NUMERICAL MODEL OF TWO TIERED REINFORCED SOIL WALL

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ABSTRACT: This paper presents a study on numerically modeled two tiered reinforced soil retaining wall. A numerical model of 6m high concrete blocked reinforced soil wall is developed with finite element programme ANSYS. The numerical model of reinforced soil wall is validated with physical model test conducted by Ling et al. (2000) at PWRI Japan. A 6 m high two tiered reinforced soil wall is modeled using validated material properties. The horizontal and vertical deformation of the wall and lateral stress on the wall faces are being studied. The parametric studies are conducted for wall with higher reinforcement stiffness and longer length of reinforcement at lower tiers. The results shows that upon increasing lower tier reinforcement stiffness value the wall deformation, the stress distribution and reinforcement strain decreases. The longer reinforcements have little effect on wall deformation, stress distribution and reinforcement strain. This parametric study on multitier retaining wall provide a better understanding on the nature of tiered wall and the results obtained give a more effective design approach for tiered wall.

Keywords: Retaining wall, Tiered retaining wall, Finite element modeling, ANSYS, Stiffness

1.0 INTRODUCTION

The use of tiered reinforced retaining wall over conventional retaining wall is increasing worldwide due to its several advantages such as sound performance, aesthetics, low cost and construction requirement etc. Recent years many researchers studied the responses of multi tiered walls and its positive behaviour compare to single tiered walls (Bathurst & Hatami, 2009; Leshchinsky and Han, 2004; Ling et al, 2000; Yoo and Jung, 2003; Yoo and Kim, 2008). In this paper finite element model of two tiered wall is developed using software ANSYS. The parametric studies are conducted on the tiered wall with higher stiffness and longer lengths of reinforcement at lower tier.

2.0 PHYSICAL MODEL OF REINFORCED SOIL WALL

Figure 1 shows geometry of concrete blocked reinforced retaining wall constructed at the Public Works Research Institute (PWRI), Ministry of Construction, in Japan (Ling et al, 2000).The wall is 6m high and 5m wide constructed in a concrete test pit with a concrete floor. For reinforcement uniaxial geogrids (Tensar SR55), manufactured from extruded high-density polyethylene (HDPE) are used. The wall consists of total six primary and five secondary geogrid layers of lengths 3.5m and 1.0m respectively. The facing wall is made of 12 blocks having each block 500mm high and 350mm wide. A silty sand having D_{50} = 0.42 mm; γ = 16.0 kN/m^3 are used as the backfill.

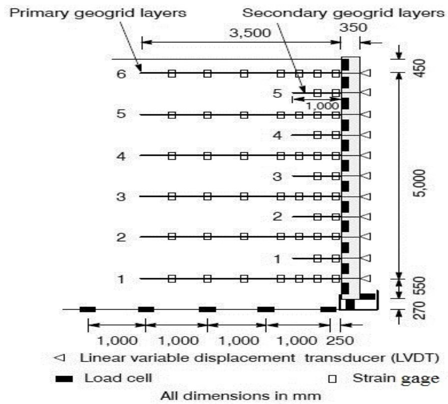

Fig. 1 PWRI wall geometry (Ling et al, 2000)

2.1 Finite Element Model in Ansys of PWRI wall

Figure 2 shows the finite element model of 6 m high concrete block geosynthetic retaining wall is developed using the program ANSYS. Dimensions of the numerical model are same as the physical model. The foundation, concrete blocks and backfill soil are simulated using the quadrilateral element PLANE82. Interface between concrete-concrete are assumed to be bonded and are simulated using target element TARGE169 and contact element CONTA172. The concrete blocks for foundation and facing are modelled as linear elastic material. The backfill soil is modelled as an elasto-plastic material following Drucker-Prager yield criterion (Cakir, 2013). The interface between backfill soil and concrete facing are assumed to be bonded in initial contact. Geosynthetic reinforcements are modelled with two dimensional cable elements LINK1 with non-linear material properties. The material properties are tabulated in the Table 1 and Table 2. The numerical model follows same construction sequence as that of physical model (Ling et al. 2000). At each stage solution is iterated to convergence.

Table 1 Material properties of numerical model

Materials	**Backfill**	**Concrete**	**Geogrid**
Elasticity (Pa)	2×10^6	2×10^8	8.264×10^8
Poisons ratio	0.42	0.17	0.3
Density(Kg/m3)	1631	2400	0.23
Cohesion (kPa)	6	-	-
Internal friction angle	45^0	-	-
Dilatancy angle	5^0	-	-
Yield stress (Pa)	-	-	5.46×10^8
Tangent modulus (Pa)	-	-	2×10^8

Table 2 interface properties of the numerical model

Interface properties	**Concrete-concrete**	**Soil-concrete**
Friction angle	19.6^0	16.5^0

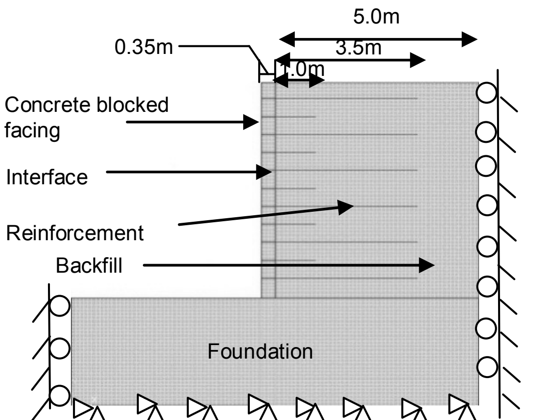

Fig. 2 Finite Element model of 6m high reinforced soil wall

The comparison of results obtained from numerical model with that of measured value of PWRI wall is shown in Figure 3. The maximum horizontal displacement is 28.75 mm and 30.0 mm for numerical and physical model respectively. At top measured and predicted lateral stress values are 0.1 kPa and 0.15 kPa and at bottom 13.8 kPa and 17.5 kPa respectively. It is observed that predicted displacement and stress distribution is almost same as that of measured values.

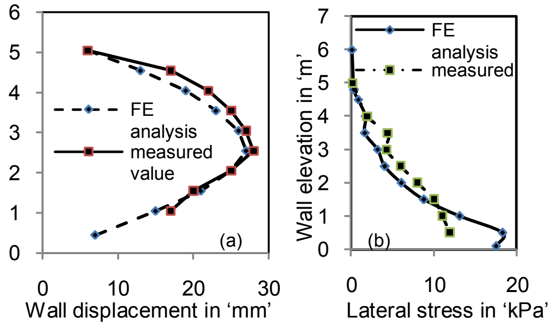

Fig.3 Numerical and measured (a) horizontal displacement (b) lateral stress distribution

3.0 DEVELOPMENT OF TWO TIERED WALL

Using the validated material properties numerical model of a two tiered wall with 0.2*H* tier offset is designed where *H* is the height of two tiered wall. Each tier wall has 7 concrete blocks and 6 geogride layers. The size of each blocks are 0.35 m × 0.5 m. Length of reinforcement is 0.7 times total height of wall (FHWA 2001). Thickness of the concrete foundation block is 3m.

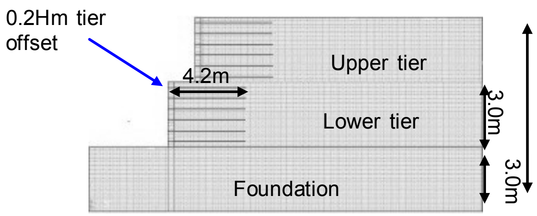

Fig. 4 numerical model of two tiered wall

Figure 5 shows the horizontal deflection of wall face and the lateral stress distribution near the face of two tiered wall. Maximum horizontal wall displacement value 30.6 mm is just above the tier offset point. Minimum wall displacement value 2.91 mm is at the bottom of backfill of lower tier wall. In case of lateral stress distribution on both lower and upper tier wall facing shows a typical triangular stress distribution pattern.

Figure 6 shows the axial strain along the length of geogride layer 6, 3 and 1 of lower tier wall at height of 2.75 m, 1.25 m and 0.25 m from the base of wall. Figure shows at a distance 1.4 m from the back of wall face peak strain in geogride layers occurs. This sudden increase in strain is due to the surcharge effect of concrete blocked upper tier wall. Peak strain values are 0.52%, 0.31%and 0.14% for layer 6, 3 and1. Since layer 6 is directly below upper tier wall surcharge effect is more. Strain values decreases from top to bottom layer for lower tier wall.

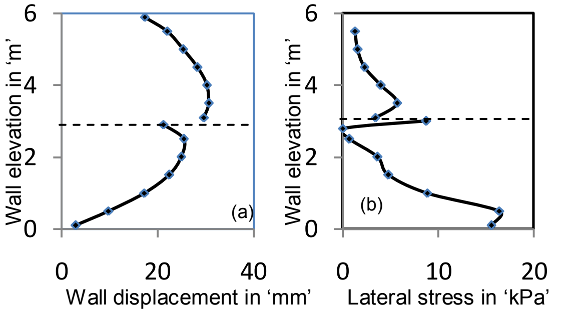

Fig.5 (a) horizontal wall displacement, (b) lateral stress on wall face of two tiered wall

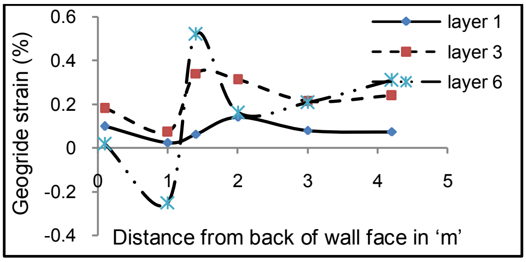

Fig. 6 Geogrid strain of lower tier wall reinforcement layers of two tiered wall

4.0 PARAMETRIC STUDIES

The performance of the reinforced soil wall depends on length and stiffness of reinforcement, backfill soil etc. In this paper response of two tiered wall to the change of reinforcement stiffness and length is studied. Considering the variation of reinforcement strain in lower tier of two tiered wall, the parametric studies are conducted by varying the stiffness and lengths top two reinforcement layers of lower tier. Table 3 shows the parameters considered for parametric studies.

Table 3: Parameters considered for parametric studies

Parameters	**Values**
Reinforcement Stiffness (Pa)	8.264×10^{8} , 1×10^{10}, 1×10^{12}
Reinforcement Length	0.7H, 0.9H, 1.0H and 1.2H

4.1 Effect of change in stiffness of lower tier reinforcements

Figure 7 and Figure 8 show the lateral wall displacement and lateral stress distribution of two tiered wall at the wall face with reinforcement stiffness mentioned in Table 3 for top two reinforcement layers of lower tier. Maximum wall displacement values are 30.6 mm, 28.9 mm and 29.2 mm for wall with lower tier reinforcement stiffness of 8.264×10^{8} Pa, 1×10^{10} Pa and 1×10^{12} kPa respectively. The variation in lateral stress values due to change in reinforcement stiffness is not as significant as wall deflection change. Figure 9 shows the axial strain distribution of reinforcement layer 6, 5, 3 and 1 of lower tier wall with reinforcement stiffness mentioned in Table 3. It is observed from the figure that maximum change in strain occurs at layer 6, 5. The maximum strain in geogrid layer 6 and 5 are 0.52% and 0.51% for reinforcement stiffness 8.264×10^{8} Pa . For the same layers maximum strains are 0.265% and 0.248% for reinforcement stiffness is 1×10^{10} Pa and 0.262% and 0.171% for reinforcement stiffness 1×10^{12} Pa. In other reinforcement layers strain distributions are almost same.

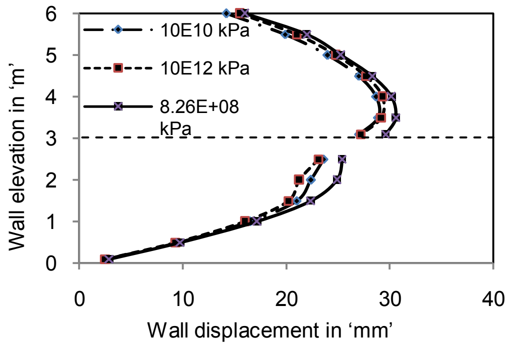

Fig. 7 lateral wall displacement of two tiered wall when stiffness of lower tier wall reinforcements are changed

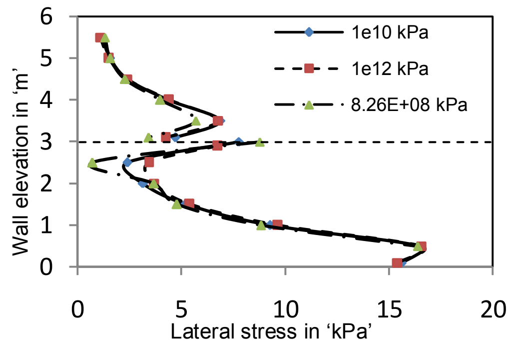

Fig. 8 lateral stress distribution of two tiered wall when stiffness of lower tier wall reinforcements are changed

4.2 Effect of change in length of lower tier reinforcements

Figure 10 and Figure 11 show change in horizontal displacement and lateral stress at due to change in reinforcement length of lower tier. The change in lateral stress and wall displacement of two tiered wall due to change in reinforcement length of lower tier wall reinforcement length is very less.

Figure 12 shows the axial strain distribution of reinforcement layer 6, 5, 3 and 1 of lower tier wall due to change in reinforcement length of lower tier wall. Except layer 6 variation strain distributions of all the geogride layers are almost negligible.

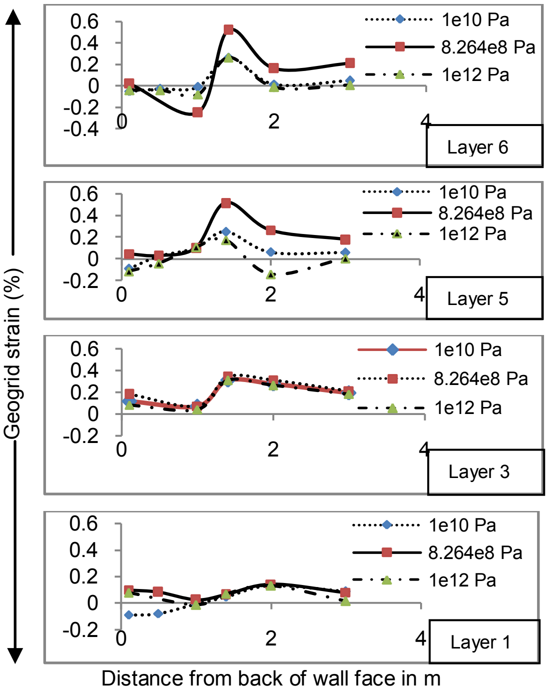

Fig.9 Axial strain distribution of lower tier reinforcement layers of two tiered wall

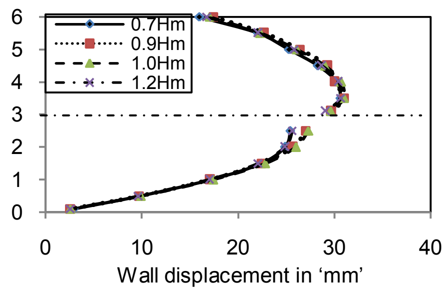

Fig. 10 Horizontal wall displacement when length of lower tier wall reinforcements is changed

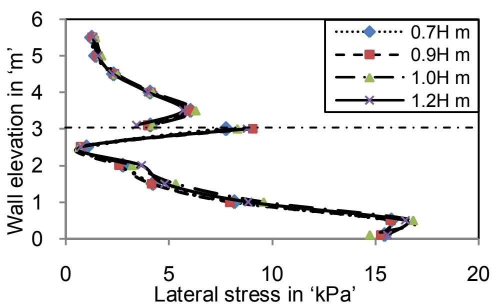

Fig. 11 Lateral stress distribution for wall with different length of reinforcement at lower tier

5.0 CONCLUSIONS

The behaviour of numerical models of two tiered walls is studied. Results shows tier wall is more sensitive to

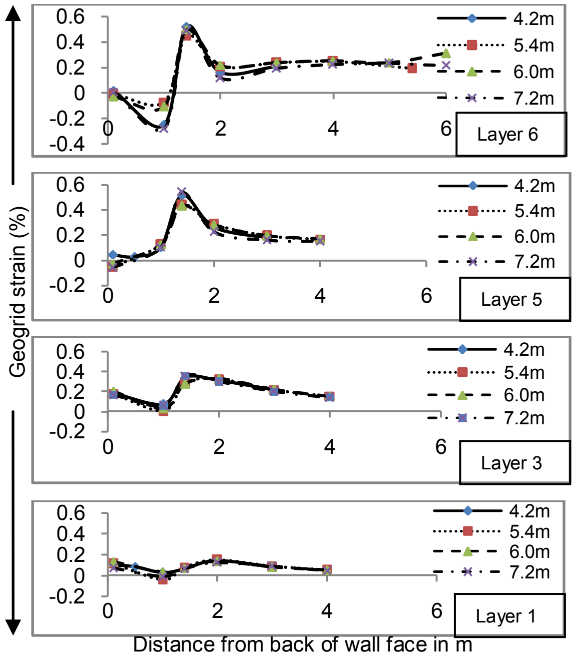

Fig. 12 axial strain distribution of lower tier reinforcement layers of two tiered wall

change in reinforcement stiffness compare to change in reinforcement length. With increase in reinforcement stiffness wall displacement, lateral stress on wall face and the strain in geogride layers decreases. Other important parameter such as soil and concrete facing properties also plays a vital role in designing of wall. By changing all this parameters better design of multi tiered wall can be achieved.

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