IMPROVEMENT OF THE MECHANICAL PROPERTIES OF GYPSEOUS SOIL BY ADDITIVES

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Abstract

The presence of gypsum in soil as bond agent alters its behavior, in other words, there is a large influence of gypsum on the physical and mechanical properties of soil. This influence depends mainly on the amount and type of gypsum presented in the soil.
The soils used in this study were brought from one locations at Al-Tar region west of Al-Najaf city. These soils had gypsum content of 35%. The classification tests indicate that the soil is poorly graded. In this paper an experimental study is carried out on the effect of three different additives to the gypseous soil in order to improve the compaction properties of the gypsum soil. The additives used in this study were cement, ceramic and mix of cement and ceramic. The percentages of ceramic was varied between 4-12% in the first series whereas percentage of cement was between 4-8% by weight in the second series. In the third series the percentage of cement was kept constant 4% by weight while the percentage of ceramic varied from 4 to 12% by weight. Control groub without any additive was also tested to determine the effect of additives. The results show that the best improvement in compaction characteristics test is achieved when the sample is treated with adding mix of cement and ceramic, the maximum dry density only increase with the increases in mixing content, while the opposite is true for the optimum water content. The results also show that the maximum dry density of treated gypsum soil with ceramic material increases with the increase in ceramic content up to 8% after which the density decreases.

Key words: Soil, Gypsum, Ceramic, Cement, Compaction

تحسين الخواص الميكانيكية للتربة الجبسيه بواسطة إضافات

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الخلاصة

وجود الجبس في التربة كعامل ربط يغير سلوكها، بتعبير أخر، هناك تأثير كبير للجبس على الخواص الفيزيائية والميكانيكية للتربة. يعتمد هذا التأثير بشكل رئيسي على كمية ونوع الجبس الموجود في التربة. لتربة المستخدمة في هذه الدراسة أخذت من موقع واحد من منطقة الطار الواقعة غرب مدينة النجف. كانت التربة ذات محتوى جبسي (٣٥%). أشار اختبار التصنيف بأن التربة رمليه ضعيفة التدرج. في هذا البحث أجريت دراسة تجريبية على تأثير ثلاث إضافات مختلفة إلى التربة الجبسيه لكي تحسن خواص الرص للتربة الجبسيه . الإضافات المستعملة في هذه الدراسة هي الخزف ، الأسمنت وخليط الأسمنت والخزف. النسب المئوية لمادة الخزف كانت تتفاوت بين (٤-١٢%) في السلسلة الأولى بينما نسبة الأسمنت كانت بين (٤-٨%) من وزن التربة في السلسلة الثانية. في السلسلة الثالثة كانت نسبة الأسمنت ثابتة (٤%) بينما تتراوح نسبة السيراميك بين (٤-

١٢%) من وزن التربة. كذلك فحصت التربة بدون أي إضافات لإيجاد تأثير هذه الإضافات. بينت النتائج بأن أفضل تحسين في خصائص الرص ينجز عندما تعالج العينة بإضافة خليط الأسمنت والخزف، حيث وجد أن الكثافة الجافة العظمى تزداد بزيادة محتوى الخليط، بينما العكس صحيح لمحتوى الماء الأمثل. بينت النتائج أن الكثافة الجافة العظمى للتربة الجبسيه المعالجة بمادة الخزف تزداد بزيادة محتوى الخزف إلى حد ٨% بعدها تتناقص الكثافة.

List of Abbreviations and Notations

Abbreviations	Meaning
ASTM	American Society for Testing and Materials
A	Ceramic Content by Weight (%)
BS	British Standard
C	Cement Content by Weight (%)
e_o	Initial void ratio
SP	Poorly graded sand
χ	Gypsum content (%)

Introduction

Gypsiferous soils usually stiff when they are dry, but these soils may be affected greatly when subjected to changes in water content due to water table fluctuation, or due to water infiltration which may dissolve gypsum causing pores, crack and producing cavities that lead to increase the permeability in gypseous soils. Therefore, the safety and good performance of the foundation of structures and earth structures such as embankments and dams will be governed by the changes in the properties of these soils. Gypsiferous soils occupy about 100 million ha (one million km^2) in the world across Algeria, Argentina, Australia, Iraq, Libya, Somalia, Spain, Sudan, Syria, the former USSR and other arid and semi aired countries with annual rainfall of less than (500)mm **(FAO, 1990).**

Compaction is the improvement of the engineering properties of the soil mass which occurs through increasing strength, reducing compressibility, volume change and permeability, and increasing the stability of structures **(Lambe and Whitman, 1979, Holtz and Kovacs, 1981)**

Kattab (1986) reported that the maximum dry density for treated and untreated granular soils increases with the increase in gypsum content up to (15%) after which the density decreases.

Subhi (1987) found, for compacted soil, that the maximum dry density only decreases with the increase in gypsum content, whereas the optimum moisture content increases or decreases according to the size of the added gypsum grains.

The work of **Al-Heeti (1990)** on compacted gypsified silty clay showed a different behavior. The maximum dry density increases as the gypsum content increases, while for another silty clay, originally gypseous soil, the maximum dry density decreases as the gypsum content increases and after a certain value it starts to increase again.

Al-Layla and Al-Obaydi (1993) showed that for high gypseous soils, the maximum dry density is slightly affected by the change in gypsum content, while the optimum water content decreases with the increase in gypsum content.

Al-Obaydi (1999) noticed that using the standard and modified compactive effort, the maximum dry density increase with the gypsum content, due to the more gypsum occupying the voids and the optimum water content decreases slightly. Also, the maximum dry density increases by about (12%) when the compactive effort increases from standard to modified, while the average reduction in the optimum water content is about (15%).

Al-Gabri (2003) showed that the optimum moisture content decreases and maximum dry density increases with the increase of gypsum content.

The Purpose Of The Study

The purpose of this study is to investigate the effect of three different additives (ceramic, cement and mix cement and ceramic) to the gypseous soil on compaction properties.

Laboratory Testing Program

The testing program in this work can be summarized in the following groups:

- Classification tests are performed firstly including physical and chemical tests. The physical tests include specific gravity, Atterberg limits, grain size distribution and water content.
- Standard Proctor compaction tests are carried out to determine the moisture-density relationship for the virgin soil and for treated soil by three addition (cement, ceramic and mix cement and ceramic) as follows:
    - **Group one:** The soil is tested in the natural case (untreated soil).
    - **Group two:** In treated case with

1- Ceramic (three various percents are used 4, 8 and 12% by weight of soil).
2- Cement ((three various percents are used 4, 6 and 8% by weight of soil).
3- Mix cement and ceramic (the percentage of cement was kept constant 4% by weight while the percentage of ceramic varied from 4 to 12% by weight).

Classification Tests

Physical Tests

- Specific Gravity:

The specific gravity of the soil is determined according to the British standards **(BS 1377: 1975, Test No.6 (B), Head 1980),** but Kerosene is used instead of water due to the dissolution of gypsum in water.

- Atterberg Limits:

Liquid limit test is carried out in accordance with **(BS 1377: 1975, Test 2(A)),** using cone penetrometer method. The plastic limit is determined in accordance with **(BS 1377: 1975, Test No. 3).** The liquid and plastic limits are carried out on soil passing sieve (No.40) and the temperature used for drying is maintained at (45–50)°C due to the presence of gypsum in the soil, **(ASTM 2216-80).**

- Grain Size Distribution:

The grain size distribution is determined by sieve analysis test, which is conducted in accordance with **(ASTM D922-72)** with dry sieving.

- Water Content

This is performed in accordance with **(BS 1377: 1975, Test (A), Head 1980).** The water content is determined at drying temperature of (45)°C because the soil contains a significant amount of gypsum, to avoid the loss of crystal water is required.

Chemical Tests

- Total soluble salts **(TSS)%** are determined accordance to the **(BS 1377: 1975, Test (9)).**
- The gypsum content is found according to the method presented by **Nashat and Al-Mufty, (2000).** This method consists of oven drying the soil at (45°C) until the weight of the sample becomes constant. The weight of sample at (45°C) is recorded. Then, the same sample is dried at (110°C**)** until the weight becomes constant and recorded.

The gypsum content is calculated according to the following equation:

$$\chi\ (\%) = [(W_{45°C} - W_{110°C}) / W_{45°C}] \times 4.778 \times 100$$

Where:

χ = Gypsum content (%)

$W_{45°C}$ = Weight of the sample at (45°C)

$W_{110°C}$ = Weight of the sample at (110°C)

Compaction Tests

Standard compaction tests are carried out for the untreated and treated soils to determine the moisture-unit weight relationship according to **(ASTM D 698, Method A, 2003)**. A mold of (101.6) mm in diameter and height of (115.5)mm is used. Samples are compacted in three equal layers each hammered by (25) blows using (2.5) kg hammer dropped from (30.5)mm height.

Testing Material

The soil samples used in this study were brought from one location at Al-Tar region west of Al-Najaf city. The soil samples are obtained from a depth of (2.0)m below the natural ground surface. The samples are packed in double nylon bags and transported to the Soil Mechanics Laboratory at Al-Kufa University for testing.

Ceramic materials are used in this study to modify mechanical properties for gypseous soil. Ceramics are classified inorganic and nonmetallic materials. They are generally made by taking mixtures of clay, earthen elements, powders and water and shaping them into desired forms then it is fired in a high temperature oven. Often, ceramics are covered by decorative, waterproof, paint-like substances knowing as glazes. The ceramic materials are mixed with gypseous soil passing through sieve No.4. The results of physical and chemical tests are summarized in **Table (1).**

The cement material is used in this study to modify the soil. All kinds of cement are good to modify the soil, but most familiar kind in usage is the Portland cement. It helps to increase soil resistance, its endurance, durability and at the same time it decreases humidity variegation.

Results And Discussion

The soil specimens can be classified according to the Unified Soil Classification System (USCS), as poorly graded sand (SP). The result of Atterberg limit test indicate that the sample is non-plastic.

The results of standard compaction test for the natural gypsum soil (without additives) are tabulated in **Table (1).** The relationship between dry density and water content for the tested soil is shown in **Figure (1),** while **Figures (2)** to **(4)** show the relationship for samples tested after treatment with the three additives.

In **Figure (5),** the three additives content is plotted versus maximum dry unit weight in normal scale. It was found that the maximum dry density increases with increasing ceramic content up to 8% after which the maximum dry density decreases. It can be also noticed that, for soil samples treated with cement and mix cement and ceramic the maximum dry density increases with increasing additives content. A summary of data is given in **Table (2). In Figure (6),** the change in optimum water content is plotted versus the additives content which indicates that the optimum water content increases or decreases with increasing ceramic content, while it increases with increase in cement content. It can be also noticed that the optimum water content increases up to 4% after which the optimum water content decreases.

Conclusion

1. The best improvement in maximum dry unit weight is achieved when the samples are treated with mix cement and ceramic.
2. The maximum dry unit weight increases with increasing ceramic content up to 8% after which the maximum dry unit weight decreases.
3. No apparent behavior can be concluded from the behavior of samples treated by ceramic material, especially for the optimum water content.
4. As the cement content increases, the optimum water content increases from 17.1 to 19.6%.
5. Adding waste of ceramic material may add extra cost but the overall cost of the mix may become economical. However, it requires further research to study the mix from economical point of view.

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Table (1): Summary of Physical and Chemical Tests.

Soil property	Soil
Gypsum Content (%)	35
Total Soluble Salts (%)	8
Specific Gravity (Gs)	2.61
Initial Void Ratio (e_o)	0.54
Initial Water Content (%)	0.49
Maximum Dry Unit Weight (kN/m^3)	18.2
Optimum Water Content (%)	15.9
Soil Classification According to (USCS)	SP

Table (2): Result of Compaction Tests after Treatment.

Soil Property	Ceramic %			Cement %			Cement % +Ceramic %		
	A=4	A=8	A=12	C=4	C=6	C=8	4+4	4+8	4+12
Maximum Dry Unit Weight, kN/m^3	19.1	19.5	18.6	19.7	20.3	20.8	20.8	21.3	21.8
Optimum Water Content, (%)	16.3	13.5	15.7	17.1	19.4	19.6	17.7	16.1	14.6

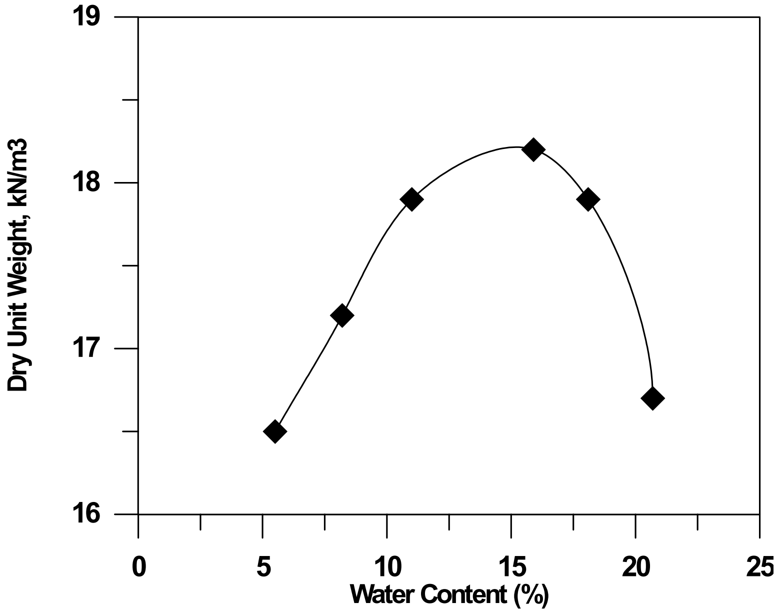


Figure (1): Standard Compaction Curve for Untreated Soil.

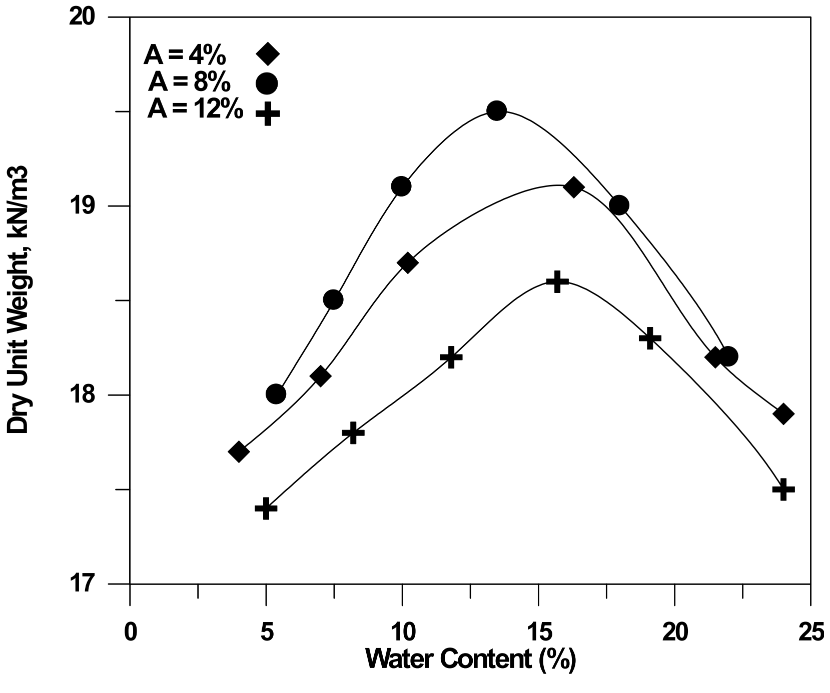


Figure (2): Standard Compaction Curves for Soil Treated with Ceramic.

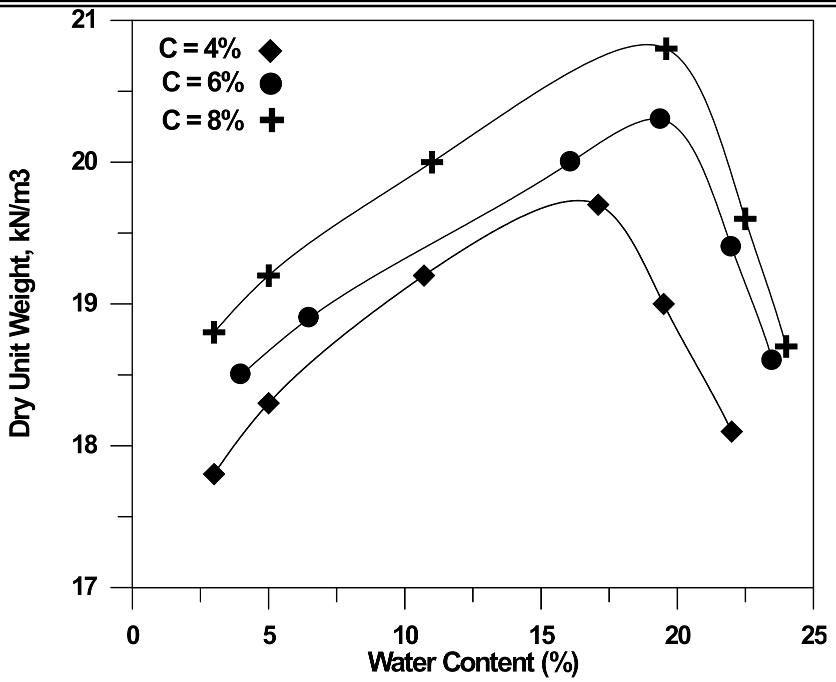


Figure (3): Standard Compaction Curves for Soil Treated with Cement.

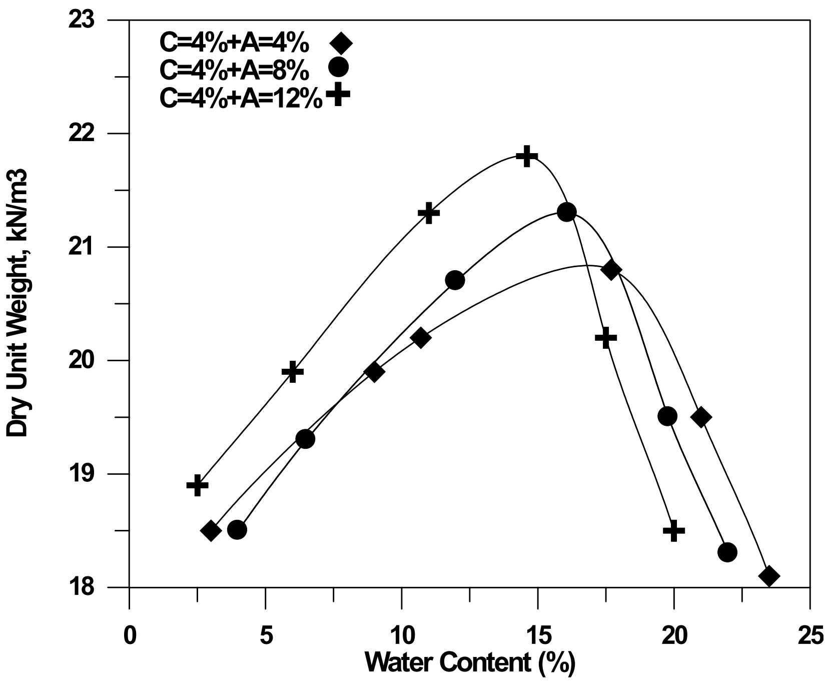
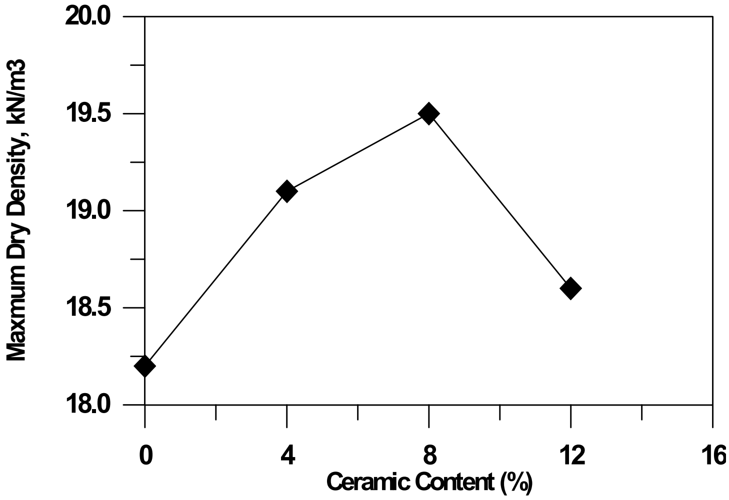


Figure (4): Standard Compaction Curves for Soil Treated with (Cement and Ceramic).



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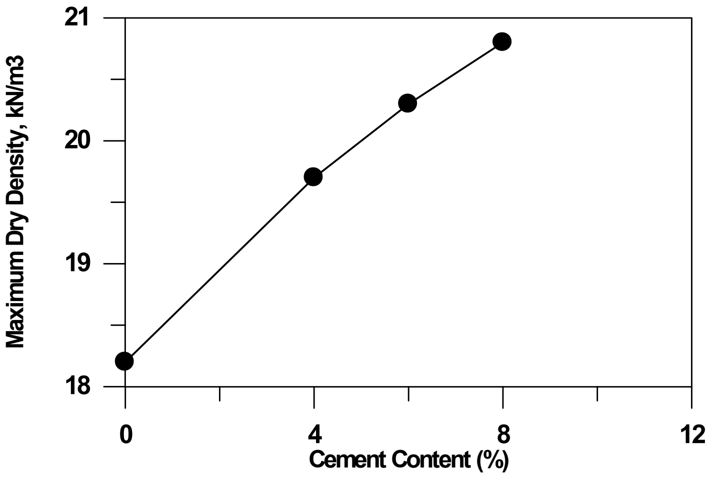

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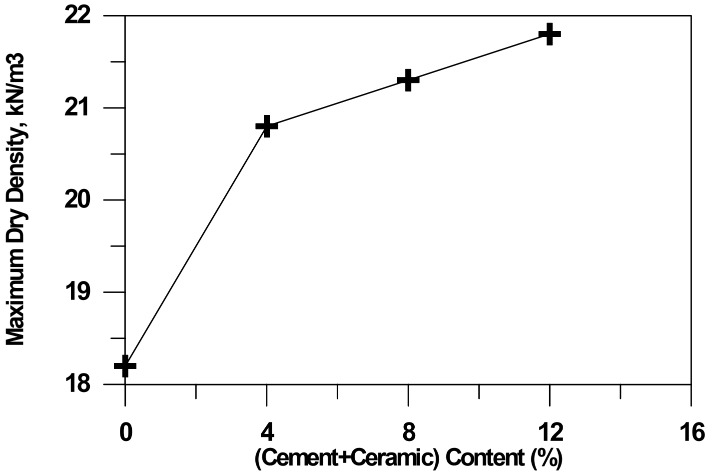
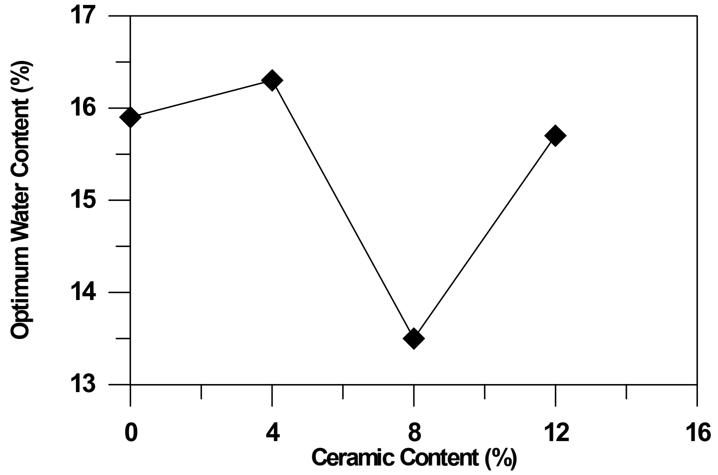


(c)

Figure (5):Effect of Additives on Maximum Dry Density. (a) Ceramic, (b) Cement, (c) Cement and Ceramic.



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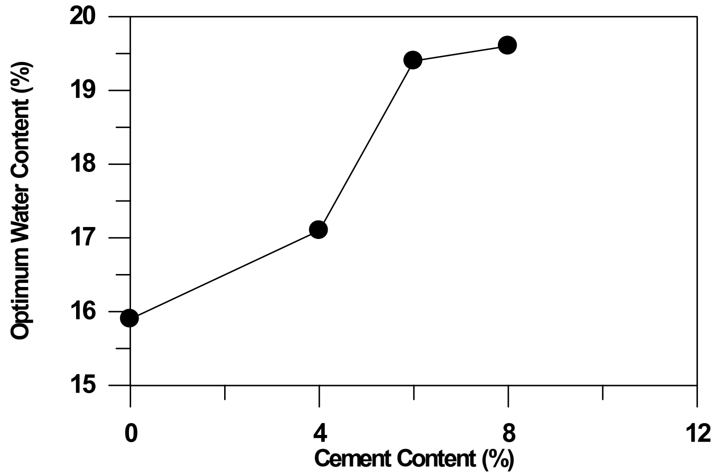

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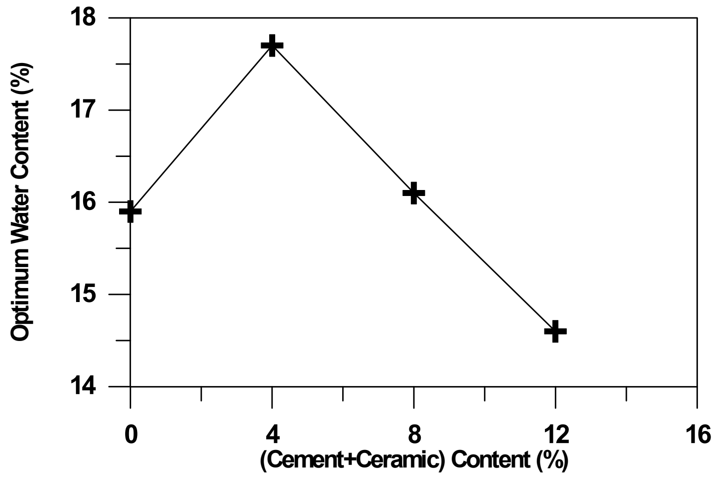

(c)

Figure (6): Effect of Additives on Optimum Water Content. (a) Ceramic, (b) Cement, (c) Cement and Ceramic