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IMPROVEMENT OF SOIL BY NAILING

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Abstract
The basic principle of soil nailing is to embed closely spaced steel bars, or "Nails," into a slope in order to reinforce and fortify the current round as construction proceeds in a "top-down" fashion. This process creates a stable component that is fortified and able to cling to the earth behind it. The soil nailing technique is used to sustain new, extremely steep cuttings because it has the advantage of strengthening the slope with large earthworks to allow construction access and operating in conjunction with widely used retaining systems.
In this article, we have examined several nail factors, including nail length, angle of inclination, spacing, and placement. The height and angle of the slope dictate the optimal nail length. The optimal nail angle has been found to be between 10 and 25 degrees below the horizon, while the slope angle also plays a role. It was shown that the most improvement in F.S. resulted from nail spacing of one millimetre.
Keywords: improvement of soil, Soil nailing, Stability, Reinforce

1. Introduction

Soil nailing is a construction technique used to safely over-steepen soil slopes and fix unstable natural slopes. It has been used in France and Germany since the 1970s for slope stabilization and excavation shoring. In Canada, the temporary excavation shoring market is the main application. The Ground Control Method (GCM) is a hybrid soil nail system that has taken over the temporary excavation shoring market in downtown Vancouver. Drilling-based bar installations involve grouted bars placed at regular intervals across the slope face [1].

1-1- Research Questions

1. How effective is the soil nailing system for varying length, diameter, angle, and distance arrangements?
2. How to optimize the soil nailing system to achieve a high safety coefficient?
3. How does the structure's stability condition differ with and without a soil nailing system?

1-2- purpose of the research

The study aims to examine the possibility of improving soil nailing and its effect on stability and settlement during construction by increasing its length, diameter, angle and dimension, and **Simulations** examining pore water pressure.

2. Previous Studies

Some studies explore the impact of advanced soil models, such as the hardening soil model and the hardening soil with small strain stiffness model, on the performance and stability of soil nail walls. It also examines the impact of soil nail bending stiffness on simulation results. The results suggest that complex models are more effective in soft soil situations [1].

Tan and Chow's 2004 article highlights the risk of additional slope failure during slope remedial works, emphasizing the importance of considering design and construction aspects to ensure slope safety [2].

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The study by Hashemolhosseini, Halabian, and Sheikhbahaei (2010) explores the behavior of soil-nailed walls under dynamic excitations. They create a three-dimensional model using the finite difference approach, considering soil hysteresis behavior. Liner and cable structural elements are used for shotcrete faces and nail bars, with semi-seismic dynamic excitation added. The model is applied to the soil subgrade, with boundary conditions considered antisymmetric [3].
Ankit Raj and Vikrama Panday's 2021 study explores the impact of soil reinforcement, specifically nails, on the stability of a c-υ soil slope. The research uses finite element limit analysis and limit equilibrium methodologies. The findings reveal that soil reinforcement can significantly enhance the stability factor of a naturally occurring c-ϕ soil slope [4].
The study presents an optical fiber monitoring system for evaluating the performance of a soil-nailed slope, overcoming limitations of conventional geotechnical instrumentation systems. The system uses fibre Bragg grating (FBG) sensor technology to continuously monitor slope movements, soil nail strains, and other slope reinforcement elements. The system was successfully tested on a roadside slope in Hong Kong, demonstrating its effectiveness and lessons learned during field deployment [5].
The paper by Babangida, Harahap, and Alsubal (2017) examines the design of soil nail systems for stabilizing soil slopes. They analyze inclination, spacing, and length of soil nails to determine the best parameters for effective stabilization. The study found that inclination affects stability when varying between 5o and 20o to the horizontal, while distance between nails reduces slope stability. The length of soil nails significantly affects stability when there is a deep-seated slip surface [6].
Ashika2, p. V. Prahatheswaran1 (2020) study explores the use of soil nailing for enhancing slope stability in natural and manmade slopes, retaining walls, earth support, and various projects. It uses Plaxsis 3D for analytical analysis and model testing, using sand-sized soil with different slope angles. The study monitors the maximum load carrying capacity, settlement, and behaviour of reinforced and unreinforced soil slopes under increasing surcharge loading [7].
The study by Sayão, Gerscovich, and Lima (2004) examines the impact of excavation depth and nail geometry on stress-strain behavior in vertical nailed excavations. The research found that excavation height and design geometry significantly affect horizontal displacements of nailing soils. However, displacements are insignificant when $L/H \geq 0.6$ and $Sv/L < 25\%$, and can be raised to 50% for shorter excavations [8].

3. Methods of soil improvement

3.1. Cement grouting

Grouting is a technique used to fill ground voids, increase deformation resistance, provide cohesion, shear strength, and compressive strength, and reduce conductivity and interconnected porosity in aquifers [9].

3.2. Dynamic compaction

Dynamic compaction, a controlled, high-energy tamping technique, fortifies weak soils, requiring technical competence and understanding of soil behavior, resulting in significant improvements at lower costs [10].

3.3. Conventional preloading

An embankment is a simple preloading technique, involving pore water to carry load on soft soil. To reduce instability, load should be applied in multiple phases (Figure 1).

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3.4. Vacuum preloading

Fill embankments can be unstable due to weak soil, so vacuum preloading is a suitable method. Originally used by Kjellman in 1952, vacuum consolidation involves air pressure replacing surcharge load. The method involves vertical drains connected to a vacuum pump, which generates negative pressure in the drainage layer. This increases soil stress, leading to negative pore water pressures and accelerating consolidation (Figure 2).

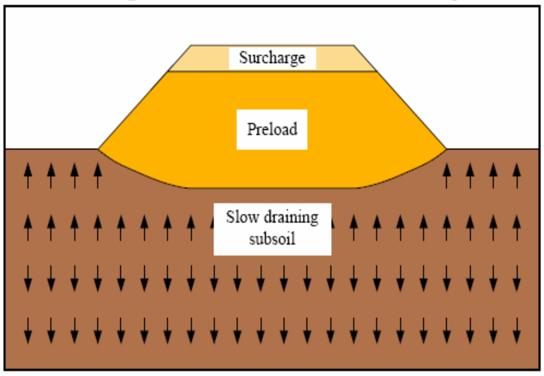

Figure 1: Preloading of subsoil [11].

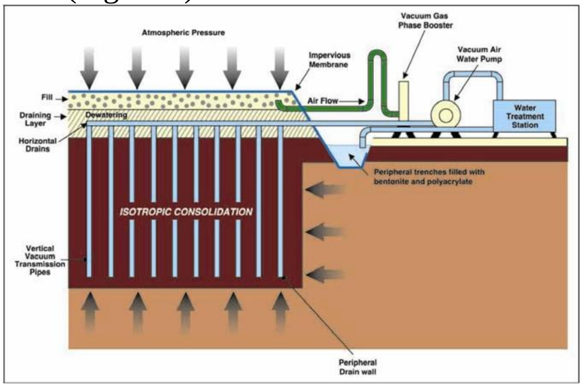

Figure 2: Vacuum system [11].

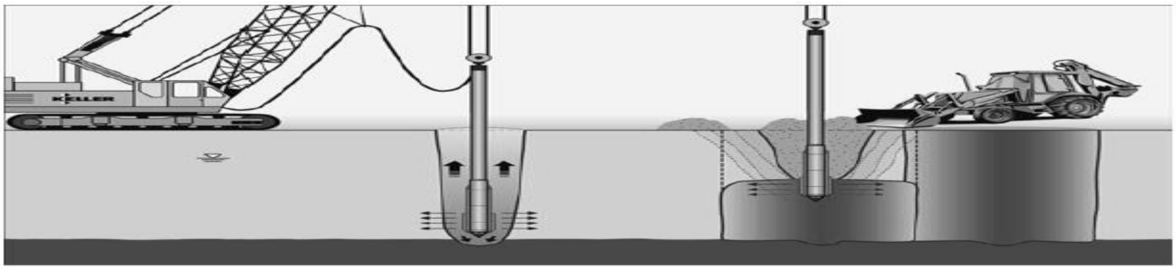

Figure 3: Vibro compaction method operating phases [11].

3.5. Deep vibro techniques

Figure 3 show the vibro compaction technology uses a cylindrical, horizontally vibrating depth vibrator suspended from a crane. It weighs 15-40 kN, is 3-5 meters long, and has a diameter of 30-50 cm. The vibrator's eccentric weight is powered by a motor, and the surrounding earth absorbs the vibration energy. A vibration damper prevents vibration from reaching the extension tubes, and additional air and water supply pipes aid in ground penetration action [12].

3.6. Jet grouting

Without a doubt, the most versatile ground improvement technique on the market is jet grouting. This technique can be utilized to simultaneously strengthen everything, cut off groundwater, and provide structural stiffness. It is also one of the most technically demanding ground improvement systems, requiring equal technical expertise in both design and construction, because failure of any component will result in the failure of the entire product [12].

3.7. Vertical Drains

Because soft clays have low permeability, consolidation settling takes a long time to complete. To shorten the consolidation time, vertical drains are positioned in conjunction with preloading, which can be accomplished through an embankment or vacuum pressure. The underlying soft clay is where the man-made drainage channels known as vertical drains are located. Therefore, the pore water that was squeezed out during clay consolidation can move more quickly in a

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horizontal manner toward the vertical drains because to the hydraulic gradients created by the preloading. The fact that most clay deposits are more permeable in the horizontal plane than the vertical has been exploited [12].

3.8. Elements of a Soil Nail

Soil nails are composed of three main components: tendons, grout, and facing. Tendons support the soil nail wall from below, while grout consists of Portland cement and water. Tendons can be hollow or solid and can be placed into strong drill holes. Grout helps transmit shear loads to the deforming ground, tensile pressures to the surrounding soil, and partially shields the tendons from corrosion.

Corrosion protection is crucial for soil nails, with the least level offered by grout alone. Encapsulating the bar is the best way to prevent corrosion, which can be achieved by gradually grouting the bars and adding a protective sheath. Other methods for preventing corrosion include galvanization, sacrificial steel, or fusion-bonded epoxy coating.

Facing consists of two components: the start and the finish. The initial face is laid on the exposed soil at each excavation lift, while the final face is built on top of the first face. Connection components include nuts, washers, bearing plates, and headed studs. A drainage system is installed beneath soil nail walls to gather and direct surface water away from the wall [13].

3.9. Construction Sequence

The construction process for soil nail walls involves several stages. The first stage involves excavation, drilling of nail holes, nail installation and grouting, and attaching a drain strip. The first face is typically composed of a 4-inch-thick layer of shotcrete with little reinforcing, and a steel bearing plate is placed over the tendon to improve bending resistance. After the shotcrete cures, hex nuts and washers are installed on the nail head, and the first shotcrete is set. The next level is constructed with hex nuts and washers to impart pressure to the bearing plate. The first shotcrete sets for 24 hours, and the next level is constructed with hex nuts and washers. The final facing is built before the excavation's bottom is reached, and nails are inserted and checked. Prefabricated panels, reinforced shotcrete, or CIP reinforced concrete can be used for the final facing. Wee pholes, drainage ditches, and foot drains are added to release any water that may have built up in the continuous strip drain. The construction sequence may need to be changed to accommodate unique project conditions, such as using shotcrete immediately after excavation or grouting the drill hole before inserting the tendon into the wet grout [13].

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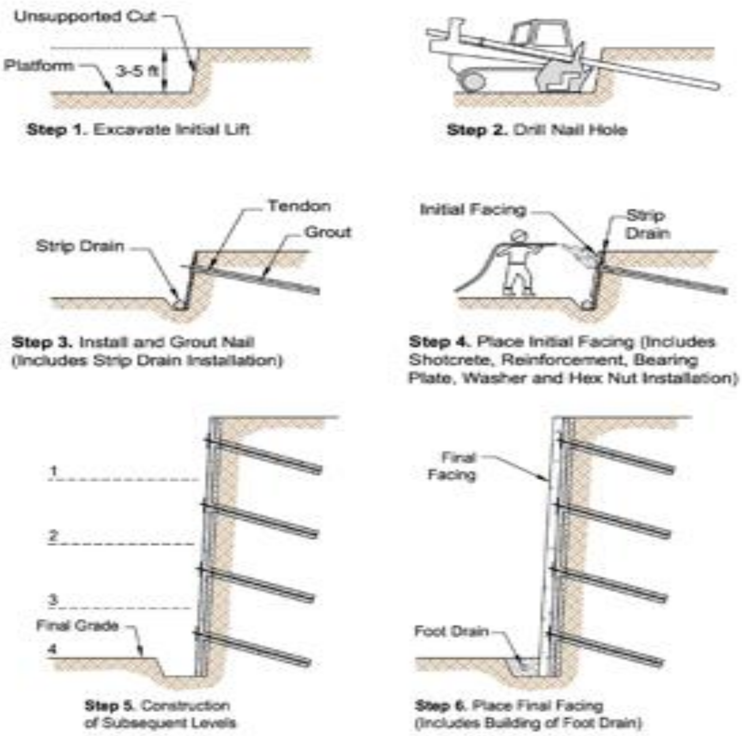

Figure 4: For example. Typical process for building a soil nail wall [14].

3.10. Applications of Soil Nail

Soil nail walls are used in various applications in roadway design, including road cuts, tunnel portals, repair and reconstruction of existing retaining structures, hybrid soil nail walls, and shored mechanically stabilized earth (SMSE) walls. Roadway cuts use soil nails due to their low excavation requirements and ample right-of-way (ROW) and clearing limits, which help alleviate environmental effects and reduce traffic impact.

Tunnel portals can also be strengthened with soil nails, but there are additional considerations in planning and construction. The shotcrete facing above the vertical stability of the tunnel must be given priority, and soil nail loads may be transferred to the tunnel structure at the portal. A detailed examination of the interactions between soil nails and the original shotcrete support and tunnel lining is required.

Soil nail walls can be used in conjunction with other wall systems such as MSE walls and ground anchor walls to maximize the advantages of each technology. This combination may be more cost-effective in cut-and-fill situations than full-height MSE walls or drilled shaft retaining walls. Hybrid soil nail walls combine soil nails with ground anchors, which can be applied in places where the usage of soil nails in the upper parts is forbidden by utilities or other subsurface barriers.

Shorted mechanically stabilized earth (SMSE) walls are increasingly being used in conjunction with MSE walls to widen low-volume roadways when fill is laid on steep terrain. Excavation is necessary for a level bench for the installation of soil reinforcement, but soil nail walls can be used in conjunction with MSE walls to provide a level bench for the installation of soil reinforcement.

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3.11. Benefits and Drawbacks of Soil Nails

Soil nailing offers several benefits, including construction, performance, and cost. It requires less ROW and is less harmful to the environment than other methods like soldier pile walls or drilled shafts. It can be easily modified to handle obstacles like stones, piles, or underground utilities, making it more cost-effective for sites with limited access. Soil nail walls can accept curves and bends more easily than other top-down construction wall systems.

In terms of performance, soil nail walls can accommodate significant differential and total motions, are durable in seismic events, and have more reinforcing elements per unit area of wall. They can also be sculpted facings for a more natural appearance. They can sometimes be less expensive than standard concrete gravity walls for walls over 12 to 15 feet high.

However, soil nailing has limitations, such as stringent wall movement restrictions, restrictions on the position, slope, and length of the nails, and potential problems with communication lines directly adjacent to the soil. These drawbacks make it a less recommended choice for projects with stringent wall movement restrictions [15].

3.12. Methods of Construction

The following are the main steps in the soil nail wall construction sequence:

1. **Excavation**

Soil nail walls may not be the ideal choice for projects with tight wall movement restrictions due to restrictions on their position, inclination, and length. They are also inappropriate in areas with significant groundwater input. Permanent soil nail walls require subterranean easements and may cause issues for communication lines. Surface water controls should be installed before starting drigging to prevent water entry. Collector trenches redirect and intercept surface water, and excavation faces are removed using mass excavation or earth-moving equipment. Manual excavation is required for rocks or cobbles. Standard nail installation requires a level work surface and a compact track drill (Figure 5).

Figure 5: Photo. Digging of a soil raise for the purpose of building a soil nail wall. Images provided by Moretrench American Corporation [15].

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2. Drilling nail holes

A variety of drilling techniques, such as rotary, percussion, auger, and rotary-percussion drilling, are used to drill nail holes. Table 3-1 provides a summary of popular drilling tools and methods (a, b, c). This chart can serve as a guide for the design engineer because the equipment chosen must meet the necessary total nail length and nail diameter, as well as operate under the expected ground conditions [16].

Table 1a: Utilizing Hydraulic Rotary Augers to Drill Competent Soils [16].

Drilling Method	Cased?	Cuttings Removal Method
Lead Flight Kelley-Bar Driven	No	Mechanical
Sectional Solid-Stem	No	Mechanical
Sectional Hollow-Stem	Yes	Mechanical (air support)
Continuous Flight Solid-Stem	No	Mechanical
Continuous Flight Hollow-Stem	Yes	Mechanical (air support)

Table 1b: Rotating Methods for Drilling Rock and Soils with Hydraulic Air and Water [16]

Drilling Method	Cased?	Cuttings Removal Method
External Flush Open Hole	No	Water
External Flush Cased	Yes	Water
Duplex	Yes	Compressed Air or Water

Table 1c: Methods for Top Hole Hammer Drilling with Pneumatic Rotary in Competent Non-Caving Rock or Soils [16].

Drilling Method	Cased?	Cuttings Removal Method
External Flush Open Hole	No	Compressed Air

3. Installing the grout and nails and Installing the strip drain

Once the tendon is inserted, use a tremie pipe to pour cement into the drill hole (Figure 6). After inserting the grout pipe all the way to the bottom, grout is poured into the drill hole. Grout adheres to the surrounding soil and the tendon as it solidifies. Gravity grouting is one technique that frequently yields bond strengths strong enough to make soil nailing practical and reasonably priced. However, in order to maintain adequate soil nail lengths, stronger bonding may be required in situations when adverse soil conditions exist. In weak fissured rock and granular soils, grout can be injected into the casing at relatively low pressures to provide good bond resistance. The surrounding grout created greater restricting forces. , These increases in bond strength can be attributed to the surrounding soils' compaction, the grout's increased effective diameter, and the improved interlocking between the soil and grout when compared to strengths attained with gravity grouting. Since pressure grouting through the casing only

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slightly improves bond resistance—especially in saturated soils—it is rarely utilized for fine-grained soils [16].

Figure 6: Solid nail tendon implantation

4. Results and Discussion

The analysis of soil nailing is presented in Chapter 4 to ascertain how the element of safety is affected by internal friction (υ), length cohesion, spacing, and number of nails (N).

4.1. Parametric Study on factor of safety (F.S)

4.1.1. Effect Soil Nail Spacing

Soil nails are typically oriented at an inclination of 10 to 20 degrees from the horizontal. Grout can move from the drill hole's bottom to its head because to these inclinations. Depending on the drill hole's size and composition, grout can frequently fill a hole without leaving air pockets. Nail inclination angles should be kept below 10 degrees to avoid grout gaps and an extended "bird's beak" at the nail head. Pullout resistance and corrosion prevention may be more challenging in the presence of void areas. [2].

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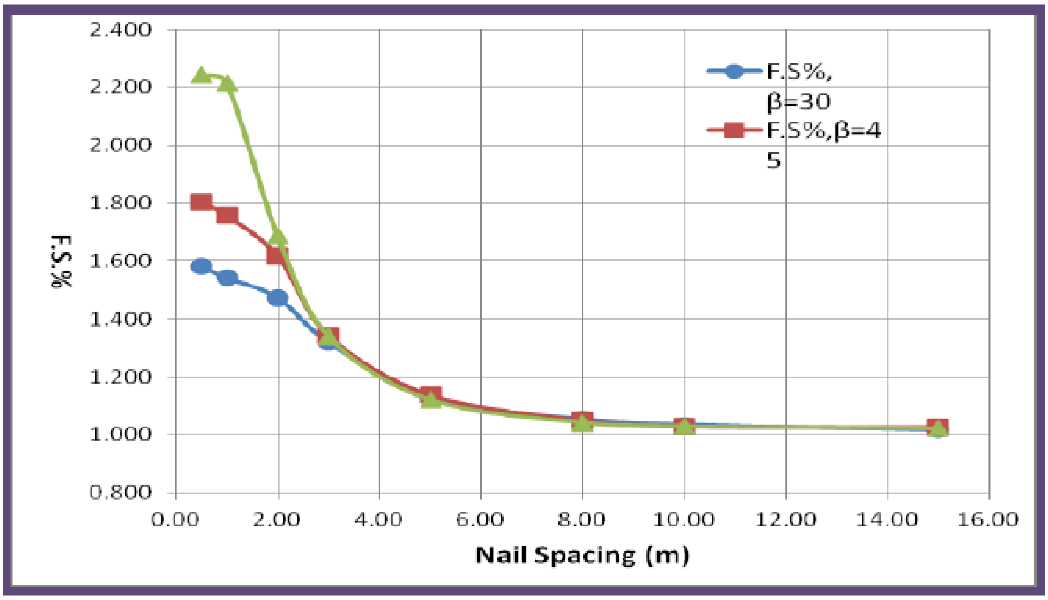

Figure 7: Nail Spacing. F.S. Improvement Percentage (F.S%)[2].

4.1.2. Effect Soil Nail Length

To get a rough cross section for investigation, the soil nail length can be roughly calculated as 0.7H, where H is the wall height. In cases of (i) poor soils; (ii) deep-seated critical slip surfaces; (iii) large surcharge loads behind the wall; and/or (iv) increasing back slope behind the wall, longer nails will be required. In general Broken nails, in speaking, get a little shorter. All other things being equal, a 10% batter reduces the soil length needs by around 10% to 15% as compared to walls with vertical faces. If, with carefully selected parameters and an acceptable stability evaluation, nail lengths are required to surpass around 1.2H, this result may suggest that the ground is unstable and should not be used with soil nail walls. It is unlikely, nonetheless, that nail lengths shorter than 0.5H will be sufficient to provide sliding stability. Nails that are longer than 0.6H are rare [2].

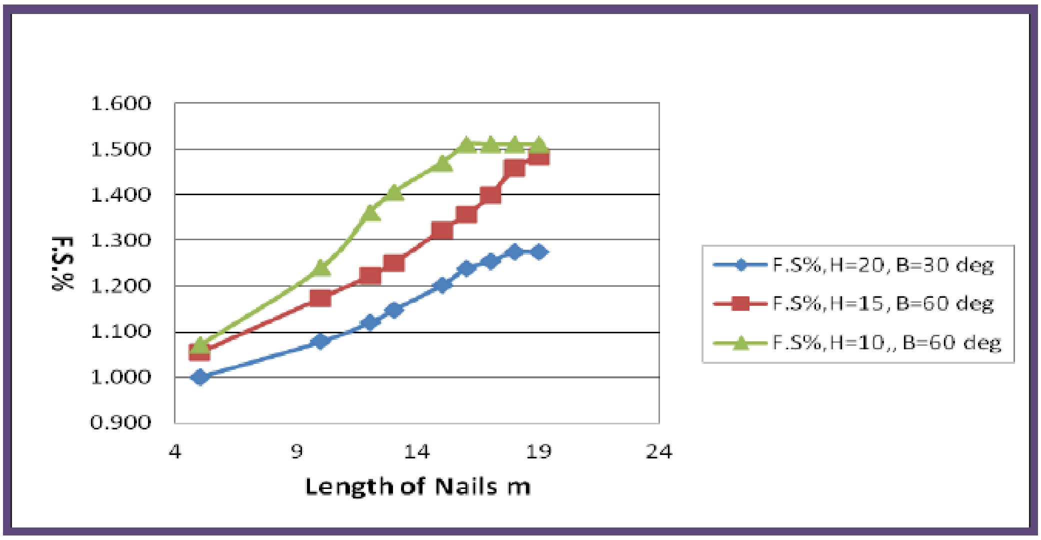

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Figure 8: Relation between Length of Nails and F.S Improvement Percentage, β=30o[2].

4.1.3. Effect cohesion of soil on satety factor

Fig. 9 illustrates the virtually linear increase in FoS with cohesiveness that has been achieved. An explanation could be found in the linear relationship between a soil's cohesiveness and shear strength. As a result, a linear improvement in FoS with cohesiveness has been found. The authors want to highlight how vegetation and a slightly moist soil matrix can both improve a geomaterial's cohesiveness[13]. This means that the FoS of the soil slope may significantly decrease following a significant rainstorm. This might cause the soil to saturate and lose its apparent cohesiveness, which would ultimately cause the soil slope to collapse catastrophically. Because of this, when determining the proper safety factor and computing. [4]

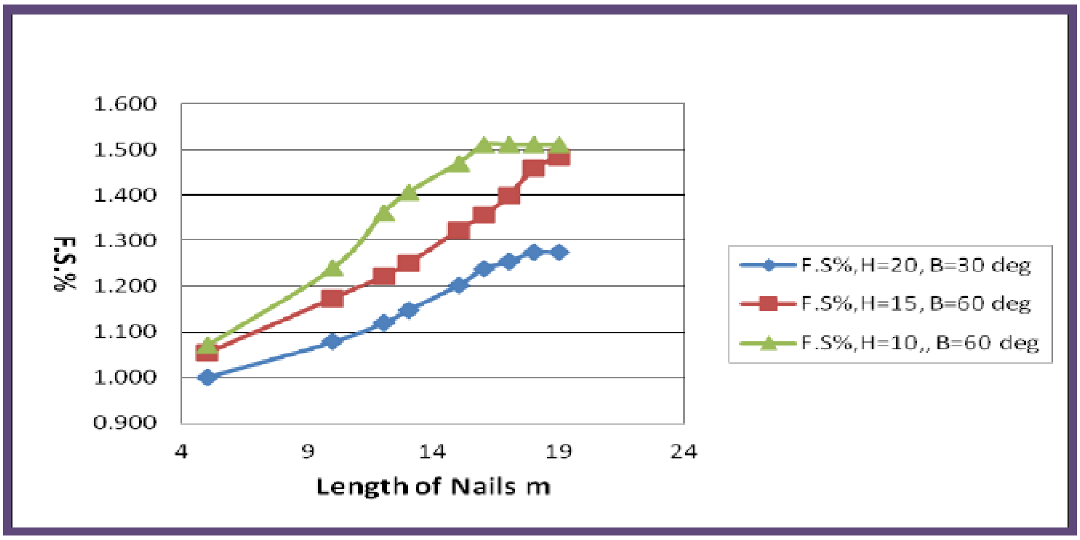

Figure 9: Variation of F.S with cohesion of soil [4].

4.1.4. Effect angle of internal friction (ϕ) on safety factor

The impact of the internal friction angle on the soil slope's overall stability factor is covered in this section. Six distinct friction angle values (ω = 10, 15, 20, 25, 30, and 35°) have been taken into consideration for the analysis. Figure 10 shows the variation of FoS with friction angle.

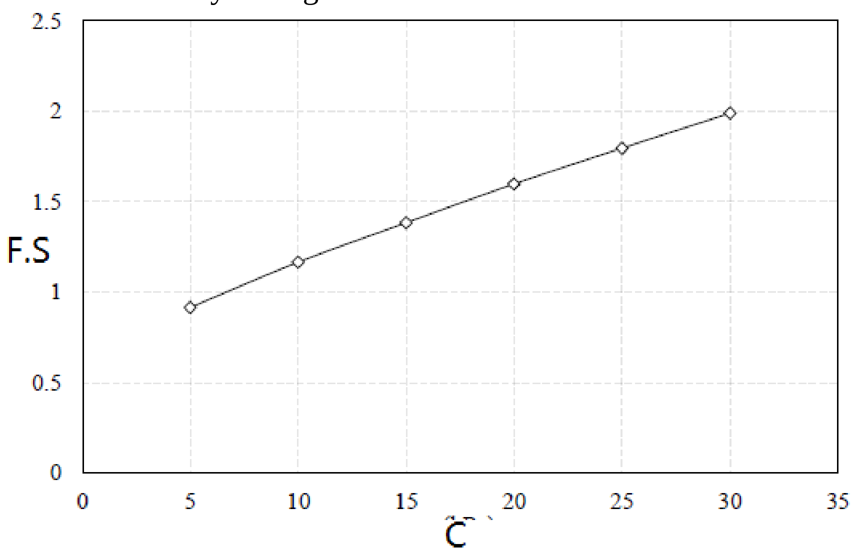

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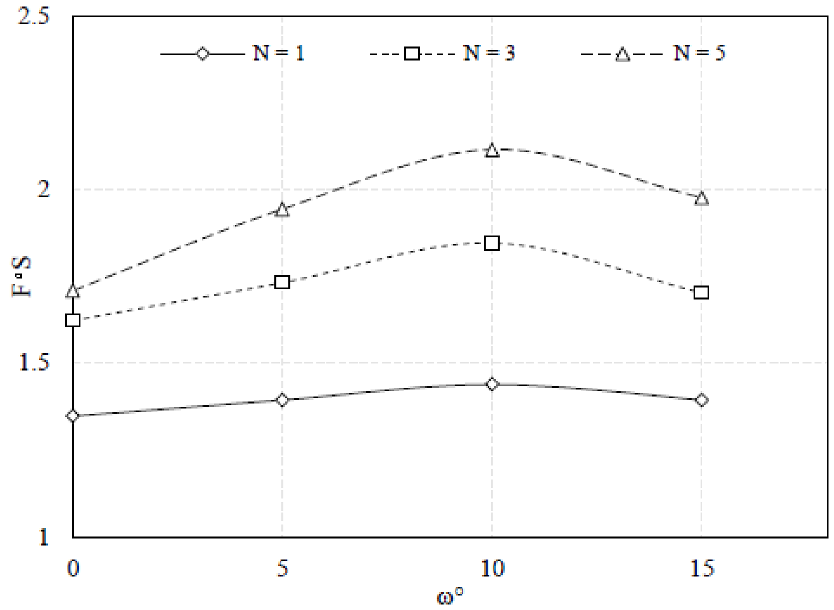
Figure 10: F.S. variation with internal friction angle (ϕ) [4].

4.1.5. Effect of number of nails (N) and inclination angle (ω)

By altering the number of reinforcing layers (N) and the associated inclination angles (ω), a series of investigations were conducted to determine the impact of these factors on the FoS of the soil slope. Fig. 11 shows the fluctuation of FoS with the number of layers (N) and inclination angle (ω).

Figure 11: Variation of F.S. with nail angle (ω) and number of reinforcement layers (N) [4].



5. Conclusions

1. The addition of nails as soil reinforcement significantly improves the FoS.
2. For every nail taken into consideration in the study, the FoS increases as the nail's inclination angle increases.
3. FoS varies almost linearly as soil cohesiveness increases.
4. Similarly, the FoS significantly increases when the soil's friction angle increases.
5. If only one nail line is being utilized, it should be positioned in the middle of the slope's two thirds length.
6. The ideal nail length, with a spacing greater than to produce a block appearance, is clearly correlated with slope angle and height. When there is a block effect due to spacing, the failure surface pushes behind the block (the nail group) and increases in length due to the inability of the failure surface to pass through. This results in an increase in failure surface length.
7. The ideal nail inclination is from five to twenty-five degrees below the horizon. It is possible to find a relationship between the slope angle and the nail angle, which could be helpful for the design process.
8. When nails are spaced more than two meters apart, the effect of the spacing is very consistent throughout a range of slope angles. The behaviour changes somewhat when determining the F.S% in the opposite scenario when the spacing is equal to or less than

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two meters since it is correlated with the slope's length (Ls). A cluster of nails spaced 1.5 meters apart may create a block in the soil between them, making it difficult for failure surfaces to move through.

References

[1]Vikas Pratap Singh • G. L. Sivakumar Babu.(2010). Article by title"2D Numerical Simulations of Soil Nail Walls".International Journal of Geotechnical Engineering , 28:299–309.

[2] Tan, Yean-Chin1 and Chow, Chee-Meng2. (2004) ." Slope Stabilization Using Soil Nails: Design Assumptions and Construction Realitiesl Taylor & Francis Group, London.

[3] Sheikhbahaei, Alimohammad; Halabian, Amir M.; and Hashemolhosseini, S. Hamid.(2010). "Analysis of Soil Nailed Walls Under Harmonic Dynamic Excitations Using Finite Difference Method". International Conferences on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics.

[4] ankit raj1, vikrama pandey2.(2021)."a comprehensive investigation on nailing technique in improving the soil slope stability". international research journal of modernization in engineering technology and science.

[5] Hong-Hu Zhu1, Albert N.L. Ho2, Jian-Hua Yin3.(2012)." An optical fibre monitoring system for evaluating the performance of a soil nailed slope ". Smart Structures and Systems , 9: 393-410.

[6] Shamsan Alsubal, Indra S. H. Harahap and Nuraddeen Muhammad Babangida.(2017). "A Typical Design of Soil Nailing System for Stabilizinga Soil Slope: Case Study".Indian Journal of Science and Technology, 10:25-51

[7] v. prahatheswaran1, p. ashika2.(2020). "an experimental and analytical study of slope stability by soil nailing".international research journal of engineering and technology,7:101-120

[8] A. P. Lima, D. M. S. Gerscovich and A. S. F. J. Sayão.(2004). "Considerations on the soil nailing technique for stabilizing excavated Slopes".Internationalsypmosium on land slides,2:1671-1676.

[9] Sina Kazemian.(2009) Assessment and Comparison of Grouting and Injection Methods in Geotechnical Engineering,27 (2):234-247

[10] Chow,Y.K., Yong, D. M., Yong, K. Y., Lee, S. L. (1990) ."Monitoring of dynamic compaction by deceleration measurements", Computers and Geotechnics, 90 (3): 189-209.

[11] Dhar, A.S., Siddique, A., Ameen, S.F. (2011). "Ground Improvement using Pre-loading with pref -abricated Vertical Drains". International Journal of Geoengineering Case Histories, 2 (2): 86-104.

[12] Moseley, M. P. (2000). "Ground Improvement".second Edition, taylor&francis Group, london.

[13] porterfield, j.a., cotton, d.m., and byrne, r.j. (1994). “soil nailing field inspectors manual, demonstration project 103,” report no. fhwa-sa-93-068, federal highway administration, washington, dc.

[14]API (2009). “Recommended Practice for Field Testing Water-based Drilling Fluids,” 4th Ed. Publication API RP 13B-1, American Petroleum Institute, Washington, DC.

Western European Journal of Linguistics and Education
Volume 2, Issue 7, July, 2024
https://westerneuropeanstudies.com/index.php/2
ISSN (E): 2942-190X Open Access| Peer Reviewed

[15] Morrison, K., Harrison, F., and Anderson, S. (2006). "Evolution of Mechanically Stabilized Earth Wall Design to Incorporate Permanent Shoring," GEO-Volution, Denver, CO, 5: 149-157.
[16] Elias, V., and Juran, I. (1991). "Soil Nailing for Stabilization of Highway Slopes and Excavations," Report No. FHWA-RD-89-198, Federal Highway Administration, Washington, DC,3:86-91.