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CONTRIBUTION OF LIQUID ASPHALT IN SHEAR STRENGTH AND REBOUND CONSOLIDATION BEHAVIOUR OF GYPSEOUS SOIL

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Abstract
This paper deals with the effect of stabilizing gypseous soil using two liquid Asphalt types (cutback and emulsion) on its behavior in shear strength and rebound consolidation.
Soil-Asphalt specimens had been constructed using various percentages of both liquid Asphalt types. One group of such specimens were tested in the direct shear box apparatus to determine the effect of liquid Asphalt on shear strength, cohesion and angle of internal friction using the unconsolidated un drained test.
Another group of the specimens were subjected to one dimensional confined compression test using both dry and saturated testing conditions in the consolidation apparatus.
The effect of liquid Asphalt on the behavior of mixes in consolidation and rebound consolidation was studied.
It was concluded that gypseous soil is usually stiff in the dry condition, but it is weak and had a collapsible behavior when saturated. The addition of liquid Asphalt provides cohesion strength to the soil mass and also acts as a waterproof agent. It creates a type of elastic properties and reduces the total strain.

Key words: Consolidation, Cutback, Emulsion, Gypseous soil, Shear strength

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والمستحاب(على ساوكيتها تتعامل هذه الدراسة مع تاثير تثبيت التربة الجبسية باستخدام نو أ
في قوة القص والانضغاط المسترجع . تم تحضير عينات من مزيج التربة . والاسفلت السائل استخدام نسب مختلفة من كلا نوعي الاسفلت
فحصت المجموعة الاولى من هذه العينات باستخدام جهاز صندوق القص المباشر لبيان تاثير الاسفلت السائل على قوة القص, التلاصق, وزاوية الاحتكاك الداخلي في حالة الفحص غير المضغوط وغير .المبزول
تم فحص المجموعة الثانية باستخدام الانضغاط احادي المحور في كل من حالتي الجفاف او التشبع .بالماء باستخدام جهاز الانضغاط
ان تاثير الاسفلت السائل على سلوكية العينات في حالتي الانضغاط والانضغاط المسترجع قد تم .تحليلها

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تم الاستنتاج بأن الترب الجبسية تظهر صلادة عندما تكون جافة ولكنها تكون ضعيفة وذات سلوك انهياري عند تشبعها بالماء, بينما يعطي الاسفلت السائل قوة تلاصق للكتلة الترابية ويعمل كذلك كعازل للماء, كم يعطي نوع من الصفات المرنة للتربة ويقلل من الانفعال الكلي.

1.0 Introduction

Gypseous soils were estimated to cover more than 30% of the area of Iraq (Buringh-1960); it covers vast areas in the southern and eastern parts of the country. The gypsum and anhydrite content which is soluble in water was within (10-70) %; (Ismail-1994); (Sarsam and Prakash-1981). Most of the physical and chemical properties of the soil in such areas are affected by the gypsum and anhydrite content.

The solution of gypsum causes many problems to the structures and road network; it changes the stable state of the soil to a collapsible state which experiences excessive settlement when it is subjected to moisture content change.

2.0 Previous Experiences

The negative effects of gypsum content have been studied by many research works (Prakash and Sarsam-1981); (Mesdary-1989). (Al-Neaimi-1999) stated that the strength of gypseous soil decreased significantly when saturated, while air drying for long period has increased the cohesion.

Damage to road and airfields pavement, buildings constructed on gypsiferous soils has been widely reported by (Razouki and Kuttah-2001; Nashat etal-2001).

(Sulaiman and Sarsam-2000) has conducted an extensive study on stabilizing gypseous soils with liquid Asphalt. They concluded that cutback has a pronounced positive effect on cohesion at both dry and absorbed test conditions, and that 17% total fluid content satisfies the design requirements for road bases construction after 12 days of curing. Such findings were adopted in this study. (Epps et al-1971) studied soil Asphalt mixture and fond that 4-5% is the optimum cutback percent for maximum stability.

(Al-Rawi-1971) suggested that both cutback and emulsion could be used to stabilize Iraqi soils. (Al-Kawaz-1990) studied the behavior of sandy soil Asphalt mix in consolidation; He reported the increase in rebound strain with the increase in binder content. (Esho-2004) reported the increase in cohesion of gypseous soil by the addition of emulsion.

3.0 Materials

3.1 Gypseous soil

The gypseous soil was obtained from Tikrit-AL-Owja at a depth of one meter below the ground surface after removing the top soil. The soil was sieved through sieve no.4, and the portion passing was air dried, oven dried at 60°c and stored into plastic containers for the study. The soil was poorly graded sand with AASHO classification of A-3.

Table 1 summarizes the various physical and chemical properties, while figure 1 shows the grain size distribution of the soil.

3.2 Liquid Asphalt

Two types of liquid Asphalt were tried throughout the investigation.

3.2.1 Cutback Asphalt

Medium curing cutback Asphalt MC-250 was manufactured in the laboratory using the same procedure followed in Dora refinery by mixing 90% of 40-50 penetration grade Asphalt cement with 10% of kerosene after heating the Asphalt cement to 120ºC in

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an oven. The mixture was subjected to continuous stirring for 20 minutes, and then allowed to cool at room temperature.

3.2.2 Emulsion

Medium setting cationic emulsion was obtained from Alzahf Alkaber Company. Table 2 summarizes various properties of cutback and emulsion.

3.2.3 Water

Distilled water was used throughout the investigation for mixing and saturation.

4.0 Specimens Preparation

4.1 Soil Asphalt mixing

The soil was oven dried, the required amount of water was added and mixed thoroughly, then the liquid Asphalt was added and mixed by rubbing the mixture between palms for two minutes so that the mixture had a homogeneous character, and a proper coating of soil particles with Asphalt occurred. The total amount of fluid content (water and liquid Asphalt) of 17%, and the dry density of 1.660 gm/cm³ which were obtained from previous work on a similar materials (Sulaiman and Sarsam-2000) have been maintained throughout this investigation. Table 3 shows the mix properties.

4.2 Direct shear specimens' preparation and testing

After mixing the soil with the required amount of fluid content, the predetermined weight of the mix which gives the required dry density was compacted in a mould of 6x6x2 cm in dimensions using a static compaction. Specimens were withdrawn immediately from the mould and subjected to curing at a room temperature of 25±3ºC for 12 days; such curing period represents the minimum required time for cutback curing as obtained from the same previous work. Using the unconsolidated undrained direct shear test, the test was conducted with various normal loads of 75, 105, and 140 kPa, so that the cohesion and angle of internal friction could be obtained.

4.3 Consolidation specimens' preparation and testing

The predetermined weight of the stabilized soil which gives the required dry density was compacted in a mould of 75mm diameter and 20mm height using static compaction. Specimens were withdrawn immediately from the mould and subjected to curing at a room temperature of 25±3ºC for 12 days; Specimens were divided into two groups, the first group was tested in dry condition, while the second group was subjected to water absorption inside the testing mould for one hour as per the standard testing procedure of (ASTM-2735). 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 taken. 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, then 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.
Another group of specimens with 5% liquid Asphalt (cutback and emulsion) were subjected to continuous load increments up to800 kPa, and then allowed for rebound strain by releasing the load to 200 kPa, then the load was increased again to 800 kPa. This procedure of load application and release was continued three times for each specimen to study the elastic behavior of the stabilized soil since it was felt that the addition of liquid Asphalt will create a type of elastic properties in the soil. This could be demonstrated well when using rebound consolidation test.

A total of 16 shear box specimens and 16 consolidation test specimens have been compacted and tested and an average value

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of duplicate specimens were considered for analysis.

5.0 Analysis and Discussion on Test Results

5.1 Behavior in cohesion and shear strength

As illustrated in figure 2, the addition of emulsion has significantly increased the cohesion and angle of internal friction of soil Asphalt mix, lower percentage of emulsion of 5% shows the highest cohesion values. This could be attributed to that 5% emulsion supplies optimum soil particles coating. Further increase in emulsion content will give thicker Asphalt film surrounding the soil particles, this may cause excessive lubrication action, separating soil particles, and cause reduction in friction resistance. The shear strength of the mix has increased many folds; this is in agreement with (Abid Al-Hussain et al,1998).

On the other hand, figure 3 show that the addition of cutback Asphalt has a negative effect on cohesion, while the angle of internal friction increases. Lower cutback content of 5% shows higher shear strength at high normal stresses. This may indicate that lower cutback content could give higher shear strength. Table 4 summarizes the results of stabilized soil in shear.

5.2 Behavior in consolidation

Figure 4 presents the effect of testing condition on the behavior of gypseous soil in one dimensional confined compression. The saturated test condition has decreased the void ratio especially at high stress level of 800 kPa, such reduction is within 3%.

As illustrated in figure 5, the addition of liquid Asphalt has considerably reduced the void ratio. This may be attributed to more lubrication effect on soil particles which results in better interlocking and voids blocking.

The addition of 5% emulsion has decreased the void ratio by 56%, while the addition of 5% cutback reduces the voids ratio by 27% at high stress value of 800 kPa using the saturated test condition.

The variation in soil behavior when two types of liquid Asphalt were incorporated is clear, cutback can decrease the void ratio 50% lesser than what can the emulsion do.This could be attributed to the nature of emulsion components which is mainly (water, Asphalt, and emulsifying agent). When adding the emulsion to the soil- water mix, the water from both sources will spread the asphalt more homogeneously, coat the soil particles and block more voids, while the cutback components are (Asphalt and kerosene).

When adding this cutback to the soil- water mix, the kerosene will take part of the total fluid content although its properties is different from that of water. This could cause an inefficient coating and spreading of the Asphalt. Same effects were noticed in the shear strength behavior.

Figures 6-a, and 6-b further supports such findings, the addition of more cutback will show a negative effects on void ratio reduction. 7% cutback reduces the void ratio by 15%, and 14% cutback increases the void ratio by 15%.

At the dry test condition, the void ratio increases by 7% when 7% cutback was incorporated in the mix.

It could be concluded that 5% cutback or lower percentages is effective in stabilizing the gypseous soil.

5.3 Behavior in rebound consolidation

Figure 4 shows that when the applied load of 400 kPa is decreased to 200 kPa at the first rebound cycle, and when it is reduced from 800 kPa to 200 kPa in the second cycle, there was a minor change in voids ratio which indicates high permanent strain condition for both dry and saturated test conditions.

When adding 5, 7 and 14% of cutback, same behavior was noticed at low stress level.

Figure 5 illustrates the rebound behavior of the soil by the addition of 5% liquid Asphalt, the release of the applied stress at cycle one from 800 kPa to 400 kPa, then 200 kPa, has increased the void ratio, indicating the formation of certain type of elasticity in the mix, a rebound of 8% in the total

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settlement was indicated. In cycle two,(the load was increased from 200 kPa to 400 kPa then 800 kPa, and released to 200 kPa again), same behavior was noticed, such behavior agrees well with (Al-Kawaaz-1999) findings.

Tables 5 and 6 demonstrate the change in consolidation variables at both testing conditions; They show the reduction of permeability by the addition of liquid Asphalt. The permeability decreases approximately by 15% due to the incorporation of both liquid Asphalt at dry or saturated testing conditions.

Figure 7 shows that the addition of 14% cutback gives almost full protection to the soil against saturation. The consolidation of the stabilized soil was decreased by 67% at saturated test condition when compared to pure soil. It also indicates the high collapsible nature of the soil when saturated. The rate of increase in consolidation decreases as the applied stress increases.

Figure 8 illustrates the decrease in compression by the addition of cutback at various void ratio; It shows the improvement in consolidation resistance by 66% due to cutback addition at saturated test condition.

Figure 9 demonstrates the decrease in permeability coefficient by the addition of cutback, as the void ratio increases, the permeability decreases. This could be attributed to the blockage of voids and proper coating of soil particles by cutback Asphalt.

6.0 Conclusions

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

1. The gypseous soil is stiff when dry and has a collapsible nature when saturated.
2. The addition of 5% liquid Asphalt (cutback or emulsion) creates a type of elastic properties and behavior in the soil at high stress application when tested for rebound consolidation, and the permanent strain was reduced.
3. Emulsion has a significant positive effect on shear strength, it increases the cohesion and angle of internal friction, 5% emulsion and 12% water could give perfect stabilization.
4. The addition of 14% cutback and 3% water can give full protection to the gypseous soil against the effect of saturation, and reduces the settlement.
5. The emulsion reduces voids ratio, and the permeability at both dry and saturated testing conditions, while 5% cutback or lower will act the same.
6. Cutback Asphalt increases the resistance of gypseous soil to permeability, such resistance increases as void ratio increases.

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TABLE 1 Physical and chemical properties of the soil

Physical properties		Chemical properties	
Specific gravity	2.66	Organic content %	0.75
Max. standard dry density gm/cm³	1.260	Carbonate content %	14.4
Optimum moisture content %	12	Gypsum content %	28.0
Max. modified dry density gm/cm³	1.660	Chloride content %	0.06
Optimum moisture content %	10.5	Total soluble salts %	13.7
% passing sieve No. 200	4.45	pH value	7.8
Coefficient of uniformity CU	3.05		
Coefficient of curvature Cc	0.91		
Unified classification system	SP		
AASHTO classification system	A-3		

TABLE 2 Properties of liquid Asphalt

Cutback MC-250		Emulsion	
Viscosity (S.F.V.)	140	Particle charge	+ve
Kinematic viscosity at 60º C Cst	32	Viscosity Cst	45
Flash point º C	45	Cement mixing (%)	1.2
Residue from distillation properties:-		Settling time (hr.)	19
Penetration at 25 º C, 100gm, 5 sec.	200	Coating ability & water resistance	Good
Ductility at 25 º C, 5cm/min.	+100	Coating dry & wet aggregate	Fair

TABLE 3 Properties of soil- Asphalt mix

Maximum modified dry density KN/m³	16.60
Optimum fluid content (%)	17

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TABLE 4 Effect of liquid Asphalt on cohesion and angle of internal friction

Mix type	Cohesion c kPa	Angle of internal friction φº	% Change in Cohesion	% change in φ
Pure gypseous soil	115	24.5		
Soil+5% emulsion+12% moisture	190	43.4	+64	+77
Soil+8% emulsion+9% moisture	150	45.4	+30	+85
Soil+11% emulsion+6% moisture	93	49	-19	+100
Soil+5% cutback +12% moisture	50	48	-57	+96
Soil+8% cutback +9% moisture	45	39	-61	+59
Soil+11% cutback+6% moisture	32	30	-72	+22

TABLE 5 Effect of liquid Asphalt on consolidation parameters (dry test)

Mix type	k(m/sec)	Cc	cv(cm²/sec)	av(cm²/kg)
Soil+17%moisture	0.0014	0.077	0.0405	0.0075
Soil+10%moisture+7%cutback	0.00132	0.18	0.0616	0.00439
Soil+3%moisture+14%cutback	0.00121	0.14	0.0275	0.0090
Soil+12%moisture+5%emulsion	0.00120	0.20	0.0300	0.0098

TABLE 6 Effect of liquid Asphalt on consolidation parameters (saturated test)

Mix type	k(m/sec)	Cc	cv(cm²/sec)	av(cm²/kg)
Soil+17%moisture	0.00156	0.102	0.0490	0.0065
Soil+10%moisture+7%cutback	0.00136	0.465	0.0907	0.0026
Soil+3%moisture+14%cutback	0.00131	0.143	0.0346	0.0077
Soil+12%moisture+5%emulsion	0.00130	0.099	0.0330	0.0095

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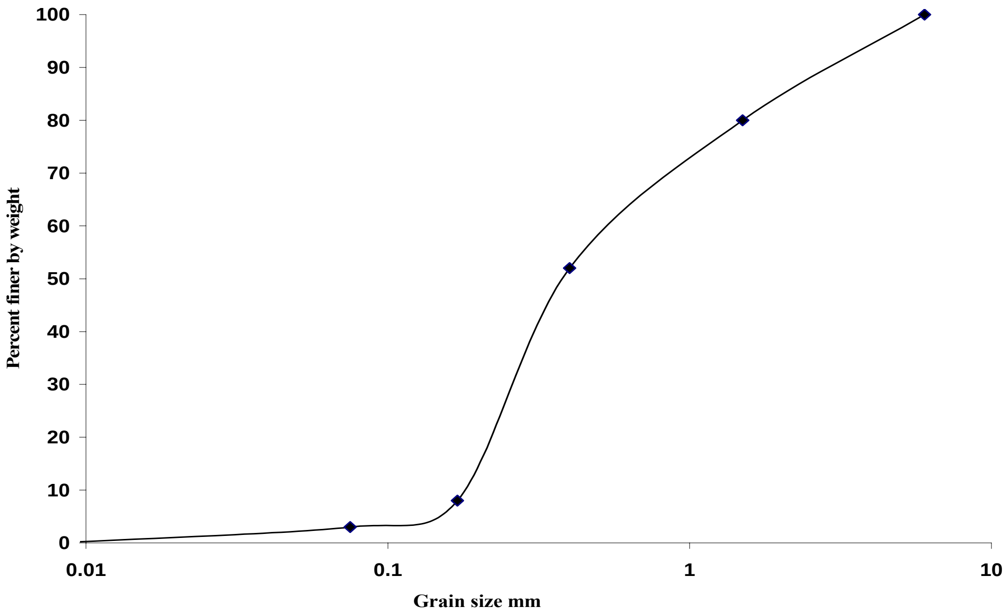

FIGURE 1 Grain size distribution of gypseous soil

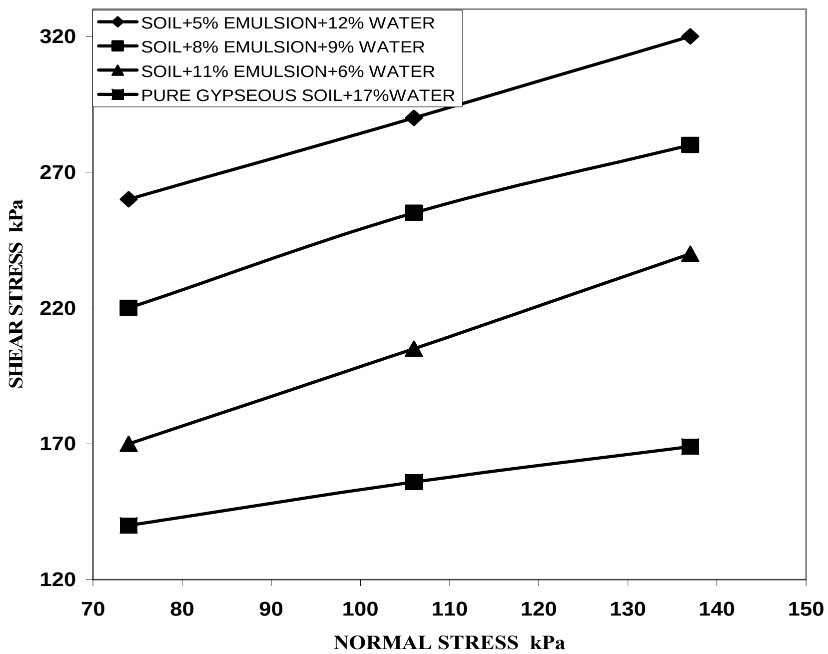

FIGURE 2 Coulomb`s failure lines for soil- emulsion mixes

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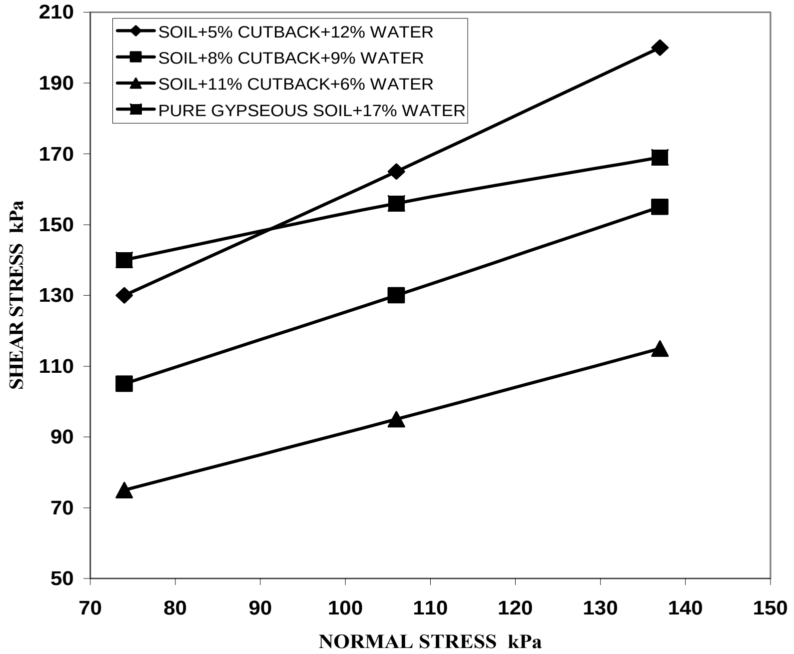

FIGURE 3 Coulomb`s failure lines for soil-cutback mixes

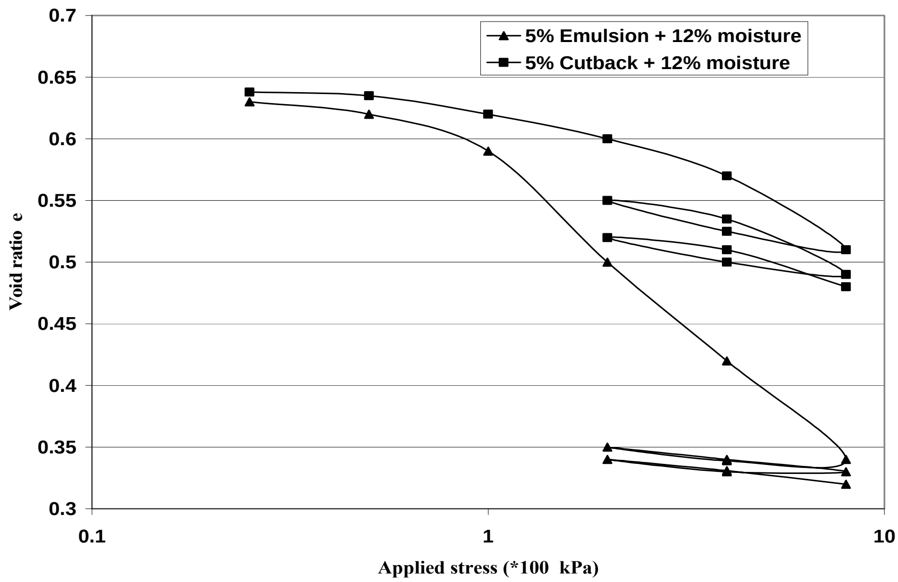

FIGURE 4 Effect of stabilizer type on rebound consolidation

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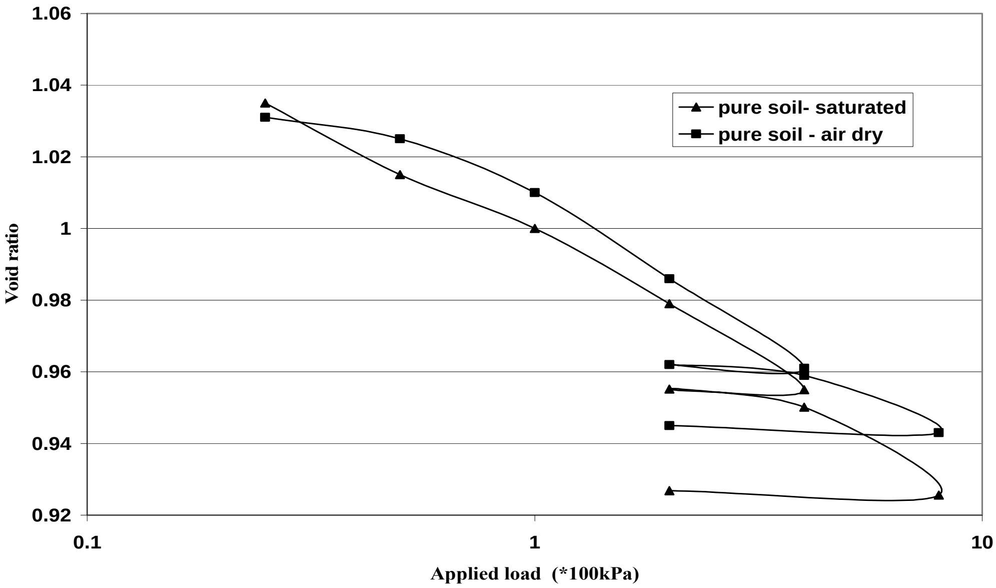

FIGURE 5 Behaviour of pure soil under rebound consolidation

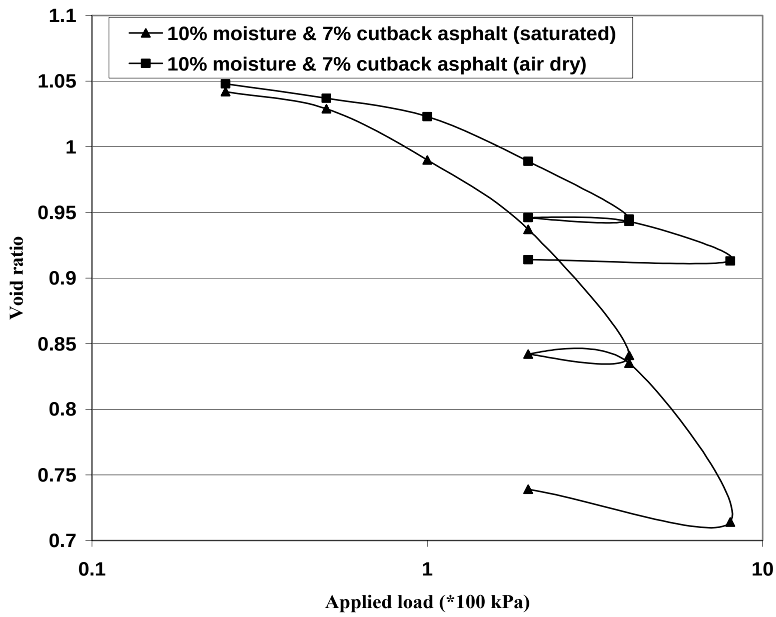

FIGURE 6-a Behaviour of soil cutback mix under rebound consolidation

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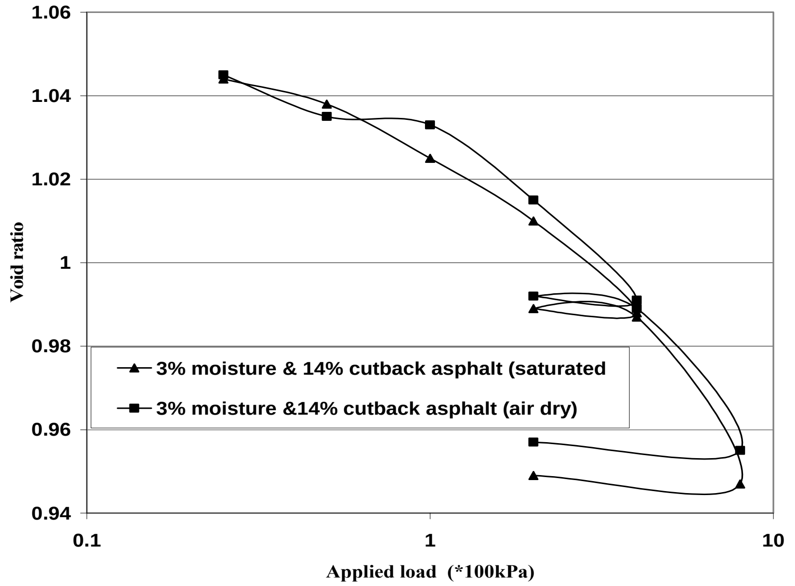

FIGURE 6-b Behaviour of soil cutback mix under rebound consolidation

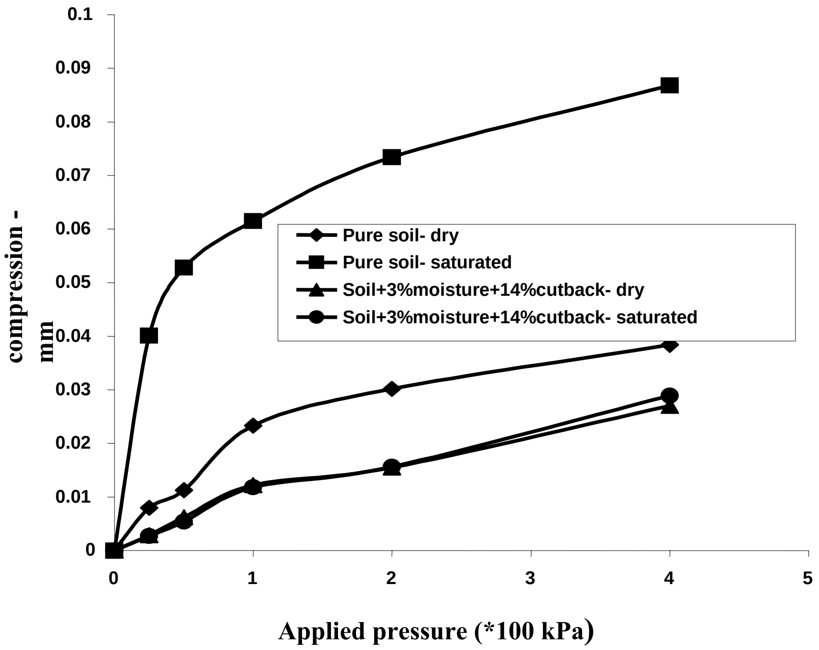

FIGURE 7 Effect of cutback Asphalt and applied pressure on compression of gypseous soil

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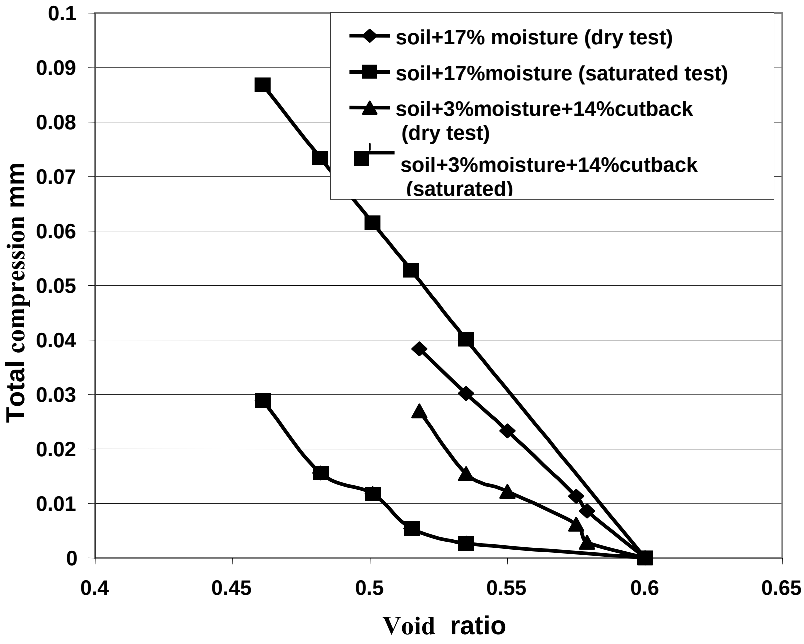

FIGURE 8 Effect of testing condition and liquid Asphalt on total consolidation of gypseous soil

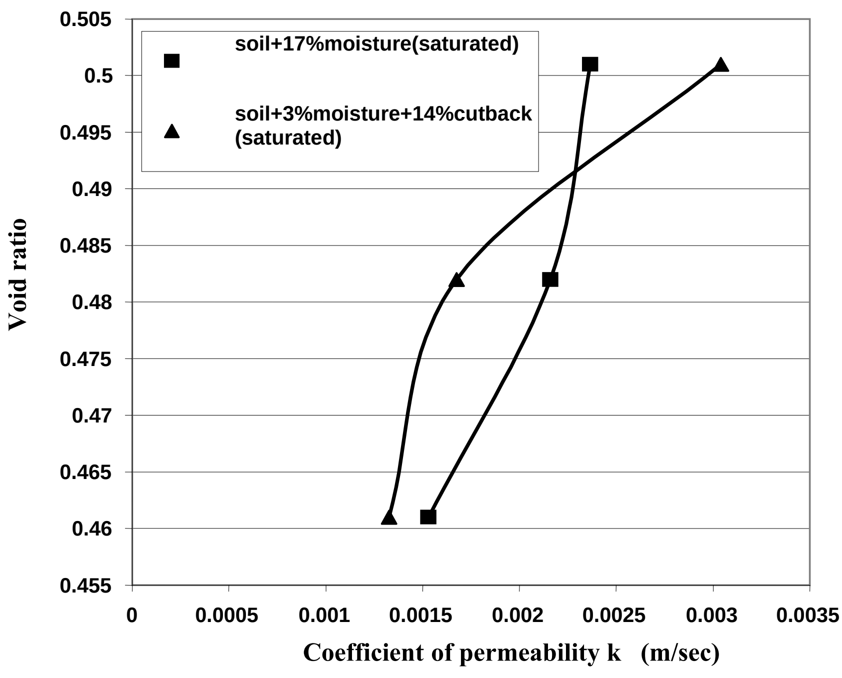

FIGURE 9 Effect of cutback Asphalt on permeability of gypseous soil

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