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Numerical Study of Deep Excavations Stability with Nailing Method: Representation of Help Design Tables and Diagrams

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ABSTRACT: Due to the constructions rate in mega cities, deep excavations have been done in civil engineering projects in the past few years. Strengthening the excavation wall is of great importance and has been pointed out in the seventh issue of national construction rules. There are different ways of achieving the critical strength for the excavations wall, such as Truss method, reciprocal support, sheet piling, piling method, diaphragm wall, anchorage and nailing.The initial design of nailed wall in a condition that deep excavation, surcharge, and soil type are difference can be the major challenge for most designers, employers and administratives. These tables and diagrams can give good and appropriate initial view to construction industry insiders.In this article, with the change of resistance characteristic of the soil (cohesion and angle of internal friction) in the range of common soils and as well as a variety of surcharge (0 to 60 kN/m^2) in the brink of the excavation, designs have been made for different deep excavation (maximum for five basements). For each excavation with different characteristics and according to valid codes, several models (on average 50 models) in the limit equilibrium (for calculation safety factor) and finite element software (for calculation displacement and force) reviewed until design have been made economic and finally provided help design tables and diagrams. Nailing system is responsive for a depth of 13 meters in the appropriate lands, but for more depth and surcharge is needed to combined system (For example combined system of nailing and anchorage).

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1- Introduction

One of the important problems and challenges in the construction is protection from excavations and adjacent structures. In most of the constructive projects, especially in cities, earth excavation with the upright wall is necessary.
Using nailed soil method began from three recently decades and until now is taken into consideration as one effective technical method for stability of tranches and protection from excavations. Nailed walls, means soil remained reinforcement by installing steel bars close together in a slope or excavation is in place. Nail tattoo of a cross-section that is stable operation has the ability to hold back the soil.

Reinforced effect for the improvement of the stability can be achieved with the below performance

- As a result of increasing the normal force and shear strength of sliding in the soil friction
- Reducing thrust on the sliding surface of friction and soil adhesion

Many researchers have done a variety of numerical and experimental studies on the stability of walls of the excavation by using nailing [1, 2]. The first paper on the nailing walls was published in 1991. Codes were published by Federal Highway Administration (FHWA) in 2003 which contains tips for drawing. The codes also provide different charts for the initial design without the overhead for the boats, the initial values of the nails and axial force created to show. This study shows that the walls of nail tattoo design are approached additionally with implementation in rural areas [3]. Another study, on the wall nailing materials shown that nailing fittings in the system used inherently in tension and tension within them caused by friction between the nail and the soil. It was also shown that rebars work to resist bending and shear stresses [4]. System design and analysis in this paper are the simultaneous use of two software. Software Geoslope helps to achieved safety factor and if the pit wall is within the acceptable range, with finite element software Plaxis, vertical and horizontal displacement of the pit wall and axial force will be controlled tool.

2- Methodology

In the design of nailed walls assumptions about the design and specifications are required. In this section, the basic values to determine the design assumptions based on the recommended limits in the regulations and recommendations have been presented [3]:

- Slope angles of 90 degrees
- Determine the horizontal and vertical spacing of 1 to 2 m

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between the nails to have an easier performance so that the product is not more than 4 square meters
- Modeling of the nails are rectangular
- The length of nails 0.5H to H.
- In the bottom of the excavation wall, the height shorter than the length of the nails used. It is recommended that the nails should never be shorter than half the height of the wall because of the sliding probability of failure increases.
- As the temporary supporting structures, involved earthquake forces are not considered to be at least 1.35 safety factor the stability.

It should be noted that some soil parameters such as modulus of elasticity, density and Poisson's ratio within a reasonable range, have been fixed. Continue to see results presented in design, reliability coefficients and horizontal displacements of the design in terms of changes in soil cohesion are shown in the graph.

Design variables in this study are:

- Excavation height (H): 4, 7, 10, 13 and 16 m (equivalent to a negative number of floors one to five)
- Surcharge sidelines (Q): 0, 20, 40 and 60 kN/m^2 (equivalent buildings up to six stories)
- Soil cohesion strength (c): 10, 15, 20, 25, 30 kPa (based on soil cohesion proper implementation nailing).
- Internal friction angle (Φ): 27, 31, 35, 39 degrees (based on the values recommended in FHWA)

3- Results and Discussion

In this section and for example, a preliminary design system for excavation to a depth of 10 meters nailing was done Figure 1 shows nailed wall profile with a depth of 10 meters, schematically.

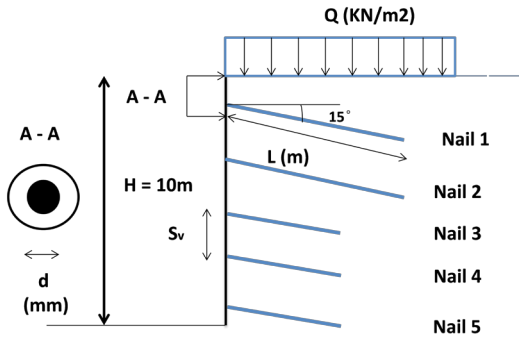

Figure 1. Properties of nailing wall to depth 10 m

In this preliminary design, the vertical distance of the nails (S_v) is 2 meter. Nails horizontal distance from each other (S_h) up to 2 m and at least 1.5 meters is considered. To better control the displacement, a narrow distribution of non-uniform nails and the nails are more superior. Nail tattoo in the axial force into the lower nails (nails No. 4 and No. 5) higher for that reason the diameter of the nails is considered lower. For instance, for a soil with cohesion of 10 kPa and internal friction angle of 35 degrees and a surcharge of 40 kN/m^2, nails properties such as length, diameter and vertical and horizontal distances to adjacent nails in the design table are visible. Nail No. 1 with the length of 9m and diameter of 28 mm while the No. 5 length is 6 m and its diameter is 40 mm. The horizontal displacement and safety factor designed for soils with more cohesion design diagrams in the design diagrams are visible.

Using control charts:

- Horizontal displacement of soil

Considering different soils and surcharges, horizontal displacement of various design model are calculated. That shows for a variety of internal friction angle (Φ), horizontal displacement limit in the range of allowable (for example, for excavation to a depth of 10 m is the maximum displacement 50mm) and by increasing soil cohesion (c) reduce the amount of horizontal displacement excavation walls has found.

- Safety factor

Considering different soils and surcharges, safety factors of various design model are calculated. In all diagrams, safety factors fell into an acceptable range (at least 1.35) and with increasing soil cohesion safety factor will increase. It was observed that all models are located in the range of allowable safety factor, horizontal displacement, and axial force. It should be considered that presented models are primary and in projects with sensitive and special conditions design properties should be changed based on current specifications.

4- Conclusions

In this study, by changing soil resistance properties in common soil territory, as well as a variety of overhead on the sidelines, for excavation with different depths, according to valid codes and using the software limit equilibrium and finite element (calculate more than 300 models) nailing system was designed to stabilize the excavation walls.finally, it helps to provide primary tables and designed charts.

This nailing system is appropriate for excavation to the depth of 13 meters (four basements) with a maximum surcharge of 60 kN/m^2 (Equivalent to the 6-floor building), but for deeper excavations or heavier surcharges, the combination of nailing and anchor is required.

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