JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

CASE STUDY ON SOIL NAILING FOR SLOPE STABILIZATION

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Abstract: Soil nailing is being used in many geotechnical applications to improve stability of excavated vertical cuts and existing slopes. This paper presents a few case studies on the stabilization of a vertical cut and improvement of slope stability using soil-nailing technique. It was found that the vertical cut stability/slope stability improved due to the reinforcing effect of nails. The study illustrates that the technique is a viable technique to improve the stability of vertical cuts and stability of existing slopes and its advantages need to be exploited on a large scale in infrastructure projects.

***Index Terms* – Soil Nailing, Stabilization.**

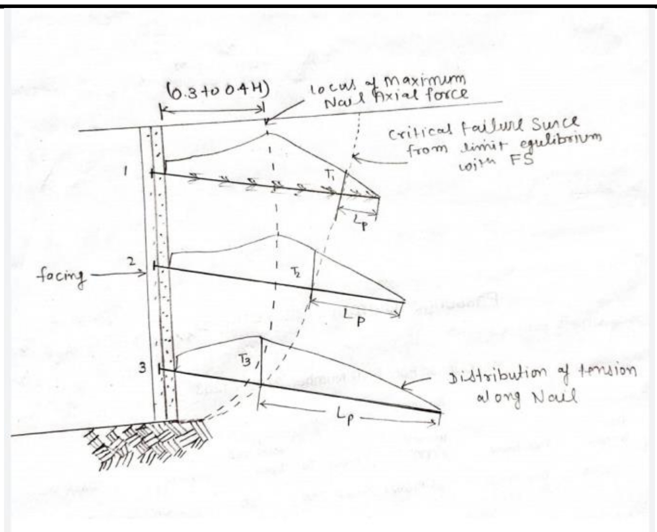
I.INTRODUCTION

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.APPLICATIONS OF SOIL NAIL WALLS

Soil nail walls are particularly well suited to excavation applications for ground conditions that require vertical or near- vertical cuts. They have been used successfully in highway cuts; end slope removal under existing bridge abutments during underpass widening; for the repair, stabilization, and reconstruction of existing retaining structures; and tunnel portals.

Soil nail walls can be considered as retaining structures for any permanent or temporary vertical or near-vertical cut construction, as they add stabilizing resistance in situations where other retaining structures (*e.g.*, anchor walls) are commonly used and where ground conditions are suitable.



The relatively wide range of available facing system sallow for various aesthetic requirements to be addressed. In this application, soil nailing is attractive because it tends to minimize excavation, provides reasonable right-of-way and clearing limits, and hence, minimizes environmental impacts within the transportation corridor.

Soil nail walls are particularly applicable for uphill widening projects that must be constructed either within an existing right-of-way or in steep terrain. Figure 1 shows examples of the use of soil nail walls in temporary and permanent cut applications. The objective of current study is to emphasize on the feasibility of soil nail wall as an effective technique of stabilization of vertical cuts, restoration of failed slopes and in underpass construction. To accomplish this purpose three case studies are described.

2.1.1Case Study I (Excavation)

The proposed depth of excavation is 11 m and the area is meant for Hotel complex. Two boreholes made in the site indicate that the soil up to 5 to 6 m is of cemented sand type followed by disintegrated rock. The average SPT value up to about 5.5 m is 15 and there is no ground water table within the proposed depth of excavation. Site observations indicated that the excavations are stable up to depth of 3 to 4 m beyond which there is a tendency for collapse particularly in the presence of seeping water which suggests there is an apparent cohesion which makes the slopes stable for a limited period. Hence, it is suggested to have a retaining system in the form of soil nailed excavated slopes and shotcrete facing for erosion stability with appropriate drainage measures.

To facilitate the soil nailing, Torsteel rods of 20 mm diameter (with yield strength of 415 MPa) are used as nails. Table 1 provides the soil parameters used in the slope stability analysis. Detailed analyses with various permutations and combinations of nail spacing and length are performed and recommended sections (corresponding to a factor of safety of 1.4 or more for temporary works) are arrived at. The excavated slopes strengthened with soil nailing shows that the sections are safe with nailing. Table 2 gives the reinforcement properties along with suggested spacing and lengths.

Material	*Bulk density (kN/m^3)*	*Cohesion (kPa)*	*Friction angle (degrees)*
Cemented sand	17	5	28

Table 1: Values of the Parameters Used in the Analysis

Reinforcement properties	Parameter
Length	8 m
Diameter	20mm
Vertical Spacing	0.5m
Horizontal Spacing	0.5m
Tensile Capacity	100kN
Bond Strength	10KN/m

Table 2: Reinforcement Properties

The factor of safety of the section was improved to 1.4. This shoring support was for temporary purpose of six months and it was able to provide safety during the construction of foundations for the super structure. Pull out tests conducted also confirmed that the reinforcement bars had the required bond stress.

2.1.2Case Study II (Stabilization of Slope of Reservoir)

One of the earthen slope sections forming section of an impounding reservoir failed at the interface of core and cover over about 200 m length and it was indicated that the casing soil that was used initially in the construction was cohesion less and prone to erosion and hence failure occurred. Hence in the reconstruction, a better soil was used which had good silt and clay content and is less prone to erosion, which also did not prevent failure along the interface. However, in both the cases, the sliding occurred.

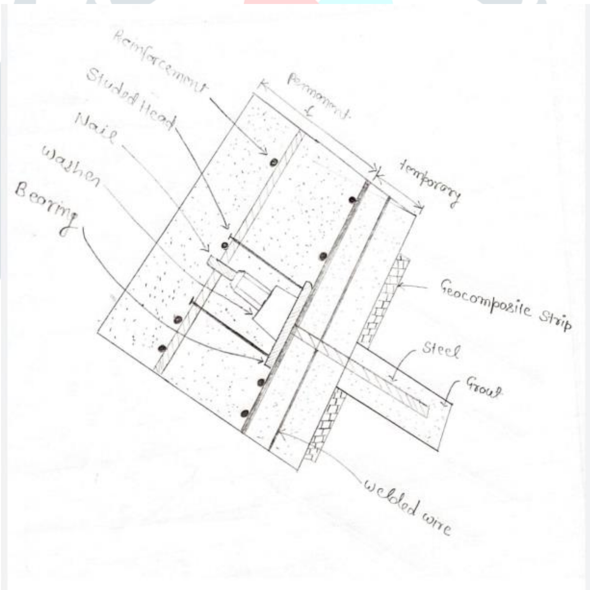


Fig:2 Design of Soil Nailing

Tables 3 and 4 provide the soil parameters used in the stability analysis and the results indicate that the critical factor of safety varies depending on cohesion of the casing material. Figure 1 shows a typical result for cohesion value of 5 kPa. Table 4 shows that the factor of safety reduces to values lower than unity when the cohesion reduces to values in the range of 2 kPa. It may be noted that compacted soils such as the casing materials have cohesion values due to capillary stresses which get reduced during the rainy season. Loss of cohesion leads to overall reduction in shear resistance of the soil and when the driving forces under the influence of infiltrating water, seepage pressures through the tensions cracks increase, the available resistance being less, slopes fail as happened in the present case. In order to increase the available shear resistance, introduction of reinforcement is useful. Hence tor steel (with yield strength of 415 MPa) rods of 20 mm dia and 5 m length, spaced at 0.5 m vertically and 1m horizontally are suggested and the section is analyzed. Figure 4 shows the results of the analysis. It is reported that the stability of the bund section is satisfactory.

Table 3: Values of the Parameters Used in the Analysis

Material	*Bulk density (kN/m^3)*	*Cohesion (kPa)*	*Friction angle (degrees)*
Hearting soil	17.8	30	14
Casing soil	20.3	10	20

Cohesion (kPa)	*Factor of safety*
10	1.62
5	1.22
3	1.06
2	0.98

Table 4: Variation of Factor of Safety with Cohesion of the Casing Soil

It is important that in cases like the above, shear strength properties of the core and embankment materials need to be determined based on effective stresses and also the back pressure saturation of compacted samples need to be ensured.

2.1.3 Case Study III (Approach Road for Underpass)

In one of the metropolitan cities, an approach road for an underpass has become necessary and the soil strata of the area are as under:

Depth in metres	*Type of soil*
0–1.50	Made up Soil
1.5–3.00	Non plastic Silty Sand
3.0–10.0	Non Plastic Poorly Graded Silty Sand

The SPT values vary from 6 to 17 and the soil is reported to have negligible cohesion with friction angle values in the range of 27^o to 31^o and bulk density is in the range of 17.4 kN/m^3. Observations indicated that the excavations are stable up to depth of 1m beyond which there is a tendency for collapse. Even an excavation of 1 m could not be done. It is time consuming, hinders the movement of materials and personnel during underpass construction. It is also risky and involves stage construction removal which may pose danger. It was felt that soil nailing technique is safe as the excavation is stabilized after the soil is removed and is useful in the construction of underpasses as the movement of personnel and material during the construction of underpass is not hindered. The value is low and only confirms the type of soil that exists in the site is poor.

III. RESULT

This value is comparable to the theoretical estimate of pullout resistance given by –

Pullout resistance per metre length = overburden (γh) × area of contact of the nail (πd) × tan $\o_\mu$.

$= 18 \times 6 \times 3.14 \times 0.02 \times \tan 28$

= 3.6 kN.

Hence a value of 3 kN/m is used in the analysis. The depth of excavation varies from 3 to 9.5 m and soil nailing technique was adopted. Nail lengths of 7 m with spacing of 0.5 × 0.5 m were provided to impart stability and the factor of safety is 1.4.

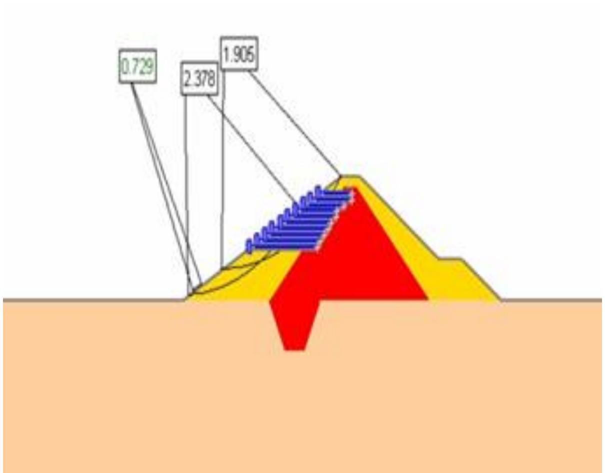


Fig:4 Analysis Result.

IV.CONCLUSIONS

In the paper, a few case studies on soil nailing have been presented illustrating its advantages. There is a need to use this technique on large scale in India in many infrastructure projects wherever applicable to realize the technical and economic advantages associated with the technique.

V.ACKNOWLEDGEMNET

I would like to acknowledge Mr. Baijnath Nishad (Assistant Professor) for his/her vital cooperation and help in ensuring the successful completion of my assignment. He/she deserves the utmost credit for the assignment's outcome.

Finally, I would want to convey my sincere thanks to my friends and supporters; without them, the task would not have been accomplished in such a timely manner.

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