Behavior of Oil-Contaminated Sands in CBR Test

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ABSTRACT

Several factors affect the bearing the load of natural and engineered embankments and slopes including the crude oil leakage, leading to a severe decrease in resistance. This is especially important for oil-rich countries, such as Iran, which have several crude oil resources. The main purpose of this study is to investigate the load bearing (i.e. load versus settlement) and strain-stress behavior of crude oil contaminated sandy soils using California Bearing Ratio (CBR) Test. In this paper, 10 different types of sand with different characteristics used. At first, a series of CBR experiments performed for natural sands (i.e. clean sands) and then contaminated sands with 6% crude oil tested under similar conditions and densities to obtain the reduction in bearing the load of crude oil contaminated sands quantitatively. Experimental results showed that bearing the load of sand containing 6% of crude oil decreased at least 50% compared to clean sands and the stress-strain diagram of these contaminated soils would decrease significantly. Based on the results of investigation, it can be stated that particle shape (sharpness or roundness), coarse particle ratio, and finally the type of aggregation influences the resistance of crude oil contaminated sands. It was also found that standard Ottawa sand had 83% reduction in strength and sand with a coarse particle had 57% decrease in strength. Sand contaminated with crude oil experience a severe loss of bearing capacity, so in designing foundations and engineering structures, greater safety factors should be considered, where there is a risk of crude oil leakage.

KEYWORDS

Sand, Crude oil, Bearing the load, California Bearing Ratio, Grain shape

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1. Introduction

Load bearing is one of the classic concepts of foundation engineering, which is subject to several conditions. Increasing the bearing tolerance with the help of technical methods has always been of interest to geotechnical researchers. If the soil of the site reduced for any reason, the bearing capacity of that area will be reduced, which will result in a serious threat to the safety of the structures. Crude oil leakage are a major threat in areas near oil wells. Accordingly, awareness and knowledge about the importance of reducing the load tolerance of these areas is more important.

Mohammadi et al. [1] used three types of pollutants (diesel, crude, and engine oil) to investigate the effect of oil contamination on the interaction between sandstone piles. The results of their research showed that the presence of oil between the sand particles would have significant negative effects on reducing the piles load bearing capacity. AL Adly et al. [2] research showed that sand pollution with crude oil changes the load-settlement curve and drastically reduces the load bearing capacity. They also indicated that the failure mode changes from local to punching failure. Joekar and Hajiani Bushehrian [3], by numerically examining the bearing load tolerance of the strip footing on the sandy slope contaminated with crude oil, concluded that by increasing the thickness of the contaminated layer and increasing the amount of pollutants, the bearing tolerance decreases. Nasr [4] showed that the CBR of contaminated sand using heavy engine oil dropped sharply. If such contaminated sand stabilized with cement, the CBR value will increase dramatically, indicating the importance of stabilizing contaminated sands.

Despite numerous studies on bearing tolerance and CBR testing, there is a dearth of literature about the reduction in load bearing tolerance of crude oil-contaminated sandy soils. Therefore, in the presented paper, an attempt has been made to answer this question by performing a series of CBR experiments on different types of sand in clean (non-contaminated) state and in contaminated conditions with 6% crude oil. At the end of this study, the basic questions of how the shape of particles, the size of particles, and the type of grain size distribution play role in reducing the bearing tolerance of crude oil-contaminated sands can be answered.

2. Material Characteristics

In this research, 10 different types of sand have been used; the specifications of each sand are given in Table 1. Preliminary experiments were performed on each of the sands to obtain the parameters and characteristics of each type of soil. The sands used are Ottawa standard sand, Firoozkooh 161 and 171 sands, Bushehr sand, two models of Kermanshah river sand (KRSS#1 & KRSS#2) and Kermanshah river sands with specific grading, one passing from sieve No. #4 and blocked on sieve No. #10 (KRSS#1A & KRSS#2A) and the other passing through sieve No. #10 and blocked on sieve 60 (KRSS#1B & KRSS#2B).

Table 1. Sand Characteristics

Sand Type	*USCS*	*Cu*	*Cc*	*D50*	*Gs*
Ottawa	SW	7.231	1.010	0.971	2.660
Bushehr Sand	SP	2.876	0.909	0.197	2.696
FiroozKooh#161 Sand	SP	2.065	1.072	0.230	2.644
FiroozKooh#171 Sand	SP	1.990	1.192	0.184	2.592
KRSS#1	SP	4.701	0.489	0.963	2.660
KRSS#2	SP	6.866	0.968	1.487	2.786
KRSS#1A	SP	-	-	_	2.720
KRSS#1B	SP	-	-	_	2.614
KRSS#2A	SP	-	-	_	2.747
KRSS#2B	SP	-	-	_	2.711

Grain size distribution of these sands are shown in Figure 1. In this figure, the diagram of the first six sands is given. The other four types of sand that are not shown in this diagram have specific grains, stated previously.

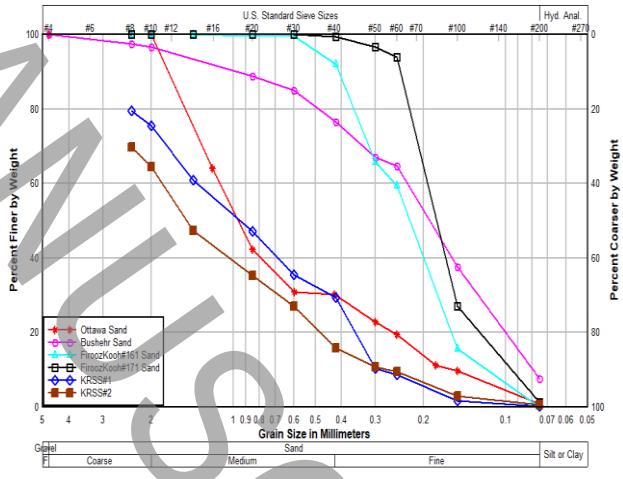

Figure 1. Sands grain size distribution

Since one of the parameters studied in this paper is the shape of the particles, Figure 2 shows the sand samples under optical microscope to better and further understand the shape of the particles in each soil. The CBR test performed in this study is based on the ASTM D1883 standard. The internal dimensions of the mold have diameter of 150 mm and height of 120 mm.

Figure 2. Sand particles under optical microscope

3. Sample Preparation

In this study, the amount of crude oil contamination with the clean soils was 6% of the dry soil weight. According to previous research on oil-contaminated soils [4-6], the highest percentage of pollution was selected for sandy soils is 6%. Because at higher percentages, the efficiency of the soil is practically lost and it is not possible to test it. In addition, in fewer percentages, the effect of pollution will not be clearly visible. Figure 3 shows how Firoozkooh 171 sand contaminated with 6% crude oil prepared.

Figure 3. FiroozKooh#171 contaminated sand preparation

4. CBR Experiments

All 10 types of soil were tested in conditions of contaminated with crude oil. Figure 4 shows the results from the CBR test on 6% crude oil contaminated sands.

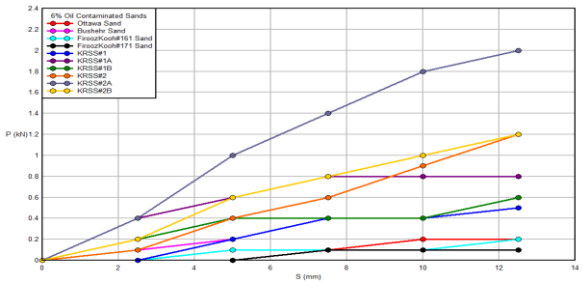

Figure 4. CBR Test results on 6% oil contaminated sands

5. Results

Based on the data from the experiments, as it is clear, the drop in load tolerance and the reduction of the resistance of sandy soils contaminated with 6% crude oil is quite evident. In all tested soils, the reduction in CBR of contaminated samples was more than 50%. Firoozkooh 171 sand (which is fine-grained sand) has the largest decrease with a drop of 91%, indicating that this type of sand is much more sensitive to oil contamination than other soils. However, since KRSS #2A has a CBR drop of about 58%, it performs better that other soil samples, which the shape of its grains can explain the reason for this phenomenon.

6. Conclusions

The purpose of this study is better understanding of the behavior of sands contaminated with crude oil. In this study, 6% of crude oil was used to contaminate 10 types of sands. With the help of CBR experiments on non-contaminated sands and contaminated sands, the following results were obtained. However, in the case of load bearing in non-contaminated conditions, the type of sand grain distribution has a significant effect. Nevertheless, in the case of sand contaminated with crude oil, the most important factor is the shape of the particles, and the granular particles perform better than the rounded particles, so that the least reduction in load tolerance or stress tolerance in stress-strain graphs belong to these type of soils.

7. References

[1] A. Mohammadi, T. Ebadi, A. Eslami, and S. E. Van der Zee, Axial compressive bearing capacity of piles in oil-contaminated sandy soil using FCV. *Marine Georesources & Geotechnology*, *37*(2), (2018), 164-179.

[2] A. I. F. Al-Adly, A. I. Fadhil, and M. Y. Fattah, Bearing capacity of isolated square footing resting on contaminated sandy soil with crude oil. *Egyptian Journal of Petroleum* (2019), Article in Press.

[3] A. Joekar, and A. Hajiani Bushehri, Studying the behavior of strip foundation rested on the kerosene oil contaminated sand slopes. *Sharif Journal of Civil Engineering*, (2020), Article in Press, (In Persian).

[4] A. M. A. Nasr, Utilisation of oil-contaminated sand stabilised with cement kiln dust in the construction of rural roads, *International Journal of Pavement Engineering*, 15(10), (2014), 889-905.

[5] H. A. Al-Sanad, W. K. Eid, and N. F. Ismael, Geotechnical properties of oil-contaminated Kuwaiti sand, *Journal of Geotechnical Engineering*, 121, (1995), 407-412.

[6] A. M. A. Nasr, and S. V. Krishna Rao, Behaviour of laterally loaded pile groups embedded in oil-contaminated sand, *Géotechnique*, 66(1), (2016), 58-70.