Numerical Analysis of 44 m High MSE Wall at Kanakadurga Temple, Vijayawada Using PLAXIS 3D

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ABSTRACT: MSE walls have been widely used for several purposes in place of traditional constructions of major retaining walls keeping in view the technical and economic versatility of the technology. A 44 m height MSE wall was constructed for widening of the ghat road of kanakadurga temple in Vijayawada. This wall suffered distress in terms of large settlement and lateral deformations. This wall is analysed for its settled deformations by numerical analysis (PLAXIS 3D) and it is found that the predicted wall deformations are close to the actual measurements. Hence, numerical simulations of real time MSE structures helps to predict their behavior prior to their construction and suitable amendments can be adopted in case of need.

KEYWORDS: Mechanically stabilized earth wall, wall deformations, PLAXIS 3D software

1 INTRODUCTION

Reinforced earth is also referred as mechanically stabilized earth, which has emerged as a versatile civil engineering material for building huge infrastructure in the form of retaining walls, widening the highways with steep slopes, underground grain storage systems, bridge abutments, earth dams and railway embankments over soft grounds and to support foundations with improved bearing capacity (Jones, 1985). Among these applications, MSE walls have been widely used in place of traditional retaining walls. The MSE wall construction is resulted by the use of standard backfill, reinforcement and facing. The free draining frictional soils with fine content less than 15% are suggested to be used for MSE wall construction in order to ensure no development of pore pressures and to ensure the mobilization of the interfacial frictional resistance under all condition (Vidal, 1969). Sometimes the cohesive backfills, referred as marginal soils have been used wherever standard backfill soils are not available and this deviation without adequate internal drainage arrangements lead to several failures of MSE walls across the world (Glendinning et al., 2005)

In the present study, the results obtained from numerical analysis (using PLAXIS 3D) of 44 m high MSE wall constructed in four tiers for widening of ghat road of kanakadurga temple in Vijayawada; which suffered distress after construction in the form of settlements and lateral bulging.

2 METHODOLOGY

Fig.1 Four tier MSE wall of 44 m height

Figure1 shows the constructed 44 m high MSE wall in which the lateral bulging and cracking also could be seen. This wall was constructed using locally available soil having gravel = 39 %, sand = 35% and fines = 36%. As finer fraction is more than 15%, river sand was mixed in the ratio of 50:50 to reduce the fines to less than 20%. For reinforcement, high strength polymeric composite was used which has excellent strength and drainage properties. For facing, Rockwood type modular block system was used and each unit weighs around 30kg.

3 NUMERICAL MODELLING

Numerical modeling using PLAXIS 3D software was carried out for the above said MSE wall. Four different constitutive models were used in this case that is, Linear elastic model for facing panels; Mohr coulomb model and Hardening soil model for soil; and Hardening soil model with small strain (HSsmall model) for dynamic analysis. The loading corresponding to IRC class A is applied to the structure to simulate the field condition. Horizontal and vertical boundary conditions were applied for the safe and accurate designing. Interfaces are assigned to the facing panels as well as geogrid layers. Secant stiffness in standard drained test (E^{ref}_{50}) value is calculated from triaxial test data. Similarly, Tangential stiffness for primary oedometer loading (E^{ref}_{oed}) and Elastic unloading, reloading (E^{ref}_{ur}) value is obtained from oedometer test for finite element modeling.

Table 1 Input Parameter for Mohr-Coulomb Model

SOIL/ ELEMENTS	BACKFILL	FACING PANEL	GEOGRID
Material Model	Mohr Coulomb	Linear Elastic	Elastic
ϒunsat (kN/m^3)	18	25	
ϒsat (kN/ m^3)	20	25	
E(kN/m^2)	11520	25000	
Poisson's ratio	0.35	0.2	
Cohesion (kN/m^2)	1		
Angle of internal friction	32		
Axial Stiffness (kN/m)			150

Table 2 Input Parameters for Hardening Soil Model with small stiffness for dynamic analysis

SOIL/ ELEMENTS	BACKFILL	FACING PANEL	GEOGRID
Material Model	HS small	Linear Elastic	Elastic
ϒunsat(kN/m^3)	18	25	
ϒsat(kN/m^3)	20	25	
$E^{ref}50$ (KN/m^2)	65726		
$E^{ref}oed$ (kN/m2)	49418		
$E^{ref}ur$ (kN/m^2)	197178		
m	0.5		
Gref (kN/m^2)	83.17×10^{-3}		
Strain	1×10^{-3}		
E(kN/m^2)		30000	
Poisson's Ratio		0.2	
Cohesion (kN/m2)	1		
Angle of internal friction	32		
Axial Stiffness (kN/m)			150

To carry out the numerical analysis using PLAXIS 3D, finite element mesh was created and the material properties and boundary conditions were specified. This is done by preprocessing of input data. To set up a three dimensional finite element model point, line, surface, geogrid and other components were created in 3D plane. Here 12456 node elements were generated after mesh.

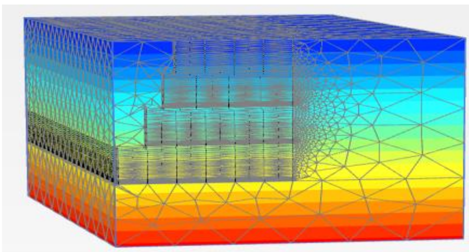

Fig 2 Mesh generation of wall

Initial stresses were generated using K_0 procedure. Calculation process was divided into total 11 phases including safety and dynamic analysis in calculation.

4 RESULTS

For different constitutive models, results were varying due to change in parameters. Wall deformations, stress, strain, factor of safety values were calculated. The failure pattern is shown in figures 3.

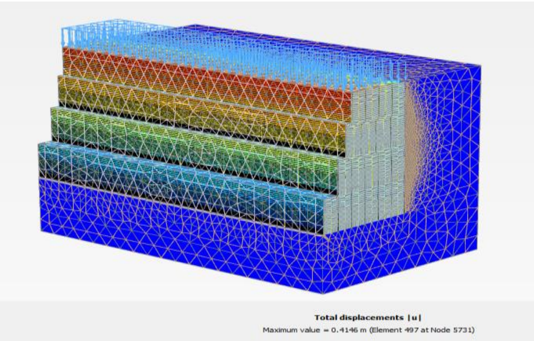

Fig 3 Failure pattern of wall for Hardening soil model

In PLAXIS 3D, a dynamic impulse is specified by means of an initial value and a multiplier. Dynamic multipliers can be assigned to the dynamic component of a load or to a prescribed displacement and in this case, prescribed displacement is used. Acceleration-time data is used for dynamic action. Damping ratio of 5% is used for analysis. From figure 4, decay of vibration due to dynamic loading can be observed.

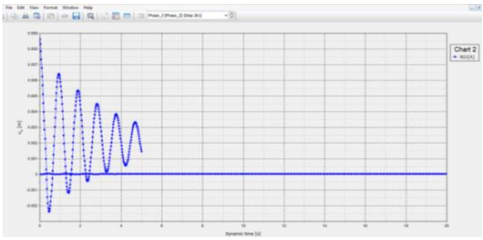

Fig 4 Decay of amplitude for HSsmall model

The factors of safety and wall deformations for different models are presented in Table 3.

Table 3 Results of analysis

MATERIAL MODEL	FACTOR OF SAFETY	DEFORMATION (mm)
Mohr-Coulomb	1.29	828
Hardening soil	1.32	523
Hardening soil model with small strain	1.38	463

Distress of the wall was caused due to excessive nailing and differential settlement. So, analysis was carried out for both the cases i.e without nails and with nails installment. It is found that, deformation and bulging is higher with the application of nails. Keeping in view the large wall deformations with the adopted design parameters and materials, it is felt to study the influence of 5% cement content if added to the backfill soil on the wall deformations. Though sand was mixed with the native soil, pockets of virgin soil could be left without mixing with sand due to its high plasticity. To this effect, a soil sample was collected and amended by mixing it with 50% sand as was done in actual wall construction. To this soil mix, 5% cement content was added and triaxial testing was done after 7 days curing period. The required Young's modulus and shear strength parameters were obtained from this testing. Incidentally, the material has become non-plastic. A parametric study was also carried out with variation in angle of internal friction.

Table 4 Parametric study for MSE wall

MATERIAL MODEL	FACTOR OF SAFETY	DEFORMATION (mm)
Hardening soil model with small strain (HSsmall model) 34^0	1.42	401
HSsmall with $\varphi= 36^0$	1.51	347
HSsmall with $\varphi=38^0$	1.60	272
HSsmall with cement modification ($\varphi=42^0$)	1.68	112

The reported value of FS and wall deformation were 1.47 and 500 mm respectively and with the reanalysis, the obtained values were 1.38 and 463 mm respectively.

With 5% cement modification, factor of safety is increasing with reduced wall deformations. This could be attributed to improved stiffness of the material with modified plasticity. The factor of safety and wall deformations obtained are also presented in table 4.

5 CONCLUSIONS

Based on the numerical analysis of 44 m height MSE wall, the following conclusions are drawn.

1. The numerical analysis using PLAXIS 3D software is found to be a promising approach to predict the behavior of MSE walls. As in this case, deformation and factor of safety values are close approximation to the predicted values.

2. Among the models available within PLAXIS 3D, Mohr-Coulomb model is more conservative followed by Hardening soil model and Hardening soil model with small strain. Deformation values were quite higher for Mohr-Coulomb model, as this is the first initiation to any geotechnical problem. For static analysis, Hardening soil model will give good results; whereas, for dynamic analysis hardening soil model with small strain can predict the failure plane, deformation values in better way to simulate actual field conditions.

3. Soil - cement can be a potential alternative to inferior soil backfill in order to overcome the ill-effects of excess fines and plasticity. Improved stability with reduced wall deformation was observed with the addition of 5% cement to the soil mass.

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