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Geotechnical properties of gas oil-contaminated kaolinite

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ABSTRACT

The leakage of petroleum products contaminates the soil and changes its physical and mechanical properties. This paper is a part of an extensive laboratory program aimed at promoting greater understanding of the influence of petroleum-derived contaminants on the geotechnical properties of soils. The laboratory tests included basic properties, Atterberg limits, consolidation, direct shear, and unconfined compression tests, all of which were carried out on clean and contaminated kaolinite specimens at the same relative compactions. Contaminated specimens were prepared by mixing kaolinite with different gas oil contents. Results indicate an increase in the cohesion and a decrease in both the friction angle and compressibility of kaolinitic soils with increasing the gas oil content. Results are intended to provide an alternative to the treatment methods currently used in practice for petroleum-contaminated sites and help bridge/narrow the gap between research and practice in environmental protection of the sites.

1. Introduction

The leakage and spillage of gas oil (also known as diesel fuel) from old and corroded storage tanks, pipelines, processing plants, and petroleum transportation facilities contaminate the surrounding soil. The extent of contamination depends on the filtration and retention properties of the soil (Fine et al., 1997). Such contamination not only results in immediate or future damage to the soil environment, but also changes the physical and mechanical properties of the soil. A variety of remediation methods such as vacuum extraction and separation by centrifuge, biological methods, and soil washing methods have been used to clean up the contaminated soil (Riser-Roberts, 1998). However, it is recognized that their implementation in practice is limited, especially for widely contaminated areas, due to the huge expense demanded. A clever solution could be the use of contaminated soil in civil engineering practice, including embankments, road bases, and backfills. In addition to the environmental concerns about groundwater pollution and other possible effects, an investigation on the geotechnical characteristics of the contaminated soil is required. The investigation can also be used to design a storage tank foundation in order to ensure that the foundation will satisfactorily serve its purpose during the tank's lifetime. The investigation also provides knowledge to revise the foundation design of the existing structures subjected to the contamination.

A number of studies have already been carried out on the geotechnical properties of the soils contaminated by petroleum hydrocarbons. Cook et al. (1992) experimentally investigated the compaction, compression, and strength properties of uniformly graded sands contaminated by crude oil. They reported that although oil contamination had no significant effect on the compaction characteristics, it decreased the friction angle and considerably increased the compressibility of the sand. Similar results were obtained by Puri et al. (1994) and Meegoda and Ratnaweera (1994) for sandy and clayey soils, respectively. Furthermore, the geotechnical properties of oil-contaminated Kuwaiti sand were studied by Al-Sanad et al. (1995). Again, results indicated a small reduction in strength and permeability as well as an increase in the compressibility of the sand. Later, Al-Sanad and Ismael (1997) reported an increase in the strength and stiffness for the oil-contaminated Kuwaiti sand due to aging and oil content reduction. Aiban (1998) investigated the influence of temperature on the geotechnical properties of the oil-contaminated sands and reported the insensitivity of their shear strength to the temperature in contrast to the compressibility of the soil which increased with temperature. A drastic reduction in the bearing capacity of a shallow strip foundation constructed over oil-contaminated sand was observed by Shin and Das (2001).

Studies on the geotechnical characteristics of fine-grained soils have just recently gained momentum. Khamehchiyan et al. (2007) studied the geotechnical properties of the oil-contaminated clayey and sandy soils and found a reduction in strength, permeability, maximum dry density, optimum water content, and Atterberg limits of these soils. Singh et al. (2008) found an increase of 35%–50% in the consolidation settlement of fine-grained soils upon contamination with petroleum hydrocarbons. They also introduced a correction factor to the empirical equation proposed by Skempton and Jones (1944) to estimate the

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