Dewatering Effect on Virtual Settlement of Pile Foundation: case study in Bab AL-Mudham area, Baghdad-Iraq.

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Abstract

The need for Dewatering is very important in construction workshops field and sometimes it needs to pay more attention as a result of its impacts on causing additional settlement of nearby pile foundations. Dewatering construction may become a costly topic if ignored during project planning and designing .In this paper a simplified procedure maybe adopted to calculate the foundation settlement induced by using dewatering system which is required to lower the water table level to reach a dry condition during construction. Synthesized case study adopted at a specified location in Baghdad city and analysis are computed for two types of piles both of them are submerged with water. Results shows the effect of dewatering on pile foundation settlement, consolidation of soil around the pile shaft, soil-pile interaction and negative skin friction.

KeyWord: Dewatering, Negative Skin Friction, Pile Foundation Settlement, phreatic surface.

1-Introduction

The need for a relatively dry condition for geotechnical and underground excavations sometimes could be carried out in the area of existing piles. Dewatering process almost increase the effective stress as well as the compression of the soil which lead to the settlements of the nearby building supporting by piles.

[6] describes the Under Planning Dewatering Process (UPDP) for the tunnel of Muslim Bin Aqeel and constructions activities nearby Kufa Mosque.

He concluded that the UPDP of tunnel which deals with higher flow of water quantities (i.e. about 691 m3/day) observed from a high permeable sandy soil that caused huge cracks in Mosque walls and differential settlement in foundations for the exterior walls especially in Bab Al-Huja.

A drop in the groundwater level (at any site) will result in a stress increase within the soil deposit because of the reduction in buoyancy (Archimedes principle). A stress increase will be accompanied by strain (Hooke's Law). Settlement (or deformation) is the integration of strain over the effected volume of material. The amount of settlement depends on the stiffness (or modulus) of the soil and the soil stress history. In other words, consolidation settlement due to an increase in effective stress will occur when groundwater is lowered in compressible soils. [13]

Currently available scientific methodologies and analytical methods indicate the subject residence experienced damaging settlement as a result of groundwater lowering caused by nearby construction dewatering.

This study deals with the increase in effective stress as a result of soil losing its water by artificial dewatering which will produce soil settlement that will exerts negative skin friction on nearby pile shafts and thus causes additional pile foundation settlement.

2 Materials And procedure

2.1 Area study description

In Baghdad city there are many high buildings and overpasses which mostly built on pile foundations.

The water table in Baghdad city ranging between 2 m to 5 m .Generally, ground water table is shallow in the regions close to the rivers in middle part of the governorate, while it becomes deeper towards east and west [1].

Bab AL-Mudham is a neighborhood of the Rusafa district of Baghdad, Iraq, it is 20.9 km2 in area and 1,312,052 capita which can be described as crowded not Fareast of the Tigris River. It is the location of the Iraq National Library and Archive, a campus of the University of Baghdad, Baghdad Medical City, the former Garden of Ridván, the government departments, schools, shops, carpentry workshops and residential neighborhoods. [16].

The tunnel is surrounding by a Clayey soil with the parameters used in the analysis of the basic problem are presented in Table (1)

The following procedure [3] is employed to estimate the dewatering induced pile settlement:

Pumping induced groundwater drawdown calculation.

The corresponding effective stress and compressive strain increments.

The corresponding negative skin friction on pile shaft.

Calculation of the dewatering induced pile foundation settlement.

Artificial dewatering process are taken out in Bab AL-Mudham area in Baghdad city in order to induce pile foundation settlement **Figure1**.

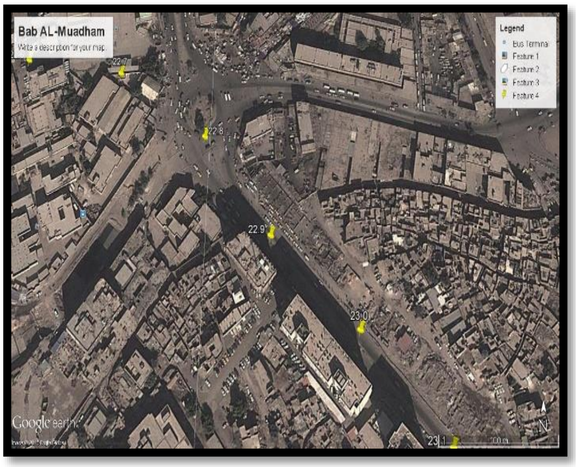
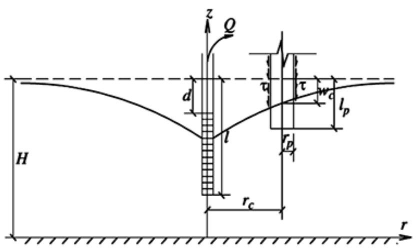


Figure. 1. Bab AL-Mudham area in Baghdad city (artificial case study)google.maps

In this study the drawdown of water table at piles are estimated from the summation of the drawdown of each dewatering well on piles. Which then can be adopted for calculating the corresponding pile foundation settlement.

As shown in **Figure2** , two pile foundations building are located at the left and the right sides of the tunnel each pile of a 1.0 m diameter to support area of 5.5m by 5.5 m dimensions.



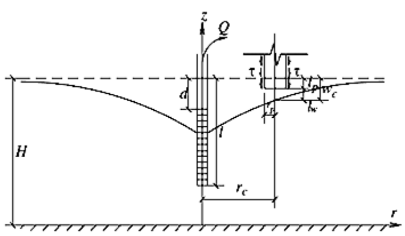


Figure 2. Phreatic surface location:

$w_c \leq l_p$,

$w_c > l_p$

τ the induced negative skin friction on pile shaft.

w_c Drawdown at pile center.

l_p The pile portion below the initial phreatic surface.

l_w The length between the pile tip and the depressed phreatic surface below).

Data collection and analysis

The soil data are collected from Unpublished Report by the National Center of Construction Laboratories Research 2007 which helps to get information about district soil properties as well as a published paper at Eng. & Tech. Journal ,Vol.32, Part (A), No.6,p 1562-1578 as shown in **Table1**, The following parameters will be used in prediction pile foundation settlement

Soil properties.

Number and dimensions of wells.

Pumping rate.

The pile length as a whole and the length below the initial phreatic surface and the distance between the pile tip after and the drawdown phreatic surface after dewatering.

Table1 Engineering properties of soil and lining used in the present study (After Metro Baghdad at Bab Al-Muadham substation) [14]

Parameter	Value	Unit
Tunnel depth(H)	10	m

Tunnel diameter(D)	10	m
Modulus of elasticity of soil(E)	10000	kPa
Initial void ratio (e)	0.7	dimensionless
Poisson's ratio of soil(μ)	0.4	-
Cohesion of soil (C)	70	kPa
Angle of internal friction (∅)	40	-
Unit weight of soil (γ)	20	kN/m^3
surcharge	100	kPa
Transmissivity (T)	150	(m^2/day)

PUMPING-INDUCED PILE FOUNDATION SETTLEMENT

Settlement calculation.

Dewatering for construction purposes has occasionally resulted in settlement of the surrounding area, sometimes with damage to existing structures [11], a procedure for calculation has been proposed by different researchers to calculate the estimated pile settlement which is induced by the dewatering.

1.1 The Drawdown Calculation

An approximation of the theissian model for pumping test clarification advanced by [8] for the Theis equation and a records analysis method which does not require type-curve matching. The Cooper-Jacob offered to estimate the drawdown for a given well location over time. This approximation is good for expecting results from pump tests.

$$w = \frac{Q}{4\pi T} \ln[2.2459 \frac{Tt}{r^2 S}] \text{ ------------ } (1$$

Where
w =drawdown (m)
Q=pumping rate (m3/day)
T= transmissivity (m2/day)
t=time (day)
R=radial distance from pumping (m)
S= storage coefficient

When multiple wells are involved, the linear relationship between the drawdown and the pumping rate allows superposition for calculation of the total drawdown and for this study 10 wells are distributed in such a way that the level of the phreatic surface lowered 0.5 m under the tunnel base and the effect of the drawdown on both pile is the same as shown in **Figure3**.

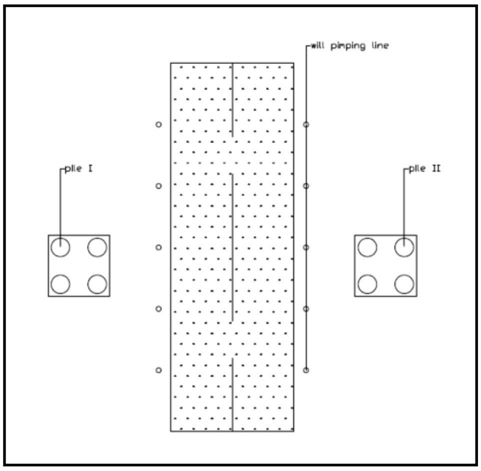


Figure 3. Layout of the wells distribution and pile locations.

3.3 Effective stress and Compressive Strain Increments

As presented in **Figure2**, the depressed phreatic surface at the pile may be above case (I) or below the pile tip case (II).

The pore water pressure has been reduced to a very low value, which can be considered negligible. Therefore, the increase in effective stress is approximately equal to the head of water multiplied by its density γ_w[11] the modulus of compression for soil and harmonic averaging can be employed for layered soil and ε is the compressive strain.

For case (I) as shown in **Figure2**, the averaged effective stress at the pile can be expressed as:

$$\overline{\Delta\sigma} = \gamma_w \cdot \frac{w_c}{2} \text{………} (2)$$

And for case (II) as shown in Figure 3(b):

$$\overline{\Delta\sigma} = \gamma_w \cdot \frac{l_p}{2} \text{……..... } (3)$$

Where:

w_c Represents the drawdown at the pile center location

l_p The pile length in the phreatic zone.

With the objective of evaluating the increase in the total effective stress, is convenient and rational to average the effective stress and the corresponding compressive strain over the vertical drawdown range (theory of elasticity assuming instantaneous consolidation and vertical of one dimensional compression) [15]:

$$\bar{\varepsilon} = \frac{\overline{\Delta\sigma}}{\overline{E_s}} \text{ --------------- } (4)$$

Where= $\Delta\sigma$ is the effective stress increment around the pile.

3.4 Negative skin friction on pile shaft calculation.

According to **[12]**, the relationship between the soil settlement, s and the induced skin friction, τ can be assumed as:

For case (I)

$$\tau = \frac{G_s}{r_p \ln\frac{r_m}{r_p}} \cdot \bar{\varepsilon} w_c \text{……. } (5)$$

For case (II)

$$\tau = \frac{G_s}{r_p \ln\frac{r_m}{r_p}} \cdot s \text{……….. } (6)$$

Where:

G_s = the averaged shear modulus of the soil around pile shaft.

r_p= the pile radius.

r_m = the effective radius of influence, $r_m = 2.5L\rho(1-\mu)$

L = the effective pile length influenced by the dewatering-induced negative skin friction.

μ = the Poisson's ratio

ρ = the ratio of the shear modulus at the pile mid-depth to that at the tip.

The difference between the two equations is related to the thickness of soil that will be consolidated as a result of dewatering.

Soil settlement can be calculated for the two cases as follow:

For case (I)

$s = \bar{\varepsilon} w_c$……… (7)

And (II)

$s = \bar{\varepsilon} \cdot l_p$…….. (8)

3.5 pile foundation settlement.

The surcharge load in this problem will be amounts as F∘ for the negative skin friction, using a semi-theoretical method called national foundation standard method [17], the total pile settlement can be calculated as:

$\delta = \varphi_s \sum_{i=1}^{n} \delta_i = \varphi_s \sum_{i=1}^{n} \frac{F_\circ}{abE_{si}} (z_i \bar{a}_i - z_{i-1} a_{i-1})$…….. (9)

Where:

a and b denote the length and width of the pile foundation base, respectively,

E_{si} Stands for the modulus of compression of the ith layer of soil below the pile tip,

z_i The distance of the bottom of the ith soil layer below the pile tip,

$\bar{a}_i$ A coefficient for the average induced stress over the range of z_i ,

φ_s An empirical coefficient assumed to be 0.2.

Substituting all the interim relationships into equation (9) yields the following expressions:

For case (I)

$\delta = \varphi_s \sum_{i=1}^{n} \delta_i = \varphi_s \sum_{i=1}^{n} \frac{l_n \pi \gamma_w w_c^2 (2v-1)}{2(v-1)abE_{si} \ln(20)} (z_i \bar{a}_i - z_{i-1} a_{i-1})$……. (10)

And for case (II)

$\delta = \varphi_s \sum_{i=1}^{n} \delta_i = \varphi_s \sum_{i=1}^{n} \frac{l \pi \gamma_w l_p^2 (2v-1)}{2(v-1)abE_{si} \ln(20)} (z_i \bar{a}_i - z_{i-1} a_{i-1}) + \frac{\gamma_w (l_p + w_c)}{2E_s} l_p$…… (11)

2. PILE FOUNDATION SETTLEMENT CALCULATION AS A CASE STUDY.

Shown in **Table1** are the related parameters of a distinctive soil profile for the assembly of a metro line in Baghdad city, where excavations frequently have to be led in the district of public building that maybe supported on pile foundations. The phreatic zone with water table level is about 4 m beneath the ground surface, a pumping well with a flow rate of 72 m3/day and a pile of a length 15 m and 8 m with a diameter of 1m of two different building foundation located in each side of the suggested tunnel and about 6 m away from the well line sink as shown in **Fig 3**. (Neglecting well storage and existence of seepage face), and the phreatic zone is about 20 m in thickness and assumed to be homogeneous and isotropic with an averaged hydraulic conductivity of 2.5*10-5 m/sec.

The understandings and the calculation of the pile foundation settlement with respect to the related parameters can be easily done by using the equations (10) and (11). For example, the pile settlement in case (I) is not explicitly related with the averaged modulus of compression of the soil around the pile shaft, while at steady state, the depressed phreatic surface is below the pile tip, corresponding to case (II), the settlement calculation of the pile settlement for both cases with respect to time can be calculated as shown in **Table2.**

Table 2 additional force and settlement calculation.

Time (day)	Drawdown (m)	Soil settlement Case I m	Soil settlement Case II m	the induced skin friction I	the induced skin friction II	additional force F/kN case I	pile foundation settlement	additional force F/kN case	pile foundation settlement
1	3.001	0.0005	0.0005	0.654	0.654	52.873	0.009	13.218	1.004
5	3.642	0.0007	0.0007	0.927	0.927	84.984	0.017	21.246	1.857
9	3.876	0.0008	0.0008	1.037	1.037	99.203	0.020	24.801	2.209
10	3.918	0.0008	0.0008	1.057	1.057	101.901	0.021	25.475	2.275
20	4.194	0.0009	0.0008	1.195	1.098	120.830	0.026	107.33	2.723
30	4.355	0.0009	0.0008	1.278	1.098	132.878	0.029	107.33	3.000
50	4.558	0.0010	0.0008	1.387	1.098	149.120	0.033	107.33	3.363
100	4.834	0.0012	0.0008	1.540	1.098	173.127	0.039	107.33	3.882

3. RESULTS AND DISCUSSION.

The construction of a metro tunnel in Baghdad cannot be done without dewatering ,so the use of soil parameters as in Table 1, and a total of 10 wells, each with a pumping rate of 72m3/day, will be convoluted for this process.

Table2 represents the calculated values of the drawdown which induced by dewatering, negative skin friction, additional force and pile foundation settlements, which point to the following notes.

The first case (I) in which foundation having longer piles, pumping duration time causing an increase in additional force as well as an increase in settlement till the steady state is reached and the final values are larger than those for the case(II) foundation but the pile foundation settlement values are smaller than case (II).

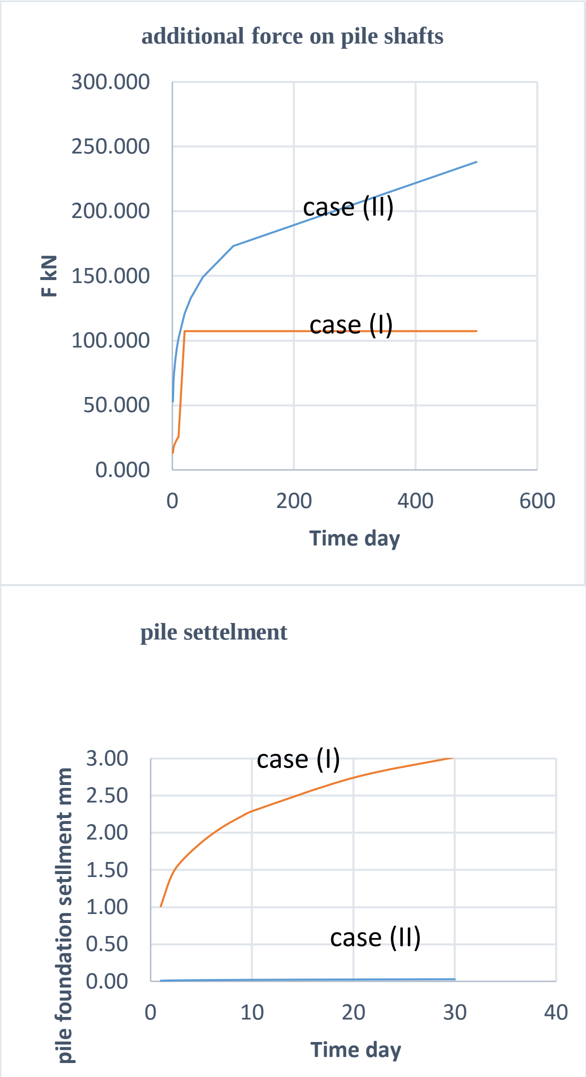


Figure 4. Pile foundation settlement for both cases.

The second case (II) such foundation will have a similar behavior like piles of case (I)

until the phreatic surface drops dawn the pile tips, the increase in drawdown increases the effective stresses which yields an additional forces on the piles. The consolidation of soil under the pile tips will result in further foundation settlement until steady state is achieved.

The dewatering prompted pile foundation settlement might exceed the consolidation of the surrounding soil as a result of both effect of the consolidation settlement of soil under the pile tips and the negative skin friction on pile shafts above the depressed phreatic surface

4. SUMMARY.

Dewatering prompted pile foundation settlement in phreatic zone influenced by the following issues:

Drawdown, deformation characteristics of soil accompanied by seepage, the interaction between soil and pile and the distribution of well system around the construction area plus quantity, an averaged effective stress approach and a linear elastic interaction model are adopted to estimate the dewatering induced pile foundation settlement. Pile foundation settlement calculation and a case analysis, are presented.

While the depressed phreatic surface is above the pile tip the drawdown and consolidation compression of the soil around the pile shaft as well as the degree of interaction between soil and pile are the main factors of the pile settlement. An additional force and pile settlement increases with continuous drawdown till the phreatic surface is depressed below the pile tip then soil consolidation below the pile tip will be included.

Pile foundation settlement Prompted by dewatering process might exceed the settlement of the surrounding soil.

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1. NOMENCLATURE.

$\bar{a}_i$ =A coefficient for the average induced stress over the range of z_i(*dimensionless*).

E_{si} =Stands for the modulus of compression of the i^{th} layer of soil below the pile tip (kPa),

G_s =the averaged shear modulus of the soil around pile shaft. (KPa),

l_p = The pile length below the initial phreatic surface (m).

l_p =the pile length in the phreatic zone (m).

l_w =The distance between the pile tip and the depressed phreatic surface below (m).

r_m =the effective radius of influence (m).r_p =the pile radius (m).

w_c =Drawdown at pile center (m).

w_c =represents the drawdown at the pile center location (m).

z_i =The distance of the bottom of the i^{th} soil layer below the pile tip (m).

φ_s =An empirical coefficient assumed to be 0.2(*dimensionless*).

$\Delta\sigma$ =is the effective stress increment around the pile (kPa).

µ =the Poisson's ratio (*dimensionless*).

a, b =denote the length and width of the pile foundation base, respectively (m).

ρ =the ratio of the shear modulus at the pile mid-depth to that at the tip (*dimensionless*)...

τ =the induced negative skin friction on pile shaft (kPa).

L =the effective pile length influenced by the dewatering-induced negative skin friction (m).

Q =pumping rate (m^3/day)

R =radial distance from pumping (m)

S =storage coefficient (*dimensionless*).

T =transmissivity (m^2/day)

t =time (day)

w =drawdown (m)

ed

تاثير انخفاض مستوى المياه الجوفية على الهبوط الافتراضي للاساسات الركائزية: حالة دراسية بمنطقة باب المعظم في بغداد-العراق.

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الخلاصة

مما لاشك فيه ان سحب المياه الجوفية من الامور المهمة في الاعمال الانشائية وبحاجة الى اهتمام متزايد نتيجة تاثيره على هبوط اضافي غير محسوب في الابنية المجاورة للمواقع الانشائية الحديثة في بعض الاحيان .
ان كلفة الاعمال الخاصة بسحب المياه الجوفية قد تكون من المواضيع المكلفة جدا اذا اهملت اثناء اعداد التصاميم الاساسية للمشاريع حيث ان تاثيرها قد يكلف المقاول دفع تعويضات جسيمة لم تكن بحساباته مطلقا. ان هذه الدراسة تهدف الى حساب مقدار الهبوط في ابنية مجاورة لاعمال حفر نفق مترو بغداد وتحديدا في منطقة باب المعظم حيث يتطلب العمل سحب المياه الجوفية لغرض تهيئة الموقع للعمل باجواء جافة نسبيا . في هذه الدراسة تم اعتماد طريقة حسابية مبسطة و اعداد حالة افتراضية لغرض اجراء حساب و تحليل مدى تاثير مجموعة ابار لسحب المياه الجوفية و مدى تاثيرها على اسس بنايتين تقعان على جانبي الشارع و بمسافات متساوية نسبيا من كل بنايه و على افتراض ان ركائز اساسات الابنية تكون احداها طويلة بحيث تبقى مغموره بالماء اثناء سحب المياه و الثانية ينخفض مستوى المياه الجوفية بمسافة معينة تحت قاعدة الركيزة . وقد بينت هذه الدراسة تاثير سحب المياه على هبوط ركائز الابنية و كذلك هبوط الترية المحيطة بالركائز و التاثير المتداخل بين الركائز و التربة و قوة الاحتكاك السالب على سطح الركائز.
كلمات رئيسية : سحب المياه الجوفية, قوى الاحتكاك السالب السطحية, هبوط الاساسات الركائزية, مستوى سطح المياه الجوفية