Experimental study on effect of wooden pile in bearing capacity of soil and settlment improvement

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Abstract

This paper presents and investigates the results of laboratory model tests on bearing capacity behavior of a strip footing on wooden pile – reinforced sand slope. The studied parameters include the edge distance of footing from slope crest, and location of the wood pile relative to the slope crest. Bearing capacity of a footing without wood pile located adjacent to a slope crest was determined and then compared with those of a footing with wood pile. The results were analyzed to study the effect of each parameter. The total wood piles force required to maintain the balance of row of wood piles depends on the forces that are due to the soil, water and external load have been estimated. The results indicated that using wood pile for a strip footing located near to a sand slope crest has a significant effect in improving the bearing capacity. This improvement increases when the location of the wood pile relative to the slope crest increases with a further improvement upon increasing the edge distance of footing from slope crest. This technique can be considered as a good method to control the horizontal movement of the subgrade and for decreasing the slope deformation.

Keywords: wood pile, stabilization, bearing capacity, settlement, sand slopes

1. Introduction

Settlement is an important criterion in the design of the foundations. Foundation settlement must be estimated carefully to ensure stability of buildings, towers, bridges, and any high cost structures. The main reason for the settlement occurrence is the compressive deformation of the soil. According to (Liu et al., 2008)

The term reinforced soil refers to a soil that has been strengthened by placement of reinforcing material within the soil mass in the form of strips, bars, sheets or grid (meshes). When load is applied to the reinforced soil mass, these materials resist tensile stresses which develop within the reinforced soil mass. When the tensile strength of an element is low, it can break or yield and become ineffective. If the tensile strength is adequate but its extension under stress is high, then the soil may show large movement or settlement because of the inadequate stiffness of the soil-reinforcement system.

Alamshahi and Hataf (2009) conducted a series of numerical and model tests to evaluate the bearing capacity of a strip footing resting on sand slopes reinforced with geogrid and grid – anchor. Their study emphasized on the effects of geogrid and grid-anchor reinforcement and its location on the bearing capacity and settlement characteristics of strip footings. In this study, laboratory model test were carried out to investigate the bearing capacity of strip footing placed on top of sand slope with and without a layer of geotextile reinforcement. The parameters varied in this study were the space between reinforcement layers, the edge distance between the footing and the crest of the slope, the relative density of sand and the number of reinforcement layers.

In many of the aforementioned structural cases, it might not be possible to use the shallow foundation system, and accordingly, using an expensive foundation system (e.g., piles or caissons) becomes the only suitable solution. For these reasons, over years the subject of improving the load bearing capacity of foundations on slopes and stabilizing the earth slopes have become among the most important areas of geotechnical researches and it has attracted a great deal of attention. In fact, both the stability of a slope and the bearing capacity of the adjacent soil can be increased in different ways, such as modifying the slope surface geometry, using soil reinforcement, or installing continuous or discrete retaining structures such as retaining walls or piles. There have been numerous studies on the use of slope reinforcement to improve the load bearing capacity of a footing on the slope (Yoo 2001; Slah 2002; and Kumar A, Kaur 2012.). These investigations have demonstrated that not only the slope stability can be increased but both the ultimate bearing capacity and the settlement characteristics of the foundation can be significantly improved also by the inclusion of reinforcements layers of geogrid, strips, or geotextile in the earth slope. Slope stabilization was mostly investigated when using the reinforcement in the conventional horizontal manner. In the last few decades, stabilizing earth slopes by using vertical reinforcement such as piles to support an active earth slope has been considered one of the important slope reinforcement techniques. Several studies reported the success of using piles as a vertical reinforcement in many situations in order to improve slope stability (Chen and Poulos 1997; Ausilio *et al.* 2001; and Azzam and Nazer 2010). In addition to these investigations on piles, (El-Sawwaf 2005) studied the strip footing behavior on sheet pile-stabilized sand slope as an extensible reinforcement adjacent to footing and slope.

Jha et al. 2010 conducted a series of load tests for three dimensional model footing in a sand box using unreinforced sand subgrade and also after reinforcing the sand with bamboo pile as vertical reinforcing elements. Reinforcements were placed laterally around the footing only thus without disturbing the subgrade directly below the footing base. They discussed effect of length; spacing and lateral extent of reinforcement on bearing capacity ratio. Also they suggested bamboo is used as reinforcement in the field.

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2. Objectives of the present study

The aim of present work is to study the behavior of reinforced sand by using wooden pile as reinforcement. The scope of the present study is

i. To determine the load settlement behavior without wooden pile and with wooden pile.

ii. To evaluate the improvement in bearing capacity of reinforced soil.

3. Laboratory model tests

3.1. Model box

The main elements of the laboratory apparatus are a tank, a horizontal steel beam over the tank, and a sand raining box. The test box, having inside dimensions of 2.00_0.58m in plan and 0.6 m in depth is made from steel with the front wall made of 20mm thickness glass and is supported directly on two steel columns. These columns are firmly fixed in two horizontal steel beams, which are firmly clamped in the laboratory ground using four pins. The glass side allows the sample to be seen during preparation and sand particle deformations to be observed during testing. The tank box was built sufficiently rigid to maintain plane strain conditions by minimizing the out of plane displacement. To ensure the rigidity of the tank, the back wall of the tank was braced on the outer surface with two steel beams fitted horizontally at equal spacing. The inside walls of the tank are polished smooth

to reduce friction with the sand as much as possible by attaching fiber glass onto the inside walls. The loading system consists of a hand-operated hydraulic jack and pre-calibrated load ring. Since the sand raining technique was used to deposit the sand inside the tank, the beam was designed to swing about one end. Therefore, the beam can be swung out during sand deposition and returned back to the original loading position, when sand set up is completed. The sand particles were rained from the box through a square grid of holes (4mm diameter and 20mm spacing) in the base plate. The height of sand raining, measured from the bottom of the box to sand surface in the tank, is adjusted up or down by using a manual winch.

4. Materials used

4.1. Sand

The Sand is collected from Abu qir beach. The collected sand is washed and cleaned to make it free from organic matters. Then the sand is oven dried and properly sieved to get the required grading. Dry sand used was medium coarse with uniformity coefficient of 4.55, and effective diameter of 0.14 mm. The specific gravity of sand particles was 2.64. Different relative densities of the sand were used by forming designed weight of sand into a certain volume of soil bin by compaction. The properties of the sand are given in Table 1. Several laboratory tests had been done to produce empirical equation. All laboratory tests are in accordance to ASTM.

Table1: Geotechnical properties of sand.

Parameter	Value
Coefficient of uniformity (C_u)	4.55
Effective diameter (D_{10},mm)	0.14
Maximum dry unit weight (kN/m^3)	18.74
Minimum dry unit weight (kN/m^3)	16.7
Specific gravity (G_s)	2.64
Residual effective angle of internal friction (ϕ')	38°

4.2. wooden pile

Wooden piles in the present study are collected from the availability of local market. The diameter of each reinforcing rod is 16 mm and the length of pile to footing width approximately 10.

5. Analysis of test results

5.1. Wooden pile-stabilized sand slope

Fig. 1 shows the test results for the different variables considered in the investigation. Plots between pressure and settlement were drawn for different cases and the ultimate loads at failure were determined using double tangent method. The bearing capacity improvement of soil due to wooden pile reinforcement is represented by a non-dimensional factor, called the bearing capacity ratio (BCR). This factor is defined as the ratio of the footing ultimate load with wooden pile reinforcement ($q_{u(R)}$) to the footing ultimate load in tests without reinforcement (q_u). BCR = $q_{u(R)}$ /q_u and settlement reduction factor (SRF) and has been defined as SRF = $S_{u(R)}$ /S_u Where $S_{u(R)}$ is the settlement of strip footing on wooden pile reinforced sand slope at ultimate load. This has been used as a base value for comparison with the other cases considered in the investigation. It can be seen from the fig 3 that the installation of wooden piles as reinforcements appreciably improved the bearing capacity of the footing. Comparing the results of fig 1 it can be seen that soil confinement by reinforcements improved the bearing pressure of un-reinforced case from 19 kN/m^2 to 46 kN/m^2 for reinforced case, when settlement reduction factor (SRF) for the un-reinforced and reinforced cases are 2.91 to 2.09. Therefore it can be concluded that, in cases where excessive settlement is controlling factor in determining the allowable bearing capacity, wooden pile reinforcement around footing may significantly reduce the settlement ratio for the same level of bearing load.

When the reinforcement is placed in varying depth in sand bed, the settlement and ultimate bearing capacity has been changed due to effect of depth of reinforcement. So these are studied and discussed through Figs. 1 To quantify or compare the performance, the BCR defined as the ratio of bearing capacity with reinforcement to the bearing capacity without reinforcement are computed at a given rate of settlement. Improvement in footing response caused by slope stabilization through wooden pile at different locations relative to slope crest b and edge distance of the footing X were investigated. Bearing capacity improvement factors (BCR) along with footing S/B were used to present test results.

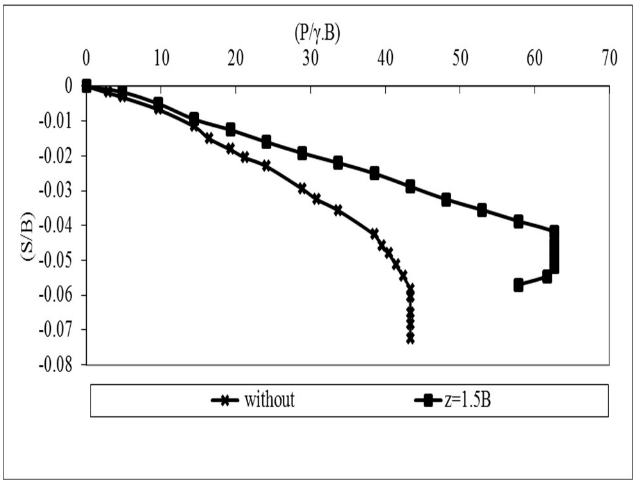
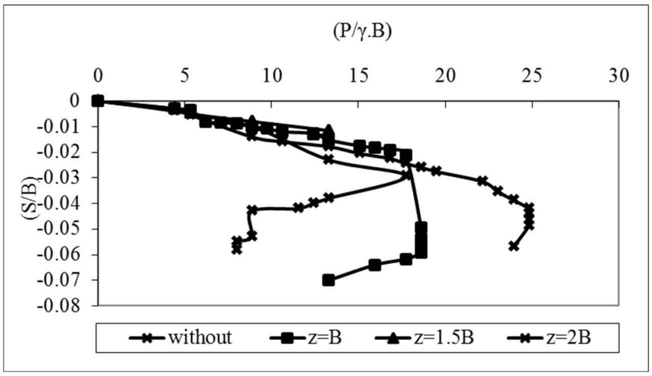


Figure 1: (P/γ.B) versus(S/B).

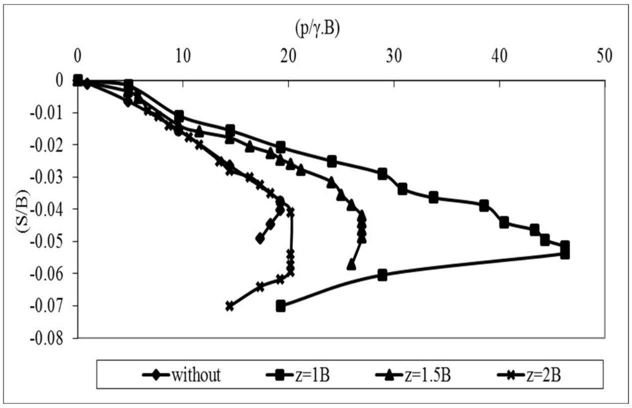
5. 2. The Effect of wood pile location on bearing capacity.

Figure 2 shows The (P/γ.B)-S/B relationships of strip footing on wood pile were plotted in Figs. 3a, 3b, and 3c. From these figures, a significant effect for the embedding row wooden pile into sandy soil obviously exists. To study the effect of the location of wooden pile on the behavior of strip footing on sand, three different embedment ratios (1.00, 1.50, and 2.00) were tested for three different groups of X/B (0.0, 1.0, and 2.0). For each group, the distance between the edges of the strip footing to the edge of the crest.

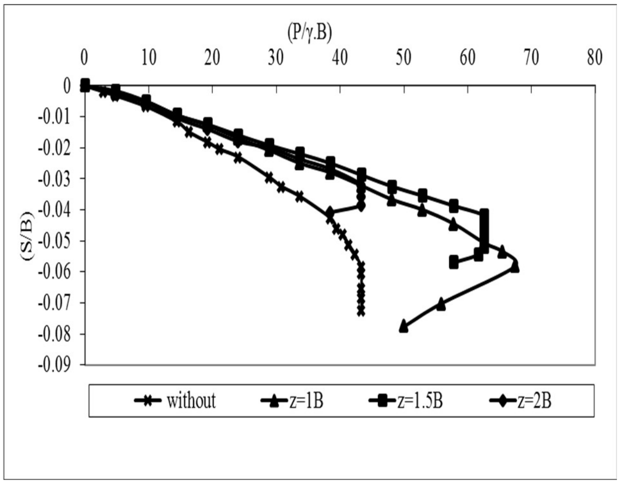
Fig. 3 presents variations of BCR with normalized wooden pile row location (z/B). The figure shows that when the wooden pile is placed nearer to the slope crest, bearing capacity response of the footing is much better than anywhere else. The same trend is confirmed by different series of studies carried out using different edge distances of the footing. Any position far from that location may increase overall stability of the slope but will not prevent or decrease lateral deformations of soil particles under the footing and near the slope.



X/B=0



X/B=1



X/B=2

Figure 2: Variation of (P/γ.B) with Location of wooden pile relative to the slope

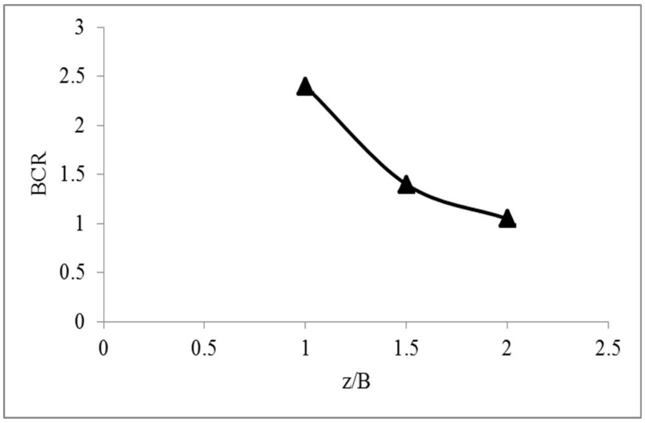


Figure 3: Variation of BCR with different locations of wooden pile relative to the slope crest.

5.3. The Effect of strip footing of slope crest distance for different wooden pile location on bearing capacity.

Figure 4 shows the BCR for strip footing on the slope which is influenced by the different wooden pile location. it was noticed that the BCR decreases proportionately with increase in the wooden pile location. It was shown that there was some confusion among researchers about the optimal location of wooden pile that gives the best stability of a slope and the maximum bearing capacity. Different locations were reported such as the slope crest and the slope toe while others stated that the row placed in the middle – part is the best location. However, it was of interest to find out experimentally the best location of wooden pile row from the point of view of the rather bearing capacity than the overall stability of the slope. So, series of tests using the same row of wooden pile (L=10) at three different locations relative to the slope crest (z = 1, 1.5, and 2 m) .figure 4 shows the variations of BCR with normalized wooden pile row location. It can be seen that as the wooden pile row is placed nearer to the slope crest is getting much better in terms of bearing capacity ratio than anywhere else. Any other position far from that location may increase the overall stability of the slope but can't prevent or decrease the lateral deformations of soil particles near to the slope. These results are Similar to the finding of El-Sawwaf (2005). Their findings demonstrated that BCR is dependent on wooden pile location for the same angle of earth slope.

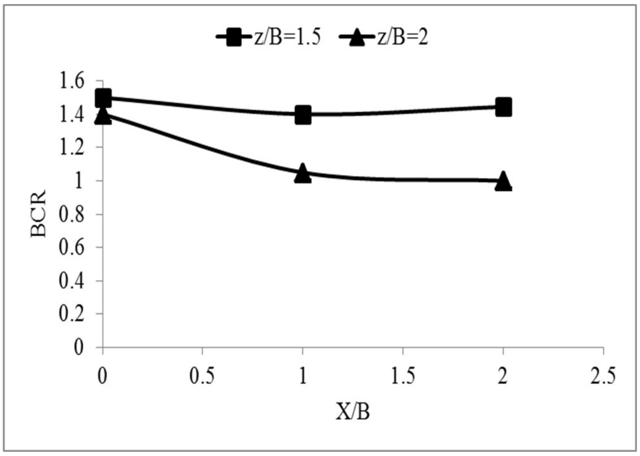


Figure 4: Variations of BCR with normalized strip footing of slope crest distance for different wooden pile location.

5.4. The effect of the location of wood pile relative to the slope crest on settlement.

A series of tests were performed for various the location of wood pile relative to the slope crest to footing width ratios(z/B) of 1, 1.5 and 2 by keeping the edge distance of the footing (X/B) of 0,1,2 and gradient of the slope face(2H:1V) constant. The tests were carried out with one type of reinforcement, wooden pile row. The variations of BCR and S/B against z/B are shown in fig. 5 .From the results of fig.5, it is obvious that the inclusion of wooden pile reinforcement would improve the performance of the footing by increasing the bearing capacity and reducing the settlement of the system. The optimum location of wooden pile z/B depened upon the edge distance X/B,in a way that z/B increases as X/B increased. The optimum location z/B is 1.5 in case of X/B=1 and 2.0 in case of X/B=2, The efficiency of the reinforcement on the bearing capacity and peak settlement seems to reduce significantly.and the performance of reinforced slope becomes rather minimal,as reflected by both BCR and SRF approaching unity.These results are highly consistent with the model test obtained by Selvadurai and Gnanendran(1989) .

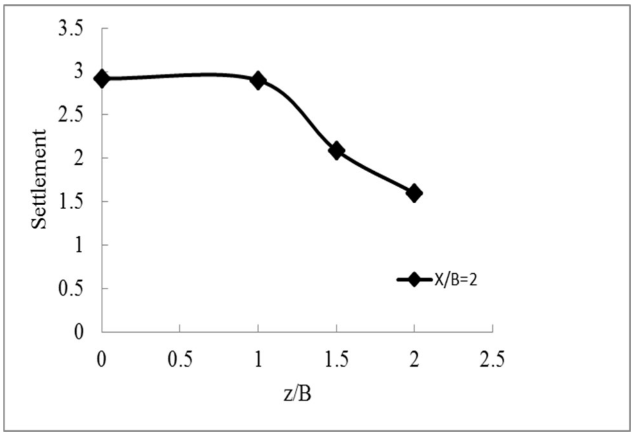


Figure 5: Variation of settlement with Location of wooden pile relative to the slope.

6. Conclusions

The beneficial effect of using wooden pile as reinforcing elements in improving the bearing capacity of sand slope have been demonstrated through a series of small scale footing tests in the laboratory. Based upon the experimental test results following conclusions can be drawn:

The most effective wooden pile location is at the slope crest can be referred to the fact that the passive wedge under the footing is relatively shallow and hence the mobilized passive resistance is getting much higher when the wooden piles are placed at the crest.

The bearing capacity of the strip footing on wooden pile reinforcement sand slope decreases with the increase of the location of wood pile relative to the slope crest.

the wooden pile row is placed nearer to the slope crest is getting much better in terms of settlement than anywhere else. Any other position far from that location may increase the overall stability of the slope but can't prevent or decrease the lateral deformations of soil particles near to the slope.

The ratio of diameter of reinforcing rods to the particles for a field installation is likely to be different, further studies on bigger model or numerical analysis is necessary to quantify the parameters for actual design conditions.

7. Acknowledgment

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