Stability Analysis of Screw and Thorn Nailed Soil Wall

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Abstract— **Recently researchers are succedded with the use of screw nails in different type of soils and proved that screw nails are efficient than ordinary shafted nails. Provision of screw increases the anchorage strength and lateral pull out resistance. The main objective of this work is to find out the pullout capacity of selected screw and thorn nail and to evaluate its influence in the lateral stability of nailed soil wall.**

Keywords—Screw nails, Thorn nails, anchorage strength, lateral pullout resistance, lateral stability, nailed soil wall.

I. INTRODUCTION

Soil nailing is cut slope retaining system generally used in non-plastic soils. There are different method of analysis of nailed soil wall which differs in the failure surface. **Loeng et.al(1990)** compared the different method of analysis and concluded that there is no significant influence of failure surface in the factor of safety. Nail lengths are obtained based on failure surface and for some target factor of safety based on frictional resistance of soil. The failure mode and stability analysis indicated that for given type of deposits, the stability of nailed slope wall depends on the physical and strength properties of nail and nail spacing. There are different types of nails depending on their method of installation such as driven, grouted and jacked nails. Recently researchers are succeeded with the use of screw nails in different type of soil and proved screw nails are efficient than ordinary shaft nails. Provision of screw increase the anchoring effect and nails with thorn increases the local anchorage. This experimental investigation is made to study about the influence of provision of screws and thorns in the lateral pull out resistance and lateral stability of nailed soil wall.

II. LITERATURE REVIEW

Tokhi and Ren (2016) have examined the interface mechanism and attempts to define the associated rupture zones in cohesion-less material with the aid of thin vertical bands of colored sand in a large distinctly fabricated pullout box. Based on laboratory testing procedure and its instrumentation testing indicate the slip mechanism, which controls the pullout behavior, is rather different to the conventional soil nails and the resultant pullout capacity is higher when compared to this type soil nails. **Chan and Halim (2016)** concluded that screw installation ensures better soil-nail grip and less disturbances during the slope stabilization procedure, especially in terms of noise and spoils. In addition, the novel nail has a hollow stem which improves shear resistance with greater soil-nail surface contact on the inner wall. **Zhou et.al (2007)** studied the pullout capacity of complete decomposed granite at the saturated condition under different grouting pressure and overburden pressure. From the study they found the effect of grouting pressure on the pullout resistance for saturated soil was much less than that of unsaturated soil, because the pullout failure was more likely to occur in the soil rather that at the soil grout interface at saturated condition. pullout tests.

Tan and Ooi (2006) discussed on pull out behavior of soil nail embedded in dry clean sand. The authors concluded that mobilization of the frictional resistance between the nail and the surrounding soil is higher for rough nails and decreases with pullout displacements. **Pradhan et.al (2006)** studied the behavior of soil nails embedded in loosely compacted sandy fills. The authors concluded that restrained dilatancy effect exists both in dense sand and in low sand. **Manchu et.al (2005)** studied the interface shear behavior between the cement grouted materials (soil nails) and completely decomposed granite soil using both a large scale direct shear apparatus and laboratory pull out test apparatus. The authors concluded that the shear stress displacement behavior of soil grout interface shear tests was similar to that of soil-soil test but was different from the behavior in at low stress level **Hong et.al(2003)** conducted the pullout tests on single and double nail in a model sand box. The parameters like roughness, L/D ratio of nails, the overburden pressure and distance between two nails are considered. The test results showed that the apparent friction between soil nail interface was depends upon the surface roughness of nail..

III. EXPERIMENTAL PROGRAM

Soil nailing is an in-situ ground reinforcement technique that has been used to retain the excavation and to stabilize slopes. Full scale field load test with proper instrumentation and careful monitoring offer the best representation of actual behavior of soil nailed systems. However, full scale testing is expensive, especially if the effects main design parameters. Although the construction procedure of a soil nailed structure is difficult to stimulate experimentally and the similitude requirements between the laboratory models and prototype is difficult to satisfy **Juran et.al 1990 ; Juran and Wilas 1987** have successfully used soil nailed models to investigate the effects of main design parameters in the failure mechanism and have demonstrated that the observed model behavior is quite consistent with filed observations on instrumental full scale structures.

Experimental setup for Pullout test

Pullout strength is the primary internal strength in a nailed soil wall function of surface roughness. This parameter is mainly contributed by the interfacial strength of soil and nail. Pullout test was carried out through the Steel box of size 400*600*600 (in mm). Sand bed is prepared for a depth of 100 mm and the nail is placed in position. Further sand bed was prepared up to the required overburden height. The head of the

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 08, August-2019

nail was welded with a ring to aid the connection of nail with tensile proving ring. The other end of the proving ring was connected by bolt and nut arrangement. The pullout force was applied by means of torque mechanism and the corresponding force was observed using proving ring. The displacement of the nail was measured by dial gauge of least count 0.01mm and travel of 50mm. A small plate of size 7cm*2cm was attached near the ring to mount the tip of dial gauge.

For Screw and Thorn nail, a lid of the tank is also fabricated and provisions are made to connect the lid with tank using bolts and nuts. The selected nail is driven at 100mm distance from the reference side (right). Tank is rotated to 90 degrees with care so that disturbances are minimum. The pull out load is applied through the nail for 300mm overburden, the 200mm height length of the tank was packed with wooden plate tightly and the tank was rotated. Figure 3.1 and 3.2 shows that fabricated thorn and screw nails. Figure 3.3 and 3.4 shows the arrangement made for pullout test of nails.

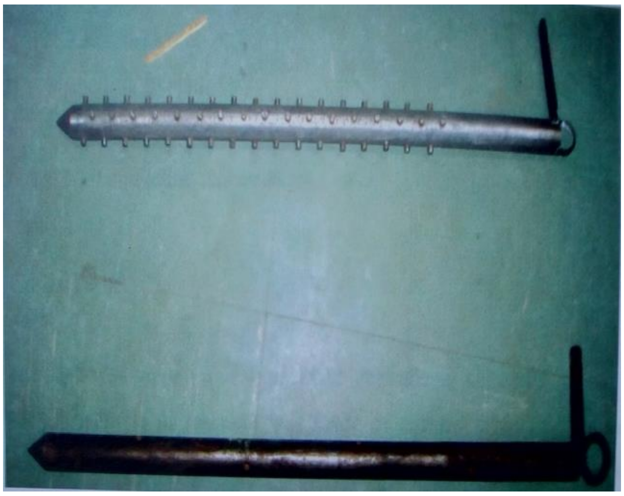

Fig.3.1 – Fabricated thorn nail

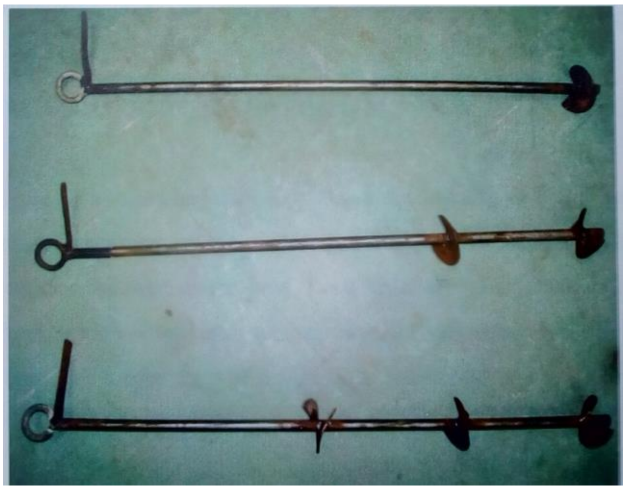

Fig 3.2 - Fabricated screw

Fig 3.3 – Tank filled with sand for pullout test

Fig 3.4 Tank with inserted Thorn nail

EXPERIMENTAL SETUP FOR LOAD TEST

Load tests were conducted to find the stability of nailed soil wall. It is assumed that the difference in the procedure in the field and laboratory will not have or little effect in the failure pattern and failure mechanism. Model tank was made up of 4mm mild steel sheets welded together and stiffened. The tank was made of acrylic sheet of thickness 8mm to reduce the friction. Once of its shorter faces were provided with sufficient holes of 12mm diameter to fix the measuring equipments. When the load was applied, the structure may move both vertically and horizontally. The arrangements were made to measure the vertical movements of soil and to measure the horizontal movements of nails by using dial gauges. The loading method was selected based on the actual field conditions. A wooden block of size 450mm*50mm was kept over the nailed wall to distribute the applied load equally over its entire area. The load was applied on the block by loading frame arrangement. In actual soil nailed cuts, where soil can stand unsupported for excavation depth of about 0.5m to 1m, a short-crete or precast panel facing is used. Since the dry sand was used in these tests, a vertical excavation face could only be maintained using as a rigid facing. A 10mm thick ply board was used as a pre-placed continuous facing. Circular holes of diameter 8mm were made on preplaced

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 08, August-2019

continuous facing at the horizontal and vertical facing. The inner periphery of these holes was made by smooth grinding to avoid any friction of the wall material with nail. The Plastic bush of size 15mm diameter was fixed at the nail head using glue. This bush held the nails with cardboard in position and eventually the soil mass also.. Figure 3.5 shows the load test arrangement. Load test were carried out two pattern of nail arrangements and they are shown in figure 3.6.

Fig 3.5 Load test arrangement

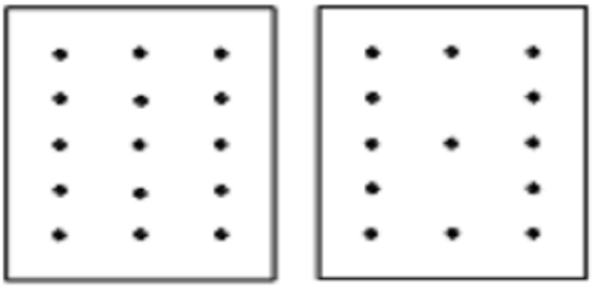

Fig 3.6 Pattern of nail arrangement

Test Media was Medium dry sand, classified as SP in the Unified Soil Classification System. The minimum dry density of the sand is determined as 1.44 g/cm^3. The properties of temedia are represented in Table- 3.1

Sl. No	Property	Symbols and Units	Values
1	Specific Gravity	G	2.67
2	Coarse sand	%	12
3	Medium sand	%	73
4	Fine sand	%	15
5	Effective size	D_{10} in mm	0.31
6	Coefficient of Uniformity	C_u	3.23
7	Coefficient of Curvature	C_c	1.16
8	IS Classification	SP	Poorly graded
9	Angle of Internal Friction	ϕ	39

TABLE 3.1 PROPERTIES OF TEST MEDIA

IV. RESULTS AND DISCUSIONS

PULLOUT TEST RESULTS

The peak pullout load and the corresponding settlement of both inserted and preplaced method of placement of different nails are listed in the Table 4.1. The observations made from the above table briefed below.

Generally increase in surcharge increased the pullout load and their corresponding settlement. However the displacement is almost same for inserted and pre-placement of nails of MS and HYSDS material. The peak pullout load is higher for preplaced nails of MS and HYSDS material. The displacement of MS and HYSDS replaced nails are higher than inserted nails for increase in surcharge. For all screw nail, the pullout resistance is higher for inserted nails than preplaced nails. For most of screw nails the displacement is maximum for preplaced nails. Comparatively the pullout load is higher for two screw nails than single screw nails. The pullout load of three screw nail is relatively lower than two screw nail. For thorn nails the pullout test are conducted for inserted nails only. Provision of thorns on the surface of the pipe increases the pullout resistance and displacement. Also increase in surcharge increases the pullout resistance. In general the efficiency of screw nails are better than other type of nails based on pullout resistance. This can be well understood from Table 4.2 which summarizes the ratio of increase in pullout resistance based on MS nail pullout resistance. This ratio is maximum for two screw nails for higher surcharge.

Nail Type	Placement of Nail	Surcharge (mm)	Pullout Load (kN)	Displacement (mm)
M.S Nail	I	300	0.065	1.1
	P.P	300	0.165	1.4
	I	500	0.075	1.1
	P.P	500	0.190	1.5
HYS DS	I	300	0.17	1.5
	P.P	300	0.2	1.5
	I	500	0.19	1.5
	P.P	500	0.22	1.7
One Screw Nail	I	300	1.1	4
	P.P	300	1.0	5
	I	500	1.8	5.8
	P.P	500	1.75	6.5
Two Screw Nail	I	300	1.35	4.8
	P.P	300	1.35	5.0
	I	500	2.25	6.0
	P.P	500	2.10	6.1
Three Screw Nail	I	300	1.4	6.5
	P.P	300	1.25	6.2
	I	500	2.15	5.5
	P.P	500	1.90	5.9
Thon Nail with pipe	I	300	0.235	a2.25
		500	0.270	2.25
Pipe with 8 thorn	I	300	0.25	2.5
		500	0.3	2.5
Pipe with weld thorn (70)	I	300	0.4	3.7
		500	0.48	3.7

I=Inserted, PP=Preplaced

Table 4.1 Peak Pullout load and Displacement

Nail type	Overburden height in mm	Ratio of Increase to MS Nail
HYSDS Nail	300	1.6
	500	1.5
One Screw Nail	300	15.9
	500	23.0
Two Screw Nail	300	19.8
	500	29.0
Three Screw Nail	300	20.5
	500	27.7
Thorn Nail (alone)	300	2.6
	500	2.6
Thorn Nail 1	300	2.9
	500	3.0
Thorn Nail 2	300	5.1
	500	5.4

Table 4.2 Percent increase in pullout resistance

LOAD TEST RESULTS

The stability of different nailed wall system assessed by means of the ultimate load based on vertical settlement and nail displacement. From the observations made from Table 4.3, the ultimate load based on vertical settlement is slightly higher than horizontal displacement for certain cases of nails. The stability of two screw nail structural pattern of nail arrangement is higher than all other patterns of nail arrangement.

Type of Nail	Ultimate Load based on Vertical settlement		Ultimate Load based on Nail displacement	
	Load (kN)	Settlement (mm)	Load (kN)	Settlement (mm)
MS Nail P-1	2.75	1.0	2.5	0.8
MS Nail P-2	2.6	1.0	2.1	0.8
Screw Nail P-1	25	3.6	24	1.2
Two Screw Nail P-2	32	3.8	29	1.3
Three Screw Nail P-2	32.5	4.0	35	1.75
Thorn Pipe P-2	4.5	1.5	4.2	1.25
Thorn Pipe with 8thorn P-2	5.5	2.0	5.5	1.5

Table 4.3 Ultimate Load for Different Nail

CONCLUSIONS

In this paper, efficiency of screw nails in the lateral stability of vertical cut in sandy soil is studied through experiments. In pullout test results and increase in surcharge increased the pullout capacity. Pullout load capacity of one screw nail is 29 times greater than same diameter of same nail. Second and third nail insertion marginally increases the pullout capacity. Pullout of thorn nail depends on the number of thorns and maximum increase in pullout resistance is observed thorn nail 2 and the maximum ratio is 5.4 to that of 10mm MS nail. In stability analysis, displacement of screw nails are maximum than thorn nails and thorn nails are maximum than MS nails. Stability of one screw nailed wall increased by 23 times than MS nail. Improvement in stability for two screw and three screw nailed wall are greater than one screwed nailed soil wall.

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