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# Inspecting the Effects of Organic Content on Compaction and Consolidation Characteristics of Organic Soil Models

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**Abstract**

The main objective of this study is to investigate the behavior of different organic soils percentages under consolidation and compaction. For this purpose, a model of organic soil samples made by the use of leaves of the Eucalyptus tree as an organic matter and then mixed with inorganic silty clay soil taken from a specific district in Baghdad city at three levels (0% as mineral soil, 20% as organic soil, and 40% as highly organic soil or peat by dry weight). The reason of make such models was that because there is no natural organic soils in Iraq with the needed percentages. The physical and the engineering properties of the mixtures where determined by conducting a series of laboratory tests including Atterberg limits, compaction, and consolidation tests. The chemical properties of the mixture where determined by the chemical composition and the pH tests. The results showed that the Atterberg limits (liquid limit L.L. and plastic limit P.L.) are increased with the increase of the organic content (O.C.), while the plasticity index (P.I.) is decreased at (20%, O.C.) then increased slightly at (40%, O.C.). The maximum dry density (M.D.D.) decreased with the increase of the organic content, while the optimum water content (O.W.C.) increased with the increase of the organic content and this concerned with compaction characteristics. Compressibility characteristics showed that the increase in the organic content made a clear increase in the whole compressibility parameters (compression index Cc, coefficient of consolidation Cv, and secondary compression index Cα).

***Keywords:*** organic matter; Atterberg's limits; compaction characteristics; consolidation.

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## 1. Introduction

Organic soils contain the organic matter that is consisting of intricate mixtures of plant and animal residues decomposed to vary extents by biological or chemical means from decomposition products, and plant and animal excretions and their decomposition products. The primary source of soil organic matter is the plant tissue. Animal are commonly considered as the secondary sources of organic matter in soil. As these materials or the residues of both plant tissues and/or animals decomposed by the effect of temperature of the soil, humidity, level of nutrients, pH-medium and the digestion by the soil organisms of many kinds, this will lead to the formation of the organic matter in the soil [1].

It is commonly agreed that the presence of organic matter in soils is generally associated with high compressibility, significant secondary compression, often-unsatisfactory strength characteristics, and low unit weight. The high compressibility and creep often increase the risks of inadmissible settlements and/or foundation failure. The unsatisfactory strength characteristics associated with the low values of the maximum dry density are a main concern in road construction [2, 3].

Past studies showed both liquid and plastic limits of illitic soils increase linearly with the increase of the organic content [1], same as for the Illinois soils when the organic content increased that made an increase in both liquid and plastic limits [4]. A study done on such soil to know the compaction characteristics, and the found results were that the maximum dry density decreased with the increase of the organic content, while the optimum moisture content increased with increase of the organic content [5]. Similar demeanor was noticed by [6]. Study done by [7] to know the compressibility behavior for tropical peat soil collected from several locations in Malaysia, using row-cell consolidation test device for accuracy results and the conventional Oedometer test for comparison purposes. He found that the fabric peat caused the highest settlements followed by hemic and sparic peat when subjected to any load over the time period. Then he tried to improve this behavior of compressibility by using cement column installed vertically in the cell containing peat sample. The results showed that the compressibility index and the secondary compression index of are decreased for the fabric peat, same as for the hemic and sparic peats. [8] Studied the compressibility characteristics of reconstituted organic soil at Khulna region of Bangladesh and the found compression index has increased with the increase of the organic content. Furthermore, the coefficient of consolidation has increased for all applied loads with increase of the organic content.

## 2. Materials and Methods

### *2.1. Soil*

The soil used in this study for the preparation of the organic soil samples was taken from Al-Doura-Baghdad from a depth of 1-1.5m and it is an over-consolidated soil with water content of 22%, medium consistency and brown color. Its swelling potential is so weak and it is classified as (CL) according to the unified soil classification system. It contains an organic content of about 0.825% using Loss on Ignition method and this percentage has no effect about the properties of this soil, so it is considered as a soil with a 0% organic content or inorganic soil. The engineering properties of this soil are shown in table 1.

**Table 1:** Properties of the soil used for the preparation of the organic soils samples

| | |
|---|---|
| Liquid limit (%) | 35.50 |
| Plastic limit (%) | 20.42 |
| Plasticity index (%) | 15.08 |
| Organic content (%) | 0.825 |
| Specific gravity | 2.65 |
| Gravel | - |
| Sand | - |
| Silt (%) | 92 |
| Clay (%) | 8 |
| Maximum dry density (g/cm³) | 1.65 |
| Optimum moisture content (%) | 18.2 |
| Maximum unconfined compressive strength (kPa) | 85.95 |

### *2.2. Organic Material*

The primary source of organic content accommodated in soil is vegetal. Therefore, the organic material that has been used for this study is a plant material. The following steps (Selection, Drying, Pulverizing, and Sieving) are the main steps used for the preparation of the organic material.

#### *2.2.1. Selection*

The organic material that has been used in this study is the leaves of the Eucalyptus tree, and the reason for selecting this material was because these trees are widespread in Iraq in general. They are grown in abundance in public parks, gardens of houses and around the territory of orchards. Eucalyptus tree is one of the deciduous trees, so in the end of the dry season, their leaves are falling on the ground. These fallen leaves by the passage of time are getting dry and then decayed so the grounded will be full with the organic content that will affect the properties of the soil from the engineering perspective.

**Figure 1:** Leaves of the Eucalyptus tree

### *2.2.2. Drying*

**Figure 2:** Dried leaves of the Eucalyptus tree

The leaves of Eucalyptus tree are dried under the ray of the sun for a certain period, until it color got change.

### *2.2.3. Pulverizing*

**Figure 3:** Blender, with the pulverized Eucalyptus leaves

The leaves of Eucalyptus tree are pulverized in a special blender, just to make it a powder and this will represent the natural situation after decomposition.

### *2.2.4. Sieving*

**Figure 4:** Powder of Eucalyptus leaves after pulverizing with the coarse particles

After pulverizing, the powder is then sieved with the No. 40 (0.425 mm) sieve just to remove the coarse particles, because the coarse particles are taking very long time to decompose.

### *2.3. Organic Sample Preparation*

#### *2.3.1. Soil Used*

The soil used for preparation of the organic soil sample is the natural soil that mentioned above. This natural soil is transported to the laboratory and then dried in the oven with a temperature of 100° C. ± 5° after this it pulverized with a pulverizing machine to be ready for mixing.

#### *2.3.2. Mixing*

The pulverized and dried soil is then mixed in an equal manner with powder of Eucalyptus leaves in the required properties to make a mixture of the following design organic content: 0%, 20%, and 40%. After that, distilled water was added to each mixture to reach a water content of 22% and this is the water content of the used natural soil, just to represent a real situation in the field.

#### *2.3.3. Curing*

**Figure 5:** Effect of the organic material on the properties of the natural soil

Each mixture was placed in a well-sealed plastic bag and left for about 5 month for curing before performing the required test. Figure 5 shows the result of the curing process and how the organic material affected the properties of the natural soil.

## 3. Experimental Work

Classification test [9], Atterberg limits [10], specific gravity test [11], compaction test [12], unconfined compressive strength test [13], organic content test [14], one-dimensional consolidation test [15], and the chemical composition and pH tests in the National Center for Construction Laboratories and Research-Chemical Laboratories-Baghdad branch were conducted on the soil samples of the organic content (0%). Then Atterberg limits [9], specific gravity tests [11], compaction tests [12], organic content test [14], one-dimensional consolidation tests [15], and chemical composition and pH tests were conducted on the other organic soil samples of the organic content (20%, and 40%) respectively. Table 2 show the results of the measured organic contents using Loss on Ignition method after the period of the curing (5 months) for the designed organic soil samples. Table 3 shows the results of the chemical composition for the all-organic soil samples, also it shows the values of the pH for the all-organic soil samples.

**Table 2:** Measured organic content using Loss on Ignition method after period of about 5 months

| The design organic content (%) | Obtained organic content (%) |
|---|---|
| 20 | 18.27 |
| 40 | 39.64 |

**Table 3:** Chemical composition of the organic soil samples

| Soil specimen | 0%, organic content | 20%, organic content | 40%, organic content |
|---|---|---|---|
| Chemical element | Percent (%) | | |
| $SiO_2$ | 45.166 | 42.226 | 40.194 |
| $Al_2O_3$ | 32.403 | 30.208 | 28.431 |
| CaO | 9.302 | 10.867 | 11.941 |
| $Fe_2O_3$ | 6.665 | 8.264 | 8.486 |
| $K_2O$ | 5.808 | 7.726 | 10.003 |
| $TiO_2$ | 0.439 | 0.540 | 0.550 |
| $SO_3$ | 0.047 | 0.108 | 0.151 |
| pH | 9.14 | 7.75 | 7.33 |

## 4. Results

Atterberg limits, specific gravity, compaction characteristics, and one-dimensional compression tests are conducted to investigate the effect of the organic material (Eucalyptus leaves) with different percentages of (0% termed as mineral soil, 20% termed as organic soil, and 40% termed as highly organic soil or peat) by dry weight of the natural soil. The following is the results of these tests:

### *4.1. Atterberg limits*

Figures 6, 7, and 8 show the effect of the content (Eucalyptus leaves) at different percentages of (0%, 20%, and 40%) by dry weight of the natural soil on the behavior of liquid limit, plastic limit and plasticity index. Table 4 is a results summary for the effect of the organic content on liquid limit, plastic limit, and plasticity index. From the figures (6, and 7), it seems that both liquid and plastic limits were increased as the organic content increases at the percentages of (20% and 40% O.C.). This behavior can be explained according to the content of the organic material. Soils of high organic content have ability for adsorb, and containing the water is too high, and that is what make both the liquid and plastic limits increasing with the increase of the organic content. Figure 8 shows that the plasticity index decreased at the percentage of (20% O.C.) with respect to the plasticity index of the natural soil of (0%, O.C.) and then the plasticity index is increased slightly at the percentage of (40%, O.C.). This is can be explained according to the mineral fractions of the soil. The natural soil of (0%, O.C.) has a large value of plasticity index because it contains more mineral fractions than of the organic soils with the (20%, and 40% O.C.). The little increase that happened for (40% O.C.) that I because soil samples with this percentage has more organic matter than of (20% O.C.).

**Table 4:** Effect of the organic matter content on liquid limit, plastic limit, and plasticity index

| Organic content (%) | 0 | 20 | 40 |
|---|---|---|---|
| Liquid limit (%) | 35.5 | 49.7 | 80.0 |
| Plastic limit (%) | 20.42 | 48.08 | 75.04 |
| Plasticity index (%) | 15.08 | 1.62 | 4.96 |

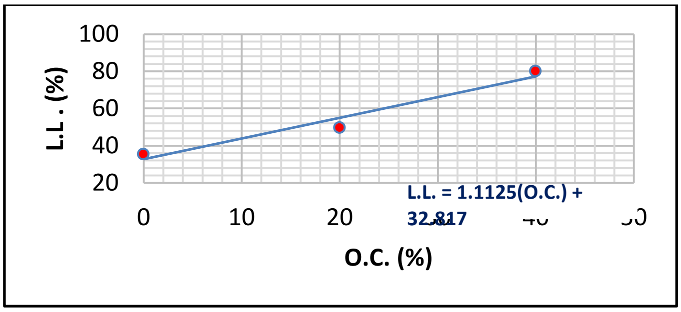


**Figure 6:** Liquid limit versus organic content

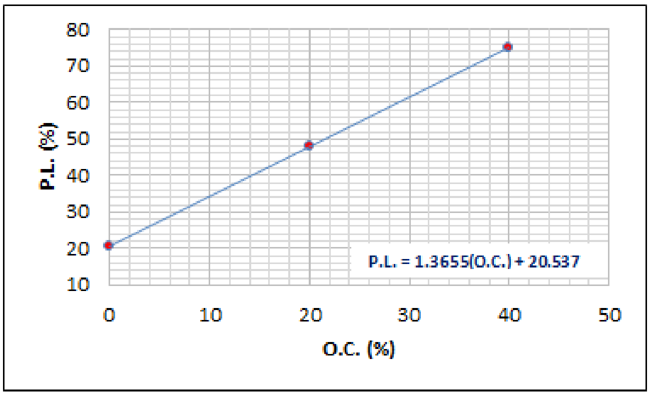


**Figure 7:** Plastic limit versus organic content

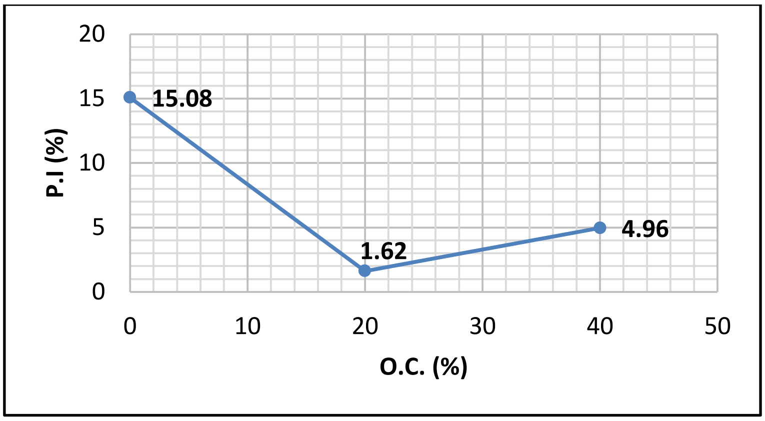


**Figure 8:** Plasticity index versus organic content

### *4.2. Compaction characteristics*

Figures 9, 10, and 11 show the behavior of the compaction characteristics for soil samples with different organic content (0%, 20%, and 40%) by dry weight of the natural soil. Table 5 shows the summary of the results of the organic content versus both of maximum dry density and optimum water content. From the figures (10, and 11), it seems that as the (M.D.D) decreases and the (O.W.C.) increases as the organic content increase. That is because the density of organic soils is smaller compared with mineral soils and that makes the (M.D.D) decreases with the increase of organic content, also the organic soils have the ability to contain and adsorb water because it has a large void ratios and low specific gravities compared with mineral soils and that makes the (O.W.C.) increase as the organic content increase. These results agree with the previous studies [1, 16, 17].

**Table 5:** Effect of the organic matter content on (M.D.D and O.W.C.)

| Organic content (%) | 0 | 20 | 40 |
|---|---|---|---|
| M.D.D (g/cm³) | 1.655 | 1.236 | 0.903 |
| O.W.C. (%) | 18.2 | 31.16 | 52.05 |

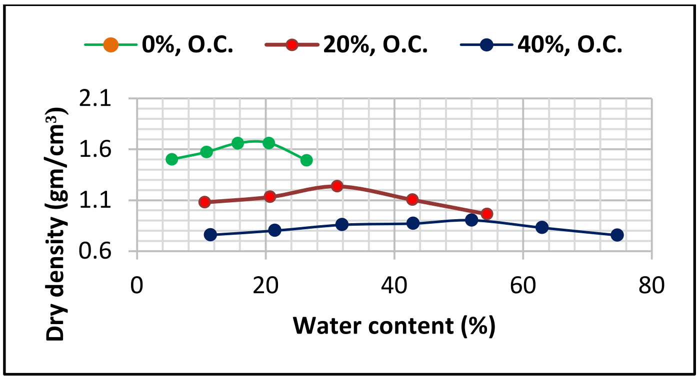


**Figure 9:** Compaction curves for different organic contents

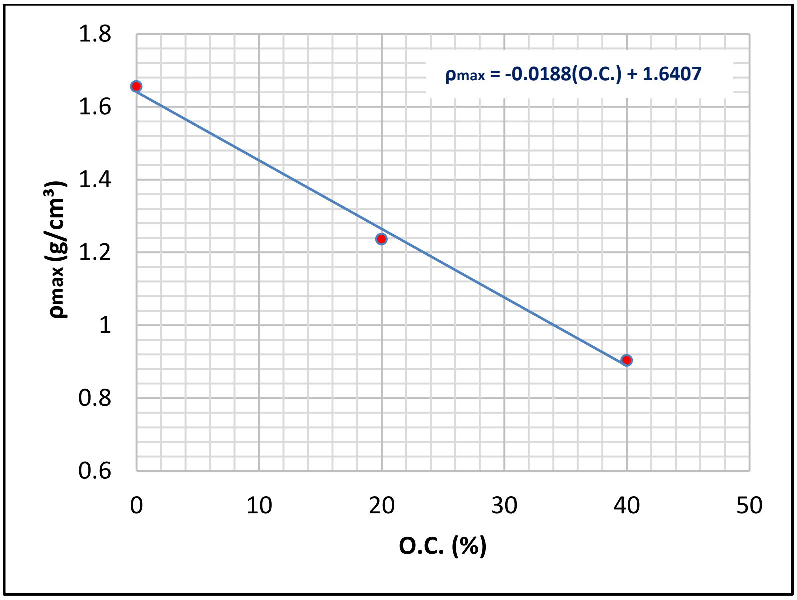


**Figure 10:** Maximum dry density versus organic content

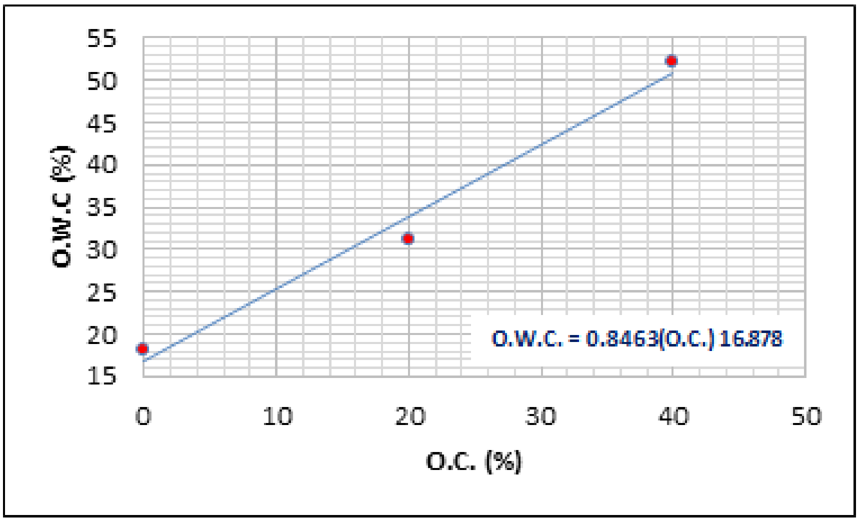


**Figure 11:** Optimum water content versus organic content

### *4.3. One-dimensional compression tests*

Test, which are conducted to study the effect of organic materials on samples with different percentages of organic matter content (0%, 20%, and 40%) by dry weight of the natural soil, on the compression characteristics (compression index Cc, coefficient of consolidation Cv, and coefficient of secondary compression Cα).

#### *4.3.1. Effect of the organic content on compression index Cc*

The compression behavior of samples with different percentages of organic matter content (0%, 20%, and 40%) by dry weight of the natural soil is shown in figure 12.

The results show that as the organic content increases, a linear relationships will happen between the void ratio and logarithm of stress as the organic content increase. Table (4-5) shows the summary of compression tests results.

**Table 6:** Effect of the organic matter content on (M.D.D and O.W.C.)

| Organic content (%) | 0 | 20 | 40 |
|---|---|---|---|
| Total unit weight (kN/m³) | 15.88 | 8.27 | 5.8 |
| Void ratio | 0.637 | 1.717 | 2.401 |
| Compression index | 0.189 | 0.598 | 0.781 |

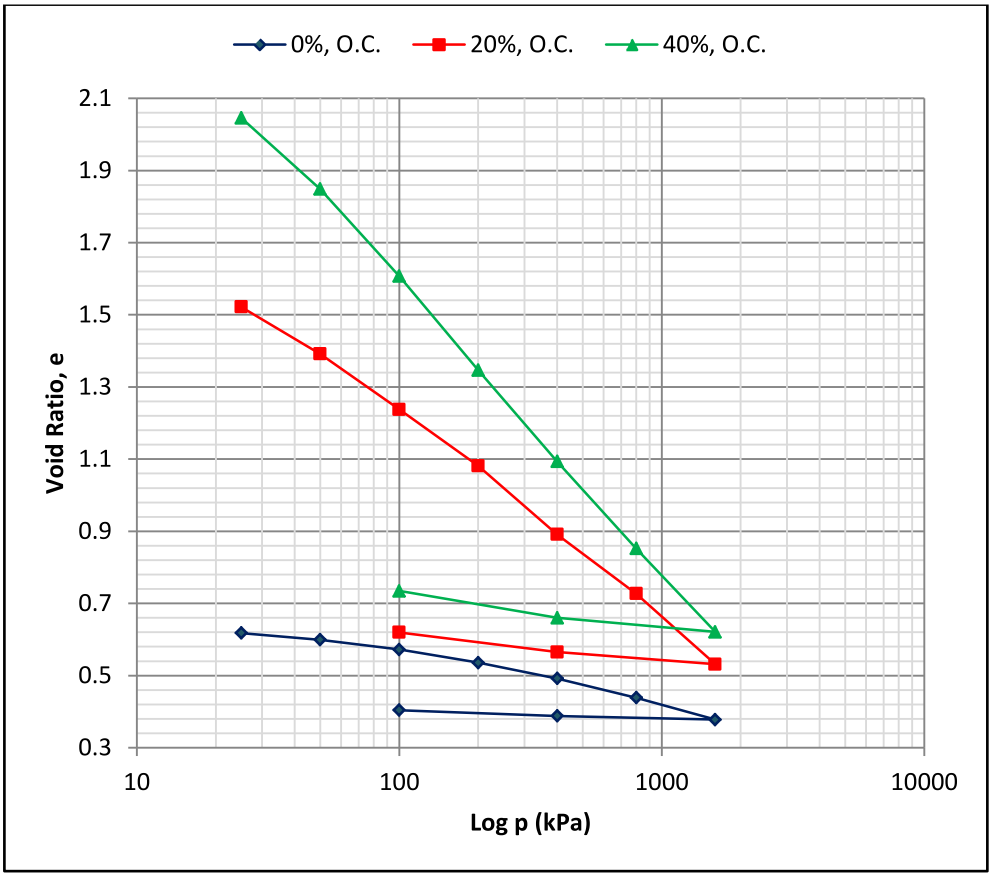


**Figure 12:** Void ratio versus logarithm of consolidation pressure for different percentages of organic soils.

Figure 13 shows the effect of the organic content on compression index of (0%, 20%, and 40%) organic soil samples. The values of the compression index (Cc) increase as the organic content increases.

This is because as the mineral content of the soil samples decreases because of the organic content as in (20% and 40% O.C.) this will make the void ratio to increase in comparison with mineral soil (0% O.C.) void ratios. And when the void ratio increases this will made the soil sample more compressible, in other words it will suffer from high compression indices. Figure 14 shows the effect of the void ratios on (Cc).

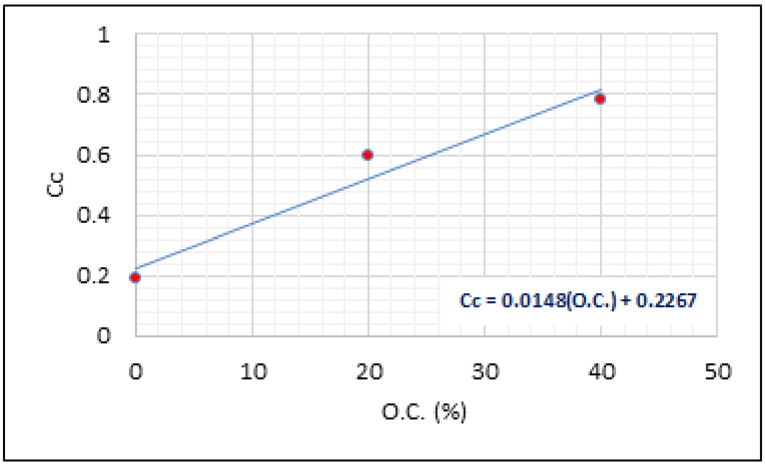


**Figure 13:** Variation of compression index with organic content

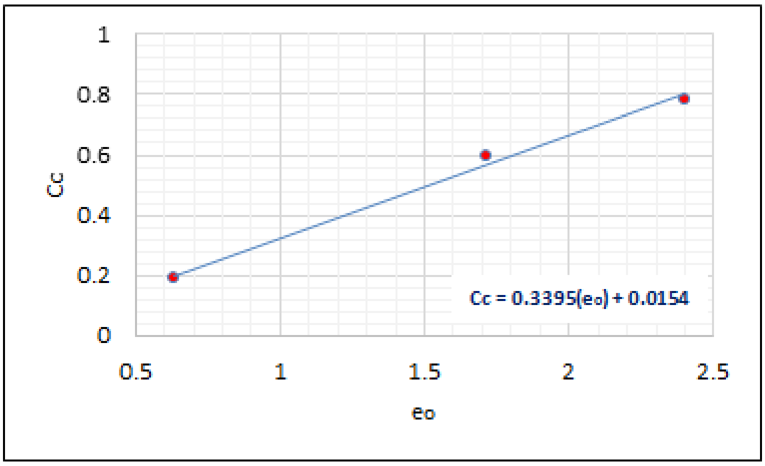


**Figure 14:** Variation of compression index with void ratio

#### *4.3.2. Effect of the organic content on coefficient of consolidation Cv*

Square root time method is used to determine the coefficient of consolidation for samples with different percentages of organic matter content (0%, 20%, and 40%) by dry weight of the natural soil using stress of (1600 kPa). The results are summarized in table 7. Figure 15 shows that coefficient of consolidation increases as the organic content increase, and the values are ranging from (0.295-5.052mm²/min).

The minimum value of (Cv) is at (0% O.C.) and the maximum value of (Cv) is at (40% O.C). This is because when the organic solids decomposed they released gases, volatile acids, and new bacterial cells. Product such as bacteria by itself will produce spores between soil particles, these spores will increase as the organic material increase, so the compressibility has been increased and this is agree with [8, 18].

**Table 7:** Values of coefficient of consolidation (mm²/min) for different percentage of organic soils

| Organic content (%) | 0 | 20 | 40 |
|---|---|---|---|
| Stress (kPa) | 1600 | | |
| Coefficient of consolidation (mm²/min.) | 0.295 | 3.621 | 5.052 |

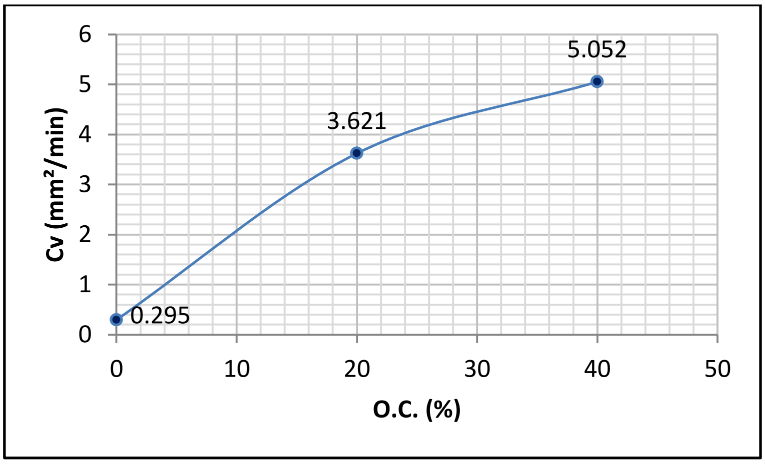


**Figure 15:** Effect of organic content on coefficient of consolidation

#### *4.3.3. Effect of the organic content on coefficient of secondary compression Cα*

Coefficient of secondary compression for samples with different percentages of organic matter content (0%, 20%, and 40%) by dry weight of the natural soil is determined from the slope of void ratio versus the logarithm of time curve for time period between (100-1000) by using the stress of (1600 kPa).

The reason for using this stress to know the highest secondary compression behavior that may exposed to the organic soils. Table 8 shows results of the coefficient of secondary compression for the soil samples. Figure 16 shows the effect of the organic content on the coefficients of secondary compression. Figure 16 shows that the values of (Cα) are increase as the percentage of the organic content increase, and the values are ranging from (0.0033-0.045).

The minimum value of (Cα) is at (0% O.C.) and the maximum value of (Cα) is at (40% O.C.). This behavior can be explained as the following:

- The organic content increases the percentage of the void ratios and this increase the compressibility.
- Decomposition process of organic solids involves microbial activity with the formation of gases, water, new bacterial cells, and volatile acids. These products are able to produce spores between soil colloids, and this will make the organic soils more compressed in comparison with inorganic soils [18].
- As the time passed and by the constant stress that applied on the soil sample, the soil particles begin to rearrange and reorient while the organic materials begin to reduce in size.

**Table 7:** Values of coefficient of secondary compression for different percentage of organic soils

| Organic content (%) | 0 | 20 | 40 |
|---|---|---|---|
| Stress (kPa) | | 1600 | |
| Coefficient of secondary compression | 0.0033 | 0.028 | 0.045 |

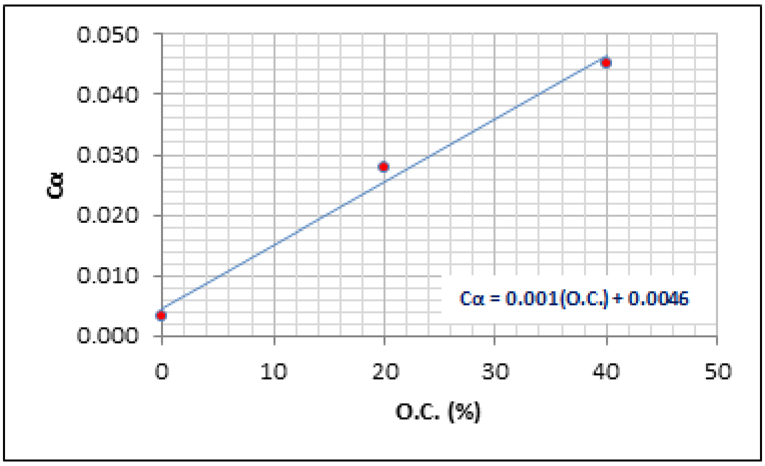


**Figure 16:** Effect of organic content on coefficient of secondary compression

## 5. Conclusions

From the results of testing program conducted on the organic soils samples of different percentages of organic content (0%, 20%, and 40%), the following conclusions may be drawn:

1. The liquid and plastic limits are increased as the organic content increase, while the plasticity index is decreased at the (20% O.C.) and then increased slightly at (40% O.C.).
2. The maximum dry density (M.D.D) decreases and the optimum water content (O.W.C.) increases as the organic content increase.
3. Compression index (Cc) is increased as the organic content increases.
4. Coefficient of consolidation (Cv) is increased as the organic content increases.
5. Coefficient of secondary compression or secondary compression index (Cα) is increased as the organic content increases.

## 6. Recommendations

The following recommendations are proposed for the future works:

1. It is recommended to use a sandy soil to study the same work.
2. It is recommended to leave the organic materials to decompose for a year or more than a year and then

see how much the decomposition period will affect the properties of the host soil.

3. It is recommended to use more than (40% O.C.) to study the effect of this percentage on the main engineering properties of the host soil.
4. About the consolidation tests it is recommended to:

a. Use one-dimensional Oedometer apparatus equipped with pore water pressure measuring device to differentiate the end of the primary consolidation and the beginning of the secondary compression.
b. Use one-dimensioal Oedometer apparatus (ACONS) Automatic Consolidation System, because it so accurate, very easy to use, no weight cause the applied load is pneumatic, and allows to cut the time of the research.

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