IMPLEMENTATION OF GYPSEOUS SOIL-ASPHALT STABILIZATION TECHNIQUE FOR BASE COURSE CONSTRUCTION

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ABSTRACT

The aim of this research work is to study the effect of stabilizing gypseous soil, which covers vast areas in the middle, west and south parts of Iraq, using liquid asphalt on its strength properties to be used as a base course layer replacing the traditional materials of coarse aggregate and broken stones which are scarce at economical prices and hauling distances.

Gypseous soil brought from Al-Ramadi City, west of Iraq, with gypsum content of 66.65%, medium curing cutback asphalt (MC-30), and hydrated lime are used in this study.

The conducted tests on untreated and treated gypseous soil with different percentages of medium curing cutback asphalt (MC-30), water, and lime were: unconfined compression strength, and one dimensional confined compression under both dry and absorbed test conditions.

The test results showed that stabilizing gypseous soil using the optimum fluid content of 16% (5% cutback asphalt+11% water) have improved the unconfined compressive strength, compressibility, rebound consolidation, and waterproofing of gypseous soil, but under absorbed condition the stabilized gypseous soil using cutback asphalt only did not satisfy the requirements for base course construction, therefore it was decided to use lime additive to improve the properties of soil-cutback mixture under absorbed condition.

Keywords: Gypseous soil, Cutback asphalt, Asphalt stabilization, Unconfined compressive strength**,** Rebound consolidation.

الخلاصة

يتضمن هذا البحث دراسة تأثير تثبيت التربة الجبسية والتي تغطي مساحات شاسعة من وسط، غرب ، وجنوب العراق بأستعمال الأسفلت السائل على خواص القوة للتربة الجبسية و ذلك لغرض أستعمال مزيج التربة والأسفلت في انشاء طبقة الاساس للطرق كبديل لأستعمال الحجر المكسر أو الحصى الخابط التي تستعمل عادة لأنشاء أساس الطرق (base course layer) والتي يندر وجودها بأسعار مناسبة ومسافات حمل اقتصادية.

لغرض الدراسة تم اختيار تربة جبسية من مدينة الرمادي، غربي العراق ذات محتوى جبسي بنسبة 66.65% وتم استعمال أسفلت سائل متوسط التصلب (medium curing cutback asphalt) (MC-30) ومادة النورة.

تضمنت الدراسة اجراء فحوصات الانضغاط غير المحصور والانضغاط احادي المحور حيث اجريت جميع هذه الفحوصات للتربة غير المعالجة والمعالجة بنسب مختلفة من الاسفلت السائل متوسط التصلب , الماء والنورة في حالتي الجفاف والتشبع بالماء.

أوضحت النتائج ان تثبيت التربة الجبسية بأستعمال نسبة المعالجة المثلى وهي 16% (5% من الاسفلت السائل المتوسط التصلب+ 11% من الماء) ساعدت على تحسين قوة الانضغاط، الانضغاط المسترجع، وعزل الماء لكن بعد اشباع التربة الجبسية المثبتة بالأسفلت السائل بالماء أصبح مزيج التربة والاسفلت غير مناسب لتصميم طبقة أساس الطريق لهذا تم في المرحلة الثامنة من برنامج العمل اضافة مادة النورة لتحسين خواص مزيج التربة والاسفلت في حالة التشبع بالماء.

1. INTRODUCTION

Soil stabilization is a process of improvement in both strength and durability of a soil in such a manner as to maintain, alter or improve the performance of the soil as a construction material (Kadiyali and Lal, 2006). The process may include the blending of soils to achieve a desired gradation or the mixing of commercially available additives that may alter the gradation, texture or plasticity, or act as a binder for cementation of the soil (Stafen, 1994).

In the selection of a stabilizer, the factors that must be considered are the type of soil to be stabilized, the purpose for which the stabilized layer will be used, the type of soil improvement desired, the required strength, durability of the stabilized layer, the cost and environmental conditions (Stafen, 1994).

The purpose of stabilization are generally satisfied if one or more of the following changes in soil properties are accomplished by the agent or additive (Building Research Advisory Board, 1969) :

1. Increased strength.
2. Reduction in swelling properties.
3. Improved compactibility.
4. Reduced permeability.

2. MATERIALS

2.1 Gypseous Soil

The soil of this investigation was taken from Al-Ramadi city, Al-Anbar Governorate, west of Iraq. A shovel was used to remove the top soil and gypseous soil was obtained from a depth of 0.5m up to 1.0 m depth. Due to the presence of gypsum in a macrocrystalline form in the soil under study, a suitable sizing process has been performed using a plastic hammer then soil was sieved through sieve No.4, and the portion passing was oven dried at 45°c. **Table (1)** summarizes the chemical properties of gypseous soil and **Table (2)** presents the physical properties of gypsies soil, while **Fig. (1)** shows the grain size distribution of the soil.

2.2 Liquid Asphalt

Medium curing cutback asphalt (MC-30) "manufactured at al-Dora refinery" by one-step:

91.2 %[(40-50) Asphalt cement] +8.8% [Kerosene] → (MC-30)

Properties of cutback asphalt (MC-30) used are given in **Table (3)**.

2.3 Water

Ordinary tap water is used throughout this study in preparing the specimens.

2.4 Lime

In this study, hydrated lime manufactured at "Tang Fani" factory in Iran was used. The chemical composition of lime is given in **Table (4)**.

3. SPECIMENS PREPARATION

3.1 Mixing Technique

To prepare the specimen, the pulverized and homogenous gypseous soil passing No.4 sieve was oven dried at a temperature of (45°) then thoroughly mixed with the required percentage of water by hand until the water dispersed throughout the mixture, then the required percentage of cutback asphalt was added and mixed by rubbing the mixture between palms for two minutes so that the mixture has a homogenous character, and a proper coating of soil particles with asphalt occurred. When lime additive was added to the soil cutback mixture to improve the properties of the soil cutback mixture under absorbed condition the required amount of lime additive was first mixed with the oven dried passing No. 4 sieve gypseous soil. Then the optimum water content of 11% was added to the soil-lime mixture and mixed thoroughly by hand. Then cutback asphalt was added and mixed by rubbing the mixture between palms for two minutes so that the mixture has a homogenous character.

3.2 Unconfined Compression test Specimens' Preparation and Testing

After mixing soil with the required amount of fluid content (cutback asphalt and water). The predetermined weight of the mix which gives the maximum modified dry unit weight of 19.8 (kN/m^3), was statically compacted in a cylindrical mould of a split type of 3.8 cm in diameter, and 7.6 cm in height in three equal layers according to the (ASTM D 5102 – 96). Specimens were allowed to cure for four days at room temperature of 25± 3ºC and the average value of the unconfined compressive strength for each duplicate specimens was calculated and considered for analysis. The unconfined compression test was carried out according to the (ASTM D 2166 – 00) standard, using a constant strain compression machine with a loading rate of 1.52 mm per minute. To determine the effect of water absorption on the unconfined compressive strength of the soil asphalt mixture the prepared unconfined compression test specimens were weighted then placed in the absorption apparatus which consisted of a container of size 35×25×16 cm depth, filled with 8 cm thickness of fully saturated sand passing 6 mm sieve, this sand layer was kept saturated throughout the absorption period with distilled water by visual inspection then the whole tank was covered by polythene sheets tightly to retain the moisture in the sand and specimens. This was done for 24 hours to allow the water to reach the samples by capillary action. This procedure was adopted to simulate the field conditions, the sand layer representing the subbase material, the polythene sheets representing the bituminous surfacing and the specimens representing the stabilized base course. After an absorption period of 9 days, the unconfined compressive strength of specimens was tested.

3.3 One-Dimensional Confined Compression Test Specimens' Preparation and Testing

This test is carried out on specimens of natural soil and on specimens prepared at the optimum fluid content of 16%; additional specimens were prepared with 1% variation of fluid content as 15% and 17% to check the effect of fluid content on the consolidation properties. Another group of specimens were prepared at the optimum fluid content of 16% mixed with the optimum lime content of 7%. After mixing the soil with the required amount of fluid content, the predetermined weight of the stabilized soil that gives the maximum standard dry unit weight of 17.7 (kN/m^3) was compacted in a mould of 75mm diameter and 20mm height using static compaction. Specimens were allowed to cure in the ring for (7) days at room temperature of 25±3 ºC, to maintain the specimen's shape, then specimen was withdrawn from the ring.

The test was conducted according to the procedure of (ASTM D 2435 – 96). The prepared specimens were divided into two groups, the first group was tested in dry condition, while the second group was flooded with water for (24) hrs. One dimensional confined compression test was conducted using the consolidation test apparatus. Each specimen was subjected to successive load increments of 25, 50, 100, 200, 400, and 800 kPa during 24 hours and the consolidation readings were recorded. The load was doubled after each increment and the time was also doubled before making the next observation. After recording the consolidation at a load of 400 kPa, the load was released to 200 kPa to allow for strain rebound and the first rebound strain was recorded after two hours release period, then load was applied again and raised to 800 kPa. The consolidation was recorded at this load, then another unloading process was conducted by releasing the load to 200 kPa, the final rebound strain was recorded after a two hour release period.

4. ANALYSIS AND DISCUSSION OF TEST RESULTS

4.1 Unconfined Compression Test

It was found as shown in **Fig. (2)** that the unconfined compressive strength increases with increasing cutback asphalt content, this increase may be attributed to the gain in cohesion which is provided by continuous film of asphalt coating the soil particles. The unconfined compressive strength reaches a maximum value at 16% fluid content (5% cutback asphalt + 11% water) which may represent the optimum particle coating, but the unconfined compressive strength decreases as the cutback asphalt content increases, this may be attributed to the increases in thickness of bitumen films surrounding the soil particles and the fluid content is such to fill the voids completely preventing the particle interlock, this causes a high reduction in friction, which in turn leads to a reduction in the compressive strength. Such results are in agreement with many researchers work (TRRL, 1974), (Al-Kawaaz, 1990), (Al- Safarani, 2007), and (Taha, et. al., 2008).

Fig. (3) indicates that the absorption of the test specimens after 9 days absorption greatly reduces the compressive strength as compared to dry condition. This reduction may be attributed to the adhesion failure or a weaking of the cohesive bond between the asphalt-particles system. This result was well confirmed with (TRRL, 1974), (Al-Kawaaz, 1990), and (Taha, et. al, 2008).After adding lime additive in different percentages to the soil cutback mixture it was found as shown in **Fig. (4)**, that the unconfined compressive strength increases with increasing lime content. This behavior may be attributed to the to the role of the reaction of lime additive with soil in improvement of the cementation and water proofing action of the soil cutback mixture thus effect of water damage on soil cutback mixture is reduced.

4.2 One-Dimensional Confined Compression Test

As illustrated in **Fig. (5)** and **Fig. (6)** at both dry and soaked test conditions the strain decreases with increasing the cutback asphalt content up to the cutback asphalt content of 5%, then strain increases with increasing cutback asphalt content. This behavior may be attributed to that the cementation between soil particles increases with increasing cutback asphalt content up to optimum cutback asphalt content of 5% then, further increase in cutback asphalt content results in a lubrication action causes the soil particles will to slide over each other and that will increases the strain. Same behavior was observed by (Al-Kawaaz, 1990), (Al-Sharrad 2007), and (Al-Safarani, 2007). Additional reduction in strain was observed when the optimum lime additive of 7% was added to the soil cutback mixture as shown in **Fig. (7)**.

It's also shown in **Fig. (5)** that that when the applied load of 400 kPa is unloaded to 200 kPa at the first rebound cycle, and when load is reduced from 800 kPa to 200 kPa in the second rebound cycle the strain was increased which indicates the formation of certain type of elastic properties and rebound consolidation in the soil cutback mixture tested under dry condition and it can be noticed that when cutback asphalt content has increased the percent of rebound consolidation has increased up to the optimum cutback asphalt content of 5% then percent of the rebound consolidation decreased with increasing cutback asphalt content, on the other hand as shown in **Fig. (6)** for specimens tested under soaked condition no significant strain change was observed(Al-Kawaaz, 1990), and (Sarsam and Ibrahim, 2008).

5. CONCLUSIONS

Based on the limited testing program, the following conclusions could be drawn:

1. The unconfined compressive strength of the soil-cutback mixture under dry and absorbed test conditions increases with increasing cutback asphalt content up to the optimum cutback asphalt content of 5%, then decreases.
2. There is a high reduction in the unconfined compressive strength of the soil-cutback mixture under absorbed condition as compared to the dry test condition. When lime additive is added to the soil-cutback mixture, the unconfined compressive strength under absorbed condition improves and increases with increasing lime content.
3. Soaking of pure gypseous soil in water causes a high increase in the volumetric strain. Addition of cutback asphalt to gypseous soil causes a reduction in the volumetric strain to the optimum cutback asphalt content of 5% then increase, additional reduction is observed when lime is added to the soil-cutback asphalt mixture.
4. Under dry test condition the addition of cutback asphalt to gypseous soil creates a type of elastic properties and rebound consolidation in the soil – cutback mixture at high stress application, and the permanent strain reduces.

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Table (1) Chemical composition of the natural soil

Organic content (%)	0.064
Gypsum content ($CaSO_4$) (%)	66.65
Carbonate content ($CaCo_3$) (%)	21.97
Total soluble salts (T.S.S.) (%)	58.1
Total (SO_3) (%)	31
pH value	8

Table (2) Physical properties of the natural soil

Physical property	**Test result**
Specific gravity	G_S = 2.42
Atterberg limits Liquid limit (%) Plastic limit (%) Plasticity index (%)	L.L. = 33 P.L. = Non plastic P.I. = Non plastic
Standard compaction properties Max. standard unit weight Optimum moisture content (%)	$\gamma_{d\ max}$=1.81 (gm/cm^3) = 17.7 (kN/m^3) O.M.C. =12 (%)
Modified compaction properties Max. modified unit weight Optimum moisture content (%)	$\gamma_{d\ max}$=2.02(gm/cm^3) = 19.8 (kN/m^3) O.M.C. =11.6 (%)
Maximum dry unit weight (kN/m^3)	$\gamma_{max.}$ =20.17
Minimum dry unit weight (kN/m^3)	γ_{min} =12.4
% passing sieve No. 200	4.69
Coefficient of curvature	C_c =0.6
Coefficient of uniformity	C_u =8
Unified classification system	SP
Group index	0
AASHTO classification system	A-3

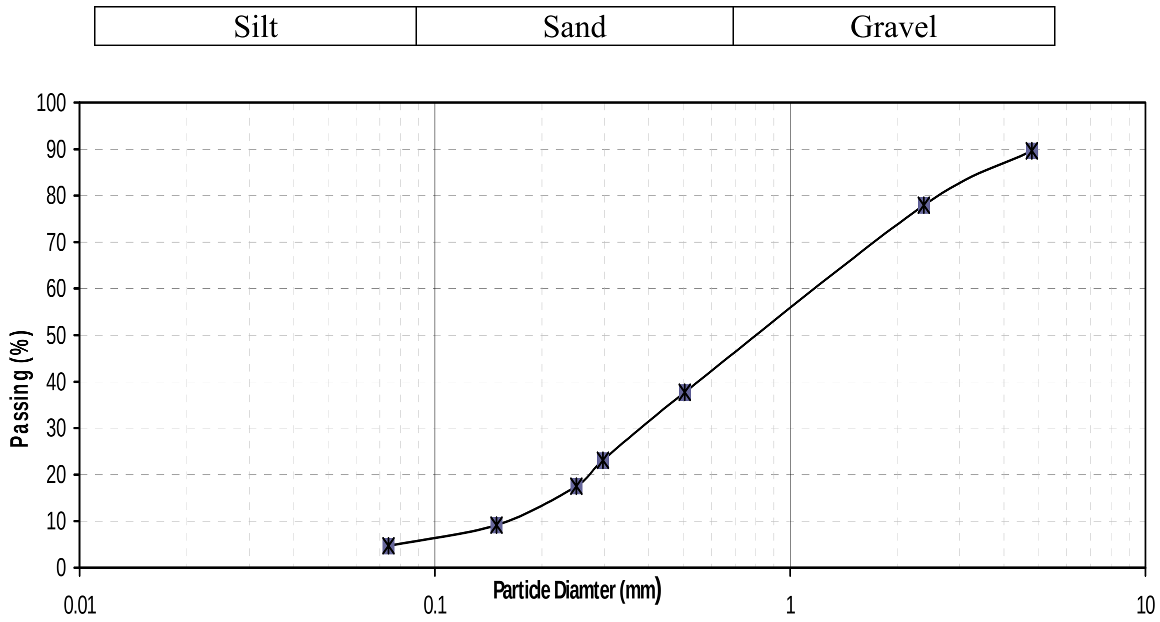

Fig. (1) Grain size distribution curve for the tested soil (ASTM D422-63).

Table (3) Properties of cutback asphalt (MC-30)*

Properties	Test results
Kinematic viscosity at 60ºC (c.stroke)	33
Specific gravity	0.99
Distillation Distillate % vol. of total distillate to 360ºC. To 225ºC To 260ºC To 315ºC Residue from distillation to 360ºC %vol. By difference	 25 max. 40-70 75-93 50 min.
Tests on residue from distillation Penetration at 25ºC (100gm, 5 sec.) Ductility at 25ºC (5cm/min) Solubility in carbon tetrachloride CCl_4 % wt.min	120-300 100 min. 99.5 min.

*After Dora Refinery Lab/Baghdad

Table (4) Chemical composition of lime

The composition	Percent by weight
SiO_2	0.74
Fe_2O_3	0.19
Al_2O_3	0.5
CaO	64.23
MgO	1.17
L.O.I. (Loss On Ignition)	29.94
Percent passing No. 200 sieve	69.9

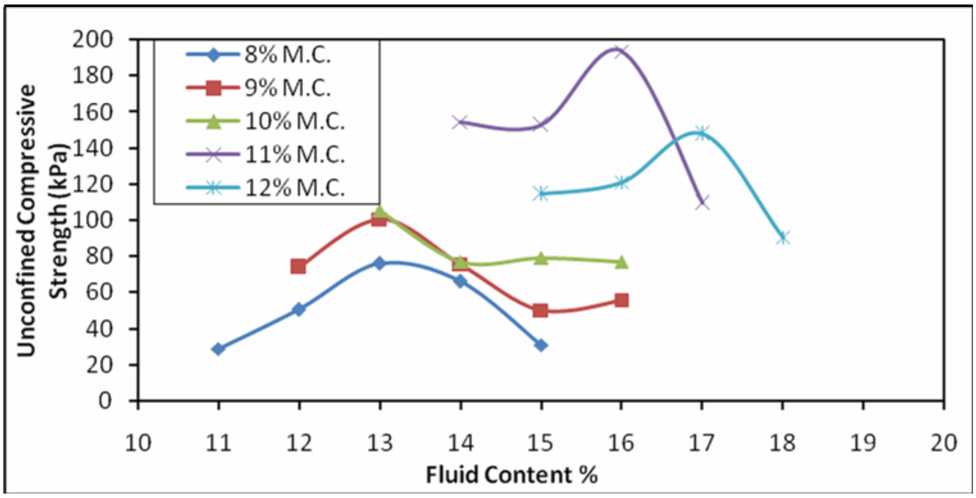

Fig. (2) Unconfined compressive strength-fluid content (%) relationship.

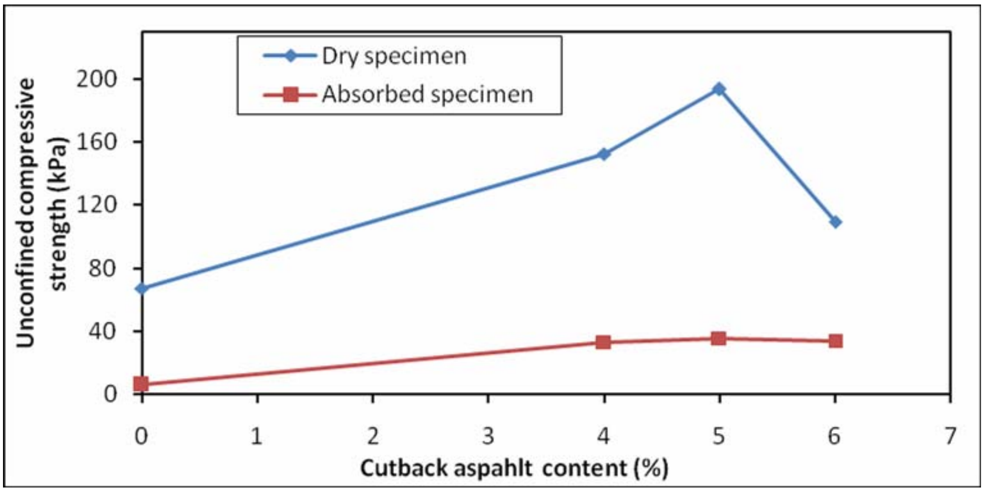

Fig. (3) Effect of water absorption on the unconfined compressive strength.

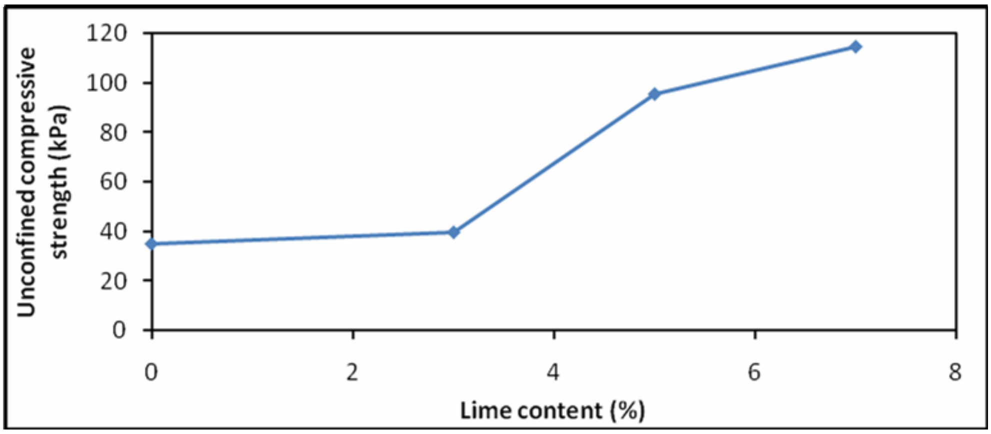

Fig. (4) Effect of lime additive content on the unconfined compressive strength of the soil cutback mixture.

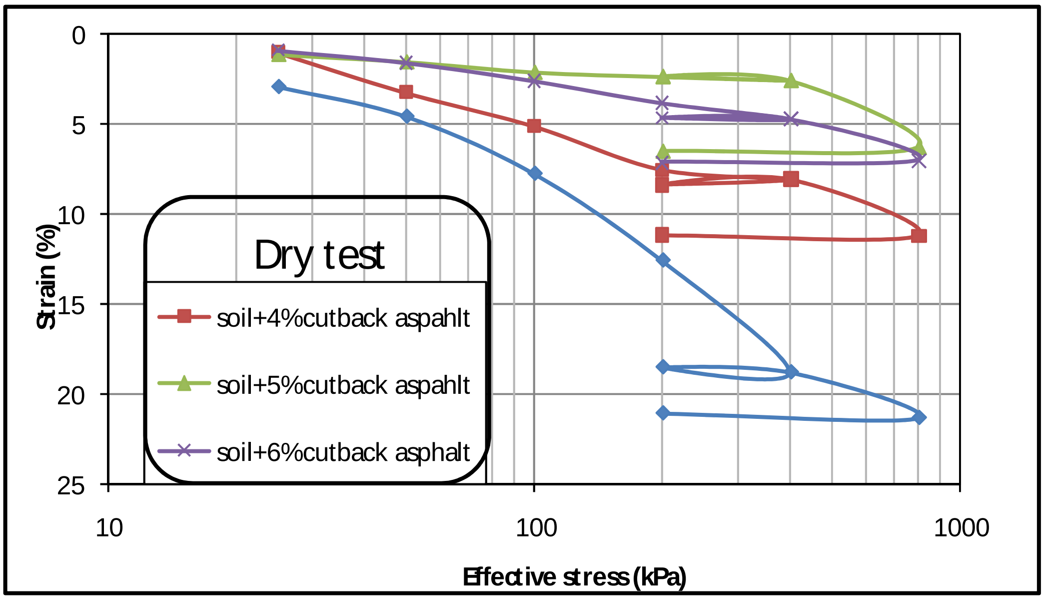

Fig. (5) Stress-strain relationship of one-dimensional compression test (dry condition).

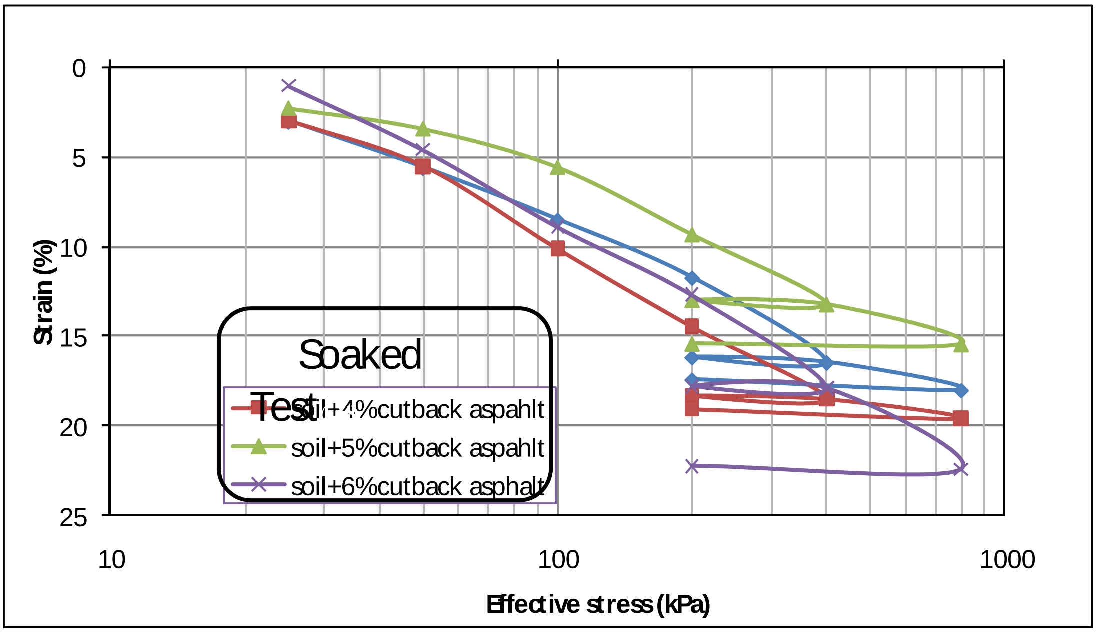

Fig. (6) Stress-strain relationship of one-dimensional compression test (soaked condition).

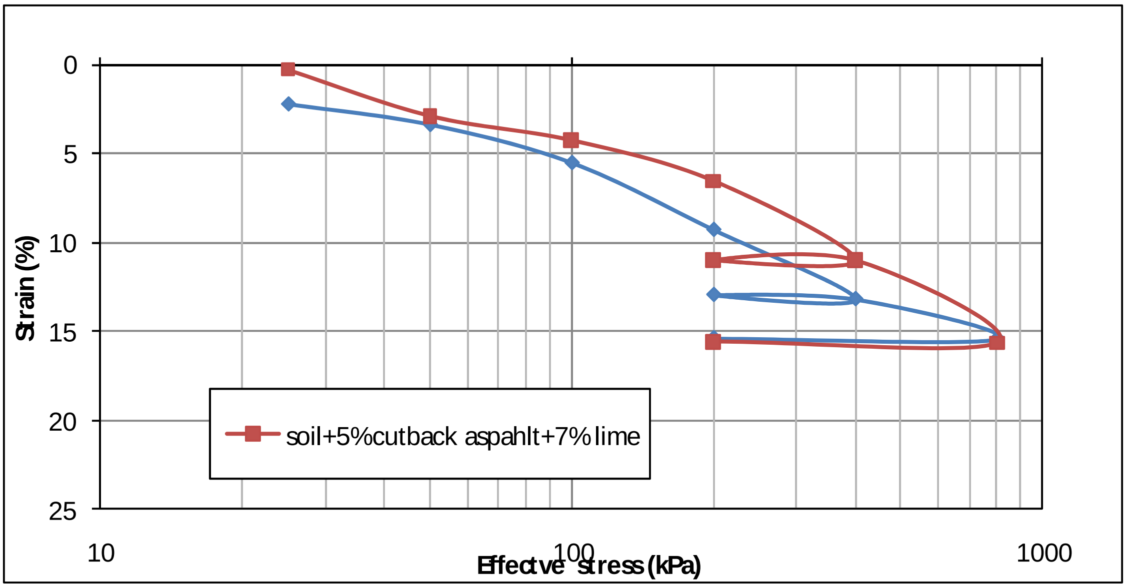

Fig. (7) Stress-strain relationship of one-dimensional compression test (soaked condition).