VOL. 13, NO. 9, MAY 2018 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences


www.arpnjournals.com

# EFFECT OF REINFORCEMENT, BACKFILL AND SURCHARGE ON THE PERFORMANCE OF REINFORCED EARTH RETAINING WALL

Anand M. Hulagabali[1], C. H. Solanki[1], G. R. Dodagoudar[2] and M. P. Shettar[3]
[1]Department of Applied Mechanics, SVNIT, Surat, India
[2]Computational Geomechanics Laboratory, IIT Madras, Chennai, India
[3]Department of Construction Management, Wollega University, Nekemte, Ethiopia
E-Mail: anandmhulagabali@gmail.com

## ABSTRACT

Behaviour of reinforced retaining wall depends upon the type of back fill soil, foundation soil and reinforcements used in the system. In the present study, reinforced wall had been analysed using finite element numerical tool PLAXIS 2D. Different types of reinforcements such as, HDPE Geogrid, PET Geogrid and Ribbed steel strip were used for wall. Also, backfill and foundation soil was varied with different types such as, sand, gravel, silt, clay. Walls deformations, ground settlement behind the wall and facing panel deformations were observed for different types of reinforcements, backfill and foundation soil. Ground settlements are found to be lesser for steel reinforcements behind the wall along the horizontal profile. HDPE and steel reinforcements are found to be more reliable, because deformations and settlements found to be less compared with PET Geogrid. Gravel found to exert lesser wall deformation because of its good drainage property. Even the settlements behind the wall were found to be lesser for gravel material. Hence it is adopted as good backfill and foundation material. Also, effect of surcharge loads on behaviour of MSE wall was studied. It was observed that, for smaller magnitude surcharge loads, deformations observed were less.

**Keywords:** reinforced earth, reinforcements, ground settlements, facing panel deformations, wall deformations.

## 1. INTRODUCTION

The combination of steel (reinforcement) and soil gives a very good engineering project. By observation of these entire phenomenon French engineer Henry Vidal proposed mechanically Stabilized Earth (MSE) wall theory in the year 1957. Later came into practice in United States in 1971 with Federal Highway Administration (FHWA-NH-10-024) [1]. Over the past three decades, GRE retaining walls have been increasingly used as structural alternative to conventional reinforced concrete retaining walls for supporting earth fills in civil infrastructural projects. Mainly the reinforced soil is made of two components, which are soil and reinforcement of different material and properties. The fundamental is that embedment of reinforcement in soil provides tensile strength to soil because of its higher stiffness also increases shear strength of the soil. MSE walls can also use at difficult foundation conditions because they are mechanically redundant and flexible structures at low cost compared to traditional conventional walls. The internal stability of the wall is provided by mechanical interactions of its three components, i.e. fill material, reinforcement, and facing. During the construction of a MSE wall, reinforcements are arranged in layers in the back-fill soil and by using the relative motion between the reinforcement and the soil the reinforced mass resists the earth pressure developed by the retained soil. Hence, the performance of a MSE wall depends on the interaction between the soil and inclusions.

The basic and important components while designing a MSE wall are retained soil, reinforced soil, foundation soil and facing panels. According to some the recommended codes like FHWA, AASHTO, NCMA and BS properties like reinforcement length should be within a range of 0.6 to 0.7 times the height of the wall, backfill or retained material should be free draining and free from organic substances. Backfill must be granular material of 100mm size and less than 15% fines with assumed unit weight of 20 kN/m$^3$ and soil friction angle of 30$^o$ and it is preferred for foundation soil. Reinforcement may be metallic, Geogrid and wire grid strips etc., and facing panel should be such that to control the erosion of soil which are of varying size and shape. In these parameters, internal stability of wall especially for embedded reinforcement depends on type, length, spacing and different configuration of reinforcement. The design includes internal, external and global stability analysis, as well as horizontal and vertical deformations of wall [2].

## 2. EFFECT OF DIFFERENT TYPES OF REINFORCEMENT ON MSE WALL

A MSE wall considers as a coherent block for flexibility, to sustain loads and deformations, which are developed due to interaction between the material and reinforcing material. From the experimental histories it is noticed that even the type of inclusion material has the significant effect on the wall movements. In this study, behaviour of different geosynthetics straps is compared with metallic strips. To model these walls significant parameters considered are; soil friction angle, cohesion, size and elastic modulus of inclusions.

Numerical analysis is carried out by considering soil and geometry as given in Tables 1 and 2. Finite element model of MSE wall is shown in Figure-1.

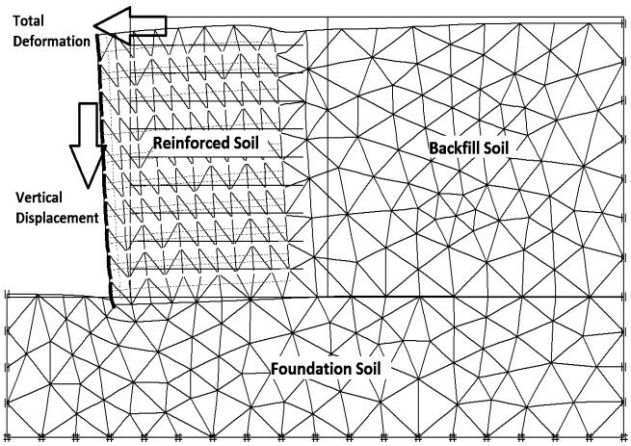


**Figure-1.** Deformations for different type of reinforcements.

High-Density Polyethylene (HDPE), Polyethylene Terephthalate (PET) Geogrid and Ribbed steel strips are considered. Different type of reinforcements and their properties used in the analysis are given in Table-3.

**Table-1.** Geometry of wall and reinforcement.

| Properties | Values |
|---|---|
| Height of the wall (m) | 4 |
| Type of facing panels | Single facing panel |
| Thickness of facing panels (m) | 0.15 |
| EA (kN/m) | 3625.950 |
| EI (kN/m$^2$/m) | 6.799 |
| Weight, W (kN/m/m) | 7.3 |
| Poison's Ratio, μ | 0.2 |
| Type of reinforcement | Geogrid |
| Length of reinforcement (m) | 7 |

**Table-2.** Properties of soil used in the model.

| Properties | Retained soil | Reinforced soil | Foundation soil |
|---|---|---|---|
| Unit weight (kN/m$^3$) | 18 | 18 | 18 |
| Cohesion (kPa) | 0 | 0 | 10 |
| Angle of internal friction (Degrees) | 30$^o$ | 34$^o$ | 30$^o$ |
| Saturated unit weight (kN/m$^3$) | 18 | 18 | 18 |
| SPT N-value | 4 | 10 | 4 |
| Modulus of Elasticity - E (kN/m$^2$) | $1.07\times10^4$ | $1.55\times10^4$ | $1.07\times10^4$ |
| Poisson's ratio $\vartheta$ | 0.3 | 0.3 | 0.3 |
| Dilation angle $\psi$ (Degrees) | 0 | 4$^o$ | 0 |

**Table-3.** Type of reinforcements and their properties.

| Material and properties | Values |
|---|---|
| HDPE Geogrid | UX-1400 SB |
| Thickness of Geogrid (m) | 0.001 |
| Modulus of elasticity - E (kPa) | 7.29×108 |
| Area (A= Thickness * Unit length) (m2) | 0.001 |
| PET Geogrid | Miragrid 3XT |
| Thickness of Geogrid | 0.001 |
| Modulus of elasticity - E (kPa) | 3.08×108 |
| Area (A= Thickness * Unit length) (m2) | 0.001 |
| Ribbed steel strip (Galvanized) | Grade 65 steel |
| Thickness of strip | 0.004 |
| Modulus of elasticity- E (kPa) | 2.0×108 |
| Area (A= Thickness * Unit length) (m2) | 0.004 |

### 2.1 Deformations of MSE wall

Analysis is carried out using different reinforcements as given in Table-3. MSE wall is modelled using the wall geometry, and soil properties as provided in the table 1 and 2. Deformations are obtained until failure of reinforcement reaches plastic condition. The analysis is carried out by different reinforcements and material properties. The wall deformations, horizontal and vertical displacements are obtained and differentiated as shown in the Figure-2.

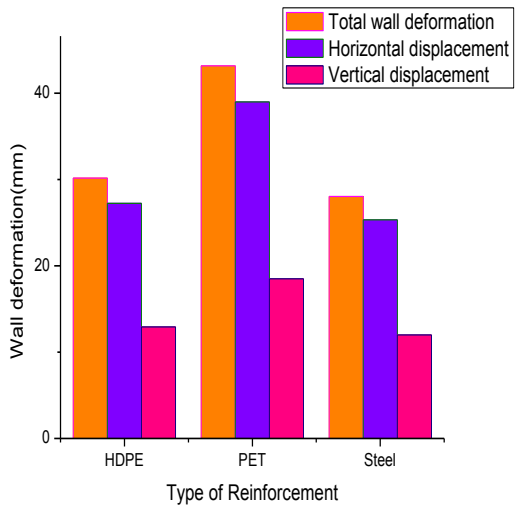


**Figure-2.** Deformations for different type of reinforcements.

### 2.2 Settlement of ground behind the wall

The variation of settlement of the ground with horizontal distance from the wall is shown in Figure-3. The settlement effect is observed up to 20 m away from the wall. From results, it is observed that soil having HDPE Geogrid shows lesser settlements.

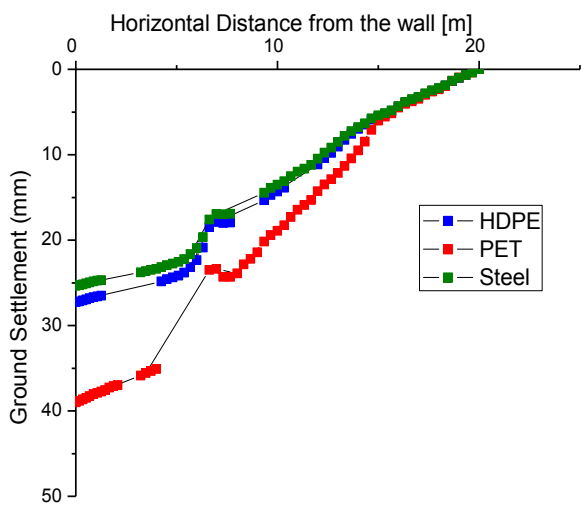


**Figure-3.** Deformations for different type of reinforcements.

### 2.3 Facing panel deformations

Lateral load will act on the facing panels due to the unit weight of reinforced earth backfill. Panel deformations along its elevation are plotted as vertical and horizontal profiles as shown in the Figures 4 and 5 respectively.

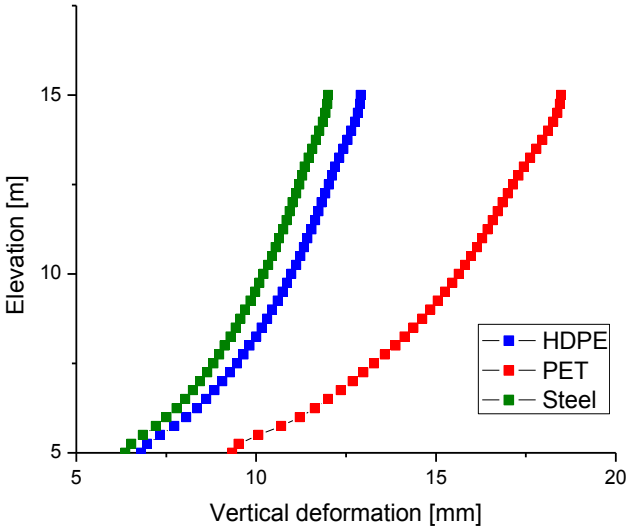


**Figure-4.** Facing panels vertical deformation profile.

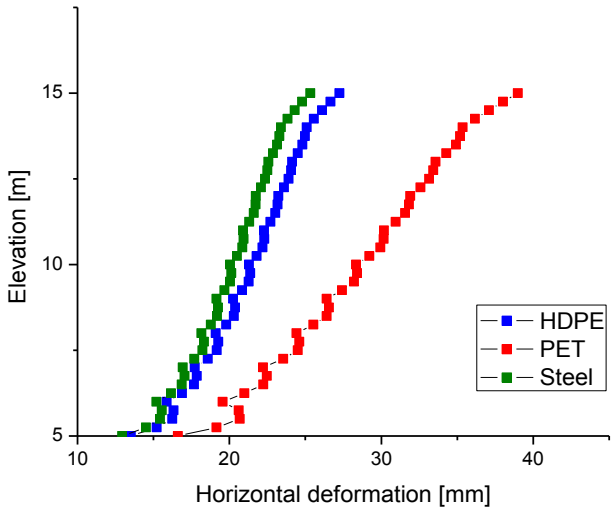


**Figure-5.** Facing panels horizontal deformation profile.

### 2.4 Summary

- For PET Geogrid, the total wall deformation, horizontal and vertical displacements are observed to be more because of its lower axial stiffness.
- HDPE and steel reinforcements are found to be more reliable and hence can be considered for construction of MSE wall.
- Settlements are found to be lesser for steel reinforcements behind the wall along the horizontal profile.

- Even the horizontal and vertical deformations are also found to be lesser along the elevation or height of the wall for steel reinforcements.

## 3. EFFECT OF DIFFERENT BACKFILL AND FOUNDATION SOIL ON MSE WALL

### 3.1. Deformations of MSE wall

In this study, the MSE wall is analysed and checked for different types of soils (sand, gravel, silt, clay) for both backfill and foundation. The soil properties adopted for the analysis are given in Table-4. The variation of wall deformations for foundation and backfill soil is shown in Figures 6 and 7.

**Table-4.** Different type of soils and their properties.

| Properties | Sand | Gravel | Silt | Clay |
|---|---|---|---|---|
| Unit weight (γ) (kN/m$^3$) | 16 | 19 | 20 | 18 |
| Cohesion (kPa) | 0 | 0 | 75 | 10 |
| Angle of internal friction (ϕ) | 30$^o$-40$^o$ | 35$^o$ | 34$^o$ | 20$^o$ |
| Modulus of Elasticity E (MPa) | 50 | 170 | 40 | 10 |
| Poisson's ratio, (μ) | 0.25-0.4 | 0.15-0.35 | 0.3-0.35 | 0.1-0.3 |

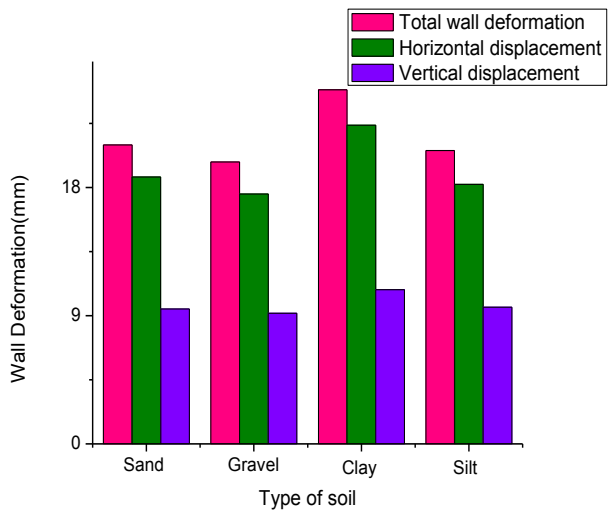


**Fig.6.** Deformations of wall for different type of soil (Foundation soil).

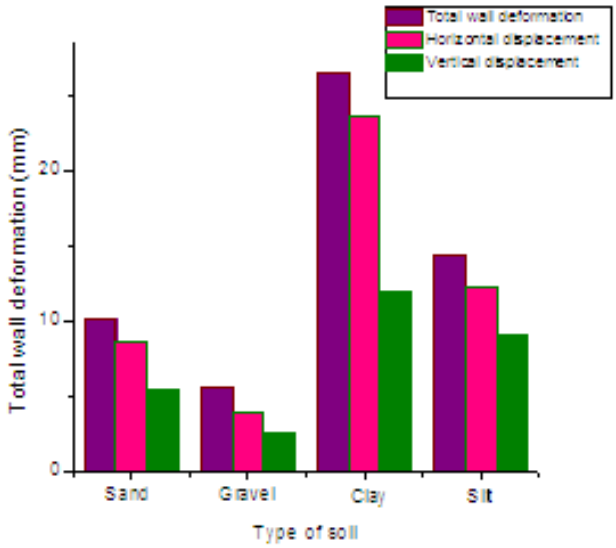


**Figure-7.** Deformations of wall for different type of soil (Backfill soil).

### 3.2. Settlement of ground behind the wall

The variation of settlement of the ground with horizontal distance from the wall is shown in Figure-8. The effect of settlement is observed up to 20 m away from the wall. Settlements of ground were more for clayey soil as shown in Figures 8 and 9.

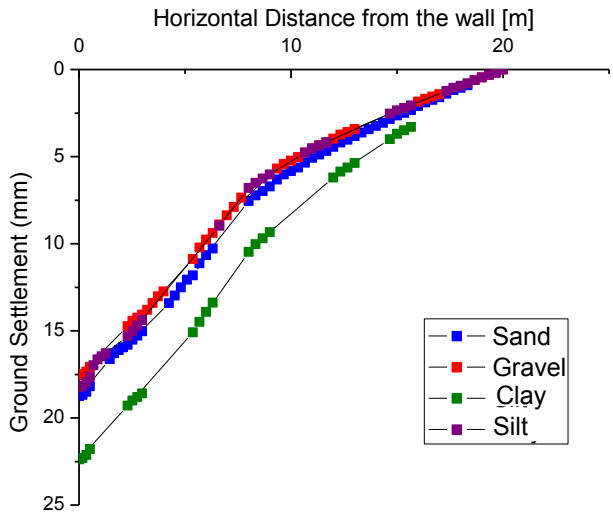


**Figure-8.** Variation of settlement with the horizontal distance from the wall (Foundation soil).

VOL. 13, NO. 9, MAY 2018 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences



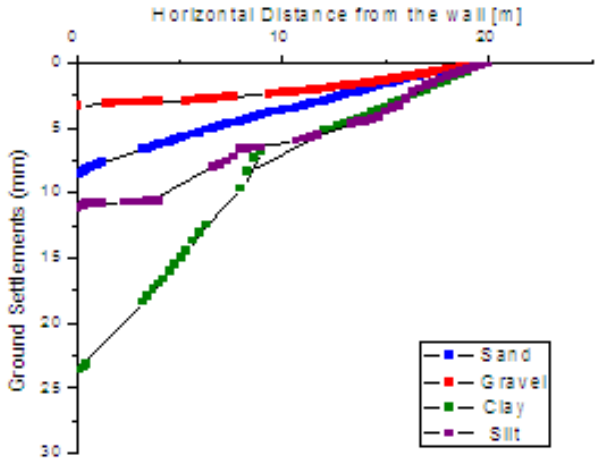


**Figure-9.** Variation of settlement with the horizontal distance from the wall (Backfill soil).

### 3.3. Facing panels deformations

Facing panel deformations were observed for all four types of backfill and foundation soil. It was observed that for clayey soil deformations were more as shown in Figure-10, since clay has low permeability, which exerts more pressure on wall panels.

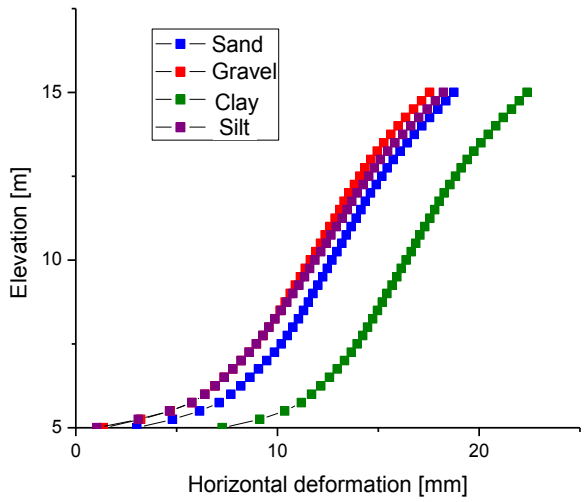


**Figure-10.** Facing panels horizontal deformation profile (Foundation soil).

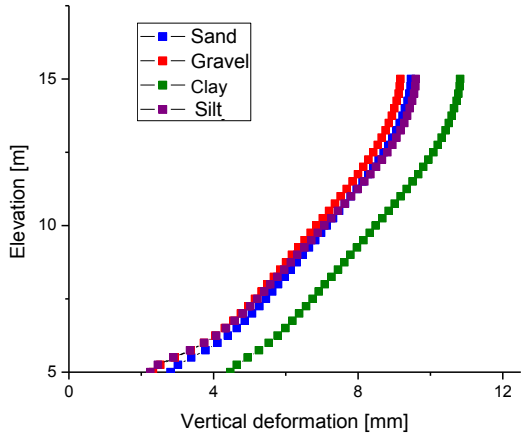


**Figure-11.** Facing panels vertical deformation profile (Foundation soil).

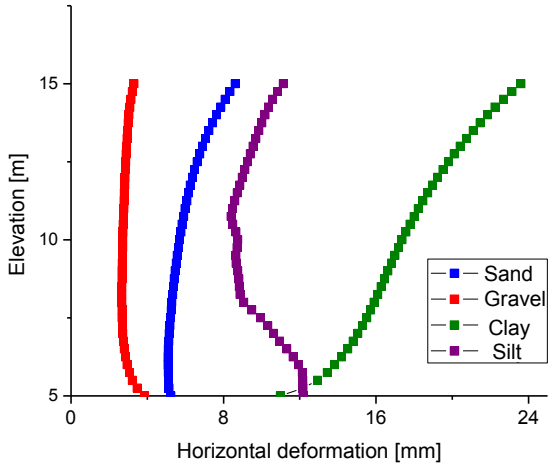


**Figure-12.** Facing panels horizontal deformation profile (Backfill soil).

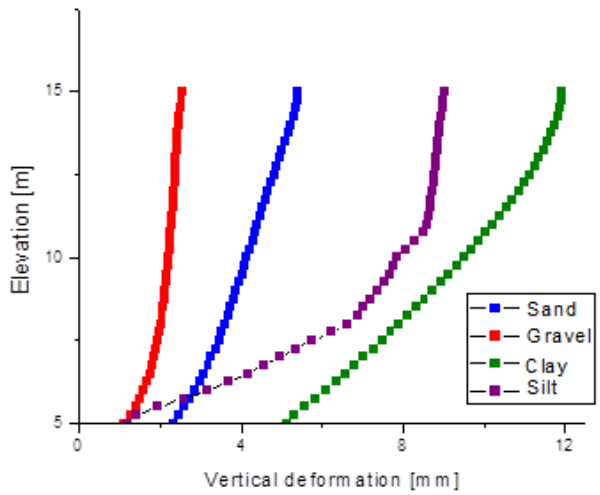


**Figure-13.** Facing panels vertical deformation profile (Backfill soil).

### 3.4. Summary

- By the analysis of MSE wall for different types of soil, it was clear that, for gravel and sand, as a backfill and foundation material, deformations observed were very less. Since permeability is more for gravel and sand, drainage will be good. There will not be any excess pore water pressure developed behind and beneath the wall.

- Wall deformations, ground settlements and panel deformations were more for clay as a backfill and foundation soil. Because, there will be excess pore water pressure develops, which leads to more deformations.

## 4. EFFECT OF DIFFERENT SURCHARGE LOADS ON MSE WALL

### 4.1. Wall deformations

Numerical modelling of MSE wall is carried out by increasing surcharge loading. Sometimes MSE wall may undergo variation in surcharge loading. For example, vehicular loadings, the traffic volume will be not constant for a lane; hence the analysis is carried out by increasing surcharge magnitude. Loads are applied exactly behind the face of the wall and along the reinforcement length.

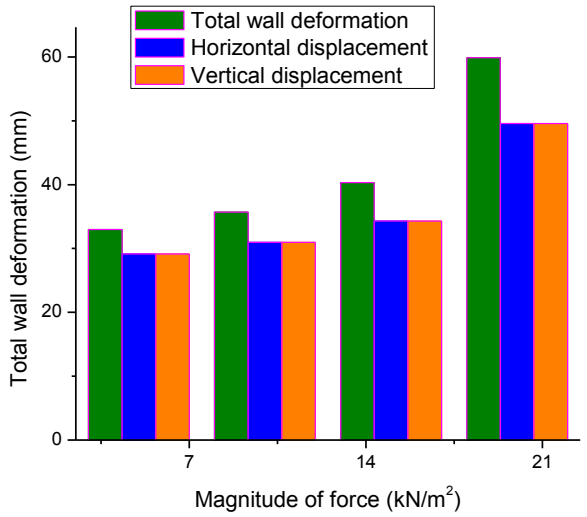


**Figure-14.** Deformations of wall for varying force magnitudes.

Wall deformations for different surcharge conditions are analysed and represented as total, horizontal and vertical deformations. The comparisons of incremental loadings are shown below in Figure-14.

### 4.2. Settlement of ground behind the wall

The variations of settlement of the ground with horizontal distance from the wall are shown in Figure-15. The effect of settlement is observed up to 20 m away from the wall. The smaller magnitude of 5kN/m2 shows lesser settlements as shown in Figure.

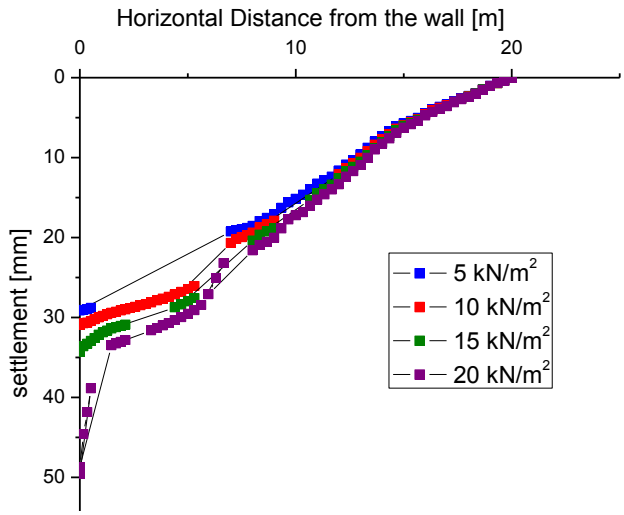


**Figure-15.** Ground settlement with the horizontal distance from the wall.

### 4.3. Facing panels deformations

Horizontal and vertical deformations of facing panels were observed for different surcharge loads as shown in Figures 16 and 17.

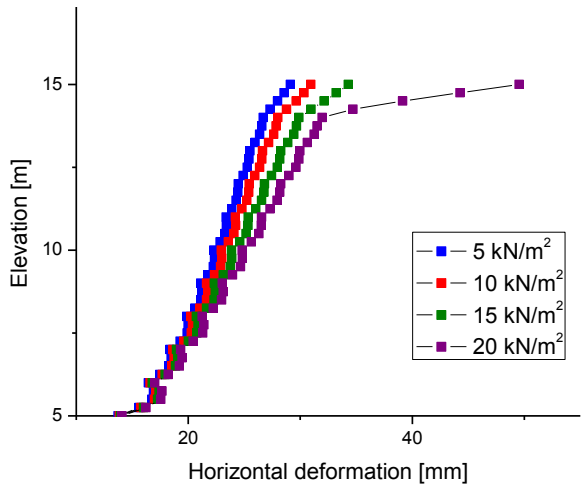


**Figure-16.** Horizontal deformations of facing panels.

### 4.4. Summary

- By the numerical analysis for varying surcharge magnitudes it is clear that smaller magnitudes show lesser deformations. Even the ground settlements observed to be lesser for small surcharge loads behind the wall along horizontal profile. Settlements and deformations were more for 20 kN/m$^2$.

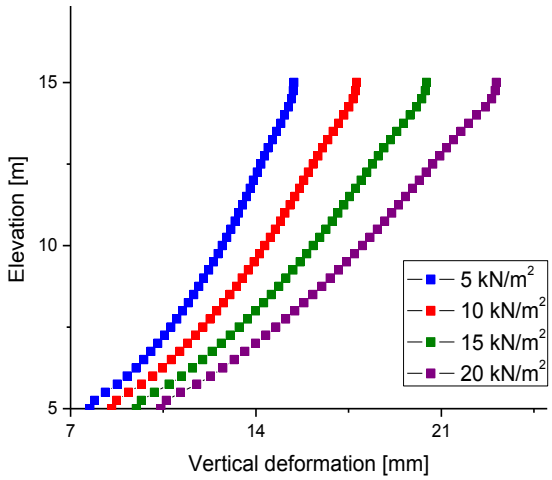


**Figure-17.** Vertical deformations of facing panels.

- Vertical and horizontal profiles drawn for wall facing deflection also shows lesser deflections for smaller magnitudes along the elevation of the wall.

## 5. CONCLUSIONS

- From the analysis of MSE wall, it was clear that, wall deformations, settlement of ground behind the wall and deformations of facing panels were found to be more for Polyethylene Terephthalate (PET) geogrid, clayey backfill and for surcharge of 20 kN/m$^2$.
- Also, from the results, it was observed that, MSE wall with steel reinforcement, gravel backfill and surcharge of 5 kN/m$^2$, showed lesser wall deformations, ground settlement and deformations of facing panels.
- This research will be useful for geotechnical engineers, to choose appropriate backfill and reinforcements.

## REFERENCES

[1] Bobet Antonio. 2002. Design of MSE walls for fully saturated conditions. Indot Research, Trb Subject Code: 62-1 Foundation Soils, Publication No.: FHWA/In/Jtrp-2002/13, SPR-2405.

[2] Omar A. M, Moudabel Garry, H Gregory, Xiaoming, Yang, Stephen, A Cross, Feifan, Ren. 2014. A Case Study of MSE Wall Stability: Comparison of Limit Equilibrium and Numerical Methods. Ground Improvement and Geosynthetics GSP. 238: 464-470.

[3] Hossain M. S, Kibria G, Khan M. S, Hossain, J, Taufiq T. 2012. Effects of Backfill Soil on Excessive Movement of MSE Wall. J. Perform. Constr. Facil. 26(6): 793-802.

[4] Golam Kibria, Sahadat Hossain, Mohammad Sadik Khan. 2014. Influence of Soil Reinforcement on Horizontal Displacement of MSE Wall. Int. J. Geomech. 14(1): 130-141.

[5] Christopher B. R, Leshchinsky D, Stulgis R. 2005. Geosynthetic-Reinforced Soil Walls and Slopes: US Perspective. GSP 141 International Perspectives on Soil Reinforcement Applications.

[6] Stulgis R.P. 2005. Selecting Reinforced Fill Materials for MSE Retaining Walls. GRI-18 Geosynthetics Research and Development in Progress.

[7] P. Damians, R. J. Bathurst, A. Josa, A. Lloret. 2014. Numerical Analysis of an Instrumented Steel-Reinforced Soil Wall, Int. J. Geomech, 04014037-1 to 04014037-15.

[8] Mosallanezhad M, Sadat Taghavi S. H, Hataf N. 2016. Experimental and numerical studies of the performance of the new reinforcement system under pull-out conditions Alfaro, Geotextiles and Geomembranes. 44: 70-80.

[9] Chen Huei-Tsyr, Hung Wen-Yi, Chang Chin-Chang, Chen Yuan-Ji, Lee Chung-Jung. 2007. Centrifuge modeling test of a geotextile-reinforced wall with a very wet clayey backfill, Geotextiles and Geomembranes. 25: 346-359.

[10] Koerner R M. 1999. Designing with Geosynthetics. Pearson publications upper saddle river, New Jersey, USA.