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STABILIZATION OF SALINE SOILS BY DIFFERENT ACTIVE TECHNIQUES

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ABSTRACT: - Saline soil scattered wide range of Iraqi territory. Its presence causes engineering problems, which arising for Structural sons erected thereon, due to collapse behavior, when moisturizing with water from any source, due to the rapid melting of the salt molecules surrounding soil granules, leading to the disintegration of the ties of the soil.

This study sheds light on the possibility of stabilizing saline soil, using a layer of graded sand with 140 mm thickness, mixed with some available additives:(1%, 3%, 6% of Fly Ash with polyester), (1%,3%,6%, 10% of Emulsified Asphalt),(5% and 10% Bentonite), (1.5% and 3% of Lime material)l, (2% and 5% of Cement material), with and without reinforcement. and investigates its effects on the collapsibility of such problematic collapsible soil. The soil used in this study was natural saline soil with 10% salinity retrieved from a region near Jurf Al-Milih region, in Diyala governorate. Number of tests was conducted using laboratory model of thick container with 400mm height and 300mm diameter.

The best improvement was achieved by using a layer of graded sand mixed with 10% Bentonite. This technique reduces the collapsibility to 96%. While mixing the graded sand layer with (5% cement, and 14.2% of randomly distributed waste ferrous materials), reduces the collapsibility to 94%.

KEYWORDS: saline soil stabilization, additives, fly ash, waste ferrous materials.

1- INTRODUCTION

Soil of Iraq among the world's soils, is Famous diversity of formations, because of their geologic nature, textural and climatic conditions. Saline soils between these types, consisting of soil particles surrounded by molecules of chlorides, sulfates or other species salts, which operates as a link agent to fill in the blanks in the dry condition. The disposal of such soil, depending on the type of salts contained in. chlorides salts, for example, is more prevalent and faster soluble in water [1]. The dissolution rate of such type of problematic soil depends on several factors including the purity of salt, acidic solvent, temperature, barometric pressure and other factors .

The problem with saline soils appears when it's at inciting first moistened. The bonding salt materials between soil particles weakened, and turn into a low-density media inside the soil. gaps between the soil particles would be generated, which leads to change the molecular composition of a of soil skeleton, which leads to the re-arrangement of soil particles and decreases the bearing capacity of soil for buildings erected thereon, which increases the rate of the decline in shear strength of soil and sudden and unexpected settlement would occurs, and thus the occurrence of structural problems for buildings and facilities constructed on. For ordinary buildings, its advises to use raft foundation to prevent such problems but it is costly. But for heavy and special structures like dams and bridges nuclear buildings, the need appears, for treatment such collapsible soil seriously.

New patterns and forms of failure started to raise and geotechnical and structural engineers have to accept this challenge and provide safety measures and remedies. Saline soils covers 15% of the surface sediments soil of Iraq which containing gypsum salts between (2-20) percent [1, 3, 4]. Saline soil covers about 30% of the world area such as Saudi Arabia, north Africa ,Mexico ,Australia, Iraq and other countries[2,5].

Saline soils is composed from hydrated gypsum minerals $CaSO4.2H2O$, $SiO2$, calcite $CaCO3$ or NaCL food salt, which covers land surface. When the water table level is raised up because of capillary action and heating of the ground and the salinity of water increase for these soils to the degree of sedimenting of these types of salts because of water evaporation so the water table plays an essential way to the presence of saline soil [2,6].

There are many factors affecting the presence of saline soil: Climatic factors. Chemical composition, geomorphological factors. And hydrological factors [7]. The construction of buildings, roads, bridges, channels, harbors and railways in such problematic collapsible soil has an always been associated with settlement associated with water infiltrates inside these soils [6].

Researchers at different institutes carried out a lengthy testing program in an attempt to understand the geotechnical properties of such problematic soils, and proposed solution for existing problems. Under these circumstances some vogue remedial proposals were, made. Some are chemical, by adding lime sodium silicate or oil product. The others are physical by compaction or soil reinforcement [8].

The possibility of using additives was studied by many researchers, and its effect on the shear strength of sabkha soils. Cement was added in percentages of 2.5, 5, 7.5 and 10%, by dry weight of soil. The soil-stabilizer mixers were allowed to cure for 7, 14 and 28 days. Laboratory tests such as compaction, unconfined compression, consolidated undrained triaxial and durability tests were performed to measure the engineering characteristics of the stabilized material. The results showed substantial improvements in the shear strength of the sabkha--cement mixtures and the mixtures are also durable with small weight loss after 12 wetting/drying cycles. Thus, cement can be used to improve the shear strength of sabkha soils. Furthermore, the effective stress path and the tress-strain relation of the sabkha--cement mixtures follow trends similar to those of cemented calcareous soils [9]. The feasibility of using lime, as a stabilization material was investigated. It is economic for the most geotechnical projects. And they showed that the usage of polymer is suggested only in special applications due to its rapid setting [10]. On the other hand the addition of unlimited quantities of these materials would increases the sulphate content in the soil mix with, which has a side effect on the concrete footing by causing cracks and erosion with time.

Bin-Shafique et al (2010) [11], presented an experimental study, which was conducted to investigate the long-term performance of fly ash stabilized two fine-grained soil sub bases. One low plasticity clay soil and one high plasticity expansive clay soil were stabilized with a Class C fly ash with fly ash contents of 0%, 5%, 10%, and 20%, and compacted statically at the maximum dry density (standard Proctor) and at the optimum moisture content of the corresponding soil to prepare ten sets of replicates from each of the combinations. He shows that, after curing all specimens for 7 days, the first set was subjected to plasticity index tests, unconfined compression tests, and vertical swell tests to estimate the improvement due to stabilization. Similar tests were also conducted on another nine sets of replicates in which six sets were subjected to 12 wet-dry cycles (three sets with tap water and the other three sets with saline water), and the other three sets were subjected to 12 freeze-thaw cycles in a laboratory controlled environment to simulate the weathering action. The effect of wet-dry cycles on stabilized soils was essentially insignificant; however, the fly ash stabilized soils lost up to 40% of the strength due to freeze-thaw cycles. He concluded that, Even after losing the strength significantly, the strength of stabilized soils was at least three times higher than that of the unstabilized soils. And the swell potential of stabilized expansive soils also increased due to freeze-thaw cycles. The vertical swell increases rapidly for first four to five cycles and then increases very slowly.

The use of Coal Ash and Coal Shale as a stabilization agent for Alkali soil, are proposed by many researchers. The availability of such material is very high, and it is used as an additive material for stabilization [17].
Another stabilization material used for soils, presented by the addition of 3% of cement. This additive gives a considerable strength for stabilization of soils when mixing with it. Above and below this number, the strength will be less. And shows that, the silica content in cement, over 5% percent, may contribute with the strength and give fewer results [12].

2. AIM OF STUDY:

The objective of this study is to investigate the feasibility of stabilizing natural saline soil, using a layer of graded sand, mixed with limited and economic stabilizing agents: Fly Ash, Emulsified Asphalt, Bentonite, Cement and Lime. By preventing or minimizing the collapsibility of such problematic soil upon wetting by water. The study includes also the feasibility of mixing the sand layer with randomly distributed waste ferrous materials, to investigate the feasibility of the most active technique recommended for stabilization such soils, using laboratory model tests.

3. EXPERIMENTAL WORK:

The soil used was brought from a region near Jurf Al-Milih region, in Diyala governorate, in which this region famous of highly salt content. The ground surface in this region is widely covers with natural NaCl salts, which is used as food salt.
The samples of soil was extruded from the ground surface at 1m depth, it is sandy soil with (10%) salt content. The soil was oven dried, pulverized placed at the oven at 50°C for 24 hours. The soil was sieved through sieve no.4 to separate large soil practically. The grain size distribution was preformed according to ASTM 422-79 the natural soil was wet sieved through NO. 200 (0.075mm) sieve, then the sample was oven dried at (65-75°C), then sieve analysis was carried out by a set of sieves. Since the soil is sandy, there is no liquid or plastic limit in sand. And it is classified as (SP). The location, in which the soil samples were taken, is shown in figure (1).

3.1. Preparation of laboratory model for soaking test:

In this study, the development of an active technique for saline soil soaking tests was used. to examine the behavior of such type of problematic soils during drying and soaking test, and the disposal of treated and untreated saline soils using different chemical and physical techniques, through the measurement of settlement of rectangular footing, with time. The criterion for improvement is the ratio of foundation settlement to the width foundation(S/B%). The model includes, an interior cylindrical plastic container for natural saline soil specimen. Placed inside a bigger one, for soaking test. Before that, 25 cm layer of sand was placed at the bottom of interior container, which works as a filter to prevent erosion of soil particles with continuous water feeding. The inner container from the lower part punched two holes to ensure a continuous flooding of water from bottom to the upper side, this process was work together with the upper feeding process, to accelerate specimen soaking as shown in figure (2). The soaking process for all models tested was curried from both, upper and lower sides, which distinguishes this technique from other methods used in soaking, to ensure quick water infiltration through soil particles, and melting salt particles quickly. The system of soaking, loading and settlement control are shown in the photograph of figure (3).

The natural saline soil was divided in to three parts in the plastic container each part of soil was compacted to the required height. To ensure good compaction homogeneous layer with soil density =14 kN/m^3 and placed inside interior container. This process continued with the second and third soil parts. The soils surface is leveled with the aid of steel sharp edge. The rectangular footing (4.8cm*6.5cm) made of stainless steel was placed at the center of soil sample.

A vertical steel shaft of high stiffness, welded to upper and lower thick plates was used to apply vertical fix stress of (36.6 kN/m^2). The shaft is held to a fix heavy table to ensure dis overturning of the loading system. Dial gage was fixed for settlement measuring, with time. The dial gage was held by a magnetic field holder, stuck to the steel table, as shown in figure (3).

3.2 Improvement techniques, used in this study:

The stabilization used in this study presented by a layer of graded sand mixed with 5 additives (Fly Ash with Polyester, Emulsified Asphalt (Crack filler liquid asphalt), Bentonite, Lime, Cement), which placed on the saline soil bed. The depth of the treated layer zone is equal 3B and the width of 3B, the author believe that, below this zone, the footing stress effect is fading. Based on Boussinesque bulbs stresses for square footing [18]. These additives were mix with graded sand, at different percentages as a stabilizing layer. The additives used in this study are shown in figure (4), and figure (5).

One of the properties of pure Bentonite is that, when wetted with water, its volume expands about 15 times [14], compared to natural size. It is expected that, using this un-expansive material may work as a balance agent to minimize the collapse of the saline soil upon wetting. So it may prevent the damages for structures constructed on.

Cement or lime, are common materials used to stabilize soils and very effective to stabilize soils. It works as a cementing agent between soil particles when mixed with soils. Number of researchers shows that the best and most economic percent is 3% [15].

This study includes also the effect of mixing additives with the addition of randomly distributed waste ferrous materials,. Mixed with the treated sand layer, with different percentages 11%, 14.2% and 21.4%.

4. RESULTS AND DISCUSSION:

Figures (7) to (13), shows the results gained from laboratory model tests carried on saline soil, with the aid of stabilized sand layer by different techniques , some of them are chemical by mixing it with Fly Ash and Polyester, Emulsified Asphalt, Cement, Lime, or Bentonite. The others are physical by mixing the sand layer with Waste Ferrous Materials, compaction. The third treatment is by both physical and chemical stabilization techniques. By mixing the sand layer with Cement or Lime with Waste Ferrous Materials. Results are compared with untreated model, to show the efficiency of each stabilization technique.

The standard of efficiency for stabilization, is RP% (Reduction Percent in (S/B)% value) . The S/B% value is defined as: the footing settlement (S) related to footing width (B)). The (S/B%) value taken at the end of wetting test for saline soil, in order to give a correlation between the model and a real footing behavior.

4.1 Results of unstabilized saline soil:

Figure (7) shows the behavior of natural saline soil with 10% salinity. The Settlement of single spread rectangular footing was investigated at dry and wet condition. It can be confirms that, the footing is stable and not suffering any serious settlement at the first (1400min) in the dry test.

At the first moment of wetting soil, the problem of collapse appeared because of highly dissolution of salt inside the soil, and the bond between particles weakened. This process causes a reduction in the bearing capacity of soil and the model sample was failed. And the value S/B% at the end of test for untreated model reached (76%). When simulating the model to the real case, of footing with (1m) width. The collapse settlement results from this soil, (reaches 760mm). The presence of such soil causes severe damages for structures constructing on. And it needs a radical treatment, to minimize or prevent this unexpected settlement.

4.2 Stabilization of saline soil by a layer of graded sand mixed with Fly Ash with polyester:

Figure (8), shows the results of stabilizing saline soil by a layer of graded sand, mixed with Fly Ash with three percentages (1%,3% and 6%). The result of the treated layer with 1 %

of fly ash is the most effective one; the final S/B% reaches about 40%. So this technique, reduce the collapsibility 48%, if it is related to unstabilized one. The fly ash may work as a filler material between sand particles in the treatment layer. This would make this layer impermeable when wetting from any source. On the other hand, mixing sand layer with such viscous material may increase the density by filling the voids inside soil skeleton and facilitate the orientation of soil particles. The Polyester, mix with the fly ash is (Resin Based Material) which are use for as stone-Mastic Polyester, may work as a bind agent between soil particles, and help to fill voids inside soil skeleton, and work as water proof agent, to prevent water to infiltrate through saline soil particles. So it would reduce the dissolution rate of salts inside it. The results of laboratory model carried on the saline soil, shows that, mixing granular soil layer with more than 1% of fly ash with polyester increase the compressibility even in dry test. And the danger of collapse increases when water feeding to the model, especially after the first day of soaking test. And the curve drop down. So this stabilization technique does not meet the requirements of the foundations, because the settlement is not acceptable. For example when using 1m width footing, the settlement exceeds 400 mm. so this technique is not effective for saline soil stabilization.

4.3 Stabilization by a layer of graded sand mixed with Emulsified Asphalt:

Figure (9) shows the behavior of untreated and treated laboratory model using a layer of graded sand mixed with Emulsified Asphalt, using four percentages (1%, 3%, 6% and 10%). The results of stabilizing saline soil model using sand layer with 3% Asphalt mix percent, is the ideal one. It reduces the collapsibility 79%. So Asphalt Emulsion may works as a diaphragm or isolation material, coating salt in the soil. This would prevent the water from reaching the salt. So it would prevent melting salt molecules and thus reduces the risk of collapse of such soils, by reducing the dissolution of salt inside such soil. After this percent the compressibility of the treated layer will increase, when mixing sand layer with 6% and 10% asphalt Emulsion. As can be seen at the end of collapse test. This stabilization technique, may considers fairly good, but still not within the level of ambition. Because the settlement of footing with 3% Asphalt addition is not acceptable (S/B=16 %). For example, , the settlement of 1m width footing expected, is 160 mm. which is not with the tolerable limit. dangerous for structures constructed on such soils, still present.

4.4 Stabilization by a layer of graded sand mixed with Bentonite:

Figure (10) shows the results of stabilized laboratory model with a layer of sand mixed with Bentonite ,The results of untreated laboratory model saline soil was compared with the treated one, with (5%) and (10%) Bentonite.

The author idea that: Bentonite swells when water fluctuates through its particles. Because of the Montmorilonite minerals which form this material. It became problematic when wetted with water because of swelling. On the other hand, saline soil becomes collapsible when subjected to wetting from any source. This behavior of two soil shine the lights for a new method to improve the collapse behavior of saline soil by mixing it with different percentages of reverse, swelling soil (Bentonite). This material may compensate the collapse settlement of such problematic soils, upon wetting with water.

The reduction in S/B% is the indication of improvement of saline soil model which is defined as the percent of settlement related to footing width. From fig (10), it can be seen that, the value of S/B% for treated saline soil with (5%) and (10%) Bentonite is reduced to (36%) and (96%) respectively. compared with the untreated model. So the addition of 10% of Bentonite to the stabilizing sand layer, May be consider, the most active improvement technique used in this study. On the other hand it is available material, and easy to deal with. Make it applicable for stabilizing saline soils.

4.5 Stabilization by a layer of soil mixed with Cement, lime with randomly distributed waste ferrous materials:

Fig (11) shows the results of stabilization of saline soil using a sand layer mixed with different percentages of (Cement, Lime), with 14.2% of randomly distributed waste ferrous material.

It can be seen from the results of laboratory model tests carried on saline soil, treated with two additives cement and lime, the best improvement achieved when mixing the soil with 5% cement which reduces the collapsibility more than 94%, which may consider the best mixing percent. While the lime additives is uneffective material for the improvement, the use of 1.5% lime mix with sand layer reduce the collapsibility 9% only which is very Neil. The lime material may contribute with the saline material when wetted with water. This phenomenon may be due to heat generated from the inflorescence - water interaction during the hydration process. This increases the melting process of the salt in the soil saline. , and it becomes worst when the mix percent exceed 3%, It can be seen that from the results of laboratory model test , it would weakening the soil instead of stabilization. So it is advises not to use this additive with sand layer, it may cause more problems for saline soil when the mix proportion with sand layer exceed more than 1.5%.

4.6 Stabilization of saline soil by the addition of randomly distributed waste ferrous materials, with compaction:

Compaction is one of active techniques used to stabilize gypseous soils. In this section the author recognize its effect on saline soil. The stabilization presents by compacting the sand layer to different densities. Figure (12) shows the results of laboratory model tests for saline soil stabilized by the addition of (11%) waste ferrous materials with compaction of the sand layer, to (γ=14KN/m^3, γ=16KN/m^3, γ=19KN/m^3). It can be recognize clearly, the effect of compacting and ferrous materials on the collapse settlement, when comparing with the unstabilizing model. The value of S/B% at the end of wetting test, reduced (12%, 29% and 77%) when mixing waste ferrous material with compacting san layer to (14, 16 and 19 kN/m^3) respectively. This technique works on the basis of, stabilization by both compaction and soil reinforcement. The compaction may reduce the permeability of water infiltrates through soil skeleton, so it reduces the rate of melting salt and increase the effective stress between soil particles. In addition to that, the 11% ferrous waste mixed with sand layer, may increasing the strength of the association between the soil particles and the surface of the waste ferrous which are randomly distributor inside the sand layer, to ward off the danger of landslides of molecules.by strengthening its bond. In addition to that the phenomenon of appearant adhesion between sand particles and ferrous materials may arise during first period of soil wetting. This may increase ultimate bearing capacity of soil.

4.7 Improvement of Saline Soil by the addition of randomly distributed waste ferrous materials:

The saline soil was stabilized using randomly distributed waste ferrous material mixed with sand layer with different percentages (11%, 14.2% and 21.4%). The results of stabilized models were compared with that of non-stabilized model as a referred, which are shown in figure (13). The value of S/B% is reduced from 76% for unreinforced model to 68% for reinforced model with 11% mix proportion. So the S/B% value reduces to 11.5%. While the reduction in S/B% is (21%) for the reinforced saline soil model with 14.2% proportion. The activity of reinforcement is Neil when compared to the previous technique. The reinforcement may only gave an appearant adheasion when subjected to wetting. The improvement gained using (Ln/B=21.4%), reduce the S/B% value (27%). So this stabilization technique is little effective compared with other chemical treatment techniques used in the study, on the other hand the use of ferrous material as a reinforcement, may corrosive with time specially the salinity in such soils, is high. The use of geotextile may be more active and more durability with such soils. So the author advises not to use of such technique since the degree of improvement is not at the required level.

5. SUMMERY

This study was conducted on the use of normal saline soil using locally manufactured laboratory model in order to study the possibility of stabilizing these soils using number of effective techniques, including three chemical additives (Bentonite, cement, and lime) with different mixing proportions. And others are both physical and chemical treatment using randomly Distributed waste ferrous materials with cement or lime additives. These materials are mixed with sand layer as a stabilization zone placed over the saline soil bed.

Table (1) summarizes all techniques used for stabilize natural saline soil, used in this study and the reduction in the collapsibility after using each technique.

6. CONCLUSIONS AND RECOMMENDATIONS:

- The best improvement for saline soil was achieved by mixing it with 10% Bentonite. This technique reduces the collapsibility 96%. So it considers the most applicable and effective technique, since this material is available and easy to deal with and the soil stabilized effectively even in soaking test.
- Cement dust mix with saline soil with the addition of randomly distributed waste ferrous materials, is an effective improvement technique. The addition of (5%) cement with Ln/B=14.2% reinforcement, would reduce the collapsibility to more than (94%) compared with the unstabilized one.
- Lime mixture with the sand layer is not effective additive. When use 1.5% mix proportion, it reduces the collapsibility (9%) which is very little percent and it is consider not affected technique, when compared with other additives, used in the study. On the other hand, the addition of lime to saline soil more than (1.5%) would weaken the soil and increases the collapsibility instead of stabilizing it. So the soil became more problematic
- 3% of Emulsified Asphalt mix proportion with sand layer is the ideal one, which reduces the collapsibility to about 80%. Above this percent this technique became ineffective.
- 1% Fly Ash mix proportion with Polyester and sand layer, stabilized the saline soil moderately, by reduce the collapsibility about 50%. Above this mix proportion, the reduction in collapsibility became unacceptable. So this technique is not applicable to use for stabilization such soil.

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Table (1): summery of the results of all techniques used in this study, to stabilize natural saline soil by using a sand layer mixed with different additives.

Additives and materials mixed with stabilizing sand layer		variables	Reduction percent in collapsibility*
1	Bentonite mixing	5%	36%
		10%	96%
2	Fly Ash mixing	1%	48%
		3%	26%
		6%	10%
3	Emulsified Asphalt mixing	1%	35%
		3%	79%
		6%	31%
		10%	9%
4	Lime addition+ addition of randomly distributed waste ferrous materials (Ln/B%)*=14.2%	1.5%	9%
		3%	No treatment
5	Cement addition + addition of randomly distributed waste ferrous materials(Ln/B%)=14.2%	3%	71%
		5%	94%
6	Stabilization by the addition of randomly distributed waste ferrous materials	Ln/B=11 %	11.5%
		Ln/B=14 .2%	21%
		Ln/B=21 .4%	27%

7	Stabilization by the addition of 11% waste ferrous material+ compaction	γ_{soil}=14k N/m^3	12%
		γ_{soil}=16k N/m^3	29%
		γ_{soil}=19k N/m^3	77%

*RP%: (reduction percent in S/B)=100-(S/B for stabilized saline soil)/(S/B for un-stabilized saline soil)*100.

Fig. (1) Soil sample taken from a region near Jurf Al-Milih region in Diyala governorate, which extruded from 1m depth. With 10% salt percent.

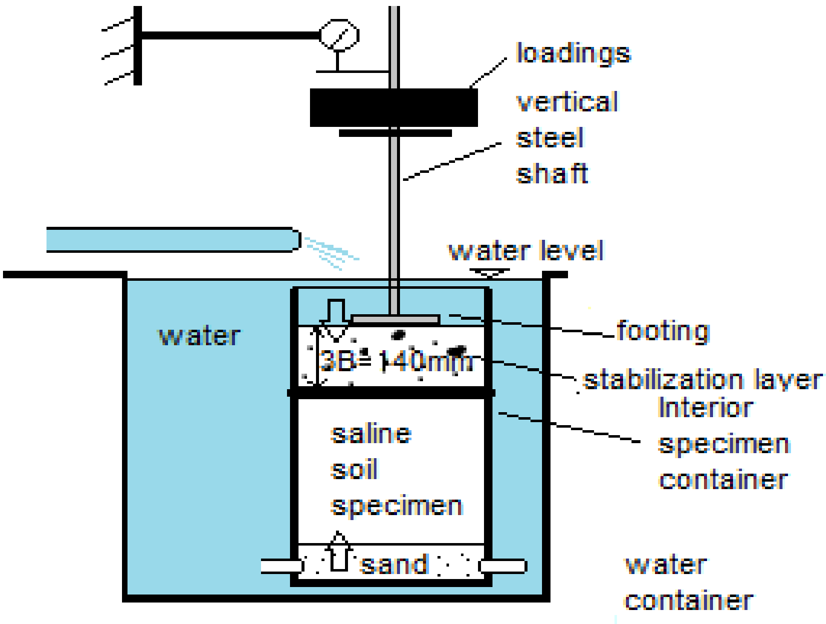

Fig (2): Laboratory model preparation, includes: equipment's, mechanism used for soaking saline soil specimen, and the sand stabilization layer zone.

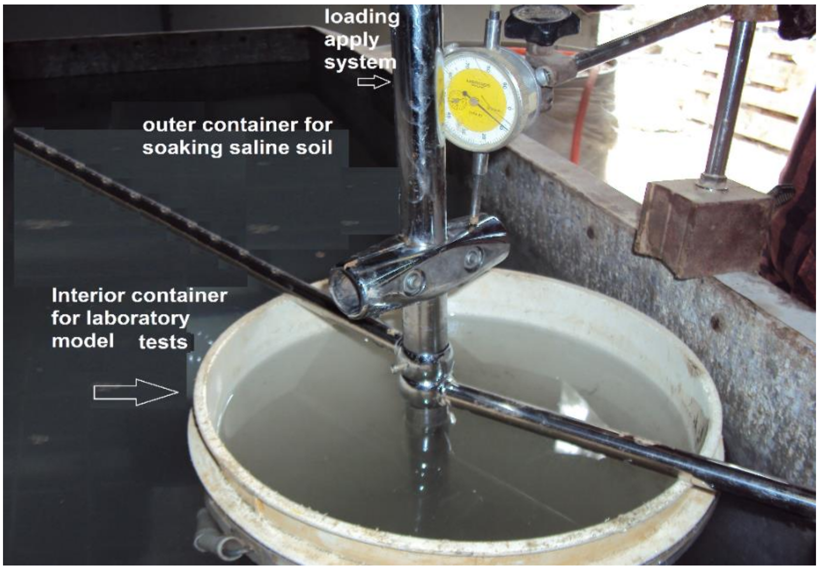

Fig. (3): Model preparation for soaking test for stabilized and unstabilized saline soil by different techniques.

Fig. (4): Some additives mixed with graded sand, as a stabilizing layer, Bentonite, Emulsified Asphalt, used in this study.

Fig (5): Preparation of sand stabilizing layer, mixed with fly ash and Polyester.

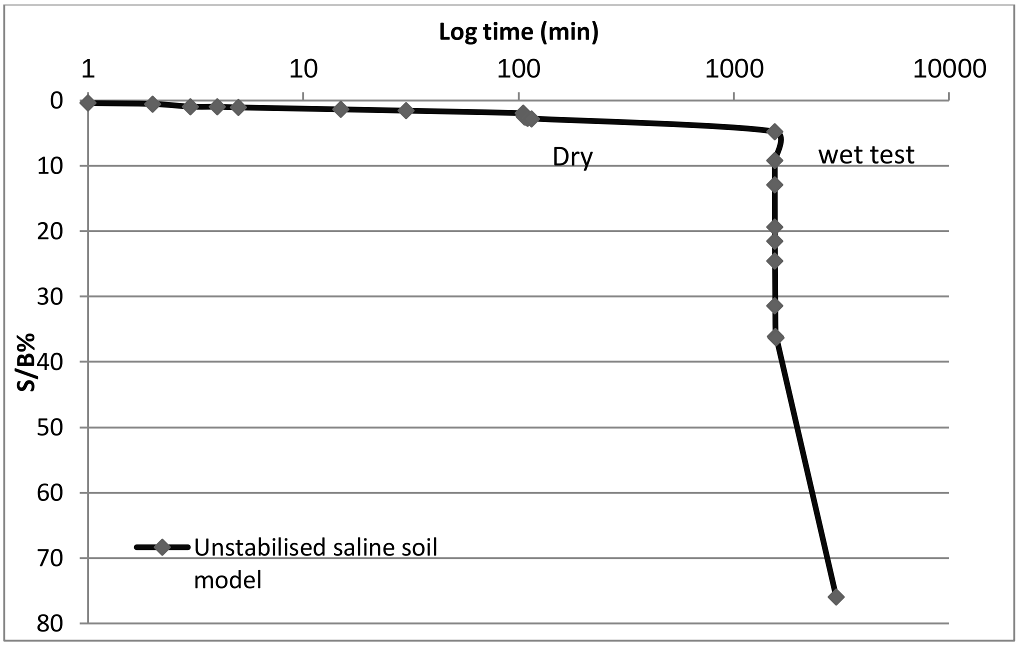

Fig (7): Results of unstabilized saline soil model for natural saline soil brought from Jurf al Milih Region in Diyala Governorate, with10% salinity. Tested at 36.6kN/m^2 applied stress.

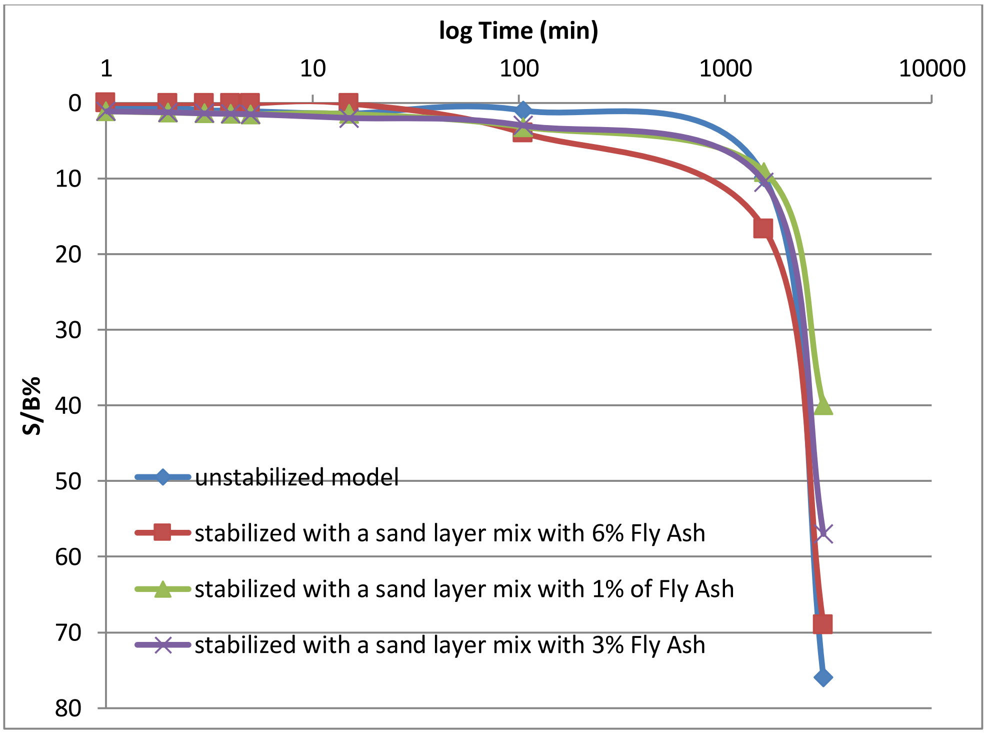

Fig (8): Effect of Fly Ash with Polyester, mix with graded sand layer as a method of saline soil stabilization.

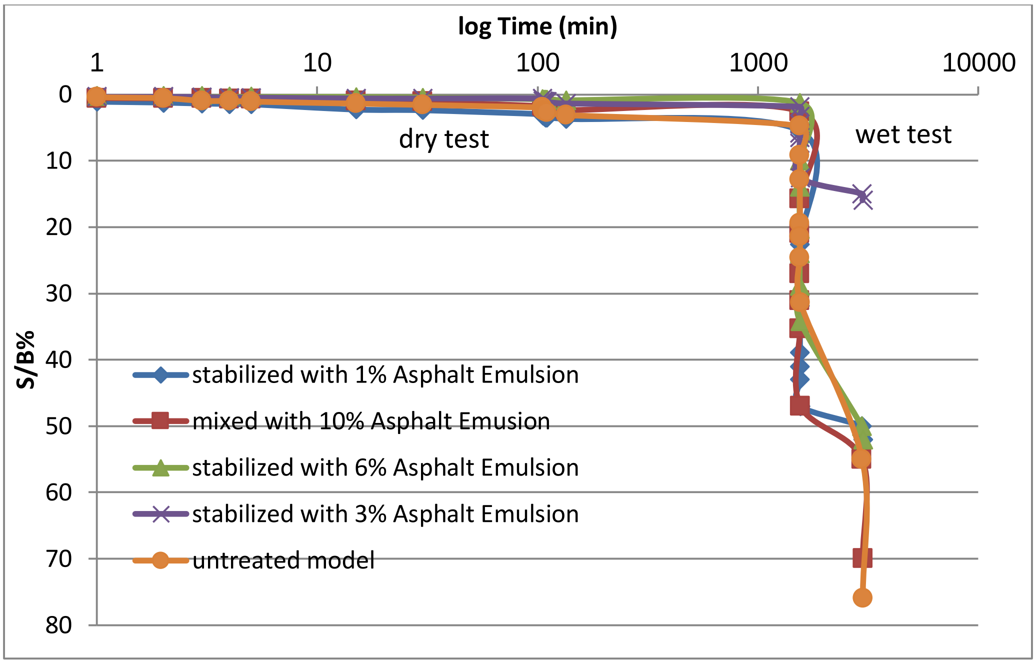

Fig (9): stabilization of saline soil by a layer of graded sand mixed with Asphalt Emulsion with different percentages (1%, 3%, 6% and 10%).

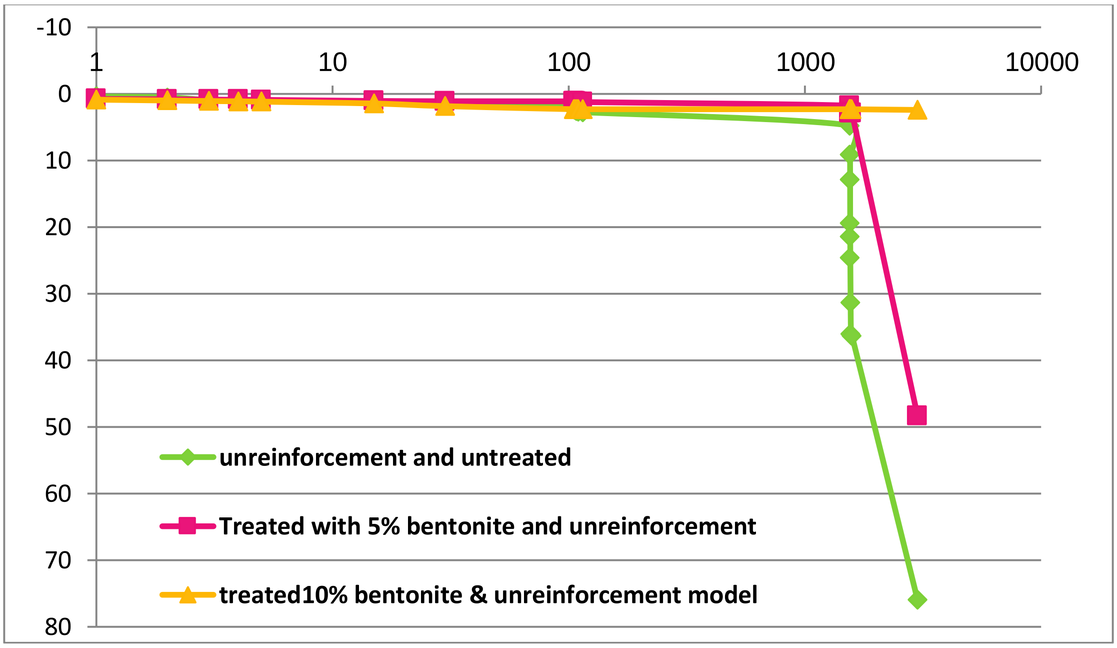

Fig (10): Results of treatment of saline soil by a layer of sand mixed with 5%and10% Bentonite.

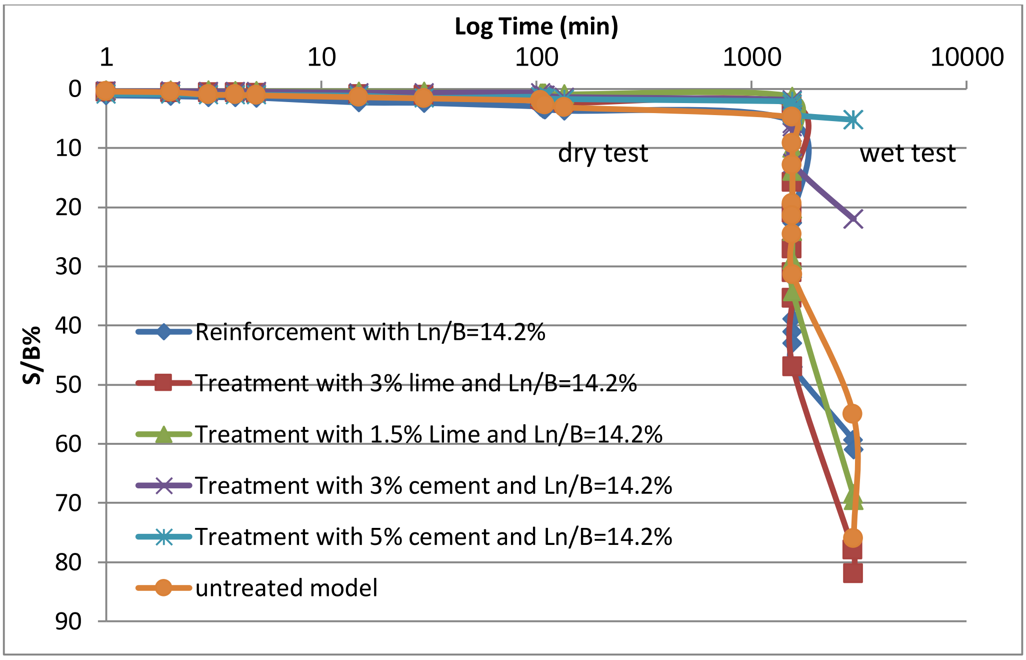

Fig (11): Stabilization of saline soil using layer of sand, mix with two additives (Cement, Lime), and 14.2% of waste ferrous materials.

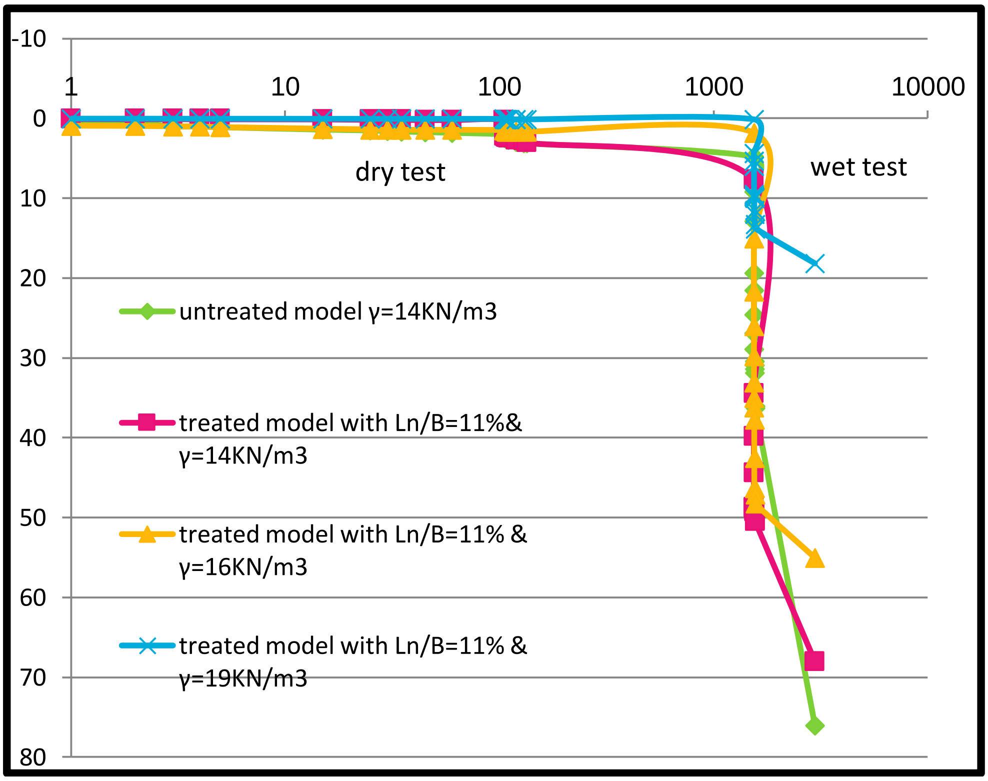

Fig (12) Stabilization of saline soil using a stabilized sand layer, by compaction and the use of 11% randomly distributed waste ferrous material.

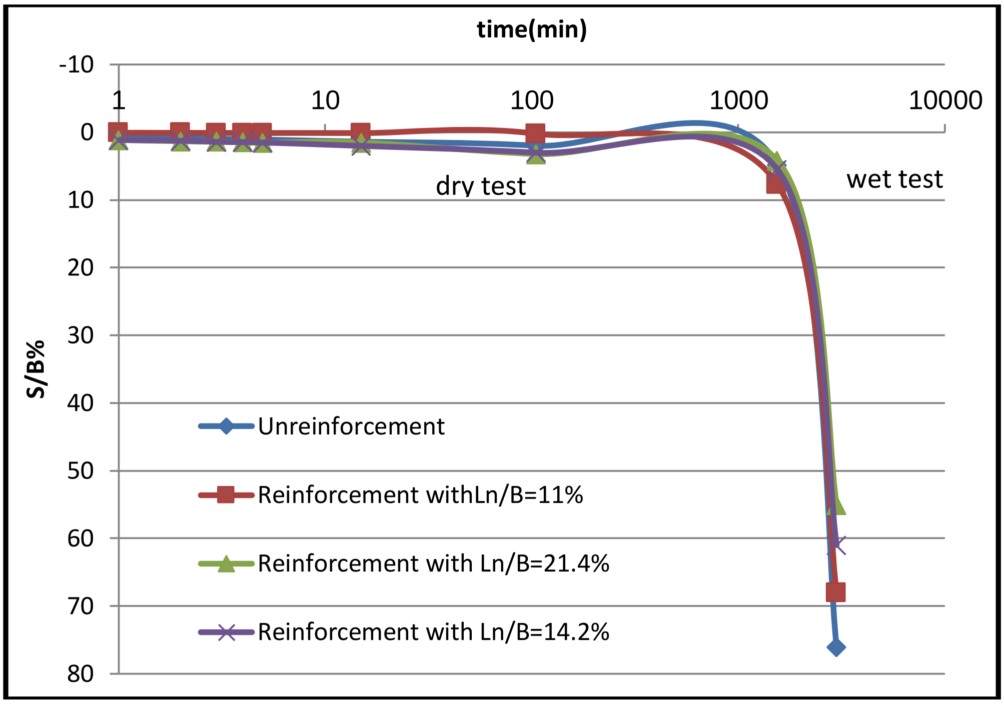

Fig (13): Stabilization of saline soil using a layer of sand with the addition of randomly distributed waste ferrous materials (11%, 14.2% and 21.4%)

تثبيت الترب الملحية بتقنيات تثبيت فعالة

الخلاصة:

تعد الترب الملحيه من انواع الترب المنتشره بمساحات واسعة من الاراضي العراقيه. حيث يسبب وجودها ظهور المشاكل الانشائيه للابنيه المقامه عليها بسبب طبيعتها الانهياريه حال ترطيبها بالماء من اي مصدر, بسبب الذوبان السريع للجزيئات الملحيه المحيطه بحبيبات التربه مما يؤدي لتفكك الاواصر وانهيار التربه.

تسلط هذه الدراسه الضوء حول امكانية تثبيت هذا النوع من الترب, وذلك باستخدام طبقه من الرمل المتدرج بسمك 145ملم المخلوط ببعض المضافات وهي مادة الرماد المتطاير بنسب خلط (1%, 3%, 6%) و مادة مستحلب السفلت بنسب خلط (1%, 3%, 6% و10%) و مادة النوره وبنسبتين مختلفتين(1.5% و 3%). ومادة البينتونايت بنسبتين (5% و10%) و مادة الاسمنت بنسبتين (2% و 5%) مع التسليح بالمخلفات الحديديه الموزعه عشوائياً. استخدمت في هذه الدراسه تربه ملحيه طبيعيه بنسبة 10% تم جلبها من منطقة قريبة لناحية جرف الملح في محافظة ديالى . تم اجراء عدد من الفحوصات على موديل مختبري يتكون من حاويه سميكه بارتفاع 400ملم و 300ملم قطر لوضع نموذج التربه.

اظهرت الدراسة ان احسن تقنية تثبيت, هي باستخدام طبقة من الرمل المتدرج بسمك 145ملم المخلوط بمادة البينتونايت الطبيعيه ,بنسبة 10%. حيث تم تقليل الانهياريه لنسبة 96%. وكان التثبيت باستخدام طبقه من الرمل المتدرج المخلوط بمادة الاسمنت بنسبة 5% مع 14.2% من المخلفات الحديديه الموزعه عشوائيا, جيداً. حيث قلل الانهياريه لنسبة 94%.

الكلمات المفتاحية: تثبيت التربة الملحيه, المضافات, مسحوق الرماد, مخلفات الحديد.