Effect of Glycerol and Acetone on the physical and mechanical properties of a clay soil

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Abstract

In this research work the effect of glycerol and acetone on the properties of a clay soil with low plasticity (CL) was studied through experimental tests. Contaminated soil was prepared by mixing 10, 15 and 20% pure glycerol or acetone with soil. A set of experimental tests including Atterberg limits, compaction, free swelling, Unconfined Compressive Strength (UCS), California Bearing Ratio (CBR), consolidation tests and Scanning Electron Microscopy (SEM) were conducted on uncontaminated and contaminated soil. The results showed that the effect of glycerol on contaminated soil was a reduction of Atterberg Limits, Free Swelling, optimum water content and increasing maximum dry unit weight but the effect of acetone was in the opposite trend of glycerol. These variations in the behaviors of soil were the function of percent of glycerol or acetone. In addition, the results indicated that both glycerol and acetone cause the reduction in the values of compressive strength and CBR number of soil but the reduction due to glycerol was more than the acetone. The results of consolidation test showed that the values of compression index (Cc) and swelling index (Cs) were independent of the percent of chemical fluids. The SEM results also reveal that these two contaminations cause some variations in the physical and mechanical properties of a clay soil becase of changing the structure of soil and the effect of these contaminations on the properties of soil was not the same.

Key words: hydrocarbon contamination, Atterberg limits, free swelling, Unconfined Compressive Strength (UCS), CBR and consolidation test.

Introduction

Soil contamination by hydrocarbon contaminants is of important environmental issues, since it could have disasterous consequences for water, air, soil and consequently for the human being life. Hydrocarbon contaminants, which have the petroleum origin, are the foundations of numerous industries such as fuel refining and petrochemical complexes. The interaction of contaminants with soil can be divided into mechanical and physicochemical interactions. Mechanical interactions usually occur in granular soils while physicochemical interactions occur in cohesive soils. Fang (1997) presented an index, called the sensitivity index, to explain the interaction of soil with contaminants. He defined the range of this index between 0 and 1 for different types of soil. The value of the sensitivity index for sand and gravel is in the range of 0.01–0.1 and for clay particles between 0.6–0.9. This index shows that the interaction of the contaminant with clay soil is more than with granular soil. Thus, the response of soil to the contaminants depends on the type of soil and nature of hydrocarbon contaminants. The review of the literature shows that investigation on the effect of pure contaminants on the behaviors of soil is relatively rare. Therefore, this work was focused on studying the behavior of a contaminated CL Soil that was contaminated with two different pure contaminant matters by conducting different tests.

Material and methods

The effects of two hydrocarbon contaminants including, Glycerol and Acetone, on physical and mechanical properties of a clay soil with low plasticity (CL) were studied through conducting a set of experimental tests. These experimental tests including Atterberg Limits, Compaction, Free Swelling, Unconfined Compressive Strength (UCS), California Bearing Ratio (CBR), One-Dimensional Consolidation tests. These tests were conducted on the samples of natural soil and contaminated soil with Glycerol and Acetone according to ASTM standards. In addition, Scanning Electron Microscopy (SEM) tests were also conducted on the samples of natural soil and contaminated soil with Glycerol and Acetone. The aim of conducting the SEM test was to get more information about the microstructure of soil at different conditions (uncontaminated, and contaminated with glycerol or acetone). The soil samples were made by static compaction method in special molds by using a loading machine. The water content and dry unit weight of prepared samples were the same as to their corresponding compaction curves. The dimensions of the molds that were used for preparing the samples for Free Swelling and Consolidation tests were exactly the same as the ring of the Oedometer with detachable collars at both ends. The dimensions of the mold used for preparing the samples for Unconfined Compressive Strength tests were 50 mm diameter and 100 mm length with detachable collars at both ends. The Free swelling tests were continued until the swelling reached a constant value. The swell potential is defined as the maximum swell that the sample could achieve. For the Unconfined Compressive Strength tests, the rate of loading was chosen as 1mm/min. The loading was continued until failure of the specimen was achieved while the value of the load was continuously recorded. Each of the aforementioned tests was repeated three times, and the average results were presented as the final results.

Results and discussion

The results of Atterberg Limits (LL, PL, and PI) for the natural and contaminated soil with (10, 15, and 20%) Glycerol and Acetone are presented in Fig.1. As shown in this figure the values of Atterberg limits are decreased with increasing the percentage of Glycerol, while Acetone showed the opposite effects. The variations of the compaction parameters (maximum dry unit weight and optimum water content) indicated that by increseaing Glycerol percentages the related compaction curves move to the left and upward of the natural compaction curve, i.e., causes an increase in the maximum dry unit weight and decrease in optimum water content, but the results for Acetone is in opposite trend. Fig.2 shows the percentage of final swelling for contaminated soil with these two matters for different percentages. The results show that by increasing the percentage of Glycerol, the potential of swelling is decreased but for Acetone it is increased. Furthermore, the final results of strength (Fig.3) for uncontaminated and contaminated soil indicated that both Glycerol and Acetone caused a reduction in the values of strength, but the reduction due to Glycerol is more than Acetone. It is obvious from the obtained results that CBR number is reduced by increasing the percentage of contaminants and the reduction is depended on the percent and type of used contaminant matter. From the results of Consolidation tests the pre-consolidation pressure was also calculated for the natural soil and the soil contaminated with different percentages of Acetone or Glycerol. The value of pre-consolidation pressure for the natural soil and the soil contaminated with Glycerol was 45 kPa and this value was 58 kPa for the soil contaminated with Acetone. The Compression Index (C_c, slope of virgin line) and Swelling Index (C_s, slope of unloading line) were calculated for the natural soil and the soil contaminated with different percentages of Glycerol or Acetone. The results show that the values of C_c and C_s for the natural soil are 0.2 and 0.032 respectively. The values of C_c and C_s for the soils contaminated with different percentages of Glycerol or Acetone are nearly 0.21 and 0.03. It is resulted that the virgin and swelling lines are nearly parallel with each other for both contaminated fluids. The SEM results show that the structure of contaminated soil is different from uncontaminated soil and it is due to the interaction of soil particles with contaminant matter.

Fig.1.The results of Atterberg Limits for the natural and contaminated soil with (10, 15, and 20%) Glycerol and Acetone

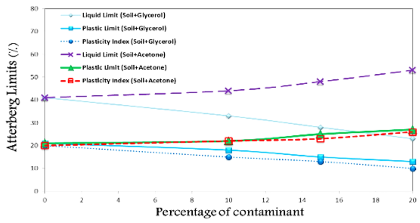
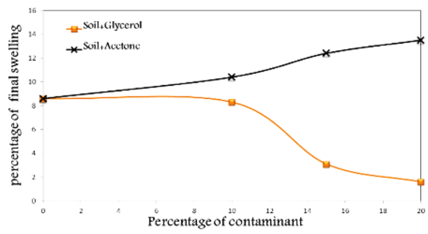


Fig.2.The percentage of final swelling for the natural and contaminated soil with (10, 15, and 20%) Glycerol and Acetone



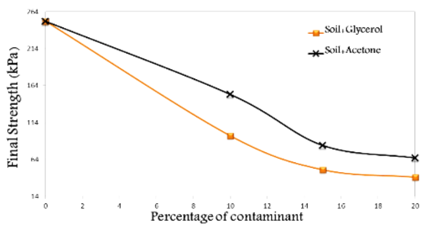


Fig.3.The final strength for the natural and contaminated soil with (10, 15, and 20%) Glycerol and Acetone

The results showed that the behaviors of contaminated soil are different from natural soil. The change in the properties of it depends on many factors, such as changing in the initial structure of soil. This can be explained by the Diffuse Double Layer (DDL) which is a thin layer of water around the clay particles. A reduction in the thickness of this layer leads to the flocculation structure of soil (Mitchell and Soga, 2005). The thickness of this layer is proportional to a number of factors, such as the square root of the dielectric constant. Thus, for Glycerol with a lower dielectric constant (42.5) than water (80), the thickness of the DDL around clay particles is reduced, and this leads to a flocculated structure of soil mass. At this condition the soil particles are pasted to each other and resulted in reduction of specific surface that the capacity of the adsorbed water is decreased. These changes result in a reduction in the Atterberg limits, Swelling Potential, and optimum water content and an increase in the maximum dry unit weight. In case of Acetone the opposite results to Glycerol is observed. According to chemical formulation of Acetone (CH_3- CO- CH_3), there is a double bond between oxygen and carbon. This bonding increases the density of electrons from carbon to oxygen, and it leads to a dipole condition. With this property Acetone can produce two molecules of acid by oxidation. Therefore, Acetone can break the bond between the particles of soil and change them to smaller particles (Charters et al., 1989). This increases the specific surface and capacity of adsorbed water, and hence increases the Atterberg limits, free swelling, and changes in the compaction characteristics (maximum dry unit weight and optimum water content). Moreover, the higher viscosity of Glycerol, which is more than that of water, in the pore fluid can facilitate the displacement of particles due to loading, leading to a reduction of strength. Although the viscosity of Acetone is nearly the same as water, the strength and CBR values of the soil contaminated with Acetone are less than natural soil. This can be attributed to the different structures of the natural and contaminated soils. The structure of the contaminated soil is composed of finer particles than the natural soil, with lamellar forms that are nearly parallel, with a relatively large space between the set particles. This can lead to a reduction of the friction between particles and compressibility of the soil mass. Therefore, the final strength and CBR values of the soil with Acetone as pore fluid are less than the natural soil.

Conclusion

The flowing conclusions can be drawn from the results of this work:

- Both Glycerol and Acetone had effects on the behavior of soil, and the amount of changes is dependent on the kind of contaminant matters and the used percentage of it.
- Glycerol causes reduction in the values of Atterberg Limits, optimum water content, free swelling, and increasing maximum dry unit, but the effect of Acetone is in opposite direction.
- Both Glycerol and Acetone cause reduction in the values of strength and CBR number of soil, but the reduction due to Glycerol was more than the Acetone.
- The SEM results showed that the interaction between soil and Glycerol or Acetone is not the same and it leads to creating different properties in soil.

References

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