Tikrit Journal of Engineering Sciences (2022) 29 (2): 15-21
DOI: http://doi.org/10.25130/tjes.29.2.3

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

Behavior of Square Footing Erected on Gypseous Soil Treated by Ceramic Wastes

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Keywords:

Gypseous soil; Shallow foundation; Ceramic; Improvement; Soaking.

ARTICLE INFO

Article history:

Received 08 Jan. 2022
Accepted 16 May 2022
Available online 14 July 2022

Citation: 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. http://doi.org/10.25130/tjes.29.2.3

ABSTRACT

Gypseous soil, as is well known, includes a specific quantity of gypsum. Gypsum is a water-soluble salt with a solubility of (2.2-2.6) gram/liter in distilled - water. As a result, the presence of gypsum poses a challenge when building structures on this soil, since gypsum dissolves when exposed to water, producing gaps between soil particles and so causing soil collapse. This study examines the behavior of a shallow foundation rested on gypseous soil. Three types of gypseous soil with gypsum contents of (61%, 45.3%, and 27.9%, respectively) are used, and treated with ceramic wastes, which is a waste product of construction. The Soil samples were collected from the site of Tikrit University's campus. The study consists of six test cases, two for each type of soil, one dry and the other wet, where the first test for each case was used as a baseline for comparison, which was the soil test without the addition of ceramic wastes, and the rest was added in three proportions (3%, 6%, and 9%) and three mixing depths for each ratio (B/2, B, 3B/2).The percentage 9% ceramic wastes gives best results of improving, the bearing capacity of the soil improved by 233%, 256 %, and 289% for high gypseous soil, and by 78%, 94%, and 111% for medium gypseous soil, with a percentage of 60%, 87%, and 113% for low gypseous soils. Adding ceramic wastes to wet gypseous soil improves the bearing strength of the soil, lowers settlement to some extent, and reduces the influence of water on it.

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سلوك اساس مربع مستند على تربة جبسيه معالجة بمخلفات السيراميك

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عدنان جايد زيدان قسم الهندسة المدنية / كلية الهندسة / جامعة تكريت / العراق.

الخلاصة

التربة الجبسية، كما هو معروف، تحتوي على كمية معينه من الجبس. الجبس ملح يذوب في الماء بقابلية ذوبان (2.2-2.6) غرام / لتر في الماء المقطر. ونتيجة لذلك، فإن وجود الجبس يشكل تحديًا عند بناء الهياكل على هذه التربة، حيث يذوب الجبس عند تعرضه للماء، مما ينتج عنه فجوات بين جزيئات التربة وبالتالي يتسبب في انهيار التربة. تبحث هذه الدراسة في سلوك الأساس الضحل الذي يرتكز على تربة جبسية. تستخدم ثلاثة أنواع من التربة الجبسية بمحتويات جبسية (61٪، 45.3٪، 27.9٪ على التوالي) ومعالجتها بمخلفات السيراميك وهو من مخلفات البناء. جمعت عينات التربة من موقع حرم جامعة تكريت. تتكون الدراسة من ست حالات اختبارية ، حالتان لكل نوع تربة ، واحدة جافة والأخرى رطبة ، حيث تم استخدام الاختبار الأول لكل حالة كخط أساس للمقارنة ، وهو اختبار التربة دون إضافة مخلفات السيراميك ، و تمت إضافة الباقي بثلاث نسب (3٪ ، 6٪ ، 9٪) وثلاثة أعماق خلط لكل نسبة (B/2 ، B ، 3B/2).أعطت النسبة المئوية 9٪ من مخلفات السيراميك أفضل النتائج لتحسين قدرة تحمل التربة بنسبة 233٪ و 256٪ و 289٪ للتربة الجبسية العالية وبنسبة 78٪ و 94٪ و 111٪ للتربة الجبسية المتوسطة ، بنسبة 60٪ و 87٪ و 113٪ للتربة الجبسية المنخفضة.إن إضافة مخلفات السيراميك إلى التربة الجبسية الرطبة يحسن من قوة تحمل التربة ، ويقلل من الاستقرار إلى حد ما ، ويقلل من تأثير الماء عليها.

الكلمات الدالة: التربة الجبسية، الأساس الضحل، السيراميك، تحسين، نقع.

1.INTRODUCTION

Gypsum is a common and soluble mineral found in soil. soils are widely distributed in many regions of the world [1]. The gypsum content varies greatly from low (less than 5%) to very high (more than 50%). Gypsum soils are widely distributed in Iraq, which constitute (more than 20%) of the regions of Iraq [2]. Because of the development in building construction such as building on gypsum soils, engineers have had problems with settling and collapsing soils, as these soils are usually solid when dry.Improving the engineering properties of the soil mass, which occurs by increasing the strength, decreasing compressibility, changing volume and permeability, and increasing the stability of the structures [3].The foundation is a portion of a system that transmits loads exclusively from the structure to the sub-soil. (Murthy, 2007) [4]. The foundation should also be capable of supporting these loads. The Shallow Base is one of the main foundation groups. Shallow foundations are square or rectangular individual footings in the plane that support columns, as well as strip footings that support walls and other similar buildings [5]. See Fig 1.

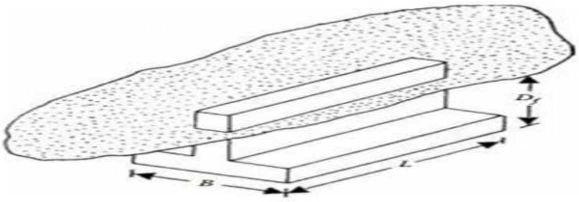

Fig.1. Individual footing (after Das, 2009).

Cracking, tilting and failure consider the most important problem that face the structures constructed on gypseous soils [6]. The problems are related with water seepage through the soil then the dissolving of gypsum causing a dropping of the ground level. The soluble gypsum may be leached out of the soil profile, which is resulted in varying the soil properties and forming cavities in the surrounding regions. This behavior presents serious problems (Alphen and Romero, 1971). Zedan and Abbas, 2020 [7] study a steel box was used to load a square footing (100*100 mm) resting on two layered soils (sand over gypseous soils) in the investigation. The results showed that when the gypseous soil was compacted to field density and saturated with an 80 percent relative density of sand, the bearing capacity improved, the findings of loading the two layers of soil also reveal that soaking gypseous soil under the sandy layer reduces sand resistance. Mahmood, 2019 [8] presents experimental results to determine the optimum length to diameter ratio of skirted foundation to get maximum bearing-capacity on soaked collapsible gypseous soil with gypsum content 54%. The study proved the ability of using skirts to protect the collapsible gypseous soil below foundations when subjected to wetting. It was concluded that the skirted footing increases the bearing capacity with decrease in the settlement and improves the load-settlement behavior of the footing. The bearing capacity of skirted footing improves and this is dependent on the surface and geometrical properties of the skirt, and characteristics of gypseous soil. Muhauwiss, 2018 [9] studies the effect of eliminating gypsum on granular soil categorization is investigated. Four gypsum soil samples were collected. 0.75, 1.10, 2.00, and 3.30 m were the depths used. The proportions of gypsum were 42.23 percent, 32.50 percent, 8.75 percent, and 19.82 percent, respectively. By washing with distilled water, the EDTA solution was utilized to breakdown and remove the gypsum particles. The results showed that removing gypsum from granular soils with an EDTA solution and distilled water was an efficient procedure. All of the specimens analyzed had a gypsum ratio of less than 2%.

2. EXPERIMENTAL WORK

2.1. Apparatus and procedures

2.1.1. Test box

The soil beds are prepared in a steel box with inside dimensions (900 mm* 900 mm* 700 mm) in height as shown in the Fig 2. The sides and the bottom are made of 6 mm thickness plate. A valve is fixed in the lower part of the box. This valve is connected with 500 mm vertical plastic cylinder tube. This tube is used to notice the level of water, the bed of soil as a piezometer, and as an indication when the soil becomes at the saturating stage. The filter material is placed at the lower part of the steel model to allow the soaking water to infiltrate through the filter material without the loss of soil particles. A perforated steel plate of 4 mm thickness is placed under the filter material. The plate is supported by four steel channels, with 150 mm high from the base of the steel box. Mark lines are drawn to give the required thickness of the layers. Several researchers, including [10], [11], [12], [13], use the same testing box in their investigations on bearing capacity on model of footing [14].

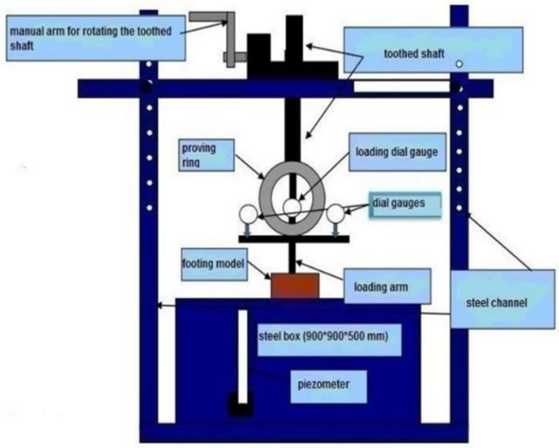

Fig.2. the test box (not to scale).

2.1.2. The model footing

A model of square footing of (100*100) mm, thickness 30mm is made of two layers of plastic sheet each one 15mm is used as footing experimental work. A 1mm depth hemispherical cavity is made to hold the metal loading ball on one face of the footing at center as shown in the Plate 1.

Plate 1. The model of footing.

2.1.3. The soil's samples

Gypseous soil was collected from Tikrit University from depth ranging (1.0-3.5) m below the natural ground level after removing the upper soil strata. The gypseous soil sieved through sieve No.4 (4.75 mm). The properties of both soils were found in the Table1 Gypsum content is found by using Al-Mufty and Nashat method [15]. All classification tests were done according to (ASTM) [16].

Table 1. Physical properties and Gypsum content of soil.

Properties		Soil A	Soil B	Soil C
Gypsum content %		61	45.3	27.9
Moisture content, (ω)%		3.24	1.74	1.56
Specific gravity, (Gs)		2.52	2.54	2.61
Atterberg Limits	Liquid limit (L.L)%	24	27	29
	Plastic limit (P.L)%	N.P	N.P	N.P
M.I.T Classification	Gravel	11	8	10
	Sand	80	85	85
	Fines	9	7	5
Coefficient of uniformity (C_U)		4.8	3.04	3.32
Coefficient of curvature (C_C)		1	.72	1.14
Unified Soil Classification		SP	SP	SP
Minimum dry unit weight, (γ_{min}) kN/m³		11.21	11.21	11.20
Field unit weight, (γ_f) kN/m³		13.48	13.65	13.74
Relative density, (D_r) %		58.7	55.5	55.3
Compaction Characteristic (Modified Method)	Optimum dry unit weight (kN/m3)	17.08	17.5	17.62
	Optimum moisture content %	14.6	12.6	11.75

2.1.4. Ceramic wastes

Ceramic waste was brought from the ceramic's sales offices in the city of Tikrit and transferred to Tikrit University. Then it is broken manually to make it smaller in size and easy to put inside the Los Angeles machine for the purpose of grinding it plate (3-2b) to pass through sieve No. (4.75) to mix it with the soil in different proportions.

Plate 2. ceramic crushing and grinding stages.

2.2. Experimental procedure

The soil is placed in the test box and compacted in layers with a thickness of 50 mm until the desired height is reached. This purpose-built hand hammer has a round iron disc of 200 mm in diameter and 12.5 mm in thickness attached to a metal tube of 25 mm in diameter, and the hammer has a total weight of 5 kg. For each layer the height of the drop of the hammer is determined to achieve the required density. The soil in the box is placed in different states. In the first time, only gypsum soil is placed and checked, and the second time is gypsum soil layers, and at the required thickness, the ceramic powder is mixed with the specified layer of soil with depth (50,100,150) mm and is compacted and checked. The relative density achieved by collecting samples is monitored in small boxes of known size placed in various locations near the side of the test box. The difference in densities measured at different sites was found to be less than 1%. The base is located in the center of the box. Test the soil in tow conditions soaking and without soaking. Plate2.

Plate 3. Testing soaked gypseous soil.

3. RESULTS AND DISCUSSION

According to [17] show Fig3. This study to calculate the ultimate bearing capacity will be use Tangent intersection method for dry condition and the (0.1B) method for wet condition.

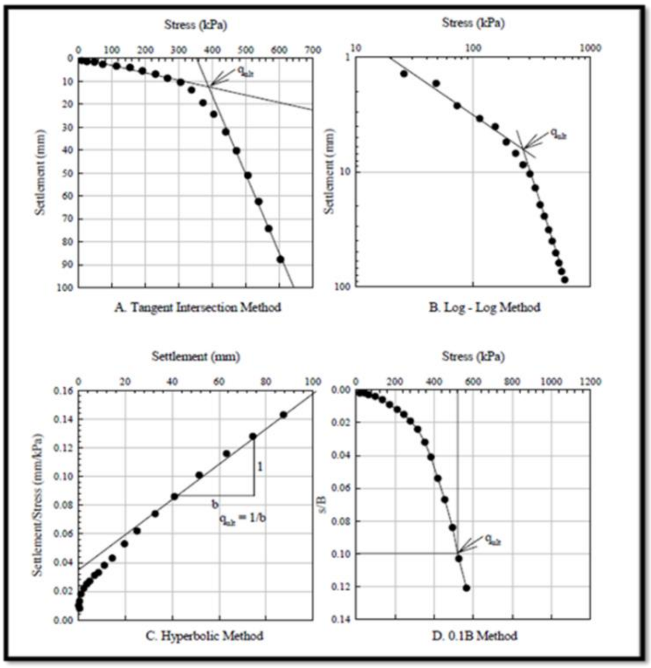

Fig.3. Different methods to define ultimate bearing capacity of foundations from load test results (Lutenegger and Adams, 1998).

Fig4 shows (settlement-pressure) for high gypseous soil with 3% ceramic at soaking state (for example).

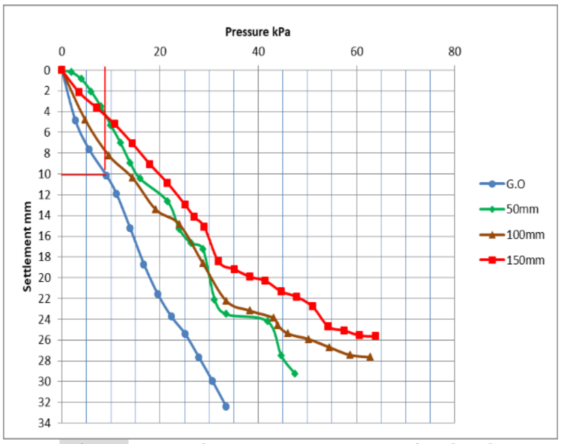

Fig.4. (Settlement-pressure) for high gypseous soil with 3% ceramic at soaking state.

3.1. *Effect of mixing depth on dry high gypsum soil*

Fig5 shows the behavior of high gypseous soil for different mixing depths (B, B/2 and 3/2B) and for the three mixing ratios, where there was a varying decrease in the resistance. It is strong in the dry state and does not need treatment.

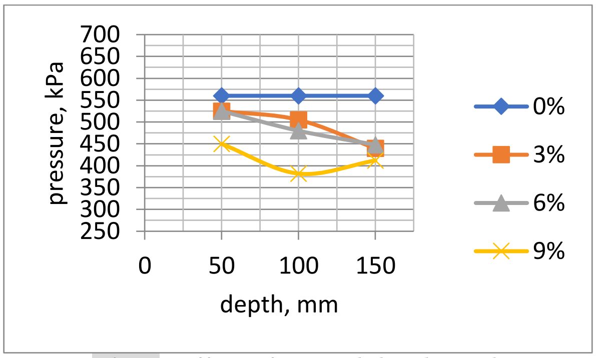

Fig.5. Effect of treated depth on the Bearing capacity high gypseous soil (dry case).

3.2. *Effect of mixing depth on wet high gypseoum soil*

Wet gypsum soil has weak resistance when testing the loading. Fig6 shows the effect of mixing depth on soil improvement. All mixing ratios showed an improvement in resistance with increasing depth.

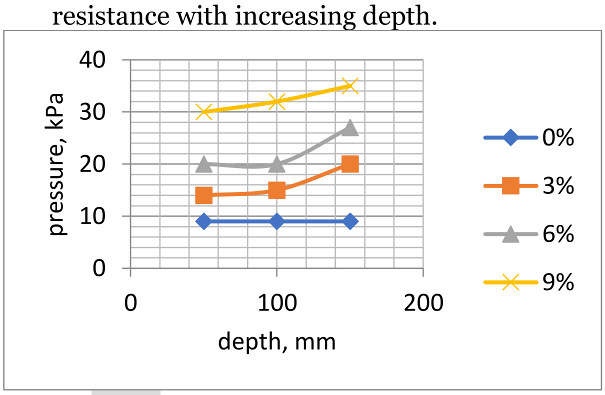

Fig.6. Effect of treated depth on the Bearing capacity high gypseous soil (wet case).

3.3. Effect of mixing depth on dry medium gypseous soil

The dry medium gypseous soil did not show any improvement despite the difference in the depth of mixing for the mixing ratios of 3%, 6% and 9% as in Fig7 compared to the original soil and the decrease in bearing capacity was gradual with increasing the mixing ratio.

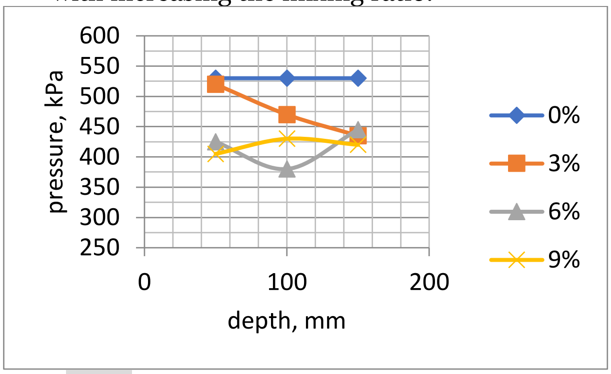

Fig.7. Bearing capacity - depth curve for dry medium gypsum soil (dry case)

3.4. Effect of mixing depth on wet medium gypsum soil

The rise in the improvement of the wet gypseous medium soil appeared by increasing the mixing depth and the mixing ratios (3%, 6% and 9%) as shown in Fig8.

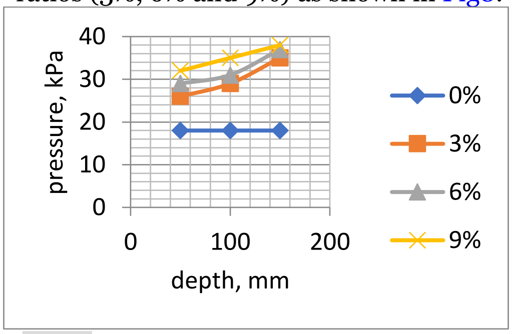

Fig.8. Bearing capacity - depth curve for wet medium gypsum soil (wet case).

3.5. Effect of mixing depth on dry low gypseous soil

The effect of the mixing depth of the mixing ratios with the dry gypseous low soil differed in the improvement of this soil as in the Fig9.

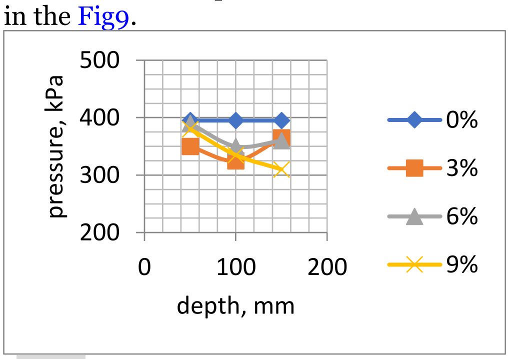

Fig.9. Bearing capacity - depth curve for dry low gypsum soil (dry case).

3.6. Effect of mixing depth on wet low gypsum soil

The effect of the depth of mixing on the improvement of the wet low gypseous soil is noticeable as in the Fig10 as all the mixing ratios with this soil gradually improved with increasing the depth and ratios of mixing.

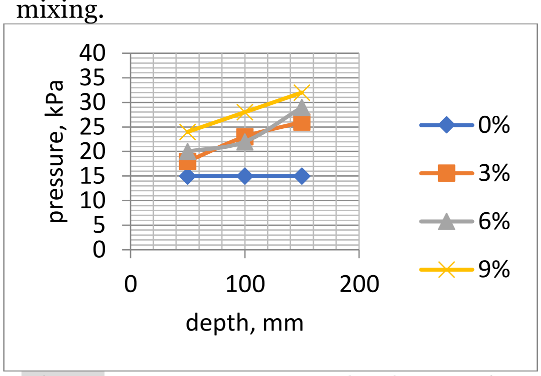

Fig.10. Bearing capacity - depth curve for wet low gypsum soil (wet case).

4. CONCLUSION

- When the soil was in its dry state, there is not notice an improvement in the engineering properties soil, as this soil is very strong and has high resistance while it is in the dry state.
- When adding 3% of ceramic powder to wet gypseous soil with depths of (B/2, B and 3B/2), the bearing capacity of the soil increased by 56%, 67% and 122% respectively for high gypseous soil and by 44%, 61 % and 94% respectively for medium gypseous soil and by 20%, 53% and 73% respectively for low gypseous soils.
- Soil in its wet state and after adding 6% of ceramic powder to it and at the same three depths, the bearing strength of wet gypseous soil improved by 122%, 122% and 200% respectively for high gypseous soil and by 61%, 72% and 106% respectively for medium gypseous soil and by 33%, 41% and 93% respectively for low gypseous soil.
- When adding 9% of ceramic powder to the wet gypsum soil at the same depths, the bearing strength of the soil improved by 233%, 255% and 289% respectively for high gypseous soil and by 78%, 94% and 111% respectively for medium gypseous soil with a percentage of 60%, 87% and 113% respectively for low gypseous soils.
- Adding ceramic powder to the gypsum soil in the wet state improves the bearing strength of the soil and reduces to some extent the subsidence and reduces the effect of water on it.

REFERENCES

[1] **World soil resources: An Explanation of the FAO World Soil Resource Map at a Scale of 1:25000000**. *FAO World Soil Resource Report 66. Rome, Italy*,1993.

[2] Al-Kaabi F. **Distribution of the Gypsiferous Soil in Iraq**. *State Company of Geological Survey and Mining*, Report No.3044. Baghdad, Iraq, 2007.

[3] Lambe TW, Marr WA. **Stress path method.** *Journal of the geotechnical engineering division*, 1979; **105**(6), 727-738.

[4] Murthy VN. **Advanced Foundation Engineering**. *New Delhi, India: CBS Publisher and Distributor*, 2007;**1.**

[5] Das BM. **Shallow Foundations, Bearing Capacity and Settlement**. *Taylor & Francis Group*, 2009;**2**.

[6] Razouki SS, Al-Omari RR, Nashat IH, Razouki HF, Khalid S. **The problem of gypsiferous soils in Iraq. In Proceeding of the symposium on gypsiferous soils and their effect on structures**, *NCCL* 1994; _: 7-33).

[7] 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.

[8] Shrestha A, Mahmood A. **Review of deep learning algorithms and architectures.** *IEEE access*, 2019; **7**: 53040-53065.

[9] Muhauwiss FM. **Physical properties of gypseous soil after gypsum removal using EDTA solution.** *Tikrit Journal of Engineering Sciences*, 2018; **25**(2): 68-73.

[10] Saleh SM. **Stress Transfer and Distribution in Reinforcement under Footings on Reinforced Earth.** *MSc. Thesis, University of Mosul, Iraq*, 1989.

[11] Adams, RD, Adams RD, Comyn J, Wake WC, **Structural adhesive joints in engineering.** *Springer Science & Business Media*, 1997.

[12] Tawfeeq SS. **Improvement of Gypseous Soils Using Different Types of Geosynthetic Materials.** *MSc. Thesis, Civil Engineering Dept., Tikrit University, Iraq*, 2009.

[13] Al-Azzawi MAH. **Behavior of Rectangular Footing Subjected to Gypseous Soil under Eccentricity-Inclined Load.** *MSc. Thesis, Civil Engineering Dept., Tikrit University, Iraq*, 2010.

[14] Al-Obaidi AH, Fattah MY, Al-Dorry, MK. **Variation of suction during wetting of unsaturated collapsible gypseous soils.** *International Journal of Engineering & Technology*, 2018; **7**(4.37): 79-85.

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

[16] **Soil and Rock, West Conshohocken, United States.** *ASTM (American Society for Testing Materials)*, 2010; **04**(08) and **04**(09).

[17] Lutenegger AJ, Adams MT. **Bearing Capacity of Footings on Compacted Sand.** *Proceedings of the 4th International Conference on Case Histories in Geotechnical Engineering*, 1998; _:1216- 1224.