Limit analysis of full scale MSE WALL- A comparative study

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ABSTRACT: In this paper a case study is considered to study the behavior of a 3.6m high MSE wall reinforced with geogrid reinforcement. Reinforcement spacing is 0.6m. A limit analysis has been carried out using LimitState:GEO (which used discontinuity layout optimization DLO) to study the performance of a full scale wall. The maximum reinforcement tension at each level was computed and the results are compared with the measured values. Computation of load coming on reinforcement under different surcharge load is done by analytical approach using MATLAB. In this paper analytical model (current AASHTO Simplified Method) are also prepared with different surcharge loading. The computed values of maximum load on reinforcement are finally compared with the measured values. The results show the LimitStateGEO analysis gives a better estimation of the maximum reinforcement tension compared to the measured values.

Keywords: Reinforced soil wall, LimitState:GEO, Analytical model.

1 Introduction

The present work deals with the Mechanically Stabilized Wall (MSW) reinforced with geogrid. For the internal stability of the reinforced soil wall which is built with frictional backfill, the design methods are based on the limit equilibrium method of analysis. This approach is based on the assumption that the loads in reinforcement are developed because of active earth pressure state in the reinforced soil which is calculated using the peak friction angle of soil. The active earth pressure is then distributed to the reinforcement based on their spacing.

Allen et al. (2003) reviewed reinforcement strain measurement techniques those are reported case studies. From the corrected reinforcement strains combined with the reinforcement stiffness values, the loads on reinforcement can be estimated.

Bathurst et al. (2008) studied case studies of reinforced soil wall. They observed that the geosynthetic reinforcement loads for walls with cohesionless backfill soils were three times lesser than the predicted values using AASHTO (2002) simplified method. Also, the reinforcement loads are more uniform with the depth than the predicted

2 Model dimension and material properties

The measurements are taken from full-scale modular block wall in the Royal Military College of Canada (RMCC) research program (Bathurst et al. 2009). The height of the wall is 3.6m, reinforcement length is 2.52m with a vertical spacing of $S_v = 0.6m$and the batter angle $\omega = 8°$(inclination of the wall with vertical).

Table 1 Properties of backfill soil

Property	**Value**
Model	Mohr Coulomb
Angle of internal friction, ϕ (degree)	44
Cohesion, c (kN/m2)	0
Unit weight, γ (kN/m3)	16.8
Drainage condition	Always drained

Properties of backfill soil is shown in Table 1, however dilation angle can't be mentioned in LimitState GEO. The modular facing units have a size of $LXHXW = 300X150X200mm$ and mass of 20kg.

3 Limitstate:GEO

This is a general purpose software program which utilizes Discontinuity Layout Optimization (DLO) to directly identify the critical collapse mechanism for a wide variety of geotechnical problems. This software can be used to model 2D models of any geometry as specified by the user. The solution is presented as an adequacy factor which can be applied on load and material strength. The solution is displayed as a failure mechanism which involves a number of blocks sliding relative to one another.

The prepared model in LimitState:Geo is shown in Fig.1.

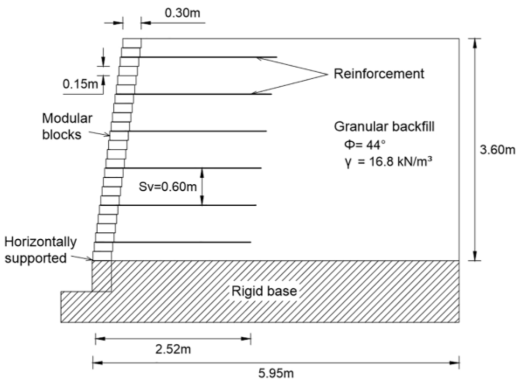

Fig.1: Geometry of the investigated model

3.1 Theory

In the Limitstate:GEO the geogrid is defined as engineered material, and soil as Mohr-Coulomb (strength is defined in terms of cohesion intercept and angle of shearing resistance) material. The adequacy factor obtained from the software is applied only for soil strength parameters.

The Engineered Material is used to represent the one dimensional object that has a pullout resistance T_1 per unit length, N_1 per unit length to lateral displacement and a plastic moment of M_{p1}.If there are m objects present per unit width then $T = mT_1$ is the pullout resistance per unit width, and $N = mN_1$ is the resistance per unit length per unit width to lateral displacement. Interaction between soil and geogrid in Limitstate:GEO is defined by equation (I) & (II) and is a linear function of vertical effective stress.

The pullout resistance per unit length per unit width

$$T = T_c + T_q \sigma_v' \qquad (I)$$

The resistance to lateral displacement per unit length per unit width

$$N = N_c + N_q \sigma_v' \qquad (II)$$

Where,

T_c= Pullout factor, the contribution of the material cohesion to the pullout resistance of the element.

T_q= Pullout factor, the contribution of the overburden to the pullout resistance of the element.

N_c= Lateral factor, the contribution of the material cohesion to the lateral displacement of the element.

N_q= Lateral factor, the contribution of the overburden to the lateral displacement of the element.

σ_v' = The vertical effective stress.

In the present case T_c ,N_c ,N_q are zero.

4 Analytical solution

AASHTO (2002) simplified method (tie-back wedge method) is used to evaluate the reinforcement tension analytically. The AASHTO calculation for maximum reinforcement load $T_{\max}$ is expressed as

$$T_{\max} = K(\gamma z + q)S_v$$

Where,

z = the depth of reinforcement layer below the crest of the wall and

K = the active earth pressure coefficient, calculated as

$$K = \frac{\cos^2(\phi + \omega)}{\cos^2 \omega[1 + (\sin\phi / \cos\omega)]^2}$$

5 Results

The tension in the reinforcement at different levels by AASHTO and Limitstate:GEO and measured experimentally by Bathurst et al. (2009) are shown in the Fig 2, 3, 4 & 5. The factor of safety at the end of construction and for different surcharge is presented in Table 2. Different failure surfaces at the end of construction, for 50kPa and 100kPa surcharge are shown in Fig 6.

The LimitState:GEO data shows that the reinforcement loads are varying with depth, and average loads are lower than the values computed using the AASHTO (2002) simplified method for geosynthetic reinforced soil walls. The difference in LimitState:GEO and predicted load values using the simplified method increases with depth of layer below the wall crest.

Table 2 Factor of safety

Surcharge	Factor of safety
At the end of construction	1.444
25kPa	1.153
50kPa	1.075
100kPa	1.033

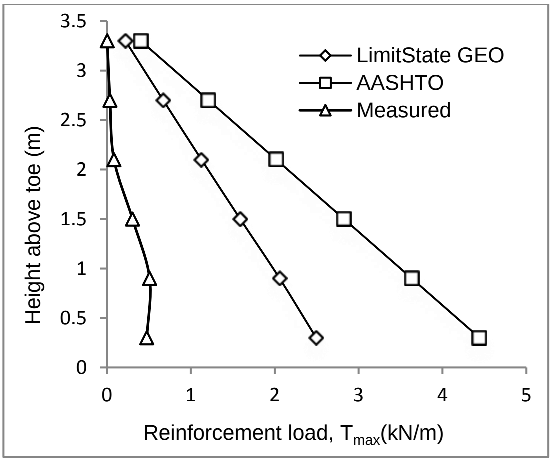

Fig.2 Comparison of LimitState GEO values with AASHTO and measured values (Bathurst et al. 2009) at the end of construction.

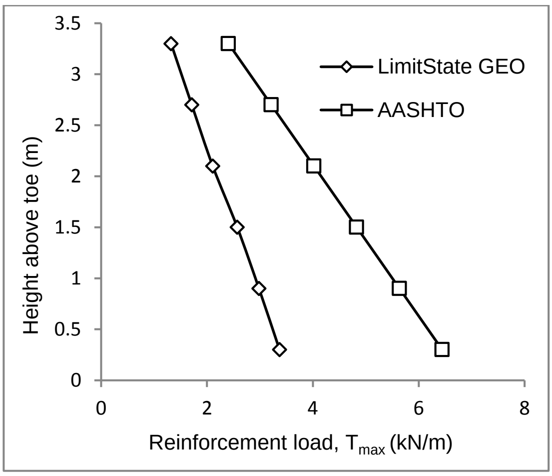

Fig.3 Comparison of LimitState GEO values with AASHTO values for 25kPa surcharge.

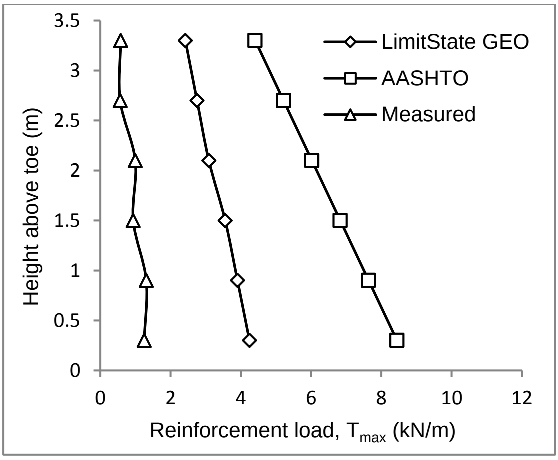

Fig.4 Comparison of LimitState GEO values with AASHTO and measured values (Bathurst et al. 2009) for 50kPa surcharge

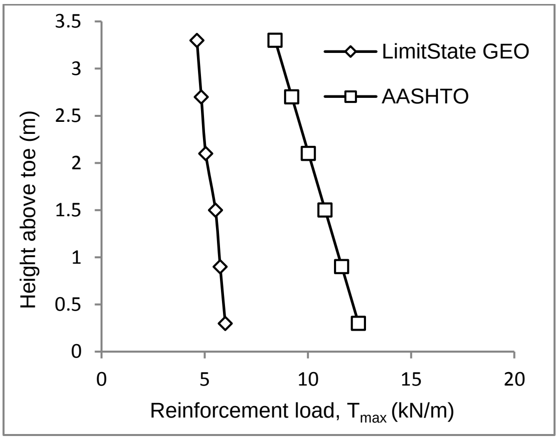

Fig.5 Comparison of LimitState GEO values with AASHTO values for 100kPa surcharge.

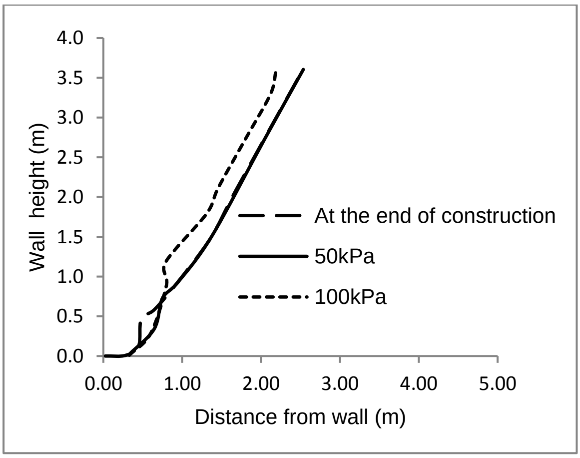

Fig.6 Failure surface

6 Conclusion

- The axial forces in reinforcement obtained by limitStateGEO lies between the forces calculated by AASHTO (2002) method and experimentally measured by R. J. Bathurst et al. (2009).

- Factor of safety against pullout failure by LimitStateGEO is much lesser than that is calculated analytically.

- Failure surface shown in output environment of LimitStateGEO is close to wall as shown in Fig 3(a) and 3(b).

- Variation of axial forces in reinforcement with height of wall is almost linear with higher value near toe of wall and lower value near crest of wall.

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