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Soil Nailing for Slope Stabilization: An Overview

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Abstract:
Soil nailing is an in-situ reinforcement technique by passive bars which can withsand tensile forces, shearing forces and bending moments. This technique is used for retaining walls and for slope stabilization. Its behaviour is typical of that of composite materials and involves essentially two interaction mechanisms. The soil- reinforcement friction and the normal earth pressure on the reinforcement. The mobilization of the lateral friction requires frictional properties for the soil, while the mobilization of the normal earth pressure requires a relative rigidity of the inclusions.

Keywords: Stabilization, Nails, Centralizers

I. INTRODUCTION

A landslide (landslip) is a geological phenomenon that comprises a wide range of ground movements, such as rock falls, deep failure of slopes etc. Landslides can occur in offshore, coastal and onshore environment. It can be controlled by the use of proper slope stabilization techniques. Soil stabilization is a term in which the natural soil is changed in order to meet the engineering purposes by means of physical, chemical, biological and combined method of either two of them or all three. Weight bearing capacity and the performance of the in-situ soil and sand can be increased by soil stabilization techniques (Sharma 2015). Soil nailing is an advance technique of slope stabilization amongst other techniques. Soil nailing is the technique used in slope stabilization and excavation with the use of passive inclusions, usually steel bars, termed as soil nail. Soil nailing is typically used to stabilize existing slopes or excavations where top-to-bottom construction is advantageous compared to other retaining wall systems (Taib, 2010). Soil nails are structural reinforcing elements installed to stabilize steep slopes and vertical faces created during excavations. Commonly used soil nails are made of steel bars covered with cement grout. The grout is applied to protect the steel bars from corrosion and to transfer the load efficiently to nearest stable ground. Some form of support, usually wire mesh-reinforced shotcrete, is provided at the construction face to support the face between the nails and to serve as a bearing surface for the nail plates (Palmeira *et al.,* 2008).

II.ORIGIN OF THE SOIL NAILING TECHNIQUE

The soil nailing technique was developed in the early 1960s, partly from the techniques for rock bolting and multi-anchorage systems, and partly from reinforced fill technique (FHWA, 1998). The New Austrian Tunneling Method introduced in the early 1960s was the premier prototype to use steel bars and shotcrete to reinforce the ground. With the increasing use of the technique, semi-empirical designs for soil nailing began to evolve in the early 1970s. The first systematic research on soil nailing, involving both model tests and full-scale field tests, was carried out in Germany in the mid-1970s. Subsequent development work was initiated in France and the United States in the early 1990s.

- Tunnelling Method in the 1960's.One of the first applications of soil nailing was in 1972 for a railroad widening project near Versailles, France, where an 18 m (59 ft) high.
- In Germany, the first use of a soil nail wall was in 1975.
- The United States first used soil nailing in 1976 for the support of a 13.7 m deep foundation excavation in dense silty sands.
- In India use of soil nailing technology is gradually increasing and guidelines have been made by IRC with the help of Indian Institute of Science, Bangalore.

III.CONCEPT OF SOIL NAILING:-

The function of soil nailing is to strengthen or stabilize the existing steep slopes and excavations as construction proceeds from the top to bottom. Soil nails develops their reinforcing action through soil-nail interaction due to the ground deformation which results in development of tensile forces in soil nail. The major part of resistances comes from development of axial force which is basically a tension force. Conventionally, shear and bending have been assumed to provide little contribution in providing resistance (Dey, *2015).*
The effect of soil nailing is to improve the stability of slope or excavation through

a) Increasing the normal force on shear plane and hence increase the shear resistance along slip plane in friction soil.
b) Reducing the driving force along slip plane both in friction and cohesive soil.
In soil nailing, the reinforcement is installed horizontally or gently inclined parallel to the direction of tensile strain so that it develops maximum tensile force develops. Soil nails are passive inclusions, which improve shearing resistance of soil. The soil nail system can be divided into active and passive region as shown in Figure. During the slope failure, active region tends to

deform which results in axial displacement along soil nails which are placed across the slip plane. This results in the development of tensile forces in soil nail in the passive zone which resists the deformation of active zone. This tension force results in increment of the normal force coming on slip plane and reduces the driving shear force. The soil nails are embedded in passive region through which it resists the pull-out of nail from slope through friction between nails and soil. Based on the above two mechanisms, the required amount of nail length should be placed in resistive zone. In addition, the combined effect of nail head strength and tension force generated in active zone must be adequate to provide the required nail tension at the slip surface (Byrne et al. 1998).

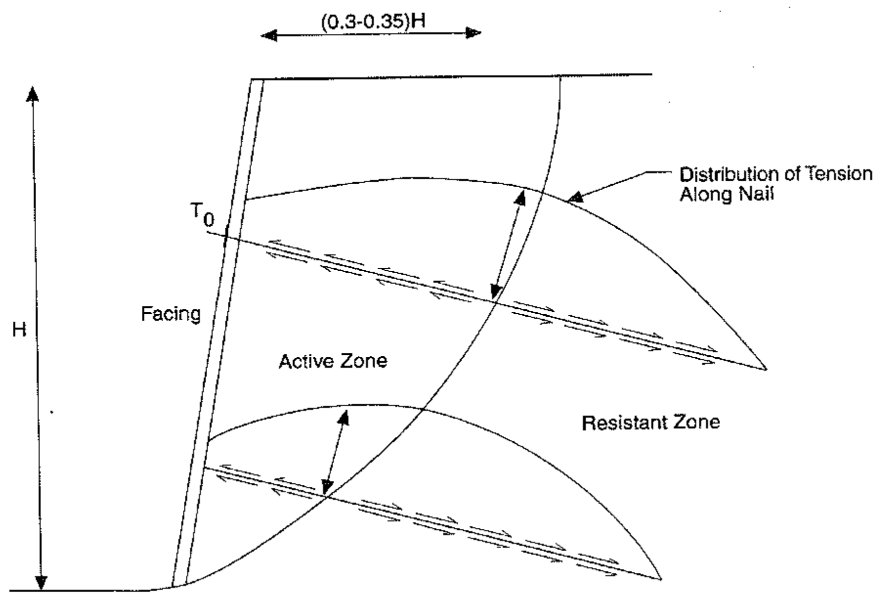

Figure.1. Conceptual soils nail behavior (Byrne *et al.,* 1998)

- **Construction of soil nailing structures**
  - **Constructional elements**
  - **Constructional procedure**

4.1. Elements of nailed structure:-

Various components of a grouted soil nail are:-

4.1.1. Steel reinforcing bars – The solid or hollow steel reinforcing bars (with minimum strength of 415 kPa) are the main component of the soil nailing system. These elements are placed in pre-drilled drill holes and grouted in place.

Figure.2. Soil nails reinforcement Bars

4.1.2. Centralizers- Centralizers are devices made of polyvinyl chloride (PVC) or other synthetic materials that are installed at various locations along the length of each nail bar to ensure that a minimum thickness of grout completely covers the nail bar.

Figure.3. Typical Centralizers

4.1.3. Grout – Shotcrete or grout can be continuous flow of mortal or concrete mixes projected at high speed perpendicularly onto the exposed ground surface. Grout is injected in the pre-drilled borehole after the nail is placed to fill up the annular space between the nail bar and the surrounding ground. Generally, neat cement grout is used to avoid caving in drill-hole; however, sand-cement grout is also applied for open-hole drilling (Shong, 2005).

Figure.4. Grout is being placed with the help of pipes

4.1.4. Nail head – The nail head is the threaded end of the soil nail that protrudes from the wall facing. It is a square shape concrete structure which includes the steel plate, steel nuts, and soil nail head reinforcement. This part of structure provides the soil nail bearing strength, and transfers bearing loads from the soil mass to soil nail.

4.1.6. Temporary and permanent facing – Nails are connected to the excavation or slope surface by facing elements. Temporary facing is placed on the unsupported excavation prior to advancement of the excavation grades. It provides support to the exposed soil, helps in corrosion protection and acts as bearing surface for the bearing plate. Permanent facing is placed over the temporary facing after the soil nails are installed.

4.1.7. Drainage system – Vertical geo-composite strip drains are used as drainage system media. These are placed prior to application of the temporary facing for collection and transmission of seepage water which may migrate to the temporary facing.

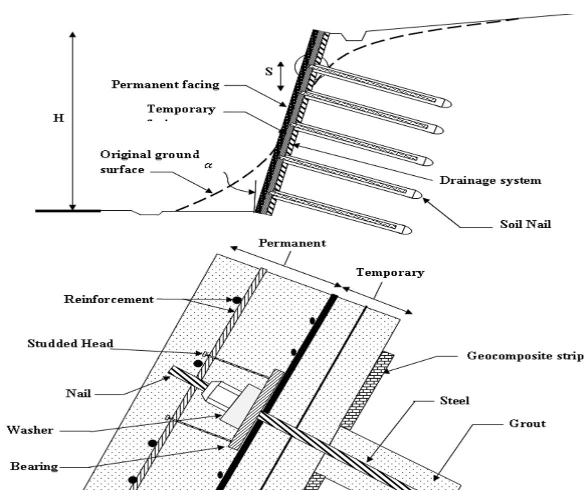

Figure.5. Typical cross-section of a drilled soil nail wall (Byrne *et al.*, 1998)

Constructional Procedure

- **Excavation**

Prior to any excavation, surface water controls should be constructed to prevent surface water from flowing into the excavation, as this condition will adversely affect construction and potentially cause instability of the excavated face. Collector trenches behind the limits of the excavation usually intercept and divert surface water. Initial excavation is carried out to a depth for which the face of the excavation may remain unsupported for a short period of time, e.g. 24 to 48 hours. The depth for each excavation reaches slightly below the elevation where nails will be installed. The width of the excavated platform or bench is such that it can provide sufficient access to the installation equipment. The initial lift is typically taken as 1 to 1.2 m high. The excavated face profile should be reasonably smooth and not too irregular to minimize excessive shotcrete quantities.

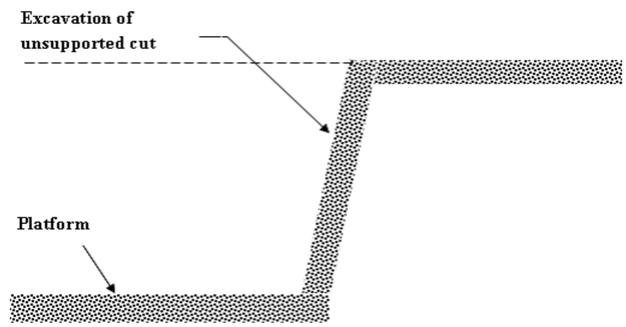

Figure.6. Excavation of small cut (Byrne *et al.*, 1998)

Drilling Nail Holes:-

There are two types of processes which can be carried out after excavation for putting the nails. The nail can be directly pushed into the soil using suitable equipment, in which the nail itself makes its way forward. Alternatively, a hole can be drilled prior to putting the nail by using some drilling equipment. Some of the drilling equipments used for this method are listed below.

- Drill bit machine
- Rope core drill
- Air leg rock drill
- Horizontal drill machine

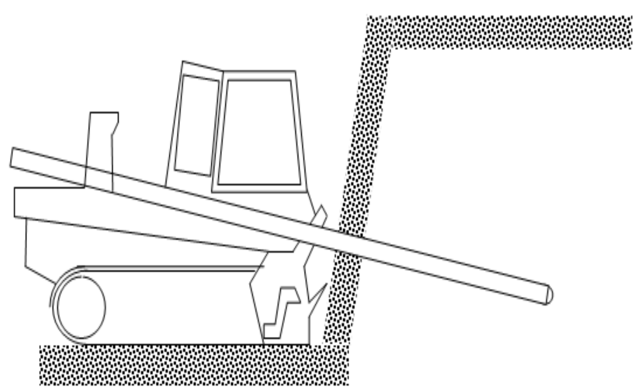
Figure.7. Drilling Nail Holes (Byrne *et al.*, 1998)

Nail Installation and Grouting:-

Nail bars are placed in the pre-drilled holes. Centralizers are placed around the nails prior the insertion of nails to maintain proper alignment within the hole and also to allow sufficient protective grout coverage over the nail bar. Grout pipe is also inserted in the drill hole at this stage. A grouting pipe is normally attached with the nail reinforcement while inserting the nail into the drilled hole. Sometimes additional correctional protection is used by introducing corrugated plastic sheathing The normal range of water/cement ratio of the typical grout mix is from 0.45 to 0.5. The grout is commonly placed under gravity or low pressure. The grouting is from bottom up until fresh grout return is observed from the hole.

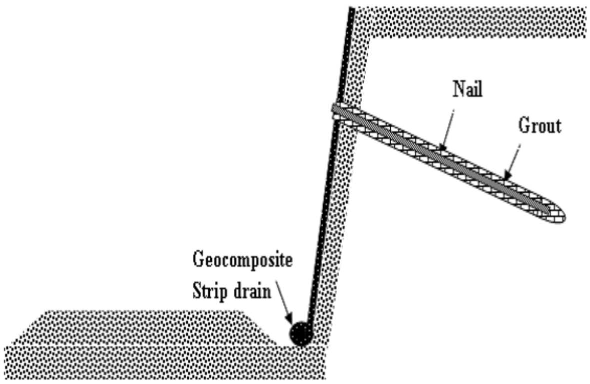

Figure.8. Nail Installation and Grouting (Byrne *et al.*, 1998)

Construction of Temporary Shotcrete Facing

The temporary shotcrete facing is placed to temporarily restrain the exposed soil in cut face. It consists of 3-4 inches of shotcrete reinforced with a single layer of welded wire mesh. Two types of shotcrete methods are commonly used: *dry mix and wet mix*. In the dry mix method, the aggregate and cement are blended in the dry and fed into the shotcrete gun while the mix water is added at the nozzle. In the wet mix method, the aggregate, cement, water, and admixtures are mixed in a batch plant and conveyed to the nozzle by a hydraulic pump. Both shotcrete methods produce a mix suitable for wall facings. Dry mix and wet mix shotcrete use a water-cement ratio of about 0.4 and produce roughly the same mix quality, although shotcrete obtained with the wet mix process yields a slightly greater flexural strength.

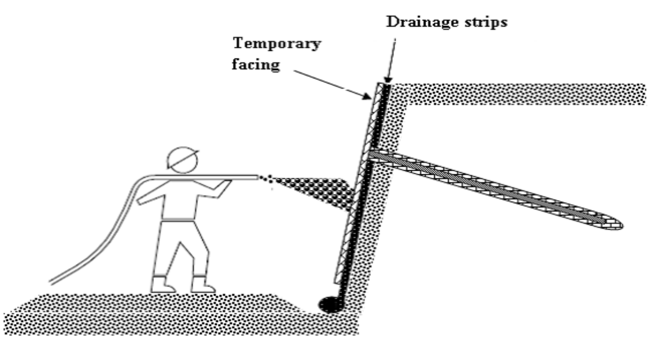

Figure.9. Construction of Temporary Shotcrete Facing (Byrne *et al.*, 1998)

Construction of Subsequent Levels:-

The steps mentioned above are repeated for the remaining excavation stages. At each excavation stage, the vertical drainage strip is unrolled downward to the subsequent stage. A new panel of WWM is then placed overlapping at least one full mesh cell. The temporary shotcrete is continued with a cold joint with the previous shotcrete lift. At the bottom of the excavation, the drainage strip is tied to a collecting toe drain.

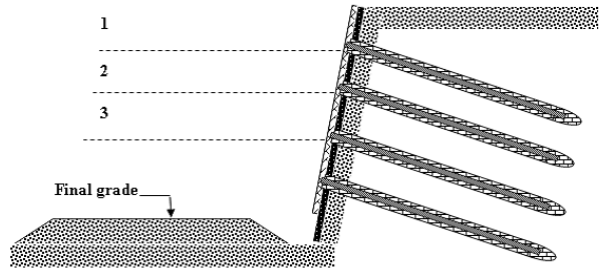

Figure.10. Construction of Subsequent Levels (Byrne *et al.*, 1998)

Construction of Permanent Facing:-

The final facing is constructed after the bottom of the excavation is reached and nails are installed. Final facing consists of cast-in-place (CIP) reinforced concrete, reinforced shotcrete, or prefabricated panels. Generally, conventional concrete bars or WWM is provided as reinforcement in permanent facing. When CIP concrete and shotcrete are used for the permanent facing, horizontal joints between excavation stages are avoided to the maximum extent possible.

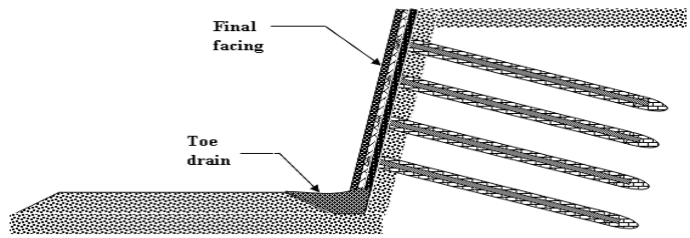

Figure.11. Construction of Permanent Facing (Byrne *et al.*, 1998)

- **VARIOUS TYPES OF SOIL NAILING:-**

Various types of soil nailing methods that are employed in the field are listed below:

- Grouted Nail: After excavation, first holes are drilled in the wall/slope face and then the nails are placed in the predrilled holes. Finally, the drill hole is then filled with cement grout.
- Driven Nail: In this type, nails are mechanically driven to the wall during excavation. Installation of this type of soil nailing is very fast; however, it does not provide a good corrosion protection. This is generally used as temporary nailing.
- Self-Drilling Soil Nail: Hollow bars are driven and grout is injected through the hollow bar simultaneously during the drilling. This method is faster than the grouted nailing and it exhibits more corrosion protection than driven nail.
- Jet-Grouted Soil Nail: Jet grouting is used to erode the ground and for creating the hole to install the steel bars. The grout provides corrosion protection for the nail.

- **Applications**

  Soil nail can be used in the following applications: (lazarte *et al.*, 2015)

6.1. Roadway Cuts

Soil nailing is attractive in roadway cuts because a limited excavation and reasonable right-of-way (ROW) and clearing limits are required. These factors help to reduce the environmental impacts along the transportation corridor. The impact to traffic may also be reduced because the equipment for installing soil nails is relatively small.

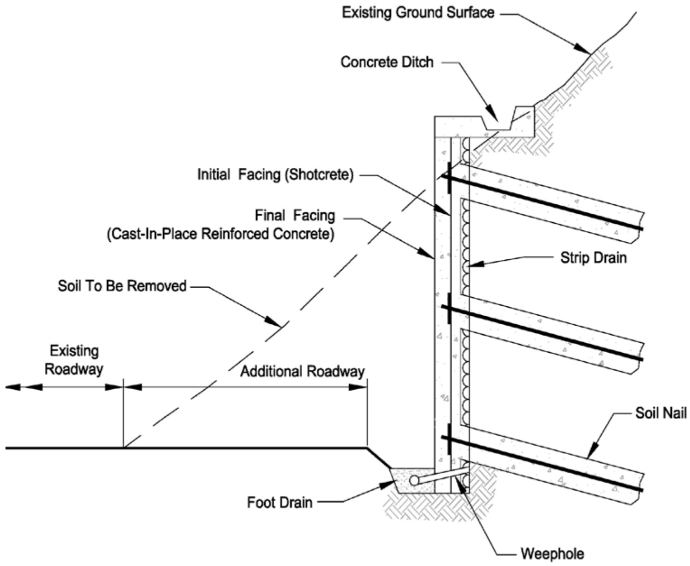

Figure. 12. Roadway Cuts (lazarte *et al.*, 2015)

6.2. Road Widening Under Existing Bridge Abutments

Soil nail walls can be advantageous for underpass widening when the removal of an existing bridge abutment slope is necessary. While the cost of installing a soil nail wall under a bridge abutment may be comparable to that of other applicable systems, the advantage of soil nailing is that the size of the soil nail drill rig is relatively small.

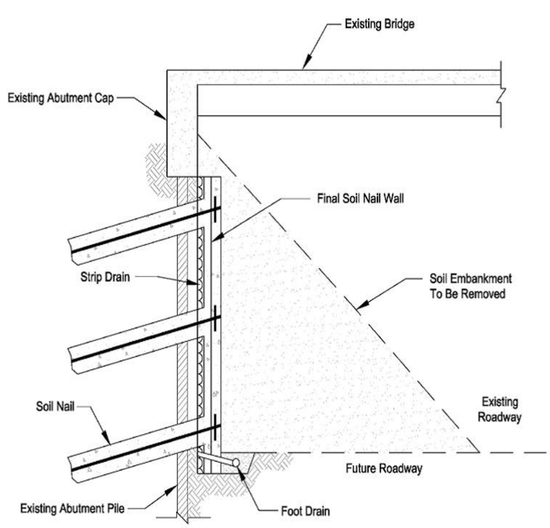

Figure.13. Road Widening under Existing Bridge Abutments (lazarte *et al.*, 2015)

Repair and Reconstruction of Existing Retaining Structures

Soil nails can be used to stabilize and/or strengthen failing or distressed retaining structures. For example, some mechanically stabilized earth (MSE) walls may exhibit excessive deformation due to poor design, poor construction, or both. Soil nails can be installed directly through the face of an MSE wall if the existing face is sufficiently stable to resist drilling. The selection of an appropriate bearing plate to support soil nails stabilizing MSE and masonry walls is very important. The bearing plate must be able to fully transfer loads without damage to the existing facing.

- **Advantage and Disadvantages of soil nailing**

Advantages associated with soil nailing fall into three main categories: Construction, Performance, and Cost. (lazarte *et al.*, 2015)

Construction

• Soil nail walls require smaller rows than most other competing systems. This is also true for ground anchors as soil nails are typically shorter.
• Soil nail walls are less disruptive to traffic and cause less environmental impact compared to other construction techniques such as drilled shafts or soldier pile walls, which require relatively large equipment.
• The installation of soil nail walls is relatively fast.
• Soil nail wall installation is not as restricted by overhead limitation as in the case of soldier pile installation. This advantage is particularly important when construction occurs under a bridge.
• Soil nailing may be more cost-effective at sites with remote access because the smaller equipment is more readily mobilized.
• Soil nails are installed using equipment that is multipurpose and can be used for other substructure elements such as underpinning or protection of adjacent, movement-sensitive structures.

Performance

Soil nail walls are relatively flexible and can accommodate comparatively large total and differential movements.
• The measured deflections of soil nail walls are usually within tolerable limits in roadway projects when the construction is properly controlled.
• Soil nail walls have performed well during seismic events.
• Soil nail walls have more redundancy than anchored walls because the number of reinforcing elements per unit area of wall is larger than for anchored walls.

Cost

• Conventional soil nail walls tend to be more economical than conventional concrete gravity walls taller than approximately 12 to 15 ft.
• Soil nail walls are typically equivalent in cost or more cost-effective than ground anchor walls when conventional soil nailing construction procedures are used.

- **Soil nail disadvantages**

Some of the potential disadvantages of soil nail walls are (Liew Shaw-Shong, 2005):

- Soil nail walls may not be appropriate for applications where very strict deformation control is required for structures and utilities located behind the proposed wall, as the system requires some soil deformation to mobilize resistance. Deflections can be reduced by post tensioning but at an increased cost.

- Existing utilities may place restrictions on the location, inclination, and length of soil nails.
- Soil nail walls are not well suited where large amounts of groundwater seep into the excavation because of the requirement to maintain a temporary unsupported excavation face.
- Permanent soil nail walls require permanent, underground easements.
- Less suitable for course grained soil and soft clayey soil, which have short self-support time, and soils prone to creeping.
- Suitable only for excavation above groundwater.

IV. REFERENCES

[1]. Babu, GL Sivakumar, R. S. Rao, and S. M. Dasaka. "Stabilisation of vertical cut supporting a retaining wall using soil nailing: a case study." *Proceedings of the Institution of Civil Engineers-Ground Improvement* 11.3 (2007): 157-162.

[2]. Byrne, R. J., Cotton, D., Porterfield, J., Wolschlag, C. and Ueblacker, G. (1998) "Soil Manual for design and construction monitoring of soil nail wall" *Manual of the Federal Highway Administration Division*, (No. FHWA0-SA-96-069R.)

[3]. Lazarte, C. A., Robinson, H., Gómez, J. E., Baxter, A., Cadden, A., & Berg, R. (2015). *Soil Nail Walls Reference Man ual* (No. FHWA-NH I-14-007).

[4]. Liew, S. S., & Liong, C. H. (2006). Two Case Studies on Soil Nailed Slope Failures. In *submitted) International Conference on Slopes, Malaysia*.

[5]. Palmeira, E. M., Tatsuoka, F., Bathurst, R. J., Stevenson, P. E., & Zornberg, J. G. (2008). Advances in geosynthetics materials and applications for soil reinforcement and environmental protection works. *Electron J Geotech Eng, Spec Issue State of the Art in Geotech Eng*, *13*, 1-38.

[6]. Shaw-Shong, L. (2005). Soil nailing for slope strengthening. *Geotechnical Engineering, Gue & Partners Sdn Bhd, Kuala Lumpur, Malaysia*.

[7]. Taib, S. N. L. (2010). A Review of Soil Nailing Design Approaches. *UNIMAS E-Journal of Civil Engineering*, *1*(2).

[8]. Jewell, R. A. and Pedley, M. J. (1992) "Analysis for soil reinforcement with bending stiffness" *Journal of* Geotechnical Engineering, ASCE, Vol. 118, No. 10, pp. 1505-1528.

[9]. Sharma, P. "Theoretical analysis of soil nailing: design, performance and future aspects (2015)". *International Journal of Engineering Research and General Science*