perfectly elastic-plastic behaviour. The development of irreversible strain is associated with plasticity.

Revised Manuscript Received on December 28, 2018.

D.V. Siva Sankara Reddy, Assistant Professor, Kallam Haranadhareddy Institute of Technology, Guntur, Andhra Pradesh, India.

Ch. Gopal Reddy, Post Graduate Trainee, Department of Civil Engineering, Megha Engineering and Infrastructures Ltd.

M. Jugal Kishore, Assistant Professor, Kallam Haranadhareddy Institute of Technology, Guntur,Andhra Pradesh, India.

K. Kowshik, Assistant Professor, Kallam Haranadhareddy Institute of Technology, Guntur,Andhra Pradesh, India.

II. METHODOLOGY

2.1 General: As India is a developing country, there is a huge demand in the construction of road embankments in the form of over bridges, express ways, and coastal roads. The construction requires a high strength material which is slowly decreasing in the volumes. In order to overcome such problems we have to adopt the soils having a little lesser characteristic strength, which can be raised by the use of various reinforcing agents. The manual calculations would be more difficult to perform and a little slower which makes use of PLAXIS a helping tool in the computation. In the present study the use of low strength soils in the retaining backfill is evaluated.

2.2 Parametric Study: with different combinations of wall height the parametric studies has been carried out, reinforcement stiffness, facing element stiffness, and base condition. A different wall heights H of 2m, 4m, 6m, 8m were considered. The length and vertical facing of reinforcement were 0.7 H and 0.4m respectively. In The current study, block face of the wall vertical is considered. And the utilized range of stiffness modulus was defined by Mohamad et al (2007).

The above mentioned cases were considered with a new base, which is a stabilized soil of 10 m depth. The soil beneath the GRS wall is clay stabilized with stone columns of 0.6 m diameter, also there is a provision of sand blanket in between the clay and backfill material. The sand blanket thickness is 0.5 m. The provision of sand blanket is to drain out the pore water present in the clay material through stone columns later during the process of consolidation.

The boundaries of the bottom base are made rigid and the wall is allowed to sway free in the facing direction. In this case the bottom of the wall is allowed freely to settle into the downward direction. Input parameters in used in the analysis of GRS wall are presented in table.1, 2 and 3.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

Table.1 Input Parameters of the Wall (as a soil element)

Parameter	Value
Model	Linear Elastic
Size (m x m)	0.4x0.2 (long x height)
Unit weight, γ (kN/m^3)	22
Facing stiffness, EI (kN-m^2/m)	2.5x10^4
Axial stiffness, EA (kN/m)	7.5x10^6
Poisson's ratio, ν	0.15
w , kN/m/m	8.3

Table.2 Properties of the Soil Elements Used in Analysis

Property	Back Fill	Bottom clay	Stone column	Sand blanket
Model	Mohr Coloumb	Mohr Coloumb	Mohr Coloumb	Mohr Coloumb
Internal friction angle, Φ(degrees)	33	25	45	31
Cohesion(kPa)	3	5	0.1	1
Dilation angle, Ψ (degrees)	0	0	0	0
Unit weight, γ (kN/m^3)	18	16	17	17
E(kPa)	1.5x10^4	1x10^4	1.3x10^4	4x10^4
E_{oed}(kPa)	2.1x10^4	1.6x10^4	4.4x10^4	1.7x10^4
G (kN/m^2)	5769.23	3703.7	1.7x10^4	5000
Failure ratio, R_f	0.9	0.9	0.9	0.9
Poisson's ratio, ν	0.3	0.35	0.2	0.3

Table.3 Input parameters for wall (as a plate element)

Property	Wall
Model	Jointed Rock model
Internal friction angle, Φ(degrees)	57
Cohesion, c(kPa)	46
Dilation angle, Ψ (degrees)	0
Unit weight, γ (kN/m^3)	21.8
E(kPa)	1x10^5
G (kN/m^2)	5000
Failure ratio, R_f	0.9
Poisson's ratio, ν	0.15

III. MODEL DEVELOPMENT

3.1 General: here is an explanation for models generated using PLAXIS 8.6 software tool, out of all the models generated the each detailing of curves and modeling are shown for one of the model. Comparison graph are drawn for various friction angles (Ø) each of three models and separate graphs are plotted for models comprising base and without base. The normal effective stress distribution along the face of the wall is also plotted for varying friction angles and base condition.

3.2 Detailing a Model: All resulting variations for a basic model of 4m wall height comprising a soil element as wall for Ø=33o as backfill and other parameters as mentioned in parametric study are shown in Fig.1 and 2.

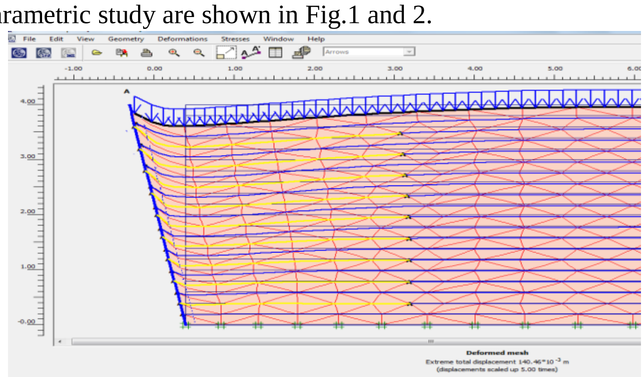


Fig.1 Deformed mesh after analysis of the model is the out-come of post construction.

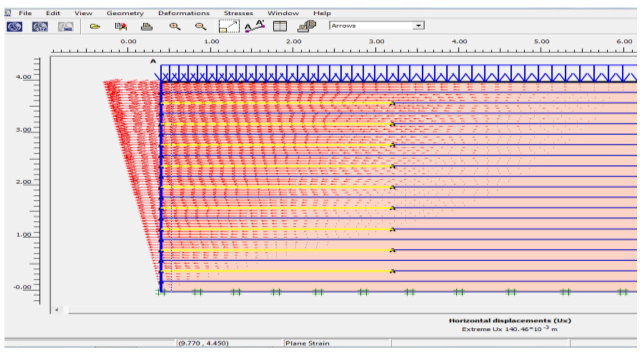


Fig.2 Sway of the wall in the horizontal direction in the form of arrows.

Published By:
Blue Eyes Intelligence Engineering & Sciences Publication

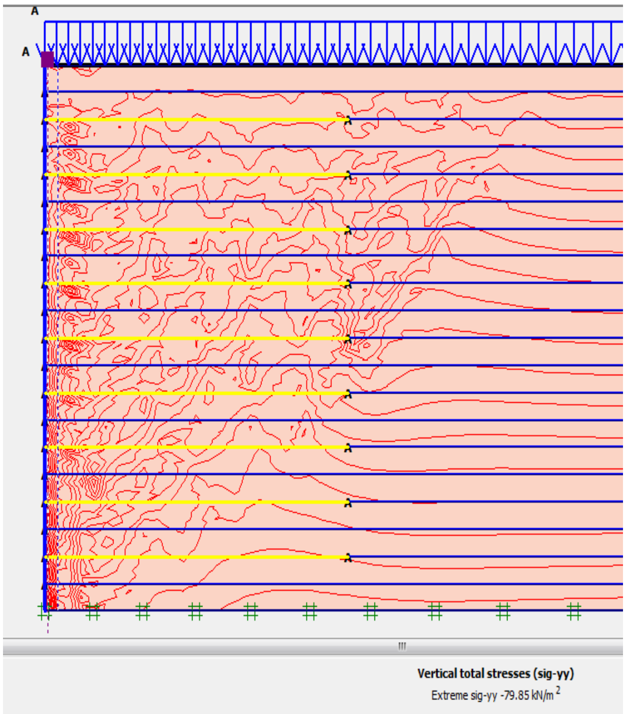
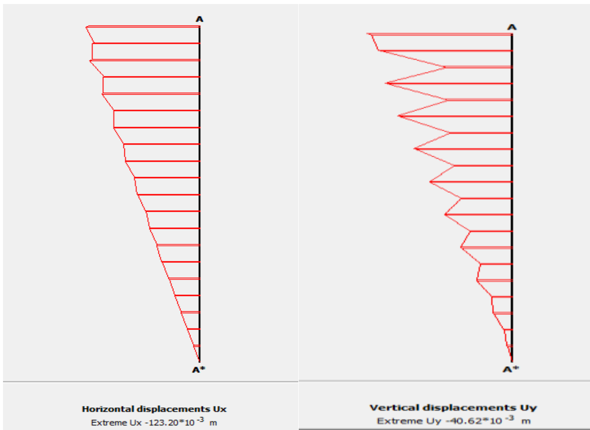
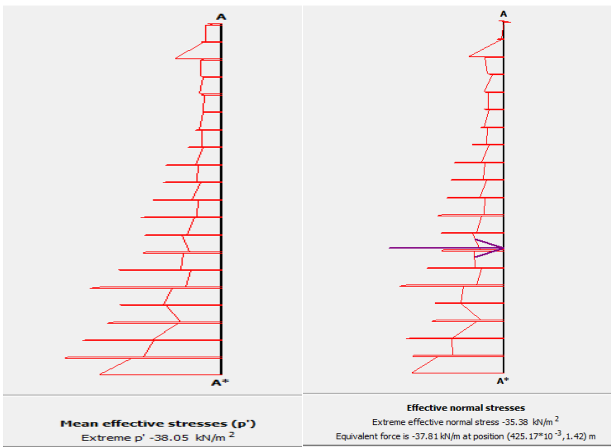


Fig.3 Vertical settlement in the backfill in the form of contours



(a) (b)

Fig.4 Cross sectional facing displacements of the soil along wall.



(a) (b)

Fig.5 Effective stresses along the face of wall representing the load points at reinforcement faces.

IV. GRAPHICAL VARIATION OF RESULTS & COMPARISION

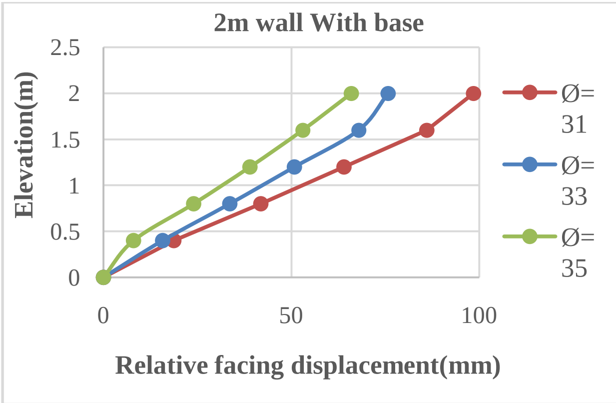


Fig.6 Wall displacements for 2m wall having base

Relative facing displacement with respect to height of wall for various (Ø) can be shown in Fig. 6 for with base and Fig.7 for without base. From the figures it is observed that for Ø=31 the displacements are more, the displacements are getting lesser in numbers as the Ø value increases. This simply makes as it is one of the shear strength parameters inducing a role in soil stability.

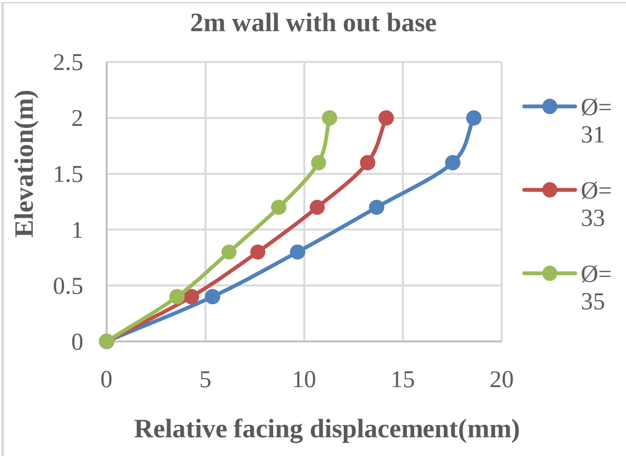


Fig.7 Wall displacement for the 2m rigid bottom wall

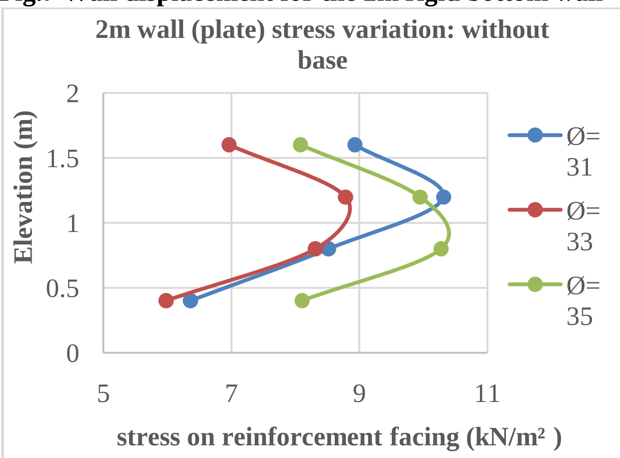


Fig.8 Stress variation along face of wall for model with rigid base

Published By:
Blue Eyes Intelligence Engineering & Sciences Publication

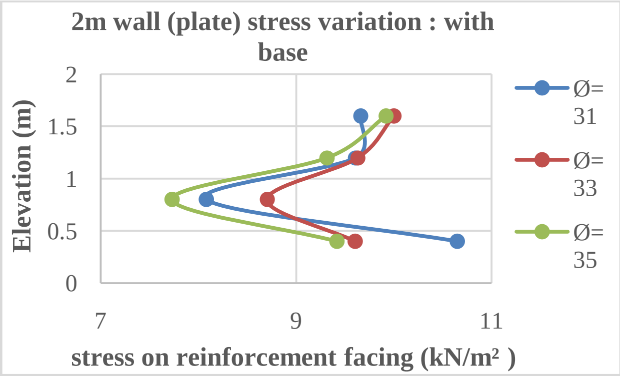


Fig.9 Stress variation along wall face for model having base

The stress variation along the wall face of the model with and without base are presented in the figures 8 and 9. The stresses variation for the wall having a base differs when compared to the model without base because due to the settlements in the bottom of the soil layers, they generate some excess pressure on reinforcement in the form of vertical consolidation of soil layers.

From the figure.9 it is observed that there is an decrease in the stress as height of wall increases this is due to the wall movement in the left direction which is being arrested by the reinforcement provided in the soil intern connected to the wall rigidly and later there is constant stress due decrease in overburden pressure.

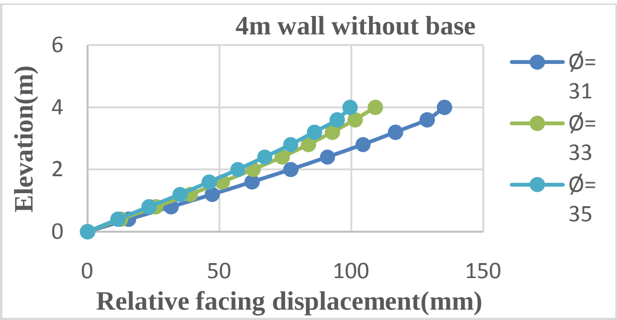


Fig.10 Wall displacements for the 4m rigid bottom wall

Relative facing displacement with respect to height of wall for various (Ø) can be shown in Fig.10 for without base and Fig.11 for with base. From the figures it is observed that for Ø=31 the displacements are more, the displacements are getting lesser in numbers as the Ø value increases. This simply makes as it is one of the shear strength parameters inducing a role in soil stability.

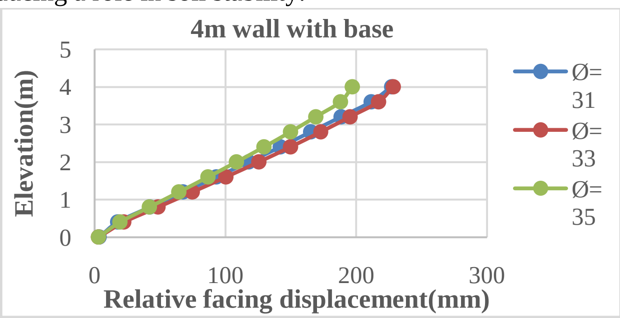


Fig.11 Wall displacements of 4m wall having a base

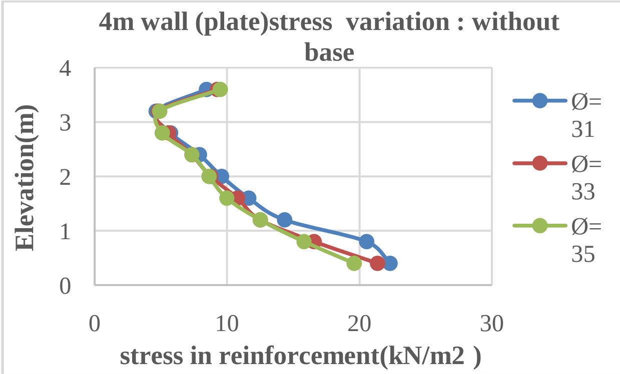


Fig.12 Stress variation along face of wall of rigid base

The figure.12 depicts the stress along the face of wall having rigid base decreases as the wall height increases due to the decrease in overburden pressure constantly but in the top layer there is increase in stress due to arresting forces in top reinforcement.

The figure.13 depicts the stress along the face of wall having stabilized base decreases as the wall height increases due to the decrease in overburden pressure constantly but in the top layer there is increase in stress due to arresting forces in top reinforcement.

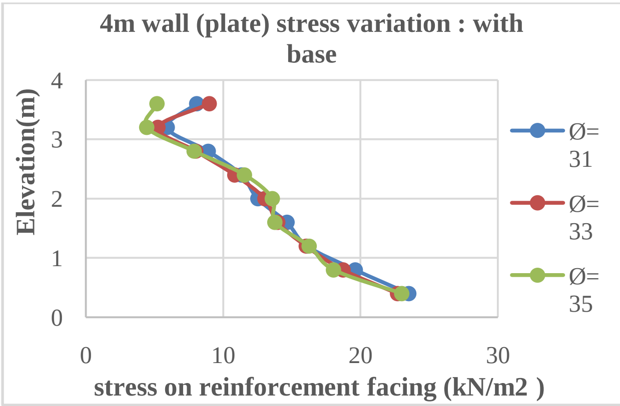


Fig.13 Stress variation along face of wall with base

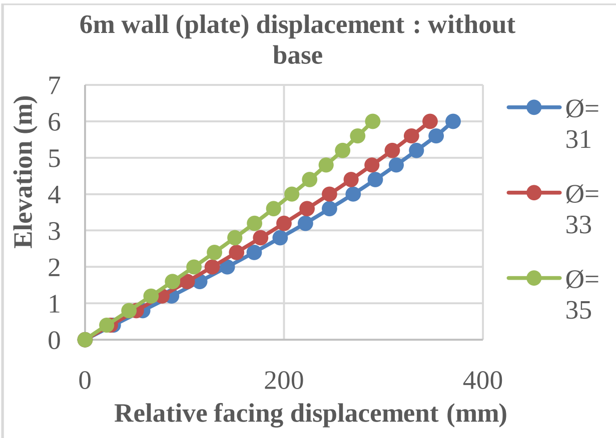


Fig.14 Face displacements of 6m wall having rigid base

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

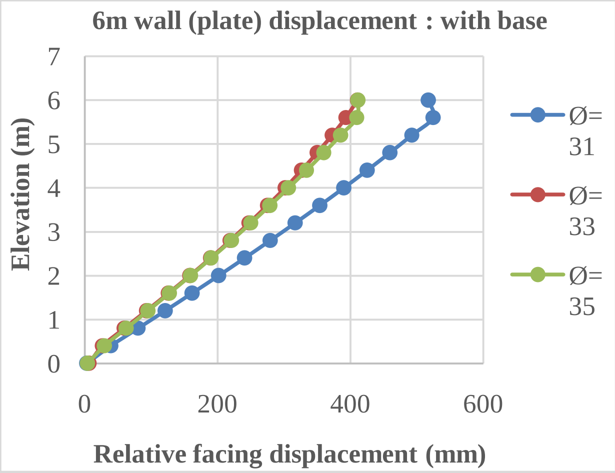


Fig.15 Face displacements for 6m wall with a stabilized base

Relative facing displacement with respect to height of wall for various (Ø) can be shown in Fig.14 for without base and Fig.15 for with base. From the figures it is observed that for Ø=31 the displacements are more, the displacements are getting lesser in numbers as the Ø value increases. This simply makes as it is one of the shear strength parameters inducing a role in soil stability. From the figure.15 it is observed that the wall displacement for backfill soil having Ø 33 and 35 the variation follows same pattern.

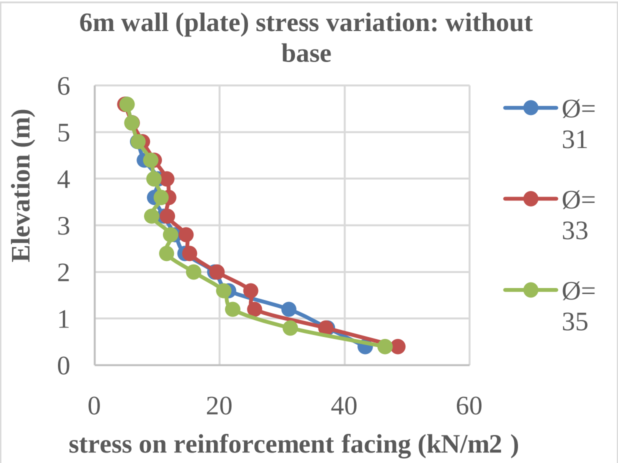


Fig.16 Stress variation along face of wall with rigid base

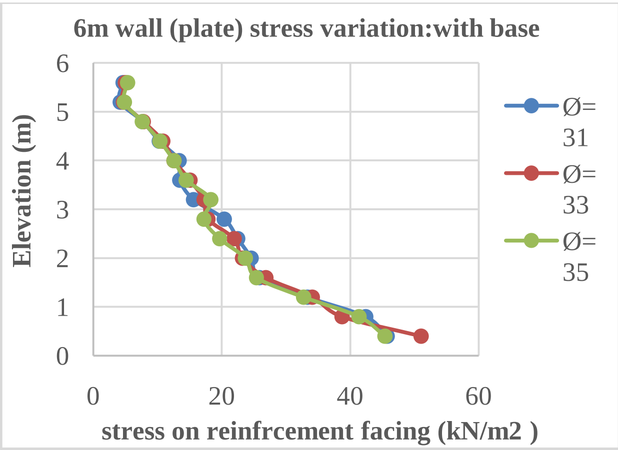


Fig.17 Stress variation along wall face for a wall with stabilized base.

The maximum and minimum magnitudes of stresses in both figures 16 and 17 are same. Similar to the 4m wall stress variation the magnitudes of the both wall face with and without bases are same approximately in physical terms, but there is a little variation in the path followed by the stress distribution along the wall in the two models.

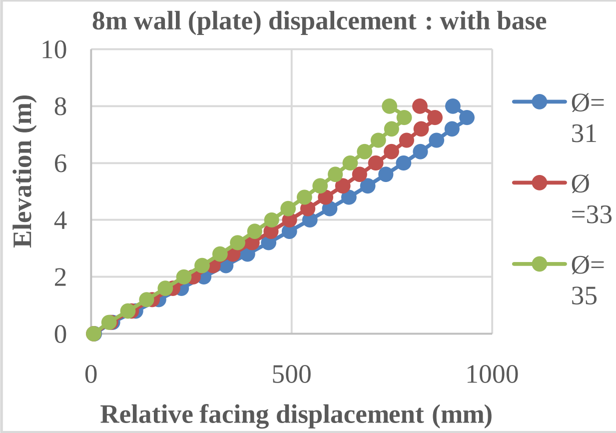


Fig.18 Face displacements for 8m wall with a stabilized base.

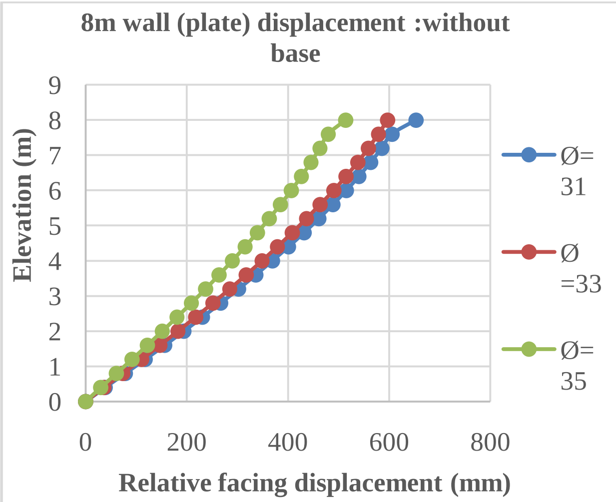


Fig.19 Face displacements for 8m wall with rigid base

Relative facing displacement with respect to height of wall for various (Ø) can be shown in Fig.18 for with base and Fig.19 for without base. From the figures it is observed that for Ø=31 the displacements are more, the displacements are getting lesser in numbers as the Ø value increases. This simply makes as it is one of the shear strength parameters inducing a role in soil stability. From the figure.18 it is observed that the wall displacement is linear up to the top layers but there is a small decrease which is due to the soil movement beneath the bottom of retaining wall. In figure.19 there is no such backdrop as it is rigidly bounded at the bottom of the retaining wall. We can see a considerable increase in the wall movement in horizontal direction for the wall having a stabilized base over that one having a rigid base.

*Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication*

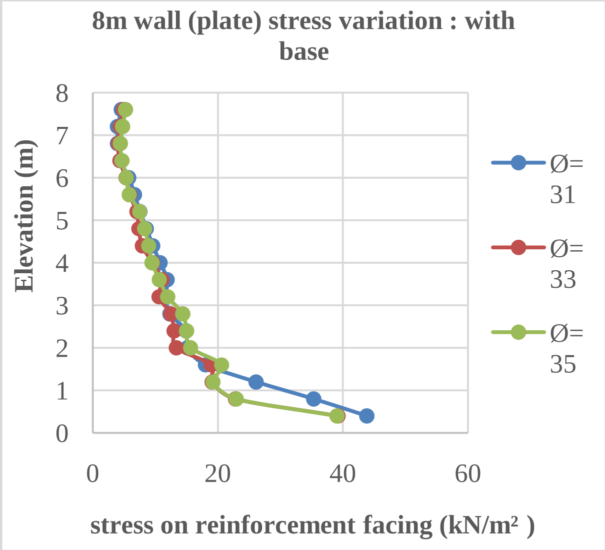


Fig.20 Stress variation for 8m wall having stabilized base

The figure.20 depicts the stress along the face of the wall to a wall having stabilized base shows a decrease in the stress as the wall height increases due to the decrease in overburden pressure constantly, but in the top layer there is a slight increase in stress due to arresting forces in top reinforcement. Here we can observe that in the bottom of the soil layers there is an enormous variation in stresses which is due to the settlement in the base soil due to the overburden pressure. This generates a high tension in the bottom reinforcement. As the height of the wall increases the variation in the stresses as well as the magnitude of stress also decreases due to decrease in overburden pressure.

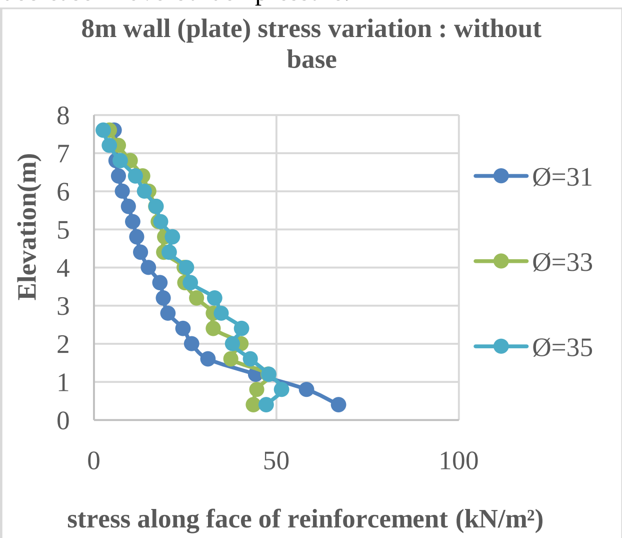


Fig.21 Stress variation for 8m wall having rigid base

The figure.21 depicts the variation in stress is observed differently as the Friction angle varies, for Ø=31 the stress gradually increases as the height decreases this shows that the reinforcement role is very minimal in that model. For Ø=33 and Ø=35 the stress variation is similar, in these models the stress is taken by the reinforcement provided, hence there is a tendency in variation of the stress.

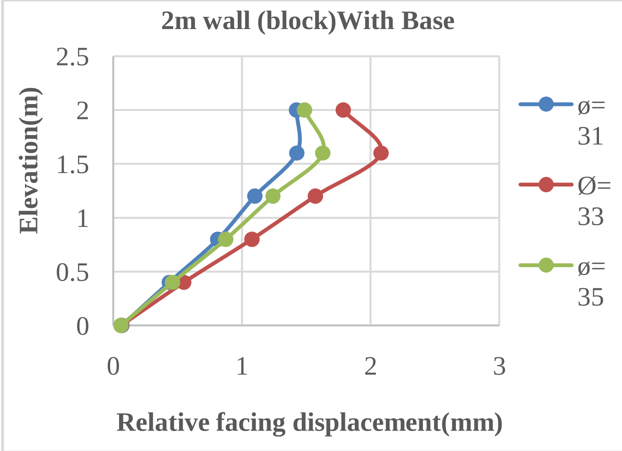


Fig.22 Relative wall displacement for 2m wall having stabilized base.

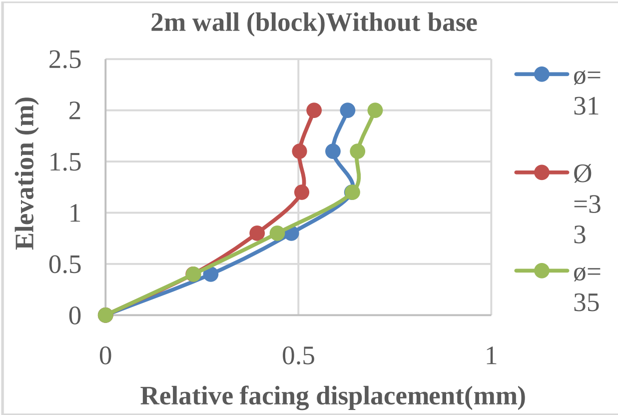


Fig.23 Relative wall displacements for 2m wall having rigid base

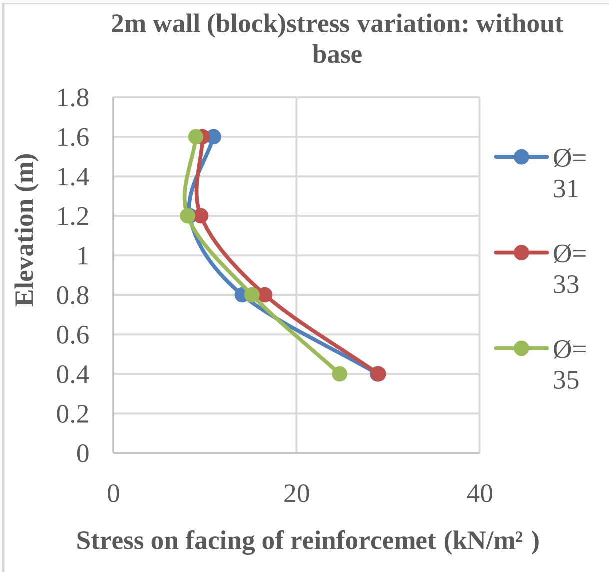


Fig.24 Stress variation in 2m wall having rigid base

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

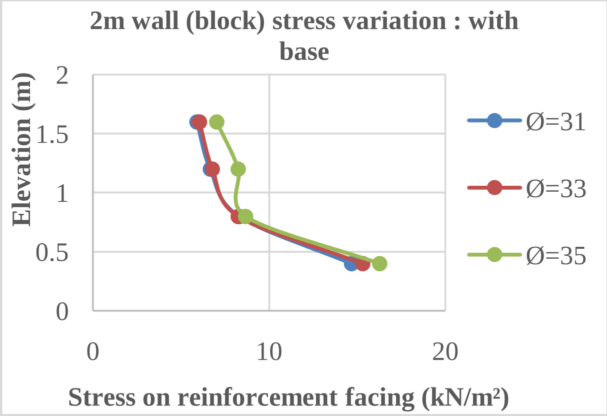


Fig.25 Stress variation for 2m wall having stabilized base

The stress variation along the wall face of the model without and with base are presented in the figures 24 and 25. The stresses variation in the wall having a base differs when compared to the model without base because due to the settlements in the bottom of the soil layers in the form of vertical consolidation of soil.

The figure.24 shows the stress variation along the face of wall, the stress decreases as the wall height increases linearly due to decrease in the overburden pressure, but in the top reinforcement there is an increase in stress due to arresting of wall movement in the top. From the figure.25 is observed that, there is a decrease in the stress as height of wall increases this is due to the decrease in overburden pressure. The wall movement in the left direction which is being arrested by the reinforcement provided in the soil intern connected to the wall rigidly shows a little variation and later there is relatively constant stress due decrease in overburden pressure.

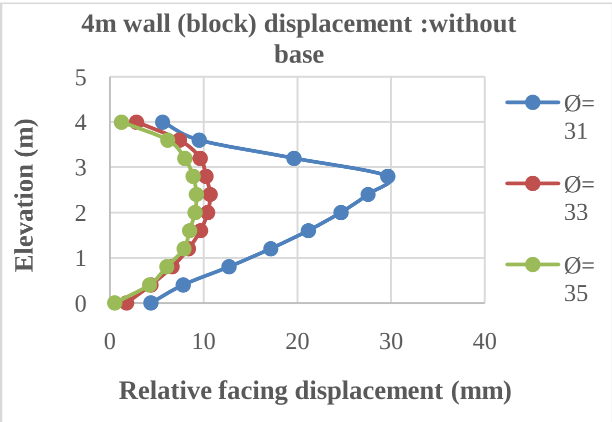


Fig.26 Relative face displacements for 4m wall having rigid base

The figure.26 shows the displacements of the wall along the height of wall which gradually increases up to some height of wall, but in the top layers due to considerable settlement in the middle layers of soil the wall movement decreases in the top and the wall displacements follow a curvilinear path due to rigid friction in between the wall components are presented. For wall having Ø=31 as backfill there is a large wall movement due to instability in the soil, the wall nearly breaks out in the middle height, but due release of stresses in the middle of wall height the top layers displace a little.

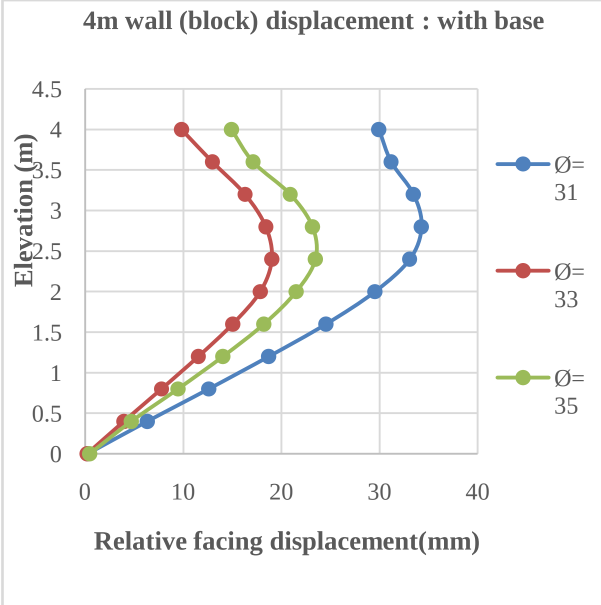


Fig.27 Relative face displacements of 4m wall having stabilized base

From the figure.27 it is observed that the same path as that followed in figure.26 by the soil retaining wall but the magnitudes in the displacements of wall is high when compared to the wall having rigid base due to the settlements in the bottom stabilized base.

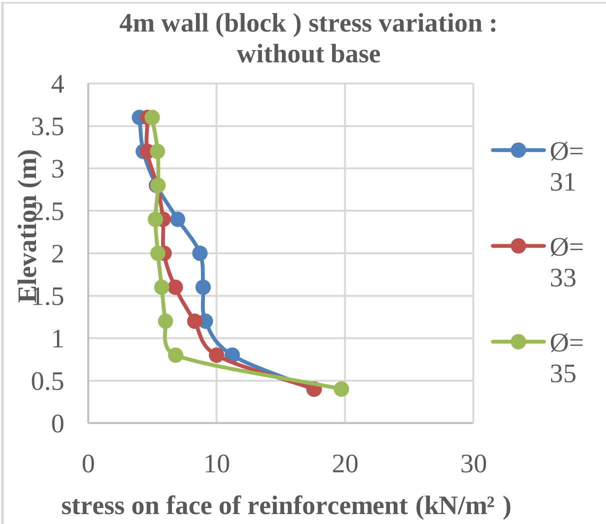


Fig.28 Stress variation along wall having rigid base

From the figure.28 it is observed that in the bottom of the soil layers there is an enormous variation in stresses which is due to the settlement in the bottom of soil due to the overburden pressure. This generates a high tension in the bottom reinforcement. As the height of the wall increases the variation in the stresses as well as the magnitude of stress also decreases due to decrease in overburden pressure.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

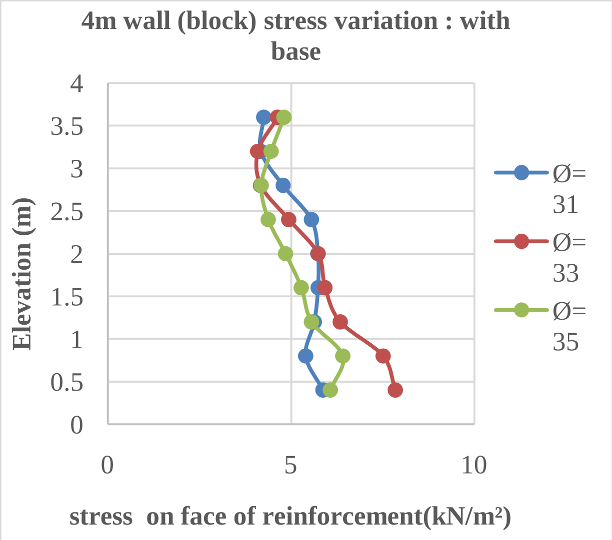


Fig.29 Stress variation along wall having stabilized base

From the figure.29 it is observed that the variation in stress is observed differently as the Friction angle varies, for Ø=31 the stress gradually increases as the height decreases this shows that the reinforcement role is very minimal. For Ø=33 and Ø=35 the stress variation is similar, in these models the stress is taken by the reinforcement provided, hence there is a tendency in variation of the stress.

4.1 Comparison:

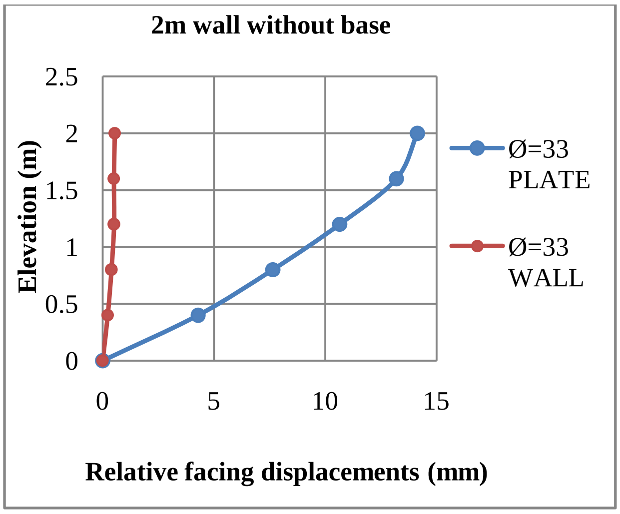


Fig.30 Comparison of wall facing displacements of walls having plate element and soil elements having rigid base

From the figures 30 and 31, the wall having a soil element tends to move less due to the frictional force between the elements, but where as in the plate element structure the wall is simply bound by the reinforcement only there will be no friction in between the elements. The magnitudes also vary a lot for wall having rigid base and stabilized base, which due to the settlements in the bottom base.

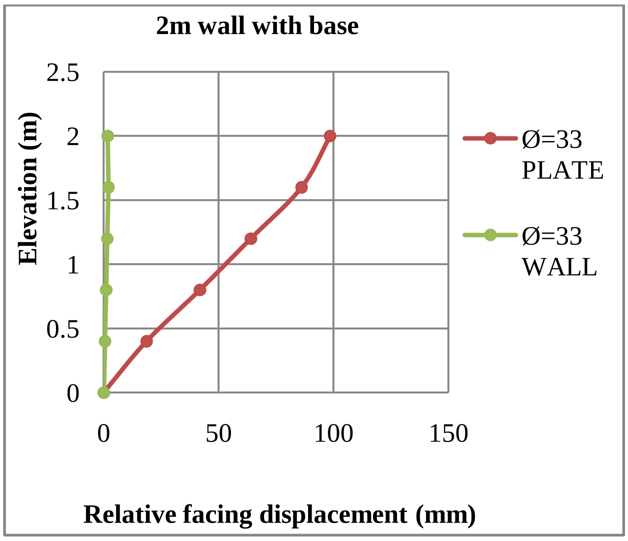


Fig.31 Comparison of wall facing displacements of walls having plate element and soil element having a stabilized base

The same follows for the walls having heights of 4m having rigid and stabilized base. The consideration of wall element in the PLAXIS software also plays a crucial role, the plate element considered in the retaining wall shows good agreement with the field situations when compared to the soil element.

V.CONCLUSIONS

From the work carried out in the thesis, to stimulate the deformations of the GRS wall with respect to the field. Here it is found that predict the settlements, normal stresses, shear stresses, even pore water pressures (if present), the points or places where the tendency to the structural failure can be seen and by this it can reanalyze the structure by providing necessary reinforcements. Care can be taken to avoid construction failures also.

The wall element, consideration as a wall shows good relation with the field conditions. The soil having weak strength can also be utilized for construction of retaining walls by proper reinforcement techniques. Even though certain limits to the height are advised. This can help in the reduction of the construction budget in the form of utilizing local available soil.

REFERENCES

1. MirmoradiS.M. and Ehrlich, M. (2014) "Numerical Evaluation of the Behaviour of GRS Walls with Segmental Block Facing under Working Stress Conditions". 10.1061/ (ASCE) GT.1943 -5606.0001235.© 2014 American Society of Civil Engineers.
2. KianooshHatami, and Richard J. Bathurst, (2006) "Numerical Model for Reinforced Soil Segmental Walls under Surcharge Loading." 10.1061/ASCE 1090-0241 (2006)132:6-673.
3. K. Hatami and R. J. Bathurst, "Verification of a Numerical Model for Reinforced Soil Segmental Retaining Walls."Deakinuniversity on 08/09/15.
4. KianooshHatami and Richard J. Bathurst ,"Development and verification of a numerical model for the analysis of geosynthetic-reinforced soil segmental walls under working stress conditions."Can. Geotech. J. 42: 1066–1085 (2005)

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

5. M. InancOnur, Mustafa Tuncan, BurakEvirgen, BertanOzdemir and AhmetTuncan, "Behaviour of Soil Reinforcements in Slopes." Advances in Transportation Geotechnics. The 3rd International Conference on Transportation Geotechnics (ICTG 2016) Volume 143, 2016, Pages 483–489.
6. S.H. Mirmoradi , M. Ehrlich, "Evaluation of the effect of toe restraint on GRS walls."TransportationGeotechnics 8 (2016) 35–44.
7. M. Ehrlich, S.H. Mirmoradi, "Evaluation of the effects of facing stiffness and toe resistance on the behaviour of GRS walls."Geotextiles and Geomembranes 40 (2013) 28-36.
8. J. Han, J. Huang, and A. Porbaha, "2D Numerical Modelling of A Constructed Geosynthetic-Reinforced Embankment over Deep Mixed Columns",GSP 131 Contemporary Issues in Foundation Engineering.
9. S.M.B. Helwany, G. Reardon, J.T.H. Wu, "Effects of backfill on the performance of GRS retaining walls." Geotextiles and Geomembranes 17 (1999) 1-16.
10. Huabei Liu, Xiangyu Wang , Erxiang Song, " Long-term behaviour of GRS retaining walls with marginal backfill soils." Geotextiles and Geomembranes 27 (2009) 295–307.
11. S.H. Mirmoradi, M. Ehrlich, "Effects of facing, reinforcement stiffness, toe resistance, and height on reinforced walls."Geotextiles and Geomembranes xxx (2016) 1-10.
12. S.H. Mirmoradi, M. Ehrlich, "Modelling of the compaction-induced stress on reinforced soil wall ." Geotextiles and Geomembranes 43 (2015) 82-88.
13. S.H. Mirmoradi, M. Ehrlich, C. Dieguez, " Evaluation of the combined effect of toe resistance and facing inclination on the behaviour of GRS walls." Geotextiles and Geomembranes 44 (2016) 287-294.
14. Mario Riccio, Mauricio Ehrlich, Daniel Dias, "Field monitoring and analyses of the response of a block-faced geogrid wall using fine-grained tropical soils." Geotextiles and Geomembranes 42 (2014) 127-138.