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Bearing Capacity of Shallow Footing on Compacted Dune Sand Underlain Iraqi Collapsible Soil

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ABSTRACT

Gypsies Soils are disturbed in many regions in the world including Iraq, which cover about (30 %) of the surface area of the country (Al-Dulaimi, 2004). Existence of these soils, sometimes with high gypsum content, caused difficult problems to the buildings and strategic projects due to dissolution and leaching of gypsum by the action of water flow through soil mass. In this research, a new technique is adopted to investigate the performance of replacement and geosynthetic reinforcement materials to improve the gypseous soils behavior through experimental set up manufactured locally specially for this work. A series of tests including dry and wet tests were carried out using steel container (600×600×500) mm. A square footing (100×100) mm was placed at the center of the top surface of the bed soil. The results showed that the most effective thickness for dune sand layer with geotextile at the interface, within the tested range, was found to be almost equal to the width of foundation. Therefore, under this depth, the soil was reinforced with geogrid and geotextile. The bearing capacity increases to (1.5-2.0) time under concentric loads and (2.5-3.0) under eccentric loads after replacement and reinforcement of gypseous soil.

K**eywords:** Gypsies Soil, Dune Sand, Bearing Capacity, Reinforcement Materials.

قابلية تحمل الأساس الضحل على الرمل المرصوص فوق تربة جبسية مسلحة

الخلاصة

تتوزع التربة الجبسية في عدة مناطق من العالم من ضمنها العراق حيث تغطي حوالي (30%) من المساحة السطحية للقطر. أن وجود هذه الترب بنسب عاليه في بعض المواقع قد سبب مشاكل معقدة

للمباني والمشاريع الإستراتيجية بسبب ذوبان الجبس بتأثير جريان الماء خلال كتلة التربة. في هذا البحث اقترحت تقنية جديدة شملت فحص تبديل التربة والتسليح بمواد نسيجية ومشبكات (Geotextile and Geogrid) لتحسين تصرف التربة من خلال موديل مختبري صنع محليا لهذا الغرض. في هذا البحث تم اجراء سلسلة من الفحوصات لنماذج جافة وأخرى مغمورة والرطبة في صندوق حديدي أبعاده (600×600×500) ملم وأساس مربع الشكل بأبعاد (100×100) ملم وضع في وسط سطح نموذج التربة المفروشة في صندوق الفحص. هذه الفحوص تشمل فحص الانهيار وفحوص التحميل المركزي واللامركزي للتربة الجبسية تحت أعماق مختلفة من التبديل برمال الكثبان وطبقات تسليح مختلفة لحالات الغمر بالماء.

بينت النتائج أن أفضل عمق مؤثر لتبديل التربة الجبسية برمال الكثبان هو العمق الذي يساوي عرض الأساس بعد استخدام المواد النسيجية بين التربة الجبسية ورمال الكثبان. ولذلك تحت هذا العمق من التبديل قد سلحت التربة باستخدام المواد النسيجية والمشبكات (Geotextile and Geogrid) وقد لوحظ أن قابلية التحمل تزداد بنسبة (1.7-2.0) في حالة التحميل المركزي وبنسبة (2.0-3.0) في حالة التحميل اللأمركزي بعد تبديل وتسليح التربة الجبسية.

INTRODUCTION

Gypseous soil is that soil which contains enough gypsum (CaSO4.2H2O) that affect the behavior of soil. Gypsum has specific gravity of (2.32) and its solubility of gypsum in water is (2gm/liter) at 20 C, but the amount of dissolved gypsum can be much greater if water contains some salts (Hesse, 1971 and Khan, 2005). Gypseous soils are classified as collapsing soils. This is due to the fact that gypsum present in the soil provides an apparent cementation when the soil is dry but the intrusion of the water causes dissolution and softening leading generally to serious structural collapse (Razouki, et al, 1994).

Upon wetting, most of soils show settlement. The amount of settlement varies from soil to another and is dependent on load-induced stresses. But such settlement will eventually cease after a certain period of time. However, under certain conditions and for specific types of soils, subsequent wetting may cause additional settlement. This type of settlement is termed (Collapse) (Casagrande, 1932).

PREVIOUS STUDIES

Collapse occurs when the soil has an open structure that has a temporary source of strength to hold the soil grain in position against shearing force. On the other hand, and as a result of building and industrial development, it is very important to improve and treat weak gypseous soil properties by using physical or chemical methods which are almost of high cost. Therefore, during the last years, the usage of low cost materials such as natural materials and residual of industrial materials to improve the properties of gypseous soil become of more benefit (Al-Obaydi, 2003). The use of earth reinforcement has become one of the most economical methods of soil improvement because of the ease of construction and the low cost compared with other similar techniques. The use of soil reinforcement has different applications; the most common uses are in the retaining walls, bridge abutments, dam, slope stability, road and

Underneath footings (Ammar, et al, 2007). The beneficial effects of soil reinforcement derive to the soil increased tensile strength and shear resistance developed from the Friction at the soil-reinforcement interfaces. Such reinforcement is comparable to that of concrete structures. Currently, most reinforced-earth design is done with free-draining granular soil only. Thus, the effect of pore water development in cohesive soils, which, in turn, reduces the shear strength of the soil is avoided (Das, 1990).

EXPERIMENTAL WORK

The material used in this study was distributed gypseous soil brought from Tikrit, Salah Al-Deen Governorate and dune sand used in replacement of gypseous soil was obtained from Baiji, Salah Al-Deen Governorate. A series of tests was performed on the gypeous soil and dune sand according to ASTM procedures. Gypseous soil can be classified as (SC) and dune sand can be classified as (SP) according to the Unified Soil Classification System. The minimum unit weight of gypseous soil was determined according to the test described by (Head, 1984). It is widely accepted as standard test for sandy soils and the maximum unit weight of gypseous soil was determined according to ASTM D-64T (Bowles, 1988). Field unit weight of gypseous soil was determined by a field test (Sand Cone Method). This test was performed according to (ASTM D1556-00). The results of the maximum and minimum unit weights of gypseous soil are (14.10) kN/m^3 and (10.75) kN/m^3 respectively. Tables (1), (2), (3), and (4) show the physical and chemical properties of gypseous soil and dune sand, respectively.

Test Box

The soil beds were prepared in a steel box with inside dimensions (600*600) mm and (500) mm in height. The sides and bottom were made of (5) mm thickness plate; the purpose of the thickness is to give rigidity against pressure which may generate during loading of the soil. One face of the steel box is made from Plexiglass with dimensions (300*300) mm. The box placed over (800) mm width and (1000) mm length of strong steel base, which is connected to a stiff loading frame. The frame consists of two columns of steel channels, which is in turn bolted to a loading platform. This platform allowed to slide along the columns and can be fixed at any desired height by means of slotting spindles and holes provided at different intervals along the columns. The footing was made of steel plate of a thickness of (3) mm. The footing was connected to suitable steel wings to facilitate the measurement of settlement. A hydraulic jack was used to apply an axial loading on footing. The load on the footing was measured using proving ring of (20) kN capacity, while the settlement was measured by two dial gauges (0.01) mm fixed on the wing of the footing by two magnetic holders. A general view of the manufactured testing equipment is shown in Figure (1).

A sketch for the test box showing some of the studied parameters is shown in Figure (2).The detailed description of the model is explained in the following paragraphs. The reinforcement used is polymer geomesh (Geogrid and Geotextile).

Table (5) shows the properties of geogrid, and Table (6) shows the properties of geotextile, as supplied by Building Research Center (Iraq).

Bearing Capacity Test Procedure

The test was conducted by using non repetitive static plate load test method according to the procedures of ASTM D1194-94. The bearing capacity was determined for various thicknesses of gypseous soil beds. In each test, the gypseous soil was placed in layers (5) cm thick. The placement density was controlled using raining technique. The gypseous soil was carefully spreaded in two perpendicular directions to ensure uniform density. When the final layer was layed, the surface was carefully leveled with the aid of straight edge. Then, the foundation was fixed in the center of test box in x and y direction in concentric loading and at determined eccentricity in case of eccentric loading and then the two magnetic holders with dial gauges in the edge of the box was connected. The load was continuously applied through the hydraulic jack. The applied load was taken from the proving ring reading while the settlement was measured by the dial gauges. When soaking is conducted, the steel box is left for (24) hours to ensure that all soil was completely soaked. On the second day, the test was begun. The application of load was continued up to failure. The failure was indicated by the increase of settlement at a constant magnitude of load intensity. When the test was done by replacing gypseous soil with dune sand, dune sand was placed in certain depth in the steel box by using raining technique and using geotextile at interface between gypseous soil and dune sand. Dune sand was carefully spreaded in two perpendicular directions to ensure uniform density. In reinforced condition, the gypseous soil was placed in the steel box by using raining technique. Before the construction of the next layer, the geotextile was placed above collapse soil and geogrid was placed in two layers through dune sand layer. The for mentioned procedure was followed for concentric and eccentric loading conditions. Test procedure the test was conducted by using non repetitive static plate load test method according to the procedures of ASTM D1194-94. The bearing capacity was determined for various thicknesses of gypseous soil beds.

RESULTS AND DISCUSSION

A series of model loading tests were carried out on gypseous soil improved by replacement with dune sand and reinforced with geosynthetics materials under concentric load. Figure (3) exhibits the relationship between the applied pressure and settlement of the gypseous soil in dry and soaked state. Figure (3) shows that the mode of failure can be described as a general shear failure. When gypseous soil is soaked for (24) hours and then loaded to failure, large draw down in bearing capacity was observed and a trend of behavior similar to that of local shear failure. This behavior may be attributed to the breaking of bonds due to soaking. The test of soil at soaked state may be considered as a reference to measure the magnitude of improvement.

Figure (3) illustrates the tests results at soaking state. From this Figure, it can be observed that the ultimate bearing capacity was (205) kPa; this denotes a high decreasing in bearing capacity after soaking if compared with the dry state. This is probably referred to the high dissolution rate of gypsum and generating voids which lead to reduce the friction areas between soil particles and then reduces the shear strength, in addition to increasing the ability of soil structure to roll slide, and deform to a new structure.

Dune sand was used at dense state to get the benefit of additional frictional resistance and it was placed in steel box by raining technique. This technique is simple and easily prepared to achieve desired density of dune sand.

Dune sand was placed at a depth of (B) and geotextile layer was used at the interface between dune sand and gypseous soil. The test results are shown in Figure (4). It can be noticed that bearing capacity increases when replacing the gypseous soil with dune sand.

The reinforcement with geotextile was used at the interface between collapsible soil and dune sand, while, the geogrid was used on two layers (at depth of 0.3B and 0.7B) within the dune sand layer, in addition to the insertion of geotextile layer at the interface. Figure (5) shows the relationship between the bearing pressure and settlement for gypseous soil before and after reinforcement. From Figure (5), it can be noticed that after reinforcement, there is a high growing in bearing capacity and reduction in settlement when compared with the unreinforced gypseous soil during soaking. Specific ratio was employed in the tests to investigate the limit of improvement in bearing capacity. This limit represents the ratio between ultimate bearing capacities of gypseous soil replaced by dune sand to the bearing capacity of collapsible soil without replacement. The term was calculated for both reinforced and unreinforced soil.

$BCR_{Layered} = q_{ult\ (Layered)} / q_{ult}$

$BCR)_{(Layered)}$ =bearing capacity ratio after replacing gypseous soil with dune sand at soaked state

$BCR_{Reinforced} = q_{ult\ (Reinfoced)} / q_{ult}$

$BCR)_{(Reinforced)}$ =bearing capacity ratio after replacing gypseous soil and reinforcing sand at soaked state

The value of (BCR) when replacing the gypseous soil with dune sand was (1.7), while it was (2.0) when using reinforcement materials. From the results, it can be shown that the bearing capacity increases and that the settlement was reduced as compared with unreinforced tests during soaking.

A series of model loading tests was conducted on gypseous soil improved by replacement with dune sand and using geogrid and geotextile under different values of Eccentricities under condition of soaking. Figure (6) illustrates the load - settlement at edge and center curves for dry gypseous soil under different eccentricity values (e=0.05 B, 0.1 B, 0.15 B, 0.2 B), respectively. These results show that the behavior of load – settlement curves seem to be like the general shear failure curve. This behavior was expected because soil was in dense state. The main problem of gypseous soil appeared during soaking because of the dissolution of gypsum. Therefore, many tests are conducted on gypseous soil during soaking under different values of eccentricity. From Figure (7), it can be observed that there is a high decrease in bearing capacity after soaking if compared with dry state. The maximum load carrying increased with the decrease of eccentricity (e=0.05 B), and decreased when (e=0.2 B).For small value of eccentricity, the difference in settlement between edge and center dial gauge is a small value. But this difference increased with the increase in eccentricity. Therefore, the settlement decreases in dial gauge reading at center increase in dial gauge reading at edge with increasing the eccentricity value. The observed values may be considered high with respect to predicated values obtained from theoretical (Terzaghi equation). Same observation was found by Al-Jebouri, (1986). Several suggestions were made to use ($Ø \cong Øp \cong 1.1Øt$) Das, (2008). The value of (Ø) determined by triaxial test and multiplied by (1.1) was used in the calculation of theoretical equation. Table (7) and (8) show the values of experimental and theoretical bearing capacity under dry and soaked states at different values of eccentricities. An attempt was introduced to improve the bearing capacity of collapsible soil upon wetting by partially replacing the soil by dune sand. The geogrid and geotextile have proved its effectiveness in improving the bearing capacity, and reducing the settlement value. Figure (8) represents load – settlement at edge and center curves after replacing gypseous soil with dune sand under depth equal to (ds=B) in a soaked state under different values of eccentricities. From examining the figures, it can be observed that the bearing capacity increases after replacement. Also, it is noticed that the gypseous soil shows less settlement. Figure (9) illustrates bearing pressure-settlement at edge and center curves for gypseous soil after replacing and reinforcing with geogrid and geotextile at different values of eccentricity during soaking. It can be seen that the maximum bearing capacity under soaking is at (e=0.05 B). This behavior may be attributed to the stiffening effect created by reinforcement. This stiffening refers to the frictional interaction which take place within the mass of reinforced soil with increasing the number of geogrid layers. In addition, geotextile also causes more bond between soil and reinforcement and result in more stable mass structure.

CONCLUSIONS

1. Dune sand appeared successful in improvement of collapsible soil together with geogrid and geotextile.

2. Collapse settlement increases due to an increase of the inundation stress and depth of the gypseous soil layer and decreases due to the insertion of the reinforcement material.
3. For concentric loads, the value of (BCR) when replacing the gypseous soil with dune sand was (1.7) time increase in ultimate bearing capacity, while (2.0) time when using reinforcement materials.
4. For eccentric loads, the load carrying capacity decreases with the increase of eccentricity value.
5. At high values of eccentricity (e=0.2B) high value obtained of (BCR), that equal to (2.8) time when using gysnothetics materials on replaced soil.

REFERENCES

[1]. Al-Dulaimi, N. S., (2004) "Characteristics of Gypseous Soils Treated with Calicum Chloride Solution", M.Sc. Thesis, Civil Engineering Department, University of Baghdad.
[2]. Al-Jebouri, J. M., (1986) "Bearing Capacity of Footings on Reinforced Sand", M.Sc. Thesis, Civil Engineering Department, University of Mosul.
[3]. Al-Obaydi, A. J., (2003) "Studies in Geotechnical and Collapsible Characteristics of Gypseous Soil", M.Sc. Thesis, Civil Engineering Department, Al-Mustansiriya University.
[4]. Ammar, H. A., Abdrabbo, F. M., and Ashmawy, A. K., (2007) "California Bearing Ratio (CBR) and Bearing Capacity of Geogrid Reinforced Soil", Alexandrie, Egypt University of Alexandrie, www.projects.go2professional .com..
[5]. Annual Book of ASTM Standard, Vol.04.08, (2000).
[6]. Bowles, J. E., (1988) "Foundation Analysis and Design", Fourth Edition, McGraw-hill, New York.
[7]. Casagrande, A. (1932) "The structure of clay and its importance in foundation engineering." J. Boston Society of Civ. Engrs., 19(4), 168-209.
[8]. Das, B. M., (1990) "Principles of Geotechnical Engineering", PWS-KENT Publishing Company, Boston.
[9]. Das, B. M., (2008) "Advanced Soil Mechanics", Third Edition, Brooks/Cole. New York.
[10]. Head, K. H., (1984-1986) "Manual of Soil Laboratory Testing" Volume 1,2, and 3. Prentch Press, London.
[11]. Hesse, P.R. (1971) "A text book of soil chemical analysis ".Chemical Publishing Co., Int., New York.
[12]. Khan, M.A.J., (2005) "Effect of compaction on the behavior of Kirkuk gypseous Soil" M.Sc. Thesis, Civil Engineering Department, University of

Baghdad. [13] Zienkiewicz, O.C., and Taylor, R.L., “The Finite Element Method for Solid and Structural Mechanics” 6th edition, Butterworth-Heinemann, Amsterdam, Boston, London, 2005.

[13]. Razouki, S. S., Al-Omari, R. R., Nashat, I. H., Razouki, H. F. and Khalid, S. (1994) "The problems of gypsiferous soils in Iraq." Symposium on gypsiferous soils and their effect on structures, NCCL, Baghdad.

Table (1) physical properties of gypseous soil.

w_c , (%)	3.2
g_{field} , (kN/m^3)	12.9
g_s	2.41
l.l, (%)	36
p.l, (%)	22
k, (cm/sec), (variable head)	$2.358*10^{-5}$
coefficient of uniformity, c_u	2.12
coefficient of curvity, c_c	1.46

Table (2) chemical properties of gypsies soil.

chemical composition	Percentage, (%)
SO_3	20.86
cl	0.053
gypsum content	45
T.S.S	47.4
$CaCO_3$	13.30
organic content	0.44
pH	8.8-9.2

Table (3) physical properties of dune sand.

g_{used}, (kn/m^3)	16.2
g_s	2.71
k, (cm/sec)	$3.452*10^{-4}$
coefficient of uniformity, c_u	1.67
coefficient of curvity, c_c	0.979

Table (4) chemical properties of dune sand.

chemical composition	Percentage, (%)
SO_3	0.055
cl	0.053
gypsum content	0.24
T.S.S	0.33
organic content	0.13
pH	8.75

Table (5) properties of geogrid used, as supplied by Building research center (Iraq).

grid dimension, (mm)	8*6
thickness, (mm)	3.3
grid weight, (kg/m^2)	0.73
tensile strength (kn/m)	7.68

Table (6) properties of geotextile used, as supplied by Building research center (Iraq).

width of meshes, (mm)	0.10
thickness, (m)	$2.26*10^{-3}$
weight, (gr/m^2)	729
tensile strength warp, (n/5cm)	10870
tensile strength weft, (n/5cm)	2020

Table (7) experimental and theoretical ultimate bearing capacity of (dry state)under different values of eccentricities.

ultimate bearing capacity, (kpa)	theoretical	experimental results
bearing capacity at (e=0.05 b)	551.23	648
bearing capacity at (e=0.1 b)	540.63	635
bearing capacity at (e=0.15 b)	530	565
bearing capacity at (e=0.2 b)	519.40	540

Table (8) experimental and theoretical ultimate bearing capacity of (soaked state) under different values of eccentricities.

ultimate bearing capacity, (kPa)	theoretical	experimental results
bearing capacity at (e=0.05)	134.85	187.5
bearing capacity at (e=0.1 b)	134.60	182
bearing capacity at (e=0.15 b)	134.36	140
bearing capacity at (e=0.2 b)	134.14	125

Figure (1) General View of Testing Equipment.

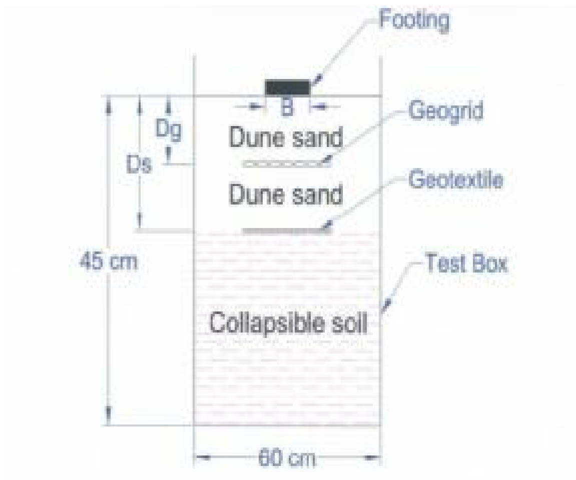


Figure (2) Sketch for the Test Box illustrates some of the Studied Parameters.

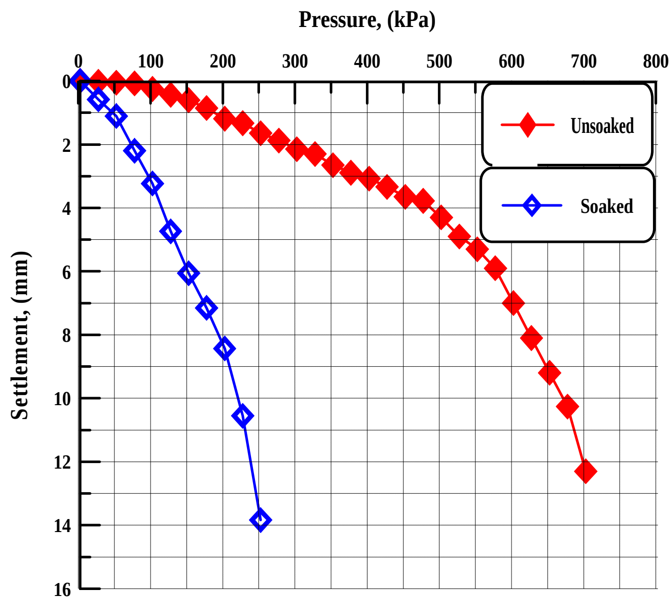


Figure (3) pressure - settlement relation for gypseous soil at dry and soaked state.

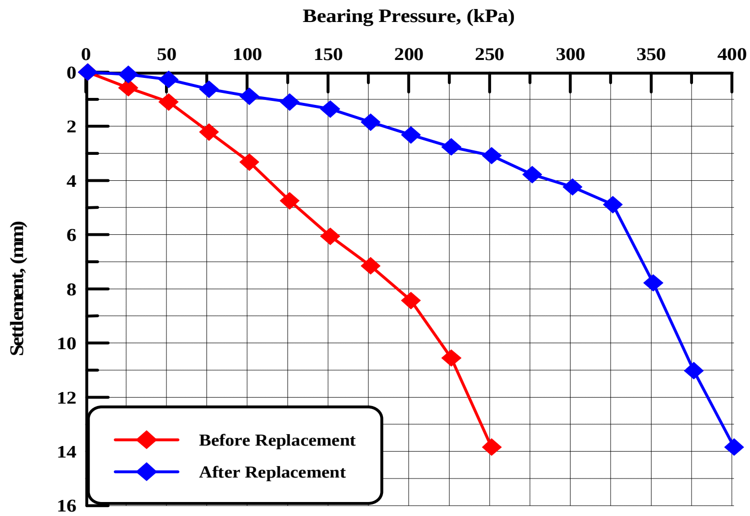


Figure (4) pressure - settlement relation of gypseous soil before and after replacement (soaked soil).

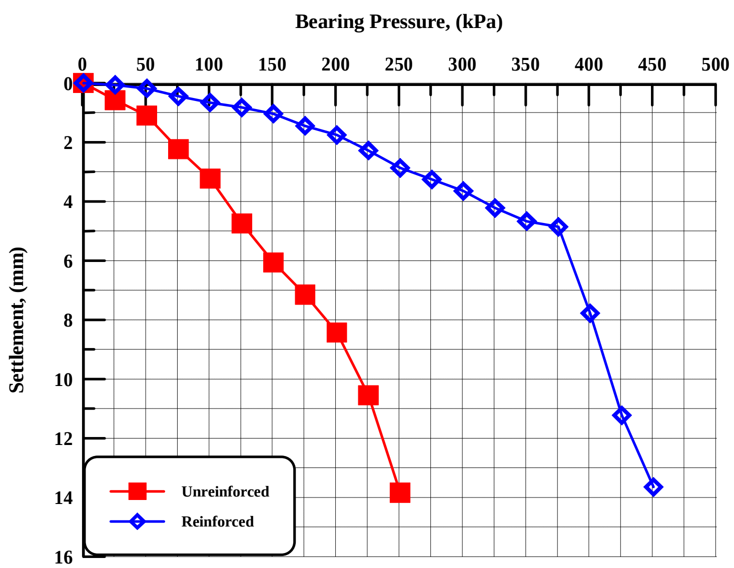
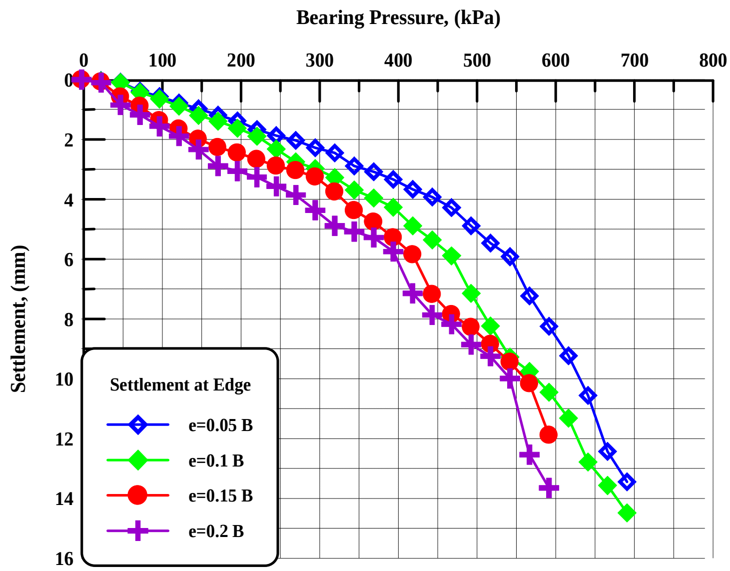


Figure (5) pressure - settlement relation of gypseous soil before and after reinforcement on replaced soaked soil.



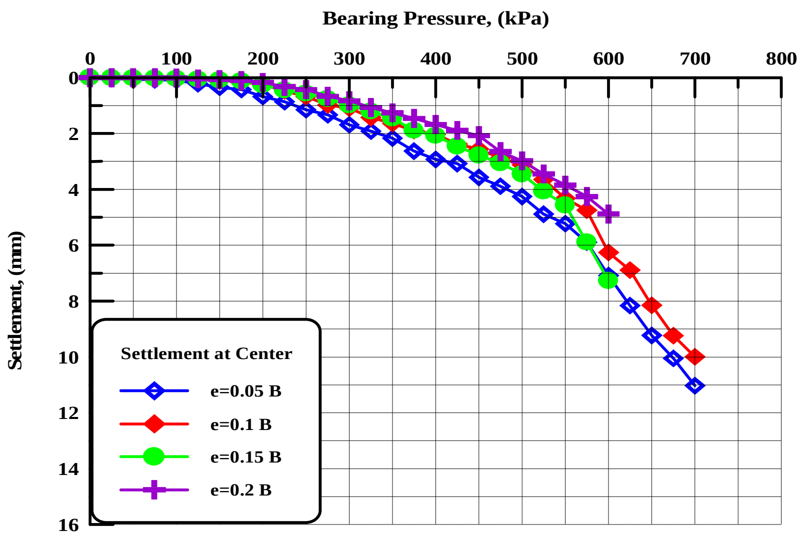
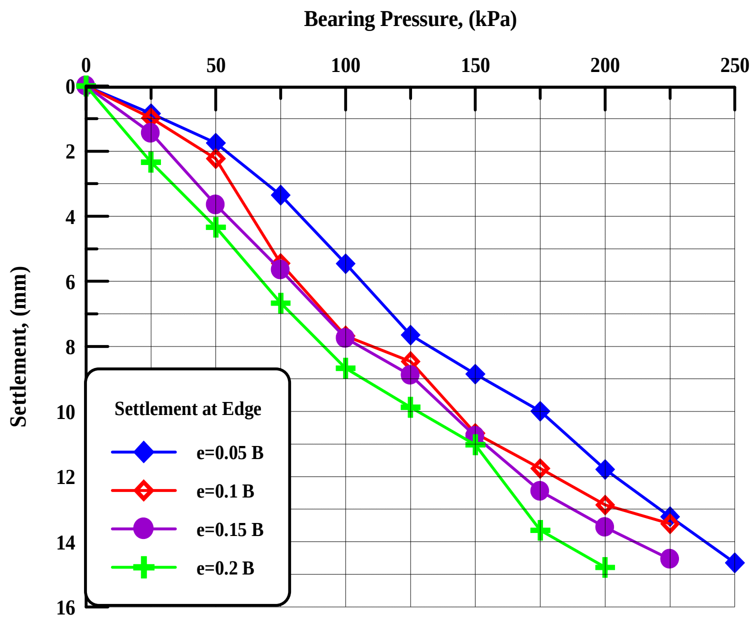


Figure (6) pressure - settlement curves at edge and center for gypseous soil at dry state.



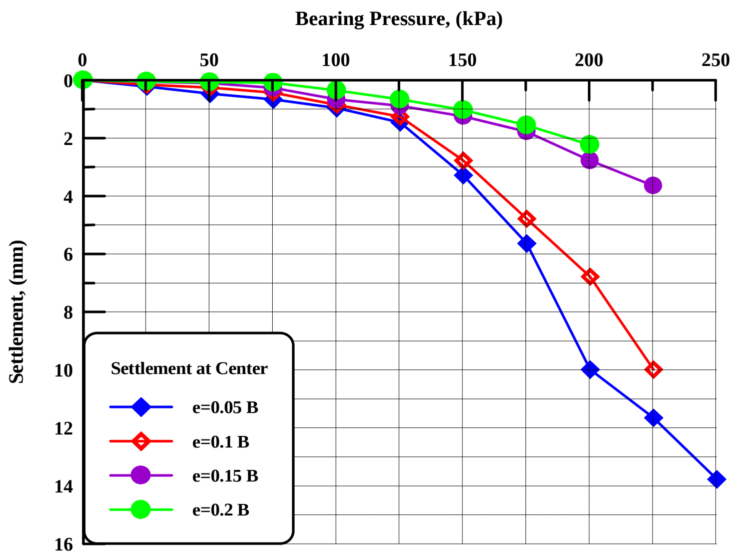


Figure (7) pressure - settlement at edge and center curves at center for gypseous soil at soaked state.

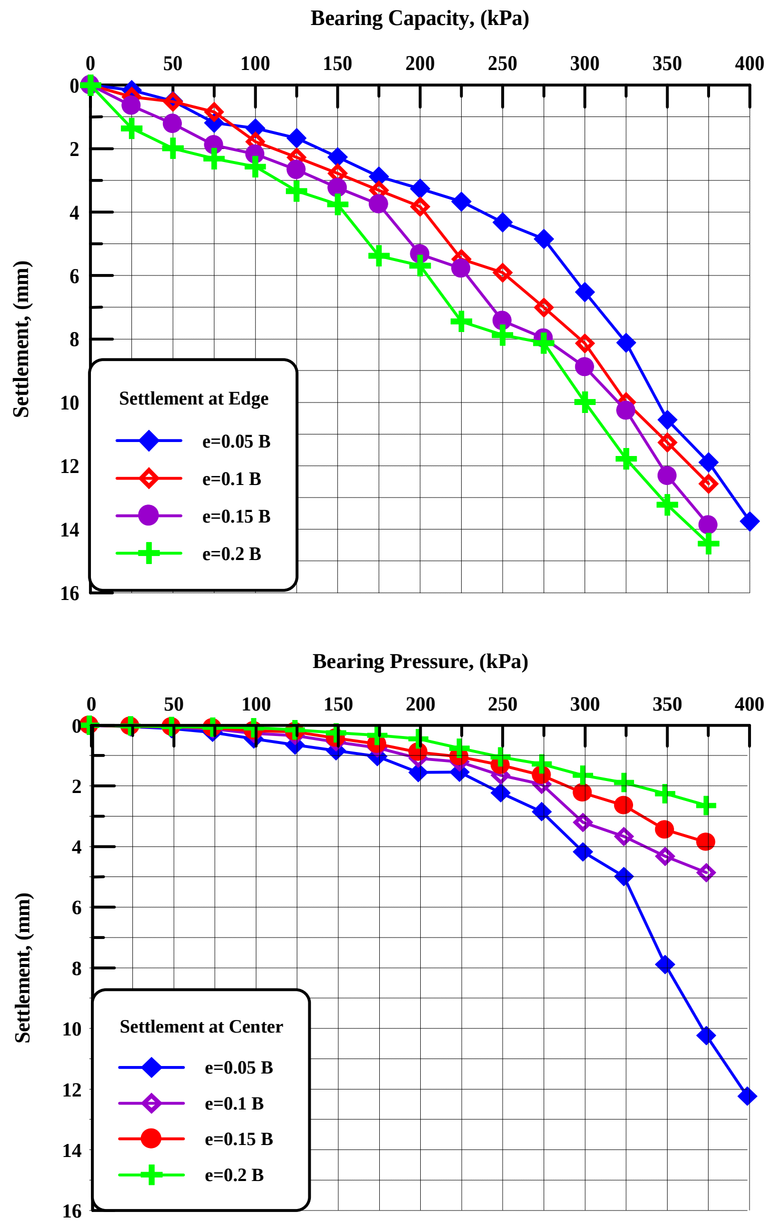


Figure (8) pressure - settlement at edge and center curves for gypseous soil after replacement.

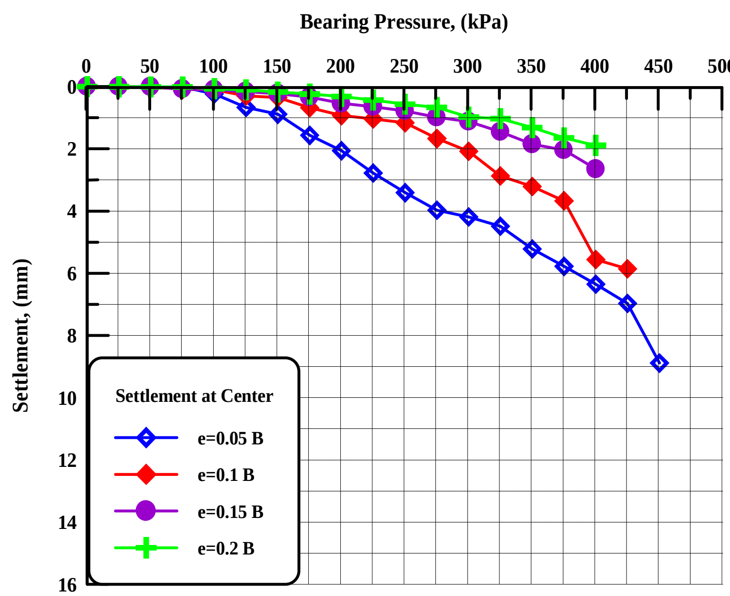


Figure (9) pressure - settlement at edge and center curves for gypseous soil after reinforcement on replaced soaked soil.