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Analysis of Load Sharing on Pile Raft Foundation under Eccentric Loads

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Abstract: The present study is mainly based on the determination of the effect of lateral loads on load sharing between piles and soil and distribution of stress under soil before and after redistributed of load from soil to pile under six piles their diameters are fixed (D=0.6 m) and the spacing between piles are various (Sp =3D, 4D, 5D and 6D) and their length are various (Lp=34D, 36D, 38D and 40D). The pile-raft foundation subjected to horizontal load equal (10%) of the vertical load. Also, the values of dynamic loads from time history (El-centro earth quake). Raft on piles the thickness of raft is (t=1.0D). Finite element package of a PLAXIS 3D version 2013. (a finite element code for soil and rock analysis) has been used to determine the Stress under pile and soil before and after redistribution of load on pile from soil, percentage load carried by pile and soil, settlement under piles and distribution of load among pile length. It was found that the load on pile due to lateral force increase by increasing length of pile and decreases by increasing pile spacing and at Sp≥5D there is no effect on load on pile.
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Keywords: Analysis; Load; Sharing; Pile; Raft; Foundation; Eccentric

1-Introduction:

Almost all piled foundations are subjected to at least some degree of horizontal loading. The magnitude value of horizontal load compared to vertical axial load is generally very small and there are no additional design calculations will normally be necessary. The sharing load between the raft and piles for piled raft foundation is affected by a number of different factors but to a varying degree.

Some Researches about load sharing between pile and soil in piled-raft foundation

Hooper (19*73)* studied the pile-raft footing behavior supporting a tower block in London. The field measurements which took along several years were accompanied with the results of a finite element analysis. It was found that the long-term effect of consolidation increases the part of load which carried by piles and decreases raft contact pressure.

Akinmusuru (1980) studied the effect of pile length and raft geometry on the piled raft load sharing. Experimental results on a single piled raft unit revealed that the raft share increases extensively by enlarging the raft width, whereas the pile length has inconsiderable impact on the load sharing.

Muthukkumaran, K. et al. (2004) introduced the load transferred from a bored cast – in – situ pile socketed 1.5 m into hard rock, instrumented with electrical resisting type strain gauges. The pile was 1.4 m diameter and 18.8 m length. The pile was tested up to 1.5 times the design load. The total settlement 3.907 mm, rebound 3.595 mm and net settlement 0.312 mm. The maximum load is mobilized at the depth from -6.87 m to -9.90 m level. Nearly 400 t load was mobilized in weathered rock layers, 200 t mobilized in hard rock layer and 200 t mobilized in the top layer of moorum fill strata of total applied load of 900 t. For the end bearing only 100 t load was taken by the hard rock. The results were clearly show that the maximum load is shared by the frictional resistance than end bearing resistance.

Chow, H.S.W. et al. (2006) analyzed the Pile-raft behavior subjected to horizontal and vertical loadings has been of particular interest in foundation engineering. Several researchers studied the effect of vertical loading but the effect of horizontal loadings has not received much attention.

Finite method is used for the analysis of piled rafts. The behavior of piled rafts supported by piles of different lengths will be examined when the raft is subjected to both vertical and horizontal loads.

El Sawwaf (2010) performed an experimental investigation to study the effects of pile length, number of piles, relative density of sand, and load eccentricity on the load settlement behavior of piled raft. It was investigated that the efficiency of the piled raft system depends on the load eccentricity ratio, pile arrangement and relative density; increasing the number of piles could only lead to reduction of settlement until reaches a certain value.

Poulos, H.G. et al. (2011) presented some principles for designing foundation. The advantages of using a piled raft will then be described with respect to two cases: a small pile group subjected to lateral loading, and then the design of the Incheon Tower in South Korea. Attention will be focused on the improvement in the foundation performance due to the raft being in contact with, and embedded within, the soil.

Kiyoshi, Y. et al. (2014) studied the behavior of sharing load between raft and piles based on the monitoring of eleven structures. For three of the structures, foundation behavior during the Tohoku Earthquake was monitored. No changes in sharing load were noticed after the earthquake for the investigated buildings and the load carried by piles ratio to the effective load decreased when pile spacing increased.

Hegazy, A. A. (2016) studied the effect of lateral load on pile-Raft foundation. A method for the analysis of piled-raft foundations using three-dimensional finite element (FLAC-3D). However, needing to studding the behavior of pile raft foundation under lateral loads doesn't take more attention in most researcher.

El-samny et al [(2017)-a] investigated the ultimate capacity, settlement and efficiency of pile groups in sandy soil. An experimental program was conducted to study the group efficiency. However, the experimental program consisted of testing single pile, pile groups of two, three and four piles in sand under axial compression load. The spacing between piles kept three diameters of piles. It was found that group efficiency of pile groups (2, 3 and 4 piles) increases with increasing number of piles.

El-samny et al. [(2017)-b] investigated the load shearing between soil and pile raft cohesion-less soil. An experimental program was conducted to study the distribution of applying loads at the lower parts of founded soil as well as pile raft. However, the experimental program consisted of testing single pile, pile groups of two, three, four, five and six piles in sand under axial compression load. It was found that the percentage of the transferred load of single pile at pile tip = 13.5% from the ultimate capacity.

El-samny et al. [(2017)-c] investigated theoretically and experimentally the settlement of single pile and pile groups. An experimental program was conducted to study the settlement of pile-raft. It was found that the settlement increases with increasing the number of piles. The values of settlement were obtained from theoretical calculations greater than the values those obtained from experimental program.

El-samny et al. (2018) studied the effect of group efficiency as well as the load distribution of the friction along the pile shaft the load transferred to the tip of the pile and load transferred to soil underneath pile cap in pile groups in cohesion less soil have been presented. Three groups of testing were performed in axial compression. First group load test was carried out on single.

El-samny et al. (2020) presented the effect of pile length on load sharing between piles and soil and distribution of stress under soil before and after redistributed of load from soil to pile. Finite element package of a PLAXIS 3D version 2013. (A finite element code for soil and rock analysis) has been used. It was found that Pile Length have a great effect on load sharing as increasing pile length increase load carries by pile.

El-samny et al. (2020) studied effect of spacing between piles and load underneath pile cap. Furthermore, the distribution of load on pile after redistributed of load from soil. The program consisted of installing four piles (Lp=1.5m, D=0.15 m) with various spacing where (Sp=3D, 4D, 5D and 6D) and the piles supported a square steel plate (1.20 X1.20) m and the plate support I-beam to ensure the load distributed uniformly from the hydraulic jack to piles in dense compacted sand placed in a soil chamber, and subjected to compressive axial load.

2-Finite element analysis:

The used computer program for proposal a three-dimensional finite element model in order to simulate theoretically effect of spacing between piles on pile raft foundation is a finite element package of a PLAXIS 3D version 2013. (A finite element code for soil and rock analysis).

2.1. Numerical program:

In the present study, a theoretical analysis has been done for a selected site (in governmental project in Semesta, Beni-suef, Governorate, Egypt. Fig. (1) illustrates a borehole for the pervious site was chosen to be used in the analysis. The soil consists of six layers and simulated by a semi-infinite element isotropic homogenous elastic material.

The analysis program consists of pile-raft foundation consists of Six piles their diameters are fixed (D=0.6m) and the spacing between piles are various (Sp =3D, 4D, 5D and 6D) and their length are various (LP=34D, 36D, 38D and 40D). The piles subjected to horizontal load equal (10%) of the vertical load. Also, the values of dynamic loads from time history (El-centro earth quake). Raft on piles: the thickness of the raft is fixed (t=1.0D).

The details and variation of these selected parameters are listed in tables from (1) to (4). And figure (2). The ultimate capacity of pile used in this study and analysis has been estimated through theoretical method by using Meyerhof (1976). The theoretical ultimate capacity for the single pile (Qu) is 1000 kN, However, the total applied load (P) is 6000kN. Thus, the number of piles is six piles.

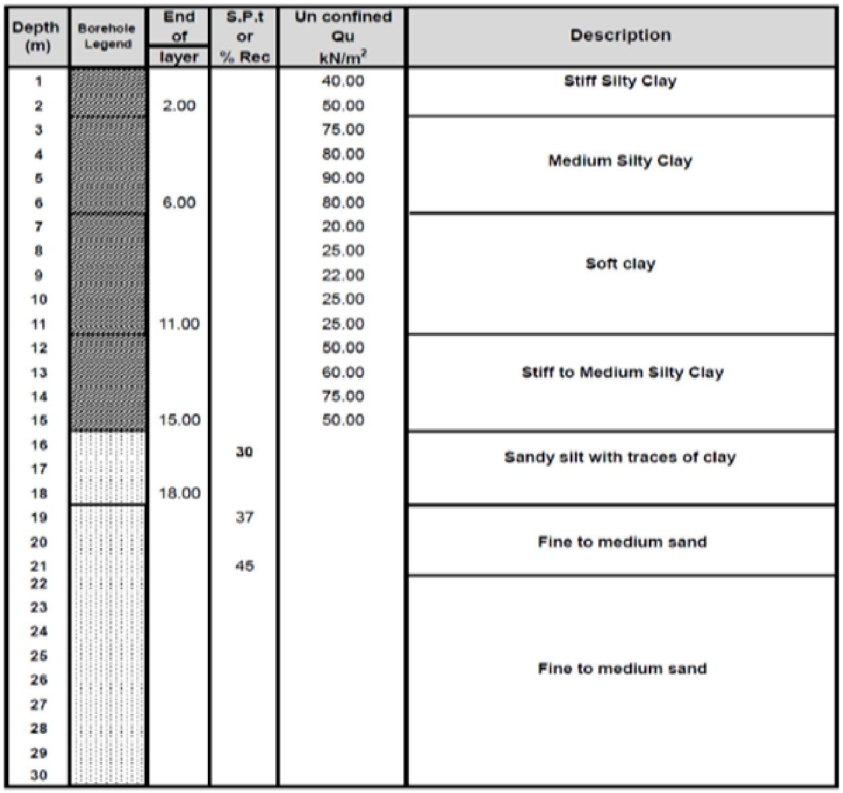

FIG. (1) BOREHOLE LOG FOR SOILUSED SESMETA, BENI-SUEF GOVERNORATE, EGYPT PROJECT

Table (1) Investigated cases of study

N0.	Number of piles	pile diameter (m)	Length of piles	Pile spacing	Raft thickness
1	6	0.6	34D	3D	1.0D
2			36D	4D	
3			38D	5D	
4			40D	6D	

TABLE (2) DISTANCE OF ECCENTRIC LOAD IN X-DIRECTION AND RAFT DIMENSION

Pile Spacing				centroid of piles raft	Raft dimension (cm)	Eccentricity from CG in X-direction (cm)			
Sp	SY (cm)	SX1 (cm)	SX2 (cm)	CG (cm)	R. D	Ec 5%	Ec 10%	Ec 15%	Ec 20%
3D	180	180	180	180	(480 X300X60)	12	24	36	48
4D	240	240	240	240	(600 X360X60)	15	30	45	57
5D	300	300	300	300	(720 X420X60)	18	36	54	72
6D	360	360	360	360	(840 X480X60)	21	42	57	78

TABLE (3) PROPERTIES FOR SOIL LAYERS

Parameters	Name	Stiff silty clay	Medium silty clay	Soft Clay	Stiff to medium silty clay	Sandy silt with traces of clay	Fine to medium sand	unit
Material model	-	Moher column	Moher column	Moher column	Moher column	Moher column	Moher column	-
Thickness	T	2	4	5	4	3	12	m
Young' s modulus	Es	5000	4000	2000	4500	7500	15000	kN/m2
Unit weight	ɣ	16.65	16.35	15.65	16.55	17	17.5	kN/m3
Poisson ratio	υ	0.25	0.3	0.3	0.3	0.3	0.25	-
Cohesion	c	50	40	12.5	25	25	0	kN/m2
Friction angle	Ø	0	0	0	25	25	30	°

TABLE (4) PILE AND RAFT PROPERTIES

Parameters	**Pile**	**Raft**
Material model	Elastic	Elastic
Types of material	Concrete	Concrete
Diameter (m)	0.6	0.6
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
Cohesion (Cu) (kN/m2)	-	-
Friction angle (Ø) (°)	-	-

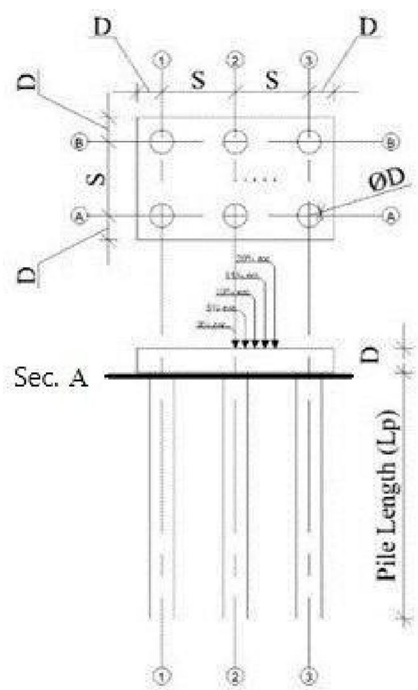

FIG. (2) CROSS SECTION OF SIX PILED-RAFT FOUNDATION MODEL SUBJECTED TO DIFFERENT ECC. LOAD

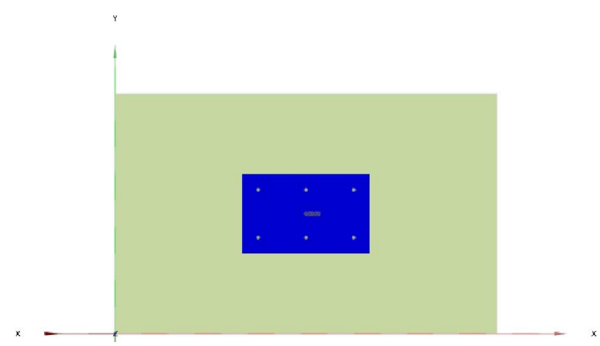

FIG. (3) PLAN IN 2-D FOR SIX PILES WITH RAFT (LP=34D, SP=3D, D=0.6 M)

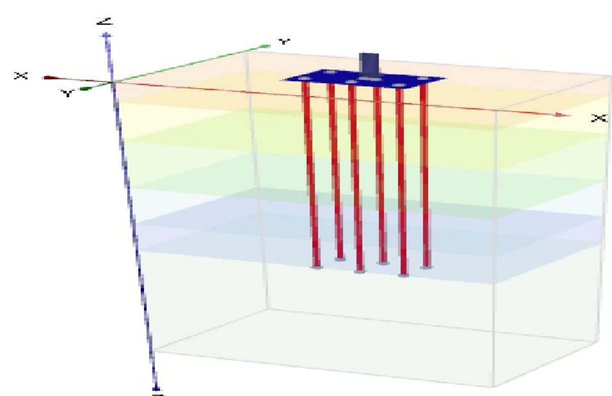

FIG. (4) PLAN IN 3-D FOR SIX PILES WITH RAFT (LP=34D, SP=3D, D=0.6 M)

2.2. Finite element model:

Figures (3) and (4) show the plan in 2-D and 3-D for a selected example for the model of Six piles (LP=34D, D=0.6 m Sp=3D).

3-Therotical Results:

The theoretical results involve the followings:

i. Deformed mesh of the soil.
ii. Settlement under piles.
iii. Distribution of load among pile.

3. 1. Finite Element Results:

The obtained results of selected examples for different cases are shown in figures (5 to 14) as follows:

Figure (5) shows the deformed mesh for six piles (Lp=34D, D=0.6 m Sp=3D)

3-Therotical Results:

The theoretical results involve the followings:

The obtained results of selected examples for different cases are shown in figures (6 to11) as follows:

Figures (6) and (7) show the vertical displacement (settlement) as shading and contour for six piles (Lp=34D, D=0.6 m sp=3D).

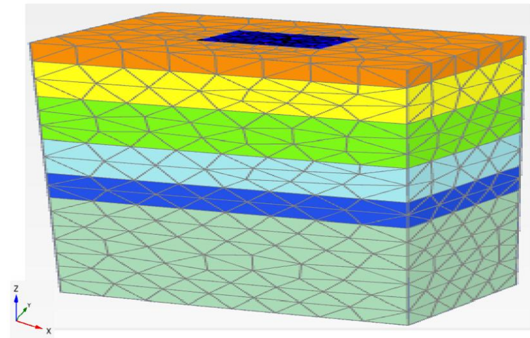

FIG. (5) DEFORMED MESH FOR SIX PILES IN 3-D WITH RAFT (LP=34D, SP=3D, D=0.6 M)

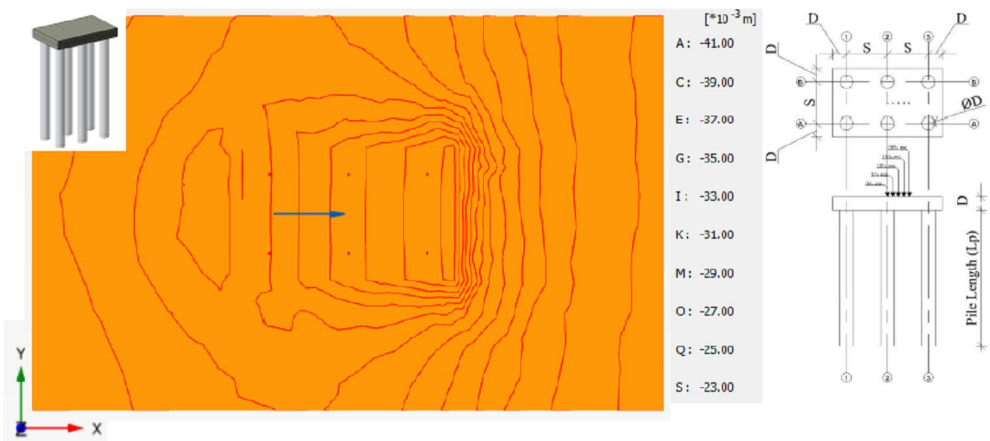

FIG. (6) VERTICAL DISPLACEMENT AS CONTOUR FOR SIX PILES IN 2-D WITH RAFT (LP=34D, SP=3D, D=0.6 M)

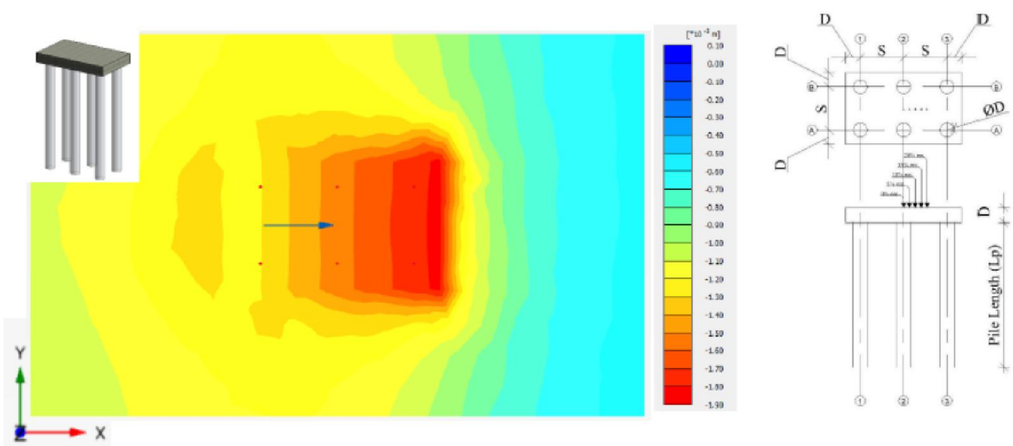

FIG. (7) VERTICAL DISPLACEMENT AS SHADING FOR SIX PILES IN 2-D WITH RAFT (LP=34D, SP=3D, D=0.6)

Figures (8) and (9) show the horizontal displacement in X and Y direction as shading for six piles (LP=34D, D=0.6 m Sp=4D).

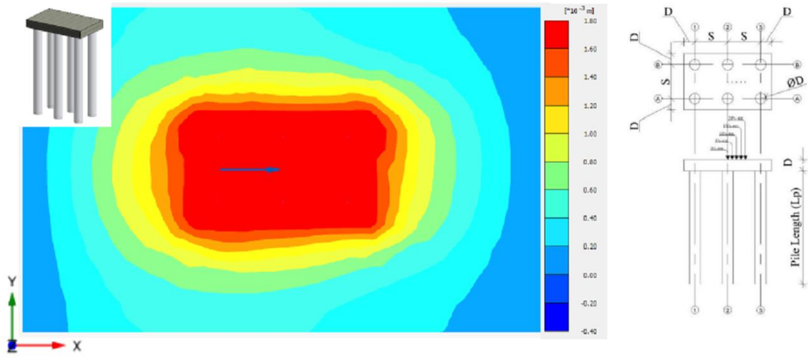

FIG. (8) HORIZONTAL DISPLACEMENT IN X-DIRECTION AS SHADING FOR SIX PILES IN 2-D WITH RAFT (LP=34D, SP=3D, D=0.6)

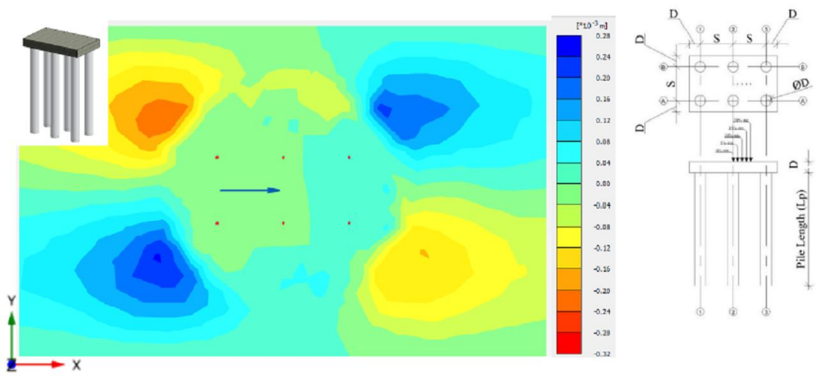

FIG. (9) HORIZONTAL DISPLACEMENT IN Y-DIRECTION AS SHADING FOR SIX PILES IN 2-D WITH RAFT (LP=34D, SP=3D, D=0.6)

Figures (10) and (11) show the vertical displacement (settlement) as shading and contour under sec (A-A) at (Sp= (3D) (LP=34D, D=0.6 m).

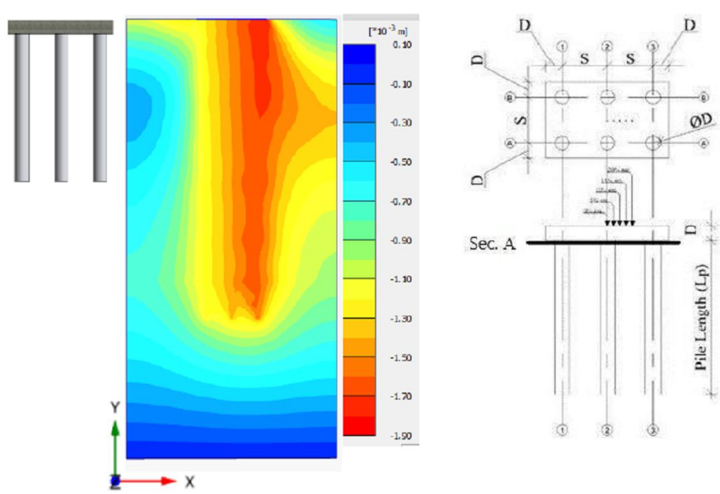

FIG. (10) VERTICAL DISPLACEMENT AS SHADING UNDER SEC (A-A) IN 2-D WITH RAFT (LP=34D, SP=3D, D=0.6 M)

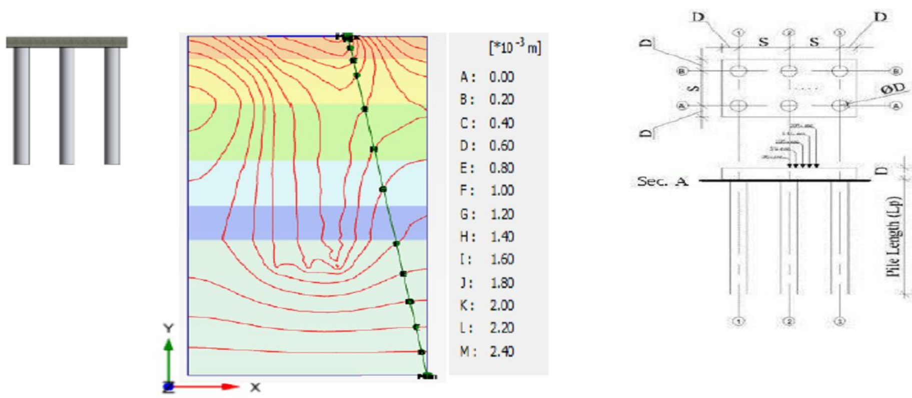

FIG. (11) VERTICAL DISPLACEMENT AS SHADING SEC (A-A) IN 2-D WITH RAFT (LP=34D, SP=3D, D=0.6 M)

3. 2. Theoretical Analysis:

Figures from (12 to 15) show the relation between max stress and eccentric loads where (Ecc. =0%,5%,10%,15% and 20%) under sec. (A-A) for various pile length where (Lp=34D,36D,38D and 40D). From these figures, it can be shown that increasing the eccentricity in X-direction has no significant effect by increasing pile length if Ecc.< 10% and Lp ≥36D

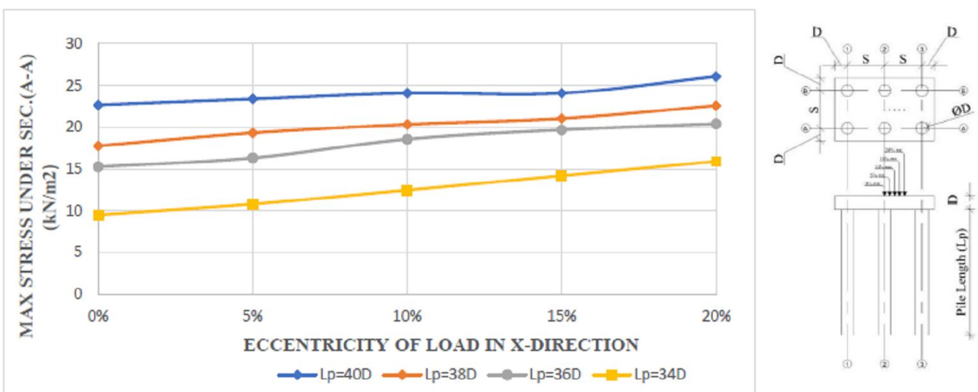

FIG. (12) THE RELATION BETWEEN MAX STRESS UNDER SEC. (A-A) AND ECCENTRIC LOADS IN X-DIRECTION FOR DIFFERENT PILE LENGT H (SP=3D, D=0.6 M)

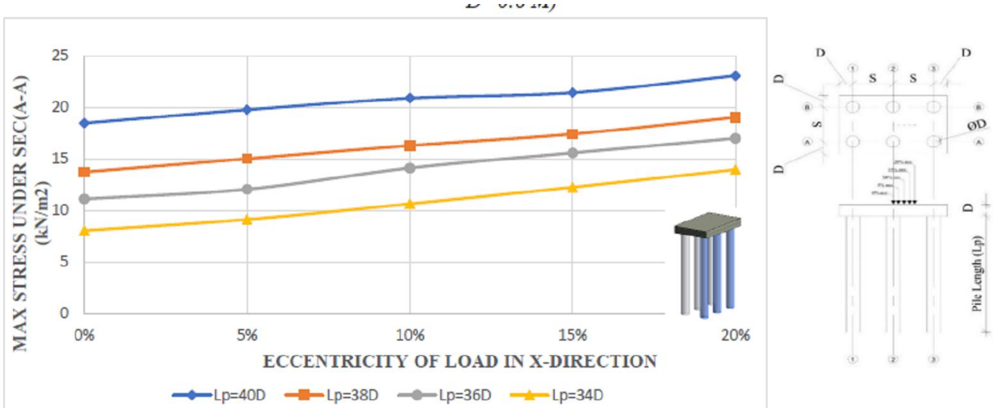

FIG. (13) THE RELATION BETWEEN MAX STRESS UNDER SEC. (A-A) AND ECCENTRIC LOADS IN X-DIRECTION FOR DIFFERENT PILE LENGTH (SP=4D, D=0.6 M)

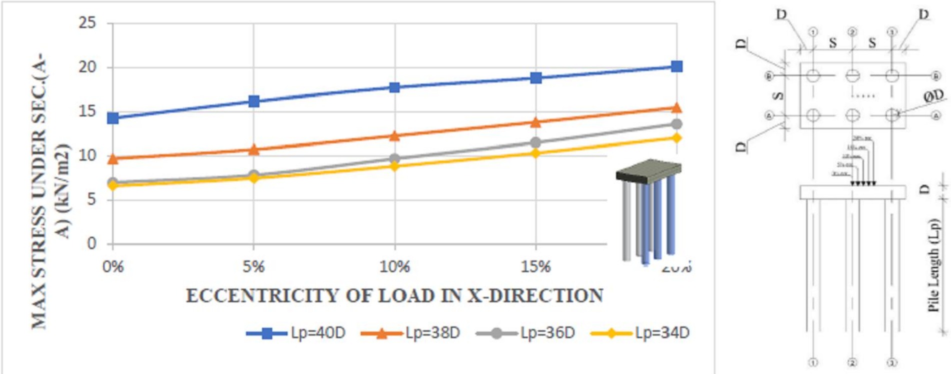

FIG. (14) THE RELATION BETWEEN MAX STRESS UNDER SEC. (A-A) AND ECCENTRIC LOADS IN X-DIRECTION FOR DIFFERENT PILE LENGTH (SP=5D, D=0.6 M)

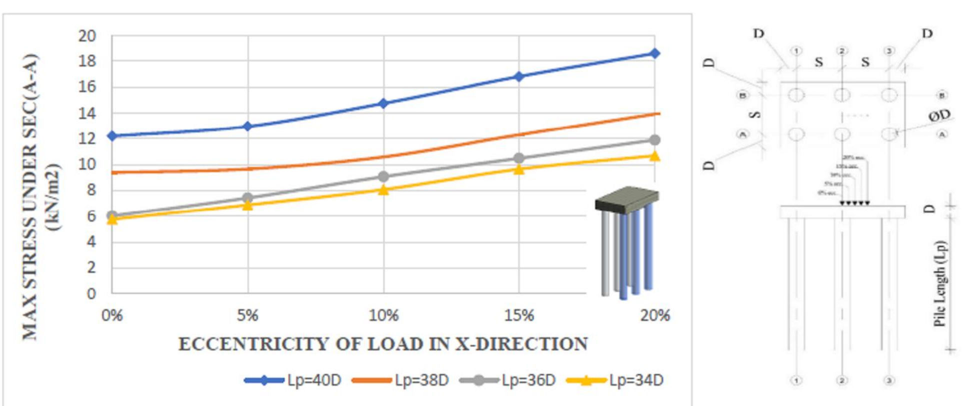

FIG. (15) THE RELATION BETWEEN MAX STRESS UNDER SEC. (A-A) AND ECCENTRIC LOADS IN X-DIRECTION FOR DIFFERENT PILE LENGTH (SP=6D, D=0.6 M)

Figure (16) shows the relation between max stress and eccentric loads where (Ecc. =0%, 5%, 10%, 15% and 20%) under sec. (A-A) for various pile spacing where (Sp= 3D, 4D, 5D and 6D). From these figures, it can be shown that increasing the eccentricity in X-direction has no significant effect by increasing pile spacing if Sp≥ 4D and Ecc. < 10%.

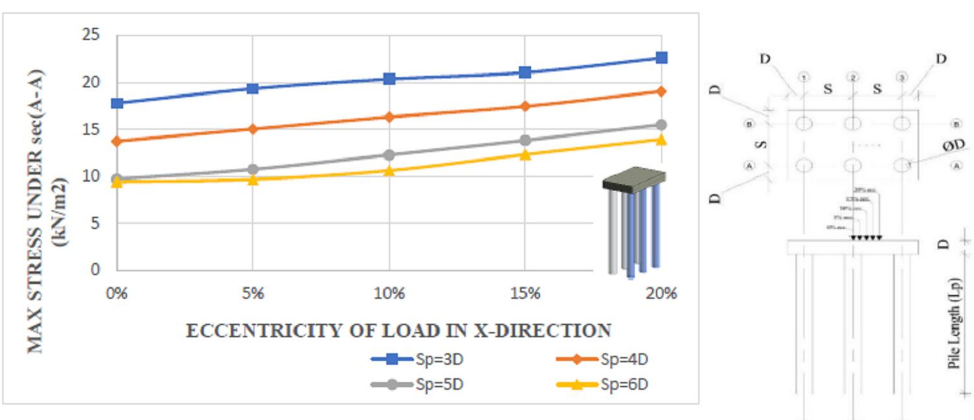

FIG. (16) THE RELATION BETWEEN MAX STRESS UNDER SEC. (A-A) AND ECCENTRICITY IN X-DIRECTION FOR DIFFERENT PILE SPACING (Lp=34D, D=0.6 M)

Figures (17) and (18) show the relationship between the distance and distribution of stress under sec. (A-A) at different eccentricity in X-direction for (D=0.6 m, Sp= 5D) and various length of pile (LP=36D and 38D).

From these figures, it can be shown that increasing eccentricity in X-direction has no significant effect in stresses.

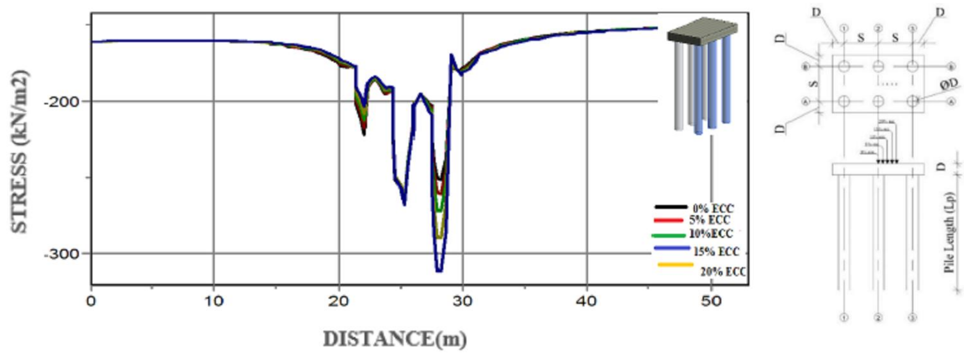

FIG. (17) THE RELATION BETWEEN STRESS AND DISTANCE ALONG SEC (A-A) FOR DIFFERENT ECCENTRICITY AT (LP=36D, SP=5D, D=0.6 M)

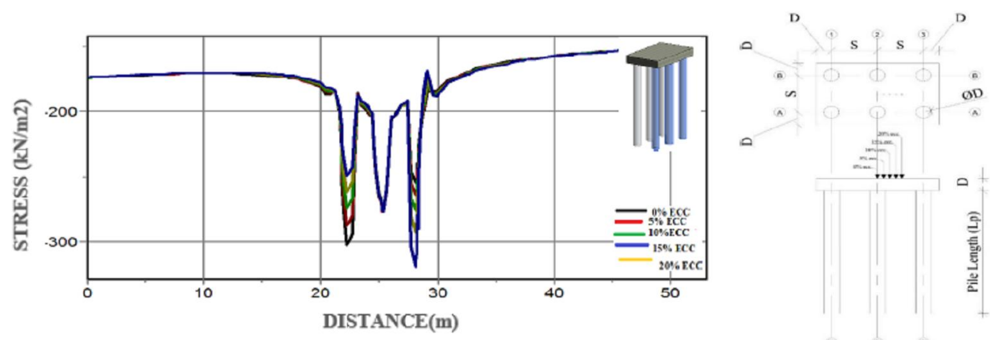

FIG. (18) THE RELATION BETWEEN STRESS AND DISTANCE ALONG SEC (A-A) FOR DIFFERENT ECCENTRICITY AT (LP=38D, SP=5D, D=0.6 M)

Figures (19) and (20) show the relationship between settlement under sec. (A-A) and eccentricity in X-direction for (D=0.6 m), various length of pile (Lp= 34D,36D,38D and 40D) and various spacing where Sp= (3D,4D,5D and 6D)

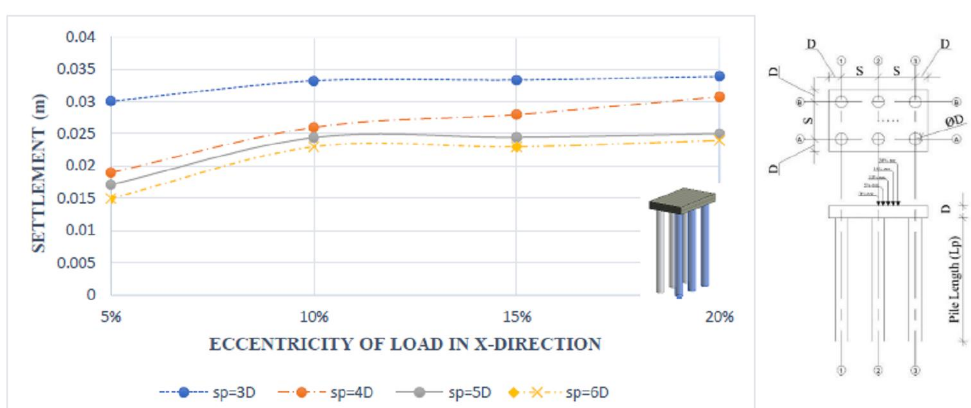

FIG. (19) THE RELATION BETWEEN SETTLEMENT AND ECCENTRIC LOADS IN X-DIRECTION FOR DIFFERENT PILE SPACING (LP=36 D, D=0.6 M)

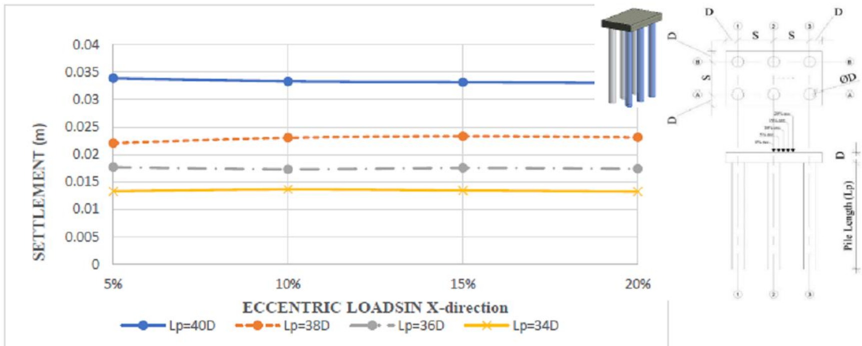

FIG. (20) THE RELATION BETWEEN SETTLEMENT AND ECCENTRIC LOADS IN X-DIRECTION FOR DIFFERENT PILE LENGTH (Sp=3D, D=0.6 m)

Figure (21) shows the relationship between settlement under sec. (A-A) and pile spacing for (D=0.6 m and Lp=,36D) and various eccentricity in x-direction where ecc= (5%,10%,15% and 20%)

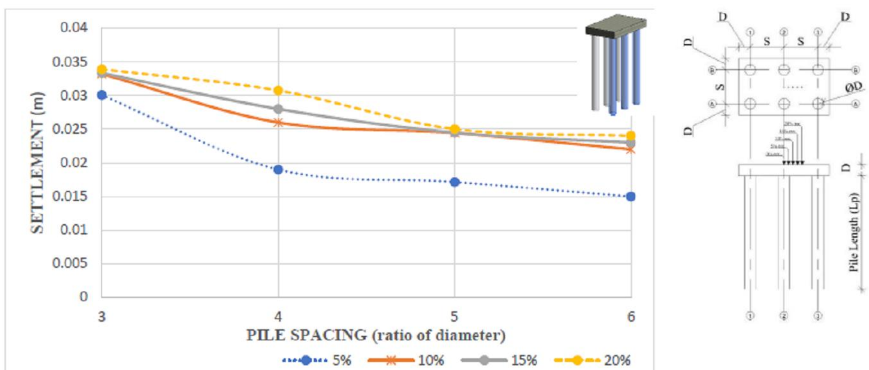

FIG. (21) THE RELATION BETWEEN SETTLEMENT AND PILE SPACING FOR DIFFERENT ECCENTRIC LOADS IN X-DIRECTION (LP=36D, D=0.6 M AND Sp=3D)

Figure (22) shows the relationship between settlement under sec. (A-A) and pile length for (D=0.6 m, Sp=3D and Lp=, 36D) and various eccentricity in x-direction where ecc= (5%, 10%, 15% and 20%) From these figures, it can be shown that the eccentricity in X-direction has no significant effect by increasing length of pile in settlement. And, it can be shown that the eccentricity in X-direction has no significant effect in case ecc. ≤15% by increasing pile spacing.

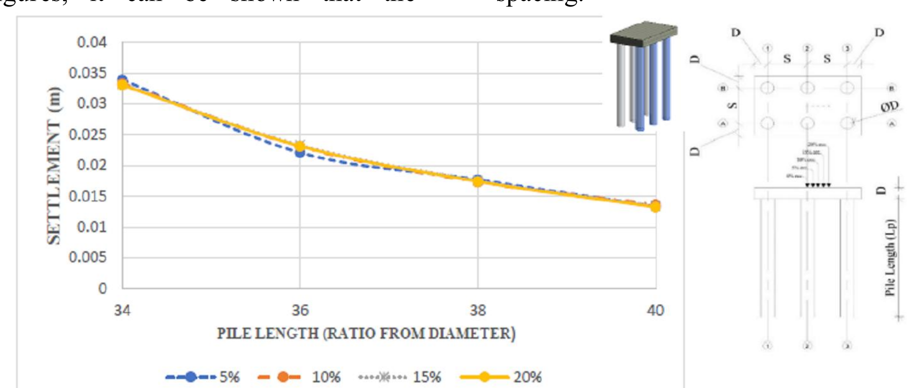

FIG. (22) THE RELATION BETWEEN SETTLEMENT AND PILE LENGTH FOR DIFFERENT ECCENTRIC LOADS IN X-DIRECTION (LP=36D, D=0.6 M)

Figures from (23) to (25) show the relationship between the distance and settlement under sec. (A-A) at different eccentricity in X-direction (ECC.= 0%,5%,10%,15% and 20 %) for (D=0.6 m, Sp= 3D) and various Lp= 34D, 36D,38D and 40D) From these figures, it can be shown that the eccentricity in X-direction has no significant effect by increasing length of pile in settlement.

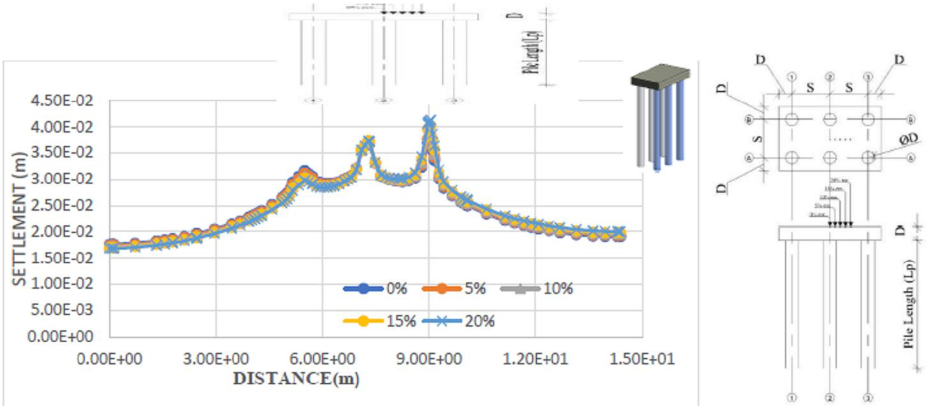

FIG. (23) THE RELATION BETWEEN SETTLEMENT AND DISTANCE ALONG SEC (A-A) FOR DIFFERENT ECCENTRICITY AT (LP=34D, SP=3D, D=0.6 M)

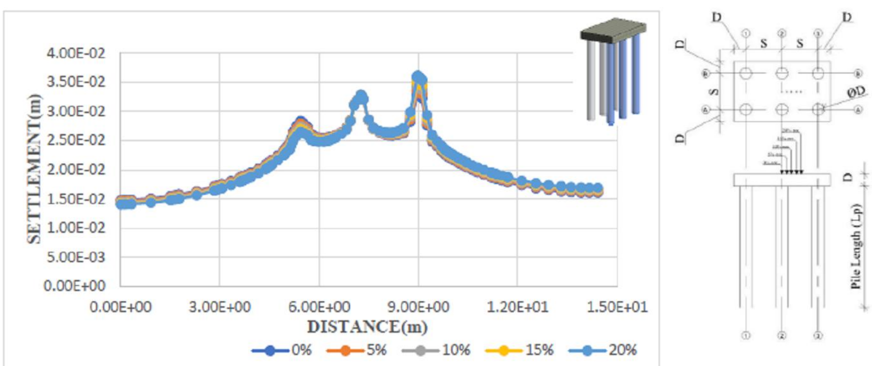

FIG. (24) THE RELATION BETWEEN SETTLEMENT AND DISTANCE ALONG SEC (A-A) FOR DIFFERENT ECCENTRICITY AT (LP=36D, SP=3D, D=0.6 M)

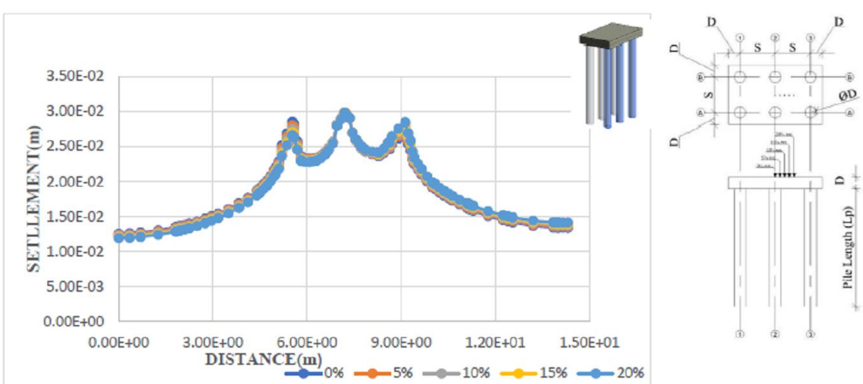

FIG. (25) THE RELATION BETWEEN SETTLEMENT AND DISTANCE ALONG SEC (A-A) FOR DIFFERENT ECCENTRICITY AT (LP=38D, SP=3D, D=0.6 M)

Figure (26) shows the relationship between load on pile and length among pile for different eccentric loads in x-direction under sec. (1-1) (Lp=34D, D=0.6 m and sp=3d)

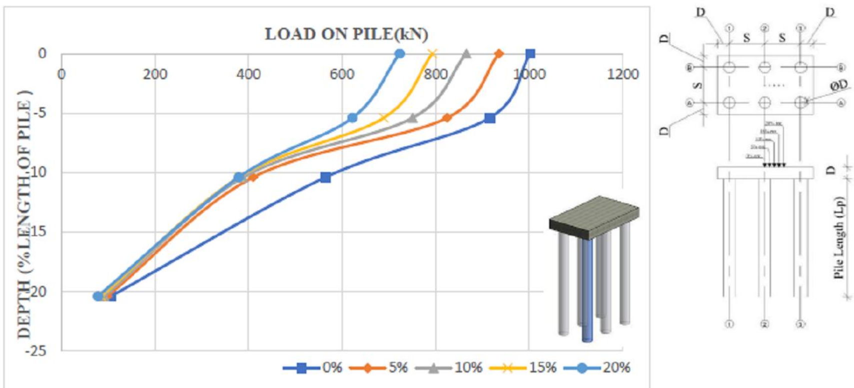

FIG. (26) THE RELATION BETWEEN LOAD ON PILE UNDER SEC (1-1) AND LENGTH AMONG PILE FOR DIFFERENT ECCENTRIC LOADS IN X-DIRECTION (LP=34 D, D=0.6 M AND Sp=3D)

Figure (27) shows the relationship between load on pile and length among pile for different eccentric loads in x-direction under sec. (1-1) (Lp= 38D, D=0.6 m and sp=3d)

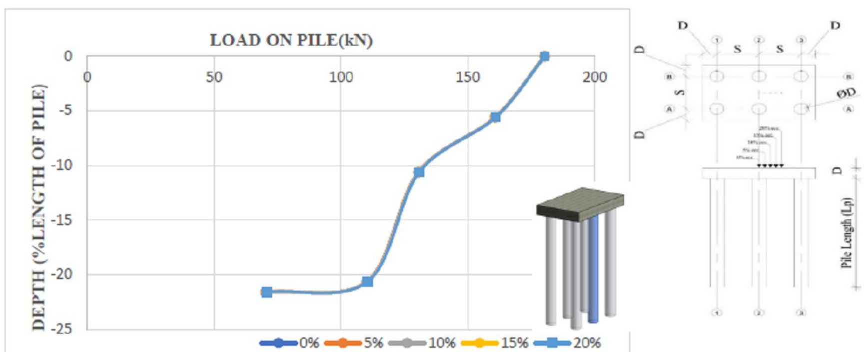

FIG. (27) THE RELATION BETWEEN LOAD ON PILE UNDER SEC (2-2) AND LENGTH AMONG PILE FOR DIFFERENT ECCENTRIC LOADS IN X-DIRECTION (LP=38D, D=0.6 M AND Sp=3D)

Figures from (28) to (30) show the relationship between load on pile and length among pile for different eccentric loads in x-direction under sec. (1-1), (2-2) and (3-3), (Lp=36D, D=0.6 m and sp=3d)

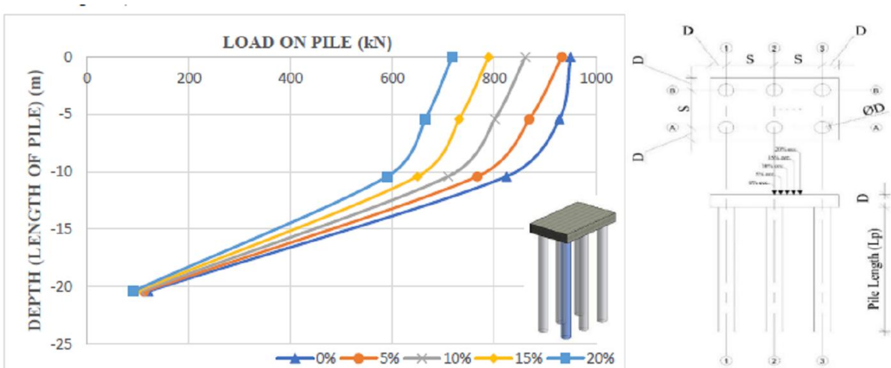

FIG. (28) THE RELATION BETWEEN LOAD ON PILE UNDER SEC (1-1) AND LENGTH AMONG PILE FOR DIFFERENT ECCENTRIC LOADS IN X-DIRECTION (LP=36D, D=0.6 M AND Sp=3D)

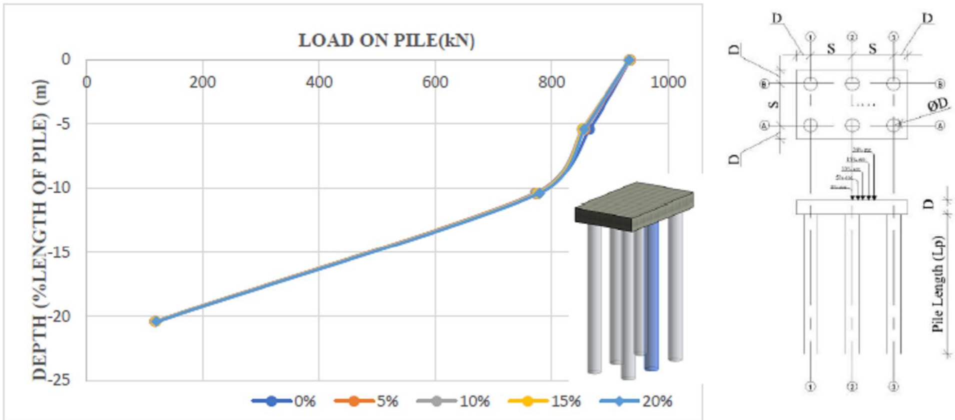

FIG. (29) THE RELATION BETWEEN LOAD ON PILE UNDER SEC (2-2) AND LENGTH AMONG PILE FOR DIFFERENT ECCENTRIC LOADS IN X-DIRECTION (LP=36D, D=0.6 M AND Sp=3D)

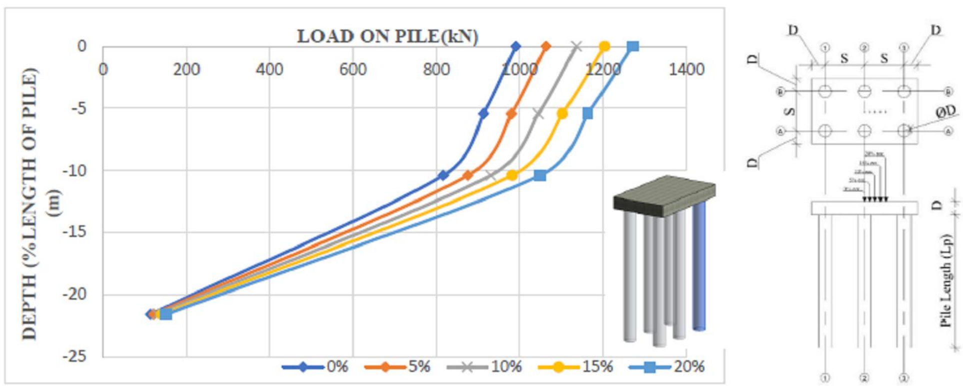

FIG. (30) THE RELATION BETWEEN LOAD ON PILE UNDER SEC (3-3) AND LENGTH AMONG PILE FOR DIFFERENT ECCENTRIC LOADS IN X-DIRECTION (LP=36D, D=0.6 M AND Sp=3D)

Figures from (31) to (33) show the relationship between load on pile and length among pile for different eccentric loads in x-direction under sec. (1-1), (2-2) and (3-3), (Lp=34D, D=0.6 m and sp=6d) From these figures, it can be shown that the load decrease by increasing eccentricity in X-direction under sec (1-1). The load increase by increasing eccentricity in X-direction under sec (3-3). Increasing eccentricity has no significant change at sec (2-2).

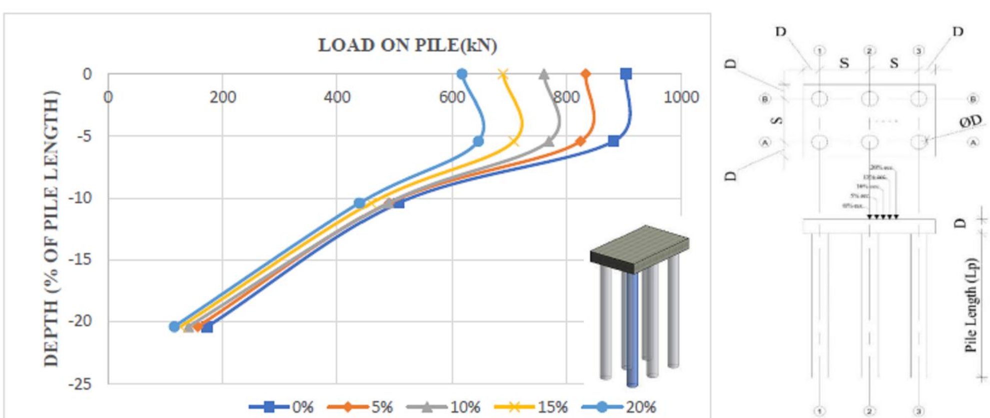

FIG. (31) THE RELATION BETWEEN LOAD ON PILE UNDER SEC (1-1) AND LENGTH AMONG PILE FOR DIFFERENT ECCENTRIC LOADS IN X-DIRECTION (LP=34D, D=0.6 M AND Sp=6D)

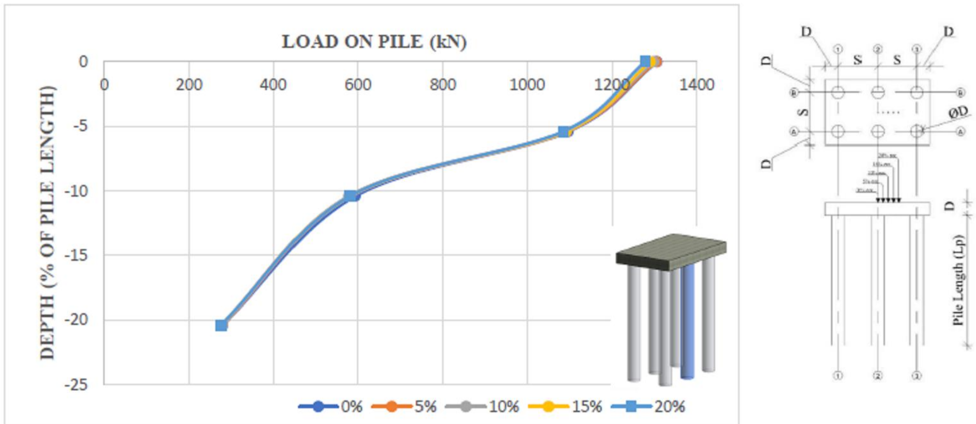

FIG. (32) THE RELATION BETWEEN LOAD ON PILE UNDER SEC (2-2) AND LENGTH AMONG PILE FOR DIFFERENT ECCENTRIC LOADS IN X-DIRECTION (LP=34D, D=0.6 M AND Sp=6D)

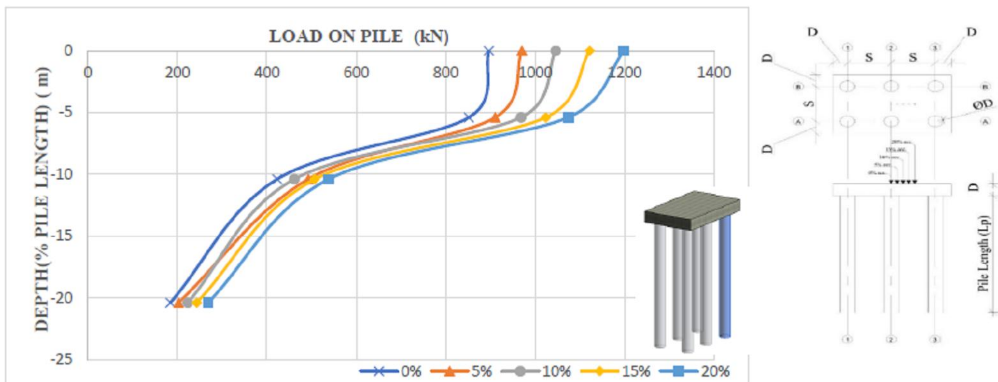

FIG. (33) THE RELATION BETWEEN LOAD ON PILE UNDER SEC (3-3) AND LENGTH AMONG PILE FOR DIFFERENT ECCENTRIC LOADS IN X-DIRECTION (LP=34D, D=0.6 M AND Sp=6D)

Figures from (34) to (37) show the relationship between load on pile due to lateral force only and length among pile for different pile length under sec. (1-1), (D=0.6 m and sp= (3D,4D,5D and 6D)). From these figures, it can be shown that the load on pile due to lateral force increases by increasing pile length if Lp≤36D and if Lp≥36D there is no effect on load on pile.

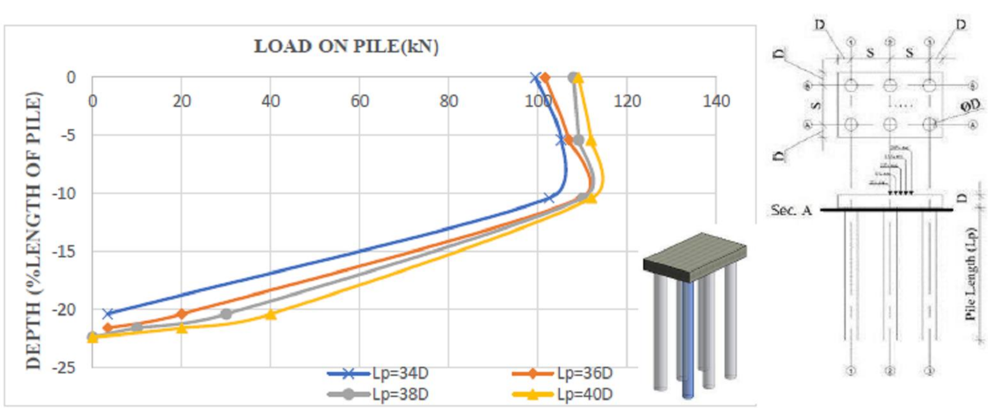

FIG. (34) THE RELATION BETWEEN LOAD ON PILE DUE TO LATERAL FORCE UNDER AXIS (1-1) AND LENGTH OF PILE AT DIFFERENT PILE LENGTH (D=0.6 M AND Sp=3D)

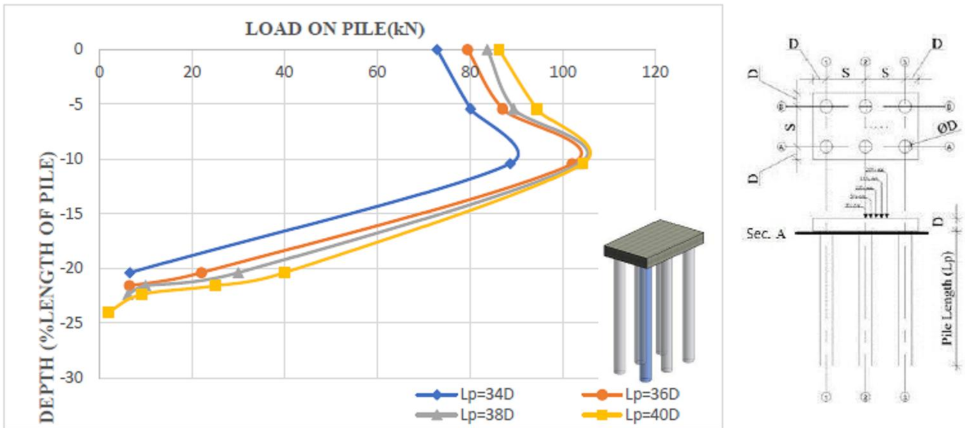

FIG. (35) THE RELATION BETWEEN LOAD ON PILE DUE TO LATERAL FORCE UNDER AXIS (1-1) AND LENGTH OF PILE AT DIFFERENT PILE LENGTH (D=0.6 M AND Sp=4D)

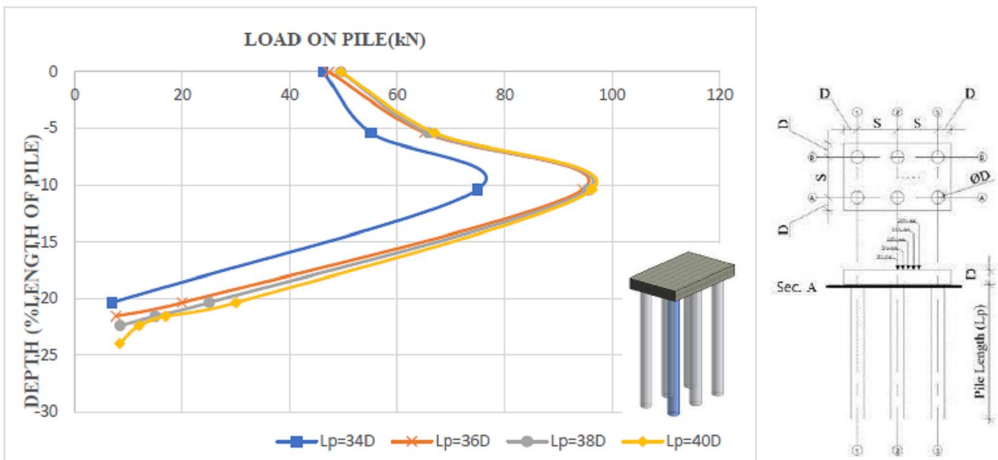

FIG. (36) THE RELATION BETWEEN LOAD ON PILE DUE TO LATERAL FORCE UNDER AXIS (1-1) AND LENGTH OF PILE AT DIFFERENT PILE LENGTH (D=0.6 M AND Sp=5D)

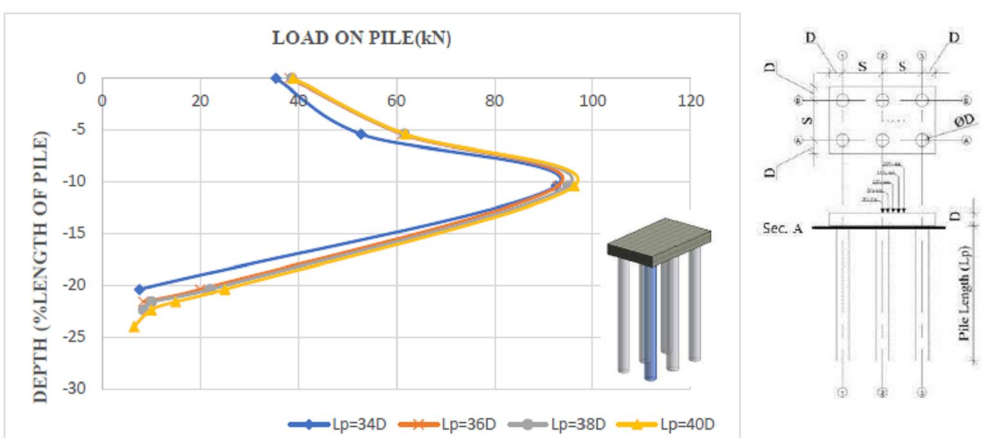

FIG. (37) THE RELATION BETWEEN LOAD ON PILE DUE TO LATERAL FORCE UNDER AXIS (1-1) AND LENGTH OF PILE AT DIFFERENT PILE LENGTH (D=0.6 M AND Sp=6D)

Figures from (38) to (41) show the relationship between load on pile due to lateral force only and length among pile for different pile spacing under sec. (1-1), (D=0.6 m and Lp= (34D, 36D, 38D and 40D)). From these figures, it can be shown that the load on pile due to lateral force decreases by increasing pile spacing if Sp≤4D and if Sp≥5D there is no effect on load on pile.

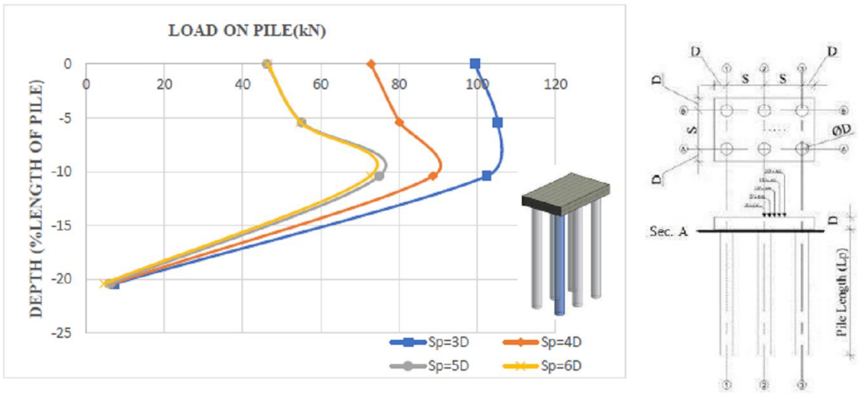

FIG. (38) THE RELATION BETWEEN LOAD ON PILE DUE TO LATERAL FORCE UNDER AXIS (1-1) AND LENGTH OF PILE AT DIFFERENT PILE SPACING (D=0.6 M AND Lp=34D)

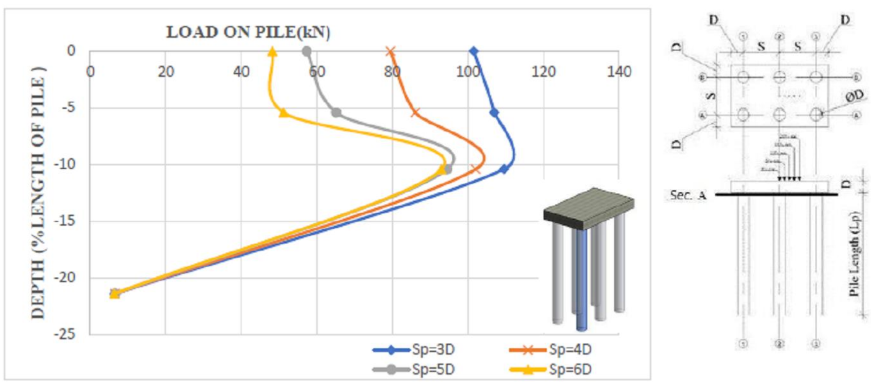

FIG. (39) THE RELATION BETWEEN LOAD ON PILE DUE TO LATERAL FORCE UNDER AXIS (1-1) AND LENGTH OF PILE AT DIFFERENT PILE SPACING (D=0.6 M AND Lp=36D)

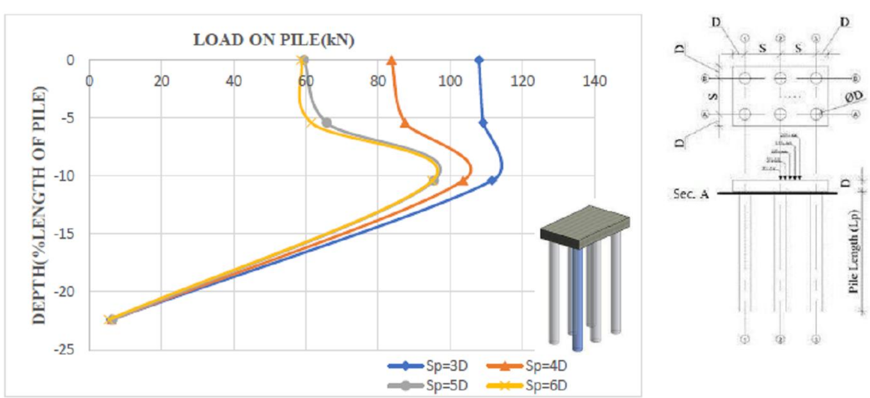

FIG. (40) THE RELATION BETWEEN LOAD ON PILE DUE TO LATERAL FORCEUNDERAXIS (1-1) AND LENGTH OF PILE AT DIFFERENT PILE SPACING (D=0.6 M AND Lp=38D)

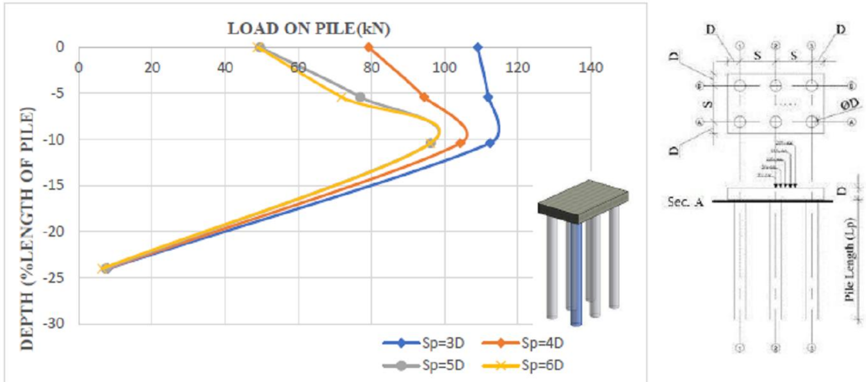

FIG. (41) THE RELATION BETWEEN LOAD ON PILE DUE TO LATERAL FORCE UNDER AXIS (1-1) AND LENGTH OF PILE AT DIFFERENT PILE SPACING (D=0.6 M AND Lp=40D)

Figure (42) shows the relationship between load on pile due to lateral force under axis (A-A) and length of pile at different pile spacing (D=0.6 m). From this figure, it can be shown that the load on pile due to lateral force increase by increasing pile length if Lp≤36D and if Lp≥36D there is no effect on load on pile and decreases by increasing pile spacing if Sp≤4D and if Sp≥5D there is no effect on load on pile.

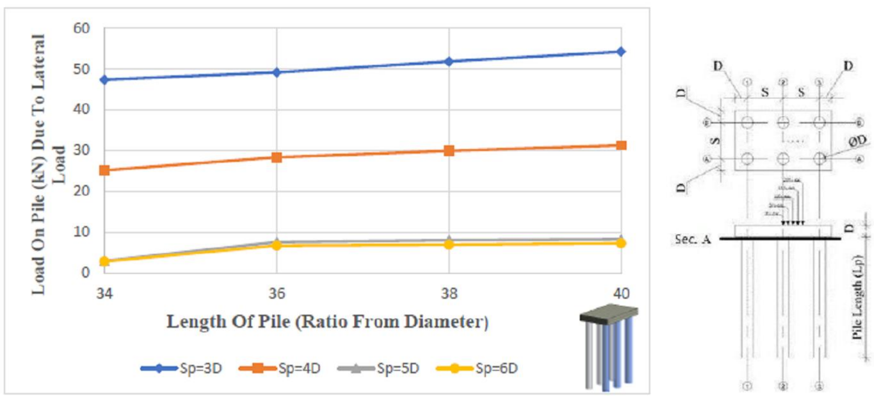

FIG. (42) THE RELATION BETWEEN LOAD ON PILE DUE TO LATERAL FORCE UNDER AXIS (A-A) AND LENGTH OF PILE AT DIFFERENT PILE SPACING (D=0.6 M)

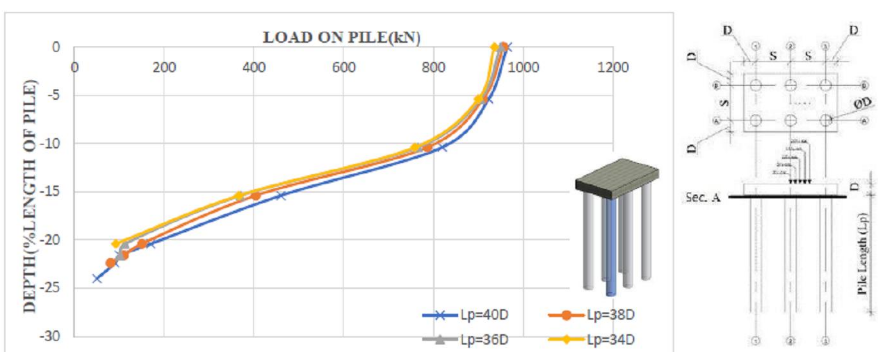

FIG. (43) THE RELATION BETWEEN LOAD ON PILE DUE TO DYNAMIC LATERAL FORCE UNDER SEC (1-1) AND LENGTH OF PILE AT DIFFERENT PILE LENGTH (D=0.6 M AND Sp=3D)

Figures from (43) to (45) show the relationship between load on pile due to dynamic lateral force and length among pile for different pile length under sec. ((1-1), (2-2) and (3-3)), (D=0.6 m and Sp= (3D). From these figures, it can be shown that the load on pile due to dynamic lateral force increases by increasing pile length.

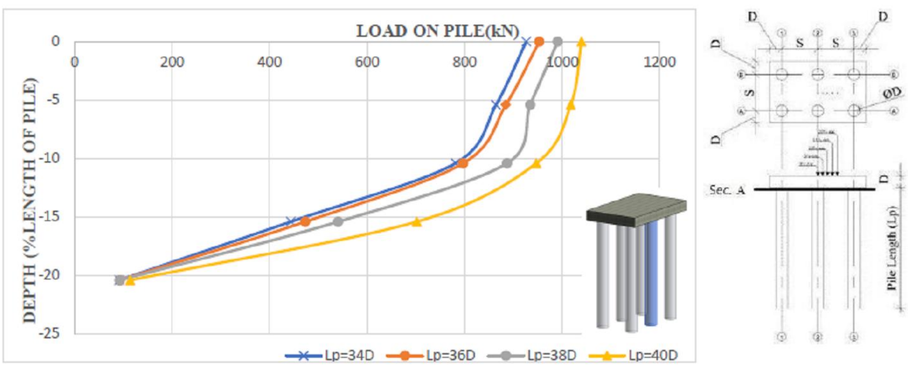

FIG. (44) THE RELATION BETWEEN LOAD ON PILE DUE TO DYNAMIC LATERAL FORCE UNDER SEC (2-2) AND LENGTH OF PILE AT DIFFERENT PILE LENGTH (D=0.6 M AND Sp=3D)

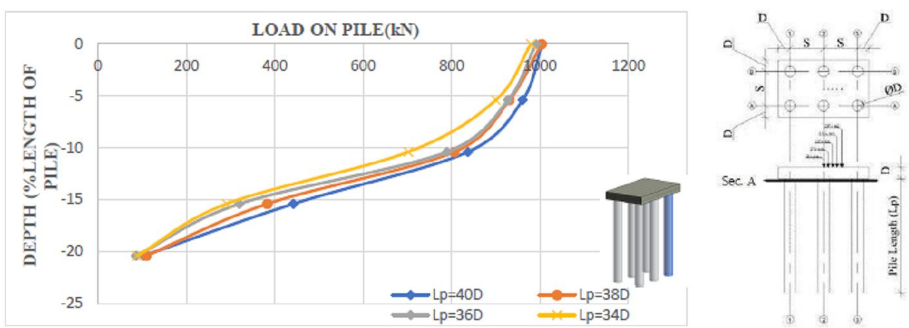

FIG. (45) THE RELATION BETWEEN LOAD ON PILE DUE TO DYNAMIC LATERAL FORCE UNDER SEC (3-3) AND LENGTH OF PILE AT DIFFERENT PILE LENGTH (D=0.6 M AND Sp=3D)

Figure (46) shows the relationship between load on pile due to dynamic lateral force and length among pile for different pile spacing under sec. (1-1) (D=0.6 m and Sp= (3D,4D,5D and 6D). From this figure, it can be shown that the load on pile due to dynamic lateral force decreases by increasing pile spacing.

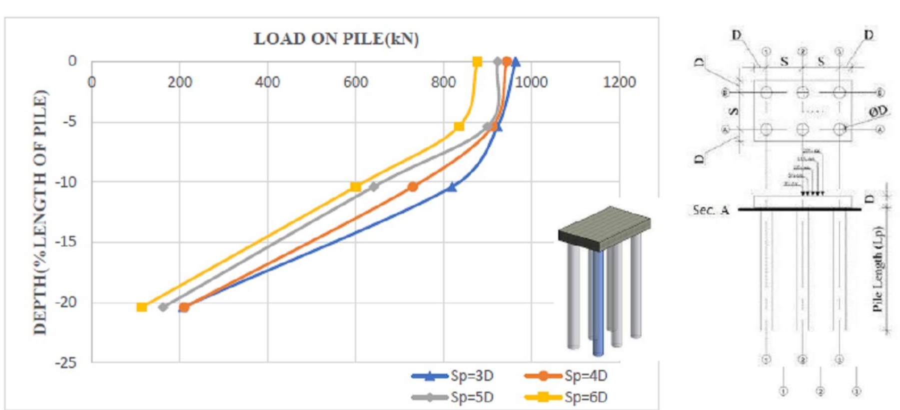

FIG. (46) THE RELATION BETWEEN LOAD ON PILE DUE TO DYNAMIC LATERAL FORCE UNDER SEC (1-1) AND LENGTH OF PILE AT DIFFERENT PILE SPACING (D=0.6 M AND Lp=34D)

Figures from (47) to (50) show the relationship between load on pile due to dynamic lateral force and length among pile for different pile length under different sections. SEC ((1-1), (2-2) and (3-3)), (D=0.6 m and Sp= (3D). From these figures, it can be shown that the load on center pile more than the load on edge pile due to dynamic lateral force.

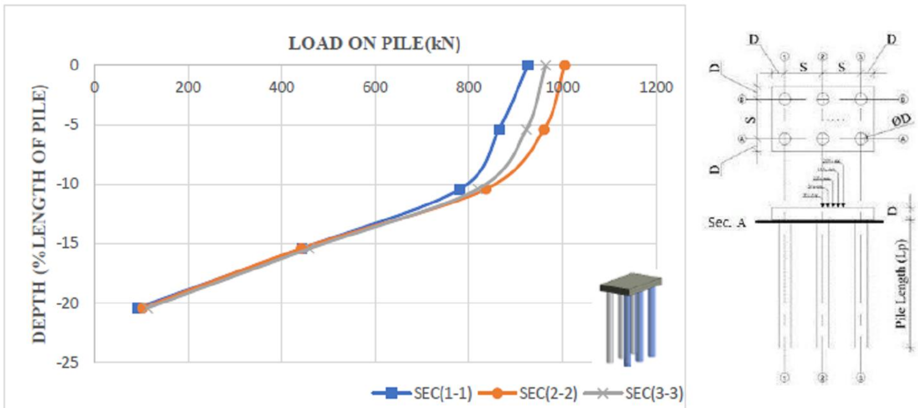

FIG. (47) THE RELATION BETWEEN LOAD ON PILE DUE TO DYNAMIC LATERAL FORCE UNDER DIFFERENT SECTIONS ((1-1), (2-2) AND (3-3)) AND LENGTH OF PILE AT (D=0.6 M AND LP=34D, Sp=3D)

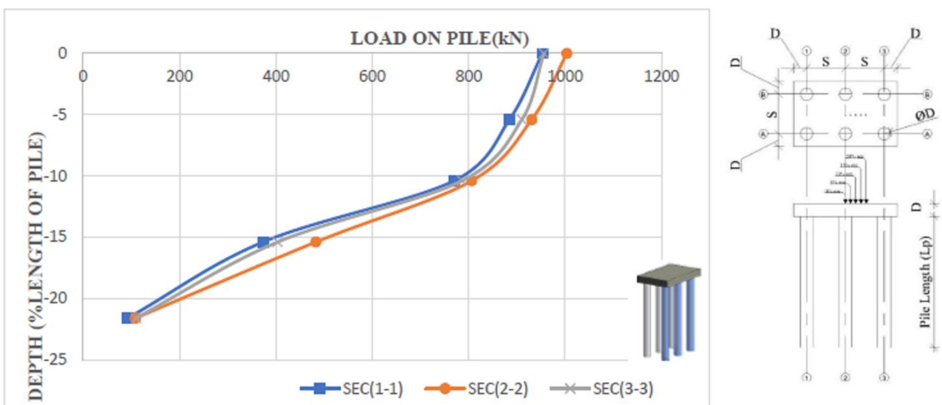

FIG. (48) THE RELATION BETWEEN LOAD ON PILE DUE TO DYNAMIC LATERAL FORCE UNDER DIFFERENT SECTIONS ((1-1), (2-2) AND (3-3)) AND LENGTH OF PILE AT (D=0.6 M AND LP=36D, Sp=3D)

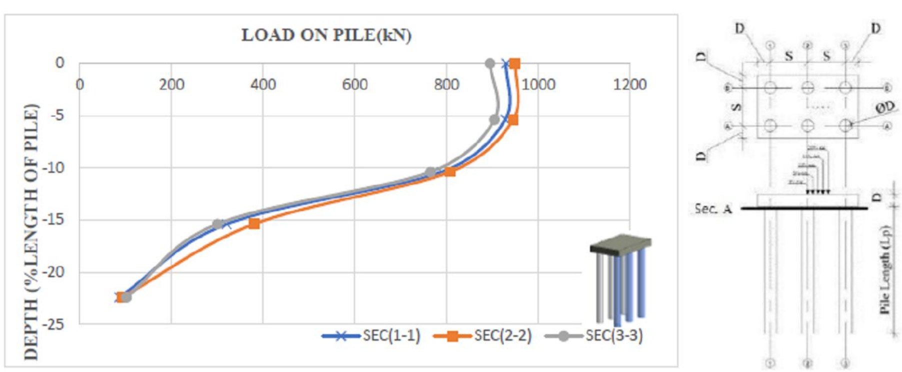

FIG. (49) THE RELATION BETWEEN LOAD ON PILE DUE TO DYNAMIC LATERAL FORCE UNDER DIFFERENT SECTIONS ((1-1), (2-2) AND (3-3)) AND LENGTH OF PILE AT (D=0.6 M AND LP=38D, Sp=3D)

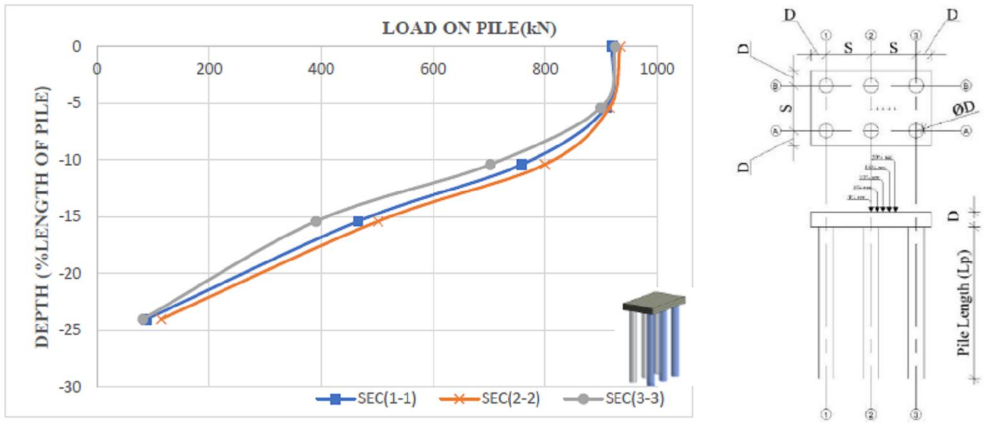

FIG. (50) THE RELATION BETWEEN LOAD ON PILE DUE TO DYNAMIC LATERAL FORCE UNDER DIFFERENT SECTIONS ((1-1), (2-2) AND (3-3)) AND LENGTH OF PILE AT (D=0.6 M AND LP=40D, Sp=3D)

Figures from (51) to (54) show the relationship between load on pile due to different types of forces and length among pile under SEC (1-1) for different pile length, (D=0.6 m and Sp= (3D).

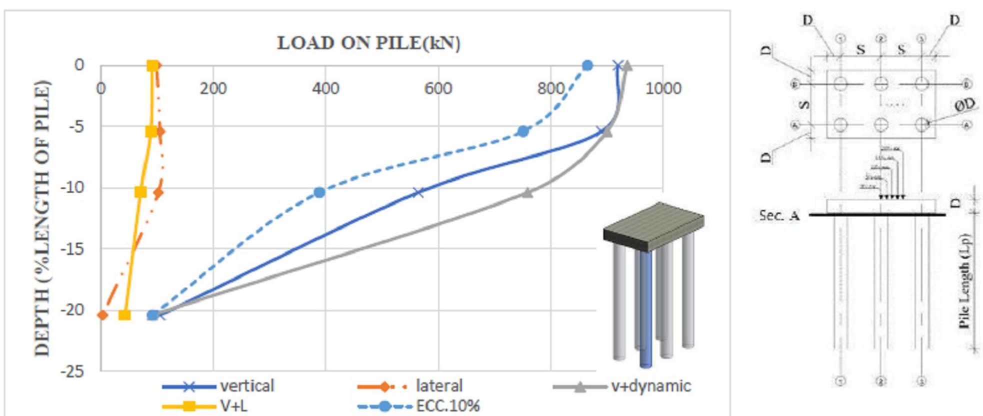

FIG. (51) THE RELATION BETWEEN LOAD ON PILE DUE TO DIFFERENT TYPES OF FORCE UNDER SEC (1-1) AND LENGTH OF PILE AT (D=0.6 M AND LP=34D, Sp=3D)

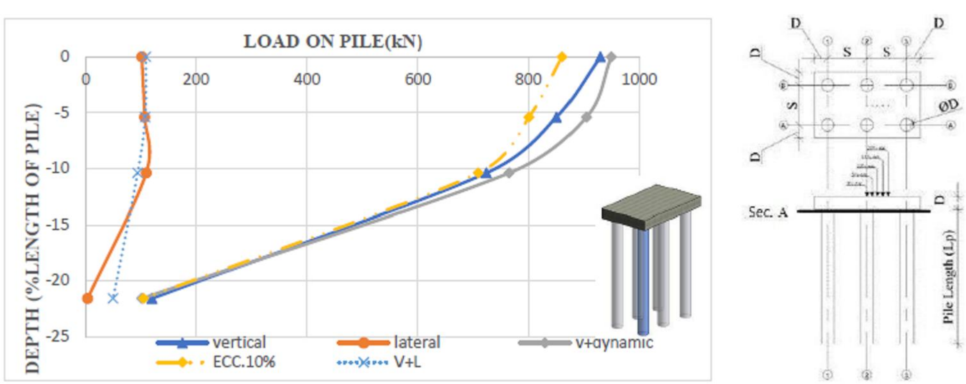

FIG. (52) THE RELATION BETWEEN LOAD ON PILE DUE TO DIFFERENT TYPES OF FORCE UNDER SEC (1-1) AND LENGTH OF PILE AT (D=0.6 M AND LP=36D, Sp=3D)

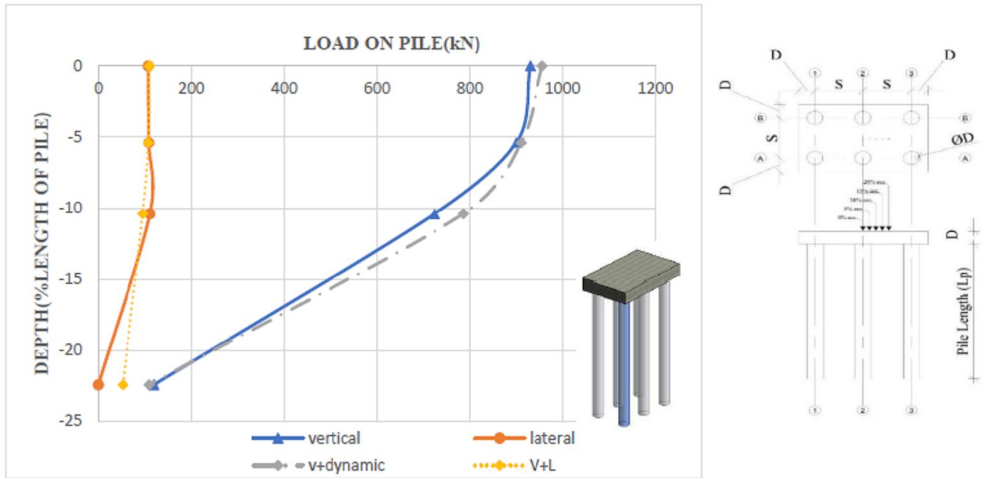

FIG. (53) THE RELATION BETWEEN LOAD ON PILE DUE TO DIFFERENT TYPES OF FORCE UNDER SEC (1-1) AND LENGTH OF PILE AT (D=0.6 M AND LP=38D, Sp=3D)

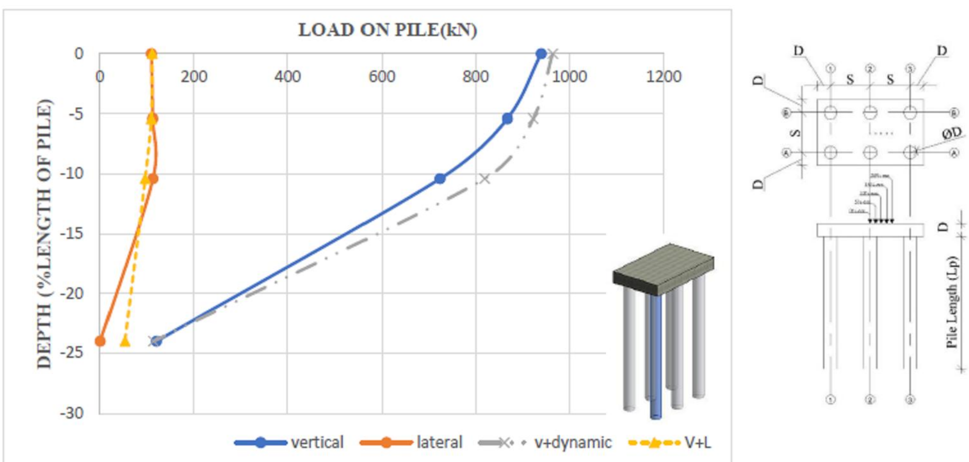

FIG. (54) THE RELATION BETWEEN LOAD ON PILE DUE TO DIFFERENT TYPES OF FORCE UNDER SEC (1-1) AND LENGTH OF PILE AT (D=0.6 M AND LP=40D, Sp=3D

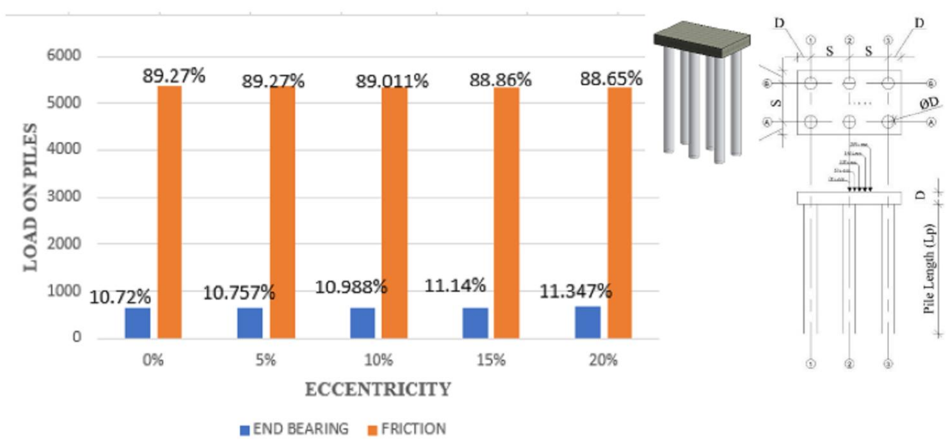

FIG. (55) COMPARISON BETWEEN LOAD ON PILES CARRIED BY END BEARING AND FRICTION AT DIFFERENT ECCENTRICITY IN X-DIRECTION AT (LP=38D, D=0.6 M AND Sp=3D)

Figures from (55) to (57) show the comparison between load on pile carried by end bearing and friction at different Ecc. (0%, 5%, 10%, 15% and 20%). From these figures, it can be shown that eccentricity has no significant effect in load sharing between piles and soil if Ecc ≤ 10%.

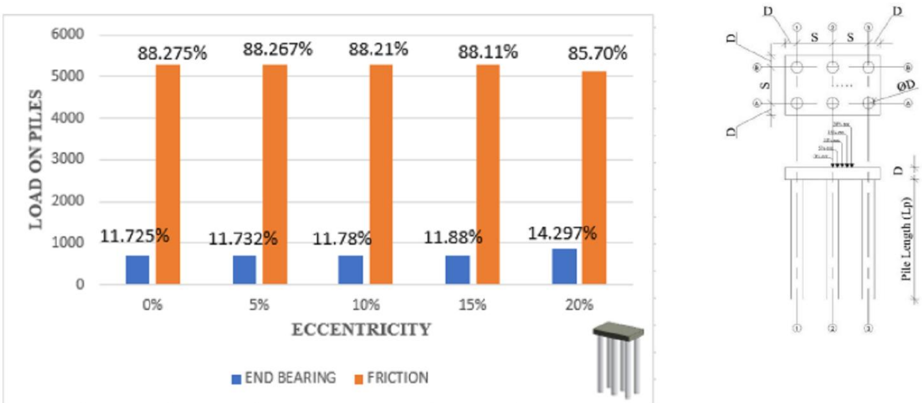

FIG. (56) COMPARISON BETWEEN LOAD ON PILES CARRIED BY END BEARING AND FRICTION AT DIFFERENT ECCENTRICITY IN X-DIRECTION AT (LP=36D, D=0.6 M AND Sp=3D)

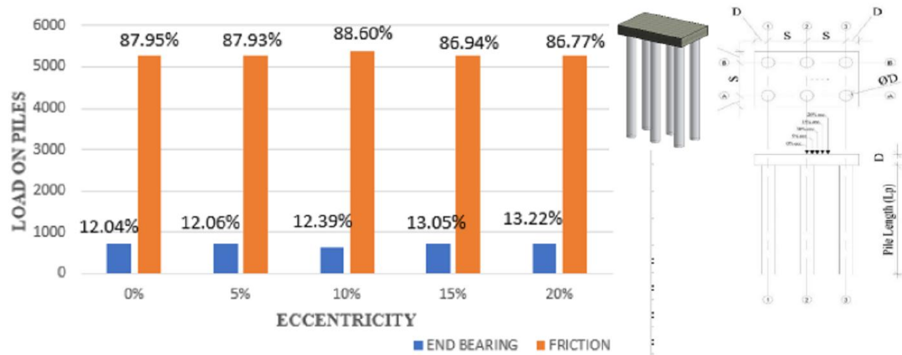

FIG. (57) COMPARISON BETWEEN LOAD ON PILES CARRIED BY END BEARING AND FRICTION AT DIFFERENT ECCENTRICITY IN X-DIRECTION AT (LP=34D, D=0.6 M AND Sp=3D)

Figure (58) shows the comparison between load on pile carried by end bearing before and after redistribution of load at different Ecc. (0%,5%,10%,15% and 20%). From this figure, it can be shown that load on piles carried by end bearing increase by increasing eccentricity after redistribution load if Ecc. ≥ 15% but if Ecc< 10%eccentricity has no significant effect in load carried by end bearing before and after redistribution of load

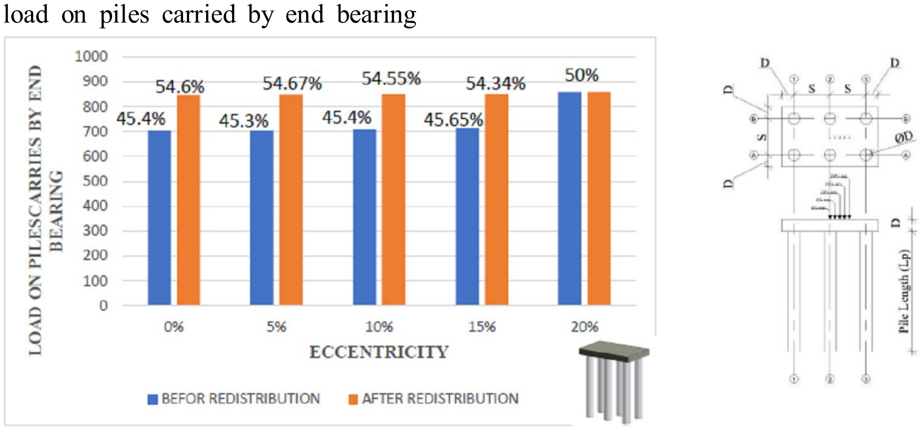

FIG. (58) COMPARISON BETWEEN LOAD ON PILES CARRIED BY END BEARING BEFOR AND AFTER REDISTRIBUTION AT DIFFERENT ECCENTRICITY IN X-DIRECTION AT (Lp=38D, D=0.6 M AND Sp=3D)

4-Conclusions:

From the present study, the followings are concluded:

i. Increasing the eccentricity in X-direction has no significant effect by increasing pile length if Ecc.< 10% and Lp ≥36D.

ii. Increasing the eccentricity in X-direction has no significant effect by increasing pile spacing if Sp ≥ 4D and Ecc. < 10%.

iii. The eccentricity load has a small effect on load shared between piles and soil. However, increasing the eccentricity causes more negative skin friction on piles.

iv. Eccentricity has no significant effect in load sharing between piles and soil if Ecc ≤ 10%.

v. Load on piles carried by end bearing increase by increasing eccentricity after redistribution load if Ecc. ≥ 15% but if Ecc< 10% eccentricity has no significant effect in load carried by end bearing before and after redistribution of load.

vi. The load decrease by increasing eccentricity in X-direction under sec (1-1). The load increase by increasing eccentricity in X-direction under sec (3-3). Increasing eccentricity has no significant change at sec (2-2).

vii. The stresses on piles increase by increasing the eccentricity in x-direction, but the stresses increase in the piles in the direction of eccentricity more than the piles further than eccentricity.

viii. The eccentricity in X-direction has no significant effect by increasing length of pile in settlement. And, it can be shown that the eccentricity in X-direction has no significant effect in case ecc. ≤15% by increasing pile spacing.

ix. The load on pile due to lateral force increase by increasing length of pile and decreases by increasing pile spacing and at Sp≥5D there is no effect on load on pile.

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