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Effect of Certain Petroleum Products on the Shear Strength of Clayey Soils

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Abstract

The effect of certain petroleum products on the shear strength characteristics of clayey soils is studied. Kerosene, Gas oil as well as water are mixed with different types of soils (kaolinite, 80% kaolinite-20% bentonite, and natural clayey soil).

Consolidated undrained triaxial tests with pore pressure measurement have been conducted to investigate the effect of these products on the shear strength of the soils studied.

The results show a distinct effect of petroleum products on the shear strength characteristics of clayey soils. The shear strength of clayey soils increased with a decrease in the dielectric constant of the pore medium.

الخلاصة

تم دراسة تأثير بعض المشتقات النفطية على خصائص التحمل للتربة الطينية. تم خلط الكيروسين وزيت الغاز إضافة إلى الماء مع ترب طينية مختلفة (كاؤلين و ٨٠% كاؤلين-٢٠% بنتونايت و تربة طبيعية).

تم أجراء فحص الأنضغاط الثلاثي المحاور المنظم غير المبزول على نماذج من هذه الترب لدراسة خواص التحمل لقوى القص.

أظهرت النتائج وجود تأثير واضح لهذه المشتقات النفطية على خصائص التحمل لقوى القص للترب الطينية التي تم دراستها يقل مقدار تحمل التربة الطينية لقوى القص مع زيادة قيمة ثابت العزل الكهربائي للسائل الموجود بين فراغات التربة.

1. INTRODUCTION

The existence of different types of materials mixed with soil is generally recognized in nature. Petroleum products is one of them, which exist due to many reasons such as leakage from storage tanks, break down of joints and pipes …..etc. Most of these materials affect the engineering properties of soils, especially clayey soil, in different ways depending upon the physical and chemical properties of these materials and soils.

The clay particles carry net negative charges. The quantity of this charge depends mainly on the isomorphous substitution. The electrical forces at particle surfaces strongly influence the behavior of the particle and their aggregation [(1)]. The concept of effective stress, as formulated by Terzaghi does not consider these electrical forces. Great efforts have been devoted for better understanding of the behavior of clay soils as affected by the various factors taking into consideration these electrical repulsive and attractive forces [(2, 3, 4, 5, 6, 7, 8)].

Sridharan and Rao [(4)], discussed the mechanisms controlling the shear strength behavior of saturated kaolinite and montmorillonite clays from a detailed experimental program based on certain theoretical concept which takes into consideration the inter-particle electrical attractive and repulsive forces. Eight organic fluids of different dielectric properties as well as air and water have been used as pore media to vary the inter-particle forces in the conventional shear box apparatus. They concluded that the net electrical attractive and repulsive forces decrease with an increase in dielectric constant of the pore medium and the drained shear strength of both clays decrease with an increase in dielectric constant of the pore medium. They found that for both clays the cohesion intercept C_d and the angle of shearing resistance Φ_d decrease with an increase in dielectric constant of the pore medium.

Anandarajah and Zhao [(9)], conducted a series of triaxial consolidated undrained test on a normally consolidated pure kaolinite to investigate the change in the stress-strain behavior during the replacement of the pore water with concentrated organic fluids of different dielectric constant. They found that the leached specimens with organic fluids behave as if they had been over consolidated, thus exhibiting an apparent over consolidation. They suggested that the apparent over consolidation is caused by a reduction in repulsive barrier and the consequent increase in the number of inter-particle contacts that develop inter-particle cohesion due to Van der Waals attraction. Also an increase in the net attractive forces, resulting in an increase in the strength of the inter-particle cohesion.

The effect of certain petroleum products on the engineering characteristics of different type of soils have been studied by number of researchers (10, 11, 12, 13). Most of them found that these products have a distinct effect on soils studied especially clayey soils. Clay soils have lost their plasticity characteristics upon treatment with the petroleum products. This was attributed to the decrease in the double layer thickness exists around the clay particles.

In this paper the effect of kerosene, gas oil, and water on the shearing strength characteristics of kaolinite, kaolinite-bentonite mixture, and natural clay soil are studied.

2. EXPERMENTAL WORK

2-1 Soil Studied

The investigation was carried out on three types of clayey soils (kaolinite, 80% kaolinite-20% bentonite mixture, and natural clayey soil). Their physical properties and chemical composition are given in Table (1).

2-2 Pore Fluids Used

Water, kerosene, and gas oil have been used as pore fluids. The petroleum products were brought from Al-Dora refinery. The laboratory tests to determine the physical properties were conducted by chemical department at Al-Dora refinery. The results are given in Table (2).

2-3 Testing Program (14)

1. Specific gravity test conducted according to BS 1377:1975 test 6B.
2. Consistency characteristics tests conducted according to BS 1377:1975 test 2B and test 3.
3. Grain size distribution test according to BS 1377:1975 test 7D.
4. Chemical composition and X-ray diffraction tests.
5. Consolidated undrained triaxial compression test with pore pressure measurement. This test was conducted according to the procedure proposed by Head (15). Samples were consolidated under a cell pressure of 200, 300, 400, 500, and 600 kPa.

2-4 Sample Preparation

Oven dry soil (cooled in a desiccators) mixed with appropriate fluid content were placed in layers in a Rowe cell (254mm in diameter and 127mm in height). Then consolidated in steps under a final pressure of 100kPa. After equilibrium was attained, the pressure was released and the soil was left to reach equilibrium condition. Then the top part of the cell was removed and Shelby tubes (38mm in diameter) were inserted in the soil specimen gently with slow rate using the compression machine until it reach the required length. Rotate the tubes with slow rate and then axial withdrawal is thus secured. Five samples as a minimum were taken from each prepared soil specimen.

3. RESULTS AND DISCUSSION

Figure (1) shows the variation of shear stress with the axial strain for natural soil mixed with different pore fluids under different confining pressures. The figure clearly shows that the shear strength was increased for the samples mixed with kerosene or gas oil compared with that of water. This result indicates that shear strength was increased with a decrease in the dielectric constant of pore fluid. The kaolinite soil and kaolinite-bentonite mixture show the same behavior as that of natural soil as shown in Figures (2 and 3). The values of average normalized strength ($(\sigma_1 - \sigma_3)_f / \sigma_3$) of the three types of soils mixed with different pore fluids are given in table 3. For the same pore fluid the value of average normalized shear strength is increased with a decrease of plasticity index.

The results presented in figures 1, 2, and 3 have been replotted as effective p_f - q_f diagram ($(\sigma_1+\sigma_3)_f/2$ vs. $(\sigma_1-\sigma_3)_f/2$) in figure 4, 5, and 6. Each line refers to a particular pore fluid. It is seen that for all types of soils the angle of shearing resistance $\Phi^{\bar{o}}$ is greater when kerosene and gas oil are used as compared to that of water. While the cohesion intercept $C^{\bar{o}}$ is almost equal zero for all tests. The results presented above are consisted with that found by others [4, 9]. The strength characteristics of clayey soils are affected by the type of pore fluid. The strength increased with a decrease of the dielectric constant of pore fluid. This is attributed mainly to an increase in electrical attractive forces and a decrease in electrical repulsive forces with a decrease of dielectric constant of the pore fluid.

So, the effective stress that controls the strength of clayey soils increased with the increase of the net attractive forces between clay particles.

4. CONCLUSIONS

The effects of water, kerosene, and gas oil as pore fluids on the strength characteristics of three types of clayey soil are studied. The following conclusions are drawn from the results of the experiments conducted:

1. The consolidated undrained shear strength of the three types of clayey soils decrease with an increase of dielectric constant of the pore fluids.
2. For all types of clayey soils studied the angle of shearing resistance Φ° decrease with an increase of dielectric constant of the pore fluids. While the cohesion intercepts are almost equal to zero irrespective of the pore fluid type.
3. For the same pore fluid, the shear strength is increased with a decrease in plasticity index of soil.

5. REFERENCES

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Table (1) Physical Properties and Chemical Composition of Soils

Property	Kaolinite	80%Kaolinite-20%Bentonite	Natural Soil
Liquid limit, %	62.6	110.5	50
Plastic Limit, %	33.05	26.5	27.5
Plasticity Index, %	29.55	84.0	22.4
Specific Gravity	2.68	2.69	2.73
Clay Size Fraction, %	54	65	39
Cation Exchange Capacity, me/100gm	10	45	14
pH	7.9	8.5	7.8
T.S.S	4.02	0.65	7.15
SiO_2 , %	46.46	50	37.2
AL_2O_3 , %	32.1	29.5	9.0
Fe_2O_3 , %	1.2	2.7	6.2
CaO , %	2.8	0.94	17.64
MgO , %	0.39	0.82	6.2
Na_2O , %	0.26	0.59	1.34
K_2O , %	0.41	0.45	1.45

Table (2) Physical Properties of Pore Fluids

Property	Water	Kerosene	Gas Oil
Specific Gravity	0.9971	0.7901	0.8398
Dielectric constant at 25 C°	80.4	2.245	2.264
Viscosity at 25 C°, Centi-stock	0.898	0.85	6 at 37.8 C°

Table (3) Normalized Shear Strength Values of Different Soils Mixed with Different Pore Fluids

Soil Type	P.I. , %	$(\sigma_1 - \sigma_3)_f / \sigma_3$		
		Water	Gas Oil	Kerosene
Natural Soil	22.4	0.37	1.31	1.38
Kaolinite	29.55	0.32	0.67	1.05
80% Kaolinite-20% Bentonite	84.0	0.305	0.65	0.85

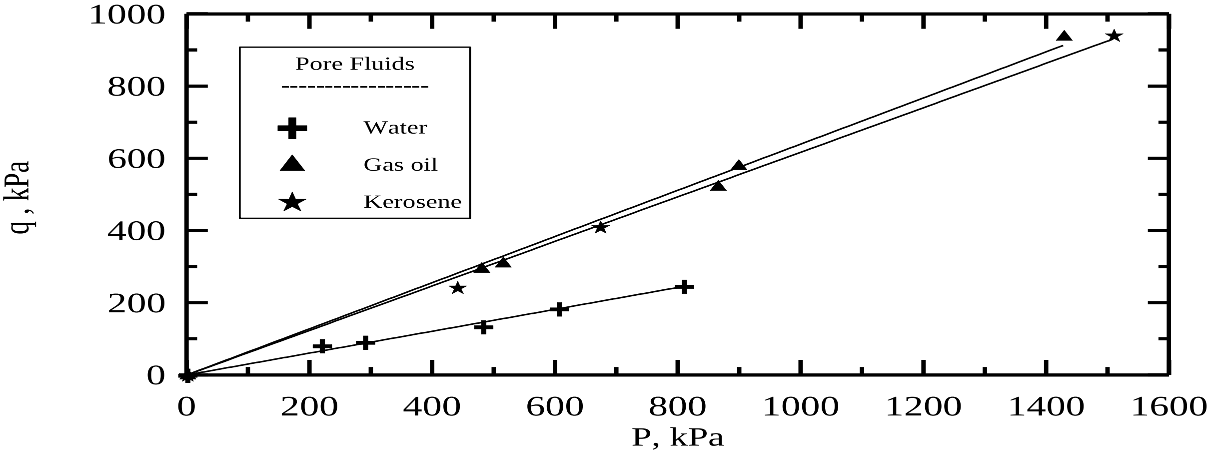

Figure 4 : p_q Diagram for Natural Soil Mixed with Different Pore Fluids.

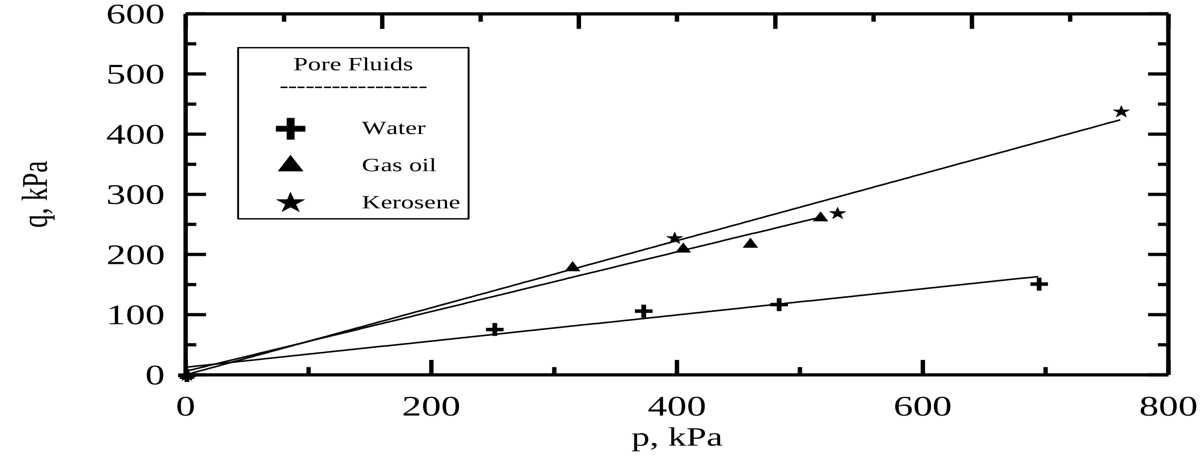

Figure 5 : p_q Diagram for Kaoline Soil Mixed with Different Pore Fluids.

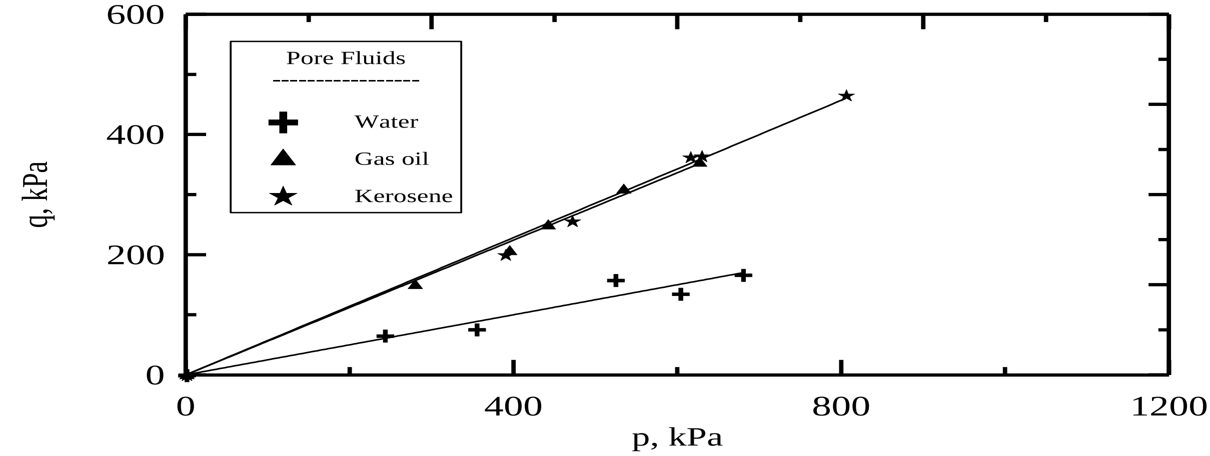

Figure 6 : p_q Diagram for (80% Kaolinite-20% Bentonite) Soil Mixed with Different Pore Fluids.

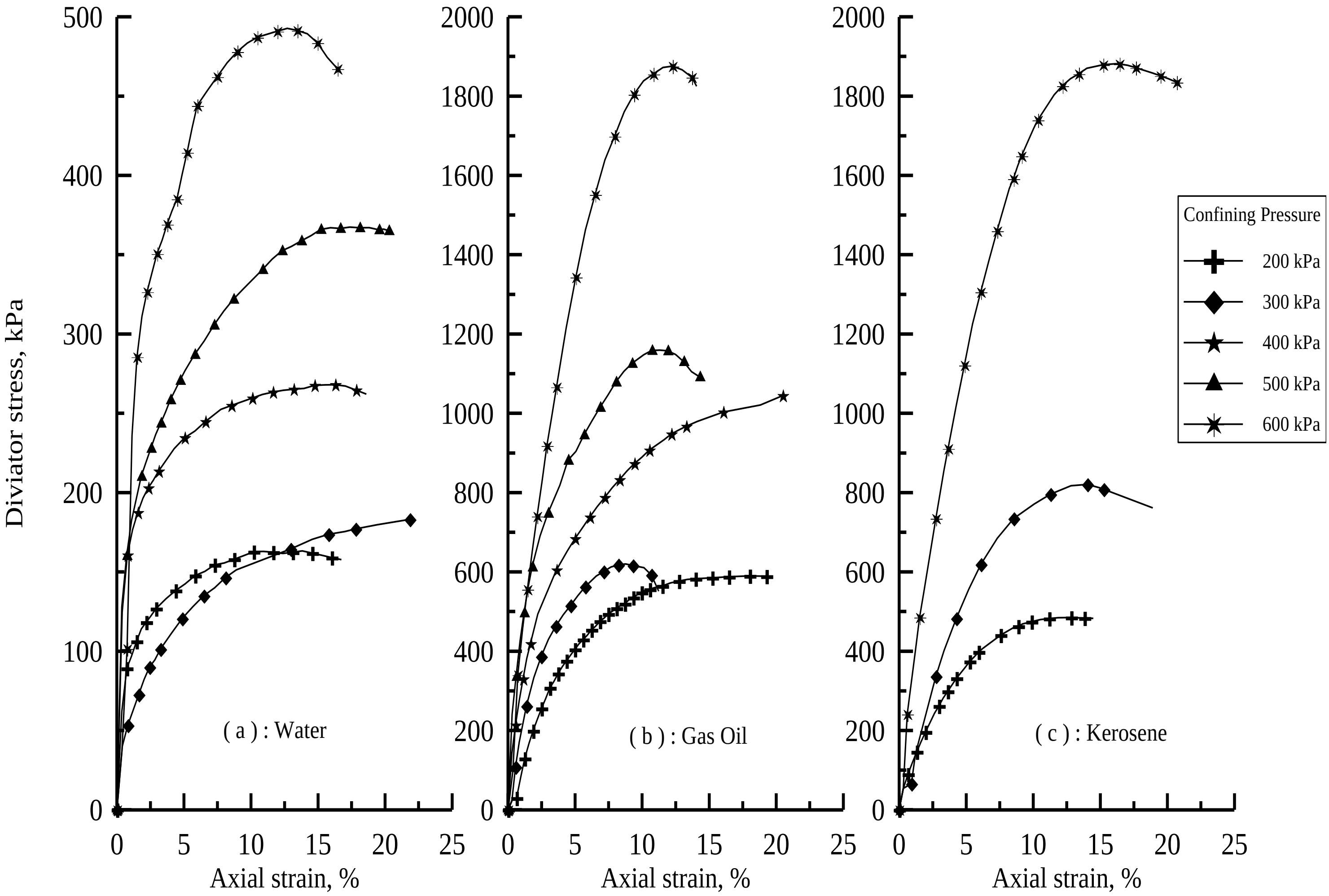

Figure 1: Diviator Stress vs. Axial Strain Relationship for Natural Soil Mixed with Differen Pore Fluids at Different Confining Presure

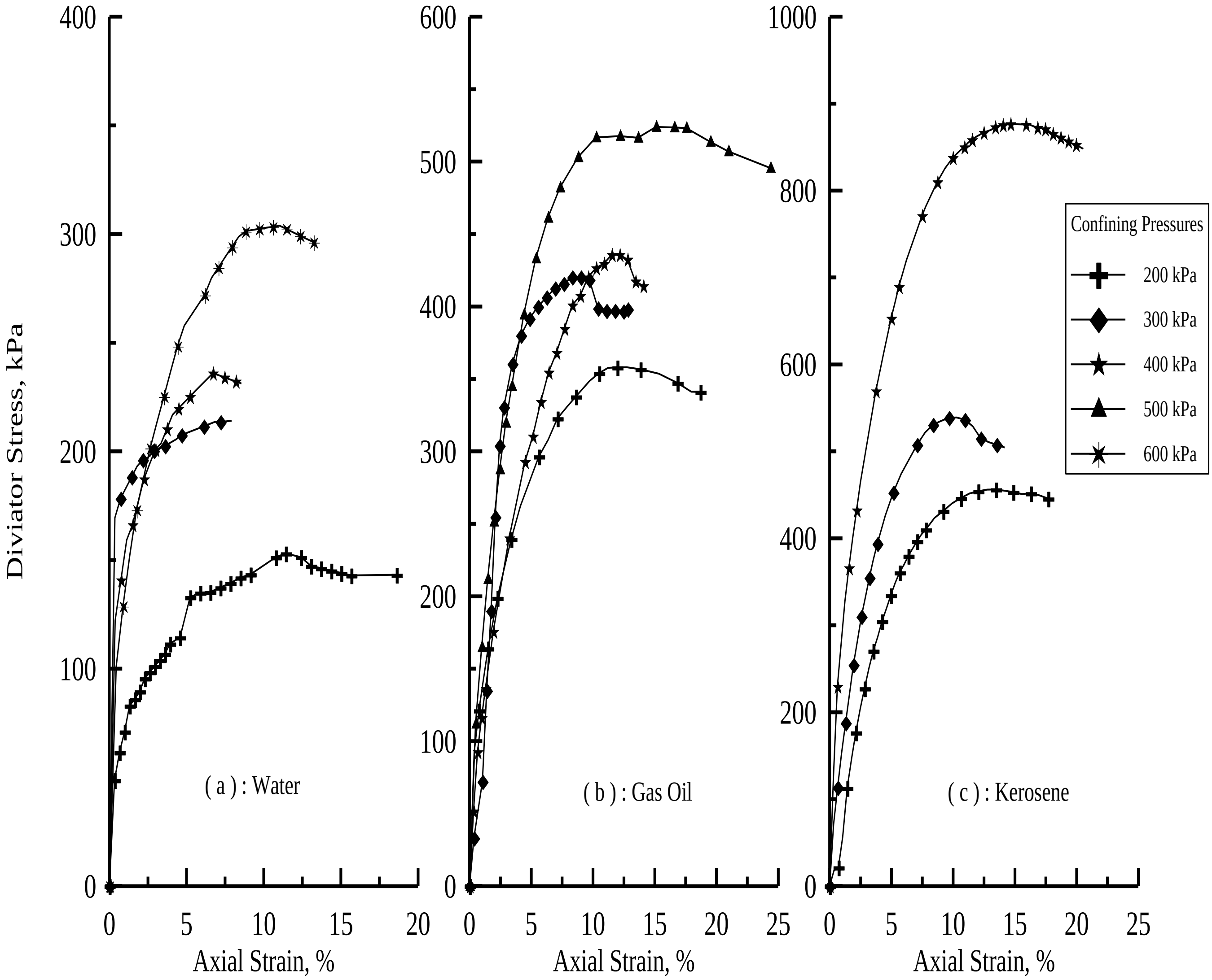

Figure 2 : Diviator Stress vs. Axial Strain Relationship for Kaolinite Soil Mixed with Differen Pore Fluids at Different Confining Presure

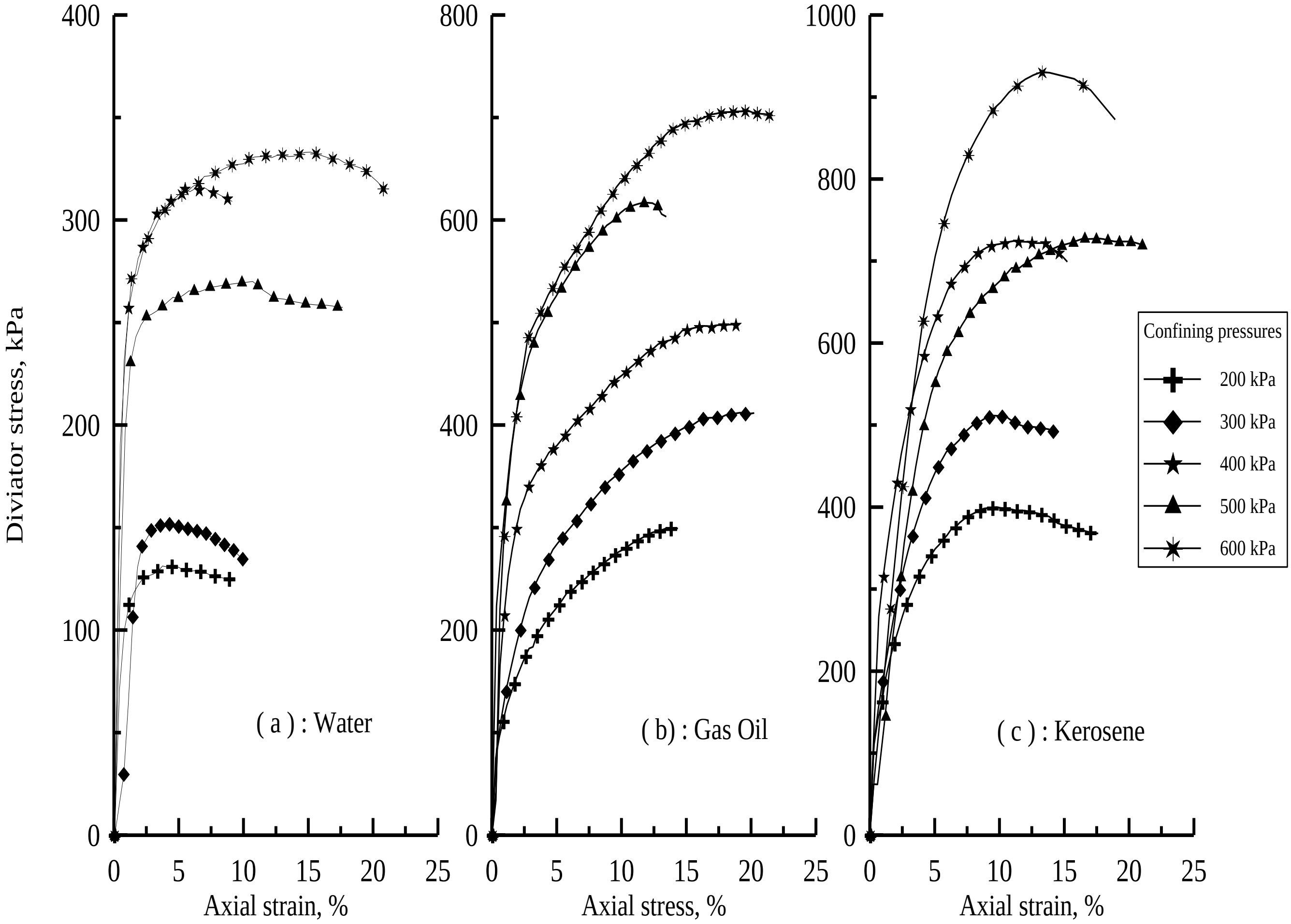

Figure 3 : Diviator Stress vs. Axial Strain Relationship for (80% Kaolinite-20 % Bentonite) Soil Mixed with Different Pore Fluids at Different Confining Presure.