Optimize the Placement of Nails in Soil Nailing By Three Dimensional Numerical Modeling

Abdolah Tabaroei[1], Mahmoud Ghazavi[2]

1- Department of Civil, Science and Research Branch, Islamic Azad University, Tehran, Iran
2- Professor, Department of Civil Engineering, K.N.Toosi University, Tehran, Iran

Abstract

In recent years, the construction of urban development is one of the important activities in civil engineering that is performance largely in cities. In many of these projects need to be vertical to the ground excavation, Due to the recent (Loss of the walls) excavation discussion of this issue is of most interest to geotechnical engineers. Therefore, the safe and economic design and selection excavation the overhead rate applied is important, especially in urban areas, one of this excavation systems today are more urban setting procedure is nailing. In this paper the method is described, then place the nails and their optimization is performed using three-dimensional numerical modeling. In three-dimensional numerical modeling nails modeled by BEAM element, Shotcrete by PLATE element, soil by hardening soil model and element interface to model the interaction of the wall and the soil used.

Key words: Excavation, Retaining structure, Soil nailing, Horizontal displacement, Settlement

1. Introduction

Today's for sustainable structures many of large urban such as tunnels, subways, and towers and etc. The deep excavation used. The excavation may have adverse effects on adjacent structures of which can be the deformation and subsidence adjacent structures; this is inevitable, especially in sandy soils. Therefore, accurate prediction of subsidence and deformation by numerical models can be effective in reducing these factors. Much research has been done on clay soil [1-6]. However, certain work has been done in sandy soils. Land and buildings are zero transverse dimensions small distance from each other in many urban areas has led the daunting task excavation concern for building owners and the neighbors. Unfortunately, many still think the application of safety measures in excavation cost and time required to impose useless, While basically a complex and highly dangerous excavation engineering to prevent the loss of potential negative consequences resulting from trench excavation, and temporary structures for containment trenches that run the so-called structural guardian [7]. Excavation appropriate way given the circumstances and the type of soil, depth and excavation size, location and placement of pit area, groundwater levels, safety of adjacent

[1] Tabarroei@sci.Iaun.ac.ir

neighbors (to prevent physical damage), cost stabilization and performance limitations is selected. A variety of approaches used in civil engineering and slope stabilization [8].

In civil engineering there are various methods for slope stabilization, classical methods such as the use of gravity retaining walls and edging to the modern technologies such as soil stabilization soil armed with various weapons systems. One method that has become prevalent over the past twenty years in the soil technology is nailing method, the main components include clay soils inhibit investment component nailing system, ability of steel (Nail) for soil stabilization and reinforcement and concrete for the final wall is a relatively low cost materials, In terms of quantity as well as materials used for this type of rebar and concrete structures in comparison with other conventional concrete piles or poles that often guard their It is less to implement such a system can be used for light equipment and devices in urban areas are faced with a lack of space can be used [9].

2. Soil Nailing Approach

The idea of using nailing approach (soil or rock) in the first decade of the 60^{th} century and for the stability of a rock tunnel in Austria came. In the early decades of $s70^{th}$ century used this technique because of high speed economic and low cost became very popular in Europe and America this technique excavation stability, protected by trenches and high flexibility are used. Soil Nailing is a construction technique for reinforcing existing ground and constructing walls in cut sections. This is accomplished by installing closely spaced, passive, structural inclusions, known as nails, into the soils to increase their overall shear strength. The term "Passive" means that the nails are not pre-tensioned when they are installed, as with tiebacks. The nails develop tension as the ground deforms laterally in response to continued excavation. Nails may be used to stabilize either existing slopes or future slopes/cuts created by excavation activities at a site. A structural facing connected to the nails is used to complete the work and to give it a finished appearance consistent with the project's aesthetic requirements. This technique is employed to enhance the performance of granular soils and stiffer clays. As far as nails length is connected, it may be around 50% of the height of the excavation requiring support. Soil nailing is constructed by staged excavations from "top down" [10-11].

2.1. Procedure of the Soil Nailing

1- Excavation is usually done with a depth of 1 to 2 meters, but generally remain stable without inhibiting the ability of the soil to one to two days.
2- Drilling the holes: The holes are drilling with a diameter 10 to 25^{cm} and length of 6 to 18 ^{m} and angle of 15 to 30 degree. The spacing of the nails in horizontal and vertical extension is 1 to 2 meters.
3- Installation of drainage strips and sprayed concrete implementation
4 - Repeat the above steps to achieve the final stage excavation
5- Run the shell if needed [10-11]
Figure (1) showed the stage construction of nailing approach.

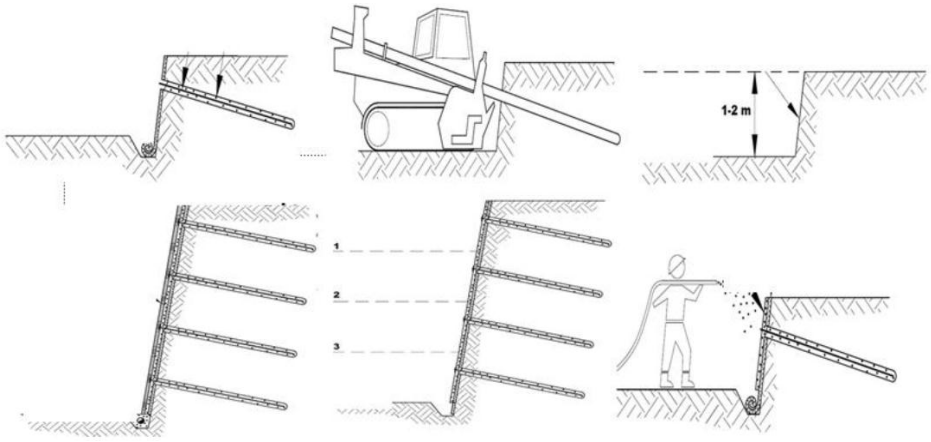

Fig 1: The excavation performance of nailing approach

2.2. Application Procedure of Soil Nailing

This method is used in the following
1 - Inhibition of excavation
2 - Stabilization of synthetic and natural slopes
3 - Strengthening and repair of existing retaining structures
4 - Alternative for in reinforcement system and bored pile [10-11].

2.3. The Appropriate Soils for Soil Nailing

1 - Alluvial soil and weathered rock along the seam inappropriate
2 - Hard cohesive soils such as sandy silt and clay with low plasticity
3 - Fine to medium sand with minimum capillary
4- The soils that stable without anchors as height of 1 to 2 meters [10-11].

2.4. The Inappropriate Soils for Soil Nailing

1 - Soils with rock and boulder
2 – Fine soil that is soft and very soft
3 - Soils with high wet percent and saturation
4 - Organic soil
5 - Corrosive soils [10-11].
Figures (2) and (3) show examples of the nailing walls.

Fig 2: Example of wall by nailing

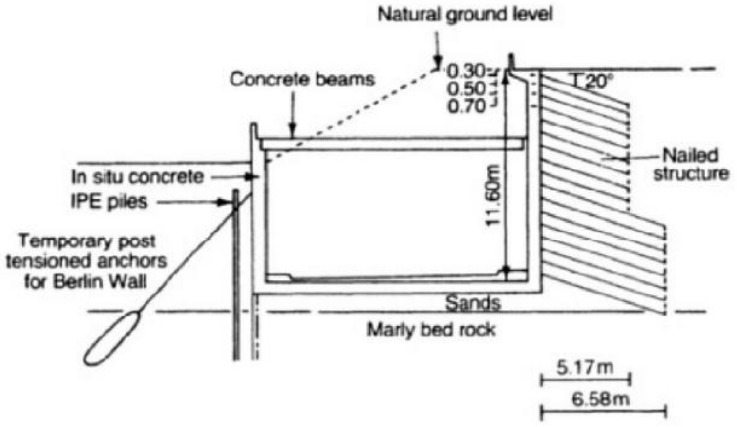

Fig 3: Use of soil nailing in the construction of cut-and-fill tunnel [10]

2-5. Advantages of Soil Nailing

There are many advantages for this method is briefly mentioned [10-11]:
1 - The execution of the top-down method and the ability to run concurrent with excavation
2 - Economy
3 - Easy to implement and less time-consuming and requires low operating force
4 - Increased safety due to the large number of nails
5- Remove the control scheme and the constraints of the strut
6 - Run effects on the environment and the privacy invasion and blocking traffic
7 - Light equipment, portable high performance in small spaces and low altitude
8 - No need embankment (unlike reinforced soil and retaining walls) and use the soil behind
9 - No need for a temporary slope on the back of location
10 - System plasticity and flexibility in meeting the general and local settlements
11 - Resistance to earthquake

12 - Ability to comply with any template and complex shapes such as arches and stairs excavation
13 - use in urban areas
14 - Improved ability to plan, execute during the trial nailed in place
15 - Ability to change the location of the nails in the obstacle
16- Low deformation

2-6. Disadvantages of Soil Nailing

The disadvantages of this method are as follows [10-11]:
1 - Sensitivity to the presence of surface water and groundwater and settlement
2 - The horizontal displacement is more than the retaining structures, not reasonable for the plants adjacent to sensitive handling.
3 - Ability to incidence with underground facilities during the run
4 - Talented plastic creep in the plastic soils, and inefficiency especially in sensitive and expansive clays
5- The excavation is difficult in hard soil with stone grain
6 - Lack of easy excavation in collapsible soils like clean gravel and sand and soft clays and Crafts

3. Three-Dimensional Numerical Modeling of Soil Nailing

As mentioned in the previous section, soil nailing is one of the in situ reinforcing soil techniques in the world's that used to retaining and stabilizing the soil. Performance of such structures result from a complex of soil-structure interaction components include venture bulk soil nail walls, steel anchors (nail) and the surface is sprayed concrete [12]. Often from difficult numerical analysis based on finite element method to study the mechanism of soil – structure interaction to identify behavior and stability of walls are used. In this regard, the use of appropriate analytical methods and nearby to actual conditions, to assess the behavior of the wall is important [13]. For numerical modeling PLAXIS 3D VIP software was used. PLAXIS 3D is a finite element program, developed for the analysis of deformation and stability in geotechnical engineering. The software can be stage excavation with different loading condition and different boundary conditions by using 6 and 15 node triangular elements. The first version of this software to analyze the construction of embankments on soft soils in low-lying parts of the Netherlands in order and its Water Resources Management University CUR Produced in 1987 and then in 1993 it was expanded capabilities and support that has been approved by the Delft Institute [14]. Special features of this software are:
1) The software is able to considering the soil, structure and water interaction.
2) Large deformation can be calculated.
3) Various behavioral models based on administrative requirements that include models Mohr -Coulomb model, hardening soil model, soft soil model and soft soil creep model.
4) The software is able to considering the effect of pore water pressure.
5) The method used in software is finite element.
In numerical modeling always one of the important steps to determine the boundaries of the geometric model is the appropriate place, so that the results of this borders on the lowest level is reached. The effects off boundary conditions have been studied by researchers using a linear elastic model. The area of ground surface settlement resulting from excavation is range

from about 2 to 3 times of excavation depth [15]. In this paper, according to the depth of 20m excavation and also the importance the ground surface settlement the range of this area is about 60m. Lateral wall deformation usually between 2% to 5% H where H is a excavation depth, the results is identity with results [16]. Figure (4) shows the three-dimensional geometric model.

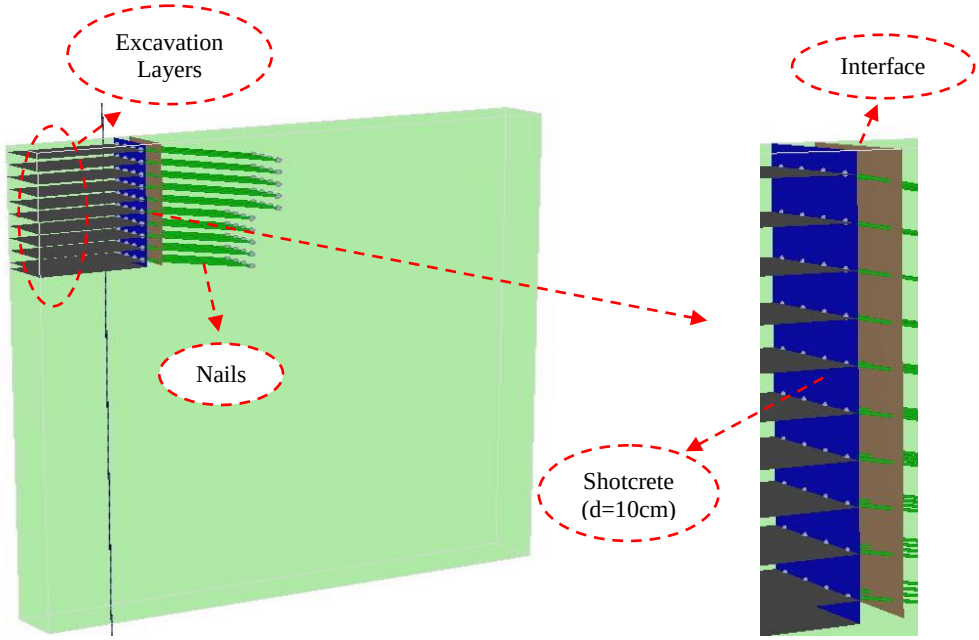

Fig 4: Three dimensional numerical model of soil nailing

3.1. Soil Parameters

One of the most important parameters in the numerical modeling in PLAXIS 3D software is properties of soil profiles. The soil used in the numerical modeling of viscosity and internal friction angle and is considering as a layer. Soil behavior was modeled using hardening soil model, this model gives better results than the Mohr-Coulomb model. The parameters used in the numerical modeling are listed in Table 1.

Table 1: Material Properties of soil

Name	Model	γ (KN/m^3)	c_{ref} (KPa)	E_{50}^{ref} (KN/m^2)	E_{oed}^{ref} (KN/m^2)	E_{ur}^{ref} (KN/m^2)	m	ν	φ	$R_{interaction}$
First Layer	HS	18	10	20×10^3	22×10^3	140×10^3	0.25	0.2	29	0.99

3.2. Nail Parameters

For modeling the nails, the beam element was used. Due to the depth of excavation 20m there are 10 rows of nails in modeling. Diameter of nails was 30 mm. The parameters that used in numerical modeling are presented in Table (2).

Table 2: Material Properties of nail

A (KN/m^2)	E (KN/m^2)	I (KN/m^2)
0.8042×10^{-3}	200×10^{6}	0.05147×10^{-6}

3.3. Shotcrete Parameters

As stated earlier, shotcrete, as a permanent facing for the walls, are utilized to create local stability among wall and to protect soil surface from weathering and environmental effects. Based on the values obtained from design procedure, the used parameters for the shotcrete in the 3D numerical modeling are given in Table (3). In 3D modeling shotcrete modeled with PLATE elements.

Table 3: Material Properties for the Shotcrete

Parameter	**Name**	**Unit**	**Value**
Type of behavior	Material type	-	Linear-Isotropic
Elastic Modulus	E	KN/m^2	20×10^{6}
Unit Weight	γ	KN/m^3	24
Equivalent thickness	d	m	0.1
Poisson ratio	ν	-	0.15

Furthermore, stability analysis and actual modeling of the problem have been performed using PLAXIS 3D VIP software through considering the effect of shotcrete, and nail-soil interaction. The stages of construction for the wall in 3D numerical modeling are discribed Table 4.

Table 4: Construction Process in Three Dimensional Analysis

Ph – No	Description
1	Excavate to EL -1m and place shotcrete and the first row of nail
2	Excavate to EL -3m and place shotcrete and the second row of nail
3	Excavate to EL -5m and place shotcrete and the third row of nail
4	Excavate to EL -7m and place shotcrete and the forth row of nail
5	Excavate to EL -9m and place shotcrete and the fifth row of nail
6	Excavate to EL -11m and place shotcrete and the sixth row of nail
7	Excavate to EL -13m and place shotcrete and the seventh row of nail
8	Excavate to EL -15m and place shotcrete and the eigth row of nail
9	Excavate to EL -17m and place shotcrete and the nigth row of nail
10	Excavate to EL -19m and place shotcrete and the tenth row of nail
11	Excavate to EL -20m and place shotcrete

3-4. Parametric Study and Results

Parametric studies on arrangement of nails into fourth case square, the triangle and the combination was of both methods (5 rows top triangular and 5 row down square and vice versa) was done and the behavior of wall and ground surface settlement in these 4 cases examined. The results showed that the best model is the triangle model and the minimum deformation occurred. 4 models used to nails arrangement in the three-dimensional numerical modeling arrangement presented in fig (5). Also the profiles of ground surface settlement and horizontal deformation in four types shown fig (6) and (7).

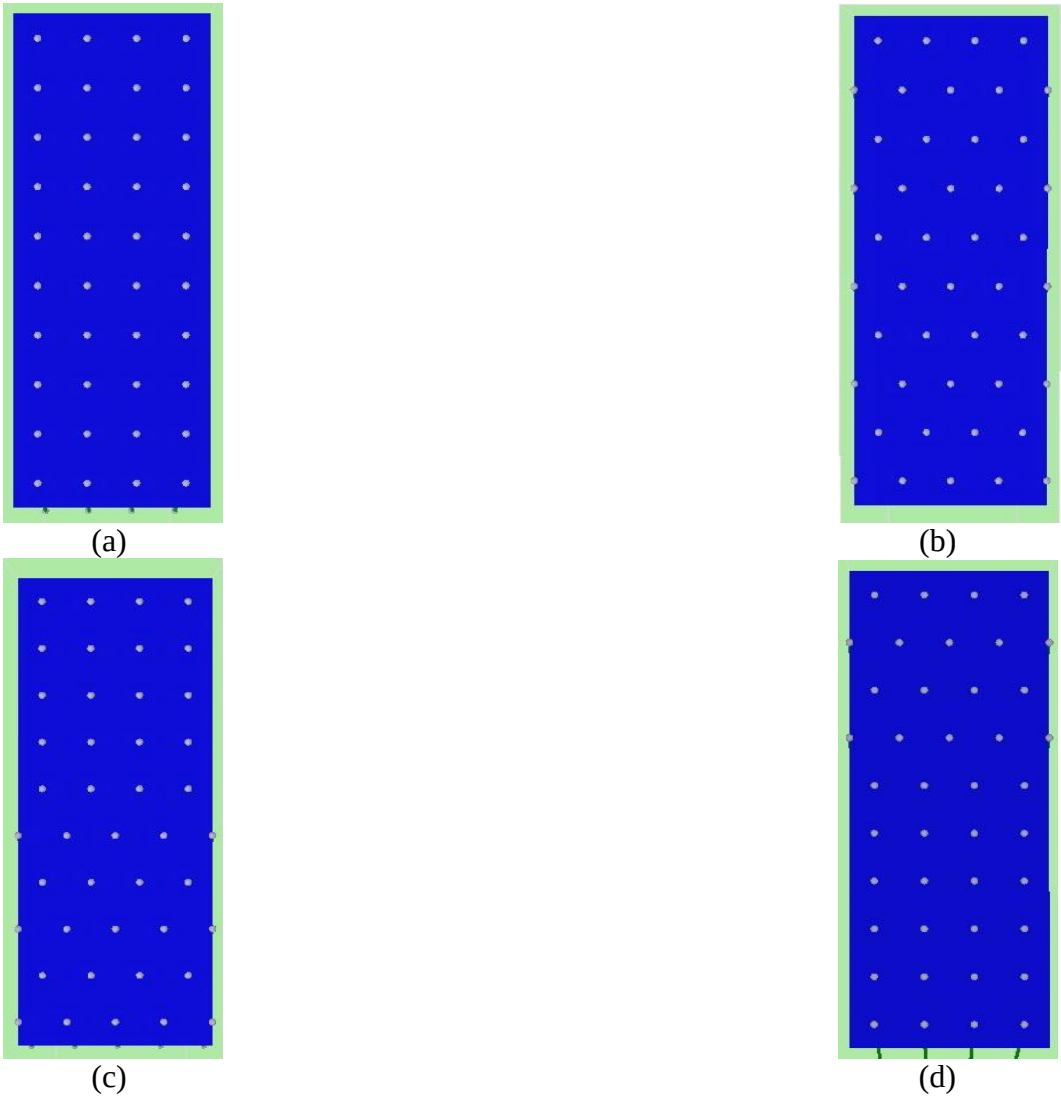

Fig 5: Different types of nails arrangement used in three-dimensional numerical modeling

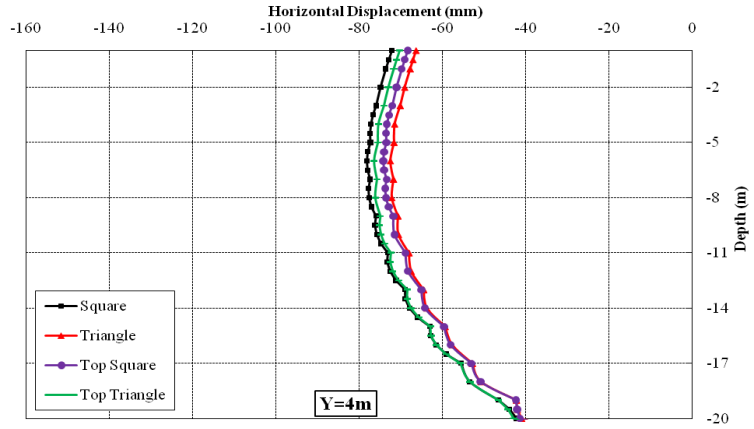

Fig 6: Deformation profiles obtained from several nails arrangement using three- dimensional numerical modeling

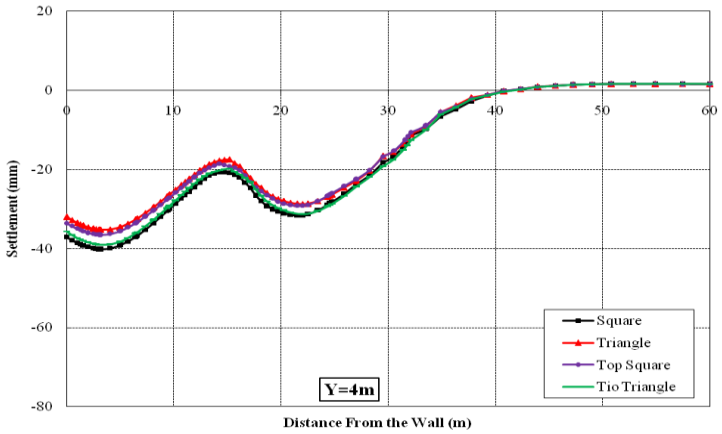

Fig 7: Ground surface settlement profiles obtained from several arrangement using three-dimensional numerical modeling

As seen in figures (6) and (7) the results of horizontal deformation and ground surface settlement in a hybrid configuration (upper square) and triangle are more acceptable.

4 - Conclusion

• One of the appropriate methods for stabilizing excavation, especially for urban excavation is soil nailing. The benefits of this approach can include:
1 - The execution of the top-down method and the ability to run concurrent with excavation
2 - Economy
3 - Easy to implement and less time-consuming and requires low operating force
4 - Increased safety due to the large number of nails and etc.
• Three-dimensional numerical modeling of soil nailing method can examined greatly effective factors that can help us to analysis and design in this method.
• Hardening soil behavior model in order to study of horizontal deformation and ground surface settlement evaluated.
• One of the important factors that affect the behavior of the wall and ground surface settlement in soil nailing method is the arrangement of nails. Arrangement of nails used in the implementation, including square, triangular and upper triangular square is mixed up, in this article evaluate the arrangement of nails and the optimized arrangement was done.
• The results of the two types of arrangement triangle and combination upper square showed minimum horizontal deformation and ground surface settlement.

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