Amirkabir Journal of Civil Engineering

Amirkabir J. Civil Eng., 53(5) (2021) 427-430
DOI: 10.22060/ceej.2020.17196.6491

Effect of Pile Pitch Variation on the Uplift Capacity Using UTM Apparatus

P. Nouhi Hefzabad, M. A. Arjomand*

Civil Engineering Department, Shahid Rajaee Teacher Training University, Tehran, Iran

ABSTRACT: Using helical piles to reinforce the soil is of little cost and time. The purpose of this paper is to investigate the effects of utilizing helical piles on performance improvement in the uplift capacity and displacement. For this purpose, laboratory specimens of simple and helical piles with the pitch of 13, 20, and 25 mm were investigated. Shahriar sand was used with a relative density of 70% and the compression operation has been performed using hammering. The universal Zwick/Roell Z150 apparatus was employed for tensile. The physical modeling of the helical pile was carried out using dimensional analysis and non-dimensionalization by the Buckingham π theorem. The results showed that the maximum uplift capacity of helical piles with the pitch of 13, 20, and 25 mm in comparison with the simple pile increased 453.57%, 518.66%, and 436.24%, respectively. When the ratio of the pitch/central shaft diameter is between 1 and 1.5, the tensile capacity was improved by the generated friction and the weight of sand on the blade as a resisting factor. By increasing the ratio of pile pitch to pile diameter to 1.92, the blade torsional angle increased and the sand weight on the blades decreased. Therefore, the uplift capacity was reduced compared to the previous two. The outputs showed that the displacements of the helical piles with different pitch-to-diameter ratios are approximately equal

Review History:

Received: Oct. 12, 2019
Revised: Jan. 12, 2020
Accepted: Jan. 14, 2020
Available Online: Feb. 02, 2020

Keywords:

Reinforcement
Helical Pile
Sand
Experimental Method
Utm Apparatus

1- Introduction

The helical piles are made of helical welded plates to steel pipes. Advantages of using helical piles to other piles are high installation speed, low noise and vibration during implementation, load-bearing immediately after installation, removal and re-use ability, and finally low weight in installation equipment [1]. Factors affecting the uplift capacity of the helical piles include the diameter of the helical plates, the thickness of plates, the distance and pitch of helical plates, and the soil compaction [2]. In a study, Sakr and Bartlett used three helical piles having different sizes, that had the same thickness of the plate and central pipe in all three, but the plate diameter and central pipe were different. They conclude that at both clay and sand sites, by increasing the diameter of the blade, the pile deformation and loads were increased [3]. Ghafarpour Jahromi and Nouhi Hefzabad reviewed the modeling of seismic loading [4]. The use of commercial software is another way to study mechanical and dynamic behavior [5]. By presenting a model, Zhang calculated the bearing capacity of helical piles in three parts [6]. Helical piles work very well in tensile loading and have been used to control tensile stresses in structures and especially offshore structures [7]. With the increase in the ratio of the width of the reinforced soil to the width of the non-reinforced soil, the uplift capacity of the anchor increases [8]. Rao *et al.* concluded that the maximum uplift capacity is obtained when the *S/D* (ratio of blade pitch-to-pile diameter) is between 0.1 and 1.5. They introduced an *S/D*-dependent correction factor. This factor was determined by trial and error using the experimental results reported in [9].

In this paper, according to the dimensions of UTM, the test tank was designed and manufactured. Physical modeling was performed using a dimensional analysis approach with the Buckingham π theorem. Under the modeling performed, the specimens of the simple and helical piles with variable pitches were prepared. A series of tests were carried out to determine soil type including soil aggregation, specific density, shear strength parameters, and minimum and maximum specific dry weight. The results of helical piles uplift with the pitch of 13, 20, and 25 mm and simple pile were presented. The extraction results include the maximum tensile capacity and its associated displacement, the effect of helical blade pitch change on the ratio of the maximum uplift capacity of helical piles to the simple pile, and the effect of the blade pitch change on the displacement.

2- Methodology

2.1. Soil Tests

To determine the type of soil, a series of soil tests were performed, which are referred to them in this section. Soil classification is performed using the unified soil classification system [10].

$$D_{10} \approx 0.29 \text{ mm},\ D_{30} \approx 0.9 \text{ mm},\ D_{60} \approx 2.2 \text{ mm} \quad (1)$$

*Corresponding author's email:arjomand@sru.ac.ir

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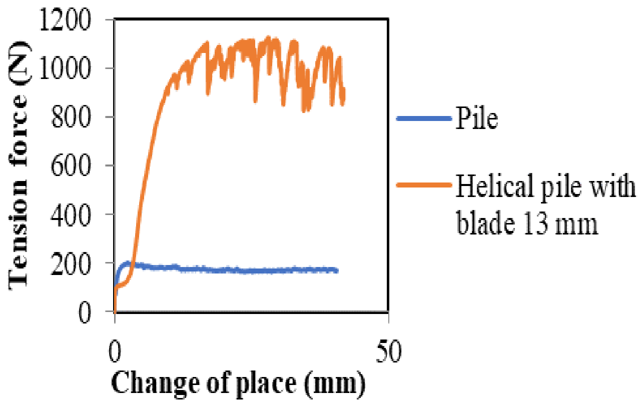

Fig. 1. The variation of Tension force versus a change of place for simple and helical piles (S=1.3 cm, d=1.3 cm, and L′=43 cm)

The uniformity coefficient (C_u) was equal to 7.6 and the curvature coefficient (C_c) was equal to 1.26, this soil is well-graded sand (SW) based on the unified soil classification system [11]. The average of the results of the specific density test with three replications was 2.465. According to the direct shear test, the internal friction angle of the compacted sand was set to 38 degrees. By having the relative density (D_r) as well as the minimum specific weight ($\gamma_{d_{min}} = 1.78$ gr/cm^3) and maximum ($\gamma_{d_{max}} = 1.98$ gr/cm^3), the specific dry weight required for the sand ($\gamma_d = 1.92$ gr/cm^3) was obtained. Mean test results showed 0.48% moisture content of sand, and concerning these cultivars, it can be considered dry and ignore the moisture content. The mean of sand moisture test results was 0.48%, and concerning these results, it can be considered dry and ignore the moisture content.

2.2. Apparatus

The universal Zwick/Roell Z150 apparatus was employed for tensile. The computer communicated with a data recorder using Test Xpert11 V3.2 software. The test speed was set at 0.2 mm/s, according to Stanier *et al.* [12] and the endpoint of the graph is 70% of the maximum force.

2.3. Helical Pile Model

According to the ratios introduced by Stanier *et al.* [12] and Fleming *et al.* [13], the dimensions and sizes of different parts of the helical pile were obtained.

$$D = 5.1 \text{ cm},\ t_b = 2.5 \text{ mm},\ S = 1.3 \text{ cm},\\ L_a = 11.5 \text{ cm},\ L'_a = 5 \text{ cm},\ H = 26.5 \text{ cm} \quad (2)$$

The distance of the blades from each other is determined by the maximum of two blades. Helical pile model has been made using Mannesmann stainless tubes with a diameter of 1.3 cm and 60 cm in length and 2.5 mm spiral blade welding, with the different pitches of 1.3, 2, and 2.5 cm. The variable parameter considered in this study is the pitch of torsion plates. Since the ratio of the blade pitch to the diameter of the blades in the articles that worked on the helical pile was in the range of 0.5 to 1.5 [14], in this study the helical plate pitch of 1.3, 2, and 2.5 cm was considered.

3- Results

In this section, the results of uplift capacity and displacement caused by uplift force have been presented for helical and simple piles. Fig. 1 presents a simple pile test and a helical pile in dense sand.

4- Discussion and Conclusion

In this paper, the performance of simple pile and helical piles with the pitch of 13, 20, and 25 mm was investigated and the effect of pitch change was studied. The test container was designed and manufactured according to the dimensions of the universal testing machine. Physical modeling was performed using dimensional analysis with the Buckingham π theorem. Under the modeling performed, the laboratory specimens of the simple and helical piles with variable pitches were prepared. The maximum uplift capacity and its associated displacement for the piles with different blade pitches were extracted and analyzed. The results showed that the maximum uplift capacity of helical piles with the pitch of 13, 20, and 25 mm in comparison with the simple pile increased 453.57%, 518.66%, and 436.24%, respectively. When the ratio of the pitch/central shaft diameter was between 1 and 1.5, the tensile capacity was improved by the generated friction and the weight of sand on the blade as a resisting factor. By increasing the ratio of pile pitch to pile diameter to 1.92 the blade torsional angle increased and the sand weight on the blades decreased. Therefore, the uplift capacity was reduced compared to the previous two. The displacement caused by its maximum uplift force in the simple pile is less than that of the helical pile, which is due to the absence of the helical blade in the simple type. It can be seen that the displacement of the helical piles is in the range of 27 to 30 cm and these values are approximately equal.

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HOW TO CITE THIS ARTICLE

P. Nouhi Hefzabad, M. A. Arjomand., Effect of Pile Pitch Variation on the Uplift Capacity Using UTM Apparatus. Amirkabir J. Civil Eng., 53 (5) (2021) 427-430

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