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Research Article

A Review On Ground Improvement Techniques By Soil Nailing

Vaibhav Singh[1], Md Mairajuddin[2], Sanghati Mutsuddi[3*]

[1,2] Ug Students, B.Tech (Civil Engineering),
[3*]Asst. Professor, Department Of Civil Engineering, Greater Noida Institute Of Technology, Utter Pradesh

***Corresponding Author:** Sanghati Mutsuddi
*Sanghati.Mutsuddi@Gmail.Com

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ABSTRACT

This paper explores modern ground improvement techniques in geotechnical engineering, focusing on their transformative impact on construction practices. Unlike traditional methods that adjust designs to accommodate natural soil limitations, modern techniques manipulate soil conditions to meet project specifications, aiming to enhance construction efficiency while reducing costs and implementation time. Over the past decade, significant advancements have been made in ground improvement techniques, offering a diverse range of methods to enhance soil mechanical and engineering properties. Each technique has its own limitations and suitability factors, aim to achieve maximum improvement with minimal effort. Two prominent ground improvement techniques discussed are micro piling and soil nailing. Micro piles, with their small diameter and grouted frictional design, are highly effective in enhancing bearing capacity and reducing settlements, especially when used to reinforce existing foundations. Soil nailing is used both to stabilize existing unstable slopes and to allow for the safe steepening of slopes during construction. Through comprehensive reviews, including numerical analyses and case studies, the efficacy of these techniques in stabilizing slopes and retaining vertical cuts is highlighted. Furthermore, the study emphasizes the broader context of slope stabilization, particularly in mitigating landslides. Soil nailing emerges as a cost-effective alternative to traditional methods such as retaining walls, offering effective reinforcement of steep slopes by driving reinforcement into the soil. Research findings indicate that soil nailing exhibits reduced deformation compared to untreated slopes and is up to 30% more economical than classical methods for slope improvement and repair. Additionally, the study explores the flexibility of facing types, with flexible facing proving more cost-effective despite allowing for greater deformation. In conclusion, the pressing need for ground improvement techniques amid rapid urbanization and infrastructure development is addressed. Various modern methods, including soil reinforcement with fibres, geosynthetics, and geocell reinforcement, are discussed as viable solutions to enhance soil strength and bearing capacity. By conducting meticulous analysis and long-term performance evaluation, engineers can develop efficient designs tailored to specific applications, further advancing the field of ground improvement in civil engineering.[1][2][3]

Keywords- Stability, Landslide, Soil nails, Facing of soil nails, Inclination of nail, Helical plates.

INTRODUCTION

In the realm of civil engineering, the stabilization of slopes and mitigation of geological hazards such as landslides are paramount concerns, driving the development of advanced techniques like soil nailing. Originating from the New Austrian Tunnelling method, soil nailing has evolved into a prominent solution since its inception in the early 1970s, demonstrating its effectiveness in a plethora of projects worldwide. At its core, soil nailing involves embedding steel bars, known as soil nails, into slopes to fortify and strengthen them against geological pressures. This top-to-bottom construction method serves as a cornerstone in modern slope

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stabilization endeavours, offering a versatile approach to reinforcing both permanent earth-retaining structures and temporary excavations.
Critical to the success of soil nailing are its constituent components, which include steel bars coated with cement grout and wire mesh-reinforced shotcrete, each playing pivotal roles in ensuring the stability and resilience of the reinforced slope or excavation face. Additionally, the incorporation of facing materials such as pre-cast concrete panels, metal sheets, and shotcrete acts as a barrier against soil erosion, bolstering the structural integrity of the system. Beyond its immediate applications, soil nailing stands as a versatile solution, adaptable to diverse soil conditions and construction exigencies, underscoring its significance within the arsenal of civil engineering solutions. With its extensive research pedigree and decades-long application, soil nailing emerges as an exemplar of an economical and effective technique for stabilizing soil slopes, offering sustainable and dependable means to mitigate the risks associated with landslides and enhance the safety and longevity of infrastructure projects. [3][4]

LITERATURE REVIEW

1. **Kouji Tei, et al. (1998)** The centrifuge tests on nailed slopes and vertical walls showed that nails primarily failed by pulling out rather than breaking, suggesting a gradual collapse process. The observed failure surfaces resembled logarithmic spirals, indicating a consistent pattern of failure. Additionally, comparisons with traditional methods like Coulomb's analysis revealed reasonable agreement in measured earth pressures, supporting the reliability of conventional techniques.
Furthermore, the tests highlighted the importance of support mechanisms in minimizing displacements during simulated excavation. Despite limitations in scaling down to model size, the results provided confidence in their validity through comparisons with full-scale prototype tests. Overall, these findings offer valuable insights into the behavior of nailed slopes and vertical walls, aiding in their design and construction for practical applications.
2. **G.L. Sivakumar Babu and Vikas Pratap Singh (2009)** The paper focuses on establishing reliabilitybased load and resistance factors for soil-nail walls, targeting six key strength limit states. By explicitly considering variability and individual limit state vulnerability, it rationalizes proposed factors. The study showcases the practical application of these factors in designing soil-nail walls under similar loading conditions and configurations, suggesting potential expansion to encompass more material parameters and variable types for a comprehensive reliability analysis.
Key aspects covered include the identification of six failure modes of soil-nail walls, ranging from global stability to facing punching shear failure. The reliability analysis process involves steps such as identifying failure modes, determining random variables, establishing performance functions, analyzing stability, and obtaining design points and factors. These factors, influenced by material parameters and determined for different variability levels, are derived through a reliability-based approach, underscoring their importance in ensuring the structural integrity and safety of soil-nail wall designs.
3. **Sanat Pokharel, et al. (2011)** The research paper delves into the utilization of flexible facing for soil nail walls, offering valuable insights into their behavior and performance. It emphasizes the importance of employing finite difference modeling and physical testing to accurately predict soil behavior and deformations. The conclusions and recommendations provided serve as practical guidance for designing soil nail walls, particularly in high-plasticity clay. Additionally, the inclusion of case studies and parametric studies enriches the research, making it a comprehensive resource for professionals in geotechnical engineering.
Over the past four decades, large-scale tests on soil nail walls have been conducted, with soil nailing finding popularity in various regions such as France, Germany, and select cities in the United States. These tests have revealed failure mechanisms stemming from factors like soil saturation. Physical testing methods employed, such as strain gages, string pots, and geofoam panels, have aided in gathering crucial data. Figures presented in the document, including compaction curves, test results, and wall failures under surcharge applications, further enhance understanding and provide visual support for the research findings.
4. **Siavash Zamiran, et al. (2012)** The paper delves into the behavior of soil nail walls under seismic conditions, offering valuable insights into their performance. The study underscores the significance of cable reinforcement in enhancing soil mass parameters and stress states, crucial for seismic resilience. Through numerical analysis utilizing the Mohr-Coulomb constitutive model, the research investigates various aspects such as earthquake input direction impact and comparison between static and seismic behavior of soil nail walls.
Key findings reveal that soil nail walls exhibit superior performance compared to classical retaining walls in seismic-prone areas. The inclusion of cable reinforcement proves beneficial in improving soil mass parameters and stress states. Moreover, dynamic analysis showcases substantial differences in wall displacement and nail forces between static and seismic conditions, highlighting the necessity for dynamic assessment in earthquake scenarios. Overall, the study contributes significantly to understanding soil nail wall behavior under seismic conditions, laying groundwork for further research in this domain.
5. **S.Rawat and A.K.Gupta (2016)** The paper investigates slope stability through soil nailing, employing both experimental and analytical approaches to study reinforced slopes at different angles. Utilizing model testing and finite element analysis with PLAXIS 3D, the authors examine the impacts of nail inclinations on

load capacities and failure patterns. Key findings highlight the pivotal role of nail orientation and length in bolstering slope stability, offering valuable insights applicable to geotechnical engineering practices.
Experimental methods involved surcharge load testing using a Universal Testing Machine, alongside analysis of soil and nail material properties. Conclusions drawn from the study emphasize the effectiveness of reinforced slopes in enhancing stability and load capacity, with nail inclination identified as a significant factor influencing load carrying capacity. Overall, the research contributes valuable insights into the behavior of reinforced soil slopes across varying conditions, aiding in informed decision-making for geotechnical engineering projects.

6. W.R. Azzam and A. Basha (2017) The research paper explores the application of soil nailing as a method to bolster the shear strength of cohesive soil and mitigate settlement. By incorporating vertical nails as reinforcing elements in clay samples, the study aims to enhance shear strength and control deformation. Laboratory experiments, such as unconfined compression and direct shear tests, are performed to evaluate the effectiveness of this method.
Findings indicate that the inclusion of vertical nails leads to increased shear stress, reduced settlement, and improved subgrade stiffness. Moreover, the depth and number of inclusions are identified as crucial factors in augmenting clay stiffness and redirecting shear failure. Overall, the research underscores the potential of soil nailing as a cost-effective strategy for enhancing clay shear strength and addressing settlement concerns.

7. Mohammad Farhad Ayazi, et al. (2020) research paper offers a comprehensive examination of soil nailing as a technique for stabilizing slopes and structures. The paper initiates with a detailed introduction, tracing the technique's origins from the New Austrian Tunneling method and its widespread adoption globally over the past three decades. It effectively outlines the methodology of embedding steel bars into slopes and highlights key components involved in the process, including facings, grout, centralizers, drainage, and connection components.
One of the paper's notable strengths is its comprehensive examination of the benefits and drawbacks of soil nailing. It adeptly discusses the environmental benefits, economic efficiency, and seismic stability of the technique while acknowledging challenges related to site compatibility, labour requirements, and material durability. This balanced assessment provides readers with a nuanced understanding of the benefits and complexities associated with soil nailing.
Moreover, the discussion on soil nailing facing is particularly informative, categorizing facings into hard, flexible, and soft types and illustrating diverse strategies employed to address specific slope conditions and environmental factors. Supported by evidence from previous research and project data, the paper's conclusions offer valuable insights into the effectiveness of soil nailing in various contexts, providing practical recommendations for researchers, practitioners, and stakeholders involved in slope stabilization and infrastructure development projects.

8. Divya Jyothi Bathini and V Ramya Krishna (2022) The study provides a comprehensive analysis of soil nailing, examining its characteristics through laboratory studies, field investigations and numerical modeling. It discusses the construction process, advantages, and disadvantages of soil-nailed walls, emphasizing their ease of construction and space efficiency compared to conventional retaining walls. Field investigations illustrate the versatility of soil nailing in stabilizing failed slopes and protecting historical structures, while numerical modeling demonstrates the technique's effectiveness in enhancing slope stability. Despite its advantages such as flexibility, cost-effectiveness, and suitability for various applications including roadway cuts and tunnel roof stabilization, challenges such as the need for permanent underground supports and limitations in certain soil types are acknowledged. Overall, the study provides valuable insights into the practical application and limitations of soil nailing, serving as a valuable resource for geotechnical engineers and researchers alike.

CONCLUSION

This review paper provides a comprehensive overview of modern ground improvement techniques in geotechnical engineering, with a particular focus on soil nailing. It underscores the transformative impact of these techniques on construction practices, highlighting their ability to manipulate soil conditions to meet project specifications efficiently. By exploring advancements in ground improvement methods over the past decade, the paper offers insights into various techniques aimed at enhancing soil mechanical and engineering properties.
Two prominent ground improvement techniques, micro piling, and soil nailing are extensively discussed, with a focus on their applications, advantages, and limitations. Micro piles are noted for their effectiveness in bolstering bearing capacity and minimizing settlements, especially in fortifying existing foundations. On the other hand, soil nailing emerges as a versatile solution for stabilizing slopes and retaining vertical cuts, offering both remedial measures for unstable slopes and construction methods for steepening slopes safely.
The review paper further emphasizes the broader context of slope stabilization, particularly in mitigating landslides, where soil nailing proves to be a cost-effective alternative to traditional methods like retaining walls. Through meticulous analysis of research findings, including numerical analyses, laboratory studies, and field investigations, the paper highlights the efficacy of soil nailing in enhancing slope stability, reducing deformation, and addressing settlement concerns.

Overall, this review paper contributes to a better understanding of modern ground improvement techniques and their applications in geotechnical engineering. It serves as a valuable resource for researchers, practitioners, and stakeholders involved in slope stabilization, infrastructure development, and landslide mitigation projects. By incorporating comprehensive reviews, case studies, and numerical analyses, the paper offers practical insights and recommendations for the effective implementation of ground improvement techniques in various engineering projects.

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