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A Review Study on Gypseous Soils Stabilized with Different Additives in Iraq

Atheer G. Ibrahim [1] Maysam Th. Al-Hadidi [2] Hateem H. Hussien [1]
Nezar K. Neamah [1]

[1]National Center for Water Resources Management, Ministry of Water Resources, Baghdad, Iraq
[2]Water Resources Engineering Department, University of Baghdad, Baghdad, Iraq
*Corresponding Author E-mail: **atheergurjee1993a@gmail.com**

Abstract

Gypseous soils are mostly found in arid and semi-arid regions and widely distributed in Iraq. It covers 31.7% of the surface area of the country. Soils which cause large damages to the foundations of structures called problematic soil such as gypseous soil. The problem in this kind of soils is the collapsibility. This problem grows up when there is a contact between water and gypseous granules of gypseous soil. The phenomenon of the collapsibility should be controlled in the soil to give good results for the foundation. The controlling process include many ways such as replacement of the soil, chemical and physical treatments. This study presented a review of literature on gypseous soil stabilization by Iraqi researchers which applied their researches in Iraq using many additive materials.

Keywords: Gypseous Soil, Additive materials, Collapsibility, Permeability, Shear strength.

دراسة مراجعة التربة الجبسية المثبتة بإضافات مختلفة في العراق

[١]اثير كرجي [٢]ميسم الحديدي [١]حاتم حميد حسين
[١] نزار كاظم نعمة

١المركز الوطني لادارة الموارد المائية، وزارة الموارد المائية، بغداد.

٢ هندسة الموارد المائية ، جامعة بغداد ، العراق

* المؤلف المراسل: **atheergurjee1993a@gmail.com**

الخلاصة

تنتشر الترب الجبسية بشكل واسع في العراق وتكثر في المناطق الجافة وشبه الجافة وتغطي حوالي ٣١,٧% من المساحة السطحية للبلد. تعتبر التربة الجبسية من انواع الترب التي تسبب اضرار لأساسات المنشآت الهندسية لذلك تسمى بالترب ذات المشاكل بسبب خاصية الانهيارية في هذه الانواع من الترب وتظهر هذه الخاصية خصوصا عندما يحدث هناك احتكاك بين الماء وحبيبات الجبس الدقيقة في التربة الجبسية. يجب الحد من ظاهرة الانهيارية والسيطرة عليها لاعطاء نتائج جيدة لاساسات المنشآت. تتضمن عملية السيطرة هذه عدة طرق منها تبديل التربة، المعالجات الكيميائية والفيزيائية. الدراسة الحالية تتضمن مراجعة ادبية لمثبتات التربة الجبسية من قبل باحثين عراقيين والتي تم تطبيق ابحاثهم في العراق بأستخدام عدة مواد مضافة.

الكلمات المفتاحية: التربة الجبسية ، المواد المضافة ، القابلية للانهيار ، النفاذية ، قوة القص.

1. Introduction

Many hydraulic structures of gypseous soil are at risk such as Mosul dam. The risk of this soil because the contacting of the soil with water. The salts of the gypseous soil wash away when there is water causing the problems (Ahmad, et.al., 2012).

The total surface area in Iraq for gypseous soil is equal to 31.7%, while the range of gypseous content is from 10% to 70% (AL-Emami, 2007), as shown in Figure (1).

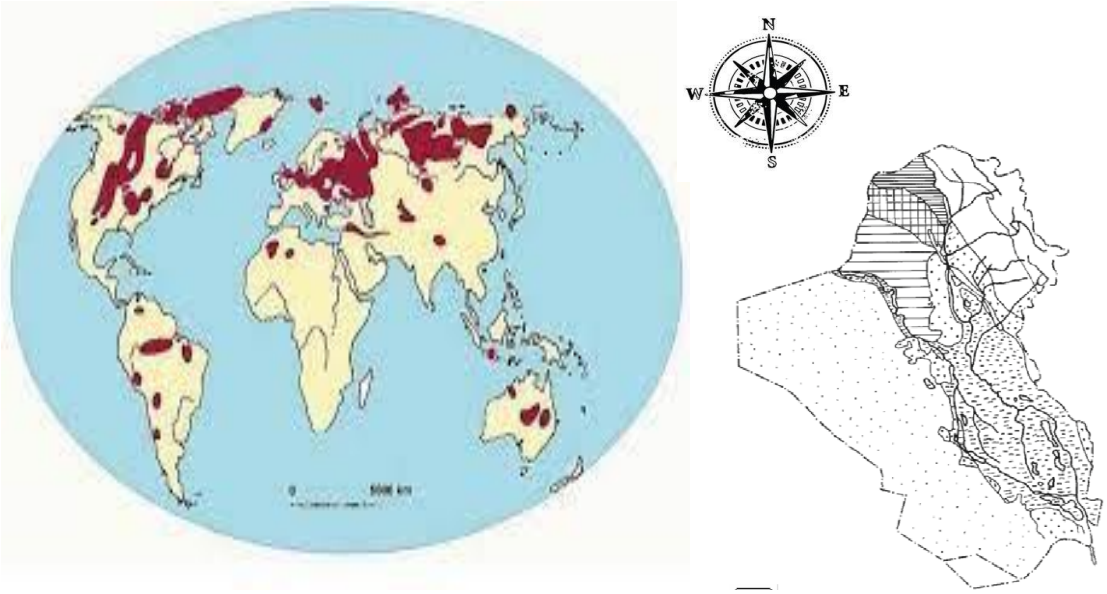

Figure (1): Distribution of gypseous soils in the world and in Iraq.

There are three names for current soil; the first name is 'gypsiferous soil' which contains some gypseous. The second one is 'gypseous soil' which is not common in the synthesis of the soil. The third one is 'gypseous soil' which used for the soil that has the largest gypseous percentage (Al-Barzanji, 1973). Pure gypseous contains calcium oxide, combined water, and sulphur trioxide and the percentages 32.5%, 20.9%, and 46.6% respectively. While the gypseous salts in Iraq are ranging between 0% to 80% as great limits (Al-Mufty, 1997).

Gypsum in its initial state consists of $C_aSO_4.2H_2O$. The forms and their represents are:

- ✓ CaSo4 is called anhydrite.
- ✓ SO_3 represents sulfate.

- ✓ H_2O is the water.

Gypseous soils are widely found in semi-arid and arid regions of Iraq. It is found in the Euphrates River basin and covers 20% of the area of Iraq, (Kuttah, 2004)

The classification of gypseous soil was explained by (Nashat, 1990) according to the to the gypseous content, as shown in Table (1).

Table 1. Classification of gypseous soil according to the gypseous content.

Gypseous content as a percentage (%)	Classification
3.0–10	Slightly gypseous
10–25	Moderately gypseous
25–50	Highly gypseous
3.0–10	Slightly gypseous
< 50	Gypseous

To improve the engineering characteristics of a soil, the ability is usually subject to the compaction of soil particles and should use the optimum moisture content, (Al-Qaissy, 2004).

When the rocks and minerals are weathering, quantities of salts are created, one of these salts is gypseous salts. These gypseous salts are found as a binder between the gypseous particles, the property of the binder here is "calcium sulphate hemihydrate". This property begins to be effective when there is no direct contact with water, as at contact the bonding becomes weak and causes failure, (Al-Mohammadi, et.al., 1987). The gypseous content of the soil is very important to determine volume change, properties of the soil, and strength that are required in geotechnical science (Aldaood, et. al., 2014). (Al-Gabri, 2003) found that there was an increase in the dry unit weight when there is a decrease in the collapse potential for the soil. He found this information when he used two samples of the gypseous soil from Al-Dour and Tikrit.

(Al-Obaydi, 2003) found the collapsibility of the gypseous soil. The soil contained a high gypseous percentage, equal to 60%. This soil was brought from Ramadi governorate. (Dudley, 1970) reported that the rate of the collapsibility is dependent on the distribution of the grain size and shape of bulky grains, moisture content, cementing agent, materials mineralogy and void ratio. (Seleam, 1988) worked with sandy soil of the Al-Habaniyah site, investigated the collapse potential between 0.4 – 0.7. So, the collapsibility of this soil is

moderately collapsible. (Abood, 1994) found the effect of gypseous content of clayey and sandy soils on its collapse potential, and investigated that when there is an increase in the gypseous content, there will be an increase in the collapse potential. (Sheikha, 1994) found that when there is increase in the applied pressure and gypseous content for the soil, there will be increase in the collapse settlement.

Al-Mufty, 1997 Investigated that the gypseous content in the soil cause cementation process to the particles of the soil which resist the soil compaction and increase the water content to reach to the maximum dry density. Also, he found that the compaction energy is giving the higher cohesion to the soil. Al-Hadithy, 2001 found for four types of the soil the compaction properties are influenced by the gypseous content. He investigated that when there is increases in the gypseous content of the soil, there will be an increase in the maximum dry unit weight. (Arutyunyan and Manukyan, 1982) found that during the first stages of the leaching, the coefficient of the permeability increases sharply in an unequal manner.

(Al-Ani and Seleam, 1993) they achieved their test on gypseous soil with gypseous content 8% and the samples are remolded with the content of gypseous 3%, with different of initial water content percentages $\omega = 5$, 10, 15, and 20 %. They founded that there was decrease in the potential of the collapsibility (C.P) with the increase of the initial water content

2. Classification of soil stabilization techniques

Stabilizations of gypseous soils are classified on the method of stabilization.

1. Mechanical stabilization: This method is considered the old method of stabilization of soil which means changing the property of the soil or other characteristics. The methods of mechanical stabilizations are:
    - ✓ Compaction process which typically employs a heavy weight to increase the soil density by applying pressure from above, Figure (2) shown the compaction process of the soil.

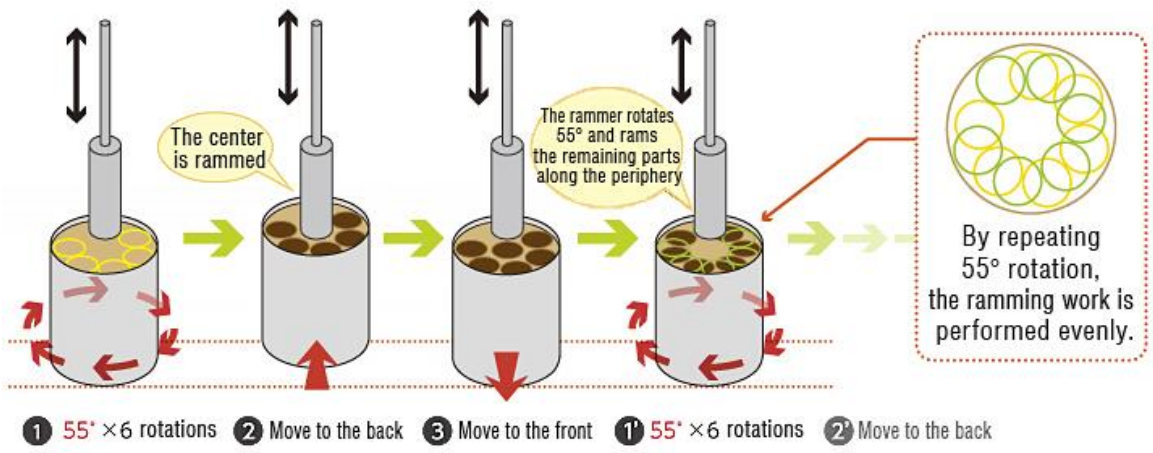

Figure (2): Compaction test.

- ✓ Soil Reinforcement.
- ✓ Addition of Graded Aggregate Materials.
- ✓ Mechanical Remediation.

2. Chemical methods: In these methods, chemicals are used to change the proportion in the soil particles. This method of treatments depends on adding additional materials to gypseous soil which interact physically and change the soil for the better such as; Cement, Clinker, Silica fume, and Cutback asphalt.
3. Soil stabilization by using polymers. Methods of using polymers for treatments should be significantly less dangerous of environment than other treatment trend to be.

3. Chemical treatment methods applied in Iraq

Additive materials, gypseous content, location of bringing the soil and the percentage of added material, and finally the main conclusions of every additive material are explained in Table (2).

Table 2. Treatment methods.

1	**Reference**	**Additive Material**	**Gypseous content%**	**Site**	**Percentage of Treatment**
	(Al-Neami, 2010)	Clinker additive	40	Al-Axandria region, Babylon Governorate	2%, 4%, 6%
	Main conclusions				
	✓ The percent of clinker 4% decreases the collapsibility of the soil sharply. ✓ The percent of clinker 4% improved the collapse potential more than 73 as percentage. ✓ Increasing in the clinker percentage decreases the compressibility of the soil. ✓ Shear strength parameters of treated soil are more those than for natural soils.				
2	**Reference**	**Additive Material**	**Gypseous content%**	**Site**	**Percentage of Treatment**
	(Aziz and Ma, 2011)	Fuel oil	S1= 51.6 S2= 26.55	Al-Therthar	0%, 2%, 4%, 6%, 8%
	Main conclusions				
	✓ For permeability-leaching test, increasing in the F.O. percentages decrease the hydraulic conductivity. ✓ Durability of soil specimen which treated with 2% fuel oil was 143 days before piping occurrence. Soil samples treated with higher precents of fuel oil were more durable than the samples treated with the percentage 2%. ✓ Increasing in the percent of F.O. decreases the collapsibility of the soil.				

	Reference	Additive Material	Gypseous content%	Site	Percentage of Treatment
3	**(Karim, et.al., 2012)**	Bentonite and Kaolinite	50%	Al-Qarma east of Al-Falluja	5%, 10%, 15%, and 20%
	Main conclusions				
	✓ For the percentage of 10 mixed bentonite and kaolinite, large reduction of collapsibility occurs and reaching to (80-82) %. ✓ It was noticed that large reduction in compressibility characteristics occurred to the gypseous soil when the above additives used. For 10% of the mix, recompression index (Cr) and compression index (Cc) have lowest values. ✓ Bentonite additive as 10 percentage gives improving results best than those of kaolinite for finer grains.				
4	**Reference**	**Additive Material**	**Gypseous content%**	**Site**	**Percentage of Treatment**
	(Fattah, et.al.,2014)	Acrylate	Sa=72 Sb=55 Sc=29 Sd=18	Karbala and Al-Najaf Governorates	values of injection the liquid were 600ml,750ml, 900ml, and 1000ml.
	Main conclusions				
	✓ From the treated samples, acrylate polymer reduced the volumetric strain of the soil. ✓ For soaking period of seven days, the percentage 27–33 of the volumetric strain for untreated soils occurred, while 10–13% occurred for treated soils.				

5	**Reference**	**Additive Material**	**Gypseous content%**	**Site**	**Percentage of Treatment**
	(Albusoda and Khdeir, 2018)	Nano-Materials	58	Salah El-Deen Governorate	1%, 2%, and 4% by weight
	Main conclusions				
	✓ Nano- Materials used were fly ash and silica fume. ✓ It was noticed that the collapsibility decreases sharply when the percentages were 4% of silica fume and 2% of fly ash. ✓ At the optimum percentages (2% and 4%), the improvement in collapse potential occurred more than (83) %.				
6	**Reference**	**Additive Material**	**Gypseous content%**	**Site**	**Percentage of Treatment**
	(Shakir, 2017)	Cutback Asphalt	30	Karbala Governorate	3%, 6%, 9%, 12%, 15%
	Main conclusions				
	✓ When there was increased in the (MC-30) percentage to 12%, collapse potential decreased from (10 to 2.6) %. ✓ The results showed that the optimum value of collapse reduction was 12% of Cutback Asphalt. ✓ For coefficient of salt dissolved, it was noticed that adding (0, 3, 6, 9, 12, and 15) % asphalt required (8, 11, 13, 15, 31, and 33) minutes to reach 90% of total dissolved salts. ✓ After treatment with the material (MC-30), bearing capacity decreased.				

7	**Reference**	**Additive Material**	**Gypseous content%**	**Site**	**Percentage of Treatment**
	(Al-Hadidi and AL-Maamori, 2018)	Cement	42.55	Karbala Governorate	✓ Two volume ratios (5% and 10%) and this mixture consists of different ratios of cement to water (w/c) 2%, 3% and 4% for each volume ratio of the mixture. ✓ Second methos was seven percentages of cement 2%,3%,5%,8%,10%,13% and 15% by weight.
	Main conclusions				
	✓ Untreated soil was eroded and suffered scouring by the effect of active water. ✓ Best percentage of cement was 10%.				
8	**Reference**	**Additive Material**	**Gypseous content%**	**Site**	**Percentage of Treatment**
	(Al-Hadidi and Ibrahim, 2019)	Polyurethane	41	Karbala Governorate	✓ The cover ratio was 5% for each of 6%, 10% and 12% polyurethane. ✓ The second cover ratio was 10% for each of 6%, 10% and 12% polyurethane
	Main conclusions				
	✓ For untreated soil, there was soil suffering a high increase in the scouring with time. ✓ Treated soil with 5% cover ratio and 10% polyurethane considered a best ratio due to giving best result for seepage and reduction in erosion of 90.93% during 60 days of continuous operation.				

9	**Reference**	**Additive Material**	**Gypseous content%**	**Site**	**Percentage of Treatment**
	(Al-Taie, et.al., 2019)	Dihydrate calcium chloride	44	North of Baghdad province, Iraq	2.5% and 5.0%
	Main conclusions				
	✓ For leaching process, significant reduction has been recorded in the cohesion of natural soil, while there was stability in the angle of internal friction. ✓ For leaching of treated soil, parameters of shear strength were unaffected.				
10	**Reference**	**Additive Material**	**Gypseous content%**	**Site**	**Percentage of Treatment**
	(Snodi and Hussein, 2019)	Tire Rubber waste	41.24	Tikrit city	2%, 4%, 6%, and 8%
	Main conclusions				
	✓ For direct shear test, when there was an addition in waste tire rubber, angle of internal friction (φ) increased. ✓ For compaction test, particles of rubber decreased the maximum dry density for the soil. ✓ Optimum moisture content decreases when the was an addition in the rubber particle.				

	Reference	Additive Material	Gypseous content%	Site	Percentage of Treatment
11	**(Al-Obaidi, et.al., 2020)**	Silica Fume and Nano Silica Fume	62	Tikrit city	SF= 5%, 10%, 20% NSF= 1%, 3%, 5%
	Main conclusions				
	1) Shear strength parameter ✓ For untreated soil, there was an increment in the cohesion when Sf percentages increased, and for treated soil, there was reduction in the angle of internal friction. ✓ There was improved in the shear strength of the gypseous soil when NSF percentages increased. ✓ NSF optimum value was 3%. 2) Collapse potential ✓ There was reduction in the collapse potential when the soil mixed with NSF of SF. ✓ Gypseous soils becomes moderately problematic when there was addition of NSF equal to 3%.				
12	**Reference**	**Additive Material**	**Gypseous content%**	**Site**	**Percentage of Treatment**
	(Ahmed, et.al., 2020)	Copolymer and styrene-butadiene rubber	36	Southwest of Baghdad	3%, 6%, 8%
	Main conclusions				
	✓ Permeability coefficient decreased as polymer material increased. ✓ There was decreasing in the collapse potential equal to 63.35% for copolymer and 67.79% for Styrene-butadiene rubber when the percentage of additives was 3%, but the percentage 9% gave increasing in the values equal to (45.66 and 14.79) %, respectively. ✓ When the percentage of Styrene-butadiene rubber equal to 6%, the bearing capacity increased.				

4. Conclusions

All researches of Iraqi engineers were carried out professionally and selected a good proportion of each additive. Therefore, it is very difficult to make a decision which method was best for gypseous soil to reach to the optimum improvement due to the properties and the gypseous content for gypseous soil and large variation of this content in Iraq.

Despite the maximum number of improvement materials and hard to find the best improvement method for gypseous soils, the main results can be explained and discussed as follows:

1. This research contains many studies that include various physical and chemical treatments. The most effective method of treatment gypseous soil depends on many factors such as:
   - ✓ The ability to decrease the collapse potential during soaking and leaching.
   - ✓ Ease of availability in the local market.
   - ✓ Cost of additive material.
   - ✓ Durability of additive material.
   - ✓ Age of additive material.
   - ✓ The percentage of acceptability of the additive material when mixed with other material.
2. Improvement of gypseous soil by using polymers is very important. The used polymers in this study such as polyurethane, copolymer, and acrylate gave good results for collapsibility, compressibility, and shear strength.

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