Pullout Capacity of Piles in Collapsible Soil

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Abstract *This study is presented to investigate the behavior of concrete pile in gypseous soil with 30%, and 66% gypsum content subjected to tension load, also including a comparison to illustrate the behavior of solid steel and concrete piles types (slenderness ratio (L/D) = 10) embedded in the same soil (66% gypsum content) for both dry and 24 hr soaked specimens. The results showed 82%, and 45% capacity decrease to soaked specimens for both 30%, and 66% gypsum content samples respectively. It is argued that this lack in capacity is due to the dissolution of the gypsum. The latter reason interprets the 66% lack in the pullout capacity for the steel pile embedded in 66% gypsum content. Increasing gypsum content enhanced capacity of concrete piles for both dry and soaked samples. The pullout capacity of steel pile illustrates general trend to be more than the corresponding values of concrete types to about 46% for dry and 5% for soaked samples. That behavior can be attributed to the friction or adhesion between pile and soil particles for steel is more than concrete types.*

Keywords- *pullout, piles, gypseous soil, laboratory model, soaking, pile capacity*

I. INTRODUCTION

Piles is a structural member made from steel, timber, and concrete which used to transfer loads of the structures to the lower layers of soil mass through weak soil layers or water. Always piles are subjecting to different types of loads like vertical (compression, and tension loads), lateral, and dynamic loads, so, it should be adequate to save the structures from any damage when it subjected to such types of loads.
Piles are subjected to uplift loads especially when it used in the structures such as, tall chimneys, transmission tower, offshore platforms, etc. Too, uplift can be a result of a reaction when the piles subjected to overturning moment or lateral load like, wind load, seismic load, water wave impacts, increase of the water table level, or when the pile used in expansive soils .
Gypseous soil is a type of collapsable soils, this soil is consider very strong and able to support any type of loads when dry due to the presence of gypsum, this behaviour does not exist with the pressence of water, the gypsum will be dissolved and settlement will happened due to the developed of cavities within the soil skeleton which results in tilting, and damages in the supported structures. So, using of pile foundation in such soil to transform the superstructures load to the lower strata through that soil may consider as solution to save that structures.

Little studies is available in the literature that focus on behavior of piles under tension loads embedded in collapsible soil. Therefore, the present study is performed to investigate the behavior of single pile when subjected to pullout load and embedded in gypseous soils considering the dry and soaked soil case for 24 hour by using laboratory model fabricated for that purpose.

TABLE I SYMBOLES USED IN THIS STUDY

Symbols	Total name
G.C%	Gypsum content of soil%
C.P	Collapse potential
L	Embedded length of pile
D	Pile diameter
L/D	Pile slenderness ratio
S/D	Upward displacement of pile to its diameter ratio
S_1	Soil one with GC=30%
S_2	Soil two with GC=66%

II. AIM OF STUDY

*****Study the effect of gypsum content on pullout capacity of concrete pile (D=20mm, L/D=10) embedded in both S_1 and S_2 for dry and soaking cases.

*Study the effect of pile type on the pullout capacity of steel and concrete piles (D=20mm, L/D=10) embedded in S_2 for dry and soaking cases.

III. SOILS USED

Gypseous soil used in the present study (S_1, and S_2) is brought from Iraqi governorate “Salah Al-Deen” north of Baghdad. Fig 1 shows the location of soil samples. Elementary soil tests are conducted according to ASTM specification to explain its physical, chemical, and engineering properties as shown in tables 2, 3, 4, and 5. Figures 2, 3, 4, 5, 6, and 7 explain the results of the laboratory tests which conducted on the soils used in the present study.

Fig.1 The location of the soil samples

TABLE II THE PHYSICAL PROPERTIES OF S_1

Properties	Magnitude
D_{10}	0.06
D_{60}	0.22
D_{30}	0.12
Coefficient of uniformity, C_U	3.67
Coefficient of curvature, C_C	1.091
Classification of soil based on USCS	SM
Specific gravity of soil, GS	2.48
The liquid limit (L.L)%	25
The plastic limit (P.L)%	N.P
Plasticity index (P.I)	N.P
Angle of internal friction, Ø, in dry case	34.5
Soil cohesion, C, in dry case	8
Angle of internal friction, Ø, in soaking case	34.5
Soil cohesion, C, in soaking case	4
Initial water content%	2

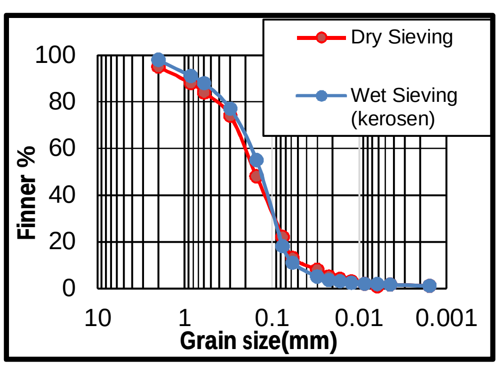

Fig.2 The grain size distribution of the S_1

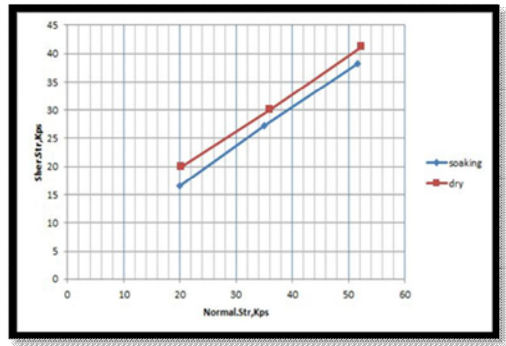

Fig.3 Shear stress- normal stress relationship for S_1 in both dry and soaking tests

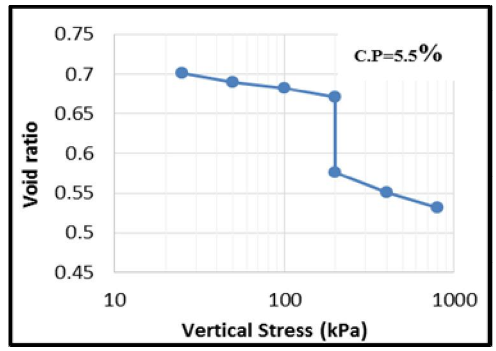

Fig.4 Void ratio- vertical stress relationship (single collapse test) for S_1

TABLE III THE CHEMICAL PROPERTIES OF S_1

Composition	Magnitude%
Gypsum content%	30
Organic matters (O.M)%	0.20
Chloride content (CL)%	0.055
PH	7
SO_3	13.9
Total soluble salts (T.S.S)%	33

TABLE IV THE PHYSICAL PROPERTIES OF S_2

Properties	magnitude
D_{10}	0.06
D_{60}	0.2
D_{30}	0.13
Coefficient of uniformity, C_U	3.67
Coefficient of curvature, C_C	1.28
Classification of soil based on USCS	SM
Specific gravity of soil, GS	2.40
The liquid limit (L.L)%	22
The plastic limit (P.L)%	N.P
Plasticity index (P.I)	N.P
Angle of internal friction, Ø, in dry case	27

Soil cohesion, C, in dry case	17
Angle of internal friction, Ø, in soaking case	26
Soil cohesion C, in soaking case	14
Initial water content%	2.5

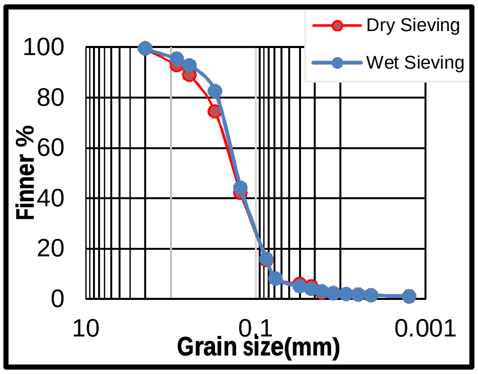

Fig.5 The grain size distribution of the S_2

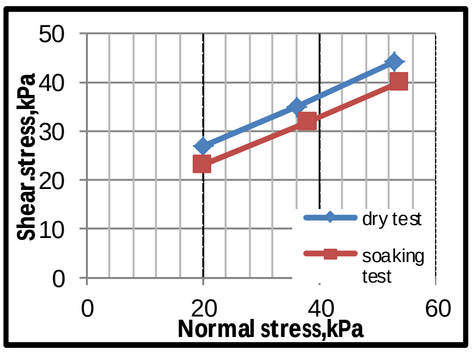

Fig.6 Shear stress- normal stress relationship for S_2 in both dry and soaking tests.

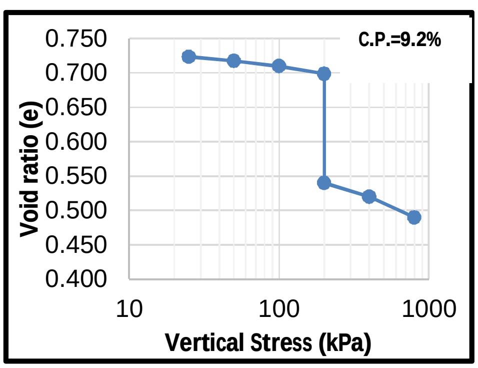

Fig.7 Void ratio- vertical stress relationship (single collapse test) for S_2

TABLE V THE CHEMICAL PROPERTIES OF S_2

Composition	Magnitude %
Gypsum content %	66
Organic matters (O.M)%	0.21
Chloride content (CL)%	0.061
PH	8
SO_3	30.4
Total soluble salts (T.S.S)%	67.7

IV. PILES USED IN THE STUDY

The piles used in the present study are concrete and steel solid piles, the concrete type has diameter of 20mm and slenderness ratio **(L/D)** of **10**. The reinforcement of piles consists of two bars with 3mm diameter with length equal to entire piles length and overall yield strength is 290MPa. The gravel used in the concrete mix passed sieve No.4 (4.75mm), water/cement ratio is 0.35, the pile cured for 28 day before the test, while compressive strength is 45MPa. Steel piles used have diameter of 20mm, slenderness ratio (L/D) = 10. Plate 1, showed both the steel and concrete piles which used in the study.

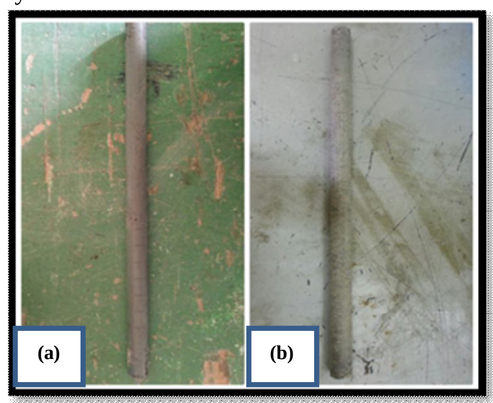

Plate 1 Piles used in the study: (a) steel pile, (b)concrete pile.

V. LABORATORY MODEL

The tests is conducted within the laboratory of soil mechanics in the college of Engineering, Diyala University using a self developed laboratory model as shown in plate 2 which is fabricated with a steel plate 4mm in thickness. The steel tank is circular with diameter equal to 400mm and height 400mm. The inside face of the steel tank is polished to reduce the friction. The effective zone of influence that affected by the installation and loading of pile specified by a many of researchers about 3-8 times piles diameter as shown by [1], and [2]. As a consequence, the dimensions for the steel tank fabricated to provide a clear distances between the perimeter and tip of piles to tanks internal satisfies the requirements.

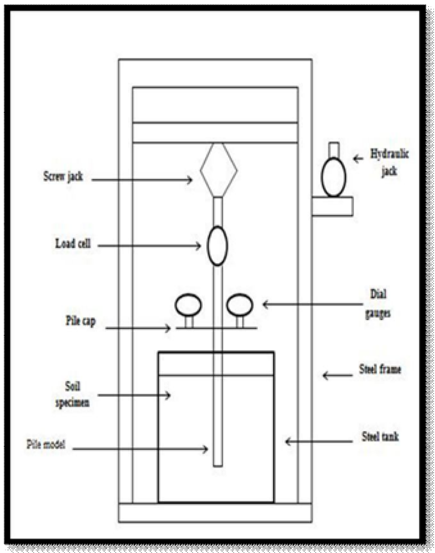

Plate 2 Laboratory model

VI. MODEL PREPARATION AND TESTING METHODOLOGY

Methodology and steps to model preparation are listed below:

1-By the presence of soil unit weight and tank volume, the weight of placed soil can be specified.

2-The total weight of soil is divided to equal layers, each one compacted inside the tank via electrical compactor.

3-Piles is driven inside the soil by using hydraulic jack based on the concept of strain control for each 2cm of the pile embedded length.

4-The tests are performed after 24 hrs. by using screw jack till failure load which is the amount of load corresponding to axial movement of 15% times the pile diameter based on the ASTM specification [3].

5-The pullout loads and upward displacement of pile is measured via digital indicator (by using tension load cell), and dial gauges respectively.

6-The above procedures is applied for both dry and 24 hrs. soaked specimens to study the effect of water presence on the pullout resistance.

VII. RESULTS AND DISCUSSION

The figures below explain the results of pullout test conducted on concrete and steel piles (D=20mm, L/D=10) installed in gypseous soil and subjected to axial tension load in dry and soaking cases. Fig. 9 shows the load- S/D relationship for concrete pile of S_1 for both dry and soaking tests, obviously, the pullout capacity of pile in dry test is more than that in soaking test to about 82% due to the dissolution of gypsum content which dictates to form cavities in the soil skeleton.

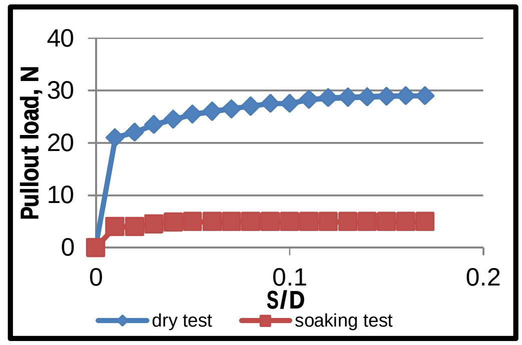

Fig.9 Pullout load- S/D relation for concrete pile for both dry and soaking test in S_1

Fig. 10 shows the load- S/D relationship for concrete pile when examined in S_2. Based on the results , the pullout capacity of pile in dry case is more than that in soaking case to about 45% due to the dissolution of gypsum.

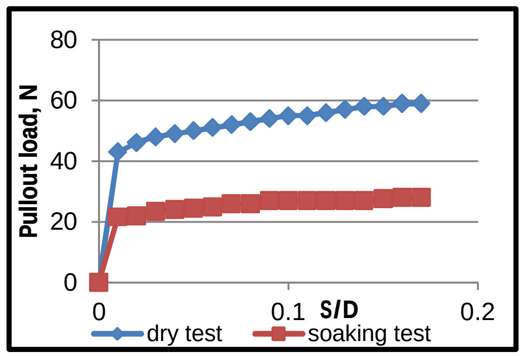

Fig.10 Pullout load- S/D relationship for concrete pile for both dry and soaking tests in S_2Page Layout

Fig.11 shows the comparison between the behavior of concrete pile when examined in both S_1 and S_2 in dry test, the pullout capacity of pile in S_2 is more than that in S_2 to about 43% because of large amount of gypsum content in the first soil which gives soil adequate capacity to support loads. Therefore, pullout capacity enhanced by increasing gypsum content of soil and vice versa.

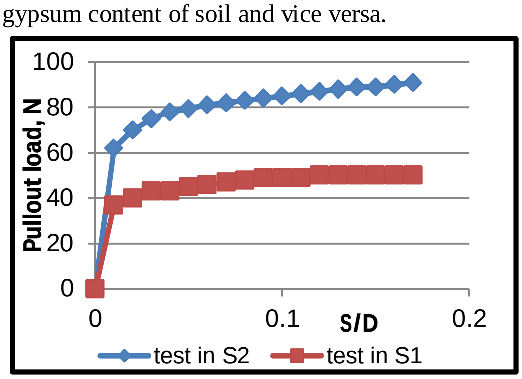

Fig.11 Pullout load- S/D relationship for concrete pile when examined in both S_1 and S_2 in dry test.

Fig. 12 shows the relationship between load- S/D for concrete pile examined in both S_1 and S_2 in soaking case as well as showed that the pullout capacity of pile in S_2 which is more than that in S_1 to about 81% due to large amount of gypsum content in the soil.

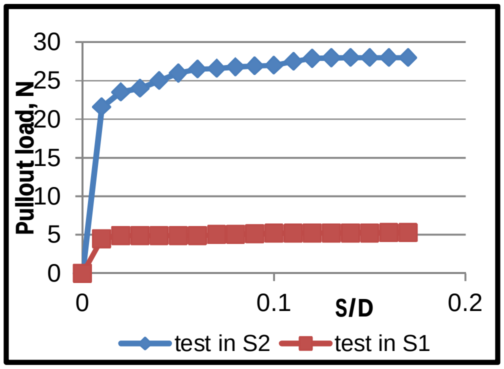

Fig.12 Pullout load- S/D relationship for concrete pile when examined in both S_1 and S_2 in soaking test.

Fig.13 illustrates the pullout load- S/D relationship for steel pile examined in S_2 in both dry and soaking tests, pullout capacity of piles illustrates a lack to about 66% due the gypsum dissolution.

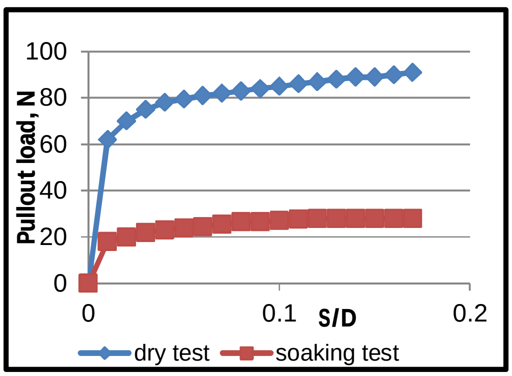

Fig.13 The pullout load- S/D relationship for steel pile examined in S_2 for both dry and soaking tests

Figures 14, and 15 show the behavior of steel and concrete piles when examined in S_2, for both dry and soaking tests. From that it can be showed that the pullout capacity of steel pile was more than concrete pile to about 46% and 5% for dry and soaking tests respectively. This may be attributed to the weight of steel pile which is more concrete pile, and to the adhesion between the steel pile and soil particles which more than concrete pile.

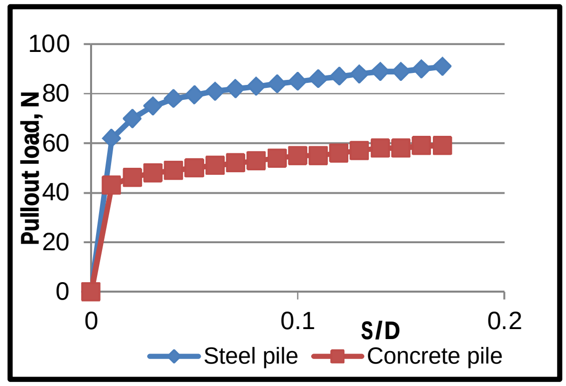

Fig.14 Pullout load- S/D relationship for steel and concrete piles examined in S_2 in dry case

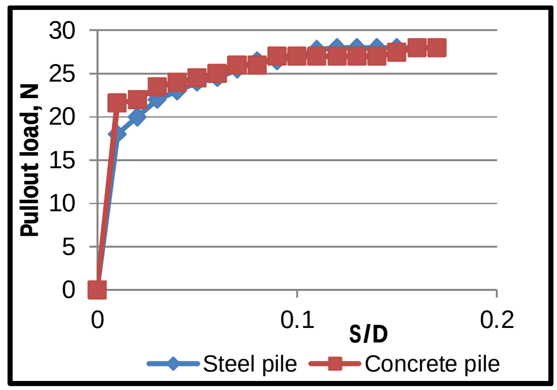

Fig.15 Pullout load- S/D relationship for steel and concrete piles examined in S_2 in soaking case.

Fig.16 showed the load- gypsum content relationship of concrete pile for both dry and soaking tests. It can be showed that the pullout capacity of pile is increased with the increase in the amount of gypsum content. Also sharp lack occurs in the pullout capacity of pile due to the soaking because of the dissolution of the gypsum content.

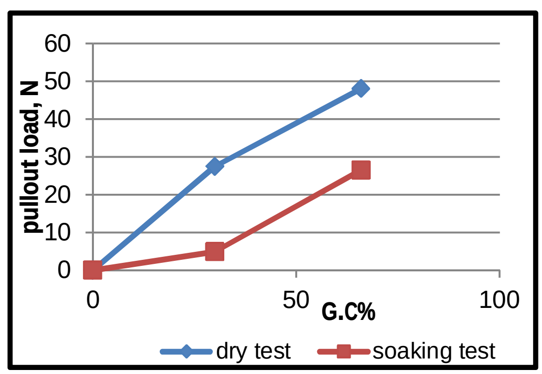

Fig.16 Pullout load- gypsum content relationship for concrete pile in both dry and soaking tests.

VIII. CONCLUSIONS

Based on the results obtained from the present study, the following conclusions are drawn:

1-The pullout capacity of pile constructed in gypseous soil in dry case is more than that in soaking case due to the dissolution of gypsum in soaking case .

2-The sharp lack that occurs in the pullout capacity of piles is due to the presence of water is about 82% in S_1, and about 45% in S_2 due to gypsum dissolution. .

3-The pullout capacity of concrete pile in S_2 is more than that in S_1 to about 43% in dry test, and 81% in soaking test due to the large content of gypsum in the first soil which led to conclude that the pullout capacity of pile can be increased by increasing the amount of gypsum content in the soil.

4-The pullout capacity of steel is more than concrete to about 46% and 5% for both dry and soaking tests respectively, and this may be attributed to the weight of steel pile which is more than the weight of concrete pile and to the adhesion occurs between the steel pile and soil particle which more than that in the case of concrete pile.

IX. RECOMMENDATIONS FOR FUTURE WORKS

In this study, it is focused on studying the effect of both the gypsum content and pile type on the pullout capacity of piles. Following points represent some recommendations for construction and future research.

1-The use of the tension piles in the soaked gypseous soil is unsuitable solution, and should be replaced by other way to save structures from damages.

2-Studying the effect of other amount of gypsum content on the pullout capacity of piles.

3- Studying the effect of long term of soaking on the pullout capacity of piles.

4- Studying the effect of cyclic tension load on the behavior of piles in gypseous soils.

5-Studying the effect of another values of slenderness ratio of pile (L/D) on the pullout capacity of piles in gypseous soils.

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