Improving Collapsibility and Compressibility of Gypseous Soil using Cement Material

Fatimah Khaleel Ibrahim

College of Engineering, University of Basrah, Basrah, Iraq

Fatimahkhaleel6@gmail.com

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Abstract

Gypseous soils exist in many regions in the world. It is necessary to study the properties of such soils due to the damage caused by these soils to buildings on or in it. This paper presents the results of experimental studies on the compressibility and collapsibility of Gypseous soil in Basrah and show the effect of mixing cement material with Gypseous soil on those properties. The sandy soil, which covers the surface layer(up to 1m) for the two investigated areas(AL-Brgsia and AL-Zubair) consists of high gypsum content (63%) and (34%), respectively. The soil was found to be a "collapsible" soil. The cement material have been used as improving agents for such soil.

The essential idea of this study represents an investigation of the possibility of using cement as additive with different percents (2%, 4%, 8%,10%, and 12%) to enhance these soils. Tests were conducted on 12 models of untreated and treated gypseous soil specimens to study their behavior as well as the effects on physical properties, collapsibility and compressibility characteristics. It is found that a reduction in collapsibility appraches 87 and 92 % for the 12 percent mixed cement to (AL-Brgsia and AL-Zubair) soil, respectively.

Keywords: Gypseous soil; Cement; Additives; Collapsibility; Compressibility.

Introduction

Gypseous soils are considered as collapsible soils, which contain high proportion of hydrated calcium sulfate (CaSO4.2H2O). Gypsum, dissolves due to water table fluctuation or water infiltration into soils leading them to be soft and highly compressible causing severe foundation problems due to collapse of soils structure and the formation of cavities AL-Mohammadi, Nashat (1987) [1] Collapsible soil exhibits large decrease in strength at saturated state accompanied by a large decrease in soil volume. Collapsible soils are also known as metastable soils. They are susceptible to large volumetric strains when they become saturated. This could cause considerable damage to the structures founded on or in such soils. Gypsum present in soil structure acts as a binder (cementing material) between soil particles and causes the soil to be very hard when it is dry. The bond between soil particles of fine materials and salts is washed away during saturation process and consequently this results in the general soil collapse. It is well known that many damages are recorded in several projects located in particular regions in Iraq due to presence of gypseous soils underneath the base of foundation. Problems associated with structures constructed on gypseous soils can be summarized as: settlement; collapse due to soaking, collapse due to leaching; delayed compression and shear failureAL-Neami(2006) [2].

Experimental work

Location and Preparation of Natural / Mixed Soil Samples

Natural gypseous soils were brought from Al-Brgsia and AL-Zubair sitetion which are located in the north of Basrah, south of Basrah respectively. Disturbed samples were taken from about 1 m below the natural ground surface. Then, these soils are transported to the Soil Mechanics Laboratory, University of Basrah where soil test has been conducted for this work. The samples of soils were air dried, pulverized and mixed thoroughly. After that, the soil becomes homogenous and ready for testing. Tap water and cement material was used in the experimental work. In this study, compacted soil samples at lab dry unit weight (18.72 and 18.54 kN/m3) were used respectively. The soil was placed loosely in the mould (or ring) of consolidation cell(by using trial and error) as layers with metal scoop and each layer was gently leveled out under compaction using wooden disk to achieve the required unit weight.

Before placing soil sample in the mould (or ring), the inner side of mould was coated with grease oil to minimize friction and to inhibit the water from flowing out through voids at the interface between the soil sample and inner surface of the mould (or ring). To study soil characteristics and its mechanical behavior, different tests have been carried out such as; soil classification, chemical, physical and mechanical tests included collapsibility and consolidation tests.

Besides, cement materials can be used as grouting materials to improve such gypseous soil characteristics, so they were used as additives to study their effects on soil properties. Ten mixes (5 for each type of soil) were prepared with different percents of ciment (2, 4, 8,10 and 12 % by weight) added to the natural soil. These additions are represented as percentages of the total weight of the mixes. The same procedure of preparation was carried out for the mixed soil specimens. A testing program was conducted on each of the 12 models of the untreated (two specimen) and treated (10 specimens) gypseous soils to explore the behavior of such soils in addition to assess the effects of used mixes on physical properties, collapsibility and compressibility characteristics.

Determination of Gypsum Content

As the fruition of gypsum content is complicated so several methods and techniques have been suggested AL-Azawi(2004) [3]. One of these is the hydration method of Al- Mufty and Nashat (2000) [4], which is used to determine the gypsum content of the natural soil in this study. The hydration method can be summarized as follows:

The soil is oven dried at 45c° temperature until the sample weight remains constant. This weight is recorded as W45c° Then the same sample is dried at 110c° temperature for 24 hrs and the weight is recorded as W110c°. Gypsum content (X) is then calculated according to the following equation:

$$X = [(W_{45C^\circ} - W_{110C^\circ})/W_{45C^\circ}]*4.778*100 \qquad \text{-------- (1)}$$

Where:

$W_{45\ c^\circ}$ = weight of sample at 45_{c° temperature.

$W_{110\ c^\circ}$= weight of sample at 110_{c° temperature.

Testing Program:

Collapse Tests also called single oedometer collapse test was suggested by Knight [5]. The test was performed similar to the standard consolidation test except that the sample loaded to 200 kPa then inundated and the strain reading was taken after 24 hours. Jennings and Knight [6] defined the collapse potential (CP) as:

$$CP\% = [\Delta e/(1+ eo)] * 100\%$$

$$CP\% = [\Delta h/ho] * 100\%$$

Where:

Δe = change in void ratio due to wetting under a pressure of 200 kPa.

eo = natural void ratio.

Δh= change in height of the soil specimen upon wetting (in cm).

h_o= initial thickness of soil specimen(cm).

They gave the following values of (CP) as expectation of collapsing, as shown in Table (1).

Table 1: The severity of collapse potential at 200kPa stress level after (Jennings and Knight (1975))

Collapse Potential (%)	Severity Of Problem
0	No problem
0.1-2	slight
2.1-6	moderate
6.1-10	Moderately severe
>10	severe

Standard Consolidation Tests these tests were conducted according to ASTM Test Method (ASTM, 2010) [7] for One-Dimensional Consolidation Properties of Soils (D 2435-80) using a front loading consolidation apparatus.

Results and Discussion

The physical and engineering properties of Al-Brgsia & AL-Zubair soils (with 63%, 34% gypsum content) have been investigated Table (2). The dry unit weights included within the table were determined from phase relationships. To study the collapsibility and compressibility of such soil, a single collapse test was carried out for such soil in its natural state and after treatment. The relationship between the void ratio and log stress for natural (or untreated) gypseous soil is shown within Figures (1) to (7) and their results are summarized in Table 2. It can be seen that the collapse potential for normal Al-Brgsia and AL-Zubair gypseous soil is 18.5 %and 9.9 respectively at stress 200 kPa, therefore, this soils can be classified as problematic soil(Seere trouble)& (Trouble) respectively according to the classifications suggested by Jennings and Knight (1975) [6] and Clemence and Finbarr (1981) [8].

The sudden decrease in void ratio is indicated by the vertical line appeared in the aforementioned figures. This line refers to the sudden collapse of soil structure when water is added under stress level 200 kPa due to the dissolution of gypsum in water leading to an increase in the volume of voids because of bonds breaking between soil particles. Therefore, rearrangement of soil particles takes place and the settlement of soil sample occurs under constant load. This was also observed by Seleam (1988) [9]; Al-Abdullah (1995) [10]; Al-Busoda, (1999) [11]; Al-Neami (2000) [12]; Al-Ahbabey (2001) [13]; Al-Obaidi (2003) [14]; and Fattah et.al. (2008)[15].

Experimental results showed that the addition of ciment had led to a reduction in void ratio of the added improving material (Tables (2). The void ratio for untreated gypseous soil (zero% improving material) for AL-Brgsia station was 88% and for AL-Zubair station was 71% and decreased for treated soil with 2% cement, then it was slightly reduced with increasing the additive material percent reaching maximum decrease for treated soil with 8%. Then, an increase was noticed for treated soil with 12%. The values of void ratio of soil at different cement percentages may reflect that the global void ratio of the soil can no longer be used to describe the behavior of the soil when a granular soil (sandy) contains fines (cement). This is because, up to a certain fines content, the fines only occupy the void spaces, and do not significantly affect the mechanical behavior of the soil-cement mixture.Typical results of single collapse test are shown in the form of eo– logarithm stress curves. Figures (1) to (12) illustrate the collapse test for normal soil and a particular percentage of ciment mixed soil, the results of collapse tests show vertical line which refers to immediate collapse that occurs suddenly when the soil specimen was flooded with water at constant stress level of 200 kPa. The loading period for this line is 24 hrs.

The change in strain upon flooding in water points out that the soil is collapsible. The bonds start losing strength with the increase of the water content and at a critical degree of saturation, the soil structure collapses Clemence(1981),Barden(1973) [8, 16]. A summary of data is given in Tables (2). It can be noticed that the collapse potential (C.P.) increases with the increase of initial void ratio. Treatment results give a considerable reduction in void ratio, increase in dry unit weight and specific gravity hence a significant reduction in collapsibility (or an increase in Collapse Reducion Factor CRF) reaching 87 to 92 % for the 12 % mixed cement for AL-Brgsia and AL-Zubair respectively. This improvement in collapse potential is a result of filling the voids between soil particles by the fine particles of cement which work as a cohesive bond (filler material) filling the voids between soil particles and provide a water proofing coat around the gypseous soil particles and makes the soil structure more stable to collapse due to water added.

Conclusions

Based on the test results, the following conclusions can be drawn:

1- Cement may be used as an improving agent for highly gypseous soil (with 63 %, 34 % gypsum content) from Al-Brgsia and AL-Zubair sites respectively.

2- The addition of cement results in improving the characteristics of the gypseous sandy soil represented by its physical properties, collapsibility and compressibility.

3- Significant reduction in collapsibility (improvement %) reaching 87 to 92 % for the treated gypseous soil with only 12 % mixed cement for each site.

4- Examining the degree of severity of the problem, it seems that the treatment process by the additives resulted in non-problematic for 12% cement mixed soil and moderate problematic soil instead of problematic natural soil (collapsible soil).

5- Sufficient reduction is noticed in compressibility characteristics of gypseous soil upon treatment with this additive. Lowest compression index (Cc) and recompression index (Cr) have been obtained using 12 % mixed additives.

Table (2) Results of collapsibility test for AL-Brgsia and AL-Zubair stations

AL-Brgsia station					
Cement %	**Collapse Potential%**	**Collaps Reduction Factor CRF%**	**e_0**	**Unit weigh g/cm^3**	**Severity of problem**
0	18.5	0.0	0.88	1.872	Severe
2	6.96	62.0	0.84	1.89	Moderately Sever
4	3.43	82.0	0.78	1.90	Moderate trouble
8	3.04	84.0	0.75	1.93	Moderate trouble
10	2.69	86.0	0.70	1.98	Moderate trouble
12	2.45	87.0	0.64	2.00	Moderate trouble
AL-Zubair station					
Cement %	**Collapse Potential%**	**Collaps Reduction Factor CRF%**	**e_0**	**Unit weigh g/cm^3**	**Severity of problem**
0	9.90	0.0	0.71	1.854	Moderately Sever
2	4.80	52.0	0.67	1.86	Moderate trouble
4	2.45	75.0	0.63	1.88	Moderate trouble
8	1.08	89.0	0.60	1.90	Slight
10	0.98	90.0	0.58	1.94	Slight
12	0.78	92.0	0.55	1.97	Slight

AL-Brgsia Station

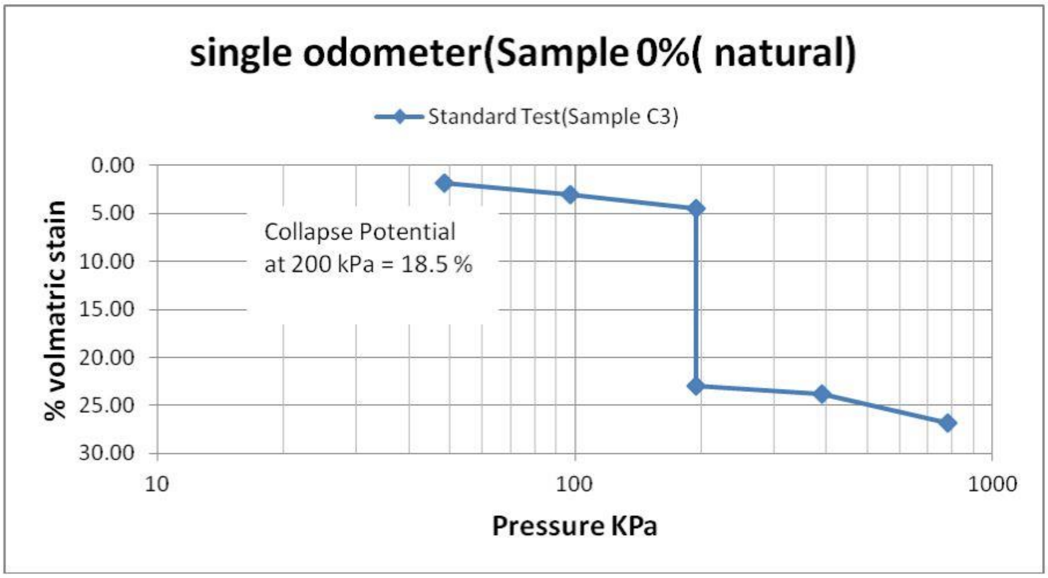

Figure (1) Sample 0%(natural)

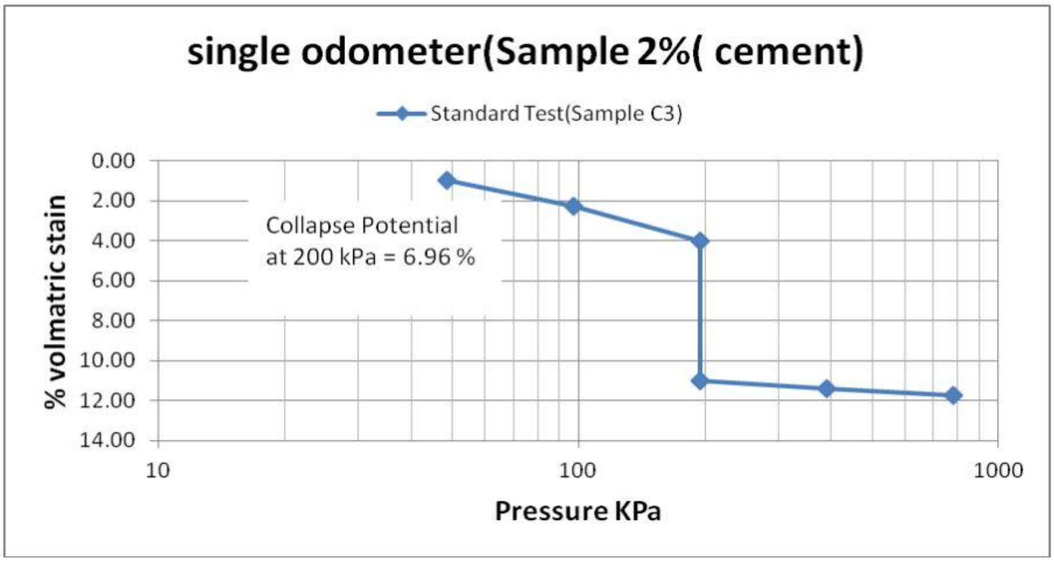

Figure (2) Sample 2%(cement)

AL-Brgsia Station

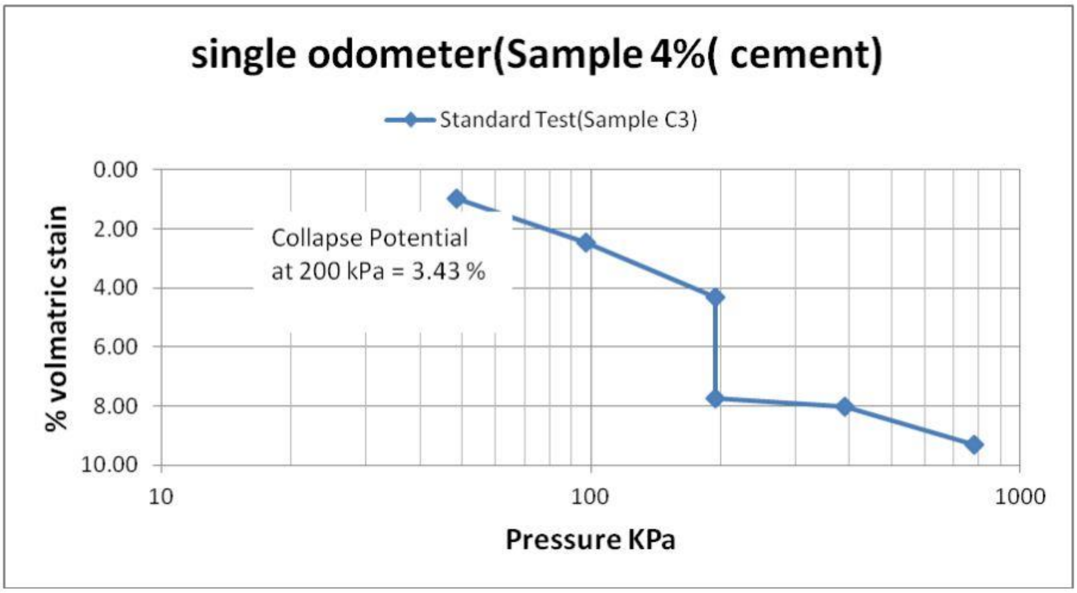

Figure (3) Sample 4%(cement)

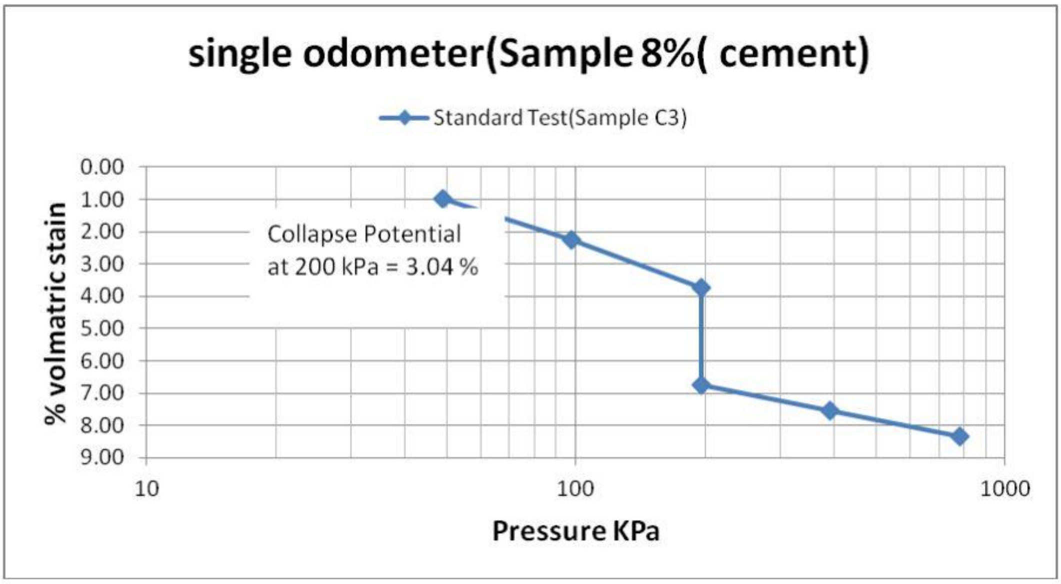

Figure (4) Sample 8%(cement)

AL-Brgsia Station

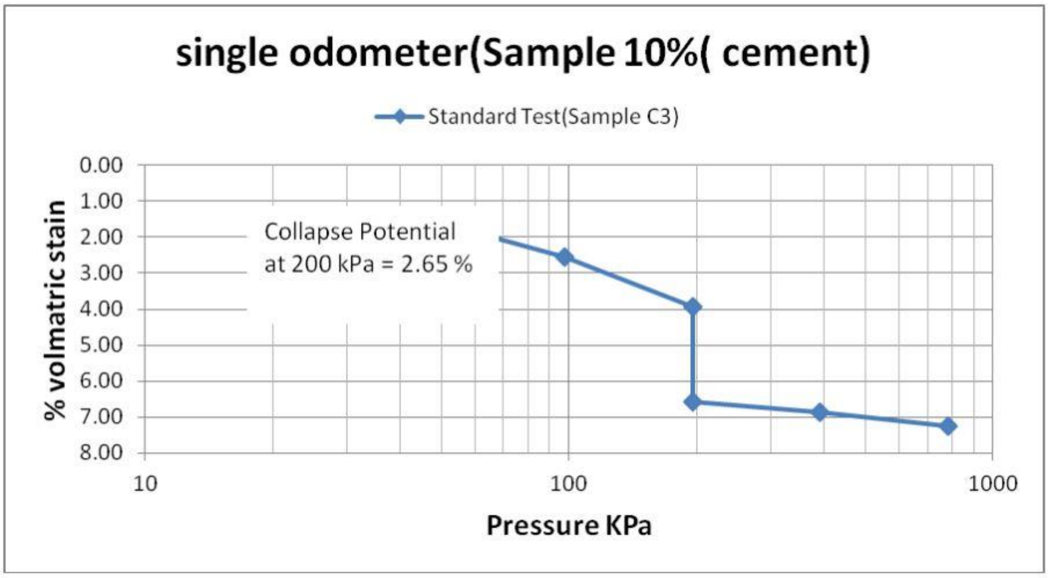

Figure (5) Sample 10 %(cement)

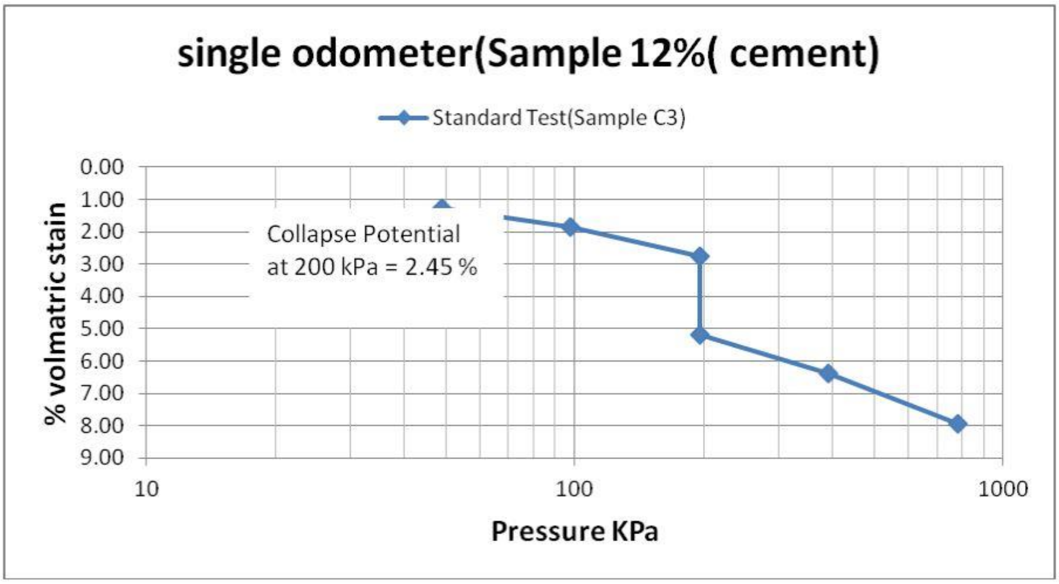

Figure (6) Sample 12%(cement)

Station AL-Zubair

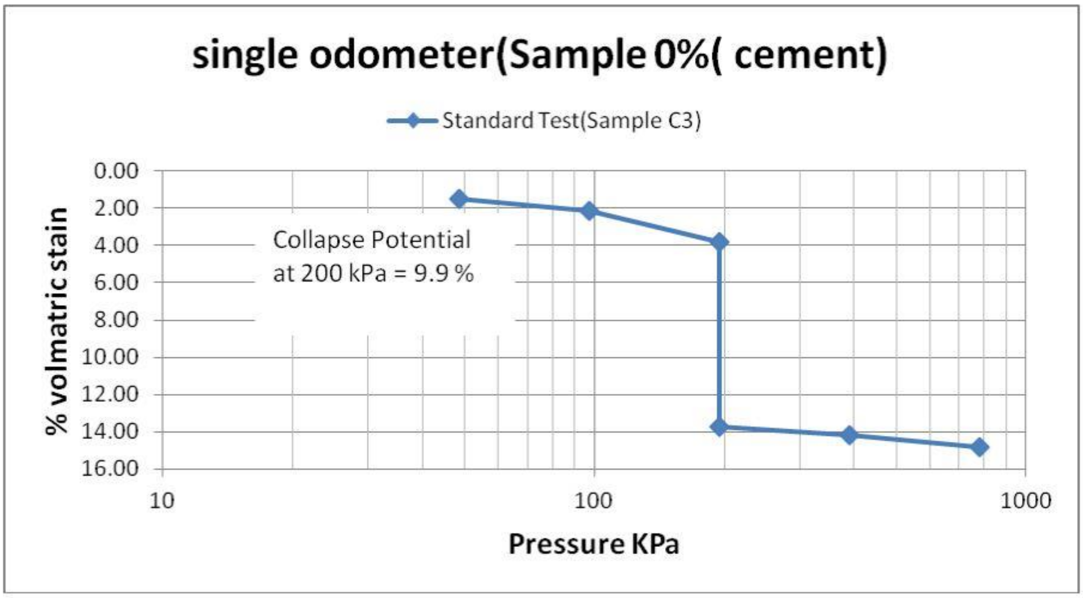

Figure (7) Sample 0%(cement)

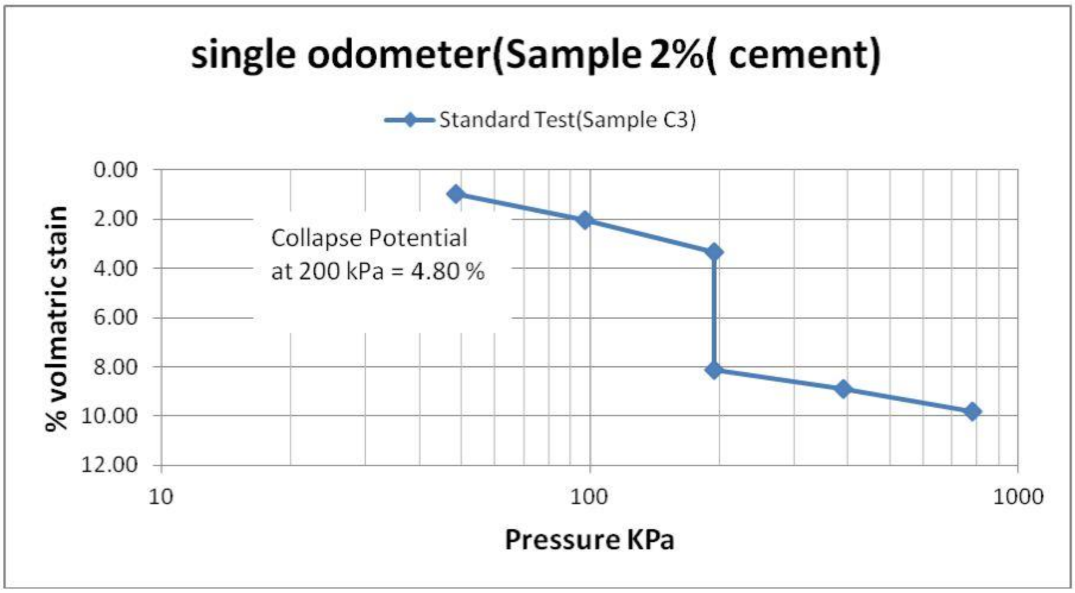

Figure (8) Sample 2%(cement)

Station AL-Zubair

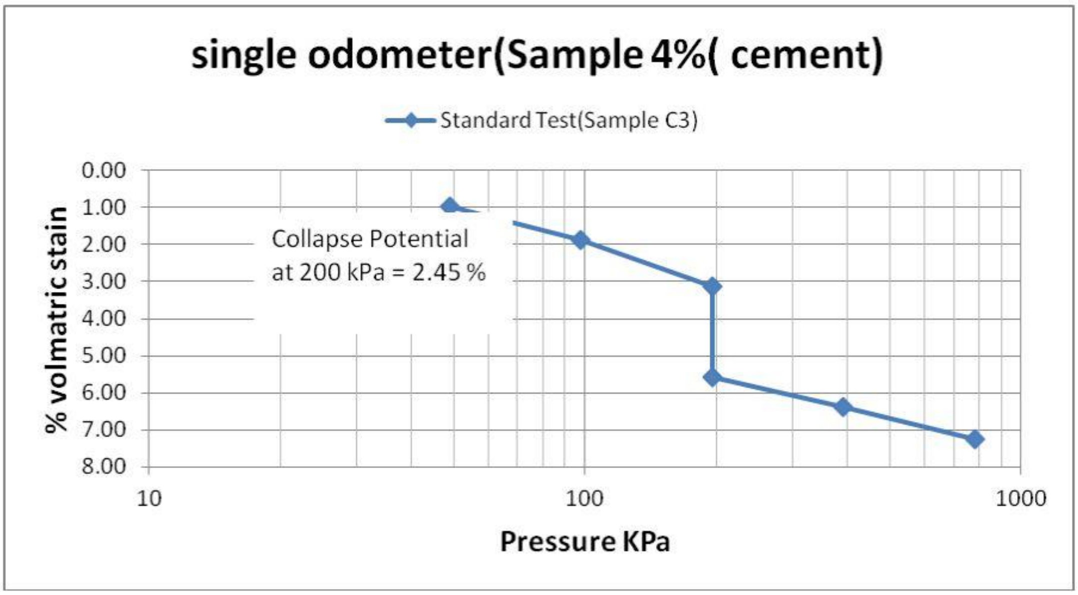

Figure (9) Sample 4%(cement)

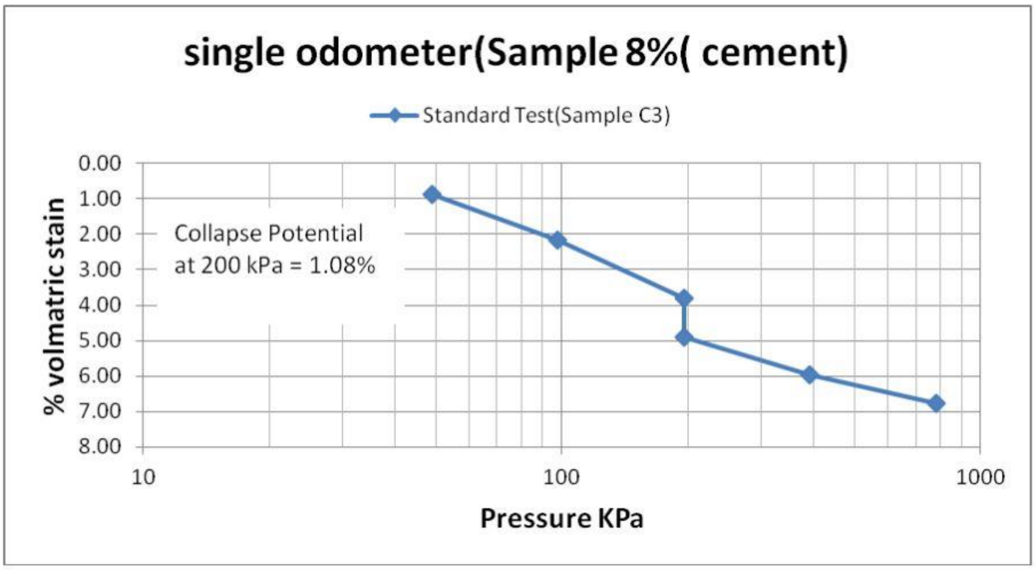

Figure (10) Sample 8%(cement)

Station AL-Zubair

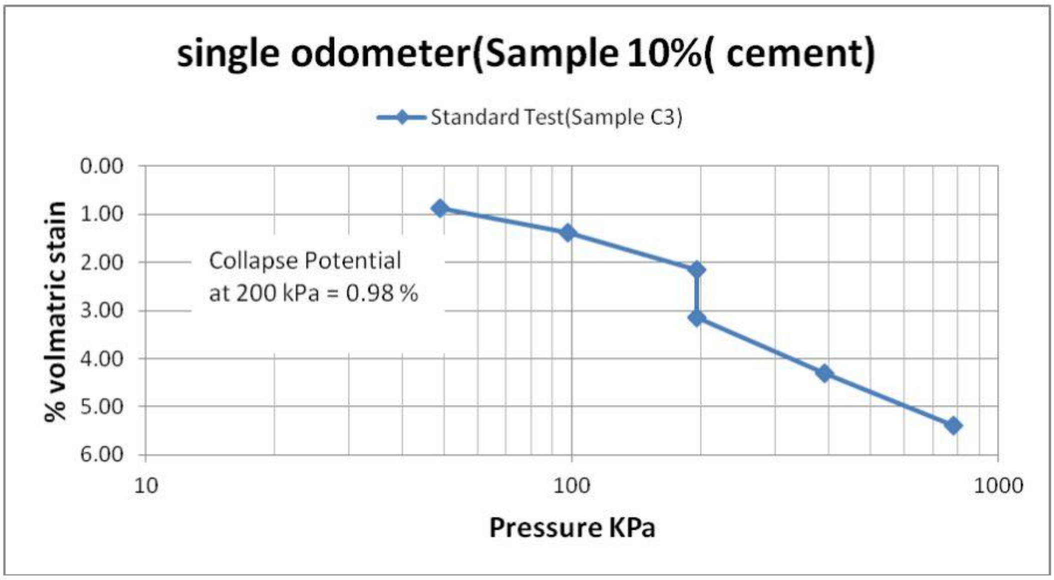

Figure (11) Sample 10%(cement)

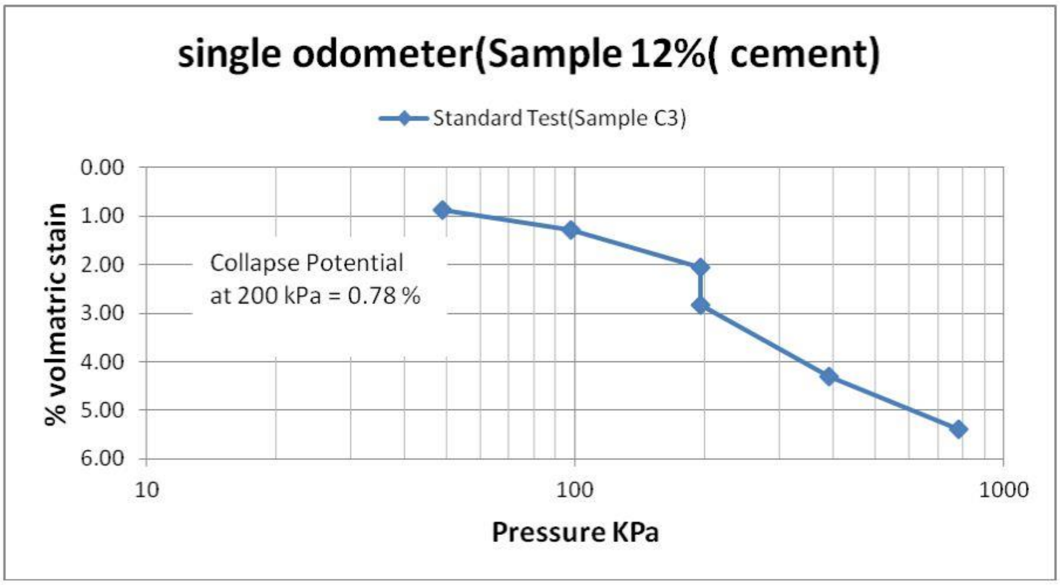

Figure (12) Sample 12%(cement)

Conflicts of Interest

The author declares that they have no conflicts of interest.

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تحسين انهياريه وانضغاطية الترب الجبسية باستخدام مادة الاسمنت

فاطمة خليل ابراهيم

كلية الهندسة، جامعة البصرة، البصرة، العراق

Fatimahkhaleel6@gmail.com

الخلاصة

التربة الجبسية منتشرة في كثير من مناطق العالم فمن الضروري دراسة خواص مثل هذة الترب بسبب المخاطر الذي تسببة على البنايات من الداخل او الخارج. يمثل هذا البحث النتائج للدراسة المختبرية على الانضغاطية والانهيارية للترب الجبسية في البصرة ويوضح تاثير المادة الاسمنتية الممزوجة مع التربة الجبسية على خواصها الفيزيائية. التربة الرملية تغطي الطبقات السطحية لمنطقتي الدراسة (تربة منطقة البرجسية وتربة منطقة الزبير) وتحتوي على نسب عالية من الجبس تقدر ب (63%) و (34%) على التوالي، ووجد ان التربة هي تربة انهيارية لذا استخدمت المادة الاسمنتية كمادة مضافة لتحسين مثل هذة الترب، وتتمثل الفكرة الاساسية لهذة الدراسة بإضافة مادة الاسمنت بنسب مختلفة (2% ، 4% ، 8% ، 10% ، 12%) للتربة الجبسية من اجل تحسين خواص هذة الترب.

تم عمل برنامج الفحص الذي يتكون من (12) موديل لنماذج التربة الجبسية معاملة وغير معاملة لدراسة تصرف هذة الخلطات وتأثيرها على الخواص الفيزيائية وانضغاطية وانهيارية التربة. ومن خلال هذة الدراسة وجد ان هناك نقصان في الانهيارية تصل الى (87% – 92%) لنسب خلط (12%) من مادة الاسمنت على الترب الجبسية لمنطقتي البرجسية والزبير على التوالي.

الكلمات الدالة: تربة جبسية، يبني، إضافات، الانهيار الانضغاطية.