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Deep excavation and stabilization of excavation walls of central branch of KarAfarin bank

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ABSTRACT: Due to regulations requiring provision of car park in typical multi-story buildings in urban areas and high cost of land, deep excavation adjacent to existing structures have become common-place in Iran. Limiting lateral as well as vertical displacement of the adjacent structure has proven to be a major geotechnical challenge especially in coarse grained unsaturated soils where determination of geotechnical parameters is tedious. Often active temporary support methods such as "rigid pad – anchoring" and/or "anchored soldier piles" are used in combination with nailing. However, arriving at the optimum design for such projects for competitiveness in the typical "design-build" tenders is difficult due multiple choices as well as poor knowledge of geotechnical parameters. Hence accumulation data from case studies has proven to be very useful. In this paper, details of an important case study are presented and guidelines for improvement of such engineering tasks are proposed.

1 INTRODUCTION

Karafarin Bank is one of the famous financial institutions in Iran and due to rapid expansion a more spacious central office became necessary. This office block is located in a built-up area in the center of Tehran. The location of the site is shown in Figure 1. The site area for construction is about 893 m^2. The building has 11 floors that 5 of them are located below ground level. The excavation has four sides and depth of excavation is 17m.

Figure 1. Location of Central branch of KarAfarin bank

2 SITE INVESTIGATIONS

Site investigation was performed by Zamiran Geotechnical consultant. Geotechnical report showed that a GC soil layer is beneath the foundation. The ground divided into three layer and each layer's parameters is explained in Table 1. These parameters were used to design the excavation wall stabilization system.

Table 1. Site investigations data

Depth (m)	Soil calcification using USCS	Specific unit weight (kN/m^3)	Dry specific unit weight (kN/m^3)	Elastic modulus (MPa)	Cohesion (kPa)	Internal friction angle (°)	Poisson's ratio
0-11	GC	18.5	17.4	50	23	36	0.3
11-19	GC	19.8	18.8	150	20	39	0.3
19-40	GC	20.9	20	180	86	35.5	0.3

3 DESIGN OF STABILIZATION SYSTEM

Two criteria were considered in designing of excavation wall stabilization system. First, limit equilibrium method that investigates the equilibrium of the soil mass tending to slide down under the influence of gravity. Transitional or rotational movement is considered on assumed or known potential slip surface below soil mass. This method is based on comparison of forces (moments or stresses) resisting instability of the mass and those that causing instability (disturbing forces). Two-dimensional sections are analyzed assuming plain strain conditions. This method assumes that the shear strengths of the materials along the potential failure surface are governed by linear (Mohr-Coulomb) relationships between shear strength and the normal stress on the failure surface. Analysis provides a factor of safety, defined as a ratio of available shear resistance (capacity) to that required for equilibrium. If the value of factor of safety is less than 1.0, slope is unstable. Results (factor of safety) of particular method can vary because method differs in assumptions and satisfied equilibrium conditions. Functional slope design considers calculation with the critical slip surface where is the lowest value of factor of safety. Locating failure surface can be made with the help of computer programs using search optimization techniques. In this project, GeoStudio 2007 software was used for evaluation of limit equilibrium condition. Fast of circular and polygonal slip surfaces provides the lowest factor of safety. External loading, stabilization forces (i.e. anchors, nails and piles etc.) also was added. The software uses solution according to various methods of slices, such as Bishop simplified, Ordinary method of slices (Swedish circle method/Petterson/Fellenius), Spencer, Sarma, etc. FHWA was opted as a technical note for Allowable Stress Design (ASD) and 1.35 was chosen as external minimum safety factor.

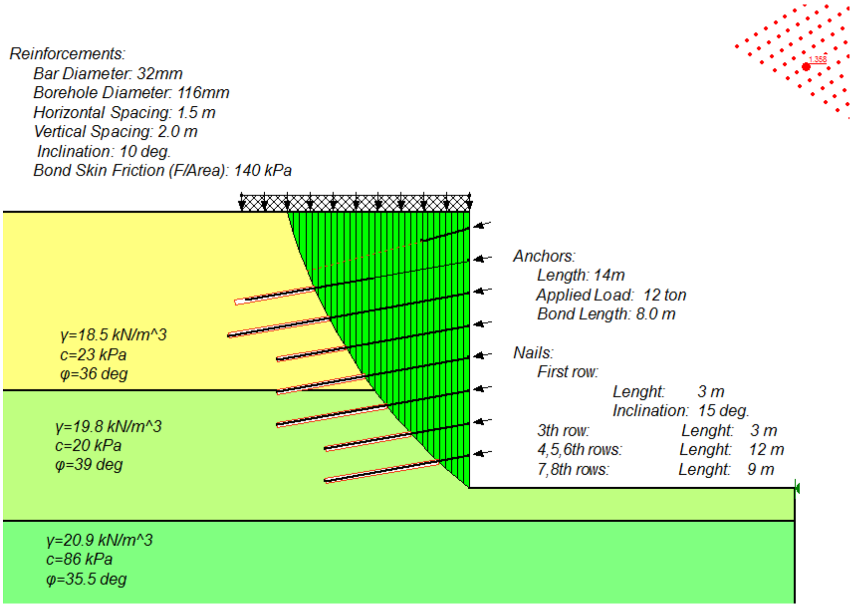

Figure 2. Geostudio results for East wall (SF=1.358)

The second method that was used to evaluate excavation stability was finite element method. The finite element method (FEM) (its practical application often known as finite element analysis (FEA)) is a numerical technique for finding approximate solutions of partial differential equations (PDE) as well as integral equations. The solution approach is based either on eliminating the differential equation completely (steady state problems), or rendering the PDE into an approximating system of ordinary differential equations, which are then numerically integrated using standard techniques such as Euler's method, Runge-Kutta, etc. In this project PLAXIS 8.2 software was used to predict the lateral and vertical movement of adjacent buildings and streets. This method analysis is crucial where adjacent structures are sensitive to vertical and lateral displacement, for example next to a building.

As mentioned before the excavation has four sides and in Table 2 information about each side and their assumed external forces are shown. This information was used to design the excavation wall stabilization system.

Table 2. Design information for each side

Side	Next to	Length (m)	External force (kPa)
West	5 story building	25	40
	yard	14	10
North	2 story building	22.9	20
East	Qasir street	39	20 (Heavy Vehicles)
South	1th alley	22.9	10

The criteria for design were to limit lateral and vertical movement of adjacent structure. PLAXIS 8.2 software was employed to assess this criterion. For instance East wall was considered, as shown in Figure 3 the maximum vertical predicted movement was 6 mm in the top of wall and maximum lateral predicted displacement was 15 mm in depth of twelve with respect to ground level. The East wall will be study carefully in next parts. For west and north walls soldier piles were employed in addition to anchors and nails to reduce displacements.

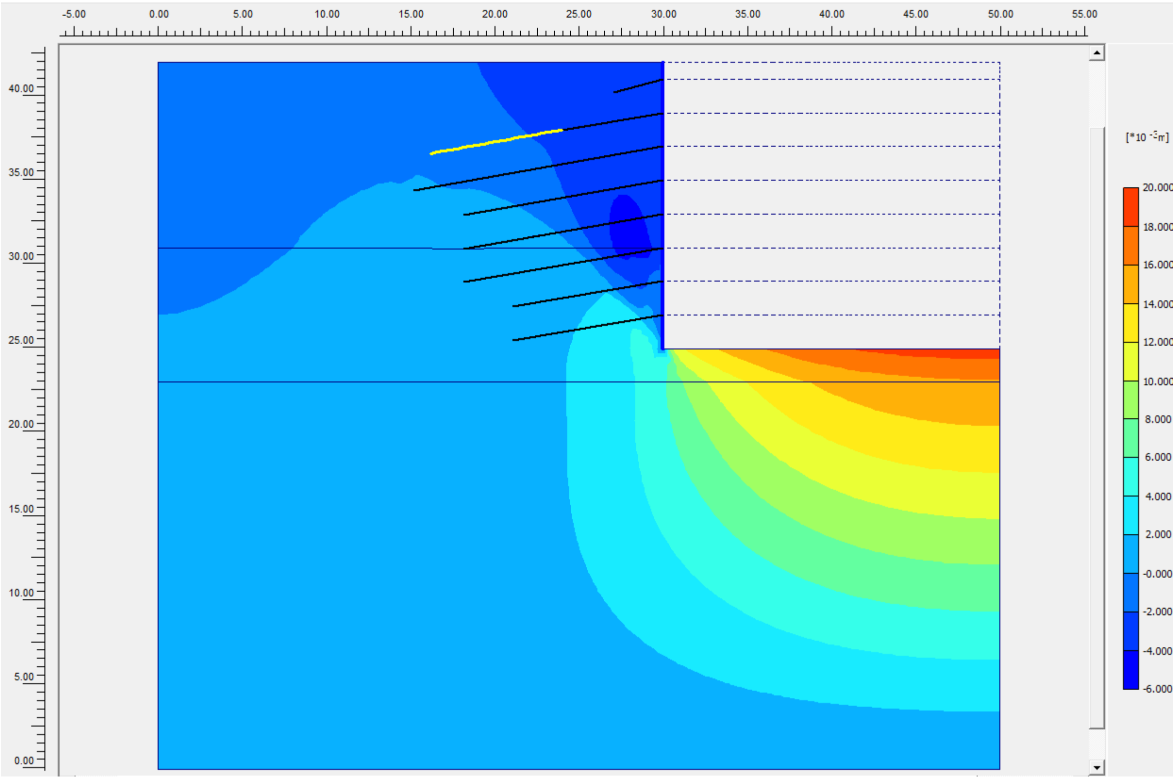

Figure 3. PLAXIS results (vertical displacements) for East wall

4 CONSTREUCTION PROCEDURES

First a cut was excavated with a Loader or a Mechanical Shovel near to boundary edge of site. Last 20 cm were scratched with workmen. Then a Drill Wagon started to drill a hole in excavated wall with rotary percussive method using air flush. In upper rows, because of unstable condition of hole and for prevent of delay in project self-drilling rods was used as a passive elements in drilled holes. But in lower rows, soil was more cohesive and had bigger internal friction angle and the shorter length of nail, ordinary rebar was used. After placement of rods (rebar or self-drilling rod), cement was grouted in the hole with 4Bar pressure at least. Then steel mesh was placed in front of wall and then a shotcrete facing was built. After drying of shotcrete, head nails and head anchors were placed. In this project sometimes shotcrete preceded drilling and placement of bars. In the case of anchors they posttensioned one week after grouting. These steps continued up to reach the bottom of foundation.


Figure 4: Posttensioning of anchors using hydraulic jack

In the west and north walls as said before soldier piles were employed. In these walls before any excavation shafts were dug by workmen in every 4 meters and then 2IPB200 were placed in the shafts.
Figure 6, shows stabilized walls. As it shown, in north and west walls, soldier piles were used to prevent damage to adjacent buildings.

Figure 5. Drilling the excavated wall using Drill Wagon

5 MONITORING AND WALL PERFORMANCE

During the construction 9 tape reflector was installed around the excavation as explained in Table 3. Measured displacements were smaller than predicted displacement that extruded from PLAXIS software. It means soil strength parameter were under-estimated. Ground level assumed zero.

Table 3. Tape reflector position and their movements

Tape number	Position	Maximum vertical displacement (mm)	Maximum lateral displacement (mm)
T1	North-Elev. +0.5m	5	6
T2	North-Elev. -0.5m	4	4
T3	West-Elev. -1.5m	7	7
T4	West-Elev. +2.5m	6	8
T5	South-Elev. -1.5m	2	5
T6	South-Elev. +1.0m	2	6
T7	West-Elev. +0.0m	4	8
T8	East-Elev. -1.0m	3	6
T9	East-Elev. -1.0m	3	7

It is hard or maybe impossible to exactly say each parameter how much was conservative. But using monitoring data back analyses was performed for east wall. Many soil strength parameters can result the measured displacements. But between all of them, following data were picked up for soil strength parameters. (Table 4)

Table 4. Chosen back analysis data for west wall

Depth (m)	Elastic modulus (MPa)	Cohesion (kPa)	Internal friction angle (º)
0-11	90	25	36
11-19	180	35	40
19-40	180	86	35.5

Figure 6. stabilized walls (East, North and West)

6 SUMMARY AND CONCLUSION

Soil nailing or anchoring system is a good method for stabilizing excavation especially when blend with soldier pile system. In this project usage of this stabilizing system improved excavation resistance for failing. Wall movements were less than the limiting values set for the projects at all monitoring points, and the wall movements were acceptable. This limitation of movement is contributed to favorable soil conditions over most of the site, high quality construction, and the exceptional quality control and quality assurance measures instituted by the field engineers.
Because of poor condition of soil in top layer contractor was forced to change bar with self-drill rod that was more expensive (near twice). Also the price of self-drilling rod was more expensive than rebar, but the speed of work with self-drilling rod was higher. This project was performed during four months that is an acceptable time for doing such an exaction.

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