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Study of Slope Stability using Flexible Facing

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Abstract

An experiment was conducted to evaluate the load-bearing capacity of a soil nailing system that consisted of four 10mm nails and four 12mm nails, reinforced in a slope with three different flexible facing materials: geo-composite facing, aluminium facing, and galvanized iron facing. The nails were spaced 200mm apart horizontally and vertically from centre to centre. The results of the stress-strain test showed that the geo-composite and galvanized iron facings with 12mm diameter nails exhibited high strength of 0.25N/mm2 with less displacement. The relationship between stress, displacement, and the type of nails used with identical facing was examined. The stability of the slope was also analysed to investigate the impact of nail parameters and type of facing on displacement under varying loading conditions.

1. Introduction

Slope stability is a critical factor in many civil engineering projects, as the failure of a slope can result in significant damage to infrastructure, property, and even loss of life. Soil nailing has emerged as a popular technique for stabilizing slopes and excavations, by inserting steel reinforcing bars or "nails" into the soil and grouting them in place. However, the use of soil nailing alone may not be sufficient in all cases, particularly when dealing with steep or highly erodible slopes. Flexible-facing materials such as geotextiles, geogrids or reinforced concrete panels are often used in combination with soil nailing to provide additional support and protection to soil slopes. The use of flexible facing in soil nailing can improve the stability of a slope, reduce the risk of failure, and enhance the aesthetics of the site. Utilizing flexible-facing materials, like geotextiles, geogrids, and other erosion control products can improve the effectiveness and durability of soil nail walls while decreasing the environmental significance of using rigid materials like concrete or masonry. These flexible materials can adapt to the shape of the soil and create a strong protective layer against soil erosion, enabling vegetation growth to contribute to the overall slope stability, the use of soil nailing with flexible facing material can offer an efficient and eco-friendly approach to address slope stability problems, leading to long-lasting slope stability while reducing environmental impacts. soil nailing is a valuable solution that offers numerous benefits for sustainable construction. Numerous factors, including soil characteristics, nail system design, and installation techniques, must be considered to ensure the effectiveness of soil nailing. Nail diameter, length, spacing, inclination, and material are some of the key parameters that can affect the effectiveness of soil nailing. Nail diameter is an essential parameter that determines the capacity of the nail to resist tensile forces. The nail spacing is another critical parameter that affects the overall stability of the soil nailing system. A careful evaluation of the soil properties and the load

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conditions is necessary to determine the most appropriate nail parameters for a given application. Optimal soil nail spacing depends on several factors, including the soil type, soil strength, slope stability, and the intended use of the structure or object being built. In general, a closer soil nail spacing provides a stronger connection between the reinforcing elements and the soil but also requires more nails and can increase the cost of the project. This study aimed to examine how various soil nailing parameters impact slopes' safety factors. The safety factor of a slope is influenced by various factors, including soil-nail horizontal spacing and diameter. Based on the results of this study, the optimal soil-nail horizontal spacing range for this slope is from 1 m to 2 m, and the optimum diameter is between 0.08 m and 0.12 m. It is essential to carefully select these parameters to ensure the stability of the slope. Further research is necessary to investigate the effects of other factors such as soil type and slope angle on the safety factor of slopes reinforced with soil nails [1]. The strength reduction approach is used in this study to investigate how slope stability is impacted by soil nail reinforcing. The goal of the research article is to use numerical analysis to examine the effect of soil nail reinforcement on slope stability. The study identifies that the ideal position for the nail is roughly midway up the slope, while the horizontal spacing of the nails influences the strength characteristics of the reinforced slope and establishes the upper and lower limits of the factor of safety when s/D increases from 1 to ∞. The behaviour of the factor of safety can be explained by a rational equation [2]. The study used numerical simulations to analyse how the angle and length of soil nails, along with surcharge loads, affect the stability and deformation of soil-nailed slopes during staged excavation. It was determined that soil nails installed higher up were more effective in improving stability, while those placed lower down were better at reducing horizontal displacement. This is because the lower nails had longer geogrid lengths that extended beyond the possible failure areas [3]. The research investigated the influence of nail spacing on soil nailing design by employing the Limit Equilibrium Method (LEM). The study presumed a bilinear failure surface consisting of two rigid blocks and computed the factor of safety utilizing the Morgenstern-Price method. Nail spacing is a crucial factor in determining the safety of a soil-nailed wall, as nails that are too far apart (greater than 2.00 m) can make the wall unsafe with a global stability factor of safety of less than 1.1. However, having nails too close to each other can result in a design that is too expensive and difficult to construct [4].The exceptional tensile and shear strength of geo-composites makes them well-suited for withstanding the utmost stress conditions in slopes. Additionally, the introduction of flexible facings redistributes stress and significantly improves stability, with stress thresholds exceeding 50% compared to slopes without such facings [5]. Through numerical analysis employing cable and pile elements, the study revealed that an increase in nail diameter resulted in elevated axial forces. Nonetheless, the increment in resisting axial and shear forces on the nail grout surface in the axial direction was insignificant, while the resisting shear force on the nail's cross-section, bending moment, and normal force mobilized on the nail grout surface in the axial direction increased. The outcomes demonstrated that bending played a critical role in the stabilization mechanism, as a larger proportion of the driving forces was countered by bending with an increase in nail diameter [6].

2.1. Physical properties of soil

Firstly, soil samples are gathered from Chandigarh University's campus. Then the soil undergoes various tests following the IS2720-1983 code to establish its index properties. The tests include determining the moisture content of the soil, specific gravity, sieve size analysis, consistency limit, and standard proctor test. The objective of these tests is to categorize the soil type. The examined soil sample has a specific gravity of 2.6. The soil's liquid limit is 16.30%, and its water content is 16%, indicating the proportion of water in the soil concerning its dry weight. The soil's highest dry density is 1.88 kg/m3, and its optimum moisture content (OMC) is 13%, which is critical in determining the quantity of water necessary to attain the desired density during compaction.

According to the sieve analysis graph Cu = 3.22 and Cc = 0.25, if Cu is less than 6 and Cc is less than 1 then the soil is considered poorly graded sandy soil.

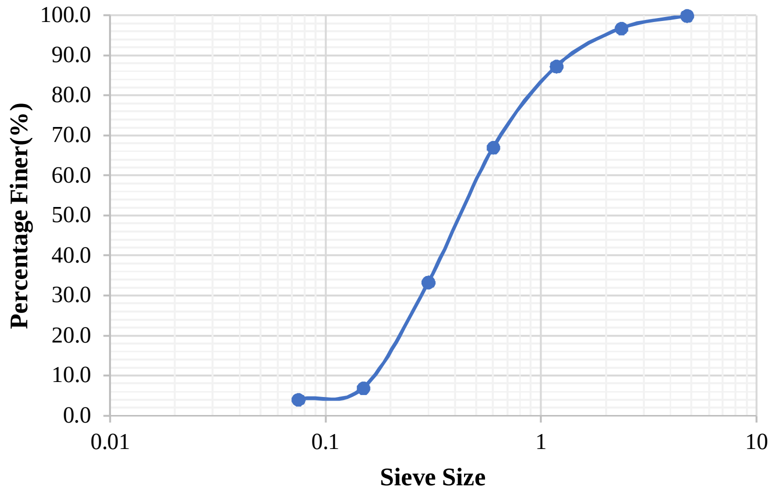

Figure 1. Sieve size analysis.

2. Materials and Methodology

The effectiveness of the soil nailing technique for stabilizing slopes is assessed through a laboratory model. The physical model is designed in adherence with the regulations specified in the US Code FHWA-NHI-14-007 [7]. A study is being conducted using a square pattern of four nails, along with different facing materials, to observe the effects of stress on them. The length of the nails can be adjusted between 0.7H to H, as per the US - FHWA NHI-14-007-FHWA-GEC 007 February 2015 code. Four Steel bars with diameters of 10mm (N) and 12mm (N′) and a length of 32 cm are being used in the experiment in a square pattern with a horizontal spacing (S_h) and vertical spacing (S_v) of 200mm centre to centre. A 5-tonne bottle hydraulic jack is used to apply pressure, operating on the screw action principle. The flexible sensor installed in the nail functions like a variable resistor, with its resistance increasing as the nails bend. Four such sensors are connected to the main electric board through copper wires and a multi-meter is used to measure the resistance detected by the flex sensor. The strain is then calculated using the formula: Strain = $\frac{\frac{\Delta R}{R}}{\Sigma c}$

Here, **Σ**c stands for gauge factor, and its value ranges from 2 to 2.5. For 200 K, the gauge factor is 2.1.

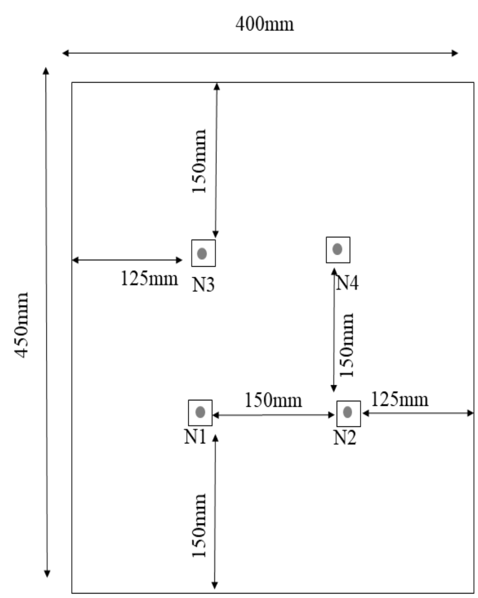

Figure 2. Square arrangement of nails

2.1. Flexible materials

This study aims to investigate the behaviour of flexible-facing materials on slopes that have been reinforced using soil nails of different diameters, particularly about their capacity to withstand displacement when loaded. The study makes use of various materials, including geo-composite facing, galvanized iron mesh, and diamond-shaped aluminium wire mesh, intending to achieve reinforcement and strength applications cost-effectively by leveraging the best properties of each material. For example, the geo-composite material combines the optimal characteristics of several materials used in these applications. Additionally, galvanized iron mesh exhibits high strength in both longitudinal and transverse directions, and it also enhances the bearing capacity of the soil, thereby minimizing soil erosion.

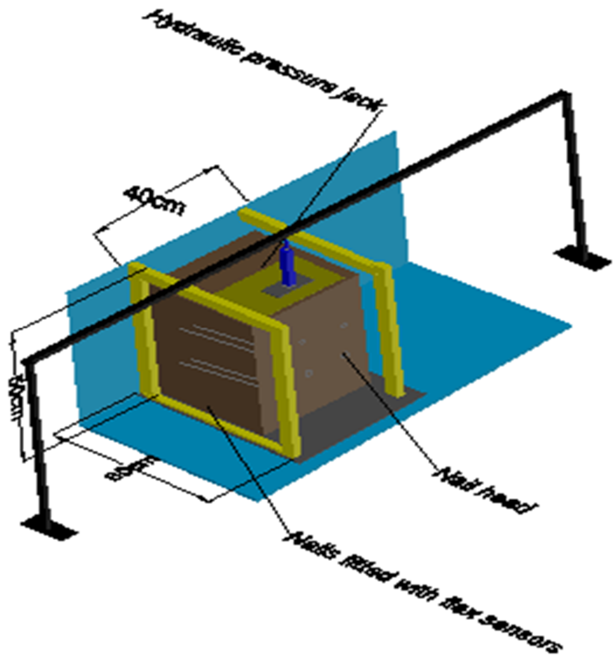

Figure 3. Physical model 3D. (10)

3. Results

The present research work aimed to assess the feasibility of utilizing different reinforcement materials, namely galvanized iron mesh, geo-composite, and diamond-shaped aluminium wire mesh, for enhancing the performance of 10 mm diameter nails placed at 200 mm from each other. The study focused on evaluating the materials' ability to endure tensile forces while minimizing both vertical and horizontal displacement when subjected to loads. Correlation graphs were utilized to analyse the stress-strain relationship, and data on displacement measurements were recorded. The results indicate distinct behaviours and performance characteristics for each material, shedding light on their suitability for specific applications. This discussion will delve into the key findings, enabling a comprehensive comparison of the materials' effectiveness in reinforcing the nails and mitigating displacement under load.

3.1. Slope without facing, nail spacing 200 mm (10 mm nail diameter)

Figure 4 reveals that the slope of the relationship abruptly decreases beyond a stress level of 0.1 N/mm², indicating a failure point for the nails without any additional reinforcement. In Figure 5, the relationship between stress, measured in N/mm², and both horizontal and vertical displacement, measured in cm, is illustrated. The recorded data indicates that there was a displacement of 1.7 cm horizontally and 1.5 cm vertically. This implies that under the applied stress, the nails experienced a significant amount of displacement in both the horizontal and vertical directions.

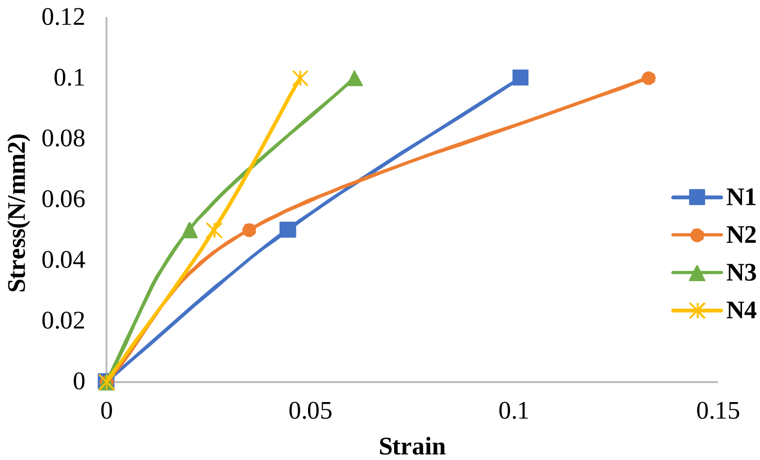

Figure 4. Stress vs. strain values for slope without facing, spacing 200 mm (10 mm).

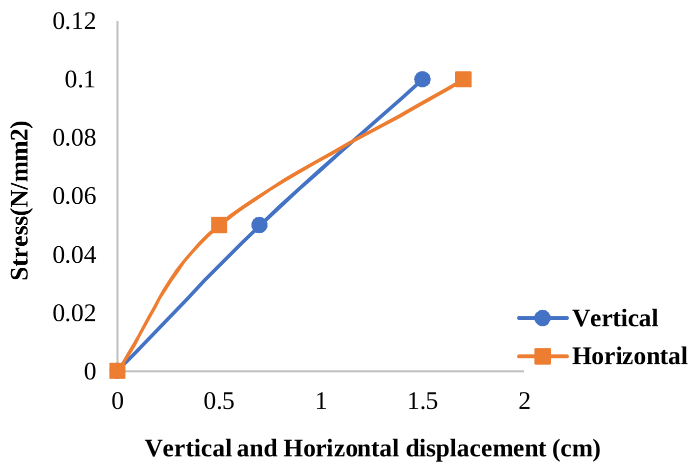

Figure 5. Stress vs. ΔV and ΔH values for slope without facing, spacing 200mm (10mm).

3.2. Slope with geo-composite facing, nail spacing 200 mm (10 mm nail diameter)

Figure 6 reveals that the slope of the relationship reaches a failure point at a stress level of 0.2 N/mm² when a geo-composite facing is utilized. This indicates that the nails, reinforced with the geo-composite facing, exhibit a higher stress resistance compared to the nails without any additional reinforcement (as shown in Figure 4). In Figure 7, the relationship between stress, measured in N/mm², and both horizontal and vertical displacement, measured in cm, is depicted. The recorded data indicates that there was a displacement of 1.6 cm horizontally and 1.5 cm vertically. This suggests that under the applied stress, the nails with the geo-composite facing experienced a significant amount of displacement in both the horizontal and vertical directions, like the nails without reinforcement (as observed in Figure 5).

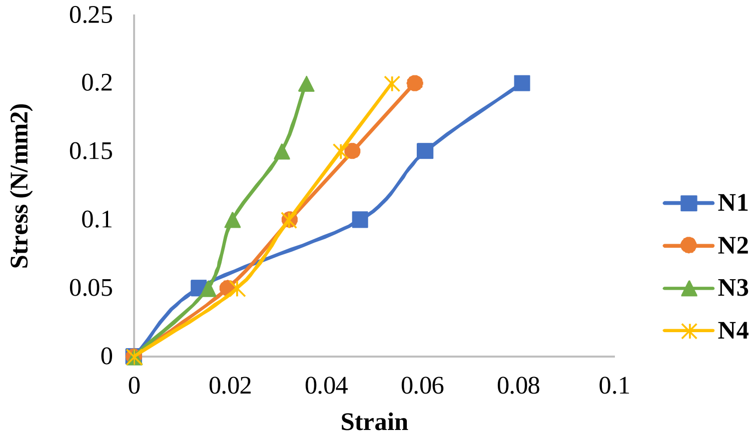

Figure 6. Stress vs. strain values for slope with LDPE geo-composite facing, spacing 200 mm (10 mm).

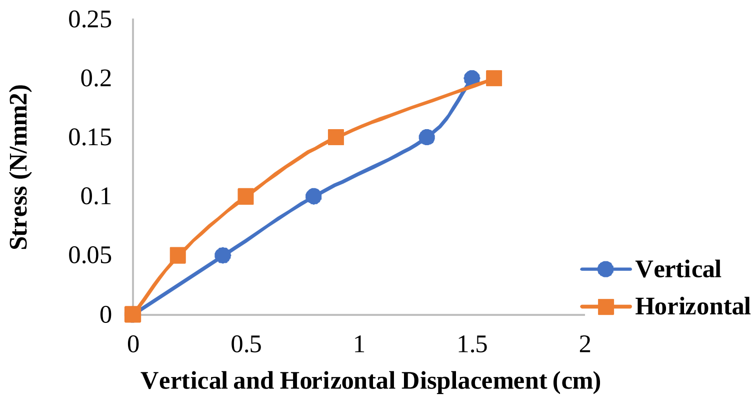

Figure 7. Stress vs. ΔV and ΔH values for slope with LDPE geo-composite facing, spacing 200 mm (10 mm).

3.3. Slope with galvanized iron facing, nail spacing 200 mm (nail diameter10 mm)

Figure 8 indicates that the slope of the relationship reaches a failure point at a stress level of 0.15 N/mm² when galvanized iron wire mesh facing is utilized. This indicates that the nails, reinforced with the galvanized iron wire mesh facing, exhibit a higher stress resistance compared to the nails without any additional reinforcement (as shown in Figure 4) but a lower resistance compared to the nails with the geo-composite facing (as shown in Figure 6). In Figure 9, the relationship between stress, measured in N/mm², and both horizontal and vertical displacement, measured in cm, is illustrated. The recorded data indicates that there was a displacement of 2.0 cm horizontally and 1.2 cm vertically. This suggests that under the applied stress, the nails with the galvanized iron wire mesh facing experienced a significant amount of displacement in both the horizontal and vertical directions, which is slightly different from the displacements observed for the nails with the geo-composite facing (as observed in Figure 7).

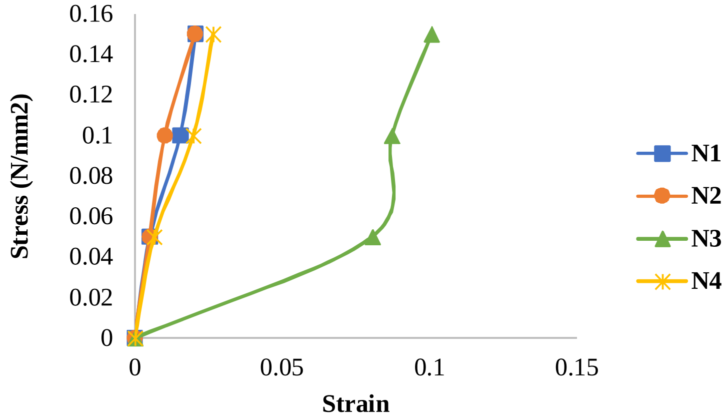

Figure 8. Stress vs strain values for slope with galvanized iron facing, spacing 200 mm (10 mm).

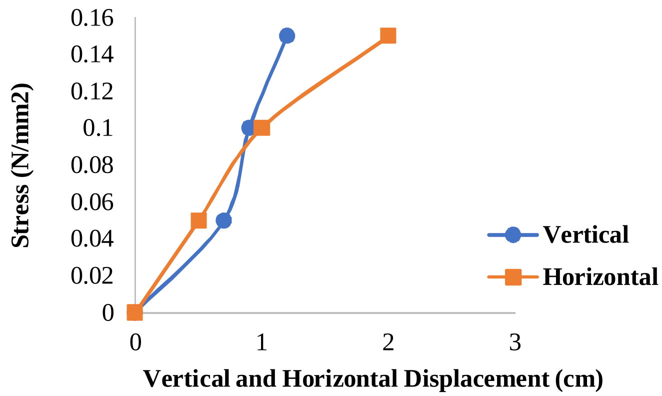

Figure 9. Stress vs ΔV and ΔH values for slope with galvanized iron facing, spacing 200 mm (10 mm).

3.4. Slope with diamond-shaped aluminium wire mesh, nail spacing 200 mm (10 mm nail diameter)

The figure 10 indicates that the slope of the relationship reaches a failure point at a stress level of 0.2 N/mm² when diamond-shaped aluminium wire mesh facing is employed. This suggests that the nails, reinforced with the diamond-shaped aluminium wire mesh facing, exhibit a higher stress resistance compared to the nails without any additional reinforcement (as shown in Figure 4) but a similar failure point to the nails with the geo-composite facing (as shown in Figure 6).

In Figure 11, the relationship between stress, measured in N/mm², and both horizontal and vertical displacement, measured in cm, is depicted. The recorded data indicates that there was a displacement of 1.5 cm horizontally and 2.2 cm vertically. This indicates that under the applied stress, the nails with the diamond-shaped aluminium wire mesh facing experienced a significant amount of displacement in both the horizontal and vertical directions. It is noteworthy that the magnitude of vertical displacement (2.2 cm) is greater compared to the horizontal displacement (1.5 cm), suggesting a greater deformation in the vertical direction.

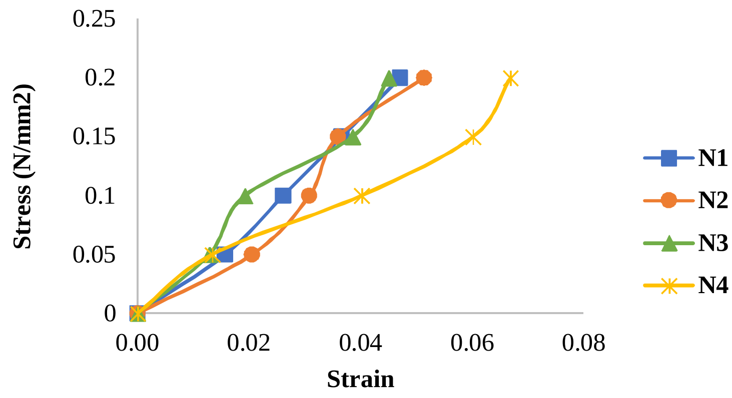

Figure 10. Stress vs strain values for slope with diamond-shaped aluminium wire mesh, spacing 200 mm (10 mm).

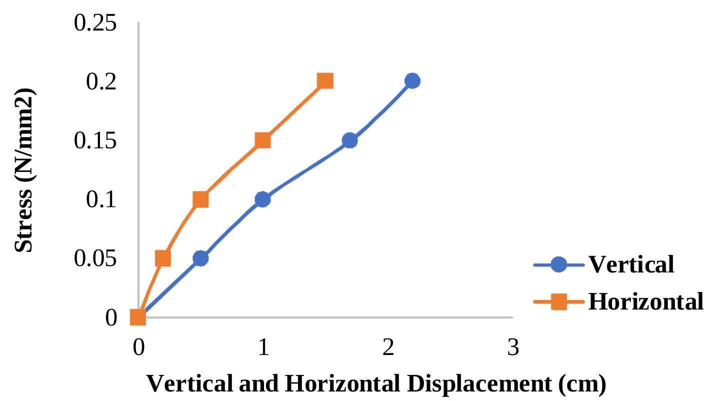

Figure 11. Stress vs ΔV and ΔH values for slope with diamond-shaped aluminium wire mesh, spacing 200 mm (10 mm).

3.5. Slope without facing, nail spacing 200 mm (nail diameter 12 mm)

Figure 12 reveals that the slope of the relationship abruptly decreases beyond a stress level of 0.1 N/mm², indicating a failure point for the nails without any additional reinforcement. In Figure 13, the relationship between stress, measured in N/mm², and both horizontal and vertical displacement, measured in cm, is illustrated. The recorded data indicates that there was a displacement of 1.4 cm horizontally and 1.6 cm vertically. This implies that under the applied stress, the 12 mm diameter nails experienced a significant amount of displacement in both the horizontal and vertical directions, similar to the behaviour observed for the 10 mm diameter nails (as shown in Figure 5). However, it is worth noting that the magnitudes of displacement for the 12mm nails are slightly lower compared to the 10 mm nails.

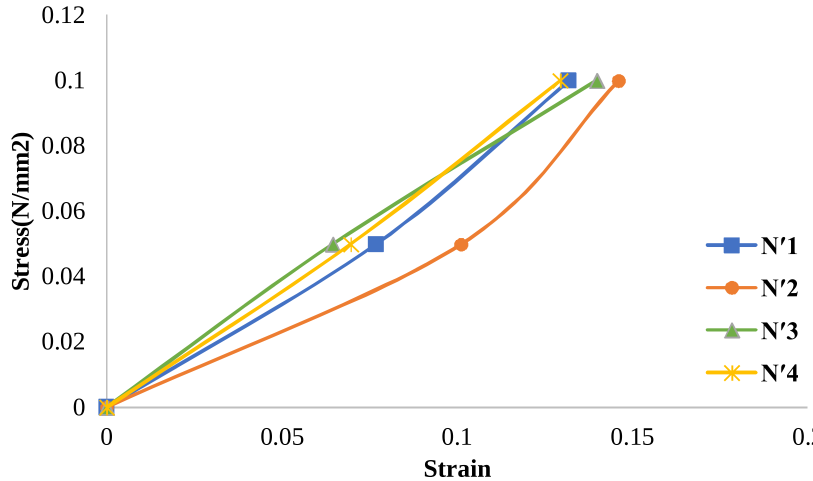

Figure 12. Stress vs strain values for slope without facing, spacing 200 mm (12 mm).

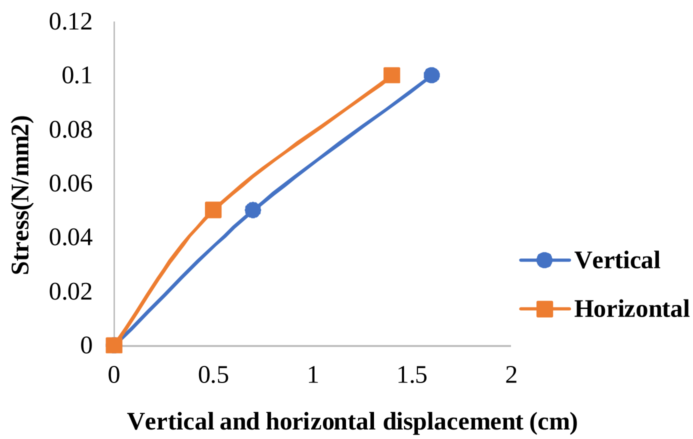

Figure 13. Stress vs ΔV and ΔH values for slope without facing, spacing 200 mm (12 mm).

3.6. Slope with geo-composite facing, nail spacing 200 mm (nail diameter 12 mm)

Figure 14 indicates that the slope of the relationship reaches a failure point at a stress level of 0.25 N/mm² when a geo-composite facing is utilized. This indicates that the 12 mm diameter nails, reinforced with the geo-composite facing, exhibit higher stress resistance compared to the nails without any additional reinforcement (as shown in Figure 12) and have a slightly higher failure point compared to the 10 mm diameter nails with geo-composite facing (as shown in Figure 6). In Figure 15, the relationship between stress, measured in N/mm², and both horizontal and vertical displacement, measured in cm, is illustrated. The recorded data indicates that there was a displacement of 1.5 cm horizontally and 1.3 cm vertically. This suggests that under the applied stress, the 12 mm diameter nails with the geo-composite facing experienced a significant amount of displacement in both the horizontal and vertical directions, like the displacement observed for the 10 mm diameter nails with the geo-composite facing (as observed in Figure 7). However, it is worth noting that the magnitudes of displacement for the 12 mm nails are slightly different from the 10 mm nails.

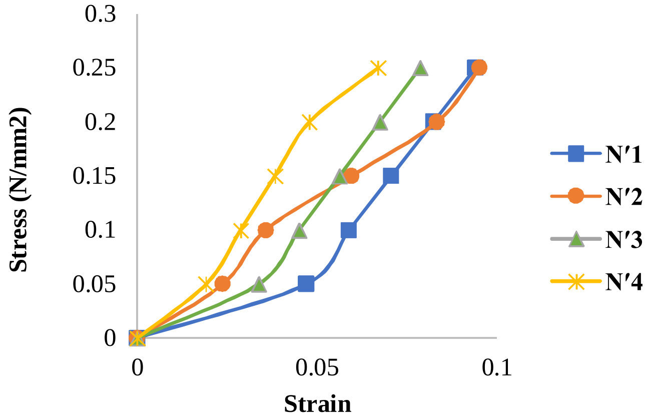

Figure 14. Stress vs strain values for slope with LDPE geo-composite facing, spacing 200 mm (12 mm).

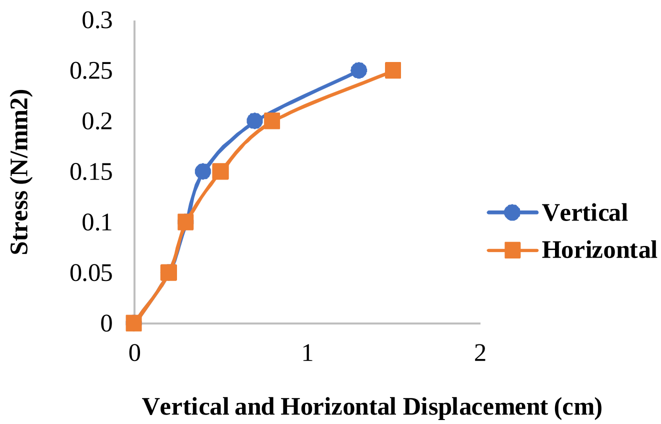

Figure 15. Stress vs ΔV and ΔH values for slope with LDPE geo-composite facing, spacing 200 mm (12 mm).

3.7. Slope with galvanized iron facing, nail spacing 200 mm (12 mm nail diameter)

Figure 16 indicates that the slope of the relationship reaches a failure point at a stress level of 0.25 N/mm² when galvanized iron wire mesh facing is employed. This suggests that the nails, reinforced with the galvanized iron wire mesh facing, exhibit a higher resistance to stress compared to the nails without any additional reinforcement (as shown in Figure 4) and have a similar failure point to the 12 mm diameter nails with geo-composite facing (as shown in Figure 14). In Figure 17, the relationship between stress, measured in N/mm², and both horizontal and vertical displacement, measured in cm, is illustrated. The recorded data indicates that there was a displacement of 1.5 cm horizontally and 1.7 cm vertically. This indicates that under the applied stress, the 10mm diameter nails with the galvanized iron wire mesh facing experienced a significant amount of displacement in both the horizontal and vertical directions. The magnitude of the vertical displacement (1.7 cm) is slightly greater than the horizontal displacement (1.5 cm), indicating a slightly higher deformation in the vertical direction. It is worth noting that these displacements are different from the values observed for the 12mm diameter nails (as shown in Figure 13).

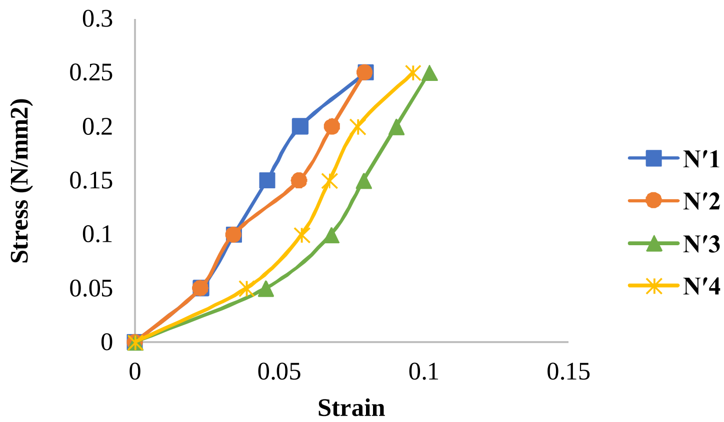

Figure 16. Stress vs strain values for slope with galvanized iron facing, spacing 200 mm (12 mm).

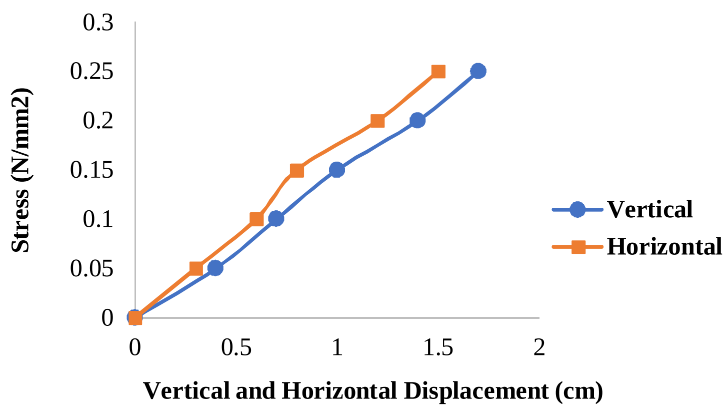

Figure 17. Stress vs ΔV and ΔH values for slope with galvanized iron facing, spacing 200 mm (12 mm).

3.8. Slope with diamond-shaped aluminium wire mesh, nail spacing 200 mm (12 mm nail diameter)

Figure 18 presents a correlation graph depicting the relationship between stress, measured in N/mm², and strain for 10 mm diameter nails positioned at a spacing distance of 200 mm. The graph indicates that the slope of the relationship reaches a failure point at a stress level of 0.2 N/mm² when diamond-shaped aluminium wire mesh facing is utilized. This indicates that the nails, reinforced with the diamond-shaped aluminium wire mesh facing, exhibit a higher resistance to stress compared to the nails without any additional reinforcement (as shown in Figure 4) and have a similar failure point to the 12 mm diameter nails with the geo-composite facing (as shown in Figure 14). In Figure 19, the relationship between stress, measured in N/mm², and both horizontal and vertical displacement, measured in cm, is illustrated. The recorded data indicates that there was a displacement of 1.0 cm horizontally and 1.6 cm vertically. This suggests that under the applied stress, the 10 mm diameter nails with the diamond-shaped aluminium wire mesh facing experienced a significant amount of displacement in both the horizontal and vertical directions. The magnitude of the vertical displacement (1.6 cm) is slightly greater than the horizontal displacement (1.0 cm), indicating a greater deformation in the vertical direction. It is important to note that these displacements differ from the values observed for the 12 mm diameter nails (as shown in Figure 13).

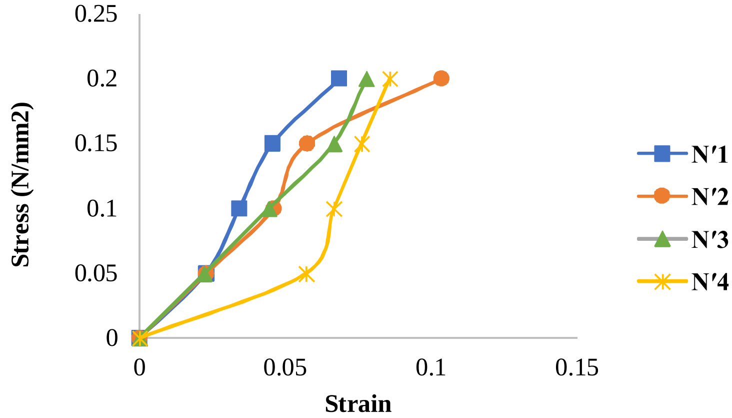

Figure 18. Stress vs strain values for slope with diamond-shaped aluminium wire mesh, spacing 200 mm (12 mm).

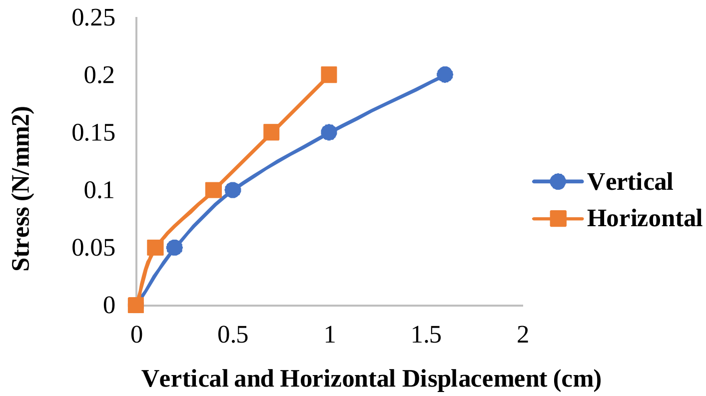

Figure 19. Stress vs ΔV and ΔH values for slope with diamond-shaped aluminium wire mesh, spacing 200 mm (12 mm).

4. Discussion

Soil nailing has emerged as a cost-effective and adaptable technique that offers resilient design solutions for soil improvement as well as temporary support of structures. Therefore, it is highly recommended to increase the utilization of soil nailing for these applications [8]. The feasibility of employing galvanized iron mesh, geo-composite, and aluminium wire mesh as reinforcement materials relies on their characteristics, particularly their ability to withstand tensile forces while minimizing both vertical displacement (ΔV) and horizontal displacement (ΔH) when subjected to loads. By evaluating these materials against each other based on these aspects, a comprehensive assessment can be made to determine their suitability for specific applications.

Galvanized iron mesh offers notable tensile strength and can effectively distribute forces across its surface. When subjected to loads, it demonstrates resistance to deformation, limiting both vertical and horizontal displacements. However, it is important to consider that galvanized iron mesh may have a lower failure point compared to other materials, such as the geo-composite or aluminium wire mesh, as indicated by the respective stress-strain correlation graphs.

The geo-composite, on the other hand, exhibits improved performance in terms of load-bearing capacity and resistance to deformation. It demonstrates a higher slope in the stress-strain graph before reaching a failure point, indicating its ability to endure higher stress levels before exhibiting significant displacement. This suggests that the geo-composite can effectively minimize both vertical and horizontal displacements, making it a suitable choice for applications requiring enhanced reinforcement capabilities.

Similarly, the diamond-shaped aluminium wire mesh displays promising characteristics in terms of tensile strength and resistance to deformation. It exhibits a failure point at a stress level comparable to that of the geo-composite. The aluminium wire mesh offers the advantage of being lightweight, which can be advantageous in certain scenarios where weight reduction is desired. Its ability to withstand tensile forces with limited vertical and horizontal displacements positions it as a viable alternative to the other materials under consideration.

The overall stability of slopes is reinforced with soil nails; it is evident that the design of a soil-nailed slope requires careful consideration of various factors. These factors include the geometry of the slope, parameters related to the soil nails, and the presence of a rising water surface. Thorough investigation and analysis of these parameters are essential to achieve an economically viable and safe design for soil-nailed slopes [9].

In conclusion, the choice between galvanized iron mesh, geo-composite, and diamond-shaped aluminium wire mesh should be based on specific project requirements and priorities. While each material demonstrates unique features and performance levels, such as tensile strength and resistance to displacement, a comprehensive evaluation should be conducted to determine the most suitable option for a given application. Factors such as load-bearing capacity, deformation limits, and the desired balance between vertical and horizontal displacements should all be considered in making an informed decision.

4.1. Comparison of horizontal displacement using 10 mm and 12 mm nails

The installation of flexible facing in slope reinforcement has a significant impact on the horizontal and vertical displacements observed. It is observed that the maximum displacements occur at stress levels that are more than 50% higher in slopes with flexible facing compared to slopes without facing [5].

In the case of horizontal displacement, the slope reinforced with 10mm nails without facing material experienced a maximum displacement of 1.7 cm at 0.1 N/mm2 stress. However, when a flexible facing material such as galvanized iron wire mesh, geo-composite, or diamond-shaped aluminium wire mesh was used, the maximum displacements were observed at stress levels of 0.15 N/mm2, 0.2 N/mm2, and 0.2 N/mm2, respectively. These stress levels are significantly higher than the stress level of the slope without facing material [10].

Similarly, in terms of vertical displacement, the slope without facing material reinforced with 12 mm nails showed a maximum displacement of 1.6 cm at 0.1 N/mm2 stress. On the other hand, the slopes with flexible facing materials, such as diamond-shaped aluminium wire mesh, galvanized iron wire mesh, and geo-composite, exhibited maximum displacements at stress levels of 0.2 N/mm2, 0.25 N/mm2, and 0.2 N/mm2, respectively. Once again, these stress levels represent an increase of more than 50% compared to the slope without facing material.

This finding emphasizes the effectiveness of flexible facing in accommodating higher stress levels and allowing for greater displacements. The presence of flexible-facing materials provides additional support and resistance to the applied stress, resulting in increased displacements before failure. This information is crucial for engineers and practitioners involved in slope reinforcement design and construction.

4.2. Stress comparison

The chart presented in Figure 20 compares the maximum stress experienced by slopes with and without facing materials using different nail diameters. The slope with a Geo-composite facing material and galvanized iron wire mesh showed the highest stress at 0.25 N/mm^2 due to its strong tensile and shear strength and stiff nature. On the other hand, the slope without any facing material showed the lowest stress at 0.1 N/mm^2, indicating that flexible facing materials provide effective stabilization for slopes. In summary, the bar chart suggests that using a Geo-composite facing material and galvanized iron wire mesh as flexible-facing materials can help stabilize slopes by reducing stress levels.

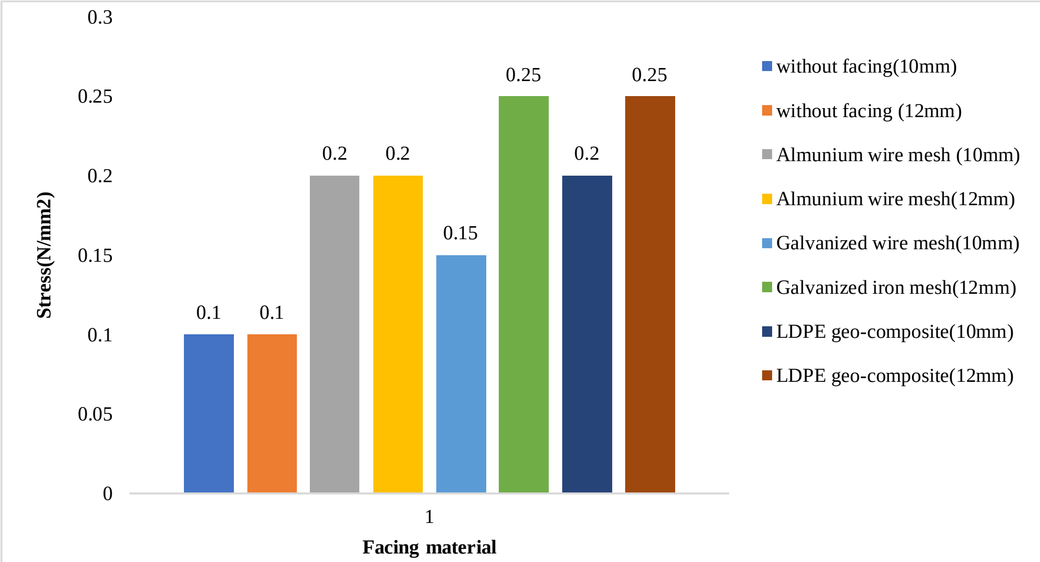

Figure 20. Comparison of facing materials with 10 mm and 12 mm diameter nails.

5. Conclusions

- The load-carrying capacity of soil-nailed slopes under stress is affected by the selection of nail parameters and facing material type. When comparing two identical slopes with the same nail parameters, it was found that the slope with geo-composite facing and galvanized iron wire mesh had a higher stress level with lower displacement. On the other hand, the slope with diamond-shaped aluminium wire mesh had a lower stress level with higher displacement. As a result, it is crucial to carefully consider the nail parameters and facing material type during the design of soil-nailed slopes to ensure optimal performance under different stress conditions.
- The results of this research demonstrate that increasing the diameter of a nail leads to maximum stress in the slope and less displacement, regardless of the type of facing material used. Therefore, it can be recommended to use nails with larger diameters when constructing slopes to ensure better stability and durability.
- The comparison between geo-composite and galvanized iron wire mesh facing showed that both types of facing have similar strength and can withstand the same amount of load. However, it is important to keep in mind that there is a limit to the amount of load that these facing materials can bear. In situations where the soil pressure is high, it is recommended to use a more rigid-facing material to ensure the stability and longevity of the structure. Therefore, it is crucial to carefully consider the soil pressure and other relevant factors when selecting the facing material for a particular project.

6. Innovation

One potential innovation that can be derived from the research findings is the development of a comprehensive design tool or software that integrates the selection of nail parameters and facing material type for soil-nailed slopes. This tool could utilize algorithms based on the research data to optimize the design process and ensure the stability and performance of the slopes under various stress conditions. The design tool could consider factors such as soil properties, anticipated loads, and desired performance criteria. By inputting these parameters, the software would generate recommendations for the optimal nail parameters, including diameter, length, spacing, and material composition. It would also guide the appropriate facing material type based on the anticipated stress levels and displacement requirements. Overall, the innovation of a comprehensive design tool or software would streamline and optimize the design process for soil-nailed slopes, enhancing their stability, durability, and performance while considering the selection of nail parameters and facing material type. This innovation would contribute to more efficient and reliable slope construction practices, reducing the risk of failure and ensuring long-term safety and sustainability [10].

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بررسی پایداری شیب با استفاده از روکش انعطاف‌پذیر

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چکیده:

آزمایشی برای ارزیابی ظرفیت باربری یک سیستم نیلینگ خاک که شامل چهار نیلینگ 10 میلی‌متری و چهار نیلینگ 12 میلی‌متری، تقویت‌شده در یک شیب با سه ماده مختلف رویه‌ای انعطاف‌پذیر است: روکش ژئوکامپوزیت، روکش آلومینیوم و روکش آهن گالوانیزه انجام شد. نیلینگ‌ها به صورت افقی و عمودی از مرکز به مرکز به فاصله 200 میلی متر از هم قرار گرفتند. نتایج آزمون تنش-کرنش نشان داد که روکش‌های ژئوکامپوزیت و آهن گالوانیزه با نیلینگ‌هایی به قطر 12 میلی متر استحکام بالای 0/25 نیوتن بر میلی‌متر مربع را با جابجایی کمتر از خود نشان دادند. رابطه بین استرس، جابجایی و نوع ناخن‌های استفاده شده با روکش یکسان مورد بررسی قرار گرفت. پایداری شیب نیز برای بررسی تأثیر پارامترهای نیلینگ و نوع روکش روی جابجایی تحت شرایط بارگذاری مختلف مورد تجزیه و تحلیل قرار گرفت.

کلمات کلیدی: شیب نیلینگ شده خاک، مدل آزمایشی، روکش انعطاف پذیر، جابجایی، فاصله.