Diyala Journal of Engineering Sciences

Journal homepage: https://en.enginmag.uodiyala.edu.iq/

ISSN: 1999-8716 (Print); 2616-6909 (Online)

Compressive Capacity of Triangular Screw Piles Group Embedded in Soft Clay

Abeer S. Jamill*, Hassan O. Abbas

Department of Civil Engineering, College of Engineering, University of Diyala, 32001 Diyala, Iraq

ARTICLE INFO

Article history:
Received 21 July 2020
Accepted 3 September 2020
Keywords:

Compressive; Group; Screw pile; Soft clay; Sandy soil

ABSTRACT

Screw piles are used in different projects such as underpinning, lateral support of retaining wall, foundation of tower and under pipeline. In recent years, the use of screw piles became wide in all world as a result of low cost, ease of installation and need simple machines to construct. A laboratory study of triangle pattern of screw piles group embedded in soft clay and extended to sand soil layer is carried out. Different parameters are investigated such as spacing between piles, number of helix plates and slenderness ratios L/ D. The results of this study showed that the efficiency of screw piles group increases when group extended to sandy layer. Also, a study showed that the compressive capacity of triangular pattern group decreases with increase spacing between piles for group of single and double helix plates. The percent's of reduction are (61, 22, 15) % and (56, 25, 29) % for single and double helix group respectively.

1. Introduction

Soft clay soils are recent alluvial deposits presumably formed through the most recent 10,000 years described by their featureless and flat ground surface, [1, 2]. The soil is identified through their low undrained shear strength Cu less than 40kPa also their height compressive (Cc =0.19 and 0.44), [1]. The soft clay soils in general, are hard when it is condition dry and loss stiff property when it becomes wet. Floods and rains want in vaporization because of roadways; structures are the common causes of cumulative water content in the clay soils, [3]. This kind of soil causes many problems related to geotechnical engineering with settlements and stability problems, low bearing capacity.

Screw piles are a deep foundation part used these piles to give strength to tension, compression and horizontal loadings [4]. the screw piles contain of a solid steel tube, square or circular tube having single or more of helix steel plates were welded with the pile end [5]. Helical piles design involves select of lengths, diameter and number of helices, spacing relation of helix above diameter of helix S/Dh and L/Dh ratio the length to diameter of helix, this limitation can be inclined in the ultimate bearing capacity of the screw piles [6].

Pile group may be by defined as a group that contains from a number of separate piles that have dissimilar lengths, in general the piles group have two plan, one, the movement of wholly the pile heads is equal and two, all the piles in group connected to the same hard cap, in add all the piles need have been settled in neutral level anywhere at the equal depth in soil [7]. In reality, there is a large lack of data can be known done the literature concerning the reaction of single and group screw piles that are subjected to the axial load in soft clay soil, most

*Corresponding author.
E-mail address: temimi71@yahoo.com
DOI: 10.24237/djes.2020.13406

previous readings dealt the problem of bearing capacity of piles. "Group efficiency" depends on some parameters as per, method of piles installation, type of soil, pile spacing.

A study performed by [8] on pile group tests in the clay soil, by different the spacing between the piles and the number of the piles. It was determined that the soil between very closely spaced piles will fail as a block; though, as spacing between the piles group increases, the failure mechanism transitions, such that the individual piles fail locally. For groups performance local failure, the group efficiency decreased slowly with decreasing spacing; though, for groups performance block failure, the group efficiency decreased quickly with decreasing spacing between the piles [8].

The axial load performance of helical piles group study on model piles in sand soil with different parameter, the sand density, the number of piles in the group and the spacing between the piles is investigated by [9]. It was resolved that in medium to lose sands the group efficiency increased as increases helical spacing, but in dense sand soil, efficiency group was greater than 100% at close spacing's and it decreased with increasing spacing between pile. In dense sand, the connection of piles increased the bulk, causing in an increase in soil shear strength nearby the pile. Row and triangular group arrangements, with different spacing's between pile groups, they originate that in dense sand, group capacity is decreased with decreasing spacing between pile, and that at an s p ≥ 5D there is negligible group interaction. In loose sands, it was defined that group performance was independent of spacing of a group, because of local pile failure [1].

A study using four bored concrete piles group in a square pattern and (L/D) ratios of (30, 50 and 70) with spacing between piles (2D, 4D and 6D) for each of the spacing conditions. The results of this study are illustrated that the group efficiency increased with increasing spacing between piles until reaches to 4D then reduced with the increasing spacing between piles. It is showed that the high efficiency happens on 4D, [11].

The behavior of single pile and pile groups of the load-displacement is carried out by [12]. The parameters are led to investigate the effect of number of piles and pile spacing on the load-settlement reply of the piles group associated to a stiff cap. The results showed that settlement of piles group is reduced with augmenting spacing between piles in the similar loading. Moreover, the efficiency of the group is augmented with increasing spacing between piles. Also, the results showed that the group settlement is reduced with increasing spacing between piles and augmented with increasing the number of piles [12]. The influence of pile spacing 2D, 4D and 8D on the load-settlement of 2×2 piles group is investigated using three-dimensional analysis. The results show that the efficiency group is augmented with increasing piles spacing until reaches to (8D), the failure mechanism slowly variations to the "single pile" mode [13]. Twelve micro piles group with four piles in a square pattern, with c/c spacing between piles of 2D, 4D, and 6D and with L/D ratio is (20, 35, 50, and 65) are fixed in sand layer that have relative density Dr% of (30%, 50% and 80%). The results showed that the greater efficiency of group is to be in spacing (4D), loose to medium dense formal of sand soil. In adding, the statement showed optimistic group effect in loose to middle state, while negative group effect is experimental in dense state (Dr of 80%). Furthermore, it found that the pile spacing, relative density and L/D ratio are greatest important effect on the group efficiency [14].

Different parameters such as spacing between piles, number of helix and L/ D ratio for triangular group piles under compressive loading are investigated in this study.

2. Experimental Work

Two types of soil are used in cylindrical container in this study. The bottom layer consists from sandy soil with thickness 35cm which is compacted into seven sublayers. The properties of sandy soil are shown in Table 1. The upper layer consists from soft clay layer with thickness 25cm which is also compacted by manual tamper to five sublayers. All properties of this soil are shown in Table 2.

Cylindrical container with diameter 50cm and height of 65 cm are locally manufactured from steel. The thickness wall of container is 4mm and internal wall are painted with multi paints to resist corrosion which may be happened during test. Screw piles were manufactured from high resisting steel solid section with a diameter of 10mm and with a length 250, 320 and 390mm as shown in Figure 1. The piles have single and double of helix plates with a diameter 20 mm, thickness 2mm and a screw plate pitch (p) of 70 mm, the spacing between two helix plates is constant 60 mm. The end of shaft is tapered with 450 to increase setting during installation process. The experimental tests are conducted on triangular group screw piles with three different spacing between piles (1.5Dh, 3Dh, 4.5Dh), where Dh refers to helix diameter.

Table 1 Properties of the sandy soil

Item	Properties	Value
1	Specific Gravity (Gs)	2.61
2	Cohesion (kN/m^2)	0
3	Angle of internal friction (φ°)	35.5
4	Coefficient of uniformity (Cu)	2.81
5	Coefficient of curvature (Cc)	1
6	Unified Soil Classification System (USCS)	SP

After preparation process of soil, the steel container is laying inside the installation device of piles, the holder is installing on the top edges of the steel container and install the circular plate with an outer diameter of 25mm and an inner diameter of 11mm placed inside the screw pile to keep the spacing between the piles. After that the pile is installed in a device and this pile was fixed slowly inside the soil by using torque that apply, appropriate down force. This torque is applied by using a hydraulic torque motor that providing the perpendicular and rotational forces to install the screw piles in the required spacing of surface the soft clay soil to the limited depth. The perpendicular speed and number of revolutions per minute are depended on the pitch of the screw pile [15]. The screw pile must be installed in such a way that the screw pile enters the earth in a quantity equal to the pitch (p) of the helix for each whole revolution in direction to decrease the disruption of the earth [16] Hence, an exact movement installation with a permeation rate of (7 mm/min) and a rotating speed of (2.5 rpm) that used for wholly tests. Duration of install the screw pile to the required depth in the soil varies according to the length of the piles, as the length 390mm took 60minute while the length 320mm took 45minute and the length 250mm took 30 minutes. After completing the installation of the first pile, the device is turned off and separates the shaft from the pile and rotates the container to install the second pile with the required spacing. By repeating of these steps until completed installation of three piles in steel container inside required of the soil depth and using this process to installation all the model tests used in this study. Figure 2 shows hydraulic torque motor.

Table 2 Summary of properties of soft clay soil

Item	Properties	Value
1	Liquid limit (L.L) %	37
2	Plastic limit (P.L) %	22
3	Plasticity Index (I.P) %	14.8
4	Specific gravity (Gs)	2.72
5	Percent of clay	51.1
6	Percent of silt	43.5
7	Percent of sand	5.3
8	Unified Soil Classification System (USCS)	CL
9	Optimum Moisture Content (O.M.C) %	19
10	Maximum Unit Weight (kN/m^3)	17.6

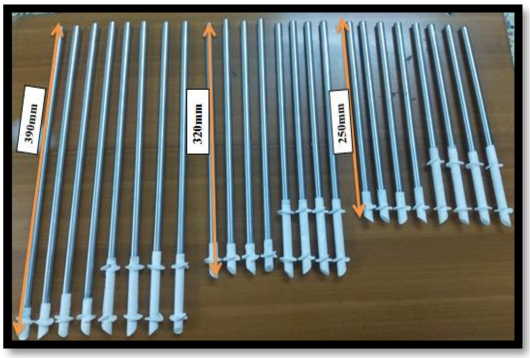

Fig 1. Screw piles types used in models' test

Fig 2. Installation device of screw piles group and the hydraulic torque motor

3. Result and discussion

The method, ISSMFE is adopted in this study which is relied in the literature, which finds the ultimate load at a movement level of 20% of the helix plate diameter, (Lutenegger, 2009). Eighteen models of triangular screw piles group in addition to six modes of screw piles with single and double helix are achieved in this study. The results of these models are discussed in detail as follows:

1. Effect of L/ D ratio on ultimate compressive capacity: It is clear from figures (3, 4) that as the ratio of L/ D increases, the ultimate capacity of compressivev of triangular piles group increases for both group of single and double helix with different spacing. The of increase in compressive capacity is about (36-76) times when L/ D varies from 25 to 39 for both single and double helix with different spacing. This dramatic increase is due to increase of friction and bearing resistance in the part of pile that extended in sand layer. Also, the existence of helix plate increases cylindrical shear resistance around the perimeter of pile.
2. Effect of pile spacing on ultimate capacity of triangular screw piles group: It is obvious from Figure 5 that when the spacing between piles increases from 1.5Dh to 4.5Dh, the ultimate capacity of group begins to reduce. The percent of reduction are (61, 22, 15) % and (56, 25, 29) % for single and double helix group respectively. This behaviour may be due to that piles in triangular pattern tend to behave as a single pile in larger spacing that decreases capacity.

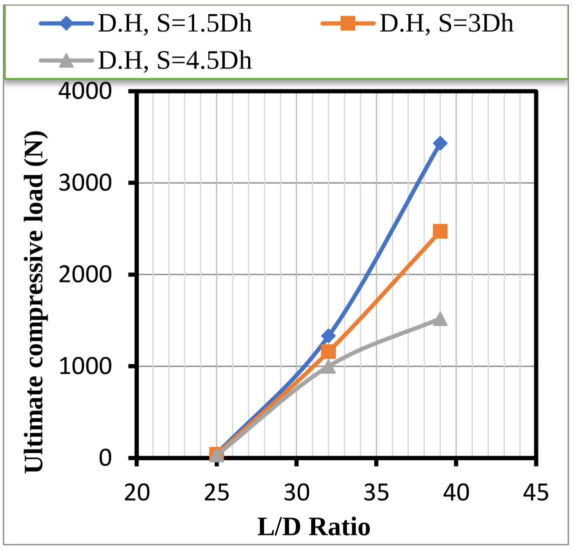

Fig 3. Load capacity and L/ D ratio for screw piles group of double helix

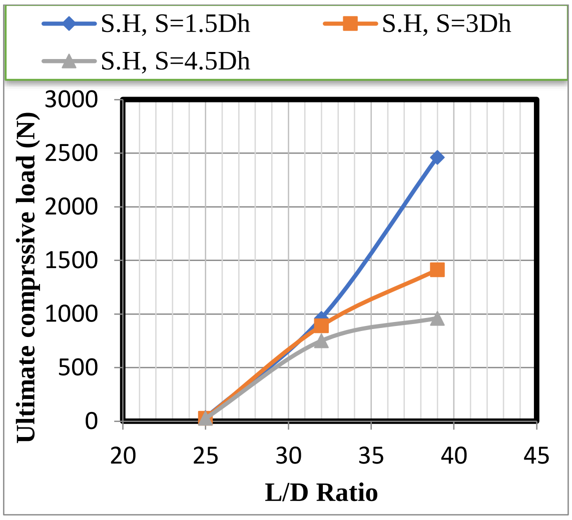

Fig 4. Load capacity and L/ D ratio for screw piles group of single helices

3. Effect of pile spacing on efficiency of triangular screw piles group: It is clear from figure 6 that the efficiency of triangular screw piles group decreases with increasing spacing between piles for group of single and double helix plates. The reduction of efficiency is high for the case of models with L/ D=39 for group of single and double helix plates. In general, the reduction in

efficiency reaches half of value when spacing changes from 1.5Dh to 4.5Dh. This is may be attributed to that in larger spacing, the group piles tend to behave as a single pile that lead to decrease in group capacity.

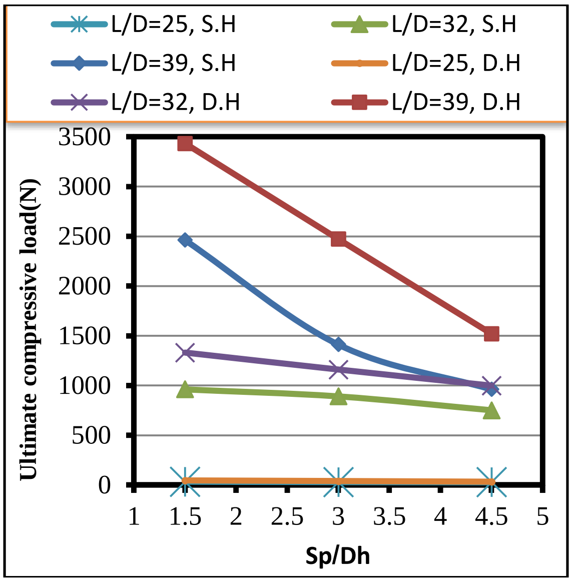

Fig 5. Load capacity and sp/ Dh ratio for screw piles group of single and double helix

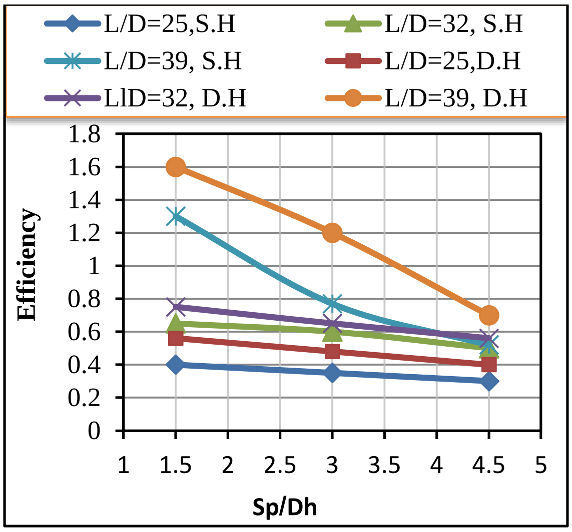

Fig 6. Spacing between piles and efficiency of screw piles group of single helix and double helix plates

4. Effect of number of helix plates on compressive capacity of triangular screw piles group: It is obvious from figure (7) that the increase in number of helices in screw pile leads to increase in compressive capacity of screw piles group. In case of L/ D=25 and for all spacings (represent group, piles embedded in soft clay only), the rate of increase in capacity is very small because that the screw piles group are ineffective in this condition. When screw pile group extended to sand layer, the effect of number of helix begin to be clear in increasing capacity. This is due to increase in surface area between piles and sandy soil which lead to increase anchorage resistance.

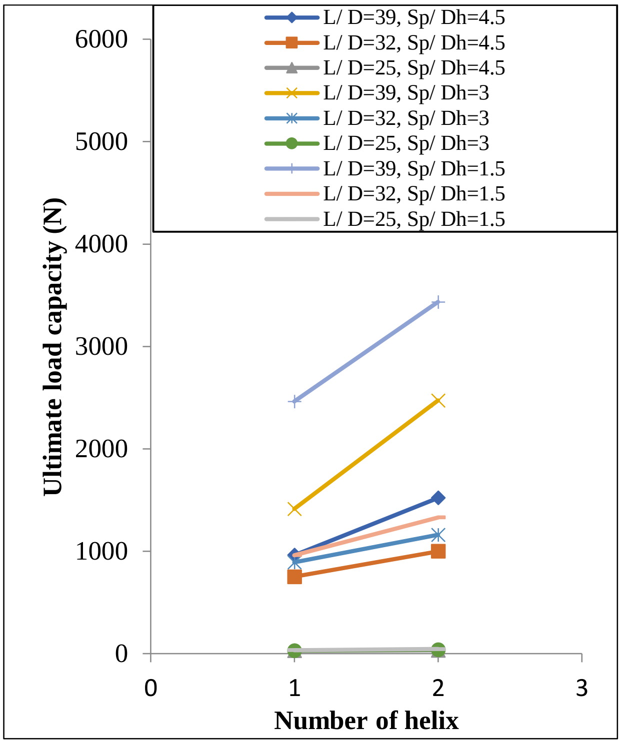

Fig 7. Number of helix plates in pile and compressive capacity of screw piles group for different spacings and L/ D ratios

4. Conclusions

Many points are included from this study which is:

1. Compressive capacity of triangular capacity screw piles group increases with increase L/ D ratio.
2. Compressive capacity of triangular capacity screw piles group increases with increasing number of helix plates in piles.
3. The efficiency of triangular pattern group of screw piles decreases with increasing spacing between piles.
4. In general, the screw piles group is ineffective if embedded in soft clay only.
5. The increase in spacing between piles of triangular group of screw piles leads to decrease compressive capacity of group. The percent of reduction are (61, 22, 15) % and (56, 25, 29) % for single and double helix group respectively.

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