Studying of the Gypsiferous Soil Suction Using Filter Paper Technique

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Abstract

Gypsiferous soils have specific feature under its suction studying. These soils contain salt solution that affects on the suction components at high water content levels. This paper investigates soil suction of three types of gypsiferous soils namely: Al-Muhallabeia, Al-Jarin, and Al-Slmanii using filter paper technique. The investigated soils were located in Nineveh province (400 Km north Baghdad capital) and found to have a gypsum content of about 35, 23, and 6%, respectively.

This study includes some factors (water content, gypsum content, and clay content) that affect the soil suction for gypsiforous soils. The effect of gypsum content on slope of the relationship between soil suction with pF unit and water content was examined.

The results revealed that there is a linear relationship between soil suction and its water content for three studied soils. Both total and matric suction values increase as soil water content decrease. On the other hand, the difference between total and matric suction values increase with soil samples water content. The soil clay content has more effect on gypsiferous soil suction than its gypsum content.

Key words: *Gypsiferous soil, Soil suction, Total suction, Matric suction, Gypsum content.*

دراسة إجهادات المص للترب الجبسية باستخدام تقنية ورق الترشيح

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الخلاصة

تمتلك الترب الجبسية ميزات خاصة عند دراسة اجهادات المص لها، بسبب امتلاك تلك الترب على محاليل ملحية والتي تؤثر على مكونات إجهادات المص عند المستويات العالية من المحتوى المائي للتربة. هذه الدراسة تأخذ بنظر الاعتبار دراسة إجهادات المص لثلاث انواع من الترب الجبسية الواقعة في محافظة نينوى (400 كم شمال العاصمة بغداد): المحلبية، والجرن، والسلماني، والتي لها محتوى جبسي تقريباً (35، 23، 6) % على التوالي. تتضمن هذه الدراسة بعض العوامل (المحتوى المائي، المحتوى الجبسي، المحتوى الطيني) التي تؤثر على إجهادات المص للترب الجبسية باستخدام تقنية ورق الترشيح. أخيرا، درس تأثير المحتوى الجبسي على ميل العلاقة التي تربط بين مص التربة بوحدة pF والمحتوى المائي.

أظهرت النتائج بان هناك علاقة خطية بين مص التربة ومحتواها الرطوبي للترب الثلاث المدروسة. وان قيم المص الكلي والنسيجي تزداد مع نقصان المحتوى المائي، من الناحية الاخرى، التغاير بين قيم المص الكلي والنسيجي تزداد مع زيادة المحتوى المائي وان تاثير المحتوى الطيني اكبر من تاثير المحتوى الجبسي على قيم مص الترب الجبسية.

1. Introduction

Gypsiferous rocks and its sediments of different origins are found through out various countries in the world especially in the arid and semi arid regions. It may be found near ground surface or at different depths depending on the climatic circumstances and the geological history of the area. Generally, there are four main forms in which gypsum deposit can be found [1]:

i)   Integrated beds through the soil layers.
ii) Small lumps of gypsum within the soil layers.
iii) Distributed small spots of gypsum within the soil.
iv) Gypsum crystals form mainly in the surface horizon as a result of evaporation
    of ground waters.

Gypsiferous soil and soils with gypsum accumulation covers large parts of the world. Iraq is considering one of the countries that contains large area of gypsiferous soils. It is about 47792 km^2 which is equivalent to about 11.0 % of total country area [2]. Earlier many studies and researches were applied to obtain more knowledge of engineering properties for gypsiferous soil [3,4,5,6,]. On the other hands, others studies were done to understand behavior, classification, treatment, and land use potential of these soils [7,8,9,10,11,12].

gypsiferous soils in Iraq are mainly situated in the basin of Iraq. These soils are associated with Lower Fars formation of the Middle Miocene. The northern part of the upper AL-Jazierah region has a slightly gypsiferous soil which is formed over a gypsum bed rocks with gypsum content below 6 %. In the southern part of upper AL-Jazierah the gypsiferous soils are formed over gypsum and anhydrate rocks, and they are moderately to highly gypsiferous, with a gypsum content range from a few percentage to more than 60%. The lower AL-Jazierah is characterizing by gypsum desert where primary gypsum bed rock which is the main source of gypsum accumulation in other region [13].

The filter paper technique intensively used for measurements of soil suction because of its advantages over the other methods which are: low cost, simpler method for measuring soil suction both total and metric, can measure the entire range of soil suction, and the equilibrium period is acceptable. Soil suction measurements using filter paper technique has been studied by several researchers [14,15,16,17,18,19]. Al-Khashab [18] found good correlations between soil suction and different engineering properties of expansive soils selected from Mosul city. Al-Ashou et al [16] reported that the clayey soils a quire more suction value than the silty soils under the same moisture condition. Also, his results showed that the effect of density on the moisture-suction relationship is insignificant. This paper attempts to clarify some factors (water content, gypsum content, and clay content) that affect the soil suction value for gypsiferous soils.

2. Soil Suction

The theoretical concept of soil suction was developed in soil physics in the 20th century. The soil-water-plant system was the main factor that leads to develop the soil suction theory. The practical studies of soil suction was appeared to explain the mechanical behaviors of unsaturated soils relative to engineering problems especially water flow in the zone of negative pore-water pressure (capillary flow)[20].

Soil suction has an important role that controls the behaviors of unsaturated soils through its effect on engineering properties of the soils. The variety of soil water content (i.e.

degree of saturation) causing change in soil suction, "a relative humidity value less than 100% in a soil would indicate the presence of suction in the soil" [20]. It is commonly referred to as free energy state of soil water [21]. Total suction in soil can be divided mainly in to two parts express in equ. (1). The first one called **matric suction**: result from interplay of attraction and repulsion forces of clay particles and polar water molecules, together with surface tension force in water. The matric suction can be expressed as the difference between pore-air pressure (u_a) and pore-water pressure (u_w). The second part is **osmotic suction**: as solution potential due to presence of dissolved ions.

Total suction (kN/m^2) = $\psi_m + \psi_\pi$ .... (1)

where:

ψ_m : matric suction (kN/m^2)

ψ_π : osmotic suction (kN/m^2)

3. Material and Methods

3.1 The soil

Three gypsiferous soils were selected from various regions near the Mosul city; Al-Muhallabeia (soil 1), Al-Jarin (soil 2), and Al-Slmanii (soil 3). Each of these soils contains various percentage of gypsum. Table (1) refers to some properties of the soils used in the study.

The three soils were oven dried at $60 \pm 3C^o$ for 48 hr and passed through a 4.75 mm sieve prior to determining its index properties and compaction characteristic.

Table 1. Soil Characterization		Soil 1	Soil 2	Soil 3
Property		Soil 1	Soil 2	Soil 3
Specific gravity		2.46	2.59	2.69
Gypsum content %		35	23	6
pH value		7.4	7.61	7.73
Grain size analysis	Sand %	74	28	21
	Silt %	11	38	38
	Clay %	15	34	41
Atterberg limits	LL %	30	31	42
	PL %	23	20	21.5
	PI %	7	11	20.5
Unified Soil Classification System		SC-SM	CL	CL
Compaction Characteristic (Modified Proctor effort)	O.M.C %	7.2	13.6	14.7
	γ_d kN/m^3	18.98	18.39	18.29

3.2 Sample preparation

The required amount of soil and water were thoroughly mixed up to obtain homogenous mixture at the desired water contents. At present study the effect of dry unit weight on soil suction has not considered, because many researchers [16,22] pointed out that there is no effect of compaction energy on soil suction.

Table (2) shows the molding water content and dry unit weight of the studied cases. The Mixtures were kept in the plastic container for 24 hr, and then the mixtures were compacted in a steel mold to produce a final dimension of the specimens with 63.5 mm in diameter and 25 mm in height.

A static compaction method under a rate of 1.0 mm/min was adopted to compact the soil samples using an electrical compressor to reach the required dry unit weight for each soil. The soil samples were kept under the static load for several minutes to avoid rebound, after that the soil samples transferred to a special container related to soil suction measurements using filter paper technique.

Table 2. Amount of molding water content and dry unit weight of cases studied			
Soil type	Dry unit weight kN/m^3	Molding water content %	Degree of saturation %
Soil (1)	18.98	4.5	41
		7.5	68
		10.0	91
		11.0	100
Soil (2)	18.39	14.0	95
		16.0	109
		17.5	119
		20.5	139
Soil (3)	18.29	15.6	95
		16.5	100
		18.0	110
		21.4	130

3.3 Soil suction measurements

Both total and matrix suction were determined using ASTM filter paper method (ASTM D 5298-03). For total suction measurement, the filter paper disks type of Scheicher and Schuell (S&S) No. 589 was fixed above the soil sample as shown in Figure (1).
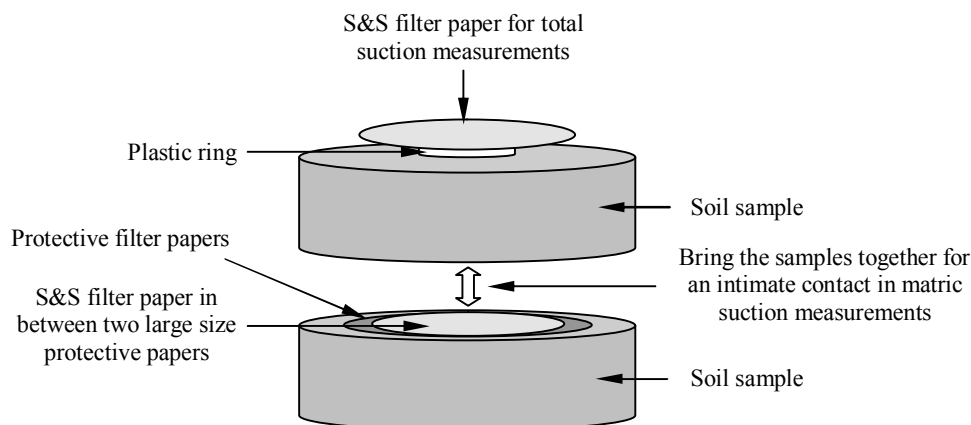

Figure (1), Total and matric suction measurements.

The plastic ring is put on the soil sample to prevent contact between S&S filer paper and the soil samples. The matrix suction was measured by putting S&S filter paper sandwiched between larger size protective filter paper. Then these sandwiched filter papers are inserted in the soil sample in a very good contact manner, i.e. intimate contact between the filter paper and the soil. Hence, it should be pointed out that the protection filter paper is

used to prevent direct soil contact with the mid S&S filter paper. Then this system was kept in a (275) ml capacity container.

The container was immediately closed with an airtight lid and was sealed with two wrappings sealing tape, then the specimen container was kept in a constant room temperature till the equilibrium state is reached (about two weeks).The water contents both of soil samples as well as those of filter papers were accurately determined. The suction was

Figure (2), Calibration curve for filter paper.[15]

calculated using the calibration suction-water content curves presented in Figure (2)[15].

4. Results and Discussion

Table (3) shows the measured values of total and matrix suction with its water content for soil (1), soil (2), and soil (3). It is obvious that both total and matrix suction varies with soil type and soil water content. The following paragraphs show the main factors that affect the suction values of gypsiferous soil.

Table 3. Measured total and matrix suction for studied cases.					
Soil type	Measured soil samples water content (%)	Dry unit weight (kN/m^3)	Total suction (kPa)	Matrix suction (kPa)	Total to matrix suction ratio (%)
Soil (1)	3.2	18.98	6079.78	3598.81	1.689
	6.82		4117.56	969.38	4.247
	8.58		570.18	99.50	5.730
	9.33		273.39	29.89	9.146
Soil (2)	13.54	18.39	19884.3	5890.17	3.375
	15.21		18574.9	6967.16	2.666
	16.44		15505.8	4528.14	3.424
	19.53		10435.1	1800.95	5.794
Soil (3)	14.62	18.29	6099.07	5546.05	1.099
	15.75		6245.74	4971.78	1.256
	17.29		5415.8	4085.07	1.325
	20.31		1072.8	644.87	1.663

4.1 Influence of water and gypsum contents on soil suction

Figure (3) shows the linear relationship between water content of the samples and both total and matrix suction for three studied soils. It is obvious that both total and matrix suction values increase as water content decrease. Both lines of total and matrix suction are closer as water content decreases. Table (3) presents total to matrix suction ratio for the studied cases. These ratios increase (i.e. the different between total and matrix suction values) with increasing water content of soil samples. This may indicates at higher soil water content

the more effective part for soil suction value is the osmotic suction. Because of the existence of gypsum as dissolved salts in soil-pore water, this may increase soil suction value due to the increasing of osmotic suction. The concept of increasing osmotic suction due to presence of dissolved salts can be explained as: the water vapor pressure over a flat surface of solvent is less than the water vapor pressure over a flat surface of pure water. Thus, the relative humidity decrease with increasing dissolved salts in the pore water of the soil and in turn the total suction increases with the increasing of osmotic suction [20].
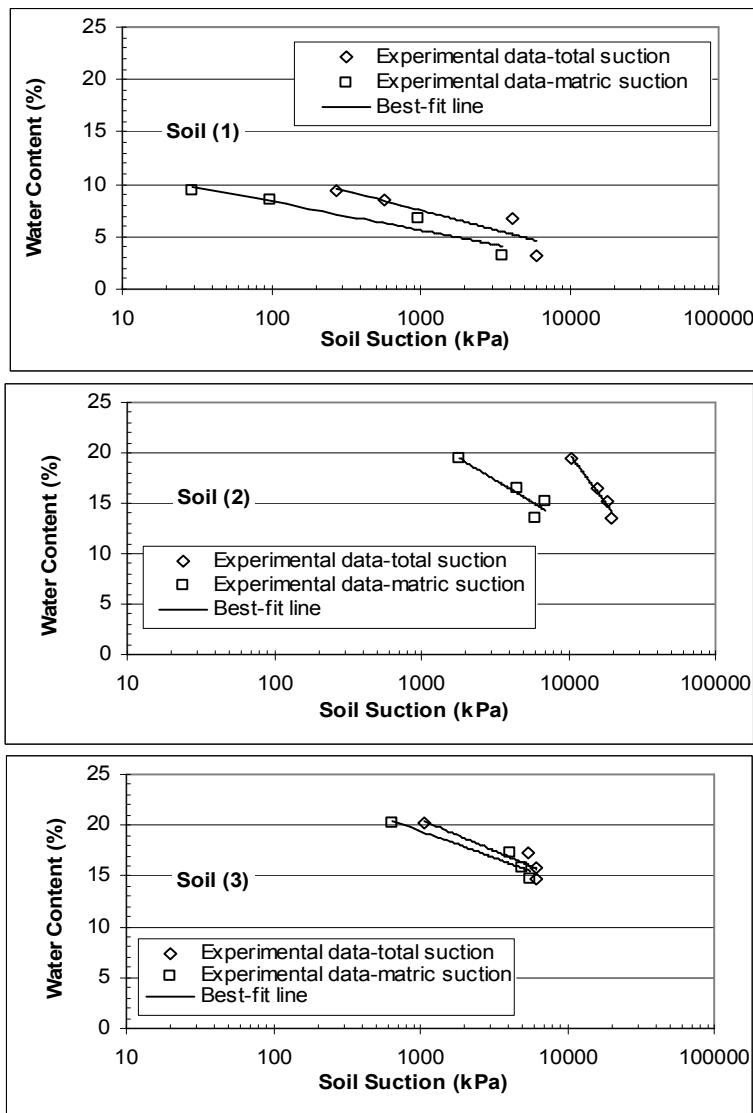

Figure (3), the relationship between water content and soil suction

Figure (4) illustrates the relationships between total to matrix suction ratio and water content of the samples. The slope of these lines increases with increasing soil gypsum content. On the other hand, the highest ratios of total to matrix suction were for soil (1) (which have maximum gypsum content) followed by soil (2), and soil (3).
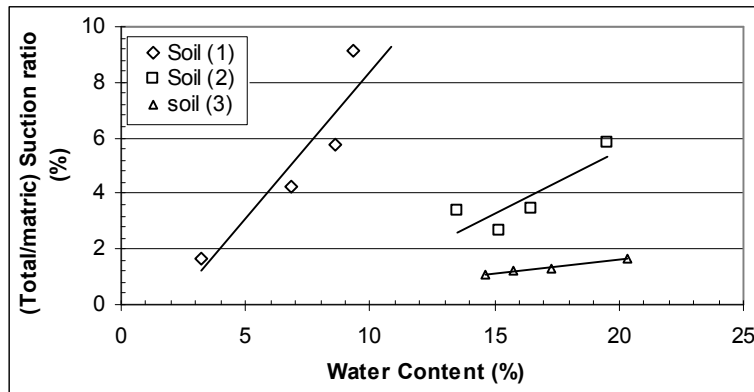
Figure (4), Total to matric suction ratio for three soil studied.

4.2 Influence of clay content on gypsiferous soil suction value

Figure (5-a) shows the relationship between matrix suction and water content. The matric suction of soil (2) and soil (3) are nearly equal to that of soil (1) when they are at relatively high water content. This is happen although the gypsum contents of soil (1) and soil (2) having relatively high values, also the clay contents of soil (2) and soil (3) is relatively having high values comparing with soil (1). This indicates the effect of clay content on soil suction is more pronounced than the effect of gypsum content. Figure (5-b) show the relation of total suction with water content, it seem that both the gypsum and the clay contents affect the total suction.
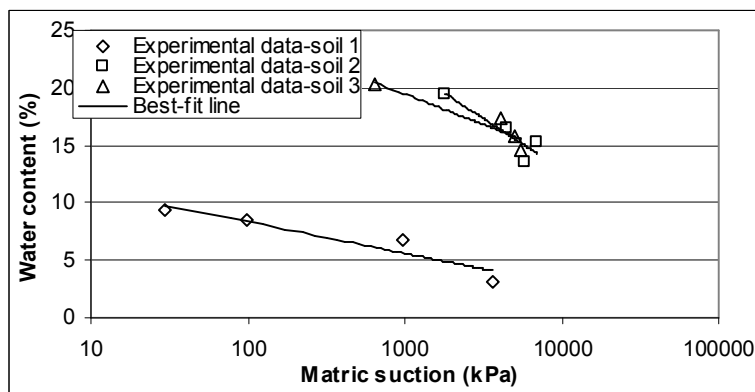
(a)
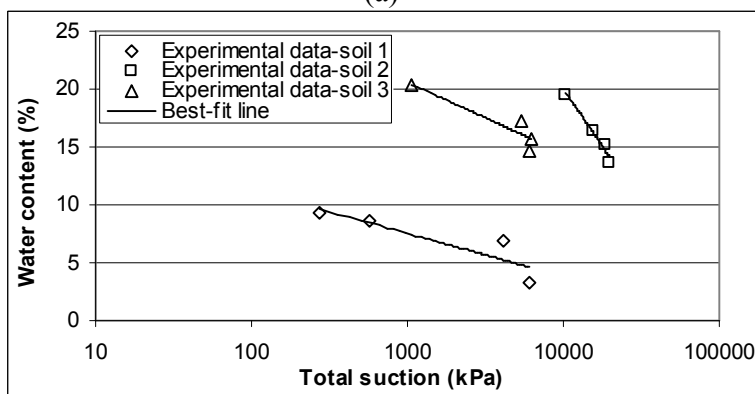
(b)

Figure (5), Total and matrix suction versus soil samples
water content for three gypsiferous soils

4.3 Influence of gypsum content on slope of pF-value versus water content

Figure (6) shows another presentation for the relationships between soil suction with pF unit (pF = $Log_{10}|h|$, where h is the suction in centimeters) and soil water content. The soil suction with pF unit was found for total and matrix suction as well as osmotic suction (osmotic suction represent the difference between total and matrix suction, equation (1)).
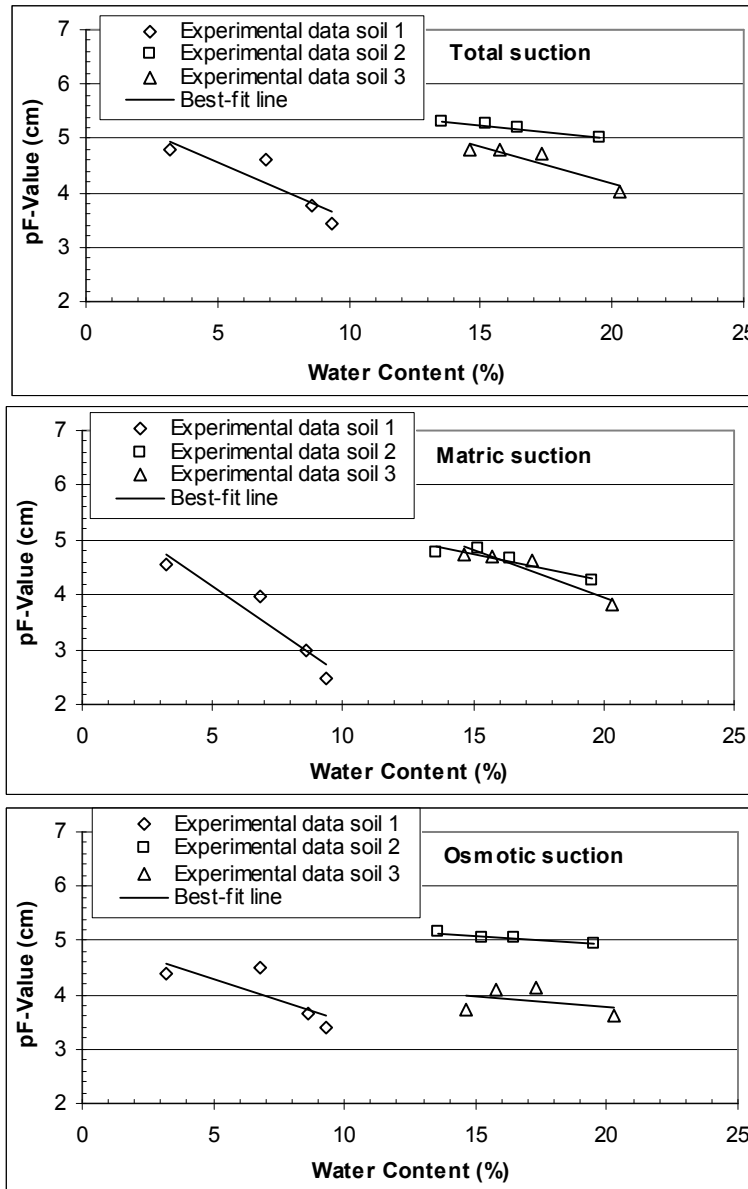

Figure (6), Suction-water content relationship for three gypseous soils.

Table (4), The slope of pF-value versus water content.						
Soil type		Total suction		Matric suction		Osmotic suction
Soil (1)		0.2133		0.3251		0.1579
Soil (2)		0.0488		0.0950		0.0339
Soil (3)		0.1386		0.1687		0.0387

A best-fit line to the experiment data were made for all studied cases. The slopes of these linear relationships were tabulated in Table (4), the varying slope of pF-value versus soil water content relationship of total, matrix, and osmotic suction is due to varying gypsum content for the soils, see Table (4). The highest slope was for soil (1) comparing with soil (2) and soil (3) respectively

A statistical analysis were adopted to the experimental results for obtaining the correlation between the slope of pF value versus soil water content and the gypsum content as shown in Table (5).

Table (5), The correlation between slope of pF value vs. soil water content and gypsum content.		
Suction type		Formulas
Total		Slope = 6.54569E-4 $(G_c)^2$ – 2.4272869E-2 (G_c) + 2.6066336E-1
Matric		Slope = 8.10261E-4 $(G_c)^2$ – 2.7845324E-2 (G_c) + 3.06587941E-1
Osmotic		Slope = 3.65853E-4 $(G_c)^2$ – 1.0897915E-2 (G_c) + 9.0909957E-2
G_c: is the soil gypsum content		

The above formulas could be reformed as the curves shown in Figure (7). We can recognize that the three curves of total, matrix, and osmotic suction have the same trend. The effect of gypsum content on slope of pF value versus water content is higher for matrix suction than total and osmotic suction. Also, for a specific soil suction part, the slope of pF value versus water content has low value at soil gypsum content up to approximately 23 %, thereafter an increase in its value has been observed.
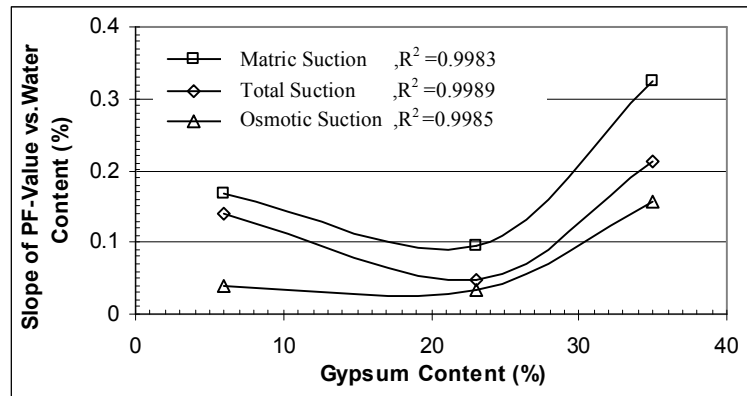

Figure (7), Gypsum content-slope of pF value vs. water content.

5. Conclusion
1. The three types of gypsiferous soils studied in this research have linear relationships between soil suction and soil water content (both total and matric suction.
2. Osmotic suction has more influence on the soil suction values for soil samples with higher water content as well as higher gypsum content. On the other hand, the soil clay contents more effect on gypsiferous soil suction than soil gypsum content.
3. The slope of pF-value versus soil water content depend on soil gypsum content as well as types of soil suction (total, matrix, and osmotic), The effect of gypsum content on slope of pF value versus water content is higher for matrix suction than total and osmotic suction. Finally, this slope were derived with respect to soil gypsum content by statistical analysis represented as coefficient of determination (0.9989, 0.9983, 0.9985) for total, matric, and osmotic suction respectively.

Reference

1. Blyth, F. G. H. "A Geology for Engineers", Fifth Edition,1971, Edulard Arnold Ltd, London.

2. Food and agriculture organization, World soil Resources. "An explanatory note on the FA0 World Soil Resources Map at scale 1 : 25 million", FA0 World Soil Resources Report 66, 1991.

3. James, A. N. and Lupton A. R. R. "Gypsum and Anhydrite in Foundations of Hydraulic Structures", Journal of Geotechnical Engineering, ASCE, Vol. 28, No. 3, 1978, pp.249-272.

4. Al-Ani, H., J. Sherief, S. Mansour and H. Hasso. "An Investigation into the Effect of Gypsum on the Properties of Highway Materials", Proceeding of Conference on Highways University of Technology Iraq, September 8-10, Wasat Ltd.,1988, pp 1-6.

5. Mohammed, R. K. "Effect of Wetting and drying on Geotechnical characteristics of Gypseous Soil", Ph.D Thesis, 1993, Iraq, Baghdad, University of Technology.

6. Azam, S. and Abduljauwad, S. N. "Influence of Gypsification on Engineering Behavior of Expansive Clay", Journal of Geotechnical and Geoenviromental Engineering, ASCE, Vol. 126, No. 6, 2000, pp.538-524.

7. Barazanji, A.F. "Gypsiferous soil of Iraq", Ph.D. Thesis, 1973, State University of Ghent, Belgium.

8. Al-Kaissy, A. A. "Effect of Bentonite Application on Some Properties of Al-Dor Gypsiferous Soil and Plant Growth", M.Sc. Thesis, 1983, College of Agriculture, University of Baghdad, Baghdad, Iraq, (In Arabic).

9. Verheye, W. H. and Boyadgiev, T. G. "Evaluating the Land Use Potential of Gypsiferous Soils From Field Pedogenic Characteristics", Soil Use and Management, Vol. 13, 1997, pp. 97-103.

10. Shihab, R. M., Al-Ani, A. N., and Fahad, A. A. "Dissolution and transport of gypsum in gypsiferous soil treated with fuel oil and bentonite", Emir. Journal Agriculture Science, Vol. 14, 2002, pp. 1-7.

11. Al-Zubydi, A. H. "Tensile Strength of Gypseous Soil Containing Soluble Salts Treated With Lime", M.Sc. Thesis, 2007, Civil Engineering Department, University of Mosul, Iraq, (In Arabic).

12. Ismail, A., and Hilo, W. J. "Deformation of Gypsum Sand During Cyclic Soaking and Drying", Journal of Applied Sciences, Vol. 8, No. 24, 2008, pp. 4610-4616.

13. Al-Qaissy, F. F. "Effect of Gypsum Content and its Migration on Compressibility and Shear Strength of the Soil", M.Sc. Thesis, 1989, Building and construction Dept. University of Technology, Baghdad.

14. Chandler, R. J. and Gutierrez, C. "The Filter Paper Method of Suction Measurment", Geotechnical, Vol. 36, No. 2, 1986, pp. 265-268.

15. Greacen, E. L., Walker, G. R., and Cook, P. G. "Evaluation of the Filter Paper Method for Measuring Soil Water Suction", International Conference on Measurement of Soil and Plant Water Status, 1987, pp. 137–143.

16. Al-Ashou, M. O., AL-Khashab, M. N. , & Al-Bayati, A.H. "The Effect of Compaction and Density on Suction of Expansive Soils", Zanko. The Scientific Journal of Salahaddin University, Vol. 3, No. 4, 1990, pp. 1-25.

17. Rifat, B. S. "A Re-evaluation of the Filter Paper Method of Measuring Soil Suction", M.Sc. Thesis, 1996, Texas Tech University, united states.

18. Al-Khashab, M. N. "Correlation Between Soil Suction of Expansive Soils with Their Index Properties", Eng. Technology, Vol. 20, No. 11, 2001, pp. 619-632.

19. Leong, E. C., He, L., and Rahardjo, H. "Factors Effecting the Filter Paper Method for Total and Matric Suction Measurements", Journal of Geotechnical Testing, Vol. 25, No. 3, 2002, pp. 1-12.

20. Fredlund, D.G. & Rahardjo, H. "Soil Mechanics for Unsaturated Soils", 1993, John Wily & Sons, Inc., USA.

21. Edlefsen, N.E. and Anderson, A.B.C. "Thermodynamics of Soil Moisture", Hilgardia, Vol. 15, 1943, pp. 31-298.

22. Al-Juari, K. A. K. "The Effect of Clay Percentage on Volume Change of Collapsible Soil in Mosul City", M.Sc. Thesis, 2005, Civil Engineering Department, University of Mosul, Iraq, (In Arabic).

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