NUMERICAL STUDY ON THE EFFECT OF FOOTING SHAPE ON THE BEARING CAPACITY

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Abstract: The aim of this research is to investigate numerically the effect of foundations shape on bearing capacity. The shapes studied are square, circular and rectangular footing of width to length ratios L/B=1.5 and 2 respectively. The soil beneath foundation was compacted sand of relative density Dr=60% and Dr=80%. Finite element computer software Plaxis 3D version 2020 was used to predict the load-settlement behavior of footings resting on compacted sand. The results obtained from numerical analysis were compared with that obtained from theoretical method approach. It was found that square footing bearing capacity was higher than circular footing. Also, it was observed that in case of rectangular footing the bearing capacity varies with increase of L/B ratios. It was concluded that the shape of foundation has significant effect on its bearing capacity and settlement.

Keywords: foundation shape effect, bearing capacity, settlement, compacted sand, L/B ratio, finite element, Plaxis 3D, theoretical method approach.

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1 INTRODUCTION AND PREVIOUS RESEARCH

Estimating bearing capacity of foundations is one of the most important subjects in geotechnical engineering. Many factors affect the bearing capacity of foundations, one of the is the effect of shape of foundation.

The purpose of this research is to investigate numerically the effect of foundation shape on bearing capacity and settlement.

This paper is based on the previous work done by **Manav Petal et al. (2019),** they conducted an experimental model as shown in fig. (1) to study the effect of footing shape on its bearing capacity. The footing shapes studied were square, rectangular and circular footings of the same widths. Experimental model results were compared with results obtained using Terzaghi's approach to validate the experimental results. They concluded that the shape of the footing has a significant effect on its bearing pressure and settlement.

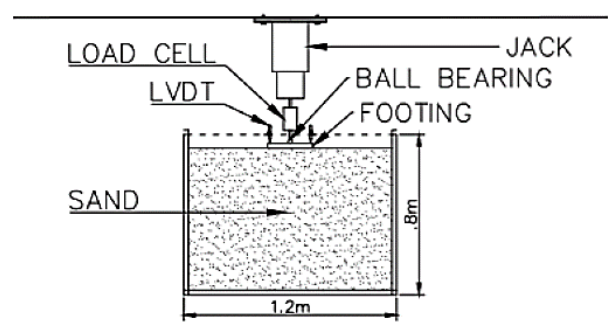

Fig. (1) Experimental model setup

by Manav Petal et al. (2019)

Some previous work done on this subject includes:

M.S.A. Siddiquee et al (1997), They investigated the effect of footing shape on its bearing capacity and settlement on Sands.

An experimental model tests was conducted and numerical simulation of the model was carried out to verify the results.

Tests were performed on two large footings of widths 10 and 23cm and varying lengths resting on sand soil of different densities. It was concluded that bearing capacity increases with increase of B/L ratios.

S. R. Pathak et al (2008), They studied the behavior of square, rectangular and circular footings resting on cohesive soil using a physical model. The aim of their research was to investigate the effect of various parameters such as L/B ratios, shape of footing and its size on bearing capacity. The results obtained from physical model was compared with results obtained from analytical methods lole Terzaghi's and Vesic's methods.

It was concluded that footing size has an important effect on bearing capacity where ultimate bearing capacity increases with size of footing increase specially fot rectangular footings.

Also, it was observed that bearing capacity decreses with increase of L/B ratio for the same width.

Finally, it was found that the bearing capacity of square footing has bigger value that in case of circular and rectangular footing having the same area.

Du L. Nguyena et al (2015), They investigated the size effect of footing resting on sandy soil on its bearing capacity using rigid plastic finite element method. They concluded that the effect of footing size on bearing capacity was simulated using rigid plastic finite element method and proved by comparing the results obtained using mentioned method and results obtained using theArchitectural Instituteof Japan's formula.

M. S. Dixit et al (2013), They investigated the effect of Shape of Footing, depth of footing and Water Table on Bearing Capacity of Soil. It was observed that the values of ultimate bearing capacity for circular and square shaped footings are higher than strip and rectangular footings specially in case of cohesionless soils.

2 Materials and Methods

The material used in this study is sand. Sand is classified as SP according to Unified Classification System. The Sand was compacted to reach relative density Dr=60% and Dr=80%. The properties of sand sample are given in Table 1.

Table (1) Summary of Sand properties

Parameter	Value
Specific gravity Gs	2.67
Maximum dry density (kN/m^3)	17
Effective diameter D_{10} (mm)	0.17
Uniformity Coefficient (Cu)	1.76
Coefficient of curvature (Cc)	0.94

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Modulus of elasticity Es (MPa)	15
Poisson's ratio υ	0.30
Angle of internal friction (ϕ)	31°

2.1 Numerical Analysis

Plaxis 3D ver. 2020 computer program was used to predict bearing capacity and settlement of footings resting on compacted sand. This threedimensional numerical analysis program is specially developed for the analysis of complex three-dimensional geotechnical problems. The modelling of the loading, footings and soil was performed.

2.2 Numerical Model Setup

. The soil was modeled using the advanced hardening soil model. The hardening soil model implemented in PLAXIS combines of plasticity theory with the logic of the Duncan-Chang model. It includes ten input parameters such as cohesion (effective) C′, angle of internal friction (effective)ϕ′, angle of dilatancy Ψ, primary loading stiffness E_{50}^{ref} , primary oedometer loading stiffness E_{oed}^{ref}, unloading-reloading Poisson's ratio ν_{ur}, unloading- reloading stiffness E_{ur}^{ref}, power m in stiffness laws and failure ratio Rf. Table (2) show the soil parameters used.

Table (2) Soil parameters used in numerical model

Parameter	Medium Sand (Dr=60%)	Dense Sand (Dr=80%)
Unit Weight (kN/m^3)	19	19.5
E_{50} ^{ref} (MPa)	40	60
E_{oed} ^{ref} (MPa)	40	60
E_{ur} ^{ref} (MPa)	120	180
Poisson's ratio for unloading- reloading υ_{ur}	0.2	0.2
Angle of internal friction (ϕ)	37°	39°
Cohesion C in (kPa)	0	0
Dilatancy angle (Ψ)	7°	9°
Rf	0.9	0.9
M	0.5	0.5

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The footings were modeled using 10-noded tetrahedral

Volume element having the following properties as shown in

Table (3)

Table (3) Properties of Footing

Property	Unit weight (KN/m^3)	Modulus of elasticity E (KN/m^2)	Poisson ratio (μ)
Value	25	3*10^7	0.1

The dimensions of the model boundaries were taken as width and length equal to 1.2m and height of the model was equal to 0.8m as shown in Fig. (2). The boundary conditions were assumed such that the vertical boundaries were fixed in horizontal direction and the bottom boundary was fixed in both directions (vertical and horizontal). Medium mesh size was used with local refinement beneath the footing area to improve results.

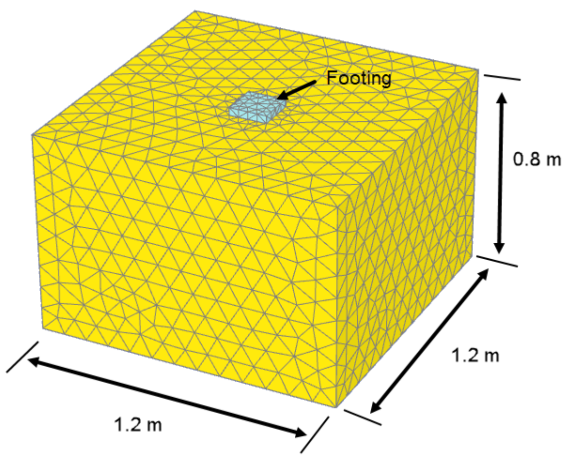

Fig. (2) Geometry of finite element model

Load-settlement curves from loading Square, circular and rectangular footings were obtained to investigate the effect of shape on bearing capacity and settlement. Fig. (3) show the total vertical displacement in case of loading a circular footing.

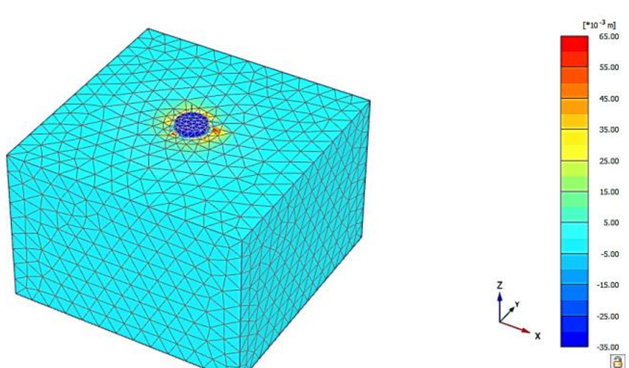

Fig. (3) Total vertical displacement in case of circular Footing

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3 RESULTS AND DICUSSION

3.1 Numerical Model Results

The following represent the load-settlement relationship for different shapes of footing resting on medium sand (Dr=60%) and dense sand (Dr=80%) to investigate the effect of footing shape on bearing capacity and settlement at different sand densities.

Fig. (4) show the load-settlemnt relationship for diffrernt footing shapes in case of medium sand (dr=60%).

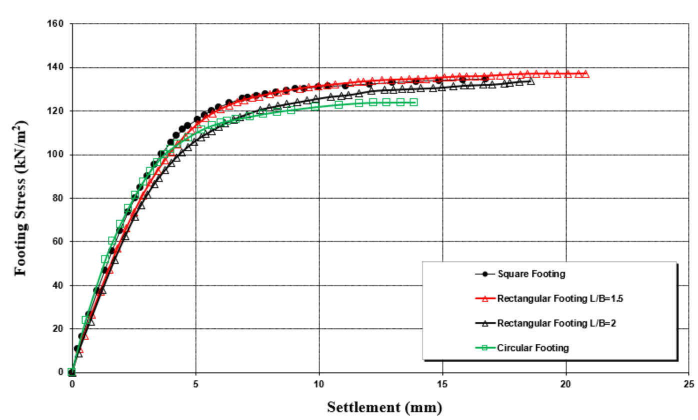

Fig. (4) Load-Settlement curve for different shapes of footing in case of medium sand (Dr=60%)

Fig. (5) show the load-settlemnt relationship for diffrernt footing shapes in case of dense sand (dr=80%).

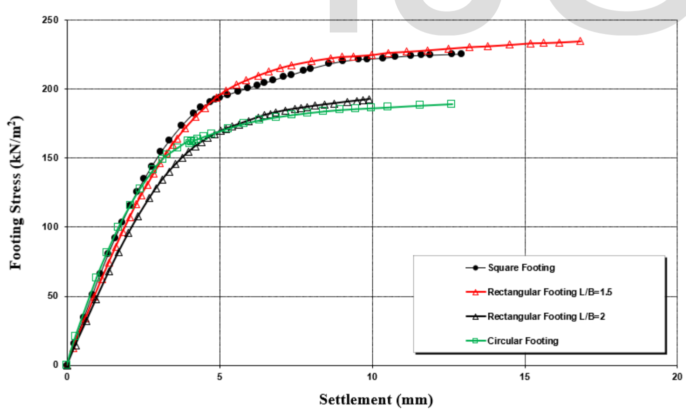

Fig. (5) Load-Settlement curve for different shapes of footing in case of dense sand (Dr=80%)

From the curves it was observed that the ultimate bearing capacity of square footing has a higer value than rectangular and circular footings for both cases of medium and dense sand. This is due to that square footing had more confining effect where the area of square footing of width equal to 15 cm is higher than area of a circular footing of the same width 15 cm. Also, it was observed that the bearing capacity of rectangular fotting with L/B ratio of 2 is less than the footing with L/B ratio of 1.5.

3.2 Compariosn between Numerical Model Results and Anaytical Results

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Results obtained from numerical model conducted using Plaxis 3D software ver. 2020 were compared with analytical approach by Meyerhof to verify the FEM results. Table (4) shows the results obtained by using both methods. The ultimate bearing capacity values are obtained using tangent intersection method **(Trautmann and Kulhawy 1988).**

Table (4) Comparison of Numerical model tests results and analytical results

Soil type	Footing Type	BC using Numerical Solution (kN/m^2)	BC using Meyerhof's Analytical Solution (kN/m^2)
Medium Sand (Dr=60%)	Square	130	106
	Rectangular (L/B=1.5)	128	96
	Rectangular (L/B=2)	120	91
	Circular	117	106

Dense Sand (Dr=80%)	Square	212	163
	Rectangular (L/B=1.5)	205	146
	Rectangular (L/B=2)	170	138
	Circular	160	163

From table (4) a good aggreament obtained between numerical model results and analytical results.

4 Conclusions And Recommendation for future Research

Based on the results obtained using plaxis 3d software, the following conclusions are obtained:

- It was found that square footing bearing capacity was higher than circular footing.
- For the case of rectangular footing the bearing capacity

  Decreased with increasing L/B ratio from 1.5 to 2.
- It was concluded that the shape of foundation has significant effect on its bearing capacity and settlement.

A comparison of this research results with field full scale tests may be investigated.

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