

## Influence of Spacing and Cross-Sectional Shaft of Screw Piles Group on Lateral Capacity

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### ABSTRACT

Although there are several high-capacity screw piles in use currently, there are few studies on their lateral performance. The aim of this study is to investigate the lateral behaviour of several models of screw pile group (1×2), (2×1), and (2×2) embedded in soft clay and extended to stiff clay under lateral static load. Three spacing between pile (1.5, 3, and 4.5) Dh (helix diameter) with a shaft diameter of 10 mm, single and double helix, and embedded length ratio L/d 40 were used. The results showed that increasing the number of the piles in the group had a larger effect, the lateral resistance of group (2×2) increase to about (2.5 and 3.2) times more than groups (2×1) and (1×2) respectively. While the increase of pile spacing in the groups from (1.5 Dh) to (3 and 4.5 Dh) increases the lateral resistance about 6-23% and 16-52% respectively. Also, the result showed that the screw pile with double helix gives an increase in lateral resistance about 3-8% from the single helix.

### 1. Introduction

Screw piles or helical piles are deep foundation elements used to resist forces exerted by tension, axial compression, and lateral loading [1]. Screw piles consist of one or more circular helical plates welded onto a solid steel shaft or hollow [2]. The number of helices, diameter of helix, and the diameter of pile shaft greatly depends on the capacity required of piles and the type of soil. Screw piles are installing into the soil by applying a torque at the head of the shaft of pile, which produce penetrate the helix or helices to the ground in circular motion [3]. The advantage of screw pile is easy in install, require minimum equipment, quickly installed, suitable for a site with restricted access, can removable and reusable, require less dewatering, able to work in slopes, low cost and produce, and low vibration and noise during installation [4,5].

Recently, large helical piles are being used as a result of the great development of hydraulic torque motors has made it easier to install screw piles of large diameter, the shaft diameter currently in use range from 73 to 965 mm and helix diameter range from 152 to 1219 mm with axial capacity larger than 3MN [6,7]. Helical piles with this relatively large diameter can used in large structures, for example offshore platforms, high-rise buildings, bridges and wind turbine foundations and these structures are subjected to lateral loads in addition to vertical loads, and this should be taken into consideration for the design [8]. Lateral loads come from many sources such as wind, waves, ice effect, earthquake vibration, slope collapse, collisions [9]. Several studies have focused on axial and uplift capacity for screw pile, while few studies conducted on lateral resistance [10]. There are also some local studies about screw piles in Iraqi soils [11,15]. This study was

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conducted on soft clay and stiff clay multilayer because this soil covers large parts of central and southern of Iraq and this soil becomes hard when dry and weak when mixed with water [12,16]. Soft clay also distinguished by low undrained shear strength 20 to 40kPa and high in compressive  $C_c$  0.19 to 0.44 and stiff clay distinguished by the range of undrained shear strength between 100 to 150 kPa [17]. In this study an experimental investigation to observe the behaviour of the of screw piles group embedded in soft clay and stiff clay multi layers under lateral static load. The parameters of this study are configuration of pile group, effect of spacing between piles and effect of helix number

## 2. Experimental work

### 2.1 Used soil

The soil used in this study consists of soft clay and stiff clay in two layers put in a cylindrical container. Stiff clay with a thickness of 40 cm used in the bottom of the container which is compacted in eight layers, has undrained shear strength of 111 kN/m<sup>2</sup> and water content equals 22%. The upper layer consists of soft clay with a thickness of 20 cm and compacted with four layers, has undrained shear strength of 38 kN/m<sup>2</sup> and water content equals 29%. The properties of clay soil illustrate in Table 1.

**Table 1.** Properties of the clay soil

Item	Properties	Value
1	Liquid Limit (L.L) %	37
2	Plastic Limit (P.L) %	23
3	Plasticity Index (I.P) %	14
4	Specific gravity (Gs)	2.85
5	Percent of clay	52.7
6	Percent of silt	43.3
7	Percent of sand	4
8	Unified Soil Classification System (USCS)	CL
9	Optimum Moisture Content (O.M.C) %	18
10	Maximum Unit Weight (kN/m <sup>3</sup> )	16.75

### 2.2 Soil container

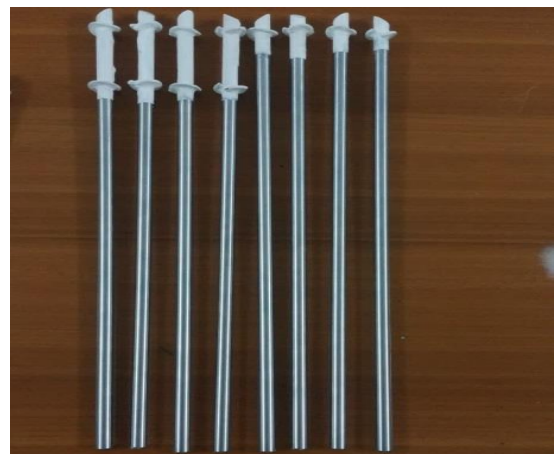
Two cylindrical containers locally manufactured from steel with thickness 4 mm are used in this study with diameter 50 cm and height of 65 cm. The container painted with two layers to resist the corrosion. The base of container consists of six wheels for free in movement in different directions.

### 2.3 Pile and pile cap

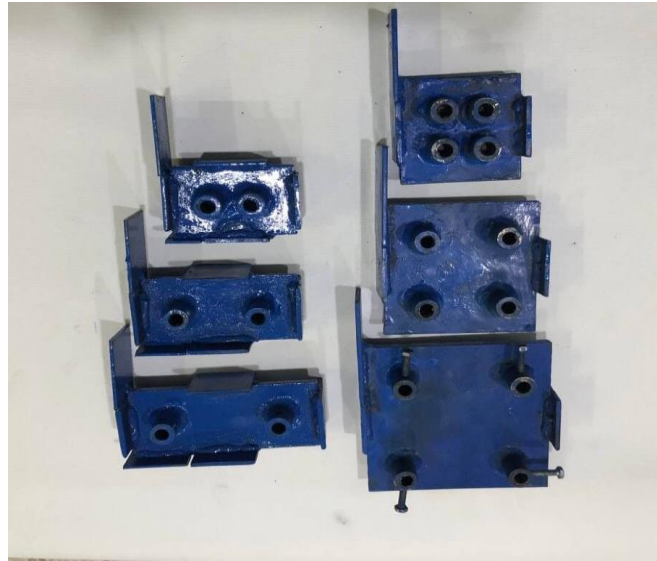
Screw pile with length 440 mm and diameter 10 mm is manufactured from solid steel used for this study as shown Figure1. The pile consists of double and single helix plates with constant spacing between helix 60 mm. The diameter of the helix 20 mm, thickness 2mm, and the screw pitch (p) 7 mm. The shift tip was termination at 45% to aid in keying during installation. Three piles group (1×2, 2×1, and 2×2) used in this study with three spacing between piles (1.5,3, and 4.5) DH where DH is the diameter of helix. The pile cap is manufactured from solid steel with a thickness of 6 mm as shown in the Fig. 2.

### 2.4 Pile installation process

After completing the soil preparation process, the container inserted into the installation device and the steel holder is installed over the upper edge of the container and fixed the pile into the circular plate an inner diameter of 11 and the outer diameter of 25mm to adjust the distances between piles. After that piles were screwed into the model of soil to the depth 400 mm by using torque (T) applied by hydraulic torque motor with downward force (N).



**Figure 1.** Used Screw piles model



**Figure 2.** Used pile cap model

The downward speed and number of rotations per minute are depended onto the pitch of the helix for screw pile [14]. The screw pile should be installed so that the pile enters the earth in an amount equivalent to the pitch ( $p$ ) for the helix for every full turn in the direction to lessen the earth disturbance [15]. Therefore, the penetration rate of (7 mm/min) and speed

rotational of (2.5 rpm) are use in all tests. After the first pile complete install to the embedded length ( $L/d$ ) 40, turn off the device and separate the shaft from the pile and the container rotated to install the second pile in the group. In this a way we complete the installation of the pile group in container as shown in the Fig. 3.



**Figure 3.** Pile installation device

### 2.5 Test device

After complete the install of piles group, the container put into the test device and fixed from the side by four stabilizers to prevent movement during the test, after that the pile cap is

connected by a wire with a high tensile strength that connects to the second end with a loading disc and extends over a two-pulley attached laterally to the test device and parallel to the pile cap as shown in the Fig 4. After that the loading is done gradually by adding weights to the

loading disc at varying intervals of time. The lateral deflection measured by dial gage fixed on the opposite side. The maximum lateral capacity is taken at the lateral deflection for the group

equal to 20% from diameter of helix Based on the Brom's failure criteria [16]. In this study twelve tests were performed as shown in the Fig.4.



Figure 4. The test of group (2x1),  $S/D_h = 3$

### 3. Results and discussion

#### 3.1 Effect of pile spacing

The effect of pile spacing in three model groups (1x2), (2x1) and (2x2) under lateral static load are shown in the Figure 5, 6, and 7 respectively. The effect of three spaces (1.5, 3 and 4.5)  $D_h$  was studied for screw pile single and double helix. Through the results, we notice that all the lateral resistance of the group's

increases with the increase in the distance between the pile this is due to the overlap of stresses between the pile, as at close distances the interference becomes very high, which leads to an increase in turbulence and ductility of the soil between the piles. For this study a comparison between the groups having distance between the piles (3 and 4.5)  $D_h$  with distance 1.5  $D_h$  is shown in the Table 2.

Table 2. Effect of spacing on lateral resistance

Pile Group Model	$S/D_h$	Increasing in lateral resistance	
		Single helix	Double helix
1x2	3	% 7	% 10
	4.5	% 38	% 37
2x1	3	% 6	% 10
	4.5	% 16	% 17
2x2	3	% 22	% 23
	4.5	% 48	% 52

#### 3.2 Effect of configuration

This study was conducted in three pile group models (1x2), (2x1) and (2x2) with three

spacing between piles (1.5, 3, and 4.5)  $D_h$  by using single and double helix. For the same number of the piles in group the arrangement of

pile effect on lateral resistance, for the same spacing and number of helices, group (2×1) give lateral resistance more than group (1×2) about 22-28 % for spacing (1.5 and 3) Dh and about 9-13 % for spacing 4.5 Dh as shown in Figure 5 and 6, this may be due to the group (2×1) have two row in the direction of static load and the group (1×2) have one row in the direction of

static load and this causes the group (1×2) to behave like a single pile, this result agree with [21]. From Figure 7 also note the increase of the number of piles in group larger effect in the lateral resistance, the lateral resistance of group (2×2) increases to about (2.5 and 3.2) times more than groups (2×1) and (1×2) respectively.

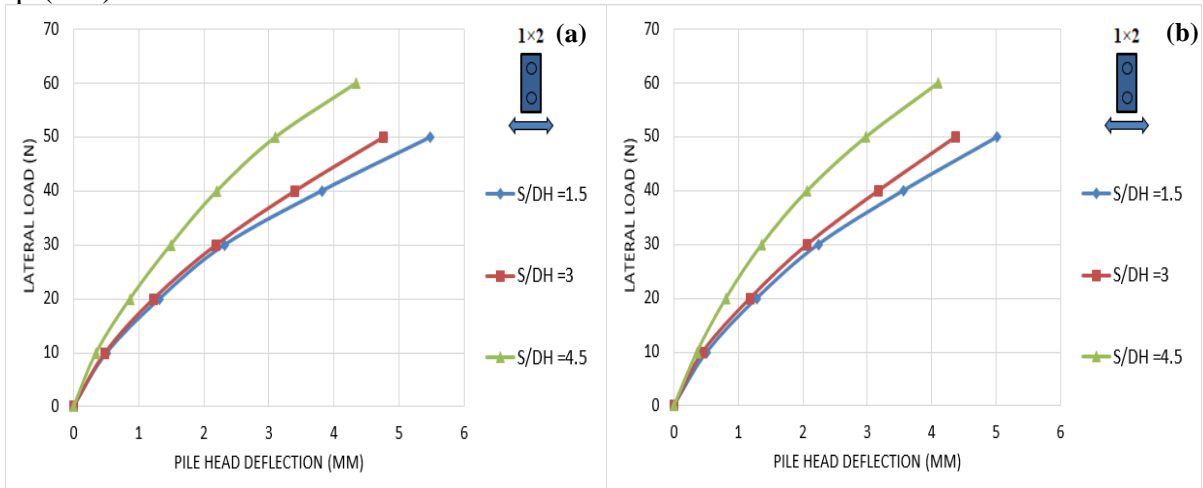


Figure 5. Load-lateral displacement curve for group (1x2), S (shaft pile spacing), Dh (helix diameter) (a) single helix, (b) double helix

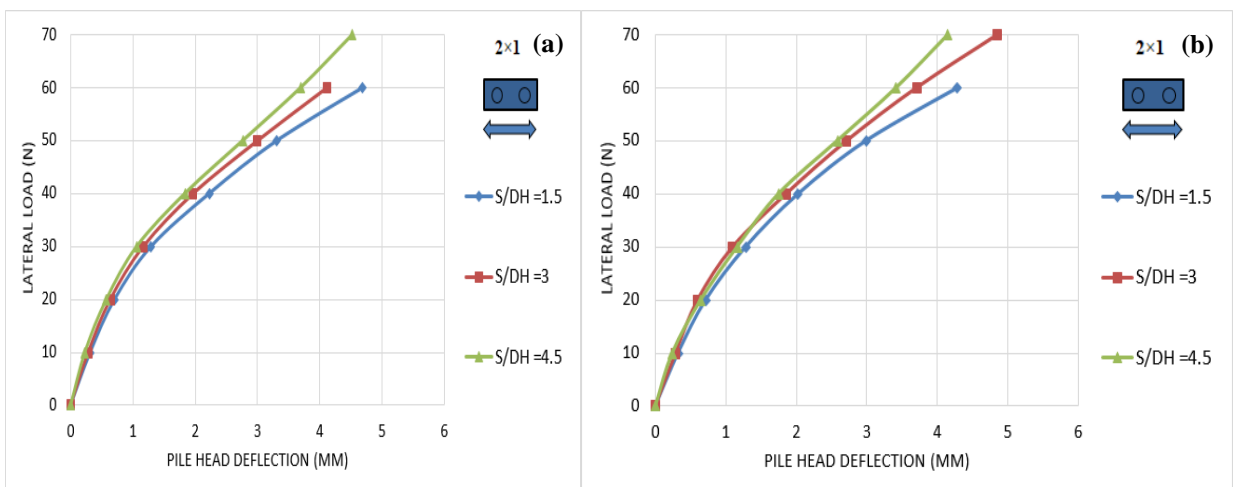
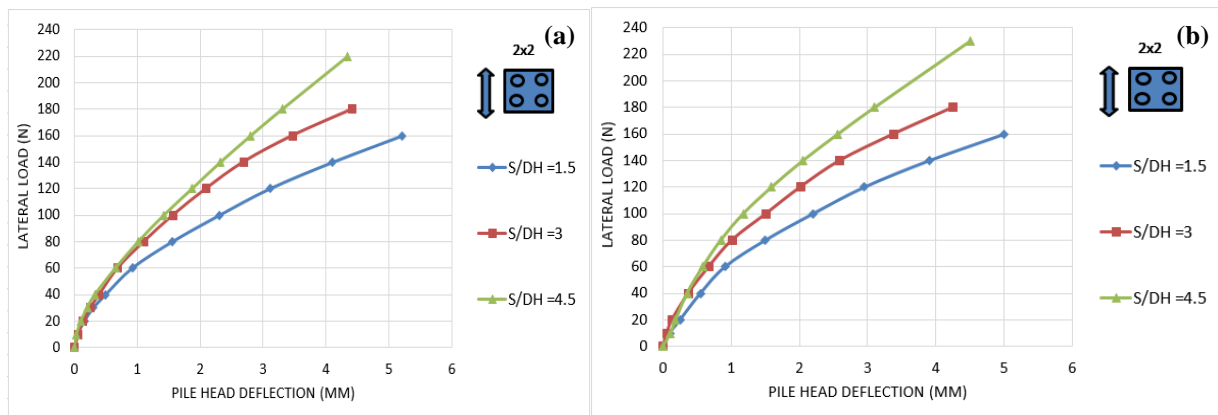


Figure 6. Load-lateral displacement curve for group (2x1), S (shaft pile spacing), Dh (helix diameter) (a) single helix, (b) double helix



**Figure 7.** Load-lateral displacement curve for group (2x2), S (shaft pile spacing), Dh (helix diameter) (a) single helix, (b) double helix

This may be due to the fact that when a lateral load is placed, the piles in the first row afford the greater part of the load and that the back row is exposed to less load, which makes the group more solid [22]. Also, in the few distances, the group of piles moves as one block. This block in a group that contains four piles is much stiffer than a double pile. These results agree with [23,24].

### 3.3 Effect of number of helices

From the results of this study, the effect of the number of helices is little on the lateral resistance. The group of double helix pile gives lateral resistance more than single helix about 3-8 %. This increase is due to the additional helix increases the surface area of the pile and increases the cohesive between the soil and the pile. This increase in lateral resistance may increase over time as a result of improved shear strength [25].

## 4. Conclusions

1. The lateral resistance increases when the spacing between screw piles increase, the group pile with spacing (3, 4.5) Dh give lateral resistances more than spacing 1.5 Dh about 6-23% and 16-52% respectively.
2. The lateral resistance increases when the number of the piles increase, group (2x2) give lateral resistance more than groups (2x1) and (1x2) about (2.5 and 3.2) times respectively.

3. The effect of spacing between piles on lateral resistance larger than the effect of number of helices.
4. The arrangement of piles in group effects on lateral resistance such as (2x1) group gives more resistance than (1x2) group about 22-28 % for spacing (1.5 and 3) Dh and about 9-13 % for spacing 4.5 Dh.
5. The lateral resistance increases when the number of helix increase.

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