The Influence of Pile Length on the Settlement and Internal Forces of a Piled Raft Foundation

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DOI: https://doi.org/10.52340/building.2025.72.02.17

Abstract This study primarily investigates the effect of pile length on the settlement and internal forces of a piled raft foundation, as well as the influence of raft-to-soil contact. The analysis was performed under both static and dynamic loading conditions. The modeling parameters included a fixed pile diameter (D = 0.5 m) and a constant pile spacing (S_p = 4.5D). The pile length was varied (Lp = 28D, 32D, 36D, and 40D). The raft dimensions were 10x10 m with a thickness of 1.00 m. The subsurface conditions were modeled based on a soil profile consisting of six layers: silty sand with traces of clay, silty sand, medium stiff clay, and dense sand. The soil mass was simulated using a semi-infinite element. The analysis was conducted using the finite element software package PLAXIS 3D version 2013, a code for soil and rock analysis. The software was used to determine the bending moment, shear force in the raft, and the settlement magnitude.

Key Findings:

1. **Effect of Pile Length for a Piled Raft Foundation (raft in contact with soil):**
   - **Under static load**, increasing the pile length resulted in a **29% reduction** in raft bending moment, a reduction to **0.5%** in raft shear force, and a **40% decrease** in settlement.
   - **Under dynamic load**, a similar reduction in parameters was observed: bending moment decreased by **29%**, shear force reduced to **0.5%**, and settlement decreased by **40%**.
2. **Comparison of Two Design Models:**
   - The **bending moment** in the raft for the model where the raft is rigidly connected to the piles (no soil contact) is **7% greater** than for the piled raft foundation model (with contact).
   - The **shear force** in the raft for the rigidly connected model is also **2% larger** than for the model with the raft bearing on the soil.
   - The **settlement** for the model with the raft rigidly connected to the piles is **10% higher** than

1. INTRODUCTION

The straining action and the settlement in piled raft foundation are affected by many different factors such as pile length, pile diameter raft thickness, and type of soil but to a varying degree.

2. Analytical Analysis by Finite Element Analysis:

The used computer program was for the proposal of a three-dimensional finite element package of a PLAXIS 3D version 2013 model to simulate the theoretical effect of pile length in pile raft foundation

2.1 Proposed model:

In the present study, a theoretical analysis has been done for a selected site (in a governmental project in Semesta city, Beni-suef, Governorate, Egypt).Fig. (1) illustrates a borehole for the previous site that was chosen to be used in the analysis. The soil consists of four layers and is simulated by a semi-finite element isotropic homogenous elastic material. The analysis program consists of a piled-raft foundation consisting of 25 piles their diameters are fixed (D = 0.5m) and the spacing between piles is fixed (Sp = 4.5D) and they have various pile lengths (Lp= 28D,32D,36D, and 40D). Analysis carried out on two categories as follows

- rested piled raft
- raft act as a slab connected the piles The details and variations of these selected parameters are listed in tables from (1) to (3). and figures (2) and (3)

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parameters are listed in tables from (1) to (3). and figures (2) and (3)

Depth (m)	legend of borehole ■	end of layer	S.P.t or%Rec	un confined QUKN/m²	Description
1					
2		2			Silty sand and trace of clay
3					
4		4			Silty sand
5					
6					
8					
10		12	12	100	medium stiff clay
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22		30	33		dense sand
23					
24					
25					
26					
27					
28					
29					
30					

Fig. (1): Borehole Log

N0.	Number of piles	pile diameter (m)	The contact of the raft with the soil	Length Of the piles	Pile spacing	Raft Thickness (m)
1				28D		
2 3 4	25	0.5	Rested on the soil	32D 36D 40D	4.5D	1
5				28D 32D 36D 40D		
6			The raft			
7			act as a			
8	25	0.5	slab connected		4.5D	1
			the piles			

Table (2): Properties For Soil Layers

Parameters	Name	Silty sand and traces of clay	Silty sand	Medium to stiff clay	dense sand	unit
Material model	-	**Moher column**	**Moher column**	**Moher column**	**Moher column**	-
Thickness	T	2	2	8	18	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	-
Raft thickness (m)	-	1
Unit weight (kN/m3)	25	25
young's modulus Es (kN/m2)	24*10^6	24*10^6
Poisson ratio (υ)	0.2	0.2

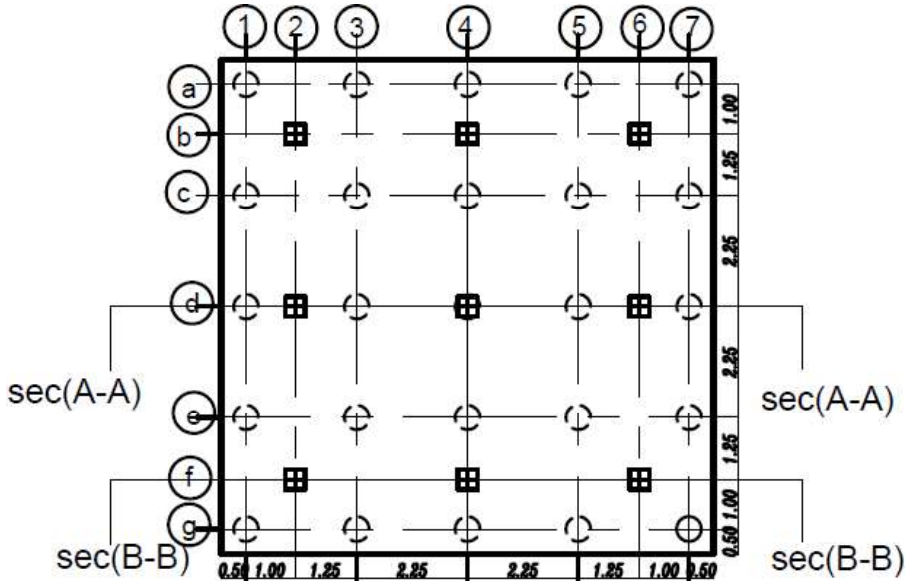


Fig (2) plane of piled raft foundation

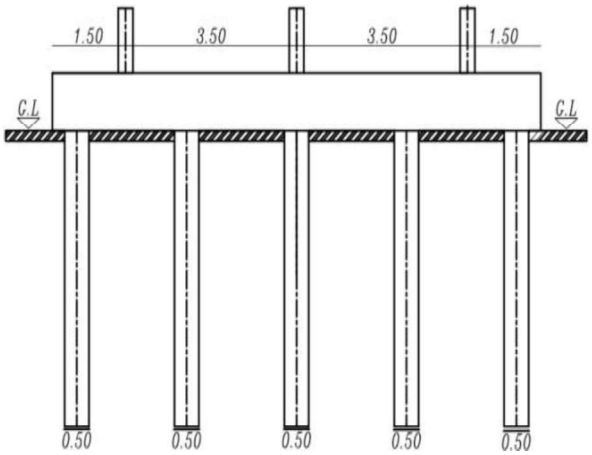


Fig (3) Cross section of piled raft foundation rested on the soil

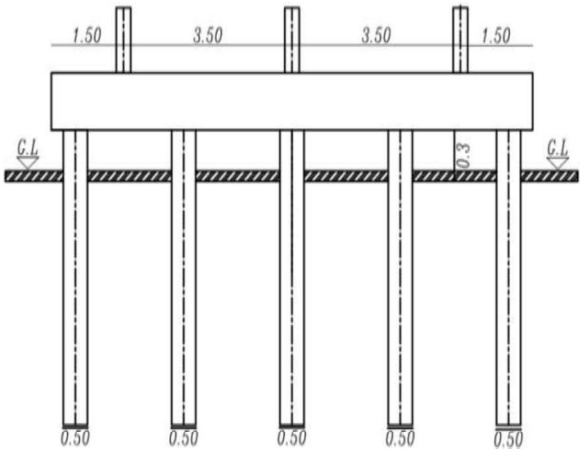


Fig (4) Cross section of piled raft foundation as raft act as slab connected the piles

Finite element model:

Figures (3) and (4) show the cross sections of the piled raft in the two cases rested on the soil and the raft act as a slab connected the piles (Lp=32D, D =0.5 m Sp =4.5D)

3 -Parametric study

The effect of pile length on the following:

i. The settlement of piled raft
ii. The bending moment on the raft
iii. The shear force on the raft

4. 1. Finite Element Results:

The obtained results of selected examples for different cases are shown in figures (6 to 17) as follows:

Figure (6) and (7) shows the bending moment on the raft in the two cases rested on the soil and the raft act as a slab connected to the piles from the soil (Lp = 32D, D = 0.5 m, and Sp =4.5D).

Figures (8) and (9) show the vertical displacement of the soil under the raft in the (x-y) plane (as shading) for the two cases (Lp = 32D, D = 0.5 m, and Sp =4.5D).

Figures (10) and (11) show the vertical displacement of soil under the raft in(x-z) plane (as shading) for the two cases (Lp = 32D, D = 0.5 m, and Sp =4.5D).

Figures (21) and (23) show the shear force on the raft for the two cases (Lp = 32D, D = 0.5 m, and Sp =4.5D

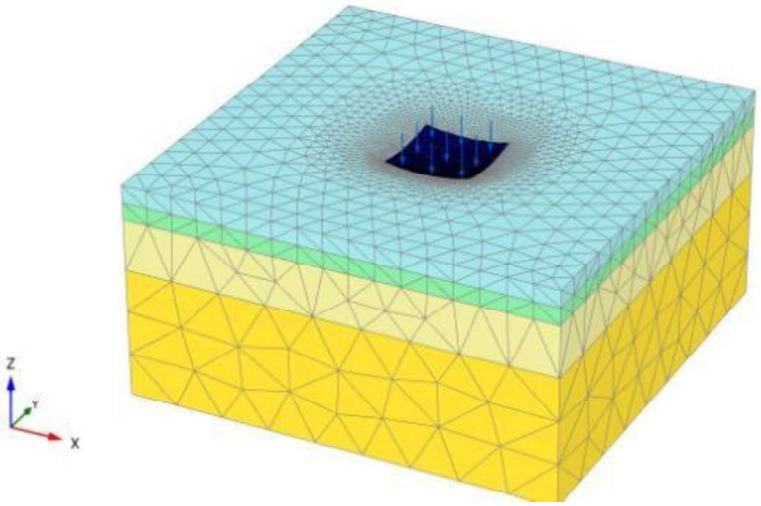
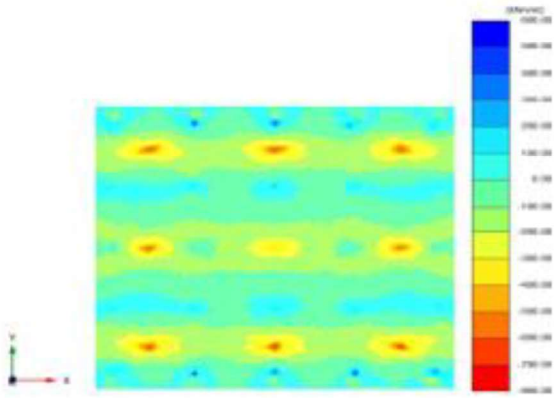


Fig (5) Deformation pattern of the finite element mesh representing the piled raft system with Lp = 16 m.



Fig(8) Bending moment in the soil-contacting piled raft (L_D = 32D)

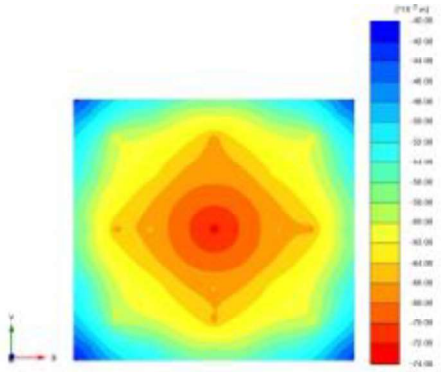
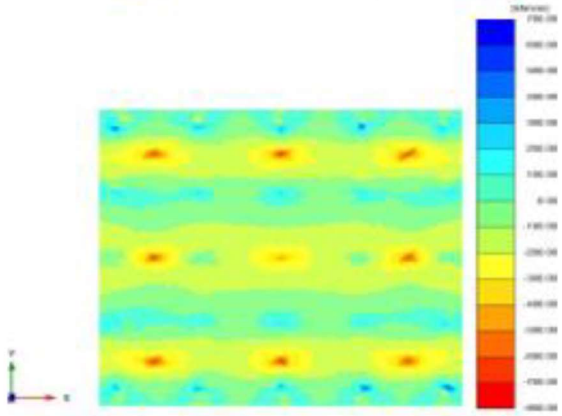
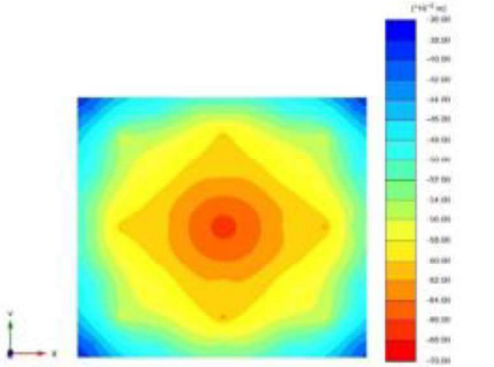


Fig (9) Vertical soil displacement beneath the raft in a soil-contacting piled raft foundation (L_D = 32D)



Fig(7) Bending moment in the pile-connected slab (L_D = 32D)



Fig(8) Vertical soil displacement beneath the raft in a pile-connected slab foundation (L_D = 32D)

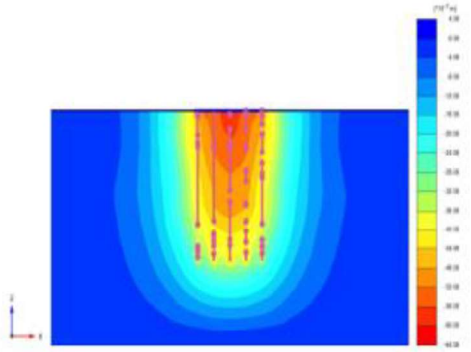


Fig (10) Vertical settlement contours (XZ plane) in the soil for a soil-contacting piled raft foundation (L_D = 32D).

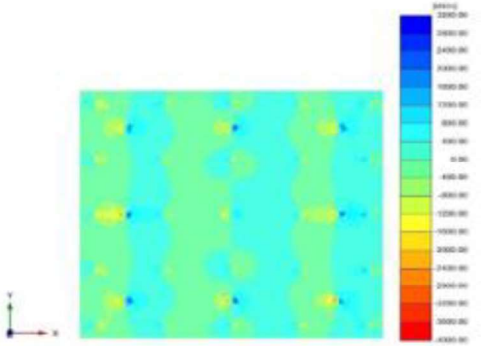


Fig (12) Shear force in the raft for a soil-contacting piled raft foundation (L_D = 32D)

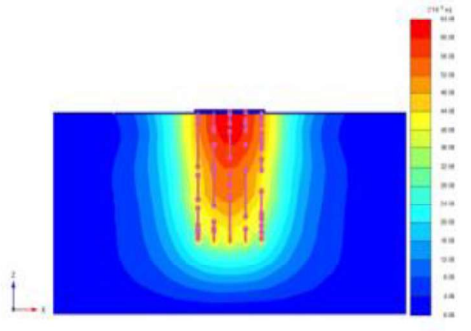


Fig (11) Vertical settlement contours (XZ plane) in the soil for a pile-connected slab foundation (L_D = 32D)

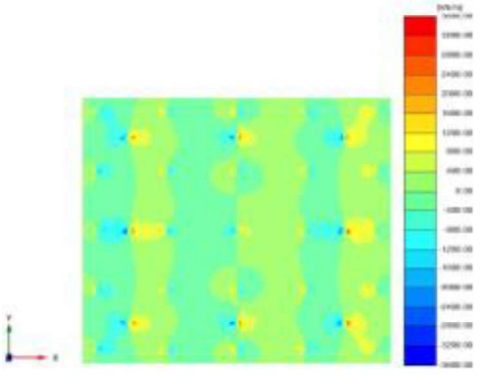


Fig (13) Shear force in the raft for a pile-connected slab foundation (L_D = 32D)

5 m), with raft thickness 1m in sec A from these figures, it can be shown with increasing pile length from 28D to 40 D the shear force on the raft decreased from 1%to0.5% in the case of piled raft rested on the soil and the shear force on the raft decreases from1%to0.5%. in the case of piled raft with raft act as slab connected the pile.

Figures (24), (25) shows the relation between the shear force on the raft in the two cases with various pile lengthwhere Lp = (28D, 32D, 36D, and 40D) for (D = 0.5 m), with raft thickness 1m in sec B .it can be observed that with increasing pile length from 28D to 40D the shear force on the raft decreases from 1%to0.5%. in the case of piled raft rested on the soil and the shear force on the raft decreases from 1%to0.5%. in the case of piled raft with raft act as a slab connected the pile.

Figures (26), (27) and fig (38) show comparison in the settlement, bending moment and shear force between piled raft foundation rested on the soil and piled raft foundation with raft act as slab connected the piles where lp=28D and raft thickness(1m). it can be concluded that the settlement in the piled raft in the case of raft act as slab connected to the piles is greater than the case of rested piled raft by 10%, the bending moment in the raft in the case of a raft act as a slab connected to the piles is greater than the case of a rested piled raft by 7% and the shear force in a raft in the case of a raft act as a slab connected the piles is greater than in the case of a rested piled raft by 2%.

Figures (29), (30) shows the relation between settlement on the raft in the two cases with various pile length = where Lp = (28D, 32D, 36D, and 40D) for (D = 0.5 m), with the effect of dynamic load and static load, with raft thickness 1m in sec A. It can be observed that with increasing pile length from 28D to 40D the settlement decreases 40% in the case of piled raft rested on the soil and settlement decreased 35% in the case of piled raft with raft act as slab connected the pile.

Figures (31) and (32) shows the relation between the bending moment of the raft with the effect of dynamic load and static load, in the two cases with various pile length where Lp = (28D, 32D, 36D, and 40D) for (D = 0.5 m), with raft thickness = 1m in sec A. It can be observed that with increasing pile length from 28D to 40D the bending moment in the raft decrease 29% in the case of piled raft rested on the soil and the bending moment in the raft decreases from 20% in the case of piled raft with raft act as slab connected the pile. Figures (33), (34) shows the relation between the shear force on the raft in the two cases with various pile length where Lp = (28D, 32D, 36D, and 40D) for (D = 0.5 m), with the effect of dynamic load and static load with raft thickness 1m in sec A from these figures, it can be shown with increasing pile length from 28D to 40 D the shear force on the raft decreased 0.5% in the case of piled raft rested on the soil and the shear force on the raft decreases 0.5%. in the case of piled raft with raft act as slab connected the pile.

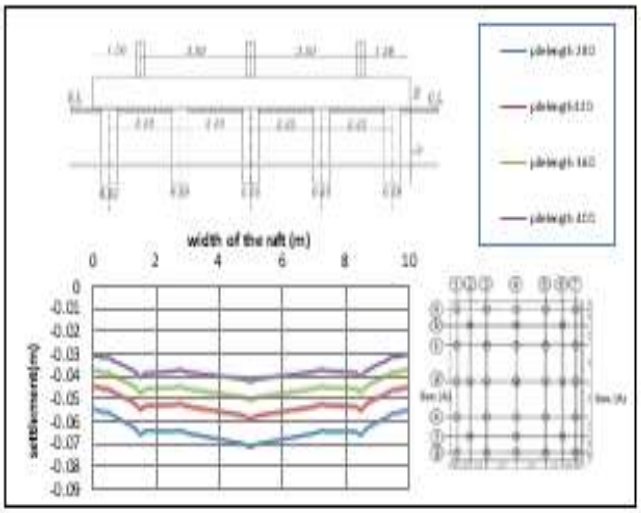


Fig (14) Relationship between pile length and settlement at Section A for a soil-contacting piled raft foundation

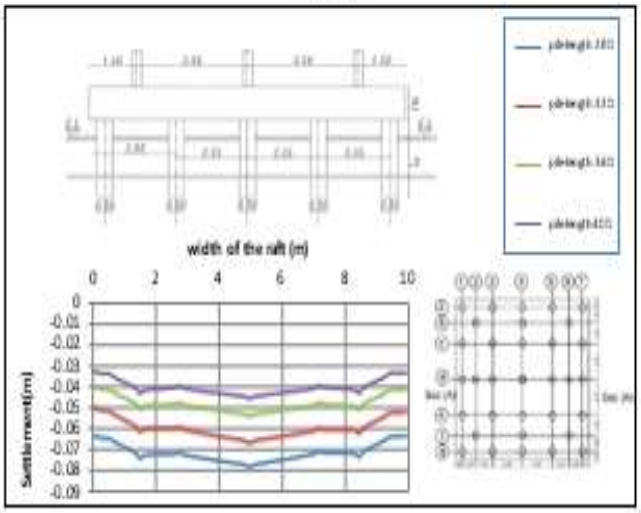


Fig (15) Relationship between pile length and settlement at Section A for a pile-connected slab foundation

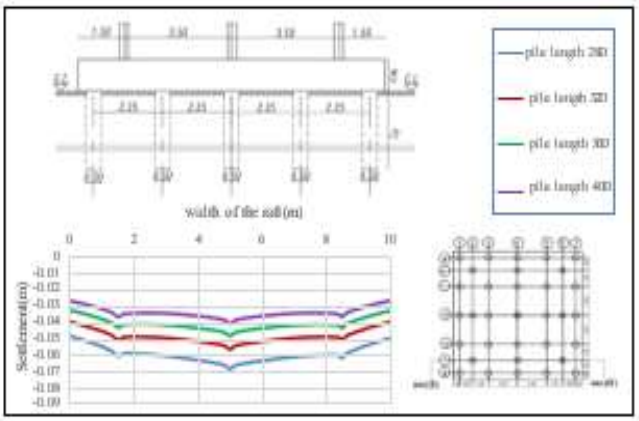


Fig (16) Relationship between pile length and settlement at Section B for a soil-contacting piled raft founda

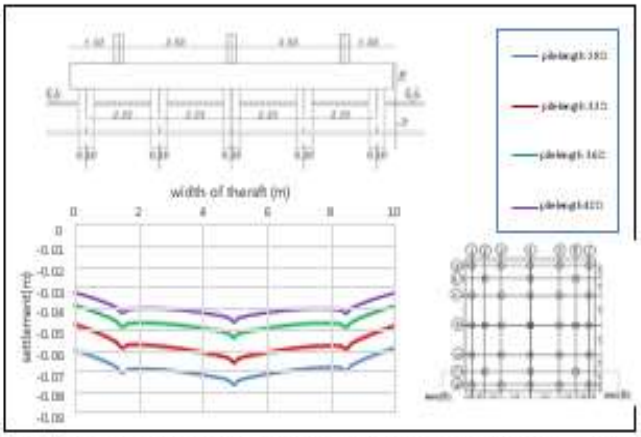


Fig (17) Relationship between pile length and settlement at Section B for a pile-connected slab foundation.

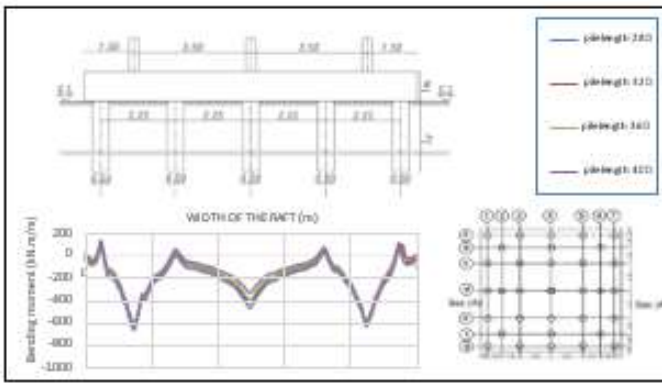


Fig (18) Relationship between pile length and raft bending moment at Section A for a soil-contacting pile foundation.

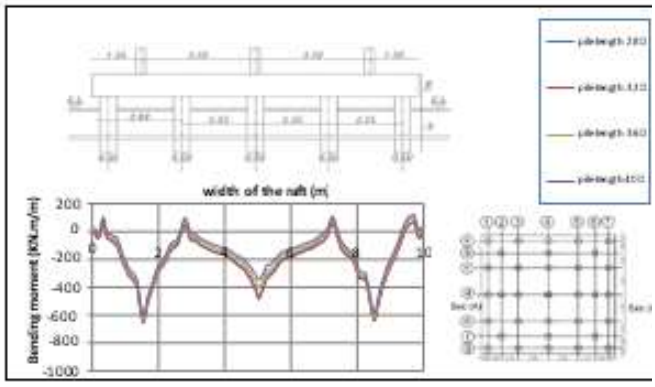


Fig (19) Relationship between pile length and raft bending moment at Section A for a pile-connected slab foundation.

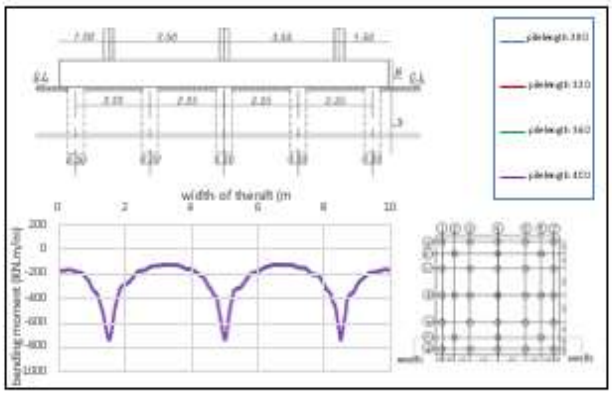


Fig (20) Relationship between pile length and raft bending moment at Section B for a soil-contacting piled raft foundation

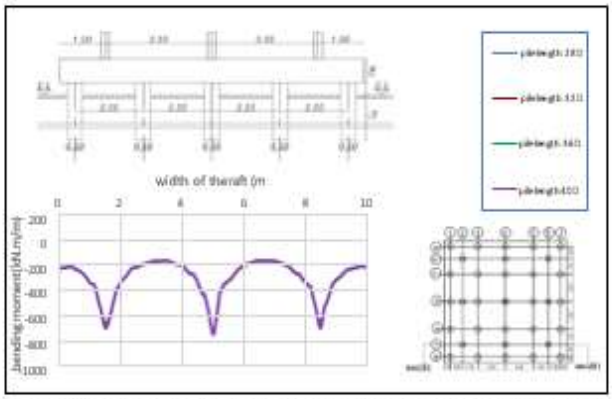


Fig (21) Relationship between pile length and raft bending moment at Section B for a pile-connected slab foundation.

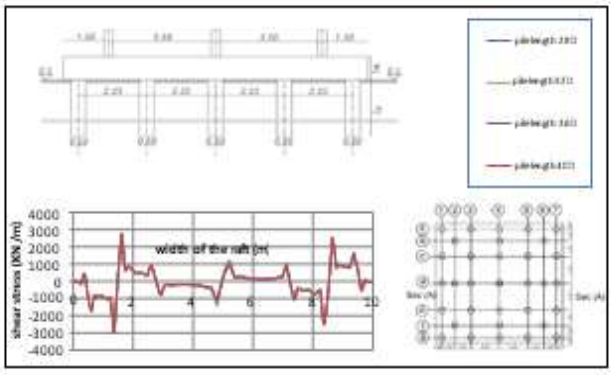


Fig (22) Relationship between pile length and raft shear force at Section A for a soil-contacting piled raft foundation

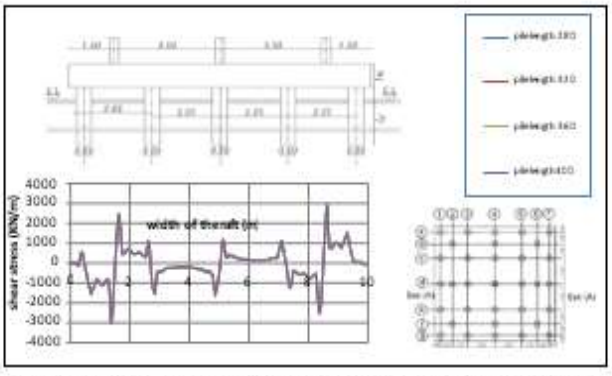


Fig (23) Relationship between pile length and raft shear force at Section A for a pile-connected slab foundation.

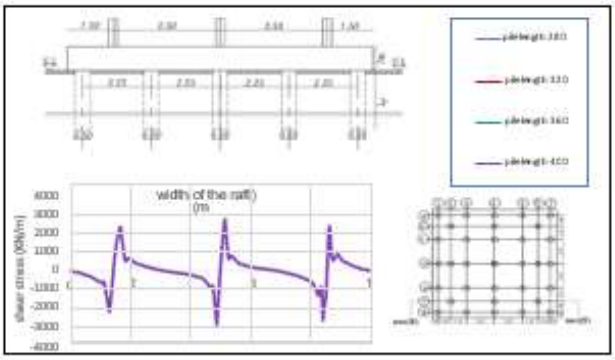


Fig (24) Relationship between pile length and raft shear force at Section B for a soil-contacting piled raft foundation.

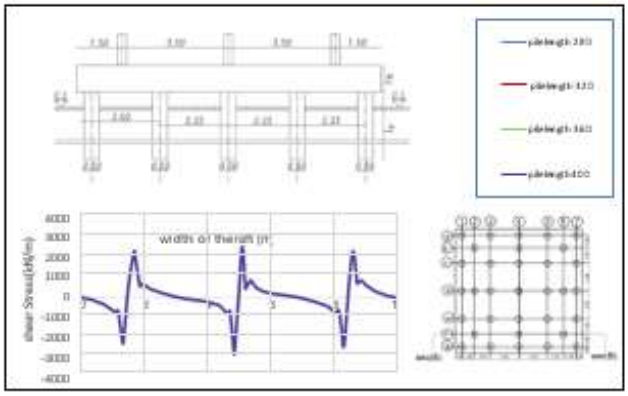


Fig (26) Relationship between pile length and raft shear force at Section B for a pile-connected slab foundation.

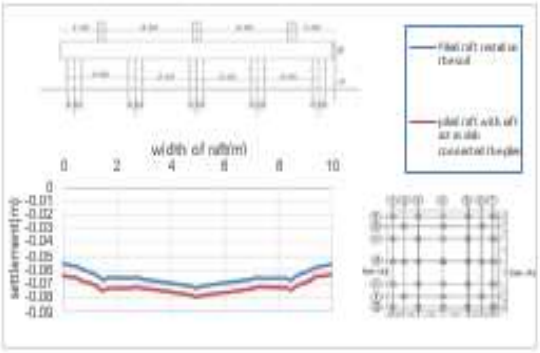


Fig (28) Settlement comparison: soil-contacting piled raft foundation vs. pile-connected slab foundation.

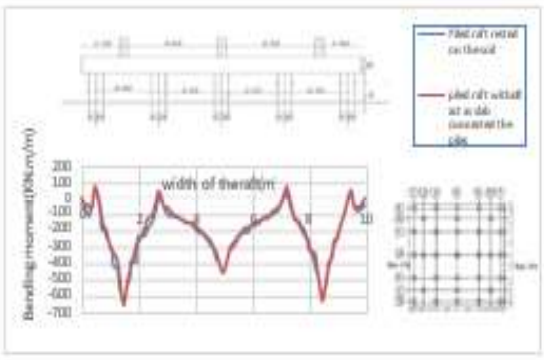


Fig (27) Bending moment comparison in the raft: soil-contacting piled raft foundation vs. pile-connected slab foundation.

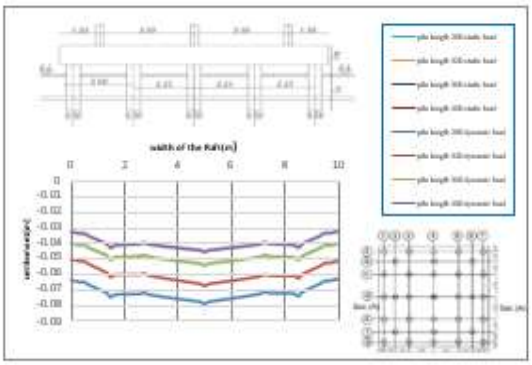


Fig (30) Relationship between pile length and settlement at Section A for a pile-connected slab foundation under static and dynamic load

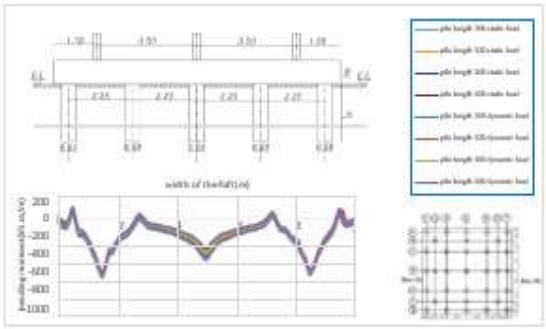


Fig (31) Relationship between pile length and raft bending moment at Section A for a soil-contacting piled raft foundation under static and dynamic load

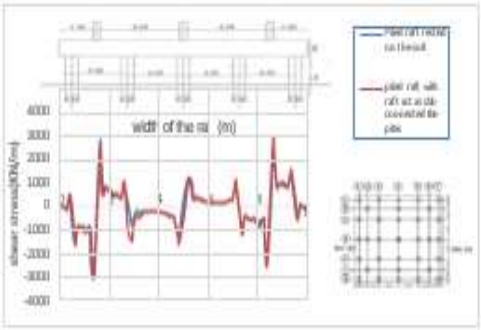


Fig (28) Shear force comparison in the raft: soil-contacting piled raft foundation vs. pile-connected slab foundation.

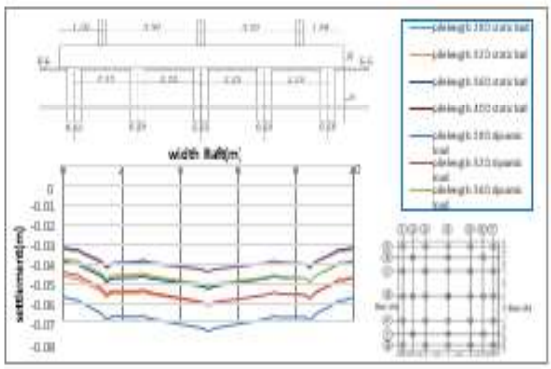


Fig (29) Relationship between pile length and settlement at Section A for a soil-contacting piled raft foundation under dynamic load

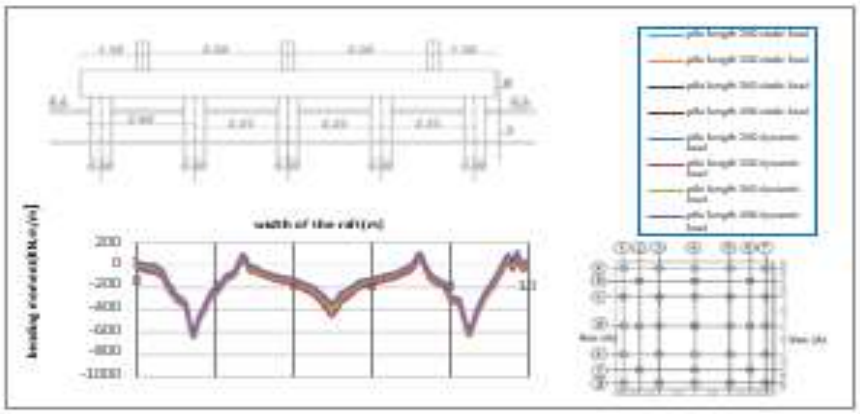


Fig (32) Relationship between pile length and raft bending moment at Section A for a pile-connected slab foundation under static and dynamic load

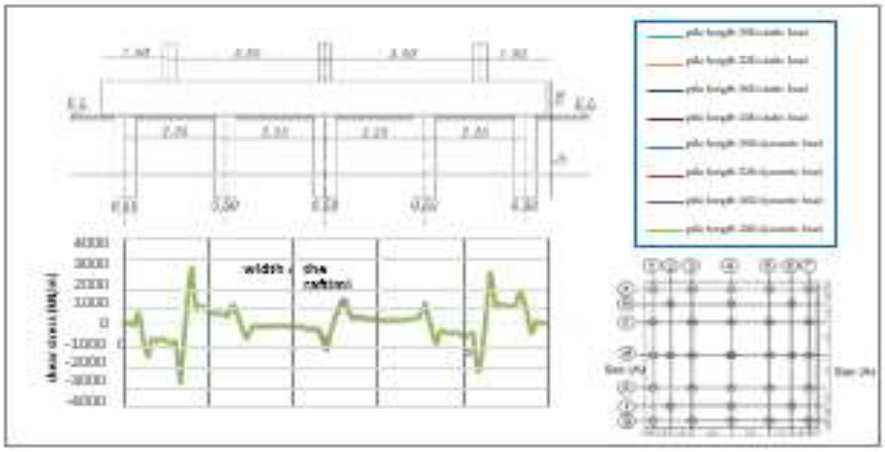


Fig (33) Relationship between pile length and raft shear force at Section A for a soil-contacting piled raft foundation under static and dynamic load

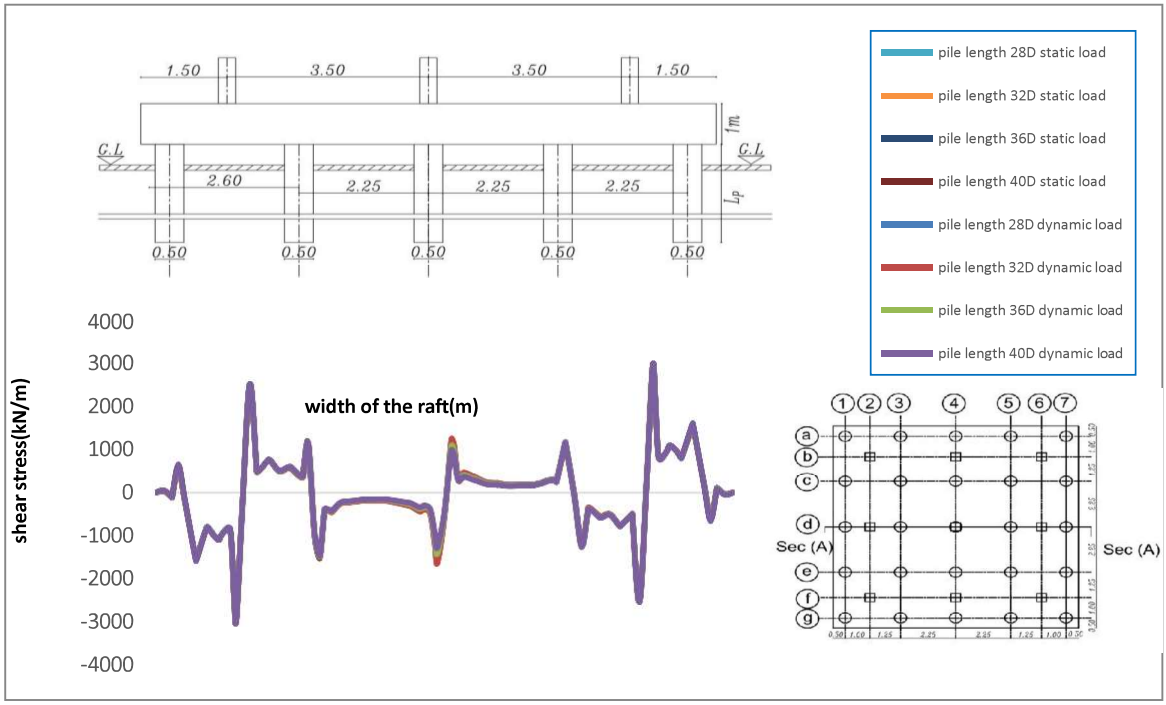


Fig (34) Relationship between pile length and raft shear force at Section A for a pile-connected slab foundation under static and dynamic load

Conclusions:

From the present study, the followings are concluded:

1. In the case of rested piled raft increasing pile length leads to
- The bending moment in the raft decreases 29%
- The settlement decreases 40 % of piled raft foundation
- the shear force in the raft decreases from to 0.5%

2. In the case of a raft act as a slab connected the piles increasing pile length leads to
- The bending moment in the raft decreases 20%
- The settlement decreases 35 % of piled raft foundation
- the shear force in the raft decreases 0.5%

3. The comparison between the two cases piled raft rested on the soil and piled raft act as a slab connected the piles

The bending moment in the raft in the case of a raft act as a slab connected to the piles is greater than the case of a rested piled raft
- by 10 %
- the settlement in the piled raft in the case of raft act as slab connected to the piles is greater than the case of rested piled raft by 7%
- The shear force in a raft in the case of a raft act as a slab connected the piles is greater than in the case of a rested piled raft by 2%

4. The effect of pile length with dynamic force

In the case of rested piled raft increasing pile length leads to
- The bending moment in the raft decreases 29%
- The settlement decreases 40 % of piled raft foundation

5.the shear force in the raft decreases from 0.5% In the case of a raft act as a slab connected the piles increasing pile length leads to
- The bending moment in the raft decreases 20%
- The settlement 35 % of piled raft foundation
- The shear force in the raft decreases 0.5%.