

SOIL NAILING FOR HIGHWAY CONSTRUCTION

SRINIVASA.H.N

Selection Grade Lecturer

Civil Engineering Department

Government Polytechnic, Ramanagar-562159 (Karnataka state)

ABSTRACT

In the construction industry, slope or excavation failure is a common issue and to avoid its risk on human lives and properties, Soil nailing technique is widely used since last two decades. It consists of solid or hollow steel bars, which behave as passive reinforcement, encased in grout at an inclination to the horizontal into the soil with definite horizontal and vertical spacing. In general, when compared to other traditional stabilization methods like retaining walls, the soil nailing system has the advantages of lower cost, quicker construction procedure and less impact on the adjacent ground structure. To study about soil nailing, its important parameters need to be reviewed. This paper presents applications of soil nailing and some previous researches for improvement of slope stability and stabilization of a vertical cut.

KEYWORDS: Soil nailing, Slope failure, Slope stabilization, Reinforcement techniques,

I.INTRODUCTION

Soil Nailing is widely used in civil engineering. In early 1970s, concrete gravity and semi-gravity type earth retaining structures were in vogue to retain the earth structures in highway projects [1]. If excavation support system is required to retain the soil slope then internal bracing for excavation is needed. For this, numerous alternative wall-retaining system have been introduced. In highway projects many of these earth retaining systems like Mechanically Stabilised Earth (MSE) wall, Reinforced Soil Slopes (RSS); anchored wall, diaphragm wall, sheet pile; and in-situ reinforced wall system such as soil-nailed wall and micro pile walls etc. are used O'Rourke and Jones [2] suggested changes and development in the earth retaining system in highway construction during period 1970-1990. According to them due to growth in underground construction, there is a requirement for advances in construction material and equipment for anchored wall system, advances in the use of polymeric material for mechanically stabilised earth wall construction and the use of soil nailing technique to support the excavation. There has been growing demand of these earth-retaining systems in highway projects during 25-year period after 1970 and they lead to cost and time savings.

Over the past few years, increasing demand of soil nailing in highway and railway construction was observed particularly in hilly regions. There is large scope of soil nailing in road widening projects due to less impact on moving traffic vehicles. The term 'soil nailing' comes from New Australian Tunnelling Method, where rock bolts were applied to support underground excavation in rock followed by shotcrete. In soil nailing method, closely spaced tendons are inserted in soil slope at some inclination to horizontal to restrain the soil or improve the shear strength of soil. These tendons known as nails behave as passive reinforcement to the soil structure. Origin of technology, types of construction, construction process and design methods, etc. are discussed in this paper.

II.ORIGIN OF SOIL NAILING TECHNOLOGY

Soil nailing has been widely used during last 30 years in various civil engineering projects as it proved to be more cost effective and time saving method than other conventional methods of retaining the earth structure. The origin of soil nailing comes from rock bolting in tunnelling (NAT method) in 1960 and then extending to relatively less cohesive material like soil [3]. After its application in rock, the nailing method extended in less cohesive materials like silt, gravels and sands with application in metro tunnels during 1970 in Frankfurt and in construction of a double tube subway station in Nuremberg. Use of soil nailing technique has been growing rapidly in Europe and North America since the early 1970s. In 1972, the first recorded use of soil nailing was in Europe for an 18 m high cut slope in sand as part of a railway widening project near Versailles, France [4]. The first major research project titled 'Boden-vernagelung' with 'Boden' meaning soil and 'Vernagelung' meaning nailing, thus the technical word soil nailing comes in application and undertaken in Germany from 1975 to 1980 by the University of Karlsruhe and the construction company Bauer [5]. In 1976, U.S. first used soil nailing for the support of a 13.7-meter deep foundation excavation for an extension of Good Samaritan Hospital in Portland, Oregon [6]. In 1986, a 4-year research project named CLOUTERRE was initiated in France to promote soil nailing for temporary and permanent soil nailed walls in excavation involving private and public participants with special emphasis on safety and durability [7].

Meanwhile the new technique soil nailing became popular in North America [9], with the name of 'lateral earth-support system' [9, 10], United Kingdom [11], Australia [12] and Hong Kong [13], Brazil [14], and Japan [15]. The use of soil nailing was reported as a permanent retaining wall for subway underneath a busy national highway in India [16]. In India, soil nailing technique is also rapidly increasing and design guidelines have been formed by Indian Road Congress (IRC) with the help of Indian Institute of Science, Bangalore [17] wherein till date guidelines given by FHWA are adopted.

III.DESIGN APPROACH OF SOIL NAILING

Soil-nail retaining system are designed to satisfy the requirement of stability, serviceability and durability of their design life. Other issues like the cost, time and the environmental impacts are also important in the design of the soil retention systems. In design approaches, the initial design considerations include wall layout (wall height and wall length), vertical and horizontal spacing of nail, the inclination of nail, orientation of nail and nail length, soil nail material and relevant ground properties. After considering all these parameters, the design engineer has to be evaluate the nail length and maximum nail force. Nail length, nail diameter, and nail spacing typically control external and internal stability of the wall. These parameters could be adjusted during design until all external and internal stability requirements are met. After the initial design is completed, final design progresses where the soil nail wall is tested for external and internal failure modes, seismic considerations and aesthetic qualities. Drainage, frost penetration and external loads such as wind and hydrostatic forces also have to be determined and included in the final examination of the design.

IV.ELEMENTS OF SOIL NAILING

The typical soil-nail system consists of the following basic elements: (a) Reinforcement bar, (b) centralizer, (c) grout, (d) nail head connectors (hex nut, washer and plate), (e) facing and (f) drainage.

Reinforcement Bar or Nail: Soil nail is a structural member consisting of passive reinforcement used to resist the shear, bending and tension forces. These reinforcements are generally known as nails. They can be hollow or solid type of nails. Solid nails are used when soil conditions are stable to drill hole and grouting, when soil is not able to withstand drilling then hollow nails are used with drilling and grouting process simultaneously. These nails are placed close to one another at some spacing when construction proceeds from top to down. These nails can be driven or pre-bored and grouted type depending on the soil condition. Soil nail should also be corrosion protected. Grouting acts as lower level of corrosion protection in hollow soil nails but in case of solid nails when driven, there is tendency of corrosion when nails get contact with soil and that depends on the corrosion potential of surrounding soil. So, the composite form of grouted, corrosion protected nail is highly dependent on the in-situ condition and in turn governs the installation process for these soil nails. Hence based on different installation techniques, soil nails can be classified as: grouted soil nails, self-drilling soil nails, jet-grouted soil nails and driven nails.

Facing: Facing of soil nailing wall acts as an additional support to prevent outward deformation of soil-nailed system. It is also used to improve the aesthetic appearance of the nailed structures. Facing material used should be of non-corroded type as it is exposed to atmosphere. Facing can be temporary or permanent. The facing consists of welded wire mesh carried by shotcreting of cement water and aggregate of fixed ratio as permanent facing. Shotcrete may be wet shotcrete or dry shotcrete. Dry shotcrete is preferred for small construction work. For vertical slope, thicker facing is used in comparison of inclined slope.

Grout: When nail is placed in the borehole then to fill the annular spacing between the reinforcement bar and surrounding soil, the grout is injected into the borehole followed by centralizers. Grout acts as corrosion protection to the soil and transfers stresses to the soil to form stabilized bond between nails and soils. Moisture present in soil can corrode the nail by time but with the use of grouting, it prevents nails from corrosion. For grouting neat cement and water mix is used; sometimes cement, sand and water mix also used for the open-hole drilling. Pipe is used for injecting grout to the borehole.

Drainage system: It is necessary to provide a drainage system behind initial facing or adjacent excavation face. It regulates the pore water developed in soil slope and protects the facing and soil nail bonding. Usually vertical geo-composite strip drains are used as a drainage system.

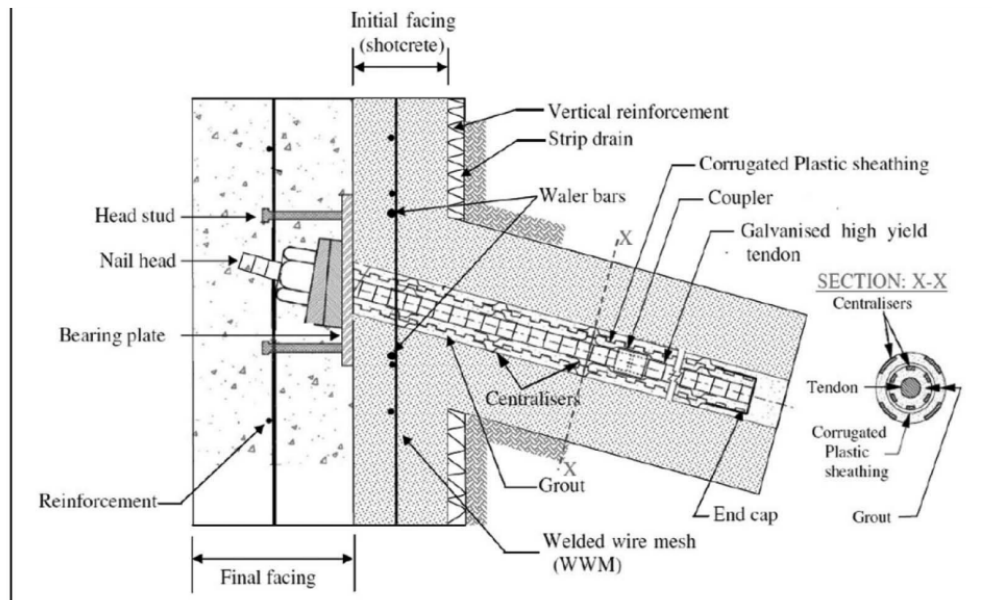


Figure 1. Typical cross-section of a complete soil nail wall.

V.APPLICATIONS OF SOIL NAILING

Soil nailing method has various applications:

- Slope stabilization
- Landslide prevention
- Deep excavation or vertical cut stabilization
- Stabilization of roadway and highway cuts
- Road widening under existing bridge abutments
- Tunnel portal in steep stratified and unsupported slopes
- Repair and reconstruction of existing retaining structures
- Use for deep vertical excavation in densely populated areas.
- Stabilizing of over steep existing embankments
- Protection and preservation of historical buildings.

VI.ADVANTAGES AND DISADVANTAGES OF SOIL NAILING

Soil nailing technique has various merits and demerits addressed by Geoguide 7, FHWA-NHI-14-007 [2] and by other researchers as follows:

Advantages of soil nailing

- Soil nailing technique is more advantageous than other conventional techniques of slope stabilization i.e. retaining wall, ground anchors etc., as it is less disruptive to traffic and causes less environmental impact.
- Soil nailing is top down construction method so relatively faster in installation and uses less construction material.
- Soil nailing method requires less space for movement of equipment as they are comparatively small so can be advantageous for sites at remote location.
- Soil nailing technique does not use bracing to support excavation unlike other techniques so causes less congestion to excavation.
- Soil nailing technique is also well performed in seismic region.
- Facing of soil nailing gives good aesthetics to the structure and more natural appearance than other finishes.
- From cost point of view convention soil nails are more economical than concrete gravity walls and equivalent in cost or more cost-effective than ground anchor walls.

Disadvantages of soil nailing

- Soil nailing method is not recommended where strict wall movement exists, posttensioning of soil nails can be used for this shortcoming but it adds extra cost to the project.
- Soil nailing technique cannot be preferable near ground water condition. High ground water table causes difficulty in excavation during construction and ground water corrodes the reinforcement and grout water ratio disturbs.

- Soil nailing is not suitable for loose soil and cohesionless soil because during the nailing process, un-grouted holes can collapse.
- Underground drainage system, underground cables, pipes get disturbed during soil nailing process. So, for that proper care should be taken during installation of nails.

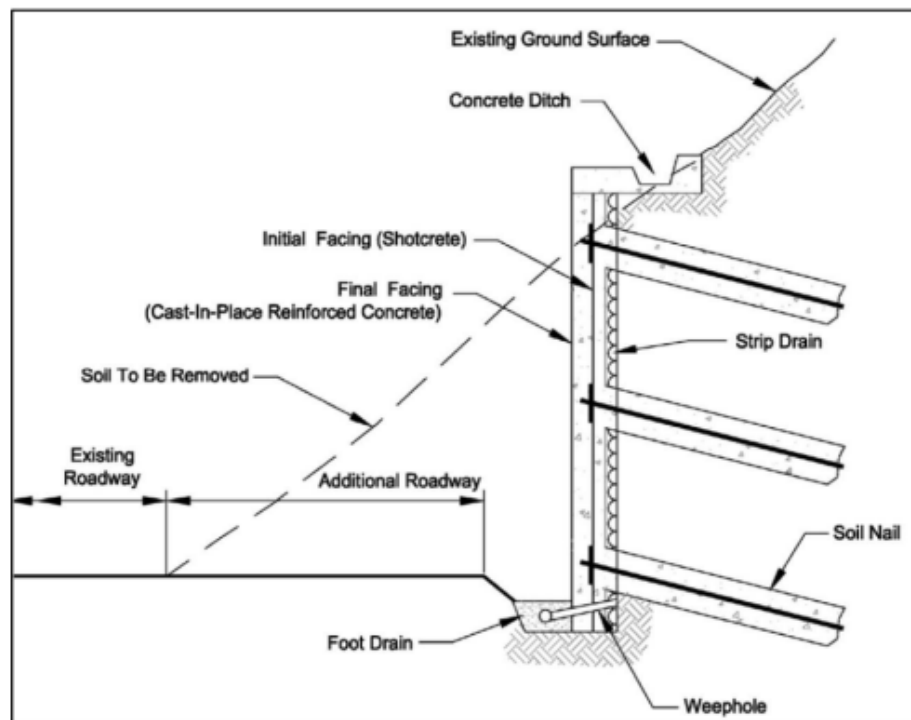


Figure 2. Roadway cut supported with soil nails.

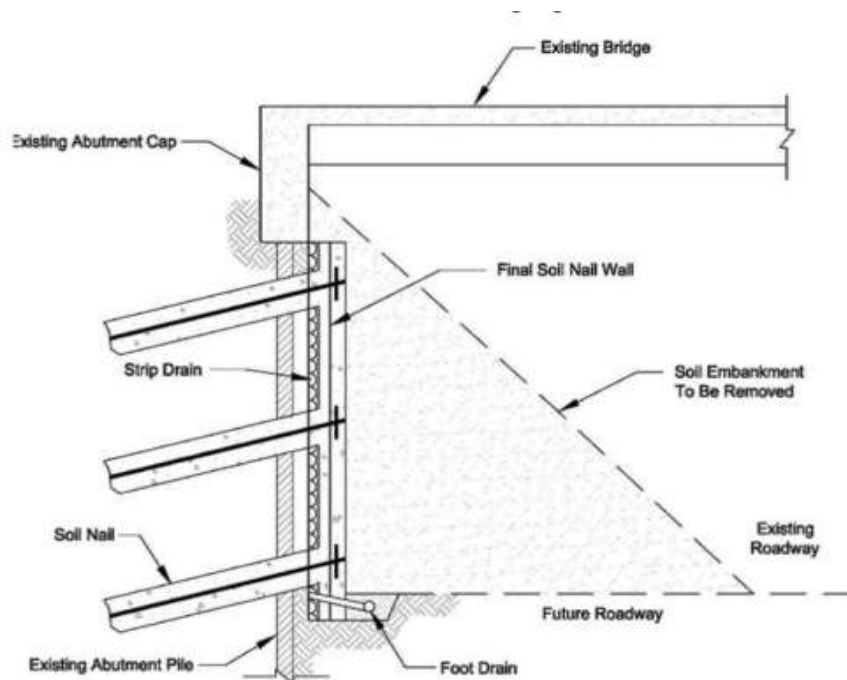


Figure 3. Road widening under existing bridge

VII.CONCLUSIONS

This 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 highway construction practices, highlighting their

ability to manipulate soil conditions to meet project specifications effectively. By exploring advancements in ground improvement methods over the past decade, the paper offers insights into various advantages of soil nailing technique.

The 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. The paper highlights the efficacy of soil nailing in enhancing slope stability, reducing deformation, and addressing settlement concerns.

REFERENCES

- [1] FHWA, "Geotechnical Engineering Circular No. 7: Soil Nail Walls", Report No. FHWA0-IF-03- 017, Federal Highway Administration, Washington, USA, 2003.
- [2] T.D. O'Rourke and C.J.F.P. Jones, "Overview of Earth Retention Systems: 1970-1990, Design and Performance of Earth Retaining Structures, American Society of Civil Engineers, Geotechnical Special Publication No. 25, pp. 22-51, 1990.
- [3] L.V. Rabcewicz, "The new Austrian tunneling method", Water Power, vol. 16, no.11 pp. 453-457, Nov. 1964.
- [4] S. Rabejac and P. Toudic, "Construction of a retaining wall between Versailles-Chantiers and Versailles - Matelots", Revue générale des chemins de fer, French railway review no. 93, pp. 232 – 237, 1974.
- [5] M.D. Stocker, G.W. Korber, G. Gassler and G. Gudehus, "Soil nailing", Proc. Int. Conf. Soil Reinforcement, Paris, vol. 2, pp. 469–474, March 1979 .
- [6] FHWA, "Manual for design and construction monitoring of soil nail walls", FHWA-SA-96-096R. U.S. Department of Transportation, Federal Highway Administration, Washington, D.C., 1998.
- [7] R. Clouterre, "Soil nailing recommendation 1991", An English translation of 'Recommendations CLOUTERRE — 1991, USA Report No. FHWA-SA-93-026, US Department of Transportation, Federal Highway Administration, Washington DC, 1991.
- [8] C.K. Shen S. Bang and L.R. Herrman, "Ground movement analysis of earth-support system", J. of Geotech. and Geoenv. Engg., ASCE 107 (GT12), pp. 1609-1624, 1981.
- [9] V. Elias and I. Juran, "Soil Nailing for Stabilization of Highway Slopes and Excavations", Publication FHWA-RD-89-198, Washington D.C., Federal Highway Administration, 1991.
- [10] FHWA, "Soil Nailing Field Inspectors Manual - Soil Nail Walls", Report No.FHWA-SA-93-068, Federal Highway Administration, Washington DC, 1994. pp. 665-670, 1981.
- [11] R. Jewell and M. Pedley, "Analysis for Soil Reinforcement with Bending Stiffness", Journal of Geotechnical Engineering, vol. 118, no. 10, pp. 1505-1528, 1992.
- [12] P. Seto, G.W. Won and K.Y. Choi, "Use of soil nailing in stabilization of a freeway embankment", Earth Reinforcement Practice: Proc. Int. Symp. on Earth Reinforcement Practice, Fukuoka, Kyushu, Japan, pp. 11-13, 1992.
- [13] A.T. Watkins and G.E. Powell, "Soil nailing to existing slopes as landslip preventive works", Hong Kong Eng, vol. 20, no. 3, pp. 20-27, 1992.
- [14] J.A.R. Ortigao, E.M. Palmeira and A.C. Zirlis, "Experience with soil nailing in Brazil:1970-1994", Proc. Int. Civil Engineer, Geotechnical Engineering, vol. 113, pp. 93-106, 1995.
- [15] M. Hirano, "Actual status of the application of Soil Nailing to expressway cut slope construction in Japan", Landmarks in earth reinforcement. Proc. Int. Earth Reinf.,Kyushu, Japan, pp. 919-934, 2001.
- [16] B.R. Srinivasa Murthy, G.L. Sivakumar Babu and A. Srinivas, "Analysis of prototype soil - nailed retaining wall", Proc. Institution of Civil Engineers-Ground Improvement, vol. 6, no. 3, pp. 129-136, 2002.
- [17] G.L. Siva Kumar Babu and Vikas Pratap Singh, "Appraisal of Soil Nailing Design", Indian Geotechnical Journal, vol. 39, no. 1, pp. 10–17, 2009.
- [18] R.A. Jewell, "Some Effects of Reinforcement on the Mechanical Behaviour of Soils", PhD thesis, University of Cambridge, 1980.
- [19] J. Long, "Stability analyses for soil nailed walls", Geotechnical Special Publication, vol. 25, pp. 676-691, 1990.
- [20] F. Schlosser, P. Unterreiner and C. Plumelle, "French research program CLOUTERRE on soil nailing", Proc. 1992 ASCE Specialty Conference on Grouting, Soil Improvement and Geosynthetics, 25-28 Feb. 1992, New Orleans, LA, USA.
- [21] E. Güler and C. Bozkurt, "The effect of upward nail inclination to the stability of soil nailed structures", Geotechnical Engineering for Transportation Projects, American Society of Civil Engineers: pp. 2213-2220, 2004.

- [22] S. Khatami and F. H. Dabaghi, "River bank erosion control by soil nailing", *Geotechnical and Geological Engineering*, vol. 24, pp. 1821–1833, 2006.
- [23] A. Hossain and A. Islam, "Numerical analysis of the effects of soil nail on slope stability", *International Journal of Computer Applications*, vol. 141, pp. 0975-8887, 2016.
- [24] S. Singh and A.K. Shrivastava, "Effect of soil nailing on stability of slopes", *International Journal for Research in Applied Science & Engineering Technology*, vol 5, Issue X, pp. 752-763. 2017.
- [25] J.A. Potterfield, D.M. Cotton and R.J. Byrne, *Soil Nailing Field Inspectors Manual FHWA Report SA-93-068*, 1994