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Impact of gasoline contamination on mechanical behavior of sandy clay soil

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Abstract

Oil leakage causes soil contamination and induces changes in the physical and mechanical properties of soils. In areas contaminated with oil products such as gasoline, the implementation of civilian operations requires determination and prediction of soil behavior in the existing conditions. In this research work, the effect of oil contamination by gasoline obtained from the National Oil Company in the Yazd Province is considered to investigate the effect of contaminants on the geotechnical properties of fine-grained sand. In order to examine the geotechnical characteristics of contaminated soil, compaction, undrained triaxial (CU), and consolidation tests are conducted. The tests are carried out on the samples of clean soil and contaminated soil with 1, 3, and 5% gasoline. The results obtained show that added gasoline reduces the optimum moisture content and increases the maximum dry density. In addition, based on the results of the triaxial test, the amount of friction angle and the cohesion of clay sand decrease by 21% and 14% with increasing contamination up to 5%, respectively, compared to the clean soil sample. Furthermore, adding gasoline significantly increases the compressibility and compression index.

1. Introduction

Contaminants are divided into two types, organic and inorganic. The origin of organic contaminants is hydrocarbon oil. Oil contamination is generally caused by the leakage of oil compounds from reservoirs and transmission lines or tanker accidents, whose leakage depends on the contaminant and soil characteristics [1]. Penetration of oil contaminants into soil changes the structure, tissue, and physical and mechanical properties of the soil, and causes hazards such as contamination of groundwater resources [2]. Two prominent aspects regarding contaminated soils are contaminated transmission and geotechnical properties [3]. Contaminated soils can be purified from oil compounds through some methods such as biological soil washing, pollutant degradation, and vacuum extraction of pollutants from soil [4]. However, using the proposed methods to purify soil is not sometimes economical, and the contamination risk can be reduced using the mechanical and physical properties of soils so that they can be used in civil projects. Any change in the engineering properties and behaviour of the soil layers may lead to a loss in the bearing capacity and an increase in the total or differential settlements of the foundation systems of structure. For this purpose, it is essential to identify the effect of pollutants on the geotechnical behavior of soils [5-10]. Evgin and Das [11] have conducted the triaxial tests on clean and oil-contaminated quartz sand. The results obtained indicated that the higher the amount of oil contamination, the lower the angle of internal friction in the loose and dense samples.

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Meegoda and Ratnaweera [12] have assessed the compressibility of fine-grained soils with low and high plasticity and contaminated with propanol and glycerin. They indicated that compressibility could be determined by the physico-chemical and mechanical agents through comparison by numerical formulas. Al-Sanda et al. [13] have investigated the effect of time on the strength parameters of crude oil-contaminated sand, and indicated that hardness of samples increases with time due to oil evaporation.

Choura et al. [14] have investigated the effect of crude oil on the physico-chemical, mechanical, and geotechnical properties of granular soil. The results of the study indicated that increasing crude oil up to 5% led to an increase in the friction angle and shear strength. They attributed this increase in strength to the effect of oil on the agglomeration of grains and the decrease in the distance between them caused by a thin oil film covering the soil grains, and, therefore, creating a denser structure and higher shear strength. However, higher amounts of crude oil reduce the shear strength and strength parameters. In addition, maximum dry density remained constant up to 5% contamination, and the optimum moisture content reduced to some extent. For higher percentages of contamination, a further increase in the crude oil reduced both parameters. Moreover, permeability of contaminated soil decreased compared with that of virgin soil.

Rahman et al. [15] have studied the effect of oil contamination on silty soil. The results obtained indicated that the undrained shear strength and permeability decreases with increase in the amount of contamination. Ijimdiya and Igboro [16] have investigated the effect of motor oil contamination on fine-grained soils. The results obtained showed that the uniaxial strength of the samples decreased with increase in the contamination percentage. Kermani and Ebadi [17] have studied the effect of oil contamination on the geotechnical properties of fine-grained soils. The results obtained indicated that increasing the amount of contamination decreased the optimum moisture content of soil. Sim and Lee [18] have also performed some studies on the effect of palm biodiesel on the shear strength and permeability of sandy soil, showing that shear strength and permeability decreases. Other researchers have conducted a series of direct shear and undrained triaxial tests on crude oil-contaminated sand. The results obtained indicated that the strength parameters of contaminated soil decreased with increase in the contamination percentage [19, 20, 9]. Estabragh et al. [21] have assessed the mechanical behavior of contaminated clay with 10, 25, and 40% of glycerol and ethanol. They indicated that the internal friction and compressibility decreased with increase in soil contamination. The results of the study by Safehian et al. [22] have confirmed that increasing diesel oil contamination in clay soil reduces uniaxial strength, friction angle, and cohesion of polluted soil. Khamehchiyan et al. [19] have investigated the effect of oil contamination on the geotechnical properties of clayey and sandy soils (CL, SM, and SP soil samples prepared from Bushehr beaches). The results of the study showed that crude oil reduced the permeability, optimum moisture content, and maximum dry specific gravity of all the studied soils. However, the effect of this pollutant on the shear strength parameters were not uniform and depended on the type of soil. In CL soil, adding crude oil reduces cohesion and increases friction angle. However, in the SM and SP soils, the friction angle reduces, although there is no specific and uniform trend in cohesion. In a study by Evgin and Das [11], the triaxial tests were conducted on oil-contaminated and clean quartz sand. The results obtained indicated that full saturation with motor oil significantly reduced the friction angle of both dense and loose sands, and significantly increased volumetric strains. They also indicated through a finite-element analysis that footing settlement increased as a result of oil contamination.

According to the literature, oil pollutants and environmental problems change the soil geotechnical properties such as the strength parameters and physical characteristics of soils. However, few studies have been carried out in this field. In the present work, the effect of gasoline on fine-grained sandy soil was assessed to determine the geotechnical properties and mechanical behavior of the contaminated soil such as compressibility and strength parameters.

2. Materials and methods

2.1. Soil

The soil tested in this research work was fine-grained sand obtained from NE part of Yazd Province, Kholdebarin area. Figure 1 shows the extraction area, the geographic characteristics, and the soil sample. Soil grading (determining coarse-grained and fine-grained parts of the soil and other physical properties) was performed using grain size analysis and a hydrometer (ASTM D422 [21]).

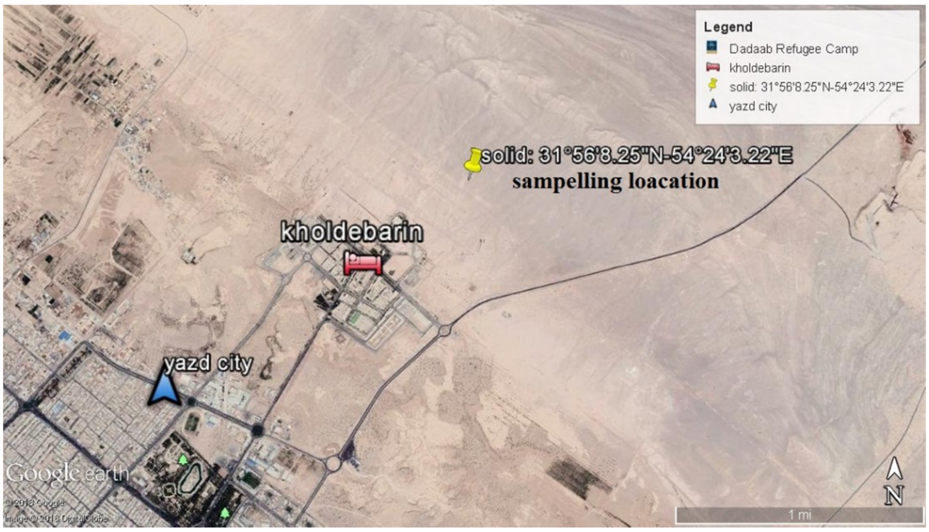

Figure 1. Extraction area, geographic characteristics, and soil samples.

2.2. Contamination

Gasoline, a transparent liquid, is derived from petroleum and used mainly as a fuel in spark-ignited internal combustion engines. It is largely composed of organic compounds derived from petroleum through fractional distillation, and is enhanced using different additives. Gasoline consumed by internal combustion engines significantly affects the environment both locally (e.g. smog) and globally (e.g. effect on the climate). It may also enter the environment as a vapor or liquid in different ways such as leakage, spills over-storage tanks, handling during production, transportation, and delivery [22-25]. Table 1 shows the properties of gasoline.

Table 1. Technical specifications of gasoline.

	Fire point	Pour point	Density	Flash point	Hydrocarbon range
	110 °C	0 °C	820-860 kg/m3	60 °C	C4-C20
ASTM standard	ASTM D92	ASTM D97	D12-98	ASTM D92	ASTM D71-69

2.3. Tests and preparation of samples

The samples used in all tests were mixed with gasoline at the amount of 1.5%, 3%, and 6% by weight of the dry soil, and maintained in the soil for 48 h at the ambient temperature (29 ± 3 °C) and in a closed container (nylon) to allow chemical reactions and uniform distribution of contamination. After processing the samples in the experimental molds, compaction, consolidated undrained triaxial, and consolidation tests were performed to evaluate the geotechnical properties of the contaminated soil according to the ASTM standard [21].

2.3.1. Specific gravity of soil

The specific gravity of a given material is defined as the ratio of the weight of a given volume of the material to the weight of an equal volume of distilled water. It is denoted by Gs, and is defined as (ASTM-D854):

$$G_s = \frac{\rho_s}{\rho_w} \tag{1}$$

where,

ρ_s = unit weight of soil solids only

ρ_w = unit weight of water

2.3.2. Compaction test

The standard proctor test was conducted on the contaminated and clean soils based on the ASTM-D698 standard [21]. To perform the compaction test based on the standard proctor test, a mold, 4 inches in diameter and about 944 cm^3 in volume, was filled with three equal layers of the sample. Each layer was compressed by a 10-lb hammer dropped from a distance of 18 inches for 25 times at a uniform rate of about 1.5 s per drop. Subsequently, the dry density and the moisture content (%) of the sample obtained were calculated. Afterwards, the sample was placed in a tray, grinded into pieces so that they could pass through a number 4 sieve, and received as much water as 2% of the original sample mass. This procedure was repeated twice. Finally, the water content (%) and dry density of the sample were calculated and compaction test plots of water content (%) versus dry density were drawn.

2.3.3. Triaxial test

To study the changes in the shear strength parameters of the contaminated soil, some undrained triaxial (CU) tests were performed based on the ASTMD 4767-95 standard [21]. The samples were prepared in a two-piece mold with the dimensions of 33 mm in diameter and 75 mm in height and almost the optimum moisture content to reach maximum unit weight. In this work, the under-compaction method, a particular form of wet compression, was used. This method was proposed by Ladd [26] and Been et al. [27] to achieve a uniform compaction. In this method, each layer is slammed to a density lower than the target density. The amount of reduced compaction is pre-determined, and is defined as the percentage of under-compaction (Un). The amount of Un in each layer varies linearly from the lower layer (the first layer) with the maximum value to the upper layer with the minimum value. If an appropriate value is selected for Un in the first layer, the samples with uniform density can be obtained. The value of Un changes mainly from 0% for the dense samples to about 15% for very loose samples. In this method, the maximum thickness of layers should not exceed 2.5 cm. The value of Un for different layers is determined as follows:

$$U_{ni} = U_{n1} - [(\frac{U_{n1} - U_{nj}}{j-1}).(n_i - 1)] \qquad (2)$$

where Uni is the under-compaction percentage for each layer, Un_1 is the under-compaction percentage for the first layer (maximum), Unj is the under-compaction percentage for the last layer (usually zero), and j represents the total number of layers that should be selected. After determining Uni, the thickness of compacted materials in each layer is determined using the following relation:

$$h_n = \frac{h_t}{j}[(n_i - 1) + (1 + \frac{U_{ni}}{100})] \qquad (3)$$

where h_t is the total height of the sample and h_n is the thickness of compacted materials in each layer.

After preparing the sample, it is placed in a triaxial container and saturated with CO_2 and distilled water (B = 95%). Afterward, the samples are consolidated at the three effective confining pressures of 50, 100, and 150 kPa. Finally, the sample is loaded at a constant strain of 1 mm per minute, and loading is continued until the sample cannot tolerate further loading and completely ruptures.

2.3.4. Consolidation test

In order to investigate the changes in the consolidated settlement, the consolidation test was performed on the clean and contaminated soil samples according to the ASTM D2435-96 standard [21]. The diameter and height of the tested samples were about 75 mm and 20 mm, respectively. The samples were prepared at the optimum moisture content and maximum specific gravity, and saturated with distilled water before loading.

3. Results and discussion

3.1. Grading curve

Figure 2 and Table 2 show the grading plot and soil properties, respectively. Based on the results obtained, the studied soil has a well-graded sand with clay (SW-SC) classification, and its coefficient of uniformity (Cu) and coefficient of curvature (Cc) values are 5.3 and 1.2 (based on Equations 4 and 5), respectively.

$$C_u = \frac{D_{60}}{D_{10}} \qquad (4)$$

$$C_c = \frac{D_{30}^2}{D_{60} * D_{10}} \qquad (5)$$

where D_{60}, D_{30}, and D_{10} are the particle diameters corresponding to 60%, 30%, and 10% finer on the grading curve, respectively.

Table 2. Properties of the studied soil.

Property	Value
Gs	2.68
Cu	5.3
Cc	1.2
Unified classified	SW-SC

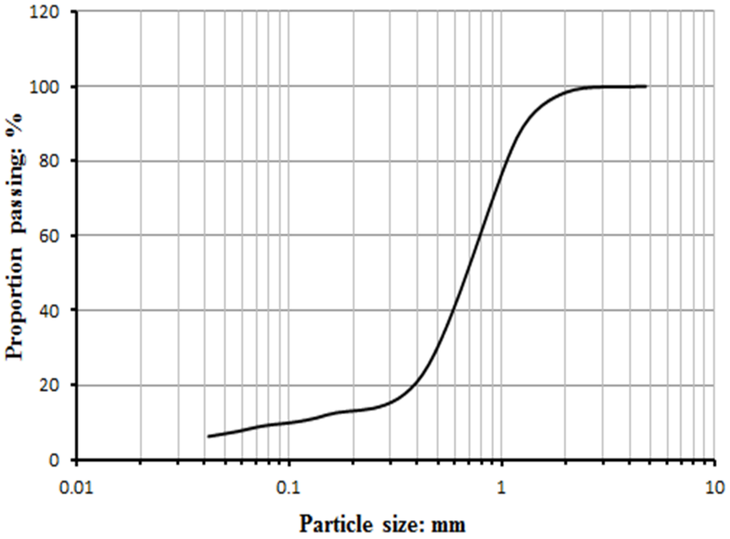

Figure 2. Gradation curve of soil.

3.2. Compaction test

The compaction test was performed to investigate the effect of gasoline pollution on the compressive properties (maximum dry unit weight and optimum moisture content). Figure 3 shows dry unit weight versus water content and optimum conditions, respectively.

According to Figure 3, increasing the amount of gasoline increased the maximum dry unit weight but decreased the optimum moisture content. With increase in the amount of contamination, and therefore, increase in the grain surface covered by the contaminant, a pollutant with a high viscosity acts as a strong lubricant and facilitates the sliding of particles, making them close to each other and reducing the pore space between the particles and pore volume of soil. Consequently, a maximum dry unit weight is obtained with less moisture content than in normal conditions and with a lower contamination. Figure 4 shows a microscopy image of the soil contaminated with 5% gasoline. As it can be observed, gasoline has filled soil pore spaces and enclosed particles in a thin film, and, in addition to attaching particles, facilitated the sliding of particles, and consequently, led to better densities due to its lubrication effect.

3.3. Triaxial test

The effect of pollutant on the stress-strain behavior of soil is shown in Figures 5 to 8. The amount of stress increased with steep gradients up to 5% strain and continued at an about constant rate for higher amounts of strain. As it could be observed, the ultimate strength of the contaminated specimens was lower than that of the non-contaminated specimen, and the amount of ultimate strength decreased more with increasing contamination. In addition, strength reduction was lower at lower confining pressures.

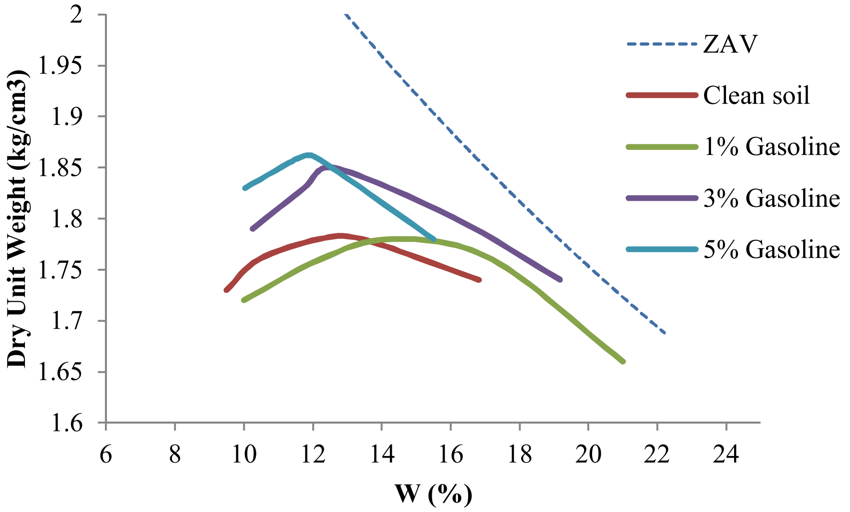

Figure 3. Plot of dry unit weight versus moisture content of clean and contaminated soils.

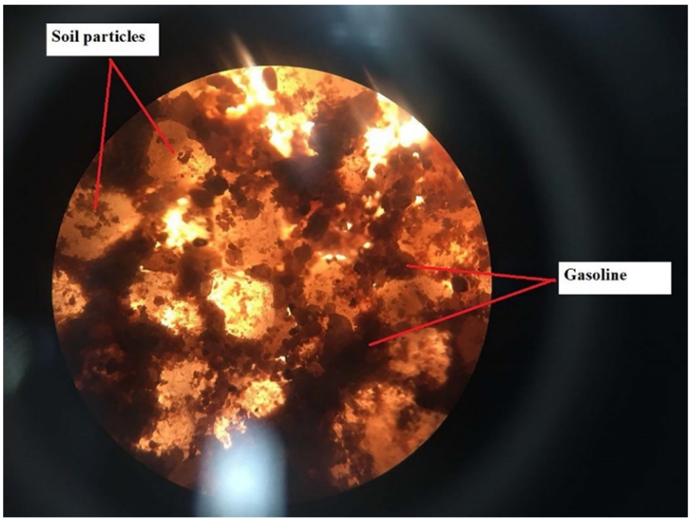

Figure 4. The microscopic thin section of the soil contaminated by 5% gasoline.

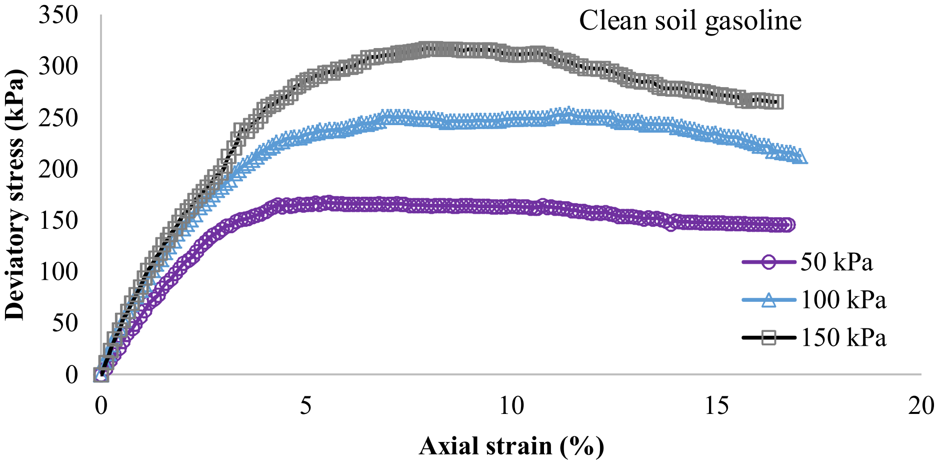

Figure 5. Stress-strain behavior of uncontaminated soil.

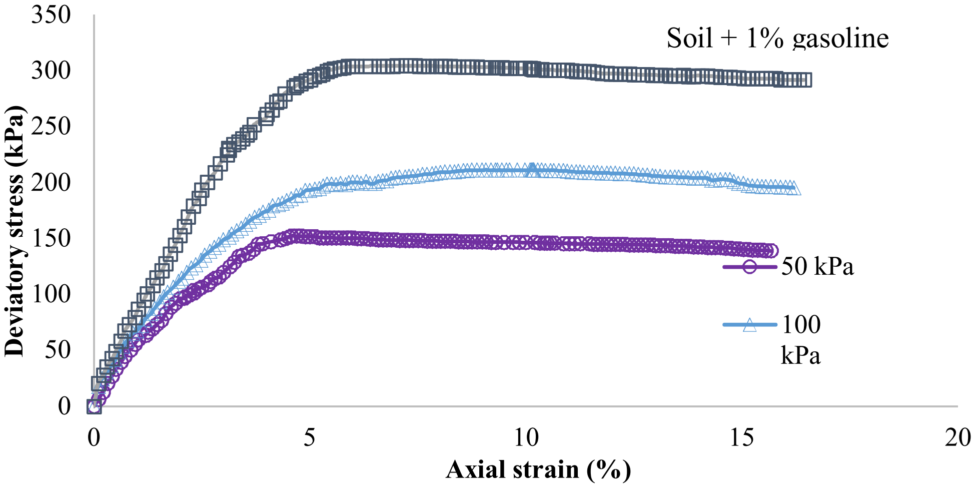

Figure 6. Stress-strain behavior of the soil containing 1% gasoline.

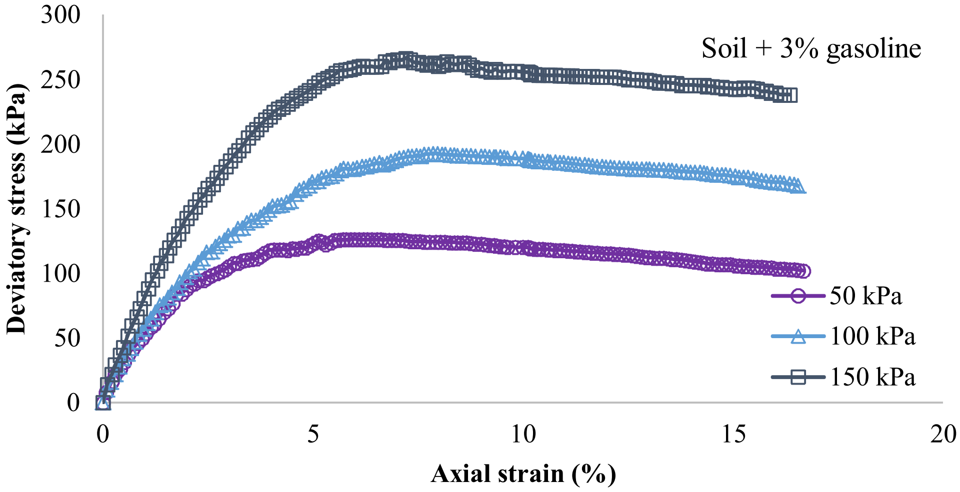

Figure 7. Stress-strain behavior of the soil containing 3% gasoline.

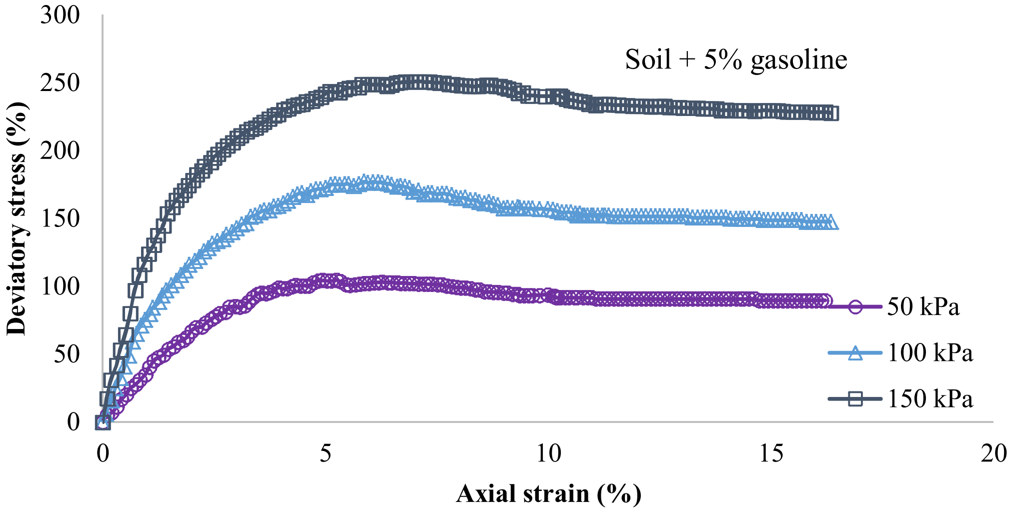

Figure 8. Stress-strain behavior of the soil containing 5% gasoline.

Figure 9 presents the failure envelope of the effective stresses based on the pore water pressure measured within the $p^{'}-q^{'}$ space. As it can be seen, the slope of failure envelopes decreases with increasing contamination, which indicates a decrease in the friction angle and cohesion. Also the amount of cohesion reduction is more than the decrease in the friction angle. Using the failure envelope, effective shear strength parameters including the friction angle and the cohesion value are plotted in Figures 10 and 11. As observed in Figure 10, the friction angle was a function of contamination and the amount of pollutant, and the addition of gasoline reduced the friction angle. The friction angle of the uncontaminated soil was 28.4 degrees and reduced 20%, reaching 22.8 degrees for the contaminated soil with 5% gasoline. Effectively, gasoline as an organic fluid with a high viscosity covered soil particles and reduced the friction between particles, and therefore, particles slid on each other more easily, and the friction angle reduced. The results of the present work are similar to those obtained by [2], [14], and [28-30]. Accordingly, it can be stated that reduction in the friction angle resulting from the leakage of carbon pollutants can have a destructive effect on the stability of contaminated slopes and structures in contaminated sites.

According to Figure 11, adding gasoline to soil reduced cohesion, and the soil cohesion of 14.9 kPa for clean soil reduced by 12% reaching 13.1 kPa for the soil with 5% gasoline contamination. The reduction in cohesion can be attributed to the effect of gasoline on the fine-grained part of soil.

Settlement of gasoline molecules instead of the water around clay particles is one of the reasons for the reduction in cohesion. In fact, one of the causes of clay cohesion is the surface tension of water molecules in the clay double-layer. Since gasoline molecules have less surface tension, the presence of gasoline molecules around the clay reduces the cohesion of clay particles to some extent. In addition, the reduction of the specific surface area of clay and cation exchange capacity due to the presence of gasoline molecules around the fine-grained part can be considered as the reason for the reduction in the cohesion of the soil fine-grained part, and consequently, the reduction of soil cohesion. Similar results were observed by Ur-Rehman et al. [30], who investigated the effect of crude oil on clay. Moreover, the results of the studies performed by Mehdizadeh et al. [31] on the effect of oil on sandy soil, silty sand, and clayey sand indicated that oil causes reduction in the cohesion of clayey sand in contrast to other studied soils, where oil increases cohesion.

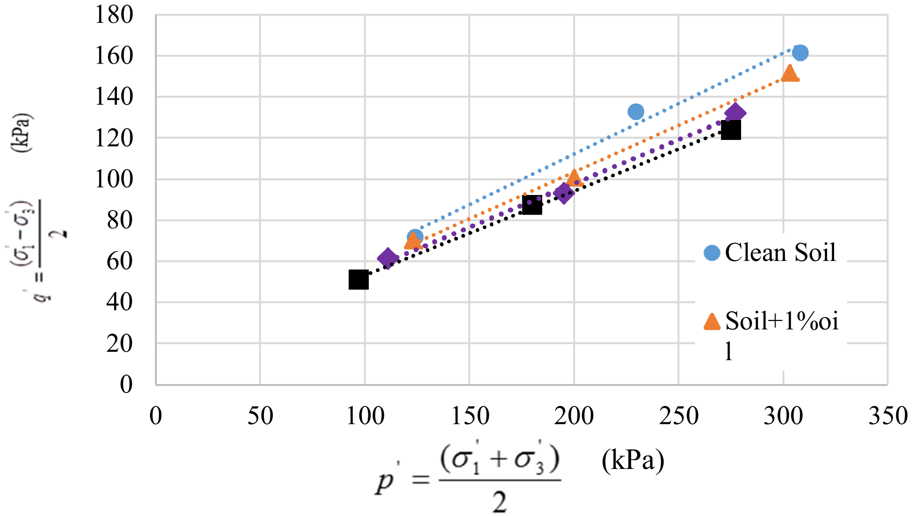

Figure 9. Assessment of shear strength parameters of samples based on the effective stress.

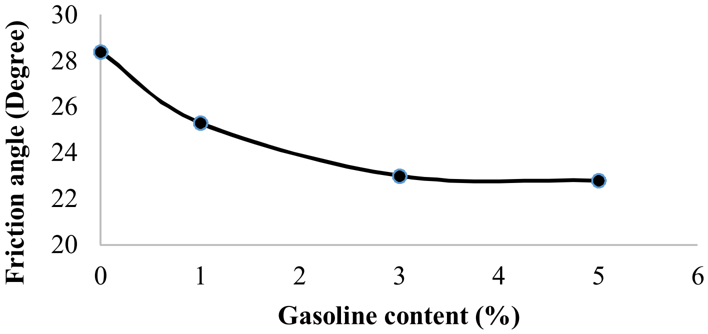

Figure 10. Frictional angle as a function of the percentage of gasoline contamination (%).

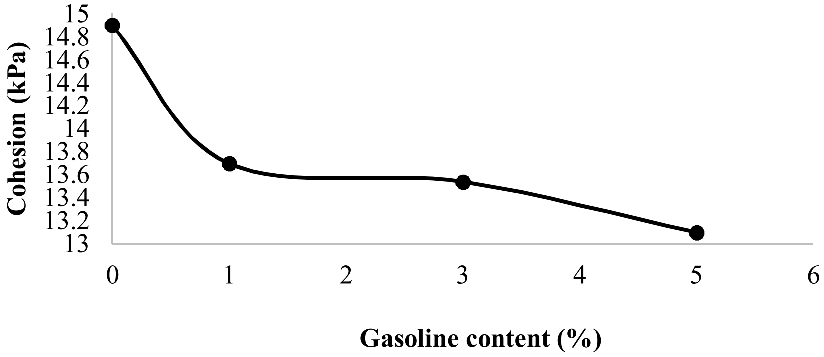

Figure 11. Cohesion as a function of the percentage of gasoline contamination (%).

3.4. Consolidation

The consolidation experiment results are presented in Figure 12 as the $e-\log p'$ diagrams. As it can be depicted from the results, compressibility significantly rises with increase in the contamination. These results are in agreement with the findings of the studies by Meegoda and Ratnaweera [12], Ur-Rehman et al. [30], and Al-Sanad [8]. This phenomenon can be attributed to the lubrication influence of gasoline and the decrease in friction amongst soil particles. Given that the viscosity of gasoline is higher than that of water, adding this pollutant, compared with water, facilitates sample compaction.

Figure13 presents the changes in the compression index as a function of the amount of contaminant. The compression index of clean soil and samples with 1%, 3%, and 5% gasoline was 0.045, 0.053, 0.067, and 0.77, respectively. As it could be seen, the compression index was a function of the amount of contamination and increased with increase in the amount of pollutant.

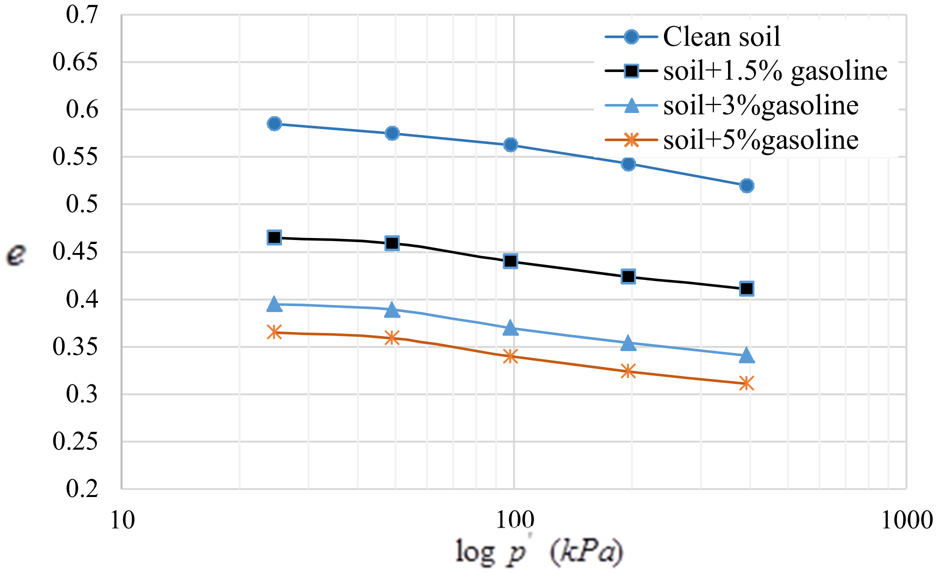

Figure 12. The e-log *p* plots for the clean and contaminated samples.

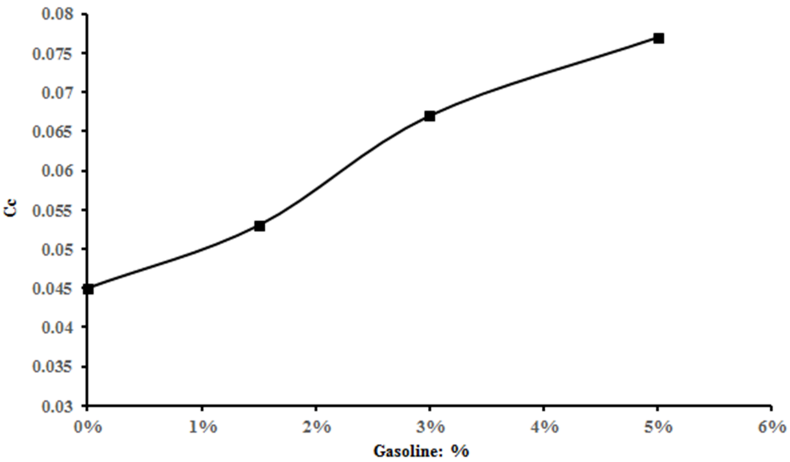

Figure 13. The compression index as a function of the percentage of gasoline contamination (%).

4. Conclusions

In the present work, we evaluated the effect of gasoline contamination on the geotechnical properties of fine-grained sandy soil. The contaminated specimens were prepared and examined by mixing soil with different amounts of gasoline (1%, 3%, and 5%). Compaction, undrained triaxial, and consolidation tests were performed on the samples.

The results of this work can be summarized as follows:

- By increasing the amount of contamination in the studied area (up to 5%), highly viscous gasoline acts as a very strong lubricant, facilitating the sliding of particles over each other and causing the compaction of particles and further reduction of soil pore space, and, therefore, a reduction in the optimum moisture content and an increase in the dry unit weight.

- Gasoline contamination decreased peak shear strength in all the samples.
- The friction angle and soil cohesion of the studied soil were affected by the percentage of contamination, and the mentioned parameters decreased with increase in the contamination.
- The lubricant effect of gasoline increased compressibility of the contaminated soil compared with clean soil.
- According to the results obtained from this research work, oil contamination reduces the resistance parameters of the soil and increases the subsidence; these changes should be considered in the design of structures constructed in these areas and the areas susceptible to contamination.

References

[1]. Fine, P., Graber, E.R. and Yaron, B. (1997). Soil interactions with petroleum hydrocarbons: abiotic processes. Soil Technology. 10 (2): 133-153.

[2]. Shin, E.C. and Das, B.M. (2001). Bearing capacity of unsaturated oil-contaminated sand. International Journal of offshore and polar Engineering. 11 (03).

[3]. Yong, R.N. (2000). Geoenvironmental engineering: Contaminated soils, pollutant fate, and mitigation. CRC press.

[4]. Aiban, S.A. (1998). The effect of temperature on the engineering properties of oil-contaminated sands. Environment international. 24 (1-2): 153-161.

[5]. Shah, S.J., Shroff, A.V., Patel, J.V., Tiwari, K.C. and Ramakrishnan, D. (2003). Stabilization of fuel oil contaminated soil-A case study. Geotechnical & Geological Engineering. 21 (4): 415-427.

[6]. Elisha, A.T. (2012). Effect of Crude Oil Contamination on the Geotechnical Properties of Soft Clay Soils of Niger Delta Region of Nigeria. Electronic Journal of Geotechnical Engineering. 17: 1929-1938.

[7]. Nasr, A.M.A. (2009). Experimental and Theoretical Studies for the Behavior of Strip Footing on Oil-Contaminated Sand. Journal of Geotechnical and Geoenvironmental Engineering. 135 (12): 1814-1822.

[8]. Karkush, M.O. and Kareem, Z.A. (2019). Behavior of passive pile foundation in clayey soil contaminated with fuel oil. KSCE Journal of Civil Engineering. 23 (1): 110-119.

[9]. Mohammadi, A., Ebadi, T., Eslami, A. and van der Zee, S.E. (2018). Axial compressive bearing capacity of piles in oil-contaminated sandy soil using FCV. Marine Georesources & Geotechnology,. pp. 1-16.

[10]. Shin, E.C., Lee, J.B. and Das, B.M. (1999). Bearing Capacity of a Model Scale Footing on Crude Oil-Contaminated Sand. Geotechnical & Geological Engineering. 17 (2): 123-132.

[11]. Evgin, E. and Das, B.M. (1992). Mechanical behavior of an oil contaminated sand. Environmental Geotechnology, Usmen & Acar (eds), Balkema, Rotterdam.

[12]. Meegoda, N.J. and Ratnaweera, P. (1994). Compressibility of contaminated fine-grained soils. Geotechnical Testing Journal. 17 (1): 101-112.

[13]. Al-Sanad, H.A. and Ismael, N.F. (1997). Aging effects on oil-contaminated Kuwaiti sand. Journal of geotechnical and geoenvironmental engineering. 123 (3): 290-293.

[14]. Choura, M., Salhi, S. and Cherif, F. (2009). Mechanical behaviour study of soil polluted by crude oil: case of Sidi El Itayem oilfield, Sfax, Tunisia. Environmental Earth Sciences. 59 (3): 573.

[15]. Rahman, Z.A. Hamzah, U. and Ahmad, N. (2010). Geotechnical characteristics of oil-contaminated granitic and meta sedimentary soils. Asian Journal of Applied Sciences. 3 (4): 237-249.

[16]. Ijimdiya, T. and Igboro, T. (2012). The compressibility behavior of oil contaminated soils. Electronic Journal of Geotechnical Engineering. 17 (10): 3553-3562.

[17]. Kermani, M. and Ebadi, T. (2012). The effect of oil contamination on the geotechnical properties of fine-grained soils. Soil and Sediment Contamination: An International Journal. 21 (5): 655-671.

[18]. Sim, Y.L. and ChoonYong, L. (2012). Some geotechnical properties of palm biodiesel contaminated mining sand and weathered granite soil. International Journal of Advanced Scientific Engineering and Technological Research. 1 (4): 1-8.

[19]. Khamehchiyan, M., Charkhabi, A.H. and Tajik, M. (2007). Effects of crude oil contamination on geotechnical properties of clayey and sandy soils. Engineering geology. 89 (3-4): 220-229.

[20]. Puri, V.K., Das, B.M., Cook, E.E. and Shin, E.C. (1994). Geotechnical properties of crude oil contaminated sand. In Analysis of soils contaminated with petroleum constituents. ASTM International.

[21]. Estabragh, A.R., Beytolahpour, I., Moradi, M. and Javadi, A.A. (2016). Mechanical behavior of a clay soil contaminated with glycerol and ethanol. European Journal of Environmental and Civil Engineering. 20 (5): 503-519.

[22]. Safehian, H., Rajabi, A.M. and Ghasemzadeh, H. (2018). Effect of diesel-contamination on geotechnical

properties of illite soil. Engineering Geology. 241: 55-63.

[23]. ASTM (American Society for Testing and Materials). (1999). Annual book of ASTM standards. Section 4, Construction. Soil and Rock. ASTM, Philadelphia, PA.

[24]. U.S. EPA. Evaluation of the Carcinogenicity of Unleaded Gasoline. U.S. Environmental Protection Agency, Washington, D.C., EPA/600/6-87/001 (NTIS PB87186151).

[25]. Baumbach, J.I., Sielemann, S., Xie, Z. and Schmidt, H. (2003). Detection of the gasoline components methyl tert-butyl ether, benzene, toluene, and m-xylene using ion mobility spectrometers with a radioactive and UV ionization source. Analytical chemistry. 75 (6): 1483-1490.

[26]. Ladd, R.S. (1978). Preparing test specimens using under-compaction. Geotechnical Testing Journal. 1 (1): 16-23.

[27]. Been, K., Jefferies, M.G. and Hachey, J. (1991). Critical state of sands. Geotechnique. 41 (3): 365-381.

[28]. Abousnina, R.M., Manalo, A., Lokuge, W. and Shiau, J. (2015). Oil contaminated sand: An emerging and sustainable construction material. Elsevier Procedia Engineering. 118: 1119-1126.

[29]. Saberian, M. and Khabiri, M.M. (2018). Effect of oil pollution on function of sandy soils in protected deserts and investigation of their improvement guidelines (case study: Kalmand area, Iran). Environmental geochemistry and health. 40 (1): 243-254.

[30]. Ur-Rehman, H., Abduljauwad, S.N. and Akram, T. (2007). Geotechnical behavior of oil-contaminated fine-grained soils. Electronic Journal of Geotechnical Engineering. 12: 1-12.

[31]. Mehdizadeh, M.J., Ghiassi, R. and Behnia, K. (2016). Evaluation of Oil Contamination Effect on Permeability and Shear Strength of Sandy Soils. Petroleum Research. 26: 45-55 (in Persian).

تأثیر آلاینده گازوئیل بر رفتار مکانیکی خاک ماسه رس دار

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چکیده:

نشت مواد نفتی باعث آلودگی خاک و تغییر در خصوصیات فیزیکی و مکانیکی خاک‌ها می‌شود. در مناطق آلوده به مواد نفتی مانند گازوئیل اجرای عملیات عمرانی نیازمند شناسایی و پیش‌بینی رفتار خاک در شرایط موجود است. در این پژوهش، اثر آلودگی نفتی از نوع گازوئیل که از شرکت نفت استان یزد تهیه شده، برای بررسی تأثیر آلاینده بر خواص ژئوتکنیکی ماسه حاوی ریزدانه (Sw-SC) استفاده شده است. برای بررسی خصوصیات ژئوتکنیکی خاک آلوده آزمایش‌های تراکم، سه محوری زهکشی‌نشده (CU) و تحکیم انجام شده است. آزمایش‌ها بر روی نمونه‌های خاک تمیز و خاک آلوده به ۱، ۳ و ۵ درصد گازوئیل انجام شده است. نتایج به دست آمده نشان می‌دهد که افزودن گازوئیل موجب کاهش رطوبت بهینه و افزایش حداکثر وزن مخصوص خشک می‌شود. همچنین بر مبنای نتایج حاصل از آزمایش سه محوری مقدار زاویه اصطکاک و مقدار چسبندگی ماسه رس‌دار با افزایش آلودگی تا ۵ درصد به میزان ۲۱ درصد و ۱۴ درصد نسبت به خاک تمیز کاهش می‌یابد. به علاوه، آلودگی موجب افزایش قابلیت فشردگی خاک مورد مطالعه شده و شاخص فشردگی به طور قابل‌توجهی با افزایش مقدار آلاینده در محدوده مورد مطالعه افزایش می‌یابد.

کلمات کلیدی: خاک آلوده، گازوئیل، زاویه اصطکاک، چسبندگی، نسبت فشردگی.