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Experimental study of the effect of adding clay nanoparticles to improve strength properties of contaminated clayey-sand soil with gasoil

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ABSTRACT: The release of oil pollutants in the soil causes changes in the structure, texture and the relationship between the soil particles. This has destructive effects on the physical and mechanical properties of soils. In recent years, improvement of degraded engineering properties of these soils for their use in construction projects has been a challenge for researchers and engineers. In this paper, the effect of adding two types of clay nanoparticles on the improvement of mechanical properties of Clayey Sand contaminated with gas-oil has been investigated. For this purpose, after determining the basic properties of natural soil, soil with 6% and 8% gas-oil, contaminated soil stabilized with nano-clay in values of (0.5, 1, 2 and 3%) and organo-clay in values of (0.3, 0.5, 0.7 and 1%), standard compaction and unconfined compressive strength tests during the two curing periods (7 and 28 days) were performed on them. Scanning electron microscopy (SEM) was also used to evaluate the microstructure of natural soil samples. Also, the microstructure of natural soil, contaminated soil and contaminated soil stabilized with nanoparticles was studied with the help of SEM. The results of the tests showed that maximum dry density, optimum water content, and unconfined compressive strength have decreased in the soil with gas-oil. The stabilization of contaminated soil using clay nanoparticles showed that adding 2% of nano-clay to contaminated soils of 6 and 8% of gas-oil resulted in the highest increase in compressive strength of 58% and 56%, respectively. In addition, adding 0.7% organo-clay to soil containing 8% of gas-oil leads to an increase of 37.56% in compressive strength. It was also observed that the addition of nano-clay and organo-clay to the contaminated soil resulted in an increase in optimum water content and a decrease in the maximum dry density. In general, it can be concluded that the contaminated soil with gas-oil has the potential to improve strength properties by adding clay nanoparticles.

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1. INTRODUCTION

In recent years, changes in physical and mechanical characteristics of soils due to leakage of oil compounds have been identified as a challenge for engineers and researchers in the field of environmental geotechnical. Reports by various researchers in this field can be divided into two main parts of the study of the physical and engineering properties of contaminated soils with petroleum and improve the characteristics of various soils and remove environmental pollutants. To provide suitable solutions for improving of the characteristics of contaminated soils, the first research was conducted to investigate the characteristics of the soils [1-4]. In recent years, researchers tried to modify and remediate of the contaminated soil properties by application of some additives including lime, fly ash and cement and less attention is paid to the role of the remediated nanoparticles and organo-clays [5-8]. In this study, the possibility of improving it for the treatment of physical and mechanical characteristics were studied by the addition of two kinds of clay nanoparticles in both hydrophilic and organophilic types of substances.

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2. MATERIALS AND METHODS

2.1. Materials

The studied soil was prepared from the airport district of Zanjan city, Iran. Other physical and mechanical properties of the studied soil (SC) are presented in Table 1.

Characteristics of the consumed gas-oil are presented in Table 2.

Sodium montmorillonite nanoclay, with an average bulk density of 0.335 gr/cm^3 and the specifications provided in Tables 3, are used as remediates of the contaminated samples. In addition, the organo-clay with commercial brand of Cloisite 30B with a density of 0.365 and other physical and chemical properties presented in Table 4 are used in the gas-oil-contaminated samples.

2.2. Methods

Experiments performed in this research, are divided into two groups of determining physical and mechanical properties of the studied soils. For the purpose, the studied soil was artificially contaminated at 6% and 8% of the dry weight. The mixture put into closed containers in the room temperature

Table 1. Physical and chemical properties of the studied virgin soil (SC)

Characteristics		Standard designation	Values
Specific gravity		ASTM D854	2.71
Particle size distribution (%)	Sand fraction	ASTM D422	56
	Silt fraction		20
	Clay fraction		24
Atterberg limits (%)	Liuid limit, w_L	ASTM D4318	32.2
	Plastic limit, w_P		19
	Plasticity index, I_P		13.2
Optimum water content (%)		ASTM D698	15.5
Maximum dry unit weight (kN/m^3)			18.2
Unconfined compressive strength (kpa)		ASTM D2166	253.44

for 2 weeks to reach to equilibrium. Then considering the difference in the nanoparticles' density, for nanoclay additive, four different quantities (0.5%, 1%, 2% and 3%) of dry weight of the contaminated samples and for organo-clay four weight percentages of 0.3, 0.5, 0.7 and 1 were used. In the category of mechanical tests, by performing a regular set of compaction and unconfined compression strength (UCS) tests, was tried to study the effect of clay nanoparticles on the properties of gas-oil contaminated clayey sand soil. For preparing samples, the soil was compressed into 5 layers (sample length: 70.1 mm and diameter 33.3 mm) and there were 16 blows per layer using a special hammer for Harvard compaction apparatus with the maximum dry weight being obtained from the standard proctor density test, according to ASTM standards.

3. RESULTS AND DISCUSSIONS

The results of standard Proctor compaction tests on the remediated contaminated soil with nanoclay and Cloisite 30B shows that the maximum dry density decreased while the optimum water content of contaminated soils increased due to the addition of clay nanoparticles (Figure 1). According to the results, for samples containing 6% gas-oil combined with the highest amount of nanoclay (3%), the reduction of the maximum dry density was 3.55% while optimum water content to 34.78% was increased. Also, for the soil with 8% contamination, adding 3% of nanoclay resulted in a decrease in maximum dry density, and an increase in optimal water content of 3.74 and 51.94% respectively. In addition, for soil containing 8% of gas-oil, adding the highest content of organo-clay (1%) resulted in a decrease in maximum dry density and an increase in optimal water content of 3.85% and 37.91% respectively. The comparison of the results for nanoclay and organo-clay shows that the organo-clay needs less water than the nanoclay to reach the maximum dry density.

Based on the results presented in Figures 2 and 3, the

Table 2. Characteristics of the consumed gas-oil

Properties	Values
Specific gravity (at 15.56 °C) (kg/l)	0.82 - 0.86
Viscosity (at 20 °C) (m^2/gr)	3
Dielectric constant	2.1
Boiling point (°C)	150 – 390
Flash point (°C)	54

Table 3. Physical and chemical properties of nanoclay

Properties	Value/Description
Mineral	Montmorillonite
Particle Size (nm)	1 – 2
Specific Surface Area (m^2/gr)	220 – 270
Space between the particles (Å)	11.7

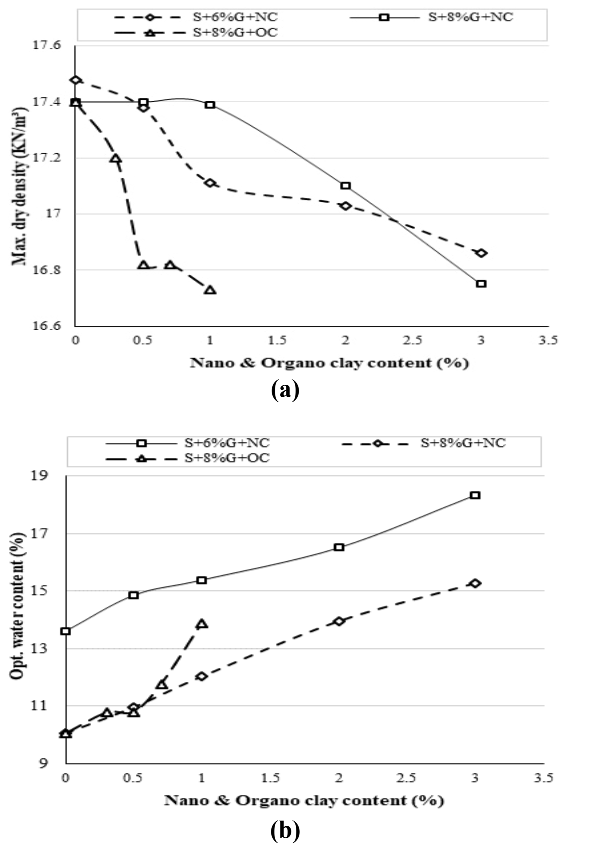

Fig. 1. Influence of montmorillonite nanoclay (MMT-Na) and Cloisite 30B content on (a) Maximum dry unit weight, (b) Optimum water content of the clayey sandy soil with 6 and 8% contamination

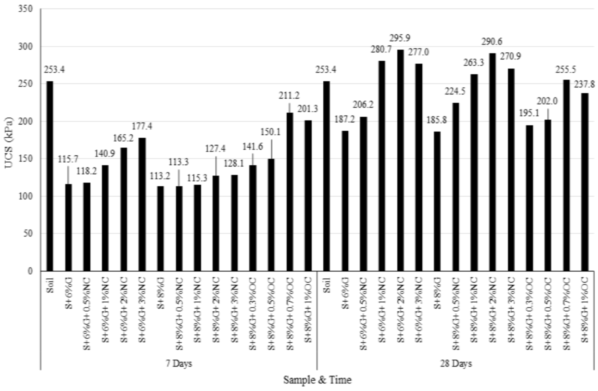

Fig. 2. Unconfined compressive strength in samples with 6 and 8% contamination stabilized with nanoclay and organo-clay at curing period of 7 and 28 days

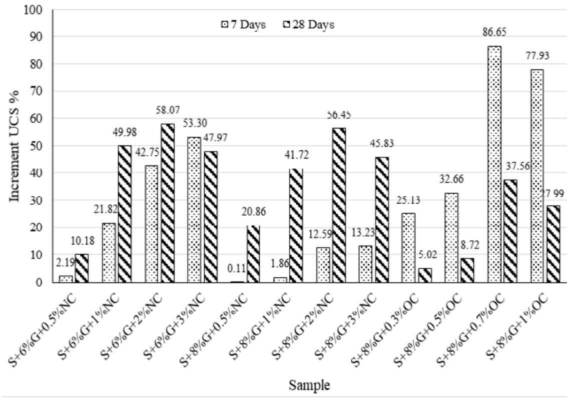

Fig. 3. Changes in unconfined compressive strength of the samples with 6 and 8% contamination stabilized with nanoclay and Cloisite 30B at curing period of 7 and 28 days

Table 4. Physical and chemical properties of organoclay

Properties	Value/Description
Commercial designation	Cloisite 30B
Bulk density (gr/cm^3)	0.365
Cation exchange capacity (meq/100gr clay)	90
Space between the particles (Å)	18.5
Average particle size (µm)	6
Specific surface area (m^2/gr)	750

strength of virgin soil was 253.4 kPa. By contamination of soil with 6 and 8% gas oil, compressive strength for the 7-day curing period was 119 and 124%, respectively, and for the 28-day curing period, 35 and 36% respectively.

According to the results, for stabilized samples with nanoclay, the maximum compressive strength was related to the addition of 2% nanoclay and strength of the soil with 6 and 8% contamination on 28-day curing period resulted 295.9 and 290.6 kPa respectively. In fact, by adding 2% of nanoclay in the soils with 6 and 8% gas-oil on the 28-days curing period were increased 58.07 and 56.45% respectively in the strength compared to the contaminated soil without additives. Also, the evaluation of the results stabilized samples with organo-clay showed that by adding 0.7% of the organo-clay within the 28-d curing period, the highest increment of the unconfined compressive strength (37.56%) was obtained. These results show that the use of nanoclay and organo-clay increases the strength of contaminated soil. In a general conclusion, the addition of 2% nanoclay and 0.7% of the Cloisite 30B lead to return the missed strength of soil due to the gas-oil contamination.

4. CONCLUSIONS

Based on the results developed in this investigation, the following conclusions can be drawn:

In the results of the UCS test, increased the unconfined compressive strength of contaminated soil for a 28-day curing period despite lack of pozzolanic reactions.

· Due to the addition of nanoparticles (MMT-Na^+ and Cloisite 30B), the optimum water content of the contaminated soil showed an increasing trend while for the maximum dry density it showed a decreasing trend.

· The results of axial loading of soil contaminated stabilized with nanoclay indicated increasing the compressive strength and the highest strength is related to 2% of the weight of dry contaminated soil.

· According results, the contaminated samples modified with organo-clay encountered an increase in unconfined compressive strength. The highest compressive strength was obtained for samples containing 0.7% of additive of the weight of contaminated soil.

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