

Improvement of Gypseous Soil by Compaction and Addition of Cement

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Abstract:

The engineering problems faces civil engineer in building and construction, is almost foundation problems results from the properties of the beneath soil. One of the effected problems is the presence of gypseous soil. The presence of gypsum in some regions reaches up to 70%. Gypsum salts is one of highly dissolved salts in water. The solubility depends on temperature degree, atmospheric pressure, PH of the dissolved liquid. There are many treatments for such soils, some of them are physical like earth reinforcement, compaction. The others are chemical like the addition of lime, asphalt emulsion, oil products...etc⁽¹⁾.

The aim of this study is to investigate the ability of improving gypseous soil by reducing the collapsibility during wetting with water, by the addition of Portland cement with different percentages:(1.5%, 4%, 6%,7.5%, 10%), to gypseous soil with at different densities 14 kN/m³ and 11 kN/m³.

*A laboratory model test consists of a cylindrical plastic container of 250 mm diameter and 400mm height. The soil was artificially prepared by mixing natural soil brought from a location near the Civil Engineering Department building in Diyala University, and mixed with 70% gypsum. The density of the soil was controlled by placing the required weight inside the container of known volume, to the required height. A rectangular footing 25mm*40mm made from steel was used. The stress was applied from a fix loading system designed especially for model tests and applying 46kPa stress. The aim of this setting is to control stress and to ensure keeping the dial gauges dry during tests.*

The results of laboratory test on model samples shows a considerable reduction in collapsibility for gypsiferous soil models treated with cement and compaction, during soaking with water. The reduction percent in collapsibility was (95%) for treated model by (10%) of cement addition and with increasing soil density up to (14 kN/m³).

Keywords: *gypseous soil, improvement, wetting.*

تحسين خواص الترب الجبسيه باضافة الاسمنت و الدمك

الخلاصه:

من المشاكل الهندسيه التي تواجه المهندس المدني في اعمال البناء, هي مشاكل الاسس الناجمه عن خواص التربيه في تلك المنطقه. وان من اكثر المشاكل تاثيراً, هو وجود التربيه الجبسيه. حيث تصل نسبتها في بعض المناطق لاكثر من 70%. والجبس من الاملاح السريعه الذوبان في الماء, ويعتمد ذوبانه على درجة الحراره, الضغط الجوي, حامضية السائل المذيب وعوامل اخرى. هنالك العديد من المعالجات لهذه الترب, منها الفيزيائيه كالتسليح والحدل. والاخرى كيميائيه مثل اضافة النوره, مستحلب الاسفلت, بعض المنتجات النفطيه واخرى.

تهدف هذه الدراسه امكانيه تحسين التربيه لجبسيه بتقليل الانهياريه اثناء ترطيبها, وذلك باستخدام تقنيه اضافة الاسمنت البورتلندي المقاوم للاملاح بنسب مختلفه (1.5%, 4%, 6%, 7.5% اضافة الى 10%) مع دمك التربيه بكثافه رص مختلفه (11 كيلو نيوتن/متر مكعب و 14 كيلو نيوتن/متر مكعب).

تم استعمال نموذج مختبري يتالف من اسطوانه بلاستيكيه ابعادها 400ملمتر ارتفاع * 250 ملمتر قطر. التربيه المستعمله في هذه الدراسه هي تربيه جبسيه تم تحضيرها مختبرياً بخلط تربيه طبيعيه تم جلبها من موقع قريب من مبنى قسم الهندسه المدنيه في جامعه ديالى مع الجبس بنسبه 70%. تم التحكم بكثافه التربيه من خلال تهيئه وزن التربيه المطلوب رصها داخل النموذج المختبري المعروف حجمه بالكثافه المطلوبه. تم استخدام اساس مستطيل واجهاد ثابت مقداره 46 كيلو باسكال, من خلال نضام تثقيب ثابت صمم لهذا البحث, الغرض منه الحفاظ اجهزه قياس الهبوط, اثناء فحص الاعمار للتربيه الجبسيه بالماء.

اضهرت نتائج الفحوصات التي اجريت على الموديل المختبري للتربيه الجبسيه في فحص الغمر بالماء, تقليل في الانهياريه يصل الى اكثر من 95%, خاصه للنموذج المضاف له 10% اسمنت مع كثافه رص 14 كيلو نيوتن/متر مكعب. تم مقارنة النتائج مع دراسات مشابهه وتحت نفس الظروف. مما يضره فاعليه هذه الطريقه للحد من انهيارية التربيه ذات المحتوى الجبسي العالي.

الكلمات الداله: تحسين, الترب الجبسيه, ترطيب.

1- Introduction:

Collapsible soils consist of loose, dry, low-density materials that collapse and compact under the addition of water or excessive loading. These soils are distributed throughout the southwestern United States, specifically in areas of young alluvial fans, debris flow sediments, and loess (wind-blown sediment) deposits⁽¹⁾. In Iraq it covers more than 10% of the whole area⁽⁸⁾. The gypsum percent in some regions, reaches more than 70%, especially in middle and north of country. Soil collapse occurs when the land surface is saturated at depths greater than those reached by typical rain events. This saturation eliminates the clay bonds holding the soil grains together⁽³⁾. Similar to expansive soils, collapsible soils result in structural damage such as

cracking of the foundation, floors, and walls in response to settlement. In one particular case of soil collapse, 14 houses in a Cedar City, Utah neighborhood had to be jacked off their foundations and relocated due to severe settlement⁽⁷⁾.

Human activities that facilitate soil collapse include:

1. Irrigation;
2. Water impoundment;
3. Watering the lawn;
4. Changing the natural drainage; and
5. Disposal of wastewater

Geologists work with geotechnical engineers to identify collapsible soil, and evaluate their potential to fail under loading and/or saturation. Collapsible soil be removed and replaced with approved and properly compacted materials. Collapsible materials can also be saturated (hydro compaction) to force the soils to collapse prior to construction ⁽³⁾. Petrukhin and Boldyrev ⁽⁵⁾ studied the effect of compaction on the improvement of the properties of gypseous soil. Results of unconfined, Triaxial and plane strain tests indicated that there is an increase up to 20 %. This increment accompanied by a decrease in the value of cohesion and the increase in the amount of the angle of friction.

Gypseous soil is usually considered to be problematic and exhibit unpredictable behavior, which cause significant troubles concerning civil engineer (salaam, 1988). Therefore, many researchers studied the efficiency of some techniques and addition some additives to improve the properties of such collapsible soil like (Barium chloride, Carbonate components, lime and Kaolin.(al-Busoda, 1999),(Al-Naeami,2000, Al-Neami, M. A. (2010) concluded that the collapsibility of gypseous soil decreases more than 70% when adding 4% clinker after crushing. Sabah S. Razoukih and Nashat 2007 showed that the increase of compaction effort from standard to modified proctor causes a significant increase in cohesion ⁽⁸⁾ ⁽⁹⁾.

2-Aim of Study:

The major purpose behind this study is to improve the properties of gypsiferous soil by reducing the collapsibility using the compaction technique with the addition of different percentages of cement using laboratory model with specially constructed loading frame

3- Experimental Work:

Initially the soil itself is brought from a location placed about 100 meters behind the civil engineering building. As the natural soil possesses too low coefficient of permeability ,the

original soil is mixed with 50 percent by weight of pure sand in order to accelerate the time – settlement testing procedure . Then this soil composition is mixed with pure gypsum with 70 percentage by weight in order to get the gypsiferous soil used in the model of test specimens.. The soil type is ML. Classification test was made for the soil includes: liquid limit, plastic limit, grain size distribution. A compaction test was made for the soil according to modified proctor test giving max dry density= 21.34kN/m^3 , with optimum moisture content = 16%. The choice was made to use this soil for all model samples with the same test conditions(Gypsum content=70%), $\gamma=11\text{kN/m}^3$.

3-1 Laboratory Model Preparation:

A cylinder with 25 cm diameter and 40 cm height made from thick plastic material was prepared. The soil was oven dried, pulverized and sieved through No. 4 sieve. The soil was placed in the cylindrical container with different densities (14.4, 14.6, 15, 15.3, 15.8kN/m^3), mixed with the same initial moisture content 2.5%. The soil was mixed thoroughly with different (cement/soil%, C/S%= 1.5%, 4%, 6%, 7.5% and 10%). A model with no treatment was made for making a comparison with the treated one with compaction and cement addition. The testing program flow chart is shown in Fig (1).

The soil density was controlled by dividing it, to three patches; each individually compacted to the recorded level until reaching the last layer. The soil surface was leveled with the aid of sharp instrument. A rectangular footing $2.5*4$ cm made from steel, was placed at the center of the model, over the last bed of soil.

3-2 Loading Frame and Settlement Control:

The system of loading frame chosen for all laboratory model tests was fixed loadings, to ensure continuous and long term loading application and easy stress controlling and loading additions during test. The system of loading was designed and manufactured in Diyala laboratory by the authors and working staff. It consists of vertical steel shaft of circular diameter (75 cm length, 2 cm diameter), connected from the lower 25cm by a horizontal steel shaft connected to the plastic model. A hinge was connected from the top of the shaft with the aid of thickened plate to ensure no tilting of more than 15 kg weight loading system.

The settlement was measured using 0.01mm sensitive dial gauge, fixed out of the model with the aid of magnetic holder. A plate was welded to the vertical shaft to measure the deformation of steel footing and the reduction in settlement for the treated models.

The loading frame and settlement control was designed especially for these tests type on model samples to investigate collapsibility during soaking gypsiferous soil with water, to prevent

damages of dial gages by wetting it in soaking test during the addition of water to model from top.

3-3 Testing Methodology:

The settlement was recorded with time for model tests at dry test, this test takes about 2 hours, which represents the immediate settlement. At soaking test, the water was opened and starting wetting the soil in the model from top to bottom. Dial reading recorded with time, until fixing of reading. Actually it takes about one week for the untreated model, after which, no additional deformation was recorded. the sequence of each test is carried out as follows :the load is applied (46 kpa) on soil through (45*60)mm footing model and time zero started .There is some settlement (instantaneous) on the wet soil specimen settlement is recorded with time until these is little recorded and then water is added to start the soaking phase which in term is continued till the recorded reading for settlement is almost leveled off .The day phase (before socking) did not last more than one day at most while each entire test lasted for about 6 days in then to have a settlement stop .

4- Results and Discussion:

Gypseous soil, as mentioned earlier, are obviously having good engineering properties when dry, i.e., high bearing capacity with low settlement and almost very little creep. But once are wetted with water, it loose the entire structure, and undergo very large instantaneous settlement called potential collapse even if there is no or very little applied stress. Bad policy one follows in building an engineering facility over such soils without any counter measures taken in both the foundation soil and the structure itself. Some condition, may enforce the designer or project manager to make use of local available resources in spite of their bad Strength properties like gypseous soil .So one may at least try to improve the behavior of such local soils to the limit that they may be used in a Specific project without future serious problems as well as the whole total finance will be in the range of acceptable limits.

In this study authors preferred to use ordinary Portland cement in several percentages by weight of gypseous soil and provide some sort of compaction to the mixture in order to simulate natural soil as possible as can be. The compacted soil mixture is then soaked with water in order to find time – settlement curve and compare it with the gypsiferous soil specimen that does not contain any improvement or cement material. In this may, how much improvement got is obtained. Then after, the gypsum content is changed in order to scan the mass of problem. Test results are shown separately in

figure (3) to (7), while figure (8) shows data accumulation which are piled in one drawing and figure (9) referred to the test of the sample for adding 4.5 percentage of cement by weight with compaction and figure (11) show the improvement by using compaction with constant percentage of cement (4.5%), on the other hand table (1) represents the numerical data for such curve. The results obtained from figure (9) shows that, the collapse settlement is reduces with cement addition. The settlement for case of no cement addition is continued and does not stop until leveled off at measured quantity of 9.86 mm that is an S/B ratio of 0.22mm. That is a very large settlement and authors believe that there is no such domestic building or installation that can withstand such a numerical value. If settlement takes place suddenly the structure would not have time to adjust the stresses induced or distribute the distresses unlike the case of consolidation settlement. This situation imposes an additional problem to the structure. It is doubtful that any skilled engineer would like to take the risk of using such soil in engineering facilities directly without some sort of treatment. Just adding 1.5 percent cement to soil reduces the settlement almost to half the value for untreated gypsiferous soil (i.e., $S/B^*=0.11$). Although this value is still high to handle by most building. But for minor roads or earth embankments this value may be acceptable. The other curves shown are for different cement ratios as additives and have all almost similar trend of behaviors. A summary for final results are listed in table 1`:

Table 1: The Relationship between the Cement Ratio by Weight of Soil and the Recorded S/B* Ratio.

Cement Ratio by weight of soil %	Recorded Deformation Ratio S/B%*
No cement added	0.22
1.5	0.11
4.5	0.06
6	0.05
8	0.03
10	0.01

**Deformation Ratio S/B %=(Footing Settlement S / footing width B) %*

Results of the effect of cement addition are shown from Fig (4) to Fig (10). It is the opinion of author that a ratio of 5% of cement addition and more is rather hard to follow because of the large expense and finance needed. If we consider 5% as maximum practical limit that can be used then we may get an improvement of $((0.22 - 0.055) / (0.22) = 75\%)$ which is not a little value.

5- Conclusions:

From mass of work done in this study the following points are drawn in brief:

- 1- It is not recommended to use gypseous soils in any engineering construction, unless they receive some sort of treatment.
- 2- There are many solutions of soil improvements in order to reduce the collapse potential of gypseous soils .The addition of improving materials such as cement is one of these choices. The cement addition provides an easy mean to reduce settlement. The addition of 1.5% cement, reduce 50% of the collapsibility of gypseous soil laboratory model tested in this study.
- 3- The maximum percentage of cement used, is 10 % which leads to a deformation ratio S/B% of 0.01 or an improvement of more than 95% .But the amount of cement use is hard to follow and difficult to be justified in practical engineering projections . Never the less that large amount of cement use did almost eliminated the collapse settlement potential of gypsum soils. So 5% cement addition is the maximum practical limit that can be used which reduce the settlement 75%.
- 4- The bearing stress used in the laboratory models are about 46kPa .This may represent the average and actual bearing stress in most domestic buildings. Higher stresses will of course cause higher settlement collapse.
- 5- In using 4.5% of cement by weight of gypseous soil, and compacting the soil to 14kN/m^3 reduce the deformation ratio (S/B%), from 0.22 to 0.01. Which is a pronounce improvement result for gypseous soil.

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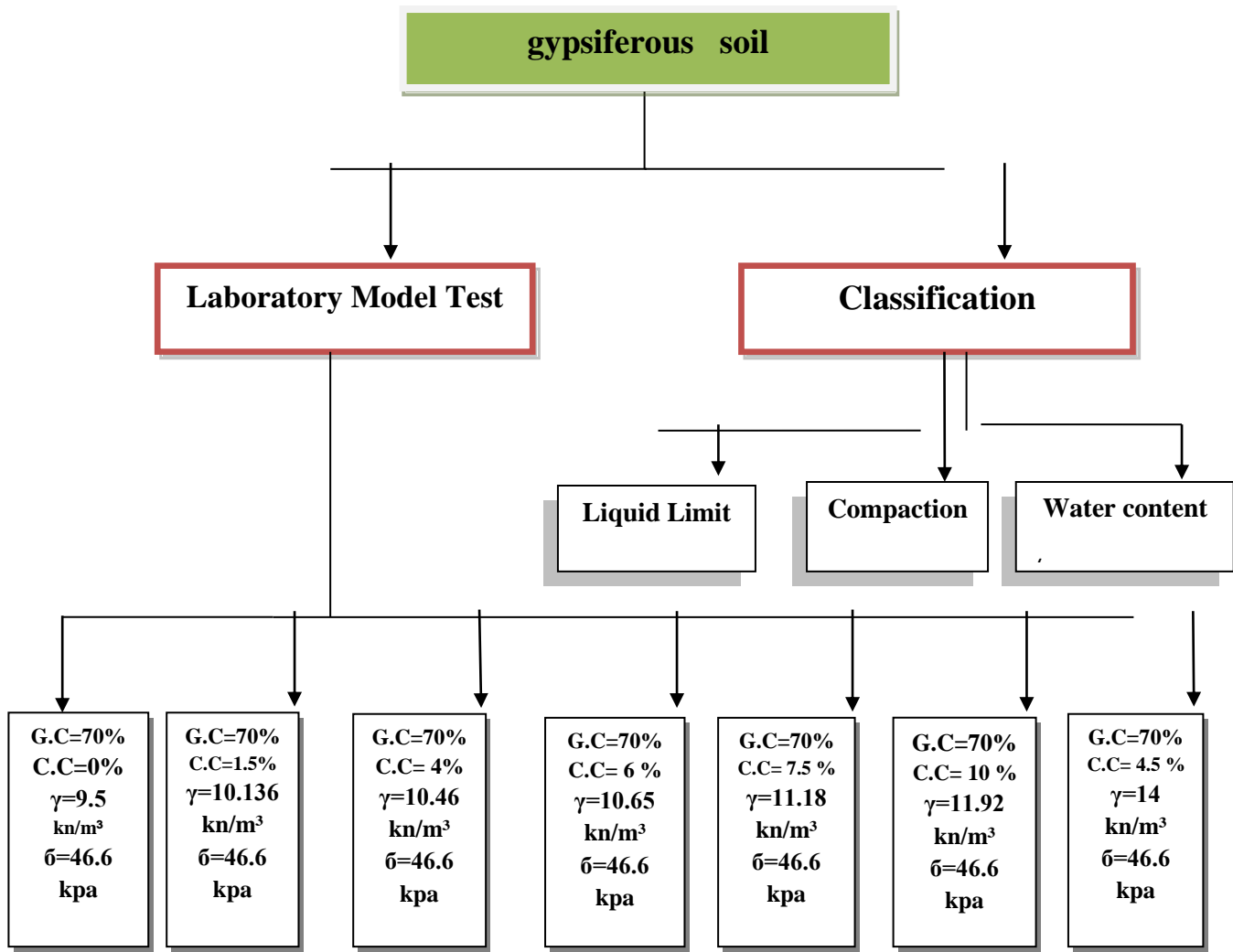
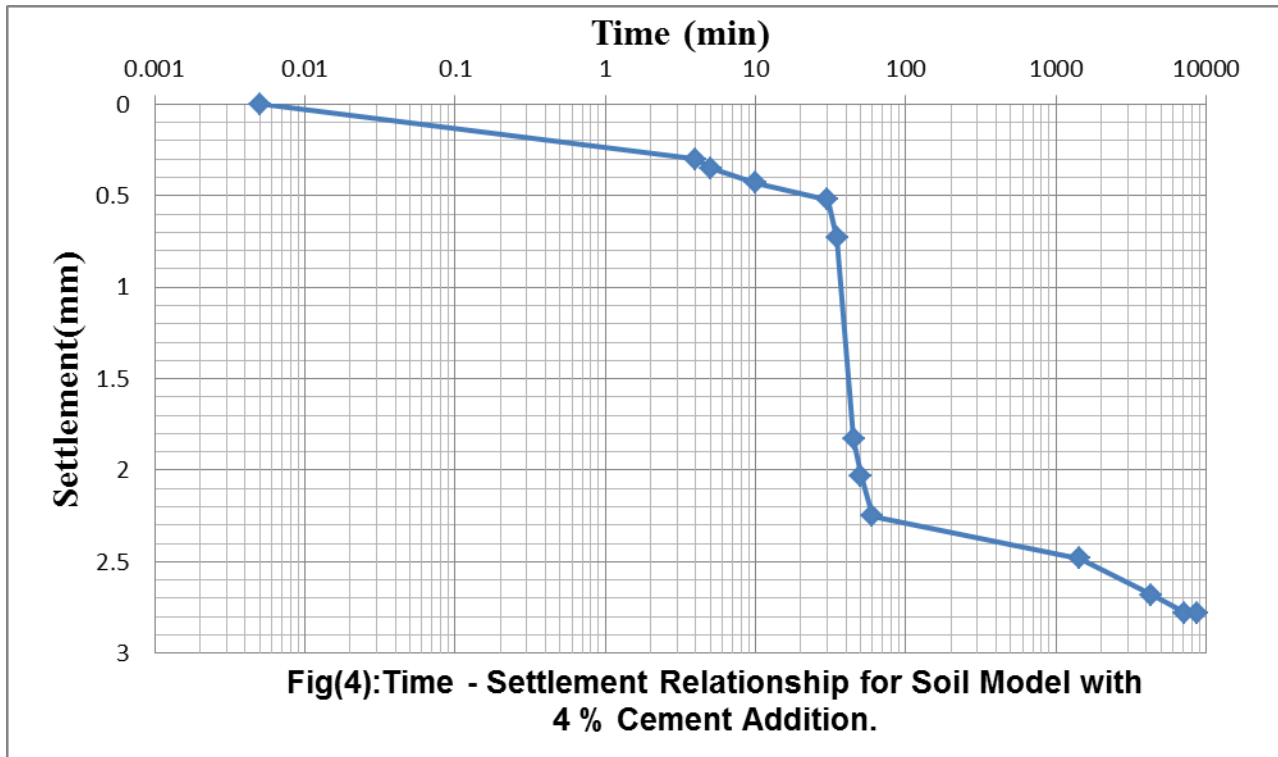
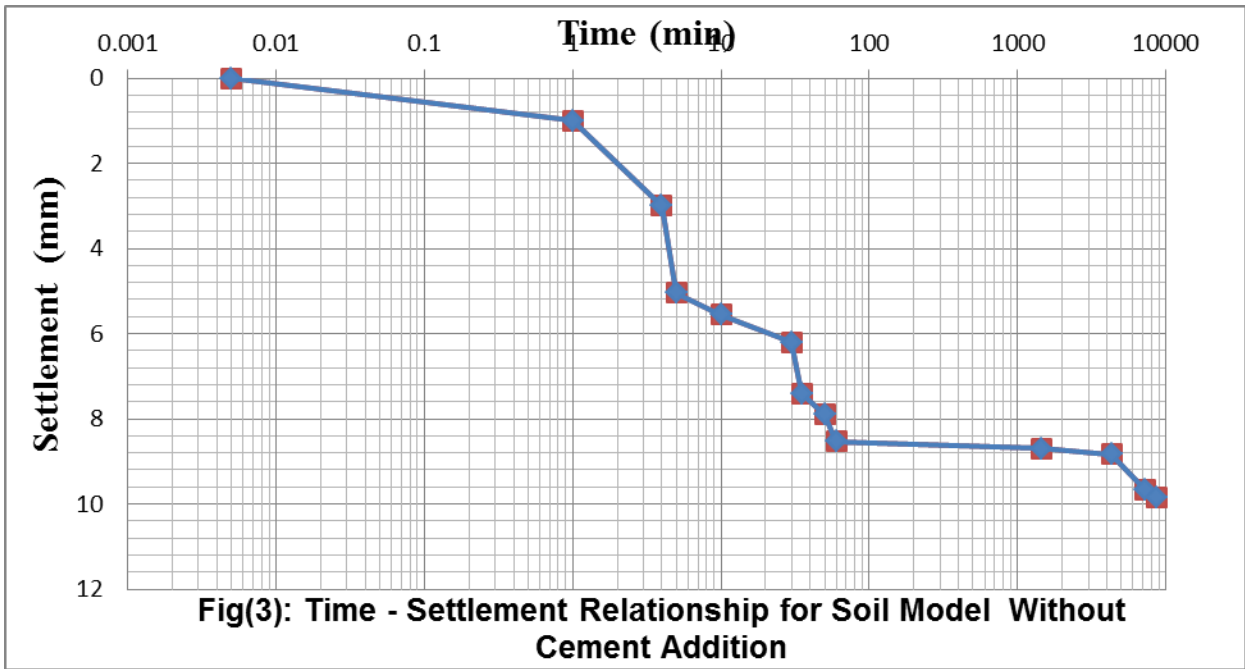
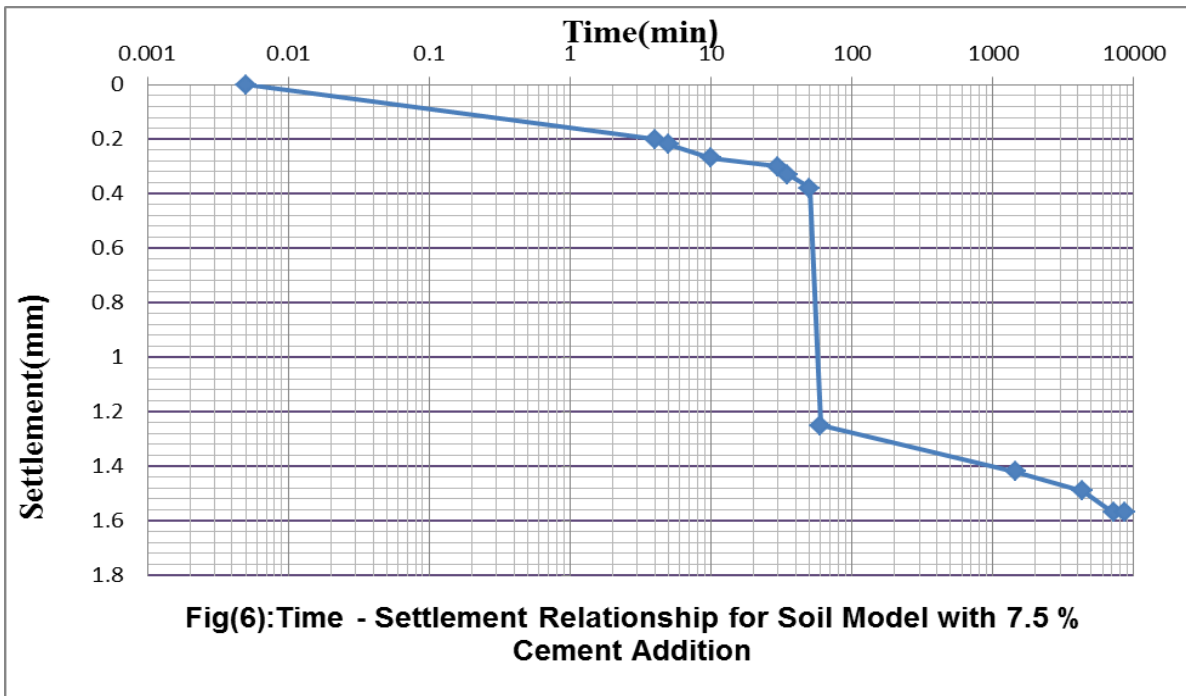
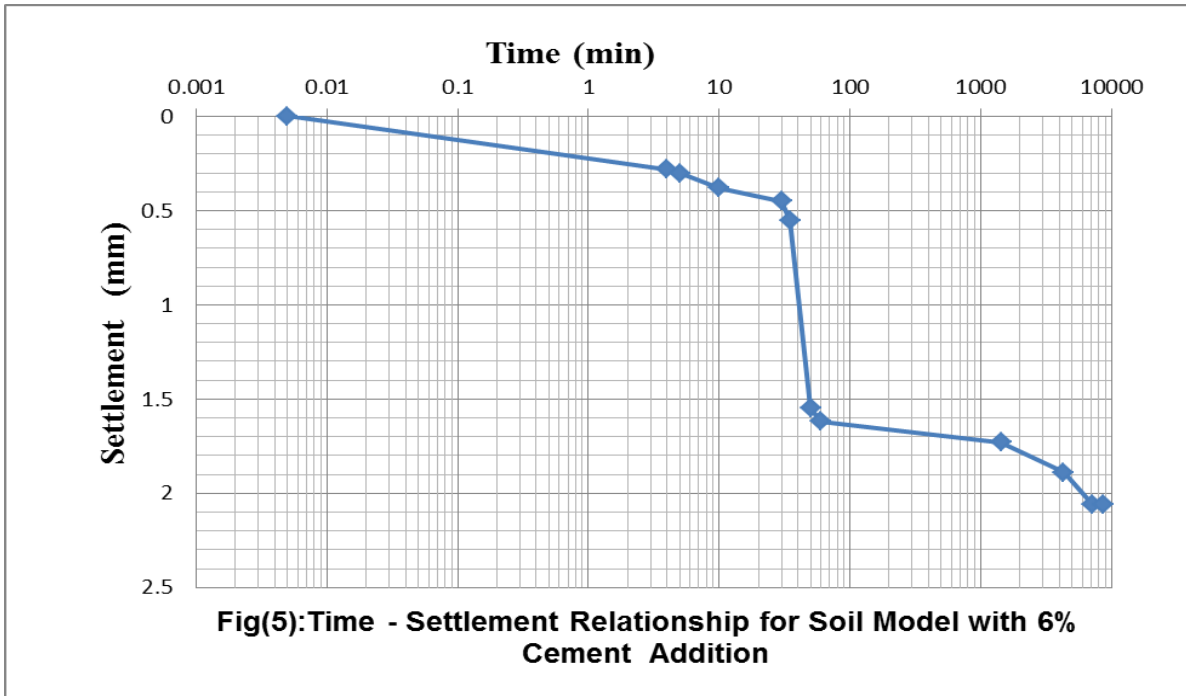


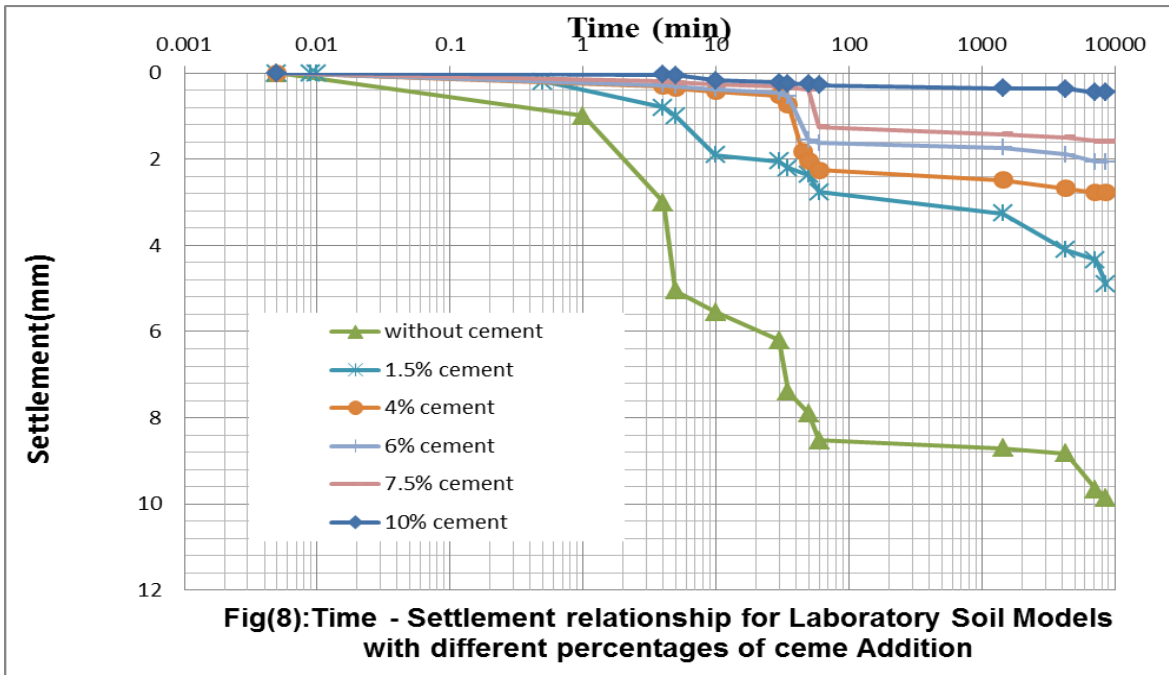
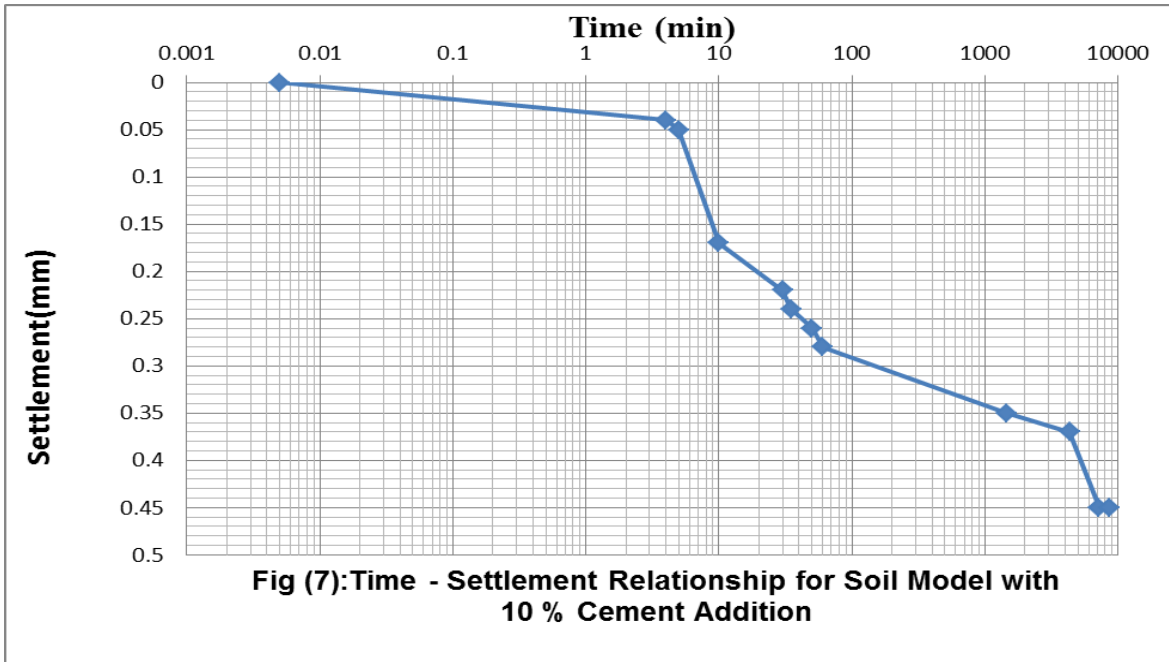
Fig. (1): Flow Chart Program of Experimental Work.

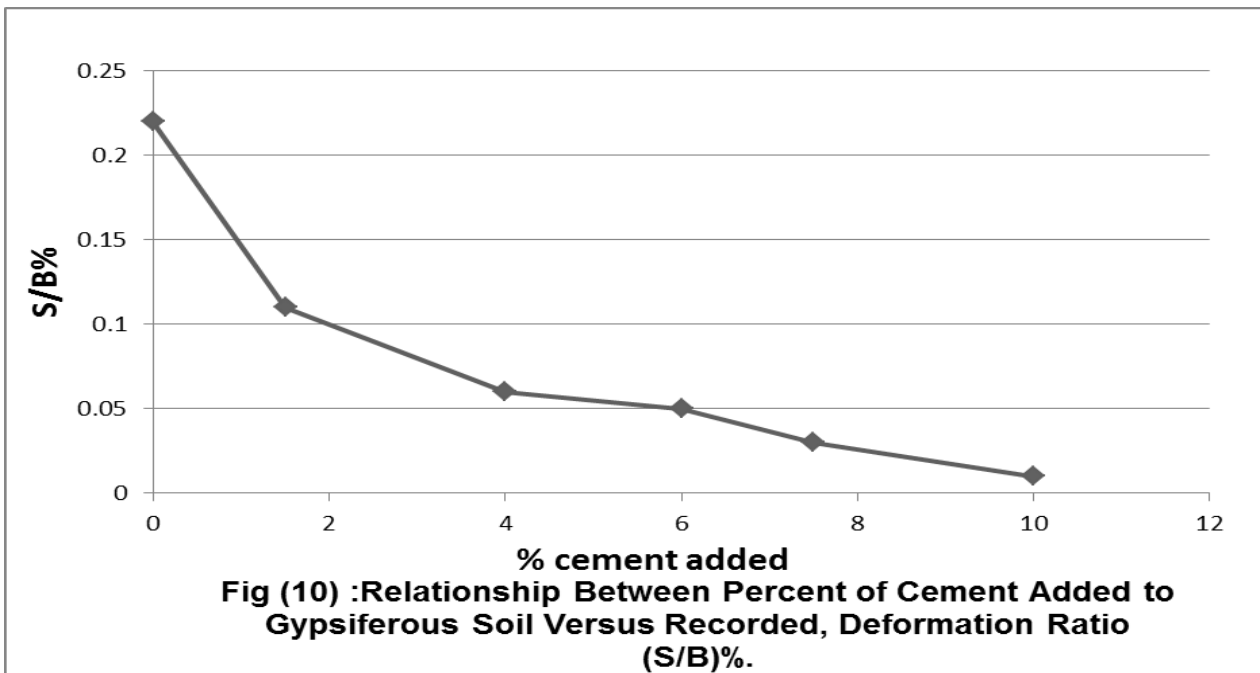
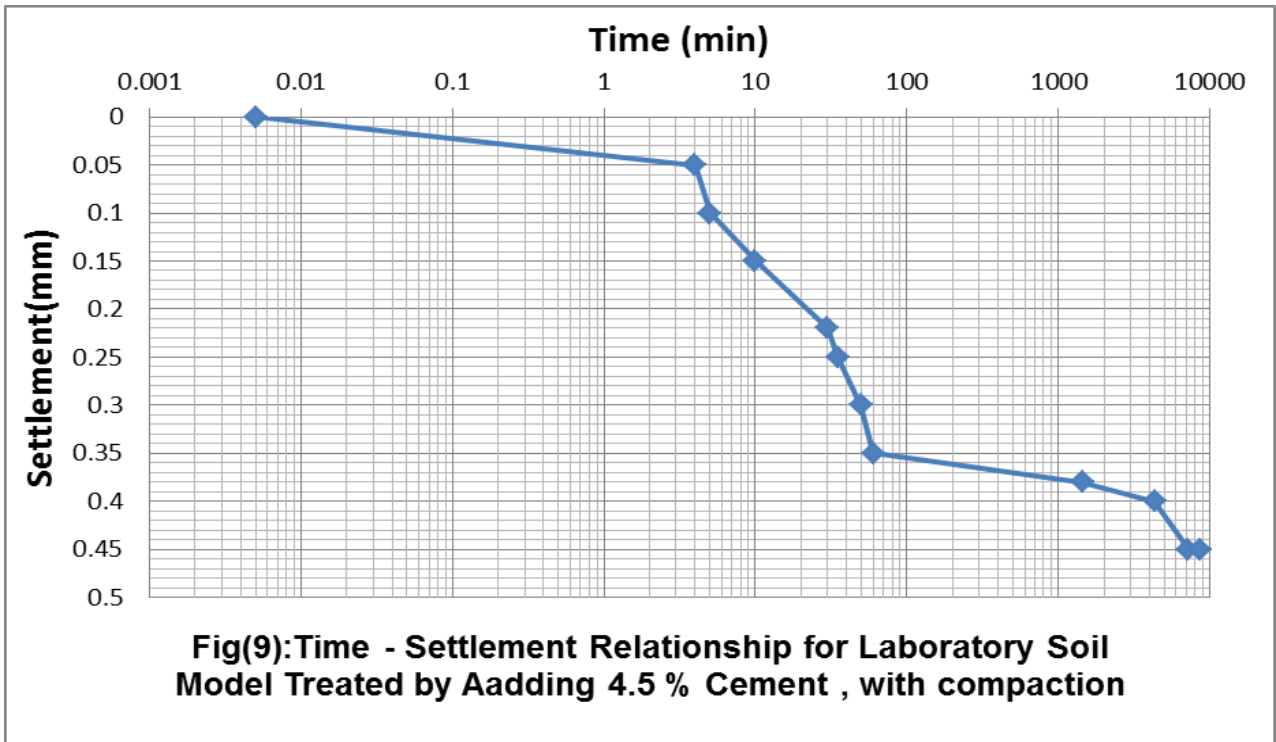


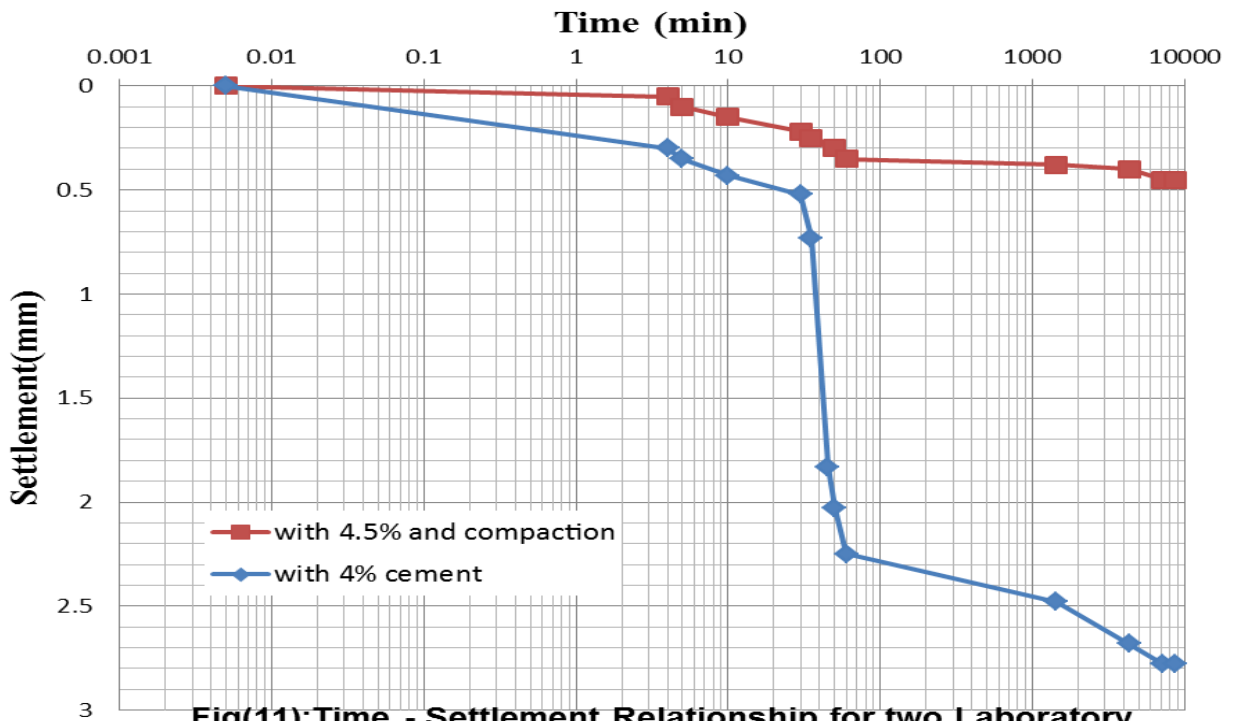
Fig (2): Loading Frame and Settlement Control Used for Laboratory Model











Fig(11):Time - Settlement Relationship for two Laboratory Soil Model,one Treated by Adding 4.5 % Cement+Compaction gypseous soil to14kN/m³. the other is Treated By Adding 4% Cement without compaction (unit weight=11kN/m³).