Geotechnical Aspects of Infrastructure Projects in Gypseous Soils

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ABSTRACT: This paper presents the behavior of single tension pile in collapsible soil (Gypseous soil) by experimental work. The natural Gypseous soil with 66% gypsum used in the study was brought from Salah Al-Deen governorate in Iraq while that of the sand was brought from Karbalaa governorate, south of Baghdad, Iraq. The model pile used is smooth steel pipe pile with slenderness ratios (L/D) of 10, 15, 20 and 25. The effect of the gypsum content included in the soil as well as the effect of rest time and the effect of (L/D) on the pullout capacity of pile were studied in the laboratory scale model pile. The results showed that the pullout capacity of pile in Gypseous soil is more than its capacity in Sandy soil by about 64%. When the rest time was increased, the pullout capacity of tension pile embedded in Gypseous soil decreased. Increasing (L/D) ratio of pile in Gypseous soil from 15 to 20 increases pullout capacity of pile to about 65%, while increasing that ratio from 20 to 25 increases pullout capacity of pile to about 76% .

KEYWORDS: Model piles, Pullout capacity, Time effect, Slenderness ratio, Gypseous soil, Sand

1. INTRODUCTION

One of the important issues that the engineer should take into account is the type of soil in the construction site, especially when soil is a problematic soil like collapsible soil. Collapsible soils can be defined as any saturated soil that goes through a radical rearrangement of particles and great loss of volume with or without additional loads (Clemence and Finbarr, 1981). Gypseous soil is considered as a type of the problematic soils due to its complex and unpredictable behaviour. This soil can support any types of loading normally when dry due to the presence of gypsum. But, with the presence of water, sudden collapse (cavities) in the structure of soil due to the dissolution of gypsum will happen. That collapse causes settlement, tilting, and other great damages to the structures constructed on Gypseous soils. The gypsum content varies from very low (less than 1%) to very high (more than 80%) (Buringh, 1960).The presence of gypsum in soil changes its engineering properties and decreases specific gravity because of the low specific gravity of gypsum (2.32).

Gypseous soils are found in many places of the world such as Algeria, Somalia, Namibia, Mali, Tunisia, Morocco, Iraq, India, Syria, China, Spain, Turkey, etc. Gypseous soil occupied about 31.7% of the surface area of Iraq (Ismail, 1994). The Gypseous soil was found in arid and semi-arid regions because the amount of water is not sufficient to remove this salt (Nashat, 1999), so, the study of the behaviour of foundation in such soil is required. One of the remedies which used to save the structures constructed on Gypseous soil and to reduce the damages is use of pile foundation. Pile foundation can support different types of load like, vertical compression load (weight of the structures, snow, etc.), vertical tension load (when pile is used in offshore structures, towers, and when pile is used in expansive soil), lateral loads (wind, action of water waves, etc.), dynamic loads (earthquake). The study of behaviour of tension pile in collapsible soil is limited, so, this study focuses on the behaviour of Gypseous soil and the effect of gypsum on the pull-out capacity of piles.

2. THE AIM OF STUDY

This study is proposed to investigate the behaviour of single pile constructed in Gypseous soil and subjected to axial tension load including making a comparison between the behaviour of steel pile in both sand and Gypseous soils as well as the effect of the rest time on the pullout capacity of pile in Gypseous soil, and study the effect of the slenderness ratio (L/D) on the pullout capacity of pile embedded in Gypseous soil.

3. THE MATERIALS USED

3.1 Sandy soil

The sand used in the present study was brought from Karbalaa governorate, south of Baghdad, Iraq. Table 1 shows the physical properties of Gypseous soils and Sand used.

Table 1 The physical properties of Gypseous soils and sand used

Physical properties	Gypseous soils	Sand
D_{50} (mm)	0.18	0.45
D_{10} (mm)	0.06	0.191
D_{60} (mm)	0.23	0.55
D_{30} (mm)	0.13	0.32
Coefficient of uniformity, C_U	3.67	2.88
Coefficient of curvature, C_C	1.28	0.98
Classification based on USCS	SM	SP
Specific gravity, GS	2.4	2.67
Angle of internal friction, $Ø^O$	27.38	36.8
Soil cohesion, C (kPa)	17	0

3.2 Gypseous soils

The natural Gypseous soils used in the present study was brought from Salah Al-Deen governorate north of Baghdad in Iraq with gypsum content of 66%. Table 1 shows the physical properties of Gypseous soils as mentioned before. Figure 1 shows the grain size distribution of sand and Gypseous soil used. Figure 2 shows the result of odometer test conducted on Gypseous soils.

3.3 Model piles

The dimensions of model piles used in the present study are selected based on a number of the previous studies conducted on tension piles, the range of L/D in the previous studies varied from 2 to 32 the details of pile dimensions are as follows:
1-Steel smooth pipe with closed end (D_O=20mm, t=1mm, L/D=10).
2-Steel smooth solid pile (D=10mm, L/D=10, 15, 20, and 25).

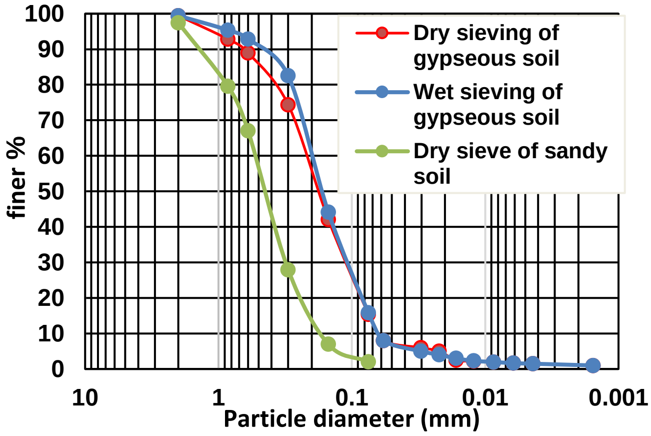

Figure 1 The grain size distribution of Sand and Gypseous soils with (GC=66%), dry and wet with kerosene

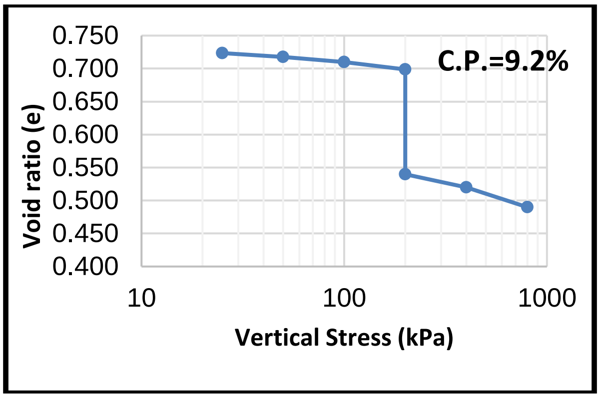

Figure 2 Void ratio- vertical stress curve for Gypseous soils

3.4 The laboratory model pile set-up

The use of physical modelling develops the understanding of foundation behaviour. Using laboratory modelling with small scale illustrates all the details of tests and facilitates soil model to be under full control (Wood, 2004). The tests in this study are conducted in laboratory model as shown in Figure 3. The model pile was manufactured from steel plate 4mm in thickness. The steel tank is circular with diameter equal to 400mm and the tank height equal to 400mm. The inside face of the steel tank is polished to reduce the friction with soil. The soil zone around pile which is affected by the pile installation method is specified by many researchers to about 3-8 times the diameter of pile ***(***Meyerhof 1956; Kishida 1963; Robinsky and Morrison., 1964***).*** The selected dimensions for the steel tank used provides a clear lateral distance from the perimeter of pile to the internal face of the tank and a clear distance below the pile tip and bottom of tank satisfying the prescribed requirements herein.

4. TESTING PROCEDURE

The unit weight of the soil is known with the presence of volume of the steel tank which means that the total weight of the soil specimen is known. The total weight of soil in the tank is divided into five compacted layers each using electrically operated compactor sequentially. The model pile was then driven inside the soil by using hydraulic jack based on the concept of strain control for each 2cm of the pile embedded length. The testing of the model pile started after rest period equal to 24hr by using screw jack till the failure of pile by means of strain control (the failure load of pile is specified as the amount of load which corresponding to axial movement equal to 15% times pile diameter based on the ASTM, D3689-07) . The values of pullout loads and upward displacement of pile is measured by using digital indicator (by using tension load cell), and dial gauges respectively. The pullout load-displacement curves is plotted and used to determine the gross ultimate pullout capacity. This procedure is applied for steel pipe with closed end pile (D_O=2cm, t=0.1cm L/D=20) when embedded in sand and in Gypseous soils to study the effect of the presence of gypsum content to the pullout capacity of pile.

To study the effect of time on the pullout capacity of steel pile (D=10mm, L/D=20), the same test procedures mentioned above is applied but after 2, 4, 24 hours, and 7 day of installation time.

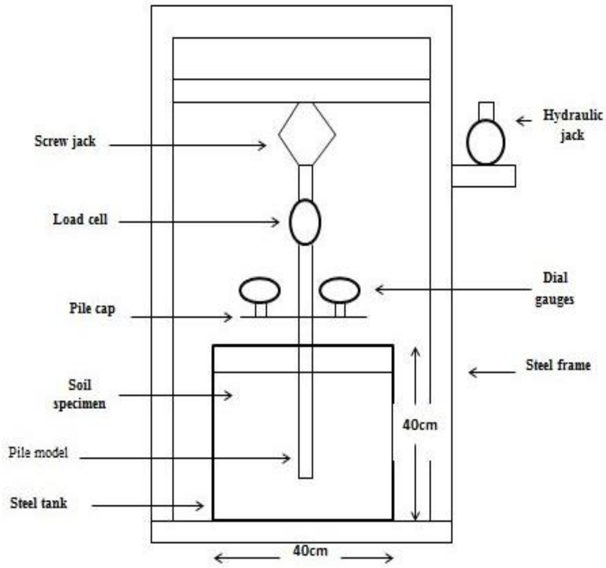

Figure 3 The laboratory model pile set-up

5. RESULTS AND DISCUSSIONS

The pullout load- displacement and shaft load-displacement curves for all the piles tested in this study are as shown in the subsequent sections with the effect of different parameters is explained.

5.1 The presence of gypsum

The pullout load- displacement relationships for the pile are as shown in Figure 4. The shaft load can be estimated by subtracting the weight of pile from the total pullout load to obtain the relationship between shaft loads- displacements as shown in Figure 5. At the primary stages of test, the behavior of the load- displacement curves is linear, and then behaves as nonlinear as shown in Figures 4, and 5. It can be shown that the pullout capacity of steel pile in Gypseous soil is more than that in Sandy soil by about 64%.

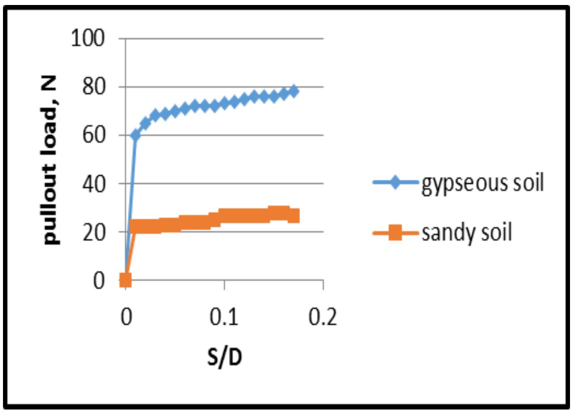

Figure 4 Pullout load-S/D relationship for steel pipe pile in Gypseous and Sandy soils respectively

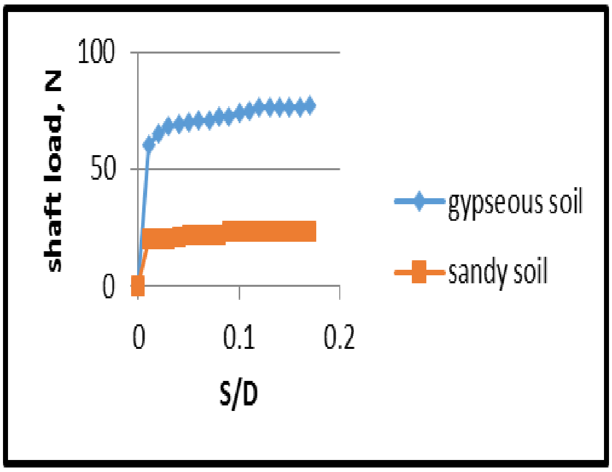

Figure 5 Shaft load-S/D relationship for steel pipe pile in Gypseous and Sandy soils respectively

5.2 The rest time

Figure 6 shows the pullout load- displacement relationship for steel pile to a number of rest times. The shaft load is obtained by subtracting the weight of pile from the total pullout load as shown in Figure 7. The first part of this curve is linear and then nonlinear. From the figures below it can be concluded that when the rest time is increased, the pullout capacity of pile embedded in Gypseous soil will be decreased.

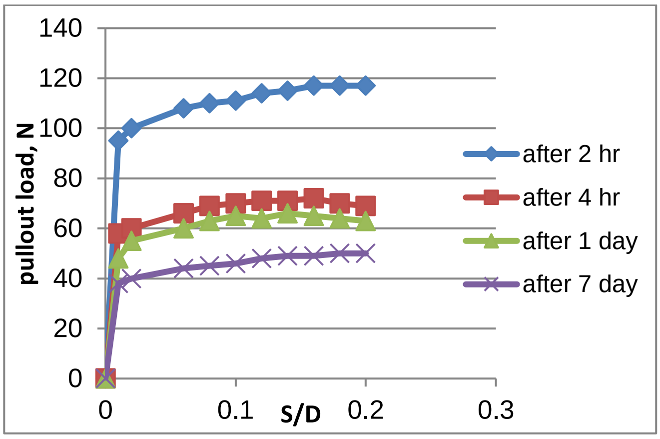

Figure 6 The pullout load- S/D relationship for the pile used when tested after 2, 4, 24 hrs, and 7 days from the installation of pile in Gypseous soil

5.3 The slenderness ratio of pile

The Figures 8 and 9 show the load- displacement relationships for tension pile embedded in Gypseous soils with different slenderness ratios (L/D). The pullout load and shaft load for tension pile will be increased by increasing slenderness ratio of the pile as found by many studies in the literature, when the L/D increases from 15 to 20 pullout capacity of pile is increased to about 65%, while increasing L/D from 20 to 25 increases the pullout capacity to about 76% due to increasing surface area of pile with depth, and due to the increasing in the amount of lateral earth pressure coefficient with depth. Figure 10 shows the shaft load-L/D relationship.

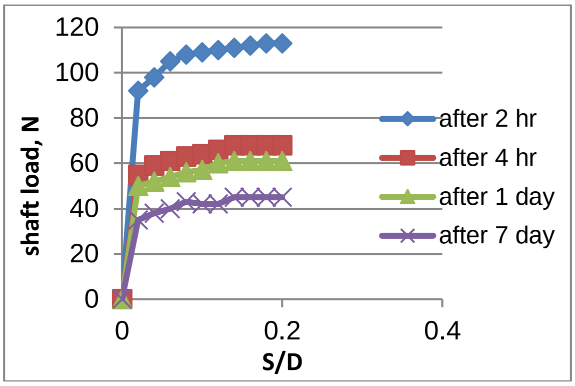

Figure 7 The shaft load- S/D relationship for the pile tested after 2, 4, 24 hrs, and 7 days from installation of pile in Gypseous soil

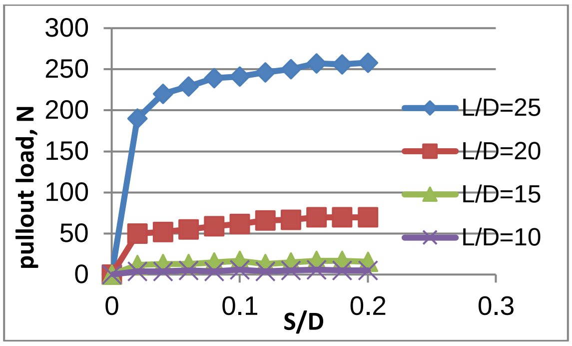

Figure 8 The pullout load- S/D relationship for each pile slenderness ratio (L/D)

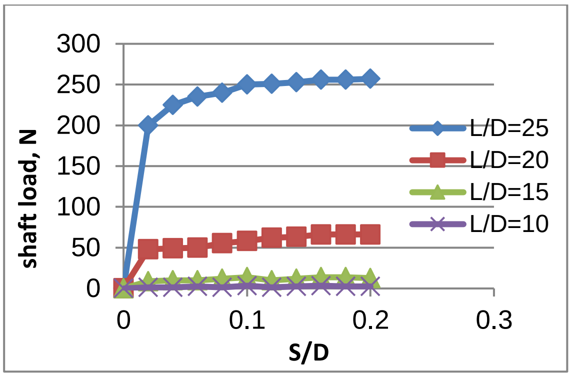

Figure 9 Shaft load- S/D relationship for each pile slenderness ratio (L/D)

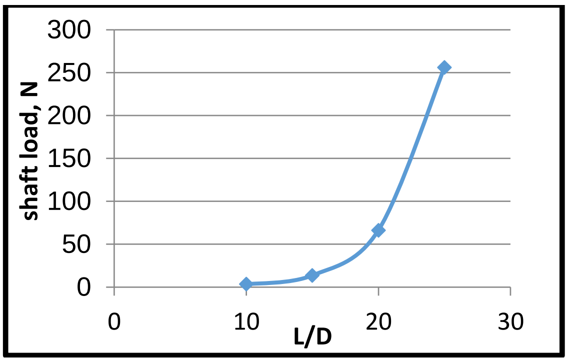

Figure 10 Shaft load- L/D relationship

6. CONCLUSIONS

Based on the results obtained from this study it can be concluded as follows:

1- The pullout capacity of pile embedded in Gypseous soil is more than in Sand in dry state by about 64%

2- Increasing of rest time (the time interval after the installation of pile in soil and before the pile test) of pile in Gypseous soil decreases its pullout capacity.

3- When the rest time is increased 2 to 4 hr, the reduction occurs in the pullout capacity of pile is 37%, and when the rest time is increased 4 to 24 hr, the reduction occurs is 8%, and when the rest time is increased 24hr to 7 day, the reduction is 25%, this may be due to the dissipation of stresses around the pile which results from the installation of pile in soil.

4- When the amount of the embedded length of pile is increased, the pullout capacity will be increased. When the slenderness ratio (L/D) is increased from 15 to 20, the pullout capacity is increased to 65%, and when (L/D) is increased from 20 to 25 pullout capacity is increased to about 76%.

7. REFERENCES

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