American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS)

ISSN (Print) 2313-4410, ISSN (Online) 2313-4402

http://asrjetsjournal.org/

Effect of Organic Soil Acidity on the Properties of Iraqi Soil

Abdulaziz Al-Kifaae[a*], Nada Hisham Aayed[b]

[a,b]*University of Al-Nahrain/College of Engineering/Civil Engineering dept., prof. Dr., Iraq*

[a]*Email: alkifaaeaziz@yahoo.com*

[b]*Email: nada_hesham93@yahoo.com*

Abstract

There are many problems with the constructing over organic soils as the existence of these types of soils always produces geotechnical and engineering problems for regional development. The geotechnical properties of inorganic soil greatly differ from organic soils, which is known for its high water content, low shear strength, high compressibility, acidity and long-term settlement. In this paper, two soils are chosen according to its organic content and acidity content then physical and chemical properties is done to know them characteristics and leaching process is performed to reduce its acidity that affect the properties of it and study the change of leaching on these properties. Dry hydrated lime is added to the natural and leached soils depending on the optimum lime content to improve their performance. From the physical tests, shear strength tests and consolidation test it can be noticed that the soils are behave better after leaching as it reduced in plasticity index, compressibility, and swelling and increase in shear strength. Furthermore, the leached soils are needed less percentage of lime content to produce a pH of 12.4 and the stabilized leached organic soils are behave better than the stabilized natural soils.

Keywords: Organic Soil; Hydrated Lime; Leaching; Acidity.

1. Introduction

The foundation of buildings is affected by physical properties (Atterberg limit, specific gravity, and compaction), chemical properties (acidity, and chemical composition), shear strength, and compressibility.

----

* Corresponding author.

Organic deposits is an undesirable subgrade material for construction of roadways and buildings because of their low shear strength and high compressibility. Subsequently, the organic content has become a source for carbon, nitrogen, sulphur, phosphorous; these elements have become a source for Cation Exchange Capacity (CEC) and acids [1].

Acids that are generated in the soil by decomposition of organic matter should be avoided due to its harmful effect on foundations. PH determines the mobility of cations and over all influences sorption reactions. Generally, neutral soils is more preferable than acidic soils, and acidic soils are limed to improve their quality [2].

In practice of soil mechanics, Leaching can be defined as a process, which removes materials from solution (e.g. salts) and cementation agent from a section in the soil profile [3].

General construction problems in this deposit are low bearing capacity, low shear strength, and high settlement of buildings, and embankments. Due to their poor properties, organic soil has to be improved before any engineering works. The improvement can be denoted by changing material in the site with the superior material or changing the engineering properties of site materials according to the standard requirement by additional material known as the soil stabilization [4].

2. Materials and methods

2.1 Soil

Two sites are chosen in Baghdad, one of them in Al-A'amiriya district from excavation of sewer pipelines to a depth of 2.5 m after agreement of site engineer, and the other in Al-Jehad district chosen for its dark color as it is domestic garbage dam to a depth of 0.5m. Both of them have a problem of organic matter in their soils. Studying the soil properties before and after leaching and stabilization may be useful to understand the effect of organic soil and its acids on the properties of soil.

2.2 Lime

In the this study, hydrated lime is used, $Ca(OH)_2$. Hydrated Lime is produced by the reaction of quicklime (CaO) with sufficient water to form a white powder**.** Lime is commonly used in hydrated form, as powder [5]. It reacts with clay particles and permanently transforms them into a strong cementitious matrix. It is reduce soil capacity to hold water and increase its stability, dry hydrated lime can be used for drying soil. The mineralogical properties of the soils will determine their degree of reactivity with lime and the ultimate strength that the stabilized layers will develop [6].

2.3 Leaching test

Leaching is a process by which water-soluble substances (such as salts, acids, and pesticides) are washed out from soil or wastes.

2.3.1 Preparation of container used in experimental test

Steel box with internal dimensions of 30cm length, 30 cm width, 30 cm height, and this box is used for performing the leaching process. The steel container are made from a steel angle (25.4 mm x 25.4 mm) with a thickness of 2 mm and steel plates of 2 mm thickness to form the walls and the base of container. This container sides is rigid enough to function as independent reaction frame. A thick glass panel of 10 mm thickness is inserted within a section of the container wall to function as a window to observe the level of the soil during the preparation of the soil model. A 5 cm layer of clean aggregate is placed over the perforated steel base (the perforation consists of 3 mm openings at spacing of 25 mm) for testing container. The aggregate layer is prepared by sieving the soil on sieve 3/4” (19 mm opening), and retained on sieve No. 4 (4.75 mm opening),and a layer of 13 cm clean sand is placed over the layer of aggregate, the sand layer is prepared by sieving on sieve No.4 (4.75 mm opening), and retained on sieve No.(0.15mm opening). Figure (1) showed the container used in the tests.

Figure 1: Testing container.

2.3.2 Preparation of Soil sample for leaching test

In this study, the soil is prepared in accordance with the maximum dry density and optimum moisture content. The preparation procedure of soil sample is summarized as follows:

An organic soil is mixed carefully with the calculated amount of the optimum moisture content. The box of soil leaching process is prepared and greased to coat the contact surfaces between soil and inner face of box to reduce interface friction and a paper is put above the sand layer to eliminate the extraction of fine particles as a filter paper. The soil sample is compacted by a steel hummer of (100*100) mm in size inside the box in four layers to obtain the maximum dry density. The soil is immersed with tap water after preparing longitudinal and across grooves of 2.5 cm to facilitate penetration of water in soil as shown in Figure (2) (a). Oak wooden square pad of 29.5 cm *29.5 cm shown in Figure (2)(b) is placed over the soil to distribute the load, then the soil is loaded by weights as shown in Figure (2)(c) to apply a stress of 60 kPa to leach the water down word, out of the soil to get rid of acids. The pH of soil is read for several times by taking samples from the soil, until the pH is being neutral. The leaching process is continued from 25 to 30 days.

(a) Making grooves.

(b) Oak wooden pad (c) Loaded soil

Figure 2: preparation of leaching test (a) Making grooves, (b) Oak wooden pad, (c) Loaded soil.

3. Experimental work

Classification tests [7], Atterberg limit [8], compaction test [9], chemical test in General Company of Geological Survey and Mining, organic content [10], and pH [11] were conducted on natural soil. Then Atterberg limit [8], compaction test [9], unconfined compression test [12], direct shear test [13], optimum lime content test [14], and consolidation test [15] are conducted on leached organic soil and stabilized organic soil. Physical and chemical properties for natural soils are shown in table1 and table 2 for al A'amiriya and al Jehad soil, respectively and table 3 is the chemical test for lime.

Table 1: the summary of physical and classification tests for both soils.

properties	standard	Al-A'amiriya soil	Al-Jehad soil
Sand (0.06 to 2mm) %	ASTM D 422	39	27
Silt (0.005 to 0.06)	ASTM D 422	32	30
Clay (less than 0.005mm)	ASTM D 422	29	43
Liquid limit	ASTM D4318-10	43.7	48.7
Plastic limit	ASTM D4318-10	25.3	18.3
Plasticity index	ASTM D4318-10	18.4	30.4
Optimum moisture content (%)	ASTM D698-12	30	33
Max. dry density (kN/m^3)	ASTM D698-12	14.3	13.4

Table 2: chemical test of al-A'amiriya and al- Jehad soil.

Chemical element	al-A'amiriya soil	al- Jehad soil
Total dissolved salts	2.87	1.32
SO_3 (%)	1.56	1.108
$CaCO_3$ (%)	9.57	4.72
CaO (%)	8.24	6.37
Organic content (%)	21.46	28.72
pH	6.2	5.7

Table 3: chemical test for lime.

Chemical Element	Percent (%)
CaO	69.8
MgO	2.4
Fe_2O_3	1.9
AL_2O_3	1.2
SiO_2	2.3
SO_3	0.5
CO_2	2.7
Loss of Ignition	19.1

4. Results

Physical tests, consolidation test, unconfined compression test, direct shear test, and optimum lime content test are conducted on natural organic soil, leached organic soil and stabilized organic soil. The following is the results of these tests:

4.1 Atterberg limit

Liquid limit tests are carried out using the Casagrande method according to [8], and then the plastic limits were carried out on the soils. In tables (4) and (5), it can be noticed that, the liquid limits, and plastic limits of natural organic samples are greater than that of leached organic samples. The results of the liquid limits, plastic limits tests and plasticity indices on natural organic soils and leached organic soils treated by the optimum lime content illustrated in section 4.3 shows that the treated soils have low plasticity index compared to the untreated soils for both types. These results are attributed to that, the lime decreases the plasticity index of plastic soils [16] because ions exchange for lime with soil particle.

Table 4: results of Al-A'amiriya soil Atterberg limit

Al-A’amiriya Soil	Natural organic soil pH (6.2)	Natural organic soil with 6% lime pH (12.4)	Leached organic soil pH (7.5)	Leached organic soil with 4% lime pH (12.4)
Liquid limit (%)	43.7	48.5	42.4	49.3
Plastic limit (%)	25.3	33.4	24.8	35.4
Plasticity index (%)	18.4	15.1	17.6	13.9

Table 5: results of AL-Jehad soil Atterberg limit

Al-Jehad Soil	Natural organic soil pH (5.7)	Natural organic soil with 8% lime pH (12.4)	Leached organic soil pH (7.4)	Leached organic soil with 6% lime pH (12.4)
Liquid limit (%)	48.7	55.9	46.5	51.2
Plastic limit (%)	18.3	33.7	16.8	30.6
Plasticity index (%)	30.4	22.2	29.7	20.6

4.2 Compaction test

Standard compaction test were carried out on the soil using rammer of 2.5 kg, drop of 350 mm and mold of 105 mm in diameter and 115.5 mm in height, with three layers of soil and 25 blows according to [9]. The test were carried out on natural organic soil, leached organic soil and stabilized soil samples, from tables (6) and (7) it can be noticed that the max. dry density for both soils are relatively low. It can be found that leaching process has slightly effect on the max. dry density and the optimum moisture content for both soils. The optimum lime contents described in section 4.3 are used to prepare the compaction specimens for the stabilization samples of natural organic soils and leached organic soils. Soils treated with lime give notable increase in optimum moisture content while undergoing a decrease in maximum dry density these results agreed with [17].

The results for AL-A'amiriya and AL-Jehad soils are shown in tables (6) and (7).

Table 6: results of AL-A'amiriya soil compaction test

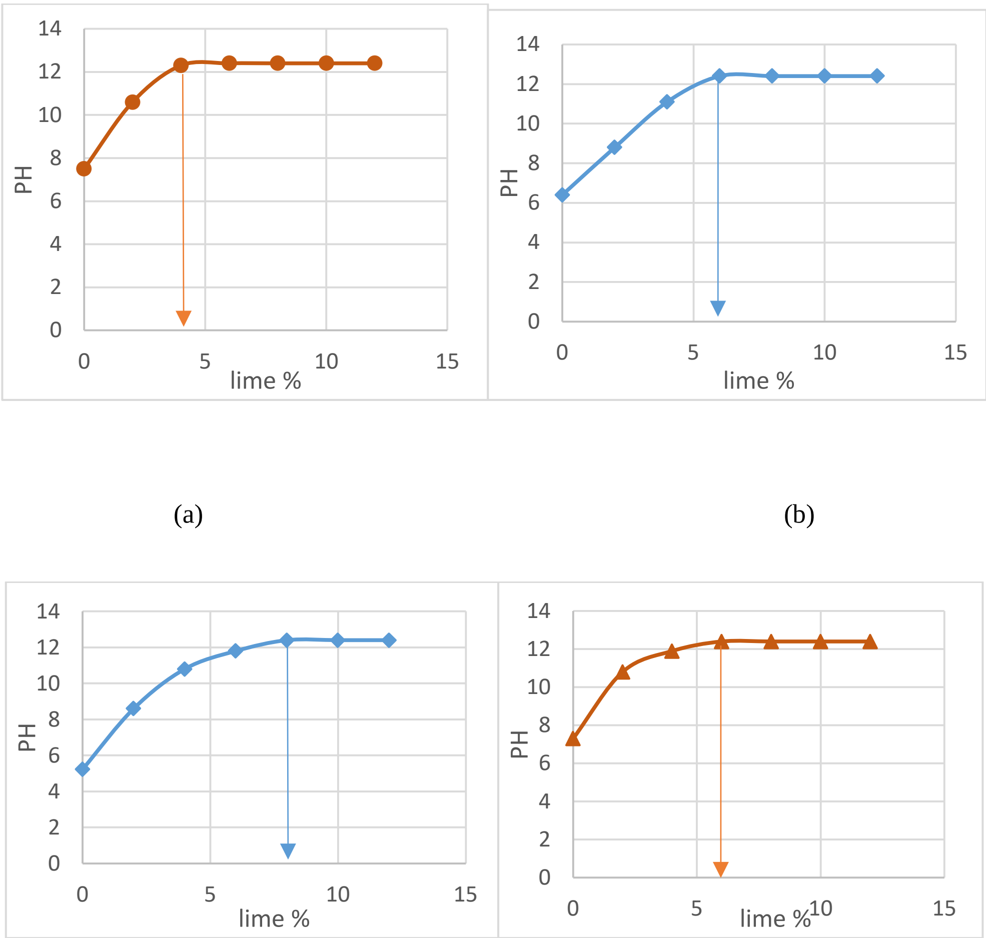
Soil type	natural organic soil	natural organic soil with 6% lime	Leached organic soil	leached soil with 4% lime
Max. dry density	14.3	13.1	14.5	13.8
Optimum moisture content %	30	35	29	32

Table 7: results of AL-Jehad soil compaction test

Soil type	natural organic soil	natural organic soil with 8% lime	Leached organic soil	leached soil with 6% lime
Max. dry density	13.4	12.2	13.9	12.7
Optimum moisture content %	33	38	31	35

4.3 Optimum lime content

The optimum lime content is determined by using Eades and Grim procedure [14]. The pH was conducted according to [11]. The lime content is determined by performing the pH test on the soil samples by adding 2%, 4%, 6%, 8%, 10% and 12%. The lime content corresponding to pH concentration equal to the 12.4 is taken as optimum lime content percentage. Graphs of optimum lime content determination is shown in the Figure (3) from (a) to (d).



(a) (b)

(c) (d)

Figure 3: results of the optimum lime content (a) natural organic soil for al A’amiriya, (b) leached organic soil for al A’amiriya, (c) natural organic soil for al Jehad, (d) leached organic soil for al Jehad.

4.4 Unconfined compression test

Unconfined compressive strength tests were conducted according to [12] on samples of natural organic soils, leached organic soils, stabilized soils with the optimum lime content at different curing intervals of 7, 14, 28 and 56 days and the same tests on these soils were conducted on samples at zero days. It can be noticed that the shear strength of leached organic soils is higher than that of natural organic soils that is due to the presence of acids and bacterial spores that are increase the void ratio of soil and reduce the cohesion between soil particles resulted in shear strength reduction. In addition, it can be noticed that a slight reduction in strength of leached soils after 56 days due to the decomposition of organic matters, and increasing in strength for stabilized soils for natural and leached soils because of the strong bonds that creating between soil particles, which form a strong structure [18]. Figures (4) and (5) showed the unconfined compression strength tests on all soil samples is carried out at different curing periods.

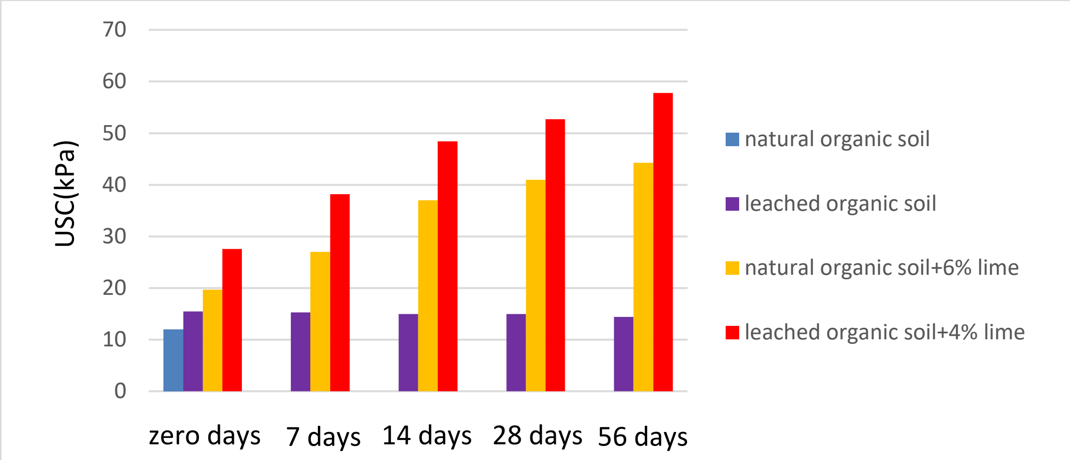


Figure 4: results of USC for AL-A'amiriya soil

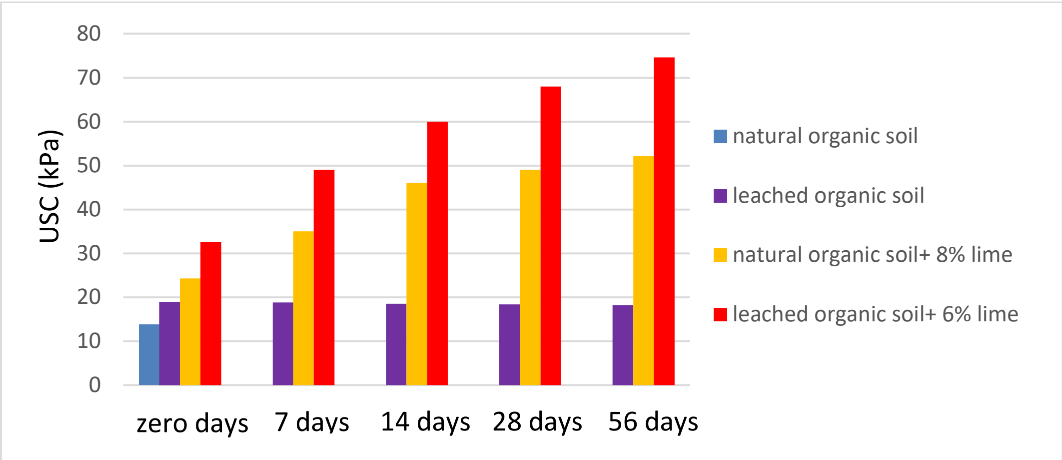


Figure 5: results of USC for AL-Jehad soil

4.5 Direct shear test

Direct shear test is used to predict the behavior of shear strength parameters, angle of internal friction (Φ) and cohesion (c) for natural organic soil, leached organic soil, and stabilized soil. Shear strength characteristics of natural organic soil, leached soil, and lime stabilized soil are studied by conducting direct shear test according to [13] at three normal stresses 27.24, 54.48 and 81.72 kPa including the weight of the hanger. The results of direct shear conducting on soil samples are shown in figures 6 and 7. The figures showing the maximum shear stress versus normal stress, and the shear strength parameters, angle of internal friction (Φ) and the cohesion (c). It is clear that the cohesion of leached organic soil is greater than the cohesion of natural organic soil because of the decomposed materials are surround the soil particles and impede the cohesion between fine soil particles. While the angle of internal friction remains constant for both soils because of there is no losses in organic matters and coarse particles during leaching process. In addition, the stabilized leached soil has shear parameters higher than that of stabilized natural organic soils this may be due to the acids that enclose the soil particles and hinder the reaction between soil and lime added. It is obvious that the alkalinity is an effective agent for stabilization [19]. For a stabilized soil, it can be shown that the angle of friction and the cohesion increases for both soils. These results are attributed to the pozzolanic reaction, which occurs between lime, alumina, and silica of the clay mineral and produces cementing material including calcium-silicate-hydrates and calcium alumina hydrates [18].

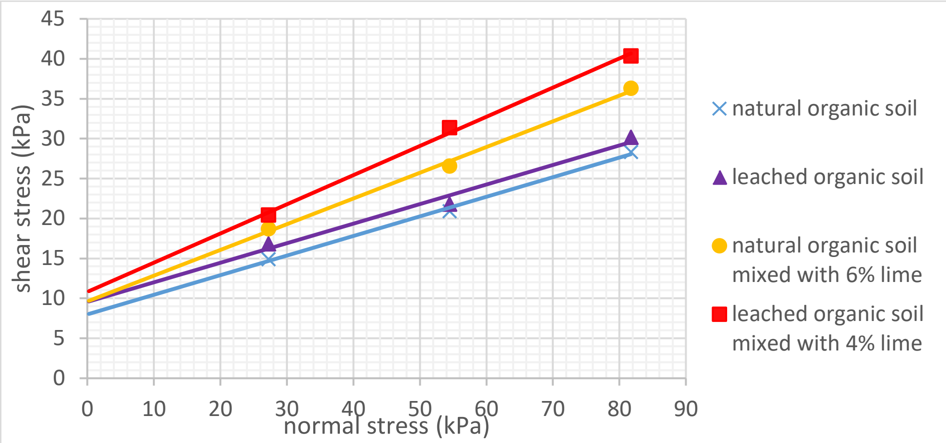


Figure 6: direct shear test for al A'amiriya soil

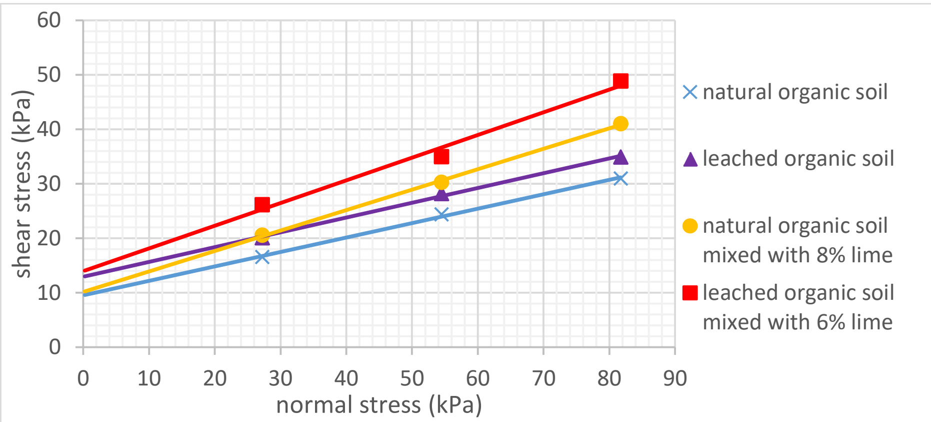


Figure 7: direct shear test for al-Jehad soil

4.6 Consolidation test

These tests are conducted to study the compressibility of natural organic soil, leached soil and lime stabilized soil by determining the compression parameters (compression index C_c, and swelling index C_s.

4.6.1 Effect of organic content on compression index (C_c) and swelling index (C_s)

From figures (8) and (9), it can be illustrated, the effect of organic content on compression index for natural organic soil and leached organic soil. Compression index (C_c) and swelling index (C_s) for natural organic soil samples is greater than that of leached organic soil samples as C_c is (0.57 and 0.43) and (0.83 and 0.67) for al A'amiriya and al Jehad soil respectively and C_s is (0.076 and 0.053) and (0.102 and 0.086) for al A'amiriya and al Jehad soil, respectively . This is due to the decomposition of organic solids that include microbial activity with the formation of gases, water, new bacterial cells, and acids. These products are able to produce spores between soil colloids and tend to increase the voids ratio; therefore, compressibility is increased [20]. The addition of the optimum lime content to the soil is lead to bond the soil particles that increased the soil resistance to applied stresses [21]. This is clear for the stabilized natural organic soil and leached organic soil as C_c is (0.39 and 0.25) and (0.64 and 0.59) for both AL-A'amiriya and AL- Jehad soil, respectively and C_s for natural and leached stabilized soils are (0.068 and 0.053) and (0.067 and 0.041) for AL-A'amiriya and AL-Jehad soil, respectively. The values of swelling indices depend on the percentage of organic material and the decomposition of the organic matter and these affect the optimum lime content for (natural organic and leached organic soil). It can be observed that the lime addition reduced the swelling index for natural organic soil and leached organic soil for both soils. These results may depended on the interaction between organic fibers and soil particles. Furthermore, the interaction of both materials with lime and the chemical reactions which may develop between these materials.

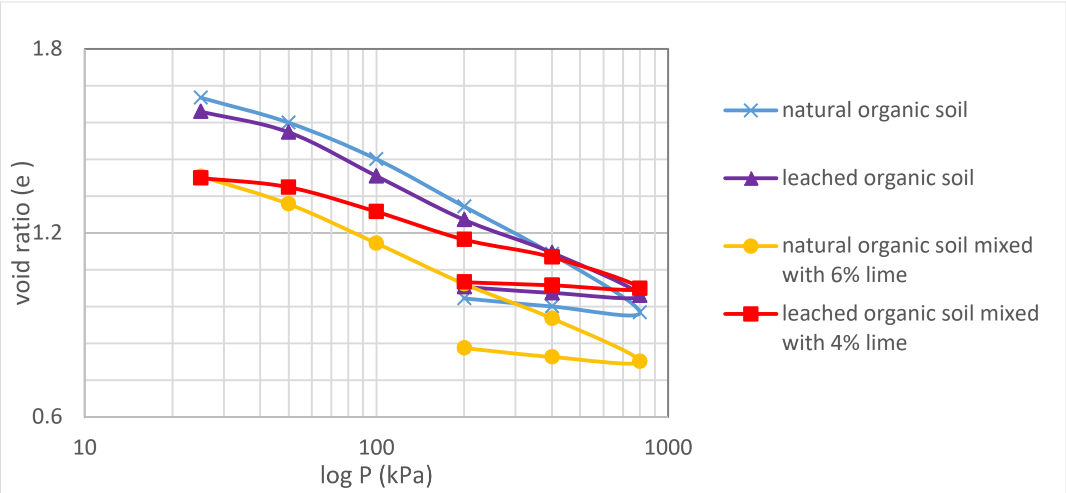


Figure 8: consolidation test for al-A'amiriya soil.

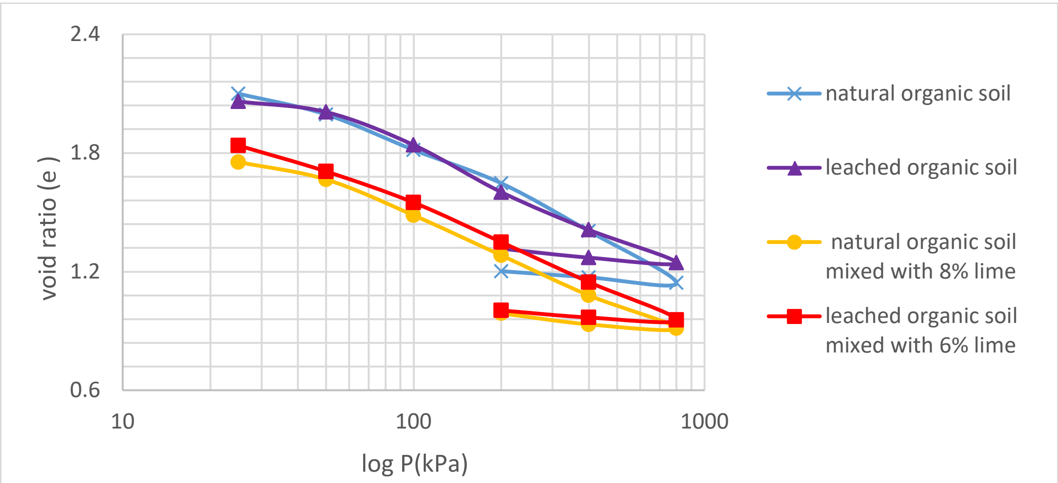


Figure 9: consolidation test for al-Jehad soil.

5. Conclusions

The effect of organic soil acidity can be concluded as follows:

i. Effect of leaching

1. The liquid, plastic limits and plasticity index of leached soils are less than that of natural organic soil, for both soils.
2. The maximum dry unit weight increases and the optimum moisture content decreases for leached soil for both soils.
3. The values of cohesion for leached samples increases by (33% and 35%) for al A'amiriya and al Jehad soil , respectively, while the angle of internal friction (Ø˚) remains constant for both soils.
4. The unconfined compression strength increases compared with leached soil by (29% and 37%) for al-A'amiriya and al-Jehad soil, respectively but it is decreased after curing for both soils.
5. The compression index (C_c) decreased by (24% and 19%) and swelling index (C_s) decreases by (27% and 16%) for leached soil for al-A'amiriya and al-Jehad soil, respectively.

ii. Effect of lime on natural organic soil and leached organic soil.

1. The liquid and plastic limits generally increase with the addition of the optimum lime content for natural organic soil and leached organic soil for both soils, but the plasticity index decreases for both soils.
2. The max. dry unit weight decreases and the optimum moisture content increases with the addition of optimum lime content for both soils.
3. The cohesion of soil increases slightly with the addition of the optimum lime content. It is increased by (34% and 17%) for natural stabilized soils for al A'amiriya and al Jehad soil and by (13% and 8%) for leached stabilized soils for al A'amiriya and al Jehad soil. The angle of internal friction increases clearly with the addition of the optimum lime content by (29% and 33%) for natural organic soil and (45% and 47%) for leached organic soil for both al A'amiriya and al Jehad soil, respectively.
4. The unconfined compression strength increases with the addition of optimum lime content by (2.69 and 2.73) for al A'amiriya soil and by (277% and 286%) for al Jehad soil for natural organic soil and leached organic soil, respectively.
5. With the addition of optimum lime content for soils the compression indices (C_c) for natural organic soil are decreased by (32% and 23%) for al A'amiriya soil and al Jehad soil, respectively. In addition, by (41% and 12%) for leached organic soils for al A'amiriya soil and al Jehad soil, respectively. swelling indices (C_s) decreases by (17% and 34%) for natural stabilized soil for al A'amiriya and al Jehad soil. The leached organic soils are decreased by (26% and 42%) for al A'amiriya soil and al Jehad soil, respectively.

6. Recommendations

1. The effect of higher organic materials with more acidic content on the engineering properties of the

soil.

2. Studies the effect of leaching on the engineering properties for a long time.
3. The effect of leaching with chemicals on the acidity of soil.
4. The effect of further chemicals such as (fly ash, cement, and silicate) for soil treatment.

References

[1] H.L. Bohn, B.L. McNeal, and G.A. O'Connor. Soil chemistry. United States: John Wiley and Sons, 2001, pp.155-171.

[2] S. Kazemian, A. Prasad, B. B. K. Huat, B. J. Bolouri, N. A. A. Farah, and A. M. Thamer. "Effect of Aggressive pH Media on Peat Treated by Cement and Sodium Silicate Grout", J. Central South Univ. Technol., Vol 17, No. 3, pp. 309-318, 2011c.

[3] R. Brenner, P. Nutalaya, G. Chilingraian, and J. Robertston. "Engineering Geology of Soft Clay" in Soft Clay Engineering, 20, Brand and Brenner, Ed. New York: Elsevier Scientific Publishing Company, 1981, pp.205- 211.

[4] O. G. Ingles and J. B. Metcalf. Soil Stabilization Principles and Practice, New York: Wiley, 1972, pp.127- 132.

[5] k. Harichane, M. Ghrici, W. Khebizi, and H. Missoum. "Effect of the Combination of Lime and Natural Pozzolana on the Durability of Clayey Soils" EJGE, Vol. 15 Bund. L, PP.1194-1209, 2010.

[6] American Road Builders Association Subcommittee on Lime Stabilization. Lime-treated Soil Construction Manual Lime Stabilization and Lime Modification. United States: national lime Association lime the universal chemical, January 2004, pp. 4-10.

[7] ASTM D 422-63."Standard Test Method for Particle-Size Analysis of Soils" in Annual Book of ASTM Standards, Vol. 04.08, ASTM International, Ed. West Conshohocken, PA,USA, 2007,pp.1-8.

[8] ASTM D 4318-10."Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils" in Annual Book of ASTM Standards, Vol. 04.08, ASTM International, Ed. West Conshohocken, PA, USA, 2014, pp.1-16.

[9] ASTM D 698-12."Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12 400 ft-lbf/ft3 (600 kN-m/m3))" in Annual Book of ASTM Standards, Vol. 04.08, ASTM International, Ed. West Conshohocken, PA, USA, 2012, pp.1-13.

[10] ASTM D2974. "Standard Test Method for Moisture Content, Ash and Organic Matter of Peat and Other Organic Soils" in Annual Book of ASTM Standards. Vol. 04.08. ASTM International, Ed. West Conshohocken, PA, USA, 2006, pp. 33-37.

[11] ASTM D 4972-13."Standard Test Method for pH of Soils" in Annual Book of ASTM Standards, Vol. 04.08, ASTM International, Ed. West Conshohocken, PA, USA, 2013, pp.1-4.

[12] ASTM D 2166-13. "Standard Test Method for Unconfined Compressive Strength of Cohesive Soil" in Annual Book of ASTM Standards, Vol. 04.08. ASTM International, Ed. West Conshohocken, PA, USA, 2013, pp. 1-7.

[13] ASTM D 3080-11. "Standard test method for direct shear test of soils under consolidated drained conditions." in Annual Book of ASTM Standards, Vol. 04.08. ASTM International, Ed. West Conshohocken, PA, USA, 2013, pp. 1-9.

[14] ASTM D6276-99a. “Standard Test Method for Using pH to Estimate the Soil-Lime Proportion Requirement for Soil Stabilization.” in Annual Book of ASTM Standards, Vol. 04.08. ASTM International, Ed. West Conshohocken, PA, USA, 2006, pp.1-4.

[15] ASTM D 2435-80. "Standard Test Methods for One-Dimensional Consolidation Properties of Soils Using Incremental Loading" in Annual Book of ASTM Standards. Vol. 04.08. ASTM International, Ed. West Conshohocken, PA, USA, 2004, pp. 1–15.

[16] P.P. Raj. Ground improvement techniques. New Delhi: Laxmi Publications, 1999, pp.189-199.

[17] Z. H. Sadiq. ”Improvement of Engineering Properties of Model Organic Soils.” M.A.thesis, Al-Mustansiriya University, Iraq, 2015.

[18] M. R. Hausmann. Engineering Principles of Ground Modifications, New York: McGraw Hill Publishing Company, 1990, pp.308-315.

[19] M. H. Ghobadi, R. Babazadeh, and Y. Abdilor. ”Utilization of lime for Stabilizing Marly Soils and Investigating the Effect of pH Variations on shear Strength Parameters” Journal of Engineering Geology, Vol.8, No.1, pp. 1939-1962, Spring 2014.

[20] N. C. Brady. “Organisms of the Soil” in The Nature and Properties of Soils, 9th edition. New York: Macmillan publishing Company, 1984, pp.223-245.

[21] H. V. Fang**.**” Soil Stabilization and Grouting” in Foundation Engineering Handbook, 2nd edition, Vol. 2, New York: Springer Science and Business Media, 1991, pp. 337-344.