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Effect of Sulfuric Acid on the Shear Strength and Consolidation Parameters of a Clayey Soil

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ABSTRACT: The vast use of chemical productions and the large amount of leachate which produced by human, lead to the pollution of the soil and groundwater supplies. Acidic contamination is one of the most common contaminations that goes to the nature by different ways such as leachate of factories, industry and acidic rains. These contaminants which cause environmental hazards, are also important in geotechnical perspectives and need more investigations. In this paper, the effects of sulfuric acid contamination on the shear strength and consolidation parameters of a clay soil is studied. Unconfined compression strength and one-dimensional consolidation test conducted on the soil under specific conditions. The soil itself was clean at first, and it was contaminated by adding sulfuric acid in three different pH values (5, 3 and 1). Also in order to compare the test results, one test conducted with drinking water (pH=7.8). The results showed that acidic contamination and pH reduction, decreases the shear strength of clay. Also, by reducing the pH values, the coefficients of compression and swelling increased under the influence of the contaminant. The presence of the acid, increases the coefficient of consolidation and the rate of consolidation.

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1- Introduction

Umesh et al. (2011) studied the effect of sulfuric acid contamination (0-15%) on the behavior of three types of soils with varied clay content. They stated that the unconfined compressive strength has significantly reduced due to loss of cohesion [1]. Three marine deposits were subjected to long-term acidic leaching in order to study the influence of contamination on the compressibility of natural soils by Gratchev and Towhata (2011). It was found that clay mineralogy and soil structure had a significant effect on the compressibility of clays at low pH. In the case of the Osaka and Ariake clays, the compressibility significantly increased with a decrease in pH values, a finding that was primarily attributed to change in the soil's structure. In contrast, the effect of acidic leaching on the properties of Kawasaki mud was observed to be the opposite [2]. Prakash and Arumairaj (2013) conducted an extensive laboratory testing program to study the effects of acid and base contamination on clay (CH) samples. The acid contaminants used are hydrochloric acid, nitric acid and sulfuric acid. The base contaminants used are sodium hydroxide, potassium hydroxide and calcium hydroxide. The acid and base was added at an increment of 5% by weight of dry samples to make the soil artificially contaminated. The shear strength decreases with increase in acid contamination. The shear strength increases with increase in base contamination [3]. Gratchev and Towhata (2016) studied the effects of acidic fluids on the compressibility of soil by conducting some standard compression tests. It was found that the soil structure had a significant effect on the compressibility of clay at low pH. The undisturbed specimens yielded greater compression indices as pH values decreased. In addition, the data indicated that for all three soils, a decrease in pH correlated with an increase in the compression index [4].

The wide range use of sulfuric acid in different industries and the presence of the acid in the natural ecological cycles, make studying on its properties and the impacts of it on the environment valuable. In this paper, the effects of sulfuric acidic contamination on the shear strength and consolidation parameters of a clay soil by conducting some unconfined compression strength and one-dimensional consolidation tests is studied.

2- Soil and the performed tests

The soil used in this research was a clay soil. Particle size distribution of soil is shown in Figure 1. Physical properties of soil included specific gravity of particles, liquid limit, plastic limit, plastic index, dry unit weight and optimum moisture content are presented in Table 1. The selected soil was classified CL based on unified soil calcification system. Sulfuric acid (98%) was used as the contaminant.

Unconfined compression strength and one-dimensional consolidation test conducted on the soil under specific

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conditions. The soil itself was clean at first, and it was contaminated by adding sulfuric acid in three different pH values (5, 3 and 1). Also in order to compare the test results, one test conducted with drinking water (pH=7.8).

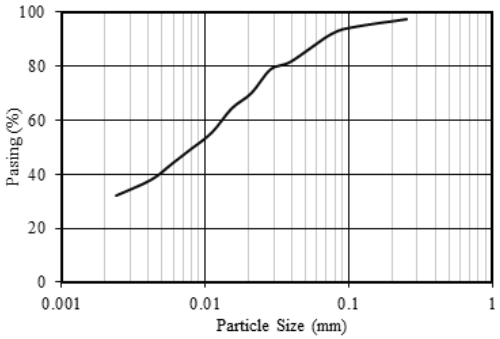

Figure 1. Particle size distribution of the soil

Table 1. Physical properties of the used soil

Property	Value
Specific gravity of particles	2.77
Liquid limit (%)	36
Plastic limit (%)	22
Plastic Index (%)	14
Optimum moisture content (%)	17.25
Dry unite weight (kN/m^3)	17.5

Samples were remained inside of plastics membranes up to 1, 7, 14 and 28 days, then, unconfined compression strength tests were performed on the samples. ASTM 2166 were used as the reference for test procedure. Generally, 16 unconfined compression tests were conducted under different curing time and pH values. At the second step, 4 one-dimensional consolidation tests were conducted on the soil with three different pH values of sulfuric acid (5, 3 and 1) and drinking water (pH=7.8) after 72 hours curing time. ASTM 2435 were used as the reference for test procedure. Totally 4 one-dimensional consolidation test were carried out.

3- Discussion and Results

Unconfined compressive strength of contaminated and clean samples is illustrated in Figure 2. Based on this figure, acid contaminated clay samples at the curing time of 1, 7, 14 and 28 days, showed 22.6, 30.5, 37.1 and 40.8 percent unconfined compressive strength reduction in the most contaminated samples (pH=1) in comparison with clean samples, respectively. Generally, acidic contamination decreases the soil strength and secant modules of the clay samples, so that by increasing the curing time and pH reduction, this decrease become more dominant.

The effects of acidic contamination on the void ratio changes of clay samples in different pH values is shown in Figure 3. Figure 4 shows the compression (C_c) and swelling (C_s) coefficients values in different pH of sulfuric acid contaminated clay samples. The coefficients of compression and swelling of the clay samples increased by curing time and acidity increase. The coefficients of compression and swelling of acid contaminated clay samples showed 0.9 and 1.2 times increase for the most contaminated samples (pH=1) in comparison with clean samples, respectively. Generally the presence of the phosphoric acid increases the coefficient of consolidation and the rate of consolidation.

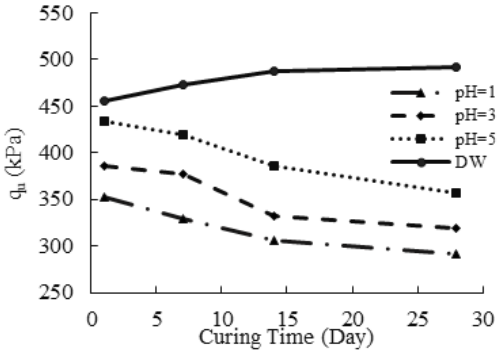

Figure 2. Influence of pH and curing time on unconfined compressive strength of the soil

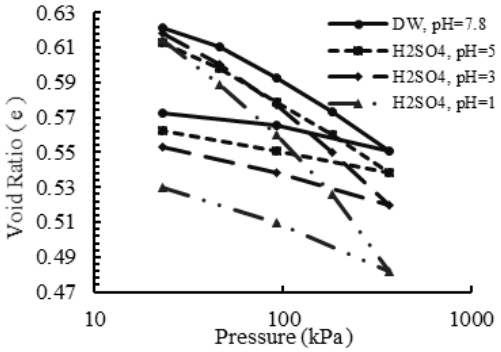

Figure 3. The void ratio versus log p (pressure) curves for the acid contaminated and clean clay samples

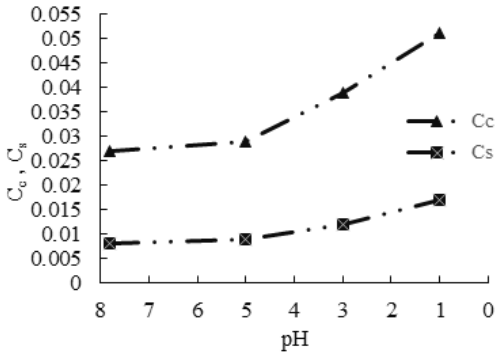

Figure 4. Influence of pH on compression and swelling indexes of the clay samples

4- Conclusions

Briefly the following results were obtained based on the unconfined compression strength and one-dimensional consolidation tests about the effect of acidic contamination on the shear strength and consolidation parameters of a clay soil:

1. Acidic contamination decreases the soil strength, so that by increasing the curing time and pH reduction, this decrease become more dominant. The unconfined compressive strength for all the clean samples increased by increasing the curing time according to thixotropic property.
2. Secant modules of the acid contaminated clay samples decreased in comparison with the clean samples.
3. The coefficients of compression (C_c) and swelling (C_s) of the clay samples increased by curing time and acidity increase. Generally the presence of the Sulfuric acid increases the coefficient of consolidation and the rate of consolidation.

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