# Improvement CBR of Gypseous Soil By Geogrid Under Soaking Condition

**Mohammed Kadum Fakhraldin** **Tawfek Sheer Ali**
*College of Engineering, Kufa University*
kadum_fekheraldin@yahoo.com tawfeeq76@gmail.com

## Abstract

The presence of gypsum in soils causes significant changes in the behavior and alters the properties of these types of soils. Gypsum and anhydrite rocks are often found in many countries of the world in extensive deposits. It was known in Greek as Gypsosa, in German as gips (which could be probably derived from Greek) and in Latin as gypsum. Large area in middle and west of Iraq is classified as a gypseous soil. This paper aims to study the benefit of using Netlon CE121 geogrid as reinforcing material on CBR (California Bearing Ratio) which is adopted as an indication for treatment. A laboratory tests were performed on a gypseous soil samples to study the effect of the first layer location (u) of geogrid and soaking on CBR are studied. 4, 15 and 30 days are adopted as a period of soaking. CBR corresponding to 14 $kN/m^3$ is adopted as a reference value to make the comparisons. The results show that the use of geogrid reinforcement increase the value of California Bearing Ratio (CBR) and the location of first layer of geogrid under the surface have a large influence on CBR, the reliable depth is 0.15D where D is the diameter of CBR mold. CBR value for the optimum point increased almost two times when compared with unreinforced soil. Also CBR decrease when the period of soaking increases for unreinforced and reinforced soil. The experimental results shows that the ultimate bearing capacity increase when CBR increase for unreinforced and reinforced soil.

**Keywords:** Gypseous soil, CBR test, Geogrid.

## الخلاصة

إن وجود الجبس في التربة يسبب تغيرات مهمة في التصرف و يغير من خواص هذه الترب. الجبس و الصخور غير المتميأة توجد عادة في دول عديدة من العالم على شكل تجمعات واسعة. عرفت عند الإغريق بالجبس (Gypsosa) و عند الالمان بالجبس (Gips) (والمشتق من تعبير الإغريق) في اللاتينية (Gypsum). هنالك مساحات واسعة في وسط و غرب العراق تصنف على أنها تربة جبسية. هذا البحث يهدف الى دراسة فوائد استخدام مشبكات تسليح التربة من نوع Netlon CE121 كمادة تسليح على نسبة التحمل الكاليفورني (CBR) الذي أعتمد كمؤشر للمعالجة. أجريت مجموعة من الفحوصات المختبرية على نماذج من التربة الجبسية لدراسة تأثير موقع الطبقة الأولى لتسليح التربة و فترة تنقيع التربة والتي أخذت 4 و 15 و 30 يوم. قيمة الـــ CBR المقابلة لكثافة 14 $kN/m^3$ أعتمدت كأساس للمقارنة. النتائج بينت أن استخدام مشبكات تسليح التربة يزيد من قيمة الـــ CBR و إن موقع طبقة التسليح الأولى له تأثير كبير على هذه القيمة وقد وجد أن الموقع الأمثل للطبقة الأولى هو 0.15D و D هو قطر قالب الـــ CBR. إن قيمة التحسن في الـــ CBR تصل الى الضعف مقارنة بالتربة غير المسلحة وأن قيمة الـــ CBR تقل بازدياد فترة التنقيع لحالتي التربة الغير مسلحة والتربة المسلحة. النتائج أوضحت كذلك أن قابلية تحمل التربة القصوى تزداد بازدياد قيمة الـــ CBR في حالتي التربة الغير مسلحة والتربة المسلحة.

**كلمات المفتاحية :** التربة الجبسية، أختبار CBR، مشبكات تسليح التربة.

## 1. Introduction

Gypseous soils are those containing more than two percent gypsum by weight. Gypsum [$CaSO_4.2H_2O$] is the most important and abundant hydrous sulphates. The structure of gypsum consists of parallel layers of $SO_4$ groups strongly bounded to $(Ca)^{+2}$. Successive layers of this type are separated by sheets of $H_2O$ molecules. The bonds between $H_2O$ molecules in neighboring sheets are weak which explains the excellent clearage in gypsum. Gypseous soils cover about 60% of the world area (Van Alphen and Romero, 1971).

The gypsum content usually varies in such soils from few percents to more than (90%) as in rocks of gypsum. Specific gravity of gypsum is 2.3 (Blyth, 1971), and is considered to be a fairly soluble salt and a highly gypseous soil when the percent of gypsum is 25% (Barazanji, 1973). Gypseous soils in Iraq covers about 31.7% of the total area.

Nashat (990) investigated the properties and behavior of gypseous soil taken from three different sites in Iraq (Baiji, Tellafer and Al-doara). The influence of soaking and leaching on the mechanical properties was investigated using one dimensional row cell consolidated–undrained triaxial cell (CU). The results showed that the conventional testing procedures were not applicable to the gypseous soil because it did not take into account the solubility of gypsum and its mobility to leaching, the conclusions show also that the soaking and leaching process of gypseous soil lead to great reduction in shear strength and high settlement.

Shewnim (2006) presents the analysis results of 7 researchers in Iraq. The data collected included basic properties for each sample in addition to the results of the two collapsibility tests. A total of 50 samples were analyzed and it was noticed that 33 % of the investigated soils have a CP (Collapsibility Potential) less than 1% which are considered as "No Trouble" soils and about 60% have a CP ranging between 1 and 5 which are considered as "Moderate Trouble" soils. The factors affecting collapsibility were presented and it appeared that the initial water content, void ratio and total unit weight are the major factors while the gypsum content and plasticity index seem to have lesser effect.

Aziz and Ma (2011) investigated the fuel oil suitability in improving gypseous soil. Laboratory tests were performed on two samples of soil (soil I with 51.6% gypsum content, and soil II with 26.55%), where the two soils obtained from Al-Therthar site (Al-Anbar Province-Iraq). The study examined the improvement properties of soil using the gypsum material which is locally available with low cost to minimize the effect of moisture on these soils by using the fuel oil. The main results show that the increasing the fuel oil content was effective in Increasing the durability that the percent of 2% of treatment gives more durable time than the untreated soil, while the percent of 4, 6 and 8% give durability for all periods of the test and may be still durable for all age of the structure. Also, using of 4% for sandy soils and 3% for clayey soils of fuel oil is the suitable solution for treatment the gypseous soil from the collapsibility. In the same time maintain enough value of bearing capacity suitable for carrying the loads coming from the structure.

Bushra and Rusul (2013) conducted many tests on model loading gypseous soil improved by replacement with dune sand and use of geotextile and geogrid under different values of eccentricities with condition of soaking. Tests were performed on homogenous soil partially replaced gypseous soil with dune sand reinforced with geotextile reinforcement layer at the interface. After replacement and reinforcement of gypseous soil bearing capacity increases to (2.5-3.0) times.

Laith (2014) presented a theoretical models by using PLAXIS 2D Professional v.8.2 to study the improvement of bearing capacity of gypseous soil under circular footing by two methods, first by use of a trench of cement dust under footing and the second by geogrid. Main conclusions presented that the ultimate bearing capacity increased as D/2R ratio increased, The largest ratio of improvement gotten for soil improved by cement dust at D/2R=3 and the use of geogrid increase the ultimate bearing capacity when u/B increases, the results also show that after the value of u/B = 0.3 the ultimate bearing capacity be a relatively constant value.

## 2. Materials and Testing

### 2.1 Soil Properties

The soil used in this study is taken from an arbitrary site in Bahr Al-Najaf which is characterized with an assemblage of gypseous soils. Table 1 shows a physical and chemical of the soil. Physical properties include water content, sieve analysis, specific gravity and maximum density. Chemical properties include gypsum content, SO3 content and total soluble salt content (T.S.S).

Figure 1 shows a sieve analysis of soil which is carried out according to ASTM (D422-2007). The soil was classified as SP type (Poorly graded sand with little or no fines) according to the Unified Soil Classification. The used soil is classified as a highly gypseous soil according to Barazanji (1973).

**2.2 Geogrid**

Geosynthetics are the generally polymeric products used to solve civil engineering problems. This includes nine main product categories: geotextiles, geogrids, geonets, geomembranes, geosynthetic clay liners, geofoam, geocells and geocomposites geopipe. The polymeric nature of the products makes them suitable for use in the ground where high levels of durability are required. Properly formulated, however, they can also be used in exposed applications.

Netlon CE121 geogrid shown in Fig. 2 is used in this study. Selection of this type was according to the results of the study of Fakhraldin (2013) in which he pointed out that among eleven geogrid types the **Netlon CE121** geogrid have tensile strength and elastic modulus higher than that of other geogrids made by different manufactures. Fakhraldin (2013) presented a stress-strain behavior of Netlon CE121 geogrid as in Fig. 3. The properties of this type is listed in table 2.

**Table 1:** Chemical and physical properties of used soil

| **The chemical Properties** | |
|---|---|
| $So_3$ | 4.6% |
| T.S.S | 1% |
| Organic | 0.1% |
| Gypsum | 27.76% |
| **The physical properties** | |
| $G_s$ | 2.6 |
| $\gamma_{d\ max}$ | 21.2 kN/m$^3$ |
| $e_{min}$ | o.44 |
| O.M.C | 9.5% |
| LL | 30% |
| PL | 19% |
| PI | 11% |
| $C_u$ | 2.1 |
| $C_c$ | 1.15 |
| M.C | 7.25% |

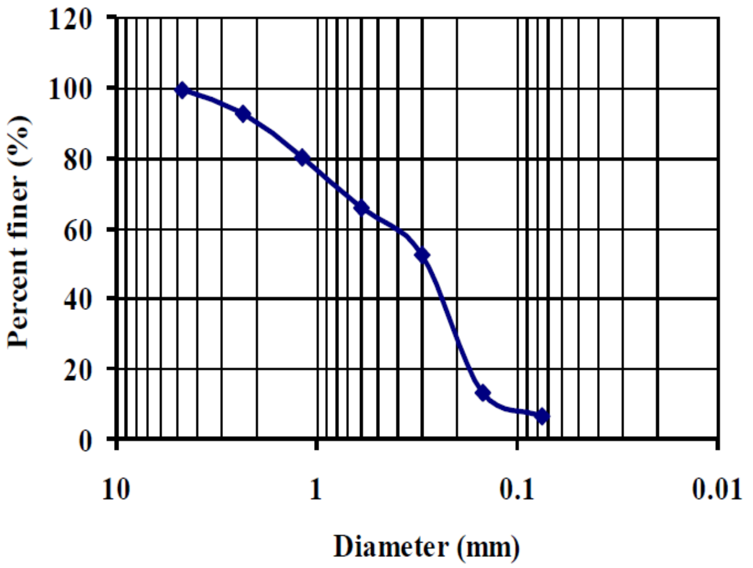


**Figure (1) Grain size distribution of used soil, ASTM (D422-2007)**

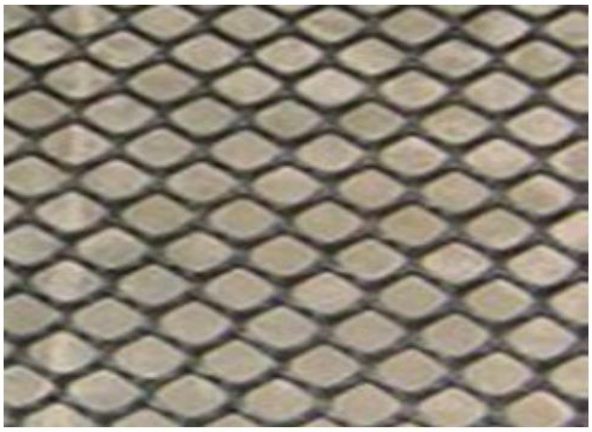

**Figure (2) Grain size distribution of used soil**

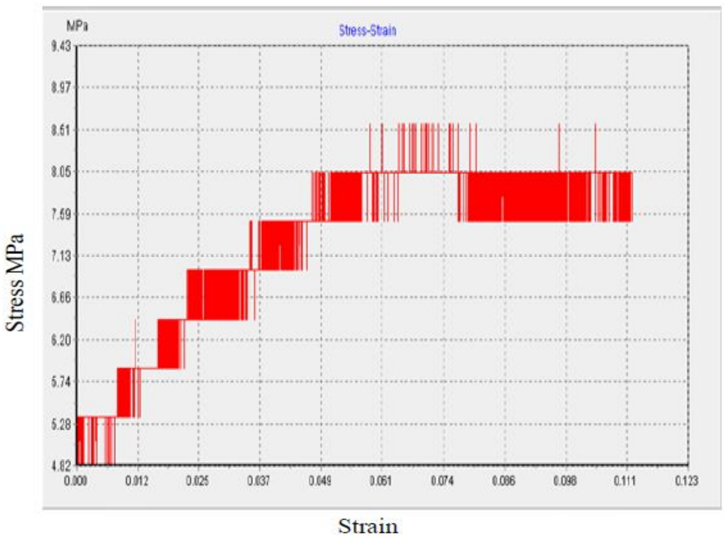


**Figure (3) Stress-Strain behavior of Netlon CE121 geogrid, (Fakhraldin, 2013)**

## 2.3 CBR Test

CBR test is a laboratory penetration test used to evaluate of base, subbase and subgrade layer strength of roads and pavements. The CBR was developed in the 1950's by the California Department of Transportation, and since then it has been used extensively for pavement design purposes. Initially it was intended to describe granular aggregates with sizes ranging between 4.75 mm and 20 mm. More recently it has been used for soil materials. Renovation of the CBR Design Procedure," Second International Airports Conference: Planning, Infrastructure & Environment. São Paulo, Brazil. California Bearing Ratio test is performed according to ASTM D1883-07, the equipment and the accessories of the test are shown Fig. 4.

To simulate the effect of long – term soaking field condition, the soaked CBR is determined on a representative sample of the soil, at the beginning of compaction of each specimen and other sample of the remaining material after compaction of each specimen, the moisture content is determined then according to D2216. The optimum moisture content and maximum dry density in accordance with the compaction method specified D1557 are determined. The complete water content-unit weight relation for the 10-blow and 30-blow per layer compactions is developed and each test specimen compacted is penetrated. water content-unit weight relation for the 65-blows is developed also to specified unit weight at or near 100 % maximum dry unit weight because it will be necessary to include a compactive effort greater than 56-blows per layer (ASTM D854-05, 2007). All compaction is performed in the CBR mold. Figure 4 shows the relationship between load and penetration for the unreinforced 4 days soaking soil case presented as a sample of CBR procedure test. Using corrected stress values taken from the stress penetration curve (Fig. 5) for 2.54 mm and 5.08 mm penetrations, calculate the bearing ratios for each by dividing the corrected stresses by the standard stresses of 6900 kPa and 10300 kPa respectively (ASTM D854-05, 2007), the higher value is adopted as a CBR. The procedure performed using three specimens for each 4, 15 and 30 days soaking to achieve the requirements of a shorter immersion period adopted by (ASTM D854-05, 2007).

**Table (2)** Typical properties of Netlon CE121 geogrid, (Fakhraldin, 2013)

| Property | Units | Data |
|---|---|---|
| Unit weight | $kg/m^2$ | 0.74 |
| Dimensions | | |
| Aperture size | mm | 6 × 8 |
| Rib thickness | mm | 1.6/1.4 |
| Rib width | mm | 2/2.75 |
| Junction thickness | mm | 2.75 |
| Roll width | m | 4 |
| Roll length | m | 50 |
| The mechanical properties | | |
| Peak Tensile Strength | kN/m | 6.4 |
| Elastic modules | Gpa | 0.39 |
| Tensile strength | Mpa | 9 |
| Total extension strength | Mpa | 5 |
| Total elongation | % | 11 |

## 3. Results And Analysis

A series of CBR laboratory tests on gypseous soil samples without and with reinforcement by geogrid. The tests are performed under soaking condition to simulate the long-term soaking case. 4, 15 and 30 days adopted as a periods of soaking. CBR results are recorded and the comparisons are drawn as follows:

**Figure (4) CBR equipment**

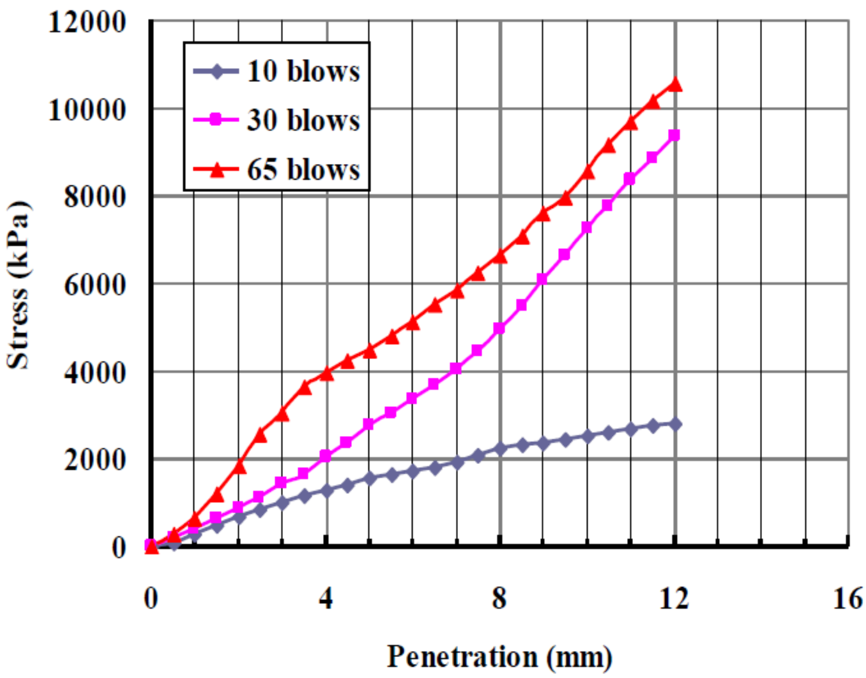


**Figure (5) Load - Penetration curves of CBR test, (ASTM D854-05, 2007)**

### 3.1 Dry Unit Weight and CBR Relationship

Design CBR for one water content only using the data obtained from the 3 specimens by plotting the CBR-dry density as molded relation for 4, 15 and 30 days as a periods of soaking as shown in Fig. 6 for unreinforced soil.

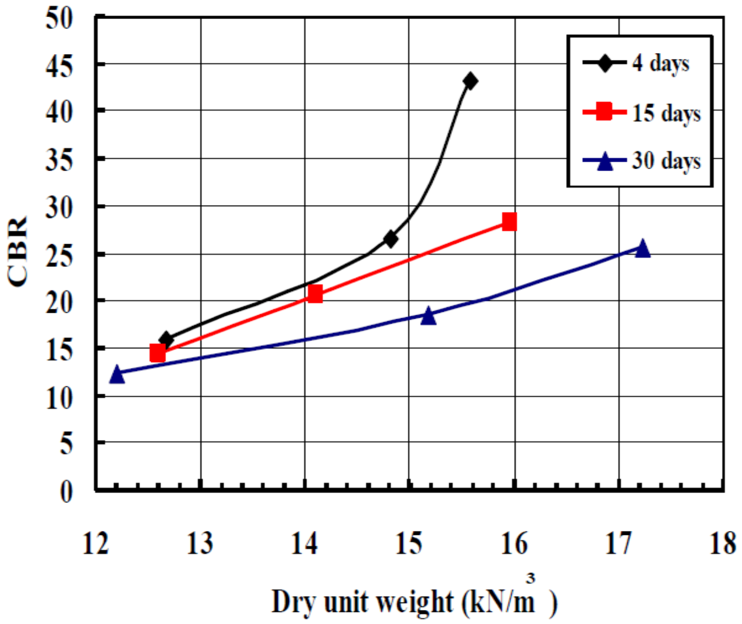


**Figure (6) Dry unit weight and CBR relationship for unreinforced soil**

To make a comparison for different cases of this study, the value corresponding to dry unit weight of 14 kN/m$^3$ is adopted as a value of each period of soaking. For the same periods of soaking, four reinforcement positions which were used (u) in reinforced soil case i.e. 0.1D, 0.15D, 0.2D and 0.25D where D is the CBR mold diameter to study the reliable position of geogrid layer, schematic explains the case is shown in Fig. 7.

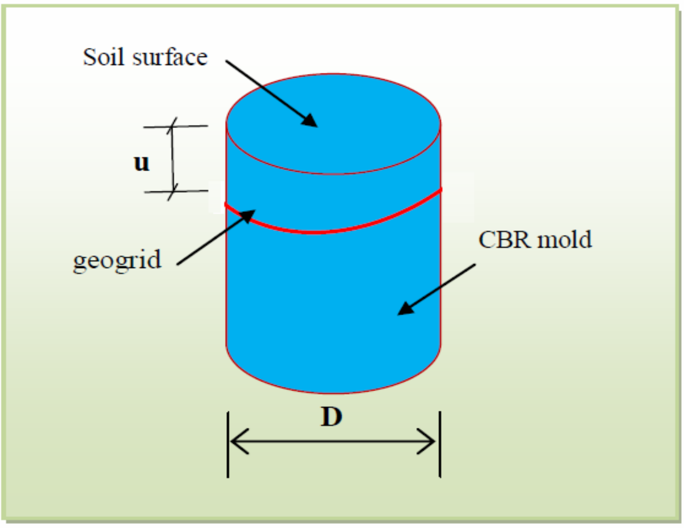


**Figure (7) Reinforced case schematic**

Figures 8 to 11 show the relationship between the dry density and CBR value for all samples which are needed to indicate the CBR value with 95% of the maximum dry density in accordance to test method.

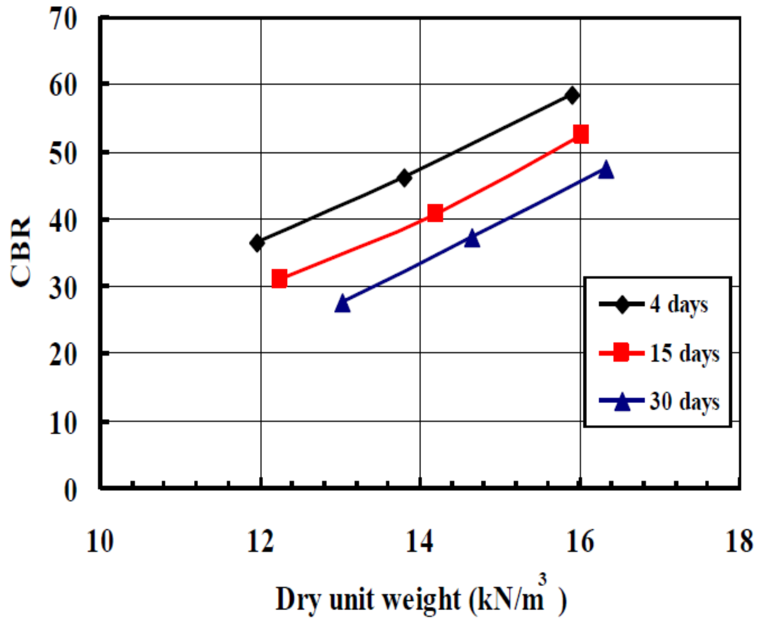


**Figure (8) Dry unit weight and CBR relationship of reinforced soil for geogrid at 0.1D**

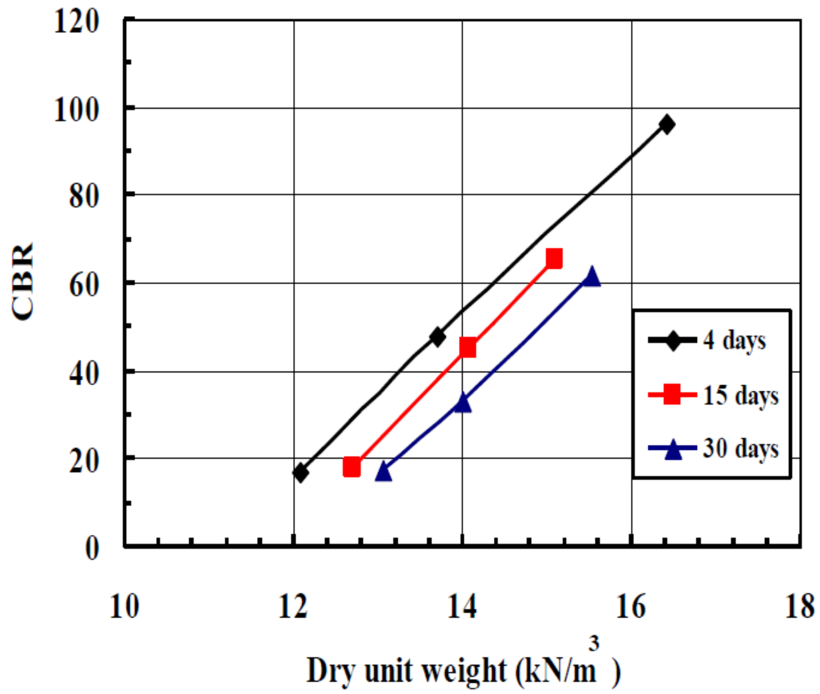


**Figure (9) Dry unit weight and CBR relationship of reinforced soil for geogrid at 0.15D**

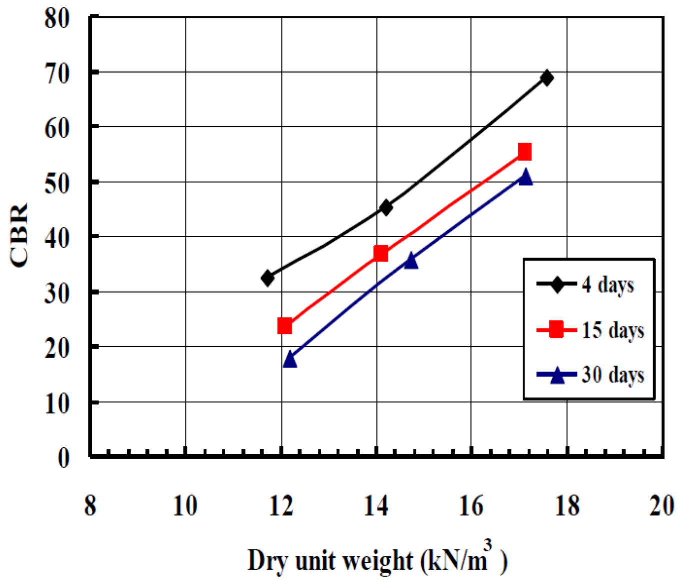


**Figure (10) Dry unit weight and CBR relationship of reinforced soil for geogrid at 0.2D**

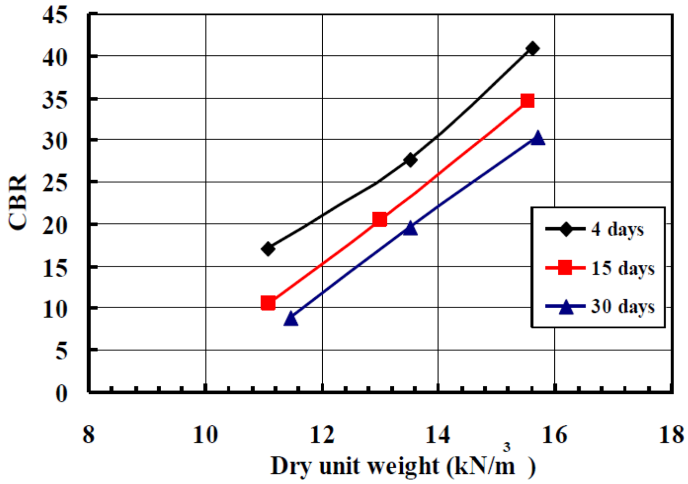


**Figure (11) Dry unit weight and CBR relationship of reinforced soil for geogrid at 0.25D**

Figure 12 presents the CBR values for individual samples (4 days soaking). The null u/D value on x-axis corresponding to unreinforced soil case. From this figure it can be seen that, CBR value increased slightly with increasing depth of geogrid layer height up to 0.1D, then there is a significant increase between 0.1D-0.15D as the latter represents the optimum position. Finally CBR value decreased slightly after 0.15D depth i.e. with 0.2D and 0.25D. Accordingly, there is a substantial enhancement in the CBR for the gypseous soil with 0.15D geogrid layer position in comparison with the unreinforced gypseous soil.

### 3.2 Effect of Soaking on CBR

From the laboratory results, it can be concluded that there is an attractive increase in CBR value when using geogrid into the soil layer. The soaking is an important factor affect the stability of gypseous soil, therefore, effect of the period of soaking on CBR was studied and presented in Figs. 13 and 14. It can be seen that the CBR value decrease when the period of soaking increase, this can be attributed to the higher suction in the soil and hence loss in strength. It can be seen also that the CBR value increase when the soil reinforced by geogrid. The larger the value of CBR when the geogrid layer at a depth of 0.15D, thus the reliable position of the geogrid layer 0.15D. Moreover, CBR value for the optimum point increased almost two times when compared with unreinforced soil.

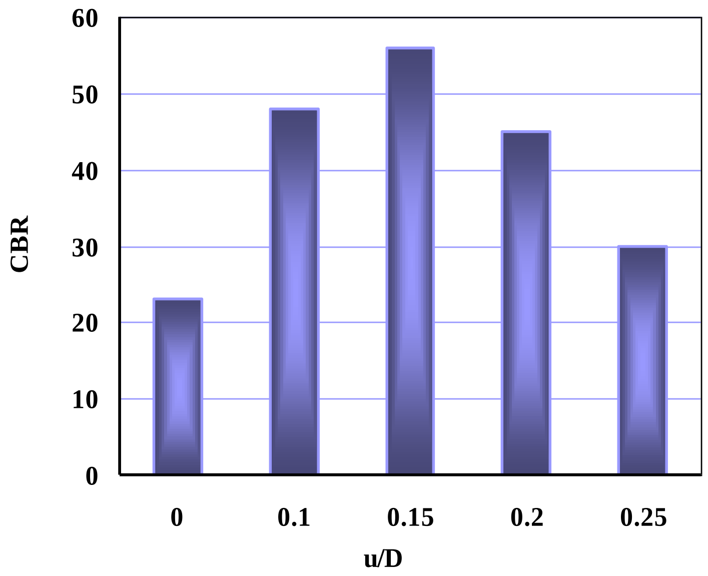


**Figure (12) CBR value for different samples for 4 days soaking**

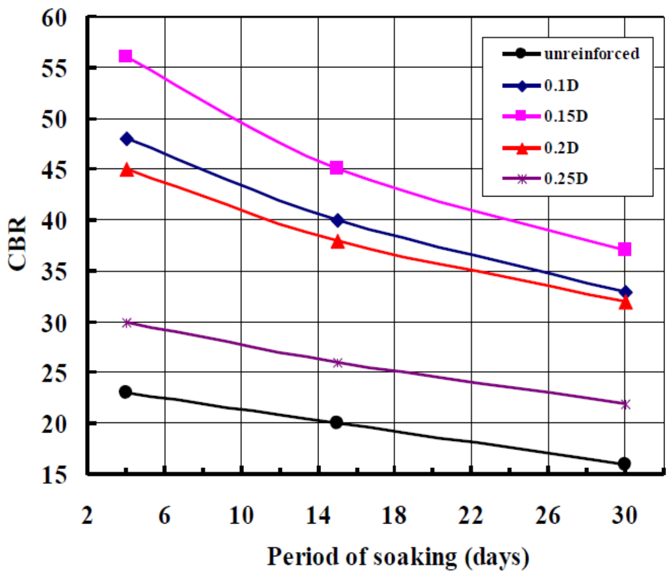


**Figure (13) Period of soaking and CBR relationship**

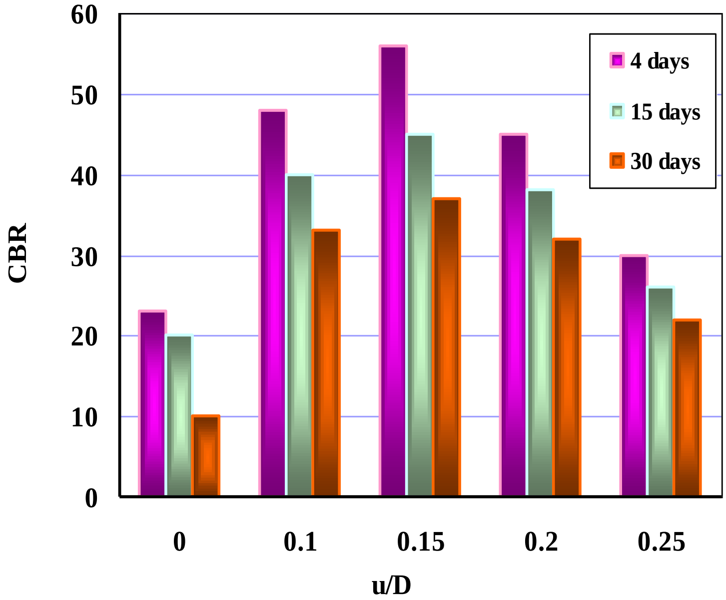


**Figure (14) u/D and CBR relationship for unreinforced and reinforced soils**

### 3.3 Correlation between CBR and Bearing Capacity

The value of CBR is commonly used as an index of soil strength and bearing capacity. This value is used and applied in design of the base and the sub-base material. CBR test is a simple strength test that compares the bearing capacity of a material with that of a well-graded soil. It is primarily intended for, but not limited to, evaluating the strength of cohesive materials having maximum particle sizes less than 19 mm (0.75 in.). The CBR test is essentially a test which results in shear failure of the soil under the plunger. Shear failure occurs when the ultimate bearing capacity is reached. The ultimate bearing capacity of the soil under the circular plunger can be determined by Terzaghi's method. It may be assumed that at a penetration of 0.1 inch the stress applied to the soil close to its ultimate bearing capacity ($P_f$). the stress on the standard material at 0.1 inch penetration is 1000 psi yielding.

$$CBR = \frac{P_{0.1}}{P_{s0.1}} \times 100 = \frac{P_f}{1000} \times 100$$

$$P_f\,(psi) = 10 \times CBR$$

$$P_f\,(kPa) = 10 \times CBR \times 6.894$$

For example, if CBR value is 50, then the ultimate bearing capacity obtained becomes 3447 kPa.

To show the relationship between CBR and bearing capacity, the case of higher value of CBR i.e. 0.15D position of geogrid layer is adopted and Fig. 15 is drawn.

Due to a linear relation between CBR value and the ultimate bearing capacity, the ultimate bearing capacity increase. Figure 16 illustrate the relationship between the period of soaking and ultimate bearing capacity. It can be found that the ultimate bearing capacity decrease when the soil soaked for a longer time.

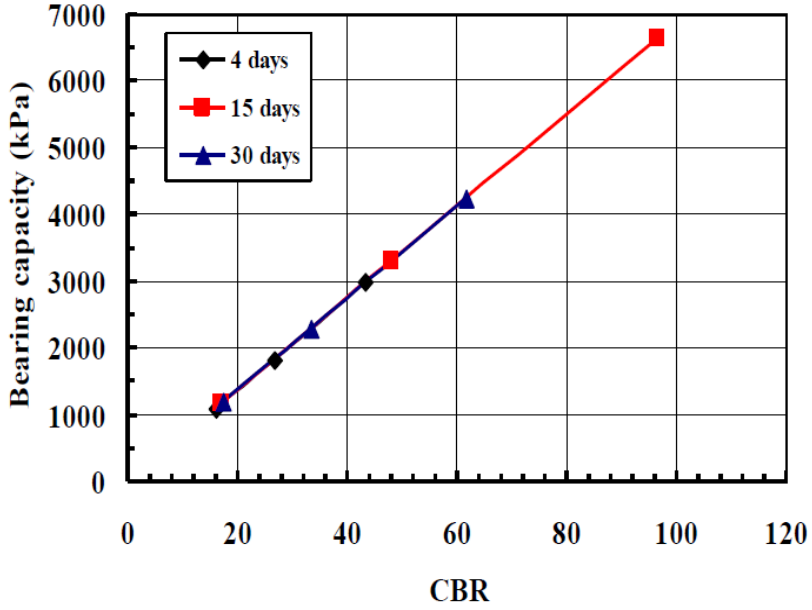


**Figure (15) CBR and bearing capacity relationship for position 0.15D geogrid layer**

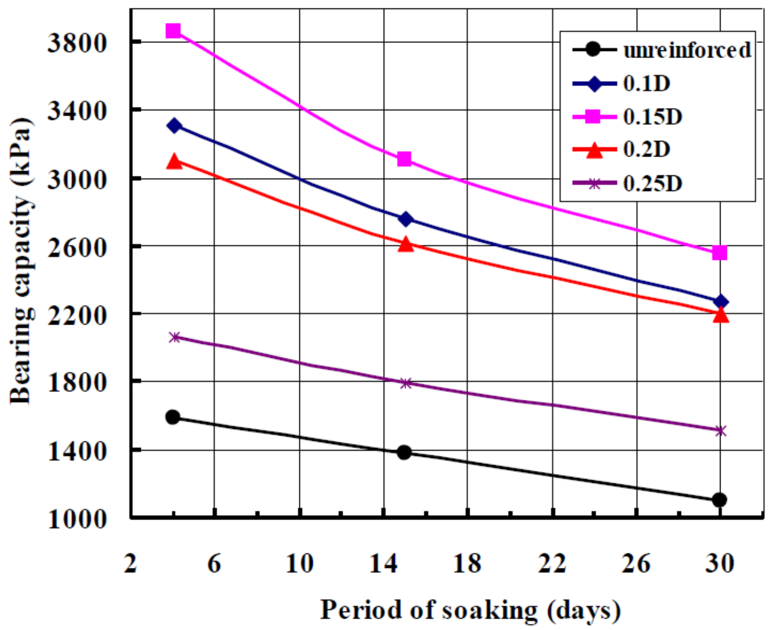


**Figure (16) Relationship between period of soaking and bearing capacity relationship**

**4. Conclusions**

This paper describes an experimental study which is concentrated on studying the reliable position of the first layer of geogrid used to improve CBR value of the gypseous soil which is covers a large area of Iraq. 4, 15 and 30 days' periods of soaking for unreinforced and reinforced gypseous soil with different depths of geogrid layer i.e. 0.1D, 0.15D, 0.2D and 0.25D.

Many conclusions can be drawn from the results of the study as:

1. For all samples the use of geogrid reinforcement increase the value of California Bearing Ratio (CBR), CBR value for the optimum point increased almost two times when compared with unreinforced soil.
2. CBR value increased slightly with increasing depth of geogrid layer height up to 0.1D, then there is a significant increase between 0.1D-0.15D as the latter represents the optimum position.
3. CBR value decreased slightly after 0.15D depth i.e. with 0.2D and 0.25D. Accordingly, there is a substantial enhancement in the CBR for the gypseous soil with 0.15D geogrid layer position in comparison with the unreinforced gypseous soil.
4. The position of first layer of geogrid under the surface have a large influence on CBR, the position 0.15D gives a higher value of CBR for all samples, therefore it can be say that the reliable depth is 0.15D where D is the diameter of CBR mold.
5. CBR decrease when the period of soaking increase for unreinforced and reinforced soil. This reduction in CBR in highly gypseous soils because of the duration of soaking is of great significance as the dissolution of gypsum is increased the longer the soaking period.

6- CBR has a direct effect on the ultimate bearing capacity of gypseous soil. The experimental results shows that the ultimate bearing capacity when CBR increase for unreinforced and reinforced soil**.**

## References

ASTM D854-05, 2007, "Standard Test Method for California Bearing Ratio of Laboratory-Compacted Soils".

Barazanji, A.F., 1973, "Gypsiferous Soils of Iraq", Ph.D. Thesis, University of Ghent, Belgiumm.

Blyth, F.G.H., 1971, "A Geology for Engineerings", Fifth Edition, Edward Arnold Ltd. London.

Bushra S. Albusoda and Rusul S. Hussein, 2013, "Bearing Capacity of Eccentrically Loaded Square Foundation on Compacted Reinforced Dune Sand over Gypseous Soil", paper presented at Journal of Earth Sciences and Geotechnical Engineering, vol. 3, no. 4, 47-62.

Fakhraldin M. K., 2013, "Properties Measurements and Applications of some Geogrids in Sand", PhD Thesis, Alnahrain University, Iraq.

Hussein Yousif Aziz and Jianlin Ma, 2011, "Gypseous Soil Improvement using Fuel Oil", paper presented at World Academy of Science, Engineering and Technology, Vol. 5, 03-29.

Laith J. Aziz and Suhad Abdulsattar, 2014, "The Bearing Capacity of a Circular Footing on Gypseous Soil Before and after Improvement", paper presented at Kufa Journal of engineering (K. J. E), vol. issue 1, Iraq, 2014.

Nashat, I.H., 1990, "Engineering Characteristics of Some Gypseous Soils in Iraq", Ph.D. Thesis, Civil Engineering Department, University of Baghdad, Iraq.

Shewnim N. Seleam, 2006, "Evaluation of Collapsibility of Gypseous Soils in Iraq", paper presented at Journal of engineering, vol. 13 no. 3, 712-726, University of Technology, Iraq.

Van Alphen and Romero, 1971, "Gypseous Soils, Notes on their Characteristics and Management", International Institute for Land Reclamation and Improvement, Wageningen, Netherlands.