Effect of Soil Slope on Failure Mechanism of Soil Nailed Structures by Aluminum Nails & Bamboo Nails

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Abstract. In the present day scenario, improvement of ground is necessary in various occasions due to wide range of construction requirements. Various ground improvement techniques have been developed over the past few years. Increasing the load carrying capacity by inserting steel bars generally termed as soil nails is one of the effective techniques. These are mostly used in improvement of Soil slopes. Wide range of materials can be used as Soil nails. In the present study, hollow aluminum tubes and bamboos were used as soil nails for improving the ground characteristics. Model tests were performed for soil slope with different conditions of nail inclination. Further these test results are compared with unreinforced soil. Parameters considered for the study are nail inclination and soil slope. Three nail inclinations are considered for the present study they are 0°, 15°& 30° with horizontal axis and two soil slopes they are 45° and 60^0. Constant Parameters considered for the study are soil, height, nail length and nail pattern. The results obtained are compared with the conventional unreinforced soil slope for each case and curves for load versus settlement were developed for the same. From experimental results, Soil slope with 0° nail inclination with horizontal axis gives the maximum load carrying capacity in all the cases, followed by 15° nail inclination with horizontal axis and then 30° nail inclination with horizontal axis.

Keywords: Backfill, Reinforced Soil, Soil nail, Unreinforced Soil

1 Introduction

Soil nail has gained popularity in recent years in the construction industry due to its ease of construction, Technical stability and relatively free of maintenance. This technique is used several construction activities such as slope stability by reinforcing the soil with vertical and inclined elements (Jian Liu et al., 2016: Shamsan Alsubal et al., 2017) for protection and preservation of historical monuments (Marek Kulczykowski et al., 2017) etc. The Shear strength of clayey soil has been investigated worldwide by soil nailing technique using a variety of reinforcing elements in the form of closely spaced steel bars called nails as mentioned by several researchers (e.g. Maher and Ho 1994: Indraratna, 1996: Dermatas and Meng 2003: Casgrande et al 2006 Freilichet.al.2010: Naeini et al., 2012). This technique is not suitable for soft clays due to low cohesion of soft clay which leads to small friction between the soil and soil nails soft soils properties can be improved by combined method of fracture grouting and soil nailing techniques (Cheng et al., 2009, 2015). The shear strength of cohesive soils can be increased and the settlements are reduced by the utilization of soil nailing technique (Azzam and Basha, 2017).

Soil nailing is a realistic and confirmed technique used in constructing excavations, reinforcing slopes and solving geotechnical foundation problems by reinforcing the ground with relatively small, completely bonded inclusions, typically steel bars (Stocker et al., 1979). The behaviour of slopes and excavations using the field or experimental tests (Tuner and Jensen, 2005; Wang et al., Xue et al., 2013; Liu et al., 2014; Seo et al., 2014; Zhang et al., 2014). It is noticed from the results of various studies that initialization of soil nails provides considerable changes in soil in the vicinity of nails and improves the shear strength with in the soil mass. Dai et al., (2016) mentioned an alternative method using Moso bamboo. The bamboo elements were employed as soil nails and piles using laboratory and field studies. The tests showed that the load capacity of bamboo nails is significantly increased by 250% compared with steel pipe nails. Garg et al., (2014) introduced a soft computing method called multi – gene genetic programming, which is used to predict the factor of safety for different soil properties of three dimensional (3D) soil nailed slopes.

It has been reported by many researchers, that the increase in shear strength and decrease in settlements of cohesive soils can be achieved by soil nailing techniques. In the present work an attempt is made to study the load settlement behaviour of cohesive soils with and without reinforcement in the form of nails. Two types of nails (aluminum and bamboo) were used to study the load settlement behaviour of cohesive soils.

2. Materials

Details of various materials used during the experimentation are reported below.

2.1 Soil

The soil used in the present study was collected from Godavari Institute of Engineering Technology (A) Campus Rajahmundry. The soil properties obtained from laboratory tests are specific gravity 2.68, Grain size distribution (Gravel 52 %, Sand 18%, silt &clay 30%), Maximum dry density 19.5 kN/m^3, OMC 12.5%, Liquid limit 33%, Plastic limit 19%, Plasticity index 14%, cohesion 48 kN/m^2 , Angle of friction (Ø) 6.0^0.

2.2 Aluminum Tubes

Hollow tubes of cross sectional area 34.57 mm^2. 150 mm Length, Modulus of Elasticity E is 6.9×10^4 N/mm^2 were used as nails.

2.3 Bamboo sticks

Bamboo sticks of same cross sectional area, same length and Modulus of Elasticity is 1.68×10^4 N/mm^2 were also used as nails.

3. Experimental Study

A model box of dimensions 50 cm x 22 cm x 35 cm is fabricated by using 6mm thick glass.

3.1 Model Tests

Tests were carried out by preparing two soil slopes such as 45^0 and 60^0 in Model box in the laboratory. A fine layer of red dye is used between the layers for identification of failure pattern of the slopes, a crest of 150mm and base width of 500 mm is maintained for all the slope angles.

Fig 1.0. Model box with 45^0 soils and with nails for test.

3.2 Unreinforced soil model: Model -1

The prepared soil model is mounted on the testing machine, a bearing plate of size 15cm by 15cm x 0.6 cm is placed on the crest slope for uniform load distribution. Load is applied gradually at a rate of 10 N/s and the corresponding settlements were recorded by attaching two dial-gauges at the top of the bearing plate.

Reinforced with aluminum nails: Model – 2

The soil model was reinforced with aluminum nails at 0^0,15^0 and 30^0 inclination with horizontal in a square (10cm x 10 cm) nail pattern with 3 rows and 2 columns and is tested similarly as model – 1.

Reinforced with bamboo nails: Model – 3

The soil model was reinforced with bamboo nails at 0^0,15^0 and 30^0 inclination with horizontal in a square (10cm x 10 cm) nail pattern with 3 rows and 2 columns and is tested similarly as model – 1.

Load tests were conducted on unreinforced soil model and reinforced soil model in the laboratory till the failure occurs.

Fig 2.0. Model box under load test.

4.0 Results and Discussions

The results obtained from laboratory experimentation were tabulated and are discussed below.

Table 1. Failure Load vs settlement curves of 45° soil slope for different Aluminum and Bamboo nail inclinations.

Model	Failure Load (N)	Settlement (mm)	Nail inclination
Model -1	2025	8.05	No reinforcement
Model -2	2850	7.00	0^0
	2625	7.42	15^0
	2250	7.805	30^0
Model -3	3000	6.685	0^0
	2775	7.00	15^0
	2475	7.70	30^0

Table 2. Failure Load vs settlement curves of 60˚ soil slope for different Aluminum and Bamboo nail inclinations.

Model	Failure Load (N)	Settlement (mm)	Nail inclination
Model -1	1890	9.6	No reinforcement
Model -2	2625	8.4	0^0
	2400	8.92	15^0
	2175	9.24	30^0
Model -3	2925	7.92	0^0
	2625	8.28	15^0
	2325	8.96	30^0

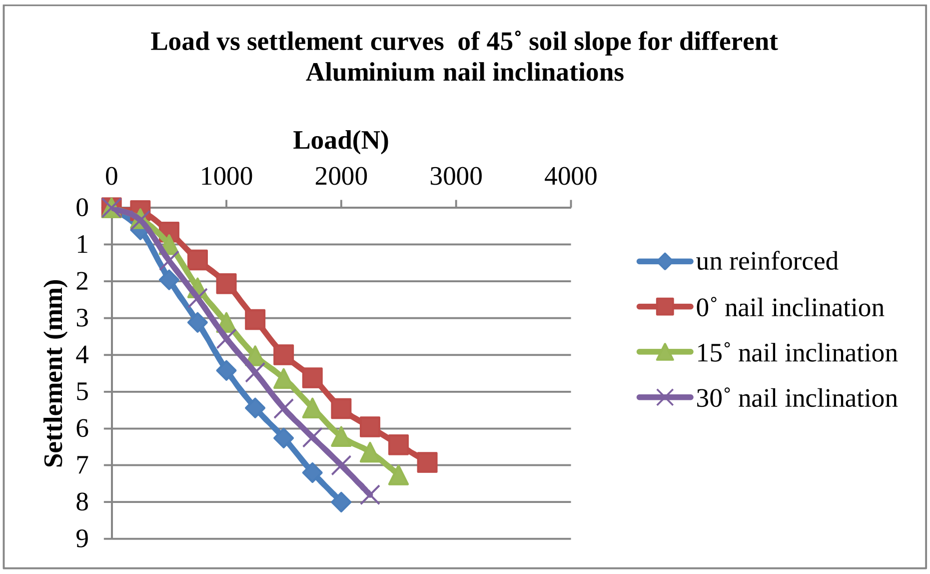

Fig 3 .0 Load vs settlement curves of 45˚ soil slope for different Aluminum nail inclinations

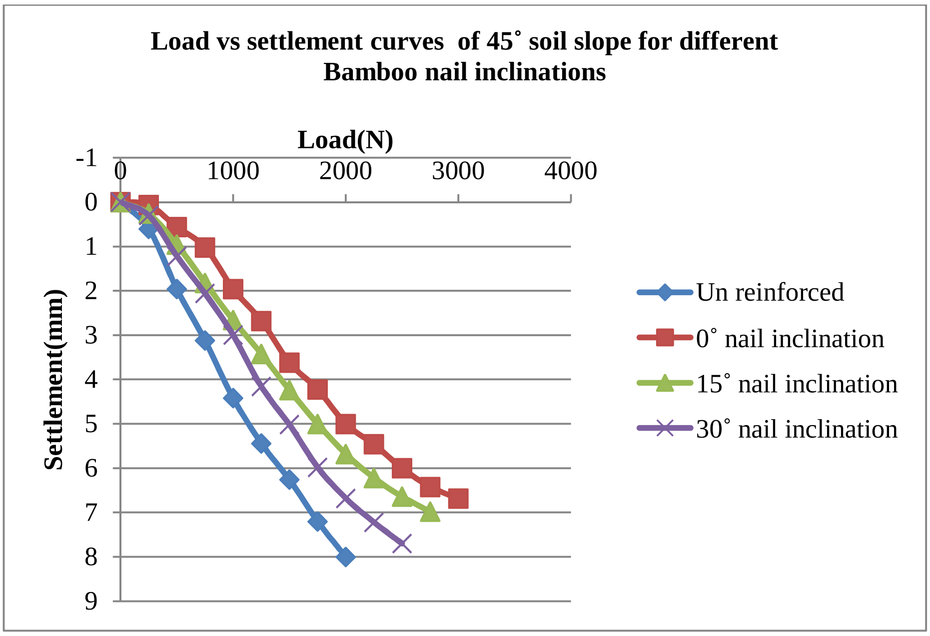

Fig 4 .0 Load vs settlement curves of 45˚ soil slope for different Bamboo nail inclinations

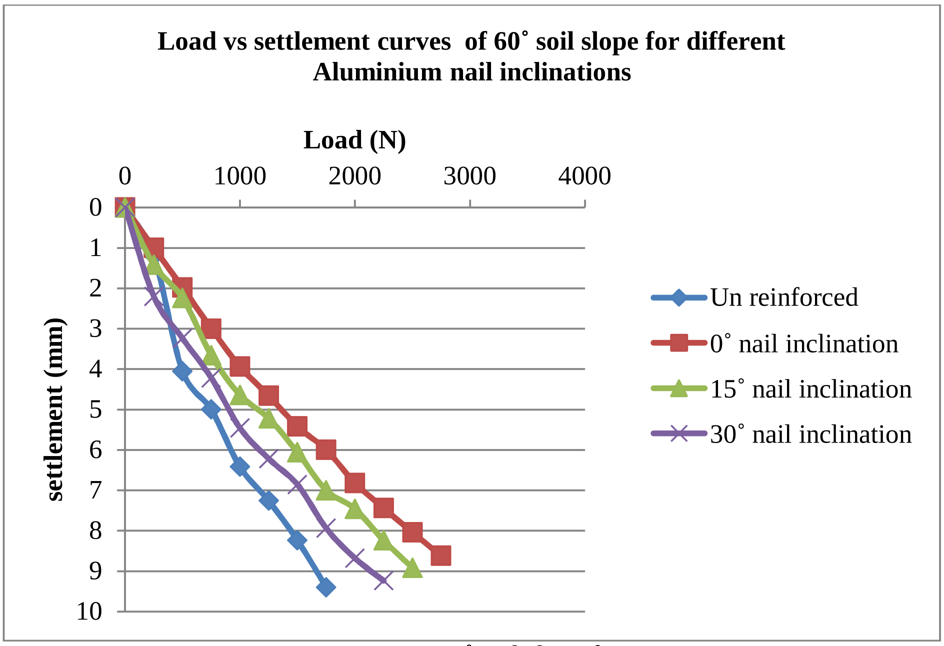

Fig 5 .0 Load vs settlement curves of 60˚ soil slope for different aluminum nail inclinations

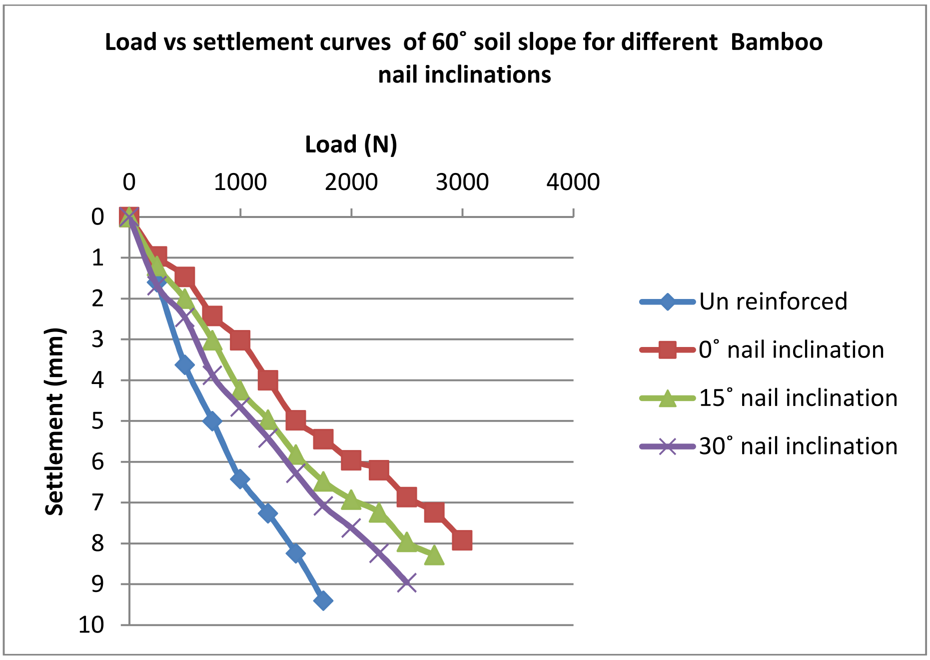

Fig 6 .0 Load vs. settlement curves of 60˚ soil slope for different Bamboo nail inclinations.

Figures 3.0 to 6.0 depicts the load settlement curves for different soil models constructed with 45^0 soil slope and 60^0 soil slope with aluminum and bamboo nails at different nail inclinations.

For 45^0 soils slope the load carrying capacity increased by 40.7% for 0^0 nail inclination, 29.6 % for 15^0 nail inclination and 11.11 % for 30^0 nail inclinations and settlement were decreased by 13.0 %, 7.8 % and 3.0% respectively for aluminum nails with respect to unreinforced soil model.

For 60^0 soils slope the load carrying capacity increased by 39.0% for 0^0 nail inclination, 27.0% for 15^0 nail inclination and 15.1 % for 30^0 nail inclinations and settlement were decreased by 12.5 %, 7.1 % and 3.8 % respectively for aluminum nails with respect to unreinforced soil model.

For 45^0 soils slope the load carrying capacity increased by 48.1% for 0^0 nail inclination, 37.0 % for 15^0 nail inclination and 22.2% for 30^0 nail inclinations and settlement were decreased by 17%, 13 % and 4.3% respectively for bamboo nails with respect to unreinforced soil model.

For 60^0 soils slope the failure load carrying capacity increased by 54.8% for 0^0 nail inclination, 38.9% for 15^0 nail inclination and 23.0 % for 30^0 nail inclinations and settlement were decreased by 17.5 %, 13.75 % and 6.7 % respectively for bamboo nails with respect to unreinforced soil model.

It can observed form the above figures, that the load carrying capacity has substantially increased for 0^0 nail inclination for both aluminum and bamboo nails compared to15^0 and 30^0 nail inclinations. The improvement in load carrying capacity and the decrease in settlement could be attributed to the insertion of the reinforced elements into the soil mass.

5. Conclusions

1. It is observed that the 0^0 nail inclination is proved to be more efficient as it gives fewer settlements at a particular load compared to other nail inclinations.

2. For 45^0 and 60^0 soil slope the load carrying capacity of 0^0 aluminum and bamboo nail inclinations has increased by 40.7 %,48.1% and 39% ,54.8%with respect to unreinforced soil model.

3. For 45^0 and 60^0 soil slope the settlements of 0^0 aluminum and bamboo nail inclinations has decreased by 13% ,17%and 12.5%,17.5% with respect to unreinforced soil model.

4. For 45^0 and 60^0 soil slope the load carrying capacity of 0^0 bamboo nail inclinations has increased by 5%, 10.3% with respect to aluminum reinforced soil model at same inclinations respectively.

5. For 45^0 and 60^0 soil slope the settlements of 0^0 bamboo nail inclinations has decreased by 4.5% and 5.7% with respect to aluminum reinforced soil model at same inclinations respectively.

6. Out of all nail inclinations 0^0 nail inclinations shows better performance in both load carrying capacity and in settlement for both soil slopes.

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