STUDY OF SOIL NAILING FOR HIGHWAY RETAINING WALL IN GOA

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ABSTRACT: Over the past few years there has been a rising demand for stabilizing cut slopes in railway and highway construction in areas with mountainous topography. The ground slopes in these regions may not allow construction as the slopes become unstable to withstand the stresses caused by dwelling units. There is an increasing demand for stabilizing vertical cuts supporting roadways against dynamic loads. The stabilizing of vertical cuts using modern technologies will provide a new pathway for the construction industry to build roads and structures on slopes. Soil nailing is widely used method for stabilizing cut slopes for highway construction. Soil nailing is an effective and economical method of constructing retaining wall for excavation support, support of bridge abutments and high ways. The present study includes design of soil nail wall for the highway construction for Borim site in Goa. Soil nail wall is designed for a height of 5m, 6m and 7m for static and dynamic case and factor of safety against external, internal and facing failure modes are estimated. It is concluded that factor of safety against overall stability decreased with increase in the height of the wall. Factor of safety for global and sliding stability reduces as the earthquake acceleration coefficient increases.

KEYWORDS: soil nailing, static, seismic, factor of safety

1 INTRODUCTION

Soil nailing is the technique of stabilizing ground with passive inclusions or reinforcements, commonly known as soil nails. It is an effective and economical method of constructing retaining wall for excavation support, support of hill cuts, bridge abutments and high ways. This process is effective in cohesive soil, broken rock, shale or fixed face conditions. The present study deals with design of soil nailing for highway retaining wall in Goa.Soil nailing is designed for static and dynamic cases for a height of 7m and factor of safety against external failure modes, internal failure modes and facing failure modes have been evaluated. Soil nailing is designed for varying horizontal acceleration coefficient (k_h) values.

2 LITERATURE REVIEW

Literature study was done to accumulate various data in order to assume certain parameters in the design of soil nail wall.

Jaya V et al. (2013) performed analysis on behavior of soil nail wall for dynamic conditions. A soil nail wall was designed for a height of 1m based on the guidelines of FHWA (2003). Laboratory plate load tests and detailed Finite element analysis were performed to investigate thebehavior and wall deformations of soil nail wall. The laboratory study conducted on soil nail wall showed that the settlement of the soil nail wall decreased with the increase in relative density of sand. Chin et al. (2004) studied relevant design and construction issues concerning soil nailing with particular emphasis on interrelationship between design and construction to ensure safety of slopes. It was concluded that soil nailing is an effective slope stabilization method especially for remedial works involving failed slopes. However a properly designed and constructed soil nailing works are essential for optimum performance. Ghazavi et al. (2004) performed pseudo-dynamic analysis for analysis of soil nail walls subjected to seismic loading. Parametric study on influence of loading frequency showed that with increasing frequency tension forces in soil nails decreases.

In present study soil nailing is designed as per FHWA (2003) and Factor of safety in static and seismic condition is evaluated.

3 DESIGN CONSIDERATIONS

The wall is designed for height of 5m, 6m and 7m and Factor of safety against global, sliding, nail pullout failure, nail tensile failure, facing flexural failure and facing punching shear failure is calculated. Factor of safety is also calculated for different horizontal pseudo static coefficient (K_h) values.

Figure 1 shows various parameters of a soil nail wall

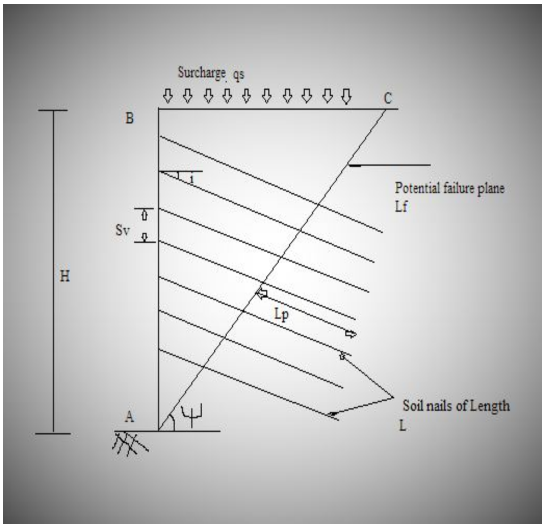

Figure 1. Typical soil nail wall design parameters

3.1 Design parameters

Height of the wall: 7m, Face batter angle $\alpha=0^0$, Back slope angle $\beta=0^o$, Soil nail inclination i $=25^0$, Soil nail spacing $S_h=S_v=0.5$m; Unit weight of soil $\gamma=14KN/m^3$, Cohesion C=20KPa, Friction angle $\phi=28^0$; Surcharge load Q=50KPa, Ultimate bond strength qu=50KPa; Length of failure plane $L_F=8.9$m, Failure plane angle $\psi=59^0$

4 STATIC CONDITION

For design of soil nail wall under static condition following factors were calculated as per FHWA (2003)

Lateral earth pressure coefficient Ka=0.36; Maximum axial tensile force Tmax=13KN/m; Diameter of soil nail=20mm; Length of soil nail=4.9m

Based on the given parameters the factor of safety against various modes of failure is calculated and shown in Table 1

Table 1 Factor of safety for various failure modes

Height (m)	FS_G	FS_{SL}	FS_P	FS_T	FS_{FF}	FS_{FP}
7	1.63	3.9	1.02	9.99	11	9.5

In Table 1, FS_G = Global stability failure; FS_{SL} = Sliding stability failure; FS_P = Nail pullout failure; FS_T = Nail tensile failure; FS_{FF} = Facing flexural failure; FS_{FP} = Facing punching shear failure.

Factor of safety against Nail pullout failure is less because driven nails are used. Factor of safety can be increased by using grouted nails at a spacing of 1m

Fig. 2 shows Factor of safety against global and stability for heights 5m, 6m and 7m

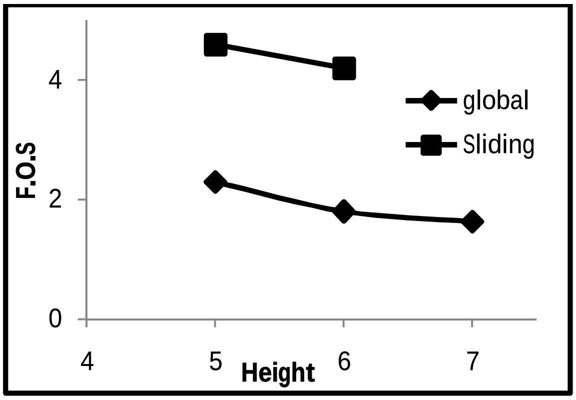

Figure 2: Height v/s F.O.S for global and sliding stability

Figure 3 shows Factor of safety against nail pullout and nail tensile failure for heights 5m, 6m and 7m

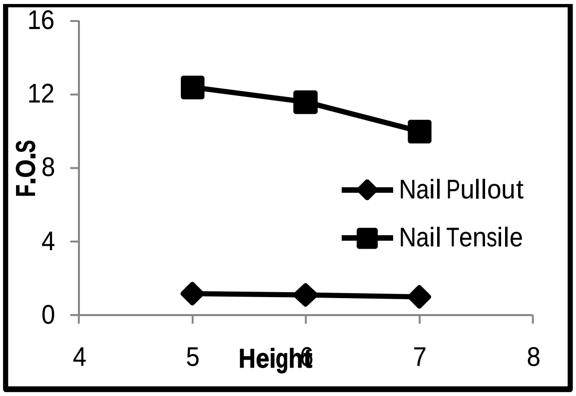

Figure 3: Height v/s F.O.S for nail pullout and nail tensile failure

Figure 4 shows Factor of safety against facing flexural failure and facing punching shear failure for heights 5m, 6m and 7m

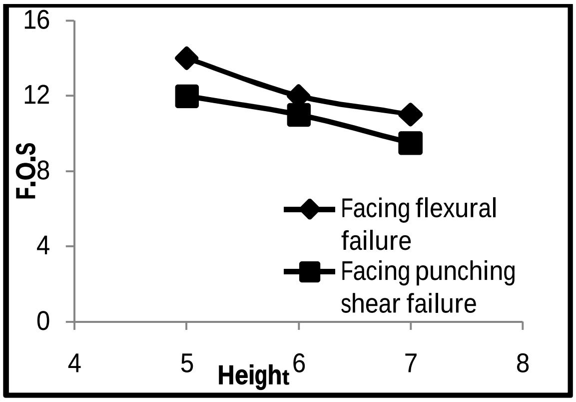

Figure 4: Height v/s F.O.S for facing flexural and facing punching shear failure

5 SEISMIC CONDITION

For design of soil nail wall under seismic condition horizontal earthquake coefficient (k_h) is considered for Zone II, III, IV and V and Factor of safety against Global and sliding stability is calculated.

Fig. 5 shows forces acting on soil nail wall under dynamic condition

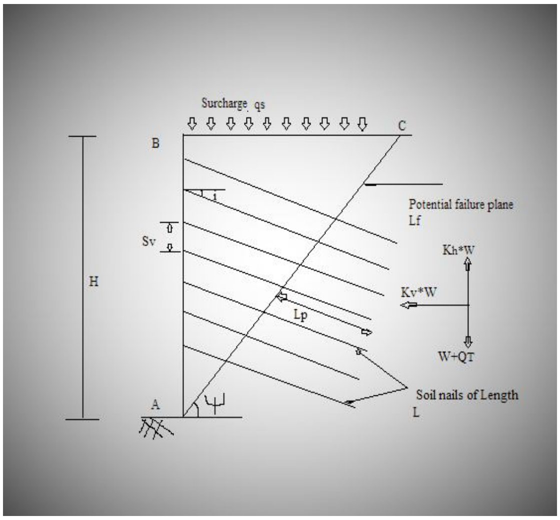

Figure 5. Forces acting on soil nail wall under dynamic condition

In Figure 5, W = weight of failure wedge; $F_v = k_h$ xW; Q_T = surcharge load acting on length AD; Lateral earth pressure coefficient for seismic condition K_{AE} =0.42

For Zone II, k_h = 0.1 and k_v = 0.05;

For Zone III, k_h = 0.16 and k_v = 0.08;

For Zone IV, k_h = 0.24 and k_v = 0.12;

For Zone V, k_h = 0.36 and k_v = 0.18;

Based on the above parameters Factor of safety is calculated for Global and Sliding stability.

Factor of safety against global and sliding stability is shown in Table 2 for k_h values for Zone II to Zone V.

Table 2 Factor of safety against Global and Sliding stability

k_h	Factor of safety against Global stability	Factor of safety against Sliding stability
0.1	1.76	1.42
0.16	1.74	1.37
0.24	1.70	1.29
0.36	1.64	1.20

Fig. 6 shows k_h v/s Factor of safety for global and sliding stability. In Fig. 6 it can be seen that as the value of horizontal acceleration coefficient k_h increases the Factor of safety against Global and Sliding stability decreases. Factor of safety is given by ratio of resisting force to driving force. As k_h value increases the driving force also increases and hence decreases the Factor of safety.

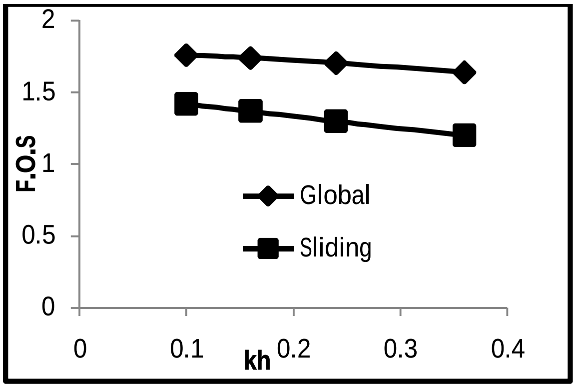

Figure 6. k_h v/s F.O.S against global and sliding stability

6 CONCLUSIONS

From the design of soil nail wall it can be concluded that Factor of safety for global stability decreases with increase in the height of soil nail wall. As the height of the soil nail wall increases the Factor of safety against soil nail pullout failure and nail tensile failure decreases. Design of the wall facing showed that the Factor of safety for facing flexural failure and facing punching shear failure reduced with increasing height of the wall. Soil nail is designed for different earthquake zones and showed high Factor of safety for Zone II. It has also been concluded that as the horizontal acceleration coefficient (k_h) values increases, Factor of safety decreases. As Goa falls in Zone III, the design is safe for seismic condition. Provision of facing results in significant improvement of the stability and performance of soil nail wall. Pseudo-static analyses are found to provide conservative estimate of factor of safety values. Soil nail construction has been shown to be a simple technology and does not need complex machines. The design is done as per FHWA (2003) and it can be concluded that Conventional design procedure using FHWA (2003) provides a safe but conservative design.

7 REFERENCES

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