Evaluating the Optimal Performance of skirted footing: A review study

Ali Saad Fezea[1*] and *Maki* Jafar Mohammed[2]

[1]Department of Civil Engineering, University of Baghdad, Iraq , Baghdad
[2]Department of Civil Engineering, University of Al-Furat al-Awsat, Iraq, Baghdad

ABSTRACT. Geotechnical engineers are currently confronted with the challenge of identifying innovative and efficient approaches to increase bearing capacity and minimize foundation settling. As a result, the skirt is regarded as one technique for enhancing the shallow foundation's carrying capability on various soil types. The skirt work mechanism involves the confining of soil beneath the foundation, resulting in a reduction of settling for the foundation. Soil engineers have endeavored to develop this approach as a substitute for pile foundations in normal structures. These foundations exhibit versatility in their applicability, as they may be useful in diverse settings, including marine environments, coastal areas, and arid terrains. This study provides a comprehensive evaluation of various research conducted on skirted foundations in different soil conditions. The objective is to assess the increase of bearing capacity and decrease in a settlement achieved via the utilization of skirted foundations. This assessment is based on laboratory testing, field tests, centrifuge models, numerical methods, and theoretical analysis; These investigations are employed to examine the behaviors skirted footing.

1 INTRODUCTION

Shallow foundations for offshore construction contain skirts to meet the requirements for bearing capacity and to provide the additional vertical resistance required by offshore environmental loading. The use of a skirt enhances the load-bearing capacity by redistributing the weight to subsurface layers of soil that are often more stable and compact compared to a conventional surface foundation. In offshore hydrocarbon development projects, the skirted foundation has been an anchor or support for huge fixed substructures. In recent years, bridge substructures placed in water have used skirt suction foundations. Even though there are a variety of theories that can reasonably forecast the bearing capacity of shallow footings, it appears that there is a converging prediction of bearing capacity. In contrast, semi-empirical formulas are best for estimating the bearing capacity of skirted foundations. Researchers have estimated the skirted footings' bearing capacity and the factors that affect it by using numerical analysis, theoretical formulation, model tests, and prototype field tests.

1.1 Bearing Capacity Theory and Skirted Foundation

The term "bearing capacity" refers to the soil's ability to withstand loads placed on it. It is also referred to as the maximum average contact pressure that should exist between the soil and the foundation without causing shear failure in the soil. Vertical loads on shallow foundations are developed using Terzaghi's (1943) classic bearing capacity theory. He was the first to put up a hypothesis for determining the maximum bearing capacity of shallow foundations. Terzaghi (1943) expanded on Prandtl's (1921) work to propose the solution. According to Terzaghi's hypothesis, a foundation is shallow if its breadth, B, and depth, Df, are both equal to or less than one another. Vertical loads on shallow foundations are developed using Terzaghi's (1943) classic bearing capacity theory.

* Corresponding author: ali.fezea.tcm.28@student.atu.edu.iq

He was the first to put up a hypothesis for determining the maximum bearing capacity of shallow foundations. Terzaghi (1943) expanded on Prandtl's (1921) work to propose the solution. According to Terzaghi's hypothesis, a foundation may be classified as shallow when it's depth, denoted as Df , is either less than or equal to its breadth, represented as B. Terzaghi employed the general shear failure as the failure mechanism in order to ascertain the maximum bearing capacity. He further believed that a uniform surcharge (q=γDf) might replace the soil weight above the foundation base. Terzaghi stated the strip foundation's maximum bearing capacity as follows:

qult=CN+qNq+1/2γBNγ (1.1)

Where:
c = soil cohesion
q = uniform surcharge equals to γDf
γ = the soil unit weight
Df = foundation depth
B = foundation width
Nc, Nq, and Nγ: Terzaghi's ,(1943) bearing capacity factors are only presented as a function of internal friction angle (∅).In engineering, this equation has been applied frequently. By including shape considerations, it has also been adjusted for different foundation shapes, including rectangular, square, and round. Following Terzaghi's studies, several scientists examined the soil-bearing capacity and presented their finding

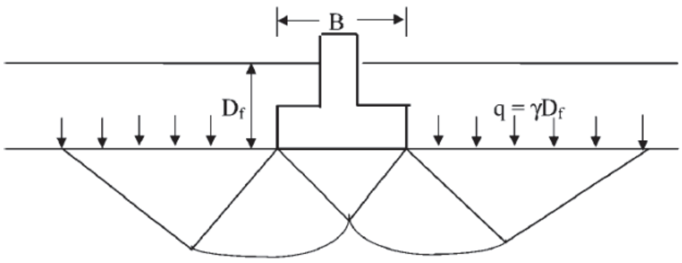

Fig. 1.1. the failure mechanism of soil's bearing capacity beneath a rough, rigid continuous foundation when exposed to a vertical central load, proposed by Terzaghi (1943)

including Vesic in 1973, Hansen in 1970, Meyerhof in 1951 and 1963, Lundgren and Mortensen in 1953, and Balla in 1962.
Meyerhof (1963) provided the following general bearing capacity equation that takes into account the load inclination, the foundation form, and soil shearing resistance over the failure surface in thesoil above the foundation bottom:

$$q_{ult} = c\,N_c\,S_c\,d_c\,i_c + qN_q\,S_q\,d_q\,i_q + \frac{1}{2}\gamma N_\gamma\,S_\gamma\,d_\gamma\,i_\gamma \qquad (1.2)$$

Where: Sc, Sq, Sγ = Factor Shapes
ic, iq, iγ = factors affecting load inclination
dc, dq, dγ = depth-related fact
To account for foundations on slopes and base tilt, Hansen (1970) expanded on Meyerhof's findings by adding two more components to Eq. (1.2).

$$q_{ult} = cN_c\,S_c\,d_c\,i_c\,b_c\,g_c + qN_q\,S_q\,d_q\,i_q\,b_q\,g_q + \frac{1}{2}\gamma N_\gamma\,S_\gamma\,d_\gamma\,i_\gamma\,b_\gamma\,g_\gamma \qquad (1.3)$$

Where: bc, bq, bγ = factor bases
gc, gq, gγ = ground-level factors
The researchers' equations had a uniform fundamental structure akin to Terzaghi's, although they used distinct methodologies to assess the various components of bearing capacity. Martin (2005), Bolton (1993), and Lau (1993)

 https://doi.org/10.1051/bioconf/20249700114

used the characteristic's method to determine the precise value of the bearing capacity factors for circular and strip foundations with smooth and rough surfaces. Since bearing capacity factors estimated using the characteristics methods already took into account the influence of depth and shape factors, the shape and depth factors were not identified.

In their study, Al-Aghbari and Dutta (2008) assumed that the soil located above the lower edges of the structural skirt should be considered a surcharge. This assumption was made to change the overall bearing capacity calculation, taking into consideration the influence of utilizing skirts on the failure mechanism, as depicted in Figure 1.2.

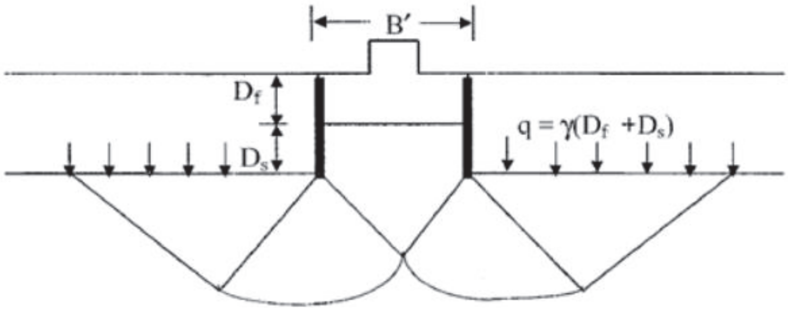

Fig. 1.2. The failure mechanism of soil beneath a continuous foundation with a structural skirt under vertical loading.

The second proposed adjustment is the inclusion of the skirt factor (FS) in the second term of the general equation to consider the properties of the skirt and soil.

$$\mathbf{q_{ult} = \gamma(D_{fs} + D_s)N_q + 0.4\gamma B'N_\gamma F_{s\gamma}} \quad \textbf{(1.4)}$$

Where **Fγ**= Factor for the skirt
Df = foundation base's depth below the surface of the ground
Ds= Depth of the skirt's lower edge below the base of the foundation
B' = Total foundation width with skirts equals B + 2ts
ts= Skirt thickness
They suggested the following phrase for the skirt factor based on the outcomes of their laboratory model:

$$F_\gamma = 1.15\left[0.4 + 0.6\left(\frac{\tan \emptyset'}{\tan \delta f}\right)\right].\left[0.57 + 0.1\left(\frac{Ds}{B'}\right) + 0.37\left(\frac{\tan \delta s}{\tan \delta f}\right)\right].$$
$$(1.2 - 0.002Dr)$$

Where Ø′= The effective internal friction angle
δf = The friction angle at the base of the foundation
δs= Angle of friction at the skirt's sides
Dr = density relative
Ds=Depth of the skirt's lower edge below the base of the foundation

2- Historical Studies on the Foundation for the Skirt

The table below provides an overview of earlier research on skirted foundation behavior. Finding the contributions made by researchers to the skirted foundation reaction is the goal of the previous investigations.

Table 1: Historical Researches on Skirt Foundation

Refrence	Description of work	Results

(Yun & Bransby, 2003)	Performed a sequence of centrifuge model experiments to analyze the behavior of skirted foundations on drained loose sand under various combined loads, such as horizontal, vertical, and moment stresses. It indicates that adding vertical slabs or “skirts” beneath the foundation raft is one technique to strengthen a weak foundation.	The foundation's horizontal bearing capacity was improved to a level that was roughly three to four times higher than that of the raft footing. The findings also showed that the failure mechanism has been modified from a sliding mode to a rotating mechanic.
(Al-Aghbari & Mohamedzein, n.d.-b,2004)	conducted studies on foot models to analyze the behavior of tape-skirted, sand-based feet.	The results showed that increasing the depth of the skirt leads to an improvement in performance. Increasing the thickness of the skirt enhances the foundation's bearing capability. Empirical research has shown that the use of structural skirts may increase carrying capacity by up to 3.12 times.
(El Sawwaf & Nazer, 2005)	conducted field model experiments to examine the influence of soil confinement on the behavior of a model foundation situated on sandy soil. It examined the impact of cell diameter, the depth of the foundation embedded within the cell, the height of the cell, and the depth to the top of the cell.	Employing skirt With a h/D ratio of 2, sand confinement improved bearing capacity from 56.59 kPa without confinement to 562.5 kPa with confinement.
(Al-Aghbari & Mohamedzein, n.d.-a,2006)	carried out experimental work to investigate the behavior of circular foundation with a skirt sitting on the sand.	The inclusion of a structural skirt in a surface footing results in a notable reduction in settlement, with a decrease of around 11% compared to a footing lacking such a skirt
(M.Y. Al-Aghbari 2007)	conducted an investigation of the architectural structures characterized by circular footings, examining both instances with and without the presence of structural skirts.	The findings showed that at a given skirt depth, the SRF decreased as the stress increased The use of skirts may lead to a settlement reduction improvement ranging from 0.1 to 1.0 percent, based on the thickness of the skirt and the amount of load that is applied
(Villalobos 2007.)	presented experimental findings of foundations with scale skirts constructed in dense and loose sand exposed to loaded vertically in a regular method. In research, different skirt lengths, mineral composition, and sand density were taken into account.	it discovered that the bearing capacity increased with skirt length.
((Saleh, et al., 2008)	Examined the effects of eccentric inclined loads on the behavior of one-sided skirted strip foundations. To determine the effects of modifications to load eccentricity, load inclination angle, skirt length, and skirt inclination angle, an experimental analysis was carried out as part of the inquiry. Version 7.1 of the	The findings suggest that the improvement in a skirted footing's ultimate bearing capacity relative to a footing without a skirt may be best measured using a non-dimensional statistic called the ultimate bearing capacity ratio (BCRu). the amount that using skirts for different load

	finite element program PLAXIS was used to perform the numerical research.	inclination degrees of 10°, 20°, and 30° increases the ultimate bearing capacity ratio.
(Al-Aghbari & Dutta, 2008)	Conducted lab experiments to study the behavior of a square foundation with a structural skirt supported by sand and exposed to vertical load. A series of studies were conducted in a controlled test-tank setting to evaluate the performance of a square footing, both with and without a structural skirt.	The findings demonstrate that the application of this particular form of reinforcement increases the load-bearing capacity, decreases settlement, and alters the load-settlement characteristics of the foundation. The findings also show that as the applied load increases, the settling reduction factor falls for a fixed depth of the skirt.
(Nazir & Azzam, 2010)	Conducted a set of laboratory-model tests to examine the efficacy of sand piles that were partly replaced, with and without confinement, in improving soft-clay layers. This experiment aims to examine the influence of sand piles on improving the bearing capacity and managing settling. The objective of this work is to analyze the variability of the subgrade modulus and its impact on the failure mechanism of shallow circular footings on replacement soil, with and without skirts.	The findings showed an important increase in load-bearing capability when utilizing both partially restored sand piles with and without confinement by skirts. By using this method, the footing resting on a layer of soft clay can have its stress displacement curve dramatically altered, it's settling greatly reduced, and the rebuilt soil block inside the skirts acting as a deep foundation
(Eid, 2013)	evaluated the bearing capacity improvement and settlement decrease of shallow foundations on sand related to the introduction of skirts. The study employed surface- and skirting-square foundations positioned in a layer of sand, each exhibiting different shear-strength characteristics.	The findings obtained from the experimental modeling were evaluated, revealing that the inclusion of skirts leads to enhancements in both the bearing capacity and settlement behavior of surface foundations situated on sand.
(El Wakil, 2013)	conducted laboratory experiments were carried out to investigate the influence of skirts on the bearing capacity of shallow footings. The experiments focused on circular stainless steel foundations with varying diameters Conducted laboratory experiments were carried out to investigate the influence of skirts on the bearing capacity of shallow footings. The experiments focused on circular stainless steel foundations with varying diameters. The purpose of skirts is to increase the load-bearing capability of shallow foundations on sandy soil!	The findings indicated a significant increase in the durability of shallow foundations under applied load with the incorporation of a skirt. Specifically, the load capacity was enhanced by a coefficient of upwards of 6.25, given the precise conditions and elements that were considered during the investigation.

(Golmoghani-Ebrahimi & Rowshanzamir, 2013)	Conducted lab experiments to assess the bearing capability of foundations with skirts. They investigated the impact of skirt stiffness using three different types of skirts with thickness of 1 mm, 3 mm, and 5 mm, in addition to the influence that skirt depth has on the bearing capacity of skirting footing utilizing three distinct depth ratios (D/B = 0.5, 1, and 1.5)	According to the findings, foundations with flexible skirts exhibit greater bearing capacity at high settlement values than those with rigid skirts, which have skirt thickness above 3 mm and do not significantly affect the foundation's bearing capacity.
(Shaligram Pusadkar et al., 2013)	investigated the performance of one-sided and two-sided skirted foundations lying on sand using the finite-element-software PLAXIS 2D.	The findings of the examination indicate that the inclusion of a vertical skirt has a notable impact on increasing the load-bearing capability of the raft foundation. Increasing the depth of skirts in a two-sided skirted foundation with a 10 m raft results in a decrease in settlement and an increase in bearing capacity.
(Y. Fattah et al., 2014)	Conducted an investigation and examination of the behavior of foundations under the restrictions imposed by a wall. The study specifically focused on foundations positioned at diverse distances from the wall and with different depths.	The test results indicate that the presence of a wall significantly affects the bearing capacity values, with the degree of enhancement being contingent upon the ratio of the distance between the wall and the edge of the footing to the width of the footing (referred to as h/B) and the ratio of the depth of the wall to the width of the footing (referred to as d/B). Under the specified parameters of h/B = 0.5 and d/B = 2, the square footing enclosed by walls in loose sand demonstrates a notable enhancement in its bearing capacity, with a maximum increase of 43%.In medium sand, the bearing capacity of a square footing enclosed by walls exhibits a notable enhancement of 56% at its maximum when the ratio of the footing's height to its width (h/B) is 0.5, and the ratio of the footing's depth to its width (d/B) is 2.
(Krishna et al., 2014)	Conducted a series of experimental tests to examine the load-carrying capacity of a square foundation situated on sandy soil. The lateral confinement of the footing is achieved by utilizing mild steel plates that are welded together to create a hollow box structure with varying depths.	The findings indicate that the load-carrying capacity exhibits an upward trend with increasing confinement depth, reaching its peak at a confinement ratio of D/B=2.

(Prasanth & Rajendra Kumar, 2015)	tested a small model of a circle footing in the lab. The diameter (D) was 75 mm and the width was 20 mm, the footing models were fabricated using steel plates. The ratio of skirt length (L) to footing diameter (D), denoted as L/D, is seen at values of 0.0, 0.4, 0.8, 1.2, 1.6, and 2.0. The skirts have been safely perfectly welded to the footings.	Based on the results obtained from the conducted laboratory experiments, the bearing capacity ratio (BCR) is found to be 2.0 and 7.3 for sand with a relative density of 30%, corresponding to length-to-diameter (L/D) ratios of 0.4 and 2.0, respectively. Therefore, it is necessary to improve the skirt length to diameter ratio L/D in order to provide more effective skirted footing performance.
(Momeni et al., 2015)	Investigated the axial bearing capacity of an innovative precast thin-walled spread foundation called an Advanced Building System (IBS) footing.	The utilization of a thin-walled foundation, as an alternative to a simple foundation, This improvement amounted to a 3.6-fold increase.
(Kannan & Seetharaman, 2016)	conducted model experiments to determine the lateral load-carrying capability of circular skirted foundation with varying L/D ratios on loose submerged sand.	The findings proved that as the L/D ratio rises, lateral capacity increases as well. The skirt foundation's lateral capacity at L/D = 2.5 was 94.598, which is 6.6 times greater than at L/D = 1.0.
(Sarma & Chetia, 2016)	)DID an Investigation and Analysis utilizing Finite-element Analysis with the use of Plaxis 2D. The objective of their research was to examine the impact of skirts on the behavior of uniformly loaded surface foundations, situated on sand. The finite-element-soil-model used for analysis has the following geometry: 15BX20B, with raft sizes of B = 10m, 15m, and 20m, and skirt depth (DS) = 0.5B, 1B, 1.5B, 2B, 2.5B, and 3B.	the results clearly showed the increase in bearing capacity and decrease in settlements achieved by the use of skirts.
(Khatri et al., 2017).	Conducted a sequence of load tests on a prototype test tank. The aim was to evaluate the improvements in the pressure-settlement characteristics and load-bearing capability of square and rectangular prototype footings, with and without structural skirts.	The use of a structural skirt demonstrates a substantial enhancement in the load-bearing capability of the footing. The research findings revealed that the load-bearing capability of footing with skirts was much greater than footing without skirts.
(Renaningsih et al., 2017)	Performed a sequence of twelve laboratory experiments, specifically targeting steel circular footings. These experiments involved the manipulation of both the diameter and skirt length of the footing.	Based on the conducted examination and analysis of nine skirted footing models and three non-skirted footing models, the findings indicate that, for circular footing with identical diameters, an increase in skirt length is consistently associated with an increase in maximum load capacity. The results showed that the addition of a 75 mm skirt to a non-skirted circular footing with a diameter of 75 mm resulted in a 224% increase in ultimate bearing capacity. In addition, replacing the 75 mm skirt with a

		100 mm skirt resulted in a significant increase of 321% in the final bearing capacity. The inclusion of a skirt of 150 mm under the footing led to a consistent increase of 421%.
(Listyawan et al., 2018)	Did various tests to see what happened to clay when the skirted footing was used. In their study, Six laboratory experiments were conducted utilizing a reduced-scale model of a circular foundation constructed from steel plates. The diameter (D) of the footings varied between 75 mm, 100 mm, and 150 mm, with a uniform thickness of 20 mm. Additionally, three tests were conducted without skirts to serve as a comparison.	The findings provide that the use of skirts has major effects on reducing the settling of the foundation on Clay. The effect is evident under a comparable load of 1 kN. The length of the skirt impacts the settlement, and the longer the skirt, the less settlement there is. The settling lengths (L) for a 150 mm diameter are as follows: 0.00 mm (1.72 mm), 100 mm (0.90 mm), and 150 mm (0.52 mm).
(**Mahmood et al., 2018)**	Investigated laboratory tests aimed at determining the optimal length-to-diameter ratio for skirted foundations .The aim was to determine the highest load-bearing capacity attainable on gypsum soil with varying levels of relative density.	The study's results show that the inclusion of skirts enhances the load-bearing capability of surface footing on gypsum soil. The relationship between the increase in the base bearing capacity ratio (BCR) and the length-to-diameter ratio of a skirted footing is more pronounced when the footing is immersed in gypsum soil with a greater relative density.
(Haddad & Amini, 2019)	performed laboratory experiments to investigate the behavior of buckets and embedded foundations in sand	The findings of the study indicate that the inner soil within the bucket foundation behaves as a rigid body when subjected to vertical loads. Additionally, the presence of skirts around the bucket foundation restricts soil movement, leading to a reduction in settlement.
(Abd-alhasan et al., 2020)	Performed laboratory studies to investigate the behavior of skirted foundations positioned on dry medium sandy soil under vertical and inclined load conditions	The findings indicated that the Augmentation of skirt length resulted in an enhancement of load settlement characteristics. The rate of improvement demonstrates an increase, as the load's angle of incline with the horizontal increases.
(Mohammed et al., 2021)	Conducted laboratory tests to investigate the bearing capability of skirted foundations. The studied involved the use of models that were experimentally placed on a bed of sand.	Based on the findings, Researchers revealed that by increasing the length-to-breadth (L/B) ratio of the skirt, the foundation's depth also increases. This results in a greater extent of failure within the soil and an increase in soil resistance. As a result, there is a noticeable improvement in the maximum load-bearing capacity and a decrease in settlement for all types of soil.

(Magdy et al., 2022)	Conducted laboratory tests to investigate the impact of skirts on the load-settlement behavior of shallow footing. The researchers conducted a comparative examination of the behavioral characteristics shown by rectangle and circle foundations. Fourteen small-scale physical models were constructed to examine the effects of skirt depth, skirt cell form, and footing shape. The models were produced on circular and square footings, with different skirt depths. . The skirts had depth ratios of 0.25, 0.50, 0.75, 1.00, 1.25, and 1.50, using PLAXIS 3D-Software.	Based on the findings, it is possible to draw the following conclusions: The implementation of skirts beneath the footing resulted in enhanced load-settlement curves behavior due to the observed improvement in bearing capacity. The BCIR readings showed this to be true. The sand, which possesses a relative density of 35%, exhibited BCIR values of 2.09 and 5.67 for Ds/B ratios of 0.25 and 1.50, in the case of square footings. while BCIR values obtained for the circular footing were 2.55 and 8.97, corresponding to Ds/D ratios of 0.25 and 1.50, the Bearing Capacity Increase Ratio (BCIR) may be defined as the ratio between the ultimate load of a skirted footing and the ultimate load of a surface footing
(Gnananandarao et al., 2023)	Investigated the performance of a multi-edge T-shaped footing, both with and without a skirt, when put on strongly graded sand and subjected to compressive loading. The analysis was carried out using a laboratory model study. Forty model tests were conducted with and without a skirt to investigate the increase in bearing capacity and reduction in settling of a T-shaped footing.	The results indicate that the inclusion of a skirt on the multi-edge T-shaped footing led to a notable enhancement in the bearing capacity ratio under conditions of partial roughness and complete roughness. Specifically, The skirted footing showed a bearing capacity that was about 1.26 to 3.86 times higher than the footing without a skirt.
(Abd-Alhameed & Al-Busoda, 2023)	conducted laboratory experiments to investigate the impact of the use of a square foundation skirt on the load-settlement characteristics of gypsum soil. The tests involved applying inclined loads to the soil samples while varying the ratio of skirt depth (Ds) to foundation width (B) at four different levels (0, 0.5, 1, and 1.5)	The results show that installing a skirt with a square base improves a foundation's capacity to support loads and reduces settlement when it is built on loose gypsum soil. Moreover, the degree of improvement is directly proportional to the increase in the ratio of skirt depth to foundation width (Ds/B).

3. Impact of Various Parameters on the Performance of Skirted foundations

To evaluate the effects of using a square-shaped skirt with a base width of 100 mm on arid gypsum soil. Tests were done to evaluate the load-bearing capacity of soil samples by adjusting the ratio of skirt depth (DS) to foundation width (B) at four different levels (0, 0.5, 1, and 1.5). The increase in load-bearing capacity was quantified using the Improvement Ratio (IR), a non-dimensional metric, in order to assess the effects of increasing skirt depth. The "improvement ratio" refers to the ratio between the bearing capacity of a foundation with a skirt and a foundation without a skirt, assuming they have the same relative density. The results indicate that using a skirt with a square foundation improves the load-bearing capacity and reduces the settling of the foundation on loose gypsum soil. Figure 3.1 illustrates the effect of increasing the depth of the skirt on the improvement ratio (IR) measured in dry gypsum soil with a composition of 33%.

 https://doi.org/10.1051/bioconf/20249700114

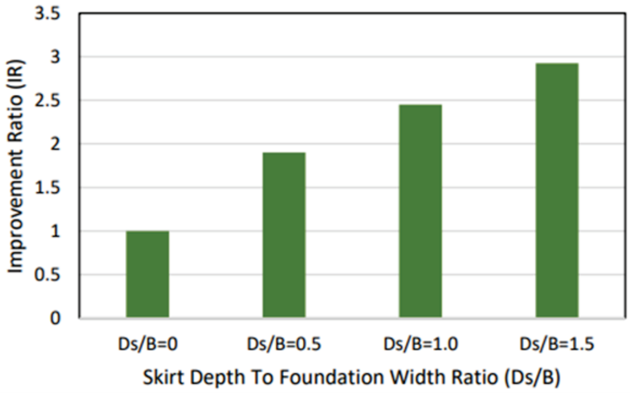

Fig. 1.3. Variation of the improvement ratio (IR) with Ds/B ratios of the 100 mm wide foundation lying on dry gypseous soil. (after Hind and Bushra 2023)

In order to evaluate the influence of relative density on soil behavior, a series of loading tests were performed on three different soil types (with relative densities of 35, 65, and 90). The final results are determined by various factors, like the bearing capacity ratio, the (L/D) ratio, and the relative density, as specified in table (3.1).

Table 2: The bearing capability relationship with different relative densities of soils (El Wakil (2013).

Footing diameter, D (mm)	Sand relative density, D_r (%)	L/D	BCR
1	2	3	4
100	35	0.0	1.00
100	35	0.5	2.25
100	35	1.0	3.75
100	35	1.5	6.25
100	65	0.0	1
100	65	0.50	1.45
100	65	1.0	1.9
100	65	1.5	2.1
100	90	0.0	1
100	90	0.50	1.14
100	90	1.0	1.3
100	90	1.50	1.6
75	35	1.0	—
75	65	1.0	—
75	90	1.0	—
150	35	1.0	—
150	65	1.0	—
150	90	1.0	—

4- CONCLOSIONS

Based on the above researches, we may deduce that:

1- A new mathematical equation has been proposed to estimate the load-bearing capacity of shallow foundations with structural skirts that are supported by sand. The equation is an improved version of the traditional Formula used to calculate the ultimate carrying capacity.

2- The use of a skirted foundation has resulted in an enhancement of the soil's load-bearing capacity under both static and dynamic conditions, as well as a reduction in the settlement. This improvement may be related to the confinement of the soil beneath the foundation, which allows the transmission of loads to deeper zones.

3- The most essential characteristic impacting the overall stability of the flat strip foundation when it comes to a high load inclination angle is sliding resistance. Because of the horizontal soil response that develops on the skirt side, the presence of a skirt increases the footing's resistance to sliding. Increasing the skirt inclination angle results in a reduction in related settling and an increase in ultimate bearing capacity. As the load inclination angle increases, the rate of improvement also increases.

4- Skirts do not greatly impact the response of the footing when the load level is low, provided that the sand has a relative density greater than 65%. However, at high load levels, Skirts have the effect of reducing the movement of the foundation while improving the load-bearing capability of the footing-soil system. . Skirts will prove to be the most advantageous solution when the relative density of the sediment is below 65%. As the ratio of skirt length to footing diameter increases, skirted footings exhibit enhanced performance.
5- The increase in bearing capacity is contingent upon several factors, including the ratio of skirt depth to footing width, the kind and qualities of the soil, the composition of the foundation, and the factors at the contact between the soil and the skirt.
6- 5. Skirted foundations are utilised to address bearing capacity and settling issues in difficult soils (collapsible soils, soft clay soils)(Tripathy, 2013)(Haider & Ali, 2014)

REFERENCES

1. M.Y. Al-Aghbari.(2007). Settlement of Shallow Circular Foundations with Structural Skirts Resting on Sand. The Journal of Engineering Research Vol. 4, No.1 (2007) 11-16
2. Abd-Alhameed, H. J., & Al-Busoda, B. S. (2023). Experimental Study on the Behavior of Square-Skirted Foundation Rested on Gypseous soil Under Inclined Load. Journal of Engineering, 29(3), 27–39. https://doi.org/10.31026/j.eng.2023.03.03
3. Abdulhasan, O., Mustafa, F., & Al-Zuhairi, A. (2020). PERFORMANCE OF SKIRTED CIRCULAR SHALLOW FOOTINGS RESTING ON SANDY SOIL UNDER INCLINED LOADS. Kufa Journal of Engineering, 11(2), 10–27. https://doi.org/10.30572/2018/kje/110202
4. Al-Aghbari, M. Y., & Dutta, R. K. (2008). Performance of square footing with structural skirt resting on sand. Geomechanics and Geoengineering, 3(4), 271–277. https://doi.org/10.1080/17486020802509393
5. Al-Aghbari, M. Y., & Mohamedzein, Y. E. (2006). Improving the performance of circular foundations using structural skirts.
6. Al-Aghbari, M. Y., & Mohamedzein, Y. E. (2004). Model testing of strip footings with structural skirts.
7. Eid, H. T. (2013). Bearing Capacity and Settlement of Skirted Shallow Foundations on Sand. International Journal of Geomechanics, 13(5), 645–652. https://doi.org/10.1061/(asce)gm.1943-5622.0000237
8. El Sawwaf, M., & Nazer, A. (2005). Behavior of Circular Footings Resting on Confined Granular Soil. Journal of Geotechnical and Geoenvironmental Engineering, 131(3), 359–366. https://doi.org/10.1061/(asce)1090-0241(2005)131:3(359)
9. El Wakil, A. Z. (2013). Bearing capacity of Skirt circular footing on sand. Alexandria Engineering Journal, 52(3), 359–364. https://doi.org/10.1016/j.aej.2013.01.007
10. Gnananandarao, T., Onyelowe, K., Khatri, V. N., & Dutta, R. K. (2023). Performance of T-shaped skirted footings resting on sand. International Journal of Mining and Geo-Engineering, 57(1), 65–71. https://doi.org/10.22059/IJMGE.2022.340418.594955
11. Golmoghani-Ebrahimi, S., & Rowshanzamir, M. A. (2013). Experimental Evaluation of Bearing Capacity of Skirted Footings. Civil Engineering and Architecture, 1(4), 103–108. https://doi.org/10.13189/cea.2013.010401
12. Haddad, A. H., & Amini, R. (2019). AUT Journal of Civil Engineering Performance of Bucket Foundation Resting on Sand Subjected To Vertical Load. Civil Eng, 3(2), 139–148. https://doi.org/10.22060/ajce.2018.14812.5498
13. Haider, L., & Ali, A. (2014). PERFORMANCE OF SKIRTED FOUNDATIONS SUPPORTED ON SAND SOIL SUBJECTED TO VERTICAL LOADS .
14. Kannan, M., & Seetharaman, C. (2016). Lateral capacity of skirt foundation on loose submerged sand 1 PUBLICATION 2 CITATIONS SEE PROFILE. In Article in International Journal of Chemical Sciences. https://www.researchgate.net/publication/311067873
15. Khatri, V. N., Debbarma, S. P., Dutta, R. K., & Mohanty, B. (2017). Pressure-settlement behavior of square and rectangular skirted footings resting on sand. Geomechanics and Engineering, 12(4), 689–705. https://doi.org/10.12989/gae.2017.12.4.689
16. Krishna, A., Viswanath, B., & Keshav, N. (2014). PERFORMANCE OF SQUARE FOOTING RESTING ON LATERALLY CONFINED SAND. In IJRET: International Journal of Research in Engineering and Technology. https://www.researchgate.net/publication/330425441
17. Listyawan, A. B., Renaningsih, & Kusumaningtyas, N. (2018). Bearing capacity of circular skirted footing on clay soil. IOP Conference Series: Materials Science and Engineering, 403(1).

https://doi.org/10.1088/1757-899X/403/1/012019
18. Magdy, K., Altahrany, A., & Elmeligy, M. (2022). COMPARATIVE STUDY OF THE BEHAVIORS OF SKIRTED FOUNDATIONS OF DIFFERENT SHAPES. International Journal of GEOMATE, 23(96), 104–111. https://doi.org/10.21660/2022.96.3328
19. Mahmood, M. R., Fattah, M. Y., Khalaf, A., & Fattah, M. Y. (2018). Article ID: IJCIET_09_10_190. International Journal of Civil Engineering and Technology (IJCIET), 9(10), 1910–1922. http://www.iaeme.com/IJCIET/index.asp1910http://www.iaeme.com/ijciet/issues.asp?Type=IJCIET&VType=9&IType=10http://www.iaeme.com/IJCIET/index.asp1911http://www.iaeme.com/IJCIET/issues.asp?JType=IJCIET&VType=9&IType=10
20. Mohammed, M. S., Mahmood, M. R., & Al-Wakel, S. F. A. (2021). Bearing Capacity Behavior of Skirted Foundations on Unsaturated Soils. E3S Web of Conferences, 318. https://doi.org/10.1051/e3sconf/202131801014
21. Momeni, E., Nazir, R., Armaghani, D. J., & Sohaie, H. (2015). Bearing capacity of precast thin-walled foundation in sand. Proceedings of the Institution of Civil Engineers: Geotechnical Engineering, 168(6), 539–550. https://doi.org/10.1680/jgeen.14.00177
22. Nazir, A. K., & Azzam, W. R. (2010). Improving the bearing capacity of footing on soft clay with sand pile with/without skirts. Alexandria Engineering Journal, 49(4), 371–377. https://doi.org/10.1016/j.aej.2010.06.002
23. Prasanth, T., & Rajendra Kumar, P. (2015). A Study on Load Carrying Capacity of Skirted Foundation on Sand. International Journal of Science and Research, 6, 2319–7064. https://doi.org/10.21275/ART20174885
24. Renaningsih, Satria, I. F., Susanto, A., & Listyawan, A. B. (2017). Method to increase ultimate bearing capacity of skirted circular footing. AIP Conference Proceedings, 1855. https://doi.org/10.1063/1.4985458
25. Saleh, N. M. (2008). Performance of Skirted Strip Footing Subjected to Eccentric Inclined Load. https://www.researchgate.net/publication/282325293
26. Sarma, K., & Chetia, N. (2016). Load-Displacement Behaviour of Skirted Raft Foundations on sand using PLAXIS 2D. International Journal of Advanced Engineering Research and Science (IJAERS), 3(4). https://www.researchgate.net/publication/330180486
27. Shaligram Pusadkar, S., Pusadkar, S. S., & Bhatkar, T. (2013). Behaviour of Raft Foundation with Vertical Skirt Using Plaxis 2D. www.ijerd.com
28. Tripathy, S. (2013). Load Carrying Capacity of Skirted Foundation on Sand. M.Sc. Thesis, Civil Engineering Department, National Institute of Technology, Rourkela., December, 14–17.
29. Villalobos, F. (2007). BEARING CAPACITY OF SKIRTED FOUNDATIONS IN SAND.
30. Y. Fattah, M., T. Shlash, K., & A. Mohammed, H. (2014). Experimental Study on the Behavior of Bounded Square Footing on Sandy Soil. Engineering and Technology Journal, 32(5), 1083–1105. https://doi.org/10.30684/etj.32.5a.1
31. Yun, G. J., & Bransby, F. (2003). Centrifuge modeling of the horizontal capacity of skirted foundations on drained loose sand https://www.researchgate.net/publication/255606747
32. Terzaghi, K. (1943): "Theoretical Soil Mechanics", Wiley, New York.
33. Meyerhof, G. G. (1951): "The bearing capacity of foundations", Geotechnique, Vol. 2, No. 4, pp. 301-331.
34. Meyerhof, G. G. (1963): "Some Recent Research on the bearing capacity of foundations", Canadian Geotechnical Journal, Vol. 1, pp. 16-26.
35. Hansen, J. B. (1970): "A revised and extended formula for bearing capacity", Danish Geotechnical Institute, Bulletin No. 28, Copenhagen.
36. Balla, A. (1962): "Bearing capacity of foundations", Journal of the Soil Mechanics and Foundations Division, ASCE, Vol.89, No. SM5, pp. 12-34.
37. Vesic, A. S. (1973): "Analysis of ultimate loads of shallow foundations", Journal of the Soil Mechanics and Foundations Division, ASCE, Vol. 99, No. SM1, pp. 45-73.
38. Bolton, M. D. and Lau, C. K. (1993): "Vertical bearing capacity factors for circular and strip footings on Mohr–Coulomb soil", Canadian Geotechnical Journal, Vol.30, No. 6, pp. 1024-1033.
39. Martin, C. M. (2005): "Exact bearing capacity calculations using the method of characteristics", Proc. IACMAG. Turin, Vol. 4, pp. 441-450.
40. Lundgre, H. and Mortensen, K. (1953): "Determination by the theory of elasticity of the bearing capacity of continuous footing on sand", Proceedings, 3rd International conference on soil mechanics and foundation engineering, Vol. 1, pp. 409-412.