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STRAINING ACTIONS AND SETTLEMENT OF PILED RAFT FOUNDATION WITH DIFFERENT PILE DIAMETERS RESTED ON SOIL OR NON-RESTED

Ezz- Eldeen, H. A.

Civil Engineering department, Al- Azhar University, Cairo, Egypt

الملخص العربى :

تهدف هذه الدراسة لمعرفة تأثير قطر الخوازيق على سلوك اللبشة المرتكزة على خوازيق فى حالة اللبشة مرتكزة على الأرض مباشرة أو فى حالة وجود مسافة بين اللبشة و سطح الأرض. تمت دراسة القوى الداخلية و الهبوط للبشة فى حالة ارتكازها على 36 خازوق بقطر 0.30 م و 16 خازوق بقطر 0.50 م. تم كذلك دراسة سلوك اللبشة فى حالة ارتكازها مباشرة على التربة و كذلك فى حالة وجود مسافة بين اللبشة و سطح الأرض بمقدار 0.50 ، 1.00 ، 1.50 قطر الخازوق. تمت هذه الدراسة باستخدام برنامج العناصر المحددة PLAXIS 3D foundation version 15 لنموذج ثلاثى الأبعاد للبشة مربعة طول ضلعها 10.00 متر و سمك 1.00 متر. أظهرت النتائج ، فى حالة استخدام 16 خازوق بقطر 0.50 متر بدلاً من 36 خازوق بقطر 0.30 متر (زيادة قطر الخوازيق و تقليل عددها) يزيد الهبوط بنسبة من 30 % إلى 58 % و تزيد العزوم بنسبة من 55 % إلى 86 % و تزيد قوى القص بنسبة من 2.7 % إلى 47 % فى حالة ارتكاز اللبشة على التربة مباشرة و فى حالة وجود مسافة بين اللبشة و التربة على الترتيب.

ABSTRACT :

The present study is mainly based on the determination of the effect of pile diameter on straining actions and settlement in the raft rested on piles and the effect of the contact of the raft to the soil. Two groups of piles were studied, first group consists of 36 piles with 0.30 m diameter however, the second group consists of 16 piles with 0.50 m diameter with fixed length (Lp = 16 m) and spacing between piles are fixed (Sp = 6 Dp). The raft thickness (Tr) was taken = 1.00 m and the dimensions of raft were 10.00*10.00 m. the case of raft rested on soil or non-rested with space (Srg) = 0.50, 1.00 and 1.50 pile diameter (Dp) were invstgated. Finite element package of a PLAXIS 3D version 2015 (A finite element code for soil and rock analysis) has been used to determine the bending moment, the shear force on the raft and the settlement of piled raft foundation. According to the results, using 16 piles with diameter 0.50 m instead of 36 piles with 0.30 m increasing the raft settlement from 30 % to 58 %, the bending moment in the raft increasing from 55 % to 86 % and the shear force of raft increasing from 2.7 % to 47 % for raft rested soil and non-rested respectively.

Keywords: Piled Raft Foundation, Pile Diameter, Rested On Soil, Non-Rested Foundation Straining Action, Settlement, Finite Element Analysis.

1. INTRODUCTION

The straining actions and the settlement in piled raft foundation is affected with different factors as pile diameter and the contact between raft and soil below (raft rested on soil or non-rested). Ismael, N. F. (2001) examined the behavior of bored pile groups in cemented sands by a field testing program. The program consisted of axial load tests on single bored piles in tension and compression and compression tests on two pile groups each consisting of five piles. The spacing of the piles in the groups was two and three-pile diameters. Test results on single piles indicated that 70% of the ultimate load was transmitted in side friction that was uniform along the pile shafts. The calculated pile group efficiencies were 1.22 and 1.93 for a pile spacing of two and three-pile diameters, respectively. Since settlement usually controls the design of pile groups in sand, the group factor defined herein as the ratio of the settlement of the group to the settlement of a single pile at comparable loads in the elastic range was determined from test results. Moreover, the increased capacity of the piles in the groups is principally due to increased skin friction along the pile shafts. The side friction remains interestingly larger for pile groups compared to single piles, despite the interference of the shear zones.Elgendy, M. et al. (2009) presented an analysis for piled raft foundation by finite element method .Varied cases have been carried out to get the optimization of the piled raft. It was observed that the maximum settlement in piled raft slightly decreases with increase of raft thickness. For 0.1m increase in raft thickness reduces settlement about 1 %. The moment in piled raft is affected by pile length, pile spacing, pile diameter and raft thickness. The increase in pile length and pile spacing decreases the moment, while the increase in raft thickness increases the moment. The Moment in piled raft is nearly dose not affected by pile diameter. El-Garhy et al. (2013) conducted an experimental program on model piled rafts in sand soil reducing piles. Three lengths of piles are used in the study to represent slenderness ratio, L/D, of 20, 30 and 50, respectively. The results of the tests show the effectiveness of using piles as settlement reduction measure with the rafts. As the number of settlements decreasing piles increases, the load improvement ratio increases. Elarabi. H. (2015) studied the effect of pile spacing by using finite element. The spacing effect was studied for bending moment and settlement of the raft for five values of spacing. In the analysis, the raft thickness is 0.8m and the piles length is 16m and the dimensions of the raft will increase with increased pile spacing. It was observed that. The increase in pile spacing has the effect of increasing the raft settlement .The settlement is significantly increased when the spacing reaches 7d and equals 0.111m at point A (left corner). The increasing pile spacing is accompanied with increase of bending moment at pile locations. Talikoti, R. S. and Lodha. M.C (2015) studied different parameters like size of the raft, thickness of the raft, length of piles diameter of the piles, which affect the behavior of piled raft foundation by using Finite Element Software. However, it the pile diameter increases settlement decreases significantly, and the pile length increases settlement decreases. In addition, if the thickness of raft increases the settlement decreases due to flexible behavior of raft. Roy, S. (2017) presented a study on pile-raft-soil interaction by finite element analysis .modeling of the foundation soil for the piled raft system was done with 15 nodes elements. Piles and raft are modeled as solid plate element. The complete model with 15 nodes for individual soil element. It was found that Load sharing between the raft and pile for different raft thickness and pile spacing and ratio of raft width to pile diameter are plotted. The percentage of load shared by the raft is found to decrease with increase of raft thickness. Raft with lower thickness is found to take more load than the thicker raft. Further, plotted data shows that increasing the raft thickness does not influence the load sharing to the pile as a whole. Mohammed, Y. F. et al. (2018) studied the effect of pile diameter on the behavior of fully plugged pipe pile group in sandy soil it was found that the increasing of pile diameter from 60-80 cm and 100 cm will cause a reduction in pile settlement to 83% and 87%, respectively. Elsamny, M. K. et al. (2018) presented a Comparison between pile- raft foundations non- rested and directly rested on soil it was found that the group efficiency of pile groups for piles cap rested on soil is more than that for piles cap non-rested on soil. 2. The group efficiency was found to be ranging from 1.43 to 1.60 for four piles cap rested on soil and was found to be ranging from 1.13 to 1.25 for four piles cap non-rested on soil. The load transferred to soil underneath pile cap rested on soil was found to be 7.98% from the ultimate load capacity. However, the load transferred to soil by friction was found to be 88.27% from the ultimate load capacity. In addition, the load transferred to soil at pile tip was found to be 3.75% from the ultimate load capacity. 4. The settlement of pile groups for pile cap rested on soil is less than that for pile cap non-rested on soil.

2. Proposed model

In the present study, a theoretical analysis has been done for a selected site (in governmental project in Semesta city, Beni-suef, Governorate, Egypt). Figur (1) illustrates a borehole for the pervious site was chosen to be used in the analysis. The soil consists of four layers and simulated by a semi-infinite element isotropic homogenous elastic material. The analysis model consists of two groups of piled-raft foundation consists of 36 piles have diameters (Dp = 0.30 m) for the first group and 16 piles with diameters (Dp = 0.50 m) and the spacing between piles is fixed (Sp = 6 Dp). The piles have a constant 16 m length. The raft dimensions 10 m * 10 m and 1 m thickness. Analysis carried out on case of piled raft rested on soil and non-rested with space value between raft and soil (Srg) = 0.50 Dp, 1.00 Dp and 1.50 Dp.The details and variation of these selected parameters are listed in table (1).

3. Finite element program

A finite element package of the PLAXIS 3D-foundation version 15 has been used in order to simulate the chosen model. Mohr-Coulomb model has been used to represent the soil behavior. The material properties for soil, piles and raft foundation which have been used in the finite element model are shown in tables (2) and (3)

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Depth (m)		Legend of borehole	Layer thickness	S.P.t or %Rec	unconfined QU kN/m^2	Description
1 2			2			Silty sand and trace of clay
3 4			2			Silty sand
5 6 7 8 9 10 11 12			8	12	100	medium stiff clay
13 14 15 16 17 18 19 20			8	38		dense sand

Figure (1): Borehole Log for Soil used Sesmeta, Beni-Suef Governorate, Egypt Proje

Table (1): Investigated cases of study

Case No.	Raft Thickness (m)	Piles length (m)	pile diameter (Dp) -(m)	Number of piles	Pile spacing	Contact between raft and soil
1	1.00	16.00	0.30	36	6 D_P	Rested on the soil
2			0.50	16	6 D_P	
3			0.30	36	6 D_P	Non-rested on soil with space (Srg = 0.5 Dp)
4			0.50	16	6 D_P	
5			0.30	36	6 D_P	Non-rested on soil with space (Srg = 1.0 Dp)
6			0.50	16	6 D_P	
7			0.30	36	6 D_P	Non-rested on soil with space (Srg = 1.5 Dp)
8			0.50	16	6 D_P	

Table (2): Soil layers properties

Parameters	**Name**	**Silty sand and traces clay**	**Silty sand**	**Medium to stiff clay**	**dense sand**	**units**
Material model	-	Moher column	Moher column	Moher column	Moher column	-
Thickness	T	2	2	8	8	m
Young's modulus	Es	7500	8000	3000	15000	kN/m^2
Unit weight	ɣ	17	16.6	17	18	kN/m^3
Poisson ratio	υ	0.3	0.4	0.3	0.25	-
Cohesion	c	25	12.5	30	0	kN/m^2
Friction angle	Ø	25	35	0	37	°

Table (3): Pile and raft properties

Parameters	**Pile**	**Raft**
Material model	Elastic	Elastic
Types of material	Concrete	Concrete
Diameter (m)	0.5	-
Pile length (m)	16	-
Unit weight (kN/m^3)	25	25
young's modulus Es (kN/m^2)	$24*10^6$	$24*10^6$
Poisson ratio (υ)	0.2	0.2
Cohesion (Cu) (kN/m^2)	-	-
Friction angle (Ø) (°)	-	-

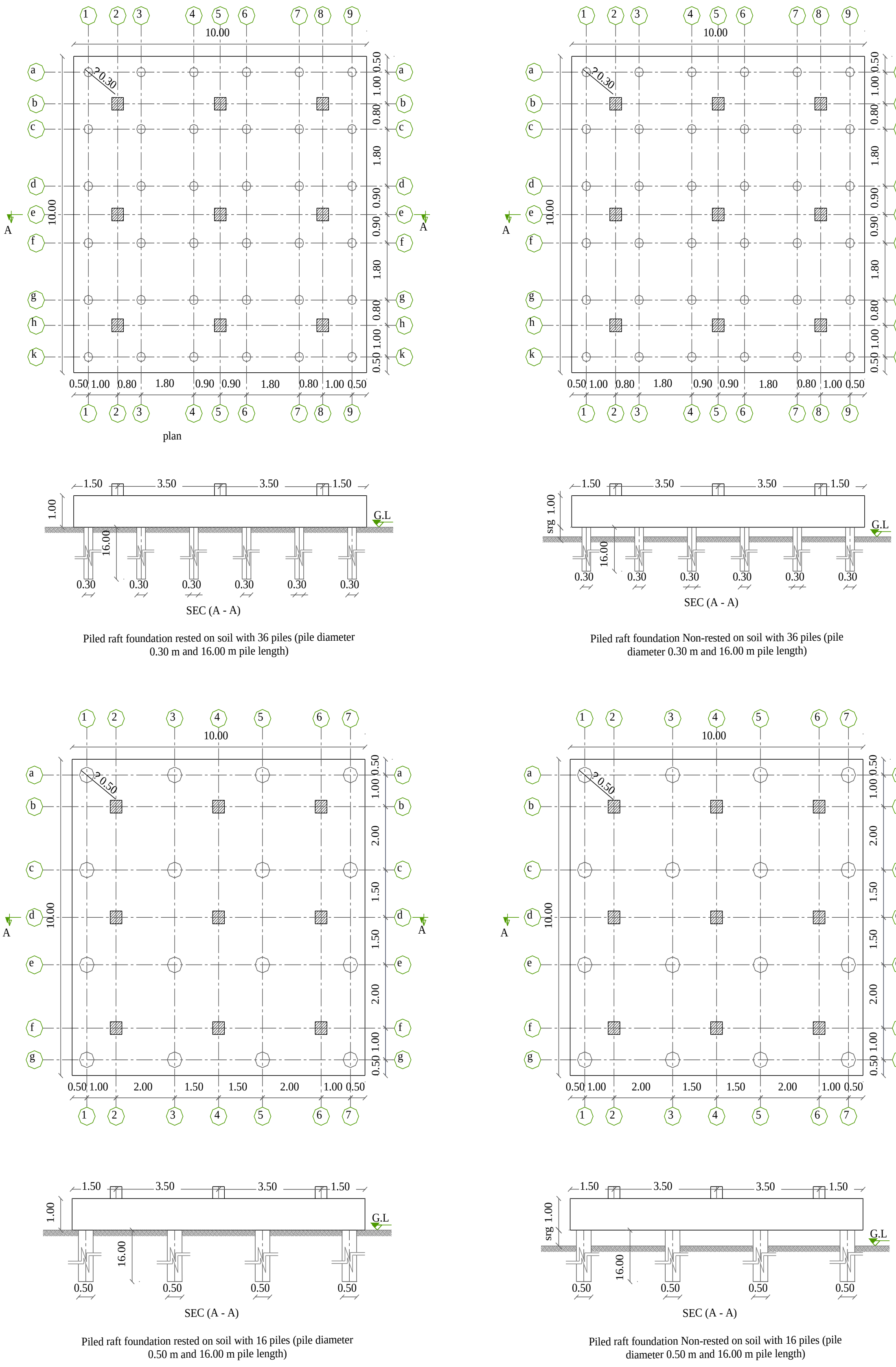


Figure (2): Details of piled raft foundation models and dimensions of raft and piles in meter

4 .Parametric study

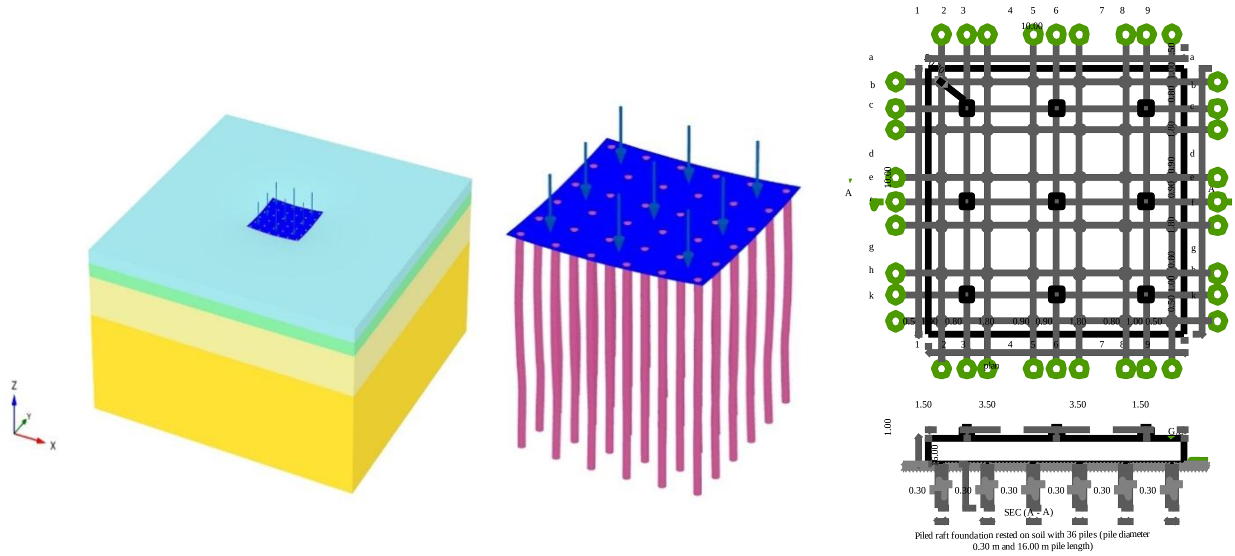
The effect of pile diameter and the raft position of ground surface, rested on soil and non-rested with spacing (Srg) 0.50, 1.00 and 1.50 Dp on the following:

1. The settlement of piled raft
2. The bending moment on the raft
3. The shear force on the raft

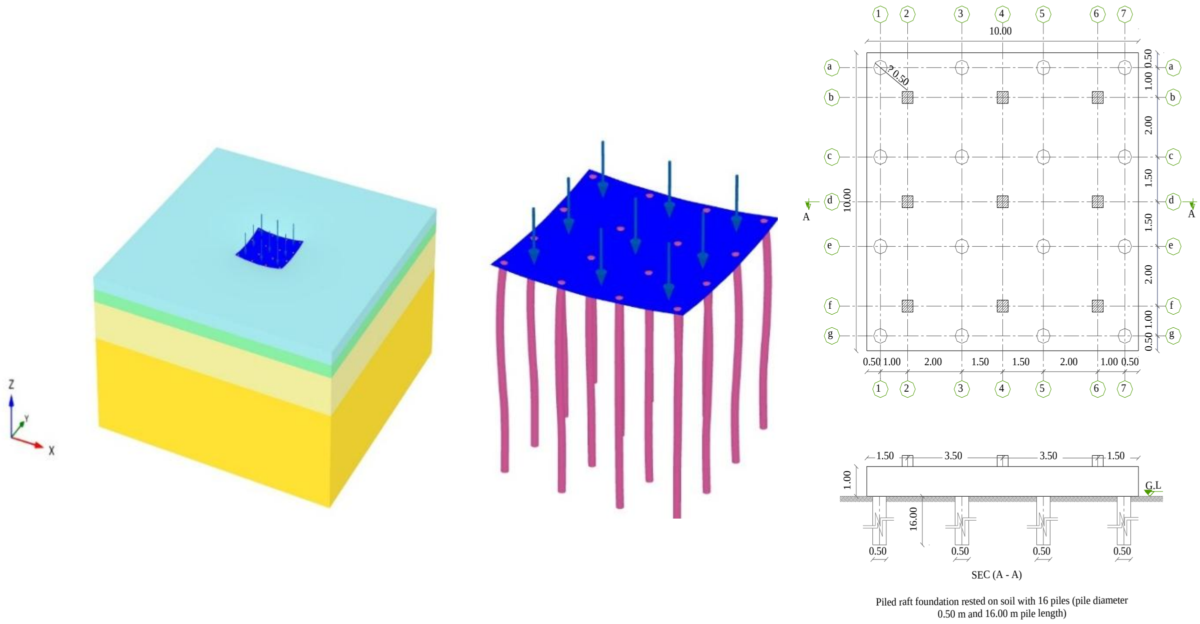
5. Finite Element Results

The obtained results of selected example for different cases are shown in figures (3 to 12) as follows:

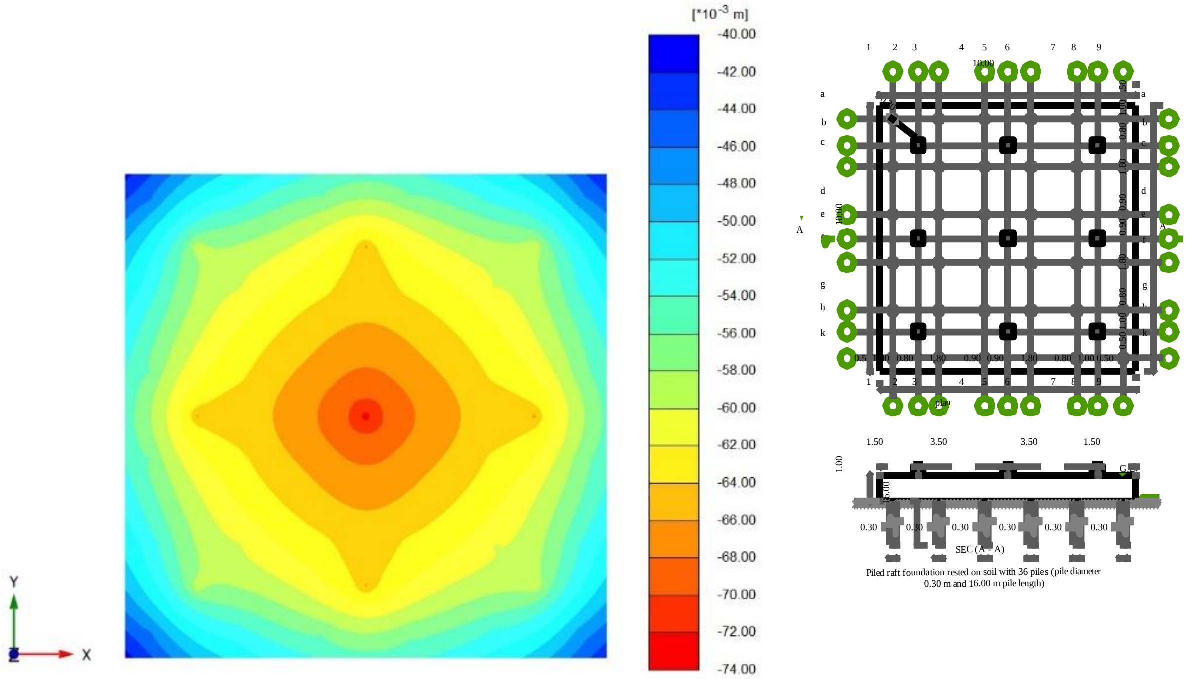
Figure (3) and (4) shows the deformed mesh of piled raft foundation rested on soil with pile diameter 0.30 m and 0.50 m. figure (5) and (6) shows the settlement of the raft of piled raft foundation rested on soil with pile diameter 0.30 m and 0.50 m. Figure (7) and (8) shows the bending moment of the raft of piled raft foundation rested on soil with pile diameter 0.30 m and 0.50 m. Figure (9) and (10) shows the shear force of the raft of piled raft foundation rested on soil with pile diameter 0.30 m and 0.50 m. Figure (11) and (12) shows the settlement as shading for the soil in XZ plane of piled raft foundation rested on the soil with pile diameter 0.30 m and 0.50 m



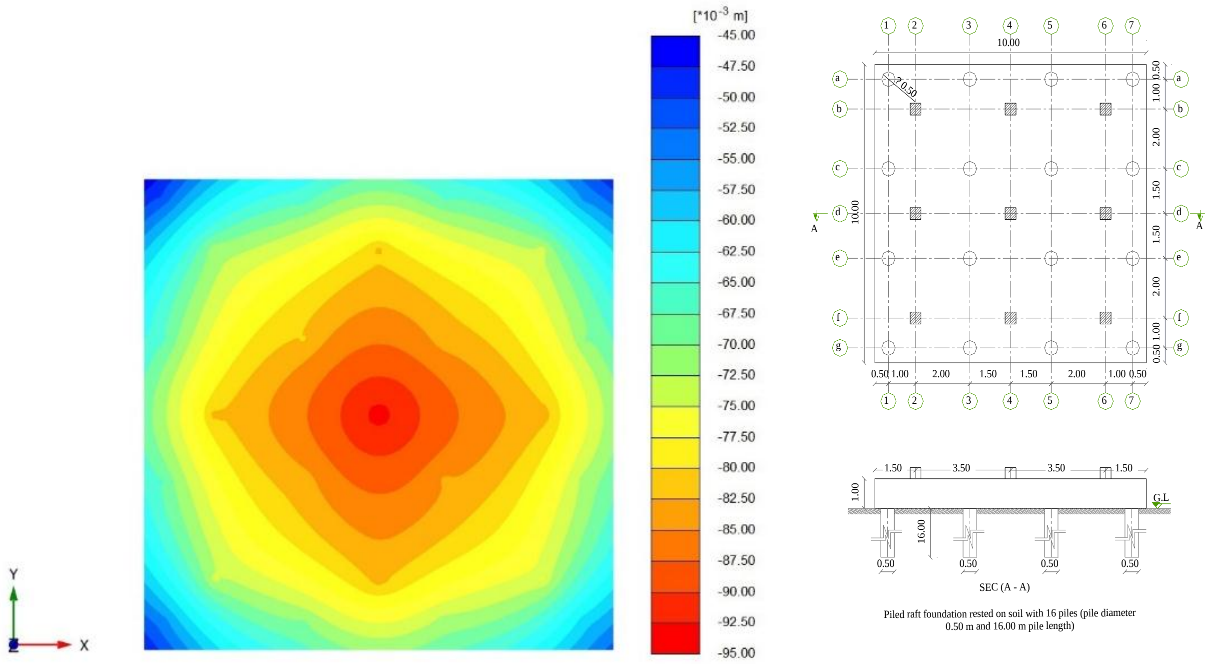
Figur (3) The deformed mesh of piled raft foundation rested on soil with pile diameter 0.30 m**.**



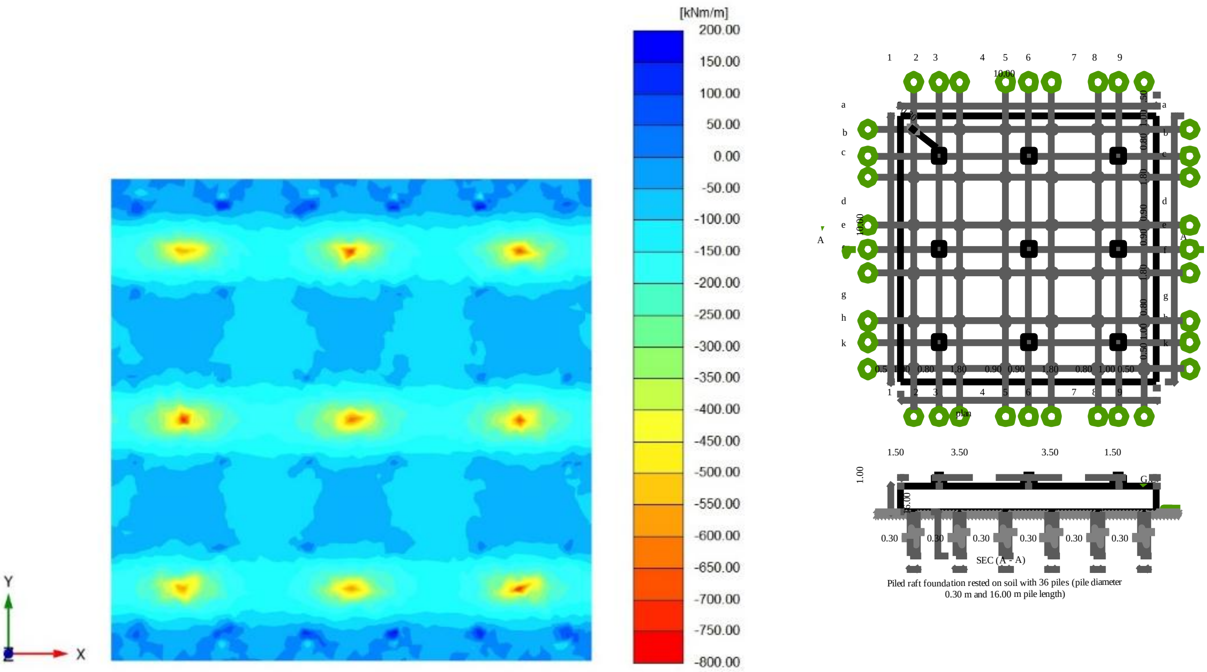
Figur (4) The deformed mesh of piled raft foundation rested on soil with pile diameter 0.50 m.



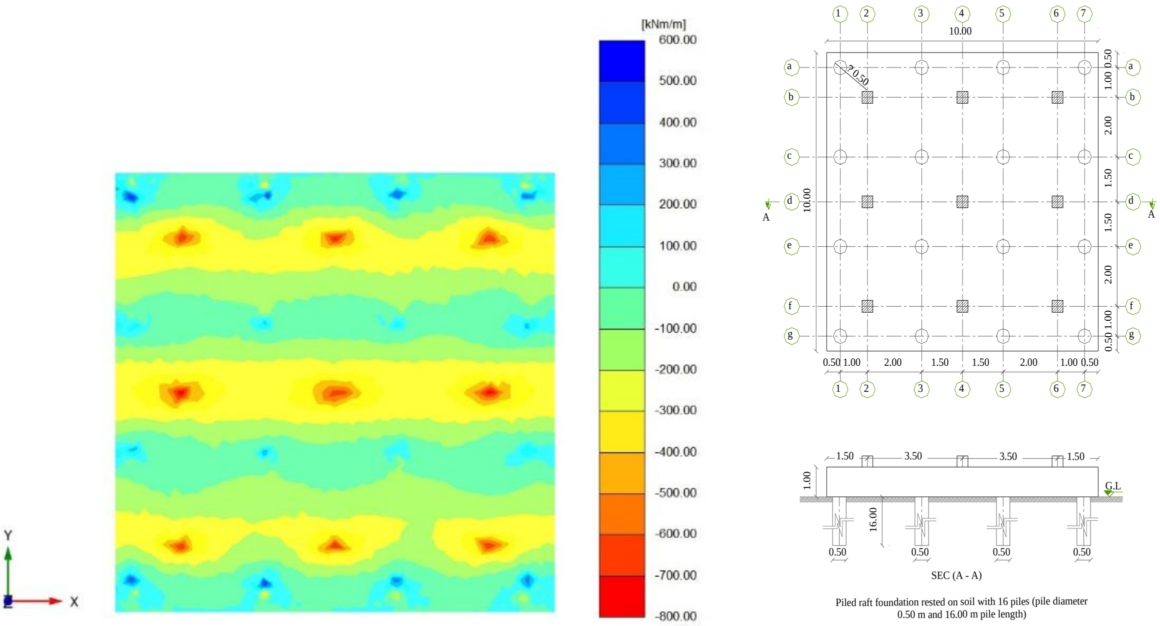
Figur (5) The settlement of the raft of piled raft foundation rested on soil with pile diameter 0.30 m.



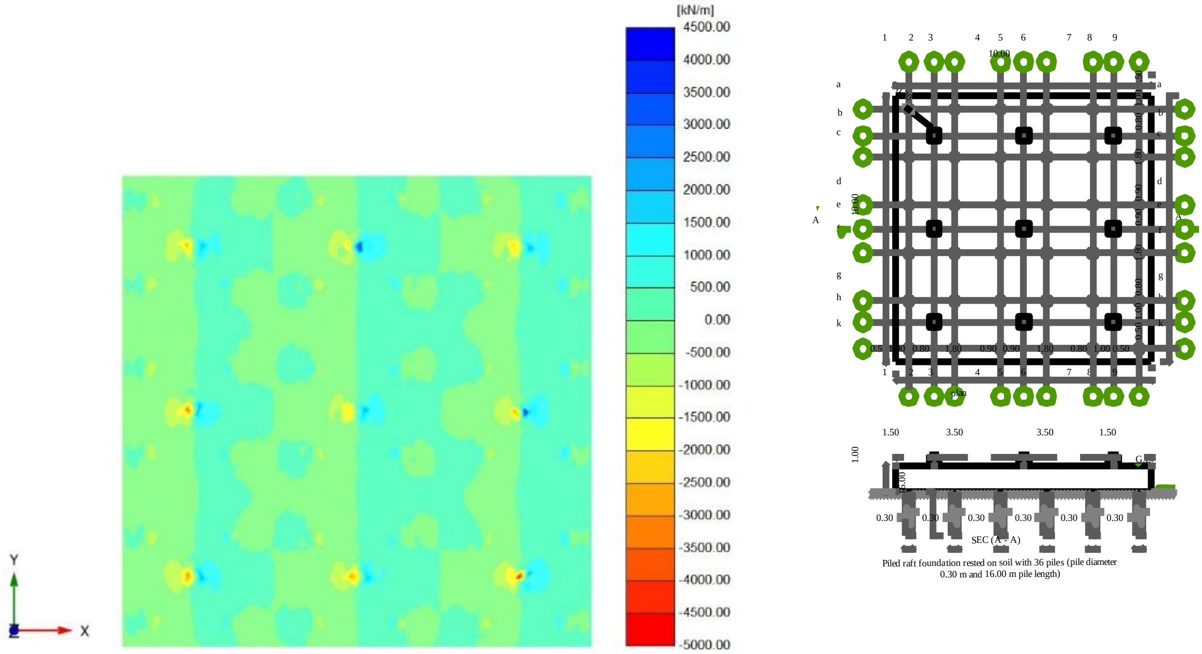
Figur (6) The settlement of the raft of piled raft foundation rested on soil with pile diameter 0.50 m.



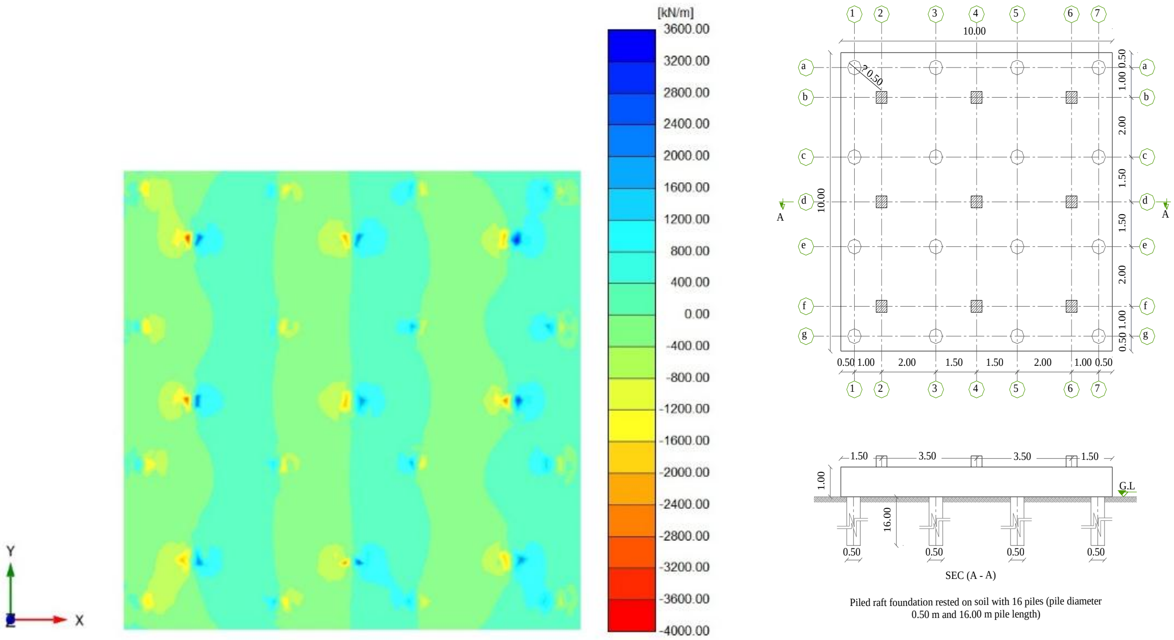
Figur (7) The bending moment of the raft of piled raft foundation rested on soil with pile diameter 0.30 m.



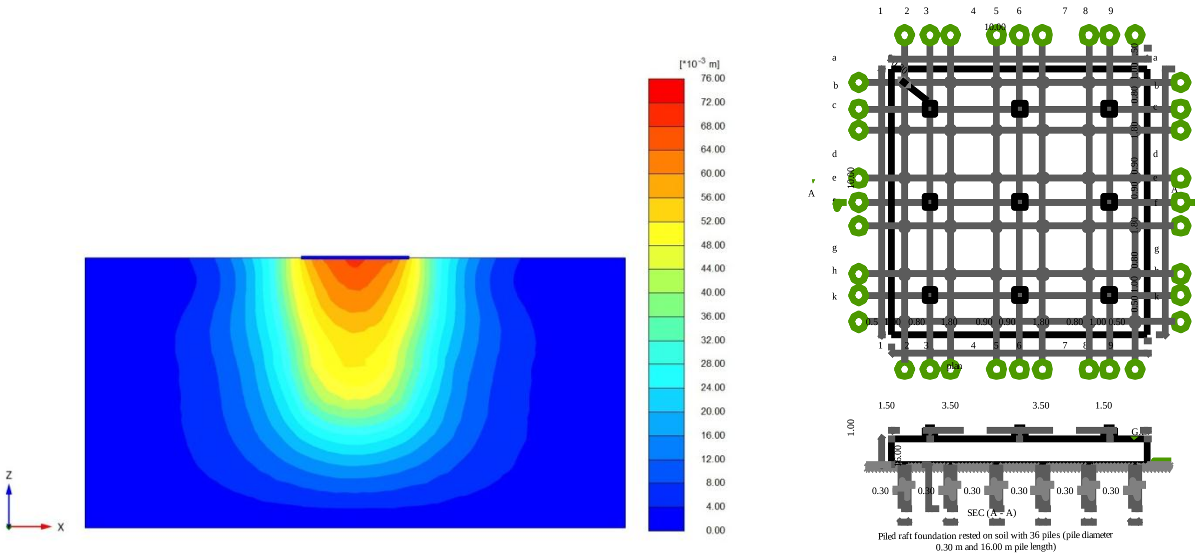
Figur (8) The bending moment of the raft of piled raft foundation rested on soil with pile diameter 0.50 m.



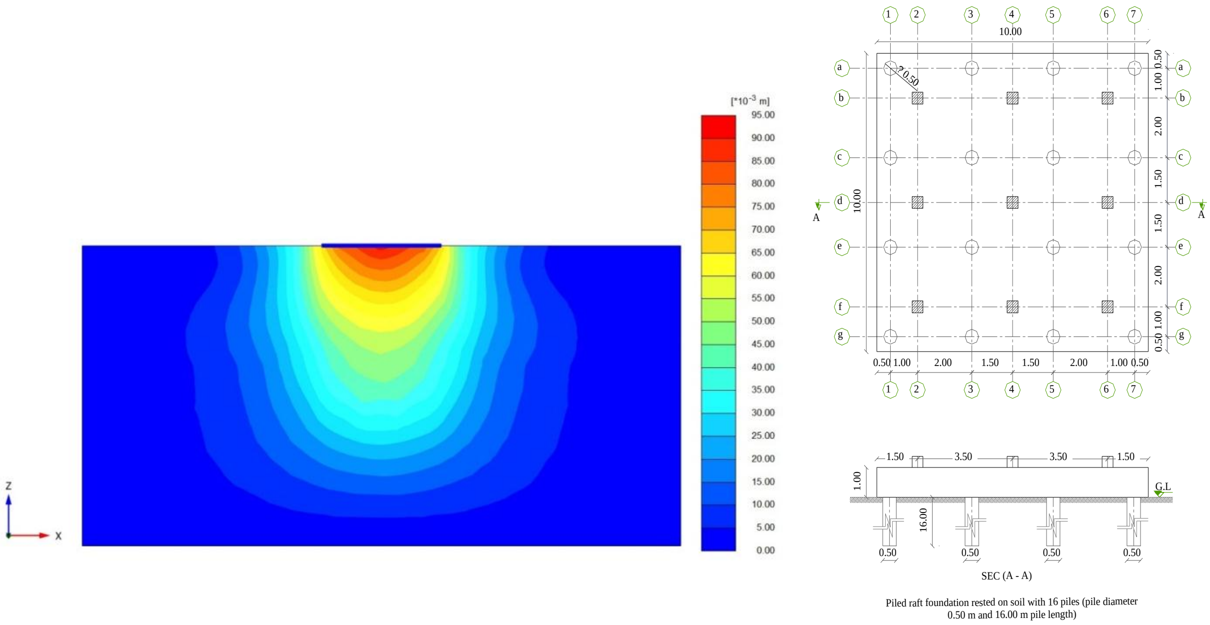
Figur (9) The shear force of the raft of piled raft foundation rested on soil with pile diameter 0.30 m.



Figur (10) The shear force of the raft of piled raft foundation rested on soil with pile diameter 0.50 m.



Figur (11) The settlement as shading for the soil in XZ plane of piled raft foundation rested on the soil with pile diameter 0.30 m.



Figur (12) The settlement as shading for the soil in XZ plane of piled raft foundation rested on the soil with pile diameter 0.50 m.

6. Analysis of results

Figure (13) shows the settlement of piled raft foundation with pile diameter (Dp = 0.30 m) rested on soil or non-rested on soil with space (Srg = 0.5, 1.0 and 1.5 Dp) at sec (A-A).

Figure (14) shows the bending moment of piled raft foundation with pile diameter (Dp = 0.30 m) rested on soil or non-rested on soil with space (Srg = 0.5, 1.0 and 1.5 Dp) at sec (A-A).

Figure (15) shows the shear force of piled raft foundation with pile diameter (Dp = 0.30 m) rested on soil or non-rested on soil with space (Srg = 0.5, 1.0 and 1.5 Dp) at sec (A-A).

Figure (16) shows the settlement of piled raft foundation with pile diameter (Dp = 0.50 m) rested on soil or non-rested on soil with space (Srg = 0.5, 1.0 and 1.5 Dp) at sec (A-A).

Figure (17) shows the bending moment of piled raft foundation with pile diameter (Dp = 0.50 m) rested on soil or non-rested on soil with space (Srg = 0.5, 1.0 and 1.5 Dp) at sec (A-A).

Figure (18) shows the shear force of piled raft foundation with pile diameter (Dp = 0.50 m) rested on soil or non-rested on soil with space (Srg = 0.5, 1.0 and 1.5 Dp) at sec (A-A).

Figure (19) shows the relation between the settlement of piled raft foundation and pile diameter (Dp) rested on soil at sec (A-A).

Figure (20) shows the relation between the bending moment of piled raft foundation and pile diameter (Dp) rested on soil at sec (A-A).

Figure (21) shows the relation between the shear force of piled raft foundation and pile diameter (Dp) rested on soil at sec (A-A).

Figure (22) shows the relation between the settlement of piled raft foundation and pile diameter (Dp) Non-rested on soil with space (Srg = 0.5 Dp) at sec (A-A).

Figure (23) shows the relation between the bending moment of piled raft foundation and pile diameter (Dp) Non-rested on soil with space (Srg = 0.5 Dp) at sec (A-A).

Figure (24) shows the relation between the shear force of piled raft foundation and pile diameter (Dp) Non-rested on soil with space (Srg = 0.5 Dp) at sec (A-A).

Figure (25) shows the relation between the settlement of piled raft foundation and pile diameter (Dp) Non-rested on soil with space (Srg = 1.0 Dp) at sec (A-A).

Figure (26) shows the relation between the bending moment of piled raft foundation and pile diameter (Dp) Non-rested on soil with space (Srg = 1.0 Dp) at sec (A-A).

Figure (27) shows the relation between the shear force of piled raft foundation and pile diameter (Dp) Non-rested on soil with space (Srg = 1.0 Dp) at sec (A-A).

Figure (28) shows the relation between the settlement of piled raft foundation and pile diameter (Dp) Non-rested on soil with space (Srg = 1.5 Dp) at sec (A-A).

Figure (29) shows the relation between the bending moment of piled raft foundation and pile diameter (Dp) Non-rested on soil with space (Srg = 1.5 Dp) at sec (A-A).

Figure (30) shows the relation between the shear force of piled raft foundation and pile diameter (Dp) Non-rested on soil with space (Srg = 1.5 Dp) at sec (A-A).

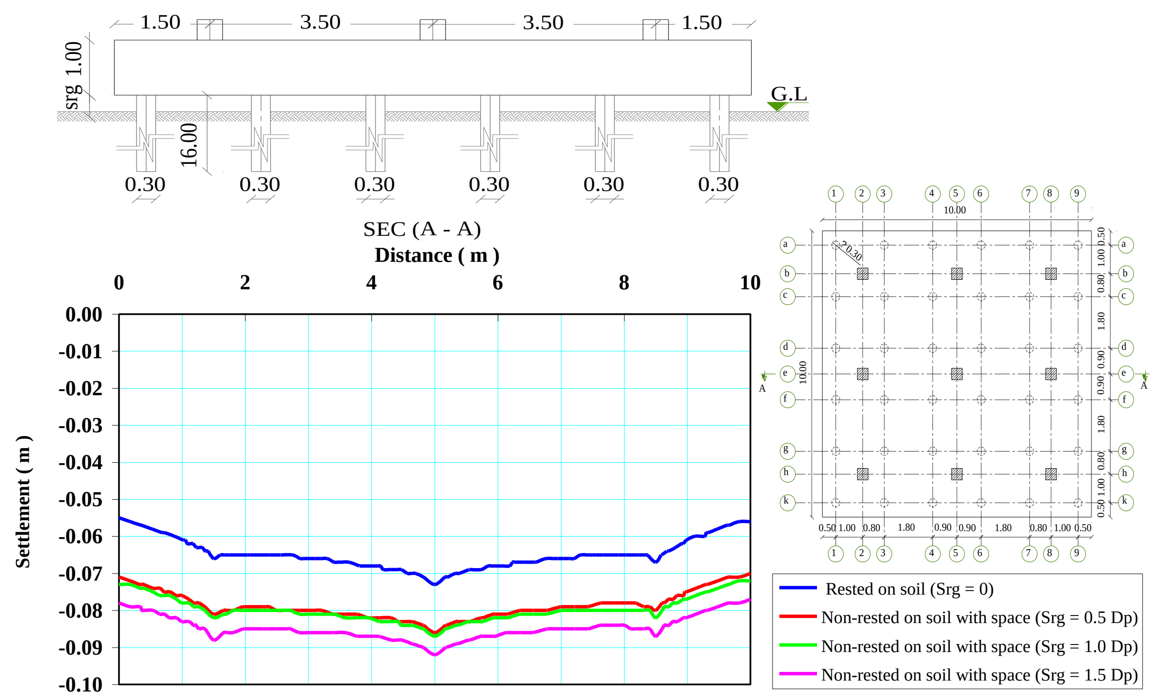


Figure (13) The settlement of piled raft foundation with pile diameter (Dp = 0.30 m) rested on soil or non-rested on soil with space (Srg = 0.5, 1.0 and 1.5 Dp) at sec (A-A).

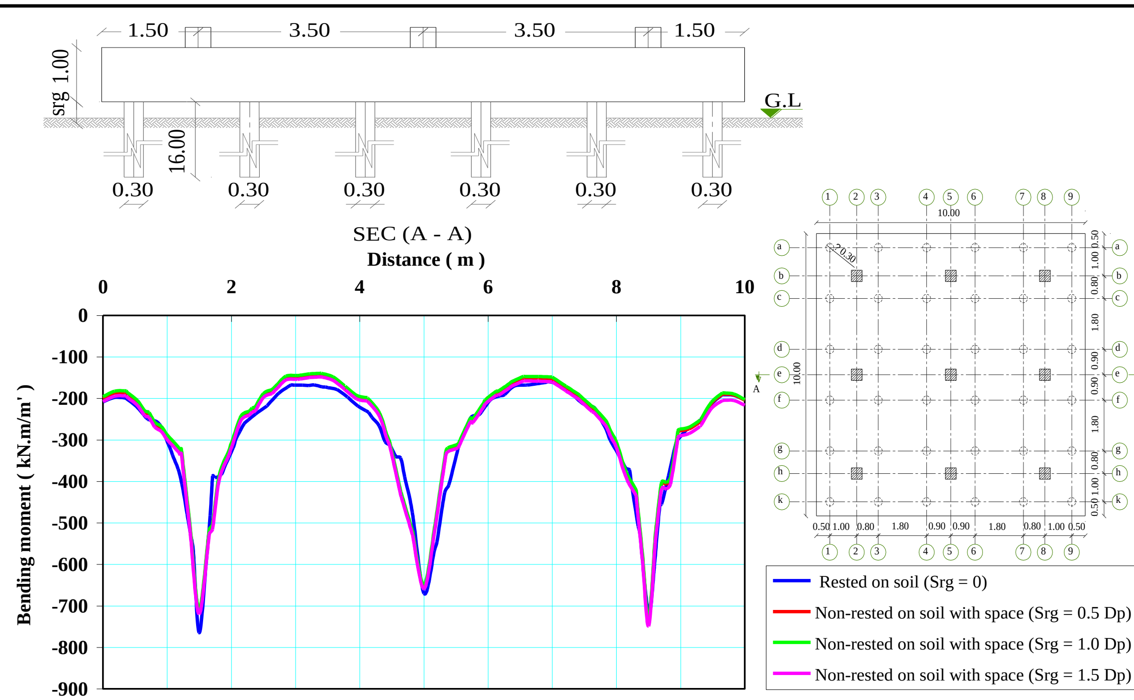


Figure (14) The bending moment of piled raft foundation with pile diameter (Dp = 0.30 m) rested on soil or non-rested on soil with space (Srg = 0.5, 1.0 and 1.5 Dp) at sec (A-A).

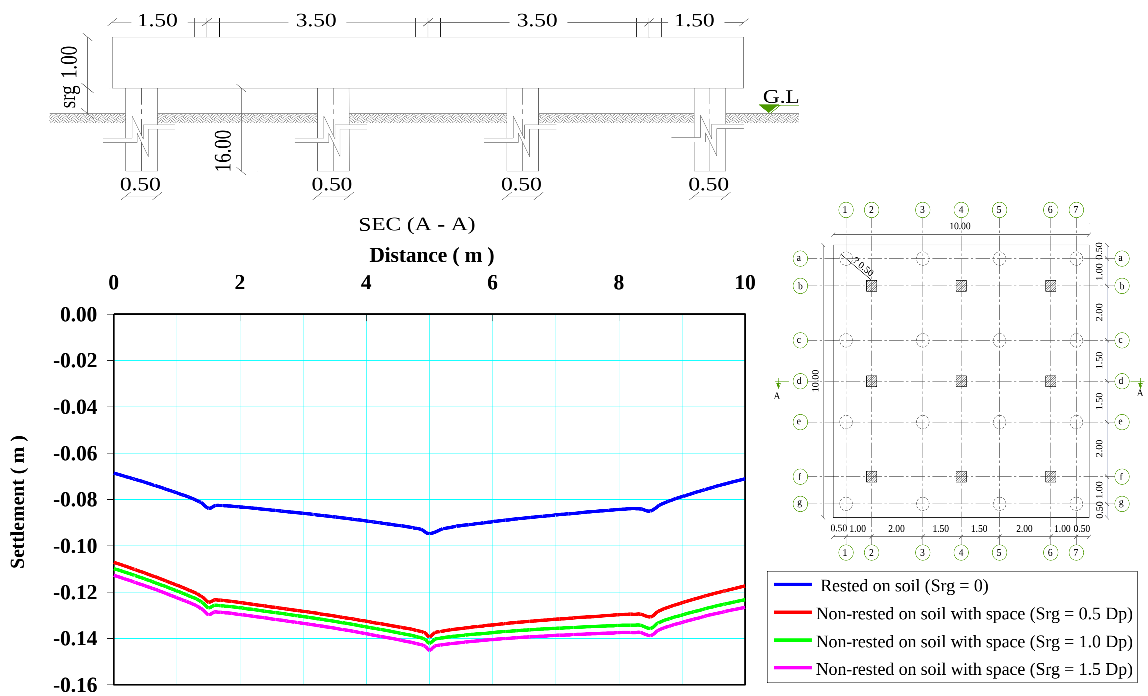


Figure (16) The settlement of piled raft foundation with pile diameter (Dp = 0.50 m) rested on soil or non-rested on soil with space (Srg = 0.5, 1.0 and 1.5 Dp) at sec (A-A).

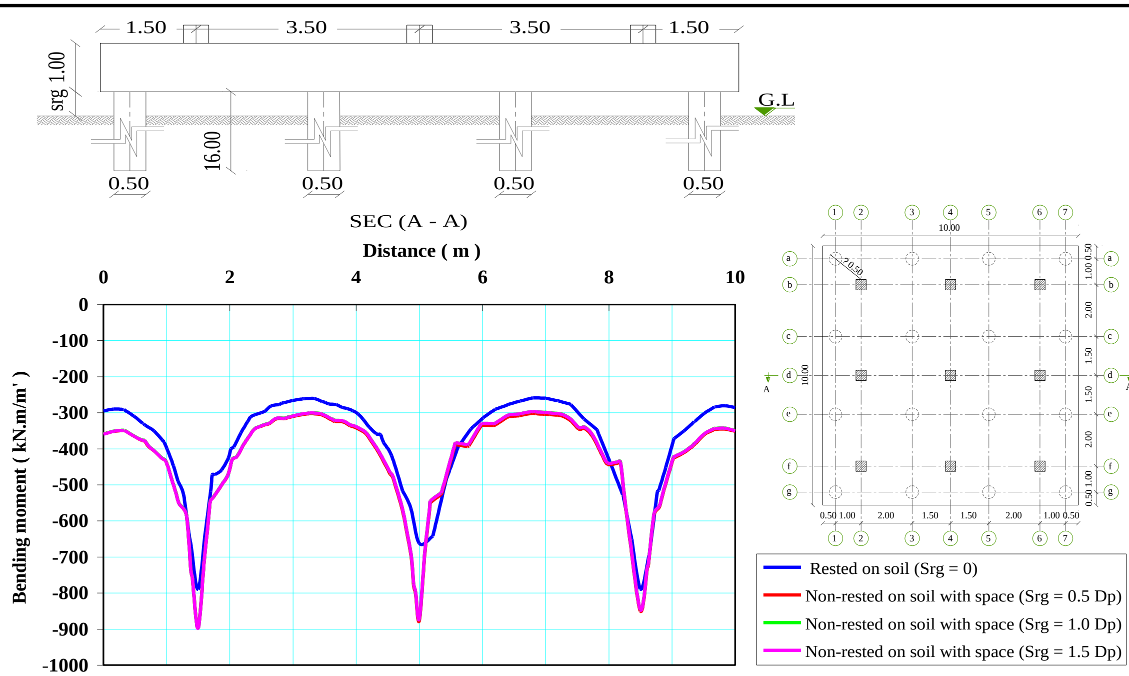


Figure (17) The bending moment of piled raft foundation with pile diameter (Dp = 0.50 m) rested on soil or non-rested on soil with space (Srg = 0.5, 1.0 and 1.5 Dp) at sec (A-A).

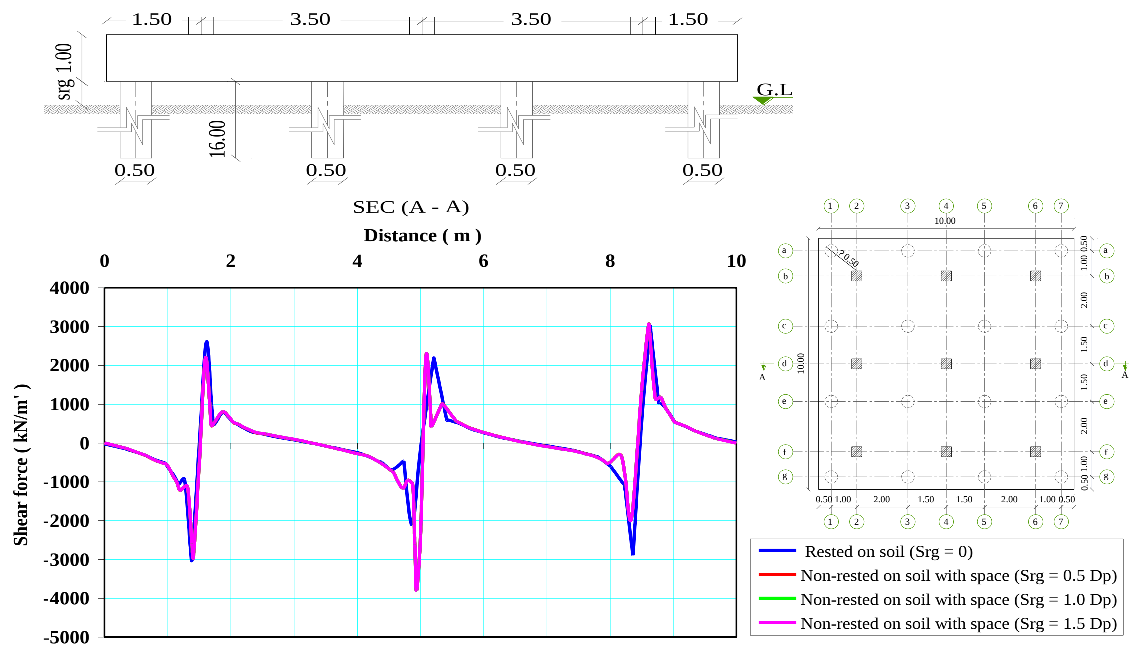


Figure (18) The shear force of piled raft foundation with pile diameter (Dp = 0.50 m) rested on soil or non-rested on soil with space (Srg = 0.5, 1.0 and 1.5 Dp) at sec (A-A).

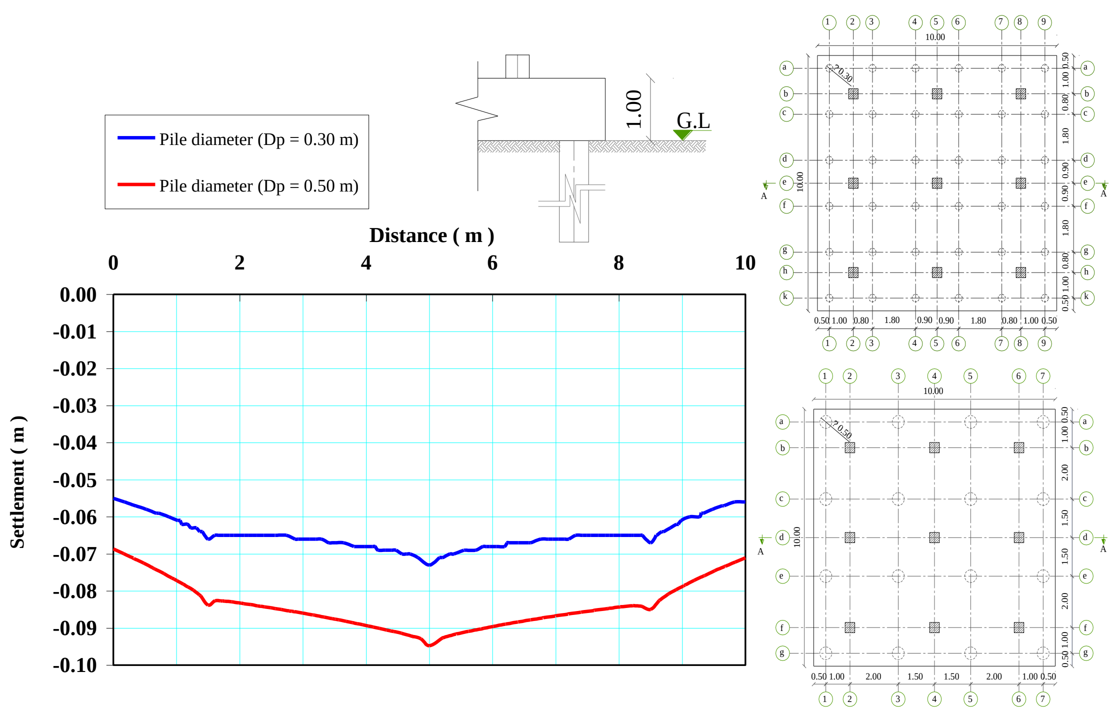


Figure (19) The relation between the settlement of piled raft foundation and pile diameter (Dp) rested on soil at sec (A-A).

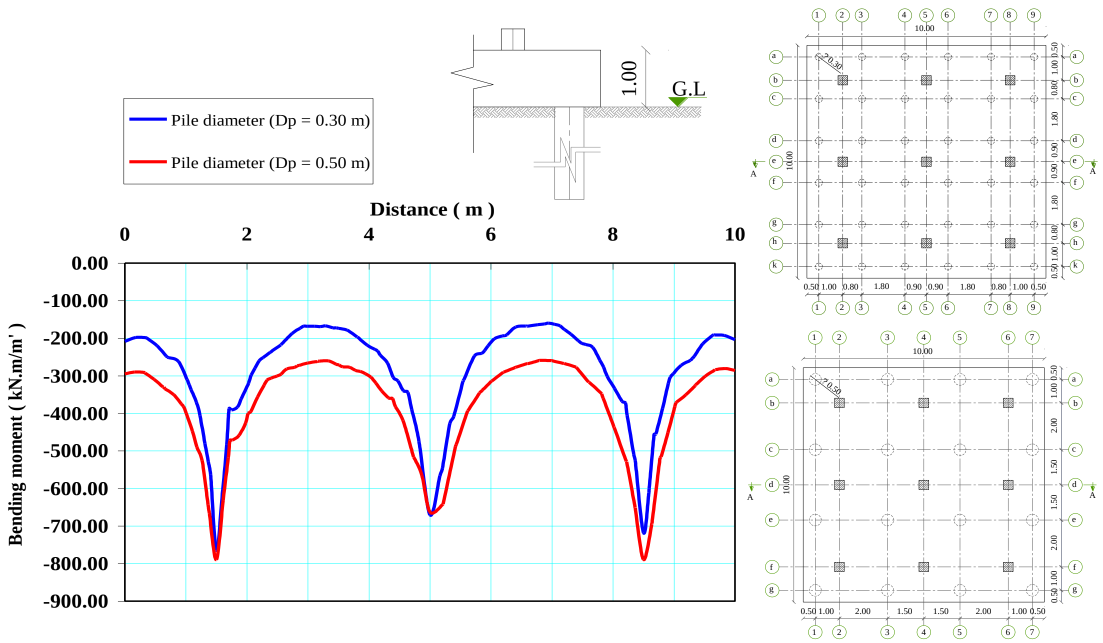


Figure (20) The relation between the bending moment of piled raft foundation and pile diameter (Dp) rested on soil at sec (A-A).

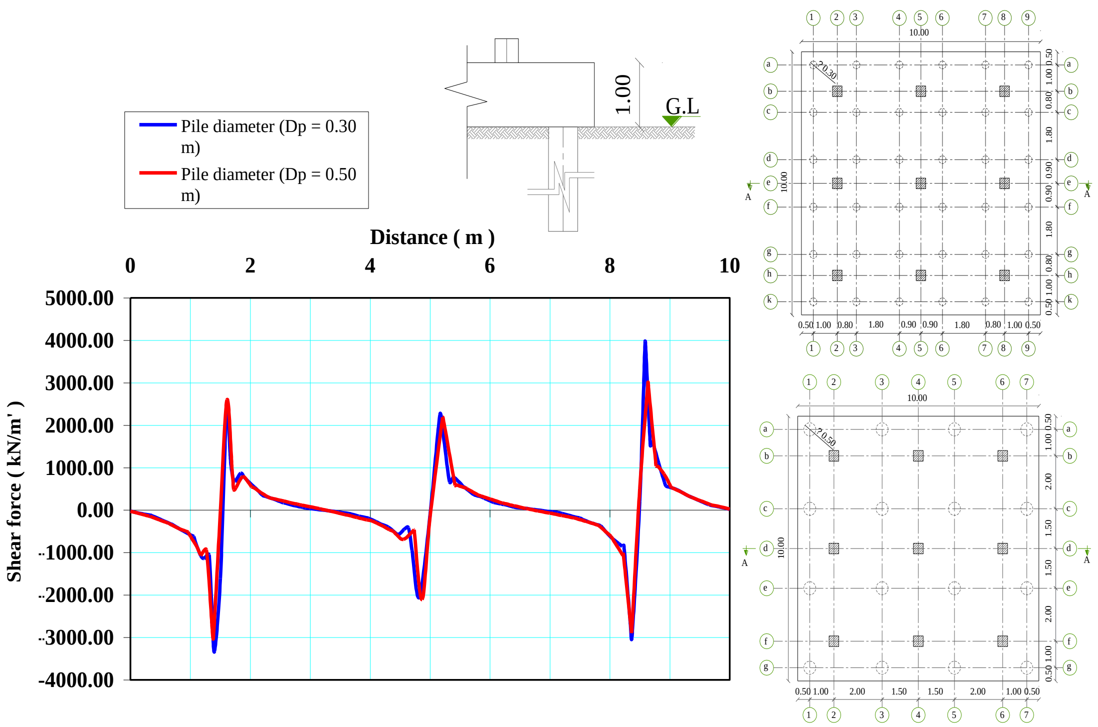


Figure (21) The relation between the shear force of piled raft foundation and pile diameter (Dp) rested on soil at sec (A-A).

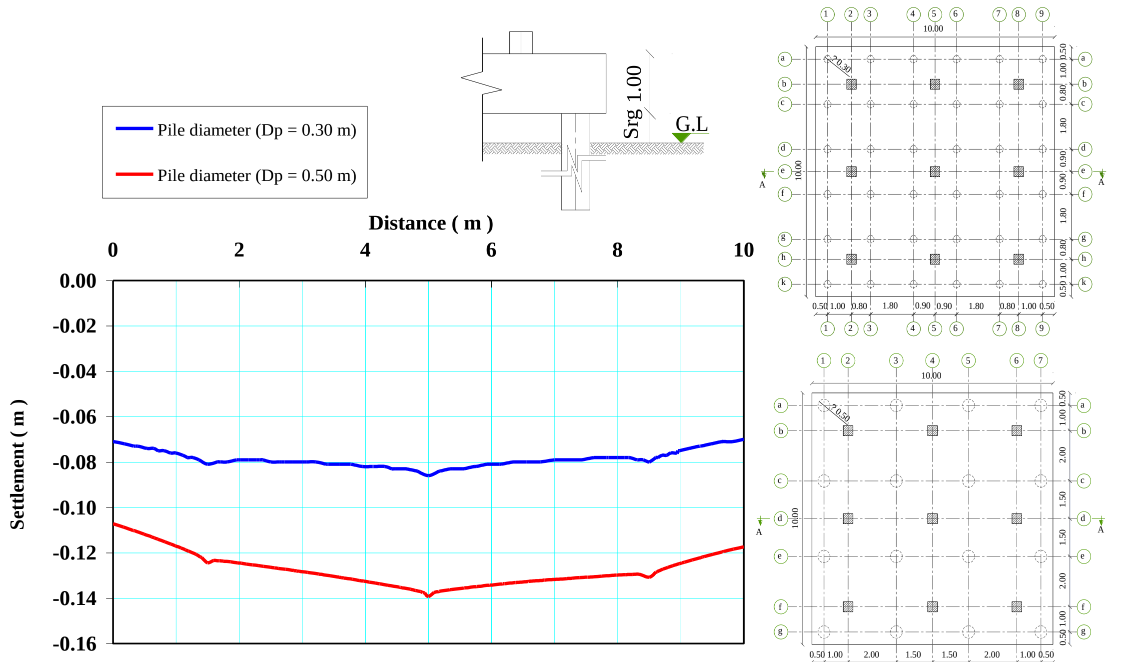
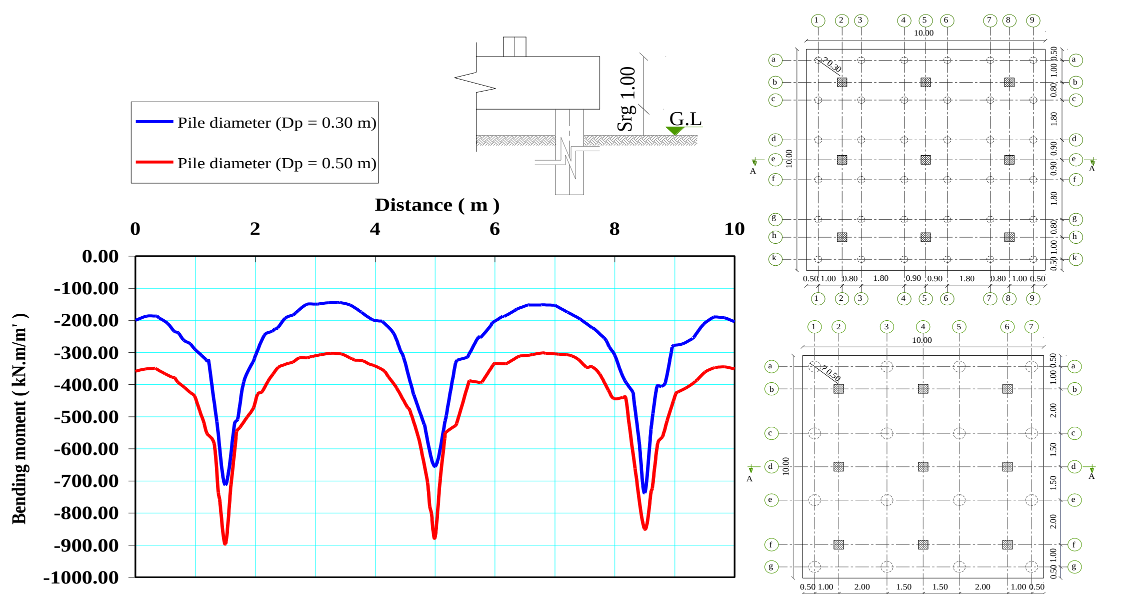


Figure (22) The relation between the settlement of piled raft foundation and pile diameter (Dp) Non-rested on soil with space (Srg = 0.5 Dp) at sec (A-A).



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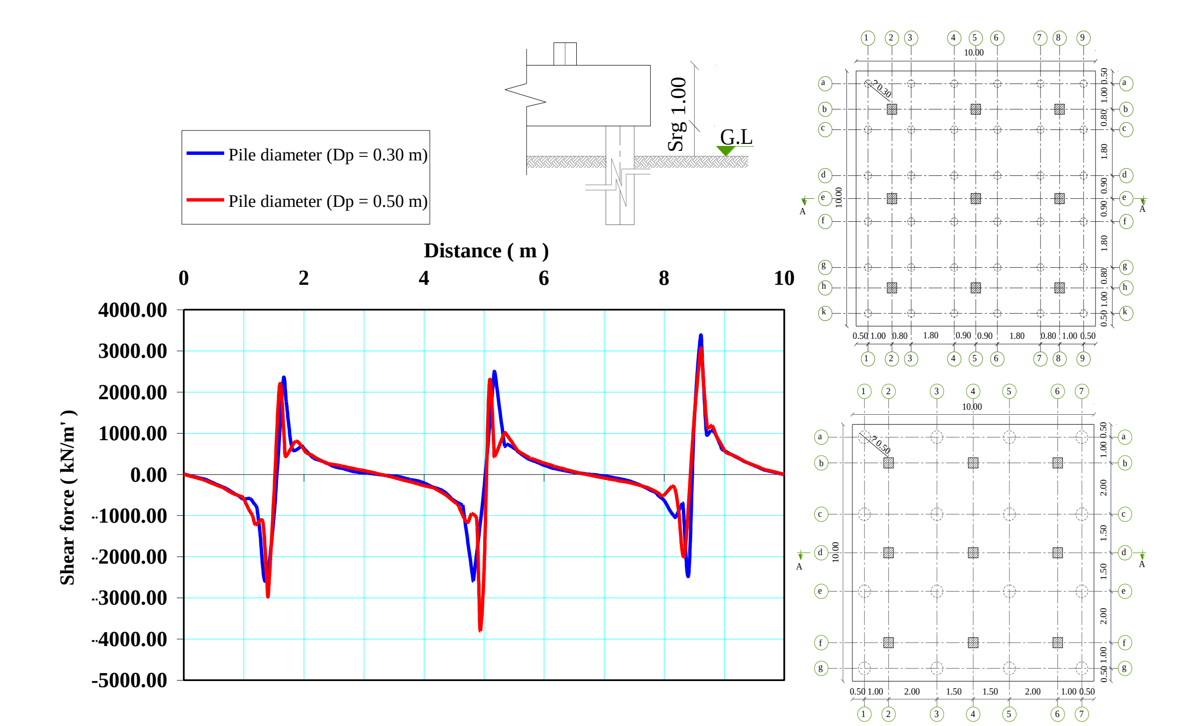

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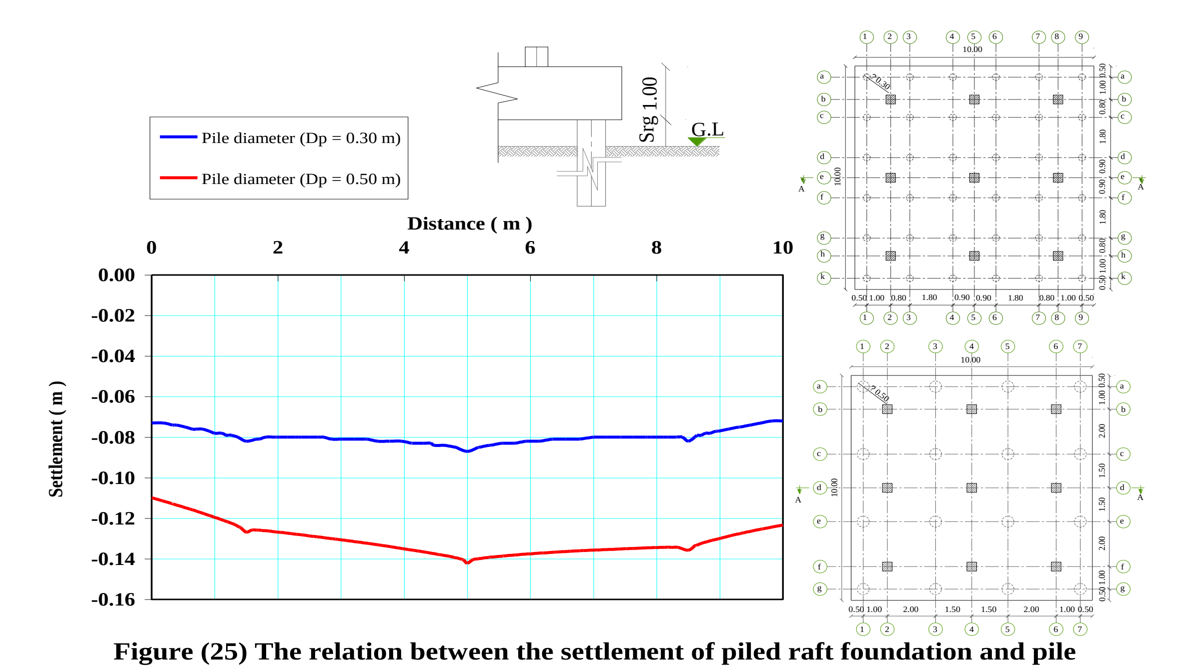

Figure (25) The relation between the settlement of piled raft foundation and pile diameter (Dp) Non-rested on soil with space (Srg = 1.0 Dp) at sec (A-A).

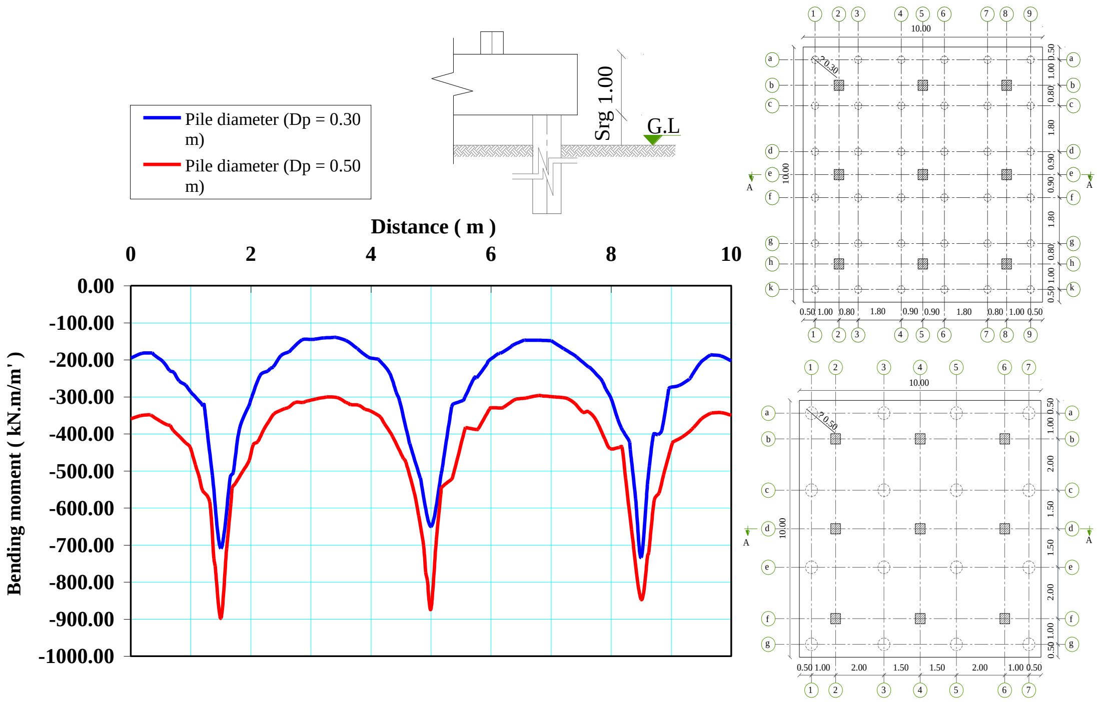

Figure (26) The relation between the bending moment of piled raft foundation and pile diameter (Dp) Non-rested on soil with space (Srg = 1.0 Dp) at sec (A-A).

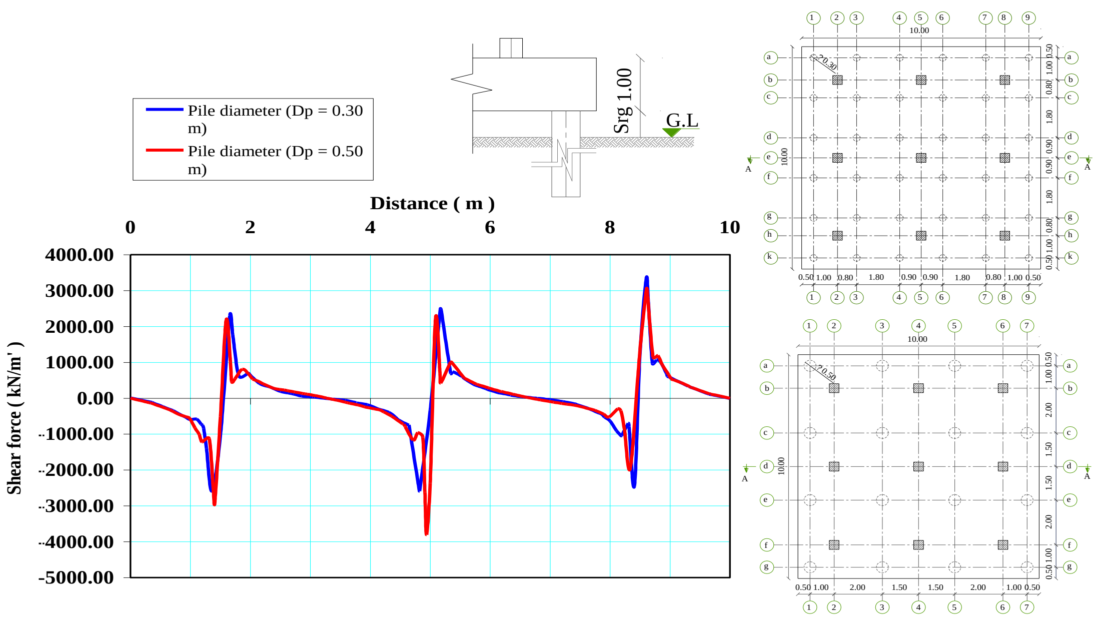

Figure (27) The relation between the shear force of piled raft foundation and pile diameter (Dp) Non-rested on soil with space (Srg = 1.0 Dp) at sec (A-A).

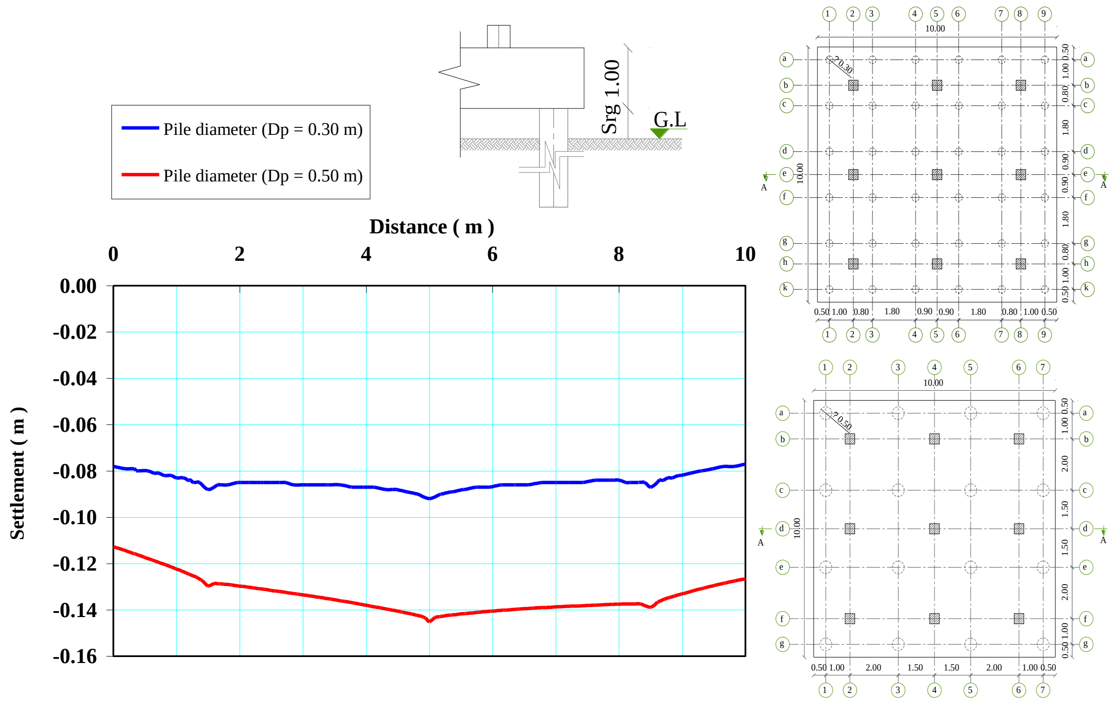

Figure (28) The relation between the settlement of piled raft foundation and pile diameter (Dp) Non-rested on soil with space (Srg = 1.5 Dp) at sec (A-A).

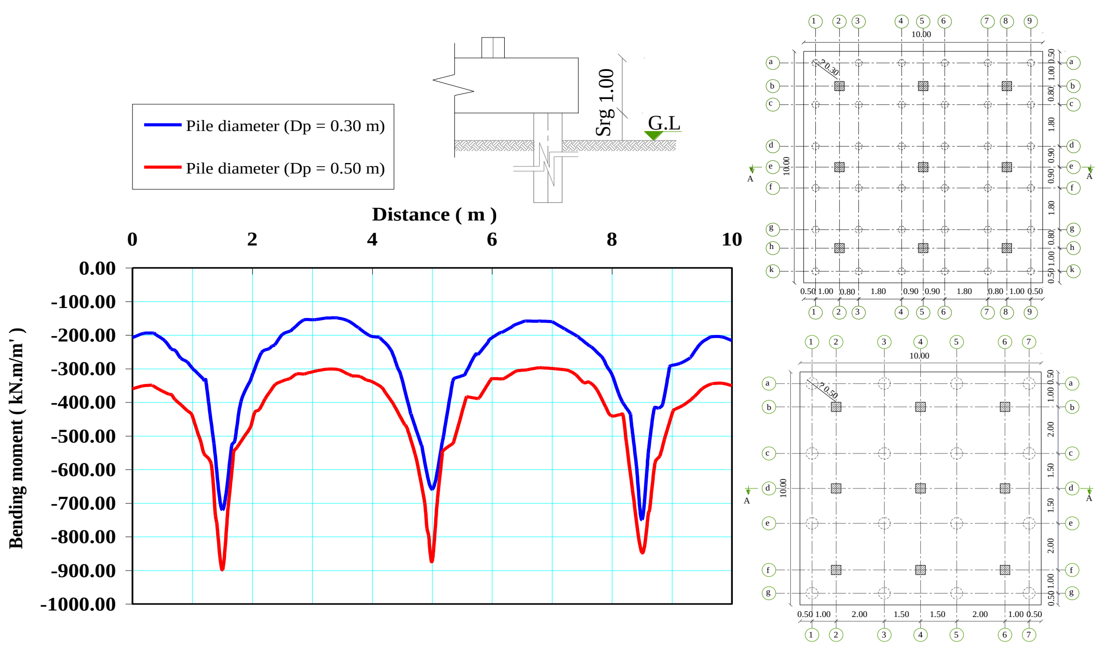

Figure (29) The relation between the bending moment of piled raft foundation and pile diameter (Dp) Non-rested on soil with space (Srg = 1.5 Dp) at sec (A-A).

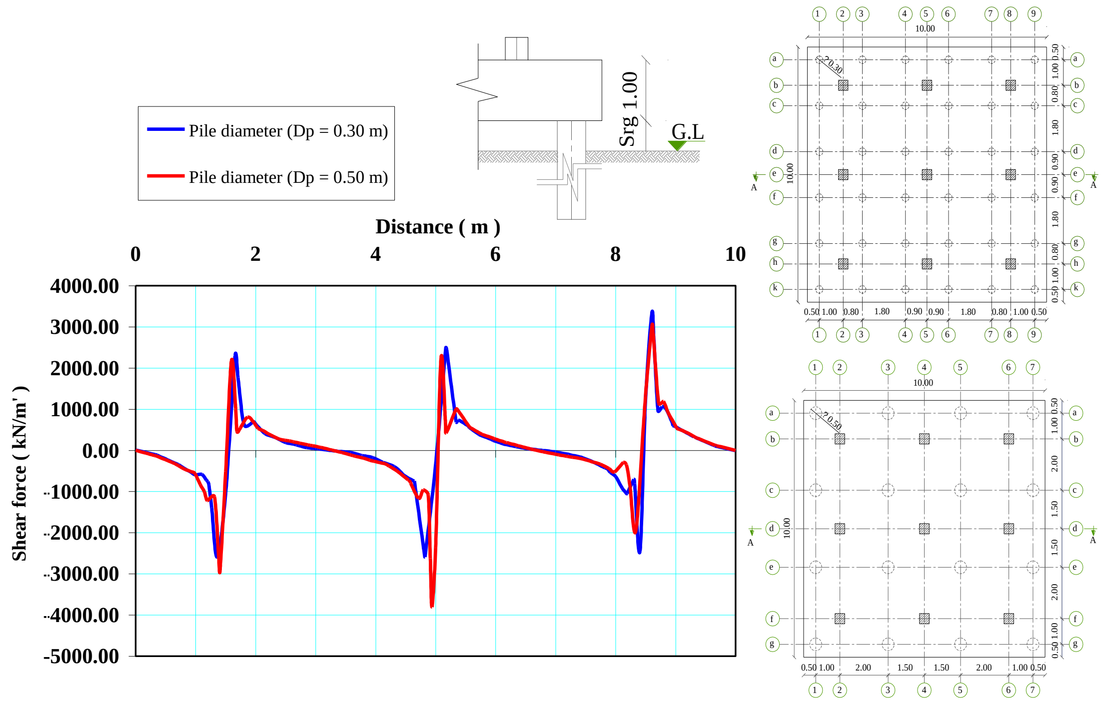

Figure (30) The relation between the shear force of piled raft foundation and pile diameter (Dp) Non-rested on soil with space (Srg = 1.5 Dp) at sec (A-A).

7. Conclusions

From the present study, the followings are concluded:

i. Using 16 piles with diameter 0.50 m instead of 36 piles with 0.30 m leads to:

- The raft settlement increasing from 30 % to 58 %.
- The bending moment in raft increasing from 55 % to 86 %.
- The shear force in raft increasing from 2.7 % to 47 %.

  For raft rested on soil and non-rested respectively.

ii. In case of 36 piles with diameter 0.30 m:

- The bending moment in the raft in the case of rested piled is greater than the case of non-rested by raft by 2% , the shear force in the case of rested piled raft smaller than the non-rested by 11% and the settlement in the case of rested piled raft is smaller than the non-rested by 17 % .

iii. In case of 16 piles with diameter 0.50 m:

- The bending moment in the raft in the case of rested piled is smaller than the case of non-rested by raft by 32% , the shear force in the case of rested piled raft smaller than the non-rested by 7 % and the settlement in the case of rested piled raft is smaller than the non-rested by 47 % .

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