British Journal of Civil and Architecture Engineering
ISSN: 2229-5558
Volume 01, Issue 01, August,2019

# Exploratory Evaluation of Bearing Capacity of Skirted Footings

G. Ibrahim[1], H. Rownak[2]
Civil Engineering Department, Isfahan University of Technology, Isfahan, Iran[1, 2.]

**Abstract**— Basic skirts have been utilized underneath shallow establishments of marine structures for a long time, because of their strength favorable circumstances. Anyway, constrained information is accessible on the presentation of the avoided establishments with regards to their use as ordinary shallow establishments. In this examination think about the bearing limit of such establishments was assessed through research center testing. In this setting the impacts of skirt firmness and profundity on the bearing limit of avoided balance models were examined. The test outcomes were then contrasted and different bearing limit conditions. It was discovered that utilizing basic skirts may improve the balance bearing limit up to 3.68 occasions relying upon the geometry and basic details of the skirts and footings, soil qualities and states of both soil-skirt and soil-balance interfaces.

**Keywords**—Bearing Capacity, Skirted Footings, Shallow Foundations, Dense Sand.

## 1. Introduction

The issue of bearing limit of shallow establishments has been generally examined in the geotechnical designing writing. Till now various strategies have been introduced for assurance of bearing limit of establishments inserted in soils. The majority of regular strategies depend on a breaking point harmony approach. In light of the point of confinement harmony hypothesis, a general shear component is expected inside homogeneous soil underneath a strip balance. The balance bearing limit is then decided dependent on static harmony of the dirt wedge framed underneath the balance. Along these lines the measure of bearing limit is legitimately reliant on the length of slip lines for example increasingly extensive slip lines yield more prominent bearing limit. An expansion in the length of slip lines might be accomplished by expanding either the balance width or implant profundity (Das, 2007). Utilization of auxiliary skirts which incorporate the dirt underneath balance may likewise be a sensible technique to expand the length of slip lines (Figure 1 with B width of balance and Ds profundity of skirt). Utilizing this kind of establishment may likewise decrease the expense of establishment development as the measure of unearthing and filling tasks lessens for the avoided establishments in contrast with those of traditional establishments. Besides utilizing fringe skirts can keep the dirt underneath establishment from crushing out and any harm because of unearthings for contiguous development works is limited. Thinking about the potential preferences of avoided establishments, it appears utilizing these establishments may have an extraordinary effect in the expense and execution of establishments. In the meantime, more examinations must be completed on the bearing limit and settlement conduct of the evaded establishments to feature their points of interest for rehearsing engineers. A few researches consider pertinent to this subject will be assessed in the accompanying area.

Bransby and Randolph (1998) and Hu et al. (1999) portrayed the uses of marine avoided establishments and their computational techniques in subtleties. Bransby and Martin (1999) presented a work-solidifying model for execution of basin establishments, under joined stacking comprising of vertical, level and minute segments. They exhibited a strategy in mix with the examination technique for container establishments for coat structures and approved it through axis demonstrating. The aftereffects of axis model tests were then contrasted and consequences of numerical examinations from which a decent understanding was finished up between these outcomes. Gourvenec (2002) contemplated the strip and roundabout evaded establishments on non-homogenous marine dirt under joined stacking utilizing two- and three-dimensional limited component investigations.

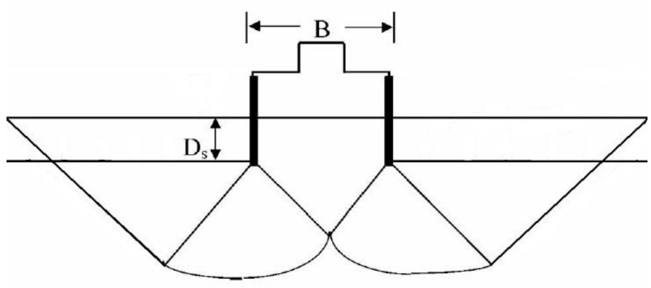



**Figure 1.** Increase in length of slip lines due to using of skirt

Acosta-Martinez et al. (2008) revealed the test consequences of a shallow avoided establishment under pressure and strain loads. The establishment execution was considered under both perpetual and transient loadings. Additionally, the impacts of solidification feeling of anxiety and stress history on establishment undrained bearing limit and perpetual burden reaction were explored. Gourvenec and Randolph (2010) inspected union underneath round evaded establishments. They utilized little strain limited component investigation for evaluating quick and time subordinate reactions of roundabout evaded establishments under vertical single-pivotal stacking. Establishments with frictionless limits and very unpleasant soil-skirt contact just as different proportions of installation profundities to distance across were examined and their reactions were contrasted and those of shallow establishments. It was discovered that both insertion and limit erosion effectsly affect the establishment union reaction. Al-Aghbari and Mohamedzein (2004) proposed an adjusted bearing limit condition for avoided strip establishments on thick sand dependent on the consequences of trial examine on evaded balance models. A few factors, for example, establishment base erosion, skirt profundity, skirt side unpleasantness, skirt firmness and soil compressibility were considered in this examination and their belongings joined in the bearing limit condition. In view of their trial thinks about they reasoned that auxiliary skirts can improve the establishment bearing limit by a factor of 1.5 to 3.9.

Al-Aghbari and Mohamedzein (2006) considered the presentation improvement of round establishments utilizing basic skirts through stacking test models. It was discovered that this sort of support expanded the bearing limit of base soil and improved the balance load–removal reaction. Additionally, it was discovered that the basic skirts decrease the settlement of surface footings contrasted and footings without auxiliary skirts. At an orientation weight equivalent to half of extreme bearing limit, the balance settlement decreased to about 11% that of balance without skirt. Al-Aghbari (2007) examined settlement of shallow roundabout establishments with auxiliary skirts laying on sand. The trial results demonstrated that utilizing evaded balance decreased the settlement of bed soil and improved the pressure relocation conduct of the balance. A settlement decrease factor (SRF) was proposed, which considered different parameters compelling on balance settlements. It was discovered that the utilization of basic skirts prompted settlement decrease in the scope of 0.1 to 1.0 contingent upon the connected burden and skirt profundity.

Nighojkar et al. (2010) considered the presentation of bi-edge molded evaded balance under two-way capricious burdens. They reasoned that the differential settlement of outrageous corners of the balance is influenced significantly because of quality of skirts. Skirts have been observed to be useful in diminishing differential settlement because of erratic stacking.

As noted above, the greater part of past investigations was committed to evaded establishments for marine structures. Albeit some test concentrates concentrated on strip avoided footings as traditional establishments, they included uniquely with incomplete fringe skirts. This paper reports the consequences of a test consider on the presentation balance models with full fringe skirts in different conditions.

**2. Testing Setup and Materials**

Stacking tests were performed on avoided model footings inserted to sand in a test box encased inside an inflexible steel outline. Concerning the range of accessible stacking outline, a test box with inside size of 440×420×450 mm was chosen. The test box comprised of a steel unbending floor and two wooden sides with metal props, while different sides were worked of 10mm thickness Plexiglas with steel bar bolsters, to keep them from parallel development. The inside essences of wooden sides were secured with a meager layer of smooth plastic to set it up for grease. To limit rubbing, the majority of the interior essences of side dividers were lubed and left for in any event one hour to permit the uniform spreading oil over the surface (Yung et al., 2004). Model footings of 70mm width were received dependent on the crate measurements to stay away from of unbending dividers impacts on the balance bearing limit (Bowles, 1996; Salençon, 2002). The footings were made of aluminum plates which their run of the mill particulars is appeared in Figure 2.

Each avoided balance comprised of an inflexible base with more than 25mm thickness and a skirt made of aluminum plate formed as box profile. The inflexible balance could be fixed to the skirt by a few appropriate sinks during the model position the sand. To keep up plane strain condition inside soil underneath the model balance, the case width was restricted about to the size of the balance length utilizing two steel profiles of 80mm width. In such a condition each finish of the balance is situated at close neighboring of the steel profile and counteracts soil removal in the longitude heading. Slim greased up movies were put at the contact surfaces of the balance closes and the steel profiles to kill grinding at their interfaces.

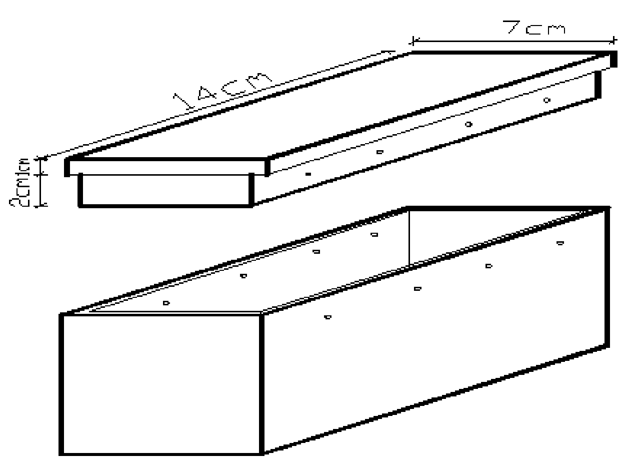


**Figure 2.** Specifications of Skirted Footing Model

## 2.1. Materials

A sandy soil was utilized in this trial examination. The reviewing bend of this sand is appeared in Figure 3. The sand reviewing attributes D10, D30, D60 were resolved 0.25, 0.47, and 0.85mm individually. These yielded consistency coefficient, Cu, 3.2 and arch coefficient, Cc, 1.04. In this manner the sand was named uniform or ineffectively evaluated sand, SP, in view of bound together soil Classification framework.
The particular gravity of the sand was estimated 2.7. The base and most extreme dry unit loads of the dirt were gotten as 16.28kN/m3 and 18.69kN/m3 individually. Utilizing sand down-pouring strategy a medium thick state was accomplished at unit weight of 17.67kN/m3 which equivalents to relative thickness of 61%. Feasible thickness in this strategy relies upon the precipitation power and consistency of sand downpour just as stature of fall (Cresswell et al., 1999). The test thickness was accomplished when the sand spilled inside the test tank at stream rate of 22g/sec through a pipe from consistent stature of 20cm.

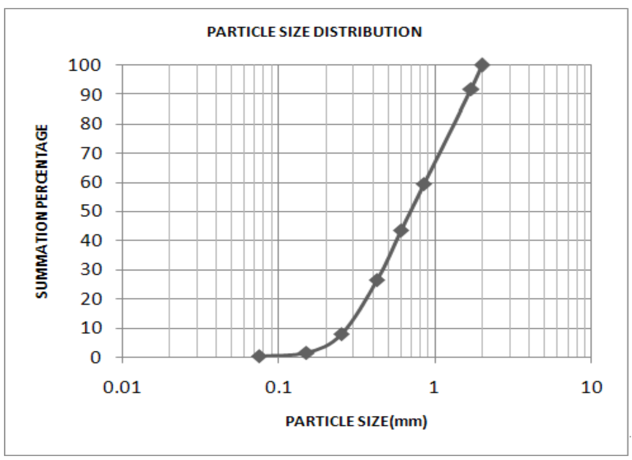



**Figure 3.** The grading curve of used sand

The quality properties of the sand were resolved through direct shear tests. These tests were done at typical burdens 39, 54.76 and 86.22kPa on 63mm width tests at shear uprooting rate of 1.06mm/min. The normal estimation of pinnacle grating edge of the sand was observed to be 42º. In balance burden tests appropriate sand paper was stuck to inward and external sides of skirt just as base face of balance to give harsh contacts sand. Rubbing point between the test sand and the rough paper was resolved 36º over a similar ordinary anxiety utilizing the immediate shear contraption. This estimation of contact erosion point is roughly equivalent to the grating edge among cement and soil and this may mimic the conditions of genuine establishments.

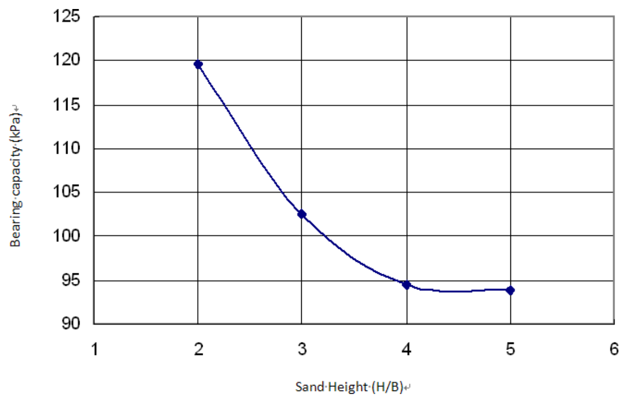
## 2.2. Test Procedures

Enough sand stature was required to stay away from of likely impacts of unbending base of test box on the balance bearing limit. Along these lines a few stacking tests on an average model balance were done at different instances of sand layer tallness inside the test box. The test brings about terms of the balance bearing limit versus the sand tallness have been appeared in Figure 4. These outcomes demonstrated that for sand thickness more prominent than 4B the balance bearing limit identified about to a steady worth (B;

ISSN: 2229-5558
Volume 01, Issue 01, August,2019

width of model balance). In this manner the sand fill of 4B tallness was set inside the test box to exclude any impact of the case inflexible base on the balance bearing limit.

To complete each stacking test, every inner face of the test box dividers was appropriately greased up. The




container was then set inside the stacking casing of the triaxial mechanical assembly and loaded up with sand. The sand situation was made by sand sprinkling system to achieve the required tallness of 4B and its top surface was leveled delicately by a light flimsy ruler. The balance skirt was then set halfway over the width of the crate. The sand sprinkling proceeded at the same time into the skirt and the test box to the level anticipated for balance base. In the wake of leveling the sand surface inside the skirt, the base was painstakingly fixed on the skirt by 8 screws. The model balance was then exposed to driven vertical stacking utilizing an uprooting control contraption at rate of 1 mm/min. The connected burden was recorded by a 30kN demonstrating ring with accuracy of 10N at each 0.5mm settlement.

**Figure 4.** Footing Bearing Capacity versus the Relative Sand Bed Thickness on Rigid Base

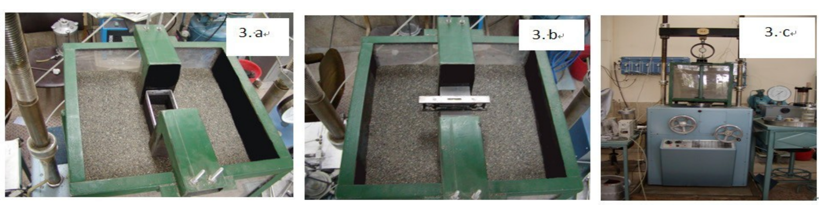



**Figure 5.** Test Preparation Sequences; a) Skirt Placement, b) Matching Base Footing, c) Load Application

Figure 5 indicates different stages balance arrangement into sand bed and stacking test. Repeatability of tests was likewise considered and despite the fact that the distinction in the outcomes were generally under 5%, the mean estimations of three replications of each test were utilized to accomplish increasingly precise outcomes.

## 3. Research Results

### 3.1. The Effect of Skirt Thickness

To explore the impact of basic skirt's thickness on the bearing limit of the avoided footings, three kinds of skirts with 1, 3- and 5-mm thickness were chosen. The installation profundity of the avoided balance for these testing cases was chosen as 1B which relates to a profundity proportion of D/B=1. The evaded balance was then exposed to dislodging control stacking and the connected burdens were recorded from a dial check at 0.5mm settlement increases. Figure 6 demonstrates the pressure settlement relationship for the avoided footings with different thicknesses of basic skirts. As it is obvious from Figure 6, stress-settlement bends of the footings with 3 and 5mm skirt thickness were coordinated well with one another, and show almost a similar extreme bearing limit and incline pattern, while the heap bearing bend of balance with 1mm skirt thickness was unique. The pressure settlement bend for 1mm skirt thickness balance pursues at first a similar way of different bends yet demonstrates much lower slant changes than different bends at high settlements. Moreover, not at all like the two different bends, the slant change happens easily so no particular intermittence point might be resolved for this situation. Actually, the pressure settlement bend of 1mm skirt thickness balance goes easily through the break purpose of the bends of 3 and 5mm skirt thickness footings, and shows more prominent bearing weight at high settlement esteems. This may credit to the horizontal development of the 1mm thick skirt at high feelings of anxiety. This parallel extension is related with an expansion of establishment width at base degree of skirt and along these lines bearing weight demonstrates a directly expanding pattern.

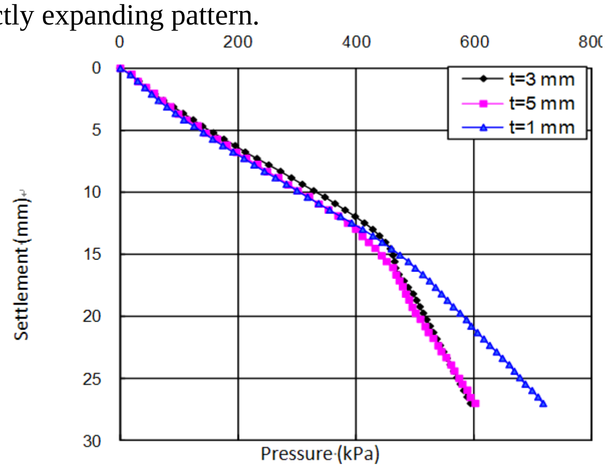
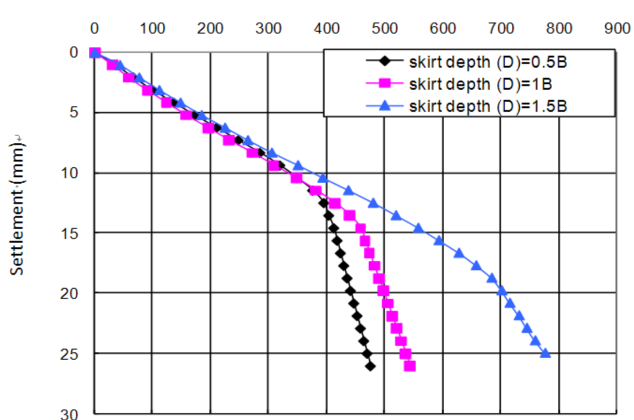



**Figure 6.** Pressure-Settlement of Skirted Footing for Various Skirt Thicknesses

### 3.2. Effects of Embedment Depth

In this area the impact of insertion profundity of skirt on the bearing limit of model footings was examined. A few stacking tests were done for various skirt dept proportions (D/B) of 0.5, 1 and 1.5. The test methods were equivalent to depicted in past area. It ought to be referenced that, in all cases, for averting the unbending base impacts on the tests results, the test box was loaded up with sand to the tallness of 4B (280mm) and the skirt was then put on the leveled surface of sand.

**Table 1.** Bearing capacity and settlement of strip skirted foundations with different height of skirts



ISSN: 2229-5558
Volume 01, Issue 01, August,2019

| Skirt height | $q_{ult}\ (kPa)$ | Failure Settlement (mm) |
|---|---|---|
| 0.5 B | 388 | 12 |
| 1 B | 463 | 15 |
| 1.5 B | 685 | 18.5 |

**Figure 7.** Pressure-Settlement of Skirted Footing for Different Depth of Skirts

The pressure settlement information acquired from these tests are exhibited in Figure 7. The majority of the weight settlement bends show almost a similar introductory incline yet include diverse disappointment point from which the balance settlement increments straightly at a generally high slant with weight increment. The weight disappointment point (the weight relating to brokenness point at weight settlement bend) was resolved as the balance extreme bearing limit. A definitive bearing limit esteems and comparing settlements have been displayed in table 1 for the model footings. Figure 8 demonstrates the varieties of the balance extreme exposing limit versus the skirt profundity proportion. As it is observed, this connection is non-direct for example with more pronounced expanding impacts on bearing limit at higher profundity proportions. Truth be told, the rate of increment in the bearing limit because of expanding profundity proportion from 1 to 1.5 is a lot higher than that brought about by expanding the profundity proportion from 0.5 to 1.

### 3.3. Comparison with Conventional Methods

Bowles (1996) presented four arrangements of extreme bearing limit conditions as the most well-known strategies for establishment plan estimations. These strategies are incorporated of Terzaghi (1943), Meyerhof (1963), Hansen (1970), and Vesic (1973) techniques. These strategies depend on utmost harmony hypothesis with certain distinctions in their suppositions in regards to slip surfaces and stacking conditions.

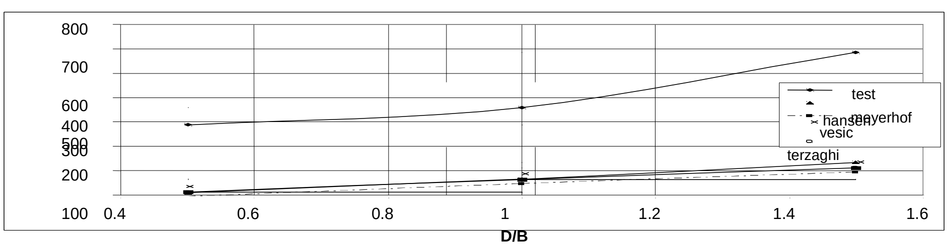


**Figure 8.** Variation of Bearing Capacity versus Skirt Depth Ratio

| | D/B=0.5 | D/B=1 | D/B=1.5 |
|---|---|---|---|
| Terzaghi | 3.46 | 2.85 | 3.22 |
| Meyerhof | 3.59 | 2.78 | 2.93 |
| Hansen | 4.18 | 3.19 | 3.55 |
| Vesic | 3.48 | 2.83 | 3.24 |
| Average | 3.68 | 2.91 | 3.24 |

**Table 2.** Improvement ratio of bearing capacity using the structural skirt

Here, a definitive bearing limit of shallow establishments with a similar implant profundity as the skirt stature was determined utilizing the ordinary strategies. An improvement proportion was then decided as the proportion of the tentatively decided extreme bearing limit of the avoided model footings to the determined estimation of extreme bearing limit of establishments with a similar insertion profundity. The estimations of the improvement proportion for different installation proportions are introduced in table 2. It is unmistakably seen that utilizing of skirt in the model footings was more successful than inserting the establishments in a similar profundity of skirts tallness. The improvement proportion of bearing limit was averagely extended from 2.91 to 3.68 contingent upon the installation profundity. Contrasting and recently revealed improvement proportions of 1.5 to 3.9 (Al-Aghbari and Mohamedzein), the least improvement proportion for the new skirt conditions (full fringe skirt rather than fractional skirt) demonstrated an upgrade of about twofold. The outcomes likewise demonstrated that utilizing avoided balance had the best proficiency at insertion proportion of 0.5. Figure 8 displays the varieties of a definitive bearing limit of the model balance versus the insertion profundity (or skirt stature) from the regular strategies alongside those of the exploratory outcomes. Again, it is intriguing to see from Figure 8 that the skirt profundity has extensive impact on the balance bearing limit in examination with the insertion profundity of customary establishments. Moreover, the test results demonstrated that a definitive bearing limit expanded nonlinearly with the skirt profundity while the bearing qualities from regular conditions had a roughly straight increment with the implant profundity for the thought about profundity proportions.

## 4. Conclusion

The presentation of evaded balance models in sand was researched under vertical stacking. The thought was centered around the impacts of skirt thickness and insertion profundity on the balance bearing limit and the accompanying ends was made dependent on the acquired outcomes:

1. Using fringe auxiliary skirt in blend with traditional balance improves the general establishment execution as far as expanding bearing limit, bringing down exhuming volume, and incorporating the dirt underneath balance.
2. Footing with adaptable skirts indicated more noteworthy bearing limit at high settlement esteems while for unbending skirts (thickness above 3mm) the skirt thickness had no huge consequences for the balance bearing limit.

3. Skirting the model footings was observed to be more viable than installing the establishments in a similar profundity as skirts stature.
4. The extreme bearing limit of the evaded balance was 2.91 to 3.68 occasions more noteworthy than the normal estimation of the determined extreme bearing limit of establishments with a similar profundity as skirt profundity. For the new skirt conditions (full fringe skirt lieu of incomplete skirt), the least improvement proportion demonstrated an upgrade of almost twofold (from 1.5 to 2.91).

## 5. References

[1] Das, B.M., 2007, Theoretical Foundation Engineering, Originally published: Amsterdam, Elsevier Science c1987.

[2] Bransby, M.F., and Randolph, M.F., 1998, Combined loading of skirted foundations, Geotechnique, Vol. 48, No. 5, P.P. 637-655.

[3] Bransby, M.F., and Randolph, M.F., 1998, The effect of skirted foundation shape on response to combined V-M-H loadings, Proceeding of the International Offshore and Polar Engineering Conference, Vol. 1, P.P. 543-548.

[4] Hu, Y, Randolph, M.F., and P.G., Watson, 1999, Bearing response of skirted foundation on nonhomogeneous soil, Journal of Geotechnical and Geoenvironmental Engineering, Vol. 125, No. 11, P.P. 924-935.

[5] Bransby, M.F., Martin, C.M. 1999, Elasto-plastic modeling of bucket foundations, NUMOG VII International Symposium on Numerical Models in Geomechanics, Netherlands, A.A.Balkema, P.P. 425-430.

[6] Gourvenec, S, 2002, Combined loading of skirted foundations, Proc. ANZ YGPC Rotorua, New Zealand, Ed Davies, P.P. 105-110.

[7] Acosta Martinez, H.E., Gourvenec, S.M., Randolph, M.F., 2008, An experimental investigation of a shallow skirted foundation under compression and tension, Soil and Foundations, Vol. 48, P.P. 247-254.

[8] Gourvenec, S., Randolph, M.F., 2010, Consolidation beneath circular skirted foundations, International Journal of Geomechanics, Vol. 10, art. No 003001QGM, P.P. 22-29.

[9] Al-Aghbari, M.Y., Mohamedzein, Y.E.-A., 2004, Bearing capacity of strip foundations with structural skirts, Geotechnical and Geological Engineering, Vol. 22, No. 1,

P.P. 43-57.

[10] Nighojkar, S., Naik, B., Pendharkar, U., Mahiyar, H., 2010, Performance Study of Bi-Angle Shape Skirted Footing in Yellow Soil Subjected to Two-way Eccentric Load, Proc. of Int. Conf. on Advances in Civil Engineering, P.P.101-106

[11] Al-Aghbari, M.Y., 2007, Settlement of Shallow Circular Foundations with Structural Skirts Resting on Sand, The Journal of Engineering Research Vol. 4, No.1 , P.P. 11-16

[12] Al-Aghbari, M.Y. and Mohamedzein, Y.E. (2006) “Improving the Performance of Circular Foundations Using Structural Skirts”, Journal of Ground Improvement, Vol. 10, No.3, pp. 125-132.

[13] Salençon, Jean, 2002, “The influence of confinement on the bearing capacity of strip footings”, C.R.Mecanique 330, P.P. 319-326.

[14] Bowles, J.E., 1996, Foundation analysis and design, 5th ed., McGraw-Hill Publishing.

[15] Yung, S.F., Tesang, J.C., Holtz, R., Wai, F.L., 2004, Reduction of boundary friction in model tests, Geotechnical Testing Journal, Vol. 27, No. 1, P.P. 312.

[16] Cresswell, A., Barton, M.E., Brown, R., 1999, Determining the maximum density of sands by pluviation, Geotechnical Testing Journal, Vol. 22, No. 4, P.P. 324-328.

[17] Terzaghi, K., (1943) "Theoretical Soil Mechanics", John Wiley & Sons, New York, 510pp. (as cited by Bowles, 1996).

[18] Meyerhof, G. G. (1963), “Some Recent Research on the Bearing Capacity of Foundations” CGJ, vol. 1, no. 1, Sept, pp. 16-26. (as cited by Bowles, 1996).

[19] Hansen, J. B. (1970), “A Revised and Extended Formula for Bearing Capacity” Danish Geotechnical Institute, Copenhagen, Bul. No. 28, 21 pp. (successor to Bul. No. 11), (as cited by Bowles, 1996).

[20] Vesic, A. S. (1973), “Analysis of Ultimate Loads of Shallow Foundations” JSMFD, ASCE, vol. 99, SM 1, Jan, pp. 45-73. (as cited by Bowles, 1996