Diyala Journal of Engineering Sciences

Journal homepage: https://en.enginmag.uodiyala.edu.iq/

ISSN: 1999-8716 (Print); 2616-6909 (Online)

An Experimental Study on Settlement for Gypseous Soil Using Electrical Method

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ARTICLE INFO

Article history:
Received 17 January 2020
Accepted 13 February 2021

Keywords:

Gypseous soil; Electro osmosis; DC voltage; Settlement; Boundary conditions.

ABSTRACT

This paper presents an experimental study on the effect of electro-osmosis in improving the properties of gypsum soils. Electro-osmosis is the process of transferring ions from the anode to the cathode by appling an electric field. The experimental model for this study is by preparing a soil sample with dimensions of (30 x 30 x25) cm, and contained a wooden box of (30 x 30 x 30) cm. This box was put in a water tank of (50 x 50 x 35) cm to confine the water. Two types of gypsum soil used in this study are placed inside the wooden box with gypseous content of (30% and 60%). Rectangular plate (5x5) cm with thickness was 3 mm used to simulate a rigid foundation and time-leveling tests were performed for (10) volt model in addition to take reference readings (without applying any voltage for comparison) with change of load applied where its use (20 and 28) T/m2. The variables in this study are gypsum content, time, applied load and corresponding settlement. The results showed a responsed the soil to the electro-osmosis, while noted the improve is occur in the settlement.

1. Introduction

Soil improvement is done by using many techniques through which good improvement results are obtained, and among these techniques is the electro-osmosis technique. The electro-osmosis is the process of using electric current in saturated soil where the positive particles move towards the negative electrode, i.e., water flows from the anode towards the cathode by Nichloson (2015) [1]. This technique was used for the first time in the year 1809, as it included the first preparation of an electrical osmosis device, which was suggested by Reuss (1809) [2]. After that time, many attempts were made to explore improvement for different types of soils and for different criteria, including some of the successful case histories. Casagrande (1952) studied the electro-osmosis of soil stabilization [3].

Hamir et al. (2001) proposed the osmosis cell and applied a load from the top in a parallel way to the electrical potential, and they switched the copper electrodes used in this study with geographic materials and they concluded that the electrodes used give similar results to the copper electrodes [4].

S.Hansbo (2008) studied the potential gradient between the anode and the cathode and hypothesized the study of settlement and its relationship with in terms of power consumption and electric current. This technique is considered one of the good alternatives for improving and treating soft soil [5].

Hui and Liming (2012) proposed a one-dimensional devise to investigate the behavior of electro – osmosis process in expansive soil. The electrical current, the water discharge, the voltage distribution and the excess pore water

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DOI: 10.24237/djes.2021.14107

pressure were observed as well as the moisture content and vane shear un drained shear strength. The results showed that the water content is high at the cathode and the un drained shear strength is high at the anode [6].

Estabragh (2014) studied that the effect of electro-osmosis on clay, the experimental results showed that electro-osmosis caused a significant increase in the settlement and undriand strength of soil [7].

Wu et al. (2015) proposed an apparatus similar to Moris (1984) to verify the effect of electrode material with respect to, drainage rate, electrical current and voltage loss within the expansive soil during the electro- osmosis consolidation. The apparatus was provided with a camera to conduct an image analyses and examine such effects qualitatively at the zone of soil – electrode [8], and this technique has been used in many applications such as excavation, slopes, dams, dewatering, clay soil strength and pollutant recovery (Hu et al. 2013) [9].

Gypseous soil is considered as one of the problematic soils that is subject to collapse when exposed to water, as many soils that collapse upon moistening lose their strength provided by a support agent such as calcium sulfate. As the cause of the collapse is due to the materials included in the composition of gypseous soil, which are sand, clay, or other materials [10][11]. Barazanji (1973) classified Gypseous soils into five classes according to their gypsum content [12].

Gypeous soils are found in many regions of the world such as China, India, Australia and Europe, and also found in a number of Arab countries such as Bahrain, Iraq, Algeria, Syria and Jordan. The gypseous soils in Iraq covers about 31.7% of the surface area with a gypseous content of about (10-70) according to Ismail (1994) [13][14].

The wetting or saturation of gypseous soil during the lifetime of structure can cause a sudden settlement due to collapse (Razouki et. al., 1994) [15]. Civil engineers often face severe problems when constructing hydraulic structures in or on gypseous soils and rocks. by excessive leakage may take place because of defects in structural arrangements of the underlying strata if they contain gypsum, which dissolves when exposed to movement of water withen the soil.

In Iraq, many constructions have been built upon gypseous soils. As a result of this phenomenon, there is a lot of damage threatening these constructions, as presented by (Razouki et. al. 1994) [15].

The level of groundwater varies in many buildings built in regions of Iraq, so it is necessary to conduct a study on the height of this level without drainage, in addition to the different loads imposed,Which will be explained by this study on gypsum soils, to find out the response of gypseous soils to the electro-osmosis technology and the effect of this technique on settlement that occurs in gypseous soils at different times.

2. Materials and methods

2.1. Soil

Gypseuos soil used in this study is brought from the center of Salah-Aldeen governorate (Tikrit) which is located in the middle of Iraq and north of Baghdad by 180 km, by with two gypseous content (30% and 60%) and encoded as S1 and S2 respectively,as shown in figure1. This soil is used to study the effect of electricity on improving the settlement that occurs in the soil when constructing projects. The physical and chemical engineering properties have been performed for gypseous soils as shown in Tables 1 and 2. Moreover, as Figures 2 and 4 showed the results of the laboratory tests conducted on the soil used in the current study. In addition, the hydrometer test is accomplished by usingwater saturated with gypsum to avoid the dissolution of gypsum, as suggested by Ahmed (2013) [16]. Figure 3 shows the grain size distribution of two samples of gypseous soil used in the current study. The results show that there is a difference between dry and wet sieve analysis due to decrease in soil particles sharp edge and distraction of particle cementation bonds resulting from minerals, which are dissolved by kerosene (Karkush, et al. 2008) [17]. the relative density test is based on the standard of (ASTM D4254-00). a preliminary the moisture content test is obtained according to (ASTM D2216-02). The drying temperature of 105°C-110°C is not recommended for gypseous soil, therefore, the samples are dried at temperature at (40-50) °C avoid losing crystal of gypseous soil.

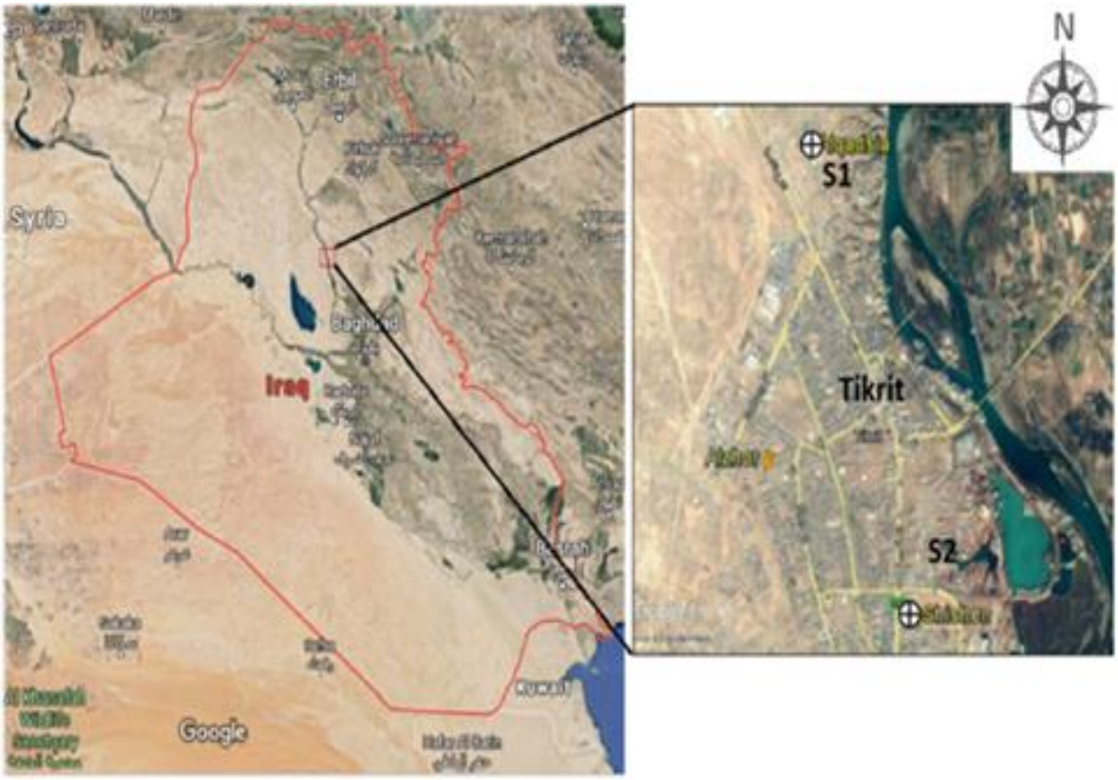


Figure 1. The location of the soil samples

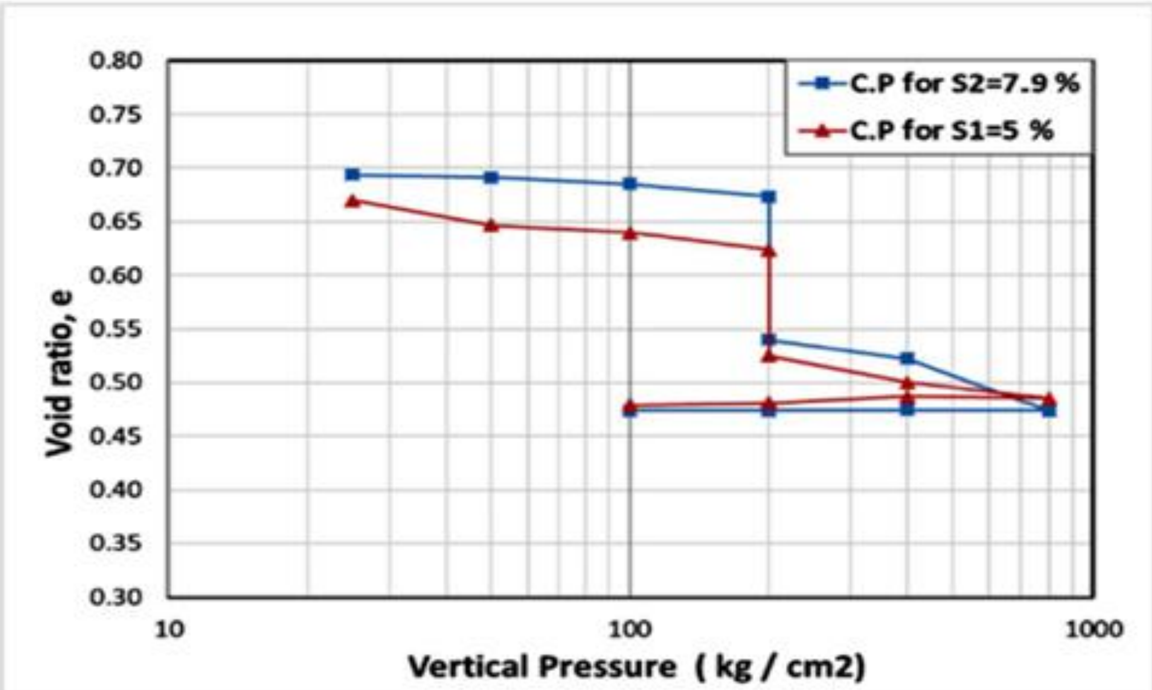
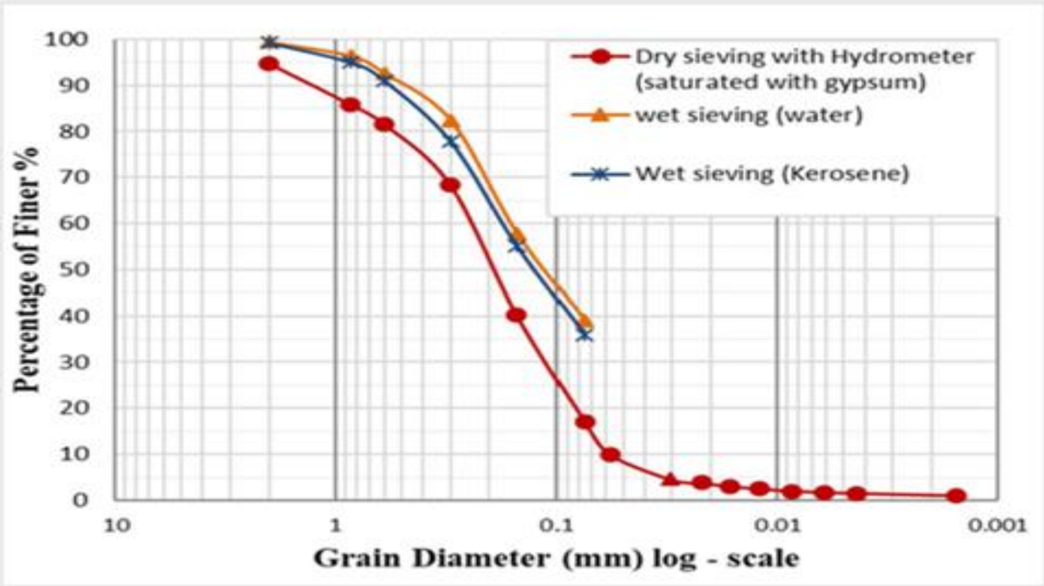


Figure 2. Collapse test (odometer test) in G.C 30% Device



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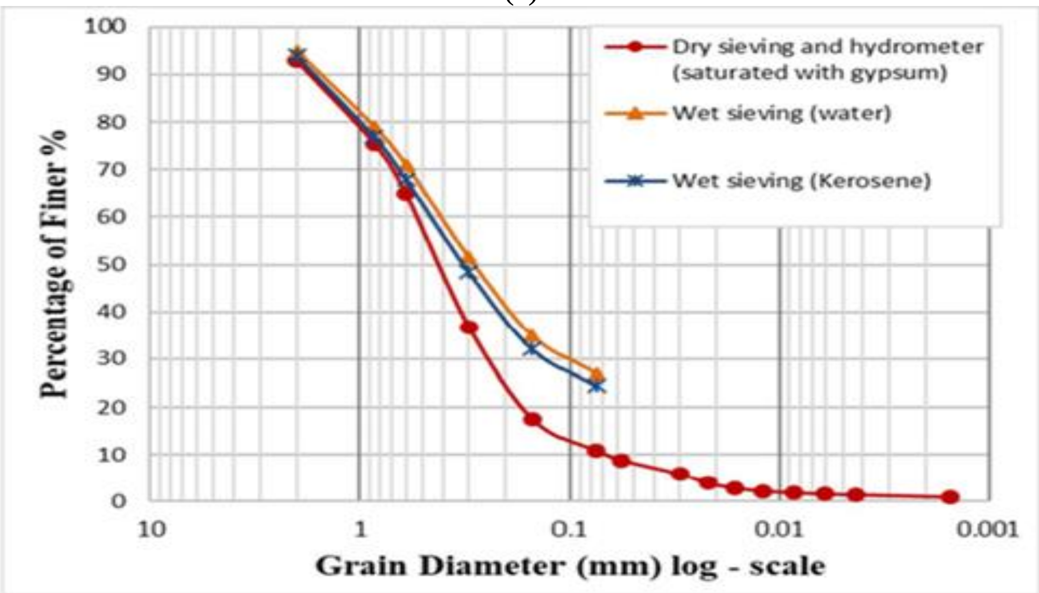


(b)

Figure 3. Grain size distribution curve for gypseous soil: (a)S1 (G.C30%), (b) S2 (G.C60%)

Table 1. Results of chemical properties of two samples based on (BS 1377: 1990, Part 3)

Properties	Sample1	Sample2
Total soluble salts (T.S.S.) %	33	68
Gypseous content%-by - NCCL	30 31.5	65 63
Sulphate content (SO_3) %	13.9	30.4
Organic matters (O.M) %	0.2	0.21
Chloride content (Cl) %	0.055	0.061
pH value	7	8

Table 2. Results of physical properties of two samples of soils

c			Sample1 (G.C 30%)	Sample2 (G.C60%)	Specification
Grain size analysis	D10 (mm)		0.06	0.07	ASTM D422-2002
	D30 (mm)		0.07	0.14	
	D60 (mm)		0.18	0.25	
	Coefficient of uniformity, C_u		3	5	
	Coefficient of curvature, C_c		0.45	0.8	
	Passing sieve No. 200 (%)	D(dry)	17	6	
		K(kerosene)	37	24	
		W(water)	40	27	
Classification of soil based on (USCS)			SM	SM	
Specific gravity, G_s			2.49	2.43	ASTM D854-00
Atterberg's limits	Liquid limit (L.L) %		22	10	ASTM 4318-00
	Plastic limit (P.L) %		N.P	N.P	
	Plasticity index (P.I)		/	/	
Angle of Internal Friction (Ø) in dry for γ test			34	38	ASTM D3080-98
Angle of Internal Friction (Ø) in soaked for γ test			31	34	
Soil Cohesion (C) (kN/m^2) in dry			9	14	
Soil Cohesion (C) (kN/m^2) in soaked			4	5	ASTM D3080-98
Dry unit weight	Maximum, γ_d (max.) kN/m^3		16.75	16	
	Minimum, γ_d (min.) kN/m^3		12.54	11	
	Relative density, D_r%		70	70	
	Test unit weight (kN/m^3), γ_d test with accordance of D_r =70%		15.22	14.08	
Field density ((kN/m^3), γ_{field} by (Tikrit university)			15	14.06	ASTM D1556-07
Initial void ratio, e_{test}			0.64	0.72	
Initial water content %			0.8	0.5	ASTM D2216-02
Compaction characteristics	Max. Dry unit weight (kN/m^3)		17.96	16.63	ASTM 698-00
	Optimum Moisture content (%)		14.12	11.2	
Collapse Potential %			5	7.9	ASTM D5533-2003

2.2 Apparatuses of model

Figure 4. shows the model with apparatuses

1. Load arm
2. Riged footing (5 x5) cm
3. Anode
4. Soil sample (30 x30 x25) cm
5. Cthode
6. Plywood box (30 x30 x30) cm
7. Steel water tank (50 x50 x35) cm
8. Dail gage

2.3 Test setup

In this study, it used the water tank is made of steel with (50 ×50 ×35 cm) for contain water and the plywood box of (30×30 ×30 cm) which is used for contain the soil. The aluminum electrodes (3 mm) are placed on the sides with equal dimensions from the foundation and these electrodes are connected to a device DC voltage that provides different levels of voltage these electrodes are connected to a device DC voltage that provides different levels of voltage (it is argued that there are no recognized criterions are now available regarding the rang of DC voltage through that literature, however, the level of DC voltage has taken valuse between 5-10 V). In addition, the rigid arm (5×5) cm is made of steel with thickness 3mm and is connected to the foubdation to deliver the load from the structer to the foundation. The electric current is projected by the DC voltage and the readings are taken by the dial gage until there is a collapse in thesoil.

(a) (b)

Figure 4. (a) expremential model (b) (water tank, electroed, DC voltage,plywood box)

3.Test procedure

3.1 Soil bed preparation

The gypsous soil used in this study is dried in a sufficient quantity to fill the wooden box (30 x 30 x 25) cm. It is divided into two layers and each that each layer has dimensions (15×15× 15.5) cm.the hammer is used to obtain the required density of the soil where a steel plate with dimensions (200 × 200) mm and a thickness of 5 mm is installed in the front. It is shows in Figure 5. A number of tests are performed to ensure that the adjustment process is controlled and to achieve the required density of the test in an optimal way and to avoid any different in the density values between one test and another to ensure accurate results.

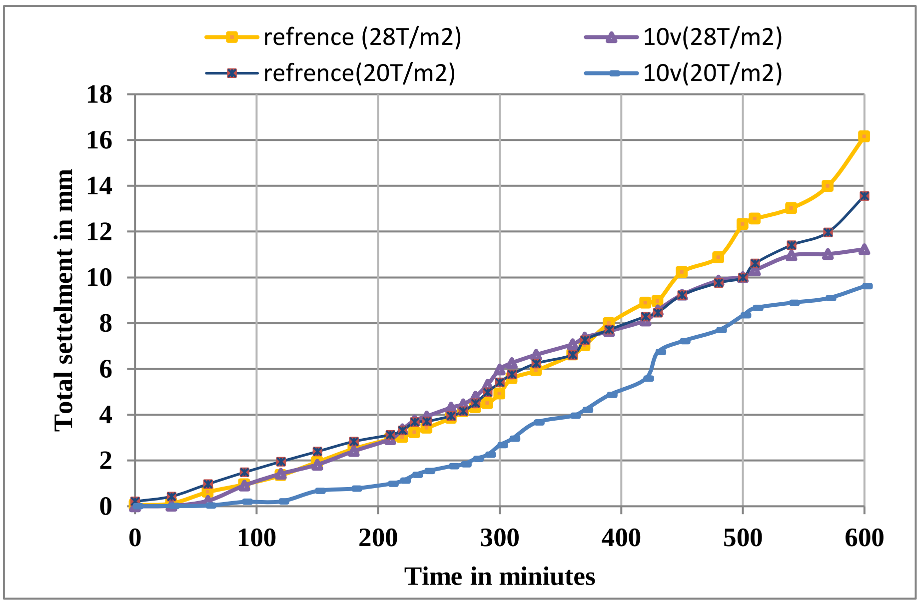
Figure 5. The device which is used to obtain the required density

3.2 Installation of model

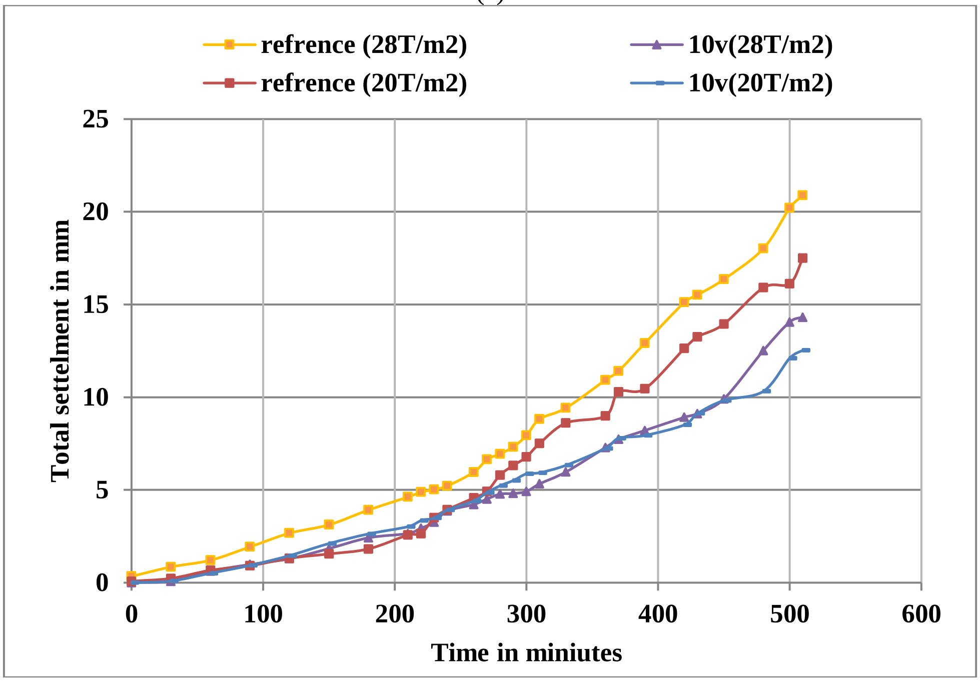
The current study was conducted by prepared soil samples with dimensions of 30cm×30cm×25 cm and placed them in a wooden case 30cm ×30 cm× 30 cm and used a steel box 50 cm × 50 cm ×35 cm to be filled with water until the level of the soil sample and then the loads are applied .This expermantial is carried out without applying the electric voltage and considering this test as a reference source for the purpose of comparison, and with the same steps, the expermantial process is carried out with being applied the voltage by the DC volts and the readings are taken until the collapse of the gypseous soil occurs.

4. Results and discussion

The results of this study showed improvement in both types of soil with different soil breakdown times, as it was observed that soil 1 collapse occurs after about 600 minutes. As for the other type, soil 2 takes about 510 minutes to collapse, as in Figure 6 which shows the results of the two soils. Increasing the applied loads causes a consequent increase to the electro osmoses deflection response due to the effect of excessive stresses. The difference in the time of collapse is due to the different percentage of gypseous.



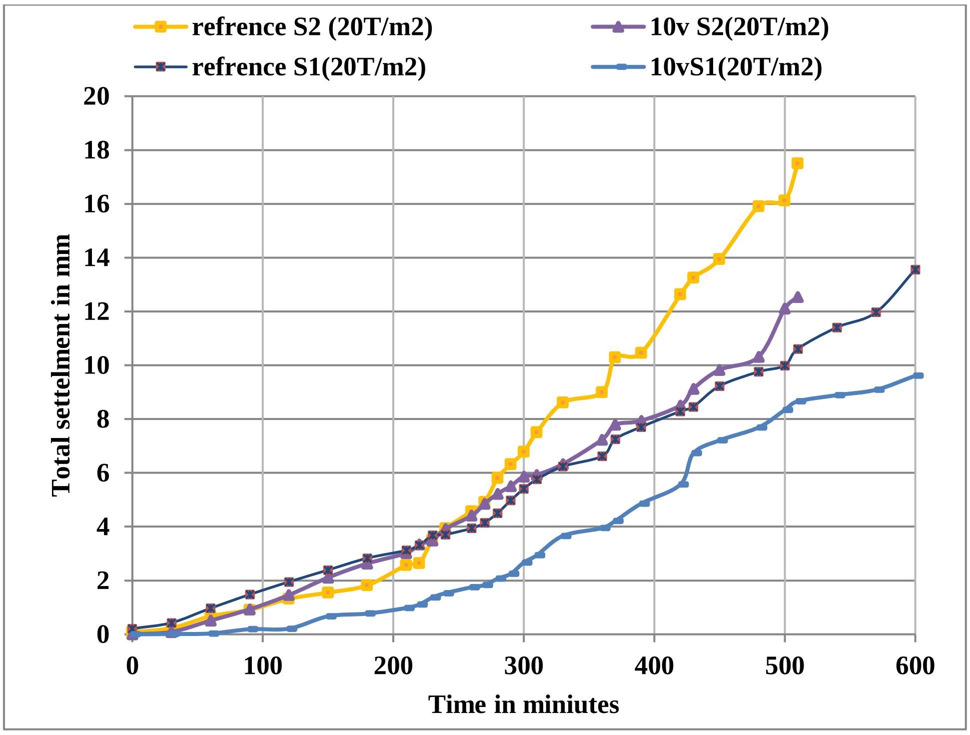
(a)



(b)

Figure 6. (a) Time - settlement relationship for soil 1 (b) time - settlement relationship for soil 2

In addition, it can note that settlement in soil 2 is higher than soil 1. which is the gypseous content increase the deflection electro osmosis response due to the softening of the soil which increased as the gypseous content increased. with noted a good improvement of the soil in both ratios od gypseous compared to the soil without the use of electrical voltage. Figure 7 shows the results for the two soils with different time.



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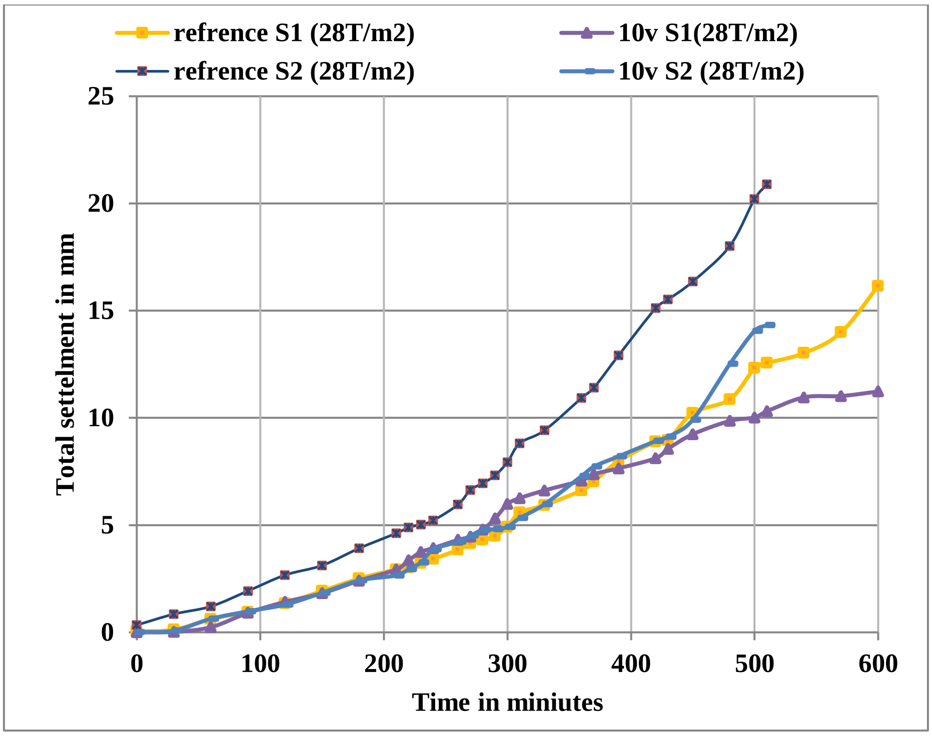

(b)

Figure 7. (a) Time - settlement relationship for two soils at 20 T/m^2 (b) Time - settlement relationship for two soils at 28 T/m^2

6. Conclusion

1. Applying DC voltage to the gypsious enhances the surface settlement versus time behavior of such soils.
2. The soil gypseous is responsed to technique the electro- osmosis.
3. Increasing the applied loads causes a consequent increase to the electro osmoses deflection response due to the effect of excessive stresses.
4. There is no recognized context to the variation of degree of improvement due to time of testing progress.
5. many researches can be done by changing the levels of voltage, as well as changing the type of electrodes used, in addition to the possibility of changing the dimensions of a rigid footing.

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