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Load-Displacement Behaviour of Skirted Raft Foundations on sand using PLAXIS 2D

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***Abstract*—** *Skirted foundations are the shallow foundations in which the footing is reinforced by the addition of vertical plates or skirts. Skirted foundation is one of the new approaches for improving the performance of shallow raft foundation by using skirts to it. The improvement in performance of skirted foundation depends on the geometrical and structural properties of the skirt and footing such as shape, depth of the footing and skirt, skirt geometry etc; soil characteristics namely index properties of soil and the interface conditions of the soil-skirt-foundation systems such as roughness and material of the skirt etc. In the present work an attempt has been made to determine the behaviour of surface raft with and without skirts under two different soil model- Hardening soil model and Mohr-Coulomb model using a finite element software PLAXIS 2D. The analytical results show that with the increase in skirt depth, the bearing capacity increases and settlement decreases for both the model.*

***Keywords*—** **Raft foundation, Bearing capacity, settlement, Plaxis 2D, structural skirt**.

I. INTRODUCTION

The shallow footings fail mainly due to the shear failure of soil below it. When the superstructural load gets transferred to the soil below the footing, it is displaced from its position due to shear failure of soil. Such failure can be duely taken care of by providing some kind of confinment around the soil below the footing. In this case, structural skirts serve as an alternative method of improving the bearing capacity and reducing the settlement of footing resting on soil. Skirts provided with foundations, form an enclosure in which soil is strictly confined and acts as a soil plug to transfer superstructural load to soil. In comparison to a surface foundation, the skirt transfers the load to a greater depth i.e. to a stronger layer of soil; thus mobilising higher bearing capacity.

Now a days shallow skirted foundations have been used in structures like oil and gas industry, replacing usual piled foundations. Also they have been used as support for large fixed substructures or as a anchorage for floating structures in offshore applications.

II . LITERTURE STUDY

M. Y. AL-Aghbari and Y. E-A.Mohamedzein (2004) performed a series of tests on a foundation model to study the factors that affects the performance of a foundations with skirts. The affective factors includes- foundation base friction, depth of skirt, skirt side roughness, stiffness of skirt and soil compresibility. Based on these parameters they proposed an equation for skirted foundation and the results obtained from this equation were compared with results obtained from Terzaghi, Meyerhof, Hansen and Vesic bearing capacity equations for foundation without skirt.

M. Y. AL-Aghbari (2007) conducted a series of tests on circular footing with and without structural skirts in a large tank setting to study the settlement of circular footing on sand. These experimental results showed that the structural skirts reduces the settlement of subgrade depending on stress applied and skirt depth and modifies the load-settlement behaviour of footing.

Dr. Sunil S. Pusadkar and Ms. Tejas Bhatkar (2013) has performed the analysis for two sided and one sided vertical skirted raft and raft without skirt using a finite element software PLAXIS 2D with varying skirt depth and raft sizes. The results showed that using structural skirts for raft foundation has a significant effect in improving bearing capacity and this improvement increases with the increasing skirt depth with varying raft sizes for two sided raft foundation, whereas with the vertical skirts there is increase in both bearing capacity and settlement for one sided raft foundation.

II. NUMERICAL MODELLING

An extensive finite-element analysis is carried out using plaxis 2D to study the effects of skirts on the behaviour of uniformly loaded surface foundation on sand. The geometry of the finite element soil model taken for the analysis is 15BX20B with different raft sizes of B= 10m, 15m, 20m with skirt depth (D_s) =0.5B, 1B, 1.5B, 2B, 2.5B, 3B. Figures 1 and 2 shows the geometric model of raft foundation without skirt and with two side vertical skirt for one typical case 15m raft foundation.

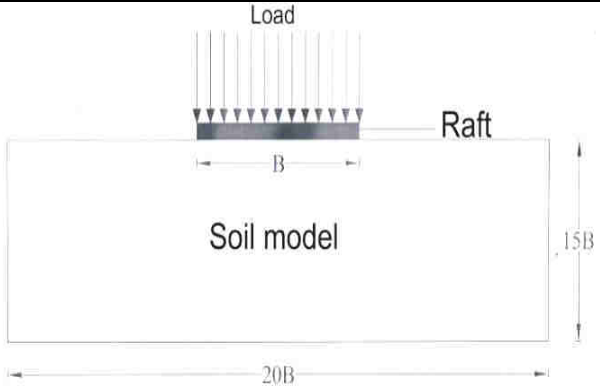


Fig.1: Model of Raft foundation without skirt

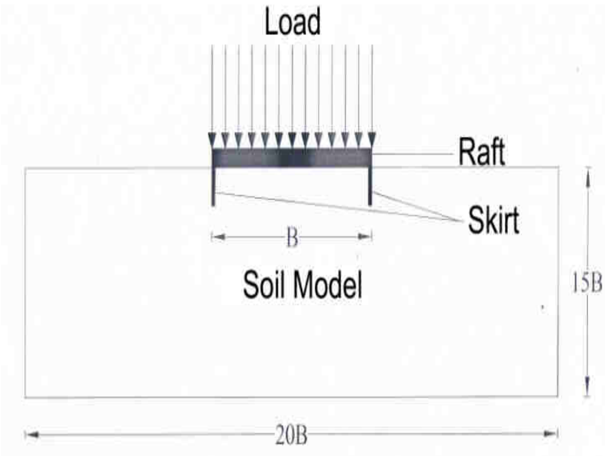


Fig. 2: Model of Raft foundation with skirt

The Soil properties considered for the analysis are tabulated in table1. The soil used for the analysis purpose was basically cohesionless sandy soil. The Hardening-soil model and Mohr-Coulomb model are used separtly to represent the behaviour of sand using Fifteen-node triangular elements. Both the footing and skirts were considered as linear elastic material.
The soil properties used in the analysis are shown in table 1

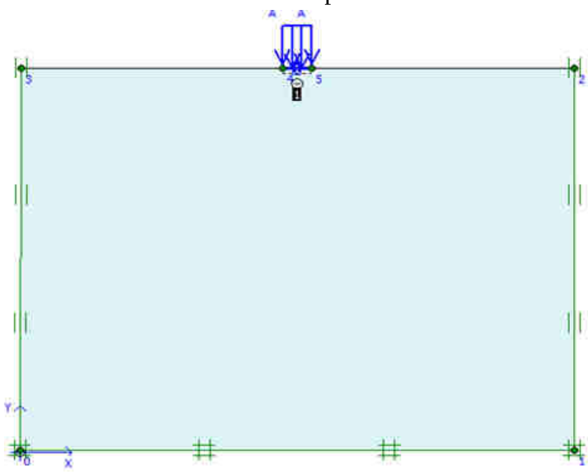
Table 1: Material properties for the analysis

Parameter	Value
Type of Material	Sand
Material Model	Mohr-Coulomb/ Hardening-Soil Model
Material behaviour	Drained
E_{50} (kN/mm^2)	40000
γ_{sat} (kN/m^3)	17
γ_{unsat} (kN/m^3)	20
Permeability in horizontal direction(m/day), k_x	1.0
Permeability in vertical direction(m/day), k_y	1.0
Poisson's ratio, υ	0.3
Cohesion (c)	0.1
Friction angle (ϕ)	35°
Angle of dilatancy (Ψ)	2°
Interface Reduction Factor (R_{inter})	0.7
Axial stiffness of steel skirt	31500 kN/m

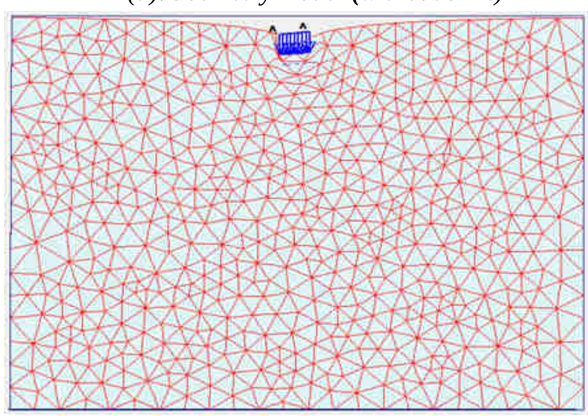
Six different skirt ratios (D_s/B) were tried for namely 0.5, 1,1.5, 2, 2.5 and 3 to study the performance of differnent skirts on raft foundation. Mostly two parameters were studied for. Firstly, bearing capacity for a constant settlement and secondly settlement for a constant bearing capacity.

III. RESULTS AND DISSCUSSION

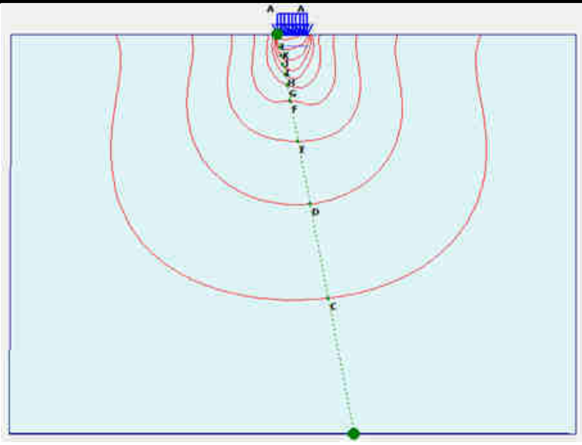
Using the tabulated soil properties analysis was done in Plaxis 2D for raft foundation without skirt and with vertical skirt at two sides. The modelling and results obtained from PLAXIS 2D is presented hearwith.



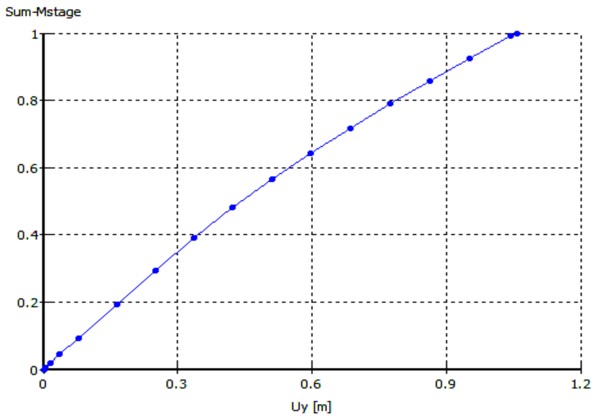
(a):Geometry model (without skirt)



(b):Deformed mesh (without skirt)



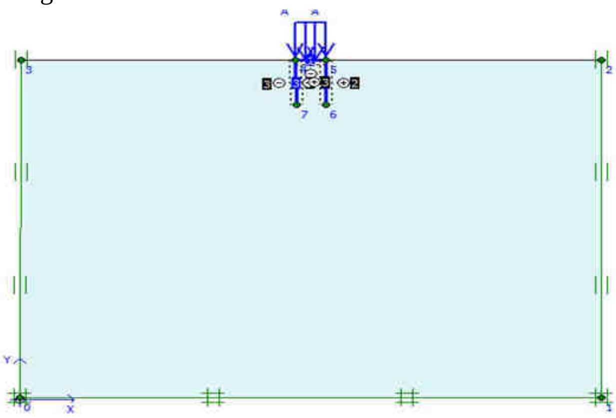
(c):Total Displacement Contours (without skirt)



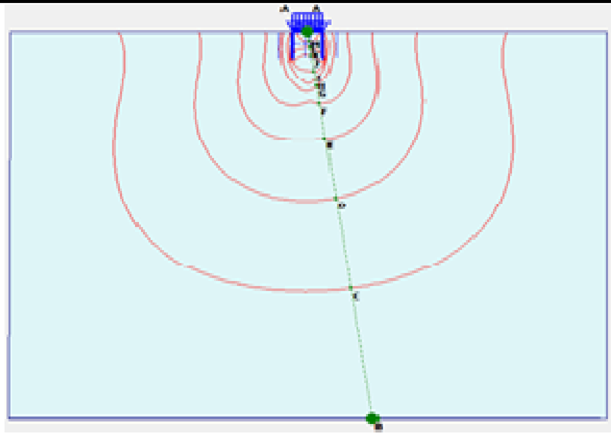
(d): Load-Displacement Curve (without skirt)

Figure 3: Results of analysis in plaxis 2D for 15m raft foundation without skirt. (Mohr-Coulomb model)

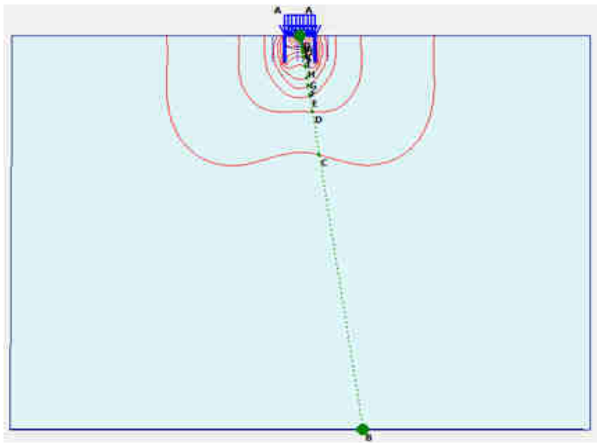
Analysis of 15m raft foundation with vertical skirt was carried out as stated earlier and results has been presented in figure 4.



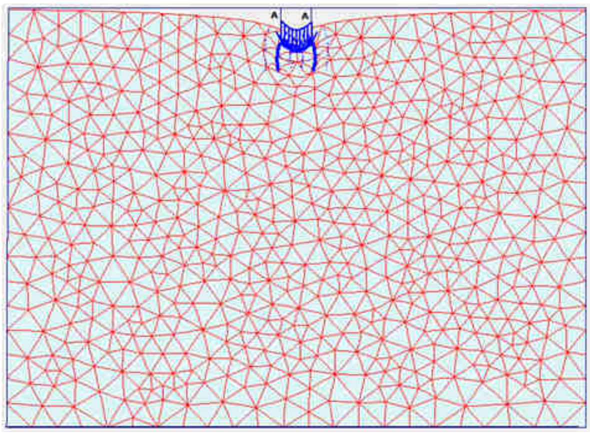
(a) *Geometry model (with skirt)*



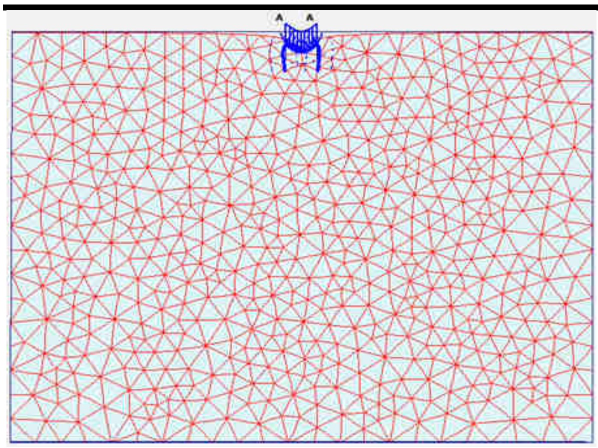
(b) Total Displacement contours in Mohr-Coulomb Model (with skirt)



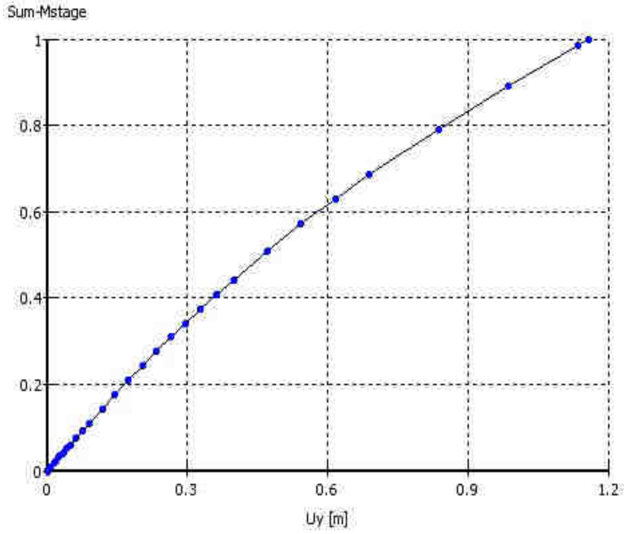
(c) Total Displacement contours in Hardening-soil model



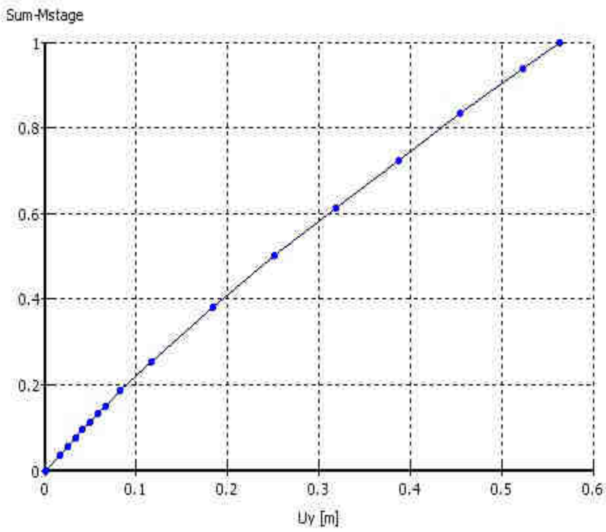
(d)Deformed Mesh in Mohr-Coulomb model



(e)Deformed Mesh in Hardeening-soil model



(f) Load-Displaecement Curve in Mohr-Coulomb Model



(g) Load-Displacement Curve in Hardening-soil Model

Figure 4: Results of analysis in Plaxis 2D of 15m Raft Foundation with skirt for both the soil models

Results obtained from Load-Displacement curves for a 15m Raft foundation with and without skirt for different skirt depths were ploted in figure 5 and 6. In the analysis, for the maximum applied pressure of 1000 kN/m^2 the corresponding settlements are measured and at settlement of 100mm which is considered as the permisible settlement for Raft Foundation; the corresponding pressures were noted. The values thus obtained are listed in table 2 and 3 for Hardening model and Mohr-Coulomb model respectively.

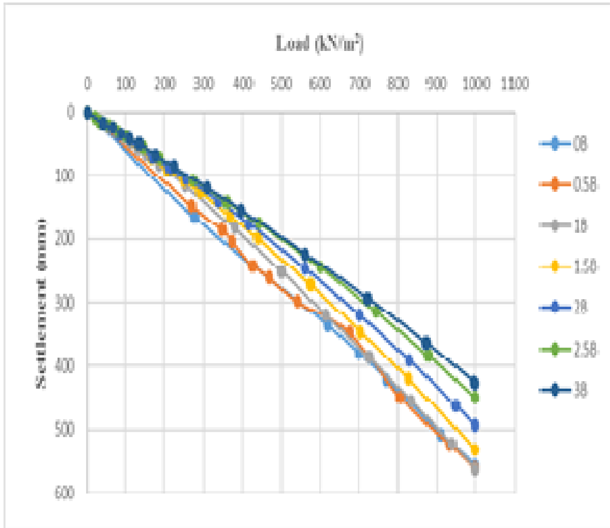


Figure5: Load-Settlement Curve for 15m Raft Foundation with vertical skirt for Hardening-Soil Model

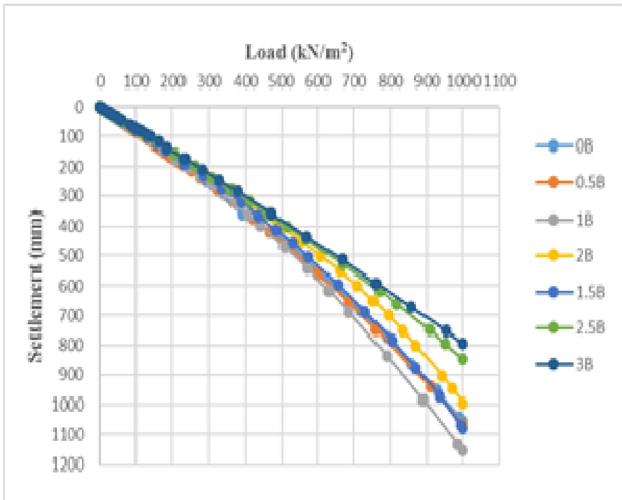


Figure6: Load-Settlement Curve for 15m Raft Foundation with and without vertical skirt for Mohr-Coulumb Model.

The enhancement of bearing capacity and reduction in settlements by skirts were clearly observe from both the models. The settlement obtained from Mohr-Coulomb model was more than that by Hardening-soil model. In Hardening-soil model the reduction in settlement for different skirt ratios 2 and 3 are 88% and 76% whereas the corresponding reductins for skirt ratios 2 and 3 for Mohr-Coulomb model are 94% and 75% respectively.

Table 2 : Results of 15m Raft skirted foundation for Hardening-Soil Model

Skirt ratio D_s/B	Settlement for 1000 kN/m² (mm)	Bearing capacity for 100mm settlement (kN/m²)
0	**557**	**160**
0.5	**561**	**186**
1	**562**	**220**
1.5	**531**	**227**
2	**494**	**240**
2.5	**450**	**265**
3	**427**	**269**

Table 3 :Results of 15m Raft skirted foundation for Mohr-Coulomb Model

Skirt ratio D_s/B	Settlement for 1000 kN/m²(mm)	Bearing capacity for 100mm settlement (kN/m²)
0	**1055**	**110**
0.5	**1065**	**112**
1	**1156**	**115**
1.5	**1077**	**118**
2	**994**	**125**
2.5	**847**	**132**
3	**795**	**138**

Similarly bearing capacity corresponding to 100mm settlement was observed to be more in Hardening-soil model as compaired to Mohr-Coulomb model. In Hardeing-soil model increase in bearing capacity for skirt ratios 1,2,3 were 38%,50% and 68%. the corresponding increase in bearing capacity in Mohr-Coulomb model was 4%,14% and 25% respectively.

IV. CONCLUSION

The performance of the skirted raft footing is investigated under two different soil models for varying skirt depth and raft sizes. Results of the analysis indicate that the use of structural skirts reduces the settlement and increases the bearing capacity for both the models but performance of the Hardening-soil model is better then the Mohr-Coulomb model. Also the bearing capacity improvement factor and settlement reduction factor varies depending upon the geometric properties of sand, skirt and the footing.

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