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Improvement of Earth Canals Constructed on Gypseous Soil by Soil Cement Mixture

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ABSTRACT

The gypseous soil may be one of the problems that face the engineers especially when it used as a foundation for hydraulic structures, roads, and other structures. Gypseous soil is strong soil and has good properties when it is dry, but the problem arises when building hydraulic installations or heavy buildings on this soil after wetting the water to the soil by raising the water table level from any source or from rainfall which leads to dissolve the gypsum content.

Cement-stabilized soil has been successfully used as a facing or lining for earth channel, highway embankments and drainage ditches to reduce the risk of erosion and collapsibility of soil. This study is deliberate the treatment of gypseous soil by using a mixture of soil-cement. Collapsibility and settlement tests were carried out on gypseous soil brought from Karbla Governorate with a gypsum content (42.55%) soil mixed with various amounts of cement (2%,3%,5%,8%,10%,13%,and 15 %) by Wight and compacted to max. dry density 16.5 kN/m^3 with O.M.C.(12.8 %) . The experimental tests were conducted on a flume with constant velocity (0.148 m/sec) during the test. The results marked that (10) % of cement decreases the collapsibility about 86.54% and the gypsum contained in the soil remain the same nearly after 28 day. Beside that the research shows that the minimum curing time is 14 days.

Key words: Earth Canals, gypsum contained, Soil Cement Mixture, collapsibility

معالجة القنوات الترابية المنفذة على التربة الجبسية باستخدام خليط التربة والسمنت

الخلاصة

يمكن ان تعتبرالتربة الجبسية واحدة من اهم واحدة من اهم المشاكل التي تواجه المهندسين وبالاخص عند استخدامها كأساس للمنشأت الهيدروليكية والطرق و المنشأت الاخرى.ان التربة الجبسية تكون قوية ولها خصائص جيدة عندما تكون جافة ولكن تنشأ المشكلة عند بناء المنشآت الهيدروليكية أو المباني الثقيلة على هذه التربة بعد ترطيب المياه للتربة عن طريق رفع مستوى سطح الماءالجوفي من أي مصدر أو من الأمطار التي تؤدي إلى انحلال المحتوى الجبسي.

تثبيت التربة بالاسمنت حققت نجاحا عند استخدامها للتغليف او لتبطين القنوات الترابية والسدود الترابية وسواقي المبازل لتقليل خطر التعرية وانهيارية التربة . في هذه الدراسة اعتمدت معالجة التربة الجبسية باستخدام خليط الاسمنت والتربة .اختبار الانهيارية والهطول اجريت على تربة جبسية جلبت من محافظة كربلاء وبنسبة جبس (42,55)% .خلطت التربة مع السمنت بنسب % (2,3,5,8,10,13,and 15) كنسبة وزنية ثم رصت لتصل الى الكثافة الجافة العظمى (16.5 كغم/م^3) وباضافة المحتوى المائي (% 12.8).الفحوصات المختبرية اجريت في قناة مختبرية وبسرعة ثابتة (0.148 م/ثا) خلال الفحص . اوضحت النتائج ان استخدام نسبة 10% من السمنت قللت الانهيارية بنسبة (86.54%) كمابقيت نسبة الجبس بالتربة هي نفسها تقريبا بعد 28 يوم الى جانب ذلك اظهر البحث الى ان اقل وقت لازم للانضاج هو 14 يوم .

الكلمات الرئيسية: القنوات الترابية ،المحتوى الجبسي ،خليط التربة-الاسمنت ،الانهيارية.

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1. INTRODUCTION

The stability of earth channels depends on many factors such as strength of bed channels, slope and bank materials and the flow characteristics. Erosion that occurs in the earth channels is the dangerous problem especially when it is constructed on gypseous soil. As well as there are several places in the world having a problem of gypsum contaminated soil is known as gypsiferous soil.

Gypseous soil in Iraq cover about 0.6% of the area of the world ,**Alphen and Remero, 1971**, and cover nearly (31.7%) of the surface sediment in Iraq with gypsum content (about 10-70%) **Ismail, 1994**. The gypseous soil is considered as collapsible soils, the gypseous soils consist of gypsum which is Mineral salt known as calcium sulphate sulfate ($CaSO_4.2H_2O$). Gypseous soil with high bearing capacity, it is hard unless the water infiltrated into it or attracts it.

The water due to dissolve gypsum content causing the soil to highly compressible and make it soft that leading to several foundation problems due to collapse of soils structure and the formation of cavities when constructed earth dams, highway embankments and other engineering structures, loose soil must be compacted to increase the unit weight of it. The compaction is to improve the engineering properties of mass of the soil by reducing compression, increasing strength, changing volume and permeability and improving the stability of structures, **DAS, 1990**. Therefore, many researchers conducted to study the behavior and properties of this soil because a problem observed when constructed above the gypseous. On the contrary when the gypseous soils are exposed to water a sudden collapsible behavior was reported, **Al-Saoudi, et al., 2013**. **Aziz** and **Jianlin, 2011**, were reported that many of former researches were trying to find an effective materials for improvement the gypseous soils like, **Aziz, 2001**, was improved the gypseous soil by fuel oil, **Al-Zory, 1993** , studied the stability of lime in treatment of gypseous soil, while **Al-Hello, 2008** and **Al-Numai ,2010,** were suggested additives for improvement this type of soil , such materials are cement ,clinker. **Ramaji, 2012**, studied the using of low-cost methods to stabilize of soil, by using Portland cement and lime and fly ash and other All of these methods may have disadvantages because they are inefficient and expensive. **Gomez** and **Anderson, 2012**, present the soil-cement mix design, results and field-laboratory procedure. Cement and soil mixtures are prepared with varying cement content ranging from 4% to 6% by weight. The mix design requirement was to determine the cement content necessary to obtain a minimum of unconfined compressive strength.

Mahawish, 2013, study the chemical stability of the gypseous soil under the soil that used for the construction of roads in Iraq and stabilized the gypsum soil with a different percentage of cement to determine the effect of phosphorus when it was mixed with other additives Soil was taken from Abu Ghraib city with gypsum content of 35%. The addition of 6% of the cement and 1% of the phosphorus oxide will improve the soil.

In **2015, Eskisar**, published experimental results for the use of cement in the installation and adjustment of medium plastic clay. The soil was mixed with Portland cement at 5% and 10% dry weight so the water content was 40 and 60%. The treatment period ranged from 7 to 28 days. The results of the fusion tests showed that the compression index decreased and the pressure increased before the cement content increased.

Al-Abd Allah, 2015, studies the effect of the mixing gypsum soil-cement on the usability of compression, the result show that the cement addition to the soil reduces the usability of compression and the reduced the collapsibility of it.

Raman, et al., 2016, studies the stabilization of the loose soil stratum by grouting the soil with the cement. The Cement grout are injected into the soil with different ratio of 10:1 (Water: Cement), 8:1, 6:1, 4:1 with the low pressure. After 3 and 7 days of curing the strength properties of the grouted soil are determined. From this study it is proved that the grouting can be an effective method for reducing the permeability of the grouted soil sample and increasing the strength of the grouted soil sample in loose and medium dense state.

Woods, 1960, explained that the Soil-cement is a mixture of soil material shovel and measured quantity of Portland cement and water, high density compaction. The soil-cement technique used as effective way to stabilization soil which was used during Second World War (1939 – 1945) ,**Woods, 1960**. This technique founded acceptance especially in roads and airports that's belong to contains of strong cementation compound this compound is differ in its behavior than the soil properties or cement behavior ,**Herzog, 1963**.

2. EXPERIMENTAL PROGRAM

This project consists of mixing soil with cement so the both were tested as follow:

2.1 Soil tests:

The soil was taken from Karbla Governorate, and several laboratory tests are employed on samples to describe the soil properties of soil study. Before conducting any test the soil was sieving from sieve 4# for compaction test. The tests were embodied the following:

- **Specific gravity:** The determination of the specific gravity was according to BS 1377 the, to avoid the dissolving of gypsum in water kerosene is used instead of water, **Head, 1980**.
- **The grain size distribution curve:** The grain size of the gypsum soil was distributed directly to the soil without any treatment. Distribution of grain size was determined according to ASTM (D922-72) with dry sieving. **Fig.1** shows the grain distribution curve for the soil sample. The figure clearly shows that the soil sample is classified as poorly graded sandy soil according to Unified Soil Classification System (USCS). Thus the soil has no consistency limits (liquid and plastic limits).

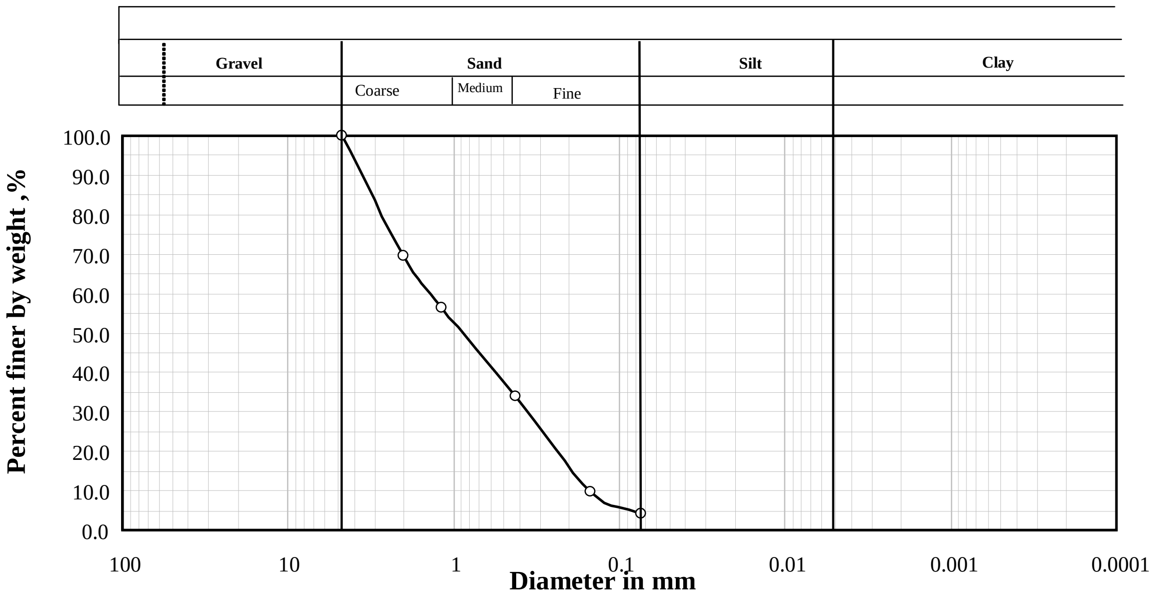


Figure 1. Grain size distribution curve for bed channel soil.

- **Standard Proctor test:** The unit weight and water content were determined according to BS 1377, the maximum dry unit weight was 16.5 kN/m^3. The water content was determined by drying the soil at temperature of 45ºC in order to overcome gypsum dehydration. The optimum moisture content (OMC) by using the standard Proctor test was 12.8 % **Fig.2**.

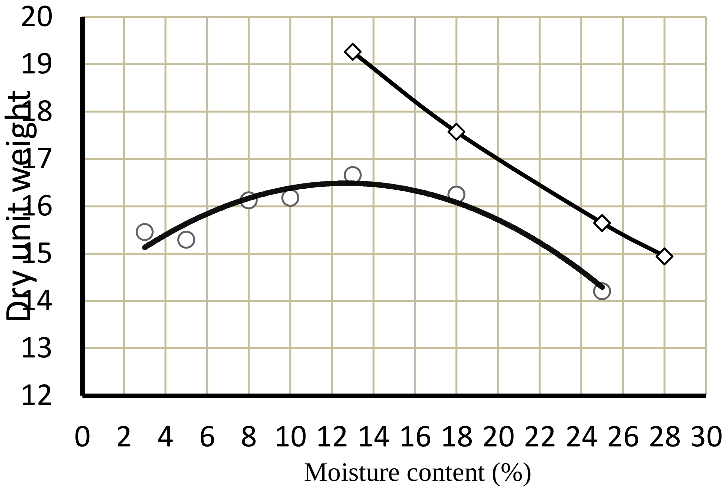


Figure 2. Compaction test.

- **Determination of Gypsum Content:** Several methods and techniques have been suggested to determine the gypsum content. One of these methods is the hydration method of **Al- Mufty** and **Nashat**, 2000, which is used to determine the gypsum content of the natural soil in this study. The hydration method can be summarized as follows: The sample is oven dried at temperature of 45°C until the sample weight remains constant. This weight is recorded as *W45°*C**.** After that the sample is dried to110°C temperature for 24 hrs. And then the weight is recorded as *W110 ° C*. Gypsum content (χ) is then calculated according to the following equation:

$$X = (W45^{o} - W110^{o}) / W45^{o} \times 4.778 \times 100 \quad (1)$$

Where:
W45 °C = weight of sample at a temperature of 45°C.
W110 °C = weight of sample at a temperature 110°C.
The results of soil tests were shown in **Table 1.**

2.2 cement test:
The cement that used in this project is Portland cement; the results of X-Ray test were shown in **Table .1**.

Table 1. Summary of Chemical and Physical Tests for Soil and Additives.

Soil		Component of the used cement	
Gypsum Content (%)	42.55%	Na_2O	1.436%
		SiO_2	17.97%
		Al_2O_3	2.79%
Maximum Dry Unit Weight (kN/m^3)	16.5%	Fe_2O_3	5.451%
		CaO	69.18%
Optimum Water Content (%)	12.8%	MgO	1.445%
		K_2O	0.5648%
		P_2O_5	0.0602%
Specific Gravity (Gs)	2.55	SO_3	2.88%
		MnO	0.267%
Soil Classification According to (USCS)	poor-graded sandy soil	CuO	0.00593%
		ZnO	0.01228%
		TiO_2	0.253%

2.3. Flume preparation:

The tests were executed at the Hydraulic Laboratory of Water Resources Engineering Department College of Engineering University of Baghdad that was performed by flume. The flume it is a glass fiber molded in steel stiffeners which it has (10) m length , (0.3) m width and (0.3) m depth which it is divided into three main parts , the first part inlet tank .The second part entering water to the most important part of the flume represents the working section . The last part of the flume is a main reservoir crest weir uses to measure the discharge over the weir point gauge with accuracy (±1) mm, the point gage are used to measure the elevation of the soil surface to evaluate the collapsibility, this point gage hold on carriage which can easily move in any direction above the working section along the flume, two gates are placed at the begging and the end of the flume, **Fig. 3** shows the flume and its parts beside the point gage and compacter that modified in this research in order to compact the soil.

3. THE COLLAPSIBILITY EVALUATION:

The collapsibility evaluation of the soil consist of measuring the elevation of the soil surface with time, to do that the soil surface elevation were measure as points in two dimension ,**Fig.4** show the mesh that proposed to measure the elevation of soil surface.

Seven soil-cement test specimens were constructed with cement contents of 2, 3, 5, 8, 10, 13 and 15 % percent cement content by weight in addition to specimen without treatment. Batch measurements were taken to prepare the soil-cement mixture. Soil-cement mixture was placed into the flume and compacted using a compactor to achieve a compacted maximum dry unit weight with thickness of 10 cm. Then the flume was operated with a velocity of 0.148 m/sec and horizontal slope, the flume shown in **Fig .3**, soil cement and compacted soil-cement mixture shown in **Fig.5**.

After operating the flume, series of measurements were taking after 3 days, 7 days, and 14 days and at 28 days to the elevation of the soil by using the point gage during the test. These reading were used to draw contour maps by using surfer program. **Fig .6** shows the contour maps for surface levels of the natural soil while **Fig .7** to **Fig .13** shows the surfer maps for the treated soil. The collapse potential is calculated according to the definition of **Jennings** and **Knight**, **1975**, in which:

$$C.P. = \Delta H / (H_0) \qquad (2)$$

Where:

ΔH = difference in height of soil specimen before and after soaking.

Ho = initial height of soil specimen.

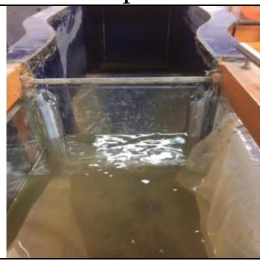
In this research the collapse potential calculated by taking the different in elevation for each pint and dividing this different on the original elevation for that point. That computation repeated for all the points along the soil surface in the flume and for each curing time (7, 14, and 28) day, in fact each batch measurements were lasted for two day. The gypsum content it's also measured after treatment of the soil and the results shown in **Fig.14**.

The flume Upstream section

The compactor

The point gage

The Flume downstream section



Inlet gate

Out let gate

Figure 3. The flume that used in the present work.

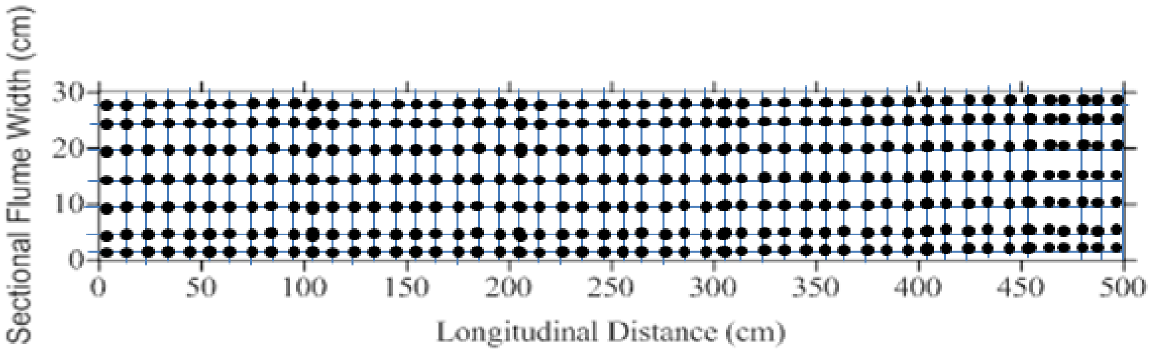


Figure 4. The mesh of the tested point along the soil surface.

Figure 5. Soil-cement mixture and compacted soil cement.

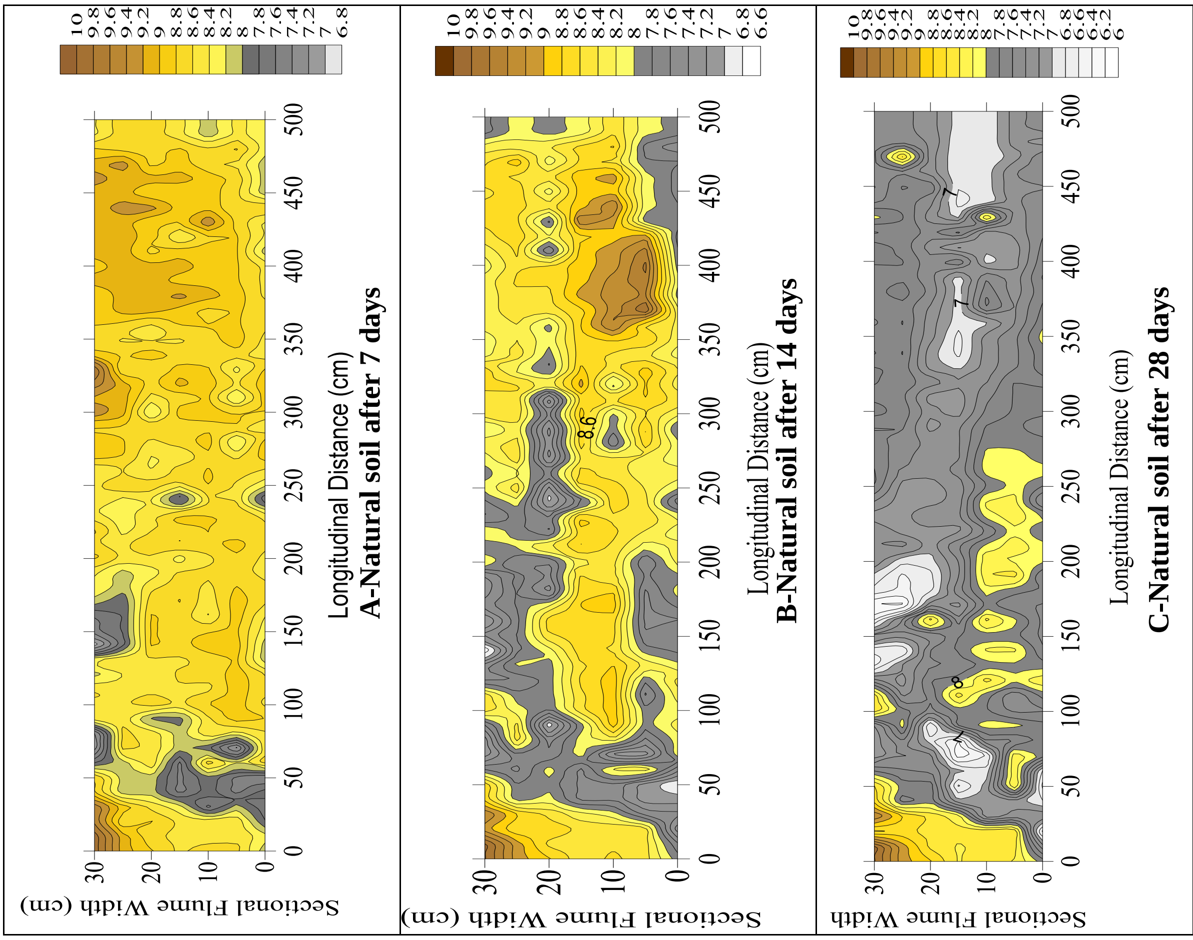


Figure 6. The contour maps for surface levels of the natural soil with time with maximum elevation of soil (10.2) cm before starting taken the reading.

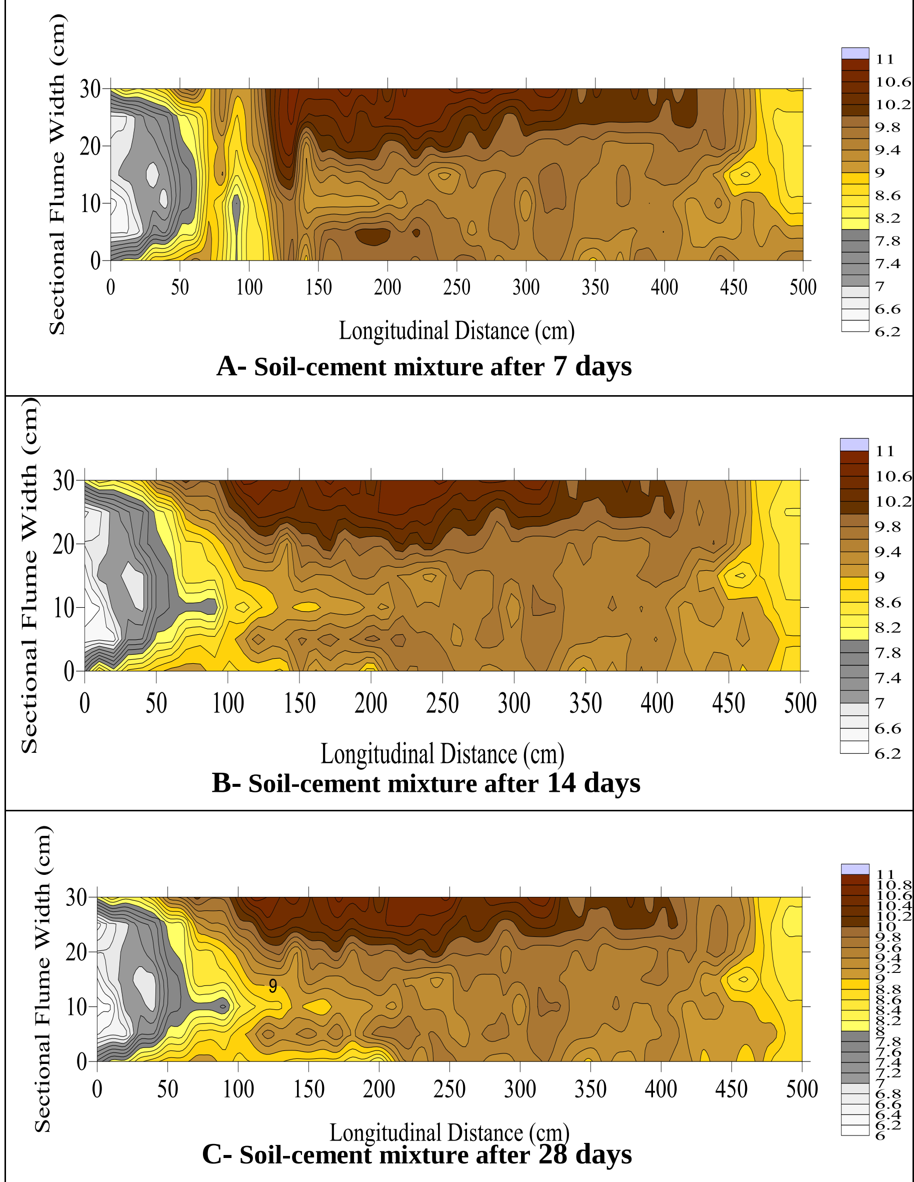


Figure 8.The contour maps for surface levels of the soil-cement mixture treated with cement ratio 3% with maximum elevation of soil (11.2)cm before starting taken the reading.

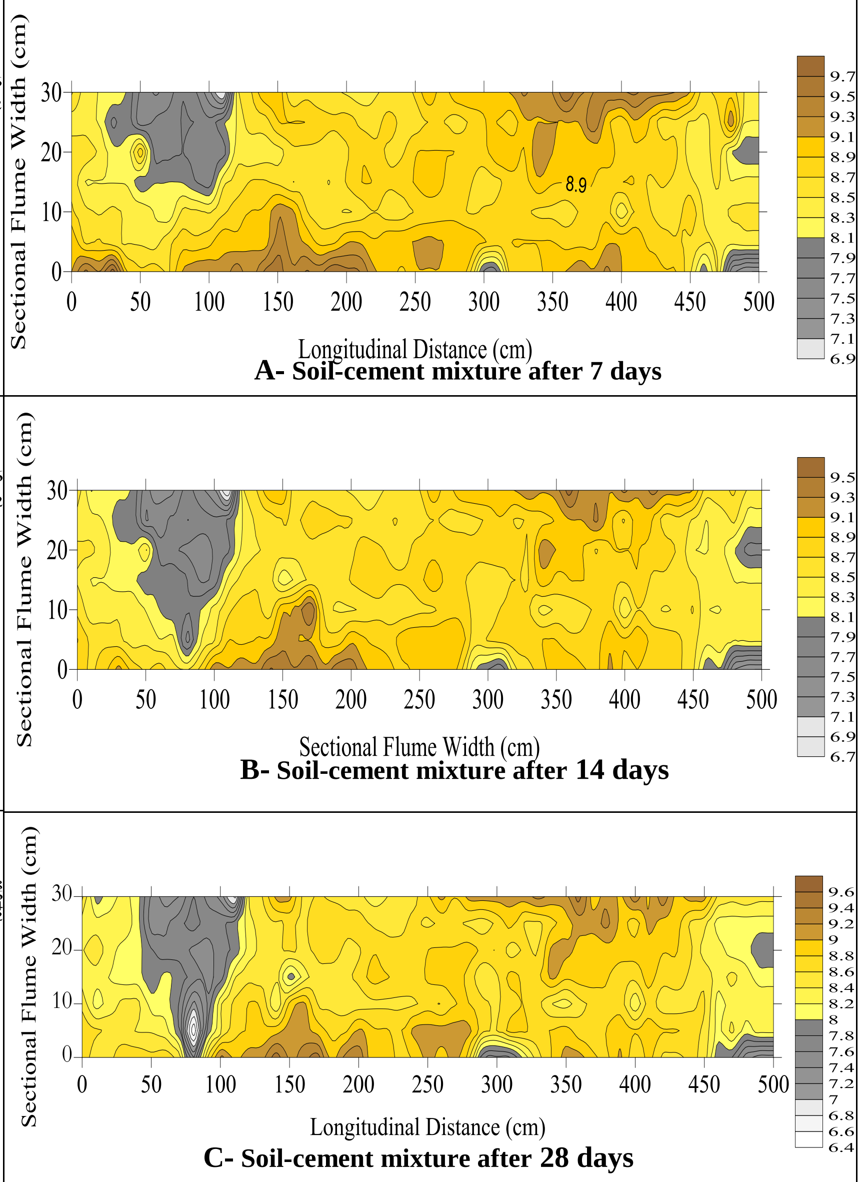


Figure7. The contour maps for surface levels of the soil-cement mixture with cement ratio 2% with maximum elevation of soil (11)cm before starting taken the reading.

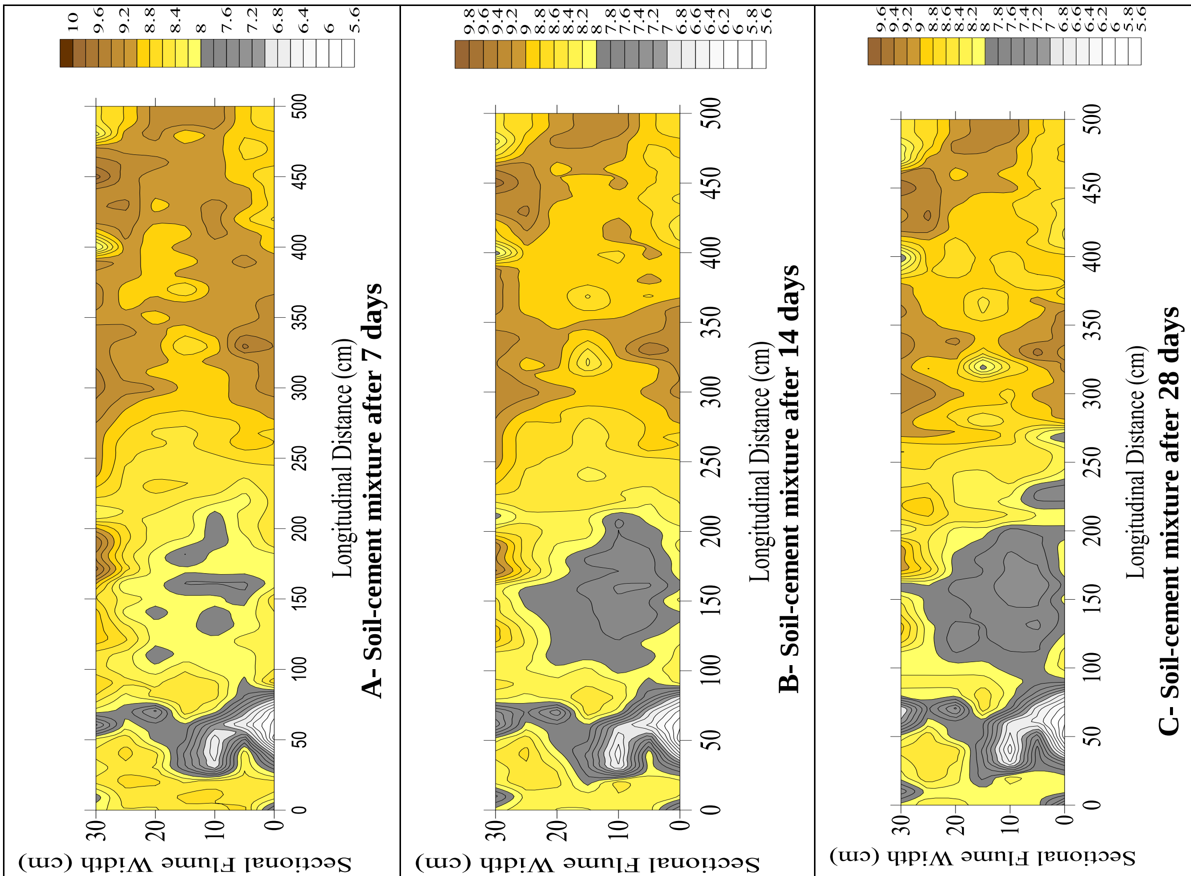


Figure 9. The contour maps for surface levels of the soil-cement mixture treated with cement ratio 5% with maximum elevation of soil (10.4)cm before starting taken the reading.

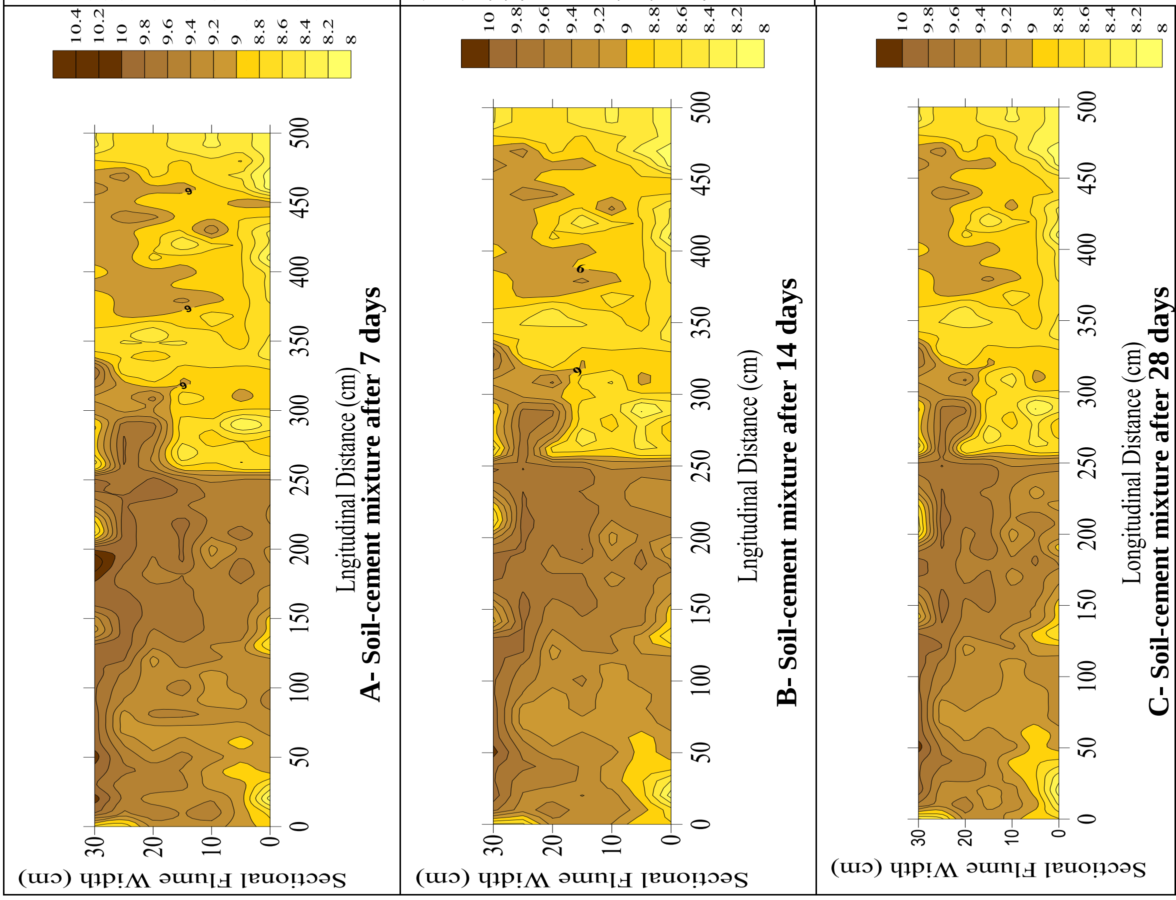


Figure 10. The contour maps for surface levels of the soil-cement mixture treated with cement ratio 8% with maximum elevation of soil (10.9)cm before starting taken the reading.

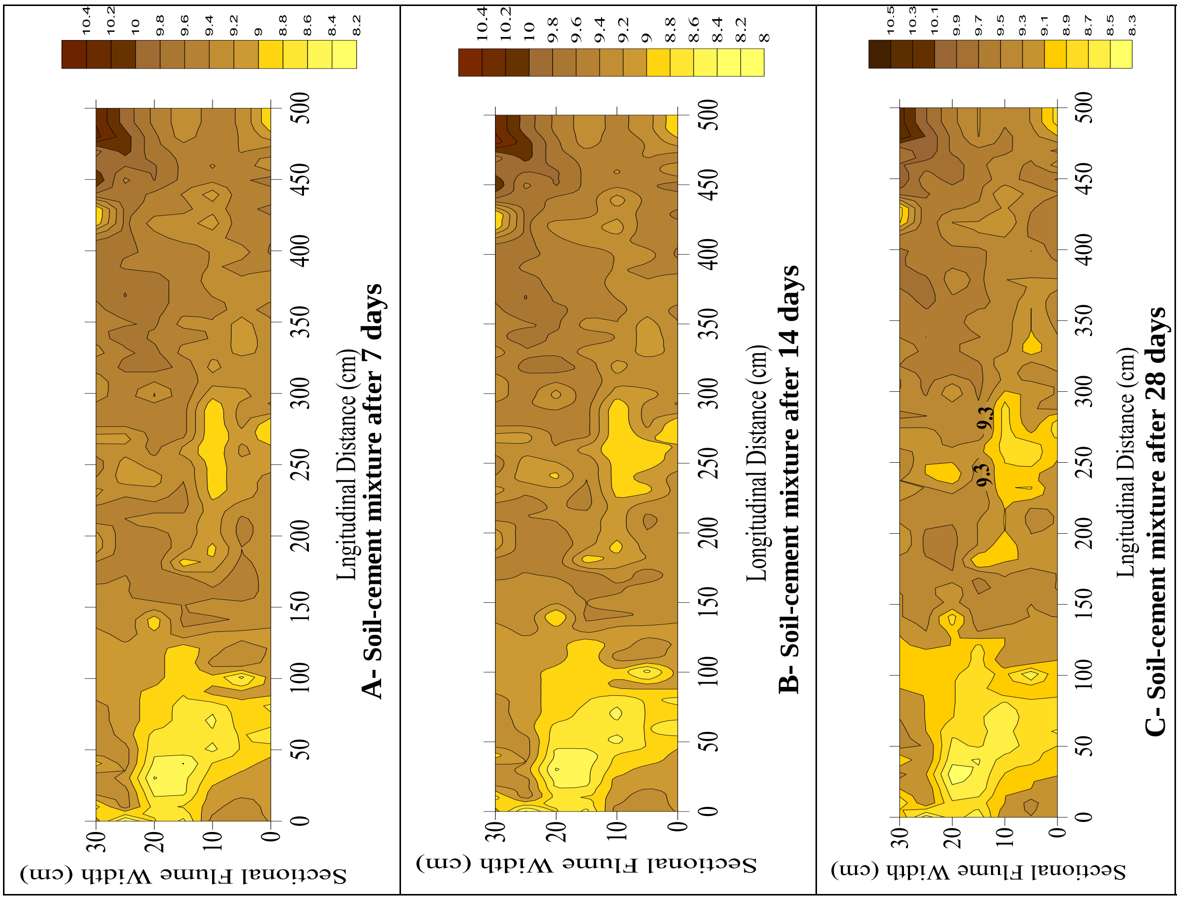


Figure 11. The contour maps for surface levels of the soil-cement mixture treated with cement ratio 10% with maximum elevation of soil (10.8)cm before starting taken the reading.

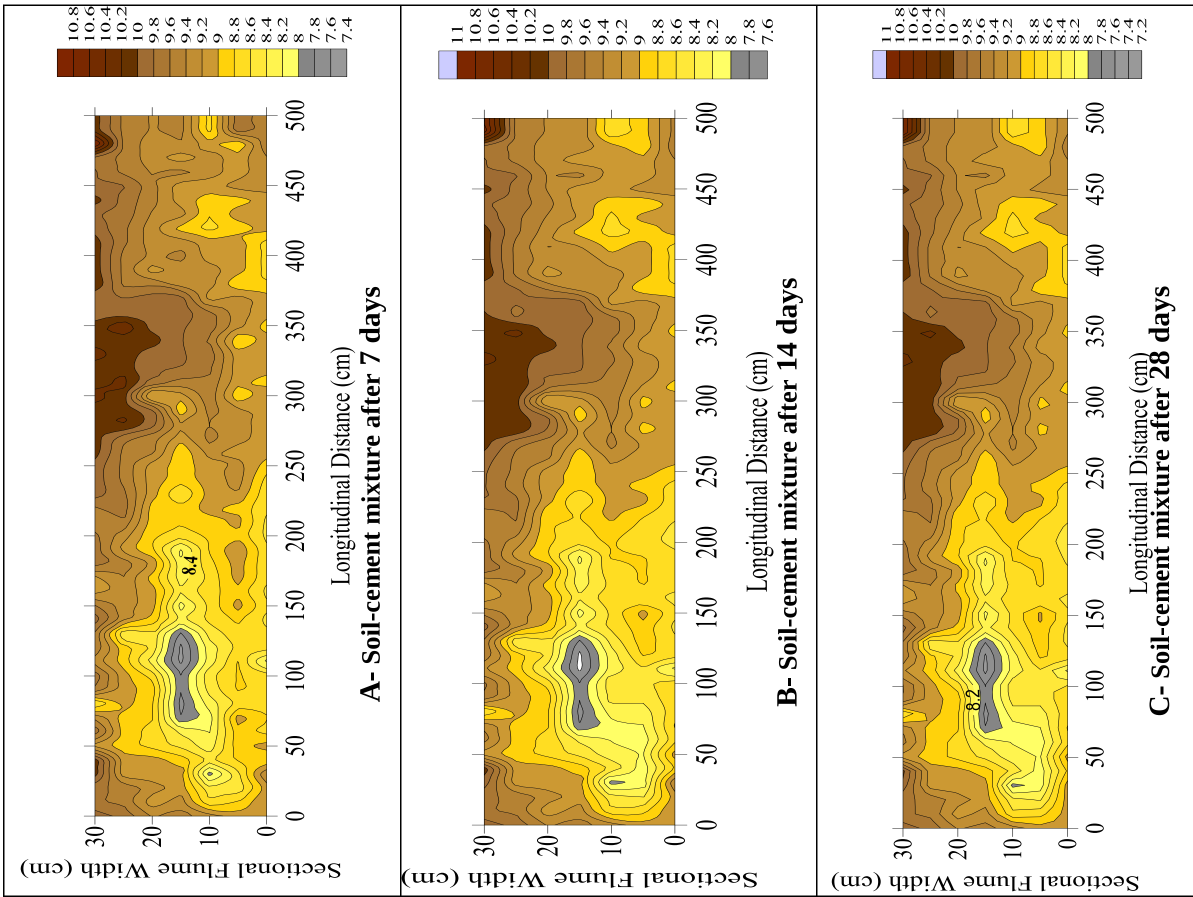


Figure 12. The contour maps for surface levels of the soil-cement mixture treated with cement ratio 13% with maximum elevation of soil (10.6)cm before starting taken the reading.

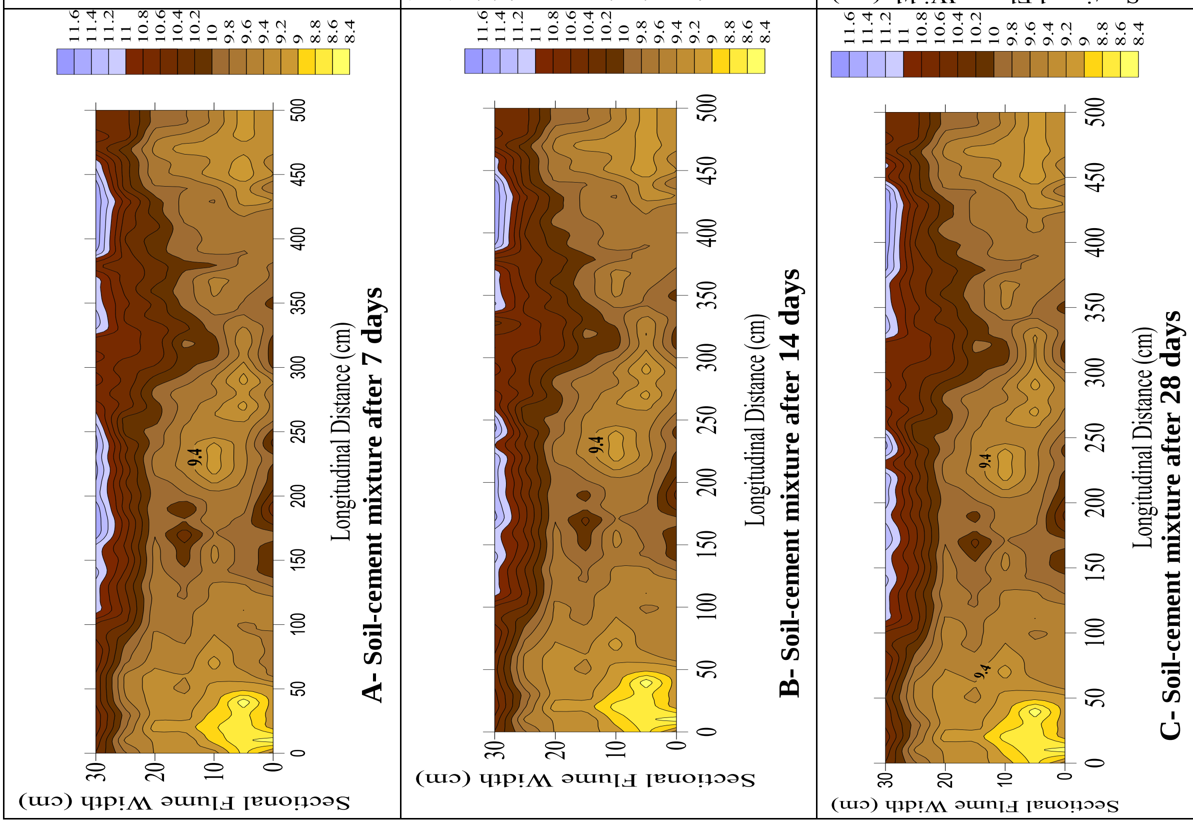


Figure 13. The contour maps for surface levels of the soil-cement mixture treated with cement ratio 15% with maximum elevation of soil (11.8) cm before **starting**

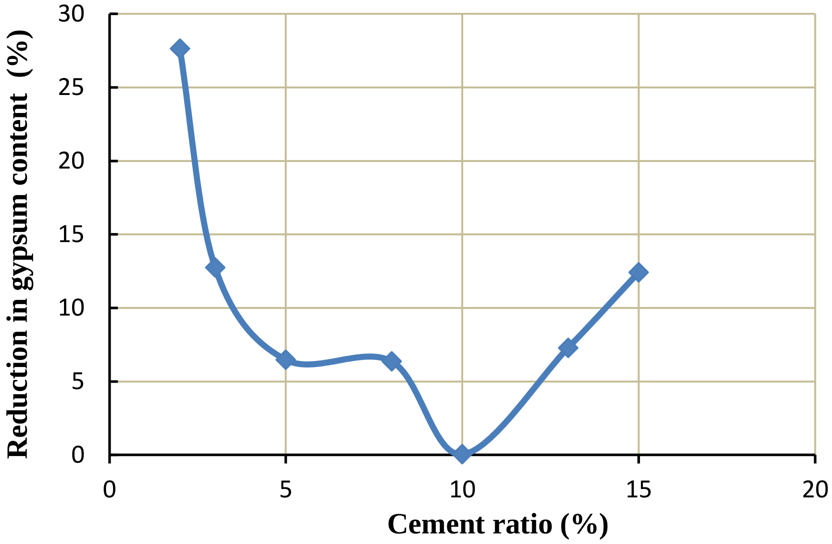


Figure 14. Reduction in gypsum content with cement ratio of soil-cement mixture after treatment.

4. EFFECT OF TREATMENT ON SOIL PROPERTIES:

For treatment of the soil, cement material was chosen cement is consisting mainly of lime, silica alumina and iron oxide. The compounds of cement are listed in **Table .1**. Seven percentages of cement additive had been chosen (2, 3,5,8,10,13, and 15) %, to investigate the effect of this material on the behavior of gypsum soil to reduce the possibility collapsibility. The cement compatible with the soil gradation, **Fig.15** illustrates the effect of soil-cement mixture on collapsibility of the soil during curing time

The comparison shows that the treatment of gypseous soil with soil-cement mixture improve the collapsibility in a good manner as compared to other method of treatment.

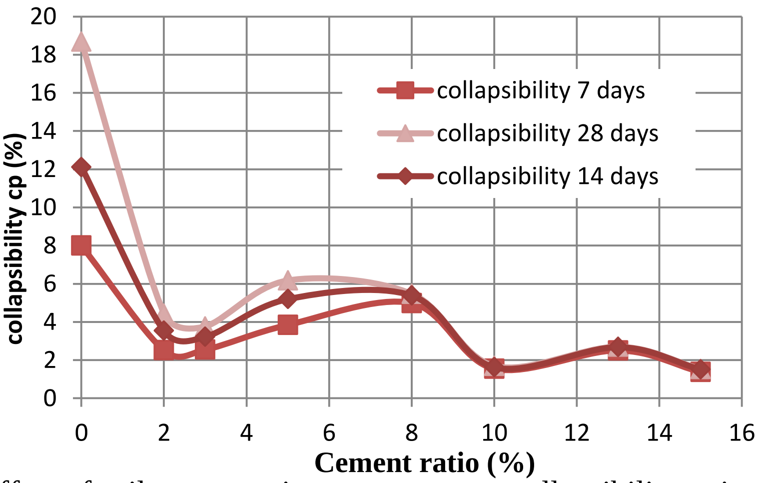


Figure 15. Effect of soil-cement mixture on average collapsibility ratio after 7, 14, 28 days.

By adding 2% of cement the collapsibility of soil reduced with comparing to the natural soil and its increased with time (after 14 and 28 days) , this decrease of collapsibility continues by an increasing the cement ratio by adding 3 % of cement . By adding 5 %, 8 % the collapsibility increased in comparison with the ratio of cement (2, 3) in which increased in 5 % (also increase with time). Then the collapsibility decrease by adding 8 % with comparing 5% of cement ratio but the change of collapsibility nearly constant with time (after 14, 28 days). At the percentage of 10 % of cement the collapsibility reaches to its minimum value with a constant rate of change in collapsibility with time. Also by adding 13 % and 15% of cement ratio to the soil the collapsibility decreases to give a value approach to the value of 10% of cement. The best ratio of cement that reduce the collapsibility to it minimum value and give a constant value of change with time (10%, 13% and 15 %) to this type of gypsum content but before chosen the best ratio, it should be ensure that this ratio of cement keep the gypsum content constant without desolation which leads to failure of soil. This may be due to filling the voids in the soil skeleton by cement material, which increases the cementing bonds between particles and decreases the solubility of gypsum. The same behavior can be observed in the results of gypsum content after treatment, **Fig .15** showed the redaction ratio of gypsum content with increasing the cement ratio , this is found by testing the gypsum content before and after the treatment ,so the reduction in the solubility found by founding the different of gypsum content between the untreated and treated soil at the end of curing and defending this value to the original value of gypsum (42.55).It noted that the reduction in gypsum content decrease with increasing the cement ratio and nearly remain constant by adding 10% of cement. The reason of that belongs to that the (SO_3) content in cement which reacts with water to product the gypsum. That appears by adding the cement in high rate. So it necessary to test the cement and determine the (SO_3) content within the cement composition.

Fig 6 to **Fig.13** shows the contour maps for the surface levels of the untreated and treated soil with curing time.

The aim of this work is to study the collapsibility of the gypseous soil with water flow over the soil that's mean the effect of corrosion over the surface of soil and the effect solubility by the water infiltration, while the other studies found the effect of water only that entered the soil from one direction by consolidation test .Because of the limited time the study was done only by using flume without made the consolidation test.so the comparison between the results of collapsibility for the treated and untreated soil considers in this study and previous studies is plotted in **Fig.16** ,a study was selected for comparison, **Al-Hello** ,**2008**, which studied the improvement of gypseous soil for Samarra-salah aldeen governorate with a gypsum content of 32% many test were carried out on soil by adding Portland cement added (1, 2 , 3%) of cement. And **Al-Neami, 2010,** treated the gypseous soil with by clinker additive for gypseous soil with gypsum content (40%) from Al-Axandria region, Babylon Governorate. He had chosen three percentages of clinker additives (2, 4 and 6 %).

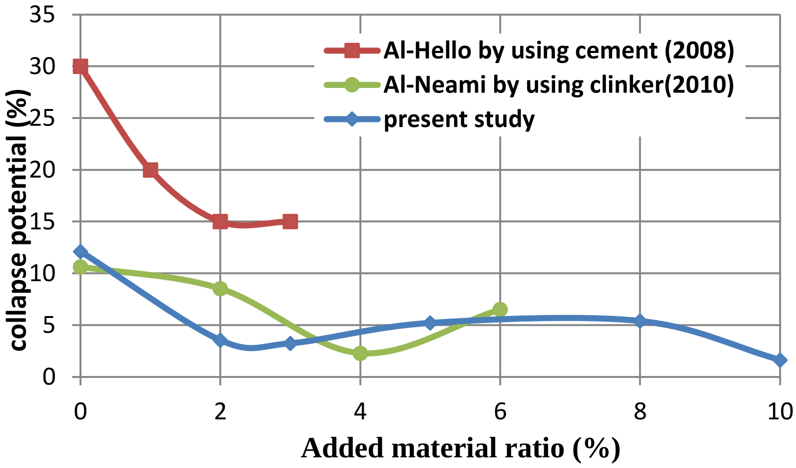


Figure 16. The comparison between the clinker and soil-cement mixture added to the gpyseous soil after seven days.

5. CONCLUSIONS

The following conclusions can be drawn from the study:

1- The treatment of sandy gypseous soil with 10 % of cement represented the optimum percentage which gives more advantage comparing with other percentages which used in this research.

2- The increase in cement percentage (in soil-cement-mixture) leads to increase the improving of soil .

3- The comparison between the treated of cement method applied in this research and the treatment of cement by Al-Hello and the treatment of clinker method applied by Al-Neami show that the cement treatment of adding 2 % or 3% show the best reduce of the collapsibility about 50% where the by Al-Hello while Al-Neami which used clinker treatment of adding 4% show the best reduce of the collapsibility about 79% but the present research show that the use of 10% of cement reduce the collapsibility to 86.54%.

4- all the research applied in previous studies use consolidation cell only with static load where in present research the flume used with flow in all the direction so in Al-Hello research the ratio of 2 % and 3% was enough to reduce the collapsibility of nearly 50% and Al-Neami research the ratio of 4% was enough to reduce the collapsibility of nearly 79% where the present research show that ratio of 10% is the ratio that should be added to reduce the collapsibility of 86.54%.

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