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Effect of wall batter angle on soil nail walls performance

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ABSTRACT: Soil nailing is a very versatile excavation retaining system for deep excavations in urban areas surrounded by major structures and infrastructures. Using Battered face for soil nail wall system can increase global stability of the system and decrease lateral deformations of the walls. But, high cost of lands in cities caused to more applications of vertical walls. In this study we have surveyed the effects of variation of batter angle of the soil nail wall face on stability and lateral deformation of the wall. Some Finite Element and Limit Equilibrium models were developed to analyze performance of the walls. The analyses results present the variation's rate of the wall stability and lateral deformation of the wall by the wall batter angle increment. These results can be used to investigate the benefit to cost of using wall batter angle in soil nail walls projects.

1 INTRODUCTION

Soil nail walls are extensively employed as temporary retaining walls in recent years, due to the demand for construction of high-rise structures and the need for obtaining enough parking spaces, to allow greater number of basements below these structures. Soil nailing is an in-situ earth reinforcement method which reinforces the soil or rock mass internally and enables an earth mass to support itself through the introduction of driven or grouted steel bars into the mass during and after excavation process.

Soil nailing is a very versatile excavation retaining system for deep excavations in urban areas surrounded by major structures and infrastructures, provided that limiting lateral displacements are not exceeded. For adjacency of urban excavation projects to facilities, building and roads, the deformation of walls is one of the most important criteria of acceptable performance of the support system in these projects. Therefore, some monitoring systems usually are applied to record deformations of the excavations walls.

In order to analyze the effect of wall batter angle on soil nail walls performance, the batter angle of the soil nailed wall were increased gradually and the effect of these changes on final factor of safety on global stability of the wall.

The wall is modeled using modeling approach verified with Polyclinic wall, with 16.76 m of height and 9 rows of nails with 9 m of length and 1.8 m of horizontal and vertical spacing.

The batter angle of wall considered 0, 5, 10, 15, 20 and 25 degree from vertical.

Plaxis 2D is a finite element software that can be used to create numerical models for simulating soil nail walls (Plaxis, 2002). Simulation of the soil nail wall construction process was carried out with the sequence of construction stages in mind.

To verify the results of the model, Polyclinic wall in Seattle was modeled and horizontal deformation of the model compared with reported field data by Thompson and Miller 1990. The results verified the applied modeling approach.

2 VERIFICATION OF MODELING APPROACH

2.1 *Project specifications*

Polyclinic wall in Seattle has been simulated, using Plaxis 2D, to verify the used modeling approaches. This case study illustrates a 16.8 m soil nail wall designed and constructed in Seattle area (Thompson and Miller, 1990). The wall was built to support a temporary shoring system for a building excavation. The spacing of the nails in the horizontal and vertical directions was 1.8 m as shown in Figure 1.

The nail bars consisted with a maximum length of 10.7 m. The holes were drilled with a 20 cm diameter and inclination of 15 degrees. The soil strength parameters φ and C were 40° and 9.6 kPa, respectively and the soil unit weight was considered 2.16 g/cm^3.

The lateral wall deformations were measured using one vertical inclinometer casing placed at a distance of 91 cm behind the wall face. Figure 2 presents recorded inclinometer deformations during excavation process.

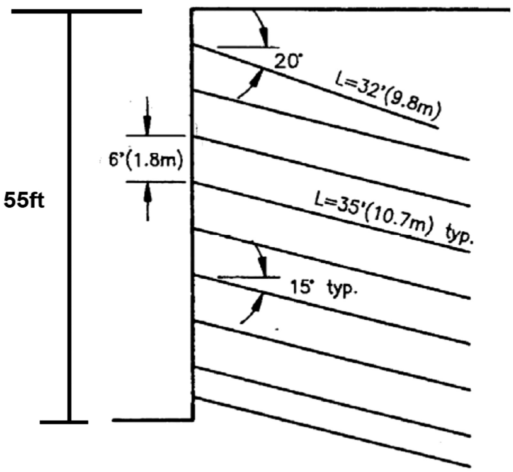

Figure 1. Geometry of the Polyclinic wall in Seattle.

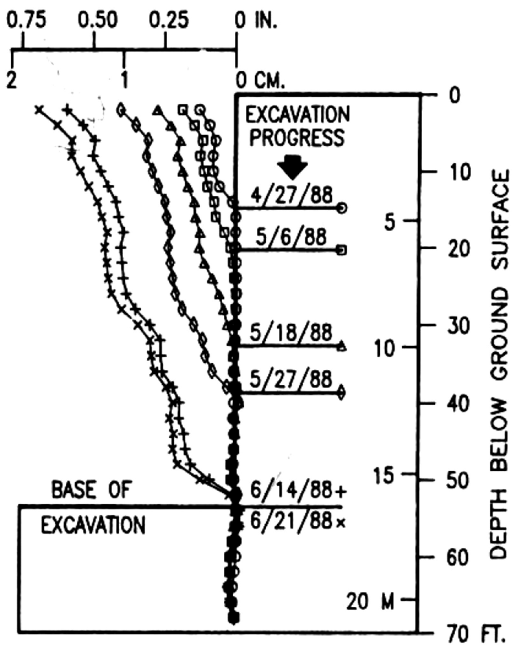

Figure 2. Measured wall deflection.

Inclinometer data showed that total lateral displacements at the top of the wall at the end of construction was 18 mm.

3 FINITE ELEMENT MODELING

The modeling approach was considered as it is recommended by Vikas et al., 2009. The 15 node triangular element type was selected for the mesh used in the FE model. The soil was modeled using the elastic-plastic Mohr-Coulomb model. Five soil layers were

Table 1. Geotechnical parameters-NE & SE ramps.

Parameter	layer 1	layer 2	layer 3	layer 4	layer 5
Thickness (m)	4.0	3.6	3.8	3.6	–
Cohesion (kPa)	9.6	9.6	9.6	9.6	9.6
Internal friction angle	40	40	40	40	40
Density (gr/cm^3)	21.6	21.6	21.6	21.6	21.6
E (kg/cm^2)	407	957	1435	3588	9234
Poisson ratio	0.34	0.32	0.29	0.234	0.20

Table 2. Walls performance.

ID	EA kN/m	EI kN/m^2/m	Poisson ratio	Weight kg/m/m
Soil nail	7.37E+4	344	0.20	143
Shotcrete	2.73E+6	39651	0.18	239

used to describe the soil condition. Soils 1–5, have the same parameters except the soil modulus (E) which was increased with depth and Poisson's ratio υ. Table 1 summarizes the parameters used in the Finite Element model of Seattle wall.

Plate elements were used to model the nails and the facing. However, no interface element was introduced between the soil and Plate elements.

The soil nails were simulated with equivalent Plates using elastic Plate elements. The shotcrete wall was modeled using elastic Plate elements and fixed connection was used between the wall and the nails. Plate elements parameters are summarized in Table 2.

A total of 9 phases were used in this model; one phase to apply initial conditions, and 8 phases to simulate the construction sequences of the soil nail wall. This model resulted horizontal displacements that matched closely with the measured data presented by Thomson and Miller (1990). The predicted lateral displacement by FE model is 19.7 mm (0.77 in). Comparing the measured data with the resulted data shows that the numerical predicted displacement is acceptable and it is just slightly larger than the inclinometer data.

4 INTRODUCTION

Using verified modeling approach, the wall is modeled with height of 16.76 and 9 rows of nail bars with length of 9.8 m and horizontal and vertical spacing of 1.8 m. Models are developed with the batter angle of wall considered 0, 5, 10, 15, 20 and 25 degree. Effects of these changes of global stability and maximum horizontal deformation of the wall and settlements of the nailed soil are surveyed. Table 3 presents the results of analyses.

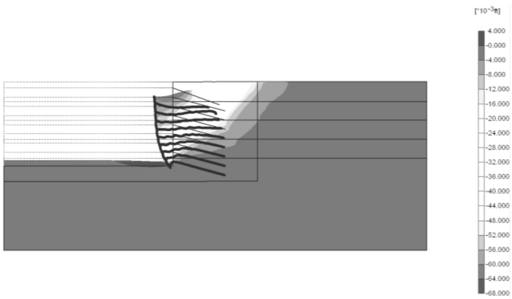

Figure 3. Horizontal displacement of the Polyclinic wall model.

Table 3. Results of varying of the batter angle.

Model	Batter angle	FS	Settlement mm	Lateral deformation mm
1	0	1.48	17.6	23.2
2	5	1.69	8.8	11.5
3	10	1.82	5.0	7.4
4	15	1.86	2.5	5.6
5	20	1.91	1.2	4.5
6	25	1.91	0.4	3.4

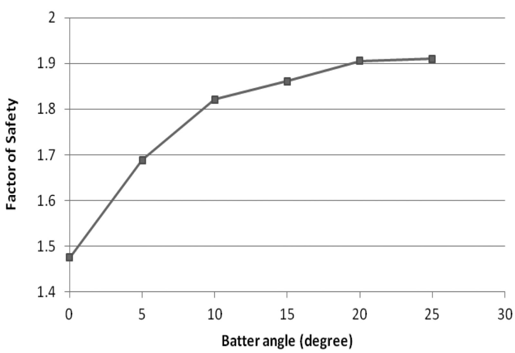

Figure 4. Effect of batter angle variations on factor of safety.

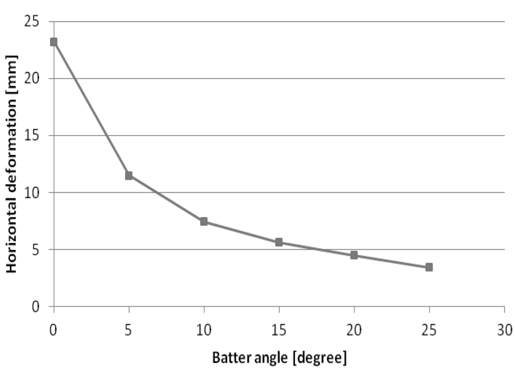

Figure 5. Effect of batter angle variations on horizontal deformations.

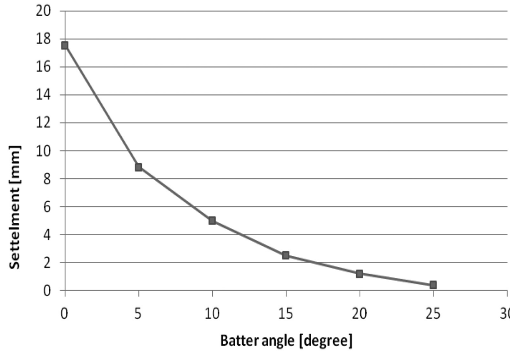

Figure 6. Effect of batter angle variations on settlements.

Table 4. Models specifications.

Model	Batter angle	Nails length m	Nail density m/m^2
1	0	9.8	2.93
b2	5	9.0	2.69
b3	10	8.4	2.51
b4	15	7.7	2.31
b5	20	7.3	2.19
b6	25	6.7	2.01

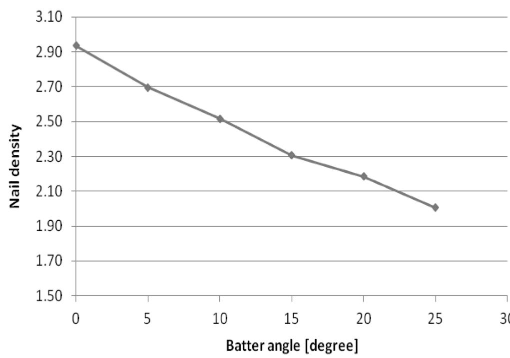

Figure 7. Effect of batter angle variations on Nail density.

As the graph shown, the factor of safety for global stability of the nailed wall, increases with the wall batter angle. In this part, we decrease nail length of battered wall to obtain same factor of safety as the vertical wall.

Some limit equilibrium models are developed to estimate the factor of safety for global stability of walls. The appropriate length of nails for each battered walls, are estimated by try and error. Table 4 presented results of the analyses. The nail density is the ratio of total length of nails, on the wall surface area.

As the graph shown, reduction of Nail density has nearly linier relation with increment of wall batter angle.

This study shown that, with increments of batter angle we have a safer nailed wall with less deformation of adjacent ground. But it causes to lose some underground space and it may be very effective to design's goals. For example in this case, for the wall with batter angle of 10 degree, we lost about 2.9 m^2 per unit width of the wall and we can decrease 1.4 m of length of the nails of the wall, in compare with the vertical wall.

5 CONCLUSION

As a result of this case study, increment of batter angle can increase factor of safety of global stability of the wall, and decrease horizontal deformation of the wall and settlements of the nailed soil. But these effects diminish with increment of the batter angle and it is obvious for angles greater than 10 degree.

As a benefit of increment of factor of safety which resulted by increment of the batter angle, we can decrease the needed length of nails to obtain a specific Factor of safety. This case study shown that, this reduction has nearly linier relation with increment of wall batter angle.

ACKNOWLEDGEMENT

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