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Experimental Studies on Effect of Nailing in Cohesionless Soil

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***Abstract*: Soil nailing is a construction remedial measure to treat unstable natural soil slopes or as a construction technique that allows the safe over steepening of new or existing soil slopes. There is failures of soil nailing and most happening failure is a pullout failure, so there is a need to identify the pullout resistance of the soil before any construction of soil nail and it's become compulsory if the soil is cohesionless, because pullout failure is generally happen in a cohesionless soil. This paper gives the experimental study to identify pullout resistance of soil in horizontal direction in a cohesionless soil.**

***Keywords*: pullout failure, nailing, nailing in cohesionless soil, pullout resistance.**

1. Introduction

The origin of soil nailing can be traced to a support system for underground excavations in rock referred to as the New Austrian Tunneling Method (Rabcewicz, 1964a, 1964b, 1965). This tunneling method consists of the installation of passive steel reinforcement in the rock (e.g., rockbolts) followed by the application of reinforced shotcrete. Soil nailing is the method of reinforcing the soil with steel bars or other material. It has been alternative technique to other conventional supporting system as it offers flexibility, rapid construction & competitive cost. The purpose is to increase the Tensile & Shear Strength of the soil & Restrain its displacements. Soil nailing is a construction technique used to reinforce soil to make it more stable. In this technique, soil is reinforced with slender elements such as reinforcing bars which are called as nails. These reinforcing bars are installed into pre-drilled holes and then grouted. Soil nailing technique is used for slopes or excavations alongside highways, railway lines etc. 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 cut-slope in sand was stabilized using soil nails (Rabejac and Toudic1974). Clouterre research program, (Schlosser 1983; Clouterre1993) is another step. In US, the first FHWA document on soil nailing was issued through FHWA's Office of Research and Development (Elias and Juran1991). Updated version of above FHWA soil nailing manual was made public in 2003 (Carlos et al. 2003). 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. In Germany, the first use of a soil nail wall was in 1975 (Stocker et al. 1979). The first major research program on soil nail walls was undertaken in Germany from 1975 through 1981 by the University of Karlsruhe and the construction company Bauer. (Gasslerand Gudehus1981; Schlosser and Unterreiner1991).

2. Failure modes of soil nail

Generally, there distinct failure modes have been observed for a soil nail system. They are as follows.

1. *Facing failure:* This type of failure develops in a soil nail wall having long nail with high tensile strength and modest facing strength facing. In facing failure, the head strength will not contribute the stability of active zone.

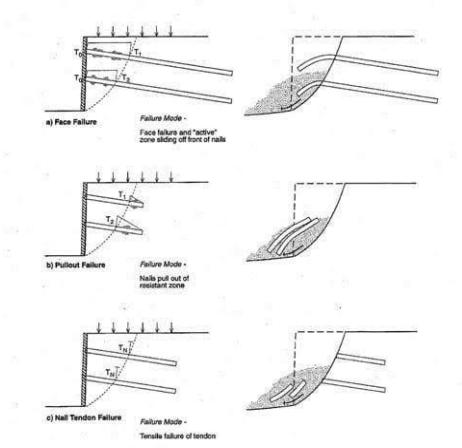


Fig. 1. Failure modes of soil nail

2. *Pull out failure:* This occurs when soil nail has limited penetration into the passive region and possesses high tensile capacity and facing strength. The force generated in active region will depend upon length of reinforcement passive zone, and is expressed as.

$$Q = \pi q D$$

Where, Q- is mobilized pull out per unit length,

q- is mobilized shear stress acting around the perimeter of soil nail and
D- is the effective diameter of the nail hole.

Considering the single nail segment subjected to a tensile force, T0, at one end, and shown in fig 1, the tensile force can be estimated from the interference shear stresses as:

$$dT = \pi q D_{DH} dx = Q dx$$

if the length of the soil nail embedded in the passive zone is L_p, then the total pullout force is estimated as:

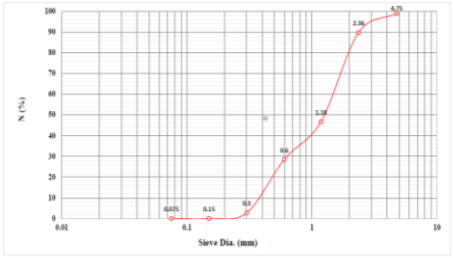
$$F = QL_p$$

3. *Nail tendon failure:* Such failure occurs when sufficient length of nail is provided but with modest tensile stress.

3. Identification of soil

To know the properties of soil various test are performed is as follows:

1. Grain Size Analysis
2. Specific Gravity Test
3. Relative Density
4. Direct Shear Test
5.



From graph: $D_{10} = 0.40$, $D_{30} = 0.65$, $D_{60} = 1.80$
$Cu = 4.50$, $C_C = 0.094$

Type of soil: Poorly Graded Sand (SP)

Fig. 2. Graph of grain size analysis

As following condition if both of these criteria are not met, the sand is classified as poorly graded or SP. If both of these criteria are met, the sand is classified as well graded or SW.

$Cu \geq 6$ & $1 < Cu < 3$

Table 1
Properties of soil medium

S. No.	Properties of Sand Tested	Values
1.	Coefficient of uniformity, Cu	4.50
2.	Coefficient of curvature, Cc	0.094
3.	Type of soil	Poorly graded sand
4.	ϱmax	1.89gm/cubic cm
5.	ϱmin	1.49gm/cubic cm
6.	Specific gravity, G	2.63
7.	Angle of internal friction, φ	38.57 deg.
8.	Relative Density, Rd	50%
9.	Field Density, pd	1.67gm/cm.sq.

So, as shown in fig. the Cu is 0.094 therefore sand is poorly graded. Soil gradation is very important to geotechnical engineering. It is an indicator of other engineering properties such as compressibility, shear strength, & hydraulic conductivity. Table 1 shows the properties of cohesionless soil which used in an experiment.

4. Experimental set-up for laboratory load test

Tank detail: Fig 3. Shows an over view of laboratory setup. Due to safety reasons and high cost, it is not possible to carry out a large number of field tests, especially when the slopes are saturated or nearly saturated. Therefore, a large-scale test box with a loading frame and pulling device was fabricated so that pullout tests can be carried out in the laboratory. It consists of three measure component: a large tank to accommodate the soil and nails; to portal frame for application of vertical pressure; and a pulling device to pull the nail at a predefined displacement rate

a) Sand tank: The sand tank is of size 0.9m in length x 0.9m in width x 0.9m in height. There one hole in one wall in front wall for allowing nail installation. The position of nail is at center of wall at a distance 0.55 from bottom and 0.45 from top.

b) Loding frame & pullout system: The loading frame consists of three pulleys, and the wire rope connection which one end is hook to the nail and on other end their provision to applied load gradually.

Fig. 3. Model tank

5. Installation of soil nail with grouting

Soil nailing is the method of construction that reinforces the existing ground. Nail are inserted into the soil in a closely spaced pattern to increase its overall shear strength; the nails develop tension as the ground deform laterally in response to ongoing excavation. In most cases, a temporary or permanent facing is added to retain the soil. This insure that the structure can resist the forces acting on it and can remain stable. Grouting should be carried out by starting at the bottom of the hole. The grout is introduced into the hole by gravity or at low pressure. The neat cement or sand cement grout should have a minimum cube strength of 0.6 MPa. A water cement ratio of 0.4 to 0.5 is common. The grout pour should be continuous without

interruption. Some contractors like to use same mix for grouting as for shotcreting. This should be discouraged because the shotcrete mix does not flow around the nail. Centralizer well enough, possibly leaving voids in the grout column.

Fig. 4. Installation of nail

Nail is driven into the soil by creating hole of 25mm diameter. And horizontally insert into soil from hole created on transparent side of tank.

6. Testing procedure

Initially front face of tank is drilled for installation of nail of 6mm dia, and insertion of nail is done surrounded with cement grout. While inserting nail, a casing is also provided for alignment of nail and proper placing of nail. Initially load test was performed on the nail with an arrangement of pulley and wire rope which gradually increases the load on the nail to pull it in outward direction. As the load is given the deflection of nail is noted with the help of marking on nail while inserting. The load is applied gradually by means of load increment on other side of wire rope and deflection can be seen on front face of nail inserted. The pullout test is continued out till pull out failure of nail bar takes place. Pullout failure is defined as the load at which attempts to further increase the test load increments results in continue pullout movement of the tested nail and the load at this stage is called as pull out capacity.

7. Pullout resistance

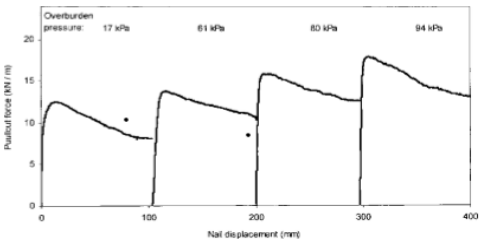


Fig. 5. Graph of force against displacement

The pullout resistance (q) of the nail was obtained by dividing the peak pullout force by the active surface area of the nail, which is

$$q_s = p/\pi DL$$

where, p- peak pullout force interpreted from the pullout force displacement curve (KN) shown in fig. 5.

D- diameter of the nail,

L- length of nail in contact with the soil

8. Soil nailing international codes and standards

UK Codes and Standards

BS 8006: 1995, BS 8002: 1994, BS 8081: 1989

TRL Report 380 (1993)

HA 68/94 (reinforced highway slopes) RT/CE/S/071 (2002) (design of earthworks & earthwork remediations)

Other International Codes and Standards

Eurocode –EC7

Euronorme –prEN 14490 (execution of special geotechnical works –soil nailing)

France –Recommendations Clouterre (1991)

USA –FHWA manual for design & construction monitoring of soil nail walls (1998 and 2003)

Scandinavia –Nordic handbook (2002) Hong Kong –Watkins & Powell (1992) and many GEO publications

Hong Kong -GEOGUIDE (2008)

9. Conclusion

A Laboratory study was conducted to investigate the behavior of soil nail imbedded in loose sandy fills comprising completely decomposed granite. The pullout resistance of soil nail increases with the increase of overburden pressure.

The interfaces parameter of the grouted nail from pullout test are fairly close to soil strength parameters determine by the direct shear box test. The study has also demonstrated that the laboratory test can provide the fairly good estimation of the field pullout resistance.

The results show that the model can be used to predict the pick pullout resistance of the soil nail.

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