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The Effect of Heavy Metal Contaminants on the Strength Parameters of Sandy Clay

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ABSTRACT: Desirable physical and behavioral characteristics of clay soils have resulted in their wide usage in engineering landfills. Clay soils are able to interact with the materials in contaminants thanks to their special mineral structure and adsorb part or all of the hazardous materials present in the leachate leaked in them. Previous studies have shown that changes in the physical and chemical characteristics of pore fluid in soil, given the type of minerals clay soils and the soil structure, significantly influence the properties of soil engineering including shear parameters, the extent of swell, and water adsorption percentage. The aim of this research is to study the effect of heavy metal contaminants on some strength and geotechnical parameters of sandy clays. For this purpose, following preparation of the samples, adsorption and direct shear experiments along with determination of the liquid limit were performed on the samples which had been exposed to the heavy metal contaminants of Pb and Zn. The results indicated that across the three studied clay types (the mixed sand kaolinite samples with different sand percentages), with the increase in the concentration of both contaminants, soil cohesion diminishes, while the internal friction angle of the samples was not affected by presence of heavy metal contaminants. When concentration of Zn increases to 25 cmmol, cohesion of samples with 90% and 60% of kaolinite decreased 20% and 23% respectively. While in the presence of Pb decrease in cohesion is 42% and 51%.

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1- Introduction

Clay soils are able to interact with the materials in contaminants due to their special mineral structure and adsorb part or all of the hazardous materials present in the leachate leaked in them [1].

Classic soil mechanics has been based on the concept of effective stress, in which the electrostatic forces of the liquid phase on the soil's strength behavior are not taken into account and the effect of the forces in the interface of water and soil which cause interaction between soil particles, soluble ions, and water is neglected [2]. The net electric charge on clay particles is negative, causing the cations dissolved in the surrounding pore fluid to be adsorbed by the surface of clay particles. A layer of water and adsorbed ions which surround clay particles is called diffuse double-layer (DDL) or electric double layer [3]. According to Guy-Chapman's double layer theory, the thickness of the double layer is only dependent on the salts dissolved and the liquid phase; accordingly, changes in the properties of the liquid phase resulting from entrance of contaminants into the soil environment cause variations in the thickness of the layer and thus the behavioral characteristics of soil. On the other hand, the higher the thickness of the double layer, the less the particles tend to flocculate [3]. Regarding investigation of the effect of heavy metals on the geotechnical properties of clay soils, various studies have been conducted [4-11].

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2- Materials and methods

The Kaolinite used in this research was in the form of a white powder which was supplied by Iran's porcelain soil industries and is known as super kaolinite. Table 1 indicates some environmental and geotechnical properties of the utilized kaolinite, which have been determined based on ASTM 2007 standard method.

Table 1. The primary physical and chemical characteristics of kaolinite soil

Property evaluated	The measured values
Liquid limit, %	46
P.I. %	20
Soil Classification	CL
pH (1:50, Soil-Water)	8.9
Carbonate, %	4

The sand used in this research belongs to ASTM-C778 classification, and is SiO_2 (Otawa) silica sand. In the pure state, the percentage of silica in it is around 8.99%. Its particles are round shaped and a diameter of the particles varies between 0.595 and 1.18 mm.

Fabrication of the kaolinite-sand mixture samples was performed by a mixture of kaolinite with weight percentages of 10, 25, and 40% sand. The reason of selection of these percentages can be related to the fact that soil nomenclature, according to unified naming system (CL), would remain constant in a relatively wide range of changes in the sand ratio.

Following preparation of the soil samples, in order to examine the effect of heavy metal contaminants on Atterberg limits and the shear strength parameters, the experiments of liquid limit determination and direct shear were done on the samples according to ASTM D4318 and ASTM D 3080-90 standards, respectively. Further, analysis of the pore water characteristics was done by [1]ICP device provided by Tarbiat Modares University in order to determine the extent of adsorbed cations.

3- Results and Discussion

The effect of the presence of heavy metal contaminants on the strength parameters of the kaolinite-sand mixture samples are presented in Figures 1 and 2.

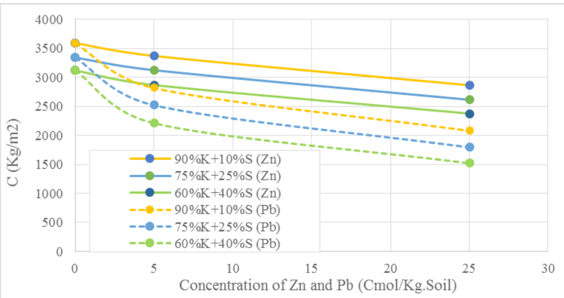

Figure 1.The changes in the cohesion of kaolinite-sand mixture samples with different sand percentages in the presence of Zn and Pb

Figure 1 demonstrates that across every soil type (kaolinite-sand mixture samples with different sand percentages), with the increase in the concentration of both contaminants, soil cohesion has also diminished.

With the presence of the heavy-metal contaminants of Pb and Zn, the thickness of the double layer declines around the clay scale. Furthermore, as was mentioned previously, the increase in the concentration of these contaminants also causes reduction of the thickness of double layer around the clay scale. In this way, considering the reduction of the thickness of the double layer around the clay scale, the surface potential on the clay scales also declines, thereby reducing the cohesion of samples in the presence of heavy metal contaminants.

Moreover, Figure 2 indicates the changes in the friction angle of kaolinite-sand mixture with different sand percentages in the presence of different concentrations of the two contaminants of Pb and Zn.

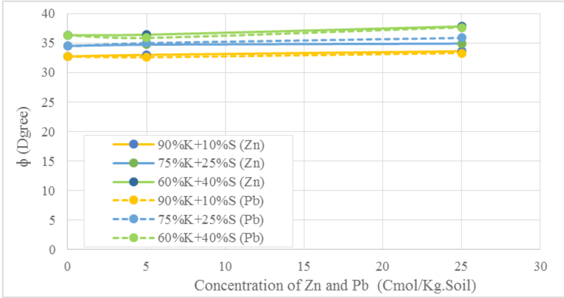

Figure 2. The changes in the internal friction angle of kaolinite-sand mixture samples with different sand percentages in the presence of Zn and Pb

The results obtained from Figure 2 suggest that the presence of both contaminants has had a very trivial effect on the internal friction angle of the samples, such that per addition of 25 Cmol/kg of soil of Pb and Zn in the kaolinite 90%-sand 10% mixture, the internal friction angle of the samples has grown by only 2 and 3%, respectively. This implies lack of effect of heavy-metal contaminants on the internal friction angle of kaolinite-sand mixture samples.

4- Conclusion

The results of this research can be summarized as follows:

a) As sand has a lower cohesion and greater internal friction angle than kaolinite sandy clay, the increase in the share of sand in kaolinite-sand mixture has caused reduced cohesion and increased internal friction angle of the samples, where the rate of changes in these two parameters has not been equal. Further, due to the lower water adsorption capacity of sand in comparison with kaolinite, it was observed that with the increase in the percentage of sand, the liquid limit of the kaolinite-sand mixture has decreased, such that this reduction rate first increased, while following elevation of sand percentage, it has decreased.

b) The results obtained from investigation of the extent of retention of Pb and Zn suggest that across all the samples and in the presence of both heavy metal contaminants, with the increase in the concentration of contaminants, the extent of retention of kaolinite-sand mixture samples has also grown. With the increase in the concentration of Zn by up to 25 Cmol/kg of soil, the kaolinite-sand mixture samples with sand percentages of 10, 25, and 40% showed an ability of retaining around 20, 22, and 25 Cmol/kg of soil for Zn. However, the retention ability for Pb for those samples has been 24, 26, and 29 Cmol/kg of soil.

c) The results obtained from direct shear experiment suggest that across all the three soil samples (kaolinite-sand mixture samples with different sand percentages), with the increase in the concentration of both contaminants, soil cohesions has also decreased. The difference between the reduction rate of cohesion of kaolinite-sand mixture samples in the presence of Pb and Zn can be attributed to selective adsorption process and ability of sedimentation in the interaction between soil and contamination.

1 Inductively Coupled Plasma

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