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Effective methods to reduce the pit wall displacement (Case study: Pars complex project)

Masoumeh, Mehrabi*[1] and Ali, Uromeihy[2]
1)Department of Geology-, Science and Research Branch, Islamic Azad University, Tehran, Iran
2)Department of Engineering Geology,TarbiatModarres University, Tehran, Iran
Corresponding Author: masoume_mehrabi@yahoo.com
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Abstract

The most important principles in deep excavation retaining structures are design and monitoring of the excavation wall displacement values. One of the best and most widely used methods of stabilizing the walls is using the anchorage and nailing systems. Shift in the excavation pit wall is very important because it can cause damage to adjacent buildings. To examine the effect of various approaches for simulation, northern wall with finite element software, Plaxis and Geoslope, was built using the methods of anchorage and nailing for examining the soil behavior and structural elements. Mohr-Coulomb is the most common constitutive model in numerical modeling with some weaknesses such as unrealistic heave of the excavation bottom and thus variations in the displacement field.

Keywords: Excavation, anchoring, nailing, monitoring, numerical simulation

1. Introduction

The issue of excavation, design and implementation of retaining structures require geotechnicaland structural, material, technological, executive, economic, and socialinvestigation. Nowadays, with regard to the excavation stabilization methods and as a consequence an increase in the depth of excavations, a concern has grown over the design and implementation of structures with high endurance in the very deep areas. It is very important especially in the neighboring areas and multi-story residential buildings. The purpose of the excavation monitoring isdetermined the exact value of displacementof horizontal and vertical components in the excavation walls and the tensions resulting from these displacements and also after finalizing the stabilization operation. The most significant factor in monitoring the excavation wall with surveying is a maximum decrease of errors available in the surveying observations. It shows the exact value ofdisplacement of excavation wall. These values in the stabilization are significant in both safety and facilities to review the plan.

Deep excavations are often used in urban areas, for example in the underground transport systems, basement and water distribution networks, underground oil tanks, etc (Gwang 2005). A deep excavation in such soil can cause large settlements and horizontal movements of ground around the excavation (Wong 1989). Horizontal movements are also a major factor to consider during the excavations (O Rourke 1990). Terzaghi (1943) was the first person that define the excavations, he defined those excavation depths were smaller than their widths as shallow excavations while those with depths larger than their widths were deep excavations. Terzaghi et al. (1943), revised that excavations whose depths were less than 6m could be defined as shallow excavations and those deeper than that as deep excavations, considering that use of sheet piles or soldier piles grows uneconomical once the excavation depth goes beyond 6m (Chana 2006).

A tieback wall is a structural system that uses an anchor in the ground to secure a tendon that applies a force to a wall (Weatherby 1982). Tieback walls are designed to stabilize and support natural and engineered structures and to restrain their movements using tension-resisting elements (Juran 1991). As tension-resisting elements, ground anchors are used in tieback walls.

Ground anchor is a main element of a tieback that functions as load carrying elements. An anchor transmits a tensile force from the main structure to the surrounding ground is used to resist this tensile force. The tensile force in anchor is that force which is necessary for equilibrium between the anchor, the structure and the ground. As a result of this equilibrium, the movement of this structure and the surrounding ground are kept to acceptable levels (Hanna 1982).

Post-grouted anchors use delayed multiple grout injections to enlarge the grout body of straight shafted gravity grouted ground anchors. Each injection is separated by one or two days. Post groutingis accomplished through a sealed grout tube installed with the tendon. The tube is equipped with check valves in the bond zone. The check valves allow additional grout to be injected under high pressure into the initial grout which has set. The high-pressure grout factures the initial grout and wedges it outward into the soil enlarging the grout body.

A prestressed grouted ground anchor is a structural element installed in soil or rock that is used to transmit an applied tensile load into the ground. Grouted ground anchors, referenced simply as ground anchors. Are installed in grout filled drill holes. Grouted ground anchors are also referred to as tiebacks. The basic components of a grouted ground anchor include the: (1) anchorage, (2) free stressing (unbounded) length: and (3) bond length. These and other components of a ground anchor are shown schematically in figure1 (Sabatini 1999).

In 1991, the Federal Highway Administration (FHWA) started to build a bracedsheet-pile wall with the true scale in the geotechnical study canter of Texas University A & M. The purpose was to use it for studying the behavior of flexible bracing guardian

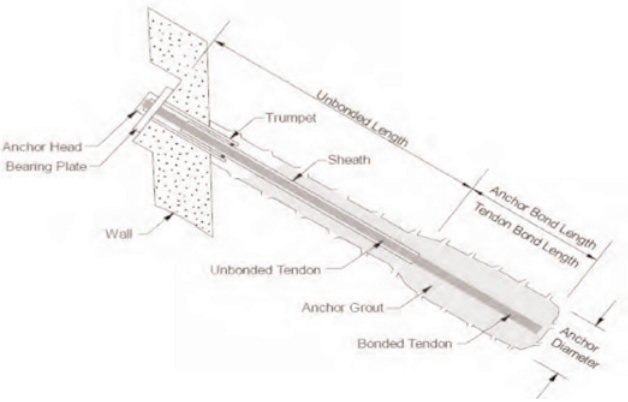

Figure 1. Components of ground anchor

Figure 1. Pars excavation project located in Shariati Avenue

walls. The numerical model of this guardian wall was built by Briaud & Lim in 1999 with 3-D non-linear elements; and hyperbolic behavior model was built through finite element method. The parameters investigated in this modelling includeunbounded length of anchor, the size of force in bracing, soldier piles fixity, and the stiffness of the wooden counter-forts between piles.

To do this study, the engineering and geotechnical geology features of Pars Commercial-Administrative Complexwere selected and the stabilization analysis of excavation wall was done using numerical simulation.

2. Study area

This project includes 10 underground floors (excavation wasdone in a depth of 40 m) and 21 ground floors. The location of this project is in Seyed Khandan Bridge, Dr. Shariati Avenue,Tehran. The excavation walls stabilization method of the projectis a mixture of pile and anchorage system, designed based the type of soil and depth of excavation.

The maximum value of displacement for the monitoring and monitoringof the excavation wall was determined through attending to the geotechnical, relative depth, and the given structure type. Some of the major factors in assessing the risk of excavation and determining the precision of monitoringof Pars project excavation walls include the dynamic bars coming from the neighboring structures in the northern, eastern and southern pit, and also the traffic jam of the western part from Shariati avenue, existence of a series of aqueducts around the building area, and probability of crossing one of them under the project in the southeastern part,existence of a deep pit in the east part, proximity of minor faults of Abbas Abad, and thrust fault, Mahmoodie fault located in the distance 5.2 K.M away from the project,Niavaran fault in the distance of 6.5 K.M., and North part of Tehran fault crossing in the distance of 7.8 K.M, the underground water, type of soil, and depth of excavation.

2.1. Geotechnical studies in the construction

Machine drilling operation of this site was carried out through excavating 8 boreholes,60-85 M deep, with two drilling machines, mobile drills, in the rotary form, with the method of wash boring. In addition, 4 hand workedboreholes13-40.4 deep, was excavated by a pitman.The samples taken from the machine and hand workedboreholeswere taken to the central laboratory, and the technicalcalculation was done by Geoslope and Plaxis through extracting parameters.

In general, the underground soil in the drilled boreholesis composed of a layer of remolded soil with a variable length of 1.5-3 M. The underground soil consists of coarse-grained layers of clayey gravel with sand, poor-graded or well-graded gravel with clay and sand, and also poor-graded or well-graded-with silt and gravel, with the spectrum of brown, dark brown and grey, along with pebbled and in some cases with some destroyingwhite or green grains. In

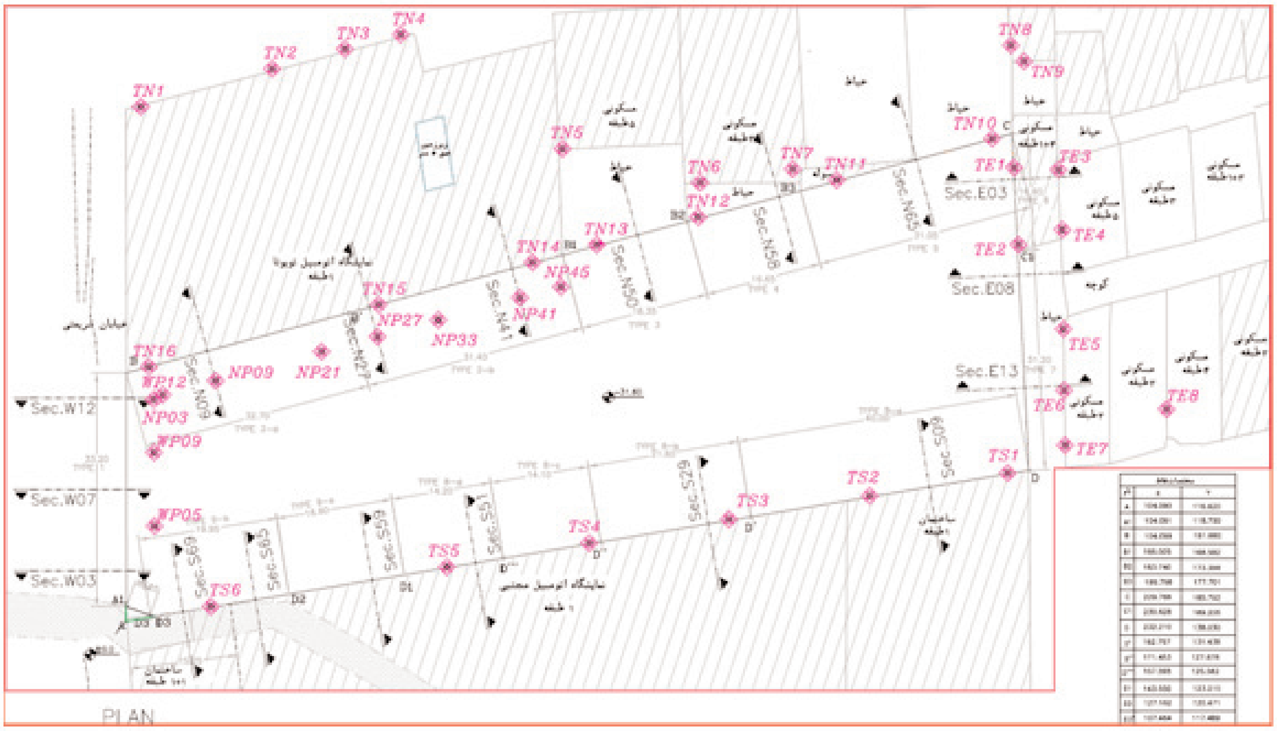

Figure 2. A view of Pars Commercial-Administrative Complex plan

Table 1. The specification of the soil

Layer	Y(kN/cm^3)	E(kg/cm^2)	C(kg/cm^2)	φ	ω($_o$\$^0$)
1	17.5	100	0.05	27	-
2	19.5	400	0.25	30	11
3	20	600	0.3	36	10
4	19.5	400	0.2	30	10
5	20.1	700	0.3	40	10

terms of endurance, it includes medium-dense up to highly-densein different depth, it is classified in the groups in the unified method as follow:

(SP-SM, SW-SM, SC, SM) (GP-GM, GW-GC, GP-GC, GC)

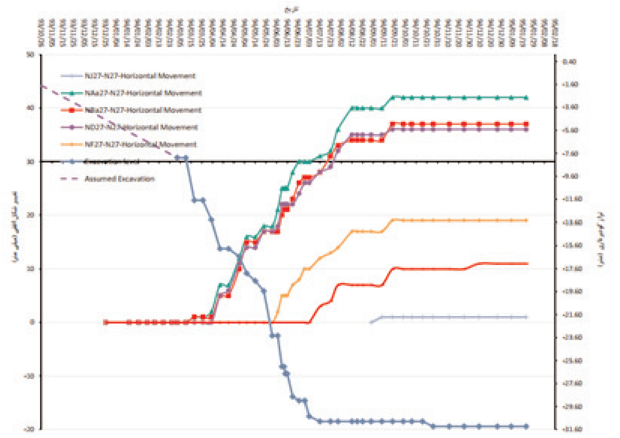

Figure 3. The diagram for the horizontal deformations of northern wall using anchoring

3. Monitoring

Because of excavation,the tension changes in soil so it is required to investigate the deformation and subsidence of its walls. In this study, one of the walls of Pars projectis evaluated. to control the system location change, the specification of reflectors installedon the surface of walls was read and registered in different intervals. The results coming from the northern side is depicted in the following diagram. Finalizing excavation and implementing anchoring, and heeding to the type of soil and impact of driving stressin the project area and holding up the anchors,the deformations decrease and get to a certain value which proves the stabilization appropriacy.

Based on the FHWA report, it is probable to change the location of pit walls after 6 monthsaway fromfinalizing theexcavation operation. Theprobable value ofmaximum of displacement after construction is 15 percent of the maximum of change of location immediately after finalizing the executive operations.

To prove the safety and appropriacy of this type of stabilization for the intended area, geotechnical

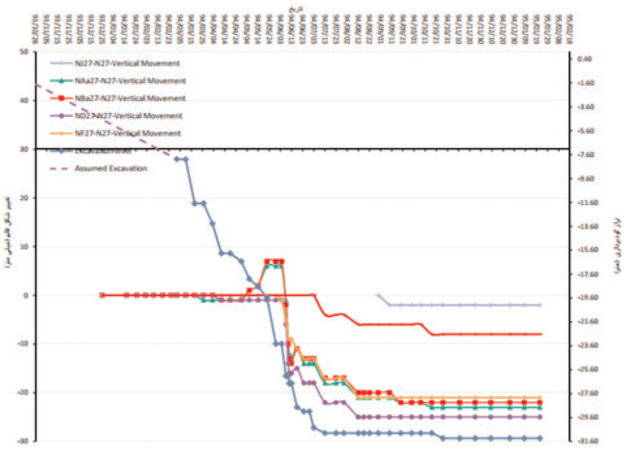

Figure 4. The diagram for the vertical deformations of northern wall using anchoring

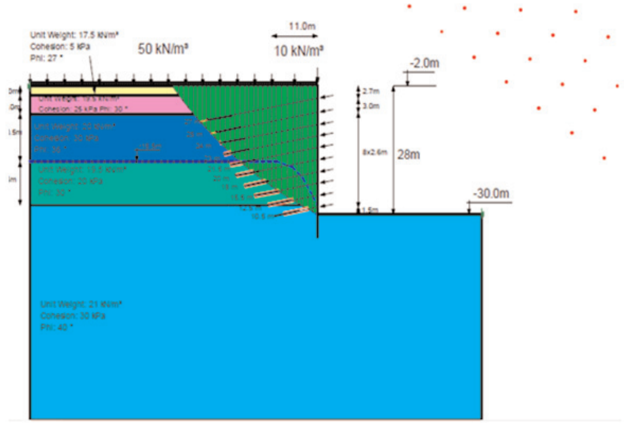

Figure 6. Geoslope output in the northern wall with the safety factor 1.522 by anchorage method

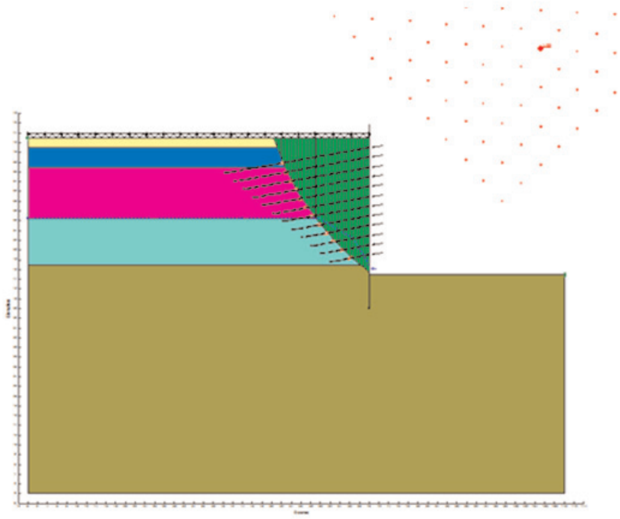

Figure 5. Geoslope output in the northern wall with the safety factor 1.1 by nailing method

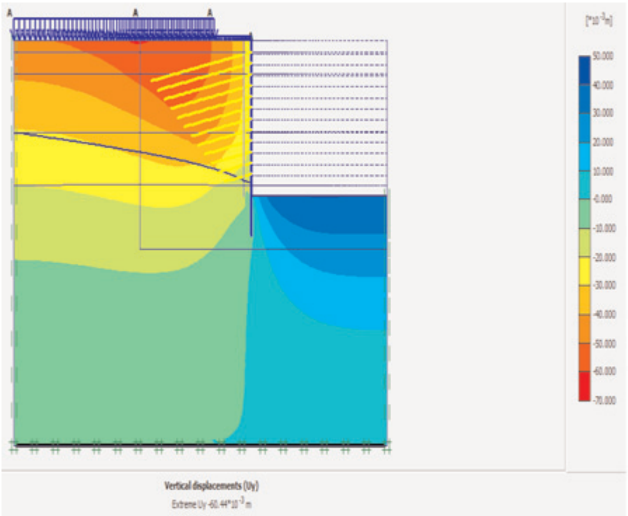

Figure 7. Vertical counterdisplacement of northern wall in nailing method inside Plaxis

information used in Geoslope software was analyzed to obtain confidence coefficient and Plaxis was analyzed to examine the figures using nailing. The results of this stabilization in the area include:

4. Numericalsimulation

To examine the effect of various approaches for simulation, northern wall with finite element software, Plaxis and Geoslope,was built using the methods of anchoring and nailing for examining the soil behavior models and structural elements.

Considering the results of analysis, although the number of reinforcementelementsis fewer than the nailing (in the nailing system, there are 12 nails, but there are 10 cables in the anchoring system), the confidence coefficient of stabilization of pit was obtained 1.522, which suggests a significant increase than the confidence coefficient 1.1 obtained for the nailing. It could be because of the performance of the two systems.

According to figure 10, the maximum of horizontal displacement of dip and dirt pile equals 0.975, and even does not reach to 1 CM. it can be observed that compared with the nailing system; the deformation of the wall has decreased to a considerable level. Based on the figure 9, it is seen that the maximum vertical displacement ofsoil mass equals 0.911 CM. based on the fact that the subsidence and deformation is accepted as 5 CM. the results of the pit stabilizedby anchoring is acceptable in contrast to the pit stabilized with nail.

As depicted in figure, the difference of the deforma-

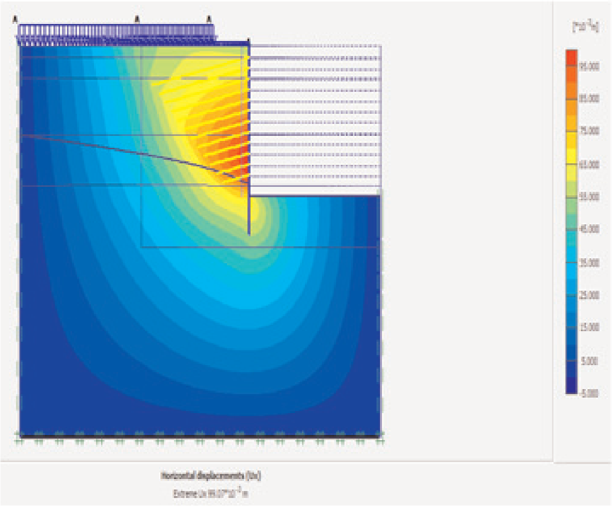

Figure 8. Horizontal counter displacement of northern wall in nailing method inside Plaxis

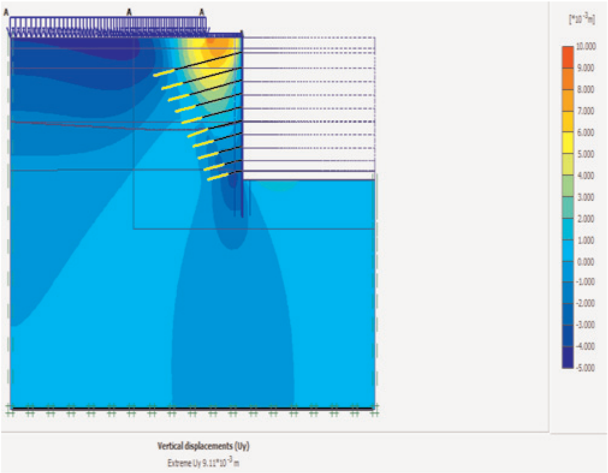

Figure 9. Vertical counter displacement of northern wall in anchoring method by plaxis

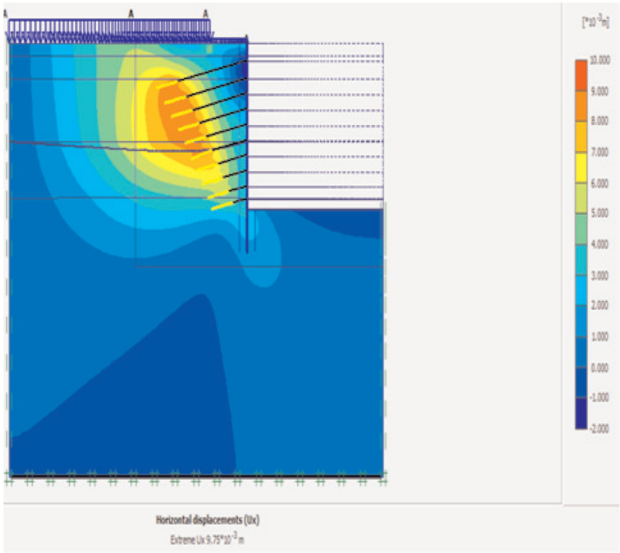

Figure 10. Horizontal counter displacement of northern wall in anchoring methodby Plaxis

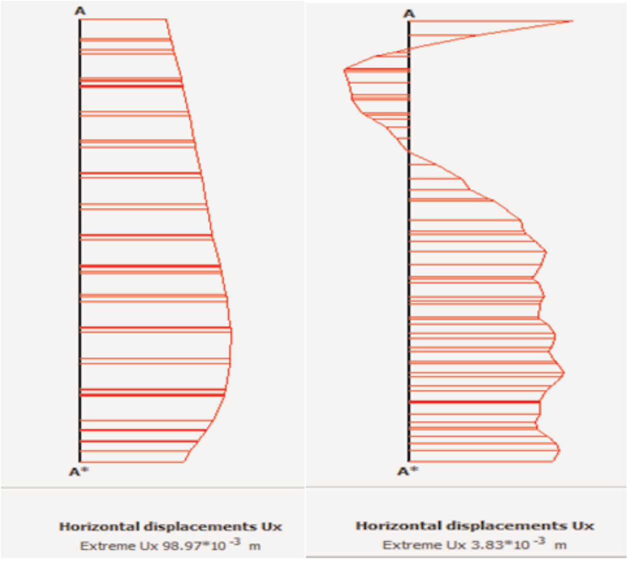

Figure 11. Diagram for the horizontal displacement of wall in nailing system (on the left) andanchoring (on the right)

tion of the wall stabilized with nailing system is much so that the maximum deformation of the wall location in this system equals 98.97 and it is 3.83 in the anchoring system which suggests its high efficiency in controlling the deformations of the wall. Based on figure7, we understand that the above part of the wall moves inward, due to the impact of anchor restraining, and makes the soil compressed.

Table 2:The results of output of numerical modeling in Plaxis and Geoslope in the northern wall

5. Results and discussion

The research topic is investigating the stabilization of excavations using two methods of anchoring and nailing, according to the geological conditions. To do this, specification ofengineering geology and geotechnical structure of Pars Commercial and Administrative Complex was used. The stabilization analysis of the excavation wall was done through calculative and numericalmethods. In the point of geology, the location of the plan was in the alluvial deposits of suite Hazarder, unit B. in terms of geotechnical, the soil was generally sand includingclay and saltymaterials of surface deposits, which reach to the 85 M deep. The distance of site from the active fault line of north of Tehran and active fault line of Kahrizak, in south of Tehran, is 30 and 60, respec-

Table 2. The results of output of numerical modeling in Plaxis and Geoslope in the northern wall

Stabilization Method	Maximum of vertical displacement	Maximum of horizontal displacement	The confidence coefficient of limit equilibrium	The confidence coefficient of Plaxis
Without anchor	-	-	0.542	0.587
Nailing	60.03	98.97	1.1	1.532
Anchoring	8.23	3.83	1.522	1.587

tively. So, the Seismic acceleration of this project is considered 0.38 g.

Since the depth for excavation is agreed 40 m from the ground, it is required to study the stabilization of the pit walls and recommend the stabilization methods. To do so, the pit stabilization analysis was carried out with two software Geoslope and Plaxis for the various modes, before and after the anchorage and nailing implementation. The results of the analyses are:

A.In the stabilization analysisof pit northern wall with Geoslope, in three modesincluding, unreinforced (normal conditions) reinforced with the nailing,and reinforced anchoring methods, wererespectively, 0.5,1.1, and 1.5. The confidence coefficient for the pit eastern wall was, respectively, 0.6, 1.2, and 1.5.

B.In the displacement value ofpit northern wall with Plaxis, in three modes including, unreinforced (normal conditions) reinforced with the nailing, and reinforced anchoring methods, were obtained, respectively, rupture mode, 10 CM and one CM.For the eastern wall, displacement was obtained, respectively, rupture mode, 7.3 CM, and 6.9 CM.

C.The value of horizontal displacement and confidence coefficient of pit wall, considering the anchor or nail'sangle constant to the horizon is related, respectively,directly and reversely to the right distance between anchor and nail.In other words, by increasing the right distance between them, the value of the horizontal displacement of the wall increases and the confidence coefficient decreases.

D.By increasing the strength of soil, using nail or anchor won't make a significant difference to stabilize the pit wall. The impact of the nail and anchor performance is more tangible when the geotechnical properties of soil include less quality.

6. Conclusion

One of the most attentions in recent year's stabilization excavation civil Engineers for the city is located to the rear is a sewing technique. The advantages of this method can be implemented quickly and cost and also because of improved soil mechanical parameters of the injection and the absence of large structures deep inside the guard said.

This paper has explained that Excavation two-dimensional numerical modeling can be a method of sewing the back wall of the factors affecting the transformation the stitching on the back of a sustainable urban Excavation investigates.

This study showed that:

"With increasing soil mechanical parameters such as modulus of elasticity of soil and soil internal friction angle of the wall decreases the maximum amount of transformation.

"Reduction of soil mechanical parameters such as modulus of elasticity of soil and soil internal friction angle of the wall increases the maximum amount of transformation.

"With increasing amounts of inhibitory Excavation tingly and transformation up to the wall decreases.

"Reducing the inhibitory Excavation tingly and transformation values of maximum wall increases.

"During the transformation Excavation on the maximum wall length is more tingly.

"Stress reduction in force, with maximum inhibitory amounts of deformation increases.

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