National Conference on Sustainable Engineering And Management (NCSEM24) ISSN 2349-6002

Study On Soil Nailing ConstructionTechniques with Integrated Smart Technology

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Abstract – Soil nailing, as a prevalent technique in geotechnical engineering, plays a crucial role in stabilizing slopes and retaining walls. This paper explores the integration of smart technology into soil nailing construction processes to enhance efficiency, safety and performance. The integration of smart sensors, real-time monitoring systems and data analytics enables comprehensive monitoring of soil behavior, structural integrity and environmental conditions during and after construction. The integration of smart technology in soil nailing construction offers numerous benefits including early detection of potential failures, optimization of construction processes and improved decision making through data-driven insights. Furthermore, real-time monitoring facilitates proactive maintenance and timely interventions, reducing the risk of accidents and minimizing the environmental impact of construction activities. This paper provides an overview of existing soil nailing techniques and discusses the integration of smart technology through various case studies and practical applications. It also addresses challenges such as data security, interoperability and cost effectiveness associated with the implementation of smart technology in soil nailing construction.

1. INTRODUCTION

Land slide is a natural phenomenon which occurs in offshore, coastal and onshore environment. Soil nailing is an effective slope stabilization method used to enhance the stability of slopes, excavations, rail or road embankment, tunnels and retaining walls. The introduction of soil nailing process has the potential to revolutionize the way this technique is implemented and monitored.

Soil nailing involves inserting closely spaced passive slender elements (commonly steel bars or steel bars surrounded by cement grout, carbonfiber reinforced polymer or glass fiber reinforced polymer) into the soil or soft weathered rock mass. It is done by the use of passive inclusions like steel barstermed as soil nails. By incorporating sensors, data collecting devices and communication systems into soil nails, helps to gather real-time information about the behavior of the soil and the effectiveness of the reinforcement. This data can be used to optimize the design of soil nail walls, improve construction technique and ensure the long term performance of the structure. Additionally, the use of smart technology can enable remote monitoring and control of soil nailing projects, reducing the need for manual inspectionsand increasing overall efficiency. The integration of smart technology into soil nailing offers the potential for more cost effective, sustainable and reliable geotechnical solutions. By harnessing the power of data connectivity, engineers can enhance theperformance and safety of soil nail structures, ultimately leading to more resilient infrastructure in the face of environmental challenges.

LITERATURE REVIEW

Kouji Tei, R Neil Taylor, George W E Milligan (1998): A series of centrifuge model tests were carried out on soil nail slopes with vertical and near vertical faces. The 200mm high wall was subjected to30g acceleration initially, which was increased to a maximum of 80g if failure did not occur. In all cases, failure was due to pull out of nails rather than breakage, with significant bending of nails observed only after slope failure. The measured earth pressure on the wall before failure matched the calculated value of Coulomb's method, but post failure, the pressure was lower than expected. Additionally the resultant force's line of action was higher than anticipated.

Mohammad Farhad Ayazi, Amanpreet Tangri, Samrity Jalota (2020): It represents detailed analysis of soil nailing techniques and their implications for slope stability. This review provides valuable insightsinto the advancements and best practices in soil nailing techniques, offering guidance for engineers and practitioners involved in slope stabilization projects. The findings underscore the importance of considering various factors, influencing nail inclination, facing options, and the use of inclusions, in optimizing slope stability and cost-effectiveness.

Vivek Gupta, Baijnath Nishad, Rohit Yadav, Vishal Kumar Guatam, Yashita Mishra (2022) Case studies on soil nailing has been conducted by illustrating the advantages. There is a large sacle need to use this technique in India for many projects.

Sukhvir, Amanpreet Tangri, Abhishek Rana (2020) Study on soil nailing with different facing material was carried out. It is observed that Galvanized iron mesh is the most suitable facing material.

W.R. Azzam, A. Basha (2017) in this paper various techniques used to improve the cohesive soil in bulk condition was stusied through laboratory tests anddirect shear tests.

Piyush Sharma (2015): In this paper it proves an overview on soil nailing construction techniques. It provides the use of soil nailing in various projects and the future use in construction in India

Sanvilate N.Simonini P, Bisson A, Cola S.(2013): This paper gives the data that the stiffness gets reduced if the facing provided loses continuity..

G.L.Sivakumar Babu, Vikas Pratap Singh (2009): It was based on the conventional design consideration given by Federal Highway Administration (2003). This system provides a safe design for the structure.

1.1 Origin

Soil nailing is a technique evolved from New Austrian Tunneling method in 1960 for underground excavation in rock. It is done with the combination of passive steel reinforcement and shotcrete in the slope of the rock in 1960. In 1970 it is used for underground tunnel in Europe.The first application was in 1972 in Versailles, France for rail road widening and to stabilize18m high slope. In this project it is proven that it reduces the utilization of cost and time compared to other method. The University of Karlsruhe anda construction company Bauer joined forces to create research program from 1975-1981. In 1976, the US implemented soil nailing technique for the first time to reinforce 13.7m deepfoundation during excavation i in dense silty sand. It is implemented when the expansion of The Good Samaritan Hospital in Portland, Oregon.

1.2 Suited soils

Clays, clayey silts, silty clay, sandy clay, glacial soil, sandy silts, sand, gravels and in weathered rocks.

1.3 Components of soil nailing

❖ Soil nails

- Tendons – Ground reinforcing elements behind a soil nail walls and equivalentto bars. They may be solid or hollow bars.
- Grout – Grout used for soil nailing usually consist of Portland cement and water
- Corrosion protection – Epoxy coating is provided in accordance.

❖ Facing

- Shotcrete - It consists of initial and finalcomponents. Initial components receive the bearing plate of soil. Final components actas structural continuity.
- Reinforcement used in the shotcrete

i. Welded wire mesh
ii. Horizontal bars
iii. Vertical bearing bars

❖ Other components

- Connection components – Connected using nuts, washer, bearing plates, headed studsetc…
- Drainage system – Installed behind soil nail walls

❖ Centralizers – Made up of PVC and other synthetic material.

❖ Components of integrated smart technology

Sensors – They are essential components that collect data on various parameters such as soil moisture, temperature and pressure.The sensors are embedded in thesoil nails to monitor the conditions of the soil and provide real timedata. Data acquisition system – It is used to collect, process and store the data obtained from the sensors. This system helps analyzing the data and making informed decision based on the information gathered.

Communication system – It is required to transmit the data collected by the sensors to a centralmonitoring station or a cloud-based platform. This system can use wired or wireless communication technologies to ensure seamlessdata transfer.

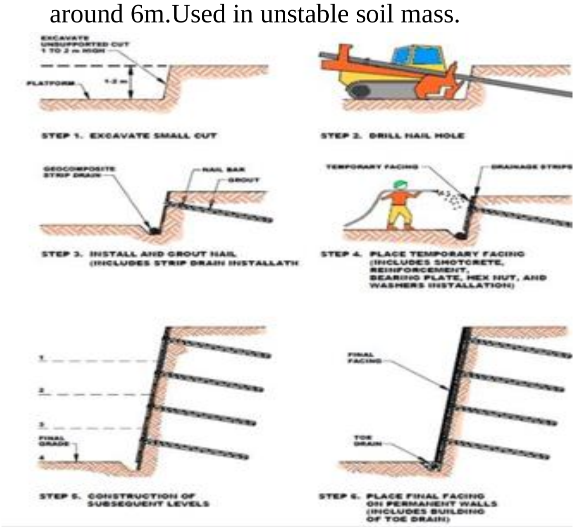
Monitoring software-It is used tovisualize and analyze the data collected by the sensors. It provides insights into the soil conditions, alerts users about any potentialissues and helps in decision makingprocesses.

Power supply-Smart technology components require a power supplyto operate efficiently. It can be achieved through batteries, solar panels or other power sources depending on the specific requirement of the system.

Integrated platform- Required to bring all the components of smart technologies together. This includes data sharing, communication between devices and overall system management.

1.4 Nailing techniques

- ❖ Drilled and grouted soil nailing method – Holes are drilled in walls or slopes and nails are inserted and filled with grouting materials. The diameter of nail ranges from 100- 200 mm.
- ❖ Self drilling soil nailing method – This method is used for temporary stabilization ofslopes. It does not provide corrosion protection to reinforcement steel or nails. Diameter of nail ranges from 19-5 mm with spacing of 1-1.2m.
- ❖ Driven soil nailing method – Hollow bars are used. Bars are drilled in slope surface and grout is injected. It is faster than the drilled grouted nailing method. Nails diameter ranges from 20 -25 mm.
- ❖ Jet grouted soil nailing method – Slopes are created on the slope surface with thehelp of jets. Steel bars are installed and grout is injected. Provide good corrosionresistance to steel bars.
- ❖ Launched soil nailing method – Steel bars are forced into the soil with single shot. Installation of nail is fast, but control over the length of bar is difficult. Nail diameter is38mm and length around 6m.Used in unstable soil mass.



1.5 Construction procedure

- Excavation – ranges from 2.5 -7 ft typically 3-5ft where first row ofnails will be installed.
- Drilling of nail holes

1)Nail installation with appropriate sensors and grouting

2) Installation of strip drains

- Construction of initial shotcretefacing
- Construction of subsequent levels –step 1-4 is repeated.
- Construction of final facing

1.6 Installation considerations

Nails must penetrate beyond the slip plane to the zone for 4-5m. Spacing of the nail must be related to the strength of soil chosen. It must be started immediately after excavation , or else it will lead to failureof the slope

1.7 Materials used

Steel reinforcement, Grout mix – water cement ratio ranges 0.4-0.5, Shotcrete or gunite – It is exposed to the ground by pneumatic air bowling for dry mix or spraying for wet mix, Integrated smart technologies include Smart sensors, Remote monitoringsystems, Data analytics

1.8 Machines used

- Drilling equipments
- Grout mixing Equipment
- Shotcreting / guniting equipment
- Compressor

1.9 Design considerations

1. Strength limit : It defines the limit state of potential failure orcollapse
2. Service limit: Point, at which the deformation of the nails exceeds, the threshold, making it unsuitable for supporting the slope.
3. Height and length: Height affects the strength of service limit. Length affects the cost. L=0.7 H, Generally between 0.6H to 1.2H
4. Spacing: It decreases with decrease in cohesion of soil and increase in cost due to number of nails for given height and length ofslope.

- Vertical and horizontal spacing of soil nails

SV=SH=5ft

- Vertical spacing from the top to bottom of the wall
    1. Spacing between first rowand top of walls should beless than or equal to 3.5 ft
    2. spacing between deepest row and bottom of wall should be less than or equal to 2 to 3f

5. Ground properties: properties like density, texture etc… affect nail spacing.
6. Nail length and diameter: Itgoverns the external and internal wall stability.
7. Stability: There must be safety margins against the potential modes of failure. And the soil must be stable.
8. Serviceability
9. Durability: The durability of the soil nailed system is governed by the resistance to corrosion underdifferent soil

texture.

10. Economic considerations: The cost of construction mainly depends on various characteristic performance of the soil.
11. Environmental considerations: The construction should be carried out without causing any damage tothe eco system.

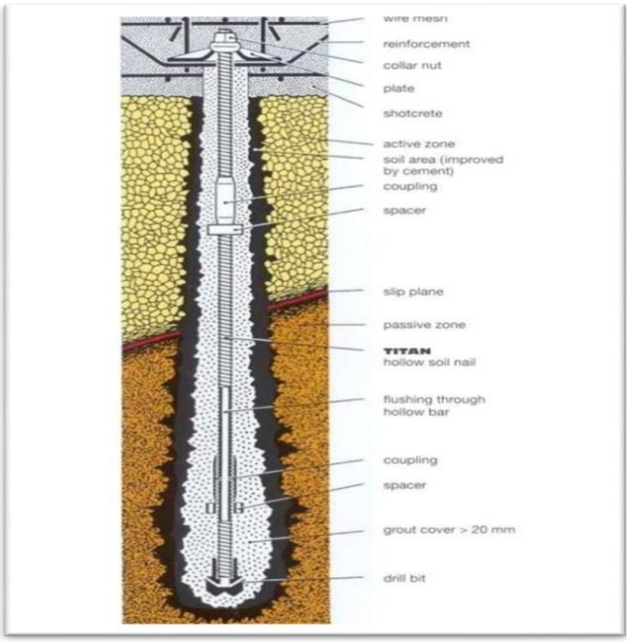


Fig b. Soil nailing Details.

1.10 Limitations

- Not suited in high water table areas.
- It is not efficient in non-cohesive , fine grained , highly corrosive , loose granular soil
- The nails are not used in permanentlong term application in sensitiveand expansive soil.
- Metal nails are limited because it gets corrode.
- Sand and gravel must not be compatible with soil nailing technique

1.11 Applications

- Stabilize existing retainingwalls
- Land slide redemption
- Steep cutting stabilization
- Temporary excavationshorting
- Stabilizing of over steepexisting embankments

1.12 Advantages

- Fast, flexible and economic
- Improve strength and stiffness
- No restriction on wall height
- Prevent slope erosion
- Need minimum slope preparationfor nailing operations

1.13 Disadvantages

- Performance of the system is affected by soil variability , corrosion , installation errors
- Cannot be applicable in allsoil conditions

Examples of the use of integrated smarttechnology in soil nailing construction.

1. Hong Kong-Zhuhai-Macao
2. Crossrail Project, London, UK High
3. Speed Rail Projects in Japan
4. Highway and Road Construction in theUnited States
5. Urban Redevelopment Projects in Singapore

CONCLUSION

Soil nailing is an accepted technology, theoreticalaspects of which are well understood and well reported in technical aspects. It is a potential solution of land slide problems. It can be used in wild types ofsoils.Proper design, installation and monitoring arecrucial for its success.It is the cost effective and sustainable method for slope stabilization. The integration of smart technology in the soil nailingconstruction techniques represents a transformative approach that revolutionizes traditional methods by providing advanced monitoring, controls, and optimization capabilities. By leveraging real time data and remote accessibility, smart soil nails contribute to safer , more sustainable and efficientsoil reinforcement solutions, ultimately enhancing theresilience and performance of civil engineeringstructures in various applications.

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