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Investigation of Matric Suction in Soil on Alkaline Water

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Abstract: Rainfall has been identified as cause of slope failures and landslides. The majority of slope failures happened after rain, and the failure was mostly due to the loss of matric suction in soil by rainwater. Matric suction also affected the behavior of unsaturated soils in terms of permeability and shear strength. The increase in net negative charges on soil particles occurs when the pH of the solution increases. The purpose of this study is to determine the matric suction in soil with different pH value of water and compared with matric suction in soil with sample water and alkaline water. Main material that has been used was kaolin as soil, tensiometer equipment, and calcium hydroxide as the chemical substance. The experiment of mixing the specimen and determine matric suction in soil was carried out at Geotechnic Laboratory and determining pH value of water was at Environmental Laboratory. The result shows the matric suction in soil was increased in the experiment, and matric suction in soil with calcium hydroxide is higher than soil without calcium hydroxide. The addition of calcium hydroxide not only can cause the decreasing size of pores, but also can increase the matric suction in soil. By adding calcium hydroxide in soil may increase the matric suction and improve the slope stability of soil.

Keywords: Matric suction, soil, alkaline

1. Introduction

Basically in Malaysia, landslides incidents happened caused by slope failures. The major effect of slope collapses or landslides happened after rain and the failure mechanism was mostly due to loss of matric suction [1]. The matric suction of soil will decrease when the pore water pressure is increased, and also reduce its shear strength.

The scheme of alkaline water is one of the causes of the weakening of rock and soil mechanical properties, and the changes in ions between rainfall infiltration and the sliding zone was affected of changes in chemical structures. Usually, the pH value of alkaline water is 7 above, it stated as strong and weak alkaline. The increasement of pH water can cause the negative charges in soil particles to rise. Matric suction at the soil surface will gradually decrease once the water infiltrates into the soil.

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Landslides are caused by a loss in matric suction which leads to a reduction in the shear strength of the soil. The properties of water were related to physical, chemical, and biological properties [2]. So, pH value was included in one of the chemical properties that have been measured to determine whether it is acidic rain or alkaline rainfall. The factors of alkaline rainfall happened is from waste deposits from factories and basic pollutions. The chemical substance and minerals that contain alkaline substances such as calcium carbonate can lead to the increasing of rainwater pH value and will provide to alkaline rain happened.

The main purpose of this study is to compare the matric suction by using different pH of water which is natural water and alkaline water and measured by tensiometer. The aim of this research to determine the effect of water with different pH influences the matric suction in soil. This study was carried out by using tensiometer method at Geotechnic Laboratory and digital pH meter to measure pH value of water at Environment Laboratory.

1.1 Matric Suction Induced Rainfall Intensity

Rainfall is assumed to be the source of landslides that occur in areas with heavy season rainfall. The decrease of effective stress caused by matric suction loss caused by rainwater infiltration in soil was the primary cause of slope collapses. The 95% of rainfall-induced landslides in residual soils are shallow slips above the groundwater table [3]. Matric suction or in other terms, negative pore water pressure has a considerable impact on soil slope stability when compared to pore air pressure. If the matric suction in the soil changes during rainwater penetration into unsaturated soils, slope stability may be threatened.

1.2 Water Quality

Water quality describes the relationship between all hydrological features of water including its physical, chemical and biological properties [2]. Malaysia is rapidly urbanizing and growing in population. As a consequence of this fast expansion, there is an increased demand for water as well as an increase in water pollutants. This factor has a substantial harmful influence on the quality of Malaysia's water. Monitoring water quality may help forecast and learn from natural processes in the environment, as well as assess human influences on ecosystems. The arrangement of surface and subsurface waters in the waste bowl is impacted by common variables such as geographical, land, climatic, hydrological and natural factors, as well as regular differences in overflow quantities, climate conditions and water level.

2. Materials and Methods

The materials and methods section, describes all the necessary information that is required to obtain the results of the study.

2.1 Materials

i. Kaolin

The previous study from Agi Augustine Aja, Gbonhinbor Jeffrey Randy, (2013), Table 1 stated that kaolinite, nacrite and halloysite can be classified as kaolin [4]. Kaolin is the group of aluminium silicates that form as a result of weathering or hydrothermal action in aluminium rich silicate rock.The physical characteristics of kaolin is it appear in heaps of white clay and it white when pure. The properties of kaolin clay have been stated in the table below.

Table 1: Properties of kaolin

Parameter	Value
Specific gravity (Gs)	2.60
Liquid limit (W_L)	80
Plastic limit (Wp)	35
Compression Index (Cc)	0.562
Swelling Index (Cs)	0.122
Permeability on NC clay (at 100 kPa)	2.0×10^{-8} m/s
Consolidation coefficient (at 100 kPa)	40 m^2/yr

ii. Sample of Water

Tap water in the laboratory is in range 6-7. According to David Castelbaum and Charles D. Shackelford, (2009) Table 2 shows the properties of tap water that is usually used in laboratory [4]. In this experiment, tap water was mixed with kaolin for natural sample, and a chemical substance (calcium hydroxide) was mixed with tap water to produce the alkaline solution.

Table 2: Properties of tap water

Property	Value
Ionic species (mg/L)	
Ca^{2+}	13.6
Mg^{2+}	2.1
Na^{+}	3.1
K^{+}	0.8
B^{3+}	<0.01
CO_3^{2-}	<0.1
HCO_3^{-}	42.1
SO_4^{2-}	10.8
Cl^{-}	3.2
NO_3^{-}	<0.1
NO_3—N	<0.1
pH	7.9
Hardness as $CaCO_3$ (mg/L)	43
Alkalinity as $CaCO_3$ (mg/L)	35
Total dissolved soilds (mg/L)	76
EC (mS/m) at 25°C	9.01

iii. Tensiometer

The equipment that is used to measure matric suction in the soil is tensiometer. According to F.A.M. Marinho et al., (2008), tensiometer and axis translation method is the acceptable equipment that able to measure the soil matric suction [5]. The value of negative pore water pressure can obtain by using tensiometer from range 0 kPa-80 kPa. Figure 1 below shows tensiometer equipment.

Figure 1: Apparatus of tensiometer

2.2 Methods

Figure 2 shows the procedure of adding a chemical substance into tap water to get alkaline solution with pH 9.04, 10.03 and 11.01. After mixing the chemical substance with tap water, the alkaline solution was transferred into natural water by drop to avoid the pH value of water not more than proper value. Table 3 described sample water that has been used in this experiment.

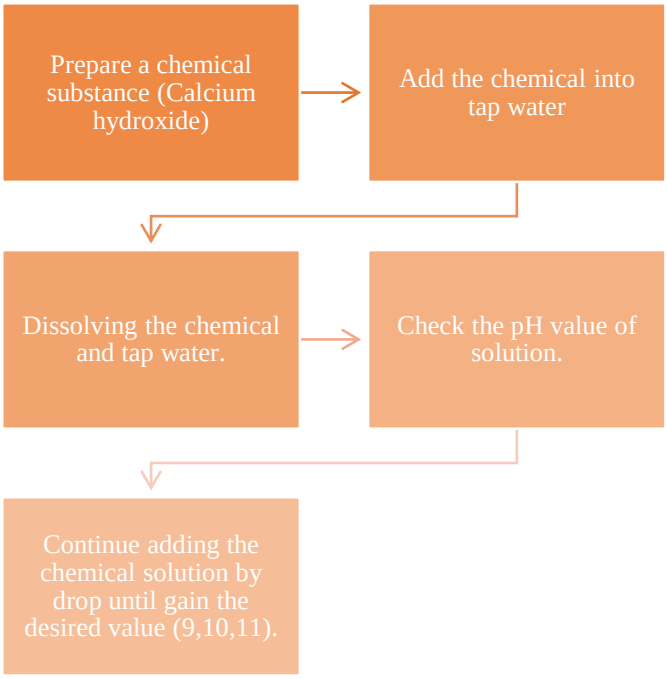

Figure 2: Process of mixing alkaline substance and tap water

Table 3: Sample water and its mixture

Sample	Water mixture	pH
Natural water	375 mL	6.45
A	375 mL + 10 drops calcium hydroxide	9.04
B	375 mL + 15 drops calcium hydroxide	10.03
C	375 mL + 20 drops calcium hydroxide	11.01

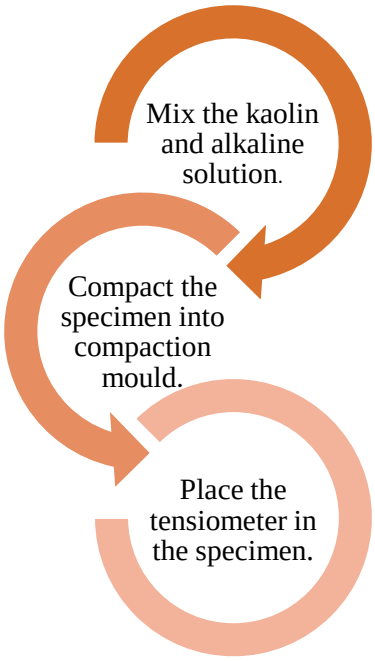

Figure 3: Process of mixing alkaline water and kaolin

Based on Figure 3, it explains the process in mixing alkaline solution with kaolin. Alkaline solution was mixed with kaolin evenly before compact it into the mould. Tensiometer was placed in the specimen and left for a day before recorded the results.

3. Results and Discussion

The results and discussion section presents data and analysis of the study. The data has been elaborated specifically includes physical properties such as moisture content of soil and pH value of water. All the data was successfully recorded in two weeks.

3.1 Relationship between pH and Matric Suction

Based on the data obtained in Table 4, it shows the increasing of matric suction in soil with alkaline reaction. From the data, the increasement of pH water, matric suction in soil can be increase too. From the results, matric suction for specimen without calcium hydroxide is 35 kpa, while specimen with calcium hydroxide is 37 to 40 kPa. It shows the highest reading for matric suction is 40 kPa comes with the highest pH value which is 11.01. According to M.I.S. Fazlina (2021), the additional of calcium hydroxide not only can caused the decreasing of size pores, but also lead to increment of matric suction in soil [7]. Figure 4 shows the graph of matric suction versus pH value. From the graph, it can conclude

that matric suction in soil can be affected by pH water. Calcium hydroxide may reduce the matric suction also improve the slope stability of the soil.

Table 4: Matric suction in soil

pH Value	Matric suction
6.45	35
9.04	37
10.03	38
11.01	40

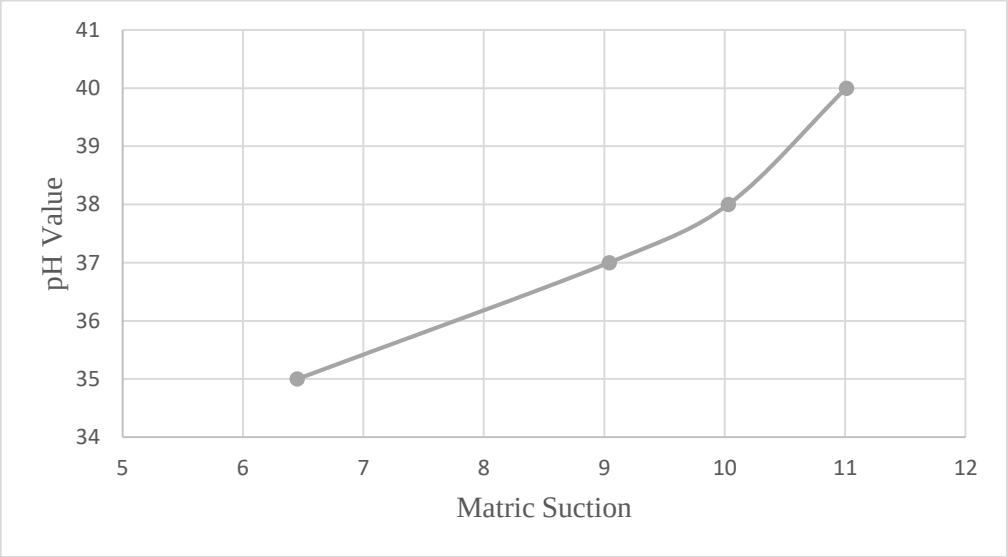

Figure 4: Graph matric suction versus pH value

3.2 Relationship between pH and moisture content

Table 5 shows the data from experiment by determining moisture content in soil with and without alkaline substance. The sample with moisture content 10% will be the driest sample. Based on the result, for specimen with calcium hydroxide shows sample A is the highest moisture content which is 15.4% compared with others. While, the specimen without calcium hydroxide is 20%. Figure 5 shows the relationship between moisture content and pH water. From this experiment, it may be concluded that as the size of pores decreased, so the moisture content of soil decrease too. The higher pH value in soil, the less the concentration of hydrogen ions in soil [5].

Table 5: Data obtained for moisture content

Sample	Wet mass (kg)	Dry mass (kg)	Moisture content (%)
Natural water	0.018	0.015	= 20%
A	0.015	0.013	= 15.4%
B	0.009	0.008	= 12.5%
C	0.011	0.010	= 10%

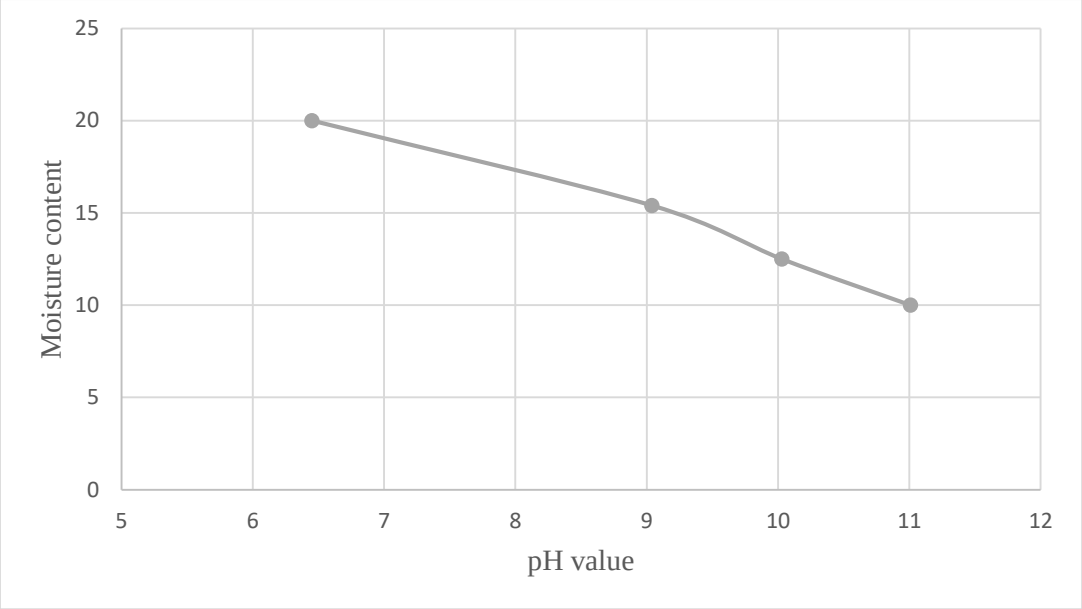

Figure 5: Graph moisture content versus pH value

4. Conclusion

The conclusion can be pinch out is include:

i. These objectives are successfully achieved by presenting relationship between matric suction in soil and alkaline water.
ii. The result shows that the soil treated by alkaline water will create a process to reduce the size of pores and brings out it to the increasing in matric suction.
iii. At the end of this study, all can conclude and summarized how polluted water can affected the soil properties that can be one of the causes of landslides due to soil properties and water content in soil.

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