Tikrit Journal of Engineering Sciences (2024); 31(3): 1-9
DOI: http://doi.org/10.25130/tjes.31.3.1

IRAQI Academic Scientific Journals

ISSN: 1813-162X (Print); 2312-7589 (Online)
Tikrit Journal of Engineering Sciences
available online at: http://www.tj-es.com

TJES Tikrit Journal of Engineering Sciences

Ring Footing Bearing Capacity Erected on Dry Gypseous Soil

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Keywords:
Capacity of Bearing; Dry Gypseous Soil; High Content of Gypsum; Low Gypsum Content; Ring Footing.

Highlights:
- *Comparing the behavior of ring footing erected on gypseous soil with the circular footing.*
- *Bearing capacity for high-gypsum content soil with the low-gypsum content.*
- *Tests was done using steel box with big dimensions.*

ARTICLE INFO
Article history:

Received	23 June	2023
Received in revised form	29 July	2023
Accepted	17 Sep.	2023
Final Proofreading	25 Feb.	2024
Available online	01 July	2024

Citation: Al-Janabi KAE, Snodi LN, Zedan AJ. **Ring Footing Bearing Capacity Erected on Dry Gypseous Soil**. *Tikrit Journal of Engineering Sciences* 2024; **31**(3): 1-9.
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Abstract: This study investigates the behavior of ring footing erected on gypseous soil and compares it with the circular footing, including conducting (24) experiments of loading ring footings, where the inner and external diameter ratio was ($D_{in.}/D_{out.}$ = 0, 0.2, 0.3 and 0.4), resting on two types of Gypseous soil, for the circular footing the external diameter was (150mm) and thickness (15mm) made from solid steel. The results for study showed the ring footings were best than the circular footings. The ratio ($D_{in.}/D_{out.}$ = 0.4) was beast for all ratios of (D_f/D). Capacity of bearing increased when the ratio (D_f/D) increase. Bearing capacity for high-gypsum content soil showed good results compared to the low-gypsum content soil. The first was high content of gypsum (63.42%) obtained from the Tikrit University, and the second was low content of gypsum (8.15%) from the Baiji area. The tests were doing inside box have dimensions (900×900×700 mm). The experiments were divided into twelve tests for dry gypsum soil condition with high gypsum content using density of (13.76 kN/m^3), and twelve tests for dry soil with low gypsum content using density of (14.87 kN/m^3). Experiments were conducted for different ratios (D_f/D=0, 0.5, and 1).

قابلية تحمل الاساس الحلقي المستند على تربة جبسية جافة

خضر علي عيد، لمياء نجاح سنودي، عدنان جايد زيدان
قسم الهندسة المدنية / كلية الهندسة / جامعة تكريت / تكريت – العراق.

الخلاصة
تناولت هذه الدراسة سلوك القاعدة الحلقية المقامة على التربة الجبسية ومقارنته مع الأساس الدائري، تم إجراء (٢٤) تجربة لأساس حلقي حيث كانت نسبة القطر الداخلي / القطر الخارجي (D_i / D_o) هي (, ٠,٣,٠,٢ , ٠ و٠,٤ (على نوعين من الترب الجبسية، الأساس الدائري يتكون من قطر خارجي (١٥٠ملم) وسمك (١٥ملم) مصنوع من الحديد الصلد، أظهرت النتائج أن الأساس الحلقي أفضل من الاساس الدائري. أفضل نسبة كانت (D_i / D_o = ٠,٤) لجميع النسب (D_f / D). تزداد قابلية التحمل مع زيادة النسبة (D_f / D). قابلية التحمل للترب ذات المحتوى الجبسي العالي اعطت نتائج جيدة مقارنة بمحتوى التربة المنخفض الجبس. الأولى الترب ذات محتوى جبس عالي (٦٣,٤٢٪) تم الحصول عليها من جامعة تكريت والثانية الترب ذات محتوى جبس قليل (٨,١٥٪) من منطقة بيجي. تجرى اجراء التجارب باستخدام موديل بأبعاد (٩٠٠ * ٩٠٠ * ٧٠٠ ملم) قسمت التجارب إلى (١٢) فحص للتربة الجافة ذات المحتوى الجبسي العالي باستخدام الكثافة الحقلية (١٣,٧٦ كيلو نيوتن / م ٣)، و (١٢) فحص للتربة الجافة ذات المحتوى الجبسي المنخفض باستخدام الكثافة الحقلية (١٤,٨٧ كيلو نيوتن / م ٣). أجريت تجارب على نسبة مختلفة من العمق / القطر للاساس (D_f / D) وهي (٠، ٠,٥، و١) أظهرت النتائج أن الأساس الحلقي أفضل من الاساس الدائري. أفضل نسبة كانت (D_i / D_o = ٠,٤) لجميع النسب (D_f / D). تزداد قابلية التحمل مع زيادة النسبة (D_f / D). قابلية التحمل للترب ذات المحتوى الجبسي العالي اعطت نتائج جيدة مقارنة بمحتوى التربة المنخفض الجبس.

الكلمات الدالة: قدرة التحمل، التربة الجبسية الجافة، محتوى الجبس العالي، محتوى الجبس المنخفض، القاعدة الدائرية.

1.INTRODUCTION

Gypseous soils are found in large portions of Iraq, covering about 20-30% of its total area. These soils are mostly found in Baiji, Mosul, Tikrit, Anna, Samarra, Ramadi, Heet, Northwest of Baghdad, and Fallujah. Problems with gypsum soils are that they have a high bearing capacity unless water reaches them. Nonetheless, cavities are created in gypsum soils beneath the soaking states, it may collapse under influence of the origin load and without additional external loads Muhauwiss and Salh [1]. Gypseous soil, includes a specific quantity of gypsum. Gypsum is a soluble salt with a solubility of 2.2-2.6 gm/liter in distilled water. Gypsum in soil poses a challenge when structures build on Gypseous soil since gypsum dissolves when exposed to water, producing gaps between soil particles and causing soil collapse Ahmed and Zedan [2]. Gypsum Soils might lead to problems with many engineering works Petrukhin and Boldyrev [3]. The bearing capacity of this soil is high when it is dry; however, it collapses suddenly if the gypseous soil is saturated with water Al-Saoudi et al. [4]. Results showed that using a square footing improved load-bearing capacity and reduced settlement for footing rested on loose gypsum soil, and value of improvement increased with footing depth to width (D/B). Bearing capacity was improved by about (193) %, and Settlement ratio (S_r) reduced from (1) % for a square footing to (0.14)% when (D/B= 1.5) at θ =0° with the y-axis (Where θ is the inclination angle of the load). The bearing capacity improved by about (162) % for the square footing at (D/B= 1.5) and θ =15° with the y-axis Abd-Alhameed and Al-Busoda [5]. When the inclination loads that subject on ring footing resting on gypseous soil increased from 0° to 15°. The ultimate load and the bearing capacity are reduced. This reduction range was 56%. When the load eccentricity of that subject on ring footing resting on gypseous soil increased from 0 to 0.16, the ultimate load was reduced by 87% because the ring footing affective area reduced Hasan and Al-Busoda [6]. The dry soil's bearing capacity was more than soaking soil under the same conditions. Ring footing represents a significant structural part in different applications, such as fuel or water storage tanks. The advantage of ring footing is related to reducing the weakness of some soils that may affect the safety of structures Nguyen et al. [7]. Boushehrian and Hataf [8] founded the best capacity of bearing for the ring footings (D_i/D_o=0.4) on sandy soil. Snodi [9] studied several ratios for (inner to outer) radius and friction angle using (ELPLA) program, better ratio when (D_{in}/D_{out}= 0.2-0.4). whereas best angle of friction (30°-35°). AL-Sumaiday and AL-Tikrity [10] used samples of sand soil with variable densities. The best result of ratio was (n= 0.4). Hataf and Razavi [11] found that (D_i/D_o), for the sand's largest bearing capacity, was range between (0.2–0.4).

2.EXPERIMENTAL PROGRAM

2.1.Apparatus and Procedures

2.1.1.Box Useing

The box using consisted of a horizontal armrest and a vertical armrest. Load was dropped using arm moved manually. Gauges was read the dropping load and contained column (cylindrical) over footing model. There were two gauges for settlement reading. The test box used for soil testing had dimensions of 900mm×900mm×700mm, as shown in Fig. 1. The test box bottom had a plate made of steel on which the first layer of soil was contacted, which allowed water to pass through during immersion. Gap was found along the box base and water was collected when the soil saturation. Also, a cylindrical valve was attached to a plastic tube with a length of 500mm, used to investigate the water level when studying the durability of footings. The test box was used according to Hussain and Zedan [12], Abbas and AL-Dorry [13], and Zedan and Abbas [14], who used the exact test box in their studies.

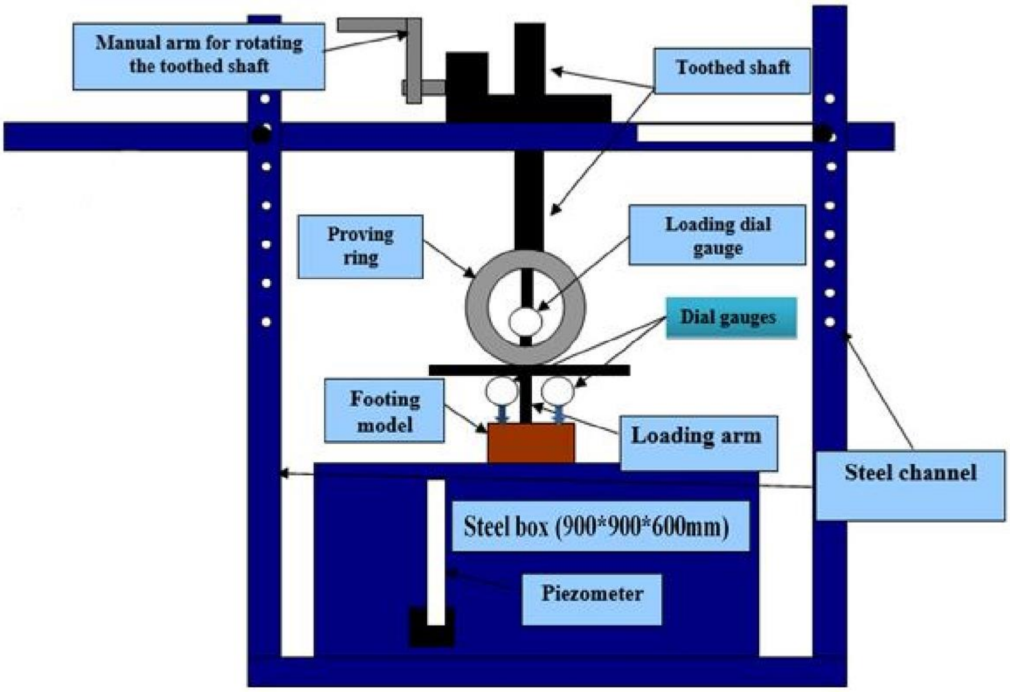

Fig. 1 The Test Box.

2.1.2.The Model of Footing

The footing's diameter and thickness were originally (150) mm and (15) mm, respectively. footing made from steel. The sheets attached to sides and prevent particles of soil from entrance to the footing. Columns that using to sheds loading on footing were made from hard iron have a diameter (14 mm) and sheets having dimensions (80×40×15 mm) to sheds loading through it to columns and after that to footing, as shown in Fig. 2.

Fig. 2 The Model of Footing.

2.1.3.The Soil

The researchers obtained the soil from Tikrit University and Baiji district. Gypsum soil collected at depth (1.0 -2.0 m) underground surface, and upper layers for soil were removed. Measurements were conducted to test the gypsum content (Al-Mufty and Nashat [15]). The chemical and physical properties are tabulated in Table 1 and Table 2, respectively.

Table 1 Chemical Test of Soils.

Sample Symbol	High Gypseous Soil	Low Gypseous Soil
Gypsum content	63.42	8.15
Organic matters (%)	0.03	0.16
Total content of salt (%)	78.09	14
pH value	7.87	7.81

Table 2 Physical Properties of Soils.

Properties		Soil A	Soil B
Moisture content, (ω)%		3.04	3.84
Specific gravity, (Gs)		2.48	2.64
Atterberg Limits	Liquid limit (L.L)%	N.L	N.L
	Plastic limit (P.L)%	N.P	N.P
AASHTO Classification	Gravel %	2	5
	Sand %	92.5	91
	Fines %	5.5	4
Field density, (γ_f) kN/m³		13.76	14.87
Compaction test (Modified Meth.)	Maximum density(kN/m³)	17.82	17.91
	Optimum mo. c.%	14.4	12.9

2.2.Experimental Procedure

The examined soil was (900×900×500 mm) and divided into five layers (100) mm for each layer, Fig. 3. The soil was compacted using a manual hammer that contained a circular disk have a diameter (200 mm) and a thick. (12.5 mm) connected to tube with diameter (25 mm). The hammer's weight was 5 kg. Extracted cans were also compressed from the predetermined size and weight to calculate and compare the density with the field density. If the required density value exceeds field density, the blows number reduced. However, if density was less than field density, the blows number must be increase. Soil was placed in the box in two cases for footings for ratios of ($D_{in.}/D_{out.}$=0, 0.2, 0.3, and 0.4), $D_{in.}$: inner diameter (mm), $D_{out.}$: outer diameter (mm), and different depth-to-diameter ratios (D_f/D=0, 0.5 and 1) D_f: depth of footing (mm), and D: diameter of footing (mm).

3.RESULTS AND DISCUSSION

3.1.High Gypseous Soil

The high gypsum soil results of (D_f/D= 0, 0.5, and 1) and ($D_{in.}/D_{out.}$= 0, 0.2, 0.3, and 0.4) are show in Figs. (4-6). It was found that the capacity of bearing improved ratio for (D_f/D= 0.5) was (53, 119, 172, and 252) %, respectively. Also, bearing capacity for (D_f/D=1) improved (73, 171, 193, and 326) %, respectively. Fig. 6. Shows that the maximum pressure happened when D_i/D_o= 0.4 the according to Das 1999, the type is General shear failure). Table 3 show the maximum pressure for highly gypsum soils.

Fig. 3 The Loading Test Device.

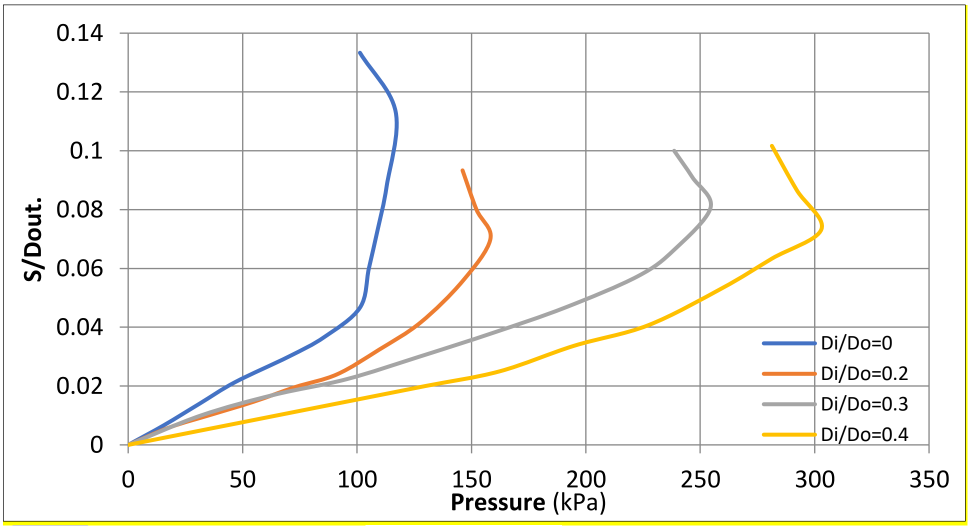

Fig. 4 Relationship between ($S/D_{out.}$ -Pressure) for High Gypsum Soil (D_f/D=0).

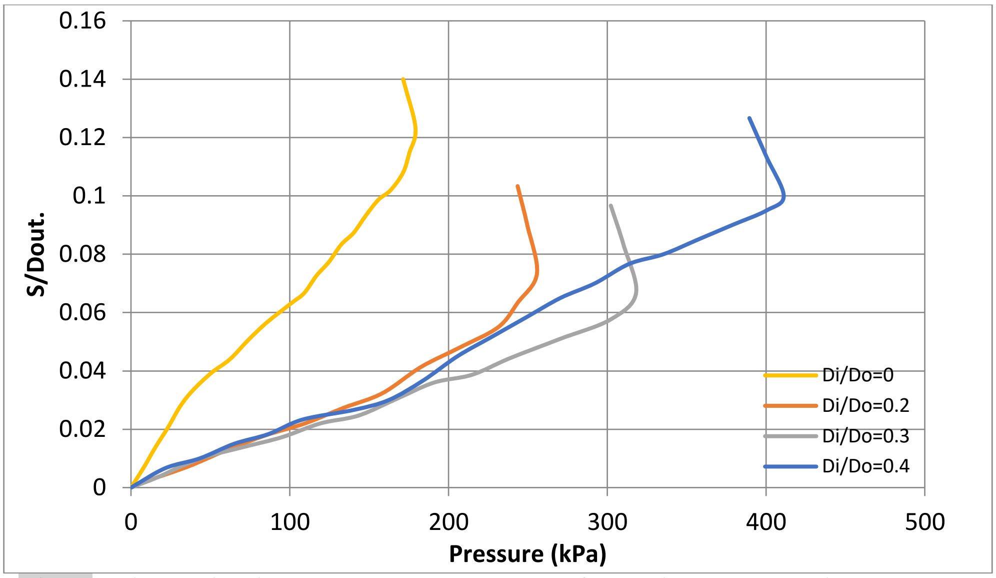

Fig. 5 Relationship between ($S/D_{out.}$-Pressure) for High Gypsum Soil (D_f/D=0.5).

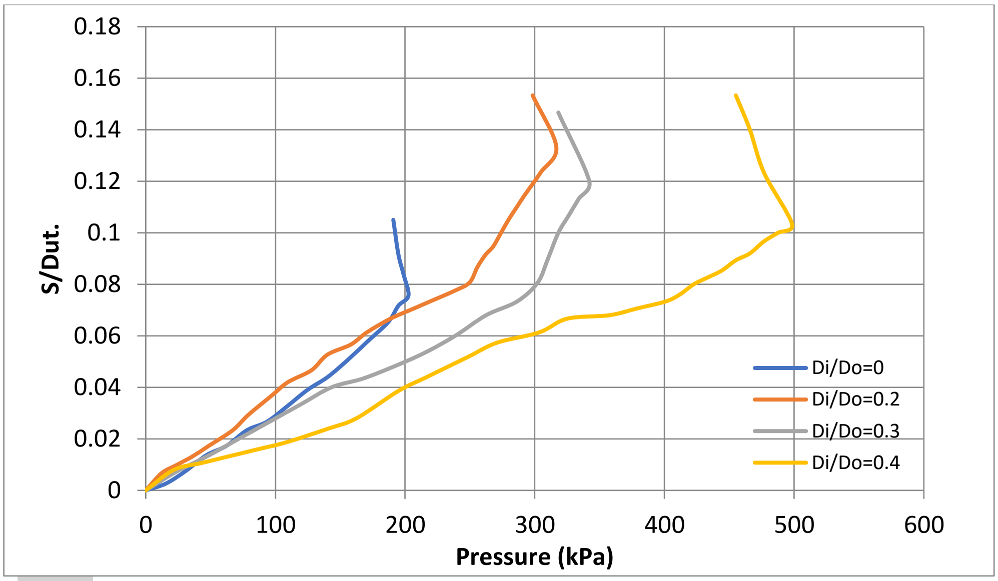

Fig. 6 Relationship between ($S/D_{out.}$ -Pressure) for High Gypsum Soil (D_f/D=1.0).

Table 3 Maximum Pressure for Highly Gypseous Soil.

High Gypseous soil	Parameters		Max. pressure (kPa)
Density	D_f/D	D_{in}/D_{out}	
Field density (13.76 kN/m³)	0	0	116.874
		0.2	158.3
		0.3	254.52
		0.4	302.964
	0.5	0	179.2
		0.2	255.716
		0.3	318.15
		0.4	411.166
	1	0	202.582
		0.2	316.6
		0.3	342
		0.4	498.393

3.2.Low Gypseous Soil

Low gypsum soil for (D_f/D= 0, 0.5, and 1) and (D_{in}/D_{out}= 0, 0.2, 0.3, and 0.4) is shown at Figs. (7-9). It was found that capacity of bearing at a ratio of (D_f/D= 0.5) improved by (48, 67, 153, and 197) %, respectively as shown at Fig. 8. The bearing capacity for (D_f/D=1) was improved (72, 153, 196, and 274) %, respectively shown in Fig. 9. By increasing the ratio of the inner diameter of the foundation divided by the outer diameter, the area of the foundation decreased. Thus, the bearing capacity significantly increased. Table 4 show the maximum pressure for low gypsum soil.

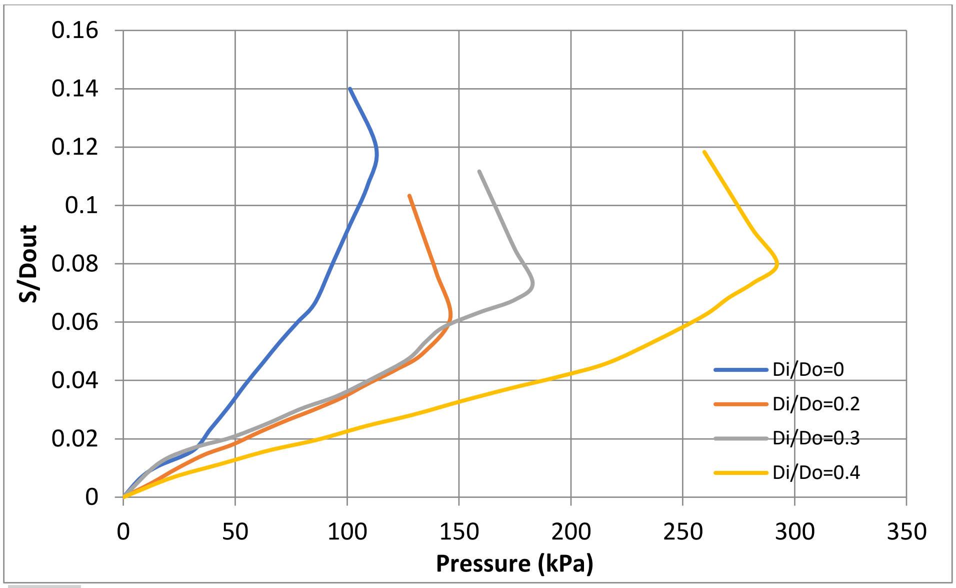

Fig. 7 Relationship between (S/D_{out}-Pressure) for Low Gypseous Soil (D_f/D=0).

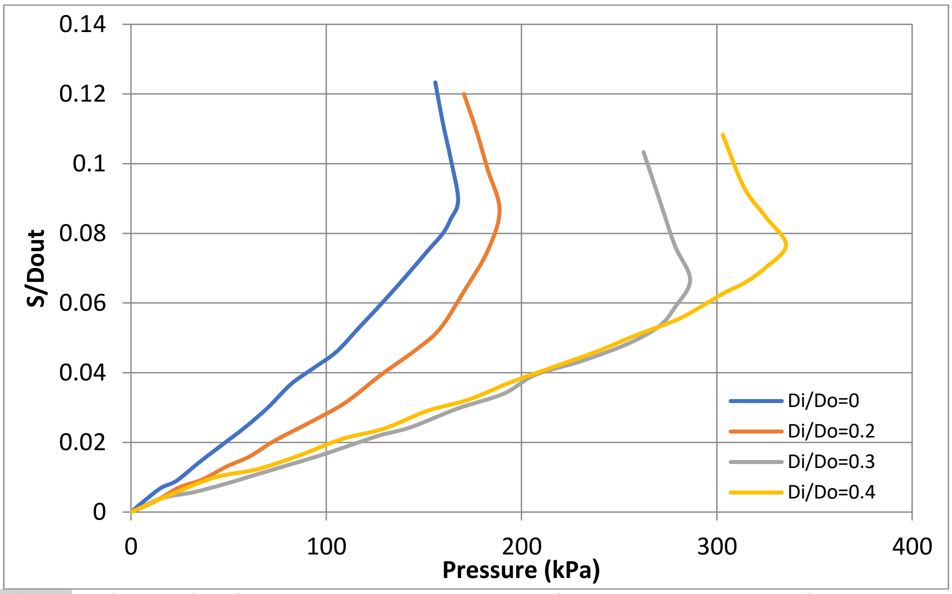

Fig. 8 Relationship between (S/D_{out}-Pressure) for Low Gypseous Soil (D_f/D=0.5).

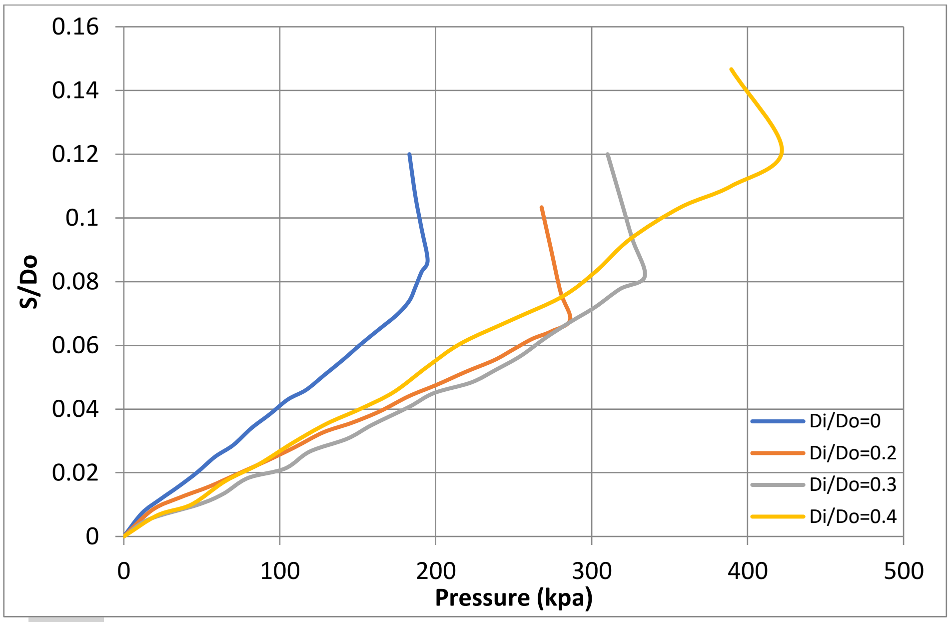

Fig. 9 Relation between (S/D_{out}-Pressure) for Low Gypsum Soil (D_f/D=1.0).

Table 4 Maximum Pressure for Low Gypseous Soil.

Low Gypseous Soil	Parameters		Max. Pressure (kPa)
Density	Df/D	Din/Dout	
Field density (14.8776 kN/m³)	0	0	113
		0.2	146
		0.3	183
		0.4	292
	0.5	0	168
		0.2	189
		0.3	286
		0.4	335
	1	0	195
		0.2	286
		0.3	334
		0.4	422

3.3. Effect of Footing Depth on the Pressure for (High and Low) Gypsum Soil

Figure 10 shows pressure for ring footing with (D_{in}/D_{out}= 0, 0.2, 0.3, and 0.4) ratios based on highly and low gypsum soils (D_f/D=0). For laboratory experiment, it founded that bearing capacity increased until it reached to the max. pressure at (D_{in}/D_{out}=0.4). Fig. 11 shows pressure for ring footing with (D_{in}/D_{out}= 0, 0.2, 0.3, and 0.4) ratios based on highly and lowly gypsum soil at (D_f/D=0.5). For laboratory experiment, it founded that bearing capacity increased until it reached maximum pressure at (D_{in}/D_{out}=0.4). Fig. 12 shows capacity of bearing for ring footings when ratios (D_i/D_o= 0, 0.2, 0.3, and 0.4) based on highly and lowly gypsum soils at (D_f/D=1.0). For laboratory experiment, it founded that bearing capacity increased until it reach to maximum value at (D_{in}/D_{out}=0.4). This study focuses on comparing the bearing capacity of the ring footing and comparing it with the bearing capacity of the circular footing on the two types for gypsum soils in the dry state.

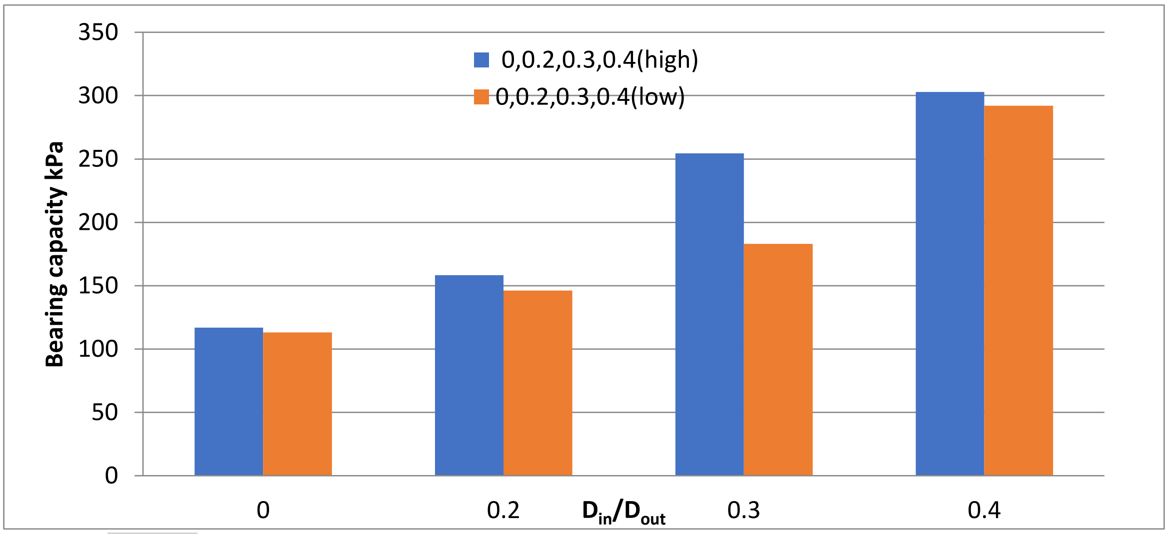

Fig. 10 Depth Effect on the Pressure of High and Low Gypsum Soils (D_f/D=0.0).

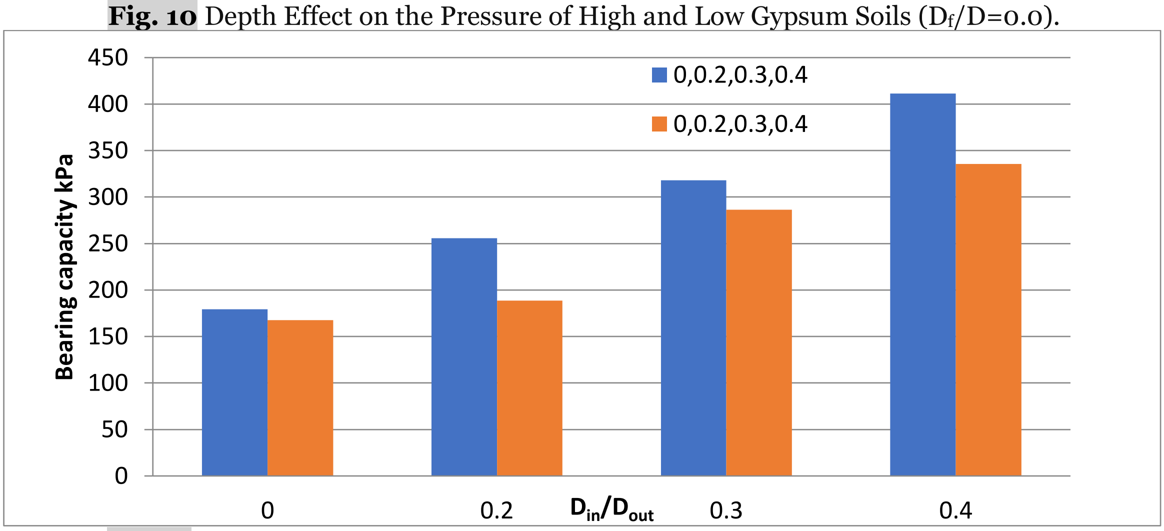

Fig. 11 Depth Effect on the Pressure of High and Low Gypsum Soils (Df/D= 0.5).

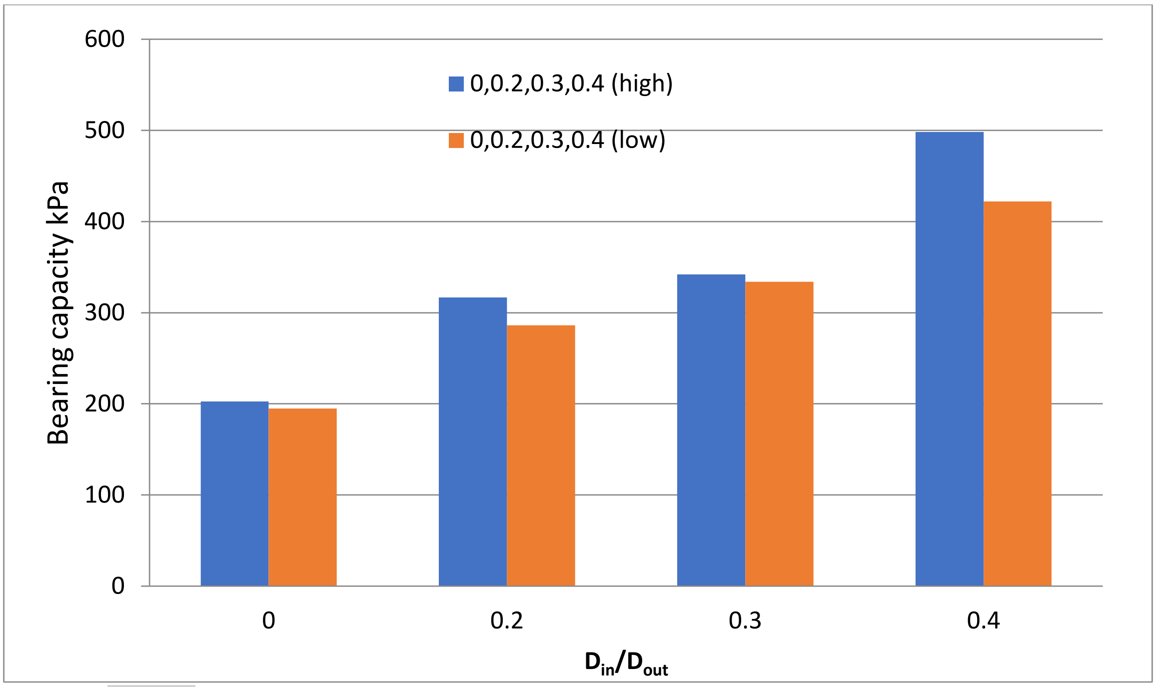

Fig. 12 Depth Effect on the Pressure of High and Low Gypsum Soils (D_f/D=1.0).

4.THE MAXIMUM PRESSURE CALCULATION

Calculation of the maximum pressure from the relationship between (S/D_{out}-pressure), i.e., S is a settlement, cited by [16] because the failure form was (General shear failure), Fig. 13. The theoretical maximum pressures for (D_f/D=0) and (D_{in}/D_{out}=0) for high and low gypseous soil are tabulated in Table 5 and Table 6.

Table 5 Theoretical Results for High Gypseous Soil.

Equations	Bearing. capacity (kPa)
Terzaghi (1943)	135
Meyerhof (1963)	158
Hansen (1970)	140
Testing model	117

Table 6 Theoretical Results for Low Gypseous Soil.

Equations	Bearing. capacity (kPa)
Terzaghi (1943)	127
Meyerhof (1963)	145
Hansen (1970)	136
Testing model	113

The practical results were less than the theoretical results.

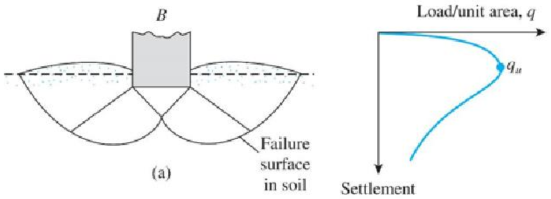

Fig. 13 Calculate the Maximum Pressure.

5.CONCLUSIONS

Through laboratory experiments, it was obtained:

1- The bearing capacity for the footings based on highly gypsum soil at (D_f / D = 0.5) when ratio (D_{in}/D_{out}= 0, 0.2, 0.3, and 0.4) was improved by (53, 119, 172, and 252) %, respectively compared when depth (D_f/D=0.0). Whereas bearing capacity for the footings based on highly gypsum soil at a depth of (D_f/D=1.0) improved by (73, 171, 193, and 326) %, respectively.

2- The capacity of bearing for the footing based on lowly gypsum soil at (D_f/D= 0.5) when ratios (D_{in}/D_{out}= 0, 0.2, 0.3, and 0.4) improved by (48, 67, 153, and 197) %, respectively compared when depth (D_f/D=0.0). Also, bearing capacity for the footings based on low-gypsum soil at (D_f/D=1.0) improved by (72, 153, 196, and 274) %, respectively.

3- Bearing capacity increased with depth.

4- Good ratio for the ring footings was (D_{in}/D_{out}= 0.4).

REFERENCES

[1] Muhauwiss FM, Salh, AH. **Shear Strength Characteristics of PPF-Treated Gypsum Soil Prepared at Various Maximum Densities.** *European Journal of Interdisciplinary Research and Development* 2022; **8**:123-134.

[2] Ahmed AAH, Zedan AJ. **Behavior of Square Footing Erected on Gypseous Soil Treated by Ceramic**

Wastes. *Tikrit Journal of Engineering Sciences* 2022; **29**(2):15-21.

[3] Petrukhin VP, Boldyrev GB. **Investigation of the Deformability of Gypsified Soils by a Static Load**. *Soil Mechanics and Foundation Engineering* 1978; **15**(3): 178-182.

[4] Al-Saoudi NKS, Al-Khafaji AN, Al-Mosawi MJ. **Challening Problems of Gypseous Soils in Iraq**. *18th International Conference on Soil Mechanics and Geotechnical Engineering* 2013; Paris: Presses des Ponts: p.479-482.

[5] Abd-Alhameed HJ, Al-Busoda BS. **Experimental Study on the Behavior of Square-Skirted Foundation Rested on Gypseous Soil under Inclined Load**. *Journal of Engineering* 2023; **29**(3):27-39.

[6] Hassan SM, Al-Busoda BS. **Evaluation the Behavior of Ring Footing on Gypseous Soil Subjected to Eccentric and Inclined Loads**. *Journal of Engineering* 2023; **29**(5):79-89.

[7] Nguyen DK, Nguyen TP. Ngamkhanong C, Keawsawasvong S, Lai VQ. **Bearing Capacity of Ring Footings in Anisotropic Clays: FELA and ANN.** *Neural Computing and Applications* 2023; **35**(15): 10975-10996.

[8] Boushehrian AH, Hataf N. **Bearing Capacity of Ring Footings on Reinforced Clay.** *Geosynthetics in Civil and Environmental Engineering: Geosynthetics Asia 2008 Proceedings of the 4th Asian Regional Conference on Geosynthetics in Shanghai, China* 2009; Springer Berlin Heidelberg: p. 328- 331.

[9] Snodi LN. **Ultimate Bearing Capacity of Ring Footing on Sand**. *Wasit Journal for Science and Medicine* 2010; **3**(1): 71-80.

[10] AL-Sumaiday HG, AL-Tikrity IS. **Experimental Investigation of the Bearing Pressure for Circular and Ring Footings on Sand**. *Tikrit Journal of Engineering Sciences* 2013;**20(**3):64-74.

[11] Hataf N, Razavi MR. **Model Test and Finite Element Analysis of Bearing Capacity of Ring Footings on Losse Sand**. *Iranian Journal of Science and Technology* 2003; **27**(B1):0-0.

[12] Hussein MA, Zedan AJ. **Behaviour of Rectangular Footing Subjected to Gepseous Soil under Eccentricity-Inclined Loads**. *Iraqi Journal of Civil Engineering* 2017; **11**(2):15-29.

[13] Abbas JK, Al-Dorry MKA. **Bearing Capacity of Ring Footing on Geogrid Reinforced Sand**. *International Review of Civil Engineering* 2013; **4**(5): 240-246.

[14] Zedan AJ, Abbas HH. **Experimental Investigation of Square Footing Resting on Sand over Gypseous Soils**. *Tikrit Journal of Engineering Sciences* 2020;**27**(1):30-39.

[15] Al-Mufty AA, Nashat IH. **Gypsum Content Determination in Gypseous Soils and Rocks**. *3rd International Jordanian Conference on Mining* 2000; Jordan: p.500-506.

[16] Das BM. **Shallow Foundations Bearing Capacity and Settlement**. 3rd ed., Boca Raton, FL: CRC Press, New York: USA; 2017.