NUMERICAL INVESTIGATION OF A FULL SCALE REINFORCED SOIL WALL – A CASE STUDY

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ABSTRACT

Reinforced soil walls (RSW) are gaining popularity as sustainable and cost effective alternatives to the concrete and masonry earth retaining structures. Limit equilibrium methods are usually used in checking the stability of these walls for its simplicity but most of these methods are empirical in nature and do not consider proper soil reinforcement interaction. Numerical analysis may offer as a useful tool in the design of reinforced soil walls however, it is still not widespread because of lack of guidance and proper training. In this paper, a case study has been considered in which a full scale soil wall is constructed and they are loaded to stress levels well beyond the working condition. A numerical analysis has been carried out using a commercially available software PLAXIS 2D to study the performance of a full scale wall at different construction stages and at the end of the construction. The backfill soil was modeled by Mohr-Coulomb constitutive relationship and the reinforcement as a tension member. The maximum reinforcement tensions at each level and the displacement of the wall facing were computed and the results are compared with the measured values. The present analysis shows a good matching with the measured values and helps to infuse confidence to the practitioner.

INTRODUCTION

For the production of cost effective reinforced soil walls, the prediction of loads and their distribution in reinforcement are necessary. This affects the strength, spacing of the reinforcement and the reinforcement length required to resists the pullout. The reinforcement loads are developed due to the active earth pressure state in the soil mass which is calculate using the peak friction angle of the soil (AASHTO 2002). Based on the reinforcement spacing this active earth pressure is distributed to reinforcement layers. Empirical methods are available to calculate the reinforcement loads (Allen et al. 2003). The reinforced soil wall mentioned here is constructed in Royal Military College of Canada (RMC) retaining wall test facility. A total of 11 full-scale walls has been constructed which are of a 3.6m height and with the same backfill material. Out of these 11 walls, 2 are considered for this paper and analyzed using a commercially available software PLAXIS 2D. The difference between these two walls is the reinforcement type, the 1st wall is built with polypropylene geogrid and the 2nd wall is built with Modified geogrid where the reinforcement stiffness is lesser.

It has been reported from Bathurst et al. (2006, 2007) that the walls which are having stiff modular block facing shows fewer deformations and reinforcement load levels compare to the walls with flexibly wrapped face construction, reported that the facing column acted as a structural member to carry earth loads.

Hatami and Bathurst (2006) investigated the segmental retaining wall using FLAC numerical model. In this study, the influence of compaction and reinforcement type on the end of construction and the surcharge loading response is reported.

The geosynthetic reinforcement loads for walls with the cohesionless backfill soils were almost three times lower than values predicted using the AASHTO (2002) simplified method. In addition, the reinforcement loads are uniform with the depth predicted Bathurst et al. (2008).

FINITE ELEMENT MODEL (PLAXIS 2D)

Plaxis 2D is a special purpose two-dimensional finite element computer program used to perform deformation and stability analyses for various types of geotechnical applications. Real situations may be modelled by either a plane strain or an axisymmetric model. The wall considered here is modelled by assuming a plane strain condition.

The model is a 15 noded triangular element which provides an accurate calculation of stresses and the failure loads. The 15-node triangle provides a fourth order interpolation for displacements and the numerical integration involves Gauss points (stress points).. During the finite element calculation, displacements are calculated at the nodes and the stresses and strains are calculated at individual Gaussian integration points (stress points).

The wall is fixed horizontally along the right vertical border, fixed horizontally and vertically at the bottom of concrete foundation. Avery fine mesh was used for the wall model, which divides the whole system into triangular elements, while calculation.

CONFIGURATION OF THE WALL

The two walls considered in this paper are full-scale modular block walls constructed in the RMC test facility. The walls are of a 3.6m height and reinforced with polypropylene geogrid reinforcement. Wall 1 and wall 2 are nominally identical walls. Figure 1 shows the geometry of the wall having six layers of geogrid reinforcement with a spacing of (S_v) 0.6m and the batter angle (inclination of the wall with respect to vertical) is 8^0. The geogrid is having a length of 2.52m measured from the front of the facing column. The facing blocks are solid masonry blocks having a size of 300mmx200mmx150mm (LxBxH) and having a mass of 20kg.

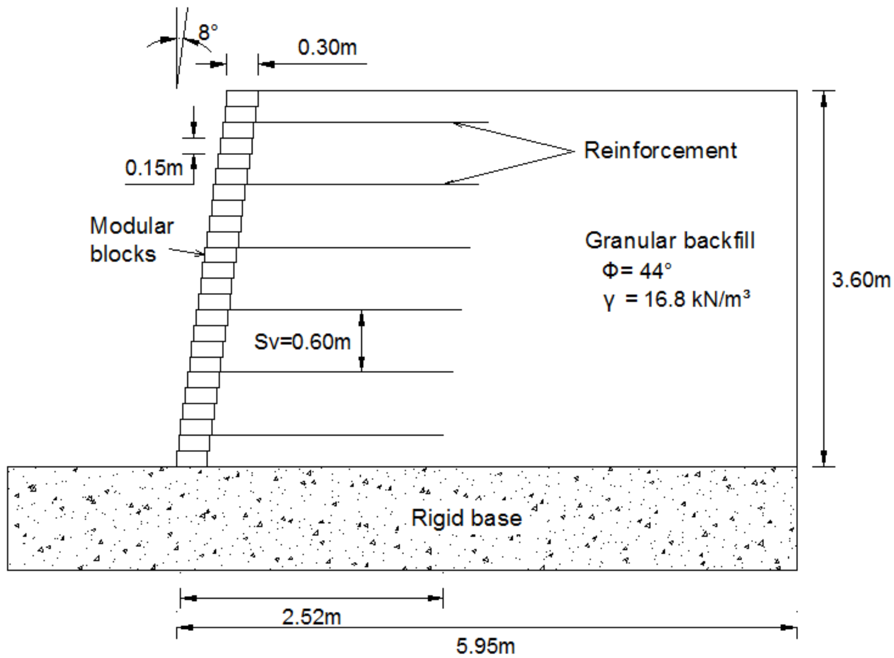

Figure 1. Geometry of the GRS wall

PROPERTIES OF SOIL AND THE REINFORCEMENT

The soil is modelled as a mohr-coulomb model which involves five input parameters i.e. E and μ for soil elasticity, φ and c for soil plasticity and ψ as an angle of dilatancy. Table 1 shows the different properties of the backfill soil (Bathurst et al. 2009).

The walls 1 and 2 are reinforced with polypropylene geogrids with global reinforcement stiffness of 477 and 238 kN/m^2 respectively (Bathurst et al. 2009). The reinforcement is modelled as an elastic material.

Table 1: Properties of the backfill soil

Property	Value
Peak plane-strain friction angle, φ (degrees)	44
Cohesion, c (kPa)	0.1
Dilatancy, ψ (degrees)	14
Bulk unit weight, γ (kN/m^3)	16.8
Youngs modulus, E (kPa)	20000
Poisons ratio, μ	0.3

RESULTS

Wall Facing Displacement:

The analysis has been carried out in PLAXIS 2D, based on that the wall facing displacements and the reinforcement loads are found out. The Figures 2(a) and 2(b) shows the wall facing displacement profile for wall 1 and for wall 2 at the end of construction and at a surcharge load of 50 kPa.

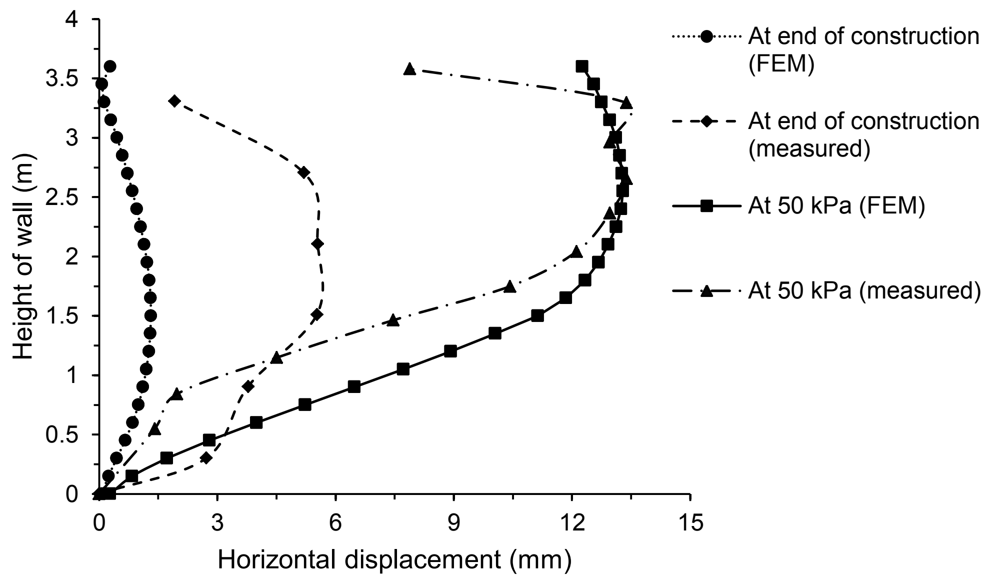

Figure 2(a). Wall facing displacement for wall 1

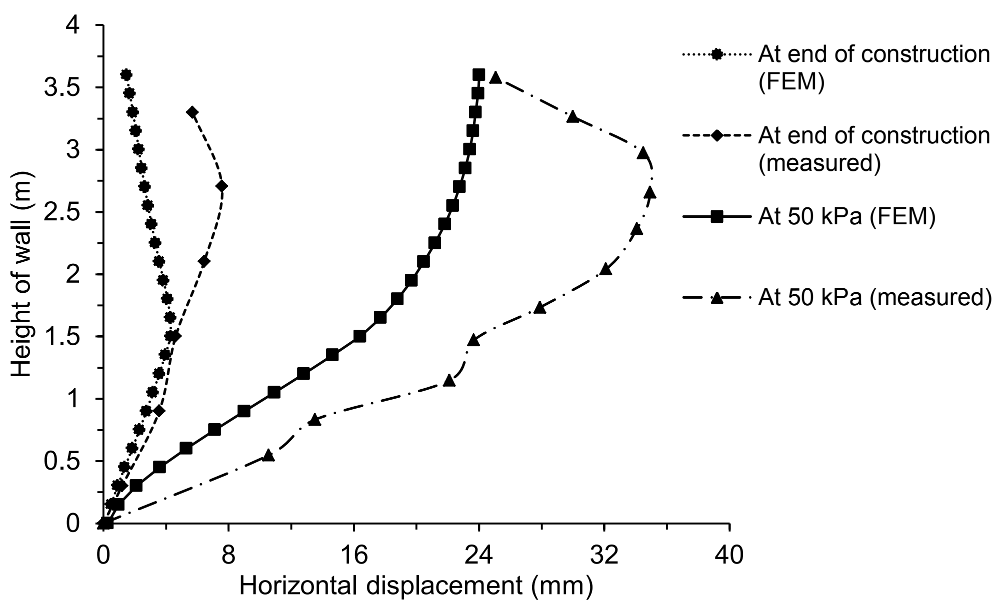

Figure 2(b). Wall facing displacement for wall 2

It is observed from the results that the maximum wall displacements are higher for measured values than the calculated values.

Reinforcement Loads:

The reinforcement loads predicted using AASHTO (2002) simplified method, calculated loads and the measured values has been compared. For Wall 1 the reinforcement loads at the end of construction and at a surcharge level of 50 kPa are shown in Figure 3(a) and 3(b) respectively and for wall 2 in Figure 4(a) and 4(b).

Wall 1

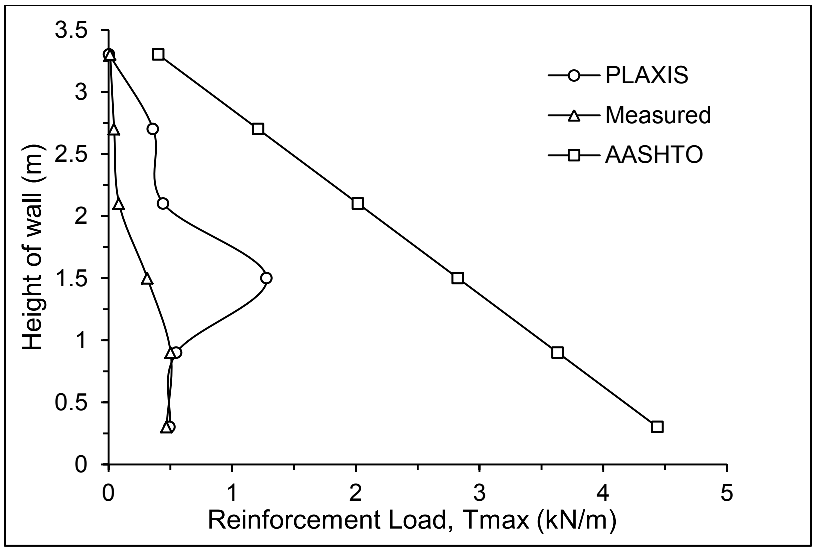

Figure 3(a). Reinforcement loads at the end of construction

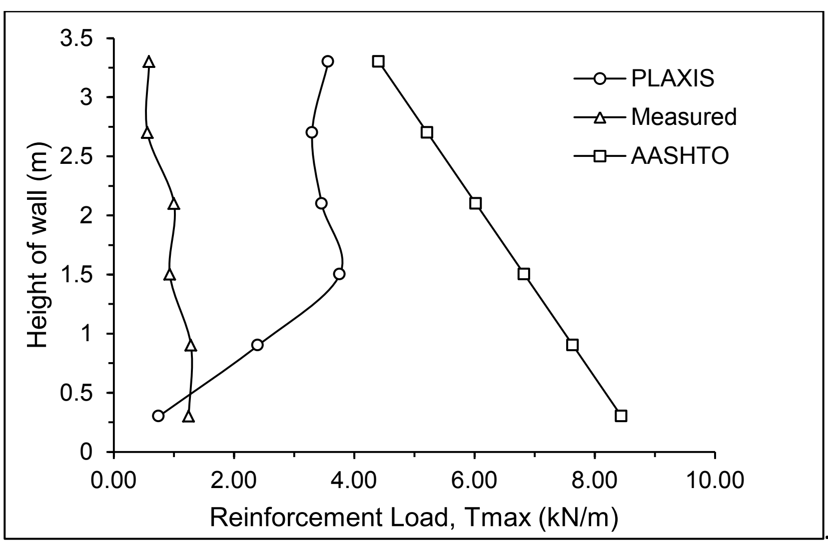

Figure 3(b). Reinforcement loads at 50kPa surcharge

Wall 2

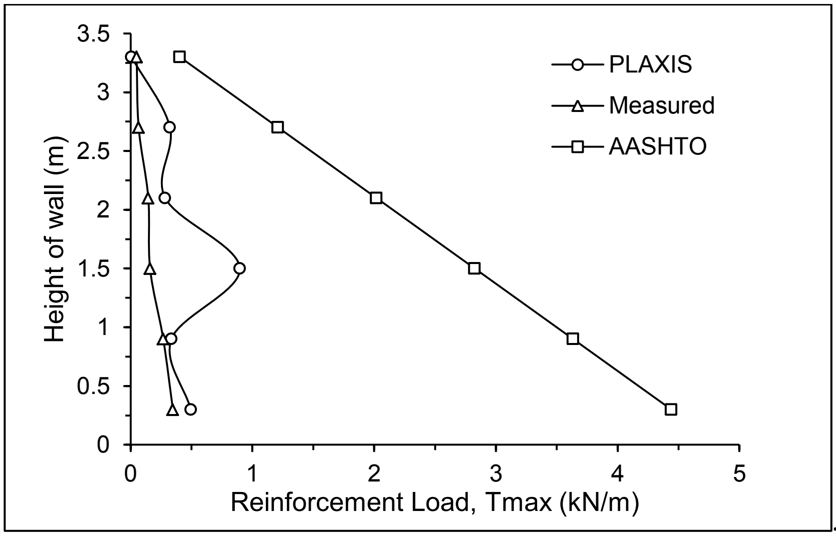

Figure 4(a). Reinforcement loads at the end of construction

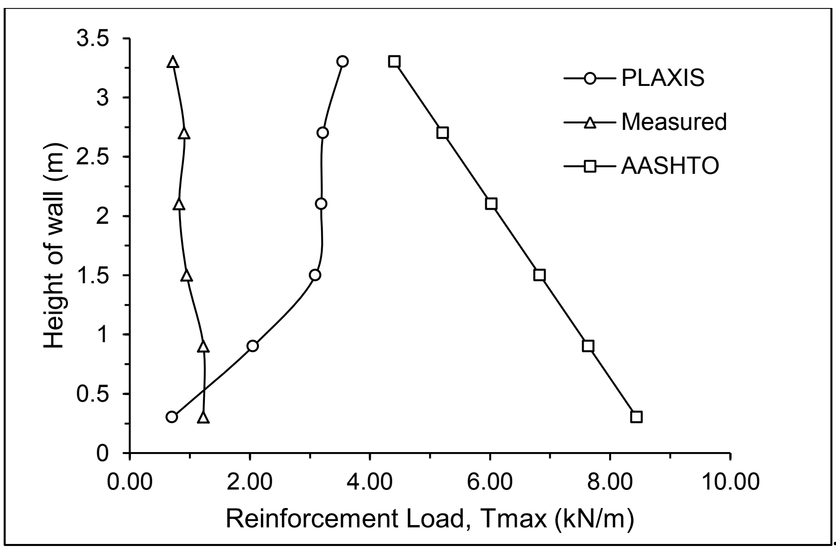

Figure 4(b). Reinforcement loads at 50kPa surcharge

CONCLUSIONS

The analysis is carried for the walls which are having different reinforcement stiffness and at same spacing. The wall is constructed on a rigid concrete foundation. The following conclusions are drawn from the study.

a) The reinforcement load obtained from the FEM analysis is in between the measured and the load obtained by AASHTO (2002) method.
b) The calculated reinforcement loads are matching with the measured loads at the end of the construction.
c) The measured facing wall displacements are higher at end of construction and at surcharge of 50 kPa compared to FEM values.

d) The facing wall displacements are almost twice for wall 2 than that of wall 1 which is having higher reinforcement stiffness.

REFERENCES

AASHTO (2002). *Standard Specifications for Highway Bridges*, 17th edn, American Association of State Highway and Transportation Officials (AASHTO), Washington, DC.

Allen, T. M., Bathurst, R. J., Holtz, R. D., Walters, D. L. & Lee, W. F. (2003). A new working stress method for prediction of reinforcement loads in geosynthetic walls. *Canadian Geotechnical Journal*, 40, No. 5, 976–994.

Bathurst, R. J., Vlachopoulos, N., Walters, D. L., Burgess, P. G. & Allen, T. M. (2006). The influence of facing rigidity on the performance of two geosynthetic reinforced soil retaining walls. *Canadian Geotechnical Journal*, 43, No. 12, 1225–1237.

Bathurst, R. J., Vlachopoulos, N., Walters, D. L., Burgess, P. G. & Allen, T. M. (2007). Reply to the discussions on 'The influence of facing rigidity on the performance of two geosynthetic reinforced soil retaining walls'. *Canadian Geotechnical Journal*, 44, No. 12, 1484–1490.

Bathurst, R. J., Miyata, Y., Nernheim, A. & Allen, T. M. (2008). Refinement of K-stiffness Method for geosynthetic reinforced soil walls. *Geosynthetics International*, 15, No. 4, 269–295.