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A Review of the Effect of Hydrocarbon Contamination on Atterberg and Plasticity Limits of Soils

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Abstract- In recent years, environmental pollution has been a significant impact on their surroundings particularly on soil medias. The most important environmental pollution can be mentioned hydrocarbon contamination. Actually, oil contaminants diffusion will have a great impact not only on soil chemical properties but also on its physical properties, particularly geotechnical properties. Also In this research review of previous studies on the geotechnical properties of soil, by reviewing the impact of hydrocarbon contamination on the Atterberg limits is one of the most important geotechnical characteristics of soils. Actually, the Atterberg limits of soils are a standard defining for the rate of moisture existent in the soil sample. In general in this field, the results of previous researches have shown a decrease on liquid and shrinkage limits of contaminated samples. In fact, this matter had caused the significant changes in the strength properties and behavior of contaminated soils compared to uncontaminated samples.

Keywords- *hydrocarbon contamination, Atterberg limits, moisture existent, liquid and shrinkage Limits*

I. INTRODUCTION

Nowadays, not only the air and water, but also soil and its surroundings are experiencing irrecoverable changes and contaminations due to human activities. In this regard, hydrocarbon compounds have a considerable share in contaminating the soil. This contamination (especially that with the crude oil) occurs through various sources among which leakage from oil transfer pipes, natural oil leakage, oil discharge from sea/land establishments, dust from oil-associated gas burning, and oil transportation or storage are very important and play vital role in spreading and dispersion of hydrocarbon contaminators in the soil medium and its surrounding aquifers. [1]

Actually leak of crude oil from mentioned source and its Penetration into the surrounding soil and buired foundation, in addition to the environmental impacts, causes changes in geotechnical properties of soil including changes in plastic limits. Of course, the effect of oil contamination on geotechnical and strength parameters is not limited to changes in the Atterberg limits. But other strength parameters will be changed such as cohesion, angle of internal friction, optimum moisture content, maximum dry density, permeability and etc. [2]. This compound affect not only on the physical and appearance properties, but also on the chemical characteristics of soils [3]. Also the changes in the strength properties of soils caused by oil contamination, in the granular soils are in the physical properties and in cohesive and clay soil are in the soil structure [4].

In recent years, some researches and tests were done on the strength and geotechnical properties of soils in particular on the Atterberg Limits. In addition to the some studies, those of Khamehchiyan and colleagues's [5], Zulfahmi and colleagues's [6], Kermani and Ebadi's [7], Pandy and Bind's [8], etc are noteworthy. The aim of this research is to investigate the results of changes in values of Atterberg limits due to penetration of hydrocarbon contamination in soil based on previous research conducted by researchers in this field.

II. A REVIEW OF THE RESEARCHES ABOUT SOME CHANGES ON THE ATTERBERG LIMITS OF SOILS CAUSED BY HYDROCARBON CONTAMINATION

In fact, in this section conducted researches are often contains similar results and close to each other in terms of affected Atterberg Limits of soils under contamination conditions. The observed differences in some results of the studies relative to each other can be due to different circumstances, such as laboratories, the type of the contaminant, the chemical and physical properties of soil, environmental conditions and the others [2]. However, all researchers' results in this field follow a certain process.

In below, several important researches in this field have been investigated:

A. The study of Khosravi, Ghasemzadeh et al.

Research Khosravi, Ghasemzadeh et al. [9] consists of a series of laboratory tests such as basic properties, Atterberg Limits, consolidation, direct shear and unconfined compressive strength on kaolinite sample under uncontamination and

contamination to gas- oil. The grain size curve of kaolinite that used in this study has shown in Fig. 1.

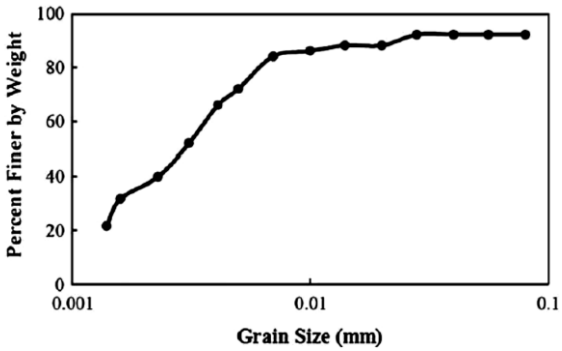

Figure 1. Grain size Curve of kaolinite samples in the study of Khosravi et al. [9]

In this study, the samples were mixed with 2, 4, 6, 12, 16 and 20 percent of gas- oil and after maintaining for 24 hours in Oven were tested in laboratory. It can be seen the physical changes of kaolinite samples before and after mixing 16 prcent of gas- oil in Fig. 2.

Figure 2. kaolinite in the study of Khosravi et al. a) before mixing the gas-oil b) after mixing 16% of gas- oil [9]

In this study, one of the important results on kaolinite samples was the effect of gas- oil contamination on the Atterberg limits of soils. The results were shown in Fig. 3.

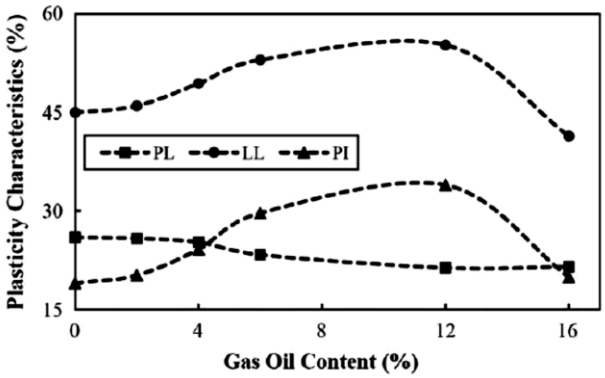

Figure 3. Profile plasticity of sample under the different percentages of gas-oil contamination in the study of Khosravi et al. [9]

As shown, by increasing the amount of gas- oil up to 12 percent, while the values of PL are decreasing, LL will increase. Finally the rate of PL for contaminated kaolinite by gas- oil will increase and then will decrease. In the Figure is known that the rate of PL will remain constant at 12%. While the values of LL and PL are decreasing. In this research, the reason of decrease in the PL is described by two-layer diffusion theory.

B. The study of Khamehchiyan, Charkhabi and Tajik

Khamehchiyan and colleagues [5] have done their analysis on SM, CL and SP samples that contaminated by 0, 4, 8, 12 and 16 percent of crude oil. In this study, the grain size distribution for all of soils samples is provided as shown in Fig. 4.

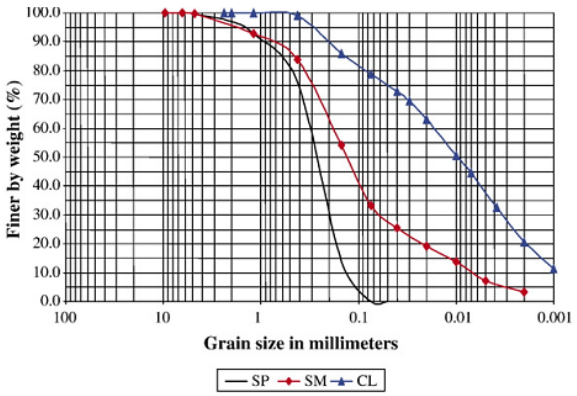

Figure 4. grain size distribution in the study of Khamehchiyan et al. [5]

As one of the fundamental results in this study, it has been reported that the values of Atterberg limits have been changed under hydrocarbon contamination, as shown in Table I.

TABLE I. THE ATTERBERG LIMITS OF SOILS SAMPLES IN THE STUDY OF KHAMEHCHIYAN ET AL. [5]

Soil	Atterberg Limits	
	Liquid Limit (%)	*Plastic Limit (%)*
SP	Not Possible	Not Possible
SM	Not Possible	Not Possible
CL	35.30	17.09

According to the table it can be seen that the Atterberg limits of CL will be possible in soil samples, exclusively. Therefore, the changes of Atterberg limits in different percentages of oil contamination in CL have been shown in Figures 5 and 6.

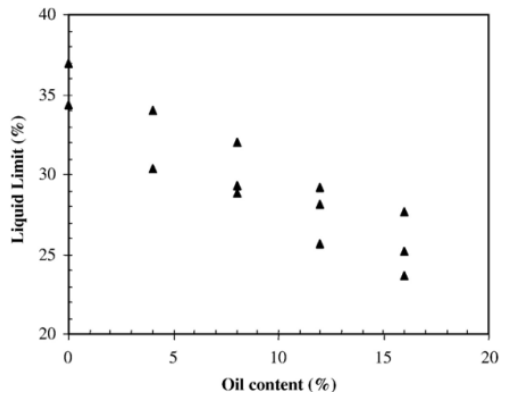

Figure 5. Influence of oil content on liquid limit of CL samples in the study of Khamehchiyan et al. [5]

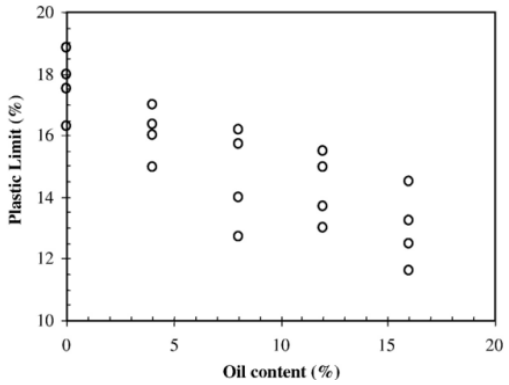

Figure 6. Influence of oil content on plastic limit of CL samples in the study of Khamehchiyan et a.l [5]

As shown, with an increase in the percentage of oil in the CL samples, the rate of the Atterberg Limits decrease. In fact, it would be due to the nature of water in the structure of clay and the performance of non-polar liquids and cohesion behavior of the sample.

C. The study of Adejumo

Adejumo [10] has done his research on soft clays obtained around three oil wells located in delta of Nigeria. In this Research in addition to studying changes in strength parameters against hydrocarbon contaminations, some changes in Atterberg limits due to the presence of oil contamination have been examined. In this study, the results of some changes in Atterberg limits have been shown in Table II.

TABLE II. THE ATTERBERG PROPERTY OF UNCONTAMINATED AND CONTAMINATED CLAY SAMPLES IN THE STUDY OF ADEJUMO [10]

Property	The Value of Atterberg Limits	
	Uncontaminated Soft Clay	*Contaminated Soft Clay*
Liquid Limit (%)	67	79
Plastic Limit (%)	43	46
Plasticity Limit (%)	24	33
Shrinkage Limit (%)	18	21

Actually, the results show that a increase about 17.9 percent in the liquid limit, increase about 6.9 percent in the plastic and increase about 37.5 percent in the plasticity index of the samples.

D. The study of Pandy and Bind

Pandy and Bind [8], have done their research with the aim of research about the effects of pollution caused by engine oils on alluvial soils samples during 0, 4, 8 and 12% of hydrocarbon contaminants. In this research the results of changes on Atterberg limits were included shrinkage, plastic and liquid limit due to contaminants are provided in Figures 7, 8 and 9, respectively.

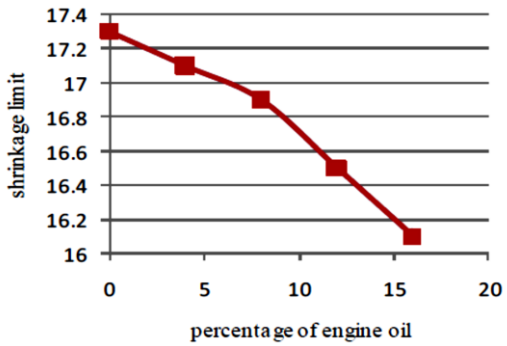

Figure 7. Influence of engine oil content on shrinkage limit of soil sample in the study of Pandy and Bind [8]

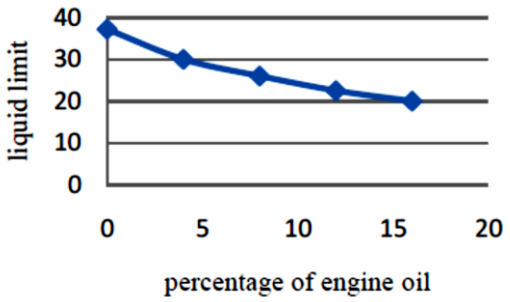

Figure 8. Influence of engine oil content on liquid limit of soil sample in the study of Pandy and Bind [8]

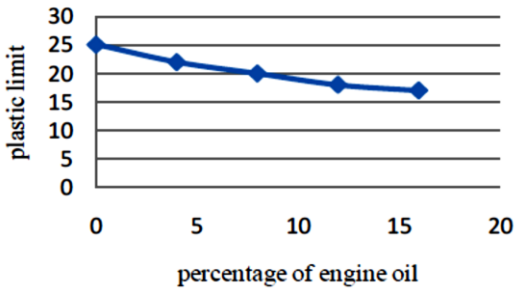

Figure 9. Influence of engine oil content on plastic limit of soil sample in the study of Pandy and Bind [8]

By reviewing the above figures, it can be realized that the Atterberg limits of soils under hydrocarbon contamination follows a downward trend. In fact this subject represents a less plastic limit related to contaminated samples compared with uncontaminated samples in similar conditions.

E. The study of Zulfahmi et al.

Zulfahmi et al. [6] have done his research on samples that obtained from weathered basaltic rock of grades V and VI under 4, 8, 12 and 16 percent of oil contamination. The studies and results of some changes in Atterberg limits are shown in Figures 10 and 11 for the weathered basaltic rock of grades V and VI.

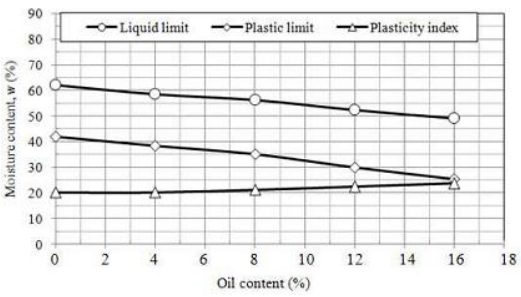

Figure 10. The results of Atterberg Limits values for the basaltic sample with V degree of weathering in the study of Zulfahmi et al. [6]

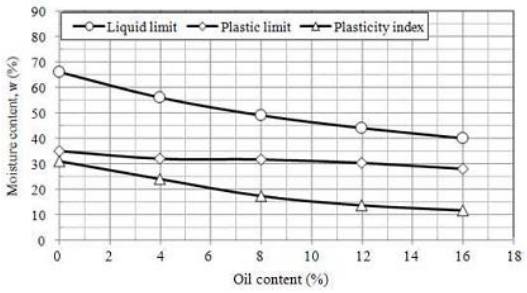

Figure 11. The results of Atterberg Limits values for the basaltic sample with VI degree of weathering in the study of Zulfahmi et al. [6]

As shown, it is clear that after applying the oil contamination, the liquid and plastic limits rate were decreased for both sample. These decreases in plastic and liquid limits for samples with V degree were 21% and 39%, respectively and for samples with VI degree were 39% and 19%, respectively.

III. Conclusion

At this study, it was discussed about review and analysis results from several investigations about some changes on the plasticity Characteristics and Atterberg Limits of different soil samples under hydrocarbon contaminations, especially crude oil. In fact, the results of these researches have shown often a decrease on the rate of the Atterberg limits under increasing pollution due to hydrocarbon contamination. Of course, these results in some of the studies have shown the different trends. On the other hand, the reason of this difference at some of the results could be due to some factors such as type of soil, different physical and chemical properties of soils, types of contamination, different environmental conditions as well as other numerous factors are tested. However, as a main conclusion resulting from the research that conducted in this field, it can be stated that the Atterberg limits of contaminated soils are far less than the sample that is free of any contamination.

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