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Physical modeling for evaluating the effect of helical anchor configuration and surcharge on wall displacement

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ABSTRACT: Helical anchors with unique characteristics have several applications in constructing and reforming the foundations, as well as soil improvement. However, a limited number of study has been done on the use of helical anchors in walls and slopes stability. In the performed studies, the behavior of the helical anchor's wall was investigated. For this purpose, a laboratory study was designed to evaluate the wall stability with three types of helical anchors and two types of back-slopes in sandy soil. The aim of the study was to investigate the effect of anchor's shape and the back slope above the wall on the wall crest displacement. To increase the accuracy of measurements and determine the shear strains, photogrammetry and particle image velocimetry (PIV) methods were employed. Finally, to evaluate its implementation potential, the results were compared with those of the nailing method. The results of modeling revealed that an increase in diameter and the number of the helices led to decreasing in wall crest displacement. The reduction percentages were 30% and 60% respectively for increased diameter and increased number of helices and diameter. If the significant reduction in displacement is required, it is suggested to increase the number of helices without any changes in their diameter. Besides, anchors need a small amount of displacement to be activated and this issue cannot be solved by changing the type of helical anchor. Finally, the results indicated that the slip surface created on the wall of helical anchor using light surcharge is parabolic in shape.

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1. INTRODUCTION

The ever-increasing number of construction in urban areas and excavation near the structures lead to increasing the need for constructing proper retaining structures to control deformations and prevent damage to adjacent buildings. Nailing and grouted anchors are the most applicable methods used to stabilize the walls in Iran. The grouted anchors method has its own shortages including drilling with high vibrations and noise, the difficulty of implementation in poor soils, and grout curing time for anchor pull out. On the other hand, helical anchor methods with its unique characteristics have gained great attention by improving the problems of grouted anchors method.

Among the several studies conducted in the field of wall stability using helical anchors and the effect of helical anchors on wall bearing capacity, one can name the studies of Ghaly et al. (1991), Perko (1999), and Deardorff et al. (2010) [1-3]. In addition, from 2012 to 2016 the new studies on helical anchors were performed by Tsuha et al. [4-7]. They evaluated the effect of the shape of the helix (its number and diameter) and soil properties on the uplifting capacity of multi-helix anchors under gravity and high acceleration in a centrifuge. Motamedinia et al. (2018) investigated the failure surface and calculated the pullout capacity of helical anchors in sand using particle image velocimetry/digital image correlation (PIV/DIC) method [8]. Cerfontaine et al. (2019) studied the geometry of failure mechanism and stress distribution of plate and helical anchors in sandy soil using soil finite element method [9]. All mentioned studies stated the effect of the number of helical plates and their shape on bearing capacity of helical anchors. Moreover, all of the studies have been evaluated the vertical pull out of one or a group of helical anchor and no research have been studied the effect of anchors' deformation on the wall. Clemence and Lutenegger (2015) indicated that the behavior of the helical anchor group and its use in wall stability should be investigated in details [10]. As a result, in order to determine the behavior of helical anchor-stabilized walls as well as expanding their usage, the present study aims to evaluate the helical anchor-stabilized walls using PIV method.

2. METHODOLOGY

To determine the effect of anchor's shape on wall displacement, three types of helical anchors with two and three helices and different diameters were made. Then, the anchors were tested on 10° and 20° soil slopes over the wall. Totally, six tests were performed.

First, the sand was prepared through sand pluviation

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method and the wall was put in the box and was adjusted in a vertical position using a spirit level and a set square. The soil height was increased up to the location of helices by pouring the sandy soil in both sides of the wall. In the modeling, we assumed that the helices were already in the soil; because placing the helices during the construction disrupts the model and makes the test repeatability difficult or impossible. On the other hand, the effect of installing helical anchor and soil disturbance on bearing capacity of the helical anchor is insignificant. Therefore, during the model preparation, the helices were placed at a 15° angle in the sandy soil and then the soil height was increased until the next raw of helices. These steps were continued until the wall was completed. To make a 10° and 20° back-slope on the top of the wall, a transparent colored sheet was used. Finally, its surface was flattened using a spatula and ruler.

After model preparation, wall behavior was modeled during the construction. The best method of building a wall was used in the present study so that first, the excavation was done and then helices were put into the soil. As mentioned, soil disturbance during the installation of helical anchors has an insignificant effect on bearing capacity. In this regard, and to synchronize all experiments in one condition, another method is used to model this behavior. Accordingly, during the modeling, the soil was poured in both side of the wall and then the wall behavior was modeled by the excavation of the opposite side of the wall. As a result, every step of the excavation on the opposite side of the wall means that the construction of that part of the helical anchor wall. After performing eight stages of excavation, the wall was completed. In each step, photos were taken (nine photos from the opposite side of the model).

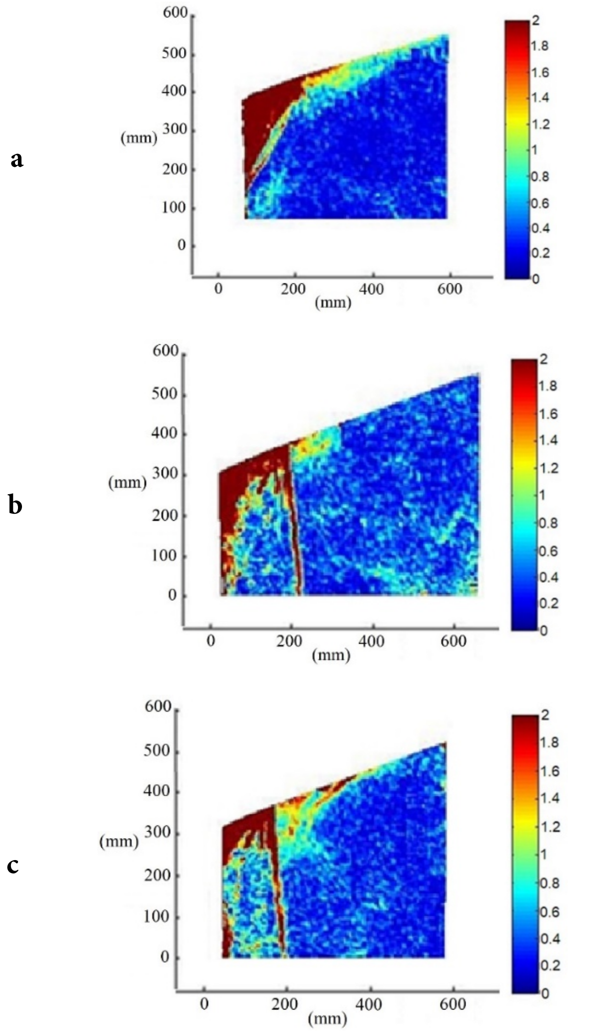

Fig. 1. The shear strain created in the stabilized wall, a: two-helices with variable diameter, b: two-helices with a fixed diameter and c: three-helices

3. RESULTS AND DISCUSSION

The results of the test were presented as the diagrams of displacement, shear strains, and comparison of displacement rate in each excavation step. Ultimately, a comparison was made between the displacement of the stabilized wall using nailing and helical anchor methods.

An example of PIV results, the shear strain created in the soil behind the wall for three types of anchors and 20° back slope is presented in Figs. 1a, 1b, and 1c. As seen, a change in the type of the anchor and an increase in the number of helices resulted in a decrease in shear strains and their expansion behind the wall. The maximum shear strain and its expansion are observed in Fig. 1a because the anchors do not have enough bearing capacity under surcharge. In Figs. 1b and 1c, failure wedge was not formed due to enough bearing capacity of anchors and the shear strains were formed linearly in the region of the first anchor plate. Displacement led to occurring a tensile in anchors and proper bearing capacity of anchors played an important role in not forming a failure wedge.

4. CONCLUSIONS

1- The allowable displacement rare of wall determined the type of helical anchors used in stabilizing the wall. If the significant reduction in displacement is required, the number of helices should be increased and their diameter should be fixed.

2- By increasing the number of helices or their diameters, the effect of the surcharge is reduced about 32%.

3- All types of anchors need a small amount of displacement to be activated so if the required displacement exceeds the allowable rate of wall crest displacement, the use of post-tensioned helical anchor is suggested.

4- Considering that in helical anchor method, the displacement rate of wall crest is less than that in nailing method, in the regions that the results of wall displacement in nailing method are not in acceptable level for adjacent structure, the helical anchors can be the best alternative.

5- The slip surface created on the wall of the helical anchor was parabolic in shape. In contrast to the nailing method, the slip surface did not pass the wall foot.

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