NUMERICAL ANALYSIS OF CIRCULAR SKIRTED FOUNDATION RESTING ON SAND

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Abstract : Skirted foundation is the foundation which has vertical or inclined wall surrounding one or more sides of the soil mass below the footing. These walls (structural elements) are called as the skirts. It is nothing unusual but the normal footing except the presence of skirts hence, may vary as per their shapes-circular, rectangular, and square. These vertical skirts restricts the soil beneath and bring about a soil resistance on skirt side that helps it to resist sliding. The soil starts to behave as soil plug to transfer the loads from the super structure to the larger depths and thereby increasing its bearing capacity. The various factors affecting bearing capacity include the type of soil, water table properties. The enhancement in performance of these foundations usually rely upon footing shape, size, depth , structural and geometrical properties of skirt, roughness and material of skirt and the soil characteristics such as the index properties, interface conditions of the soil-skirt system. In the present work, the numerical analysis of circular skirted foundation resting on the sand is carried out using the finite element software Plaxis 2-D. The different parameters on which the study is based are the variable skirt depth (0.5D to 3D), variable foundation diameter(1m to 4 m) and their combined effect on the vertical load bearing capacity is being analyzed. On comparing their results using the Force v/s settlement curves, the study revealed that the load carrying capacity of the sand increased both with increase in depth of the skirt and diameter of the footing. The values of load carrying capacity considered in the analysis are corresponding to 40 mm settlement.

***IndexTerms* – Bearing capacity, Circular skirted foundation, sand, skirt depth.**

I. INTRODUCTION

All structures from a small building to a multistoried building, bridges to flyovers, dams to tunnel need an artificially laid base on which they are constructed on. That base is termed as the foundation. It acts as a bond betweenthe structure above and the soil below that supports it. These are basically needed for the distribution of the load coming from the superstructure on to the soil at a larger area. These must be designed taking two main criteria into mind- the shear force criteria and the settlement criteria. The former states that the soil below it should not fail in shear and later the settlement must be within the permissible limits.The various factors affecting bearing capacity include the type of soil, water table, soil properties(density, shear strength, permeability) etc.It may also get affected by physicalcharacteristics such as depth, shape, width of foundation. Foundations are largely categorized into two types namely shallow foundations and deep foundations. Majorly, they are differentiated by means of the Terzaghi's criterion which states that a foundation only called as shallow foundation if its depth is either equal to or less than its width. These pass the loads to a little lower depth as compared with the deep foundations. Mainly these footings undergo shear failure. When the load is transferred to the soil, the soil skits by sliding. This sliding can be controlled by restricting the soil mass below the footing. The vertical skirts usually confine the soil below them and behave as soil plug to transfer the superstructure loads to the soil. The skirted foundations are also used in the offshore constructions. The major application of these kinds of footings is in the field of designing offshore foundations where they have to put up with heavy loads and great moments created by the environmental conditions. They are also used as a means of support for large fixed substructures or as an anchorage for hovering structures.These are pertinent at places where water scour is the prime issue faced.

II. LITERATURE REVIEW

Aghbari (2007) conducted an physical modeling approach by means of a laboratory tests. The experimental set-up consisted of a rigid test tank, sand raining apparatus, a loading mechanism, and a footing. The the tank was made of wood and was stiffened with steel frames. The materal used for circular footing was a metal plate having diameter 120 mm and a thickness 30 mm.. The sand was placed in the tank by a sand raining technique. Density was maintained constant The skirts were the Stanley steel plates. The footing was placed on the top of the skirt. Two LVDT transducers were also placed there for the measurement of settlement. A no. of tests were done to have a great accuracy of the readings. The results revealed that with the aid of structural skirts, the settlement of footing got reduced there by modifying the load bearing capacity of the soil. A factor named "Settlement Reduction Factor" was also proposed.

Pusadkarand Bhatkar(2013) performed the analysis for two sided and one sided vertical skirted raft and with and without using skirts in PLAXIS 2D. The study revealed the structural skirts for raft foundation have proved to have a great effect in the enhancement of load bearing potential of the soil. Various parameters on which the study was based were the distinct raft sizes and addition of skirts. Different raft sizes used were 10m, 15m, 20m, 30m with skirt depth (Ds) from 0.25B to 3B.A Detailed comparison was shown between raft with and raft without vertical skirt. The final results showed up that when two sided raft foundation vertical skirts were used, there was an increment in bearing capability and decrement in settlement butwhen one sided raft foundation with vertical skirt was used, both bearing capacity and settlement got enhanced.

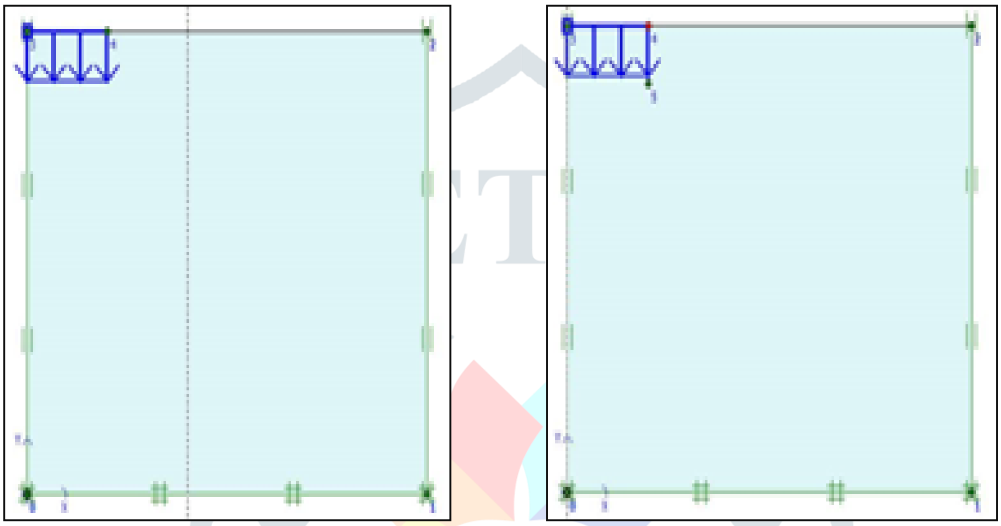
Pachauria et al. (2014) used physical modeling approach to determine the effect of diameter of the foundation on load bearing ability of skirted loose sand having relative density of 40%. Foundations with four different diameters (40 mm, 60 mm, 80 mm and 100 mm) were used.The skirts that were made up of PVC pipe were used in variable diameters (46 mm, 59 mm, 71 mm and 85 mm). A large no. of tests was done for the accuracy and precision. The test result revealed that with the increase in diameter of foundation with the same diameter of skirt the bearing potential increases, and when increasing the diameter of skirt with constant diameter of foundation, the loading capacity also increased.

Haider and Mekkiyah (2018) conducted the experimental approach of circular skirted foundation on dry sand. The experiments were performed in a huge container having dimensions 1000x1000x800mm. Different skirt length varied from 0.5D to 1.5D was attached to the edge of shallow circular foundations having three different diameters (D=60, 90 and 120 mm). Skirts having open end and closed end both were examined. The relative density was kept constant and equal to 60%. The foundation without skirts was tested and the results were computed and compared to it as a reference point. The values of the various tests done revealed that the skirt modified the load- behavior, increased the load carrying capacity and lowered the foundation settlement. The closed end skirts showed better results for the bearing capacity than that of the open end.

III. NUMERICAL MODELLING

The General procedure followed for the geometry modelling, profiling, executing of a finite element calculation and the evaluating of the output results is given below:-

- The very first step in the analysis is to begin a new project by crafting an axisymmetric model. The finite element analysis is based on six-nodded triangular elements and the soil is modelled using the Mohr-Coulomb model. Plate elements are used to represent the footing and skirts. This analysis is conducted by applying vertical prescribed displacements (100mm) and zero horizontal displacements.A typical case of the same is explained in brief.
- The geometry of the soil model detemined for the analysis is 8m x 8m with circular foundation resting on sand having radius 1m and skirt depth 0.5B =0.5m. The figure below shows the geometry model of circular foundation on sand with skirt and without skirt respectively.



Without Skirts With Skirts

Fig 1. Geometry of circular footing

The Soil used in the project is considered to be dry sand. The properties considered for the same are tabulated in table1

Table1-Material properties of the sand

PARAMETER	VALUE	UNIT
Material model	Mohr - coulomb	-
Soil unit weight above phreatic level	17.5	kN/m^3
Soil unit weight below the phreatic	20	kN/m^3
Young's modulus	13000	kN/m^2
Poisson's ratio	0.300	-
Cohesion	0	kN/m^2
Friction angle	30	Degree

The work is further divided into 4 main cases which include foundations with variable diameter (D = 1,2,3,4m) and skirt depth varying from 0.5D to 3D resting on sand .

The thickness of the skirts used in the analysis is assumed to be 0.3 m. The material used for the foundation is concrete and for the skirt is steel. Based on the model footing and model skirt dimensions, axial rigidity, EA and flexural rigidity, EI are calculated.The values of EA and EI for concrete are 750000 (kN/m) and 56250 (kNm^2/m) respectively.

Table 2 Depicting different values of EA and EI for Dia 1m

EA(kN/m)	EI($kNm^{2/}m$)	DIAMETER(m)	SKIRT DEPTH(m)
3.0E+07	6.25E+05	1	0.5D = 0.5
6.0E+07	5.0E+06	1	1D = 1
9.0E+07	1.68E+07	1	1.5D =1.5
1.2E+08	4.0E+07	1	2D = 2
1.50E+08	7.81E+07	1	2.5D = 2.5
1.8E+07	1.35E+08	1	3D = 3

Table 3 Depicting different values of EA and EI for Dia 2m

EA(kN/m)	EI(kNm$^{2/}$m)	DIAMETER(m)	SKIRT DEPTH(m)
6.0E+07	4.0E+07	2	0.5D = 1
1.2E+08	3.20E+08	2	1D = 2
1.8E+07	1.08E+09	2	1.5D = 3
2.4E+08	3.20E+08	2	2D = 4
3.0E+08	6.25E+08	2	2.5D =5
3.60E+08	1.08E+09	2	3D = 6

Table 4 Depicting different values of EA and EI for Dia 3m

EA(kN/m)	EI(,kNm$^{2/}$m)	DIAMETER(m)	SKIRT DEPTH(m)
9.0E+07	1.688E+07	3	0.5D = 1.5
1.8E+07	1.35E+08	3	1D = 3
2.7E+08	4.5E+088	3	1.5D = 4.5
3.6E+08	1.08E+09	3	2D = 6
4.5E+08	2.10E+09	3	2.5D =7.5
5.4E+08	3.64E+09	3	3D = 9

Table 5 Depicting different values of EA and EI for Dia 4m

EA(kN/m)	EI(kNm$^{2/}$m)	DIAMETER(m)	SKIRT DEPTH(m)
1.2E+08	4.0E+07	4	0.5D =2
2.4E+08	3.20E+08	4	1D = 4
3.6E+08	1.08E+09	4	1.5D = 6
4.8E+08	2.56E+09	4	2D = 8
6.0E+08	5.0E+09	4	2.5D = 10
7.2E+08	8.645E+09	4	3D = 12

As the analysis is known as the finite element analysis, after the completion of the geometry model and assigning of material, the geometry is being alienated into finite elements so that the calculations can be conducted easily. These finite elements are collectively called as the mesh. It takes full account of the points and lines and helps in transforming the input data from geometry to the mesh.

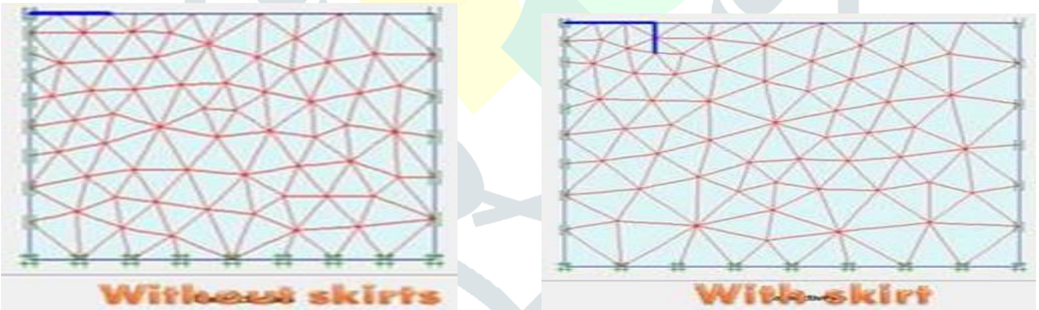


Figure2 Mesh generation for both the cases

IV. RESULTS AND DISCUSSIONS

Using the modelling and soil properties analysis as described above, the analysis was performed in PLAXIS 2D for circular skirted footing . As a result in the output program, the deformed mesh is shown at the end of calculation phase. Deformations can be properly determined or checked by controlling the scale of the deformed mesh. In the deformations menu, the total displacements are being plotted having different color shadings. The graphs are plotted as force on x-axis and settlement on y-axis. These graphs give the value for load bearing capacity.

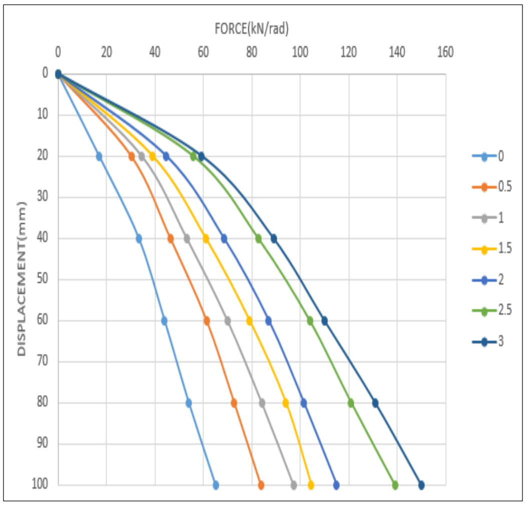


Fig. 3: Force-Settlement Curve for forndation having Dia 1

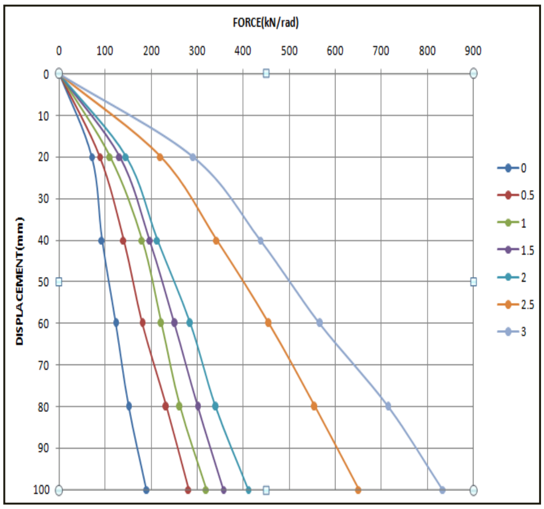


Fig.4: Force-Settlement Curve for foundation having Dia 2m

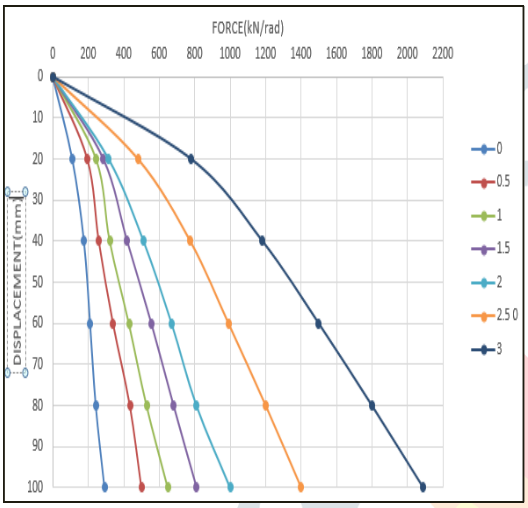


Fig. 5: Force-Settlement Curve for forndation having Dia 3m

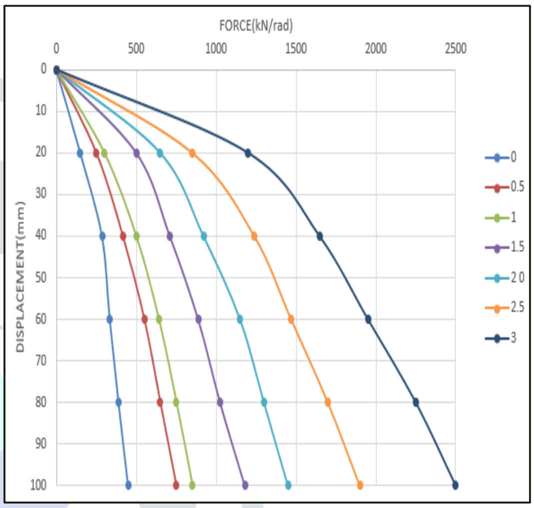


Fig. 6: Force-Settlement Curve for foundation having Dia 4m

The above graph shows increase in bearing capacity with the increase in both diameter of the footing aswell as the skirt depth.The load values plotted in this are corresponding to 40 mm settlement.

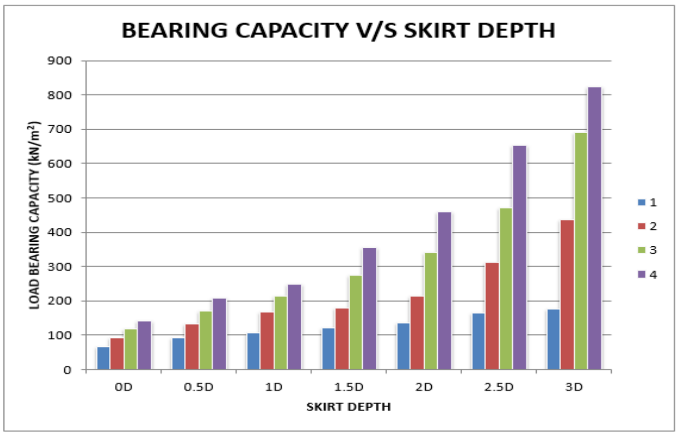


Fig. 7: Effect of diameter and skirt depth for the foundations on sand

Each Figure is plotted for fixed foundation diameter and varied skirt lengths. It is clear that application of skirts improves the performance of foundations, enhance load carrying capacity of foundations.The magnitude of improvement increases with increasing skirt length as well as foundation size. It is because that the skirts confine the soil below the footing and behave as soil plug.

Table 6 Comparative increase in bearing capacity for dia 1m

Skirt Depth Ratio	Load corresponding to 40mm settlement on sand	Comparative Increase in BCR
0	66.37	-
0.5	92.7	0.38
1	106.35	0.59
1.5	122.32	0.83
2	135.78	1.03
2.5	165.22	1.47
3	178.62	1.67

Table 7 Comparative increase in bearing capacity for dia 2m

Skirt Depth Ratio	Load corresponding to 40mm settlement on sand	Comparative Increase in BCR
0	93	-
0.5	141.12	0.5
1	183.41	0.87
1.5	197	1.11
2	213.31	1.20
2.5	342.15	2.66
3	437.04	3.69

Table 8 Comparative increase in bearing capacity for dia 3m

Skirt Depth Ratio	Load corresponding to 40mm settlement on sand	Comparative Increase in BCR
0	117.27	-
0.5	173.33	0.47
1	215.13	0.83
1.5	273.33	1.33
2	341.42	1.91
2.5	450.48	2.84
3	689	4.87

Table 9 Comparative increase in bearing capacity for dia 2m

Skirt Depth Ratio	Load corresponding to 40mm settlement on sand	Comparative Increase in BCR
0	143	-
0.5	208.09	0.45
1	249.65	0.74
1.5	355.02	1.48
2	460.55	2.22
2.5	653.55	3.57
3	823.5	4.75

V. CONCLUSIONS

Application of skirts to the circumference of the circular footing confines the soil beneath it and generates a soil resistance on skirt side. This leads to enhancement in the performance of footings. From the present research work, it can be concluded that

- The load bearing capacity corresponding to 40 mm settlement appears to increase with increase in the skirt depth.It is seen that the values of force for 1D increased 1 to 1.3 times in all the cases, and for 2D, it almost gets more than the double of 0D value and for 3D, it increased 4 to 4.5 times.
- With increase in the dia of the footing, the bearing capacity increases uptodia 3m and there is a marginal decrease of the same at dia 4m.

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