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CREEP BEHAVIOR OF IRAQI GYPSIFEROUS SOIL

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Abstarct: The work describes a research study the creep behavior of a gypsiferous soil, the soil used throughout this study was taken from location of Tikrit University site in Salah El-Deen City in Iraq. The soil was clayey sand and classified as (SC) according USCS with a gypsum content of (48.92%). The mineralogical and chemical properties of the soils were determined. The Odometer test was used throughout the test programs. A series of double and single oedometer tests for a long period time were performed in this work .The results indicate that the soil is of low compressibility when loaded under drying condition for both 1day and 64 day respectively while high compressibility it can be noticed for wet soil sample under the same loading period. The collapse potential increases with logarithm of time noticed for 200 kPa stress (8.17% at 1day to 16.17% at 64 days) and (12.2% at 1 day to 14.7% at 64 day) for 1600 kPa stress. The results showed that the increases in collapse potential with the increasing applied stress for the samples loading for 1 and 64 day, also it can be observed high decrease in collapse potential (21.2 % to 14.7 %) after 800 kPa stress for 64 day loading sample. Also the results show nonlinear relations between the creep rate and logarithm of time, the creep rate decrease about (4.4% and 2.5 %) from 1day to 64 day for 200 and 1600 kPa stress respectively.

Keywords: *Creep, gypseous soil, collapse, time, creep rate.*

تصرف الزحف في التربة الجبسية العراقية

الخلاصة: يصف العمل دراسة بحثية سلوك زحف التربة الجبسية، التربة المستخدمة في اجراء هذه الدراسة مأخوذة من موقع جامعة تكريت في مدينة صلاح الدين في العراق. التربة صنفت نوع رمل طيني و (SC) على اساس النظام الموحد مع نسبة جبس (48.92%). استخدم فحص الانضمام لاجراء هذه الدراسة. أجريت سلسلة من الاختبارات فحص الانضمام المزدوج والمفرد لمدة فحص طويلة في هذا العمل. بينت النتائج أن التربة منخفضة الانضمام عند التحميل في حالة الفحص لنموذج جاف ليوم واحد 64 يوم على التوالي بينما الانضمام عالي في حالة فحص نموذج التربة الرطبة تحت نفس الفترة تحميل. احتمالية الانهيار يزداد مع لوغارتم الزمن لحالات الإجهاد 200 كيلوباسكال (8.17% في يوم واحد إلى 16.17% في 64 يوما) و (12.2% في يوم واحد إلى 14.7% في 64 يوما) للاجهاد 1600 كيلوباسكال. أظهرت النتائج الزيادة في احتمالية الانهيار مع زيادة الضغط للعينات تحميل 1 و 64 يوما، كما يمكن ملاحظة انخفاض كبير في احتمالية الانهيار (21.2 % إلى 14.7 ف%) بعد 800 كيلوباسكال. ايضا اظهرت النتائج علاقة غير خطية بين معدل الزحف ولوغارتم الزمن حيث ان معدل الزحف يقل بمقدار (4.4 % و 2.5 %) لمدة 1 و64 يوم وتحت اجهاد 200 و 1600 كيلوباسكال بالتوالي.

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1. Introduction

Gypsiferous soils are problematic from the engineering view. There are many problems that have been noticed when structures were constructed on gypsiferous soils in the last three decades in Iraq. These problems are related to collapsing of the soil, increasing leakage of water through the soil, softening of the soil and attack of sulfate to concrete. All these problems are related to the continuous and slow dissolution of gypsum by seeping water through the gypsum containing soil. The presence of gypsum in soil affects its engineering properties and behavior in a degree, which is greatly dependent on the amount of gypsum present in the soil. Gypsiferous soil in Iraq constitutes 7.3 to 10 percent of the total world gypsiferous area and it forms 11 to 15 percent of the area of Iraq [1]. The presence of gypsum in soil alters its behavior, in other words, there is a large influence of gypsum on the physical and mechanical properties of soil. This influence depends mainly on the amount and type of gypsum present in the soil.

Gypseous soils are characterized by decreasing strength upon wetting and increasing primary and secondary compression in addition to the dissolution in continuously seeping water.

In general, gypseous soils are reliable for construction under dry and even under short term flow, but become problematic, collapsible and undergo large settlement under long term flooding with water, [2]. Gypseous soils offer a relatively rapid settlement due to the addition of water because the loose particle structure is cemented together with soluble minerals and/or with small quantities of clay. Water infiltration into such soils can break down the inter-particles cementation, resulting collapse of the soil structure.

Time-dependent deformation and stress relaxation in soils are important in a variety of geotechnical problems where long-term behavior is of concern. Previous studies on soils showed that the magnitude of delayed compression (creep) is controlled by compressibility and soil sensitivity in addition to preconsolidation [3].

1. Creep of Soil

When a soil is loaded under a constant total vertical stress in one-dimensional conditions, it continues to settle after dissipation of the excess pore pressures, which is known as creep. Estimating creep settlement has been an interesting area of research for a long time [4]. In geotechnical engineering, the consolidation of soils comprises three distinct phases corresponding to three different phenomena.

a. Instantaneous or immediate settlement, before the expulsion of water, corresponding to the undrained deformation of soil.
b. Primary settlement (or hydrodynamic consolidation), corresponding to the dissipation of the interstitial pore water pressure, u. The duration of this phase (for u=0) can be estimated, provided the configuration of the layer, compressibility and permeability are known.
c. Secondary settlement, which is the consequence of creep, obeys a linear law in the logarithm of time .

In the time-dependent deformation (secondary consolidation), the coefficient of secondary consolidation Cα, is helpful in determining the creep settlement at the end of primary consolidation and is often considered to be the slope of the linear portion of the void ratio (or compression) versus the logarithm of time curve in the secondary compression region. It is noted that the secondary consolidation is the creep settlement after the end of the primary consolidation. In fact, creep occurs during the whole consolidation process [5].

Results of long term creep tests have shown that the relationship of creep strain to log (time) is not a straight line [6]. The slope of the graph of creep strain against log (time), commonly denoted by coefficient of "secondary" consolidation decreases with time. Thus, the use of logarithmic function may overestimate the creep settlement.

The previous researches [7]; [8]; [9]; [10]; [11]; [12]; [13] and [14] having concentrated their efforts on experimental studies of the creep behavior of clayey soils. The conventional drained creep test (or oedometer test) can be adopted to study the nonlinear creep behavior of soils. It can reflect the time-dependent stress-strain behaviors of soils in most soil foundations, embankments and other earth works .

The secondary consolidation phase (creep) is usually characterized by the secondary compression index:

$$C_\alpha = -\Delta e / \Delta \log t \qquad (1)$$

Where:

C_α = secondary compression index (creep coefficient)

Δe = change in void ratio

$\Delta \log t$ = change in logarithmic of time.

The creep coefficient C_α is considered to be the slope of the linear portion of the void ratio versus logarithm of time curve in the secondary compression region. It is noted that this coefficient is not a constant, but varies with time [5]. Mesri and Godlewski, (1977) [15] showed that C_α is related to the compression index C_c of the soil and more precisely, that the ratio C_α/C_c is constant for a given soil. This has been confirmed for a large variety of geotechnical materials by [8] and many other researchers. For creep behavior, actually there are volumetric creep which causes no failure and deviatoric creep which ultimately leads to rupture. It is critical to develop a proper constitutive model to consider both creep behaviors, which can be further implemented into numerical simulation for reasonable interpretation and prediction of the creep behavior of soils in varied stress states from different initial stress condition. Experimental and constitutive studies on the creep behavior in different scales and conditions are of significant importance for understanding the time-dependent stress-strain behaviors.

3. Experimental Work

1. Soil Used

The soil used throughout this study was taken from location of Tikrit University site in Salah El-Deen City in Iraq from a depth of 1.5 m. Table (1) shows the physical properties of the soil used and figure (1) shows the grain size distribution. The total soluble salts, SO_3% and gypsum content were determined according to British Standards (BS 1377). Table (2) shows the results of some chemical and composition tests conducted on the sample. All the experimental work and tests were carried out in the NCCL[9].

Table (1): Physical properties of soil

Properties	Value
Specific Gravity (G_s)	2.48
Liquid limit (%)	49
Plastic Limit (%)	23
Plasticity Index (%)	26
Field Unit weight (kN/m^3)	15.3
Natural Water Content (%)	10
Natural Void Ratio (e_o)	0.65
Passing Sieve No.200 (%)	18
Classification according to USCS	SC

Table (2): Chemical properties of soil

Properties	Value
pH	8.3
SO_3 (%)	20.43
T.S.S. (%)	54.4
Gypsum Content (%)	48.92

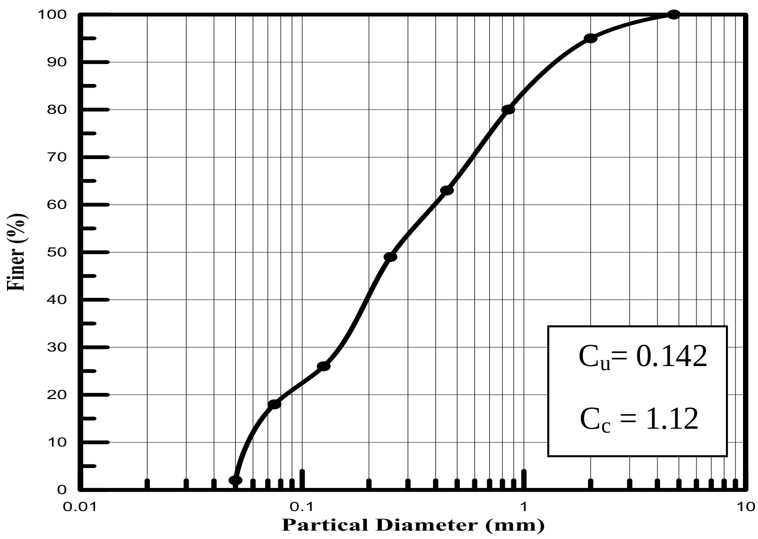

Figure (1): Grain Size Distribution of Soil Particle.

2. Testing

Compressibility Tests

A series of double oedometer tests and collapse tests were performed according to (ASTM D5333, 2003). The load increment ratio (LIR=1), and load increment duration

LID=1day. To conduct the tests, the fixed type consolidometer cells and loading frame with specimens of (75) mm, diameter and (19 mm) height are used.

3. Results and Discussion

3.1 Creep Strain - Stress Relationship

Figure (2) show the relations between creep strain and logarithmic of applied stress for wet (saturated) and dry (unsaturated) soil that compacted at natural water content (10%). The loading of the dry soil is the same as the loading of the wet soil one from 25 to 1600 kPa. The relations indicate that the soil is low of the compressibility of when loaded under drying condition for both 1day and 64 day respectively while it can be noticed for wet soil high compressibility recorded at 50 to 100 kPa stress for 64 day, this can be attributed to that the bonds start losing strength with the increase of the water content that cause the soil structure collapses, [1].

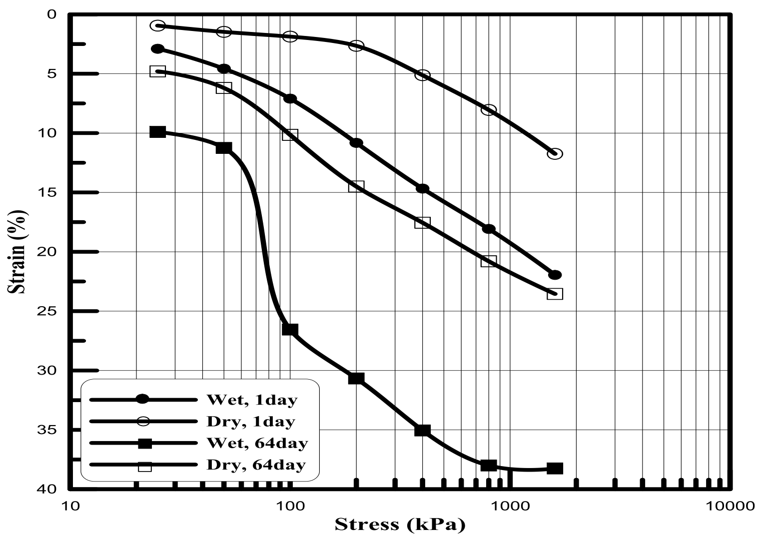

Figure (2): Stress Creep Strain Relationship

3. 2 Creep Strain Time relationship

In figure (3), the vertical creep strain is plotted versus logarithmic of time. The curve is approach linear during the loading period for dry sample under stress of 200 and 1600 kPa respectively. For wet samples, small change is observed in the initial loading period and a sudden soil collapse is noticed within the creep stage. This may be explained by high heterogeneity of soil with the existence of gypsum crystals in these samples [4].

3.3 Collapse Potential of soil

The collapse potential (C_p) defined as:

$$C_p = \frac{\Delta e}{1+e_o} \qquad (2)$$

Where:

Δe = change in void ratio

e_o = initial void ratio

The relationship between the collapse potential and logarithm of time at 200 and 1600 kPa for 64 days are shown in Figure (4). The percents of collapse potential curves for the sample under 200 kPa is generally a straight line with a higher increase in the strain then the curve became nonlinear after 15 day of loading and then reached constant collapse after 30 days, this is due to gradually increases in compressibility at initial period . But the curve of the sample under 1600 kPa differs; the curve is nonlinear for initial loading period where the strain increases rapidly and the curve has a higher concave upward where, the strain decreases. This may be attributed to the rearrangement of sand particles which when loaded to higher stresses show some increases in volume. Lambrechts and lenoardos, (1978) [17] showed that this expansion in collapse may be attributed to the presence of montmorillonite clay mineral, since that gypsum is not expansive. Another source of this expansion can be attributed the fine sand is directly related to the parent minerals [18].

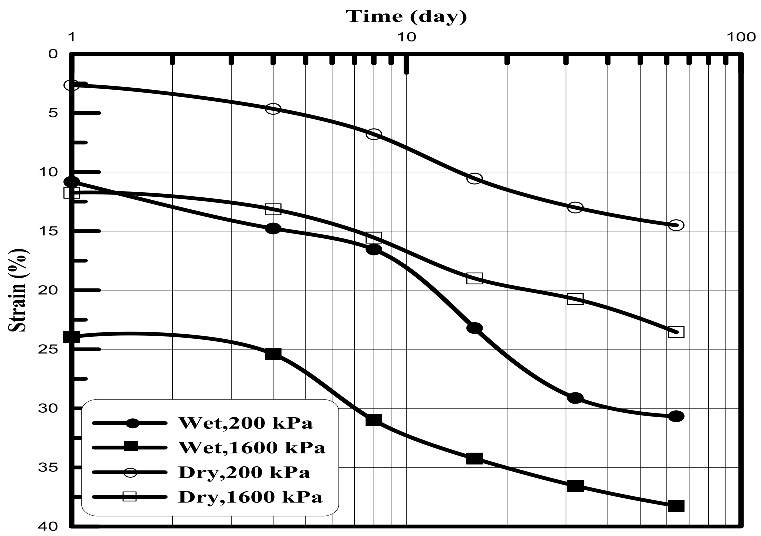

Figure (3): Creep Strain Time Relationship

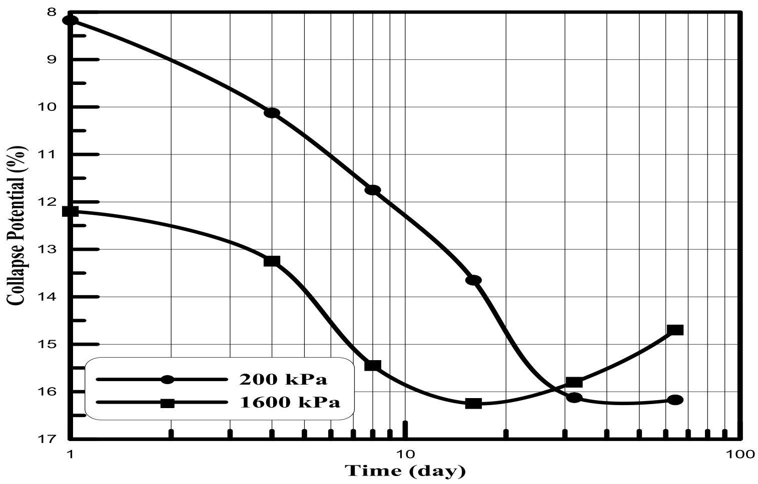

Figure (4): Collapse Potential Time Relationship

Figure (5) shows that the collapse potential increases with the increasing stress for the samples loading for 1 and 64 day. It can be observed from the figure the high decrease in collapse potential after 800 kPa stress for 64 day loading sample occur and for sample of 1 day loading a continuous increase in collapse potential occur when the applied stress increases. The collapse may be caused by break-down of the interparticle bonds under high loads.

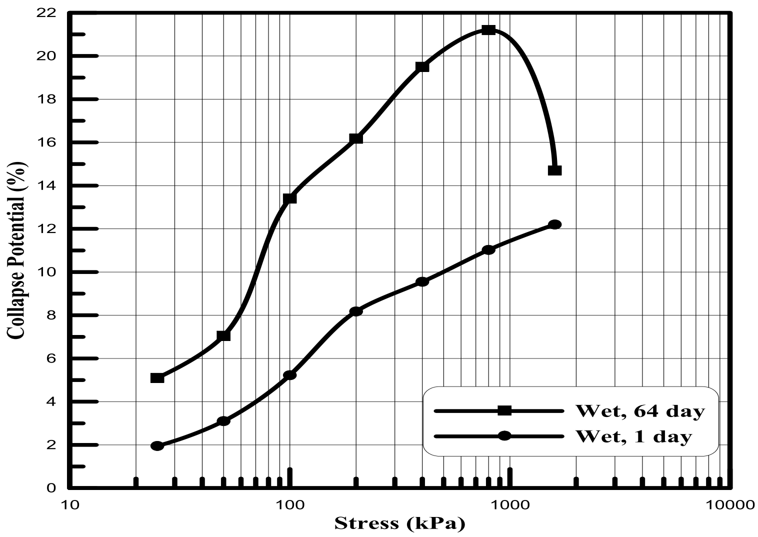

Figure (5): Collapse Potential Stress Relationship.

3.4 Creep Rates time Relation

Creep rates are defined as the change in creep strain per unit time. Creep strain rates at various values of time may be computed graphically or mathematically. In this study creep rates were computed mathematically to obtain more accurate values. From the test results in Figure (3), the creep time relation can be expressed by the relation:

$$C_s = A + B \log (t) \quad (3)$$

Where:

C_s = creep strain

A & B = constants

log (t) = logarithm of time

The creep rate (C_r) at any time is:

$$C_r = C_s / t \quad (4)$$

Figure (6) shows creep rate time relationship, nonlinear relations appear to exist between the creep rate and logarithm of time for stress of 200 and 1600 kPa stress respectively under drying and wetting condition. Also it can be noticed after period of 30 day the linear relation obtained and the decrease in creep rate is smaller and the relations indicate little variation in creep rates.

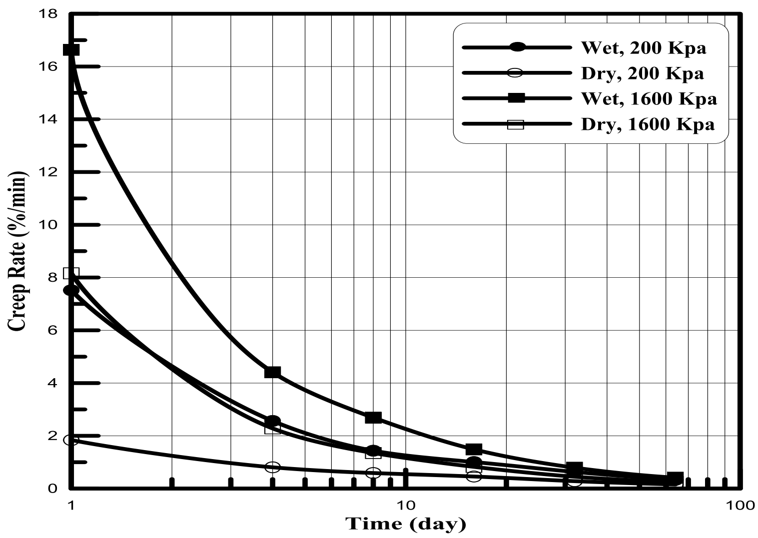

Figure (6): Creep Rate Time Relationship.

3.5 Void Ratio Time Relationship

Figure (7) shows the relationship between void ratio and time under 200 and 1600 kPa applied stress. It can be noticed the (e) decreased as the time increased (0.4715 to 0.144 and 0.255 to 0.22) for 200 and 1600 kPa applied stress respectively.

The slope of the last portion of the curve represents the creep coefficient (c_{α}) that calculate from equation (1), the value of c_{α} decrease from (0.104 to 0.077) as the applied stress increased from 200 to 1600 kPa respectively.

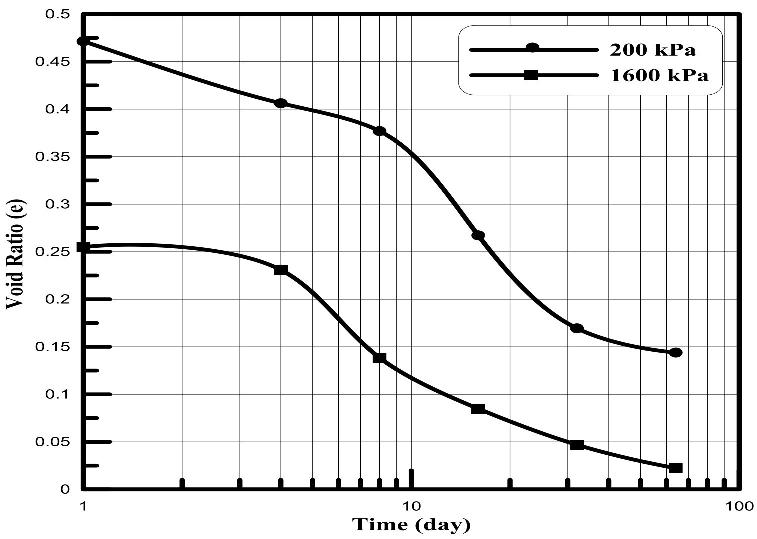

Figure (7): Void Ratio Time Relationship.

4. Conclusions

Based on the results presented in this study, the following conclusions can be made:

1. The results showed that the relationship between the vertical strain and logarithm of effective stress indicates that the soil is of low compressibility when loaded under drying condition for both 1day and 64 day respectively while it can be noticed that for wet soil sample, high compressibility is recorded at 50 to 100 kPa stress for 64 day.
2. The relationship between the vertical strain and logarithm of time approach linear during the loading period for dry sample under stress of 200 and 1600 kPa, respectively while for wet samples, small change is observed in the initial loading period and a sudden soil collapse is noticed within the creep stage.
3. The results of tests showed that the relationship between the collapse potential and logarithm of time, for samples loaded to 1600 kPa for 64 days, the curve is a nonlinear behavior for initial loading period where the strain increases rapidly and the curve has a higher concave upward where. Also significant decrease in collapse potential with time is noticed for 200 kPa stress (8.17% at 1day to 16.17% at 64 days) and (12.2% at 1 day to 14.7% at 64 day) for 1600 kPa stress.
4. The collapse potential increases with the increasing stress for the samples loaded for 1 and 64 day. It can be observed that there is high decrease in collapse potential (21.2 % to 14.7 %) after 800 kPa stress for 64 day loading sample, and for sample of 1 day loading a continuous increase in collapse potential occur when the applied stress increases.
5. Nonlinear relations appear to exist between the creep rate and logarithm of time for stress of 200 and 1600 kPa, stress respectively under drying and wetting condition. The creep rate decrease (16.63% / min to 0.415 % / min) for 64 day and 1600 kPa and (7.51% / min to 0.332 % / min) for 1 day and 200 kPa stress.

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