EFFECT OF ACETIC ACID ON THE COMPRESSIBILITY OF GYPSIFEROUS SOIL

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ABSTRACT:- Gypseous soils contains either Sodium or Calcium salts, which may be considered the most problematic material for foundation engineer. It is associated with settlement problem especially for heavy and hydraulic structures with the presence of water. The risk begins from the first period of wetting or soaking these soils from any source: (rainfall, rising of water table or from any reason). The water will fluctuate or infiltrate through the soil particles and dissolve gypsum particles that fill the voids in the soil. The soil particles will roll and slide and arrange at new positions, because of the disintegration of the soil skeleton and the loosening of soil with the continuous dissolution of gypsum, which translate the soil from solid to semi solid media, with time.

The dissolution of gypsum depends on many factors (gypsum content, temperature, atmospheric pressure, and other factors). Another important factor which is the acidity of the dissolves liquid must be considered. This study shades the lights on the effect of Acetic acid (CH_3COOH) on the collapsibility of gypseous soil.

A laboratory model includes 350mm diameter and 400mm height thick plastic container and 18.4kN/m3 density gypsiferous soil prepared locally and compacted in three layers, with70%gypsum content. The stress fixed at 47kPa was applied over 50mm diameter circular footing. The relation between the soaking time and the deformation ratio (settlement/width of footing S/B%) was investigated, with 5 cycles of soaking by the Acetic acid.

The results of laboratory model tests show a pronounce effect of the acidity on the collapsibility of gypsiferous soil. The results of deformation ratio S/B% was (1.22, 8, 12, 15.7, 50%) at the end of (1,2,3,4,5) prewetted cycles by CH_3COOH acid, respectively. So the

effect of Acetic Acid percent was considerably accelerating the collapsibility of gypsiferous soil with cycling technique.

Keywords:- gypsiferous soil, compressibility.

PATH OF IMPROVEMENT

In the design of any engineering structure, many cases must take into consideration:

A-Prevent soil problem in question.

B-Absorb soil problem in advance before construction.

In case of soil problem is the collapsibility, i.e., the high and fast compressibility of soil mass with or without load when there is positive change in soil water content(al-Janabi, M. D 1997), the first point A can be explained by the following:

1-The soil mass underneath the structure is surrounded by any technique so that the water or ever moisture cannot reach such soil. In this case the soil structure is preserved and theoretically there is no fear of sudden settlement or collapse of soil structure, which in such case can cause severe damages to the superstructure.

2-Another path is the injection of so called waxing agent. These agents have the property of surrounding the gypseous soil particles thus preventing somehow in general forgoing technique is to prevent any change in soil moisture content to prevent collapsibility. From authors point of view, this path of improvement somehow practically impossible especially if soil has low permeability, since authors feel that preventing water from penetrating the soil mass is something impossible. In the nature, there can be floods, heavy, rains, domestic water use, or any cause so that water may percolate through soil (Al Muhammadi, N. 1987).

Another problem arises here as well is how to inject the agent into soil, and how can one be sure that the agent is completely surrounding the majority of soil particles. This is another problem that adds to the difficulties using this type of improvement. On the other hand, if the structure already exists on collapsible soil, then this method is the only way to prevent the large and sudden settlement that can result if positive change in water content takes place is the foundation soil.

About point (B) mentioned earlier, this type of treatment is concerned with the case in which the structure is not built yet on the proposed collapsible soil. In such condition, the soil having an advantage that it can be treated by any mean wished to absorb the property of collapsibility of soil.

PURPOSE OF STUDY

The aim of this study is to find any technique that will cause a great and fast compression of soil to take place before any construction activity. These techniques, in general, use vibration or/and any liquid solution (usually water) to cause collapse of soil in advance.

In this study, the basic idea falls behind using liquid solution to cause greater and faster (rate) of compression to soil than using water alone for treatment. The governing criteria, believed, for choosing such a solution liquid are as follows:

   i- The compressibility of soil in using such a solution must be greater in magnitude and rate than the compressibility of the same soil but with using water alone.

   ii- The solution must be relatively cheap, available, make no damage to concrete foundation.

   iii- The solution must be harmless to man and easy to handle and transport.

   iv- The depth of effect depends on permeability of soil (Al Noori, I. A. and Al Qaissy F. F. 1990). If deep effect is wanted then injection must be used and in such case, the solution must be unharmfull to grouting machine and easy to handle.

After a thorough review of thinking, the choice has been made on the acidic acid, although the second point (ii) is violated since the acidic acid in Iraq is fairly expensive.

Nevertheless, if the structure is considered important, the land seepage or estate is highly expensive (as usually is), and the improved is fairly small, then the cost of using such a technique can be tolerated.

As will be mentioned later the acidic acid is used in different degrees of concentration in order to have a comprehensive study on its effect on compression. The stresses applied to the soil, while collapsing are believed the domestic loads coming from domestic houses and light hard ware stores. And since gypseous soils are fairly available in our country, it is believed that the study is a good background for soil improvement in Iraq.

EFFECT OF COLLAPSIBILITY OF STRUCTURES

If gypseous soils have assess to water source so that there is an increase in water content then there we have a good and almost instantaneous settlement in soil resulting in great distress in the overlying structure (Nashat, 1990). As far authors know, there is no exact formula or criterion relating the amount of settlement with the amount of crack propagation, but there are tables which relate the amount of collapsibility using same

laboratory tests with the amount of distress that may damage the structure (Knight, 1957). In other words, it is difficult to predict the settlement in situ since there are large number of factors that control the amount and rate of collapse settlement in situ, unlike the consolidation settlement where there is a direct theory for settlement prediction.

EXPERIMENTAL WORK

The experimental work consists of performing laboratory model tests, to investigate the behavior of gypsiferous soil with 70% gypsum content at soaking number of prewetting cycles by acidic acid, with fixing all other parameters (initial moisture content, room temperature, applied soaking stress and soil density. In other word, shows the feasibility of prewetting this soil with CH3COOH many cycles in order to reduce collapsibility upon soaking, as a method of improvement.

SOIL USED

The soil was artificially prepared, by mixing sand with 70% pure gypsum to get the required gypsiferous soil. The grain size distribution was performed according to ASTM 422-79. The natural soil was sieved through No.200 sieve, then the sample was oven dried at 45°C, then sieve analysis was carried out by a set of sieves. The liquid and plastic limit tests were performed according to ASTM d4316-84. The collapse test also called single Oedometer test, suggested by Knight 1963 was carried using the consolidation cell.

MODEL PREPARATION

The model used consists of 350mm diameter and 400mm height, plastic cylindrical container. The loading system consist of fix weights applied directly over 50mm diameter steel footing, the footing was placed over the soil layer which is locally density controlled (18kN/m^{3}). The upper part of the plastic container was opened and a water control system was fitted as shown in figure(), to control the head of water.

Fix weight was used to apply equal soaking stress on gypsiferous soil. The weighs used is concrete cubes placed over footing, and applies 47kN/m^{2}.

SOIL PREPARATION

The gypsiferous soil was oven dried at 45°C for two days, sieved by no.4 sieve, mix thoroughly with 10% water. The cylindrical model was fitted at its position, the soil was devided to 3 equal patches and spread in to container in three layers of 25mm thickness sub layers, each layer was compacted by falling weight 5kg from 0.25m height. The procedure

was proceded until the final bed thickness of soil became 75mm. Soil density was controlled and fixed to 18.4kN/m3 during testing models.

TESTING METHODOLOGY

The circular steel footing was situated on the surface of prepared soil at the center of container, settlement dialgages were fitted at the surface of footing with the aid of magnetic steel holder, fixed outside the container. The fixed stress applied gradually until reaching 47kN/m2 maximum stress, after this, the footing may tilting, the dial gages measure the dry settlement which represent the initial settlement.

At the end of dry test, the dissolve liquid was fed from the liquid control system to ensure continuous flooding of liquid, as shown in figure (1-b). The water level in the model was controlled to ensure full soaking of soil. The soaking test started with taking dial reading at different periods with keeping soaking pressure unchanged (47kPa) as shown in figure (1-c).

RESULTS AND DISCUSSION

The following graphs show, in general, the relationship between the soaking time versus the settlement in normalized from S/B in percentage for various cycles of soaking in to CH3COOH solution. In order to make the curves more indicative and comprehensive, the time is drawn, as x-axis, in logarithmic scale. One model sample, tested by wetting with water instead of acid, to make a comparison between the behaviors of such soil for two cases.

The curve in figure (2-a) shows the logarithm of time against settlement. Until time is about 7000 second, there is very minor increase and magnitude in settlement which is almost linear. After that there is a break point of change in path in which the settlement curve goes to increase almost in a strength path as well. The final settlement got about 1.5% of S/B so if we imagine a footing of 2m width we may get a settlement of 24mm in two days only. On the other hand figure (2-b) shows the relation between the deformation ratio and logarithm of time for gypsiferous soil wetted with water one cycle. We can see a pronounce increase in the collapsibility for model sample wetted with acidic acid about 3 times that for the model wetted with water one cycle tested at the same conditions.

Figure (3) shows the time-settlement relationship for two cycles of soaking. There is a break point of sharp increase in settlement in about 7000 seconds in which the curve has a change in rate to increase of settlement with time. It is roughly the same break point location for the previous case, the case of one cycle of soaking. The curve has an S shape and the final settlement recorded after two days is 8% or a settlement of 160 mm for 2m footing. The

settlement of this magnitude is high, but for domestic houses in which width of foundation may be of 0.80m, the settlement is 64mm which is high as well.

Figure (4) shows the time-settlement curve for 3 cycles of soaking. There is a "not well obvious" break point at about 5000 seconds. The curve has an S shape as the one before. The maximum settlement recorded after two days is about 12% of S/B. That is a settlement of 240mm for a 2m width footing which is very high to any footing to withstand.

The points located between 100 seconds to end of soaking test, seems not to be located through a smooth curve of settlement. This phenomenon is due to the uneven settlement due to the collapse effect of soil. The reader may think that this is due to some measuring errors or errors in preparation of model.

In figure (5) which represents four cycles of soaking, the break point seems to be observed in very early time which is about 40 seconds from starting of test, unlike the three other cases before. After this break point the settlement increases in almost linear pattern in the order of logarithm time verse settlement mode. A final settlement was recorded after two days was 16% of S/B or 320mm settlement for two meters footing. Authors believe that no such structure can withstand such a settlement. And as with the figure before, points are not so uniformly located on smooth curve due to collapsibility of soil.

The fifth cycle of soaking is shown in figure (6). Here there is a sharp clear break point near 9000 seconds. Also the final settlement recorded is more than 50% of S/B. The break point seems to shift little to the right more than the other cases. No structure ever can withstand such a settlement, i.e., half the width of footing.

A first look at this curve shows that points are somewhat uniformly located on a rather smooth curve. It seems that large number of soaking cycles eventually transform the soil in a more uniform state in skeleton causing a more uniform settlement to occur. May be cycles of more than five maybe show us this hypothesis more clearly and this is a minor drawback in this study.

Now all the curves are combined together in figure (7) to give a perspective look at all soaking cycles. It can be noticed that all break points in curves are located somewhat near 10000 seconds. It seems that soaking needs some time to be effective to all the footing so that larger settlement after time 10000 seconds will begin to occur. This was the break point.

Now the question is as follows: Is this break point unique?. Authors believe that this break point in reality. Nevertheless it is a function of so many parameters depending on nature of soil, gypsum content, concentration of CH_3COOH, cycles of leaching and so many

other factors. Thus each soil has its unique break point that must be determined by experiments (imperial methods).

The histogram in figure (8) gives the final settlement measured in S/B% against number of cycles for soaking in CH3COOH. The data show increasing in collapsibility with increasing number of cycles.

It is to be mentioned here that although not shown in curves, it is believed that all curves will eventually level off since settlement cannot go "forever". This major drawback in this study and it is needed to have data for long term of soaking time. And due to the high settlement (collapsibility) observed in the model, it is why not possible to treat or improve such soils were essential structures are constructed upon it. So reinforcing such soils with geotextiles or grids may reduce some of the settlement but not transforming it to a normal natural soil.

In general, all curves obtained add to the sum of troubles that could be forced in foundations containing collapsible soils. Even in using prewetting with water and not with CH3COOH, the results obtained for settlement from so many authors are tremendous as well. It can be concluded that constructing buildings on gypseous soil not received any treatment is very dangerous.

And as said before the path of improvement lie in triggering the collapsibility of soil in advance, replacing soil if possible, or improving it**.**

CONCLUSIONS
1. The results of laboratory tests on model samples shows considerable increase in the deformation ratio (S/B%), about 3 times, achieved by prewetted gypsiferous soil 1 cycle with acetic acid, compared with that prewetted with water.

2. The presence of acids in the soil, increases dissolution of gypsum inside the soil mass, and so increases the collapsibility.

3. The collapsibility in the model prewetted 5 cycles with acetic acid (CH3COOH) increase more than 40 times that for sample wetted one cycle using the same dissolution. This behavior may attributed to the increase in the concentration of acid with cycle number, and cause what we call $Ca(CH3COO)_2$ chemical product material (Jargees I. (1986), as we can see from the chemical equation below:

$$2CH3COOH+CaSO_4+H_2O \xrightarrow{\quad SiO_2 \quad} Ca\,(CH3COO)_2 \downarrow + H_2SO_4 \ + \ H_2 \uparrow$$

4. Other types of acids which may be more economy than acetic acid may be effective.

5. The need appear for full scale field models to support the results of this study. Also taking in to consideration using natural gypseous soil instead of gypsiferous soil.

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Table (1): average results for physical tests for gypsiferous soil used in the study.

| Moisture content	Specific gravity	Soil type	Liquid limit	Plastic limit	Density used kN/m^3	Cohesion of soil	Angle of friction	Collapse potential %
2.6%	2.41	ML	32	21	18.4	7.8	35	6%
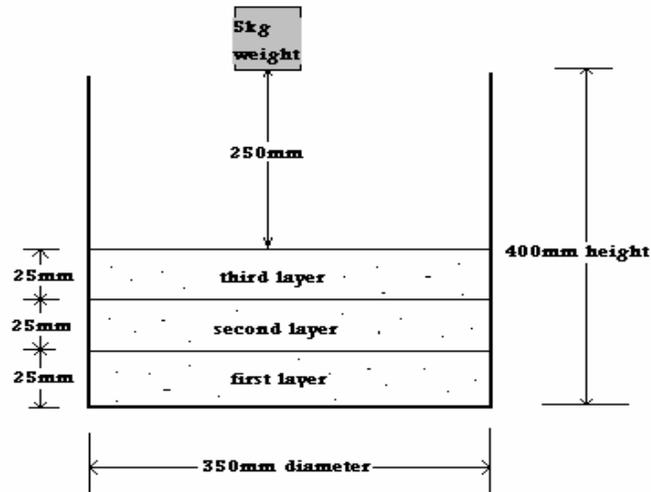
Fig.(1-a): Soil preparation and density control for laboratory model sample.
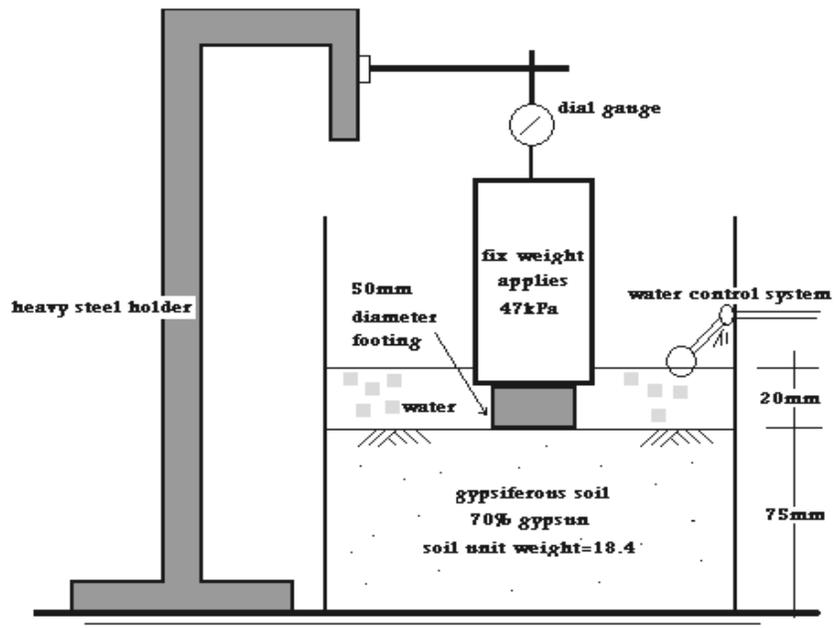
Fig. (1-b): Loading and water control system for gypsiferous soil model sample.

**Fig.(1-c):** A photograph presents laboratory model and testing equipments.
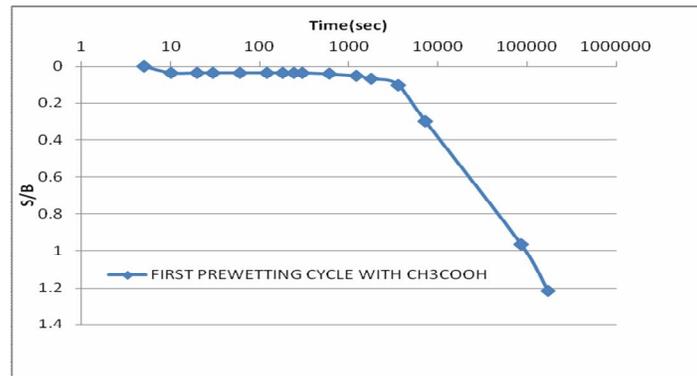
Fig.(2-a): Soaking time vs. S/B% for gypseous soil model prewetted by CH_3COOH acid.(G.C=70%, soil density=17.3kN/m^3).
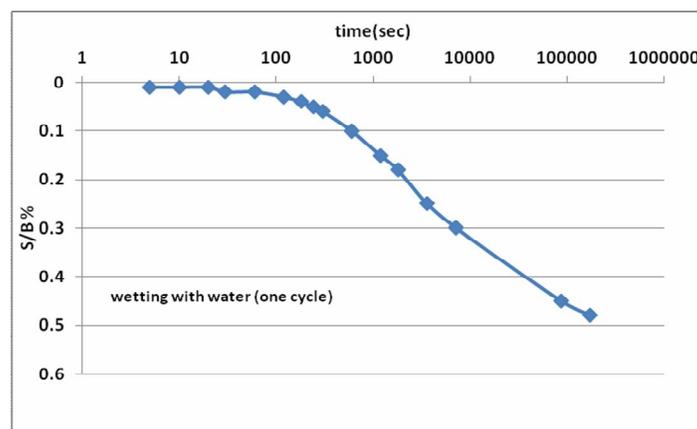

Fig.(2-b): Soaking time vs. S/B% for gypseous soil model wetted by water.(G.C=70%, soil density=18.4kN/m^3).
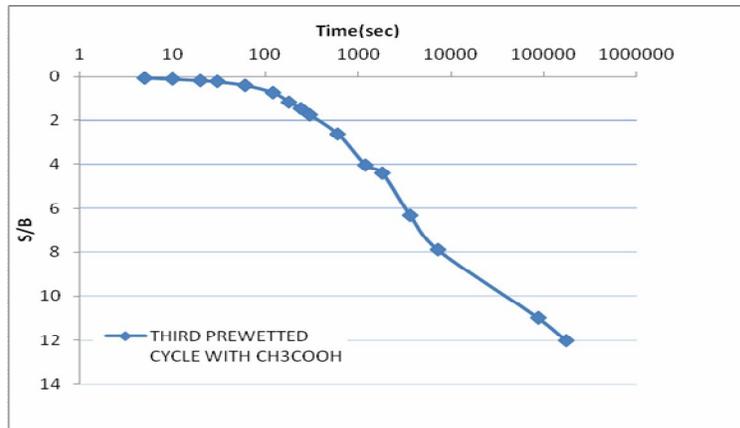
Fig.(4): Soaking time vs. S/B% for gypseous soil model wetted three cycles by CH_3COOH acid.(G.C=70%, soil density=17.3kN/m^3).
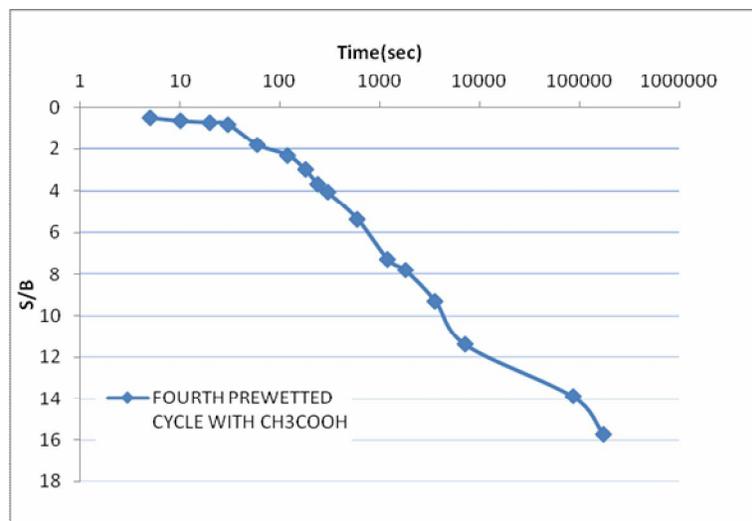
Fig.(5): soaking time vs. S/B% for gypseous soil model wetted four cycles by CH3COOH acid. .(G.C=70%, soil density=17.3kN/m^3).
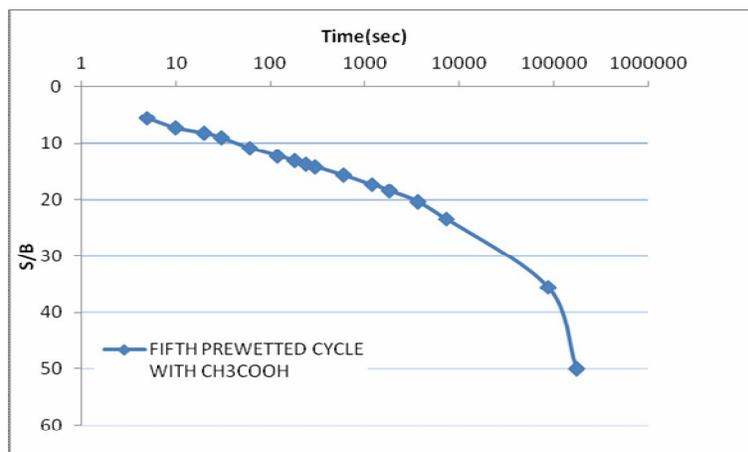
Fig.(6): soaking time vs. S/B% for gypseous soil model wetted five cycles by CH3COOH acid. .(G.C=70%, soil density=17.3kN/m^3).
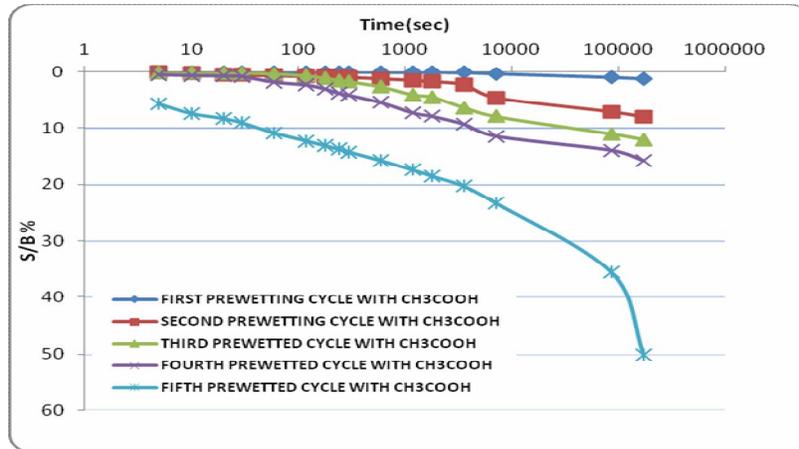
Fig.(7): Effect of wetting cycles by CH3COOH acid on the collapsibility of gypseous soil. (G.C=70%, soil density=17.3kN/m^3).
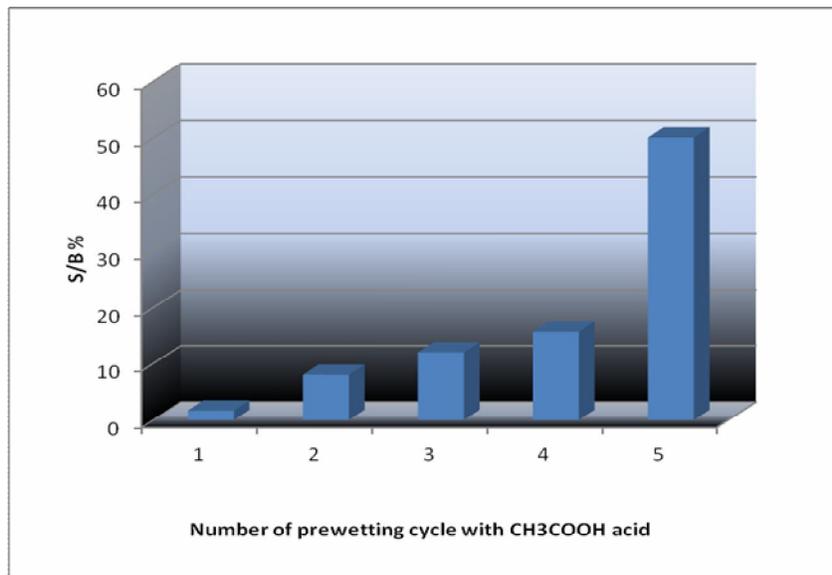
Fig(8): Final collapse settlement in terms of S/B%, against number of cycles of wetting gypseous soil by CH3COOH acid.(G.C=70%, soil density=17.3kN/m^3).

تأثير الحوامض على انضغاطية التربة الجبسية

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الخلاصة

تحتوي التربه الجبسيه في مكوناتها على املاح الصوديوم او الكالسيوم والتي تعد من المسببات الرئيسيه للمشاكل الانشائيه في الهندسه المدنيه بشكل عام, ولمهندس الاسس بشكل خاص لما تسببه هذه الترب من تصدعات وشقوق وقد تصل الى انهيارية المبنى, خصوصا للابنيه الثقيلة والمنشات الهايدروليكيه.

تظهر مخاطر هذه الترب لحظة ترطيبها او غمرها بالماء من اي مصدر,كأن يكون من هطول الامطار , ارتفاع منسوب المياه الجوفيه او كسرفي احد الانابيب الناقله للماء او لاي سبب اخر . حيث يتغلغل الماء من خلال جزيئات التربه بواسطة الخاصيه الشعريه, ويعمل على اذابة الجبس الموجود بين دقائقها . يحصل بمرور الوقت تدوير واعادة ترتيب لجزيئات التربه بسبب عدم تكامل هيكليتها نتيجة لذوبان الجبس وضعف تماسك اواصر التربه مع الذوبان المستمر المصاحب لعمليه الغمر , فيتحول وسط التربه الى شبه سائل. لذلك يحدث الانهيار المفاجئ للاسس او المنشات الهايدروليكيه المقامه على تربه ذات محتوى عالي من الجبس.

يعتمد ذوبان الجبس على عدد من العوامل التي تؤثر بشكل مباشر وغير مباشر في سرعة ذوبانه (نسبة الجبس, درجة الحراره, الضغط الجوي...وعوامل اخرى). هنالك مسبب اخر وهو حامضية السائل المذيب.   يسلط هذا البحث الضوء حول تاثير تركيز حامض الخليك (CH$_3$COOH)على انهيارية تربه بمحتوى جبسي عالي.

تم استخدام موديل مختبري مصمم لفحوصات التربه الجبسيه, يتكون من اسطوانه بلاستيكيه سميكه بقطر 350ملم وارتفاع 400ملم متصله من الاعلى بمنظم لدخول السائل المذيب لتسهيل الية التحكم اثناء عملية غمر التربه الجبسيه.   تم استعمال تربه جبسيه رمليه مخلوطه بمحتوى جبسي 70%, تم رصها بكثافة رص 18.4كيلو نيوتن/متر مكعب.   تم تسليط ضغط عمودي ثابت بمقدار 47كيلو نيوتن/متر مربع من خلال اساس دائري مصنوع من الحديد بقطر50ملم. تم استخدام حامض الخليك المخلوط مع الماء بتراكيز مختلفه كمذيب للجبس. تم دراسة العلاقه بين زمن الغمر مع معامل التشوه للتربه الجبسيه(S/B%) نسبة هبوط الاساس/عرض الاساس, وتاثير اغمار التربه الجبسيه بحامض الخليك.

اظهرت نتائج الفحوصات التي اجريت على النماذج المختبريه, تاثيراً واضحاَ لحامض الخليك في زيادة انهيارية التربه الجبسيه بشكل عام. حيث كان معامل التشوه S/B% (1.22, 8.0, 15.72,12, 50.0%) في نهاية فحص الاغمار بحامض الخليك (CH$_3$COOH) عدد من دورات الاغمار المسبقه (1,2,3,4,5)على التوالي.

كلمات الدالة: التربه الجبسيه, انضغاطيه.