Amirkabir Journal of Civil Engineering

Amirkabir J. Civil Eng., 56(1) (2024) 7-10
DOI: 10.22060/ceej.2024.21779.7823

Two-dimensional experimental and analytical study of reinforcement behavior in piled embankments

M. Fakhrian nejad [1], S. H. Lajevardi [1,*] , S. J. M. van Eekelen [2], A. Nayeri [1]

[1] Department of Civil Engineering, Arak Branch, Islamic Azad University, Arak, Iran.
[2] Department of Geo-engineering, Deltares Institute, Delft, Netherlands.

ABSTRACT: Amethod to improve soft soil is to use embankments along with geo-synthetic reinforcement on piles. This embankment system is called a piled embankment. The objective of this system is to transfer a large part of the load to the piles through the embankment and the reinforcement. Due to the soil arching in the embankment, part of the surcharge load (A) was directly transferred to the piles, reducing the remaining surcharge load (B) applied to the reinforcement between the piles, and if applicable: (C) the subsoil between the piles. One of the objectives of piled embankment design regulations is that the reinforcement can transfer higher load to the piles with less settlement. In this article, 2D tests were performed using rigid steel rods as embankments with 2D behavior. Then, analytical calculations were performed, using the deflection of the reinforcement measured in the tests. The test device was designed and made in such a way that can measure the values of A and B separately. The effect of varying the embankment height and the number of reinforcing strands was studied. It was shown increasing the height of the embankment by a factor four, resulted in the formation of a more stable arch and an increased load accumulation near the piles, allowing the reinforcement to transfer higher loads to the piles, up to 3.7 times a fixed settlement. Similarly, tripling the number of reinforcing strands, while maintain a fixed settlement of the reinforcement, led to a 1.78 times increase in the maximum load transferred to the piles.

Review History:

Received: Sep. 18, 2022
Revised: Dec. 05, 2023
Accepted: Jan. 06, 2024
Available Online: Jan. 19, 2024

Keywords:

Piled embankment
reinforcement
embankment height
distributed load
soil arching

1- Introduction

One of the methods of improving soft soil is using a geosynthetic-reinforced pile-supported embankment [1]. This system consists of piles with a suitable arrangement, and then placing a geosynthetic reinforcement on the piles, followed by an embankment on the reinforcement. The purpose is to reduce the load on the soft subsoil by transferring a large part of the surcharge load and the soil weight to the piles. The transfer of load towards the piles is relatively efficient due to soil arching. Soil arching occurs when differential movement develops. In geosynthetic-reinforced pile-supported embankments, soil arching takes place when the geosynthetic deflects in the area between the piles. Due to the soil arching, a relatively large part of the load is transferred towards the piles directly. This load part is called load part A (Figure 1) [2]. The residual load part is exerted on the geosynthetic reinforcement between the piles. Part of this residual load is transferred via tension in the geosynthetic reinforcement towards the piles, with this second load part being B. If subsoil is present underneath the reinforcement, this may carry a third part of the load, which is part C.

Also, the load transfer to the piles depends on the geometry of the model; higher embankments and higher coverage rate of the piles result in more effective arching. This effect has been widely studied. Applying a sufficiently stiff reinforcement improves the soil arching, and in addition, it helps transferring vertical load towards the piles. This reduces the load exerted on the subsurface between the piles [3-7].

2- Methodology

A two-dimensional test device was developed to investigate which part of the load is transferred directly to the piles by soil arching and which part of the load is transferred to the piles via the reinforcement (Figure 2). The fact that A and B can be measured separately makes the test device different from several similar test set-ups such as those presented by Jenck et al [8] and Rui et al [9].

For the two-dimensional experimental study, a mixture of three types of steel rods was used as analogical soil. The steel rods in the current test set-up had circular cross-sections with diameters of 1.5 mm, 2.5 mm, and 4.0 mm. The rods had a length of 100 mm and were mixed in an equal weight ratio of 1: 1: 1 and placed perpendicular to the two-dimensional plate.

A camera with a resolution of 24 megapixels (6000 x 4000) was positioned on a tripod approximately 1 m in front of the test box. The movement of the soil and SPW was tracked using one digital photograph every five seconds

*Corresponding author's email: Sh.lajevardi@iau.ac.ir

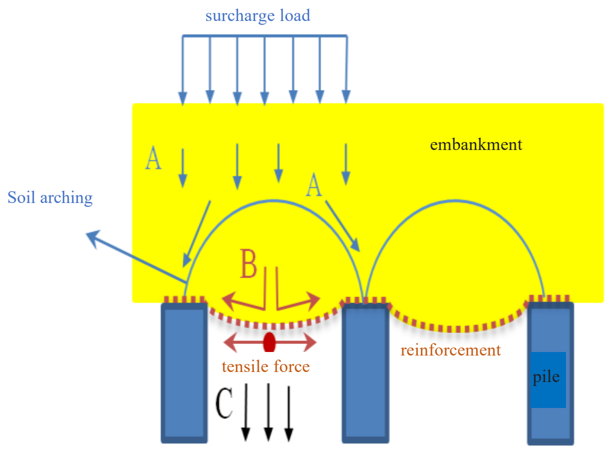

Fig. 1. Distribution of the surcharge load and soil weight to the piles [2]

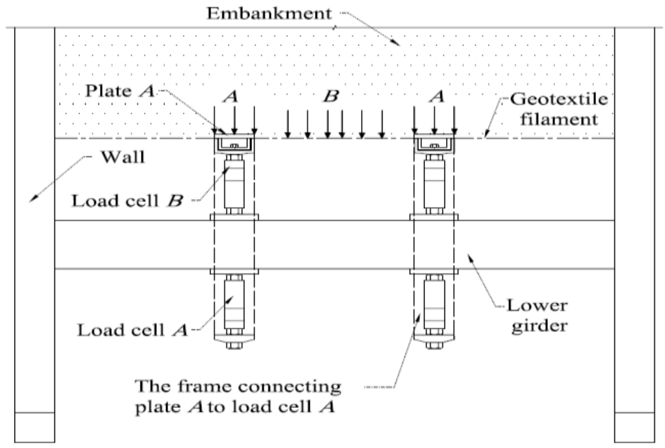

Fig. 2. Details of the test device

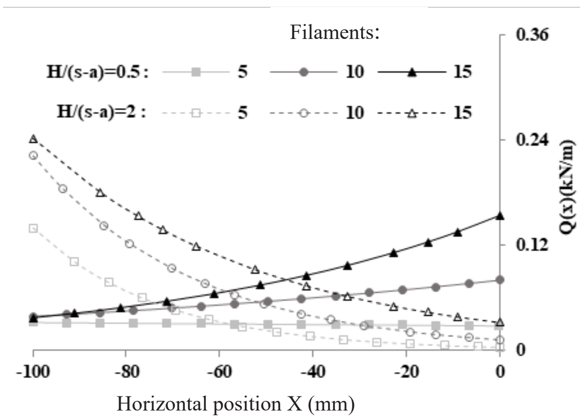

Fig. 3. Distribution of the surcharge load and soil weight on the reinforcement

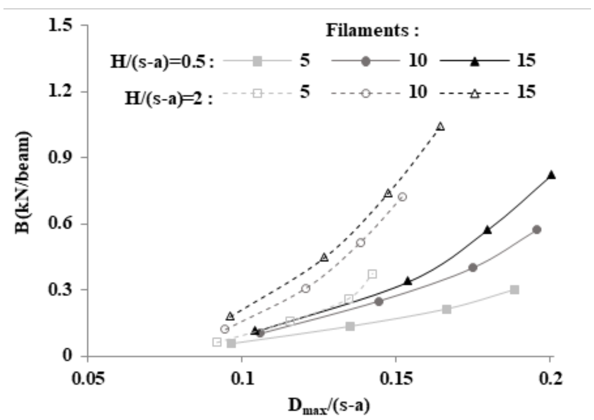

Fig. 4. The effect of embankment height ratio and the number of reinforcement filaments on Dmax/(s-a)

and the digital Particle Image Velocimetry (PIV) technique. The geometric strain of the geosynthetic reinforcement was obtained from the reinforcement deformation between two piles which was obtained using PIV.

3- Results and Discussion

In the higher embankment, the geometry of the arches formed in the embankment changes less during the test. And this causes the formation of more stable arches in higher embankments. For high embankments (H/(s-a)>1), the concentration of the surcharge load distribution and the maximum changes of the reinforcement slope occur during the increase of the tensile force in a part of the reinforcement next to the beam. For embankments with low height (H/(s-a) <1), during the increase of tensile force in the reinforcement, the maximum changes of the slope of the reinforcement and the concentration of load distribution occur at the position of the center of the reinforcement (Figure 3).

In the case where the concentration of tensile force is higher in the part of the reinforcement near the pile (high soil), with constant tensile strength, the reinforcement will be able to reduce the average strain, decrease the settlement (Figure 4) and increase in the slope of the deformation curve next to the pile (Figure 5) will transfer more load (B) directly to the pile.

4- Conclusions

By increasing the height of the embankment by 4 times, the reinforcement can transfer higher load up to 3.7 times to the piles with a fixed settlement. While by tripling the number of reinforcing strands, for a fixed settlement of the reinforcement, it can increase the maximum load transferred to the piles by 1.78 times.

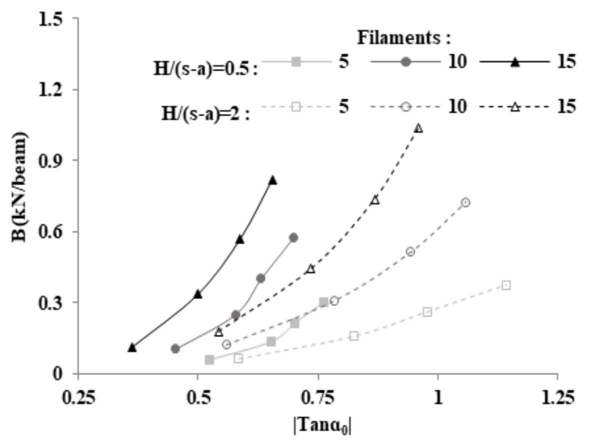

Fig. 5. The effect of embankment height ratio and the number of reinforcement filaments on the reinforcement slope at the edge of the pile

References

[1] S.J.M. van Eekelen, J. Han, Geosynthetic-reinforced pile-supported embankments: state of the art, Geosynthetics International, 27(2) (2020) 112-141.

[2] S.J.M. van Eekelen and M.H. Brugman, Eds, Design guideline basal reinforced piled embankments, (2016).

[3] M. Fakhrian Nejad, S.H. Lajevardi, S.J.M. van Eekelen, A. Nayeri, Two-Dimensional Experimental and Analytical Investigations of Load Distribution on Piled Embankments, International Journal of Geosynthetics and Ground Engineering, 8(6) (2022) 72.

[4] O. Jenck, D. Dias, R. Kastner, Discrete element modelling of a granular platform supported by piles in soft soil–Validation on a small scale model test and comparison to a numerical analysis in a continuum, Computers and Geotechnics, 36(6) (2009) 917-927.

[5] B. Le Hello, P. Villard, Embankments reinforced by piles and geosynthetics—Numerical and experimental studies dealing with the transfer of load on the soil embankment, Engineering geology, 106(1-2) (2009) 78-91.

[6] R. Rui, Y.-q. Ye, J. Han, Y.-x. Zhai, Y. Wan, C. Chen, L. Zhang, Two-dimensional soil arching evolution in geosynthetic-reinforced pile-supported embankments over voids, Geotextiles and Geomembranes, 50(1) (2022) 82-98.

[7] C. Yun-Min, C. Wei-Ping, C. Ren-Peng, An experimental investigation of soil arching within basal reinforced and unreinforced piled embankments, Geotextiles and Geomembranes, 26(2) (2008) 164-174.

[8] O. Jenck, D. Dias, R. Kastner, Soft ground improvement by vertical rigid piles two-dimensional physical modelling and comparison with current design methods, Soils and Foundations, 45(6) (2005) 15-30.

[9] R. Rui, J. Han, S.J.M. van Eekelen, Y. Wan, Experimental investigation of soil-arching development in unreinforced and geosynthetic-reinforced pile-supported embankments, Journal of Geotechnical and Geoenvironmental Engineering, 145(1) (2019) 04018103

HOW TO CITE THIS ARTICLE

M. Fakhrian nejad , S. H. Lajevardi , S. J. M. van Eekelen , A. Nayeri, Two-dimensional experimental and analytical study of reinforcement behavior in piled embankments , Amirkabir J. Civil Eng., 56(1) (2024) 7-10.

DOI: 10.22060/ceej.2024.21779.7823