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Comparative Study on the Performance of Circular Skirted Foundation on Different Densities of Sand

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Abstract—*Improvement of bearing capacity and reduction in settlement of shallow foundation is a matter of utmost concern on weak soil conditions. Structural skirt to a conventional shallow foundation may prove to be beneficial in this context. Generally structural skirts consist of a slab and a shell and may have any shape depending upon the shape of the shallow foundation. Structural skirt restrains the soil beneath laterally and behaves as a single unit with the confinement to transfer the load from superstructure to soil.* ***It generally increases the effective depth of the foundation.*** *The aim of this study is to compare the improvement in Bearing Capacity (BC) by using skirted foundation in three different relative densities of sand i.e. 32.8% (loose sand), 50.8% (medium sand) and 67.9% (high density sand). Experiments are performed for two different sizes of model footing and bearing capacities are calculated. The ultimate bearing capacities obtained from experiments are in good agreement to the values obtained from Terzaghi's equation. The close proximity proves the reliability of the results and hence the study is extended for skirted foundations. Parametric variations have been done for different Skirt Depth ratios (S-D_p). The improvements are estimated by a non-dimensional term Improvement Factor (IF). Improvement factor is the ratio of value of bearing capacity of skirted foundation to the value of bearing capacity of foundation without skirt taken from the experiments done in different density sand. Improvement factor is found to be increased upto 4 for S-D_p ratio 1 in loose sand. It is seen from the result that use of circular structural skirt is more beneficial in loose sand than medium or high density sand.*

1. INTRODUCTION

Present day situation demands utilization of all types of lands either in strong or in weak condition to raise different types of structures due to increase in populations and limited land on Earth. Since most of the Civil engineering structures are connected to the ground and the availability of good construction ground are in a declining trend, Civil Engineering structures founded on weak soil or on soil having variable properties often need proper design, construction and maintenance. For this the geotechnical engineers have to either modify the structures or to make use of appropriate soil improvement techniques. Nowadays numbers of soil improvement techniques have been used to increase the performance of the ground. Different types of reinforcements have been used to improve the performance of the soils in different ground conditions. According to Mahmoud and Abdrabbo, 1989 confining the soil using horizontal reinforcements helps in increasing the bearing capacity of supporting soil. **Confined cylinders such as structural skirts are used to improve the resistance of soil to all types of bearing failure and to reduce settlement (Al-Aghbari, 2002; Al-Aghbari and Mohamedzein, 2004).** Azzam and Farouk (2010) found that installation of the skirt is a good method to control the horizontal movement of the subgrade and to decrease the slope deformation. Choice of appropriate ground improvement technique depends upon environmental, economical and technical feasibility. Some examples of ground improvement techniques are micropiles, jet-grouting, vibro concrete columns, skirted foundation, surface compaction, admixtures, heating, freezing etc. Although most of the aforementioned techniques are well developed, they are sometimes prohibitively expensive and restricted by different site specific conditions.

Skirted foundations are cost effective and can be installed in any site condition. It does not require any excavation in the soil to install the skirts. Its use is not restricted by the presence of high water table. Generally structural skirts are rigid plates penetrating a sufficient depth into the soil to provide anchorage to the foundation. These skirts may or may not be fixed to the edge of the foundation. Structural skirts fixed to the edges of shallow foundations have been used mainly to increase the effective depth of the foundations in marine and other situations where water scours may be a big problem. It restrains the soil beneath laterally and behaves as a single unit with the confinement to transfer the load from superstructure to soil. This type of technique is commonly seen in offshore structures, storage tank, oil tank, wind mill tower etc.

2. MOTIVATION AND OBJECTIVE

The aim of this study is to estimate the improvement in bearing capacity by using circular skirts. Parametric variations have been done for different skirt-depth ratios, S-D_p in loose, medium and dense sand. The improvement will be estimated by a non-dimensional term Improvement Factor which is defined as the ratio of bearing capacity of skirted foundation to the bearing capacity of foundation without skirt.

3. METHODOLOGY

The load test set up consists of a loading frame and steel plates properly loaded with cement concrete cubes, a mechanically operated inverted hydraulic jack of capacity 20 kN from which load is transferred to the subgrade soil through the footing and a test tank. The test tank of size 0.95m × 0.95m × 0.95m constructed with steel plates facilitates the experiments with the various footing assembly. The width of the test pit should not be less than 5 times the size of the test plate, so that the failure zones are freely developed without any interference from sides (Basheeruddin and Narayan, 2016). For this study the width of the test tank is almost 5 times the size of model footing and the depth below the tallest skirt is 6 times the tallest footing height. By adopting the above tank size for the model footings, it is ensured that the failure zones are fully and freely developed without any interference from the sides and bottom of the tanks. Figure 1 shows the prepared test set up for this study.

Figure 1: Test set up

Pre-calibrated pressure gauge of capacity 20 kN with least count of 50 N is clamped to the pumping unit to measure the magnitude of the applied load. Minimum of two deflection dial gauges of accuracy 0.01mm are placed on the centre line of the plates with the help of the horizontal datum bars to measure the settlements of the plates. The datum bar arrangement is kept free from any connection so that any disturbance of the loading arrangement does not affect the deflection dial gauge system.

4. MATERIALS USED

4.1. Sand

The material used for this study is coarse sand from Kanaighat (Kalioni River) of Golaghat District, Assam. The sand is first air dried and then sieved through IS sieve size of 4.75 mm and portion passing through is taken for our study. The properties of sand such as angle of internal friction (ϕ), uniformity coefficient (C_u), co-efficient of curvature (C_c) and grading characteristics D_{10}, D_{30}, D_{60} etc. are determined as per different Indian standard codes and shown in Table 1. Direct shear tests are done according to IS: 2720 (Part 13)-1986 to obtain angle of internal friction (φ).

Table 1: Properties of collected Kanaighat sand

Material	$\varphi(^0)$	D_{60} (mm)	D_{30} (mm)	D_{10} (mm)	C_u	C_c
Sand	32.8	0.55	0.34	0.19	3	0.87

Grain size distribution curve is shown in Figure 2.

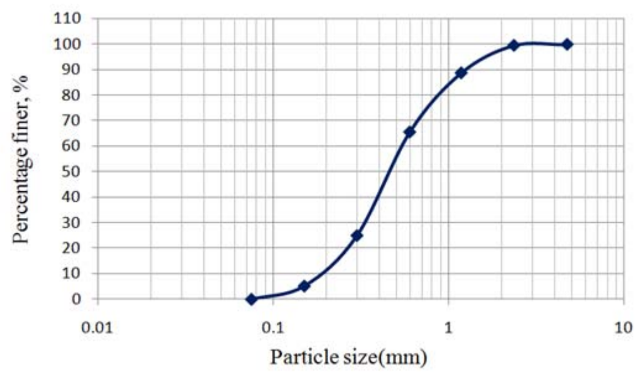

Figure 2: Particle size distribution curve

The maximum and minimum dry unit weights are 21.18 kN/m^3 and 12.77 kN/m^3. The model tests are performed on sand beds prepared with relative densities 32.8%, 50.8% and 67.9% which represents loose, medium and high density respectively.

4.2 Model footing and model structural skirts

Model footing for the tests is made up of mild steel plate having diameter (B) 0.15m and thickness 0.006m. For validity of test set up model footing of diameter 0.30m is also taken. Model skirted footings are also made up of mild steel sheets having diameters 0.15m and 0.30m and depths 0.075m and 0.15m. Model footing and model skirts are shown in Figure 3.

Figure 3. Model footing and model skirts used for study

For a model footing of diameter 0.15 m and 0.30 m, the skirts are fabricated maintaining S-D_p 0, 0.5 and 1 which are shown in Figure 4.

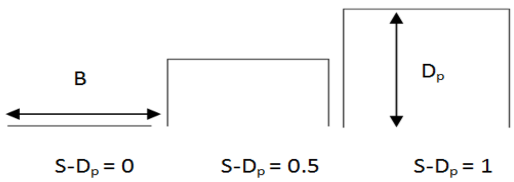

Figure 4: Different S-D_p ratio used for study

Sand raining technique is used for the preparation of sand bed. Consistency in the placement density is checked with small aluminium cans of known volumes at different locations and at different heights. After filling the sand into the tank, the top surface is leveled.

5. METHODOLOGY FOR LOAD TEST

Load test is performed on the model test tank and test procedure is taken same as for plate load test as per IS 1888:1982. After the preparation of sand bed model footing is placed centrally, under the spindle of jack so that the plate, reaction girder and the spindle are coaxial. The dial gauges are arranged in diametrically opposite manner and settlement is measured continuously without any resetting in between. Load is applied in cumulative equal increments of 10 kg without any jerk, impact and eccentricity. Dial gauges observations are recorded for each load increments after the time interval mentioned in IS: 1888-1982. Next higher load is applied and the process is repeated. Test is continued till a very high settlement is obtained. For the testing of skirted model footing the skirt is inserted centrally into the sand bed and then the model footing is placed above it. The test procedure explained here for model footing is also followed for model skirted footing.

6. INTERPRETATION OF RESULTS

At first average settlements of model footings (MF) are calculated from the dial gauges readings and cumulative settlement corresponding to load intensity is found. Load intensity and corresponding cumulative settlement are plotted on log-log scale as per IS: 1888-1982. The ultimate bearing capacities for two different diameters of model footing in Kanaighat sand are calculated from the ultimate bearing capacity equations given by Terzaghi. Bearing capacities of model footings are found experimentally and the experimental value (E_x) of bearing capacity is extracted from respective load-displacement graphs. The experimentally found values of bearing capacities for two different diameter plates (model footing) for relative density 50.8% have been compared to the analytically found values from various equations by different authors and have been presented in Table 2.

Table 2: Bearing Capacity in kN/m^2

B of MF(m)	E_x	T_r
0.15	22.63	23.56
0.30	45.27	43.85

Close proximity has been observed between the ultimate bearing capacity values obtained from Terzaghi's equations and the experimental set up. Convinced with the reliability of the test set up, now the effect of skirt-depth ratio is studied for model skirted footing of diameter 0.15 m for medium sand. For different S-D_p ratios load-settlement curves for 0.15 m diameter obtained from experiments are shown in Figure 5.

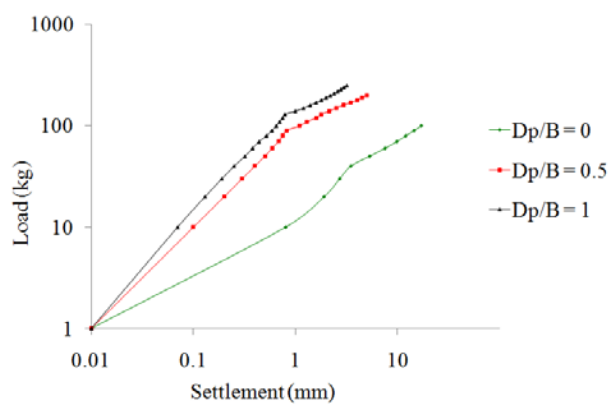

Figure 5: Load–settlement curve for different S-D_p ratio on medium sand

It is seen that as the skirt-depth ratio increases load taken by the model footing also increases and settlement decreases. Now for same S-D_p ratios load-settlement curves for 0.15 m diameter obtained from experiments done for loose sand and high density sand are shown in Figure 6 and Figure 7.

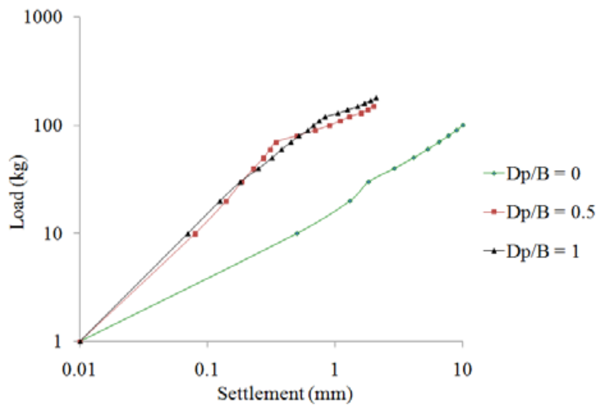

Figure 6. Load–settlement curve for different S-D_p ratio on loose sand

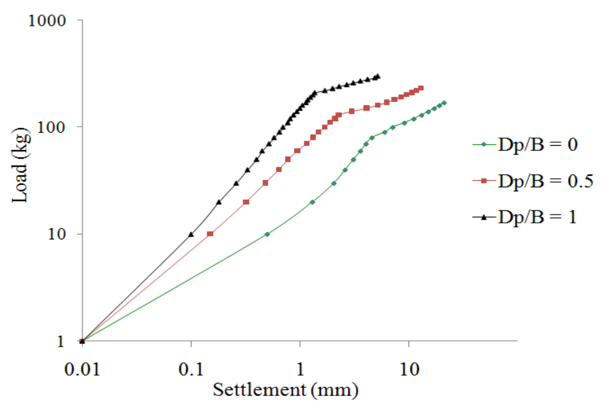

Figure 7. Load–settlement curve for different S-D_p ratio on high dense sand

It is seen that load carrying capacity of each model skirted footing with higher skirt-depth ratio is more than that with a lower skirt-depth ratio for a constant value of skirt-diameter ratio.

7. IMPORTANT OUTCOMES

The performance of a model skirted foundation can be quantified by a term improvement factor. Improvement factor may be defined as the ratio of the bearing capacity of a skirted foundation to the bearing capacity of a model unskirted footing of the same diameter. In this study the diameter under consideration is 0.15 m. The effect of skirt depth ratio for three different densities of sand by experimental has been presented in Table 3.

Table-3 Improvement Factor (IF) for different S-D_p ratio

B	D_a	D_p	S-D_P	BC (kN/m^2)	IF (E_x)
For Loose Sand					
(m)	(m)	(m)		E_x	
0.15	0	0	0	16.97	-
0.15	0.15	0.075	0.5	45.27	2.67
0.15	0.15	0.15	1	67.9	4
For Medium Sand					
0.15	0	0	0	22.63	-
0.15	0.15	0.075	0.5	50.93	2.25
0.15	0.15	0.15	1	73.56	3.25
For High Dense sand					
0.15	0	0	0	45.27	-
0.15	0.15	0.075	0.5	73.56	1.62
0.15	0.15	0.15	1	118.84	2.63

8. CONCLUSION

This paper investigates the influence of lateral confinement with skirts on the bearing capacity of circular footing on locally available Kanaighat sand. Based on the experimental study the following conclusions may be drawn.

- A structural skirt increases the bearing capacity of soil. For skirt-depth ratio consideration, maximum bearing capacity improvement factor obtained is 4 for skirt-depth ratio of 1.
- Bearing capacity is found to be maximum for a skirt-depth ratio of 1. For skirt-depth ratio 0.5, maximum improvement factor is 2.67.
- The performance of skirted foundation is best on loose sand. Because in loose sand for skirt-depth ratio 1, improvement factor is 4. For similar skirt- depth ratio, in medium sand improvement factor is 3.25 and for high dense sand, improvement factor is 2.63 only.
- Decrease in settlement is observed for bigger values of skirt-depth ratios.

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