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A Review on Utilization of Soil Nailing for Soil Stabilization

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Abstract - *The natural slope which is assumed by throwing up the mass of the earth into a heap along the roadside and the other engineering structures is usually weak in resisting shear, earthquakes, heavy rainfalls and seepage pressure due to high ground water table and may result in settlement of slopes. Thus, in order to provide stability to such slopes, and to improve the geotechnical parameters of the underlying soil, a technique named as 'SOIL NAILING' is used widely.*

The insertion of the vertical reinforcing bars into the soil slopes to increase the shear strength along with remarkable reduction in the settlement is known as soil nailing. The main contribution of my work lies in the general overview of using soil nailing to improve the geotechnical parameters of the soil slope with the help of various researches conducted earlier. The study shall help to understand the advantages and applications of soil nailing technique over the other conventional methods of stabilizing soil slopes.

***Key Words*: Slope stabilization, Pullout resistance, Soil nailing, Flexible facing, Rigid facing, Overburden and grouting pressure**

1. INTRODUCTION

1.1 Soil Slopes Failure

This is a major natural hazard along the various regions of the world. It occurs when the shear resistance along the slip plane is exceeded due to excessive imposed loads or due to seepage pressure, high water table or due to heavy rainfalls. In order to prevent these slope failures, a general remedy is to embed these slope failure planes with the reinforcing elements called soil nails.

1.2 Soil Nailing

Soil nails are the closely spaced reinforcing passive elements that are drilled and grouted sub-horizontally in the ground to support excavation in soil and in soft, weathered rocks and enhance the stability and geotechnical properties of engineering structures. It has been an alternative technique to the other conventional soil supporting systems as it offers flexibility, rapid construction cost and competitive cost. Its main purpose is to increase the tensile strength, shear strength of soil and restrain its displacement. The soil nails support the soil and transfer loads to the soil mass behind the wall.

1.3 Soil Nailing Technique and Elements

Soil nailing is a top to bottom construction method. It involves the reinforcing of soil by elongated elements called soil nails. These soil nails are inserted at a certain angle to the horizontal into the pre-drilled holes and then grouted.

Soil nailing technique has following elements:

a.) Tendons: These are the threaded elements (equivalent to steel bars) either continuous or ribbed which are installed into the soil slopes and at a certain inclination angle to the horizontal. The tensile stress in each tendon mobilizes in response to lateral movement and deformation of the retained soil. Tendons should have desired pullout resistance, tensile strength and corrosion resistance properties.

b.) Grout – A paste of Portland cement and water with a water-cement ratio varying from 0.4-0.5 is used to fill the annular spaces between the installed tendon and the soil in the drilled hole. Grouting in soil nailing is generally done using Tremie's method.

The grout has mainly two functions:

- To transfer shear stress between the deforming ground and the tendons;
- To transfer tensile stress from the tendons to the surrounding stable soil.

c.) Centralizers: They are the devices made up of PVC or other synthetic materials and are installed at various locations along the length of each tendon to make sure that soil nail is centered in the drilled hole and a least grout thickness wholly covers the tendon.

d.) Facing: After installation of the tendons and centralizers at their respective places, facing is laid. Facing consists of an initial facing built of reinforced shotcrete and a final facing of shotcrete or cast in place concrete. The function of the initial facing is to provide a temporary stability and protection to the exposed soil between the nails during excavation and nail installation. It also receives the bearing plate. It is constructed after the construction of each excavation level. The function of the final facing

is similar to initial facing except for that it also adds to aesthetic appearance. Final facing is constructed after the construction of all the excavation levels is complete.

e.) **Drainage system**: The drainage system for the soil nail wall consists of the geo-composite strips or strip drains which are installed behind the initial facing of the soil nail walls in order to reduce the developing water pressure behind the wall facing, if any. The main function of this drainage system is to first of all collect all the alighted or infiltered groundwater and then finally to direct that water away from the system.

f.) **Connection components**: The soil nails inserted into the drilled holes are required to be connected to the facing and it is done through a number of components namely hexagonal nuts, washers, bearing plates and headed studs, where, bearing plate, hexagonal nuts and washers are used to connect the nails to the initial facing whereas, headed studs are used to connect the nail end to the final facing.

1.4 Conventional Vs. Nailed walls

It can be concluded from the various previous researches that the soil nail technique is way better than the conventional one is many aspects as mentioned below:

a.) **Economical aspect:** Soil nails are way more cost effective than the conventional gravity walls and ground anchor walls. Also, the shotcreting technique used for facing is typically less costly than the structural facing used in the other wall systems.

b.) **Structural stability:** Soil nail wall has more redundancy than the anchored walls as the large number of nails is used and thus ensures the greater structural stability and involves no compromise in the level of safety.

c.) **Flexibility:** Soil nailing is comparatively flexible and thus accommodates larger total and differential settlements. Also, they have performed better during past seismic events and thus proving the better flexibility of the system.

d.) **Equipment's used:** Soil nail installation is comparatively faster and uses lesser construction and installation equipment's than the conventional ground anchors.

e.) **Ease of nail adjustment:** Nail location, inclination angle and length can be easily adjusted in soil nailing when any obstruction like cobbles, boulders or underground pipelines etch is confronted. Whereas, the modification of ground anchor's horizontal position is relatively difficult and costly.

f.) **Space requirements:** Soil nailing technique causes less trouble to the traffic and provides a relatively less congested work space. Also, it provides a greater right of way than any other system.

2. LITERATURE REVIEW

Liew Show- Shong (2005): This paper throws light on soil nail design philosophy and methodology. A supervision check test for soil nailing work and specifications for the sample were given in the appendices. It was observed that the nail resistance had improved only by a few percent because of flexural and shearing action of soil and also the ultimate ground resistance was found to be $1/4^{th}$ to $3/4^{th}$ times of the undrained shear strength.

Jian-Hua Yin and Wan-Huan Zhou (2009): A cascade of soil pullout tests were conducted with varying grouting pressure and overburden stress and were seen to have interactional effect i.e. soil nail pullout resistance depends only slightly upon overburden stress when grouting pressure was kept low, but when grouting pressure was kept high, the effect of overburden pressure was seen to have increased. Also, a new empirical equation with two parameters C_G' and μ_g' was proposed for the calculation of soil nail pullout resistance considering both grouting pressure and overburden stress.

Siavash Zamiran, Hamidreza Saba (2012): Dynamic and static analysis was carried out on a soil nail model. The 2 key parameters considered to compare static and dynamic behavior of soil nail walls were nail length and nail inclination angle. It was revealed that maximum displacement of wall occurs at top of wall and $1/3^{rd}$ of wall in dynamic and static analysis respectively. The takeaway is that the nail length contributes more in dynamic analysis than that of the static analysis.

Wan-Huan Zhou, Ka-Ving Yuen, Fang Tan (2013): A new design formula was derived to estimate the maximum pullout stress of grouted soil nails. Degree of saturation and product of overburden pressure and grouting pressure being the key factors for estimation of pullout resistance, it was found out that the proposed formula showed more accurate

results when tallied with measurements than the effective stress method.

Veerabhadra M. Rotte, Bhamidipati V.S. Viswanadham (2013): This study was conducted to observe the slope behavior when subjected to seepage on elevated ground water level during centrifuge test at 30g on 5V:1H slopes in presence and absence of nail reinforcement. When the inclinations were kept 10° and 25°, it was observed that for an identical facing type and nail layout, 10° inclination slope of 5V:1H was found to perform better than 25° inclination of soil slope.

Tae C Kim, Jinyuan Liu, Stephen Lee (2014): In this study, the behavior of unreinforced and soil nailed slopes under different surcharge loads was found out by observing inclination angle; 0°,15°, 30° and square, diamond and staggered soil patterns. It was concluded that the order of inclination was 0°>15°> 30° and that of soil nail pattern was staggered>square>diamond. Also strain gauges installed at different positions in the soil nails showed that maximum strain is obtained as: topmost nail> middle nail> bottom most nail.

Ravindra Budania, Dr. R.P. Arora (2016): This research paper throws light on the general overview of in-situ soil nailing technique for soil stabilization. Various deflections of soil nail walls were measured and were found within the tolerable limits. The study suggested that soil nailing walls are more cost effective for walls taller than 12-15ft. than conventional gravity walls also soil nail walls have more redundancy than the anchored walls.

Chee-Ming Chan and Muhammad Halim Ab. Raman (2016) This paper reflects on the innovation of soil nail with screw-in nail installation mechanism which has a hollow stem and also, nail head has an opening which allows air to escape. In this study both, conventional and these innovative nails were studied in simulation experiment of slope. 37% angular distortion was observed to be reduced along with 33% improvement in volume deformation.

Tao Sun, Yangfeng sun, Qiang Liu (2017): Field tests were conducted to check if flexible facing was a good substitute to reinforced concrete facing using a woven geomembrane for which, top slope's horizontal displacement, vertical settlement, earth pressure and tension force; and horizontal displacement of inner slope were observed. A surcharge of 117.7 KPa and prolonged artificial rainfall also rendered the slope overall stable. It was depicted with the test that flexible facing can replace the reinforced concrete but should be limited to non-critical structures where large horizontal and vertical deflections are acceptable.

Shamsan Alsubal, Indra S.H. Harahap and Nuraddeen Muhammad Babangida (2017): The nutshell of this paper which was to find out optimum of parameters related to soil nails was that inclination of soil nails to horizontal depends upon slope, more the angle of inclination and vice versa. Typically, for slopes of 30°, 45°, 60°, 70° and 90°, nail inclination should be 50°, 40°, 20°, 15° and 10° respectively was found out. Also, the ideal spacing was found out to be anywhere between 1-2 meters for nails half the height of the slope, optimal FOS's obtained at soil inclination of 20°-25° higher than that of moderate and long soil nails.

Dildar Ali Mangncjo, SJ Oad, Shahbaz Ali Kalhoro, S. Ahmed, F.H. Lagari, Z.A. Siyal (2019): To study the effects of diameter of soil nails and its inclination on the slope stability, soil nail of diameter 25mm, 40mm at inclination of 20°, 25°, 30°, 35° and 40° were tested. The value of FOS of slope using limit equilibrium method was found to be 1.19, which being low required more rows. Therefore, 3 rows of 25mm and 40mm diameter nails were used with different inclination at different locations. This analysis clearly portrayed that the usage of 40mm soil nails at 40° inclination improved the FOS of existing slope significantly when 3 rows were planted rather than 25mm diameter nails.

3. Conclusions

a. In terms of economy and redundancy, soil nail walls perform better than the conventional wall systems.

b. The innovation of soil nailing in terms of screw-in nails when used, usually three in number results into more stability.

c. Flexible facing can be used as a substitute to reinforced concrete facing, provided the structures are of short height and also made up of high strength soil allowing higher horizontal and vertical deformations.

d. The maximum displacement of wall occurs at top of the wall and 1/3rd of the wall in dynamic and static analysis respectively.

e. The order of inclination angle of soil nails in terms of obtaining better stability is 0°>15°> 30° and that of soil nail pattern is staggered>square>diamond.

f. Using the innovative screw-in nails, 37% angular distortion can be reduced along with 33% improvement in volume deformation.

g. The ideal spacing lies anywhere between 1-2 meters for nails half the height of the slope.

h. The soil nailing technique can be effectively used to retrofit the old structures, thus reducing the reconstruction and demolition costs.

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BIOGRAPHIES

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