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Parametric Study on the Effect of Water Viscosity to the Soil Matric Suction

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Abstract Matric suction of soil is the negative pore water pressure of the soil. Numerous factors are act as the inducing factors to the matric suction in the soil. Water quality is one of the main factors that influence the soil's matric suction which can be affected by different water quality parameters. Viscosity of water is a prime element in altering the action of matric suction when the soil is saturated with the different viscosities of water. This study is to determine the matric suction with controlled sample (rainfall) and different water viscosity and also aims to identify and compare the relationship between matric suction of soil with different water qualities. The method applied in this study to determine the matric suction using Tensiometer. The alteration of different viscosity of saltwater is conducted through the variation of different concentration of salinity. The viscosity is obtained through the Vertical Falling Sphere Method. The analysis of data indicates that the different viscosity of the water influenced by the level of salinity shows the different level of action of matric suction. This concludes that when the viscosity of water is increase, the matric suction of the soil decreases. The higher viscosity induced the matric suction of soil which is the negative pore water pressure of the soil becomes lower.

Keywords: Matric Suction, Viscosity, Tensiometer

1. Introduction

The environmental changes occurring in the current modernization world tend to impact and cause many different problems to the soil structure which is a base for the living thing's habitat and building structures. Numerous studies are conducted and in investigations to study about the factors inducing matric suction of soil. The determinations of various factors and its effects to the matric suction of soil have many impacts in the soil deformation, strength and failures of the soil. To identify the most appropriate solution for the soil problems, the investigations should be focused on the main characteristics of the soil such as physical, chemical characteristics and the other external factors such as the rainfall water characteristics. The hypotheses and assumptions made before the laboratory and the field trip investigation on the matric suction of soil normally gives exact results but at times came out with different, uncommon results that possibly hold other effects to the suction profile of soil. Many studies were and currently conducted to find the factors affecting the matric suction of soil.

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2. Matric Suction Influenced by the Water Quality

There are hydrological factors influencing the response of the matric suction in the soil such as hydraulic conductivity, permeability, water content, and pressure head. The changes happens in the hydrological factors may change the infiltration of water into the soil structure and also the matric suction. The action of the matric suction also tends to induce the hydraulic conductivity. Higher the matric suction, lower the hydraulic conductivity [1]. The matric suction responses in the soil also can be varying which depends on the conditions of the soil water characteristics. The presence of moisture in the soil structure influences the responses of the matric suction by measuring the wetness of the soil. By explaining the concepts of soil water, the matric suction characteristics of the soil can be measured [2]. This study also indicates that by experimenting and studying the infiltration law and working principle, the matric profile of the soil obtained. Water chemical properties similarly influence the infiltrating characteristics which also trigger the actions of the soil matric suction [3]. The soil water and water infiltrates into the soil both have significant functions in altering the geophysical characteristics of soil. This is because the physical and chemical characteristics are depends on the climate change and soil conditions. The water infiltration characteristics which is mostly influences the matric suction, also affect the safety factors of soil slopes. The intensity of rainfall clearly affects the rate of infiltration and the factor of safety [4]. Drying and wetting soil-water characteristic with the influence of the density of soil also have the impacts in soil matric suction. Then grain size and dry, wet density of soil tends to make changes in suction properties of the soil [5]. On the other side, the investigation of effect of the chemical properties of water reveals the changes happen to the matric suction of the soil. Increasing water temperature caused a significant increase in the hydraulic conductivity of the soils studied. This increase was attributed to a decrease in water viscosity [6]. The water temperature has a significant effect on the permeability of the soil, which also influences the water viscosity. increasing temperature at a given water content were attributed to a decrease in the viscosity of water [7]. This clearly explains that viscosity of the water which is temperature dependent. Studies showed that measured HC values increased more rapidly with an increase in temperature than was predicted from changes in the viscosity [8].

3. Materials and Methods

The matric suction experiment using the tensiometer is the most simplest quick instrument and recommendable method to apply in of measuring the firmness of moisture being held with the soil. The water quality (viscosity) applied in this experimentation is controlled by the concentration.

3.1 Materials

i) Distilled Water

The tensiometer tube is filled with the distilled water before the setting in the sample. Distilled applied in the tube because of it contains no solids, mineral and trace elements. This ensures the elimination of any error by the instrument.

ii) Kaolin

Kaolin used in this experimentation as the soil for its low shrink and swell capacity. Kaolin also tends to hold the moisture and insoluble when wetted with liquids. To hold the maximum moisture as possible the kaolin is applied in this experimentation. The properties of kaolin demonstrates that it fits for the experimentation when moisture content become one of the element to include in the matric suction measurement.

Table 1: Properties of Kaolin

Material	Test	Parameter	Value
Kaolin	Soil Classification	AASHTO	A-6
		USCS (Plasticity chart)	ML
	Atterberg Limit	Liquid Limit	38.43 %
		Plastic Limit	28 %
		Plasticity Index	10.43 %
	Specific Gravity	Specific Gravity	2.62
	Standard Compaction	Maximum Dry density	1.53 g/cm^3
		Optimum Moisture Content	19.50 %
	Falling Head Permeability	Coefficient of Permeability	4.806×10^{-12} m/s

3.2 Methods

Figure 1 shows the procedure of the matric suction experimentation involves different steps and material preparation to conduct the investigation of different samples with alterations made on the concentration of the salinity. Every specimen of the water with varying salinity concentration is checked the viscosity before mixed with the kaolin. The amount of water for each sample is controlled and fixed to 375ml.. The tensiometer calibration earlier is recommended before the experimentation to eliminate any possible failure and errors identified beforehand.

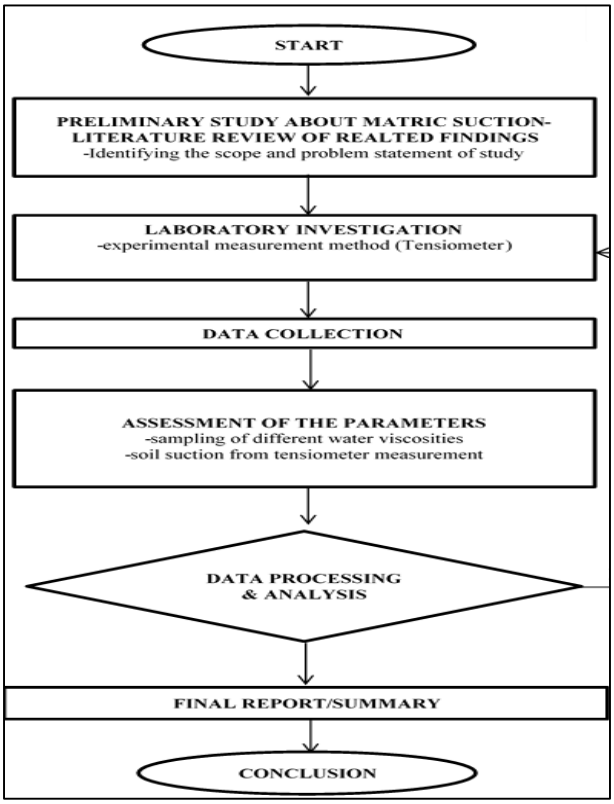

Figure 1: Methodology of Study

3.3 Formulation of Viscosity Derivation

Equation applied to determine the viscosity of the saltwater through the method of the vertical falling sphere. The gathered information from the method used to measure the viscosity of each sample of different concentration of salt (NaCl) mixed water.

$$Viscosity = \frac{2(sphere\ density - liquid\ density)\ x\ g\ x\ radius2}{9(velocity\ of\ the\ sphere)} \qquad Eq.\ 1$$

Sphere density = 0.013 kg/m^3
Sphere Radius =3.5mm @0.035m
g = 9.81 kN

3.4 Procedures of the Tensiometer Installation

Figure 2 shows that the sample preparation with different viscosity of the salt water (3 samples) and one sample with natural water without any salinity concentration. The kaolin mixed with the water samples to make sure it is saturated by the water.

Figure 2: Sample preparation

Figure 3 shows that moisture content checking for every samples to determine viscosity influences for the samples.

Figure 3: Moisture Content of the samples

Figure 4 illustrates that the setting of the tensiometer in the sample to measure the matric suction. The setting is left for 24 hours to allow the ceramic cup controls the irrigation of the water that ensures that matric suction to be measured.

Figure 4: Tensiometer Installation

Figure 5 displays that the tensiometer reading of the matric suction. The reading of the each samples recorded for the analysis of the matric suction and the correlation between the matric suction with the moisture content and viscosity.

Figure 5: The reading of the tensiometer

4. Results and Discussion

The primary data collection needed for this study are the measurement of viscosity of the salt water and the matric suction. The correlation between the elements and parameters investigated are analyzed to determinant the influences of manipulated variable (viscosity) in the finding of the matric suction.

4.1 Results

Table 2 shows the results of the saltwater viscosity that controlled by the concentration of the salinity for each sample. The viscosity derived from the vertical falling sphere method shows the changes according to the varying of the saltwater concentration. The data collection in Table 3 illustrates the measurement of the matric suction by the tensiometer for each sample. The matric suction values clearly indicated that variable of the matric suction depends on the viscosity level of the saltwater.

Table 2: Salinity and Viscosity

Sample	Salt Concentration (NaCl)	Viscosity
A	375ml Natural Water	0.7×10^{-4}
B	375ml Natural Water + 100g salt	1.6×10^{-4}
C	375ml Natural Water + 200g salt	3.17×10^{-4}
D	375ml Natural Water + 400g salt	3.2×10^{-4}

Table 3: Data of viscosity and matric suction

Sample	Viscosity (centipoise)	Matric Suction(centibars)
A	0.7 x 10-4	38
B	1.6 x 10-4	30
C	3.17 x 10-4	18
D	3.2 x 10-4	8

4.2 Relationship between Viscosity and Matric Suction

Figure 6 shows the relationship between the soil suction and the viscosity of the saltwater which shows the noticeable results of the matric suction induced by the viscosity. The increasing of the viscosity influences the matric suction responses in the soil to decrease gradually. This is because the water with high viscosity which is denser tends to make the soil fully saturated which has the potency of not quickly drying the soil particles. The thicker water particles also consume longer time to infiltrate into the soil pores. This influence the soil fully wetted with more moisture content. This results in the matric suction to reduce that specifies that the soil's negative pore water pressure is very less when moistened with high viscosity of water. The lower the viscosity, the higher the matric suction. The capacity and firmness of the soil of the soil holding the moisture from the viscosity induce the low matric suction occurs. This shows that the high matric suction tend to occurs when the less viscous water moistened the soil.

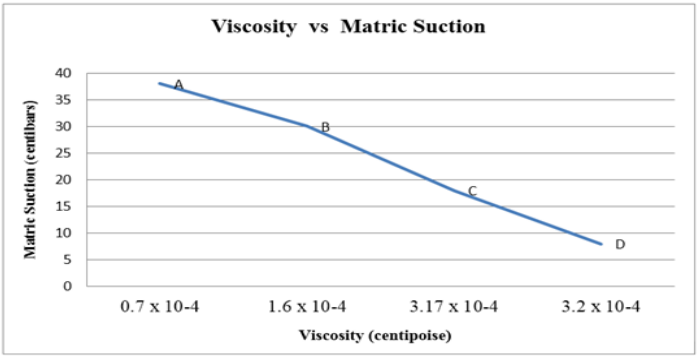

Figure 6: Relationship between the Viscosity and Matric Suction

4.3 Relationship with Viscosity of Moisture Content

Figure 7 shows the relationship between the viscosity and the moisture content of every sample. There are obvious changes in moisture content of every sample. For the reason that the presence of the different concentration of salinity. The different viscosities reflects the different level of moisture content in the soil sample. The higher the viscosity indicates that the higher percentage of moisture content. Besides that, the moisture content of the saltwater with less concentration of salinity shows the least percentage of moisture content. This is might be influenced by the soil particles which is dry before mixed with the saltwater. The dry soils absorbs the water very quickly and also inclined to dry very quickly. The induced the moisture content of the sample B is very low. The other samples with

the concentration of salt (sample B and sample C) shows the moisture content increasing accordingly with the salinity. The higher salinity in the water causes the viscosity to increase. This affects the moisture content increasing with the higher viscosity that wetted the samples and consume time to dry due to the moisture level. Figure 7 also indicates that as the viscosity of the salt water increase with the salt concentration, the matric suction of the soil is decreases as the result of the moisture content of the soil is increases. This also explains the higher the salinity ,the lower the matric suction in the soil. This is because the high salinity and viscosity of a liquid influences the moisture content by holding the moisture for a longer time. The lower viscosity and salinity gives higher tensiometer reading which shows the lower moisture content.

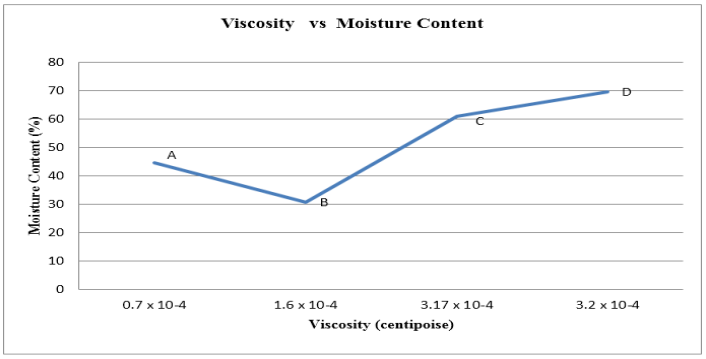

Figure 7: Relationship between viscosity with Moisture Content

4.4 Discussions

This method of determining the matric suction of the soil with different viscosity of liquid explains that the influence of the water qualities in altering the matric suction in any soil profile. The matric suction which is the negative pore water pressure in the soil tends to change when the thickness of water is changes. This clearly explains that concentration of any denser molecular elements such as the salt concentration have a tendency of modifying the viscidness of the liquid [10]. The moisture content of in different viscosity of a liquid is varying. This different moisture content in the liquid inclined to change the matric suction in the soil by making changes in the negative pore water pressure in the soil. The presence of dissolved soil salts facilitates the changes in matric suction in soils. [9]. The moisture of low viscosity of liquid is more prone to dry quicker than the high viscosity. The quick drying response is the factor for the matric suction to increase. This is because the matric suction is greater during the drying cycle compared with the wetting cycle for the same water content. The negative pore water pressure in the soil is higher when the soil is dry. In this study the high viscosity water content tend to cause the matric suction become lower because the moisture content is high in the soil that will not dry quickly.

5. Conclusion

This study achieved the hypothesis to determine the matric suction with controlled sample (rainfall) and different water viscosity which is manipulated by the salt concentration. This experimentation on the water viscosity affecting the matric suction shows that there are noticeable changes in the matric suction of the soil that induced by the different viscosity of water which results in decreasing of the matric suction while the viscosity of the water increase.

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