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Effect of Geogrid Layers on the Behavior of Unskirted and 0.4B-Deep Skirted Square Footings over Weak Dry Sand under Central Loading

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ABSTRACT

Due to the limited clarification of the combined effect of geogrid layers and a 0.4B skirt on square footings over weak dry sand, this paper summarizes the bearing capacity of a square shallow footing with dimensions of 10 × 10 cm under central loading, with the footing resting on weak dry sand with a relative density of 30%. The experimental program compared a footing without a skirt and the same footing supported by a skirt with a length of 0.4B, where B represents the footing width. The soil was studied in five cases: unreinforced soil, one geogrid layer, two geogrid layers, three geogrid layers, and four geogrid layers. A skirt length of 0.4B was adopted to evaluate its effect on bearing capacity and settlement. The results showed that the footing supported by a 0.4B skirt without soil reinforcement increased the bearing capacity and reduced the settlement. Adding geogrid layers further improved the footing response; however, the improvement became limited after the third geogrid layer. Therefore, the use of three geogrid layers can be considered the most effective arrangement. The highest bearing capacity ratio (BCR) was obtained when three geogrid layers were used with a 0.4B skirt length, reaching about 3.50 times the reference case, which corresponds to an improvement of approximately 250%. For settlement, the settlement reduction factor (SRF) reached 0.790 for the skirted footing case. Therefore, the combined use of geogrid layers and a 0.4B skirt length provided a noticeable improvement in bearing capacity and settlement behavior compared with the untreated unskirted footing.

Keywords: Geogrid layers, Skirted and unskirted square footings, Weak dry sand, Bearing capacity, Settlement improvement.

1. INTRODUCTION

Shallow foundations resting on weak soil may suffer from low bearing capacity and excessive settlement, which has encouraged many studies to develop effective soil improvement methods **(Bowles, 1997; Latha and Somwanshi, 2009; Han, 2015)**. Injection and grouting are also considered common ground improvement techniques for strengthening weak soils. In these methods, grout is injected into the soil voids to improve particle bonding, reduce permeability, and increase stiffness and load-carrying resistance.

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However, their effectiveness depends on several factors, such as grout type, soil gradation, injection pressure, and field control conditions **(Han, 2015)**. Several methods have been used for soil reinforcement, among them geosynthetic materials because of their ability to improve settlement and bearing capacity **(Al-Mosawe et al., 2010; Ronad, 2014; Ali and Al-Saidi, 2024)**.

Earlier skirted footing studies resting on sand also confirmed that skirts can increase bearing capacity and reduce settlement, and that the level of improvement is governed by the geometry of the footing–skirt–soil system **(Al-Aghbari and Dutta, 2008; Al-Aghbari and Mohamedzein, 2020; Sajjad and Makarchian, 2018)**. It was further shown that square footings supported by geogrid indicate that the arrangement of the reinforcement layers and their configuration play an essential role in the improvement compared with the tensile strength of the geogrid layer itself, where the reinforcement depth and the spacing between the layers are very important **(Latha and Somwanshi, 2009)**.

In the same context, experimental work on weak soil improved by geogrid indicated that the footing response is highly influenced by the depth of the first geogrid layer, the spacing between geogrid layers, and the number of reinforcement layers when an eccentric load is applied **(Al-Mosawe et al., 2010)**. The results of model tests on square footings resting on sand reinforced with three geogrid layers showed an increase in bearing capacity and a reduction in settlement. The tested sand densities were 1.55, 1.65, and 1.75 g/cm^3, and the optimum depth of the upper reinforcement layer was reported as u = 0.33B, which gave the maximum bearing capacity **(Ronad, 2014)**.

International investigations also reported that the nature of the applied load and settlement of skirted foundations depends on footing shape, skirt depth, and sand density, and that deeper skirts generally lead to better performance **(Khatri et al., 2017)**. Similarly, studies on skirted square footings resting on different sands indicated that the efficiency of skirts is related not only to skirt geometry but also to the characteristics of the supporting sand, while the additional benefit of more complex skirt systems may sometimes be limited in comparison with simpler configurations **(Khatri et al., 2017; Thakur and Dutta, 2020)**.

Studies on foundations resting on weak sandy soils and reinforced with geogrid proved that the use of several geogrid layers increases the bearing capacity and that the spacing between those layers has an important role and also significantly affects the Bearing Capacity Ratio **(Akinmusuru and Akinbolade, 1981; Das et al., 1994; Yetimoglu et al., 1994; Adams and Collin, 1997; Shin et al., 2002; Dash et al., 2003; Patra et al., 2006; Ronad, 2014; Khudhair and Albusoda, 2025).**

In addition to soil reinforcement methods, foundations can also be practically provided with skirts, as this is considered a successful method for improving shallow foundations by confining the soil below the foundation and reducing the lateral movement of soil **(Gourvenec and Randolph, 2010; Eid, 2013; Golmoghani-Ebrahimi and Rowshanzamir, 2013; and Mohamedzein, 2019).** Previous studies also showed that skirt geometry, skirt depth, loading condition, and internal compartmentalization have a clear influence on the bearing capacity and settlement response of shallow foundations resting on sand **(Sargazi and Seyedi Hosseininia, 2017; Al-Aghbari et al., 2019; Al Dabi and Albusoda, 2024; Kirtimayee and Samadhiya, 2024; Gholipour et al., 2025)**. It was reported that square skirted foundations with internal compartmentalization provided better bearing capacity and settlement control than non-compartmented skirts, and that increasing both skirt length and divisions led to higher BCR and SRF values under vertical and inclined loading conditions **(Tieh and Ahmed, 2025).**

Although previous studies have investigated geogrid-reinforced soil and skirted footings, most of them considered these improvement methods separately or focused on different footing shapes, loading conditions, and skirt configurations. Therefore, the combined effect of geogrid layers and a short skirt depth of 0.4B on square footings resting on weak dry sand under central vertical loading still requires further clarification. This study aims to investigate the combined effect of geogrid layers and a 0.4B skirt on the behavior of square footings resting on weak dry sand under central vertical loading. The study compares unskirted and skirted footing cases in terms of bearing capacity and settlement performance.

2. EXPERIMENTAL WORK AND TESTING EQUIPMENT

This section describes the experimental program and the testing equipment used to investigate the effect of combining a 0.4B skirt with different numbers of triaxial geogrid layers on the behavior of square footings resting on weak dry sand under central vertical loading. The study evaluates the improvement in bearing capacity and settlement performance by comparing unskirted and skirted footing models, with and without geogrid reinforcement. The experimental setup included a square steel footing, a steel skirt, a sand preparation device to achieve the required relative density, and a loading system consisting of a data logger, an electric jack operated at a constant loading rate, a load cell, and settlement sensors. The testing parameters were selected to represent the main variables controlling the behavior of square footings on weak dry sand. A relative density of Dr = 30% was adopted to represent a weak sand condition. The square footing size of 10 × 10 cm was selected as a laboratory model footing suitable for the available test tank and loading system. The geogrid arrangement was defined by placing the first layer at u/B = 0.5 and using a vertical spacing of h/B = 0.25 between successive layers to keep the reinforcement within the active zone beneath the footing. The number of geogrid layers was varied from zero to four layers to evaluate the improvement trend and the marginal benefit of adding extra reinforcement layers. The skirt depth ratio of 0.4B was selected as a short skirt configuration and was kept constant for all skirted footing tests to allow a direct comparison with the unskirted footing cases.

2.1 Footing and Skirt Model Details

The footing used was square and made of steel with dimensions of 10 × 10 cm and a thickness of 0.7 cm. The footing thickness and the material from which it was made were determined using Bowles' equation to ensure rigid behaviour during the test and to avoid any effect on the results, as shown in **Fig. 1**. The skirt was also made of steel, with a thickness of 3 mm. The skirt design equations were checked to ensure failure was avoided before adopting this thickness. The skirt length was selected as 0.4B, as shown in **Fig. 1(C),** and this length was used for all tests. This length was adopted as a short skirt configuration to evaluate the efficiency of a limited skirt depth when combined with geogrid reinforcement. The skirt depth was kept constant in all skirted footing tests to allow a direct comparison between unskirted and skirted footing cases.

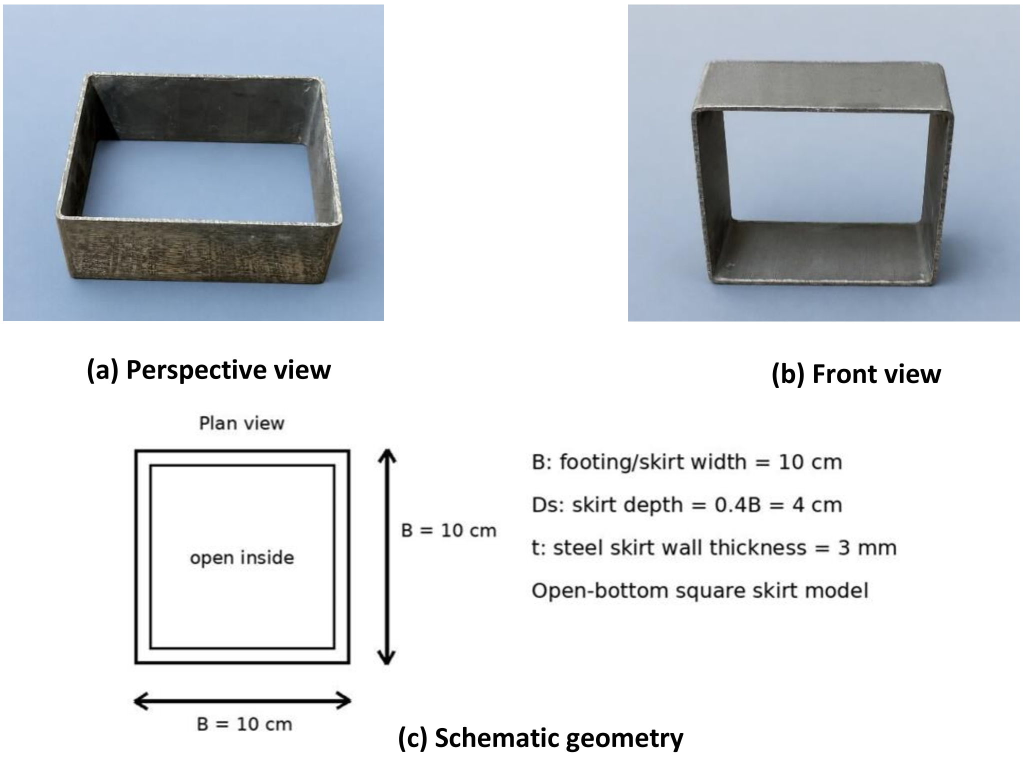


Figure 1. Actual short skirt (0.4B) model and schematic geometry: (a) perspective view, (b) front view, and (c) schematic dimensions.

2.2 The Model Tank and Test Setup

The model tank had dimensions of 60 × 60 × 60 cm and a wall thickness of 3 mm. One side of the model tank was made of glass with a thickness of 10 mm for observing the soil layers during the test and facilitating the arrangement of soil layers during preparation, as shown in **Fig. 2.** The test setup also included a steel loading frame, an electric jack, a load cell, and two LVDTs installed above the model tank to apply and record the central vertical load These dimensions were selected to reduce the effect of boundary interference when the load was applied. Since the footing width was B = 10 cm, the tank width was equal to 6B, and the clear horizontal distance between the footing edge and each side wall was about 2.5B. The sand bed depth was also 6B, which helped reduce the influence of the bottom boundary on the stress and deformation zone below the footing. In addition, the main geometric parameters were expressed in normalized forms, such as u/B, h/B, Ds/B, and S/B, to reduce scale dependency and allow consistent comparison between the tested cases. Since all tests were performed using the same tank size, footing size, sand preparation method, and loading procedure, the results were interpreted mainly in terms of relative improvement indices, such as BCR and SRF.

2.3 Soil Reinforcement by Geogrid

A triaxial polypropylene geogrid was used as soil reinforcement in this study. The geogrid had triangular apertures and a black color, as shown in **Fig. 3**. For clarity, the main physical, mechanical, and geometrical properties of the geogrid are grouped and summarized in **Table 1.**

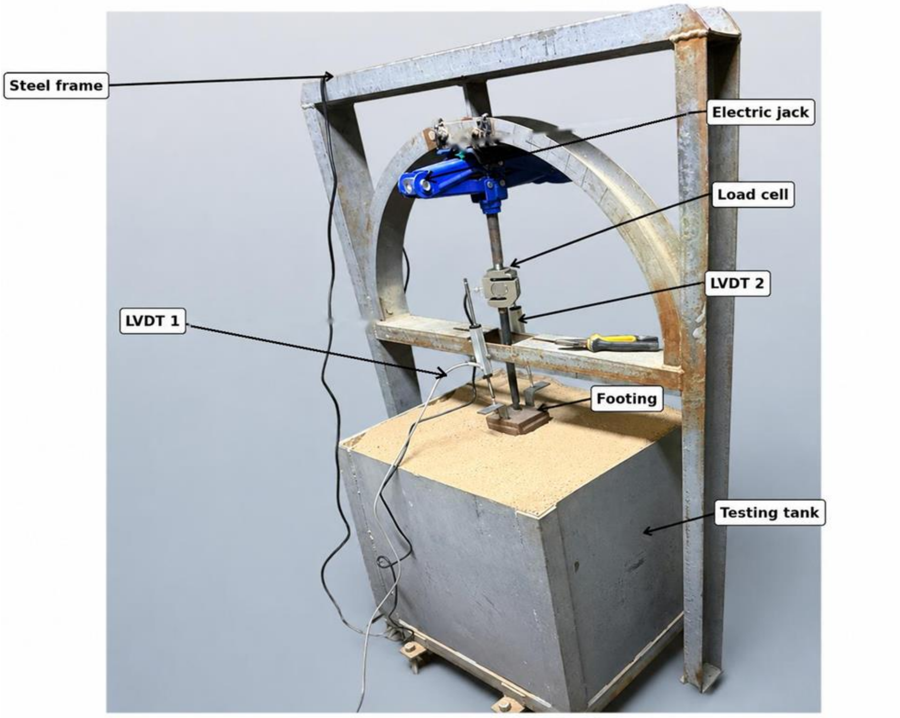


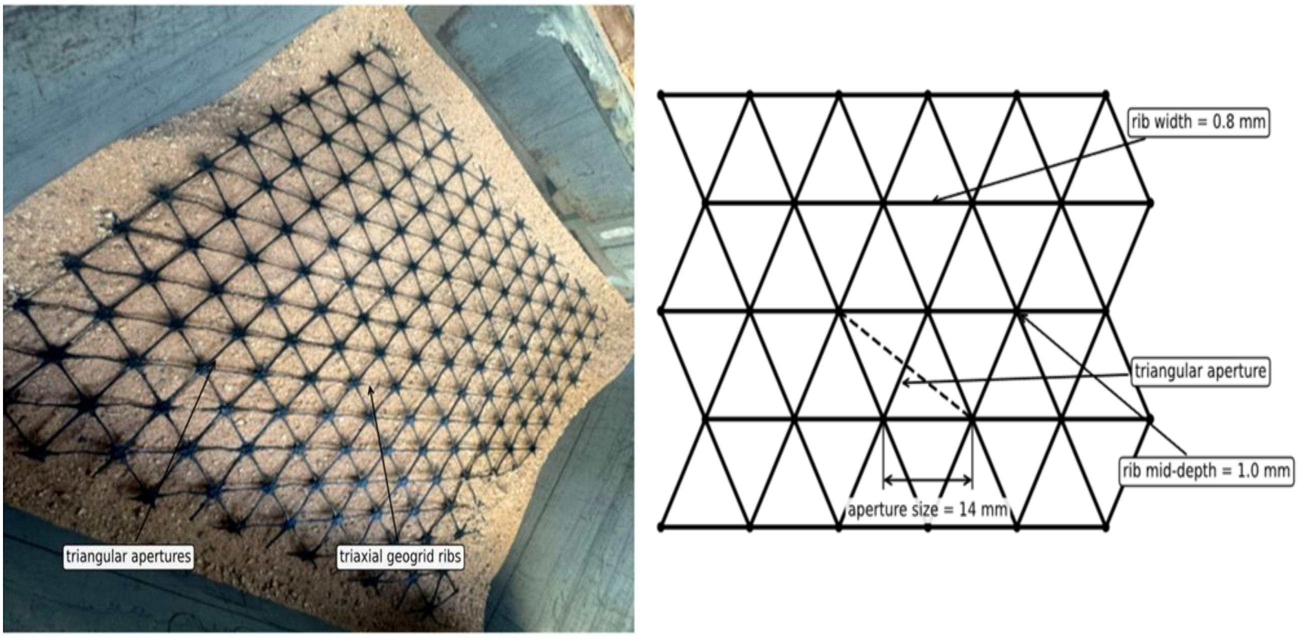
Figure 2. Model tank and central vertical loading setup used in the tests

Table 1. Main properties of the triaxial geogrid used in this study.

Category	Property	Description
General description	Geogrid type	Triaxial geogrid
	Material	Polypropylene
	Color	Black
	Aperture shape	Triangular
Mechanical properties	Ultimate tensile strength	5.5 KN/m
	Failure strain	12%
	Mass per unit area	180 g/m^2
Geometrical properties	Aperture size	14 mm
	Rib mid-depth	1.0 mm
	Rib width	0.8 mm
	Rib shape	Rectangular

2.4 Sand Preparation for the Test

Raining technique was used for the purpose of preparing the sandy soil to the desired relative density of 30%. In this technique, the controlled drop height is relied upon to determine the required density. For the soil used in this study, preliminary calibration tests were conducted using the sand raining device, and a drop height of 12.5 cm was found to produce the required relative density of 30%. The achieved density was checked based on the prepared sand weight and the known volume before conducting the footing tests. The soil was put in the model tank in the form of six layers, and each layer was prepared with dimensions of 10 × 60 × 60 cm. This method allowed the possibility of producing similar soil models for the required testing condition.



(a) Actual triaxial geogrid layer **(b) Schematic details of the triaxial geogrid**

Figure 3. Triaxial geogrid layer used in the experimental work: (a) actual geogrid layer and (b) schematic geometry and dimensions.

2.5 Instrumentation and Loading System

A 2-ton capacity load cell and two LVDTs with a measuring range of 75 mm were used in the testing program. These instruments were connected to a data logger and a computer to record the applied load and settlement readings. The data acquisition interface used to record the load cell and LVDT readings is shown in **Fig. 4.** The applied load was recorded in kilonewtons, while the settlement was recorded in mm. The readings were automatically stored at a sampling rate of 10 readings per second during load application, allowing synchronized recording of load and settlement for all tests.

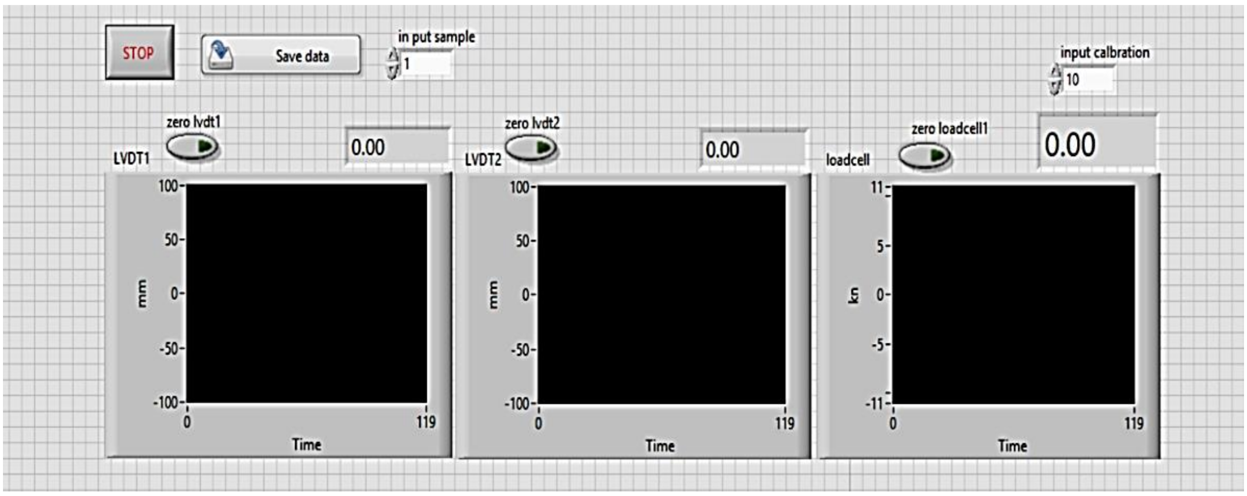


Figure 4. Data acquisition interface for load cell and LVDT readings

An electric jack was used to apply the vertical load at a constant loading rate. During each test, the load was applied gradually, and the footing was left for five minutes after each load increment to allow the settlement readings to stabilize.

2.6 The Soil Used

Dry sandy soil obtained from Karbala Governorate was used in all tests. The soil was washed to reduce clay content, sieved through a 10 mm sieve, and dried to obtain a more homogeneous material. The main index, classification, density, and shear strength properties of the sand are grouped and summarized in **Table 2.** The sand was classified as poorly graded sand (SP) according to ASTM D2487, and the grain size distribution test, as shown in **Fig. 5,** and the required dry unit weight corresponding to a relative density of 30% was 17.19 KN/m^3.

Table 2. Main properties of the sand used in this study.

Category	Property	Method	Description
Source and preparation	Soil source	-	Karbala Governorate
	Soil Condition	-	Washed, sieved, and dried
	Sieve size used for preparation	-	10 mm
Index and classification properties	Specific gravity, GS	ASTM D854	2.65
	Coefficient of uniformity, Cu	ASTM D422	3.51
	Coefficient of curvature, Cc	ASTM D422	0.90
	USCS classification	ASTM D2487	Poorly graded sand, SP
Density properties	Maximum dry unit weight	ASTM D4253	18.11 kN/m^3
	Minimum dry unit weight	ASTM D4254	16.82 kN/m^3
	Required relative density, Dr	-	30%
	Dry unit weight at Dr=30%	Calculated	17.19 kN/m^3
Sherar strength property	Internal friction angle	ASTM D3080	32.9°

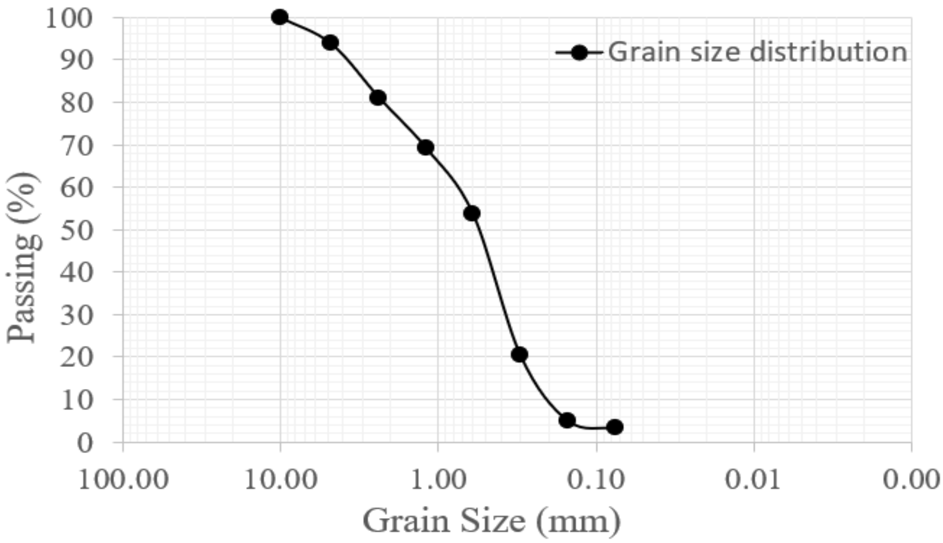


Figure 5. The grain size distribution

2.7 Testing Procedure

In each test carried out for comparison, eight cases were considered: four cases without a skirt and the other four cases with a skirt, which will be discussed later in the results. For each test, the soil was replaced, and the load was applied again. The six layers in the model tank were formed by using the raining technique. In the cases of soil reinforcement, the triaxial geogrid was placed at the required depths. After completing the soil model, the foundation was installed in the middle. In the skirted cases, the skirt was located in the sand layer, and then the footing was fixed on it.

After finishing the setup of the physical model, the testing system was installed. This system included two LVDTs and a load cell. The electric jack was connected to the electrical control system in order to control the rate of load application, and then it was connected to the power supply. The data collection system was linked to a computer for the purpose of automatically recording both settlement and applied load readings. The vertical load was applied at the central point of the footing in all cases, while each loading stage was maintained for 5 minutes until the settlement reading became stable. The failure criterion represented by 10% of the footing width was adopted **(Vesic, 1973)**, after which the loading was stopped when the failure limit was exceeded.

3. LOAD–SETTLEMENT PERFORMANCE

The results of both load–settlement tests showed positive results and improvement in the performance of the square footing when layers of geogrid layers are used and combined with a skirt of economical length. The results were analyzed under the effect of a load applied at the center of the footing, where the comparison was made between two systems: the first is the footing not improved by the skirt, and the other is a footing provided with a skirt, noting that both have a length of 0.4B. For both cases, unreinforced soil and reinforced soil were used.

3.1 Bearing Capacity and Settlement Improvement Indices

The evaluation of the tested foundation system was conducted using two evaluation parameters: BCR value SRF value. The BCR indicates the improvement in bearing capacity after improving the footing using the skirt, geogrid, or both together, while the SRF represents the amount of settlement reduction achieved after improvement at the same applied stress.

These indices were calculated using Eqs. (1) and (2), following the definitions commonly used for bearing capacity ratio and settlement reduction factor in reinforced and skirted footing **(Omer et al., 1993)**

$$BCR = \frac{q_i}{q_o} \quad (1)$$

$$SRF = \frac{S_o - S_i}{S_o} \quad (2)$$

Where q_i and q_o are the bearing resistances of the improved and reference cases, respectively, while S_i and S_o are the settlements of the improved and reference cases on the same footing stress, respectively.

3.2 The Effect of Using a 0.4B Skirt on Bearing Capacity

The isolated effect of the 0.4B skirt was evaluated by comparing an unskirted square footing with a skirted square footing under the same centrally applied load. For the unreinforced soil condition, the failure load intensity increased from 39.44 kPa for the unskirted footing to 75.30 kPa for the skirted square footing, giving a bearing capacity ratio of 1.91. This indicates that the 0.4B skirt increased the bearing capacity by about 90.9% without using soil reinforcement. When the soil was reinforced with geogrid layers, the skirted square footing also showed higher failure stress than the unskirted footing. The improvement ratios were 2.10 and 1.84 for one and two geogrid layers, respectively, while the corresponding values for three and four geogrid layers were 1.63 and 1.57, as illustrated in **Table 3.**

Table 3. Effect of the economical skirt on failure stress under the same reinforcement condition

Number of geogrid layer	Unskirted Failure Stress (kPa)	skirted Failure Stress (kPa)	Skirt Improvement Ratio
0	39.44	75.30	1.91
1	49,38	103,74	2,10
2	63,26	116,40	1,84
3	84,43	138.40	1,63
4	89,32	140.90	1,57

3.3 Effect of the Short Skirt (0.4B) and Geogrid Layers on the Bearing Capacity Ratio

The unreinforced unskirted footing case was adopted as the reference case, where the failure stress was 39.44 kPa at a settlement ratio of S/B = 10%. For the unskirted footing reinforced with one and two geogrid layers, the failure stress increased to 49.38 and 63.26 kPa, respectively, giving BCR values of 1.25 and 1.60. When three geogrid layers were used, the failure stress reached 84.43 kPa, corresponding to a BCR of 2.14. For four geogrid layers, the failure stress reached 89.32 kPa, with a BCR value of 2.26. For the skirted footing with a skirt depth of 0.4B, the case without geogrid was adopted as the reference condition, with a failure stress of 75.30 kPa. When one and two geogrid layers were added, the failure stress increased to 103.74 kPa, giving a BCR of 2.63 and 2.95 respectively. Furthermore, when three geogrid layers, the failure stress increased clearly to 138.40 kPa, and the BCR reached 3.50. The use of four geogrid layers gave only a slight additional increase in failure stress to 140.90 kPa, with a BCR of 3.57.

The results are presented in **Table 4**, and the stress–settlement relationships under central vertical loading are shown in **Figs. 6 and 7**. These results indicate that increasing the number of geogrid layers improved the bearing capacity in both footing systems. However, the difference between the three-layer and four-layer cases was relatively small, especially for the skirted footing. Therefore, the three-layer arrangement can be considered more efficient from both practical viewpoints, since the fourth layer provided only limited additional improvement. This behavior can be attributed to the combined confinement provided by the short skirt (0.4B) and the tensile resistance mobilized in the geogrid layers. The skirt restricted the lateral movement of sand beneath the footing, while the geogrid layers helped distribute the applied stress over a wider zone. However, after the third geogrid layer, the additional reinforcement was located farther from the most active stress zone beneath the footing, which explains the limited improvement obtained from the fourth layer.

Table 4. Failure stress and BCR values for unskirted and 0.4B skirted footings with different geogrid layers under central vertical loading.

Foundation condition	Number of geogrid layers	Failure Stress (kPa)	BCR
Unskirted footing	0	39.44	1.00
	1	49,38	1,25
	2	63,26	1.60
	3	84,43	2.14
	4	89,32	2,26
Skirted footing, Ds = 0.4B	0	75.30	1.91
	1	103,74	2,63
	2	116,40	2,95
	3	138.40	3,50
	4	140.90	3,57

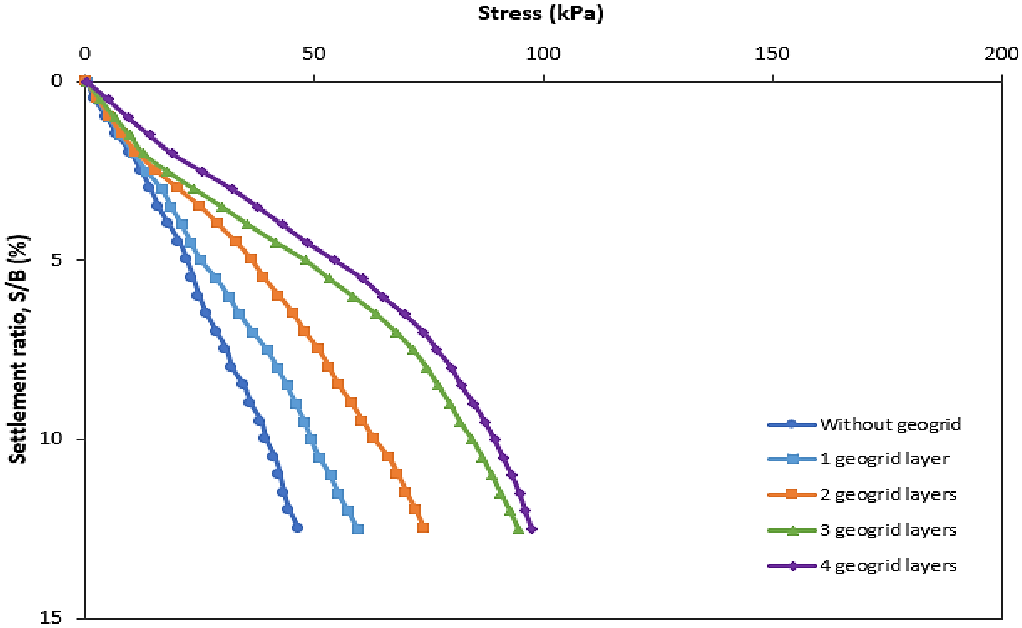


Figure 6. Load–settlement curves for the unskirted square footing with different numbers of geogrid layers at Dr = 30%

3.4 Effect of the Short Skirt (0.4B) and Geogrid Layers on the Settlement Reduction Factor (SRF)

The settlement reduction factor (SRF) values for the unskirted and skirted footing cases are summarized in **Table 5**. For the unskirted footing, the SRF increased from 0.264 to 0.501 when one and two geogrid layers were used, respectively. Further increases were observed when three and four geogrid layers were used, where the SRF reached 0.548 and 0.637, respectively. For the short skirt (0.4B) footing, higher SRF values were obtained compared with the unskirted footing. The SRF values were 0.688 and 0.698 for one and two geogrid layers, respectively, and increased to 0.790 when three geogrid layers were used. However, adding the fourth geogrid layer produced only a marginal increase, with an SRF value of 0.799. These results indicate that the combined use of the short skirt (0.4B) and three geogrid layers provided the most effective settlement reduction, while the fourth layer had a limited additional effect. The improvement in SRF indicates that the reinforced soil–skirt system was more effective in controlling settlement than the unskirted footing condition. This behavior can be attributed to the increase in soil confinement provided by the short skirt (0.4B) and the interlocking between sand particles and geogrid apertures, which reduced vertical deformation under the applied load. The small difference between the third and fourth geogrid layers confirms that three layers were sufficient to mobilize most of the reinforcement benefit within the tested stress range.

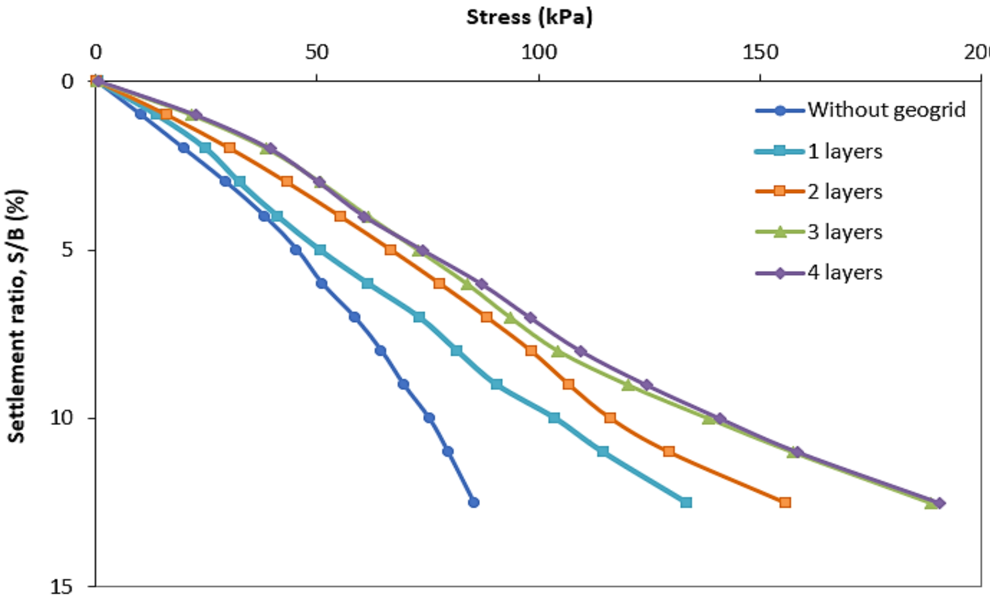


Figure 7. Load–settlement curves for the 0.4B skirted square footing with different numbers of geogrid layers at Dr = 30%

Table 5. Effect of geogrid layers and economical skirt on failure stress and SRF under central vertical loading

Foundation condition	Number of geogrid layers	Failure Stress (kPa)	SRF
Unskirted footing	0	39.44	-
	1	49,38	0.264
	2	63,26	0.501
	3	84,43	0.548
	4	89,32	0,637
Skirted footing, Ds = 0.4B	0	75.30	0,574
	1	103,74	0,688
	2	116,40	0,698
	3	138.40	0,790
	4	140.90	0,799

3.5 Comparison with Previous Studies

The results obtained were compared with previous studies on geogrid-reinforced sand and skirted footings. **(Omar et al., 1993)** reported that the improvement in bearing capacity of geogrid-reinforced sand is strongly affected by the reinforcement layout, including the depth

of the first layer, reinforcement width, and total reinforcement depth. For square foundations, they reported critical values of approximately d/B = 1.33–1.50, b/B = 4, and u/B = 0.8 for mobilizing the maximum reinforcement benefit. In the present study, the geogrid layers were placed at u/B = 0.5 and h/B = 0.25, and the total reinforced depth remained within the active zone beneath the square footing. The unskirted reinforced footing reached a BCR of 2.14 with three geogrid layers, which confirms the significant role of geogrid arrangement in improving bearing capacity
The effect of skirt depth was also consistent with the findings of **(Khatri et al., 2017),** who reported that the improvement in the bearing capacity of skirted footings increased with skirt depth. Their reported improvement ranged from 33.3% to 68.5% for a skirt depth of 0.25B, from 68.9% to 127% for 0.50B, and from 146.7% to 262% for 1.0B. In the present study, the use of a short skirt depth of 0.4B without geogrid increased the failure stress from 39.44 kPa to 75.30 kPa, corresponding to a BCR of 1.91 and an improvement of about 90.9%. This value falls within the improvement range reported for skirt depths between 0.25B and 0.50B, which supports the effectiveness of the adopted short skirt configuration When the short skirt (0.4B) was combined with geogrid layers, the improvement became higher than using either technique alone. The maximum response was obtained with three geogrid layers, where the BCR reached 3.50 and the SRF reached 0.790. This indicates that the combined system improved bearing capacity and settlement performance through two mechanisms: soil confinement provided by the skirt and tensile resistance/interlocking provided by the geogrid layers. The limited increase obtained from the fourth geogrid layer is also consistent with the concept that the reinforcement benefit decreases when additional layers are placed farther from the most active stress zone beneath the footing.

4. CONCLUSIONS

1. The results show that soil reinforcement with triaxial geogrid layers combined with a short skirt (0.4B) played a major role in improving the behavior of square footings resting on weak dry sand. Compared with the untreated unskirted footing used as the reference case, the combined system increased the bearing capacity and reduced the settlement under central vertical loading.
2. The short skirt (0.4B) helped restrain the sand beneath the footing and reduce the lateral movement of soil. This confinement effect improved the footing response compared with the unskirted footing, especially when the skirt was combined with geogrid reinforcement.
3. The experimental results indicated that the most effective improvement in both BCR and SRF was achieved when three geogrid layers were used with the short skirt (0.4B). In this case, the failure stress reached 138.40 kPa, the BCR reached 3.50, and the SRF reached 0.790 compared with the reference case.
4. The effect of the fourth geogrid layer was limited compared with the improvement achieved by three geogrid layers. Therefore, adding a fourth layer did not provide a significant additional benefit in bearing capacity or settlement reduction.
5. Based on the tested cases, the use of a short skirt (0.4B) with three geogrid layers is recommended as the most effective arrangement for improving bearing capacity and settlement performance under central vertical loading.

NOMENCLATURE

Symbol	Description	Symbol	Description
B	Width of footing (cm)	D_S	Skirt depth
C_C	Coefficient of curvature	q_i	The bearing capacities of the improved (kPa)
C_u	Coefficient of uniformity	q_o	The bearing capacities of the and reference cases (kPa)
BCR	Bearing Capacity Ratio	S_o	settlements of the reference cases on the same footing stress (mm)
SRF	Settlement Reduction Factor	S_i	settlements of the improved at the failure stress (mm)

Credit Authorship Contribution Statement

Hayder Ghazi Jassim: Conceptualization, experimental work, data collection, formal analysis, writing-original draft, and manuscript revision. Mahmood D. Ahmed: Supervision, methodology, validation, writing-review and editing, and final manuscript approval. All authors have read and approved the final version of the manuscript.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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تأثير طبقات الجيوكرد على سلوك الأساسات المربعة غير الطوقية والطوقية بعمق 0.4B فوق رمل جاف ضعيف تحت حمل مركزي

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الخلاصة

نظراً لمحدودية توضيح التأثير المشترك لطبقات الجيوكرد والطوق بعمق 0.4B على الأساسات المربعة فوق الرمل الجاف الضعيف، يلخص هذا البحث قابلية تحمل أساس سطحي مربع بأبعاد 10 × 10 سم تحت حمل مركزي، حيث يستند الأساس على رمل جاف ضعيف بكثافة نسبية مقدارها 30%. قارن البرنامج التجريبي بين أساس بدون طوق والأساس نفسه مدعوماً بطوق بطول 0.4B، حيث يمثل B عرض الأساس. تمت دراسة التربة في خمس حالات: تربة غير مسلحة، طبقة واحدة من الجيوكرد، طبقتان من الجيوكرد، ثلاث طبقات من الجيوكرد، وأربع طبقات من الجيوكرد. وُضعت الطبقة الأولى من الجيوكرد على عمق 0.5B أسفل قاعدة الأساس، بينما كانت المسافة بين الطبقات الأخرى 0.25B. تم اعتماد طول طوق مقداره 0.4B لتقييم تأثيره في قابلية التحمل والهبوط. أظهرت النتائج أن الأساس المدعوم بطوق بعمق 0.4B بدون تسليح للتربة أدى إلى زيادة قابلية التحمل وتقليل الهبوط. كما أن إضافة طبقات الجيوكرد حسّنت استجابة الأساس بشكل أكبر؛ إلا أن مقدار التحسن أصبح محدوداً بعد الطبقة الثالثة من الجيوكرد. لذلك، يمكن اعتبار استخدام ثلاث طبقات من الجيوكرد الترتيب الأكثر فاعلية في هذه الدراسة، بينما وفرت الطبقة الرابعة تحسناً إضافياً محدوداً فقط. تم الحصول على أعلى نسبة لقابلية التحمل BCR عند استخدام ثلاث طبقات من الجيوكرد مع طول طوق 0.4B، إذ بلغت حوالي 3.50 مرة مقارنة بالحالة المرجعية، وهو ما يقابل تحسناً يقارب 250%. أما بالنسبة للهبوط، فقد بلغ معامل تقليل الهبوط SRF قيمة 0.790 في حالة الأساس الطوقي. لذلك، فإن الاستخدام المشترك لطبقات الجيوكرد وطول طوق 0.4B وفر تحسناً ملحوظاً في قابلية التحمل وسلوك الهبوط مقارنة بالأساس غير المعالج وغير الطوقي.

الكلمات المفتاحية: طبقات الجيوكرد، الأساسات المربعة الطوقية وغير الطوقية، الرمل الجاف الضعيف، قابلية التحمل، تحسين الهبوط.