Experimental Study of Ultimate Load in Sandy Soil by Soil Nailing – Horizontal Nailed V/S Inclined Nailed

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Abstract. Soil nailing is one of the in-situ soil reinforcement techniques that have been used for the past four decades. During past two decades, significant development has been taken place in the techniques of in situ reinforcement using nails. Soil Nailing is one of the emerging technologies which can help civil engineers for underground construction, slope stability, housing construction on inclined or vertical cuts etc. The aim of this study is how the soil nailed structure behave at different inclination of nailed angle i.e. 10°, 15° and different Length of Nail / Height of Wall Ratio i.e. 0.6, 0.7, 0.8 with compare to horizontal nailing, i.e. 0° inclination. This experimental work has been carried out in a laboratory by using 12 mm diameter steel bars as nail on cohesionless soil (poorly graded sand) in a tank of 100 × 50 × 80 cm at a relative density of 50%. Wooden ply board of size 1.9 × 50 × 80 cm was used as a rigid facing. The Horizontal Spacing (S_h) and Vertical Spacing (S_v) between two nails was 10 cm. Maximum ultimate load has been found out by applying the load up to wall failure. It has been found from the experimental investigation that when the nail length increases i.e. 0.6 H, 0.7 H, and 0.8 H the ultimate load carrying capacity increases. In other hand 10^0 inclined nail gives maximum ultimate load and it reduced for 15^0 inclined nail in comparison to horizontal nail i.e. 0^0 inclined nail.

Keywords: Soil Nailing, Inclined Nails, Horizontal Nails

1 Introduction

Soil nailing is one of the in-situ soil reinforcement techniques that have been used for the past four decades. Soil nailing consists of the passive reinforcement (i.e., no post - tensioning) of existing ground by installing closely spaced steel bars (i.e., nails), which are subsequently encased in grout. As construction proceeds from the top to bottom, shotcrete or concrete is also applied on the excavation face to provide continuity. Soil nailing is typically used to stabilize existing slopes or excavations where top-to-bottom construction is advantageous compared to other retaining wall systems. For certain conditions, soil nailing offers a viable alternative from the viewpoint of technical feasibility, construction costs, and construction duration when compared to ground anchor walls, which is another popular top-to bottom retaining system. The stability of nailed soil wall depends on the physical and material properties of nail and nail spacing. Soil nails are installed with a near horizontal orientation and are primarily subjected to tensile stresses. Such soil nail systems are used to stabilize natural slopes and excavations. The application of passive reinforcement in soil is to the base of the slide. In this alternative sometimes used to stabilize landslides. In this case, the nails is installed almost vertically and perpendicular application, nails are also passive, installed in a closely spaced pattern approximately perpendicular to the nearly horizontal sliding surface, and subjected predominantly to shear forces arising from the landslide movement. However, this application of soil nails as a means to stabilize landslides is not often used in the current practice. The interrelation between nail spacing, nail understood for the optimum design of nailed and soil material properties are to be 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.

2 Experimental Set-Up

2.1 Model Tank and Loading Arrangement

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.

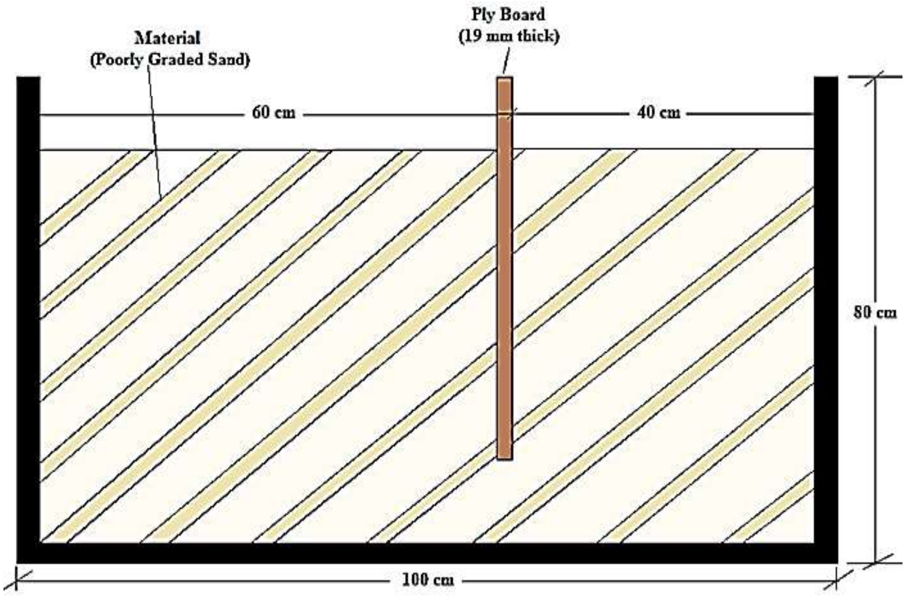

Fig. 1: Model Tank

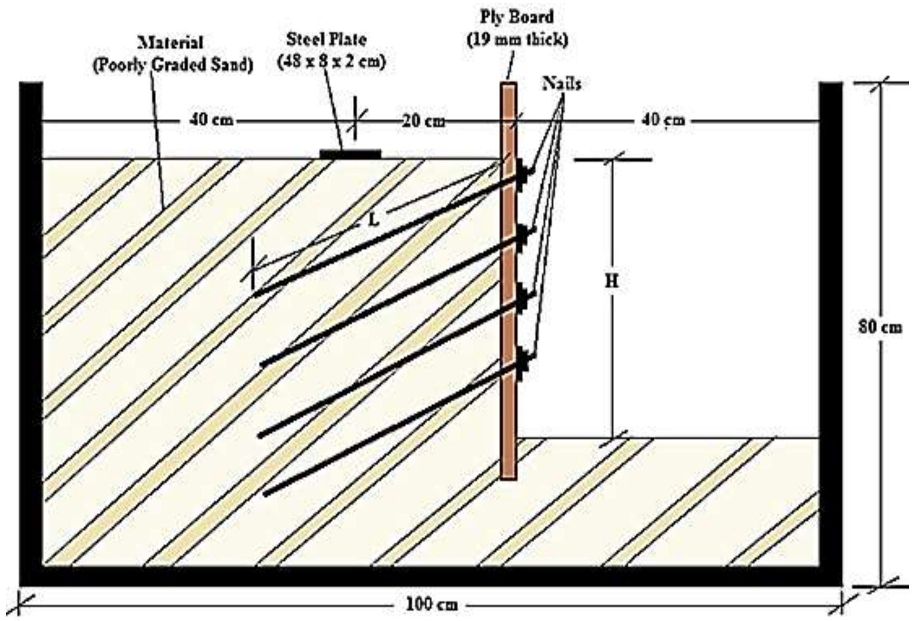

Fig. 2: Model Tank with Nail Arrangement

One side wall and both end wall was 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. The tank was placed centrally in a reaction frame fabricated from angle section and channel section. Vertical load is applied gradually by hydraulic pressure.

2.2 Model Wall 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. The inner periphery of these holes was made smooth by grinding to avoid any friction of the wall material with nail. (Fig. 3)

2.3 Preparation of Nails

The nails are made up of tor steel bars. Steel bars are cut according to design (L/H) and then threading is done on the end part of the nails and then front part is grind for easy penetration in sand. The threading is to facilitate to tighten the nuts on it (nail) to fit with ply board. Steel bars used were Fe 415 and diameter of 12 mm. (Fig. 4)

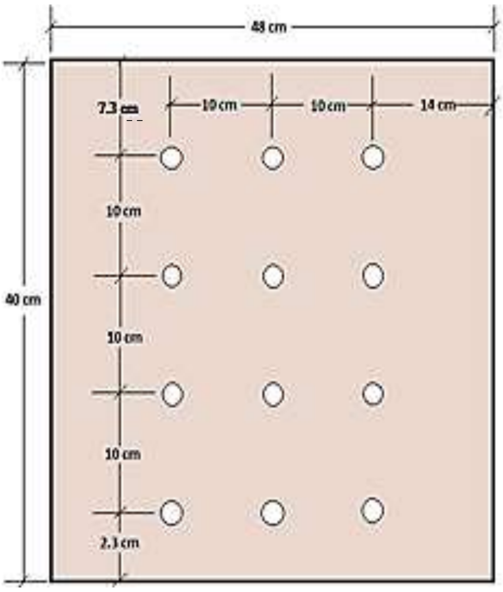

Fig. 3: Facing Wall (Ply board) **Fig. 4:** Nails

2.4 Testing Procedure

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 horizontal 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 1.67 gm/cm^3. Initially sand was filled on both sides of facing with same soil and density. Then other side of tank was emptied step by step as nailing was done so it could be similar to actual practice.

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.

Ultimate load was found out using double tangent method.
All the experiments were done twice or thrice to get average values of settlement and eliminate experimental or instrumental errors.

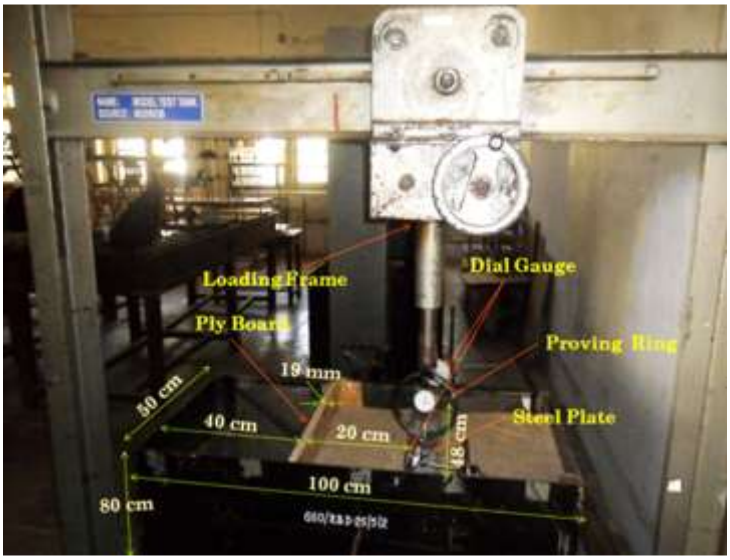

Fig. 5: Setup for Load Test (P.G. Structure Lab., BVM)

2.5 Type of Sand and Its Properties

From the Grain size distribution curve (Sieve analysis) the value of Coefficient of Uniformity (Cu) is 4.50 and Coefficient of Curvature (Cc) is 0.094 so the soil classified as poorly graded sand. Maximum density ($\gamma_{max)}$ 1.89 gm/cm^3 and Minimum density ($\gamma_{min)}$ 1.49 gm/cm^3 so take Field density as per 50% relative density is 1.67 gm/cm^3. Specific gravity (G) of soil is 2.63. From direct shear test the value of internal angle of friction (ϕ) is 38.57°.

Table 2: List of Experimental Trials

Length of Nails L (cm)	L/H ratio	Length of Nails L (cm)	L/H ratio	Length of Nails L (cm)	L/H ratio	Nail Spacing S_h & S_v (cm)	Nail Pattern	Nail Angle θ (deg.)
24	0.6	28	0.7	32	0.8	**10**	**3 x 4**	**0°**
24	0.6	28	0.7	32	0.8	**10**	**3 x 4**	**10°**
24	0.6	28	0.7	32	0.8	**10**	**3 x 4**	**15°**

3 Comparative Study

Comparison of experimental results are two types:

3.1 Effect of L/H ratio

For the different L/H ratio we can check the load carrying capacity of the nailed wall. In this practical, check the load carrying capacity of nailed wall with the same nail inclination. For example, 0° inclination and change L/H ratio of the nail and report the value of load carrying capacity as shown in Fig. 6. Same procedure repeat for the 10° and 15° inclination of the nails shown in Fig. 7 and Fig. 8 respectively.

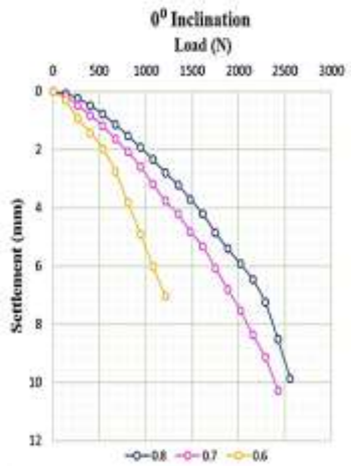

Fig. 6: Load v/s Settlement Curve for Different L/H ratio and 0° Inclination

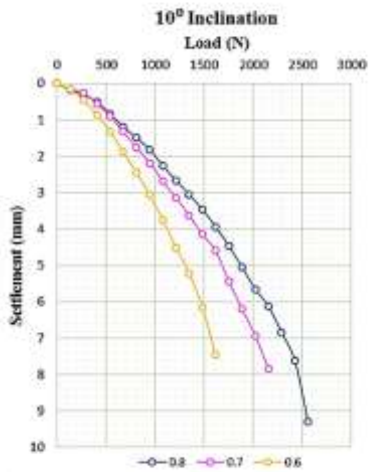

Fig. 7: Load v/s Settlement Curve for Different L/H ratio and 10° Inclination

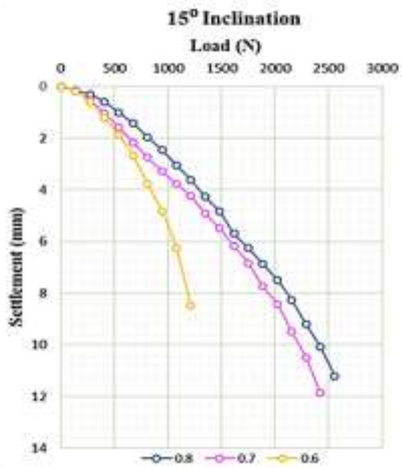

Fig. 8: Load v/s Settlement Curve for Different L/H ratio and 15° Inclination

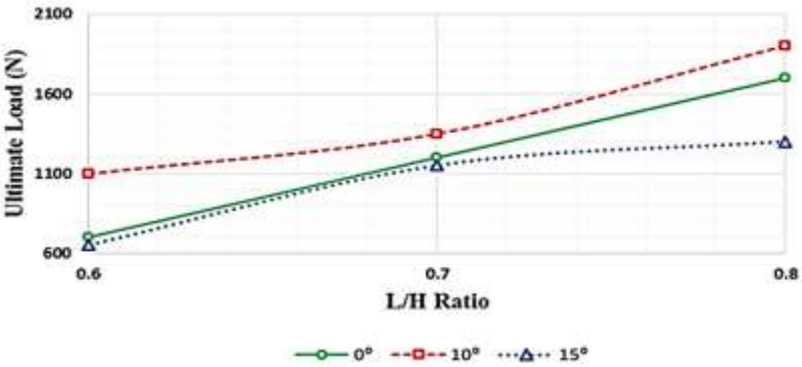

Fig. 9: L/H ratio v/s Ultimate Load Curve for Different Nail Inclination

Table 3: Effect of L/H ratio and Nail Inclination

θ^0	L/H	q (N)	S (mm)	L/H	q (N)	S (mm)	L/H	q (N)	S (mm)
0		1700	1.8		1200	3		700	1.8
10	**0.8**	1900	1.8	**0.7**	1350	2.4	**0.6**	1100	1.8
15		1300	2		1150	3.5		650	2.2

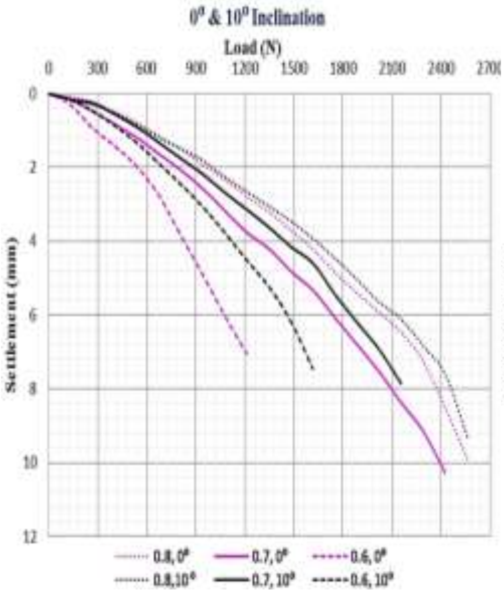

Fig. 10: Load v/s Settlement Curve for 0^0 & 10^0 Nail Inclination

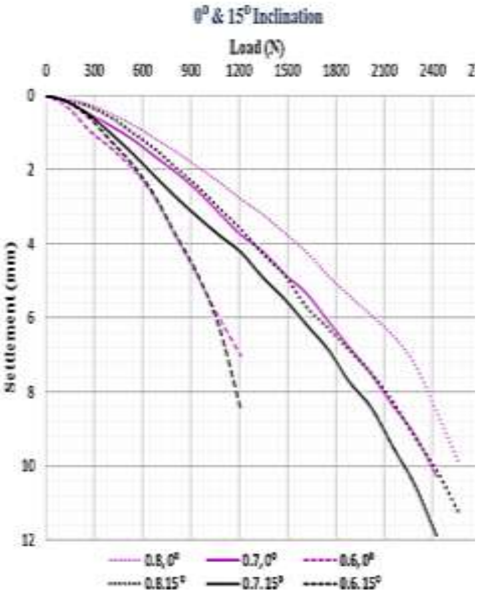

Fig. 11: Load v/s Settlement Curve for 0^0 & 15^0 Nail Inclination

From the Table 3 and Fig. 9 shows the value L/H ratio to the ultimate load carrying capacity. From the figure when L/H ratio 0.8 then ultimate load carrying capacity is more with compare to L/H ratio 0.6 and 0.7 with and without inclination of nails and L/H ratio 0.6 give the least value of the ultimate load carrying capacity.

Therefore with increasing L/H ratio the ultimate load carrying capacity of nailed wall will be increased.

3.2 Effect of Nail Inclination

Nails are inserted at 10^0 and 15^0 with respect to horizontal nail inserted to find out the effect of inclined nail as compare to horizontally inserted nails. Also find out the nail inclination effect for the same L/H ratio.
From Table 3 and Fig. 10, 11 and 12 shows that the value of ultimate load is maximum for 10^0 inclination and it is reduced for the 15^0 inclination of nail in comparison to 0^0 inclination of nail. From both, it can be concluded that when driven nails are used inclined at 10^0 in sand, load carrying capacity increases and settlement reduces in comparison to horizontally inserted nail but it gets reduced when nail inclination is increased to 15^0.

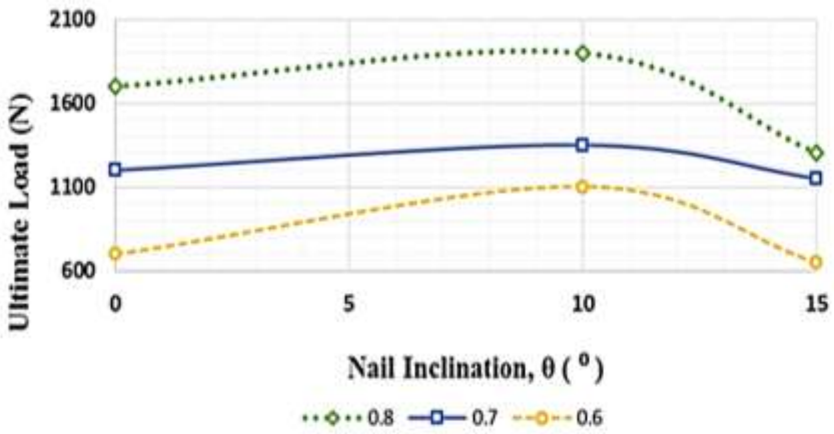

Fig. 12: Nail Inclination v/s Ultimate Load Curve for Different L/H ratio

Fig. 13 shows that for the same L/H ratio but in the different nail inclination 10^0 gives maximum load carrying capacity and minimum settlement, it reduced for 15^0 nail inclination in comparison of horizontally inserted nail. It also shows that the value of 0.8 L/H ratio is more.

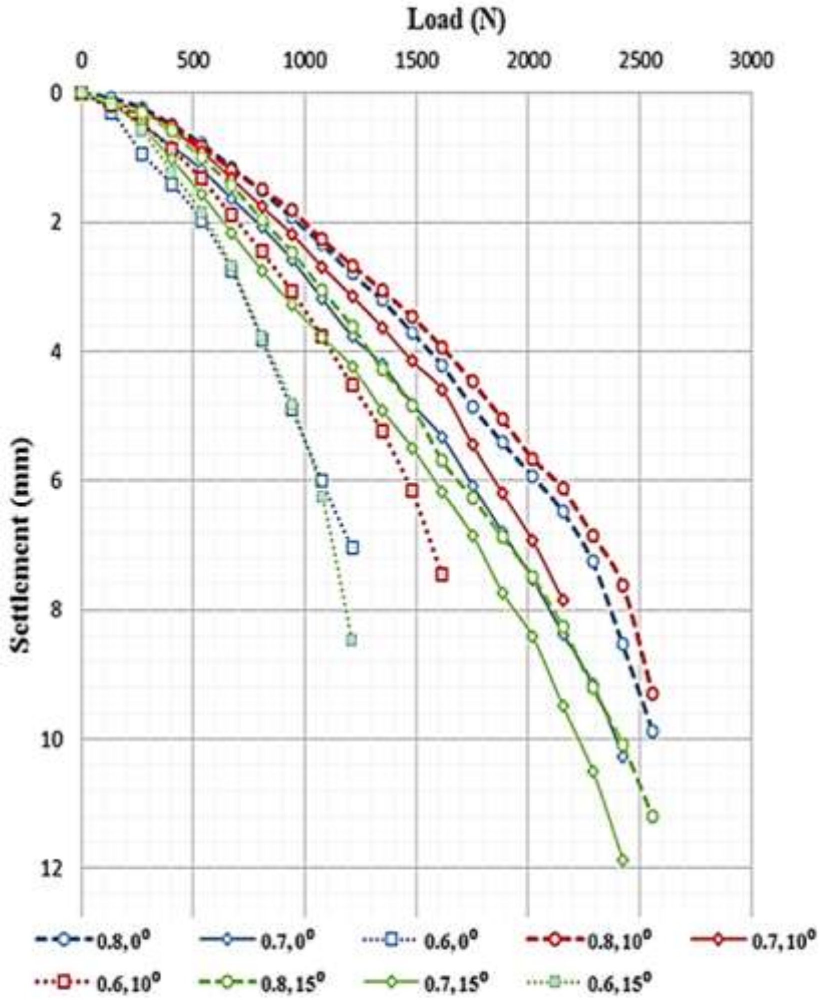

Fig. 13: Load v/s Settlement Curve for Different Nail inclination & L/H Ratio

4 Conclusion

Following conclusion were carried out from this experimental study.

Load carrying capacity is maximum for L/H = 0.8. As we increase nail length the ultimate load increases, and settlement reduces.

For the nail inclination of 10^0 the load carrying capacity is maximum and settlement reduces as compared to horizontally inclined nails. When nail inclination is 15^0 the load carrying capacity and settlement reduction reduce as compared to horizontal nails. So, inclined nail up to 10^0 are more effective as compared to horizontally inserted nails for same configuration.

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