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An Experimental Study on Horizontal and Inclined Soil Nails in Sand

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ABSTRACT

The aim of this study is to find out the effect of nailed angle on stability of nailed cuts trough model tests. For this purpose nailed open cut of height 40 cm was made in model test tank. . The plate load tests were performed on strip footing with different configurations to get load versus settlement curves. Experimental results show that horizontally driven nails have more FOS than inclined nails in sand. The results were similar to prior investigators' parametric (analytical) studies.

KEYWORDS: Soil Nailing, Inclined Nails, Horizontal Nails, FOS.

INTRODUCTION

Soil nailing is an insitu soil reinforcement technique that has been used during the last two decades mainly in France and Germany to retain excavation or slopes. 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". One of the first applications of soil nailing was in 1972 for a railroad widening project near Versailles, France; where an 18 m high cut slope in sand was stabilized using soil nails (FHWA, 2009)[1]. In India, Srinivasa Murthy et.al (2002) reported the use of a nailed soil wall as permanent retaining wall for subway underneath a busy national highway. Patra (2008)[2] used the optimization technique for the optimum design of nailed slope and Muthu Kumar M established a generalized design based on nail rigidity number (2009)[3] for the design. Sivakumar Babu (2007)[4] used this nailing technique to stabilize a vertical cut in a hilly terrain.

From the failure mode and stability analysis, it is understood for a given type of deposits, the stability of nailed soil wall depends on the physical and material properties of nail and nail spacing. The interrelation between nail spacing, nail and soil material properties are to be understood for the optimum design of nailed soil wall based on local and global stability. The main objective of this investigation is to find out the effect of nail inclination in the nail displacement and ultimate load carrying capacity of nailed soil wall.

Experimental Investigation

Although the construction procedure of a soil nailed structure is difficult to simulate experimentally and the similitude requirements between the laboratory models and prototype is difficult to satisfy, Juran et.al. 1990[5] have successfully used soil nailed models to investigate the effects of main design parameters on the failure mechanism and have demonstrated that the observed model behavior is quite consistent with field observations on instrumental full scale structures.

Experimental Setup

In the experimental investigation, there is a difficulty to exactly replicate the procedure that followed in the field. Experiments on model wall were conducted in a rigid steel tank directly rested on base frame of steel channels which in turn rested on cement concrete floor. Test tank size was 100 cm × 50 cm × 80 cm. One side wall and both end walls were built by 5 mm thick mild steel. The remaining fourth side of the tank was built by 10 mm thick Perspex sheet. The total inside length of the tank behind the facing was 60 cm and its width and height were 50 cm and 40 cm respectively (Figure 1).

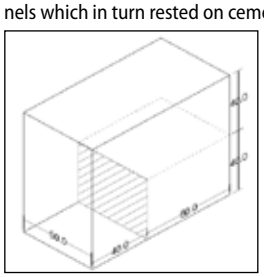

Figure 1: Experimental Setup

In actual soil nailed cuts, where the soil can stand unsupported for excavation depth of about 0.5 m to 1.0 m, a shotcrete or precast panel facing is commonly used. Since dry sand was used in these tests, a vertical excavation face could only be maintained using a rigid facing. A 19 mm thick ply board (80 cm high and 48 cm wide) was used as a pre-placed continuous facing. Circular holes of diameter 16 mm were made on pre-placed continuous facing at the horizontal and vertical spacing as illustrated in Figure 2.

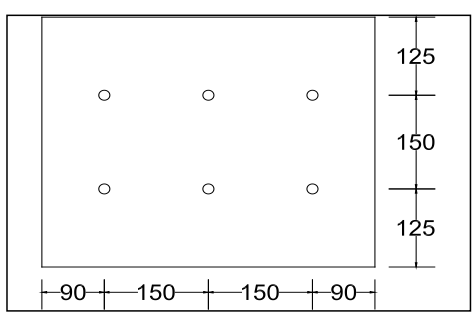

Figure 2: Nail Configuration

The inner periphery of these holes was made smooth by grinding to avoid any friction of the wall material with nail. Figure 3 (a and b) shows horizontal and inclined nailing in tank respectively.

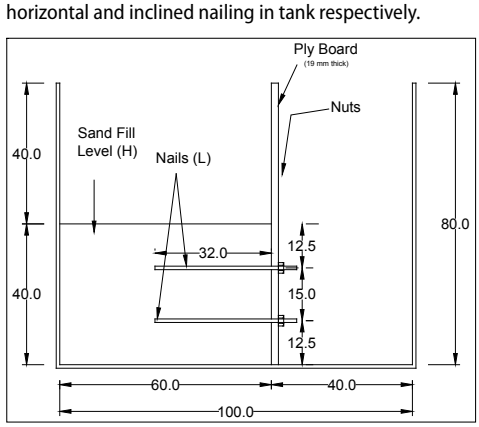

Figure 3a: Horizontal Nailing

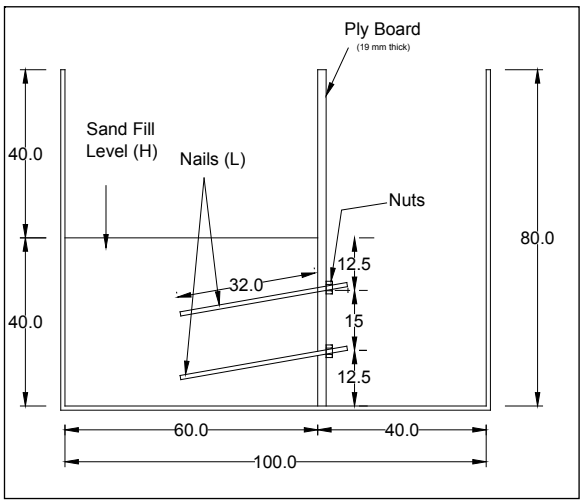

Figure 3b: Inclined Nailing

Materials

The soil used in the study was dry sand collected locally from river Mahisagar bed. According to Indian Standard (IS: 1498-1970) classification, the soil is classified as poorly graded sand (SP).

In model tests, tor steel bars of 12 mm diameter with lengths equal to 0.8 H were used as nails, where H being the height of model nailed wall. Nails were prepared by threading on the end side so that bolts could be fitted to restrain pullout of nails, and the font side was grinded so that nails could be easily inserted into the soil mass. Nail length (L) was kept 32 cm and height of sand fill (H) was kept 40 cm to maintain L/H ratio equal to 0.8.

Construction of Nailed Soil Wall

The following procedure was adopted for construction of nailed cut:

- Ply board facing was placed vertically across the tank at a distance of 60 cm from rear end of tank. The facing was brought to absolute vertical position with the help of tri-square and it was clamped at the top of its both ends to restrict the lateral movement of facing during filling of tank.
- The narrow gap between the facing and the tank sides were closed by the help of wooden packing and plastic tape to eliminate friction between tank and facing.
- Initially plate load test was performed on strip footing without nailing condition. Strip footing size was 48 cm × 8 cm × 2 cm.
- The filling of sand was done by sand raining technique to achieve uniform density of 1.55 gm / cm3. Initially sand was filled on both sides of facing with same soil and density. Then other side of sand was emptied step by step as nailing was done so it could be similar to actual practice.
- In order to insert inclined nail, a steel angle was made of size 19 cm × 5 cm. Nailing was done using this angle so that nail inserted was about 15° to the horizontal plane.
- Then the top surface was leveled properly and strip footing was placed at 20 cm from the inner side of facing. Two dial gauges were fitted diagonally on strip footing to get average deflection. The load was applied gradually by means of loading frame. The load was measured by proving ring. The least count of proving ring and dial gauges were 13.468 N and 0.01 mm respectively. The capacity of proving ring was 10 kN.
- The test was repeated using horizontal nails in order to verify the effect of nail angle in stability of nailed soil wall.

Test Results

From the tests, load and respective average deflection values were obtained. Then combined Load Versus Settlement graph was plotted (Figure 4) for both inclined and horizontal nailing & without nailing condition. The ultimate load was found out using double tangent method in Load Versus Settlement graph. The equation of factor of safety (FOS) can be written as,

$$FOS = \frac{\text{Ultimate Load in Nailed Condition}}{\text{Ultimate Load in Vergin Condition}}$$

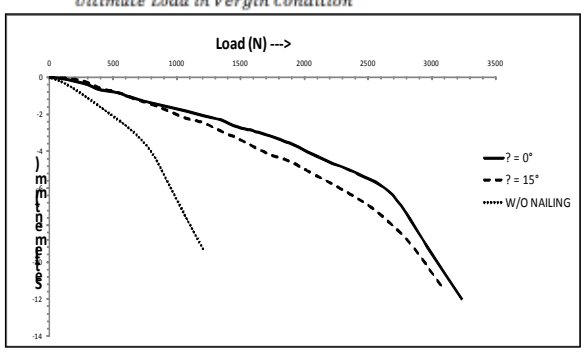

Figure 4: Load Vs Settlement

Conclusions

From graph, it is concluded that the ultimate load increases with horizontal nailing as compared to inclined nailing. A perusal of Table 1 shows that the value of FOS is higher for θ = 0° i.e. using horizontal nails in excavations having vertical face in sand for driven nails. Earlier investigators (Juran and Elias, 1990: Sabahit et al., 1996: Patra, 1998, 2001: Swami Saran et al., 2005[6]) have also obtained similar results.

Table 1: Variation of FOS with θ°

Angle	FOS	Increment in Ultimate Load
0°	3.6	36%
15°	2.4	-

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