Amirkabir Journal of Civil Engineering

Amirkabir J. Civil Eng., 53(1) (2021) 87-90
DOI: 10.22060/ceej.2018.13268.5363

Passive Remediation with Colloidal Silica Effect on Shear Strength Properties of oil-contaminated Bushehr Carbonate Sand

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ABSTRACT: Crude oil is one of the soil and water pollution sources that change the geotechnical properties of the soil via both physical and chemical processes. Carbonate sand which is found in oil-rich and continental regions is exposed to oil pollution so that studying the effect of oil and petroleum product contamination is unavoidable. On the other hand, injecting a colloidal silica solution, stabilization and improvement of oil-contaminated sand has been investigated broadly. In this research, several triaxial undrained-unconsolidated tests were conducted to investigate the shear strength of carbonate sand contaminated with crude oil as well as contaminated sand stabilized by colloidal silica injection. The results showed that oil pollution reduced the maximum shear strength and the friction angle of carbonate sand, as well as a significant decrease in elasticity modulus while oil content increased. In injected specimens, colloidal silica increases the shear strength, cohesion, and stiffness significantly relative to the oil-contaminated ones.

Review History:

Received: 8/14/2017
Revised: 1/16/2018
Accepted: 1/24/2018
Available Online: 2/12/2018

Keywords:

Carbonate sand
Oil contamination
Colloidal silica
Shear strength
Passive remediation

1. INTRODUCTION

In recent decades, many investigations have been conducted to study the oil contamination effect on the soil shear strength parameters. Soil contamination by crude oil make some problems that can affect the bearing capacity of the shallow foundation which could endanger the structure's stability as well as foundation settlement. Previous researches demonstrated a dramatic decrease in elasticity modulus especially in dense specimens which could cause more settlement beneath the existing foundations [1]. Also, some investigations have reported the shear strength experiment results which show a significant decrease in internal friction angle and bearing capacity of foundations [2, 3]. Oil contamination caused the soft behavior of the soil so that the particles could slide and rotate easier.

To overcome this problem, especially beneath the existing structure with a compacted underneath polluted soil layer, a suitable stabilization method could be useful. Encapsulation and immobilization of oil contamination are achievable by adding colloidal silica as reported earlier [4]. The injection of colloidal silica into porous media has been convinced by many researchers because of its low viscosity. Moreover, passive remediation by colloidal silica is relevant as well as an increase in shear strength envelope [5]. Iran due to having 10 percent of the world's oil reserves as one of the largest oil-exporting countries is largely exposed to soil contamination with oil products and has always been confronted with the problem of leakage and emissions of oil on the sea bed and Land.

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Therefore, in this study, the effect of oil contamination on the shear strength parameters and elastic modulus of Bushehr carbonate sand were studied, then by passive injection of the colloidal silica at a viscosity similar to water, contaminated soil stabilization was studied.

2. METHODOLOGY

Bushehr carbonate sand particle size distribution and standard protector test have been shown in Fig. 1 and Fig. 2, respectively. All specimens, included 59% CaO (measured by XRF test), were compacted up to 85% of the maximum relative density and 6% moisture content at the dry side of the proctor diagram. Crude oil was added to clean sand specimens by 3, 6, 9, and 12 percent of the dry sand mass. Stabilized specimens were prepared by injecting colloidal silica under a low hydraulic gradient. Colloidal silica particles diameter was 10 nanometers and the pH of 6 and ionic strength of 0.2 mol/lit were adjusted by adding HCl and NaCl. Also, colloidal silica dispersion was diluted to 10 percent by weight by adding distilled water. After 28days, all specimens were loaded uniaxially using triaxial apparatus. No water was injected into specimens and no consolidation has occurred. Shear strength of the specimens was measured under the confining pressure of 50, 100, and 200 kPa and the loading rate of 0.5 mm/min to

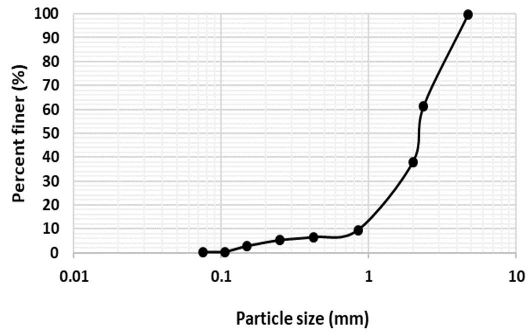

Fig. 1. Particle size distribution of Bushehr carbonate sand.

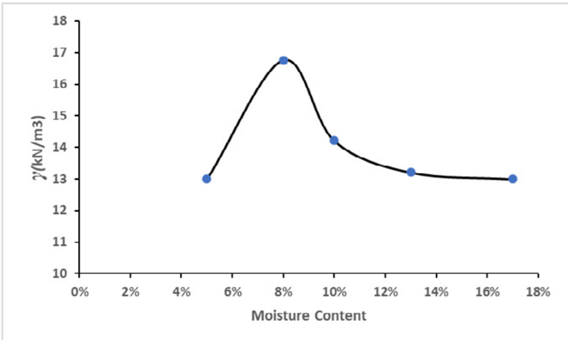

Fig. 2. Standard proctor test of Bushehr carbonate sand.

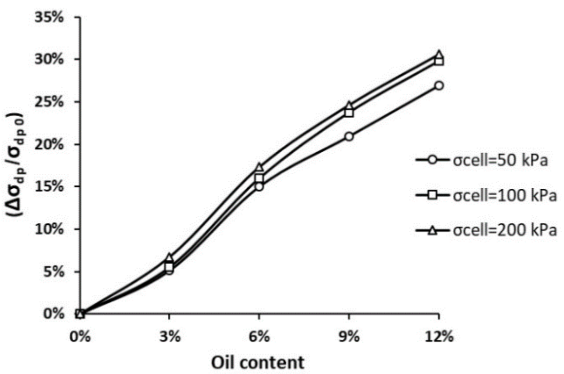

Fig. 3. Reduction percentage of peak deviatoric stress.

Table 1. Peak deviatoric stress of contaminated specimens

Oil contamination (%)	Peak deviatoric stress (kPa) at confining pressure of		
	50	100	200
0	253	477	933
3	238	451	867
6	212	401	768
9	202	364	700
12	185	333	645

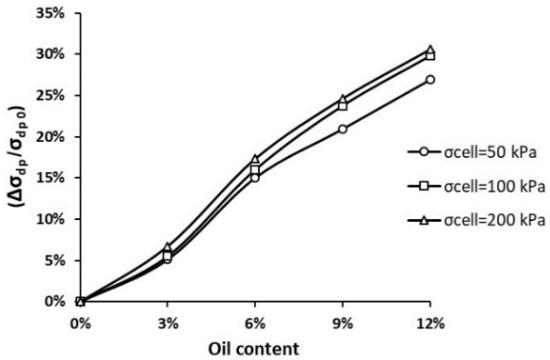

Fig. 4. Surge percentage of peak deviatoric stress after grouting relative to oil-contaminated specimens

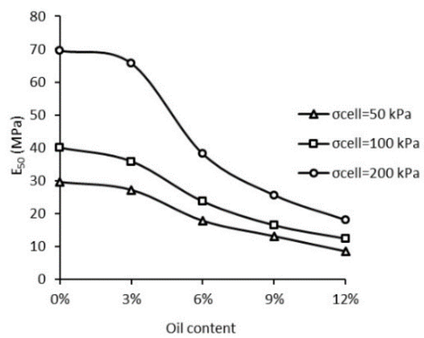

Fig. 5. Surge percentage of elasticity modulus after grouting relative to oil-contaminated specimens.

obtain the probable brittle stress-strain behavior.

3. RESULTS AND DISCUSSION

Peak deviatoric stress of contaminated specimens has been enlisted in Table 1. As it is clear, an increase in oil content led to lower Peak deviatoric stress. As shown in Fig. 3, the reduction percentage steadily increases up to 30% for 12% oil contamination. After grouting, all the specimens experienced a higher value of peak deviatoric stress. Fig. 4 displays the percentage of increase for stabilized samples relative to contaminated ones.

As it is obvious from Fig. 5, the presence of crude oil in samples caused a severe drop in elasticity modulus, especially at 12% oil content, however, the reduction is gentler at the lower values of contamination. This softening behavior originated from the fact that soil particles slide and rotate easier due to the existence of oil. The elasticity modulus of stabilized specimens surged dramatically as shown in Fig. 6 especially for higher values of oil contamination. An upward trend of the elasticity modulus with oil content stems up from more decreases at more oil content. As shown in Fig. 7, the internal frictional angle decreased about 16% due to contamination at 12% of oil content. Additionally, the cohesion of specimens increased because of the colloidal silica gelation as well as internal frictional angle. As opposed to the cohesion, the internal frictional angle after grouting is nearly equal for all specimens, whereas the obtained cohesion is higher for less

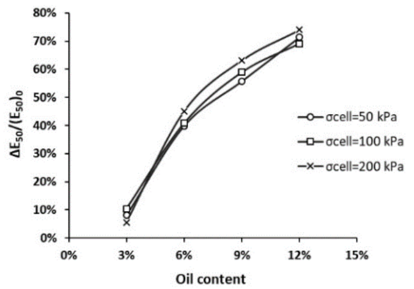

Fig. 6. Surge percentage of elasticity modulus after grouting relative to oil-contaminated specimens.

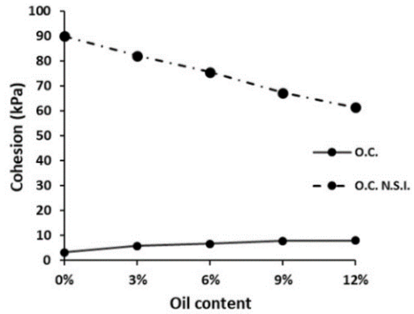

Fig. 8. Variation of cohesion after contaminating and stabilization.

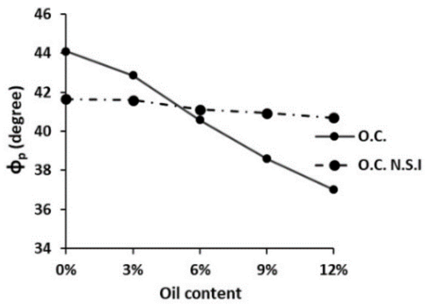

Fig. 7. Variation of the internal frictional angle after contaminating and stabilization.

polluted specimens (Fig. 8). Colloidal silica, as a stabilizer, improved the shear strength of oil-contaminated specimens so that all the shear strength parameters increased.

4. CONCLUSIONS

From the research that has been carried out, it is clearly could be determined that crude oil contamination causes a significant drop in shear strength and elasticity modulus. This reduction is caused by induced lubrication due to the presence of oil. Sliding and rotation of the soil grains would get easier if oil content was more. Stabilizing the polluted soil by crude oil could be achievable by injecting colloidal silica. All the shear resistance properties dramatically rise especially at a higher value of oil content. Eventually, it could be concluded that colloidal silica is a suitable grout to improve characteristics of oil-contaminated soil, especially for soil layer beneath the existing buildings and structures.

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HOW TO CITE THIS ARTICLE

A. Shakeri, R. Ziaie Moayed, M. A. Nozari, . Passive Remediation with Colloidal Silica Effect on Shear Strength Properties of oil-contaminated Bushehr Carbonate Sand, Amirkabir J. Civil Eng., 53(1) (2021) 87-90.

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