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The effect of soaking and wetting on the properties of the gypsum soil treated with polyurethane

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Abstract— the shear strength parameters of the treated and untreated gypsum soil under the effect of four soaking and drying cycles has studied in this paper, moreover examined the effect of wetting and drying cycles on the collapse potential of the soil and comparing between the behavior of the treated and untreated gypsum soil under the effect of the two conditions. Gypsum soil sample brought from Sawa lake in Al Muthana governorate with the content of gypsum 65.5%, the polyurethane polymer (PP) was used with different percentages 3, 6, and 10% to enhance the mechanical properties of gypsum soil, model was prepared to achieve four soaking and drying cycle to the samples before testing, this model consists of an Aluminum plate base with dimensions 70 x45 cm and glassy sides with 10 cm height, this model subdivided longitudinally into three parts by glassy breakers to compact untreated and treated gypsum soil with 3 and 6% of polyurethane, series of direct shear tests and single oedometer test carried out on the treated and untreated gypsum soil, the result shows that the polyurethane polymer can be used successfully to stabilize the mechanical characteristics of gypsum soil with high gypsum content.

Keywords— collapsibility, soaking-drying cycles, wetting-drying cycle, shear strength parameters, polyurethane, gypsum soil

1. Introduction

Gypseous soils are one of the most difficult kinds of soils, it signified in dry areas where sources for the calcium sulphate exist. It does not usually occur under wet climate conditions. the behavior of gypsum occurrence in the soil in the dry state that as a linkage between soil particles so that gypsum has a large effect on the physical and mechanical characteristics of the soil. These effects depend on the gypsum percentage presented in the soil. Gypsum is known as Hydrated Calcium Sulphate ($CaSO_4.2H_2O$) [18]Van Alphen and Romero, 1971 named the soil with gypsum content more than 2% as gypsiferous soil, [16]Saaed and Khorshid (1989) defined gypseous soils as soils that contain more than 6 % gypsum. Gypseous soil covers more than 30 % of the Iraqi area with a range of gypsum content about 30 to 70%, Gypseous soil represented one of the problematic soils when contact with water from any source like rainfall or rising level of the water table which cause a change in the moisture content of the soil, also when subjected to heavy loads that lead to the occurrence of large deformation and settlement due to removing the bonds between the soil particles this problem is known as collapsibility which represented the most common problem that usually

occurred in the gypseous soil, in the dry state the gypsum soil is very stiff and have perfect characteristic for civil engineering structures, Under the wetting state, the cementation between soil particles removed due to gypsum melting that cause loss of soil mass and occurrence of pores and voids that lead to increase permeability, compressibility, and volume change of soils so that cause a catastrophic failure, moreover, reduce the shear strength of soil During the construction and operation of structures, there is usually a severe soaking of soil mass with water leading to a continuous infiltration of solutions by soil and the leaching of salts and differences in soil's mechanical and physical properties [13](Mikheev and Petrukhin, 1973). Many studies have shown that if the soil incorporates water-soluble gypsum in its load-bearing structure of the soil, it is subjected to gradual settling before full solution and removal of the gypsum under the influence of flow leaching [2](Arutyunyan, 1978). [17]Schanz and Karim 2018 noticed that the shear strength parameters (∅ and c) decreased after soaking for the gypseous soil with gypsum content 73.88 [4]Aldaood et al. (2014) was found that during the wetting-drying cycles, the soil engineering properties, in particular their strength, were impaired and stability failure occurred. The Collapse potential of gypsum soils increases linearly with gypsum content. This result is in agreement with the findings of [9]Fattah et al. (2008). [7]Al-Mohammadi et .al, (1987) Investigated the collapsibility and compressibility of gypsum soil from the Iraq area and found that collapse potential ranges between 10-20% when the gypseous soil contact with water. Many researchers have studied the behavior of gypsum soil although a few researchers studied the durability of gypsum soil before and after improvement [5,8,15,14], Several methods were used to reduce or prevent the solubility of gypsum and to improve the collapse potential and shear strength of gypseous soils, [1]Aziz, Jianlin Ma 2011 used fuel oil to reduce the collapsibility of gypsum soil, [3]Aldaood et al. (2014) used lime to stabilized the gypsum soil and study the effect of five freezing and thawing cycles and observed that the strength has lost with increased the number of cycles. Very little of researchers used polyurethane to improve the soil such as [6]Al-Hadidi and Ibrahim, (2018) used polyurethane polymer as a chemical stabilizer to improve solubility and decrease erosion of irrigation canals soils that built on gypseous soil with the percentage of gypsum 41% and proved that can be used this material as a good stabilizer to stabilized strength, permeability, and collapsibility, 6,10, and12% from polyurethane polymer mixed with the soil and from the results found that the perfect percentage of polyurethane polymer was (10%) which gave (3%) corrosion during 28 days.[12] Liu et al., 2017 used polyurethane polymer to improve the permeability of the sandy soil. In this paper a new stabilizer (polyurethane polymer) was used to improve the mechanical properties of gypsum soil.

2. Materials

2.1 *Gypsum soil sample*

The gypsum soil sample used in this study was obtained from Sawa Lake in the west of AL- Muthanna governorate with 65.5 percent of gypsum. Taken from depth (1.5 to 2) m then soil transported to the laboratory of the civil engineering department for tested and sieved by sieve #4, Figure 1 show the location of gypsum soil which used in this research placed between latitudes (30˚, 17′, 42.83″N) and longitudes (44˚ 00′ 50.36″E).

2.2 *Polyurethane polymer*

Polyurethane polymer used as a chemical stabilizer to stabilize the properties of gypsum soil, it is a light yellow oil liquid as shown in Figure 2 its viscosity is 6-7, 650-700 mPa.s, 1.18 g / cm3 specific gravity and 30-1800 s coagulation time The main benefit of this material being environmentally friendly. Products without pollution, also used for preventing the solubility of gypsum [6] Al-Hadidi and Ibrahim, (2018), and reduce the permeability of the soil [12] Liu (2017).

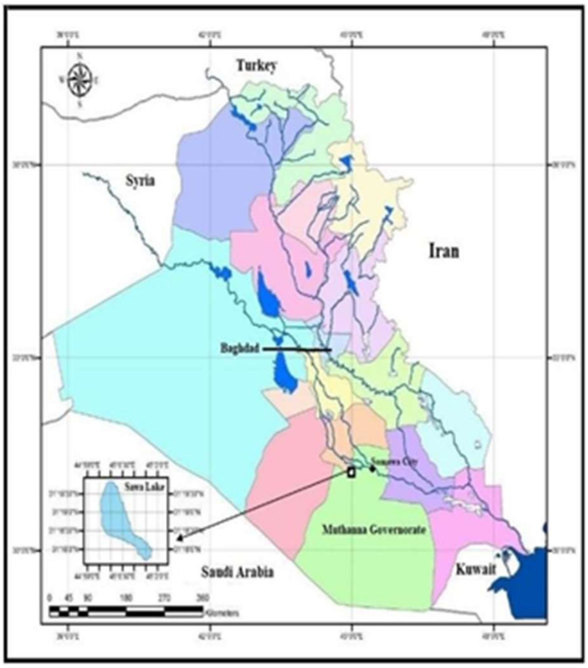

Figure 1: map of Iraq illustrates the region of a soil sample used in the study

Figure 2: polyurethane polymer material

3. Experimental work

3.1 *Classification and mechanical tests*

physical test (grain size distribution (Figure 3), specific gravity, and water content) and chemical test such as gypsum content, these tests were achieved to discover the characteristics of gypsum soil sample as shown in Table 1, mechanical tests include Standard Proctor compaction test which is Conducted to decide the relation between moisture-density for the virgin soil Its performed accordance with (ASTM D698-91, Method A, 2003), collapsible test, [10]Knight (1963) proposed the collapsible test also named single oedometer collapse test. Similar to the normal consolidation procedure, the test was performed except that the sample loaded to 200 kPa then inundated and the read of strain was taken after 24 hours. Direct shear test carried out for the natural gypsum soil sample and after treated by using polyurethane polymer also before and after soaking to for different periods to find the parameter of shear strength (cohesion (C), angle of internal friction Ø) also to predict about the effect of four soaking and drying cycles on these parameters after and before treated by polyurethane polymer a set of direct shear test performed agreeing with ASTMD (3080), the specimens prepared in rings of 60×60×20 mm. Table 2 summarized the mechanical properties of the gypsum soil model.

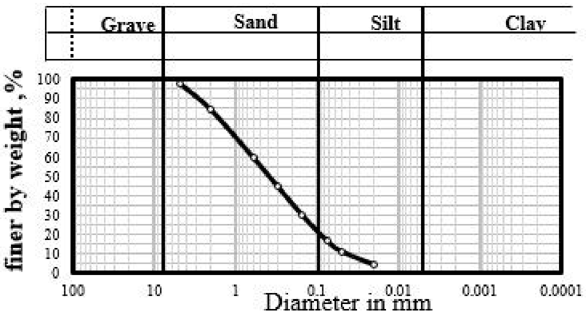

Figure 3: grain size distribution for the natural soil

Table 1: Mechanical properties of gypsum soil

properties	values	
Gypsum content	65.5%	
Maximum dry unit weight	16.5	
(O.M.C)	11.7%	
Specific gravity(Gs)	2.36	
Void ratio (e)	0.46	
Soil classification according to (USCS)	Poorly graded sand	
D10	0.05 mm	
D60	0.5 mm	
D30	0.16mm	

Table 2. Mechanical properties of gypsum soil

Properties	values	
Collapse potential (CP) %	10%	
Shear strength parameter (Cu (kN/m^2) & Ø (°)	C = 1.2 Ø = 36.6°	
Cc	0.11	
Permeability(cm/sec)	4.3×10^{-3}	

3.2 *Wetting and drying cycles and collapsible test*

After prepare 12 specimens with 3, 6, and 10% of the polymer as shown in Figure 4, Every one of the specimens was subjected to different wetting–drying cycles then the collapsible test conducted to evaluate the collapse potential (CP), this value computed by using equation suggested by [11]"Knight and Jennings (1975)", after four specimens of 3% (PP) percentage have prepared then the first specimen subjected to 1 cycle (2 days wetting and 4 days drying)and collapsibility test carried out to found (CP).The second specimen which treated by 3% from polyurethane polymer subjected to 2 cycles and the third specimen subjected to 3 cycles and the fourth specimen subjected to 4 cycles and the same procedure of collapsible test repeated for each specimen to determined (CP). the Specimens treated by 6% and 10% from polyurethane polymer prepared by following the same procedure of specimens treated with 3% from polyurethane polymer**.**

Figure 4: 12 specimens treated with 3,6,10% from (pp)

3.3 *Soaking and drying cycle model*

This model was prepared to achieve four soaking and drying cycles to the samples before testing, this model consists of an Aluminum plate base with dimensions 70 x45 cm and glassy sides with 10 cm height this model subdivided longitudinally into three parts by glassy breakers to follow up and watch the flow of water through the soil as much as possible, also holes making in the plate to permit existing of the water while seeps through the soil during the soaking process as shown in Figure 5, untreated gypsum soil compacted in the first part of the model with dimension (70x17cm) second part with dimensions (70X14 cm) fill with treated gypsum soil with 3% of polyurethane polymer and compacted to the maximum dry unit weight, the last part fill with treated gypsum soil with 6% of polyurethane polymer, the treated and untreated soil in the three-part compacted to 3 cm high depending on the maximum dry unit weight and optimum moisture content as shown in figure 6.

Figure 5: the soaking and drying cycles model

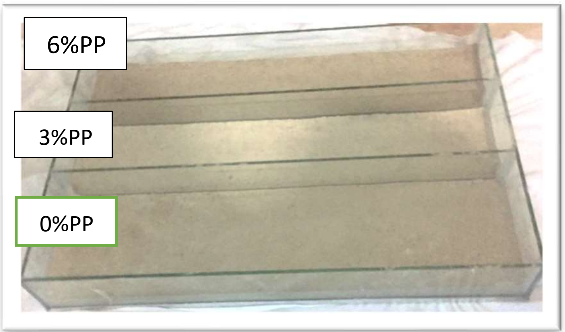

Figure 6 photo illustrates the compacted treated and untreated gypsum soil

Each part in the model was subdivided into four small part by using small and thin Aluminum plates to achieve for soaking and drying cycles as shown in Figure 7.

Figure 7: photo illustrates the subdivisions of the model

3.4 *Method of Soaking and drying cycles*

After prepares the model the water adding for the three parts in the same time and assign the level of water by the marker to observation the infiltration of the water through the soil, after all the amount of the water absorbed then the model left until completely drying, this represents one cycle of soaking and drying. After that, the water added to the all small parts in the model except the first part and leave until completely dry to achieve the second soaking and drying cycle, the third cycle achieved by adding the water for the third and fourth parts of the model, after the water absorbed by the soil and completely dry the water adding to the fourth part to achieve four soaking and drying cycle. as shown in figure 8 the same procedure applied to the second and third sections with 3% and 6% of polyurethane respectively.

Figure 8: soaking and drying process

During the soaking stage, the water does not infiltration easily through the treated soil with 3 and 6% of polymer and stopped for more than 2 days at the surface of the soil that because the stabilizer closes the channels of flow and decreased the voids between the particles of soil and wraps the particles so that prevent soaked up the water through the soil.

Finally, Direct shear test was carried out for the treated and untreated gypsum soil after subjected to four soaking and drying cycle.

4. Results and discussion

4.1 *Effect of wetting and drying cycles on Collapse potential*

Figure 9 illustrates the variation of collapse potential with wetting and drying cycle for the treated and untreated gypsum soil from this Figure observes that the untreated gypsum soil experienced continuously increasing in collapse potential with an increased the number of wetting and drying cycles that because removes the cementation between the particles due to dissolution of the gypsum between the particles of the soil and with the continuous wetting process the gypsum also dissolution continuously that causes an increase in the collapse potential, for the treated gypsum soil noticed that the collapse potential decreased with increased the percentages of the polymer and noticed that the optimum percentages of the polyurethane polymer was 10%, which gave the maximum reduction in collapse potential from 10% to 0.54% and gave the soil enough hardiness and increased the cementation between the particles, with four wetting and drying cycle the collapse potential decreased slightly. Adding 6% from the polymer also reduces the collapse potential to 1.78 as well as this value reduces continually with four wetting and drying cycles. Additionally adding 3% of the polyurethane polymer gave A significant reduction in collapse potential and continuously reduce until reached 1.43 after the fourth cycle this value represents close to the values gave by mixing 10 and 6% of the polyurethane polymer.

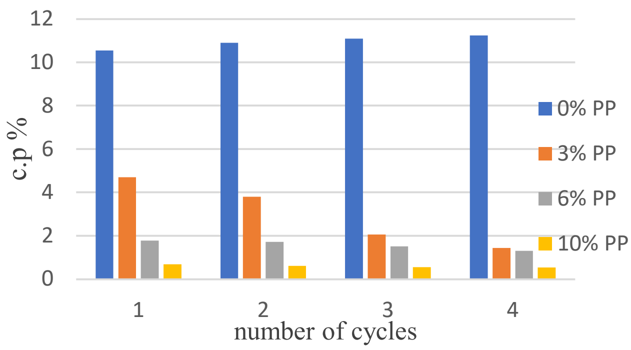

Figure 9: Variation of collapse potential with four wetting and drying cycles

Figure 10 shows the percentage of the improvement in collapse potential and as it's clear the maximum improvement in collapsibility gave by adding 10% from polyurethane polymer, gave about 93.2 after the first cycle and 94.6% after the fourth cycle moreover, the enhancement increased with increased the number of wetting and drying cycle for all percentages (3, 6,10%) of polyurethane polymer.

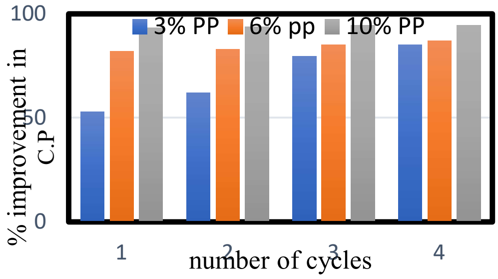

Figure 10: the effect of polyurethane on the collapse potential with four soaking and drying cycles

4.2 *Effect of soaking and drying cycles on the shear strength parameters*

Figure 11 to 14 illustrates the effect of four cycles of soaking and drying on the untreated and treated gypsum soil with 3 and 6% of the polyurethane polymer. From Figure 11 observed that the angle of internal friction slightly decreased after the first and second cycle of soaking and drying for the untreated gypsum soil, due to the dissolution of gypsum and that lead to remove the cementations between the soil particles, this result agrees with the findings of [17] Schanz and Karim 2018 and [4]Aldaood et al. (2014), after that the reduction became very small That may be because the maximum dissolution occurred at the first two cycles And very little reduction occurred on the cohesion of the soil.

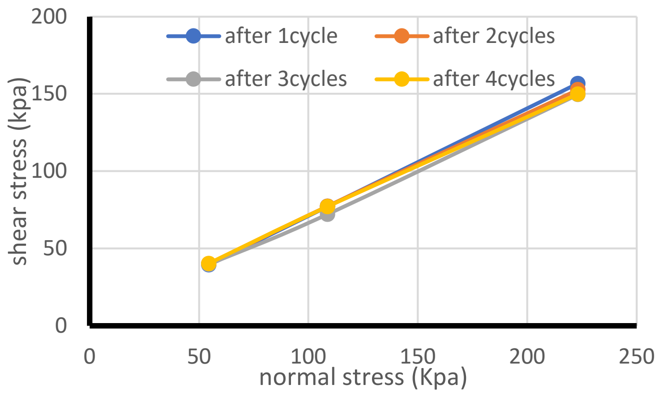

Figure 11: effect of four soaking and drying on the shear strength of untreated gypsum soil

For the soil with 3% polyurethane polymer, the angle of internal friction increased slightly with soaking and drying cycles from 36° to 39° after the first cycle and fourth cycle respectively and no significant effect on the cohesion (C) of the treated soil during the four soaking and drying cycles that because the polyurethane wrap the particles of soil and prevent the dissolution and leaching of gypsum, as shown in Figure 12.

As well as Adding 6% from polyurethane polymer also increases the angle of internal friction to 40° after the fourth cycle and no significant effect on the cohesion (C) of the treated soil that because the polyurethane wraps the particles of soil and prevent the dissolution and leaching of gypsum, as shown in Figure 13.

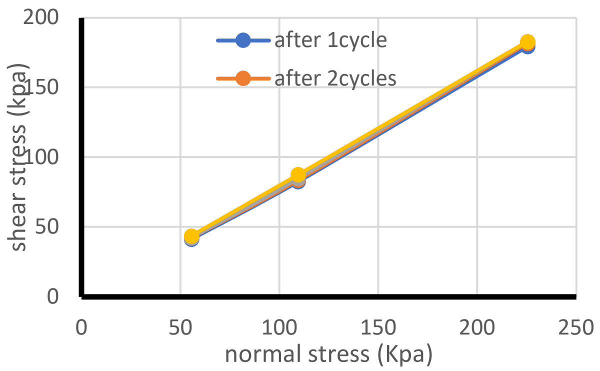

Figure 12: effect of four soaking and drying on the shear strength of gypsum soil treated by 3% of the polyurethane polymer

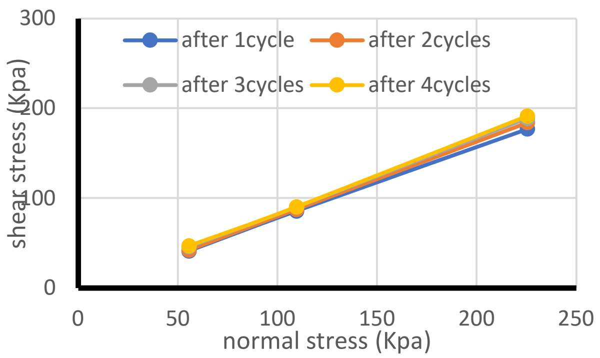

Figure 13: effect of four soaking and drying on the shear strength of gypsum soil treated by 6% of the polyurethane polymer

Figure 14 illustrates the percentages of improvement in the angle of internal friction in this figure observes that the maximum improvement in the angle of internal friction gave by adding 6% from the polymer moreover the maximum improvement occurred after the four soaking and drying cycles. Also, the durability increased with the increased number of soaking and drying cycles for the treated soil with 3 and 6% of polyurethane.

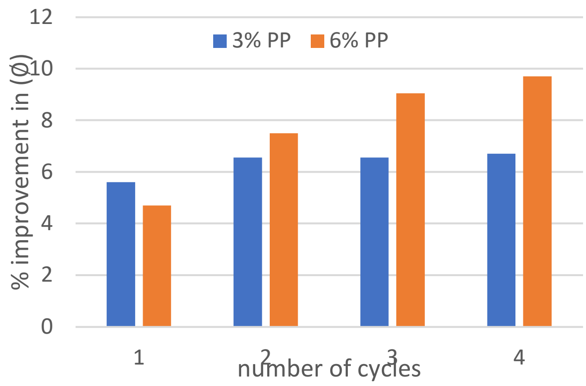

Figure 14: The percentage improvement in the angle of internal friction

5. Conclusion

1- In this research, the polyurethane polymer was used as a new stabilizer to improve the mechanical properties of the gypsum soil with a high content of gypsum this material wrap the particles of the soil and reduce the solubility of gypsum, increase the cementation between the particles, and gave enough hardiness and durability to the soil.

2- Adding 3, 6, and 10% of polyurethane polymer improved the collapse potential and increased the durability of the soil moreover 10% of the polymer gave the maximum reduction in collapse potential. Additionally, after the fourth cycle, the 3% of polymer gave improvement close to that gave by 6 and 10%.

3- The collapse potential decreased continuously with an increased number of wetting and drying cycles for all the percentages of polymer 3, 6, and 10%. while the collapse potential increased continuously with the cycle of wetting and drying cycle for the untreated gypsum soil due to the continuous dissolution of the gypsum

4- The angle of internal friction increased continuously with increased cycles number of soaking and drying for the treated soil with 3 and 6% of polyurethane, whereas for the untreated gypsum soil the angle of internal friction reduce after the first two cycle due to remove the cementation between the particles after that very little reduction has occurred in the angle of internal friction value after the third and fourth cycle.

References

[1] Aziz, Hussein Yousif, and Jianlin Ma. "Gypseous soil improvement using fuel oil." World Academy of Science, Engineering and Technology 5 (2011): 03-29.

[2] Arutyunyan, R.N. (1978): “Deformations of Gypsofied Soils in the Bases of Building and Structures in Erevan”, Soil Mechanics and Foundation Engineering”, Vol. 15, No. 3, pp. 183-185.

[3] Aldaood, A., Bouasker, M., Al-Mukhtar, M., 2014. Impact of freeze–thaw cycles on mechanical behaviour of lime stabilized gypseous soils. Cold Reg. Sci. Technol. 99, 38–45.

[4] Aldaood, A., M. Bouasker, and M. Al-Mukhtar. "Impact of wetting–drying cycles on the microstructure and mechanical properties of lime-stabilized gypseous soils." Engineering Geology 174 (2014): 11-21.

[5] Al-Obaydi, M. A., I. M. Al-Kiki, and A. H. Al-Zubaydi. "Strength and durability of gypseous soil treated with waste lime and cement." Journal Al-Rafidain Engineering 18.1 (2010): 28-42.

[6] Al-Hadidi, Maysam Th, and Atheer G. Ibrahim. "Improvement of Gypsum Soil by Using Polyurethane to Reduce Erosion and Solubility of Irrigation Canals." International Journal of Engineering & Technology 7.4.20 (2018): 372-376.

[7] Al-Mohammadi, N.M., Nashat, I.H. and Bake, G.Y. (1987) ,"Compressibility and collapse of gypsiferous soils" ,6th Asian Conference on Soil Mechanics, Tokyo.

[8] Alsafi, Shaymaa, et al. "Collapsibility potential of gypseous soil stabilized with fly ash geopolymer; characterization and assessment." Construction and Building Materials 137 (2017):

[9] Fattah, M. Y., Yousif, J., & Huda, N. (2008). Long-Term Deformation Of Some Gypseous Soils. Engineering and Technology Journal, Iraq, 26.

[10] Jennings JE, Knight K (1975) The additional settlement of foundation due to collapse of sandy soils on wetting, Proc 4th Inter Conf on Soil Mechanics and Foundation Engineering, 1:316–319

[11] Knight, K., The origin and occurrence of collapsing soils. In: Proceeding of the Third Regional Conference of Africa on Soil Mechanics and Foundation Engineering, vol. 1, pp.127–130., 1963

[12] Liu, J., Qi, X., Zhang, D., Feng, Q., Wang, Y., & Kanungo, D. P. (2017). Study on the permeability characteristics of polyurethane soil stabilizer reinforced sand. Advances in Materials Science and Engineering, 2017.

[13] Mikheev VV, Petrukhin VP, Krouik VA (1973) Properties of saline used in construction. Proceedings of 8th International Conference on Soil Mechanics and Foundation Engineering, vol. 22, Moscow, pp 133– 138

[14] Mohammed, R. K. (1993): "Effect of Wetting and Drying on Engineering Characteristics of Gypseous Soil", M.Sc. Thesis, University of Technology, Baghdad, Iraq

[15] Razouki, Sabah Said, and Bushra M. Salem. "Frequency effect of cyclic soaking and drying on the resilient modulus of gypsum-rich roadbed sand." Transportation Geotechnics 7 (2016): 13-20

[16] Saaed SA, Khorshid NN (1989) Some essential characteristics of the gypseous soil of Al-Dour area. Proceedings of the 5th Scientific Conference, Scientific Research Council, vol. 4, part 2, Baghdad (in Arabic)

[17] Schanz, Tom, and Hussein H. Karim. "Geotechnical characteristics of some Iraqi gypseous soils." MATEC Web of Conferences. Vol. 162. EDP Sciences, 2018.

[18] Van Alphen JG, Romero FDR. Gypsiferous soils – notes on their characteristics and management. Int. Inst. For Land Reclamation and Improvement, Bulletin 12, Wageningen, Netherlands; 1971.

تأثير الغمر والترطيب على خواص التربة الجبسية المثبتة بالبوليوريثان

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الخلاصة –معاملات القص للتربه الجبسية المثبة والغير مثبته تم دراستها في في البحث الحالي بعد تعريض التربه الى خمس دورات غمر وتجفيف بالاضافة الى دراسة تأثير دورات الترطيب والتجفيف على انهيارية التربه الجبسيه مع مقارنة تصرف التربه المثبة بتصرف لتربه الغير مثبه في الضروف نفسها. تم جلب التربه الجبسيه من بحيرة ساوه في محافضه المثنى بمحتوى جبسي 65% مادة البوليوريثان استخدمت بنسب مختلفة 3 6 و 10% لتثبيت التربة الجبسيه، تم تحضير موديل لتحقيق خمس دورات غمر وتجفيف للتربة المثبته والغير مثبته قبل الفحص الموديل يتكون من قاعده من الالمنيوم بأبعاد 45x 70 سم وجوانب زجاجيه بأرتفاع 10 سم ومقسم طوليا الى ثلاث اقسام بقواطع زجاجيه لرص التربة الغير مثبته والتربة المثبته بنسبة 3 و 6% من البوليمر، تم اجراء فحوصات القص المباشر وفحص الانهياريه بشكل متسلسل وقد بينت النتائج ان مادة الوليوريثان يمكن استخدامها بنجاح لتثبيت الخواص الميكانيكيه للتربه الجبسيه بمحتوى جبسي عالي.

الكلمات الرئيسية –الانهياريه، دورات الغمر والتجفيف، دورات الترطيب والتجفيف، معاملات القص، البوليوريثان، التربة الجبسية.