Journal of Engineering and Sustainable Development
Vol. 23, No.01, January 2019
ISSN 2520-0917
https://doi.org/10.31272/jeasd.2019.1.12

STUDYING THE EFFECTS OF LEACHING ON TREATED GYPSUM-RICH SOIL

Dr. Ali Nasir Ibrahim

Lecturer, Faculty of Engineering, Aliraqia University, Baghdad, Iraq.

Abstract: This wok focus on improving the permeability properties of gypseous soil by mixing the soil with three types of stabilizer materials, which are silicone oil, sodium silicate and bentonite. Four soil samples were prepared, first untreated soil, second mixture of 70% gepseous soil and 30% silicone oil, third mixture of 70% gypseous soil and 30% sodium silicate and forth mixture of 70 % gypseous soil and 30% bentonite . The leaching tests were conducted for all prepared soil using oedometer-permeability leaching device. The results show that the coefficient of permeability decreases with increasing of time, dissolved gypsum and leaching strain, this may attribute to the fact that the stabilizer materials fill the pores that produce from gypsum dissolution after leaching, thus in turn reduce the water fluctuate in the soil which minimize the gypsum dissolution.On the other hand the stabilizer materials work as an impermeable layer to prevent direct contact of water and gypsum particles. Where the leaching strain increases with increasing of dissolved gypsum as the leaching process continues. This behavior may be attributed to the continuous dissolution of gypsum that causes correspond a continuous settlement. Also leaching strain increases with void ratio increasing as the leaching process continue, where the continuous gypsum dissolution leads to increase in void ratio due to presence of pores. The treated gypseoussoil has less void ratio in comparison to untreated soil, due to reduction in gypsum dissolution for treated gypseous soil and thus in turn reduces leaching strain. Sodium silicate shows high efficiency in reducing coefficient of permeability compared to silicone oil and bentonite.

Keywords:*Leaching, stabilizer materials, gypsum-rich soil, permeability*.

دراسة تأثير الغسل على تربة جبسبة معالجة

الخلاصة: تتمحور هذه الدراسة حول تحسين خواص النفاذية لتربة جبسية عن طريق خلطها مع ثلاث انواع من المواد المثبته هي دهن السليكون ، سليكات الصوديم و البنتونايت . تم تحضير اربع نماذج من التربة لغرض الفحص الاول تربة جبسية غير معالجة ، الثاني خليط يتكون من 70% تربة جبسية و30% دهن السليكون ، الثالث خليط يتكون من 70% تربة جبسية و30% سليكات الصوديوم ، الرابع خليط يتكون من 70 % تربة جبسية و30% بنتونايت . أجري فحص الغسل بواسطة جهاز فحص الانضمام باستخدام خلية تسمح بمرور الماء خلال نموذج التربة اي تحتوي على منفذ لدخول الماء ومنفذ اخر لخروج الماء. بينت النتائج ان معامل النفاذية يقل بزيادة كل من الوقت ، كمية الجبس المذاب و انفعال الغسل ، هذا يعزى الى حقيقة ان المواد المثبته تملأ الفراغات الناتجة عن ذوبان الجبس في التربة خلال عملية الغسل ، وهذا بدوره يقلل من الماء المتغلغل بالتربة والذي يقلل بدوره ذوبان الجبس . من جهة اخرى تعمل المواد المثبته بمثابة طبقة عازلة غير نفاذة للماء تمنع التماس المباشر بين الماء وجزيئات الجبس.ان انفعال الغسل يزداد بزيادة نسبة الفاراغات في التربة خلال عملية الغسل. هذا يعزى الى استمرار ذوبان الجبس الذي يسبب هطول في التربة. التربة الجبسية المعالجة تحتوي على نسبة فراغات اقل بالمقارنة مع التربة الغير معالجة بسبب نقصان ذوبان الجبس في التربة المعالجة والذي بدوره يقلل اجهاد الغسل. بينت النتائج ان سليكات الصوديوم تمتلك كفاءة عالية في تقليل معامل النفاذية اذا ما قورنت بدهن السليكون والبنتونايت.

*Corresponding Authorali_nasir_79@yahoo.com

1. Introduction

Brenner et al. [1] defined leaching in soil as “a process which removes materials in solution (e.g. salts) and cementation agent from a section in the soil profile”.

Several studies deal with the effect of the leaching process on the geotechnical behaviour of soil deposits. Some of these studies investigate volume change and collapsibility characteristics by carrying out a field collapse-leaching test, such as tests on gypseous soil in Russia [2, 3 and 4].

The processes of leaching take place in soil deposits as a result of water movement due to ground water fluctuations, surface water percolation, the breakage of sewage pipes and irrigation channels [5].

Water due to soaking or leaching into gypseous soil causes dissolution and removing of gypsum particles away from the soil skeleton destroying the cementing bonds between the soil particles. This causes large changes in the properties like increase in the compressibility and collapsibility and decrease in the shear strength.

The leaching of gypseous soil particles causes several problems observed in soil underneath the foundation of many buildings and engineering structures due to continuous changes in engineering properties of soil with time. The combine effects of collapse and leaching cause a considerable settle of the soil especially when loading is applied.

The buildings that resting on gypseous soils suffered from cracks, tilting, collapse and leaching the soil, which caused by dissolution of gypsum. The case of collapse can be divided into two types, first, the soaking collapse, which is caused by soaking the dry soil or partly saturated soil with water, and under specific pressure, without flow of water. Second, the leaching collapse, which caused by flow of water through the soil under any specific stress [6].

There were some successful theoretical attempts in the case of leaching of the saturated soil, but in case of soaking collapse, yet there is no successful theoretical attempt to describe the behavior of partly saturated soils upon wetting.

The aim of this work is to enhance the permeability properties of gypseous soil by adding stabilizer materials (sodium silicate, silicone oil and bentonite) to gypseous soilwhere these materials work as an impermeable layer to prevent direct contact of water and gypsum particles.

2. Soil Tests and Stabilizer Materials

The gypsiferous soil samples of SP group according to unified soil classification system from Najaf area in Iraq were used in this study. The soil includes 20.55% gypsum content, which is considering moderately gypsiferous soil according to [7].

Three stabilizer materials were used to be mixed with soil (30 % of stabilizer material and 70 % of soil, these percentages were adapted in this work for theoretical research purposes), which were:

1.Sodium Silicate (Na_2O_3Si) is a colorless solution which consists of 13.7% Na_2O and 33% SiO_2, The specific gravity is 1.55 and the viscosity at 20 C^o is 600 CPS.

2.Silicone Oil, which is an oil product from polymerized siloxane with a viscosity 300 CPS.

3. Bentointe, which is produced from clay and has thixotropic properties. This mean that it forms a highly water resistance gel which, when mixed with additives, can create a permanent barrier to water flow.

Ibrahim and Schanz [8] successfully improved the gypsiferous soil strength by mixing the soil with three content ratios of silicone oil; namely, 4%, 10% and 16%. They attributed the increase in strength to the ability of the silicone oil to bond gypsiferous soil particles together and increased soil tenacity.

Ibrahim and Arash [9] used grouting technique to inject stabilizer materials in gypseous soil, then collapse tests were conducted for treated and untreated soil, the results show that the collapse potential for the treated gypseous soil was observed to be less than that for untreated soil. This can be attributed to the fact that the stabilizer materials form a gel and act as a cementing agent between the soil particles; thus, reducing the collapse potential.

The physical and chemical properties of gypseous soil used in this work shown in Table 1.

Table 1.Physical and chemical properties of gypseous soil.

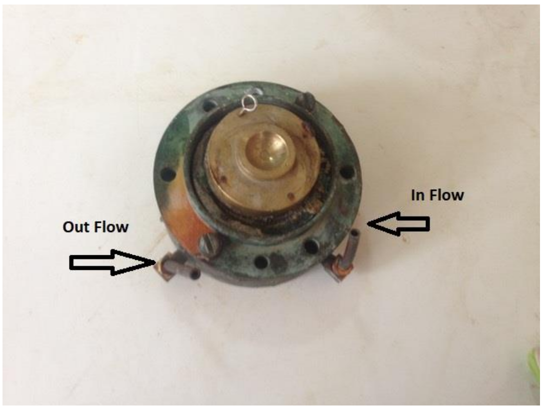
Property	Value
water content	2.4 %
Specific gravity	2.56
Field dry density (kN/m^3)	15.15
Atterberg limits	Non Plastic
Particle size distribution (ASTM D422- with kerosen)	
d10 (mm)	0.10
d30 (mm)	0.28
d60 (mm)	0.48
Gypsum Content %	20.55
Passing sieve (0.075 mm) (dry, kerosene, water) (%)	1.25 , 4.53, 39.25
Classification (USCS)	SP (poorly graded sand)
TSS	22.92 %
GC	20.55 %
SO_3	1.43 %
OM	3.46%

3. Experimental Laboratory Tests Appartus

The behavior of gypseous soil during leaching process is investigated usingOedometer permeability- leaching apparatus shown in Fig. (1), the dimensions of testing ring were 6.1cm in diameter and 2.5cm in thickness. It has inlet line in the bottom and outlet line at the top used for water overflow in soil sample, where the inlet line connected to an elevated cylindrical tank with an overflow outlet. One of the elevated cylindrical tank lines supplies water to the tank and the second line is an overflow outlet.

Oedometer permeability–leaching test is carried out for 200 kPa leaching stress level(where this stress level used in single collapse test as a limit between dry and soaked tests), with upward flow direction. The leaching process is conducted using constant hydraulic gradient (i) equal to (12).

To give a clear view for understanding the behavior of gypseous soil during leaching process, many relations are obtained from the tests. The elevation of the tank provides hydraulic gradient equals to (12), corresponding to a total head difference of 30 cm.



(a) (b)

Figure 1. a) Oedometer-permeability leaching apparatus, b) Leaching oedometer cell.

4. Oedometer permeability- Leaching Test Procedure

The procedure of the test is similar to the standard consolidation test until the desired leaching pressure is reached then, the stress is kept constant and flow is allowed upward performing the leaching. Special care is taken by greasing the inner surface of the cell ring to forbid the water from seeping through the voids at the interface between the soil particles and the inner surface of the ring. Saturation is ensured before loading the sample by opening the back pressure valve (bottom lines), until the sample was soaked, to replace the air in the sample by water. Leaching starts by opening the bottom line valve that provides a head of 30 cm for hydraulic gradient (i) equal to 12.

The flow water collected in a graduated cylinder and recording the discharge volume, as well as dial readings are taking at the same time with measuring total dissolved salts. (T.D.S.) several times each day.

The treated gypseous soil contains of a mixture of 30 % of stabilizer materials and 70 % of gypseous soil, the mixture kept for 24 hrs before test in order to produce a homogeneous mixture.

The procedure of the test was summarized by [10 and 6]as follows-:

1. Prepare the setup for testing, especially the boiled of porous stones. The preparation includes also greasing the inner surface of consolidation ring which has the dimensions (62mm diameter and 25mm height) with a thin layer of grease, the purpose beyond the greasing of the ring is to avoid friction and to forbid the water from seeping through the voids at the interface between the soil particles and inner surface of the ring.

2. Prepare the sample by compacting the soil inside the ring to satisfy field unit of (15.15 kN/m^3) weigh which determined by using sand cone method.
3. Start the loading process as in standard consolidation test, i.e., doubling the stress every (24 hrs.), until reaching the specified stress for leaching.
4. Saturate the sample with water for (24hrs.) under the specified leaching stress, 200 kPa used in this research [11].
5. Start leaching process by opening the back pressure valve (inlet line) which provides a head of (30 cm).
6. Collect the leachate in a graduated cylinder and record the volume of leachate and dial gauge reading every (24hrs.), so as to calculate and determine the permeability coefficient (k) value and the leaching strain with time.
7. The collected leachate should be oven dried at (45-50oC) [12] to determine the T.D.S. In this study, chemical tests are carried out on the salt got from the leachate. The test results showed that the most dominant salt is gypsum; therefore, the magnitude of dissolved gypsum can be determined with time from oven-dried leachate.

5. X-Ray Diffraction Test

X-Ray diffraction test is carried out on the natural gypsiferoius soil, , using XRD - 6000 , manufactured by Shimadzu Co. in Japan , at Iraqi ministry of science and technology . X- Ray diffraction and mineralogical composition results are shown in Fig. 2. The result of this test on normal sample (bulk) shows that the soil contains gypsum, calcite, feldspar and dolomite as non-clay minerals.

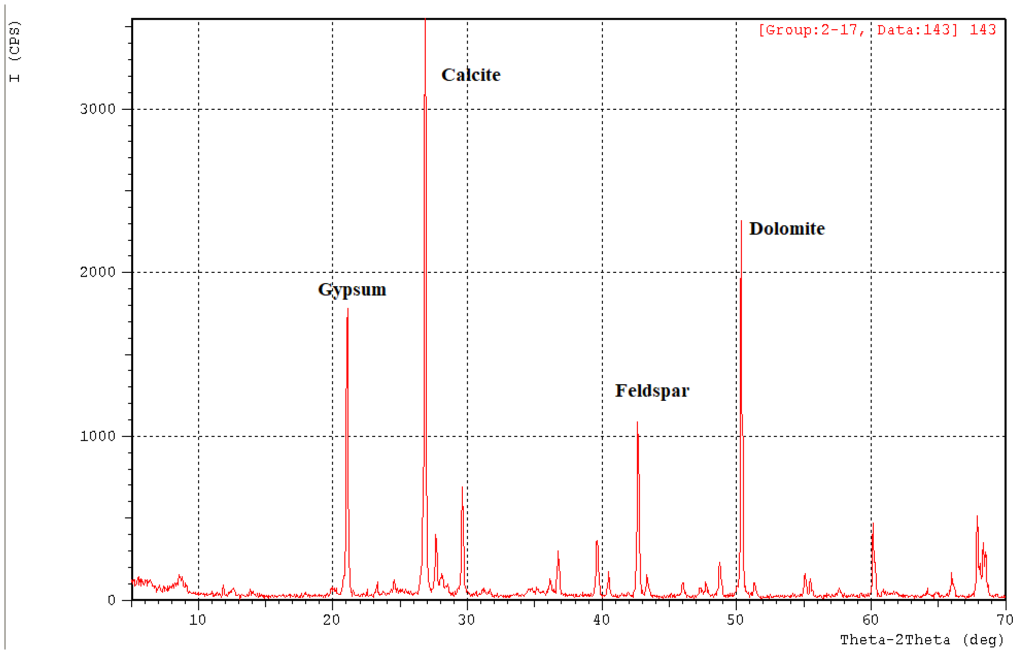


Figure 2. XRD for gypsum rich soil.

6. Test Results

Permeability–Leaching tests that adopted to investigate the permeability of soil and to study the effect of leaching on gypsum dissolution of gypseous soils using the Permeability– Leaching tests that carried out using the Oedometer permeability cell which described by [11] and followed by [10 and 6].

To give a clear view for understanding the behavior of gypseous soil during leaching process, many relations are obtained from the tests. These relations are as follows:

a- Leaching strain vs. void ratio.

b- Void ratio vs. dissolved gypsum .

c- Leaching strain vs. dissolved gypsum.

d- Permeability coefficient vs. time.

e- Permeability coefficient vs. dissolved gypsum.

f- Permeability coefficient vs. leaching strain.

Figs. (3, 4 &5) represent the [leaching strain – dissolved gypsum], [leaching strain - void ratio] and [void ratio -dissolved gypsum] relations of leaching tests. The results show that the void ratio increased with increasing dissolved gypsum, until the void ratio reached to a certain value, after which the void ratio remained almost constant and the leaching strain began to increase proportionally with dissolved gypsum. This behavior agreed with the theory presented by [13].

The behavior of gypseous soil during leaching process, conducted by Oedometer permeability–leaching test (OPLT) will be discussed briefly according to the relation of some factors and parameters, as follows:

a. Leaching Strain vs Dissolved Gypsum

The relation between leaching strain and dissolved gypsum for oedometer permeability– leaching test at 200 kPa stress is shown in Fig.3.

In general, it is found that the leaching strain increases with dissolved gypsum increasing as the leaching process continues. This behavior may be attributed to the continuous dissolution of gypsum that causes correspond a continuous settlement. Similar results are obtained by [10,14,15 and 16].

The results shows that the treated gypseous soil exposed to less gypsum dissolution, where the stabilizer materials form an impermeable layer to prevent direct contact of water and gypsum which reduce gypsum dissolution, and thus in turn reduce leaching strain.

It is worth mentioning that the gypseous soil treated with silicone oil exposed to less gypsum dissolution compared to other stabilizer materials.

b. Leaching Strain vs Void Ratio

The relation between leaching strain and void ratio for oedometer permeability – leaching test at 200 kPa stress shown in Fig.4. It is clearly shows that the leaching strain increases with void ratio increasing as the leaching process continue, where the continuous gypsum dissolution leads to increase in void ratio due to presence of pores.

The treated gypseous soil has less void ratio compared to untreated soil, due to reduction in gypsum dissolution for treated gypseous soil and thus in turn reduce leaching strain.

It is clearly noted that the silicone oil more effective in minimize gypsum dissolution and reduce void ratio compared with other stabilizer materials .

Ibrahim and Schanz [17] reported that gypsum crystal dissolute due to soaking which results in formation of large voids those are responsible for the high collapsibility of gypsiferous soils under loading. This happens when the gypsum crystal acts as a binding material which could be easily destroyed when the soil is subjected to slight loading.

C. Void ratiovs Dissolved gypsum

The relation between void ratio and dissolved gypsum for oedometer permeability–leaching test at 200 kPa stress is shown in Fig. 5. The result shows that the increase of dissolved gypsum leads to increase of void ratio as a logical result where the leaching cause gypsum dissolution and that leads to presence of voids in soil .

The treated gypseous soil exposed to less gypsum dissolution that leads to presence of less void ratio compared to untreated gypseous soil. Also silicone oil consider better stabilizer materials compared to other .

d. Permeability Coefficient vs Dissolved Gypsum Relation

The permeability coefficient versus dissolved gypsum for oedometer permeability–leaching test at 200 kPa stress is represented in Fig.6.

In general, the permeability coefficient (k) decreases as the amount of dissolved gypsum increases. This behavior may be attributed to the blockage of pores generated by the action of dissolved cementing (gypsum) bonds that leads to a reduction in permeability coefficient. These results agree with the results obtained by [13and 16].

Al Badran [6] reported that the coefficient of permeability increased in the beginning and after that decreased with continuation of leaching until it reached approximately constant value.

It is worth mentioning that the stabilizer materials reduce the coefficient of permeability, which fill the pores that produced from gypsum dissolution after leaching, thus in turn reduce the water fluctuate in the soil which minimize the gypsum dissolution.

The test result clearly shows that the gypseous soil treated with sodium silicate has low coefficient of permeability compared to gypseous treated with other stabilizer materials and untreated soil. The sodium silicate reacts with water and after short time periods the mixture of gypseous soil and sodium silicate become very stiff .

e. Permeability Coefficient vs Leaching strain

Typical curves that show the permeability coefficient (k) with leaching strain relationship are shown in Fig. 7 for oedometer permeability–leaching test.

The coefficient of permeability (k) decreases as the leaching strain increases, this behavior may attributed to the reorientation of soil particle when subjected to stress during leaching test, after gypsum particles dissolute and leached out , the induced pores fill with other soil particles under stress and block the pores , that in turn reduce the coefficient of permeability.

The treated gypseous soil with stabilizer materials reduce the permeability coefficient compared to untreated soil, where these materials act as an impermeable layer to reduce gypsum dissolution, as well as fill the induced pores which in turn reduce the coefficient of permeability. The sodium silicate shows high efficiency in reducing coefficient of permeability compared to other stabilizer materials as shown in Fig. 7.

f. Permeability Coefficient vs Time Relation

Typical curves that show the permeability coefficient (k) with time relationship are shown in Fig. 8 foroedometer permeability–leaching test.

In this test, permeability of gypseous soil investigated. At this condition, it can be generally observed, that the permeability coefficient (k) decreases sharply with time especially at the beginning of test and then continuous decreasing in small amount tell the end of test. This behavior may be attributed to the collapse of soil particles structure that conjugates with continuous removal of cementing (gypsum) materials due to leaching process .

It is clearly noted from Fig.8 that the stabilizer materials reduce the coefficient of permeability gradually where these materials fill the pores and reduce permeability coefficient .

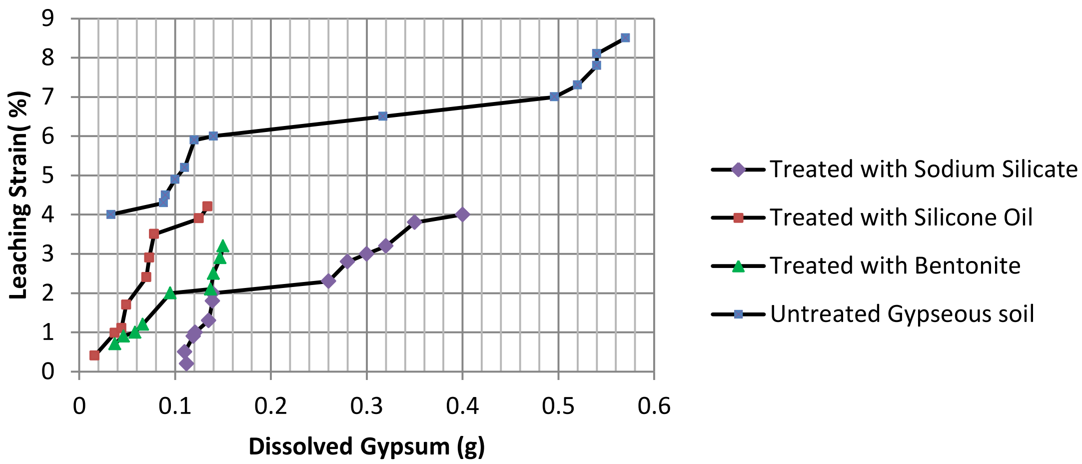


Figure (3).Leaching strain–dissolved gypsum relation for treated and untreated gypseoussoil.

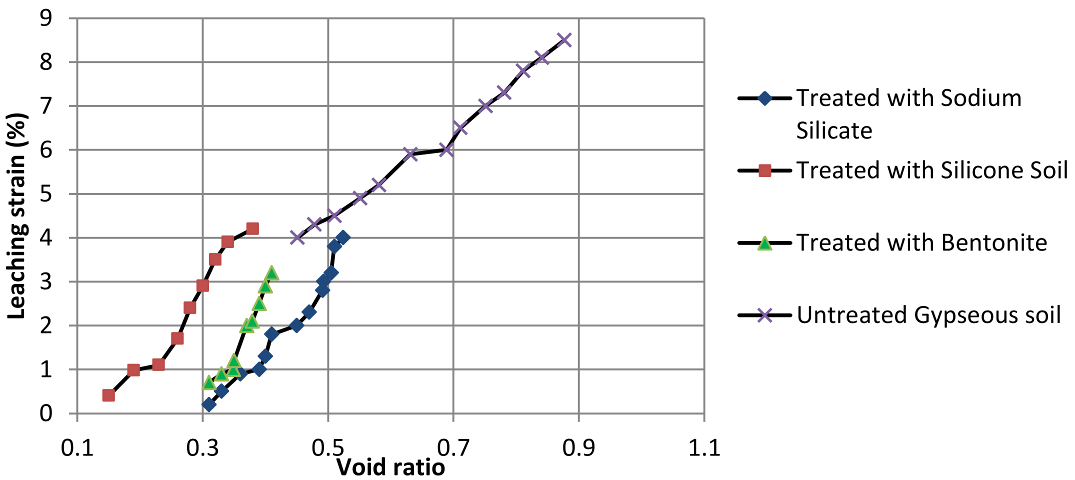


Figure 4.Leaching strain-void ratio relation for treated and untreated gypseous soil

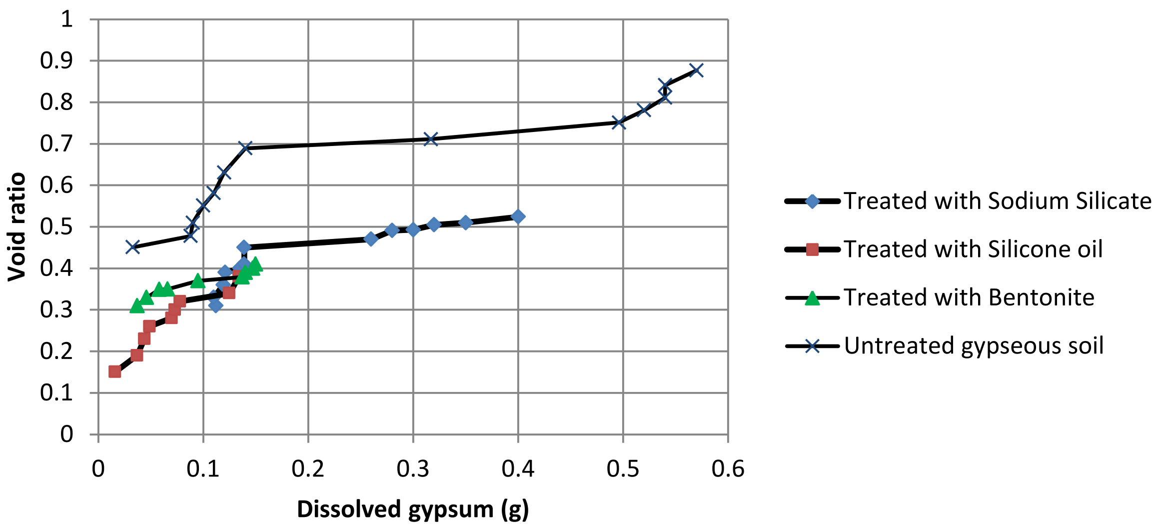


Figure 5.Void ratio-dissolved gypsum relation for treated and untreated gypseous soil.

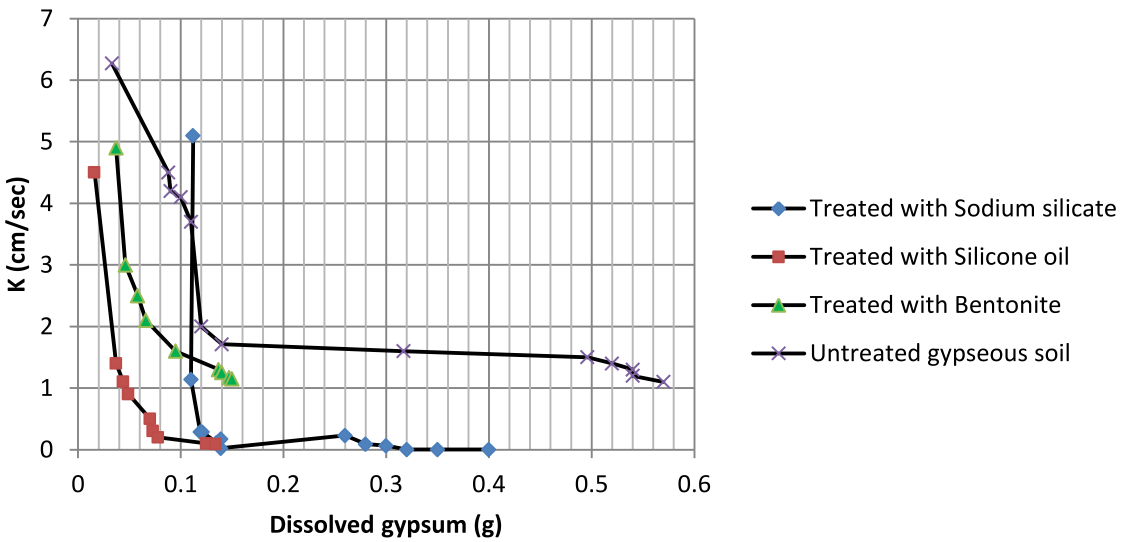


Figure 6.Coefficient of permeability-dissolved gypsum relation for treated and untreated gypseous soil.

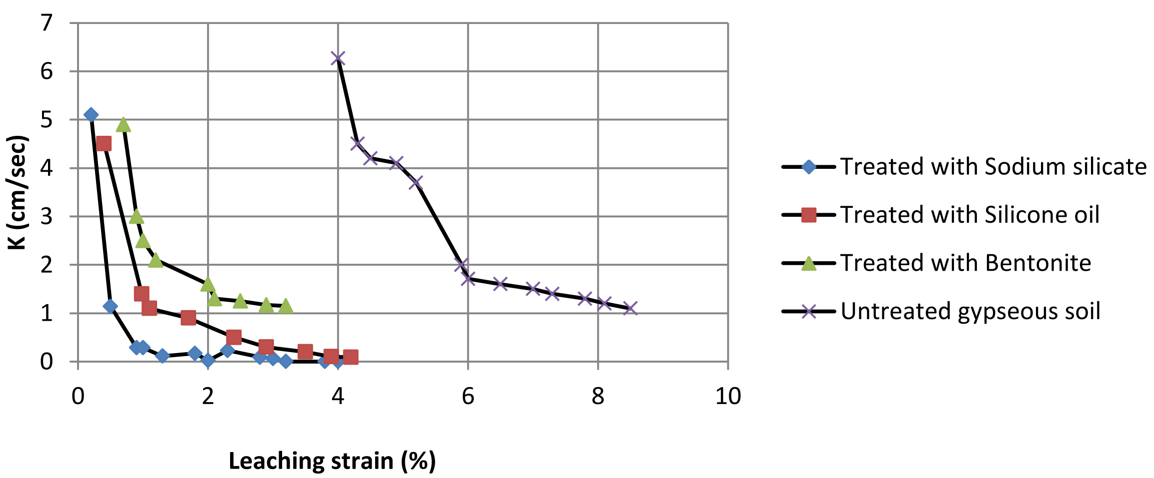


Figure 7.Coefficient of permeability-leaching strain relation for treated and untreated gypseous soil.

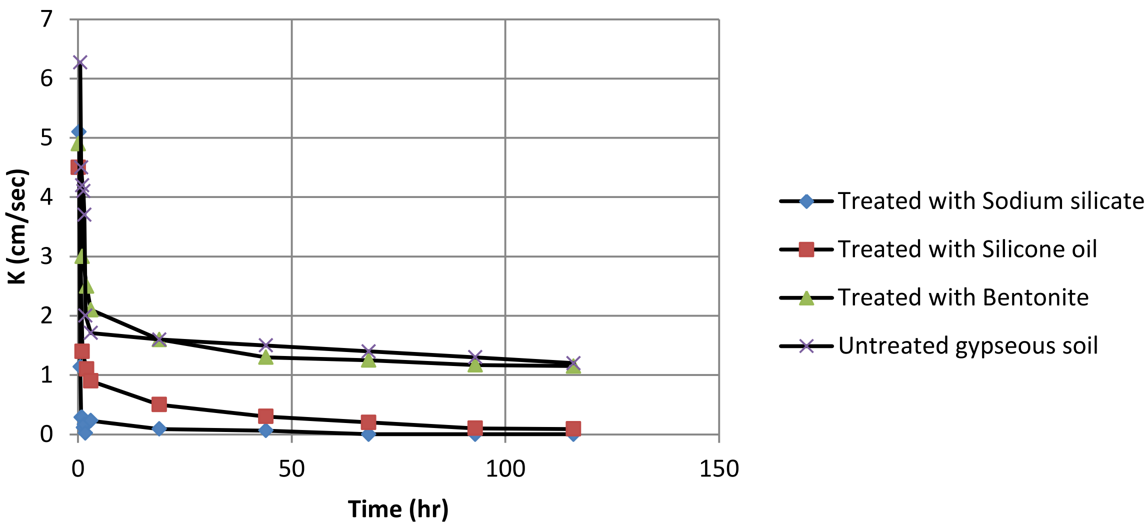


Figure 8.Coefficient of permeability-time relation for treated and untreated gypseous soil.

7. Conclusions

The conclusions obtained from this research can be summarized in the following points:

1- The treated gypseous soil exposed to less gypsum dissolution, where the stabilizer materials form an impermeable layer to prevent direct contact of water and gypsum which reduce gypsum dissolution, and thus in turn reduce leaching strain.

2- The silicone oil more effective in minimize gypsum dissolution and reduce void ratio compared to other stabilizer materials (Bentonite and sodium silicate).

3- The gypseous soil treated with sodium silicate has low coefficient of permeability compared to gypseus soil treated with other stabilizer materials and untreated soil. The sodium silicate react with water and after short time periods the mixture of gypseous soil and sodium silicate become very stiff .

4- The treated gypseous soil with stabilizer materials reduce the permeability coefficient compared to untreated soil, where these material act as an impermeable layer to reduce gypsum dissolution, as well as fills the induced pores which in turn reduce the coefficient of permeability. The sodium silicate shows high efficiency in reducing coefficient of permeability compared to other stabilizer materials.

5- The permeability coefficient (k) decreases sharply with time especially at the beginning of test and then continuous decreasing in small amount tell the end of test. This behavior may be attributed to the collapse of soil particles structure that conjugates with continuous removal of cementing (gypsum) materials due to leaching process.

8. References

1- Brenner, R., Nutalaya, P.; Chilingraian,G. and Robertston, J. (1981)."*Engineering Geology of Soft Clay, Soft Clay Engineering*". Edited by Brand and Brenner, Elsevier Scientific Publishing Company.

2- Mikheav, V. andPetrukhin, V. (1973)."*Construction properties of saline soils used as foundation beds in industrial and civil construction*". Soil Mechanics and Foundation Engineering 9(3), 30-36.

3- Mikheev, V., Petrukhin, V. andBoldirev, G. (1977)."*Deformability of gypseous soils*". Proc. of 9th Int. Conf. on Soil Mechanics and Foundation Engineering,ICSMFE, Vol. 1, pp. 211-214.

4- Petrukhin, V. andBoldyrev, C. (1978)."*Investigation of the deformability of gypsfied soils by a static load*". Soil Mechanics and Foundation Engineering 15(3), 178-182.

5- Al-Obaidi ,Q. (2014)."*Hydro-Mechanical behavior of collapsible soils, Ph.D. Dissertation*".Faculty of civil and environmental engineering, Ruhr-university Bochum, Germany.

6- Al-Badran, Y. (2001)."*Collapse behavior of al-tharthargypseous soil*". M.Sc. thesis, Civil Engineering Department, University of Baghdad, Iraq.

7- Barzanji, A. (1973)." Gypsiferous Soils in Iraq". PhD. dissertation, university of Ghent, Belgium.

8- Ibrahim, A.N. and Schanz, T. (2017)."*Improvement of gypsiferous soil by silicone oil*". Soil Mechanics and Foundation Engineering,Vol.54, issue 2, pp. 117-121.

9- Ibrahim , A.N. and Arash, K. (2017) ."*Remedial method for collapsible soil foundation of Mosul dam*". Proceedings of 42ndannual conference on deep foundations, Deep Foundation Institute (DFI), New Orleans, Louisiana, USA .

10- Al-Busoda, B. (1999)."*Studies on the behavior of gypseous soil and its treatment during loading*". Master's thesis, Civil Engineering Department, University of Baghdad, Iraq.

11- Head, K. (1982)."*Manual of Soil laboratory Testing*". London. Vol. 1, Published by:Prentch press.

12- ASTMD2216 (2010)."*Standard test methods for laboratory determination of water (moisture) content of soil and rock by mass*". Annual Book of ASTM Standards,Vol.04.08, Philadelphia, PA, ASTM,USA. Copyright, ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, USA.

13- Al-Mufty,A.(1997). "*Effect of Gypsum Dissolution on the Mechanical Behaviour of Gypseous Soils*". PhD dissertation, Department of civil Engineering, University of Baghdad.

14- Al-Khuzaie,H.(1985). "*The effect of leaching on the engineering properties of al-jazirah soil*".M.Sc. thesis, Civil Eng. Dep., University of Mosul, Mosul, Iraq.

15- Seleam, S. (1988). "*Geotechnical characteristics of a gypseous sandy soil including the effect of contamination with some oil products*". M.Sc. thesis, Building and Construction Department, University of Technology Baghdad, Iraq.

16- Nashat, I.H. (1990). "*Engineering Characteristics of Some Gypseous Soils in Iraq*". Ph.D. dissertation, Civil Engineering Department, University of Baghdad.

17- Ibrahim, A.N. and Schanz, T. (2014)."*Shear strength and collapsibility of Gypsiferous Soils*". Proceedings of IAEG XII Congress, Engineering Geology for Society and Territory, Torino, Italy, Vol. 2, pp. 1109-1115.