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Physical Properties of Gypseous Soil after Gypsum Removal using EDTA Solution

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ABSTRACT

The main structural problem in construction on gypseous soils is due to the melting of the gypsum when exposed to water. This may be creating voids in the soil leading to rearrangement of the soil structure and moving the soil particles to more stable positions. This can cause excessive settlement which directly affects superstructures. This study, investigates the influence of gypsum removing on granular soil classification. Four gypsum soil specimens were taken from Al-Qadisiyah district in Tikrit at different depths from the natural ground surface. The depths adopted were 0.75, 1.10, 2.00 and 3.30 m. The corresponding gypsum content was 42.23%, 32.50%, 8.75% and 19.82%, respectively. The EDTA solution was used to disassemble and remove the gypsum particles by washing using distilled water. The results showed that EDTA solution and washing with distilled water was an effective method to remove gypsum from granular soils. Gypsum ratio was reduced to less than 2% in all tested specimens. The percentage of organic matter was not affected, and the specific gravity of the specimens increased between 2% and 12%. The gypsum removal process affected the granular distribution curves of the soil specimens and led to a decrease in the rate of soil grain diameters. In general, classification process of the soil before and after the washing of gypsum from the soil was not affected.

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الخصائص الفيزيائية للترب الجبسية بعد ازالة الجبس باستعمال محلول EDTA

الخلاصة

المشكلة الانشائية الرئيسية في البناء على التربة الجبسية، هي بسبب ذوبان الجبس عندما تتعرض للمياه. هذا قد يخلق فراغات في التربة مما يؤدي إلى إعادة ترتيب هيكل التربة وتحريك جزيئات التربة إلى مواقع أكثر استقرارا. وهذا يمكن أن يسبب هبوط مفرط الذي يؤثر بشكل مباشر على البنية الفوقية. هذه الدراسة، تتقصى تأثير إزالة الجبس على تصنيف التربة الحبيبية. تم أخذ أربعة عينات من التربة الجبسية من حي القادسية في تكريت على أعماق مختلفة من سطح الأرض الطبيعي. وكانت الأعماق المعتمدة 0.75، 1.10، 2.00 و3.30 متر. وكان محتوى الجبس المقابل 42.23٪، 32.50٪، 8.75٪ و19.82٪ على التوالي. تم استخدام محلول (EDTA) لتفكيك وإزالة جزيئات الجبس عن طريق الغسل باستخدام الماء المقطر. وأظهرت النتائج أن محلول (EDTA) والغسل بالماء المقطر كان طريقة فعالة لإزالة الجبس من التربة الحبيبية. تم تخفيض نسبة الجبس إلى أقل من 2٪ في جميع العينات المختبرة. ولم تتأثر النسبة المئوية لمحتوى المواد العضوية، في حين زاد الوزن النوعي للعينات بنسب تراوحت بين 2٪ و12٪. وأثرت عملية إزالة الجبس على منحنيات التوزيع الحبيبي لعينات التربة حيث أدت إلى انخفاض في معدل أحجام حبيبات التربة. وبصفة عامة، لم تتأثر عملية تصنيف التربة قبل وبعد غسل الجبس من التربة.

1. INTRODUCTION

Gypseous soils contain high concentrations of salts; some of these salts are soluble in water, called gypsum salts. The solubility of gypsum salts leads to loss some soil components, and create voids which leading to rearrange soil particles. The process is accompanied with settlement in the soil and may result in a sudden collapse in soil structure.

Removal of salts such as gypsum ($CaSO_4.2H_2O$) from the soil by passing water through the soil or oscillating in the groundwater level is known as the soil wash process, and this process affects the geotechnical characteristics of the soil. Bjerrum [1] studied the effect of leaching process on the Norwegian Marine Clay, and found that the washing

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process caused an increase in soil compressibility compared to the unwashed soil. As a result of the washing process, the voids ratio increased, that leading to an increase in the value of the compression index (c_c) compared to untreated soil. It was also found that the amount of shear resistance is reduced to (50%) and a decrease in soil plastic limit. In them in-situ study by plate load test on gypsum soil, Mikheev et al. [2] found that the physico-chemical properties and mechanical properties of the soil changed due to gypsum washing from the soil. The internal friction angle and the cohesion were (37°, 21.574 kN/m^2) respectively when the gypsum ratio was (20%), however, after the washing processes, internal friction angle and cohesion decreased to (31°, 8.825 kN/m^2). In addition, there was an increase in the amount of compressibility of the soils. It was also observed that soil permeability increased with the time of washing due to the melting of gypsum. Singh and Al-Layla [3] studied the effect of the washing process on the consolidation characteristics of clay with high gypsum content that taken from Qayiara region in Iraq. It was found that the process results in an increase in the compressibility index (c_c) and the coefficient of consolidation (c_v). AL-Layla and Taha [4] studied the effect of the washing process on Qayiara soil using acetic acid with concentration of 25% to remove the gypsum from the soil. It was concluded that: (a) the washing process decreases the weight by 20-22%, (b) the values of Atterberg limits reduced due to the washing process, whereas the longitudinal contraction increased, (c) the compressibility index (c_c) increased whereas the coefficient of consolidation (c_v) decreased, and (d) the shear strength of soil decreased after gypsum removal from the soil, these results matched with those obtained from Al-Busoda [5]. Seleam [6] examined the effect of washing on silty sand soil having different percentages of gypsum (26%, 60% and 80%). It was noticed that the washing process led to: (a) significant reduction in the soils volume, (b) increasing the compressibility index (c_c) and (c), the shear strength of the soil reduced by the washing process, also the permeability decreases with time until the decrease reaches a low value after nine hours of washing.

All the above studies have found that water seeping through the gypsum soil adversely affects the engineering properties of soil. In this study the effect of gypsum dissolving on the granular soil physical properties; however, these characteristics give an indication on the behavior of the soil in their engineering properties.

2. MATERIALS AND PROCEDURES

According to the distribution map of gypsum soils in Iraq (Barzanji [7]), the soil in Tikrit city is classified as a slightly to high gypsum content soil. Four disturbed specimens were taken from Al-Qadisiyah district of Tikrit with different gypsum concentrations at different depths. Specimen's depths (0.75, 1.1, 2.0 and 3.3 m) named as (S1, S2, S3 and S4) respectively according to their depths. The surface factors affect that lead to the possibility of washing the soil are concentrated in such depths**.**

The physical and chemical properties of the specimens were also determined experimentally, these included:

Physical tests including: (a) Specific gravity (G_s) (B.S. 1377-75, noting that kerosene used instead of distilled water [8]), (b) Atterberg's Limits (ASTM. D4318-05). and, Sieve analysis (ASTM D422-63).

Chemical tests included gypsum test (Gyp. %, Al-Mufty and Nashat [9]), measurement of total dissolved salts percentage (T.D.S %), organic matter ratio (Org. %), and pH value for the soil. (B.S. 1377: 1975).

The procedure adopted to conduct gypsum removing was as follows; the gypsum was removed from the soil specimen by continuous washing the specimen using distilled water with light acids. The process must not affect the natural of the soil particles. This was achieved to preserve as much as possible the original characteristics of the specimens. For the purpose of facilitating the separation and removal the gypsum from the soil specimen, an EthyleneDiamine Tetra Acetic (EDTA) was used. EDTA is a polyprotic acid containing four carboxylic acid groups and two amine groups with lone-pair electrons that chelate calcium and several other metal ions. It is extensively used in the removal of saline and gypsum deposits. It is also capable of holding metal ions such as ($Ca2+$) and ($Fe3+$). The metal ions remain in the solution after being associated with EDTA but show less interaction. EDTA solution is produced as a multiple salts and is calibrated with a certain concentration 0.01 M (Molarity). The EDTA solution helps to separate the gypsum particles and discard them as a soluble substance that appears after drying as white particles washed with water [10]. The washing process was repeated and gypsum ratio being checked several times until a few gypsum values was reached within acceptable limits in the normal soils. After the removal of the gypsum material, all the tests were re-examined for the purpose of comparison and to study the heterogeneity of the properties of the same specimens used.

According to the nature of the soils tested, Specimen of the soil did not contain fine materials exceeding 10% for granular diameters less than 0.075 mm. Therefore, enough soil was collected for the hydrometer test, i.e., processing 50 g of specimen. The hydrometer test was performed on the collected specimens and the hydrometer readings were taken. The purpose of this experiment is to study the effect of gypsum in the case of adopting the conventional method using distilled water and dispersion solution, and observing the amount of heterogeneity in the hydrometer readings and the time of final reading. This was done in two cases; the first for specimen containing a certain gypsum content and the second for the same specimen after removing the gypsum effect. The procedure of removing the gypsum effect as a soluble substance can affect the solubility of the dispersion solution. It was treated in this study by using the EDTA solution to separate the gypsum particles and stop their melting in water. After treatment with the EDTA solution, the hydrometer test is done by the conventional method and the hydrometer readings are recorded to observe the heterogeneity between the two cases with gypsum as a soluble substance and its absence.

Variables adopted in the soil classification were calculated according to the unified classification system for specimens before and after gypsum removal [8].

3. RESULTS

Table 1 shows the depth and the type and classification of the soil specimens used in the study. The values of the gypsum content ranged from 8.75% to 42.23% at different depths. The soil specimens were classified according to the classification of Barzanji [7]. It was noted that the gypsum concentrations were high in the surface soil layers.

Table 1
Soil specimens and their classification by percentage of gypsum content

Specimen	Depth (m)	Gypsum content (%)	Classification
S1	0.75	42.23	Highly gypsiferous
S2	1.10	32.50	Highly gypsiferous
S3	2.00	8.75	Slightly gypsiferous
S4	3.30	19.82	Moderately gypsiferous

Table 2
Results of chemical tests of soil specimens before removal of gypsum**.**

Specimen	S1	S2	S3	S4
Gypsum content %	42.23	32.5	8.75	19.82
T.D.S %	46.6	36.43	11.52	23.01
Org. %	0.91	0.16	0.38	1.1
pH	7.81	7.36	7.63	7.55

Experimental tests were carried out to determine the chemical properties of the specimens in their natural state before removing the gypsum effect as shown in Table 2. It is observed that all specimens contain a few organic matter ratios and PH indicates that the soil is generally alkaline soils. Soil specimens also contain highly soluble salts because of the gypsum presence.

Table 3 shows the values of the results of the chemical tests after the gypsum removal process, using EDTA solution and continuous water washing.

Table 3
Results of chemical tests of soil specimens after removal of gypsum.

Specimen	S1	S2	S3	S4
Gypsum content %	1.61	1.3	0.3	1.1
T.D.S %	17.7	15.4	5.42	9.3
Org. %	0.83	0.12	0.21	1.00
pH	7.87	7.4	7.65	7.6

Table 4 shows the values of Atterberg's Limits and the specific gravity of the specimens before and after the gypsum removal from the soil. Due to the presence of gypsum materials, it was noted that all the specimens did not have a plastic limit before washing process. Thereafter; specimens have values of plastic limit after washing the gypsum. Specific gravity increases with the removal of gypsum from the soil because gypsum was one of the soil components, which is a material have a specific gravity less than other components of the soil. Comparisons for all properties examined before and after the removal of gypsum are shown in Figs. (1)-(4).

Table 4
Atterberg's Limits and the specific gravity of soil specimens before and after gypsum removal.

Specimen	S1		S2		S3		S4	
Test case	Before	After	Before	After	Before	After	Before	After
L.L	21.57	24.4	18.4	20.6	-	14.5	12.76	18.5
P.L	-	10.7	-	18.7	-	6.3	-	7.5
Gs	2.53	2.66	2.47	2.77	2.66	2.73	2.72	2.78

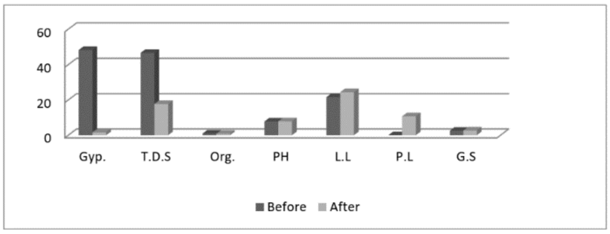

Fig 1. Comparison of physical and chemical properties of specimen S1 before and after gypsum removal.

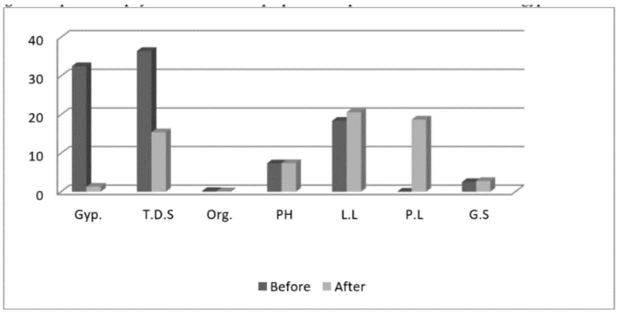

Fig 2. Comparison of physical and chemical properties of specimen S2 before and after gypsum removal.

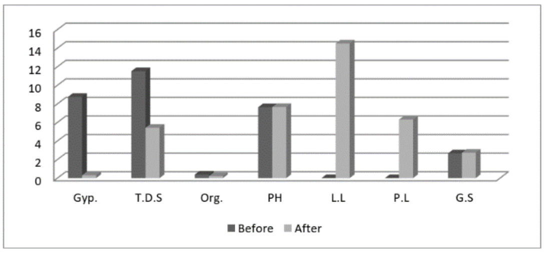

Fig 3. Comparison of physical and chemical properties of specimen S3 before and after gypsum removal.

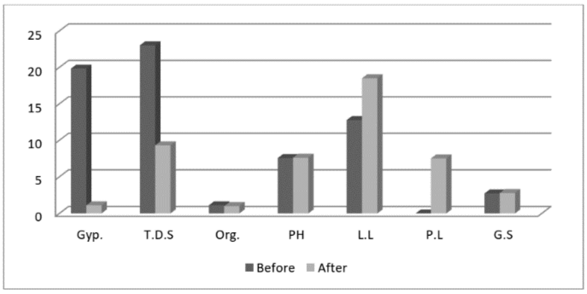

Fig 4. Comparison of physical and chemical properties of specimen S4 before and after gypsum removal.

Figs. 5-8 show the results of sieve analysis of all specimens before and after the washing process and gypsum removal from the soil. Gradiation and uniformity coefficients are shown in Table 5. The classification parameters and soil types of the specimens according to the Unified Classification System before and after the gypsum removal process are also tabulated in Table 5.

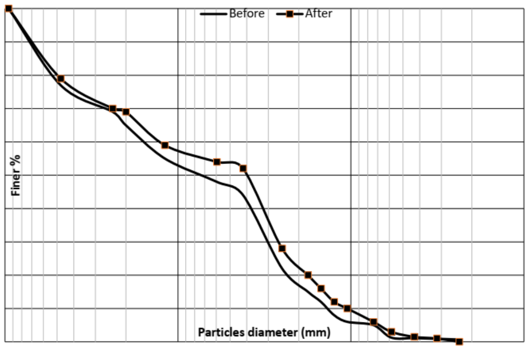

Fig 5. Sieve analysis curve of specimen S1 before and after gypsum removal.

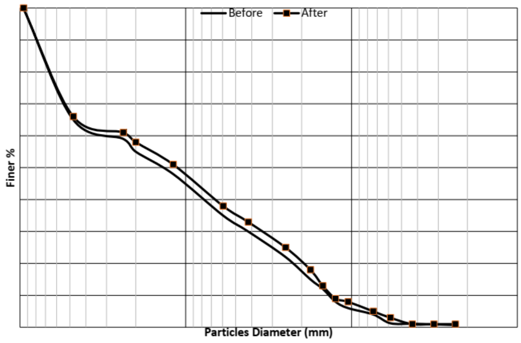

Fig 6. Sieve analysis curve of specimen S2 before and after gypsum removal.

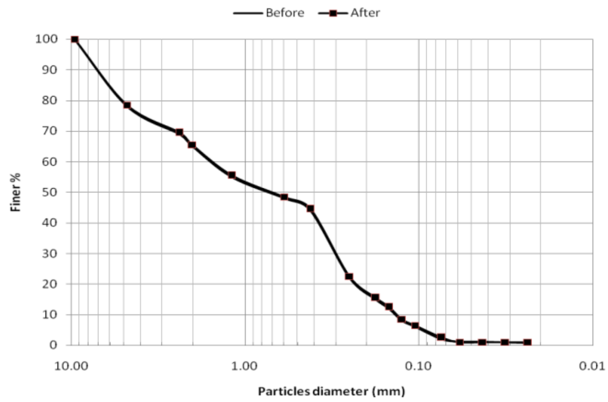

Fig 7. Sieve analysis curve of specimen S3 before and after gypsum removal.

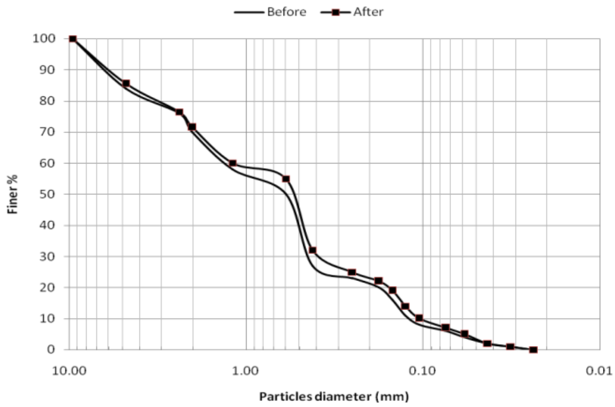

Fig 8. Sieve analysis curve of specimen S4 before and after gypsum removal.

Table 5
Gradiation, uniformity and soil classification for all specimens before and after the removal of gypsum.

Specimen	Test case	D10	D30	D60	C_C	C_U	Classification
S1	Before	0.13	0.30	1.60	0.43	12.30	SP
	After	0.10	0.26	1.20	0.56	12.00	SP
S2	Before	0.14	0.41	3.10	0.38	22.14	SP
	After	0.13	0.32	2.30	0.43	17.69	SP
S3	Before	0.13	0.30	1.60	0.43	12.30	SP
	After	0.13	0.30	1.60	0.43	12.30	SP
S4	Before	0.13	0.47	1.30	1.30	10.00	SW
	After	0.10	0.40	1.20	1.33	12.00	SW

Figs. 9-12 show the relationship of hydrometer readings versus reading time. The purpose of this representation was to give a clear view of the heterogeneity of the test values before and after the washing process and the removal of gypsum as a soluble material that may affect the results of the hydrometer test.

4. DISCUSSION

Analyze the results reveal the following:

- ***Effect of gypsum removal on the chemical properties:***

Percentage of total soluble salts was decreased between 53% and 59% after removal of gypsum salts. These were expected values, since prior to the washing process, the soil has a significant gypsum proportion of the total soluble salts found in soil specimens. There was a very slight

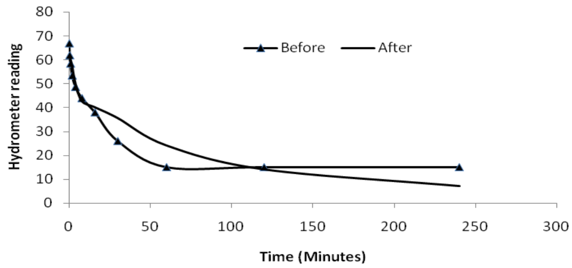

Fig 9. Relationship between hydrometer reading and time of specimen S1 before and after gypsum removal.

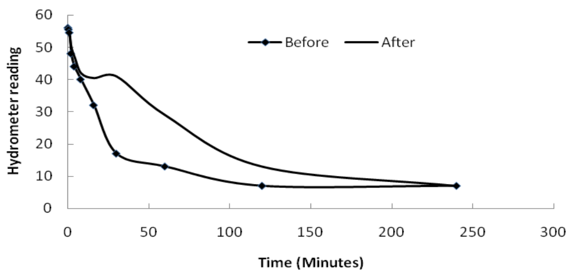

Fig 10. Relationship between hydrometer reading and time of specimen S2.

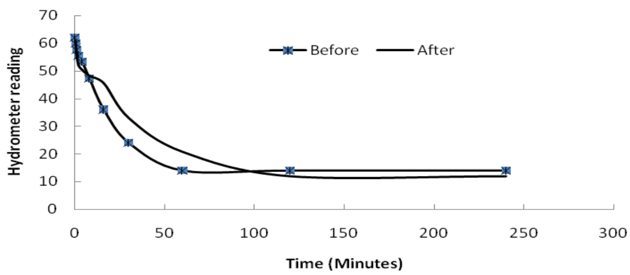

Fig 11. Relationship between hydrometer reading and time for specimen S3**.**

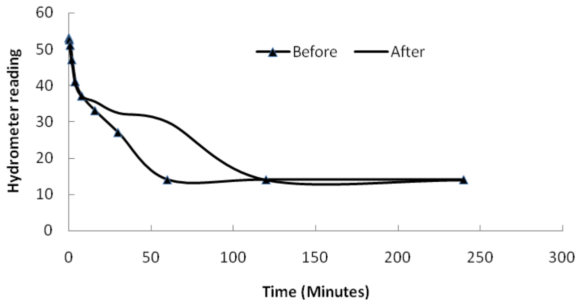

Fig 12. Relationship between hydrometer reading and time for specimen S4.

decrease in the percentage values of organic matter content in all specimens, because the washing process using EDTA solution did not affect the organic matter present in the soil. Also, the pH values for all specimens increased by percentages ranged from 0.26 to 0.76, relative to the increasing in gypsum content of specimens.

- Effect of gypsum removal on the physical properties:

As show in Table 4, all specimens have values for the liquidity limit, whereas the plasticity limit did not obtain for specimens before washing process. Liquidity limit values were increased whereas the plasticity values did been appearing after the washing and gypsum removal process. This finding is in agreement with the observations of Subhi [11]. Specific gravity increased after gypsum removal process, where the increases ranged from 2% to 12%. This increasing could be explained by the fact that the gypsum material has a small specific gravity compared to other soil components, which leads to a decrease in these values when found in the soil.

Figs. 5-8 illustrate the grain size distribution relationship for all specimens. It is generally observed that the grain distribution of the tested specimens deviated to the right of the curves for specimens before gypsum removal. The amount of deviation is directly proportional to the increase of gypsum ratio of the specimens. It was evident in specimens S1, S2 and S4) contain medium to high gypsum content. In specimen S3 no significant deviation was observed, where the ratio of gypsum content was less than 10%. Deviation of relationships in Figures indicates that the soil particles may become to have diameters less than before washing and gypsum removal process. This behavior can be explained by the fact that gypsum materials are not only aggregates within the structure of the soil. In fact, part of the gypsum can encase the soil particles by gypsum layer that can increase soil particle diameter. The conventional process of sieving analysis of involves the separation of soil blocks with a hammer or by any other means without crushing it. This process cannot remove the gypsum layer that encases the soil granules. The use of EDTA solution can removes the gypsum layer around soil particles. This can explain the decrease of the soil particles diameters and curves deviation following the washing and removal of gypsum materials.

It was observed that the values of D_{10}, D_{30} and D_{60} decreased by up to 25%, as it is clear in the deviation of the curves before and after the washing process. The ratio of decreasing in diameter did not significantly affect the values of the gradiation and uniformity coefficients, which might have led to a change in the soils classification. The classification of specimens (S1, S2 and S3) was, poorly graded sands, gravelly sands, little or no fines (SP). Specimen S4 was classified as well graded sands, gravelly sands, little or no fines (SW). Specimens Classification did not change after the gypsum was removed.

Figs. 9-12, reveals that the removal of the effect of the gypsum materials as soluble materials in the dispersion solution had an effect on the precipitation speed of the suspended soil grains. In other words, stability of hydrometer reading was taken less time for specimens after vanishing gypsum effect. Short time to reach a stable reading for hydrometer gives an indication that, proportions of silty particles were more than clayey particles in the soil specimen This may leading into a wrong estimation for the percent of silt and clay particles in soil specimen. Therefore, conventional hydrometer test using water was not effective in gypsum soils.

5. CONCLUSIONS

The results showed that the use of the EDTA solution was effective in removing gypsum from the granular soils. The gypsum ratio was reduced to less than 2% in all specimens. The soil organic matter dose not affected by the EDTA solution. When gypsum was removed from the soil, the liquidity limit and the plasticity limits found for all specimens with different gypsum contents. There was an increase in the specific gravity of soil specimens due to the removal of gypsum at rates ranging between 2% and 12%. A slight increase in pH values was also observed after the gypsum was removed.

A notice effect on the grain size distribution of the soil specimens after gypsum removal. Due to the separation of the gypsum particles using the EDTA solution washing process, gypsum layer that encases the soil particles was removed. In general, classification of the soil specimen did not affect by gypsum removal.

Gypsum melting in the diffusion solution of conventional hydrometer test yields different results after removal of the gypsum. Therefore, conventional hydrometer test was not feasible in gypsum fine soils.

The use of EDT solution in the washing and removal of gypsum from the soil was an effective and quick method in granular soils. It can safely be used to remove gypsum from granulated soils for the purpose of studying behavior of gypsum soils after gypsum removal.

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