OPTIMIZATION OF 3D GEOMETRICAL SOIL MODEL FOR MULTIPLE FOOTING RESTING ON SAND

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Abstract

The study of ultimate bearing capacity (UBC) for a group of two or more footings had been made by investigators for the effect of interference of footings by various means, which is not considered in the conventional theories of bearing capacity. The Finite Element Method (FEM) initiated with 2D/3D modelling is being used for such complex problem. In the present study 3D geometrical soil models were developed and tested with multiple footing on cohesion-less soil using 3D FEM simulation software. This paper highlights optimized 3D geometrical soil model for multiple footing on sand. The meshing parameters, soil model size observed to be influencing the displacement and stresses to great extent.

Keywords: *FEM, geometrical soil model, interference, multiple footings.*

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1. INTRODUCTION

With many assumptions, theoretical methods like limit equilibrium, limit state, method of characteristics had been developed and validated by rigorous experimental methods to predict the ultimate load carrying capacity of foundations resting on cohesion less soil. In modern days, the complex computation methods were simplified by introducing advanced numerical methods like 2D and 3D FEM in the virtue of which more complex and realistic geotechnical problems are easily getting solved to large extent.

Pusadkar & Deshkar (2012) studied different soil geometrical parameters sets to understand the effect of meshing more precisely on behavior of single footing [4]. For the FEM modeling, footings were placed centrally on soil domain. It was observed that, different soil domain geometrical configurations largely influence the displacements & the stresses patterns for square, circular & rectangular footings. The UBC for single square, circular & rectangular footings were determined using optimize 3D soil geometrical model for 3D PLAXIS FOUNDATION software. The UBC for different width / diameter footings was compared with existing IS code & various theories. The results obtained from PLAXIS 3D FOUNDATION analysis for different soils and footings shows that as element size decreases, the UBC and settlement reduces. These values are comparable with established standards & theories. It was also observed that the geometrical soil domain affect the output. The soil domain of 10B x10B x 10B to 15B x 15B x 15B found to be optimized soil model for the single footing.

In practice, footings may be due to the proximity of a nearby footing leading to interference between them. In such cases effect of interference should be taken into account. However, this fact is usually not taken into consideration in design of foundations. The interference of multiple footing is of prime concern for studying its effect on stresses & settlement. The behavior of multiple footing is different than single footing for studying the interference of multiple footing by FEM. The selection of optimized geometrical soil model will govern its effect. The present work has been initiated with an objective for optimizing the geometrical soil model for multiple footing. The appropriate meshing pattern selection process is evolved so as to increase result efficiency with lesser memory and compilation time.

2. MODE OF STUDY

In FEM, the element's size is related to the element type i.e. with higher order elements, a coarser mesh and higher gradient of the field variables i.e. change of stress with distance are used. For the smaller elements in the region, the gradients are smaller. It is advisable to design a mesh with the selection of proper starting x and y-coordinates (datum) of a problem. The easiest way to minimize related error is ensure that both the starting x-and y coordinates are as close to zero as possible.

For solving the interface problem with two footings, the boundaries of the geometry model need to be imposed with different geometrical configurations viz. X, Y, & Z dimensions as shown in Fig.1. The length (X direction) and width (Z direction) extent of the domain were varied from 8B to 50B & the vertical extent ‘Y’ (downward Y direction) of the domain below the footing was varied between 10B to 20B, where ‘B’ is width/diameter of footing . The study carried out to finalized the most perfect arrangement by three fold verification criteria’s (i) none of the yielded elements approaches the chosen bottom as well as side boundaries of the domain (ii) the magnitude of the collapse load at convergence even if `Y` is increased beyond the chosen value and iii) maintain a balance between ease of mesh generation and efficiency of processing. The problem domain is descritisized by choosing very fine mesh density and the sizes of the elements were gradually made smaller when approaching towards the edge of the footing.

3. MODELLING AND ANALYSIS

A 3D geometrical soil model was developed for investigating the effect of meshing on ultimate bearing capacity (UBC) & settlement at failure for a multiple footing resting on sand. Fig.1 defines the soil model geometry with different placement conditions for multiple square footing on sand. The footings A & A1 were placed on soil model surface and loaded equally. Centre line of footing A is considered to be coinciding with centre line of geometrical soil model. Footing A1 was placed at spacing to the right of Footing A. The soil properties such as dry unit weight, angle of friction were assumed as 17 kN/m^3 and 38^0 respectively.

Every footing placement was analyzed for different parameters involved in the pre-processing. Multiple square footings were placed on the horizontal surface of dry sand at a clear distance of ‘S’. For different footing placement cases as shown in Table 1, different calculation pattern were adopted. The magnitude of the ultimate failure load ‘q_u’ per unit length for each footing was determined. 3D geometrical soil model for multiple square footings on sand was the analyzed.

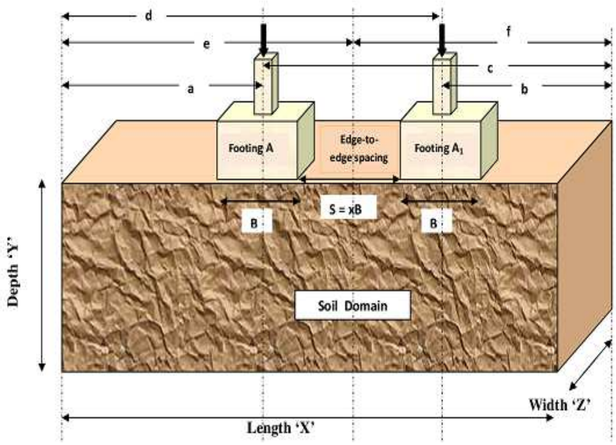


Fig -1: Typical Sketch of 3D Geometrical Soil Model Multiple Square / Circular Footings Resting on Soil Surface

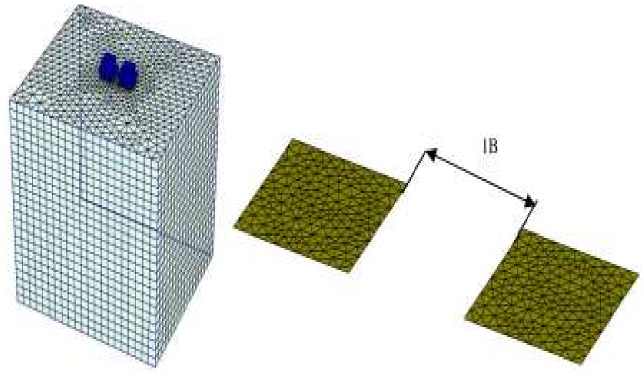
Table 1: Typical 3D Geometrical Soil Model Configurations for Multiple Square Footings for Spacing 1B

Case		Spacing Between Footing A & B (m)	Footing A Width (m)	Footing A_1 Width (m)	X from centre			Z	Y
					Right	Left	Total		
A	a + c	1.0	1.2	1.2	8.7B	10.3B	19B	15B	15B
B_1	b + d				9.1B	8.1B	17.2B	15B	15B
C	e + f				8.6B	9.2B	17.8B	15B	15B

4. FE DESCRITISATION

FE analysis of multiple footings can be carried out by two types of meshing arrangements viz. fixed meshing pattern and variable meshing pattern. In fixed meshing pattern dimensions of soil model are kept constant so as to ensure fixed number of elements & nodes throughout the analysis for each case to be studied. This can be done by considering dimensions in such a way that it should accommodate complete footing placement conditions decided during the entire analysis. In the variable meshing pattern, each time suitable dimensions for each spacing need to be considered. In this type, number of elements and nodes are simultaneously changes according to the changes in dimensions take place which ultimately influence the UBC values. For present analysis fixed meshing pattern is adopted.

The 3D geometrical soil model as shown in Fig 2 for square footing was descritisized into a number of 15 noded triangular elements and the sizes of the elements were gradually made smaller when approaching towards the edge of the footing.



(a) 3D Soil Model (b) Two Square Footing

Fig 2: Typical Descritized 3D Soil Model and Square Footing for 1B Spacing

During entire analysis for all the categories considered, it was specified that at any time equal magnitude of load will be applied on each footing and no restrictions were imposed on settlement so that is all the footings were allowed to settle freely. In the same way, no restrictions were imposed on tilting behavior as to get an effect of actual field conditions.

In order to quantify the multiple-footing influence on single footing, interference efficiency factor was determined and is denoted as 'ξ_γ' for UBC. The variation of efficiency factor due to bearing capacity (ξ_γ) with respective S/B, can be defined by the ratio,

$$\xi_\gamma = \frac{\text{Ultimate bearing capacity of single footing in presence of other footing } (q_{um})}{\text{Ultimate bearing capacity of single footing } (q_u)}$$

Where ξ_γ = interference efficiency factor for UBC; q_{um} = UBC for multiple-footing conditions respectively; and q_u = UBC for single-footing conditions.

5. RESULTS & DISCUSSIONS

Interference analysis for multiple square footings placed on sand was performed to understand the influence on UBC & settlement using PLAXIS 3D FOUNDATION Ver. 1.6 [3]. The magnitude of the ultimate failure load 'q_u' per unit length for each footing was determined. Considering all the geometrical aspects, few configurations were decided.

Typical sectional view of vertical displacement and vertical stress distribution pattern for three multiple footing with Case A for 0B to 3B spacing for square footings is shown in Fig 3.
The present analysis was performed for square footing for Φ equals to 38^0. The values of ξ_γ associated with the ultimate shear failure were compared with the theories given by Lee & Eun (2009) as per 3D FEM for square footings [2] & Das & Larbi-Cherif (1983), by experimental analysis [1]. Fig 4 illustrates comparative study of present study for ξ_γ of square footing with others . There exists a certain spacing (S_{max}) at which UBC becomes maximum which is found as at S/B = 0 for the present analysis. Overall similar trend was observed by the Lee & Eun (2009) [2].

From the comparative study, it can be noticed that, the values of ξ_γ at Smax/B given by Lee & Eun (2009) for $\Phi = 35^0$ as 2.094 was found to be closer to the 2.147 obtained from the present numerical analysis for $\Phi = 36^0$ and increase in comparatively to 2.341 for $\Phi = 38^0$ at Smax/B = 0.

The ξ_γ value as 2.00 at Smax/B obtained from experimental study on strip footing by Das & Larbi-Cherif, 1983 for $\Phi = 39^0$ is comparable to the 2.247 obtained by present analysis for $\Phi = 38^0$ for square footing as shown in Fig 4.

The results obtained from the present analysis are quite comparable with result obtained by other researchers. Thus the optimized geometrical soil model for multiple footing is validated by satisfying necessary governing conditions.

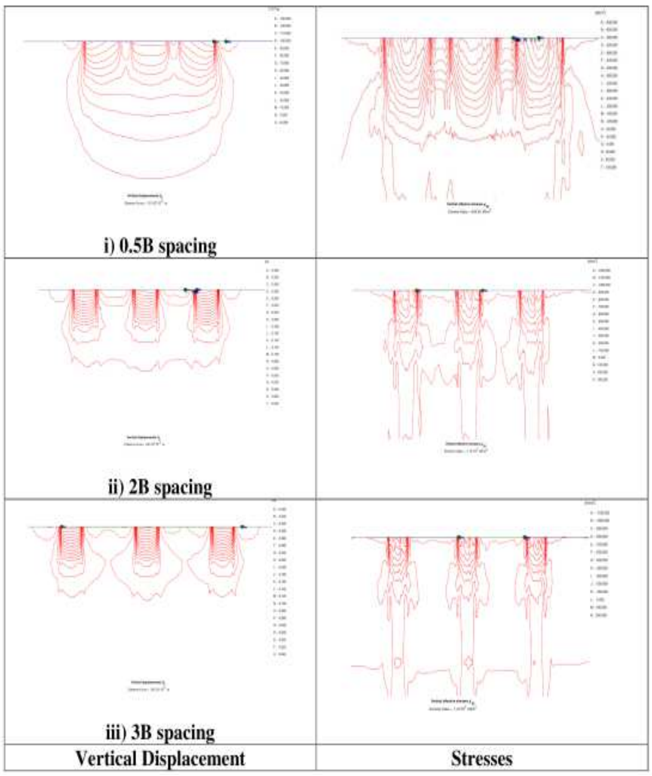


Fig -3: Views of Vertical Displacement & Vertical Stress Contours for Multiple Square Footings Optimized 3D Soil Model.

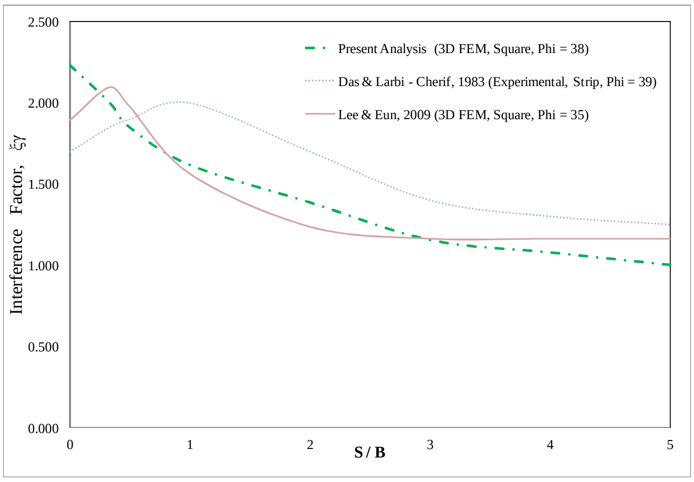


Fig -4: Comparative Study of ξ_γ for Square Footing for $\Phi = 38^0$

CONCLUSIONS

Footings are typically constructed in multiple-footing configurations, raising the need to address the multiple-footing effect on the bearing capacity. In the present study, the effects of meshing on multiple footing configurations on its bearing capacity resting on sand were investigated using Finite Element simulation software. The appropriate geometrical soil model was developed for FE analysis to study the multiple square footing interference resting on sand.

From the analysis, it was observed that the meshing influences the UBC & settlement and interaction effect of multiple-footing effect does exist. This paper provided certain guidelines to select appropriate 3D geometrical soil model for UBC determination of multiple footing on sand. 3D geometrical model dimensions of X =19 B, Y = Z = 15 B is more appropriate for 3D PLAXIS FOUNDATION for determining UBC & settlement & may be more useful for comparable results.

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BIOGRAPHIES

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