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EFFECT OF SOME CHEMICAL ADDITIVES ON THE BEHAVIOR OF SABKHA SOIL

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Abstract: The presence of salts in soil may cause severe problems to structures constructed on it, because of high dissolution of salt particles when subjected to water from any source. The primary objective for this study is to investigate the behavior of single footing over different percentages of sabkha soil (5%, 10%, 20%, and 40%). A laboratory model, manufactured locally was used for this study. The sabkha soil is prepared by mixing ordinary soil with specified quantities of sodium chloride salt to have different percentages of salinity. The footing used is 75mm diameter circular steel plate and 20mm thickness and hold fix stress, with the aid of loading frame which in turn is attached to a firm table. Dial gages is attached to the fix table and place on the footing, to record settlement with time. The study includes also the effect cement and lime addition with different percentages(1%, 3% and 5%), on the collapsibility of sabkha soil. Mixing sabkha soil with 5% of cement will reduce collapse potential (S/B%)* upon wetting, 97%. While mixing sabkha soil with 3% lime will reduce collapse settlement 47%, On the other hand, mixing sabkha soil with 1% cement slurry increase the collapsibility 3%. This study also, shines the light on the effect of compaction on the properties of sabkha soil. The collapse potential (S/B%)* reduced 50%, when increasing compaction of sabkha soil model from 17.7 to 19 kN/m3.

Keywords: *Sabkha Soil, Collapsible, Chemical Additives, Treatment, Improvement.*

تأثير بعض المضافات الكيميائيه على تصرف الترب السبخه

الخلاصه: ان احتواء التربه على الاملاح بجميع انواعها يؤدي الى حدوث اضرار كبيره للمنشات المقامه عليها نتيجة للذوبان السريع للاملاح لحظة ترطيبها بالماء من اي مصدر. تتطرق هذه الدراسه لتصرف اساس منفرد محمل مركزياً موضوع على تربه تحتوي على نسب مختلفه من املاح كلوريد الصوديوم و دراسة امكانية تحسين خواص هذه التربه الانهياريه باضافة مادتي السمنت او النوره .تم استخدام موديل مختبري تم تصنيعه محلياً ،كما وتم تحضير التربه بمزج التربه الاعتياديه مع نسب مختلفه من ملح كلوريد الصوديوم (٥%، ١٠%، ٢٠%، ٤٠%). تم استعمال اساس دائري بقطر ٧٥ملم مصنوع من الحديد بسمك ٢٠ملم. يتم التحكم بالضغط من خلال عمود تسليط الضغط الذي يثبت بصوره عموديه بواسطة طاوله حديديه ثابته ويثقل يدويا باثقال ثابته لتسليط اجهاد ثابت ٢٢ كيلو باسكال. تم تثبيت المقاييس النابضيه لقياس هبوط الاساس مع الزمن. تتضمن الدراسه تاثير اضافة مادة السمنت والنوره بنسب مختلفه على تقليل هبوط التربه الملحيه. حيث اضهرت الدراسه ان خلط ٥% من السمنت مع التربه الملحيه يقلل من مقدار الهبوط ٩٧% وهو تحسن كبير لهذا النوع من الترب الانهياريه. اضافةً لذلك فان خلط ٣% من النوره مع هذه الترب يقلل من مقدار الهبوط نتيجة الذوبان حوالي ٤٧%. من ناحيه اخرى فان الدمك يحسن من خواص هذه الترب عند الاغمار بالماء. حيث تم تقليل مقدار الهبوط ٥٠% عند زيادة الدمك من ١٧,٧ كيلو نيوتن/متر مكعب الى ١٩ كيلو نيوتن/متر مكعب.

1.Introduction

Sabkha soil is one of the many types of collapsible soil which behaves, after dry, as any c - ϕ soil. This behavior of such soil has been widely studied [1-7] .

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But once water finds out its way to soil skeleton the salts dissolved in to water leaving in between Particle-spaces . The action of over burden pressure and any applied surface Stress, if any , cause to settlement to occur in soil body underneath footing due to the resulting rearrangement of soil particles to fill in gaps are occupied By salts earlier [8,9]. The force going action goes for natural and in-laboratory soils, but in natural soil another factor exists to make the rate and magnitude of Settlement greater, that is, in natural soil the salinity works as a cementing material holding soil particles together, same as in gypsums soils in which gypsum acts as connectors to bind the soil particles. So water can cause collapse of structure (called collapse settlement) in addition to settlement stated earlier. The summation makes up the total settlement actually a summation of two types of settlements. In laboratory only the first type of settlement exists since the sabkha soil is prepared by mixing sabkha (salts) with pure soil, as mentioned in [10].

The design of a foundation is a trial and error procedure. A type of foundation and trial dimensions is selected. Analyses are then made as certain the adequacy of the proposed foundation. The foundation may be found be adequate, in which case a check may be made to determine whether a cheaper foundation might also be adequate. If the proposed foundation is found to be inadequate, a layer foundation is considered. In some cases it may be impossible to design an adequate shallow foundation upon a given soil, in which case either deep foundation or improvement soil must be considered (lamb, 1979). The selection of a trial foundation and trail dimensions is often guided by tables of allowable bearing stress.

In some cases, the engineer can avoid potential soil problems by choosing another site or by removing the undesirable soil and replacing it with desirable soil. In early days of highway construction this procedure was widely employed, e.g., highways were routed around swamps or soil with poor engineering properties. As time went on, the decision to avoid bad soil was made less frequently. With the growth of cities and industrial wears, the supply of silts with good foundation conditions became depleted. In some conditions civil engineer has been forced to construct at selected site in which problematic soil is presence.

A second approach to the problem of bad soil is to adapt the design for the conditions at hand. A Floating foundation or deep foundation can be designed to avoid many of the settlement and stability problems associated with soft foundation soils. A third approach is to improve the soil. This approach is becoming more feasible and more attractive .soil improvement is frequently termed soil stabilization.

Terzaghi (1943) was the first one who presents an approach for the bearing capacity of a single plane-strain footing resting on soil, which is based on the assumption that all the soil in a specified zone underneath foundation is to be changed from elastic behavior to totally plastic. At that stress the settlement of footing becomes very large and difficult to predict. The meaning of the terms very large settlement and hard to predict in valves judgment on the part of the engineer .Generally the bearing capacity is taken as the bearing stress causing local shear failure or the stress corresponding to the knee of the stress–settlement curve. The foregoing methodology represent a behavior of soil underneath footing, a soil with ideal engineering properties or a so-called a c- φ soil. Not all soil follow the Terzaghi approach for designing a foundation .As an example the collapsible soil ,which is one branch of problematic soil , does not follow is sense of settlement the ideal c-φ soil . Sabkha soil is a branch of collapsible soils that has the following property: when dray it behaves as an ordinary soil .But once water can reach the base soil it undergoes (foundation) a great and immediate settlement. Thus the usual Terzaghi approach design is suitable only when soil is dry.

The large settlement that occurs is not simply the change of soil property from elastic to plastic but is merely due to the dissolution of salts in to water. The salt particles occupy some space soil skeleton[13]. When water precludes through soil it leaves there spaces empty. And duo to the loading to soil coming from foundation or super structure, the soil will collapse .By collapse we mean a sudden and large settlement of footing.

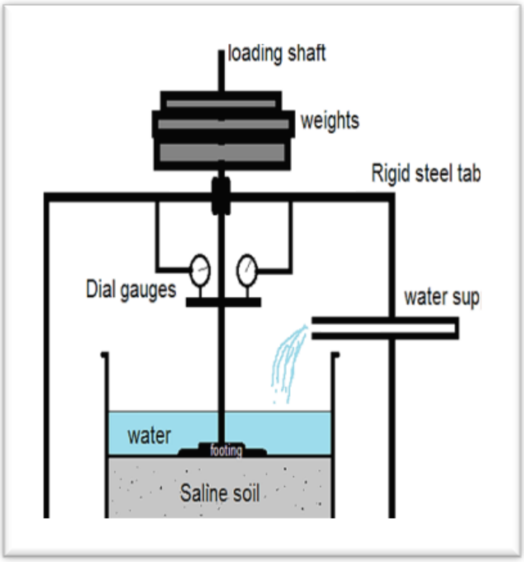
2.Scope of study

Engineering facilities and structures do not have such a property to with stand there changes in soil skeleton. Thus this collapse in soil structure is almost leads to large crackings in structure body and may eventually lead to structure failure. It is bad or almost a failure policy to build any structure over such soil without any countermeasure in sense of reinforcing the foundation or in the sense of improving the soil . The amount of settlement is directly related to the amount of salt present in to the soil. The amount of sabkha present in soil will determine however the potential danger that exists in soil contains salinity. The stabilization of sabkha soil is similar to other soils that begin simply with soil replacement technique to the advanced methods [14]. The main goal of this study is to investigate the behavior of such problematic soil, and show the feasibility of improving its properties with the addition of cement and lime materials.

3.Experimental work

3.1. Prototype Model Description

In this study it is intended to investigate the behavior of single footing resting onto sabkha soil containing different percentages of ordinary salt content. In doing so a small prototype model is used. It consists of a suitable loading frame (manufactured in college workshop) attached to fixed large steel table. The single footing is simulated with steel plate of dimension 75mm. The top surface of footing is enclosed by central four small steel bars welded to footing as to make sure that loading frame shaft is "somehow" hinged to footing, i.e., rotation and inclination of footing is permitted during testing. Another benefit of this is to prevent shaft from sliding away from the footing during loading. Several steel paddles are well fixed to loading frame by welding process. These paddles are used to placing loads and to attach the dial gauge in order to measure settlement of footing. The dial gauge holder is fixed to a large steel table. To prevent loading frame from side sway a steel plate holder is attached to the shaft of loading frame (penetrating it through a central hole). On the other hand, the footing is then placed on sabkha soil surface in a small container having width of 265mm and depth of 340mm. as shown in figures (1).



(a) (b)

Fig..(1): Laboratory model preparation and stress control, for 75mm diameter footing on sabkha soil bed with different salt percentages (5%, 10%, 20% and 40%),σ=22kPa.

3.2. Soil used and Density control

The soil used for sabkha soil preparation is classified as (SP). This soil is mixed with a specified weight of salt outside the container; they are mixed well together as to form a sabkha soil with a specific percent of salinity. Sabkha soil is then put in to container in terms of three layers; each layer is about 33mm thick. Each layer received light compaction. From the weight of sabkha soil used in container and it volume, i.e., the total unit weight of soil is known. Soil specimens were compacted to 17.7 kN/m^3; some specimens were compacted to 19 kN/m^3, to investigate the effect of compaction on settlement of sabkha soil. The grain size analysis and distribution curve of soil particles are shown in "Table (1)".

Table (1): Grain size analyses for the soil used in this study

Sieve No.	*sieve Diameter (mm)*	*Remaining weight (kg)*	*Accumulated weight (kg)*	*Accumulated Percent%*	*Percent passing %*
4	4.75	0.14	0.14	14	86
8	2.36	0.204	0.344	34.4	65.6
10	2	0.036	0.38	38	62
16	1.18	0.074	0.454	45.4	54.6
30	0.6	0.1	0.554	55.4	44.6
50	0.3	0.218	0.772	77.2	22.8
100	0.15	0.166	0.938	93.8	6.2
200	0.075	0.046	0.984	98.4	1.6
Pan	-	0.012	0.996	100	0

3.3 Testing

Methodology

After placing the sabkha soil in to container, the container is placed near the large steel table in which the loading frame and dial gauge is attached to it. The shaft of loading frame is now placed over the footing which is resting on the sabkha soil .Initial dial reading is recorded ,loads are applied in suitable sequences ,and settlement with time process is commend. The following steps shows the procedure and experimental work for this study.

1-Initially we have the case of "no load" on footing. An initial reading is recorded of the settlement dial gauge. The reading is the base or the origin for all subsequent readings.

2-The first stress level of 15 KN/m^2 was applied by placing 3.61kg weight over the footing and simultaneous reading of time and settlement are recorded in order to establish the time – settlement relationship for this particular sabkha soil.

3-After two hours the settlement is almost halted then a second load of 7.218kg is added to the previous load. The application of load is usually done with extreme care as not to have any impact on footing. Now total stress applied by footing on sabkha soil is 22KN/m^2. It is believed by another this stress may represent the normal rate of applied stress in case of domestic building .Recording time and settlement continues until settlement becomes very small or eventually stops

4-The process of soaking comes now by pouring water slowly and carefully around the footing until soil submerged in water with footing. Settlement records continue in the usual way but here it is very high compared to previous stages. The high settlement is attributed to the dissolving of salts in the sabkha soil .This dissolve of salts leaves cavities in soil structure. And since loading (or applied stress) is constant on soil settlement occurs through continues rearrangement of soil particles to fill the gaps of salts that is dissolving with time.

5-The test is considered ended if settlement records are very small with time.

4.Results and discussion

The laboratory sabkha soil experiences settlement due to dissolution of salts, which are mixed as powder with ordinary soil. Thus leading to settlement (when water particles soil) due to rearrangement of soil particles to close up the gaps which were already occupied by salt Grains. Never the less, in scientific approach so many researchers use the laboratory prepared soil. The aim is to concentrate one parameter as a variable and normalizes the other variables. It is impossible to study many variables in same time.

As a first trial a very loose soil state is chosen that is a unit weight of 10KN/m^3 and having a salinity content of 40%. This is actually very large amount of sabkha that can exist in natural soil. The test began as stated in earlier section. The data is presented as the collapse potential of sabkha soil (S/B%), versus time in logarithmic scale as shown in Fig. (2).

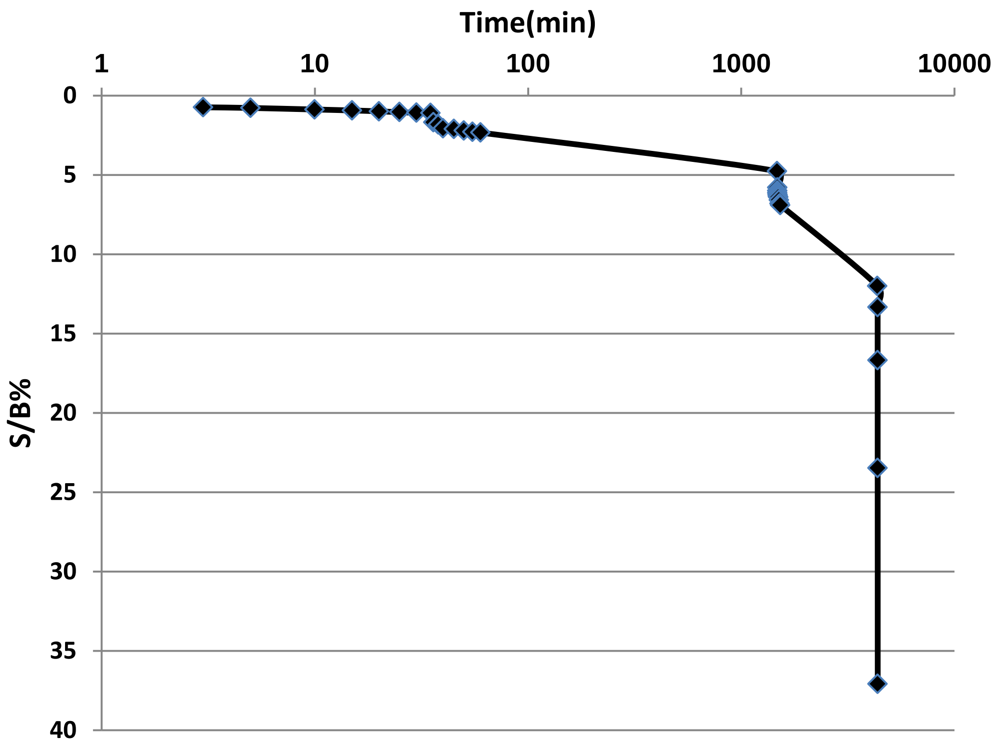


Figure (2): Time - S/B % for untreated sabkha soil model (γ =10KN/m^3, 40% salinity, σ=22KN/m^2)

Here (S) is the settlement measured and (B) is the width of footing in model used. This Normalization of settlement gives much comprehensive look at collapse settlement and it is much better than looking on pare numerical values. The test was stopped at time 4361minutes not because of negligible settlement recorded but because that loading frame came on of the holding ring that is fixed to the steel table, thus causing the total loading frame to fall down. Last settlement recorded is about S/B 0.38. From visual inspection of test the model footing "sunk" in to soil duo to large collapse settlement. In other words the settlement did not stop but loading frame went apart. From this test it is decided that the unit weight used in this model is very law and further compaction is needed in future models. It is worth to mention that the sequence of load application ,which is choose to be 22KN/m^2,is not done in one step at time but rather by two steps. The application of loading in prototype model is done very gently as not to impose any impact stress on foundation. Thus we have in this curve and in the following curves as well three downwards jumps; namely

1-The first jump is the initial jump and it relates to the initial application of load increment.

2-The second jump belongs to the application of second increment of loading, to sum up a total of 22KN/m^2

3-The third and final downward jump is the soaking period startup, which is followed by great and drastic settlement which sums up the total collapse settlement.

In Fig. (2) the total elastic settlement for total application of the 22 kPa surface loading is only a value of S/B =0.067. It is the seating and the elastic settlement. After the minute 1525 the soaking process begins. It starts with drastic draw down of footing up to a value of S/B=0.38 in which settlement did not stopped but loading frame shaft jumped out of the holding ring due to misalignment and very high settlement, which is not expected at the first time . The high value of settlement is attributed to the high salinity of soil (40 %) and the law unit weight of soil which received very little compaction energy. A value of S/B=0.38 is extremely high to any structure to handle.

Fig. (3) illustrate the result of second model in which that, the unit of sabkha soil is increased to17.7 KN/m^3 by simply increasing the compaction energy for soil to receive and the sabkha content in soil is reduced to only 10%. It can be observe that the total elastic settlement decreased from 6.7% to 1.56%. The final collapse settlement reached a value of S/B=0.3 (versus 0.38 in previous case). The value of S/B=0.3 is very high and hard to follow. To imagine such settlement consider a footing having a width of B=2m, there we may have a settlement of 600mm. This is beyond any foundation to resist or with stand. Also putting in mind that the applied stress is rather low (22 KN/m^2).

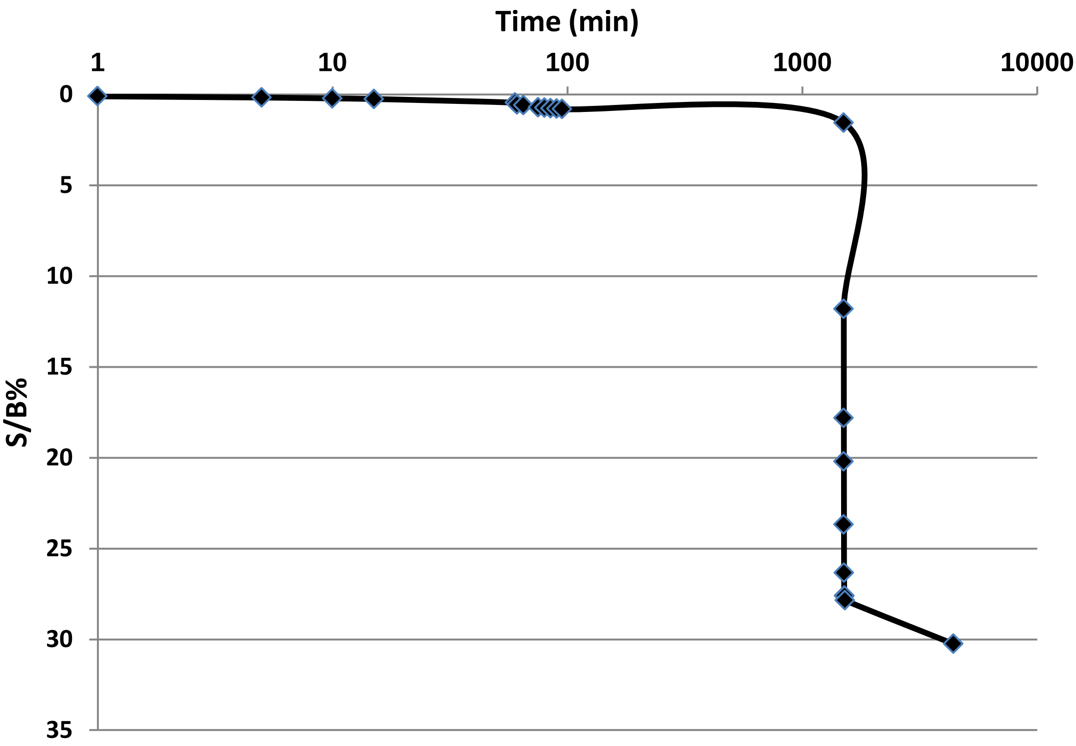
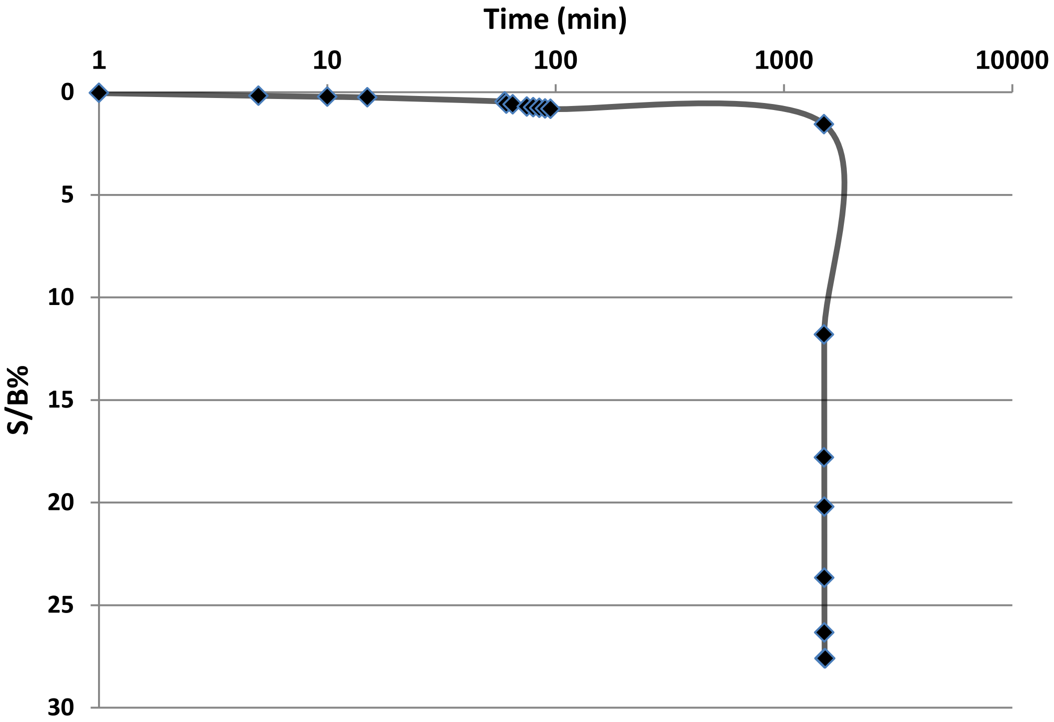


Figure (3): Time-S/B% for untreated sabkha soil model (γ =17.7KN/m^3, 10% salinity, σ=22KN/m^2)

4.1 Effect of compaction on sabkha soil

Now two tests are carried out in parallel to Lind out the effect of compaction in low salinity content soil which are shown in "Fig. (4)" and "Fig (5)". Here authors chosen two similar- condition models having each a salinity content of 5% but with different unit weight (one having a unit weight of 17.7KN/m^3 while the second having 19KN/m^3 .



Figure(4): Time-S/B for untreated sabkha soil model (γ = 17.7 KN/m^3,5 % salinity, σ=22KN/m^2)

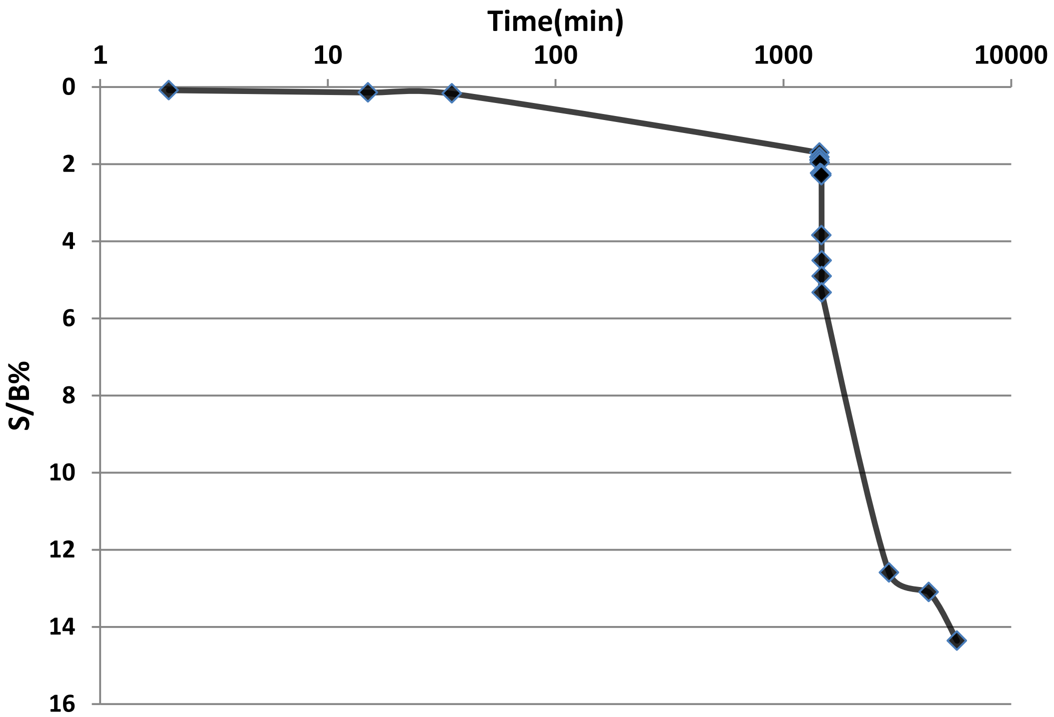


Figure (5): Time-S/B for compacted sabkha soil model (γ = 19kN/m^3, 5% salinity, σ=22KN/m^2)

From results obtained, there is great decrease in S/B values, namely, S/B%=0.28 versus S/B%=0.14, that is to be about 50% decrease as shown in Fig (7). This gives good indication that compaction can reduce the collapse settlement with great deal. In actual lift condition one should resort to simulate the in-situ density condition by a close-to reality prototype model and run full collapse tests simulating the actual loading condition and them after implying some sort of compaction effort or energy and seek how much improvement might get. The closer simulating the actual condition the more realistic data legates. Fig. (6) shows the effect of high salinity content on the collapse potential S/B% which reaches to 0.35%.

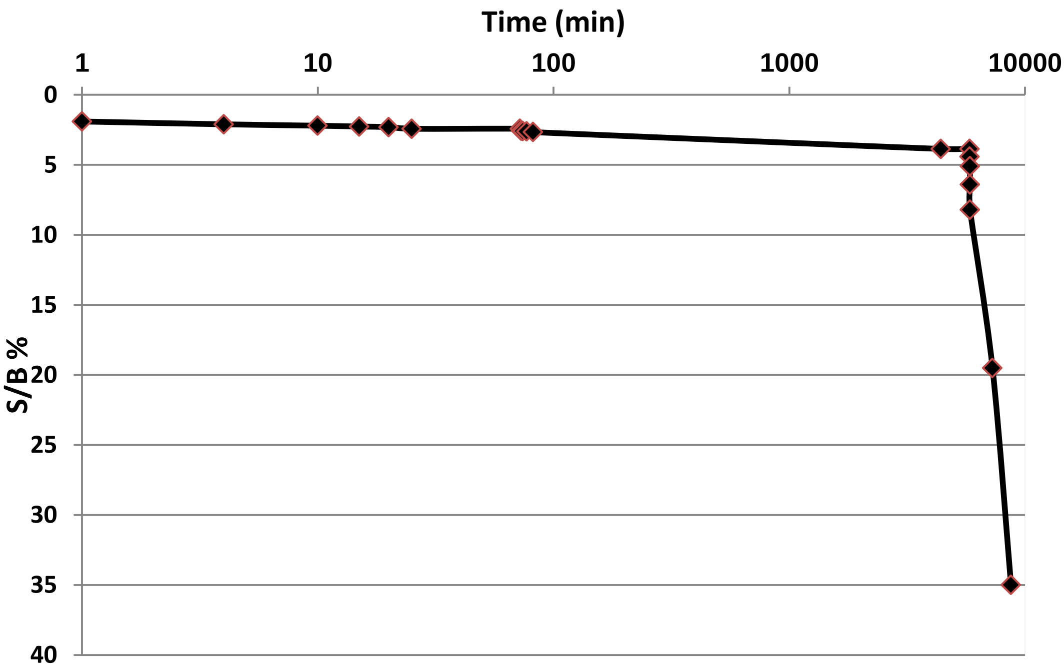


Figure (6): time-S/B for untreated sabkha soil model (γ= 17.7kn/m3, 20% salinity, σ=22KN/m^2)

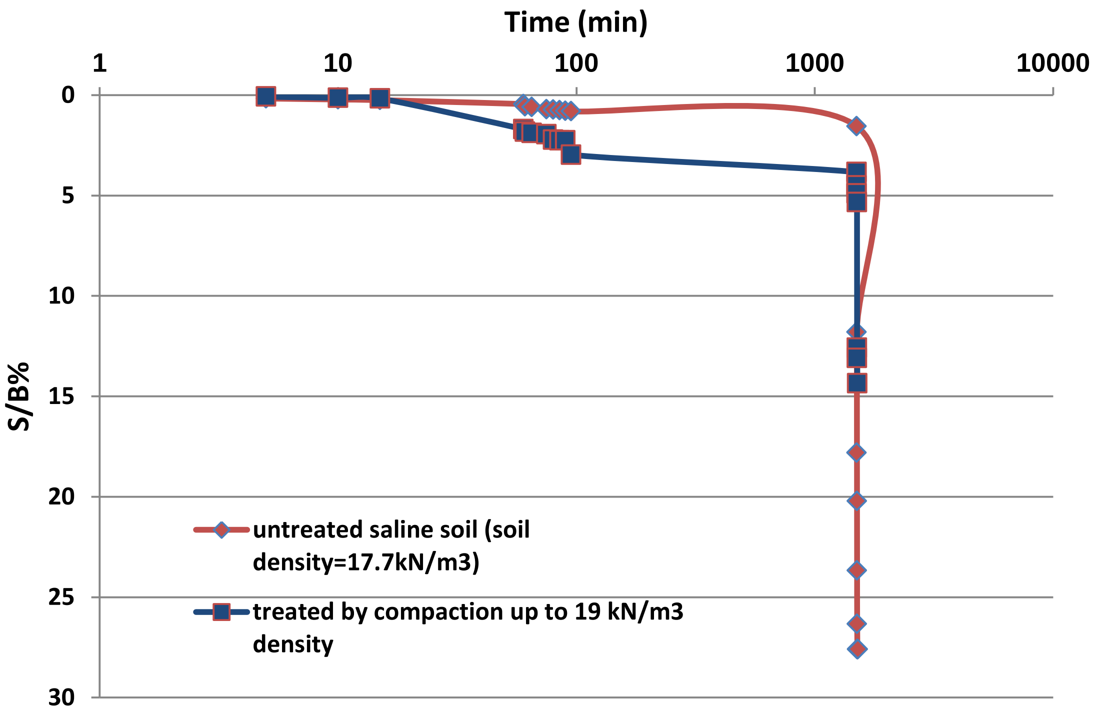


Figure (7) :Effect of compaction on sabkha soil using (17.7kN/m3 and 19 kN/m3) compaction.

4.2 Effect of additives on sabkha soil

After these tests which show the behavior and collapse potential for four salinity contents, authors have opinion to study behavior of such prototype models in case of application for some sort of improvement techniques. This is done for sleek of having, if successfully, a method to reduce the potential collapse problem of large (S/B) settlement

4.3 Effect of cement slurry addition

The first trial is by adding cement slurry to soil surface as liquid, hopping such slurry to penetrate to soil grain in deeper soil as much as possible. The viscosity of slurry must not by high, so it will not penetrate the soil. After several trial mix prepared, authors took advantage of being 1%cement concentration slurry is best. Using very low concentration slurry may not lead to successful results of improvement. Unfortunately, this method of improvement has a major drawback that its effectiveness depends heavily on soil permeability.

Thus if a civil engineer has a case of in-situ soil possessing law (rather in way) coefficient of permeability, then he should exclude this method out from his schedule of site improvement. Now in this test slurry of 1%cement concentration is prepared is laboratory.

After having a prototype model well done in properties of (5% water content) and soil density (17.7kN/$m^{3)}$ and salinity of 10%, cement slurry is added carefully in the model and left for 24 hours to have some setting . After words, the footing is placed with stresses as used. Full collapse test is conducted follow exactly same procedure as for the previous tests. "Fig (8)", shows the results of such test. In order to compare with similar sample condition but no treatment is applied, the curves for 10% salinity content is added to figure for referencing and to see how much improvement is obtained. Unfortunately, the loading frame shaft come out from the holding ring, same problem occurred in first model. Find reading recorded (not seen in figure) is about (S/B) find =30% which is almost some value for case of not adding cement sully. Thus, it is concluded that cement slurry test is insufficient in reading collapse potential of sabkha soil.

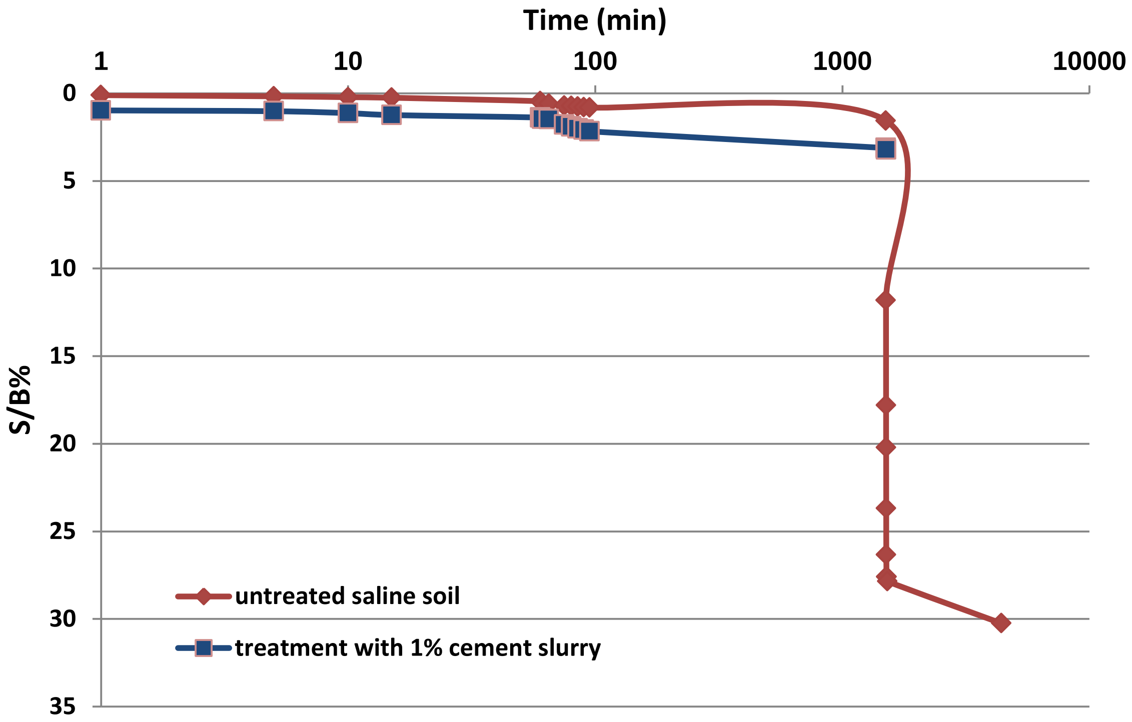


Figure (8): Behavior of sabkha soil by the addition of (1% cement slurry) Compared with the untreated one, keeping all conditions, same (10% salinity, γ =17.7kn/m^3, σ=22kn/m2).

4.4 Effect of adding cement powder to sabkha soil:

In Fig (9) the same test of Fig (10) , is repeated but with one difference and that is by increasing the cement content from 3% to 5%. The improvement obtained is very great and promising. Only on S/B ratio of about 1 is reported. This more than 96% of improvement, where:

(improvement %) after mixing soil with 5% cement= [(30-1) / 30]*100 = 96%

This test, of figure (10), opens a wide door of high spectrum to in gauge cementing material into sabkha soil treatment. Thus it can be concluded from the last two experiments that cement is quite effective in reducing the collapse potential of sabkha soil.

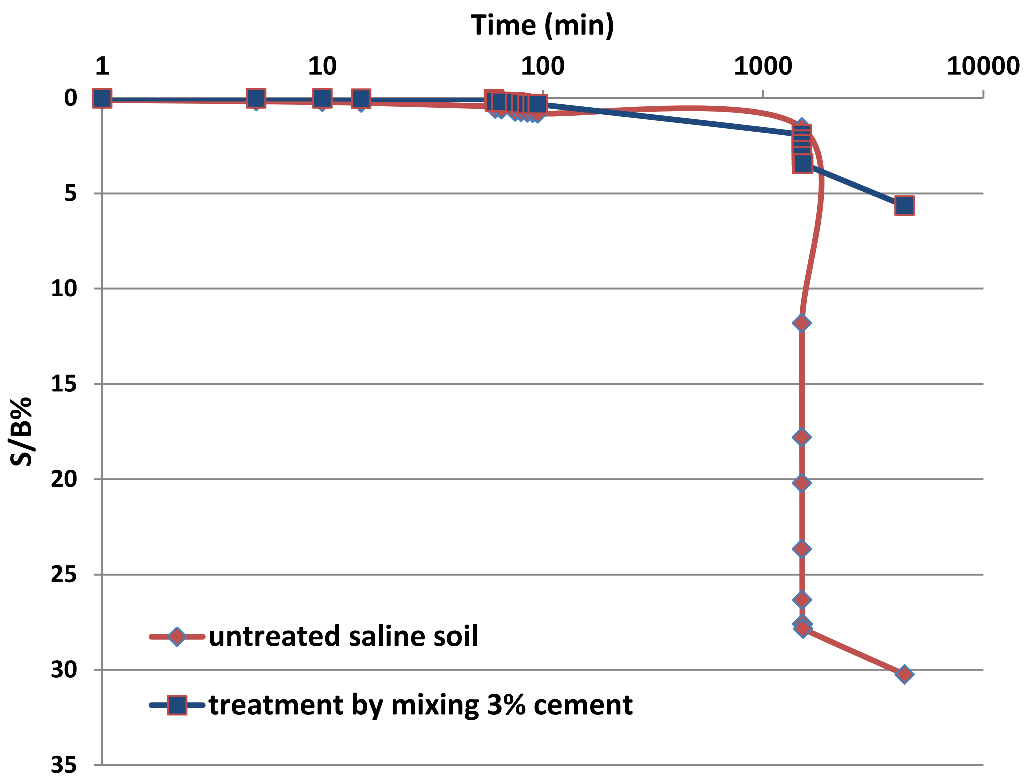


Figure (9): Behavior of sabkha soil after mixing with 3% cement dust, keeping all conditions, same (10% salt,γ=17.7 KN/m3,σ =22 KN/m2)

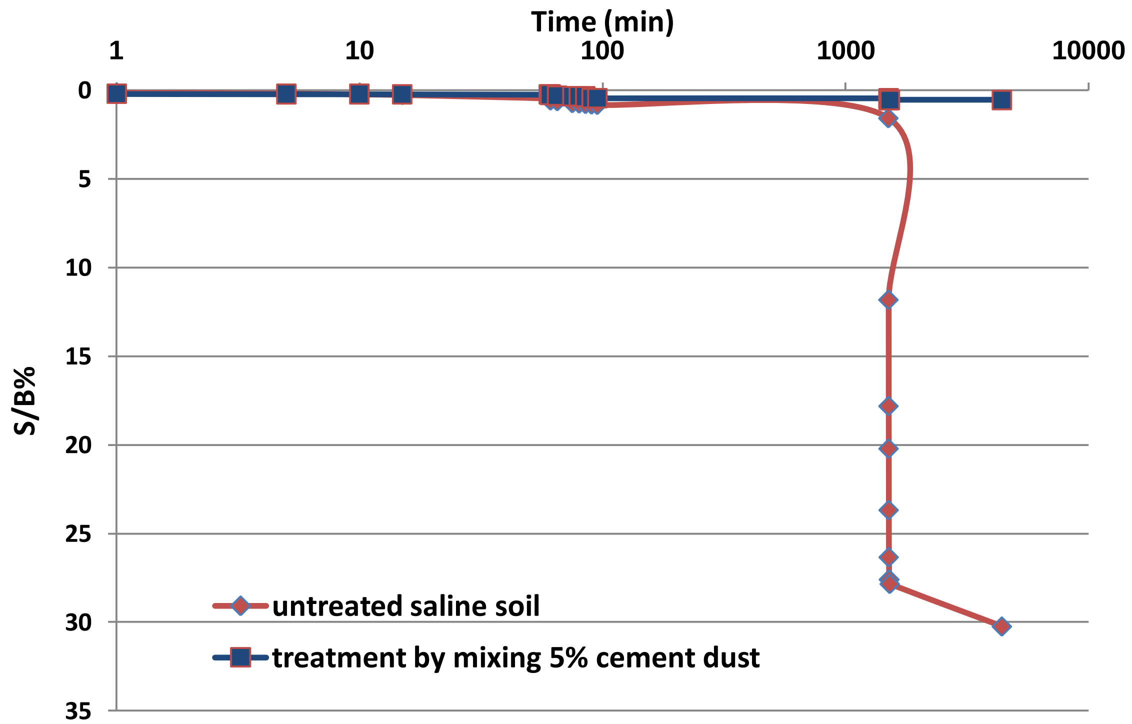
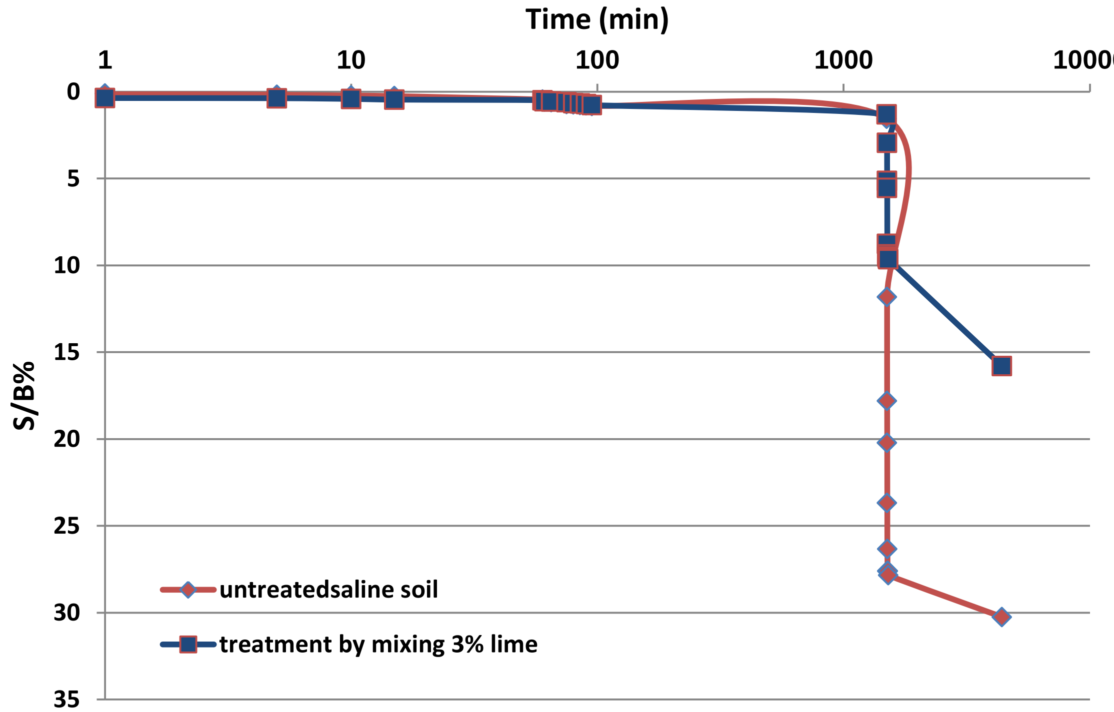


Figure (10): Behavior of sabkha soil after mixing with 5% cement dust, keeping all conditions, same (10% salt, γ=17.7 KN/m3, σ =22 KN/m2)

4.5 Effect of lime addition to sabkha soil

Fig (11) shows the effect of 3% lime addition to a 10% sabkha soil. The final (S/B) recorded is about 16% which is much less than the improvement obtained in case of 3% of cement. Thus the use of lime is not considered by authors a good technique to improve sabkha soil. Fig (12) , is the collection of all treatment methods to be in one figure as a reference.



Figure(11): Behavior of sabkha soil after mixing it with 3% lime, keeping all conditions the same (10% salt, γ =17.7 KN/m3,σ =22 KN/m2)

5.Conclusions

In this study it is desired to observe the behavior of a single footing resting on sabkha soil. For this research a container is used as a prototype model for simulation with diameter of(750) mm and length of(340)mm .The container is filled with sabkha soil and footing is applied at soil surface Also soil used is SP type thus no effect of cohesion or surcharge is considered In this study. Loading and settlement measurement is totally done through The use of suitable loading frame or which small steel plates are well welded As to apply loading steel disks and also to attach the settlement dial gauge on it. The dial gauge is fixed to a stable steel table by means of standard magnetic holder. Data of each test recorded, loads are applied in two steps (to simulate to small extend the actual condition) as to reach a stress of $22kN/m^2$. Water is added to cause collapse then after each test is considered reached to end when no further settlement is recorded or else very little settlement In element is measured. Data are represented in terms of curves having settlement in the ordinate in terms of (S/B %) and the time lapse in the X-axis drawn to logarithmic scale in a suitable way. Different percentages of sabkha content are used with four techniques of soil Improvements.

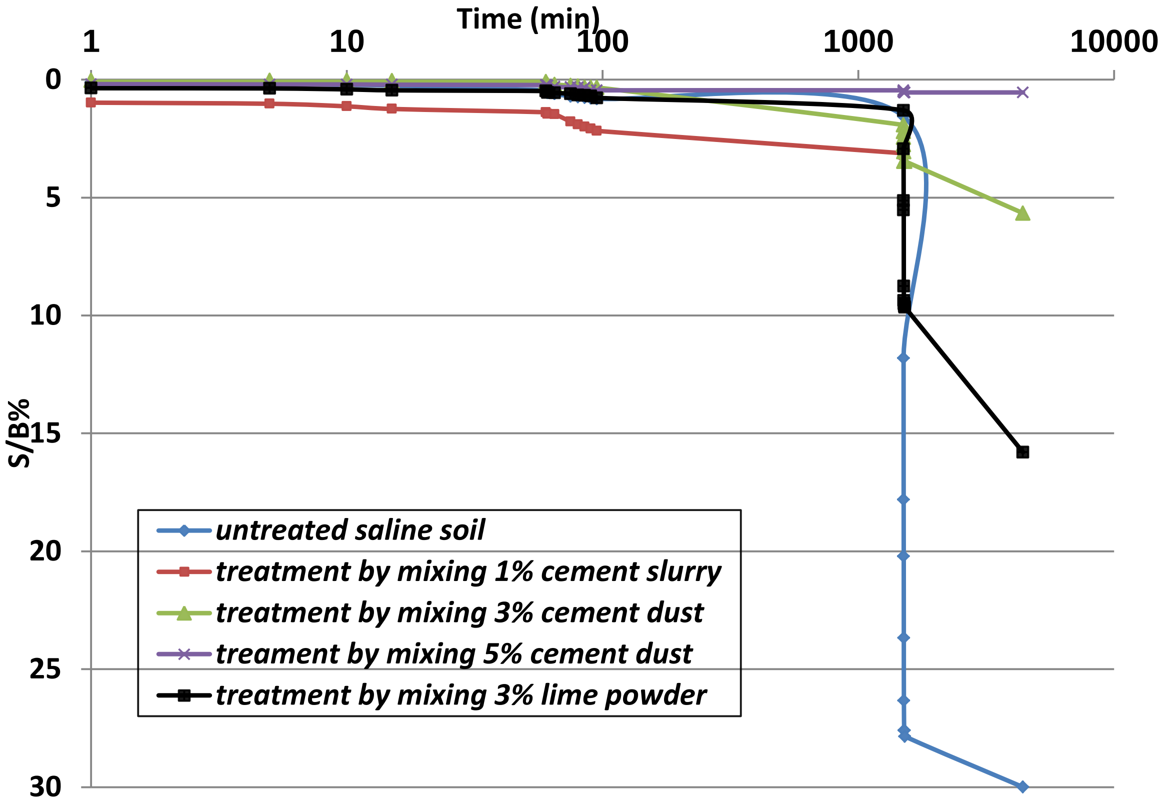


Figure (12): Behavior of sabkha soil after mixing with two different percentages of some chemical additives(Cement slurry, Cement dust and Lime powder), compared with untreated one as a reference , keeping all conditions the same (10% salt, γ=17.7 KN/m3,σ =22 KN/m2)

Authors conducted many tests and have successfully reached to the following Conclusion regarding behavior of sabkha soil with some improvement Techniques used:

1- Application of load when sabkha soil is dry experience very little settlement. It is known that all collapsible soils (such as gypsums, calcareous, Sabkha and the lime) experience very little settlement when dry but large Collapse settlement will occur when water finds its way to skeleton. These facts are well observed in this study.

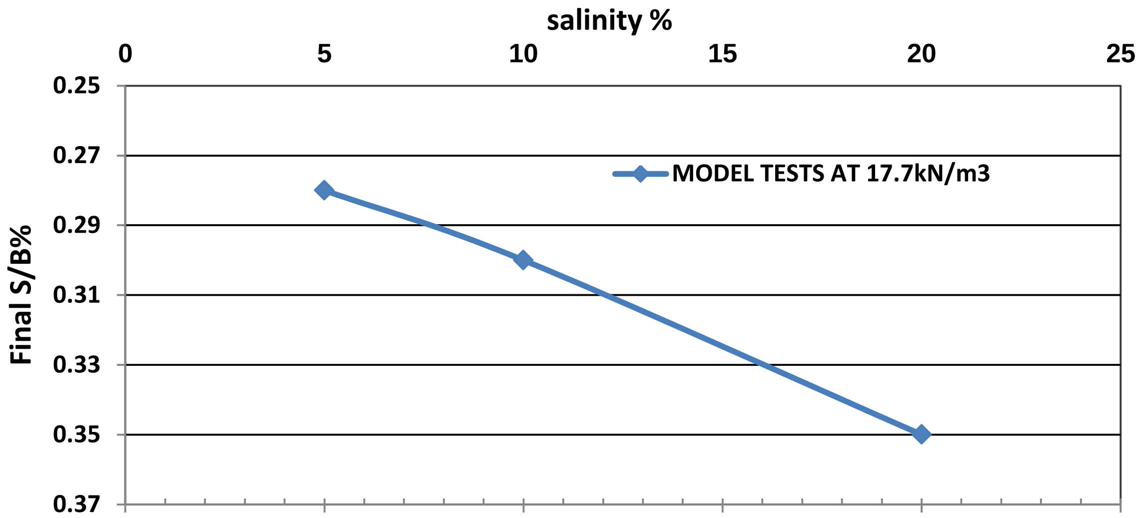
2- Through tests, it is observed that the collapse potential increases with increasing sabkha content. As an example a sabkha content of 10% leads to An (S/B %) value of about 30% which is quite a large value for any structure to with stand. The effect of soil salinity on the collapse potential (S/B)% are shown in "Fig (13)".

3- When density of sabkha soil is increased (from 17.7 to19 kN/m^3, 50% reduction in settlement is observed. A density of 10 kN/m^3 and salinity of 40% leads to about 40% in (S/B%). The improvement of saline soil by compaction are presented in a monograph in "Fig (14)".

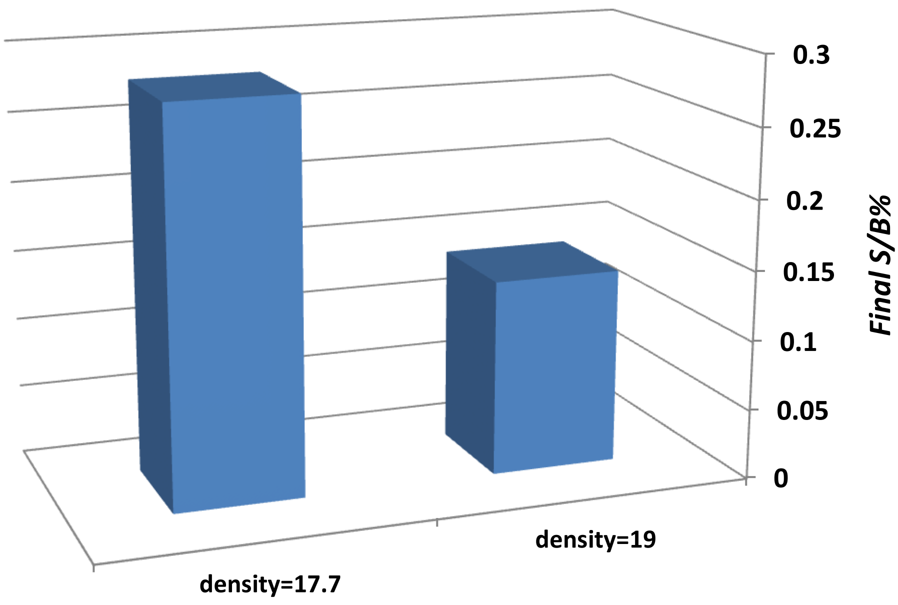
4-As a treatment to sabkha soil, pouring cement slurry to surface of sabkha soil leads to no improvement in settlement.

5-Use of lime with sabkha soil (mixed together) leads to about 50%reduction in collapsibility.

6- Mixing cement powder with sabkha soil has greatly reduced the settlement. A ratio of 3% cement content leads to 80% reduction in settlement while, , A 5% cement mixing ratio leads to 97% improvement In collapsibility which can be consider as the most effective improvement method for such collapsible soil.



Figure(13): Behavior of sabjkha soil at the end of soaking test for models tests with different salinity content (5%, 10% and 20%), all models were prepared at 17.7kN/m3 density and tested at the same conditions



Figure(14): The improvement gained by compaction sabkha soil from 17.7kN/m^3 to 19kN/m^{3}for two samples tested at the same loading conditions with 5% salinity, after wetting, obtained from this study. (S/B% is the collapse potential)

6.Recommendations

As about one year of studying with experiment of such a subject, authors recommend the following list of points:

1-The study can be extended to include many types of soils, calcareous, gypseous or any Type of collapsible soils. This may give good vision on behavior of locally collapsible soils.

2-Other treatments to improve sabkha soil may be put in to consideration. It is good to try to use methods that are cheap and are easy to perform and with no time-consuming problem.

3- Since cement as an additive is found a very good material to reduce Collapse potential, it is recommended deeply by author to extend the use of such material in order to find its total effect upon reducing settlement.

7.References

1-Ellis, g. i., “Arabian salt- bearing soil (sabkha) as an engineering material", TRRL Report LR 523, Grow Thorne, Berkshire, England, 1973.

2-Johnson, H. Kamal, M.R, Pierson, G.O. and Ramasy, J. B. “Sabkha of eastern Saudia Arabia” , Quaternary period in Saudi Arabia, spring-verlag, Berlin, 84-93, 1978.

3-AL-Amoudy, O. S. B. , EL-Naggar, Z. R. and Asi,I. M. , “The sabkha soil in the kingdom of Saudi Arabia and its engineering problems,“AL-Muhandis", vol.6, issue z, 56-62, 1992(in Arabic)”.

4-Mesri. G. and Godlewski, P.M, “Time-and Stress-Compressibility interrelationship,’’ Journal of. Geotechnical Ernginееring. Div., ASCE. Vol. 103. No.5, pp. 417-430, 1977.

5-Fox, P.J., Edil, T. B. and Lan, L., “Ca/Cc Concept applied to compression of Peat,’’ Geotech. Engrg. Journal Div., ASCE, Vol. 118, No. 5 , pp.1256-1263 1992 .

6-Mesri, G. and Castro, A., “Ca/Cc concept and K_0 during secondary compression,’’ Geotech. Engrg. Journal Div., ASCE, Vol. 113, GT. 3 ,pp.230-247 , 1987 .

7-AL-Amoudi, O.S.B. and Abduljawad, S.N. "Compressibility and collapse characteristics of arid sabkha sabkha soil". Eng. Geol.(1995) Vol.39:pp 185-202 .

8-AL-Amoudi, O.S.B.,”A state-of-the art report on the geotechnical problems in sabkha soils and methods of treatment. “Proceedings, ASCE First Regional conference and exhibition, Bahrain, pp53-77. september 1994.

9-AL-Amoudi, O. S. B. , “A Review of the geotechnical and construction Problems in sabkha environments and methods of treatment “The Arabian Journal for Science and Engineering, vol. 20, no.3, July 1995.

10-Fookes, P.G, French, W.J. and Rise, S. M, ”The influence of ground and Ground water geochemistry on construction in the middle east. “Quarterly Journal of Engineering Geology, vol. 18, pp101-128, 1985.

11-Lamb, T. W. and Whitman, R. V. 1964, Soil Mechanics, John Wiley and Sons. Inc. New York.

12-Terzaghi, K. (1943), Theoretical soil Mechanics, John Wiley & Sons, New York.

13-Abid-Awn S. H, Zakariya W. A. and Hassan O. A. " Improvement of gypseous soil by compaction and addition of cement", Journal of Eng. And Development, Vol. 16, No.2, June 2012 ISSN 1812-7822.

14-Al-Neami, M. M., 2010 "Improvement of Gypseous soil by Clinker additives", Engineering and Technology Journal, Vol.28, No.19 (المكتبه الافتراضيه).