Observation of Consolidation and Permeability Parameters of Soil Stabilized By Cutback Asphalt

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Abstract:

For design purposes, it`s necessary to know the compression rate of soil layers which might be happened when it`s subjected to effective stresses. Also, it`s essential to know the rate of flow through soil mass specially for the design of marine structures or earth embankment. These two important behavior could be predicted from the coefficient of consolidation (C_v) and the coefficient of permeability (k). This study shows the effect of cutback asphalt stabilization on C_v and k and other compressibility factors, the investigation was done for silty clay samples, specimens were prepared by mixing the soil with different percentage of asphalt from (0-10)% and subjected to one-dimensional consolidation test of 50mm diameter and 20mm height were done at soaked condition, it was conducted that C_v increased for asphaltic soil of (2-6)% Cutback and decreased for soil with cutback of (8-10)%. On the other hand, the the coefficient of permeability (k) and the coefficient of volume change (m_v) increased for soil with (2-4)% cutback and decreased by adding more cutback asphalt to soil till 10%. The compression index (C_c) value increase to the optimum value at 2% cutback content then start to decrease till reaching the 10%. The re-compression index (C_r) shows a general increase in values when add cutback asphalt to the soil, it increase until reaching its maximum value at 6% cutback content then decrease with increasing of cutback asphalt till 10%, the values of (C_r) shows an increase for the 10% cutback from 8%, that's might be due to increasing of swelling potential due to increasing of liquid limit and blocking of voids ratio.

Keywords: Cutback Asphalt, Compressibility, Stabilization, Oedometer test, Consolidation, Permeability

1-Introduction:

The Fine-grained soil covers large area in Iraq, especially in the middle and southern part. In the engineering practice, it is common to face with cohesive soils, these soils possess specific engineering properties that may causes serious problems, therefore those soils may need to be improved to be suitable for construction.

During the construction of any structure, an amount of compression layer will be expected since the layer of soil will be subjected to a compressive stress resulting from the applied loads of the structure.

Fine-grained soils are used sometimes in earth embankment and as a subgrade material construction in roads and constructions projects, the deformations due to the applied stresses are related with time and construction procedure which is very important to study, many types of improvement methods founded to improve the compressibility and consolidation parameters of soils [1]. Due to the existence of interlinked voids, soils are permeable materials which allow the flow of fluids from higher energy locations to lower energy locations [2].

Geotechnical engineers agree that excess water pressure under structures is one of the main causes of sudden and unexpected failures. Excess water reduces the frictional strength of the structural section and the base materials by creating resistance within these materials [3].

Excessive pore water pressure could be developed through surface stresses impact within subgrade and structural elements, these conditions may result in excessive deflection, cracking, load capacity reduction, raveling, and disintegration of asphalt mixtures, undergrad instability, pumping and loss of support [4].

Soil stabilization technique were developed many years ago to render soils could be used in projects within the required engineering limits [5].

Asphalt stabilization can provide more stable engineering properties for the embankment soil from the strength, stiffness, compressibility, permeability, and sensitivity to changes in moisture content [6] . The mixing of Asphalt with cohesive soils, requires finding out employed methods and types of asphalt that are capable of improving such soils [7]

[8] reported that the compression index (Cc) in Gypseous soils decreases with the increase in gypsum content of the soil, while rebound index (Cr) increases for sandy soil with the increase in gypsum content. The coefficient of consolidation (CV) remains almost constant with the increase in applied pressure.[9] found that the consolidation test results showed that total volumetric strain, coefficient of consolidation, and compression index of treated soil samples decreased upon increasing the percentage of emulsified asphalt. Also, [10] showed that both volumetric stain and compression index decreased with increasing emulsified asphalt content up to optimum and then increased, while the rebound index increased with increasing of emulsified asphalt content.[11] studied the effect of asphalt emulsion on permeability and unconfined compressive strength. It was concluded that emulsified asphalt has a positive effect on strength improvement, waterproofing and reduction of permeability potential of compacted Gypseous soil.[12] studied stabilizing the embankment of Gypseous soil with asphalt emulsion. It has been found that the cohesion has been improved by 21% and the coefficient of permeability (k) has been reduced by more than 10 to 7 times.[13] examined the effect of asphalt stabilization on a pre-treated expansive soil with lime. The study showed that the coefficient of consolidation (CV) increases with the addition of lime while the coefficient of permeability (k) are almost unchanged or slightly below the natural soil value. The aim of this investigation was to monitor the variation of coefficient of consolidation (CV) and the coefficient of permeability of cohesive soil when asphalt cutback is used as a stabilizing agent.

2. Materials Used for Investigation

2.1 Soil: the soil samples was brought from Al-Rarenjia which is located in Babylon Province, 10 km from Al-Hilla City towards Al-Najaf city as located by google map presented in Figure 1, the selected location is considered as one of the popular places that used as borrow martials for many construction project, the soil was taken from about 0.9 m from ground level, the place was as filling soil source for the projects.

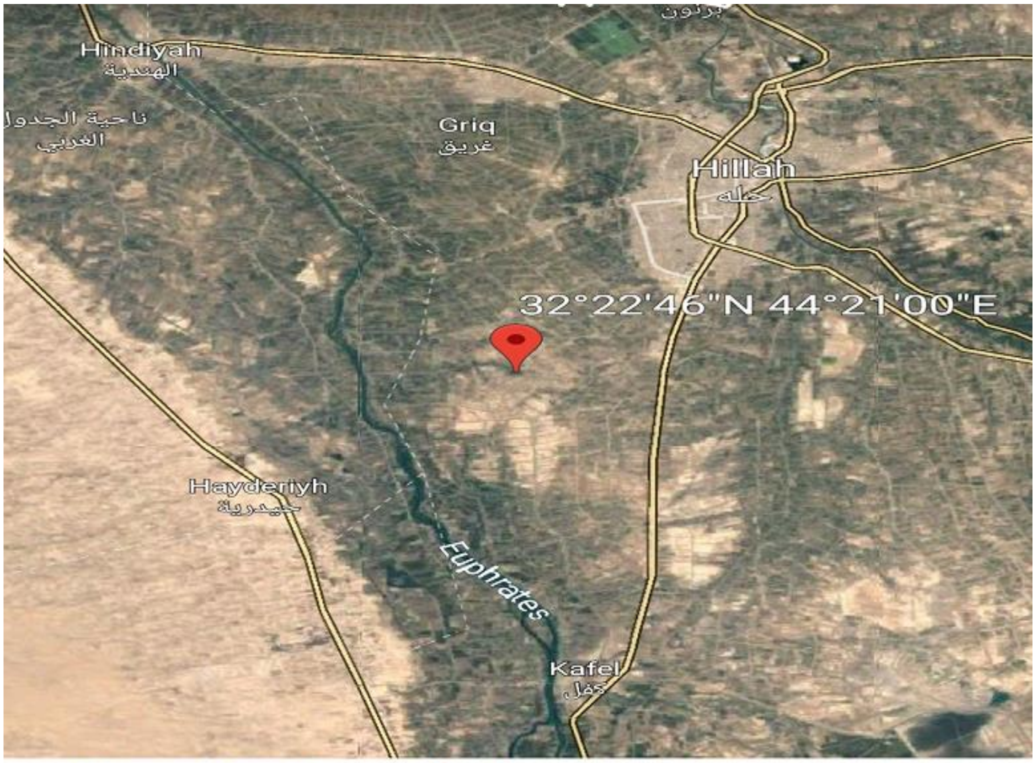

Figure No.1 Samples Location From Satellite

The physical and chemical properties was investigated for the natural soil samples, the grain size distribution shows that 0.2% was reversed on sieve No.200 by washing producer. The grain size distribution curve is given in Figure.2, on the other hand, the physical properties was illustrated in Table 1, meanwhile, the chemical composition was demonstrate in Table 2.

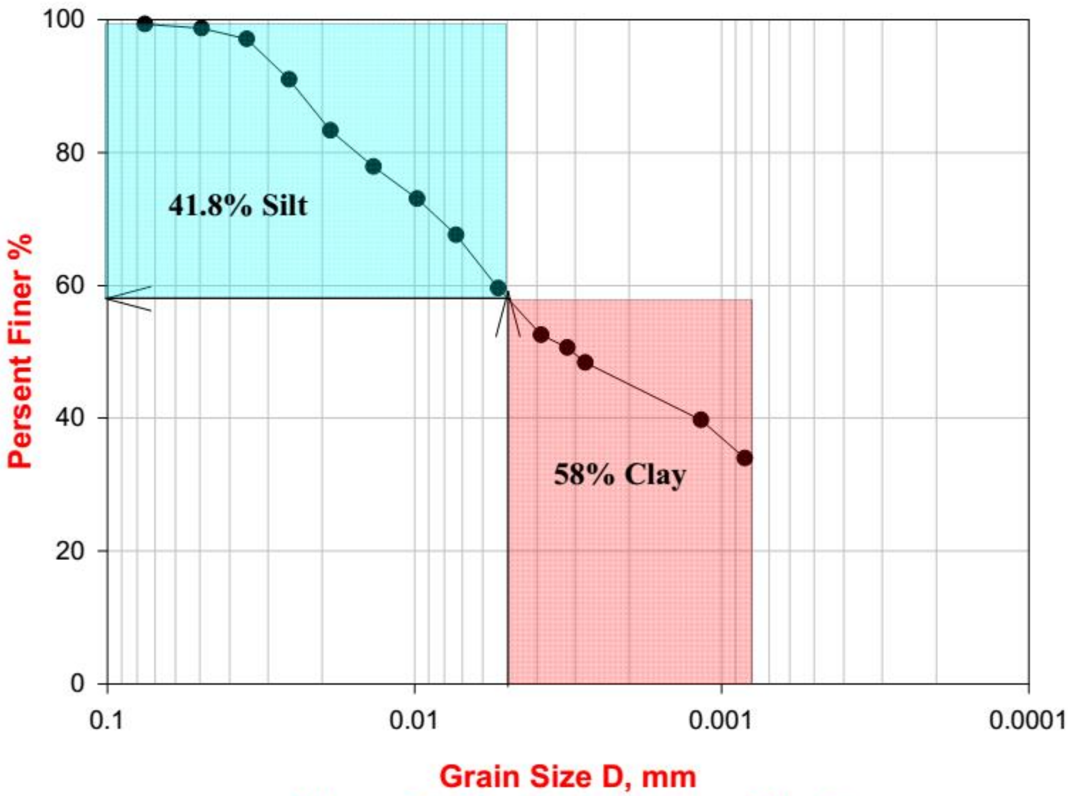

Figure 2: Size Distribution Chart

Table-1 Physical Properties

Liquid Limit %	46.3
Plastic Limit %	24
Plasticity Index %	22.3
Sieve Analysis Reversed No.200	0.20%
Specific Gravity	2.66
Optimum Water Content %	14.5
Maximum Dry Density Modified (gm/cm^3)	1.84
Unified Classification System	CL
AASHTO System	A-7-6
Coefficient of Consolidation (Cv) (m^2/year)	13.962
Coefficient of Volume Change (mv) (m2/kn)	1.55×10^{-6}
Permeability (k) (m/sec) from consolidation	6.98×10^{-12}
Compression Index Cc	0.141
Recompression Index Cs	0.019

Table-2 Chemical Composition

Total SO3 %	**1.73**
Gypsum Content %	**3.72**
Organic Content %	**12.98**
CL %	**0.0326**
Total Soluble Saults (TSS)	**6.4**
PH Value	**8.5**

The chemical Tests were done at the Soil laboratory of the ceramics and construction materials department, college of material engineering, university of Babylon. All chemical tests done according to [14]**.**

2.2 Cutback Asphalt: MC-30 Cutback asphalt was obtained from state company for mining industries, it could be produced with an appropriate cost. The properties of cutback asphalt showed in Table 3.Cutback asphalt was produced according to [15] by the standardization and quality control department of the company. The results was taken from state company of mining industries.

Table-3 Cutback Properties

Property	Test Result
Viscosity (CSt) @ 60°C	45
Flash point (C.O.C) °C (min)	38
Water % V (max)	0.2
Distillate % V of total distilled to 360 °C	
To 225°C (max.)	25
To 260°C (max.)	60
To 315°C (max.)	80
Residue from distillation to 360°C% V (min)	50
Tests on residue from distillation	
Penetration @ 25°C (100 g, 5 sec, 0.1 mm)	180
Ductility @ 25°C (cm) (min.)	100
Solubility in trichloroethylene % wt. (min)	99

2.3 Preparation of Specimen

The soil was brought from the site and prepared following the [16] standard for preparing soil samples stabilized by cutback asphalt, the soil passing sieve No.4 was dried at 60ºC and washed on sieve No. 200, the portion passed across that sieve used in the investigation. Compaction test (ASTM D1557-12e1) was carried on the natural soil and to the soil mixed with a various percentage of cutback asphalt from 0% to 10%, the maximum dry densities and optimum fluid contents was obtained as listed in Table 4. The soil was blended with the desired fluid content using a spray-bottle to insure the mixing process and afterward left for aeration at (25±2°C) room temperature for a period of two hours before being compacted as recommended by[17]. The predetermined weight of the stabilized soil, which provides the maximum dry density for each cutback percentage, was compacted using static compaction in a mold of 50 mm diameter and 20 mm height, as recommended by [18], the prepared samples were allowed to cure at (25±2°C) for 7 days [17] [19], then samples was taken to the required tests

Table-4 Compaction Test Results

Cutback Content %	0	2	4	6	8	10
Fluid Content %	14.5	15.5	15	15	15.5	15.5
Maximum Dry Density (gm/cm^3)	18.4	1.835	1.864	1.878	1.884	1.91

2.4 One-Dimensional Consolidation Test

The compacted soil specimens mixed with cutback asphalt of percentage from 0% to 10% were tested according to [20], a series of one - dimensional consolidation tests were conducted to assess the effect of asphalt stabilization on the coefficient of consolidation and permeability of cohesive soil. Since the soil had an obviously organic content as described in Table 2. The samples were soaked with water for 24 hours before testing.

2.5 Results and Discussion

2.5.1 Effect of Asphalt on Coefficient of Consolidation (Cv)

Taylor (1948), used the square root of time, as a procedure for determining Cv. Generally, a straight line throughout the initial part of the compression curve could be drawn through the datasets. To define R0 the line is projected back to zero time. The common point at R0 may be slightly lower than the original dial reading (at zero time) determined in the laboratory because of the instant compression of the 1.15 times largely corresponding values on the first line. The intersection between this second line and the laboratory curve defines R90 which is the consolidation point of 90% and the time is t90 as shown in Figure 3 [21]

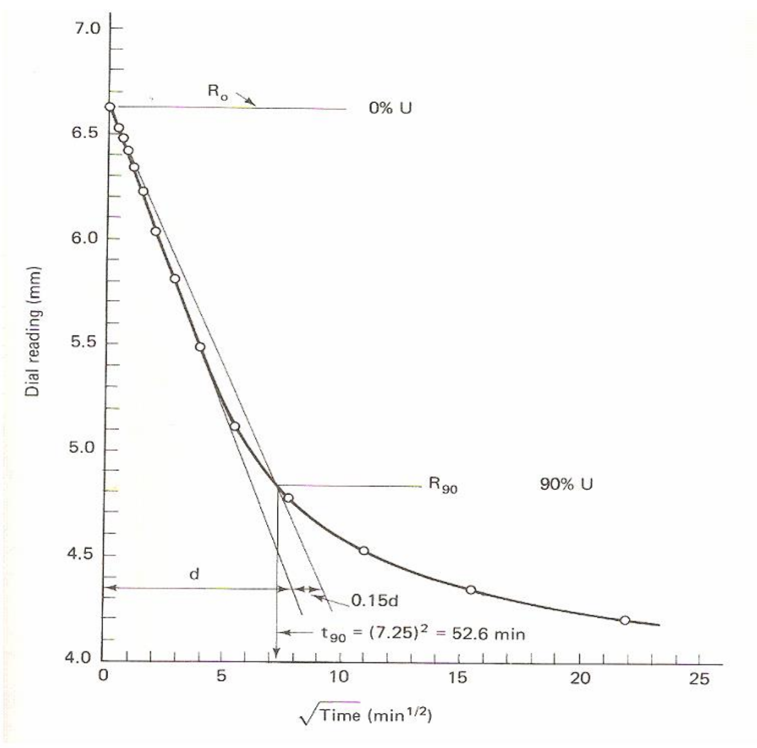

Figure (3) Determination of c_v using Taylor′s square root of time method (Holts and Kovacs,1981)

The coefficient of consolidation (Cv) signifies the rate at which a saturated soil undergoes one-dimensional consolidation when subjected to an increase in pressure. Conventional one-dimensional consolidation tests were performed on 50-ram diameter and 20-mm high soil specimens in the fixed-ring type consolidometer as per ASTMD 2435-03.The sides of the rings were smeared with silicone grease to reduce side friction. A load increment ratio (ratio of increase in pressure to the existing pressure) adopted was double. The load was sustained sufficiently long to ensure completion of primary consolidation. A square root of time method was adopted to calculate (Cv) from Time-settlement plot. The variation of the Cv with different values of the cutback asphalt is given in Figure 4

The tests results revealed that the variation of the Cv with the addition of the asphaltic materials is not linear, the results shows that there is an increase in the coefficient of consolidation of 84%, 127% and 22% for soil samples with Cutback Asphalt of 2%, 4% and 6% respectively.

While, there is a reduction in the Cv with a percentage of about 69% and 79% for soils with Cutback Asphalt of 8% and 10%, respectively. This behavior was observed by [22].

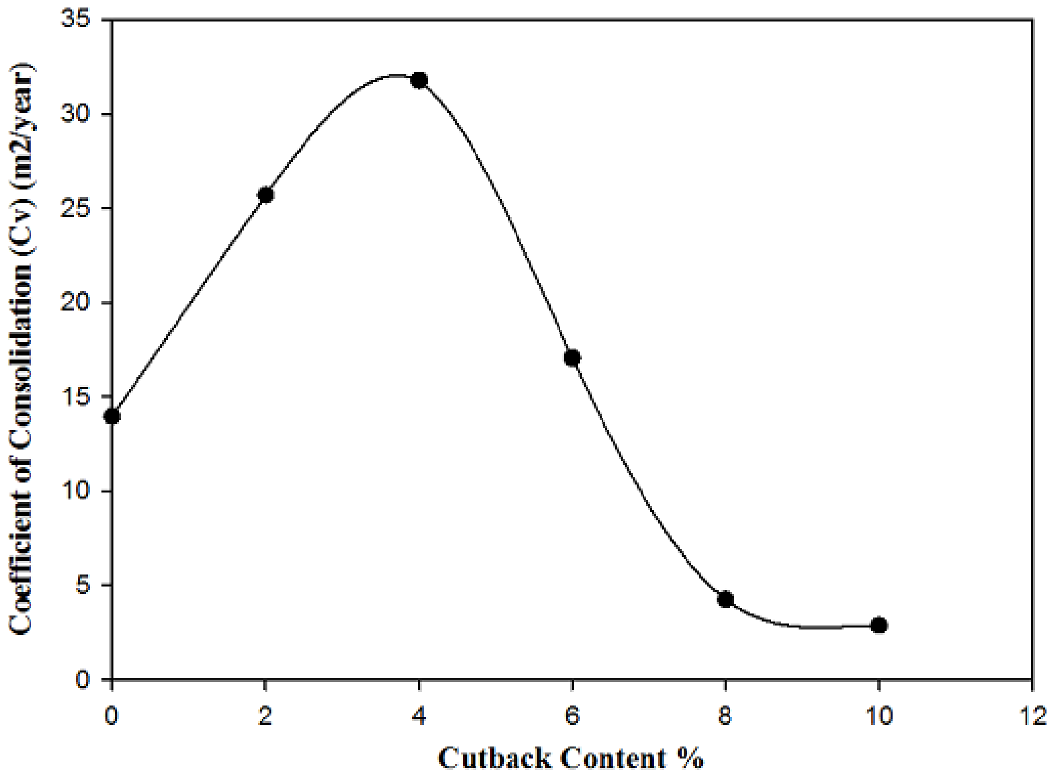

Figure 4: Coefficient of Consolidation (Cv) of Soils with Different amount of Cutback Asphalt

2.4.2 Effect of Asphalt Coefficient of Volume Change (Mv)

It is the change in volume of soil to it's initial volume due to increase in pressure. The effect of adding cutback asphalt on the coefficient of volume change illustrated in Figure 5.

The figure shows that there is an increase in the coefficient of volume of 124% and 44% for the cutback asphalt of 2% and 4% respectively. While it`s show a decrease in the coefficient of volume change of 30%, 66% and 75% for the 6%, 8% and 10% of cutback asphalt respectively.

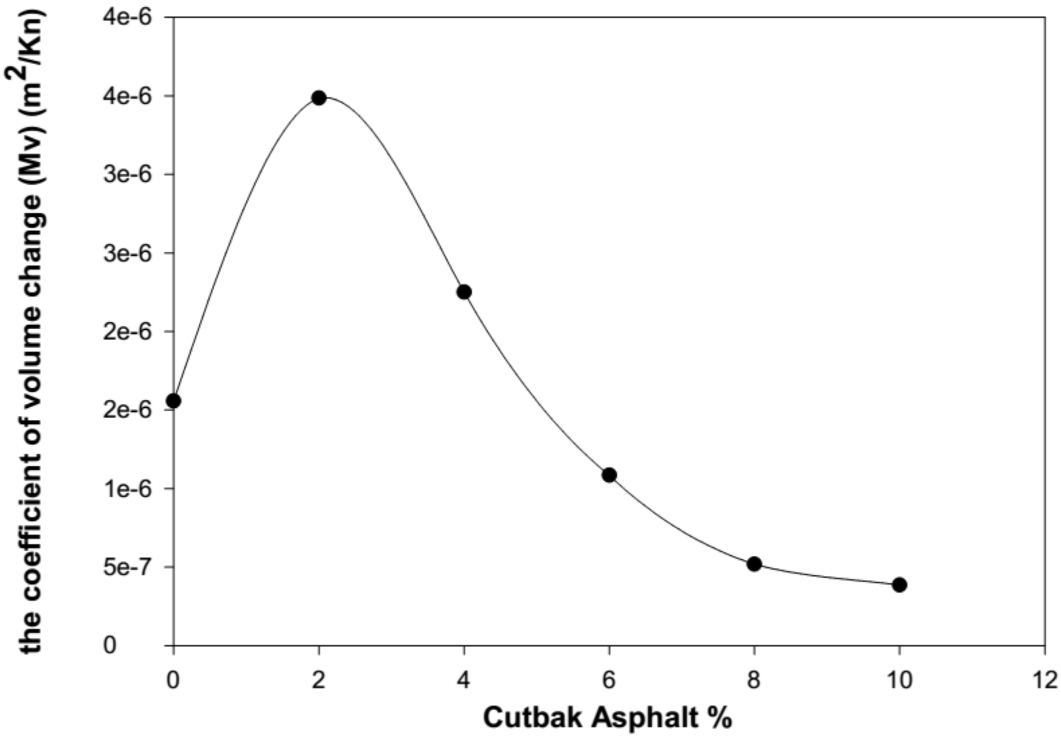

Figure 5: the coefficient of volume change of Soils with Different Amount of Cutback Asphalt

2.4.3 Effect of Asphalt on Coefficient of Permeability (k)

The permeability of a soil can be obtained indirectly from the oedometer test (Head, 1983) in addition to other direct methods such as constant and falling head method. However, in this research the permeability (hydraulic conductivity) was obtained from consolidation test, the permeability would be adopted from the Relation:

$k = Cv \times Mv \times \gamma_w$ …….. eq (1) , Where:

k: Coefficient of Permeability, (m^2/sec)

Cv: coefficient of Consolidation, (m^2/sec)

Mv: coefficient of volume change, (m^2/kn)

γ_{w}: the unit weight of Fluid, (kn/m^3).

The values of coefficient of permeability various soils with different percentage of Cutback Asphalt is illustrated in Figure.6.

The results show an increase in the permeability for the soils with percentages of cutback asphalt 2% and 4% for about 311% and 228% respectively, then the stabilized soil shows an improve in the permeability for about 14%, 47% and 95% for soils with cutback asphalt of 6%, 8% and 10%.

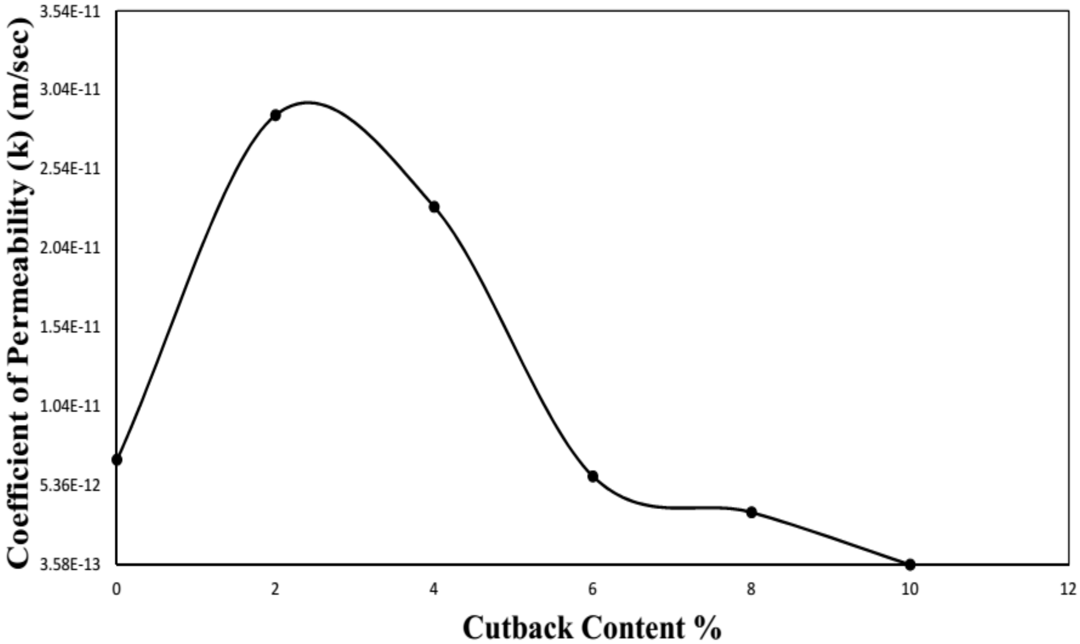

Figure 6: Coefficient of Permeability (k) of Soils with Different amount of Cutback Asphalt

2.4.4 Effect of Asphalt on the Compression Index (Cc)

[9],by his investigation on a gypseous soil, observed that the consolidation test results demonstrated that the total volumetric strain, coefficient of consolidation and compression index of stabilized soil samples by asphalt decreased as the percentage of emulsified asphalt increased.

The investigation on a cohesive soil shows in Figure 7 that the Compression Index (Cc) increased for the 2% addition of cutback then it start to decrease with the addition of cutback asphalt reaching approximately the same values for 4% and 6% of cutback and a reduction for the 8% and 10% of cutback, so the compression index in general decrease with increasing the asphalt content which is the same behavior conducted by [9] .

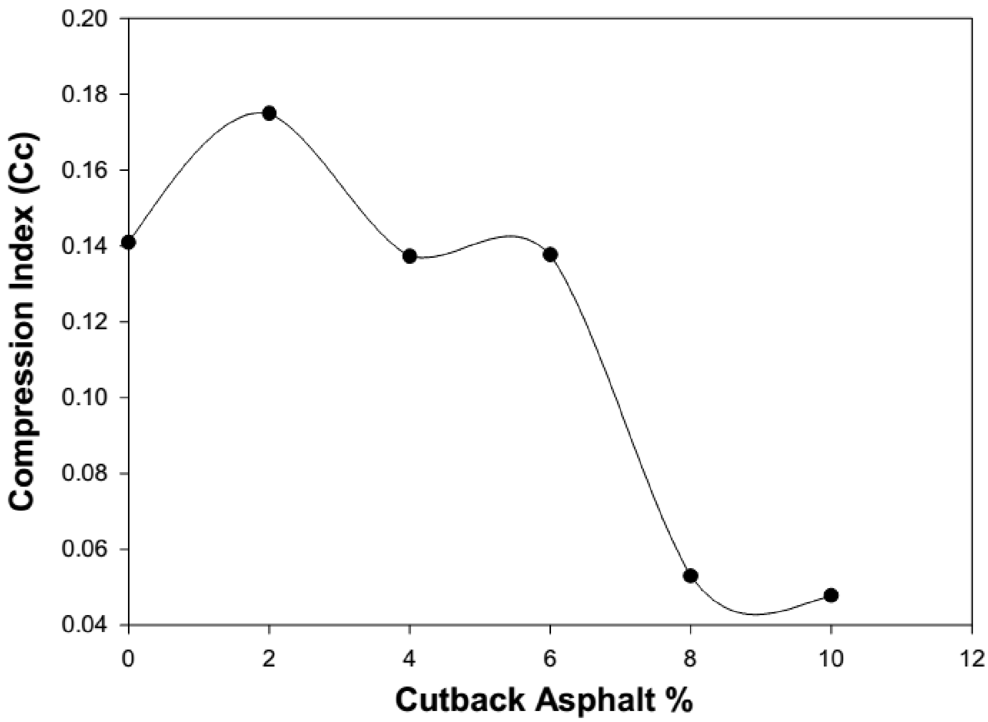

Figure 7: Compression Index (Cc) of Soil with Different amount of Cutback Asphalt

2.4.5 Effect of Asphalt on the Re-Compression Index (Cr)

The investigation shows an increase in values of The re-compression index for all amounts of cutback percentage added to the soil as shown in Figure 8. The values of Cr increase for soil with cutback of 2%, 4% and 6% by 44%, 72% and 77% respectively.

After that the Cr values decrease with the addition of cutback of asphalt due to increase in flocculation of soil particles and increase in volatiles amount of cutback, but still larger than the value of natural soil, the samples show increasing in Cr values for about 17% and 29% for soils with cutback asphalt of 8% and 10% respectively. The increase in Cr for soil with 10% of cutback might be due to increase in swelling pressure since the liquid limit of soil increased.

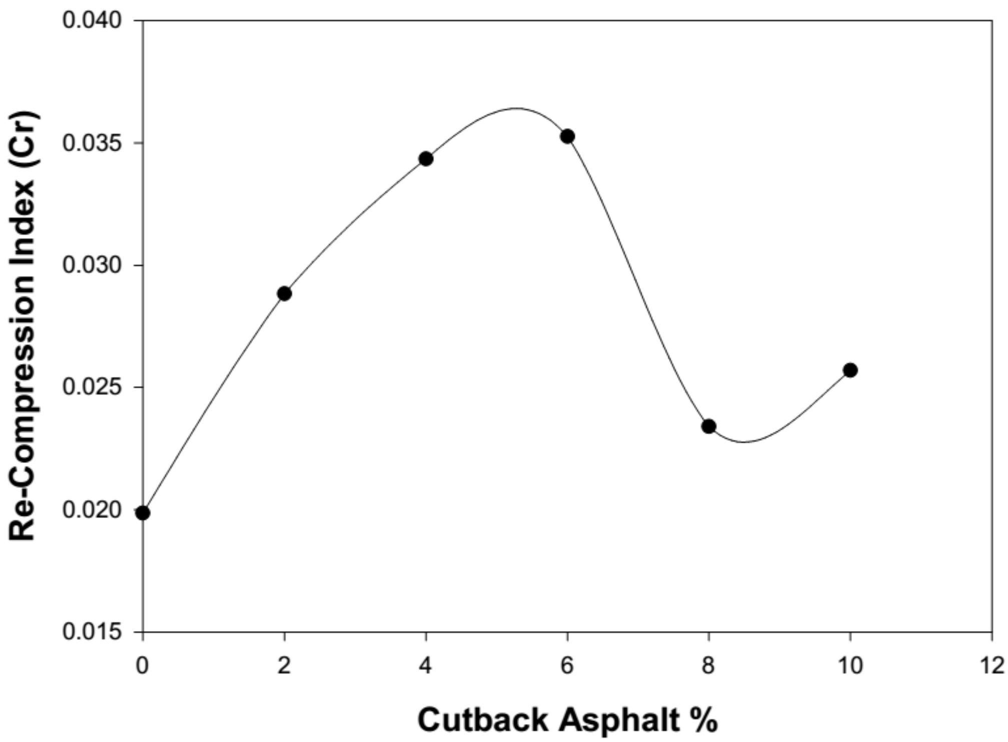

Figure 8: Re-Compression Index of Soil with Different amount of Cutback

3. Conclusions:

The test program obtained the following conclusions:

1- The soils stabilized with a cutback asphalt from (2-6)% showed an increase in the coefficient of consolidation (Cv) compared with the natural soil as the cutback asphalt evaporate from the voids ratio due to the aeration and curing process, so that the air voids would increase and the deformation also increased.

2- The soils indicate a decrease in the coefficient of consolidation (Cv) and settlement for soils with a cutback asphalt from (8-10)%, since the asphalt cement residual from aeration and curing filling the voids and increase the density extremely.

3- The coefficient of permeability (k) shows an increase for soil stabilized with cutback asphalt of (2-4) %, the air voids produced due to the evaporation process making the water flow more through soil mass than the natural soil. So that's could be useful if we want to make the cohesive soil more permeable.

4- The coefficient of permeability (k) decreased for the soils stabilized with (6-10)% of cutback asphalt, the voids between soil particles filled with asphalt and the permeable of water would be difficult since the channel of the soil mass was blocked by asphalt films. The coefficient of permeability of the soil stabilized by cutback asphalt could be defined as "very poor" or "impermeable" as mentioned by [23]

5- The study shows an improving of soil coefficient of consolidation (Cv) and The coefficient of permeability (k) for with cutback percentages (6-10) but that may not happened for strength specially for cohesive soils which may loss strength above a certain percentage of asphalt due to sliding of cohesive soils particles on each other.[16], [20], [24], [25]

6- The coefficient of compression experienced an increase for about 24% for soil with 2% cutback this increase might be due to increasing of voids ratio due to volatile process, while the compression index decrease with increasing the cutback asphalt after 2%, this might be because of the lubrication impact of cutback on soil particles which influence the interlocking and blocking of the voids. The Cc values of soil shows a slight decrease for about 3% for both 4% and 6% cutback content, the effect of decreasing was clear for 8% and 10% cutback content for about 62% and 66% respectively.

7- The re-compression index Cr in general increases with the addition of cutback asphalt, however, the Cr values increases by 44%, 72% and 77% for samples with cutback asphalt of 2%, 4% and 6% respectively, in the other hand the samples with soil cutback 8% decreases as the cutback content start to blocking the voids.

8- the coefficient of volume change (m_v) increase by 124% and 44% for 2% and 4% soil with cutback asphalt, the it deceased after optimum values to predict a reduction of 30%, 66% and 75% for soil with cutback asphalt of 6%, 8% and 10% respectively. This reduction might be due too the reduction in voids ratio by adding cutback asphalt would be more than the voids produced from volatilization process.

Conflicts of Interest

The author declares that they have no conflicts of interest.

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رصد تأثر معاملات الانضمام والنفاذية للترب المثبتة بالاسفلت المستحلب

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الخلاصة

من الضروي معرفة انضغاطية طبقات التربة المعرضة للأجهادات الفعالة وكذلك معرفة معدل جريان الماء خلال للأغراض التصميمية خاصة لمنشآت الردم و المنشآت البحرية الملامسة للتربة.ومن الأمور المهمة معرفة هذه الخصائص وذلك من خلال دراسة ومعرفة معامل الأنضمام ومعامل النفاذية للتربة.ان هذه الدراسة لمعرفة تأثير تثبيت التربة بالأسفلت على هذه الخصائص، تم التحقيق في هذه الدراسة على عينات من تربة طينية-غرينية، وتم تحضير النماذج بخلط التربة مع نسب مختلفة من الأسفلت (١٠-٠)% وتم أجراء فحص الأنضمام أحادي المحور لعينات بقطر ٥٠ملم وارتفاع ٢٠ملم مشبعة في الماء. وقد وجد أن معامل الأنضمام يزداد للترب المثبتة بالأسفلت بنسب (٦-٢)% وينخفض للترب المثبتة بالأسفلت بنسب (١٠-٨)%. في الجهة الأخرى تزداد النفاذية ومعامل الأنضغاط الحجمي للتربة المثبتة بالأسفلت بنسب (٤-٢)% ثم تقل بأستمرار أضافة الأسفلت للتربة لغاية ١٠%. ان معامل الأنضغاط يزداد الى حده الأمثل عند الترب المثبتة بنسبة أسفلت ٢% وبعدها يبدأ معامل الأنضغاط بالأنخفاض في الترب المثبتة بالأسفلت لغاية نسبة ١٠%. ان معامل أعادة الأنضغاط سوف يزداد لجميع عينات التربة المثبتة بالأسفلت، حيث انه سوف يزداد لحين الوصول لأعلى قيمة له عند الترب ذات نسبة الأسفلت ٦% ثم سوف تنخفض للترب مع استمرار زيادة نسبة الأسفلت لغاية ١٠%، ان قيم معامل اعادة الأنضغاط سوف تزداد للتربة ذات نسبة الأسفلت ١٠% عن التربة المثبتة ب٨% أسفلت وذلك قد يعود لزيادة معامل الأنتفاخ نتيجة زيادة حد السيولة و أنغلاق الفراغات الهوائية الموجودة بين حبيبات التربة.

الكلمات الدالة:الاسفلت المستحلب، الانضغاطية، تثبيت التربة، فحص الاودوميتر، الانضمام، النفاذية.