Australian Jour nal of Basic and Applied Sciences

2018 February; 12(2): pages 49-65
DOI: 10.22587/ajbas.2018.12.2.8

Research Article AENSI Publications

Effect of Tie Beam Dimensions on The Behaviors of Isolated Footings Under Eccentric Loading

Abd El Samee W. Nashaat

Civil Engineering Department, Faculty of Engineering, Beni- Suef University, Beni- Suef, Egypt.

Correspondence Author: Abd El Samee W. Nashaat, Civil Engineering Department, Faculty of Engineering, Beni- Suef University, Beni- Suef, Egypt.
E-mail: Waelnashat@eng.bsu.edu.eg.

Received date: 10 January 2018, **Accepted date:** 28 February 2018, **Online date:** 10 March 2018

Abstract

Background: Foundations may be subjected to eccentric loads. If the load is eccentric the stress distribution underneath the footing will be non-uniform causing differential settlement between the two edges. **Objective:** In the present study, the finite element program software PLAXIS 3D 2014 has been used to study the effect of tie beam dimensions connecting isolated footings under eccentric loading on settlement and horizontal displacement as well as bending moment and shear force. The investigated program consists of eccentric footings connected with tie beams with different thicknesses and widths. The details and variation of the selected parameters were presented. **Results:** It was concluded that, the settlement and horizontal displacement values in both directions as well the contact pressure values decrease with increasing the thickness and widths of tie beam. However, the values of bending moment and shear forces along axis decreases with increasing the dimensions of tie beam. In addition, the distribution of stresses under footing along axis's decreases with increasing both of tie beam thickness and width. **Conclusion:** However, the differential settlements of footings decrease with increasing tie beam dimensions.

Key words: Tie beam, contact pressure, finite element, eccentric footings, stress distribution.

INTRODUCTION

The differential settlement of isolated footings should be minimum. In order to minimize the differential settlement between isolated footings, it is recommended to connect them by tie beams. Georgiadis and Butterfield (1987) investigated the response of footings on sand, under eccentric loads. Apparatus was developed that simultaneously apply loads to footings at any eccentricity. A method was developed for predicting vertical and horizontal displacements and rotations of loaded footings on sand. The interaction diagrams between the vertical loads, horizontal loads, and moments that cause failure of the footing were presented.

Mahiyar (2000) presented the analysis of angle shape footing under vertical load by using finite element program. The analysis has been done by considering the parameters as depth of footing and eccentricity width ratio. The behavior of an Angle Shaped Footing under Eccentric Loading was studied.

Elsaadany (2004) examined the role of tie beam (strap beam) of eccentric footings resting directly on soil by using numerical parametric finite element technique. The Winkler model was used to model the soil behavior. The effect of allowable bearing capacity of soil and the tie beam stiffness on contact pressure, settlement and bending moment of tie beam-eccentric footing was presented.

Al-Omari and Al-Ebadi (2008) investigated the effect of tie beams on settlement, moments and shear developed in the foundation. A case study is selected; it is the case of grid foundation composed of nine footings. Three-dimensional nonlinear finite element analyses have been conducted. The soil has been assumed to follow the Drucker-Prager rate independent plasticity criterion. The parametric study conducted involved the effects of tie beams proportion, tie beams soil contact and an induced soil weakness beneath parts of the total foundation area. The detailed results indicated that the tie beams reduce the total and differential settlements of footings but this restriction is often on the expense of increasing the shear and moment particularly in the central footing.

Dayamond and Mahiyar (2009) investigated the behavior of angle shaped footing under inclined loads by performing experimental model tests and finite element analyses. A series of loading tests were conducted on a square angle shaped footing on sand with different angle and length of footing projection the footing was loaded at different angles from the vertical: 0°, 5°, 10°, 15°, 20°, 25° and 30°. The comparison between the experimental results and the Finite Element analysis results were presented. It was observed that eccentrically inclined loaded footing can be designed for no or very small negligible tilt by using angle shaped footing with different angle and length of footing projection Thus Model of angle shaped footing can make reasonable predictions of the inclined loading responded.

Kumawat *et al*. (2015) proposed the Tee shaped footing for improving the bearing capacity of shallow footings against the action of eccentric loads. The vertical insertion of the rigid Tee shaped footing, into the bearing soil, provides considerable resistance, against both of sliding and overturning, enough to regain the reduction in bearing capacity and increase in settlement. A series of experimental results by loading footing eccentrically along and perpendicular axes in horizontal plane for reporting ultimate loads and settlement of Tee shaped footing were considered out.

Pusadkar *et al.* (2016) evaluated the effects of eccentricity eccentric-inclined load on performance of square footing resting over sand. The laboratory load tests were conducted on the model footing with eccentric load. The eccentricity ratio (e/B) and inclination angle (α) varied from 0 to 0.2 and 00 to 300 respectively. The results showed that the bearing capacity decreases with increase in the load eccentricity and load inclination.

Elbatal and Abo-Alanwar (2017) investigated the straining actions of two square footings connected with tie beams resting on replaced soil. The effect of the interaction between natural soil deposit, soil replacement density and length and foundations were presented. Vertical displacements of soil and foundations, bending moments and shear force along the tie beam length were investigated. It was noticed that variation of replaced soil density changes final straining actions of footings and tie beams. In addition, variation of replaced soil must be considered in foundation deign to avoid error in design. However, in case of the natural soil deposit is dense, increasing the density of the replaced soil increases the maximum moment. Also, in case of the natural soil deposit is loose, increasing the density of the replaced soil has no significant effect on maximum moment.

El-Samny *et al.* (2017) investigated the effect of tie beam dimensions connecting two isolated footings on the vertical and horizontal displacement. A finite element package of a PLAXIS 3D has been used. It was found that the vertical and horizontal displacement in both directions increases with increasing the length of tie beam. The vertical and horizontal decreases with increasing the height of tie beam. Increasing the depth of footings leads to decreasing the vertical and horizontal.

Based on the literature review presented in this paper it can be reported that the effect of tie beam dimension connecting isolated footings under eccentric loading on horizontal and vertical displacement as well as bending moment and shear force needs more investigations.

MATERIAL AND METHODS

Finite element analysis:

Finite element analysis takes into account the effect of tie beam dimension connecting isolated footings under eccentric loading on horizontal and vertical displacement as well as bending moment and shear force. Therefore, the finite element method was selected in the present study to develop numerical models to study the effect of width and thickness of tie beam on horizontal and vertical displacement under eccentric loading as well as bending moment and shear force.

Investigated models:

The finite element analysis software PLAXIS 3D 2014 has been performed to simulate the chosen model. Figures (1) and (2) show the chosen model superstructure supporting on isolated footing connected with tie beam under eccentric loading. The soil is simulated by a semi-infinite element isotropic homogeneous elastic material using Mohr-Coulomb theory. The chosen superstructure technique model was chosen, as follows: system of isolated footings carrying eccentric load connected with tie beams with all footings along axis's (E-E) and (1-1) are considered neighbors at one and two sides of building. The dimensions of all footings have been calculated according to the column loads of the buildings assumed allowable soil capacity= 1.50 kg/cm^2. The details of all footings are listed in Table (1).

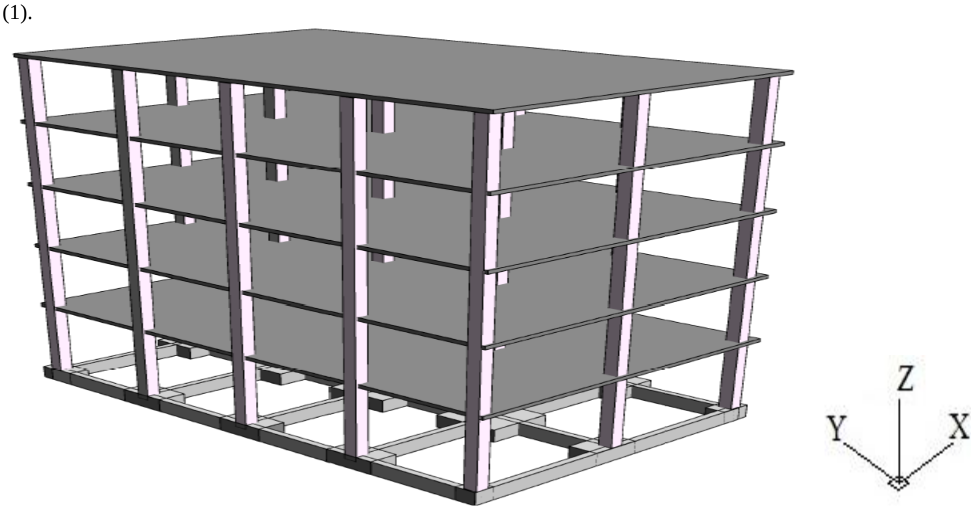


Fig. 1: 3D superstructure supporting on isolated footing connected with tie beam.

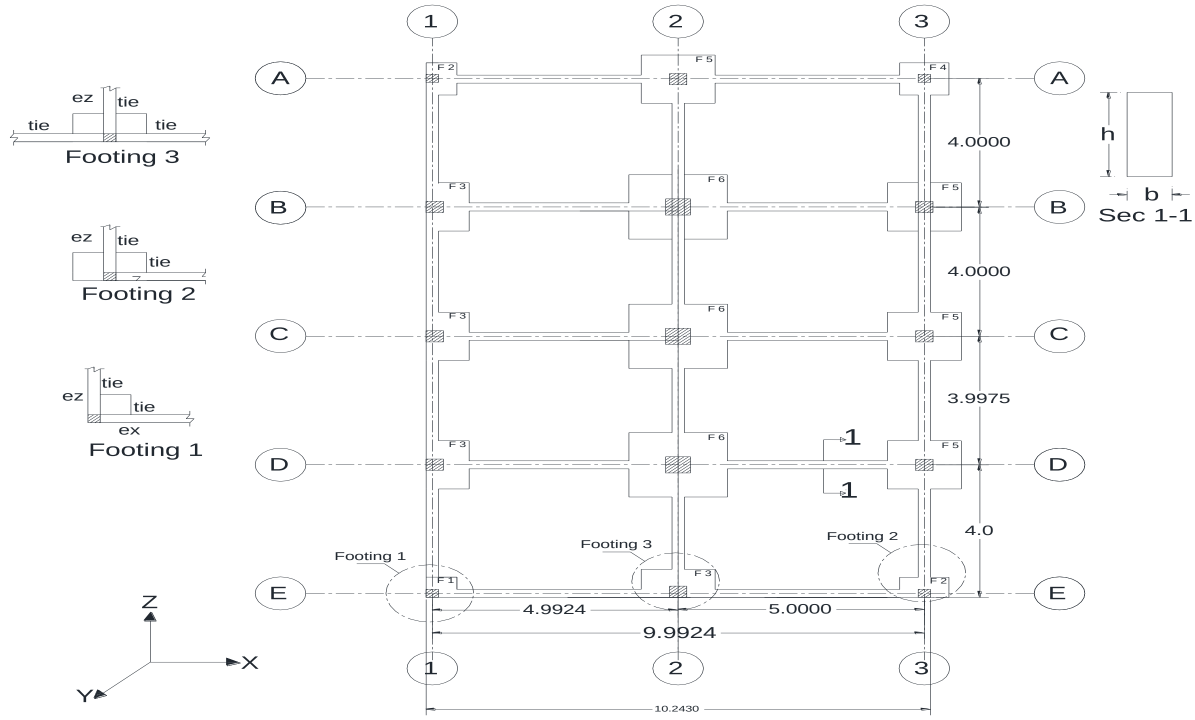


Fig. 2: plan of tie beam dimension connecting isolated footings under eccentric loading.

Table 1: Footings details.

Type	Dimension (m)	Thickness of footing (m)

F 1	0.75 x 0.75	0.60
F 2	0.75 x 1.00	0.60
F 3	1.00 x 1.50	0.60
F 4	1.00 x 1.00	0.60
F 5	1.50 x 1.50	0.60
F 6	2.50 x 2.50	0.60

Numerical program:

A numerical analysis was conducted to study effect of tie beam dimension connecting isolated footings under eccentric loading on horizontal and vertical displacement as well as bending moment and shear force. The chosen site selected for investigation is a residential building project in Beni-Suef, Egypt. In the present study a theoretical analysis has been done for different thicknesses and widths of tie beam. The details and variation of the selected investigated case of study are listed in Table (2). The foundations and tie beams properties have been selected by the following:

i. Normal stiffness (EA) = 2.10×10^7 kN/m
ii. Flexural rigidity (EI) = 1.75×10^4 kN.m^2/m.

Table 2: Investigated cases of study.

Problem No.	Width of Tie beam b (m)	Depth of footing (Df)	Thickness of Tie beam (h)	Angle of internal friction (Ø)
(1)		0.00 B	1.00 D	
(2)		0.50 B	1.25 D	
(3)	0.30	1.00 B	1.50 D	
(4)		1.50 B	2.00 D	
(5)			2.50 D	
(6)		0.00 B	1.00 D	
(7)		0.50 B	1.25 D	
(8)	0.35	1.00 B	1.50 D	
(9)		1.50 B	2.00 D	
(10)			2.50 D	30˚, 35˚, 40˚, 45˚
(11)		0.00 B	1.00 D	
(12)		0.50 B	1.25 D	
(13)	0.40	1.00 B	1.50 D	
(14)		1.50 B	2.00 D	
(15)			2.50 D	
(16)		0.00 B	1.00 D	
(17)		0.50 B	1.25 D	
(18)	0.50	1.00 B	1.50 D	
(19)		1.50 B	2.00 D	
(20)			2.50 D	

Where:
D_f : Depth of footing. D: Thickness of footing. B: Width of footing. h: Thickness of tie beam. b: Width of tie beam. L_{tie}: Tie beam length

Material properties used in the analysis:

The soil is simulated by a semi-infinite element isotropic homogeneous elastic material. The used soil properties are listed in Tables (3).

Table 3: Soil properties.

Parameters	Soil
Material Model	Mohr Coulomb
Type of Material	Sand
Unit weight, γ (kN/m^3)	18.5
Young's modulus, E_s (kN/m^2)	20000
Poisson's ratio, υ	0.3
cohesion, C_u (kN/m^2)	0
Friction angle, Ø (deg)	30˚, 35˚, 40˚ and 45˚
Dilatancy angle, ¥ (deg)	0

RESULTS AND DISCUSSION

Finite element results:

The obtained results from the numerical analysis are described as follows:

Effect of tie beam thickness and width on vertical displacement:

Figures (3) to (9) show some examples of the total vertical displacements (settlement) in soil for tie beam dimensions connecting isolated footings under eccentric loading. Figures (10) and (12) show some examples for the effect of tie beam dimensions connecting isolated footings under eccentric loading on total vertical displacements (settlement) for sandy soil along axis's (A –A, C-C, D-D, E–E, 1–1, 2-2 and 3-3) with tie beam thickness (h_t) =1.00 D and 2.00 D, width of tie (b_t) =0.30 m and at angle of internal friction (Ø) =30˚. From these figure, it can be shown that the settlement values along the axis's decrease with increasing the thickness and widths of tie beam. However, the settlement distribution under eccentric footings along axis's almost uniform at tie beam thickness more than 2.00 thickness of footing.

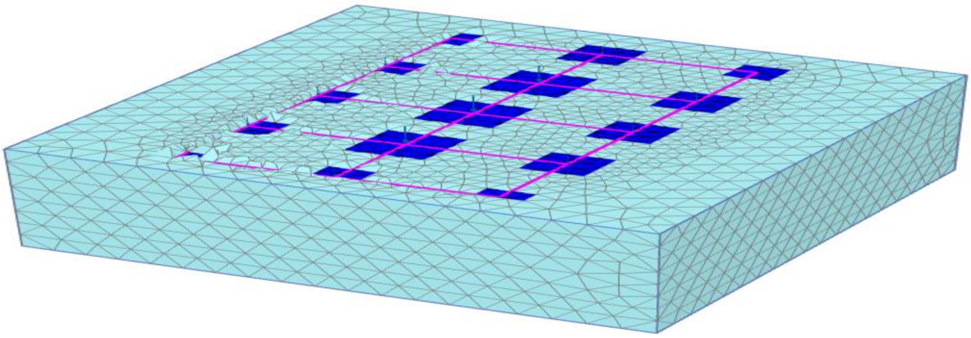


Fig. 3: Deformed mesh of soil at depth of footing D_f = (0.00) B and angle of internal friction (Ø) = 30˚ and at tie beam width b_{tie} =0.30 m and tie beam thickness h_{tie} =1.00 D.

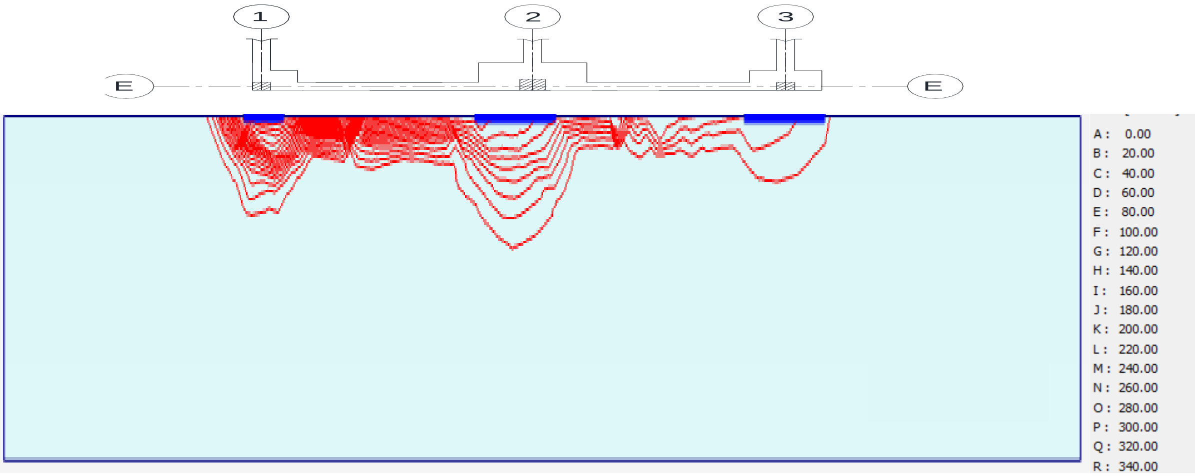


Fig. 4: Total vertical displacements in soil as contour lines at b_{tie} =0.30 m, h_{tie} =1.00 D and Ø = 30˚ along axis (E-E).

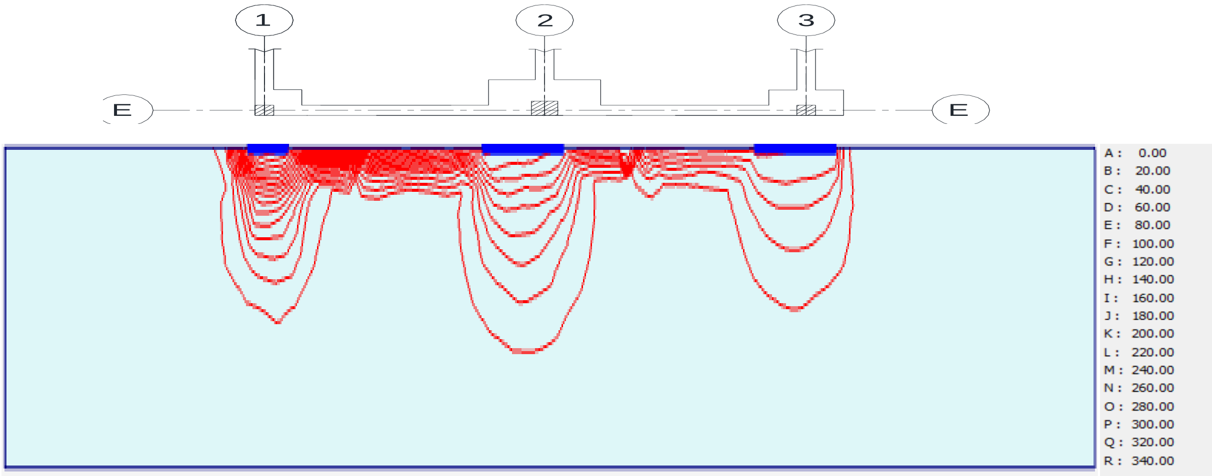


Fig. 5: Total vertical displacements in soil as contour lines at b_{tie} =0.30 m, h_{tie} =2.00 D and Ø = 30˚ along axis (E-E).

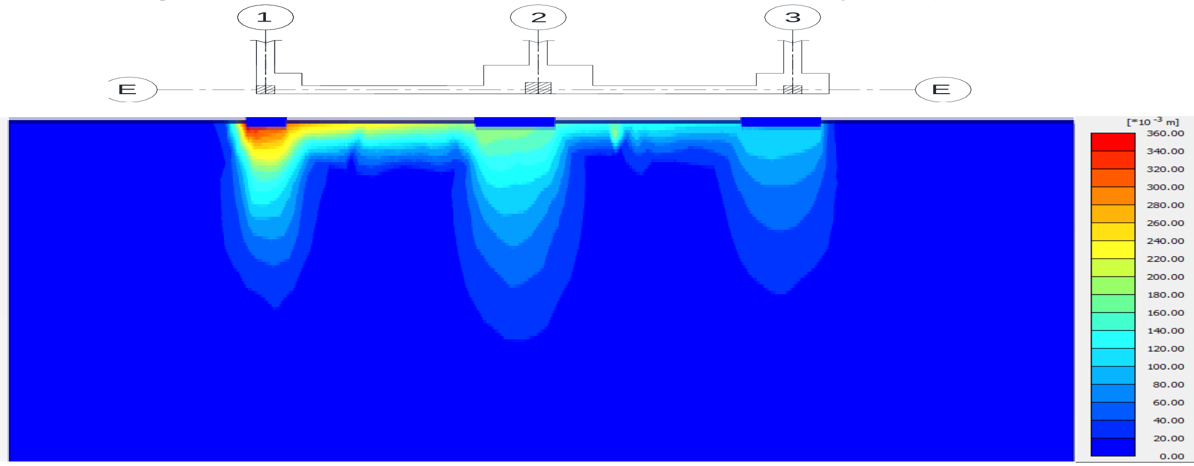


Fig. 6: Total vertical displacements in soil as shading at b_{tie} =0.30 m, h_{tie} =1.0 D and Ø = 30˚ along axis (E-E).

Citation: Abd El Samee W. Nashaat, 2018. Effect of Tie Beam Dimensions on The Behaviors of Isolated Footings Under Eccentric Loading. Australian Journal of Basic and Applied Sciences., 12(2): 49-65

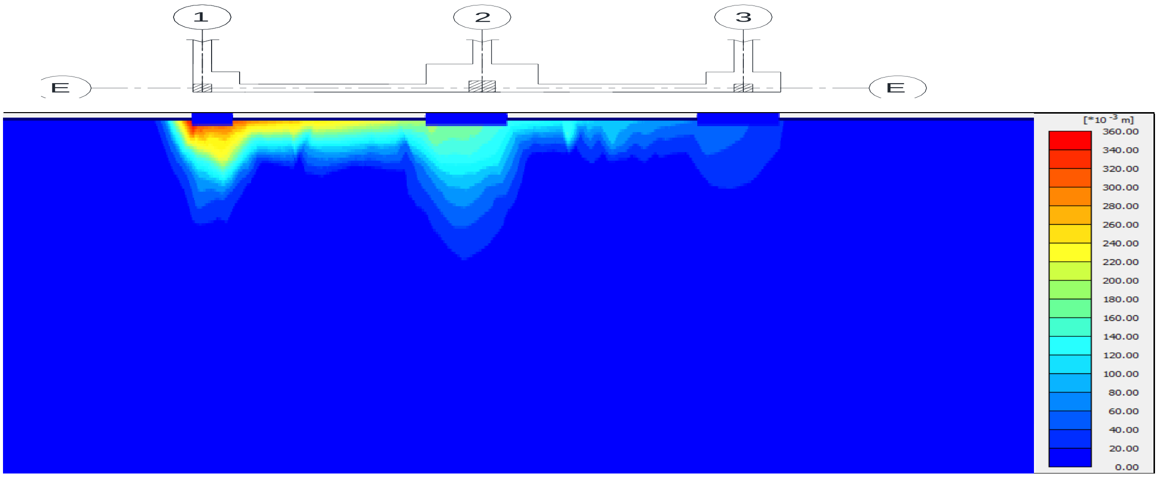


Fig. 7: Total vertical displacements in soil as shading at b_{tie} =0.30 m, h_{tie} =2.0 D and Ø = 30˚ along axis (E-E).

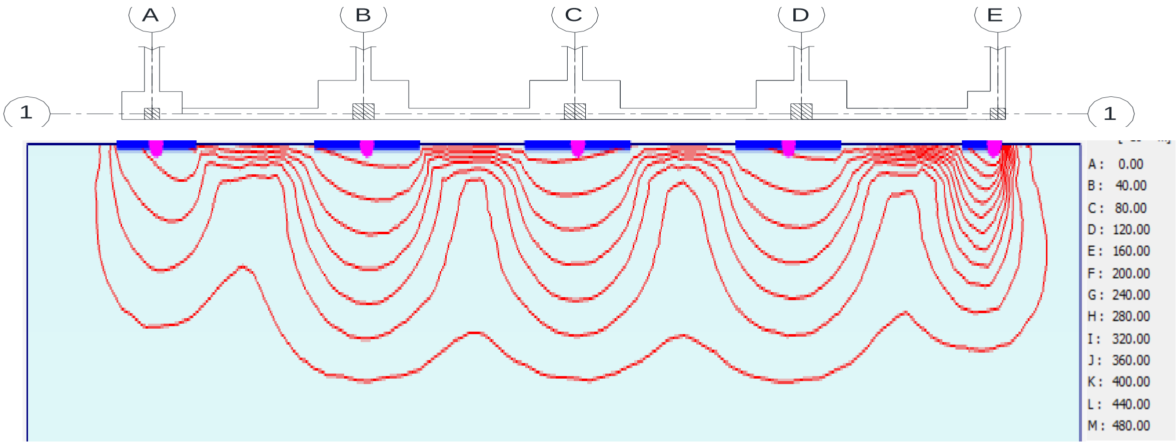


Fig. 8: Total vertical displacements in soil as contour lines at b_{tie} =0.30 m, h_{tie} =1.00 D and Ø = 30˚ along axis (1-1).

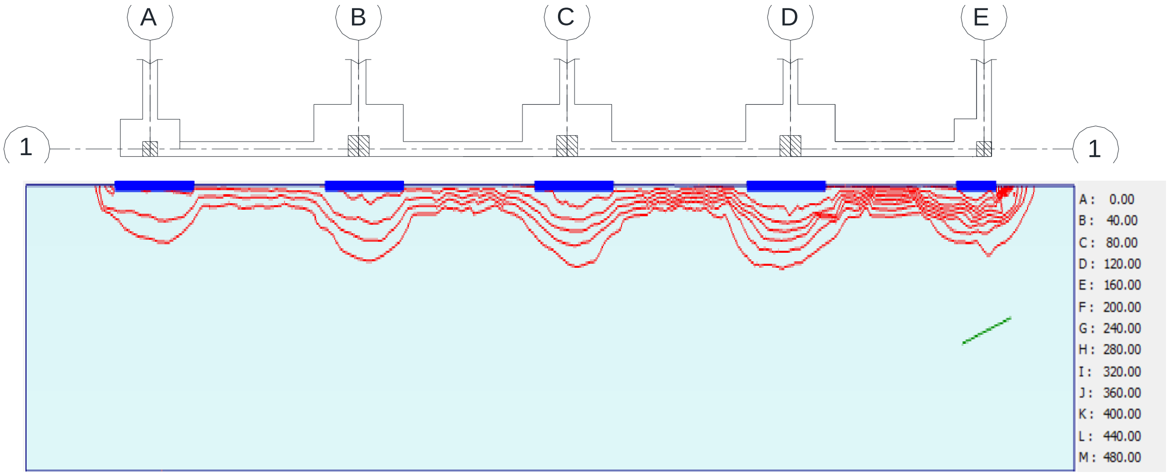
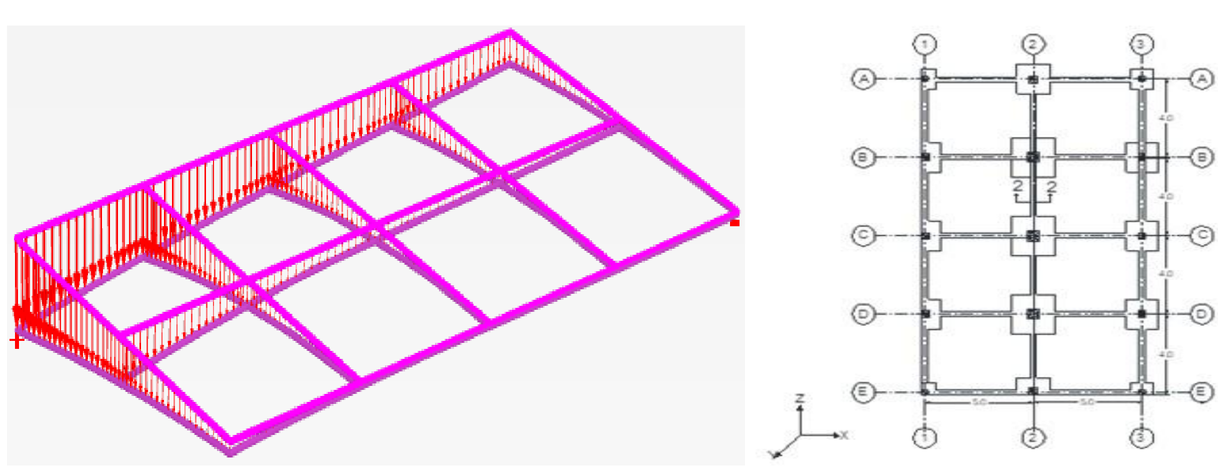
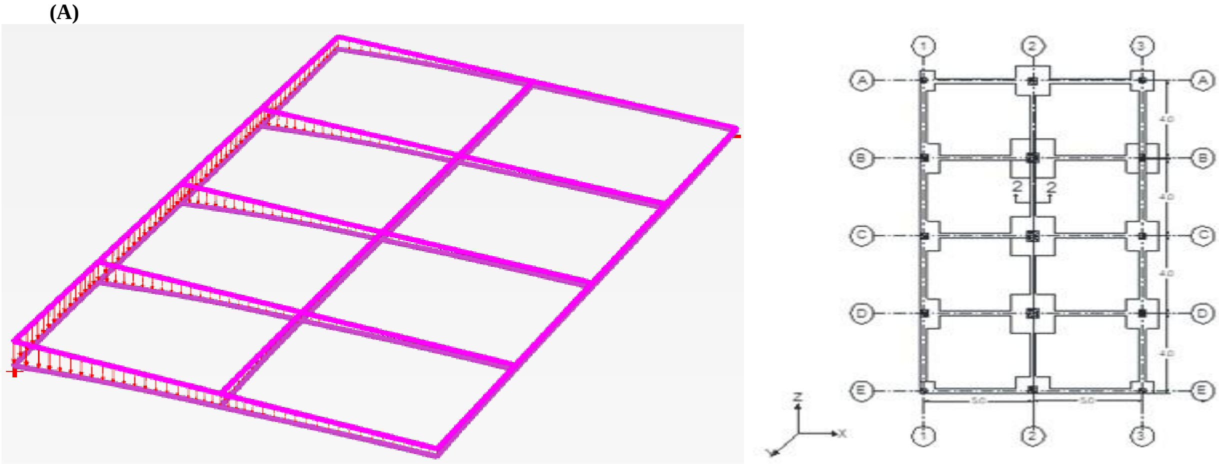


Fig. 9: Total vertical displacements in soil as contour lines at b_{tie} =0.30 m, h_{tie} =2.00 D and Ø = 30˚ along axis (1-1).

Citation: Abd El Samee W. Nashaat, 2018. Effect of Tie Beam Dimensions on The Behaviors of Isolated Footings Under Eccentric Loading. Australian Journal of Basic and Applied Sciences., 12(2): 49-65

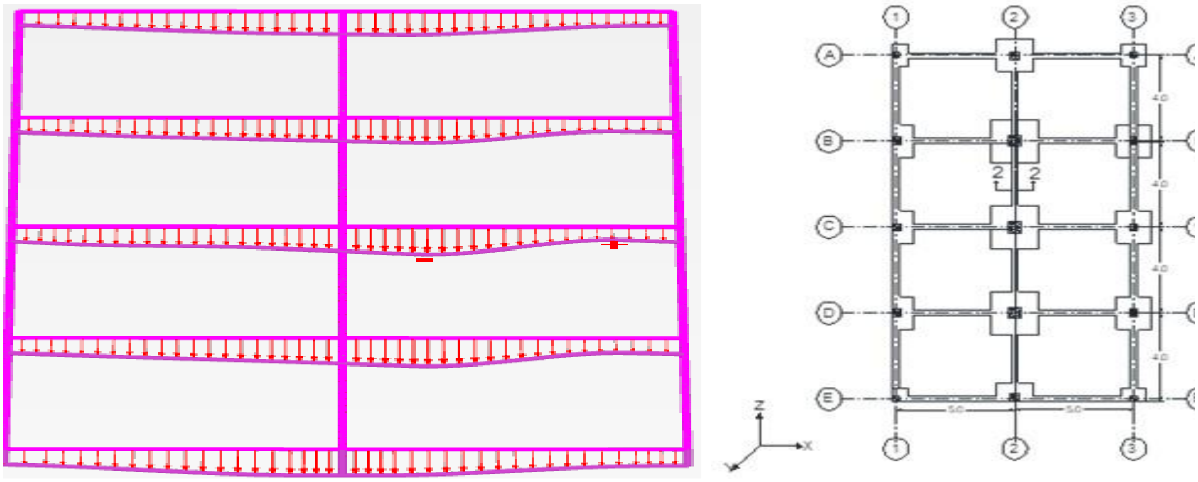


(A)

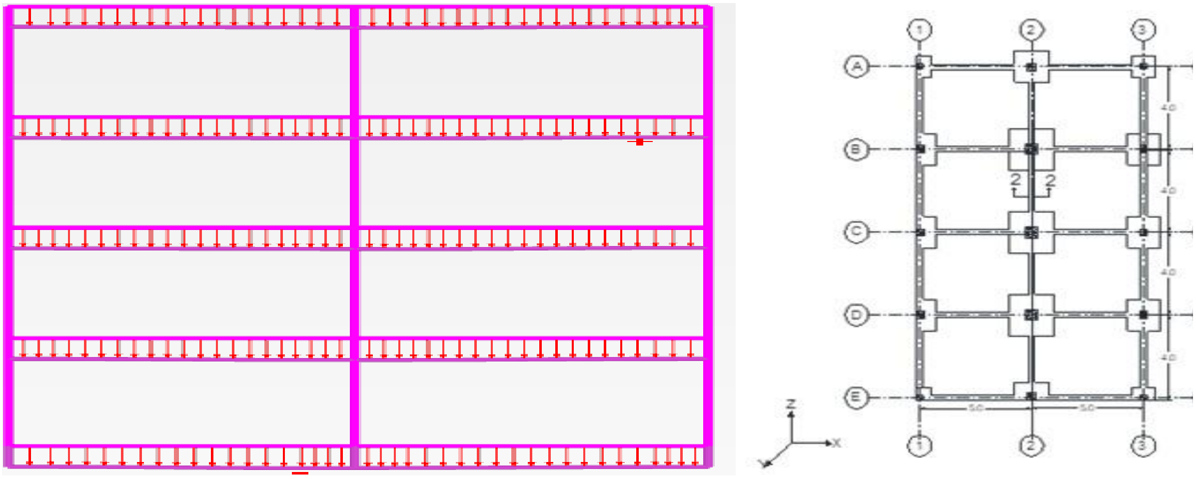


(B)

Fig. 10: The effect of tie beam thickness h_{tie} on total vertical displacements (settlement) under tie beams along all axis's at b_{tie} =0.30 m, h_{tie} = 1.00 D and 2.00 D and Ø = 30˚ along axis's.

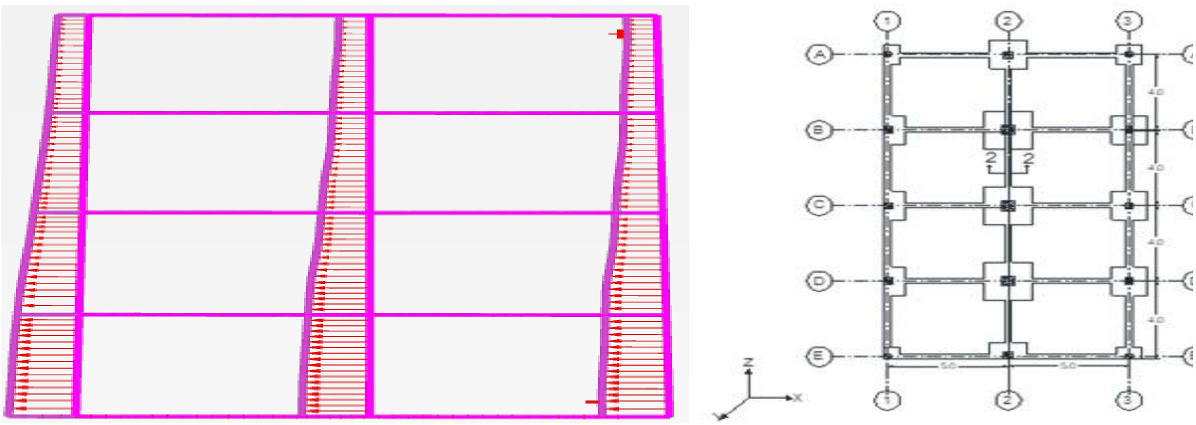


(A)

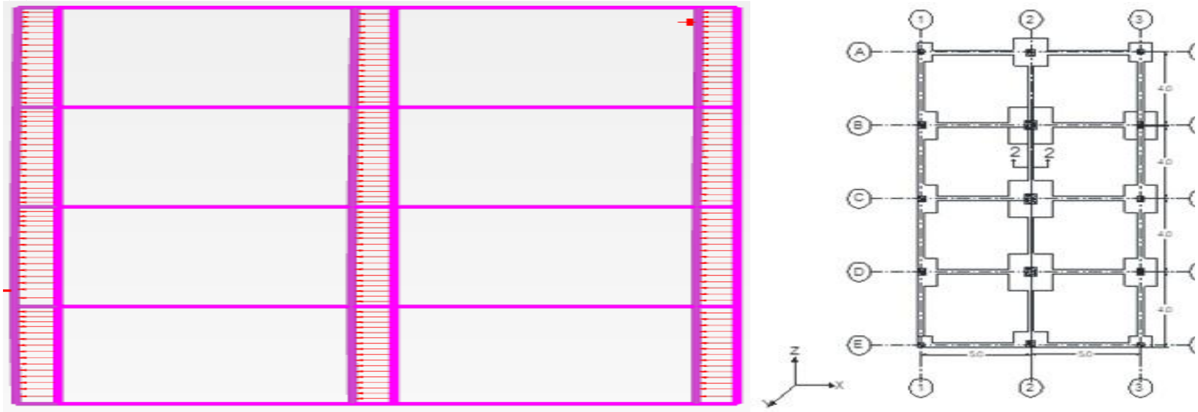


(B)

Fig. 11: The effect of tie beam thickness h_{tie} on total vertical displacements (settlement) under tie beams along all X- axis's at b_{tie} =0.30 m, h_{tie} =1.00 D and 2.00 D and Ø = 30˚ along axis's.



(A)



(B)

Fig. 12: The effect of tie beam thickness h_{tie} on total vertical displacements (settlement) under tie beams along all Y- axis's at (b_{tie} =0.30 m, h_{tie} =1.00 D and 2.00 D and Ø = 30˚) along axis's.

The effect of tie beam dimension on verticall displacement (settlement) were analyzed. Figures (13) and (14) show some examples of comparison between tie beam dimensions and settlement at different depths of footing and different angles of internal friction (Ø). From these figure, it can be shown that the settlement values along the axis's decrease with increasing the thickness and widths of tie beam.

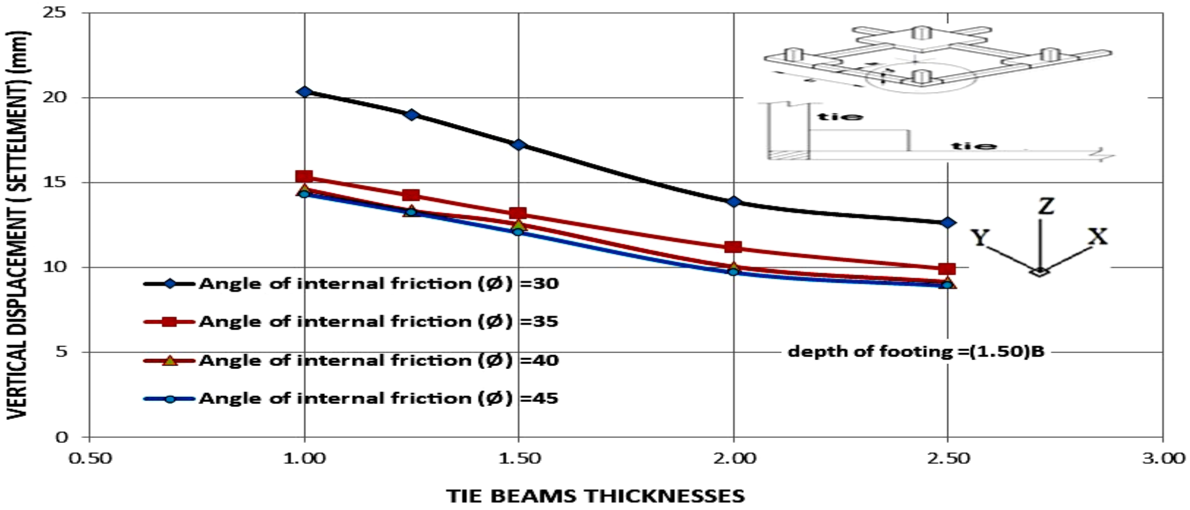


Fig. 13: Comparison between tie beam thicknesses and settlement at tie beam width b_{tie} = 0.50 m and different angles of internal friction (Ø).

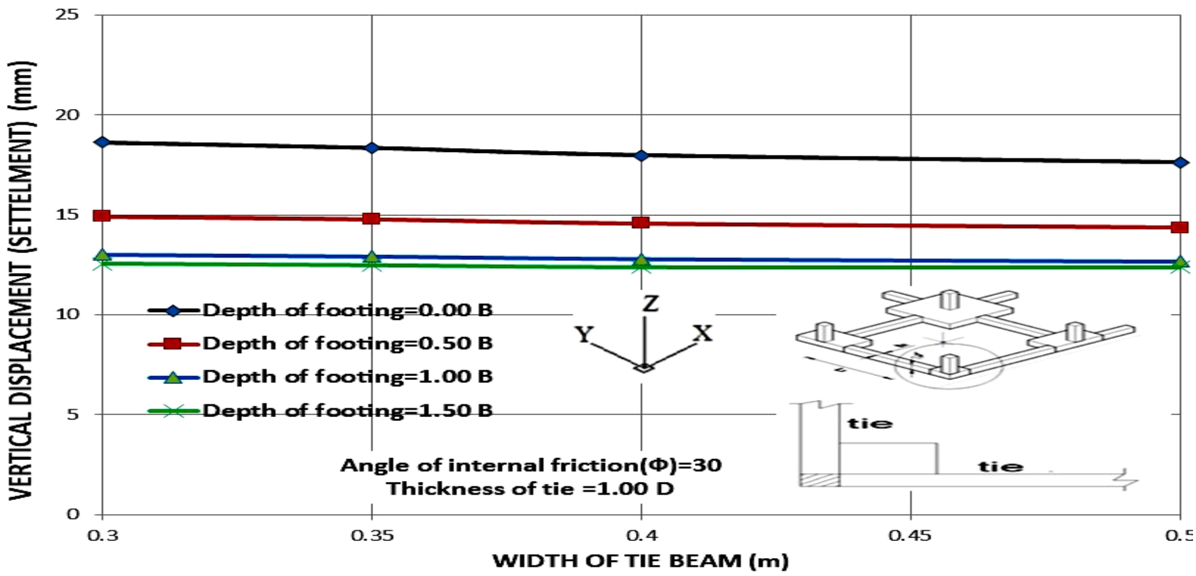


Fig. 14: Comparison between tie beam widths and settlement at tie beam thicknesses h_{tie} = 1.00 m and different depths of footing (D_f).

Effect of tie beam thickness and width on horizontal displacement:

The effect of tie beam dimension on horizontal displacement in x and y directions were analyzed as follow; Figures (15) and (16) show some examples of total horizontal displacements- (x-y) directions in soil for tie beam dimensions connecting isolated footings under eccentric loading. Figures (17) and (18) show the relationships between tie beam dimensions and horizontal displacement in x and y direction for different depths of footing and angle of internal friction. These figures show that the horizontal displacement in x and y directions decreases with increasing tie beam thickness and widths along axis. However, the horizontal displacement in x and y directions decreases with increasing depth of footing (D_f). In addition, the horizontal displacement in x and y directions decreases with increasing the angle of friction up to (Ø =40^0) after that no significant change in horizontal displacement in x and y directions.

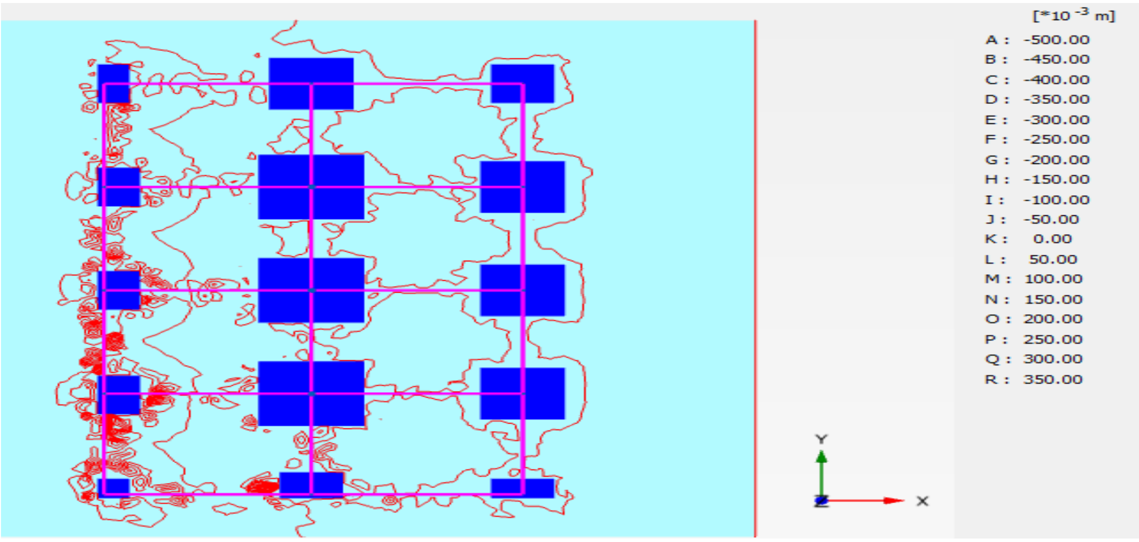


Fig. 15: Total horizontal displacements- x-direction in soil as contour lines at b_{tie} =0.30 m, h_{tie} =1.00 D and Ø = 30˚ along arises.

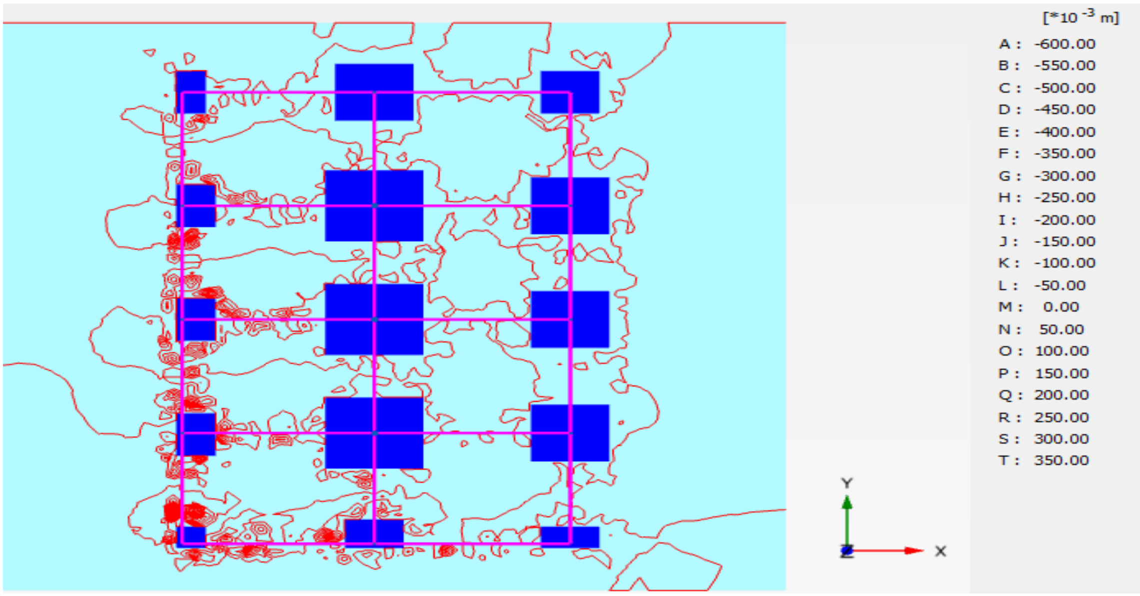


Fig. 16: Total horizontal displacements-y-direction in soil as contour lines at b_{tie} =0.30 m, h_{tie} =1.00 D and Ø = 30˚ along arises.

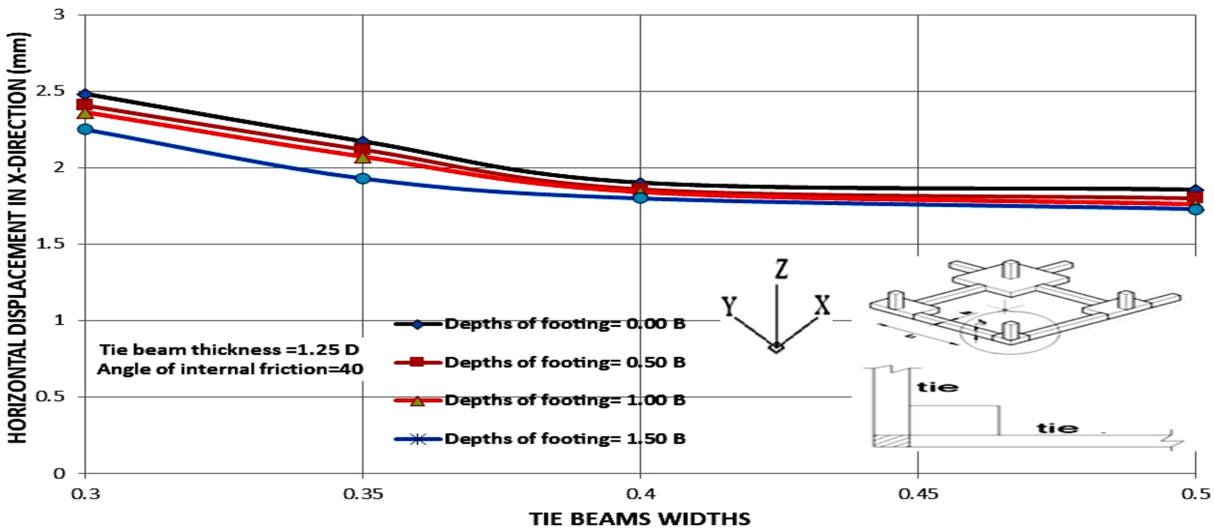


Fig. 17: Comparison between tie beam widths and horizontal displacement in x- direction for different depths of footings (D_f) at tie beam thickness h_{tie} = 1.25 D and at angle of internal friction (Ø) = 40^o.

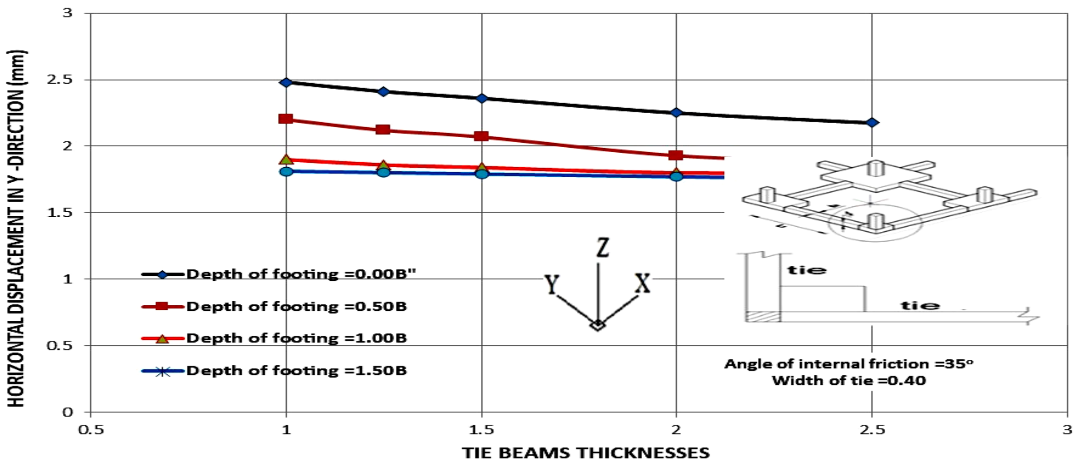


Fig. 18: Comparison between tie beam thicknesses and horizontal displacement in y- direction for different depths of footings (D_f) at tie beam width b_{tie} = 0.40 m and at angle of internal friction (Ø) = 35°.

Effect of tie beam dimensions on contact pressure:

Figure (19) show some examples for the effect of tie beam dimensions connecting isolated footings under eccentric loading on contact pressure for sandy soil along axis's (A – A, C - C, D - D, E – E, 1 – 1 and 2 -2) at tie beam thickness (h_t) =1.00 D and 2.00 D, width of tie (b_t) =0.30 m and at angle of internal friction (Ø) =30⁰. A comparison between the contact pressures under footings connected with different dimensions of tie beam is presented in Figures from (20) to (22). These figures show some examples of comparison between contact pressure and angle of internal friction (Ø), thickness of tie beam and width of tie beam. Fig. (23) shows the relationship between thicknesses of tie beam and contact pressure along axis (E-E). Fig. (24) shows the relationship between depths of footings and contact pressure along axis (1-1). From these figures, it can be shown that the contact pressure values along the axis decrease with increasing the thickness as well as widths of tie beams.

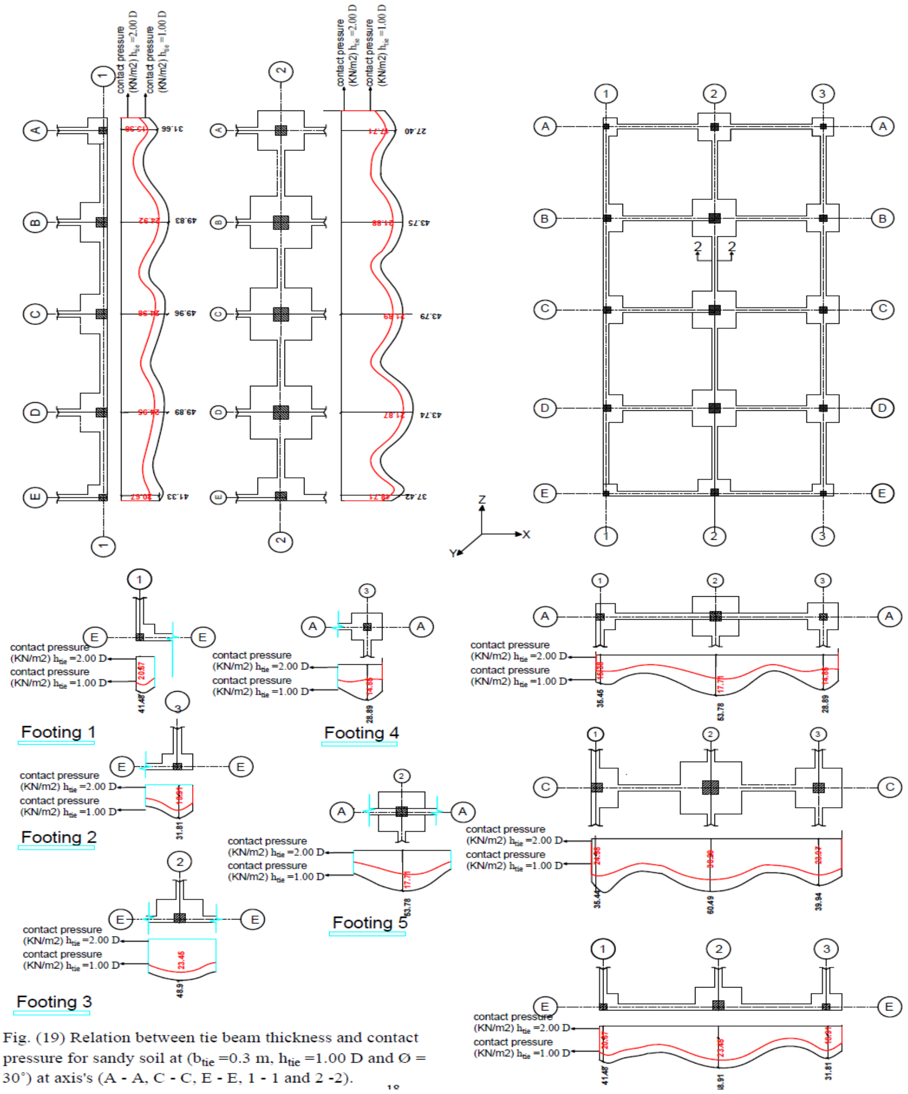


Fig. 19: Distribution of contact pressure for sandy soil at along axis's at b_{tie} =0.3 m, h_{tie} =2.00 D and at Ø = 30°) along axis's (A – A, C - C, E - E, 1 – 1 and 2 -2).

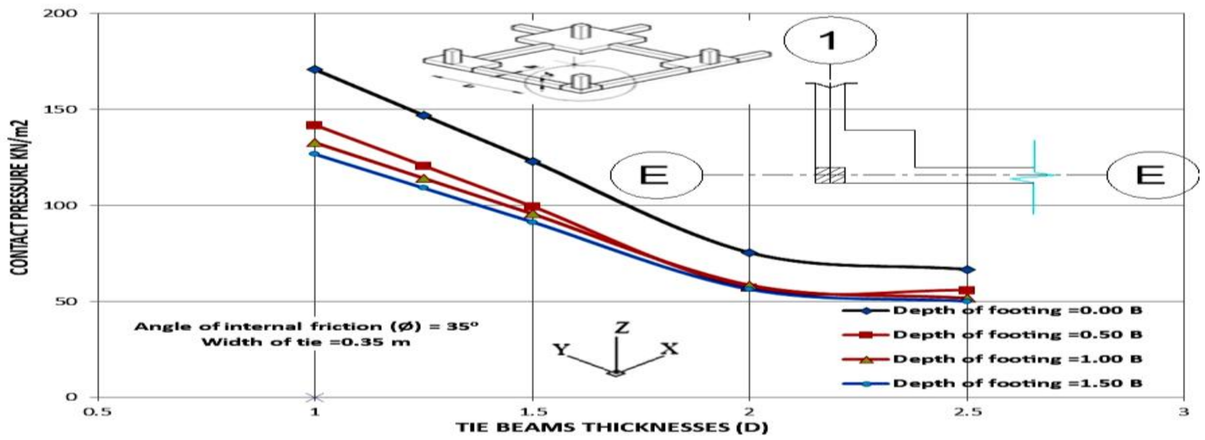


Fig. 20: Comparison of tie beam thicknesses and contact pressure at different of depth of footing (D_f) and at width b_{tie} = 0.35 m and at angle of internal friction (Ø) = 35°.

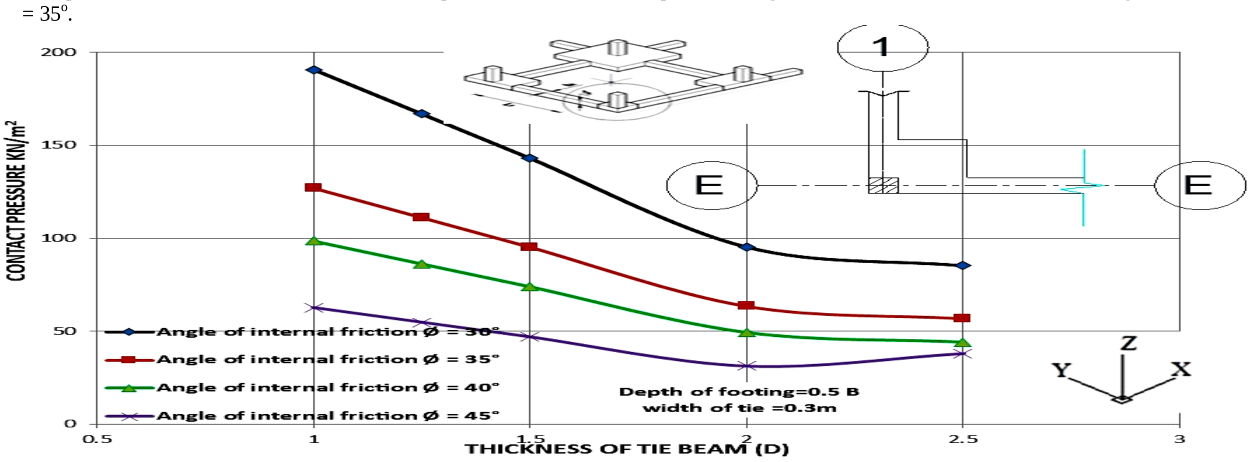


Fig. 21: Comparison of tie beam thicknesses and contact pressure at different angle of internal friction Ø and depth of footing (D_f) = 0.50 B, and width b_{tie}=0.30 m.

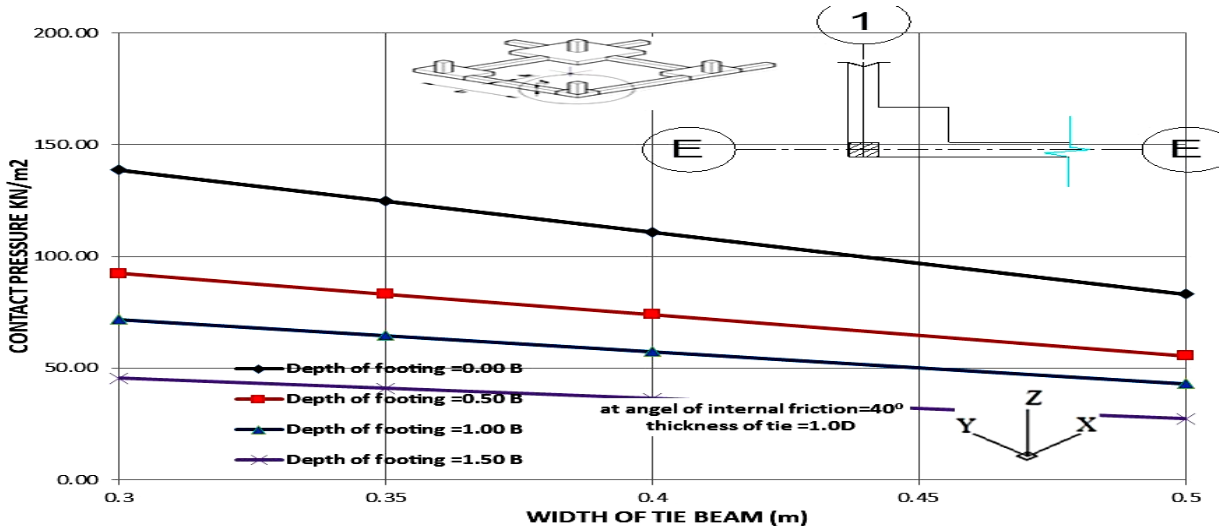


Fig. 22: Relationship between contact pressure and width of tie beam at angle of internal friction Ø = 40°, thickness h_{tie} = 1.00 D.

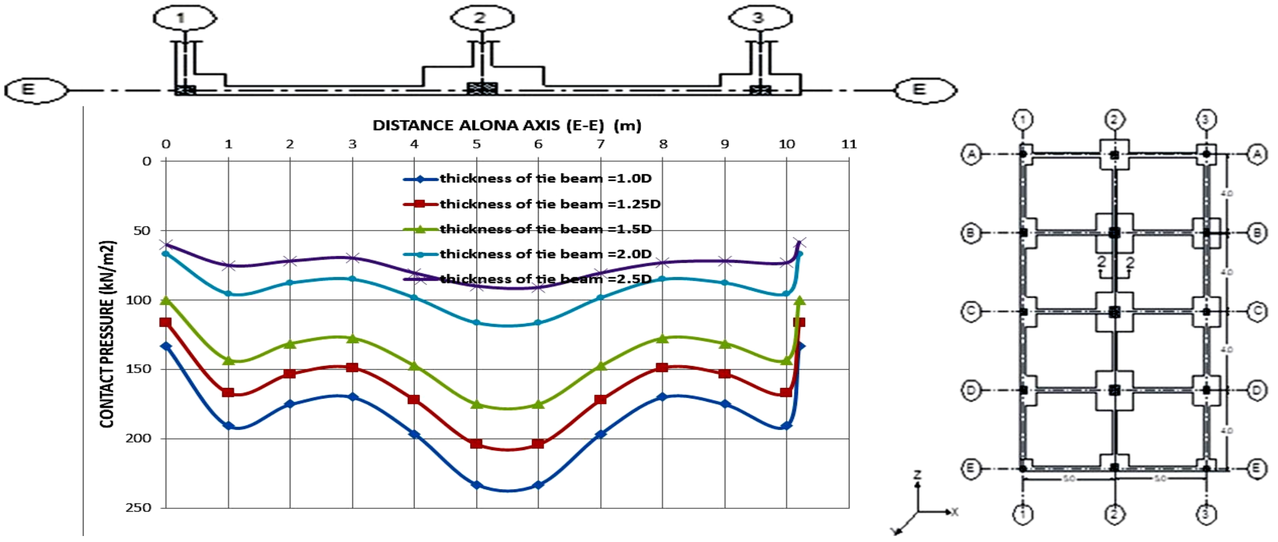


Fig. 23: Relationship between thicknesses of tie beam and contact pressure along axis (E-E) at angle of internal friction Ø = 35°, width b_{tie} = 0.30 m and depth of footing (D_f) =0.00 B.

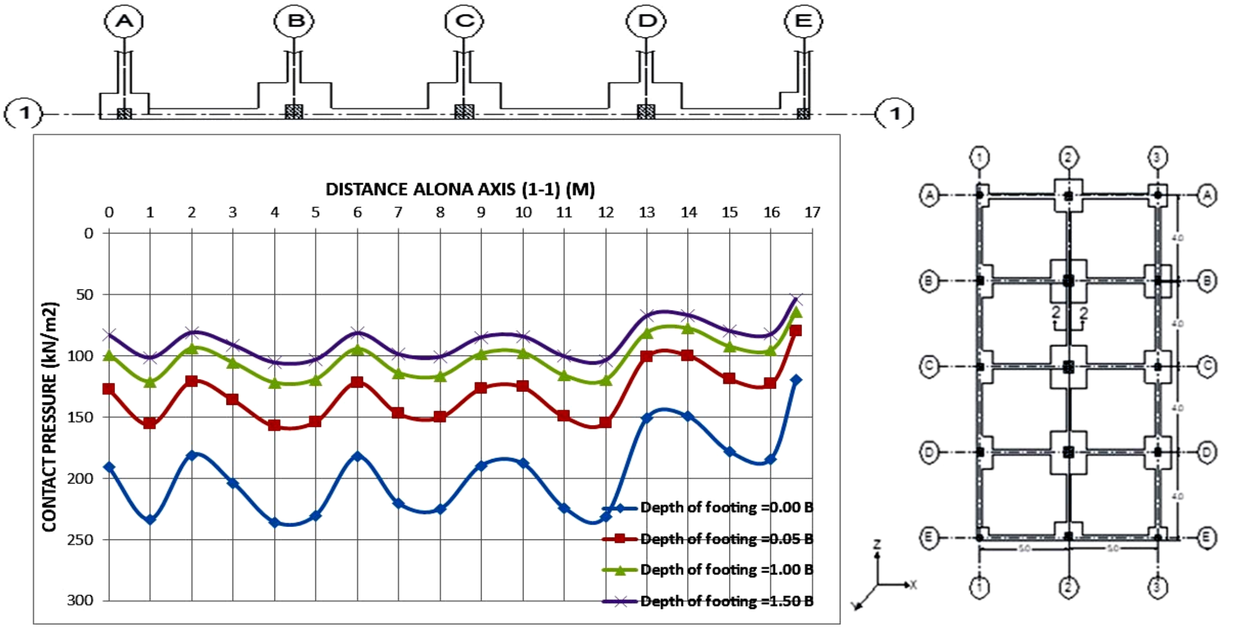


Fig. 24: Relationship between depths of footings and contact pressure along axis (1-1) at angle of internal friction Ø = 35°, width b_{tie} = 0.35 m and thicknesses of tie beam =1.00D.

Effect of tie beam dimensions on bending moment:

The effect of tie beam dimension connecting isolated footings under eccentric loading on distribution of bending moment for tie beam along axis's (E -E) and (1-1) are presented in Figures (25) and (26). These figures show some examples of the distribution of bending moment for tie beam- footing system along axis (E-E) for different widths and thicknesses of tie beam at angle of internal friction Ø = 30° and thickness of footing h_{t1} = 1.00D and h_{t1} = 2.00 D. Figures (27) and (28) show some examples of the distribution of bending moment for tie beam- footing system along axis (1-1) for different widths and thicknesses of tie beam at angle of internal friction Ø = 35° and thickness of footing h_{t1} = 1.00D and h_{t1} = 2.00D. From these figures it can be concluded that the values of bending moment along tie beams at axis decreases with increasing the dimensions of tie beams.

Citation: Abd El Samee W. Nashaat, 2018. Effect of Tie Beam Dimensions on The Behaviors of Isolated Footings Under Eccentric Loading. Australian Journal of Basic and Applied Sciences., 12(2): 49-65

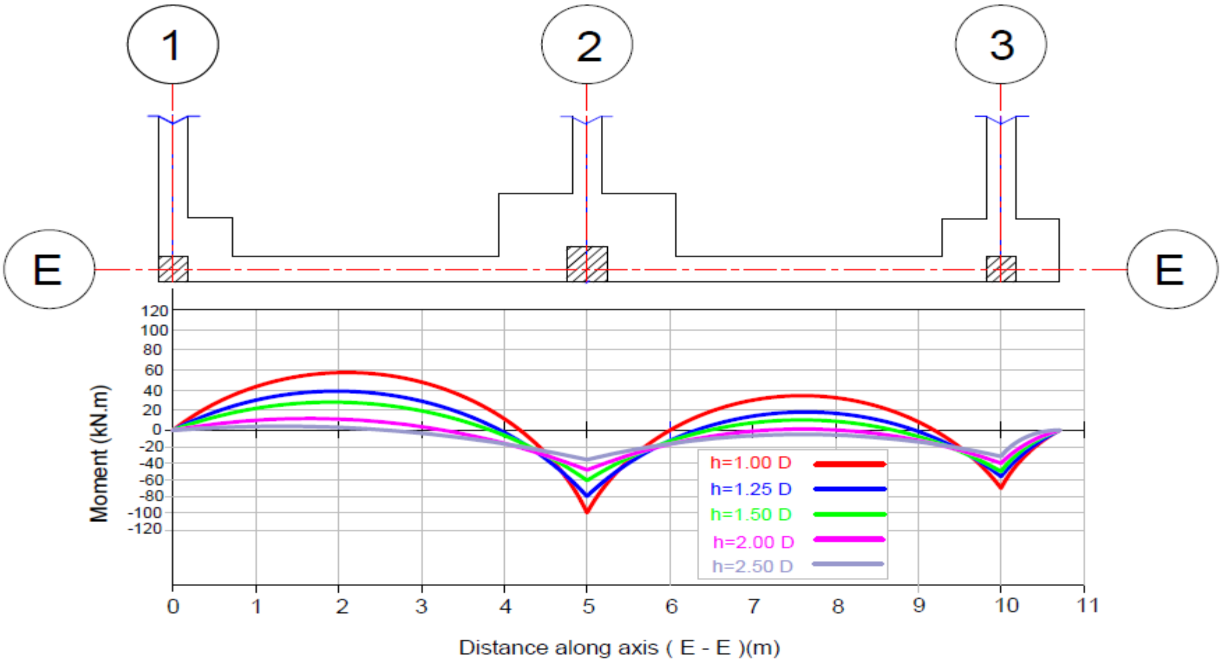


Fig. 25: Distribution of bending moment for tie beam connecting isolated footing under eccentric load along axis (E-E) for different thicknesses of tie beam at angle of internal friction Ø = 35° and width of tie b_{tie} = 0.30 m.

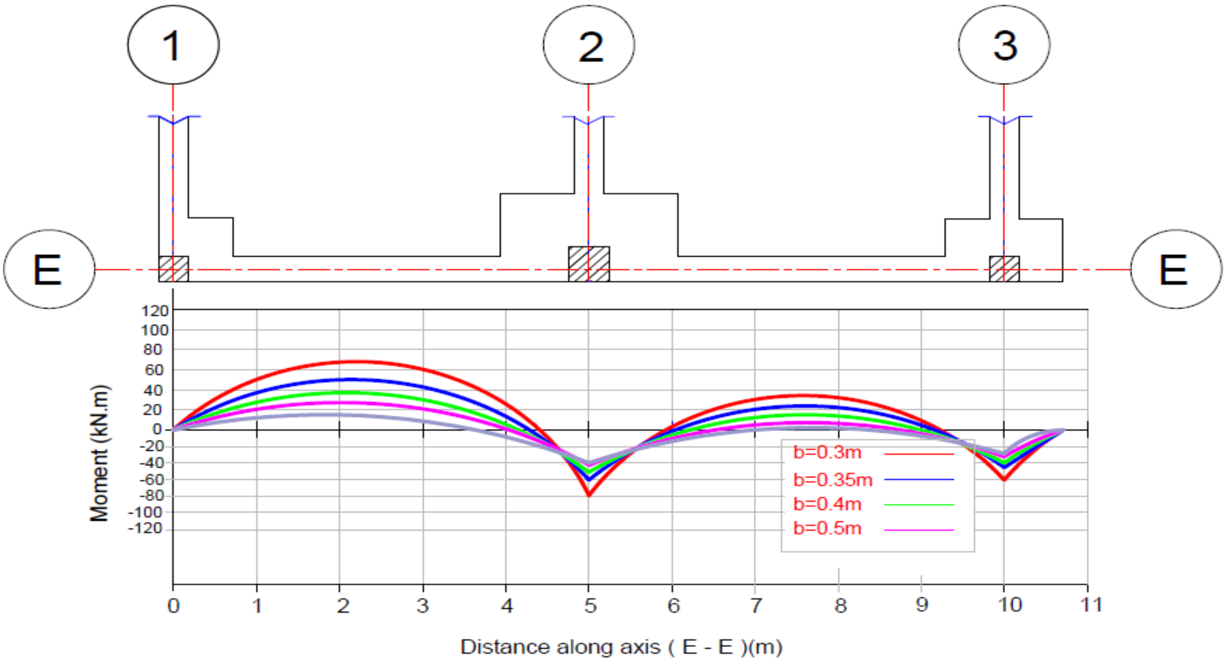


Fig. 26: Distribution of bending moment for tie beam connecting isolated footing under eccentric load along axis (E-E) for different widths of tie beam at angle of internal friction Ø = 35° and thicknesses of tie beam h_{tie} = 1.00 D.

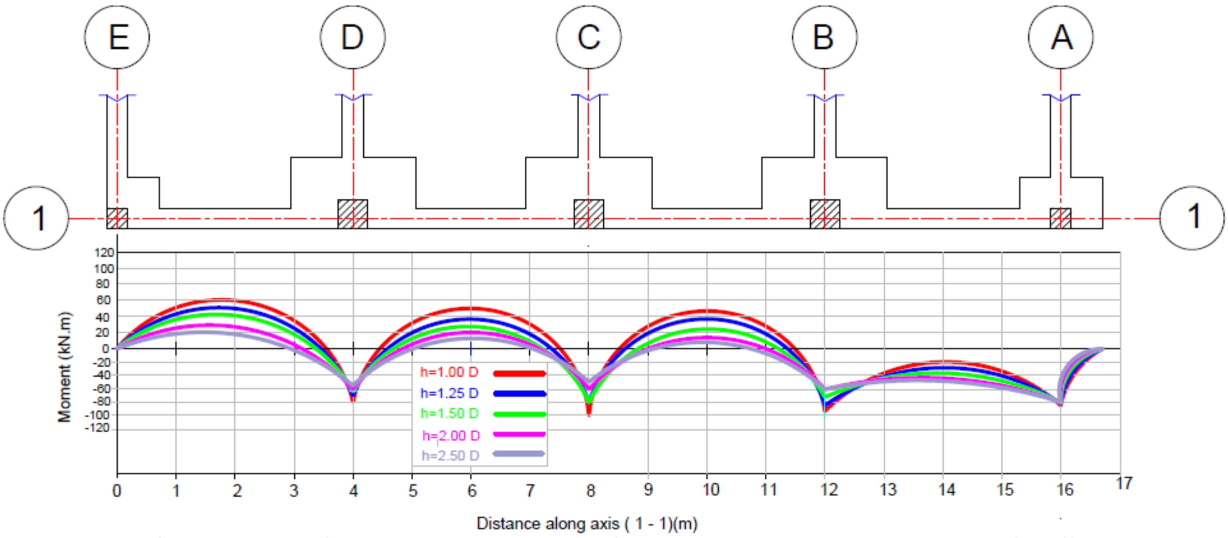


Fig. 27: Distribution of bending moment for tie beam connecting isolated footing under eccentric load along axis (1-1) for different thicknesses of tie beam at angle of internal friction Ø = 35° and width of tie b_{tie} = 0.30 m.

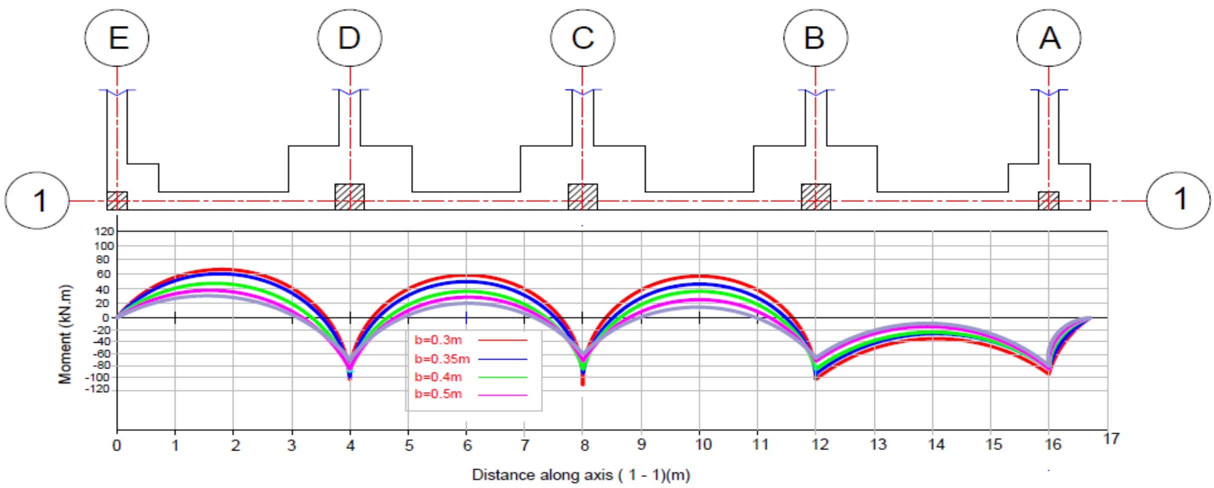


Fig. 28: Distribution of bending moment for tie beam connecting isolated footing under eccentric load along axis (1-1) for different widths of tie beam at angle of internal friction Ø = 35° and thicknesses of tie beam h_{tie} = 1.00 D.

Effect of tie beam dimensions on distribution of shear forces:

The effect of tie beam dimension connecting isolated footings under eccentric loading on distribution of shear forces for tie beam along axis's (E -E) and (1-1) are presented in Figures (29) and (30). These figures show some examples of the distribution of shear forces for tie beam- footing system along axis (E-E) for different widths and thicknesses of tie beam at angle of internal friction Ø = 30° and thickness of footing h_{t1} = 1.00 D and h_{t1} = 2.00 D. Figures (31) and (32) show some examples of the distribution of shear forces for tie beam- footing system along axis (1-1) for different widths and thicknesses of tie beam at angle of internal friction Ø = 35° and thickness of footing h_{t1} = 1.00 D and h_{t1} = 2.00 D. From these figures it can be concluded that the values of shear forces along tie beams at axis decreases with increasing the dimensions of tie beam.

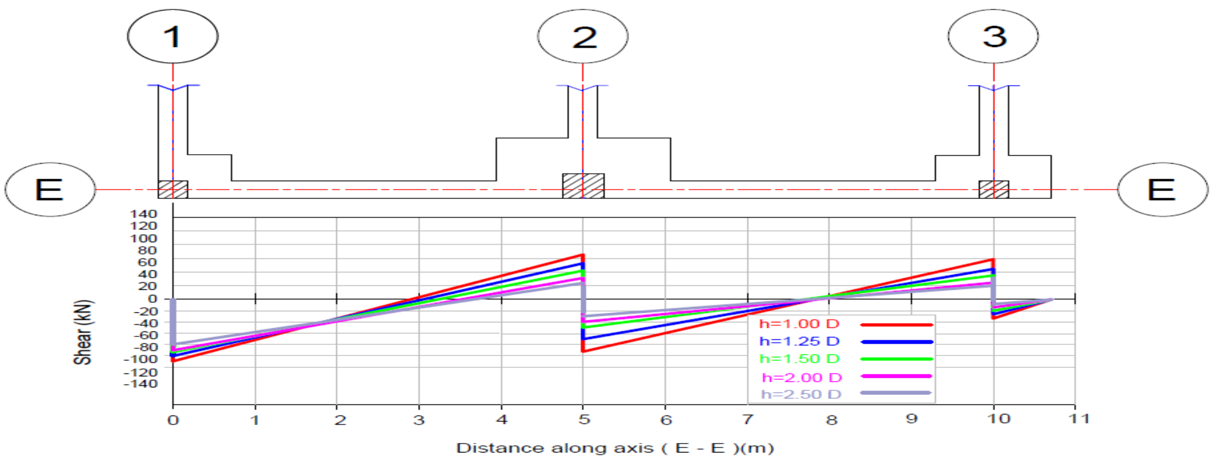


Fig. 29: Distribution of shear forces for tie beam connecting isolated footing under eccentric load along axis (E-E) for different thicknesses of tie beam at angle of internal friction Ø = 35° and width of tie b_{tie} = 0.30 m.

Citation: Abd El Samee W. Nashaat, 2018. Effect of Tie Beam Dimensions on The Behaviors of Isolated Footings Under Eccentric Loading. Australian Journal of Basic and Applied Sciences., 12(2): 49-65

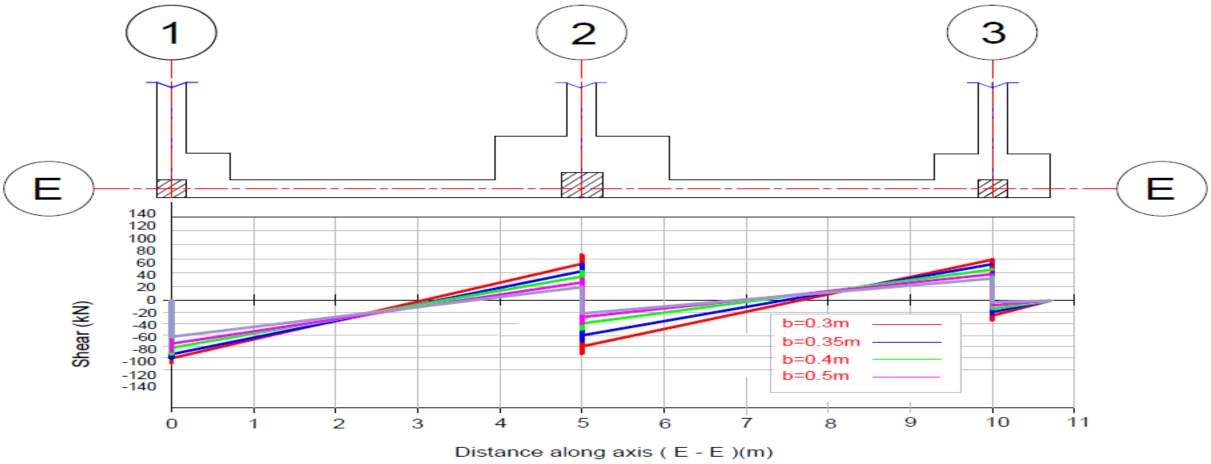


Fig. 30: Distribution of shear forces for tie beam connecting isolated footing under eccentric load along axis (E-E) for different widths of tie beam at angle of internal friction Ø = 35° and thicknesses of tie beam h_{tie} = 1.00 D.

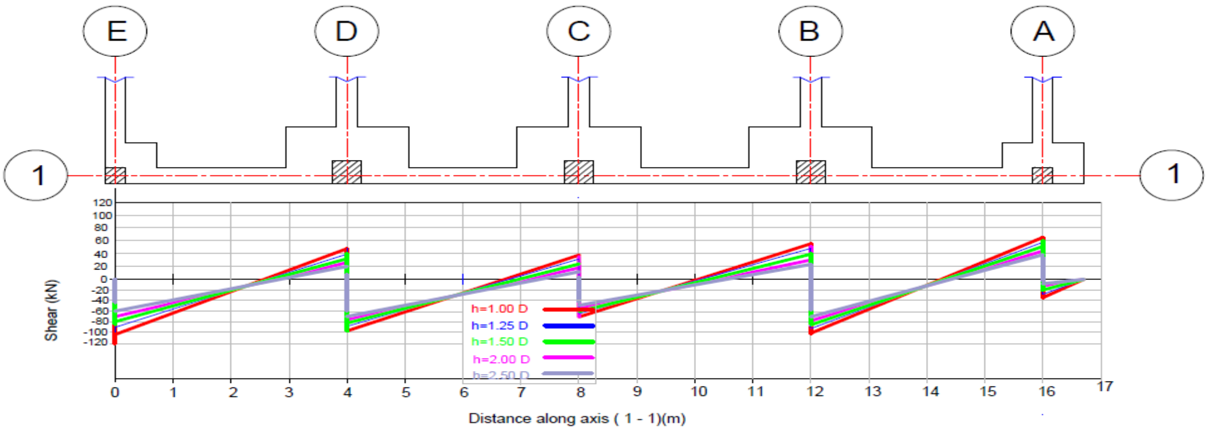


Fig. 31: Distribution of shear forces for tie beam connecting isolated footing under eccentric load along axis (1-1) for different thicknesses of tie beam at angle of internal friction Ø = 35° and width of tie b_{tie} = 0.30 m.

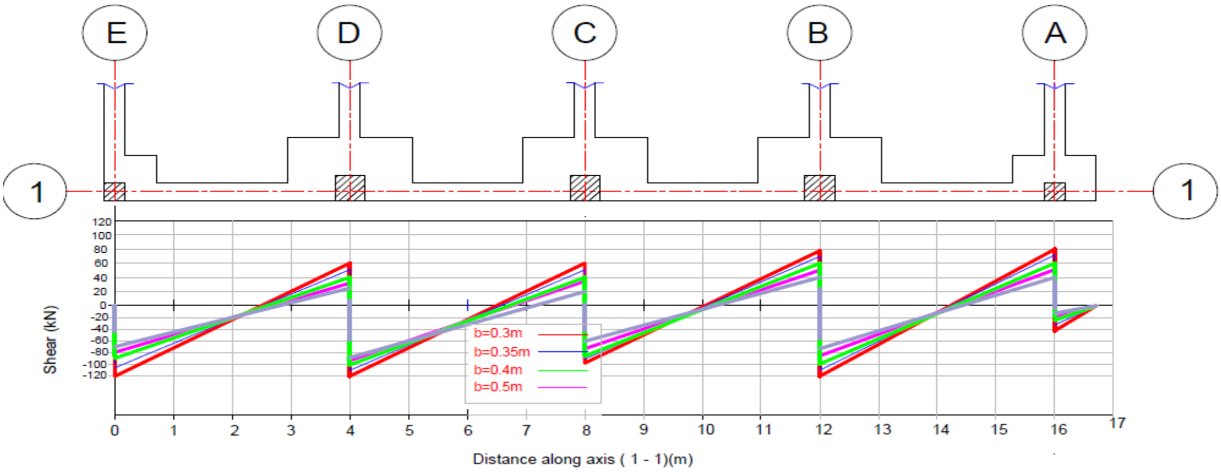


Fig. 32: Distribution of shear forces for tie beam connecting isolated footing under eccentric load along axis (E-E) for different widths of tie beam at angle of internal friction Ø = 35° and thicknesses of tie beam h_{tie} = 1.00 D.

Effect of tie beam dimensions on distribution of stresses under footings connected with tie beams:

The effect of tie beam dimension connecting isolated footings under eccentric loading on distribution of stresses under footing axis's (E -E) are presented in Figures from (33). to (35). These figures show some examples of the relationship between stresses distribution under footings for different thickness of tie beam at angle of internal friction=30° and depth of footing (D_f) =00.0B. From these figures it can be shown that the distribution of stresses under footing decreases with increasing both of tie beam thickness and width. However, the differential settlements of footings decrease with increasing tie beam dimensions. In addition, the stress distribution under eccentric footings along axis's almost uniform at tie beam thickness = 2.50 thickness of footing.

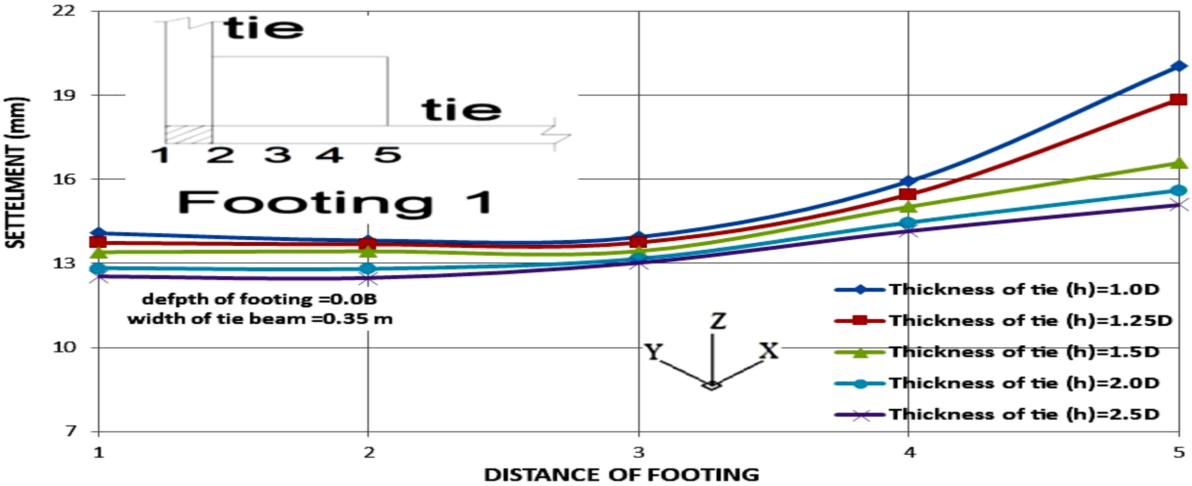


Fig. 33: Relationship between length of footing and stress distribution under footing for different thickness of tie beam at angle of internal friction = 30°, width of tie b_{tie} and D=0.50 B.

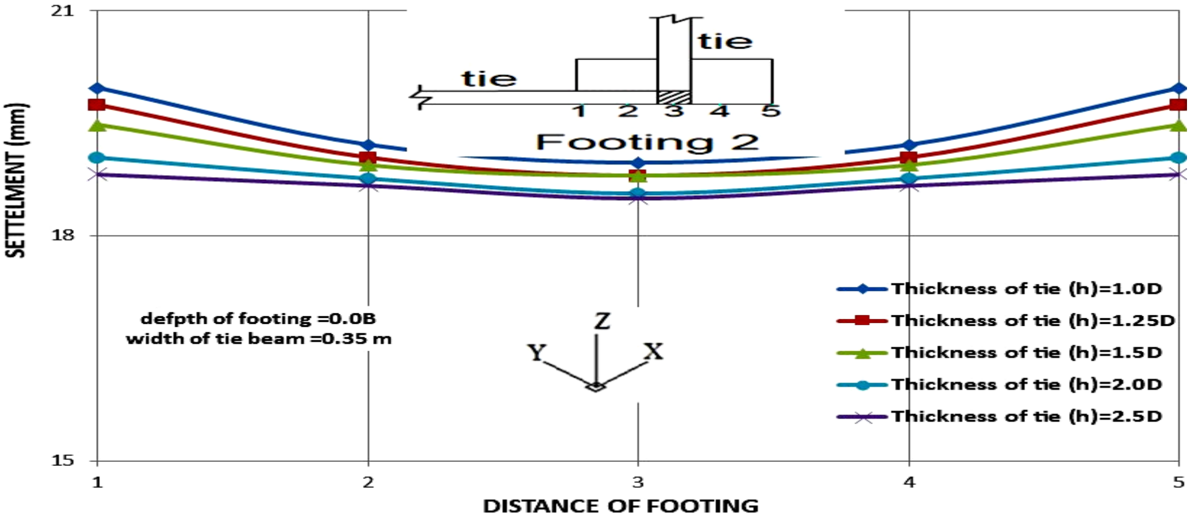


Fig. 34: Relationship between length of footing and stress distribution under footing for different thickness of tie beam at angle of internal friction = 30°, width of tie b_{tie} and D=0.50 B.

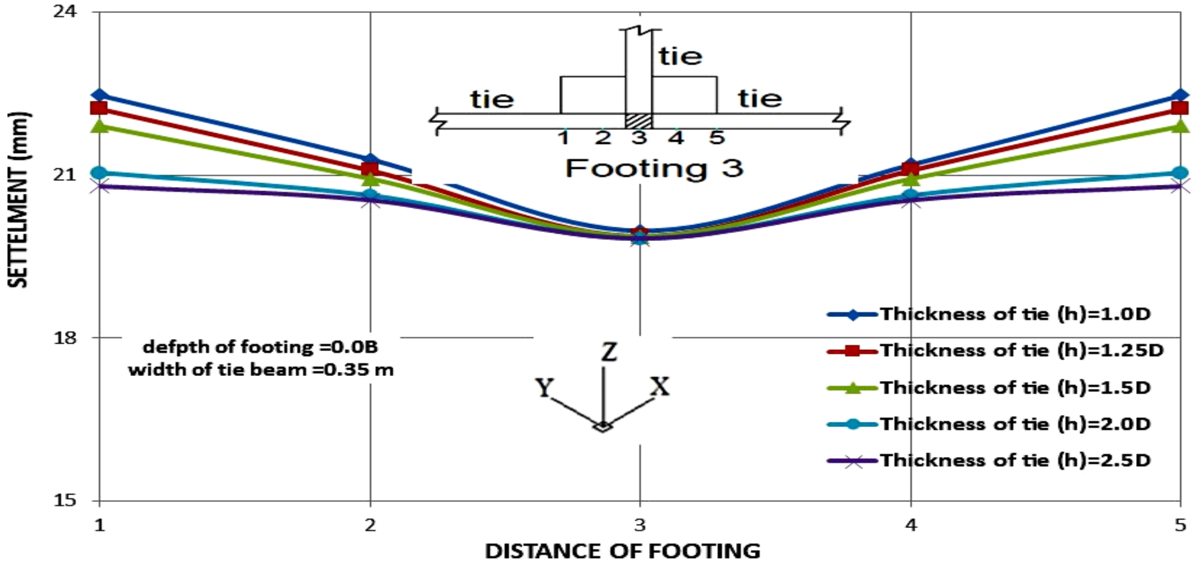


Fig. 35: Relationship between length of footing and stress distribution under footing for different thickness of tie beam at angle of internal friction = 30°, width of tie b_{tie} and D=0.50 B.

Conclusions:

From the present study, for the footing under eccentric loading the following conclusions are obtained:

i. The settlement and horizontal displacement values in both directions as well the contact pressure values decrease with increasing the thickness and widths of tie beam.

ii. The settlement and horizontal displacement in both directions decrease with increasing the angle of friction up to (Ø $=40^0$) after which no significant change in settlement and horizontal displacement.

iii. The values of bending moment and shear forces for tie beam along axis decreases with increasing the dimensions of tie beam.

iv. The distribution of stresses under footing along axis's decreases with increasing both of tie beam thickness and width. However, the differential settlements of footings decrease with increasing tie beam dimensions.

REFERENCES

Georgiadis, M., R. Butterfield, 1988. Displacements of footings on sand under eccentric and inclined loads. Canadian Geotechnical Journal, 25(2): 199-212.

Mahiyar, H., A.N. Patel, 2000. Analysis of Angle Shaped Footing Under Eccentric Loading. Journal of Geotechnical and Geo Environmental Engineering Division of ASCE, 126(1): 1151-1156.

Elsaadany, M.M., 2004. Role of Tie-Beams in Isolated Eccentric Shallow Footings. Civil Engineering Research Magazine(CERM), Faculty of Engineering Al-Azhar University Cairo Egypt, 26(1): 606-618.

Al-Omari, R.R., L.H. Al-Ebadi, 2008. Effect of Tie Beams on Settlements and Moments of Footings. The 12th International Association for Computer Methods and Advances in Geomechanics (IACMAG) October, Goa, India, pp: 3216-3223.

Dayamond, P.J., H. Mahiyar, 2009. Angle Shaped Footing under Eccentric Vertical Load. Indian Geotechnical Society, Guntur, India, pp: 609-613.

Kumawat, S., H.K. Mahiyar, 2015. Experimental Study on Tee Shaped Footing under Eccentric Vertical Loading. International Journal for Scientific Research & Development|, 2(11): 2321-0613.

Pusadkar, S.S., Y.S. Navkar, 2016. Performance of Square Footing Subjected to Eccentric-Inclined Load. International Journal of Engineering Research, 5(1): 44-46.

Elbatal, S.A., M.M. Abo-Alanwar, 2017. Straining Actions of Footings connected with Tie Beams resting on Replaced soil. International Journal of Scientific & Engineering Research, 8(5): 1-13.

El-samny, M.K., H.A. Ezz-Eldeen, B. Sameh, A.M. Kamar, 2017. Effect of Tie Beam Dimensions on Vertical and Horizontal Displacement of Isolated Footing. International Journal of Engineering Research & Technology, 6(04): 87-94.