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NUMERICAL ANALYSIS FOR THE RESPONSE OF SKIRT CIRCULAR SHALLOW FOOTING RESYING ON SANDY SOIL UNDER VERTICAL LOADS

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ABSTRACT

In this paper, the static response of a circular skirt foundation resting on a sandy soil subjected to pure vertical load was analyzed numerically using finite element software, PLAXIS 3D 2020. Linear elastic model was adopted to describe the behavior of the shallow concrete circular foundation with (1m) diameter and (0.2 m) thick, as well as the soil underneath, with and without skirt.

Different skirt's length to diameter ratios (L/D) (0.25, 0.5, 0.75, and 1.0), in addition to different skirt thicknesses (0.1 m, 0.15 m, 0.2m) were anticipated.

The results shown that, in dry sand, existence of skirts improves the foundation performance effectively by increasing its load carrying capacity particularly when the skirt (L/D) ratio become larger. However, the increase in the thickness of the skirt has marginal influence and it can be neglected for design purposes.

KEYWORDS: Skirt foundation, Circular Shallow footing, Finite Element, PLAXIS 3D 2020, Bearing Capacity of shallow Footing;

1. INTRODUCTION

Geotechnical engineers are in search of an alternative method for improving the bearing capacity and reducing the settlement of footing resting on soil. Though a variety of methods of soil stabilization are known and well-developed, they can be prohibitively expensive and restricted by the site conditions. In some situations, they are difficult to apply to existing foundations. In this case, structural skirts hold good as an alternative method of improving the

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bearing capacity and reducing the settlement of footing resting on soil. Structural skirts have been used for a considerable period to increase the effective depth of the foundations in marine and other situations where water scour is a major problem. This method of bearing capacity improvement does not require any excavation of the soil and is also not restricted by the presence of a high ground water table. Skirts provided with foundations, form an enclosure in which soil is strictly confined and acts as a soil plug to transfer super-structure load to soil (Sungyani Tripathy, 2013).

Skirted foundations own great characteristics which make them suitable for construction of structures involving heavy loads and poor soil conditions with promise of economy. It has proven to be competitive alternatives to more traditional foundation solutions like piles in various types of soils due to economic benefits which lead to cost saving through reduction in materials and in time required for installation. It is also utilized as an alternative to deep foundation in soil possess low strength at its surface (El Wakil, 2013; Thakare and Shukla, 2016).

2. LITERATURE REVIEW

Golmoghani-Ebrahimi and Rowshanzamir, (2013) conducted laboratory tests to assess the bearing capacity of footing with the skirt. They concluded the effect of skirt stiffness by utilizing three sorts of skirts at thickness of 1mm, 3mm and 5 mm and the effect of skirt length on the bearing capacity of skirted footing by utilizing three various length ratios (L/B =0.5, 1 and 1.5). The results refer to that utilizing skirts can improve the bearing capacity of the footing up to 3.68 times depending on the skirt, the geometry of the foundation, structural qualifications, soil properties.

Krishna et. al., (2014) a series of experimental model tests to analyse the load carrying capacity of a square footing resting on sandy soil. Hollow container made of steel plates were utilized to confine the soil laterally. The effect of sand relative density, embedment depth of foundation ratio and varying confinement depth was investigated. The results showed that load carrying capacity increments when the embedment depth increases, it was greatest at (De/D=0.5) for all sand relative densities.

Saleh et al. (2008) carried out numerical analysis and Laboratory work was performed to study the behavior of one-sided skirted foundation subjected to an inclined and an eccentric load. he was found, the skirt foundations in which inclined or vertical wall surrounding one or more sides of a soil mass under the foot leads to confining the underlying soil and creates a soil resistance on the skirt side that helps the foundation resist sliding.

3. NUMERICAL STUDY

A typical numerical model was considered which contained a concrete circular footing (1m) in diameter and (0.2m) in thickness and skirts, attached to the base slab of footing along its boundary, with different heights and thicknesses rested in dry dense sand. The skirt has different (L/D) ratios (0.0, 0.25, 0.5, 0.75 and 1.0), (where, D: footing diameter, and L: skirt length), and thicknesses (0.1, 0.15 and 0.2) m. The boundaries of the soil are taken as (30m x 30m x10m) which are far away from the foundation to minimize the boundary.

The displacement and initial bearing capacity of studied soil has been evaluated numerically in PLAXIS 3D 2020.

In this part, the effect of (L/D) ratios and thickness on the ultimate carrying capacity of skirt are the main points. The displacement control approach is used to evaluate the load-settlement curve.

3.1. Finite Element Model and Problem Definition

The model dimensions were selected to prevent the effect of lateral and lower boundaries on the deformation of system, (Narasimha et al., 1992)**.** Fig. 1 illustrates schematic diagram of finite element model. In this study, the dimensions of skirt are selected to be compatible with common practical dimensions.

The model is consisting of soil domain confining by lateral and lower boundaries, the loading is carried by rigid surface circular footing to cancel the contribution of the embedment depth. Fig. 1 shows finite element mesh and nodes of the numerical model. The displacement control approach is used to evaluate the load-settlement curve. In this approach, the load required to reach the desired displacement can be determined.

The ultimate capacity of footing before and after improvement is defined from load-settlement curve according to (10%) method (Briaud and Jeanjean, 1994).

3.2. Mesh Generation - Mesh Mode

When the boundaries of model is fully defined the geometry has to be divided into finite elements in order to perform finite element calculations. A composition of finite elements is called a mesh. The mesh is created in the Mesh mode. The mesh should be sufficiently fine to obtain accurate numerical results. On the other hand, very fine meshes should be avoided since this will lead to excessive calculation times. The PLAXIS 3D program uses fully automatic generation of finite element meshes. The mesh generation process takes into account the soil stratigraphy, as well as, all structural objects, loads and boundary conditions.

Fig.1. shows finite element mesh of the numerical model.

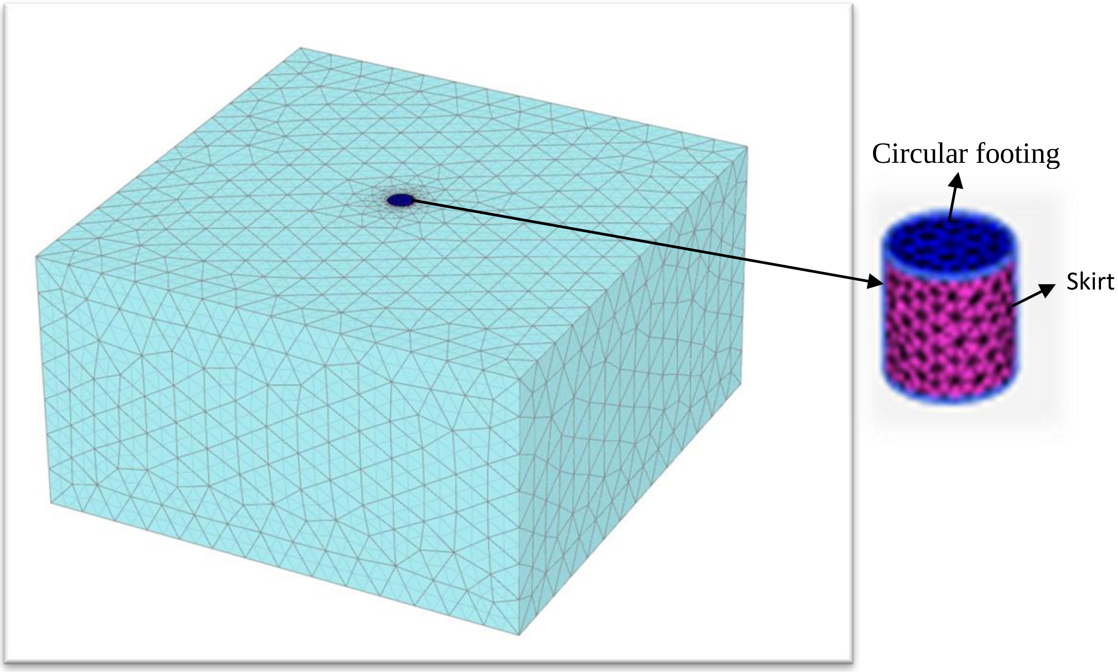

Fig. 1. Three-dimensional view of the model skirted Circular footing

4. FOUNDATIONAL MODELS AND PARAMETERS.4

The soil, concrete foundation, and skirt were modeled as Mohr-Coulomb materials. The finite element parameters of soil and structures are shown in Table 1.

4.1. Foundation Models

Circular foundation was used with diameters (D = 1m) with a thickness of (0.2m), it was made of concrete, to simulate the prototype, with unit weight (ϒ = 24 kPa) and young's modulus (E=25x10^6 kPa). The diameter of the circular footing and thickness is kept constant throughout the analysis.

4.2. Skirts

Hollow concrete cylinders with several thicknesses (0.10, 0.15 and 0.20) m are assumed to be skirts attached to the outer perimeter of foundation with different lengths to diameter ratios (0.25D, 0.5D, 0.75D and 1.0D). These skirts were used to confine the soil laterally under the circular foundation model. Fig. 2 illustrates the shape of both foundation and skirt, and Table 1 shows the properties of them.

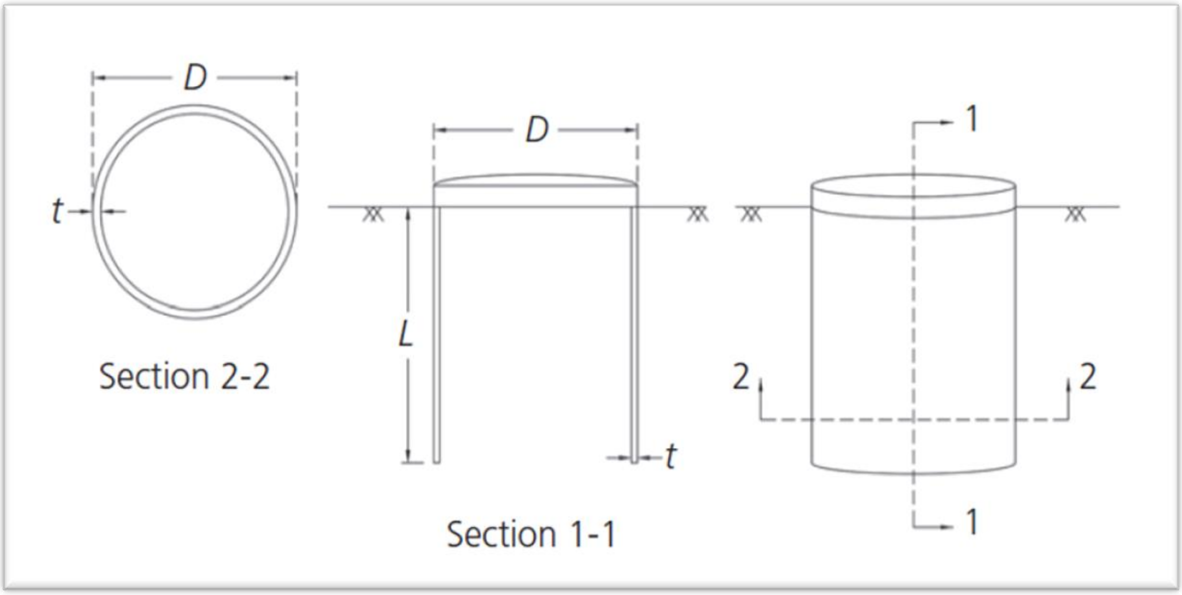

Fig. 2. Schematic view of the circular, skirted foundation.

D: foundation diameter
L: skirt depth
t: skirt thickness

Table 1. Parameters of structure elements.

Properties	Skirt	Footing
Material type	Concrete	Concrete
Unit weight, ϒ (kN/m^3)	24	24
Material model	Linear elastic	Linear elastic
Young's Modulus, E (kN/m^2)	25×10^6	25×10^6
Poisson's ratio (v)	0.15	0.15
Interface strength factor (Rinter)	1	-

Table 2. Parameters of the studied soil.

Model	Mohr-Coulomb	
Material	Material properties	Dense sand
	Drainage type	drained
	Unit weight, ϒdry (kN/m^3)	20
	Young's modulus, E (kN/m^2)	50000
	Poisson's ratio, ν	0.34
Soil	Friction angle,Φ (degree)	39
	Cohesion, C (kN/m^2)	1
	Dilatancy angle, Ψ	9
	Interface strength factor (Rinter)	1

4.3. Soil properties

Generally, for shallow foundations, the soil underneath should be compacted very well in order to increase its shearing strength, as well as, reducing settlement. Therefore, the soil used in this parametric study was considered to be dry dense sand.

The soil deposit is assumed to obey the advanced Mohr-Coulomb yield criterion, with parameters adopted from Bowels, (1996) and Murthy, (2006) except the dilatancy parameter. The effect of dilatancy is taken into account in the present study. The dilatancy of sand depends on both the density and the friction angle. It is suitable in PLAXIS to use the value of cohesion $c > 0.2$ kPa for cohesionless sands and dilatancy angle $\psi = Ø - 30$ for the soils with $Ø > 30$, and $\psi = 0$ for the soils with $Ø < 30$ (Brinkgreve et al., 2002 a). Due to this, the value of cohesion is assumed equal to 1 kPa to avoid complications and the value of the angle of dilatancy is assumed as ($\psi = Ø - 30$). The properties of soil are listed in Table 2.

5. RESULTS AND DISSUASION

The initial bearing capacity of studied soil was evaluated numerically by mean of rigid surface footing rested on the soil layer. Load settlement relationship is a direct method for obtaining ultimate bearing capacity.

A circular foundation with (1m) diameter and (0.2 m) thick is selected to get direct normalization of pressure and settlement ratio. Figs. 3, 4, 5 and 6, shows the load-settlement curve of analyzed footing using PLAXIS 3D.

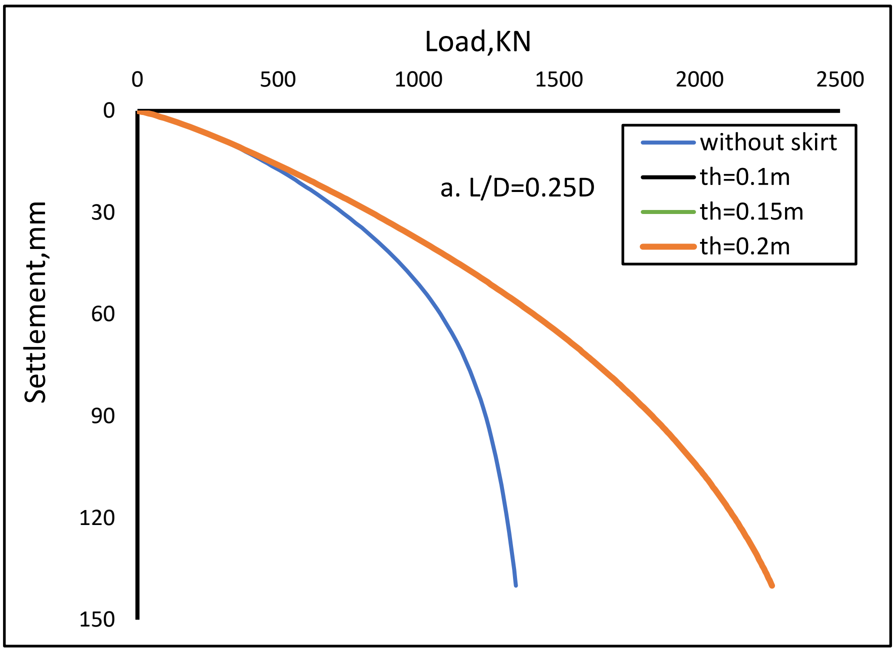

Fig. 3. Load-settlement relationship for skirt circular footing, L/D=0. 5.

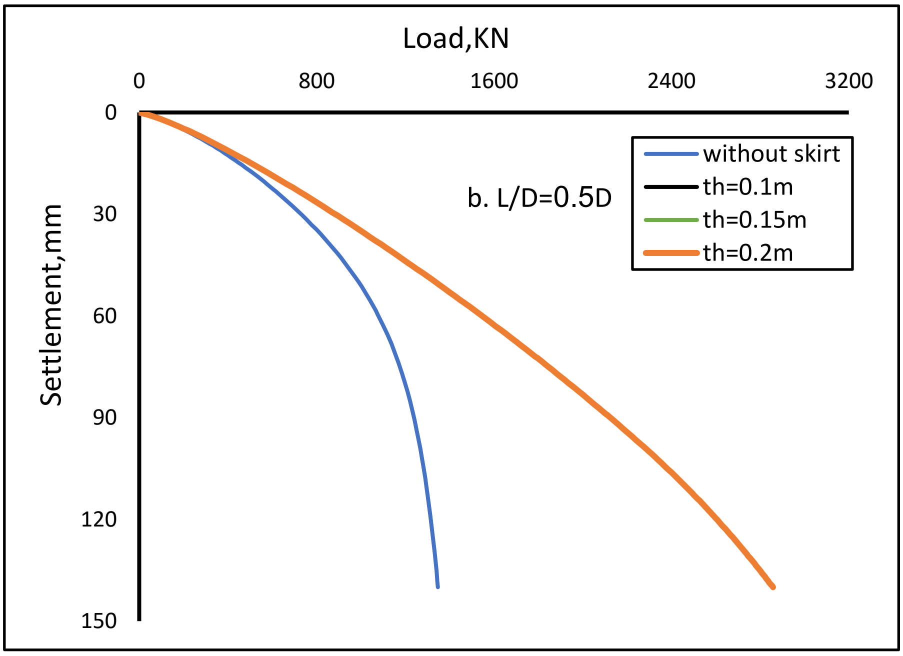

Fig. 4. Load-settlement relationship for skirt circular footing L/D=0.25.

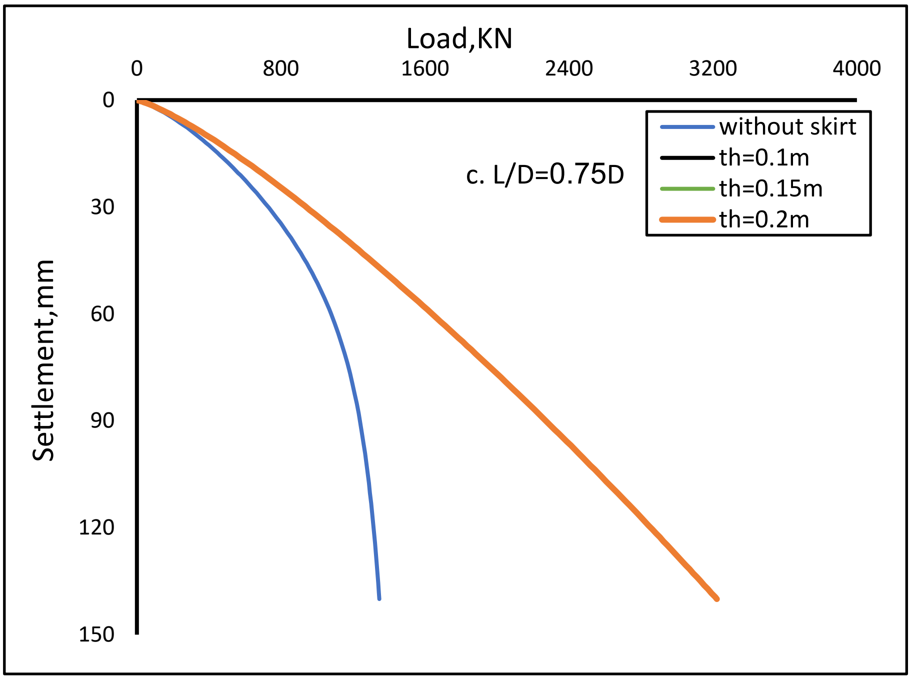

Fig. 5. Load-settlement relationship for skirt circular footing, L/D=0. 75.

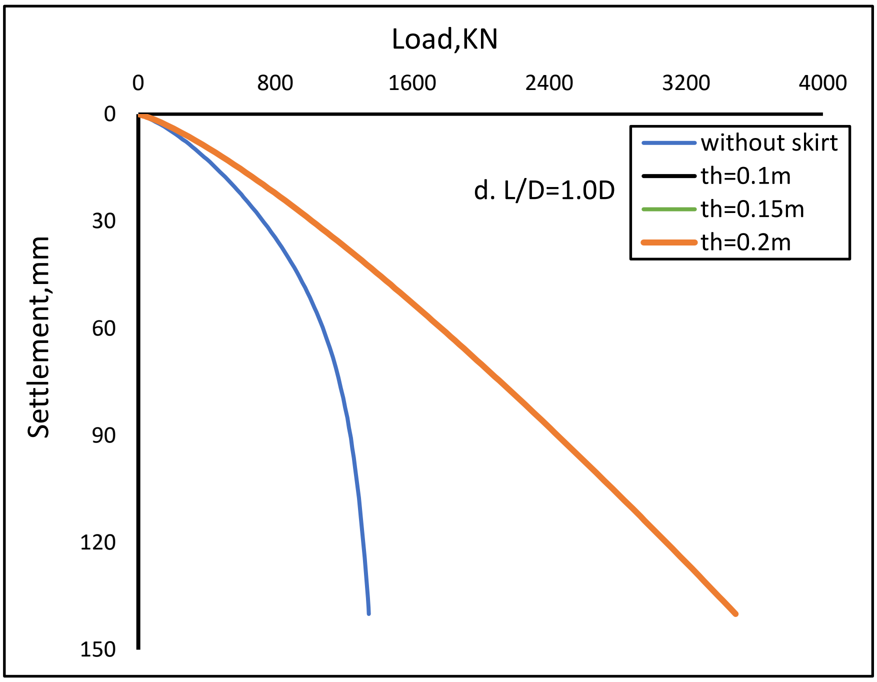

Fig. 6. Load-settlement relationship for skirt circular footing, L/D=1.0.

As for the shallow foundation with and without skirts be subjected, the results in these figures show that the use of skirt improves the performance of the shallow foundations by increasing the shear resistance before failure and reducing the settlement of the footing. In addition to that be mentioned before, the installation of skirt to shallow footing confines the soil beneath the foundation, the skirts resist the lateral movement of sand particles, therefore the confined soil behaves like a part of rigid foundation and starts to work as one unit to transfers a major part of foundation load into a deeper zone, as well as the increasing of the skirt's height leads to transfer part of the applied load by friction (i.e. skin friction) and to the tip of the skirt where the confining pressures (overburden pressure) are higher. as shown in Figs. 3, 4, 5, and 6 above. These results comply with these obtained by (Saleh et al., 2008; Penzes et. al., 2016; Pusadkar and Navkar, 2016).

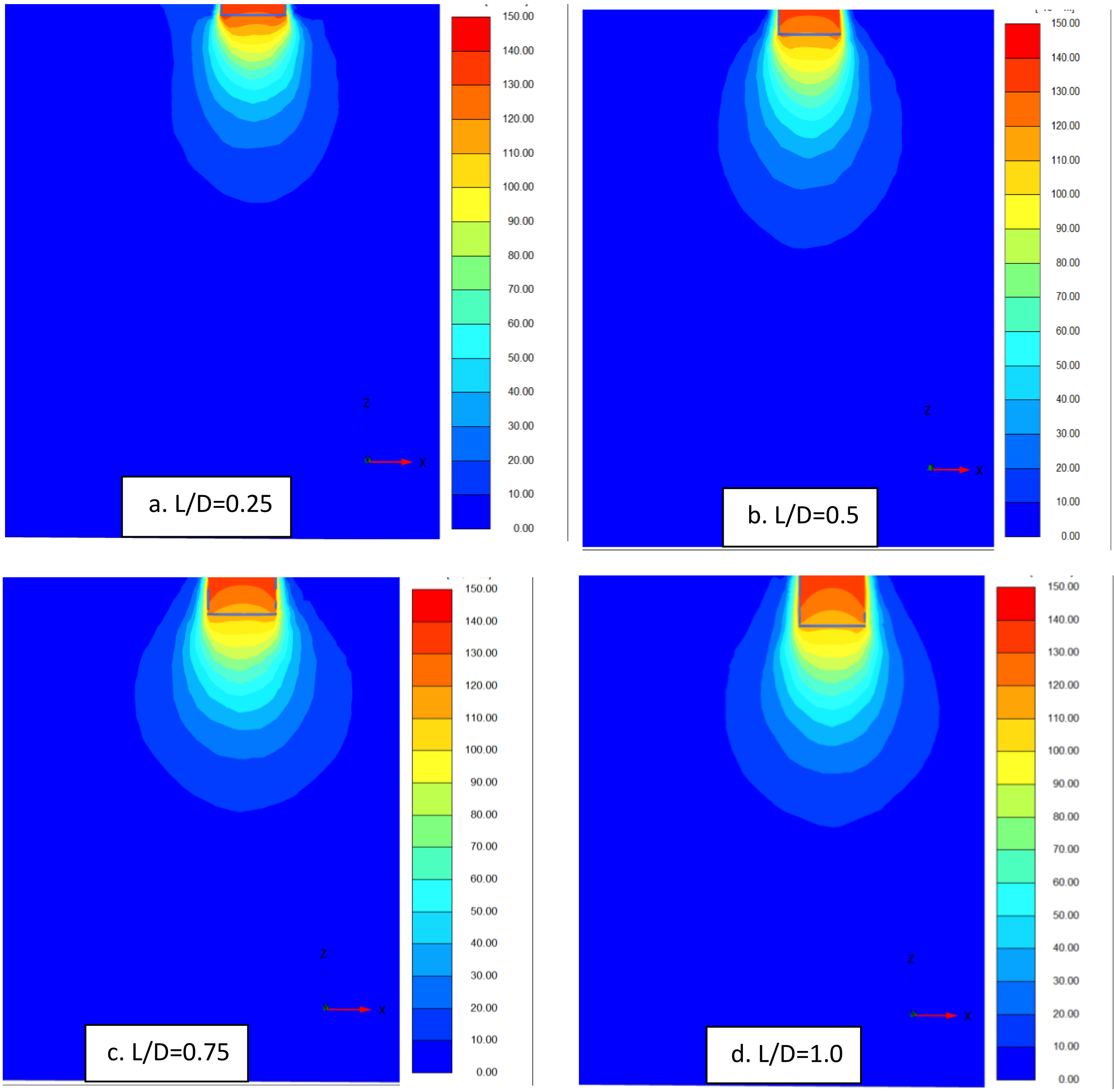

Fig. 8. Shading view result in Plaxis-3D.

5.1. Effect of Skirt Length

Figures below also show that the impacted of increasing skirt length on the observed to be most significant at L/D=1.0 for each foundations size, this mean if skirt length equals to 1.0 of foundation diameter (i.e. L/D=1.0) then the foundation performs better. The increase in skirt length results in an increase in the surface area of the skirt- foundation system; therefore, the base load will be transferred to a deeper depth leading to an increase in the improvement ratio and a decrease in the settlement. Thus, it is possible to obtain higher ultimate loads as shown in Fig. 7.

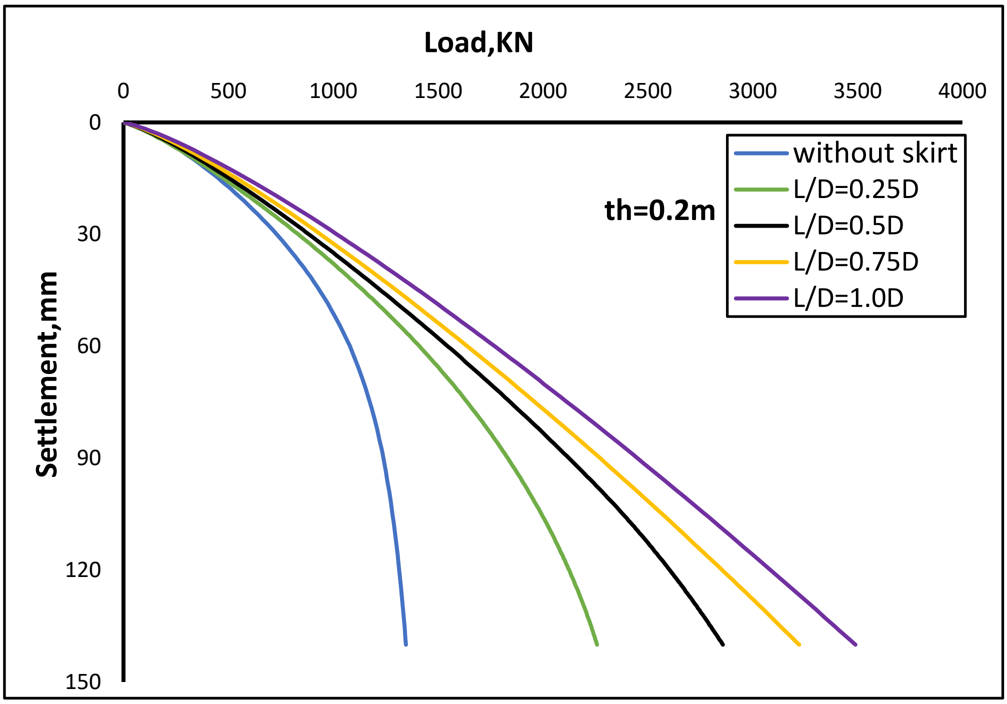

Fig. 7. Load-settlement relationship for skirt circular footing, different lengths.

5.2. The Effect of Skirt Thickness

From figures shown above, the alteration of skirt thickness has approximately no effect on of displacement particularly when the skirt (L/D) ratio is small, meanwhile, when (L/D) increased and the, thickness has a little effect on the amplitude of displaced. The skirted footing was then subjected to displacement control loading and the applied loads were recorded. As it is evident from Figs. 3, 4, 5 and 6, Load-settlement curves of the footings with 0.1m, 0.15m and 0.2m skirt thickness were matched well with each other, and show nearly the same ultimate bearing capacity and slope trend, (Golmoghani-Ebrahimi and Rowshanzamir, 2013).

6. CONCLUSIONS

A three-dimensional finite element model has been developed validated to study the efficiency of using structural skirts to reduce settlement of foundation subjected to Static Load. The main conclusions are outlined below.

1. The skirt foundation when subjected to pure vertical load, the amplitude of displacement decreases with increase in (L/D) ratio.

2. The alteration of skirt thickness has approximately no effect on the amplitude of displacement particularly when the skirt (L/D) ratio is small.

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