University of Tabriz

Journal of Civil and Environmental Engineering
Volume 54 (2024), Issue 1 (Spring), 1-12

EXTENDED ABSTRACT

Microstructural Examination of Effects of Organic Crude Oil Pollutant on the Geotechnical Properties and Geo-Environmental of Marl Soil of Mishan Formation

Mohammad Amiri *, Behzad Kalantari, Fatemeh Basereh

University of Hormozgan, Faculty of Engineering, Bandar Abbas, Iran

Received: 11 February 2023**; Review:** 13 May 2023**; Accepted:** 18 July 2023

Keywords:
Organic oil pollutant, Marl, Geotechnical properties, Microstructure.

1. Introduction

The expansion of oil-dependent industries has caused a growing rate of oil extraction and increasing oil- and its derivatives-contaminated water and soil. The impacts and damages caused by oil pollution on human resources, water, and the environment have been very complicated. Oil and its derivates leakages into the soil can change its physical and mechanical properties. Oil-contaminated lands are thought of as the main challenge to the environment. Fuel and oil-reserve sites are common oil leak sites that may penetrate the soil. However, most Bandar Abbas refineries are situated on marl soil beds. Marl is composed of clay, and calcium carbonates of varying degrees of 20-65%, which, having been hardened, are converted into marl soil, thus becoming physically stiff and impermeable. Marl soil has high stiffness and shear strength under dry conditions, as these properties experience lower rates under wet conditions. The volatile behavior of the marl soil in water and organic pollutants makes it problematic when used in geotechnical projects. Thus, the present research takes a microstructural approach to investigate the geotechnical properties and environmental geotechnics of the marl soil contaminated with varying degrees of crude oil.

2. Materials and methods

The soil utilized in this investigation was clay (CH), with its specifications outlined in Table 1. To assess the impact of oil pollution on the geotechnical and microstructural properties of the soil under examination, varying concentrations of crude oil equivalent to 0%, 2%, 5%, 15%, 20%, and 30% of the dry intensity were introduced. Subsequently, the influence of crude oil contamination on the geotechnical properties and environmental geotechnics of the marl soil was scrutinized through a series of geotechnical tests encompassing unconfined compressive strength, relaxation, Atterberg limits, and permeability assessments, alongside chemical analyses such as pH and EC measurements, and microstructural investigations utilizing XRD and SEM techniques. The chemical characteristics of marl, as determined through XRF analysis, are delineated in Table 2.

Publisher: Vice Chancellery for Research & Technology, University of Tabriz
DOI: 10.22034/CEEJ.2023.55305.2224
Online ISSN: 2717-4077
* Corresponding Author:
E-mail addresses: amirii@hormozgan.ac.ir (Mohammad Amiri), behzad996@yahoo.com (Behzad Kalantari), f.basereh@sutech.ac.ir (Fatemeh Basereh).

Table 1. Some geotechnical properties of the soil used in the study

Physical properties of South Marl	Quantity measured	References for method of measurement
Percentage of the passage of 200 sieve (%)	98	ASTM D422
Clay Fraction<5μm (%)	42	ASTMC1070-01
pH (1:10; soil: water)	8.93	ASTM D4972
Carbonate (%)	31	Hess, 1971
Plasticity Index (%)	26	ASTMD4318
Optimum water content (%)	20	ASTM D698
Classification	CH	ASTM D2487

Table2. Chemical characteristics of southern Iran marl based on XRF analysis (weight percent of soil)

Materials	Chemical compositions (%)									
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	TiO_2	MnO	P_2O_5	Cl
Marl	44.44	10.07	9.05	20.54	7.45	2.92	3.75	0.94	0.12	0.64	0.08

3. Results and discussion

Fig. 1 illustrates the fluctuations in the Atterberg limits for samples containing varying concentrations of oil pollution as a pore fluid. The results indicate that the addition of oil pollution led to an increase in both the liquid limit (LL) and plastic limit (PL) of the samples. The liquid limit of marl soil is initially recorded at 53%. However, with a 30% increase in crude oil pollutant, the liquid limit escalates to 70%. Similarly, the trend in plastic limit also demonstrated an upward trajectory with the augmentation of crude oil pollutant. A 30% increase in oil pollutant caused the plastic limit to elevate from 28% to 38%. Furthermore, as the concentration of crude oil pollutants escalated, the behavior of marl soil transitioned from a clay soil with high plasticity property (CH) to a silt soil with high plasticity property (MH). In Fig. 2, the changes in the coefficient of permeability of marl soil containing different percentages of oil are depicted. It is evident that as the concentration of crude oil increased to 15% and 30%, there was a corresponding decrease in the permeability coefficient by 13% and 22%, respectively.

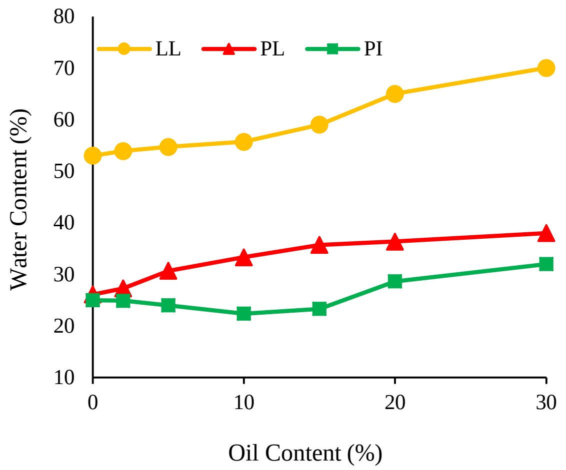

Fig. 1. The effect of different percentage of crude oil on atterberg limit

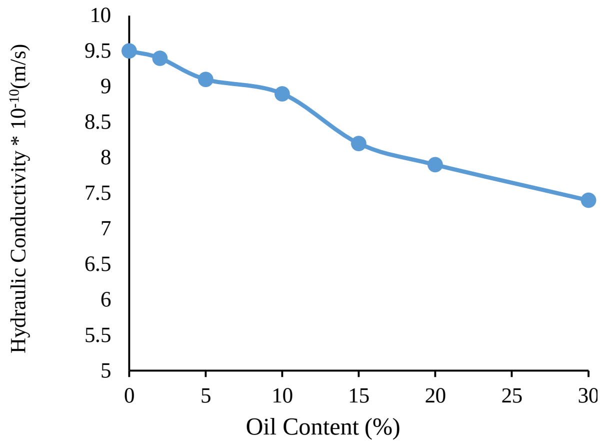

Fig. 2. The effect of different percentage of crude oil on soil permeability coefficient

As the concentration of organic crude oil pollution increased, the pH value exhibited no significant variation. Likewise, electronic conductivity (EC) decreased as marl soil contamination with oil intensified. Concurrent with the XRD findings, the intensity of the primary peaks corresponding to Palygorskite, sepiolite, montmorillonite, and kaolinite clay minerals remained relatively unchanged in the presence of varying percentages of crude oil. No significant alteration or elimination of the main clay peaks in the marl soil was observed, nor were any new peaks formed. Consistent with the SEM images, an increase in crude oil pollution resulted in the flocculation of the soil structure. With higher oil pollution content, boundary lines and sharp edges became less discernible.

4. Conclusions

1. The presence of 30% of crude oil pollutants decreases the compressive strength of marl soil by 88%, reducing it from 880 kPa to 104kPa.
2. Based on the results of the Atterberg limit, increased by increasing crude oil. In fact, the variations were due to the change in the structure, the arrangement of the clay particles, and the thickness of the double layer.
3. Since the crude oil dielectric constant is smaller than that of water, the double layer thickness of soil containing diesel decreases and forms a flocculated soil structure. As a result, the dispersed clay structure has been flocculated. It should be pointed that boundary lines and sharp edges of particles are less noticeable with increasing the diesel pollution content.

5. References

Amiri M, Dehghani M, Javadzadeh T, Taheri S, “Effects of lead contaminants on engineering properties of Iranian marl soil from the microstructural perspective”, Minerals Engineering, 2022, 176, 107310. https://doi.org/10.1016/j.mineng.2021.107310

Khamehchiyan M, Hossein Charkhabi A, Tajik M, “Effects of crude oil contamination on geotechnical properties of clayey and sandy soils”, Engineering Geology, 2007, 89 (3), 220-229. https://doi.org/10.1016/j.enggeo.2006.10.009

Okafor UC, “Evaluation of the Impact of Crude Oil Contamination on Soil’s Physicochemical Characteristics, Micro-flora and Crop Yield”, Tropical Aquatic and Soil Pollution, 2023, 3 (1), 24-35. https://doi.org/10.53623/tasp.v3i1.132

Ouhadi V, Aghaei Z, Behnia K, “Impact of initial hydration of bentonite on its plasticity properties change in interaction with organic contaminant”, Journal of Environmental Sciences and Technology, 2020, 22 (3), 1-12. https://doi.org/10.22034/JEST.2018.11648.2031

VU KA, Mulligan CN, “An Overview on the treatment of oil pollutants in soil using synthetic and biological surfactant foam and nanoparticles”, International Journal of Molecular Sciences, 2023, 24, 1916. https://doi.org/10.3390/ijms24031916

Zhang R, Zhou Z, Ge W, Wang Y, Yin X, Zhang L, Yang W, Dai J, “Superhydrophobic sponge with the rod-spherical microstructure via palygorskite-catalyzed hydrolysis and condensation of vinyltriethoxysilane for oil-water separation”, Applied Clay Science, 2020, 199, 105872. https://doi.org/10.1016/j.clay.2020.1058