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IMPROVEMENT OF GYPSEOUS SOIL BY PRE-WETTING

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ABSTRACT:- Gypseous soil is one of problematic soils facing civil engineer. The problem appears when constructing heavy buildings or hydraulic structures on these soils after wetted by water from rainfall or from the raising of water table level from any source.

On the other hand gypseous soil is considerably strong and has good properties when it is dry. The dissolution of gypsum depends on many factors: gypsum content, temperature, atmospheric pressure and others. Number of Remedies for these soils was carried out by many investigators, some of these methods are not workable, and the others are expansive.

A new method of improving the collapsibility of such soil was presented by Prewetting Gypseous soil with water many cycles using laboratory and field models with different footing stress, which reduces the collapsibility of this soil primary. A laboratory model of 320 mm diameter and 472 mm height made from thick plastic was used. Two soils with different gypsum content 50% and 70%, brought from Aldor and Balad, in Salah Al Deen government in Iraq, was used. A footing of circular base (50 mm diameter), applies 45 kN/m^2 and $100kN/m^2$ stresses with the aid of fix weights placed on it. The results of laboratory tests on the model samples shows a considerable reduction percent in the deformation ratio (Settlement/width of footing (S/B)) of 63% achieved from the 3rd wetting cycle by water for sample contain 50% gypsum. The reduction percent was 91% at the 3rd cycle of prewetting for sample containing 70% gypsum tested at stress level up to $45kN/m^2$, while it is 86% for the laboratory model with $100kN/m^2$ applied stress, with the same gypsum content. The results of field test for the soil containing70% gypsum tested at $100kN/m^2$ stress shows a pronounce improvement in the S/B value which gives a reduction percent reaches 90 %, which shows a considerable improvement in the collapsibility of this problematic soil.

Keywords:- Gypseous Soil, Soil Improvement.

INTRODUCTION

Gypsum is hydro calcium sulphate, it is one of soluble salts (with maximum solubility 2.6 gram/liter at 33-50 C temperature). The solubility of gypsum influence directly by temperature and the presence of other salts in soil. In most cases gypsum is associated with other salts like sodium or magnesium(1). The problem of collapse of gypseous soil is associated with the presence of water from any source like rainfall, breaking of pipes near footings or basements of buildings which causes breaking the bonds between soil particles and loosening of this soil, which in turn, lead to an excessive settlement and failure of structures(2). In order to get rid of this problem we have to prevent or reduce the dissolution of gypsum in the soil(3). Many trials and works to fined the proper remedy for such soils was studied during the last 3 decades, some of them were physical treatment like earth reinforcements, stone piles, cement addition etc…., the others are chemical like treatment by Lime, Oil products, Bentonite, Sodium Silicate or Emulsified Asphalt(4,5,6). Some of these treatment techniques are applicable, the other is not, because the treating material may be expensive or has low durability and may dispossess with time(7). The need was appear for more applicable, durable and fast method to improve the collapsibility of gypseous soil.

A new method was proposed in this study to improve the collapsibility of gypseous soil by primarily re-wetting with water many cycles until reaching to a negligible settlement that not affecting the efficiency of building constructed on it upon soaking. This method is applicable for light weight buildings and may be considered the faster and the most effective improvement technique.

EXPERIMENTAL WORK

Soil Used

Two types of soils (S-1 and S-2) were used in this study. The first one was brought from Al-Door area, 29-km northwest of Samarra City, Salah Al-Deen government. It is secondary, weakly cemented structure with gypsum content of 70%. The second soil was obtained from Balad region in Salah Al-Deen government with gypsum content 50%. Samples were taken from 1.25m depth. All the physical and chemical tests for the two soils are shown in Table (1).

LABORATORY MODEL

The experimental work consists of performing laboratory model tests, to investigate the feasibility of using Prewetting technique to improve the collapsibility of gypseous soil.

The testing program is shown in Fig. (1). A cylindrical laboratory model with 250mm diameter and 400mm height, made from thick plastic was used. A soil with 17.3kN/m3 density was controlled by dividing the gypseous soil to three layers, and compact each one individually. This process is more easy and accurate than placing the whole layer. A 50mm diameter circular footing made from iron steel was placed at the center of cylindrical model which applies (45 kN/m2 and 100kN/m2) stresses as shown in Fig.(2).

For all stages of test on the model samples the stress of footing was controlled by the mean of vertical shaft placed through the hollow circular weights and braced at the upper side with steel loading frame, manufactured specially for this test to prevent tilting or movement of footing of fix weight along the test stages, since there is no standard model or instrument for testing laboratory model footing resting on collapsible soil with high gypsum content. Three dialgauges were fitted at its position (on three corners of circular footing and taking the mean value of settlement with time) as shown in Fig. (3). The dial reading was recorded after applying footing stress. This presents the immediate settlement of footing at the dry state, after the reading fixed, the addition of water from the top of sample started gradually until full soaking of sample was completed with keeping stress level constant all over the test cycles, at the same time the dial gauge reading is continuously taken with time from the first soaking period, which takes about two days, after this the dial reading is fixed. The second step consist of drying the soil specimen four days in the oven with maximum temperature of 50C, to prevent any loose of water of hydration of gypsum. This test presents the first cycle of Pre-wetting. The water content is taken and the second cycle of test started again with the same steps as in the first one. These cycles of wetting and drying of gypseous soil sample was continued until reaching to a condition in which no more or nail settlement will occurs with the addition of water to the gypseous soil subjected to stresses.

FIELD MODEL

A 2500mm*3000mm steel frame was designed and constructed in a manner that works as a rigid stand holding 2 tones concrete cubes at each corner in which no additional movement that occur during loading application as shown in Fig. (4), The loading system consist of 5 tones capacity hydraulic jack, placed between the steel frame and a 450mm diameter reinforce concrete footing which cast-insitue. All stages of field instrument preparation, loading frame are shown in Fig. (5). After placing the concrete footing and fixing all measuring device, the mechanism of the dial gauges was checked. The efficiency of the hydraulic jack was checked before caring any field test. The jack was placed between the footing and the fixed proving ring carefully and the initial reading of settlement and stress were recorded as shown in Fig. (6).

FIELD TESTING METHODOLOGY

The concrete footing was subjected to stresses level up to 100 kPa which applied gradually, by moving the hand road of the hydraulic jack. The dial gauge readings were recorded with time. After 60 minutes from the beginning of load application, the dial reading is recorded, which represent the immediate settlement of footing, as in the dry test for laboratory model.

Two galvanized steel water tanks (1200*1200*1000 mm) were placed close to the field models. These tanks were fed with water twice a day by tanker. The quantity of water required for soaking test was controlled by two valves which fixed at the lower part of the tank. Each valve was connected to 12 mm diameter perforated rubber tubes. The water traveled through the rubber tubes and then through the openings made on its surface to ensure continuous feeding of water under the footing during soaking stage, as shown in Fig. (6).

The soaking pressure was controlled using the hydraulic jack, to ensure that, the stress reaches up to 100kPa. The stress is observed for mean and while and fix at this level.

Dial gauges reading were taken with time. The measurement of the settlement was accompanied with the stress observation during the collapse stage.

After soaking test, the valves of water tanks were closed and leaving the soil under the footing for drying 30 days at an air temperature (40-45^{o}C), the water content is measured.

This presents the first cycle of prewetting technique. After this step the stress increment controlled to the same stress 100kN/m^2, and follows the second cycle with the same steps as in the previous one and follows with the third cycle. The same as in the laboratory model steps.

RESULTS AND DISCUSSION

Effect of Repetitive Pre-wetting Cycles

For all cases of the existence of gypseous soil we can immediately recognize the problem of collapse especially at the first minutes of soaking, actually we can not essentially get rid of this serious problem essentially. The need was appear to reduce this collapsibility, using most applicable method of Pre-wetting of gypseous soil layer many cycles by water, until reaching reasonable settlement which is not affecting structures built on such soils. The results of laboratory and field model tests on soils with different gypsum content (70%) and (50%) shows that there is a great improvement in the collapsibility gained after pre-wetting samples more than one cycle. The deformation ratio S/B% relation with soaking time is chosen to give good comparison with other studies and with field model treated with this technique.

It is well established from laboratory model tests, that the most effective cycle of rewetting is (the third prewetting cycle), which gives a reduction percent in S/B% value of (91%)and(86%) upon soaking of gypseous soil model Prewetted by water for soil with (70%gypsum content) tested at soaking stress 45kN/m^2 and 100kN/m^2 respectively, as shown in Fig. (7) and Fig. (8). while the reduction percent in the S/B% value for field model tested at the stress level 100kN/m^2 with the same other conditions was (80%)and(90%) at the second and third prewetting cycles respectively as shown in Fig. (9) and Fig. (10). On the other hand the reduction percent is (63%) for the laboratory model soil with (50% gypsum content), tested at 45 kN/m^2 applied stress at the third cycle of prewetting.

Table (2) summarize the results of all field and laboratory tests on the model samples contain gypseous soils with (50%) and (70%) gypsum content at two different stress conditions 45kN/m2 and 100kN/m2, and the improvement which are presented by the reduction percent in the S/B% value which achieved after rewetting gypseous soils many cycles. So this method of improvement is more effective for soil tested at low stress level (less than 100kN/m^2).

CONCLUSIONS

The points drawn from the laboratory and field model tests revealed that the improvement of gypseous soil was achieved by pre-wetting this soil with water.

1. The results of laboratory tests on the model samples shows a considerable reduction percent in the deformation ratio (Settlement/width of footing (S/B)) of 63% achieved from the 3rd wetting cycle by water for sample contain 50% gypsum. The reduction percent was 91% at the 3rd cycle of pre-wetting for sample containing 70% gypsum tested at stress level up to 45 kN/m^2.
2. The results of field test for the soil containing70% gypsum tested at 100 kN/m^2 stress shows a pronounce improvement in the S/B value which gives a reduction percent in the deformation ratio S/B%, reaches 90 %, which shows a considerable improvement in the collapsibility of this problematic soil.
3. The Pre-wetting technique is preferable for light weight buildings and not workable for heavy or hydraulic structures, because of high collapsibility during high levels of loading or leaching process.
4. The improvement achieved by accelerating collapsibility before building structure, (prewetting technique) was more pronounce for the model sample with 70% gypsum rather than that with 50% gypsum, because of high desolation of gypsum which can be pronounce from the first cycle, and high collapse settlement of gypsum achieved at that stage. And so on with other cycles compare with the other soil with 50% gypsum content.

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Table (1): Average Results of the chemical and physical tests for used soils.

<table>
<tr><td colspan="8">Chemical Composition</td></tr>
<tr><td>Test</td><td>Test No.</td><td colspan="4">S-1soil</td><td colspan="2">S-2soil</td></tr>
<tr><td>Gypsum content%
BaCl2 method
Acetone precipitation method
Dehydration method at 105°C</td><td>

3
3
3</td><td colspan="4">
76.43*
59.31 Average
73.01~ 70%</td><td colspan="2">

Average
~ 47%</td></tr>
<tr><td>Total sulphate content SO3</td><td>6*</td><td colspan="4">35.6</td><td colspan="2">21.86</td></tr>
<tr><td>CaO content% using EDTA</td><td>6*</td><td colspan="4">25.8</td><td colspan="2">16</td></tr>
<tr><td>Total Dissolved Salts TDS%</td><td>5*</td><td colspan="4">79.43</td><td colspan="2">48</td></tr>
<tr><td>Water Of Crystallization W.O.C</td><td>5*</td><td colspan="4">16.67</td><td colspan="2">11.26</td></tr>
<tr><td>PH value</td><td>٥*</td><td colspan="4">7.4</td><td colspan="2">8.6</td></tr>
<tr><td>X-Ray diffraction</td><td>5*</td><td colspan="4">Gypsum, Quartz, Palygoskite, Feldspar</td><td colspan="2">Gypsum
Calcite
quartz</td></tr>
<tr><td colspan="8">Physical Properties</td></tr>
<tr><td>Test</td><td></td><td colspan="4">S-1soil</td><td colspan="2">S-2soil</td></tr>
<tr><td>Moisture content%</td><td>3</td><td colspan="4">2.6</td><td colspan="2">1.8</td></tr>
<tr><td>Specific gravity</td><td>5*</td><td colspan="4">2.43</td><td colspan="2">2.509</td></tr>
<tr><td>Grain size distribution HCl treated specimen</td><td>5*</td><td colspan="4">Classified as ML</td><td colspan="2">ML</td></tr>
<tr><td>Atterberg limits
Liquid Limit LL%
Plastic Limit PL%
Plasticity Index PI</td><td>
3
3
3</td><td colspan="4">
31
25
6</td><td colspan="2">
32
26
6</td></tr>
<tr><td>Linear Shrinkage LS%</td><td>2</td><td colspan="4">1.21</td><td colspan="2">5</td></tr>
<tr><td>Field unit weight kN/m3</td><td>3</td><td colspan="4">14.6</td><td colspan="2">16.8</td></tr>
<tr><td>Initial void ratio</td><td>3</td><td colspan="4">0.931</td><td colspan="2">0.79</td></tr>
<tr><td rowspan="3">Compaction
By Standard and
Modified proctor test
kN/m³</td><td rowspan="3">3</td><td colspan="2">Standard proctor</td><td colspan="2">Modified proctor</td><td colspan="2">Standard proctor</td></tr>
<tr><td>γ_{max}</td><td>W%</td><td>γ_{max}</td><td>W%</td><td>γ_{max}</td><td>W%</td></tr>
<tr><td>17.4</td><td>12.6</td><td>16.8</td><td>11.9</td><td>18.9</td><td>9</td></tr>
<tr><td>The used soil density kN/m3</td><td>3</td><td colspan="4">17.3</td><td colspan="2">17.3</td></tr>
<tr><td>Minimum void ratio</td><td>3</td><td colspan="4">0.42</td><td colspan="2">0.21</td></tr>
<tr><td>Minimum dry unit weight kN/m3</td><td>3</td><td colspan="4">11.52</td><td colspan="2">11.31</td></tr>
<tr><td colspan="8">* Tested by State Establishment of Geological Survey and Mining.</td></tr>
</table>

Table (2): The reduction percent in the S/B% for laboratory and field models improved by prewetting.

Type of soil	Gypsum content	Location	Stress Level kPa	Number of pre-wetting cycle	S/B at the end of cycle %	R.P%
S-1	70%	Laboratory	45	1	4.7%	-
				2	0.37%	92%
				3	0.43%	91%
S-2	50%	Laboratory	45	1	1.17%	-
				2	0.48%	59%
				3	0.43%	63%
S-1	70%	Laboratory	100	1	37%	-
				2	30%	19%
				3	5%	86%
S-1	70%	Field	100	1	5.8%	-
				2	1.18%	80%
				3	0.6%	90%

*R.P (Reduction Percent in S/B% value)=100-(S/B after n of prewetting cycles/S/B after the first wetting cycle)*100.

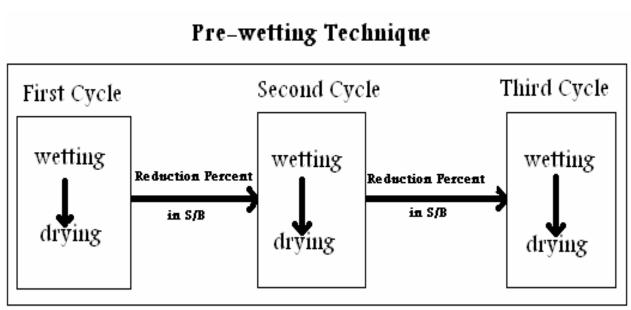

Fig. (1): Testing program for laboratory and field models using the new prewetting technique.

Fig. (2): Cylindrical model, loading frame, water control system and water tank for soaking test

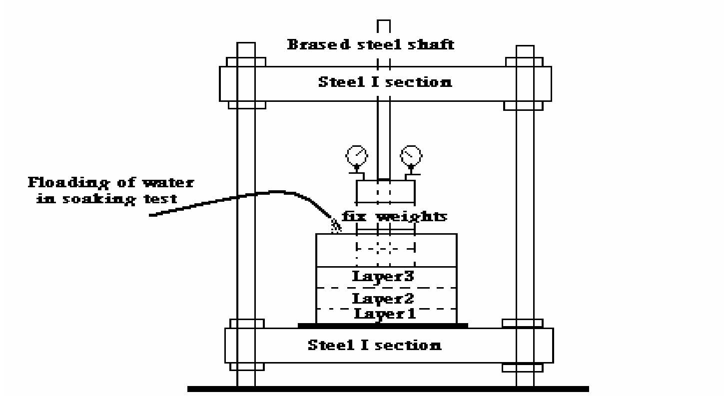

Fig. (3): Loading frame preparation, fix weights fitted at the center of model by a braced steel shaft.

Fig. (4): A 2500mm*3000mm steel loading frame fitted by 2.5 tons concrete cubes at each corner for field model.

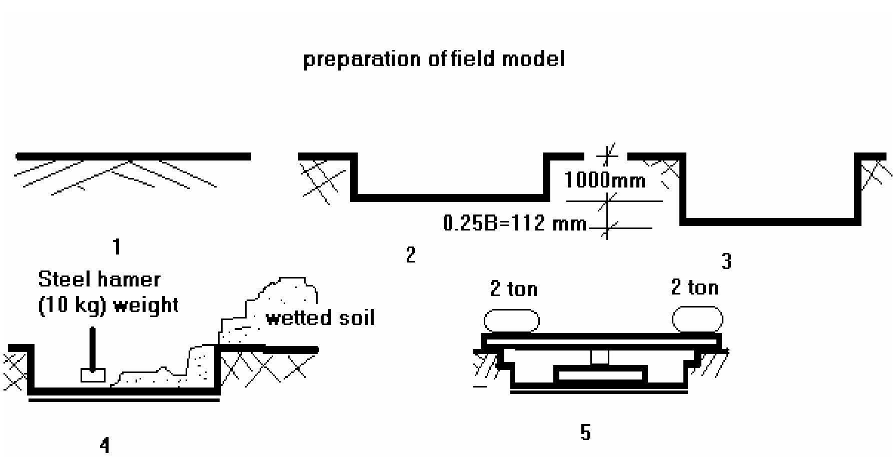

Fig. (5): field model, soil preparation and loading frame.

Fig. (6): Loading system presented by 5 tones capacity hydraulic jack, Proving ring, circular concrete footing and the soaking control for field test.

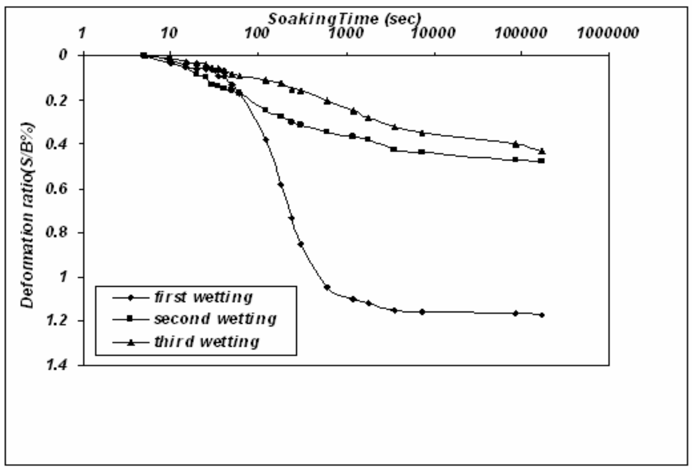

Fig. (7): Soaking time, Deformation ratio (S/B) relation for S-2 soil pre-wetted 3 cycles by water (laboratory model, gypsum content=50%, footing stress=45kPa, soil density=17.3kN/m^3.

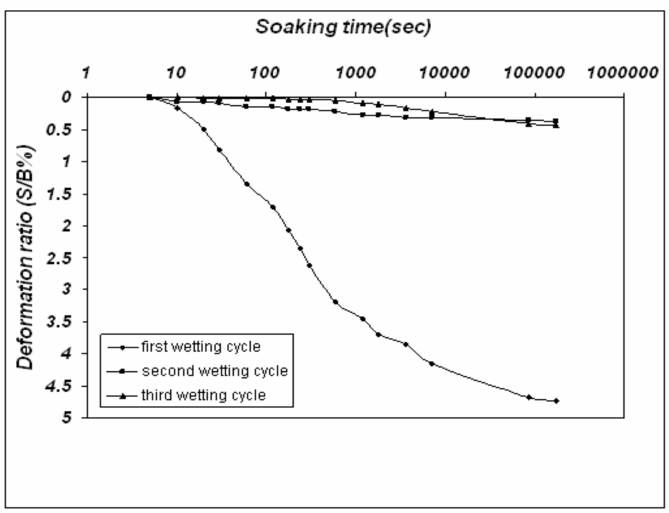

Fig. (8): Soaking time, deformation ratio (S/B) relation for S-1 soil pre-wetted three cycles by water (laboratory model, footing stress=45kPa, soil density=17.3 kN/m^3, 70% gypsum content).

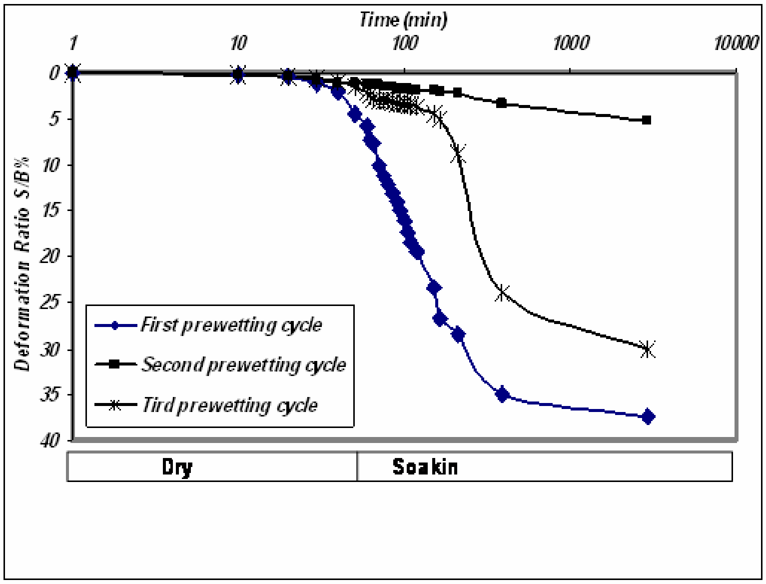

Fig. (9): Time-S/B relations for pre-wetted laboratory model by water for S-1 soil (70% gypsum content, soaking stress=100kPa, soil density=17.3kN/m3).

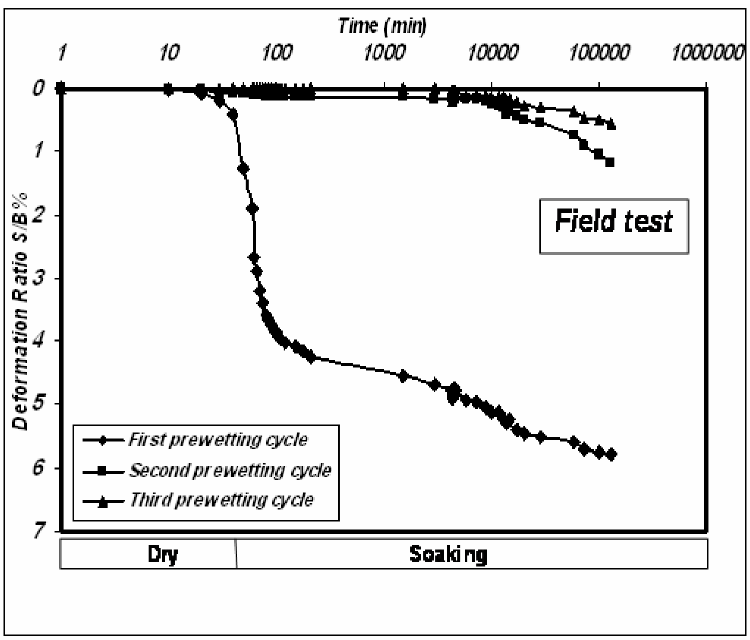

Fig.(10): Time-S/B relation for pre-wetted field model for S-1 soil (GC=70%, soaking stress=100kPa, soil density=17.3 kPa).

تحسين خواص التربه الجبسيه بعملية الاغمار المسبق

د صفاء حسين عبد عون

مدرس

كلية الهندسة _ جامعة ديالى

الخلاصة

تعد التربة الجبسية من أنواع الترب التي تسبب المشاكل الانشائيه التي تواجه المهندس المدني. تظهر مشكلاتها خاصةً في الابنيه و المنشات الهايدروليكيه الثقيله, لحضة اغمارها بالماء من الامطار او من ارتفاع منسوب المياه الجوفيه, حيث تنهار التربه تحت الاساس بشكل مفاجى نتيجه ذوبان الجبس وتفكك الاواصر لجزيئاته التي تحيط دقائق التربه. من جانب اخر تعتبر التربه الجبسيه تربه قويه و ذات خصائص جيده عندما تكون جافه. يعتمد مقدار الانهياريه في الترب الجبسيه على نسبه الجبس في التربه, درجة الحراره, الضغط الجوي اضافة الى عوامل اخرى. اجري عدد كبير من البحوث لمعلجه انهيارية هذه الترب, قسم منها غير عملي والقسم الاخر غير اقتصادي. في هذه الدراسة تم استحداث طريقة جديده لتقليل انهيارية التربه الجبسيه تتمثل بتكرار الاغمار والتجفيف لهذه التربه لعدة مرات لنماذج مختبريه و حقليه. تم استخدام تربتين بمحتوى جبسي٥٠% و ٧٠% من منطقة الدور وبلد, في محافضة صلاح الدين في جمهورية العراق. اظهرت نتائج الفحوصات التي اجريت علىنموذج مختبري, اضافة الى نموذج حقلي تم تصنيعه لهذه الدراسه, تقليل كبير في نسبة (هبوط الاساس/عرض الاساس) خاصة عند الدوره الثالثة من الاغمار بالماء وصل الى ٦٣% للنموذج الذي يحتوي ٥٠% جبس. وكانت نسبة التقليل ٩١ % عند الدوره الثالثه من الاغمار للنموذج الذي يحتوي على٧٠%جبس والمحمل باجهاد ٤٥كيلو باسكال, بينما كان٨٦% للنموذج المحمل باجهاد ١٠٠كيلو باسكال ولنفس المحتوى الجبسي. اما النموذج الحقلي بنسبة جبس ٧٠% المحمل باجهاد ١٠٠كيلو باسكال فقد اظهر تحسن٩٠% عند الدوره الثالثة مما يظهر تحسن واضح لانهياريه هذه الترب.

الكلمات الدالة: التربه الجبسيه, معالجات التربه.