International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2015): 78.96 | Impact Factor (2015): 6.391

A Study on Load Carrying Capacity of Skirted Foundation on Sand

T. Prasanth[1], P. Rajendra Kumar[2]

[1]K S R M College of Engineering, Kadapa, Andhra Pradesh-516003

Abstract: ***Skirted foundations are considered to be a viable foundation for a variety of offshore applications. Skirted foundations are used widely offshore, either as a single foundation system for gravity based structures or as discrete foundation units at the corners of jacket structures and tension leg platforms. Skirted foundations used in structures and facilities for the oil and gas industry are gradually replacing piled foundations. These foundations lead to cost savings through reduction in materials and in time required for installation. The effects of skirt length on bearing capacity were already investigated and reported in many literatures. Skirted footing capacity for combined (vertical, horizontal and moment) loads has been studied by several researchers using both numerical and physical modelling. From the accomplished laboratory tests, it is concluded that there is enhancement in bearing capacity of skirted foundations occurred both with the increase in skirt depth and relative density of sand. The ultimate bearing capacity was found to increase with the size of the footing, the length of skirts and the relative density of sand.***

Keywords: Bearing Capacity, Offshore foundation, Skirts

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 techniques 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 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 super-structure load to soil. Skirted foundations have been extensively used for offshore structures like wind turbine due to easy installation compared to deep foundation. Skirt foundations have a wide variety of functions such as control of settlement during service life, less impact to environments during operation at installation site. Skirted foundations are used to satisfy bearing capacity requirement, and to minimize the embedment depth and dimensions of the foundation. Vertical loading due to the self -weight of installation (Ex. Jacket structure, wind turbine) is improved as soft surface soils are confined within the skirt and the foundation loads are transferred down to harder underlying layers.

2. Literature Review

Susan Gourvenec and Mark. F. Randolph (2012) used the finite-element analyses to quantify the immediate and time-dependent response of circular skirted foundations to uniaxial vertical loading. Foundations with frictionless and fully rough skirt-soil interfaces with varying ratio of embedment depth to foundation diameter are considered and the results are compared with those for surface foundations. It shows that both skirt-soil interface roughness and embedment ratio have a significant effect on the consolidation response. M. F. Bransby and G.J. Yun (2009) conducted a series of plane-strain finite element analyses to investigate directly how the skirt geometry affects the un-drained strip foundation capacity under combined horizontal–moment loading and the mechanisms occurring at failure. It shows that deformation of the soil between external skirts can lead to significantly less foundation capacity than that of an equivalent solid embedded foundation. The specific geometry of the foundation must be considered in design. In addition, the failure envelopes for skirted foundations with different embedment ratios differed significantly. According to them, the significant increase in foundation bearing capacity may be achieved by adding an intermediate skirt to the foundation, which results in a foundation capacity that is almost equal to that of a solid embedded foundation. Yun and Bransby (2003) made a comparative study between load–displacement response from centrifuge test data and finite element results of skirted circular footings of different skirt roughness and skirt depth up to five times the footing diameter. They also conducted a series of centrifuge model tests on a skirted footing subjected to vertical load, moment, and horizontal load; and proved that the skirted foundation increased the horizontal capacity to about 3–4 times that of the un-skirted foundation. They suggested that the failure mode changed to rotational mode instead of sliding mechanism. Bransby and Randolph (1998) proved that vertical and horizontal capacities are affected by the footing shape and the soil strength profile using finite element and plasticity analysis. M. Y. AL-AghbarI and Y. E-A.Mohamedzein (2004) conducted a series of tests on foundation models and study the factors that affect the bearing capacity of foundations with skirts. They studied several factors including foundation base friction, skirt depth, skirt side roughness, skirt stiffness and soil compressibility. The results obtained from the proposed equation were compared with the results obtained from Terzaghi, Meyerhof, Hansen and Vesic bearing capacity equations for foundations without skirt. Villalobos (2007) presented the experimental results of scale skirted shallow foundations in sand under monotonic vertical loading. The investigation included different skirt lengths, mineralogy and density of the sand deposits. The bearing capacity formulation was used in the analysis of failure. Axial symmetric bearing capacity factors for flat footings were used.

3. Materials and Methodology

3.1 Sand

The sand was brought from nearby Penna River and was oven dried for one day. Then it was sieved in 2mm and 0.425 mm sieve. The sand which are passed in 2mm and retained in 0.425mm sieve was taken for the research work. The properties of the collected sand were given in the following Table3.1

Table 1: Index Properties of Sand

S.No	Description	Values
1.	Uniformity coefficient, C_u	2.4
2.	Coefficient of curvature, C_c	1.0
3.	Soil classification as per IS1498-1970	SP Poorly graded sand
4.	Specific gravity	2.60
5.	Minimum dry density γ_{min}	14.59 kN/m^3
6.	Maximum dry density γ_{max}	16.95 kN/m^3
7.	Maximum Void ratio e_{max}	0.505
8.	Minimum Void ratio e_{min}	0.748

3.2 Model footing used

The model footing was a mild steel circular footing of diameter (D) equal to 75mm of thickness 10mm.

3.3 Skirt footing used

Skirts are made from mild steel sheets of 3mm thick and are welded firmly and accurately to the footings. The skirt lengths (L) to the footing diameter L/D values of 0.4, 0.8, 1.2, 1.6, and 2.0 were maintained. The lengths of skirts are measured after welding to footings.

Figure 1 Model skirt footings

3.4 Loading frame used

The capacity of loading frame is 3000 kg and types of operation electrical and manual. The load frame consists of a cabinet which houses the gear system and motor loading systems comprises of screw jack with detachable handle. The lower plate moves up and down. A dailguage mounting bracket is provided on one of the two pillars. Rate of strain is 1.25 mm/min

3.5 Model test tank used

The size of tank was designed keeping in view the size of footing to be tested and zones of influence. The dimension of the tank was 30*30*40cm. Testing tank used in experimental study shown in Figure 2.

Figure 2: Model test tank

4. Testing Equipment

To study the behavior of a skirted footing on sand, laboratory tests were conducted on a small scale model of circular footing having diameter (D) equal to 75 mm. and of thickness 20 mm. The footing models were machined from steel plates. The skirt length (L) to the footing diameter ratio L/D is 0.0, 0.4, 0.8, 1.2, 1.6 and 2.0. Skirts are welded firmly and accurately to footings. The lengths of skirts are measured after welding to footings. Eighteen laboratory experiments are conducted to study the behavior of skirted footings. The model footings have smooth faces and a notch at the center of the top face for mounting a calibrated proving ring of 3000 kg maximum capacity via ball bearing. Two-dial gauges of accuracy 0.01 mm were used to measure the footing vertical displacements and rotations. The dial gauges were attached vertically far apart on the top surface of the footing.

The vertical displacement of the footing was considered as the average of the two-dial gauges readings. Rotations are not permitted during the test, and this was achieved by accurately applying the imposed load vertically and concentric on the footing model and by ensuring a homogeneous formation of sand.

5. Methodology

The sand was formed in the soil bin in layers each 50mm thickness. To ensure homogeneity of sand formation, a calculated weight of sand with an accuracy of 0.001kN was formed into a certain volume of sand by compaction to give specific relative densities. For higher relative densities 75 and 90 the soil bin was vibrated in the vibrating table with the footing embedded in it with a top plate on it till the required density was achieved. The bin was then placed on the strain controlled loading platform without disturbing the density of the soil. The load was transferred to the footing through a ball which was placed between the footing and the proving ring. Such an arrangement produced a hinge, which allowed the footing to rotate freely as the underlying soil approached failure and eliminated any potential moment transfer from the loading fixture. Finally vertical load was applied at a strain rate of 1mm/minute. Dial gauge was placed on the footings to measure the vertical settlement of the footing. Three laboratory experiments were conducted in surface footing for each relative density and fifteen tests are conducted in skirt footing. Several tests were repeated at least twice to examine the performance of the apparatus, the repeatability of the system and also to verify the consistency of test data. Very closest patterns of load-settlement relationship with the maximum difference in the results less than 5% were obtained.

6. Results and Discussions

6.1 Load Tests

To study the effect of skirt length on the bearing capacity of shallow footings, reference tests were conducted on unskirted footings with the same diameter on the same soil formation. The load–settlement relationships were plotted for all tests conducted on footings having the same diameter, while average load–settlement relationships were drawn for tests carried on footings having different diameters.

6.2 Load –Settlement Characteristics

Typical load-settlement curves for circular skirted footing with skirt ratio of 0.0, 0.4, 0.8, 1.2, 1.6 and 2.0 are shown in Figures 3, 4 and 5 respectively.

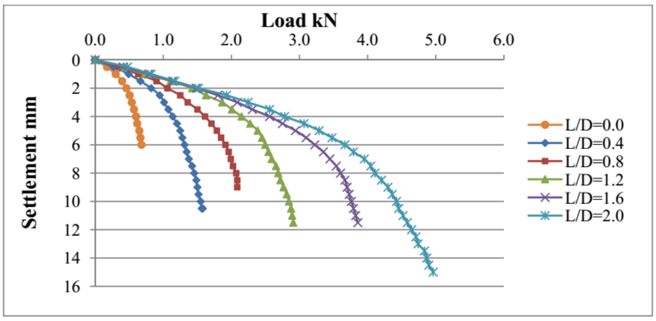

Figure 3: Load-Settlement relationships at relative density 30%

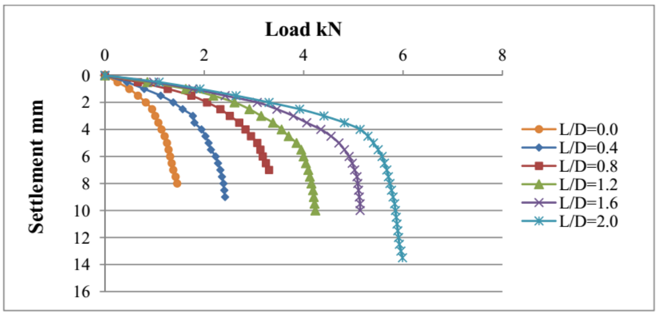

Figure 4: Load-Settlement relationships at relative density 60%

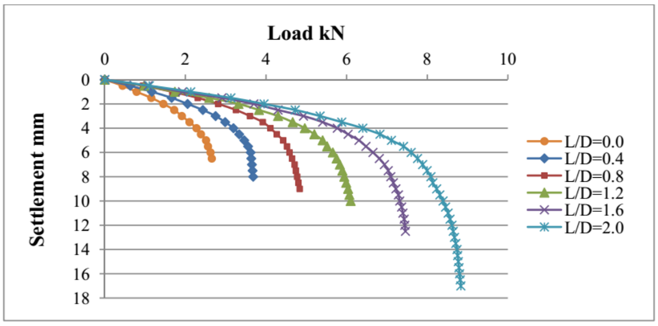

Figure 5: Load-Settlement relationships at relative density 90%

Test results shows that for sand having relative density 30%, the failure load attains at displacement equivalent to some between 8% and 20% of the footing diameter, for all L/D values. As the relative density of sand increases, the failure load of skirted footing having skirt length to diameter ratio less than 1.2 attains at a bigger displacement ratio, some between 8.67% and 13.33% in case of sand having a relative density equals to 65%, and 90%.

The figures show that the settlement diameter ratio at failure load increases as the relative density of sand increases and L/D ratio increases. Generally, the displacement of the sand underneath the footing is resulted from two basic causes, the compressibility of sand and the displacement of the sand grains associated with plastic response of soil. The proportion of the two effects in the total displacement depends on the applied load level, the relative density of sand, and the length of skirt to diameter ratio L/D. The displacement of the footing due to compressibility of sand, which takes place at early stage of loading, may be assumed proportional with the applied load, whereas the deformation due to displacement of soil grains, that is to say the plastic deformation, increases exponentially as the load level increased approaching failure load.

As L/D ratio increases, the confining pressure at skirt tip level increased and consequently the elastic and the plastic displacements of sand grains are constrained. Furthermore, as the relative density of sand increases and L/D increased, the mode of failure of footing-soil system changed due to total or partially confinement of the formed plastic zone of soil, and hence, more displacement to mobilize shear failure plane in soil is required. This may explain that footings can sustain a bigger failure load as the relative density of sand increased and the skirt length to diameter of footing ratio increased. This may explain that footings can sustain a bigger failure load as the relative density of sand increased and the skirt length to diameter of footing ratio increased. Figs. 4.2 and 4.3 demonstrated that at early stage of loading, up to proportionality limit, L/D ratio having inappreciable effects on load–displacement relationships. Beyond this limit, the displacement of the footing decreased as L/D ratio increased, contrary to Fig. 4.1 where the proportionality limit is obscured. This may be explained by the effect of strain hardening, which takes place during the process of loading, and the changes in the sand compressibility.

6.3 Effects of relative density on bearing capacity

The effects of the relative density RD on the bearing capacity ratio BCR for different L/D were reflected in Fig. 6.

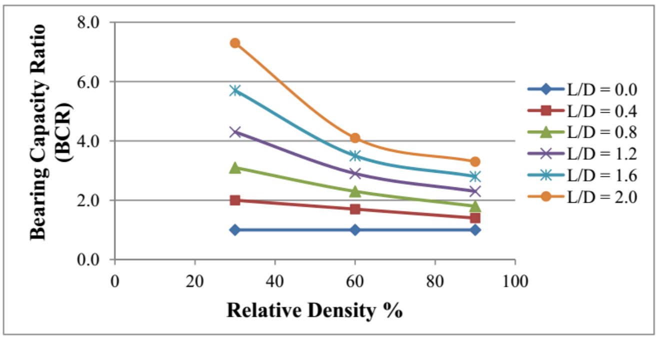

Figure 6: Variation of Bearing Capacity Ratio with Relative Density

The bearing capacity ratio BCR is disproportion with the relative density RD and proportion with L/D. BCR attains 2.0 and 7.3 in case of sand having relative density equal to 30%, for L/D equal to 0.4 and 2.0, respectively. In order to get a better performance of skirted footing, we have to increase the skirt length to diameter ratio L/D. Also the less the relative density of sand, the better the performance of skirted footings.

7. Conclusions

The experimental analyses have been carried out to study the behaviour of skirted footing on sand at different skirt ratio and at different relative density. Based on the above results and discussions, the following conclusions may be made:

1) A structural skirt increases the bearing capacity, reduces the settlement and modifies the load settlement behaviour of the footing.
2) The bearing capacity of skirted foundation increases when compared to unskirted foundation with different L/D ratio is 104.6%, 207%, 327.9%, 467.4% and 630.2%in case 30% relative density.
3) The bearing capacity of skirted foundation increases when compared to unskirted foundation with different L/D ratio is 66.3%, 127.2%, 191.3%, 253.3% and 312%in case 60% relative density.
4) The bearing capacity of skirted foundation increases when compared to unskirted foundation with different L/D ratio is 38.7%, 82.1%, 129.8%, 181% and 232.7%in case 90% relative density.
5) The bearing capacity ratio BCR is disproportion with the relative density RD and proportion with L/D. BCR attains 2.0 and 7.3 in case of sand having relative density equal to 30%, for L/D equal to 0.4 and 2.0. For better performance of skirted footing less the relative density and increase in L/D ratio.

References

[1] A.B. Cerato, A.J. Lutengger, Scale effects of shallow foundation bearing capacity on granular material, J. Geotech. Geoenviron. Eng. 133 (10) (2007) 1192–1202.

[2] Amr Z. El Wakil (2010) “Horizontal capacity of skirted shallow footings on sand”, Alexandria Engineering Journal (2010) 49, 379–385

[3] Bell, W.R. (1991), “Analysis of offshore Foundations subjected to combined loading”, Master of Science Hilary Term.

[4] Byrne, B.W., Villalobos, F., Houlsby, G.T. and Martin.C.M. (2001), “Laboratory testing of shallow skirted foundation in sand”, Conference Title. Thomas Telford, London, 2001

[5] Byron Walter Byrne (2000) “Investigations of suction caissons in dense sand”, DPhil. University of Oxford.

[6] E.E. De Beer, The scale effect in the transportation of the results of deep-sounding tests on the ultimate bearing capacity of piles and caisson foundations, Geotechnique 13 (1) (1963) 39–75.

[7] Felipe Villalobos (2007) “Bearing capacity of skirted foundation in sand” , Valparaiso

[8] G.J.Yun and M.F.Bransby (2003), “Centrifuge modelling of the horizontal capacity of skirted foundations on drained loose sand” BGA International Conference on Foundations: Innovations, Observations, Design and Practice.

[9] G.Yun and M.F.Bransby (2007) “The undrained vertical bearing capacity of skirted foundations”, The Japanese Geotechnical Society, Vol. 47 (2007) No. 3P 493-505

[10] Hisham T. Eid and M.ASCE (2013) “Bearing capacity and settlement of skirted shallow foundation on sand” International Journal of Geomechanics, Vol. 13, Issue 5 (October 2013)

[11] L Kellezi, G Kudsk and H Hofstede (2008), “Skirted Footings Capacity for Combined Loads and Layered Soil Conditions” Proceedings of the BGA International Conference on Foundations, Dundee, Scotland, 24-27 June 2008. IHS BRE Press, 2008.

[12] M. F. Bransby and G.-J. Yun (2009) “The undrained capacity of skirted strip foundations under combined loading” Géotechnique, Volume 59, Issue 2, March 2009 , pp. 115-125

[13] M.F.Bransby and M.F.Randolph (1998), “Combined loading of skirted foundations”, Géotechnique, Volume 48 Issue 5, October 1998, pp. 637-655.

[14] M.F.Bransby and M.F.Randolph (1998), “Shallow foundations subject to combined loadings” Frontiers in Offshore Geotechnics.

[15] M.Y.Al-Aghbari and Y.E-A. Mohamedzein (2004), “Bearing capacity of strip foundations with structural skirts”, Geotechnical and Geological Engineering, 22(1):43-57, 2004.

[16] Martin.C.M. (1994), “Physical and numerical modelling of offshore foundations under combined load”, DPhil Thesis, Oxford University.

[17] Susan Gourvenec and Mark. F. Randolph (2010) “Consolidation beneath circular Skirted Foundations” International Journal of Geomechanics, Vol. 10, Issue 1 (February 2010)

[18] Y.Hu, M.F.Randolph and P.G.Watson (1999), “Bearing Response of Skirted Foundation on Nonhomogeneous Soil”, Journal of Geotechnical and Geoenvironmental Engineering/ Volume 125 Issue 11- November 1999.

[19] Yihua Wang, Xiaobing Lu, Shuyun Wang and Zhongmin Shi (2006), “The response of bucket foundation under

horizontal dynamic loading", Ocean Engineering, Volume 33, Issue 7, May 2006, Pages 964-973.

Author Profile

T.Prasanth received B.Tech. Degree in Civil Engineering from J.N.T.U in 2014. He is pursuing M.Tech in Geotechnical Engineering. K.S.R.M College of Engineering. His areas of interest are Pile Foundations, Software Analysis regarding to the Geotech Field, Ground Improvement Techniques.

P. Rajendra Kumar working as an Assistant Professor at K.S.R.M College of Engineering. He has received his M.Tech in Rock Engineering and Underground Structures at IIT Delhi. His areas of interest are Tunnel Design, Slope Stability in rock and soil, Foundation Engineering, Soil Stabilizations, and Ground Improvement Techniques.