Influence of diesel pollution on the physical properties of soils

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ABSTRACT

Physical properties of contaminated soils are different from uncontaminated ones, it is necessary to detect whether the site was contaminated before construction. How to quickly, precisely judge whether the soil was contaminated is a problem need to research, soil electrical resistivity can be used as an index to evaluate whether the soil was contaminated. Diesel oil contaminated soil as a common contaminated soil gained more and more attention. This paper choose the classical Yangtze River back swamp soil as study material, 0# diesel oil (in Chinese national standard) as contaminated, mixed soil samples with water content of 7%, 10%, 13%, 16%, 20% and 25%, every water content inject diesel oil content of 4%, 8%, 12% (water and oil content all calculated in weight). The prepared contaminated soils were placed in standard curing room for 14 days, 28 days, 56 days. At every curing time, soil particle size distribution, pH were measured according to different standards. Atterberg limits, electrical resistivity of the contaminated soils was measured at 14 days curing time. Resistivity was measured by the devices designed according to Miller Soil Box, using alternating current (AC) as input power. Soil resistivity was measured at different water content, density and degree of saturation. Results show that diesel contamination can decrease soil particle size and soil pH, can decrease soil liquid limit and liquid limit, and can increase soil resistivity. Resistivity of contaminated soil decrease in power function with the increase of water content, density and degree of saturation. These results would be a help in the future work when use soil index to judge whether the soil was contaminated.

Keywords: diesel contaminated soil, physical properties, electrical resistivity, Miller Soil Box

1 INTRODUCTION

Subsurface contamination by petroleum hydrocarbon has been one of the serious environmental problems. Accidental spills and leakage from the storage facilities due to the corrosion or damage in piping connection were the major causes of petroleum contamination in the subsurface (Oh et al., 2007). Petroleum hydrocarbon contamination will change the soil properties, such as compressibility (Shin and Das, 2000), hydraulic conductivity, optimum water content and Atterberg limits (Meegoda and Rutaaweera, 1994), shear strength (Khamehchiyan et al., 2007), foundation bearing capacity (Shin and Das, 2001), and other properties. It is necessary to detect whether the site was contaminated before construction. Conventional investigation including field sampling and chemical analysis might be essential, but are expensive and time consuming (Fukue et al., 2001). How to quickly, reliably, and easily detecting whether the site was contaminated had drawn several researchers into this study area (Campanella and Weemees, 1990; Kaya and Fang, 1997; Ahn et al., 2007), and had obtained many useful conclusions.

Soil electrical resistivity is a major electrical property can reflect the status of electric fields in a medium. Previous studies revealed that the electrical properties of soil were affected by soil types, water content, porosity, degree of saturation and temperature, etc (Campanella, 2008). It has been also recognized that the electrical resistivity of soils altered when the soil was contaminated. G Mondelli et al. (2010) use RCPTU to detect a landfill for urban solid waste in Brazil, proved electrical resistivity is helpful to detect contaminated soil. S Y Liu et al. (2013) successful using electrical resistivity method in a pesticide contaminated factory to detecting organic contaminated soil. Therefore, it is possible to use resistivity as an index to determine whether the soil was contaminated.

The purpose of this paper is to study the influence of...
diesel contamination on the physical properties including particle distribution, pH, Atterberg limits and electrical resistivity of soil. Curing time influence on soil particle distribution, pH were also considered. Conclusions in this study can give a reference for detecting the diesel fuel contamination in the unsaturated clay soil.

2 MATERIALS AND METHODS

The classical Yangtze River back swamp muddy-silty clay in Nanjing, was used for the present tests. The soil was oven dried, ground and sieved through a 2 mm screen. Basic properties of the soil were presented in Table 1. 0# diesel oil (Chinese National standards) was used as contaminant, its specific gravity is 0.83 g/cm³, conductivity is 0.15 μS/cm.

Table 1 Basic engineering property index of uncontaminated soil

| index | ω (%) | γ (g/cm³) | Gs | pH | ωL | ωp | Ip |
|-------|--------|-----------|----|----|-----|-----|-----|
| value | 36.7   | 1.92      | 2.72 | 7.95 | 37.7 | 23.1 | 10.3 |

This test use Miller Soil Box which is arrayed according to Wenner method as sample container (Fig.1). Length of the box is 15 cm, its inner diameter is 5 cm. Two copper sheets are used as electrodes to measure electrical current, two copper bars are used as electrode to measure voltage, as shown in Fig. 1. Resistivity of soil sample can be calculated by equation 1.

\[
\rho = \frac{V \cdot A}{I \cdot L}
\]  

(1)

In which I is current, V is voltage, A is sample area, L is distance of two copper bars.

![Fig. 1 Principle of resistivity measure method](image)

1) Mixing of contaminated soil

The contaminated soil were artificial mixed in the laboratory. Water content of the contaminated soil are 7%, 10%, 13%, 16%, 20% and 25%; oil content are 4%, 8% and 12% (oil – dry soil mass ratio). In the mixing process, water was first mixed with dry soil, maintain in the standard curing room for 3 days, then add diesel into the soil, maintain in the standard curing room for 14 days to make sure the diesel contaminated soil homogeneous.

In order to study the influence of curing time on the properties of contaminated soil, soil samples were curing for 14 days, 28 days and 56 days.

2) Measure methods

Particle distribution test was using laser particle size analyzer – Mastersizer 2000, pH test were conducted according to ASTM D4972-13, soil resistivity were measured according to ASTM G57-06 (Reapproved 2012).

3 RESULTS AND DISCUSSIONS

3.1 Particle distribution test

Soil particle distribution test is an important method to classify soil type, is research about the relative content of different soil particles. Particle distribution test were conducted according to Standard for soil test method (GB/T 50123-1999). Particle distribution of different concentrations contaminated soil at different curing time were analyzed.

![Fig. 2 Particle distribution of different concentration diesel contaminated soil at different curing time](image)

Fig. 2 illustrate the particle distribution of each diesel concentration at different curing time. The curves of distribution are distinct separate from each other. Particle composition were list in Table 2. Both clay particles and silt part content of 4%, 8%, 12% contaminated soil were increase with diesel concentration. When soil was contaminated, diesel molecule reaction with the soil particles, decreased the particle size, the clay content increased. The longer is the curing time, the more diesel molecules have sufficient time reaction with the soil, soil particles become more finer.
Table 2 Composition of particle distribution

| Curing time | 14d | 28d |
|-------------|-----|-----|
| Oil content (%) | 12 | 8 | 4 | 12 | 8 |
| <0.005 | 158 | 148 | 134 | 226 | 194 |
| 0.005–0.075 | 687 | 670 | 668 | 709 | 705 |
| >0.075 | 155 | 172 | 198 | 65 | 101 |

Curing time 28d | 56d |
| Oil content (%) | 12 | 4 | 12 | 4 |
| <0.005 | 153 | 136 | 238 | 184 |
| 0.005–0.075 | 701 | 700 | 697 | 696 |
| >0.075 | 146 | 40 | 65 | 120 |

3.2 pH test

pH of the contaminated soil were test according to ASTM D4972-13. Test sample is composed of soil and distilled water in ratio of 1:1. In this test, 10 gram contaminated soil and 10 ml distilled water were mixed uniform, placed for 1 hour, and then conducted the pH test.

Changes of the soil pH at different curing time have similar values. pH of samples were decrease with the increase of curing time, 14 days, 28 days have a little change range, pH of 56 days has a relative bigger change. With the increase of diesel concentration, pH at every curing time decrease. As diesel has a pH of 7.52, so it is reasonable that pH decrease with the increase of diesel concentration.

![Fig. 3 pH of samples at different curing time](image)

3.3 Atterberg limits test

States of the clay change with soil water content, there is a range of water content in which clay is in plastic state, and the measure of the range is soil Atterberg limits. Value of Atterberg limits can reflect soil engineering properties. It has relationship with several factors, such as soil mineralogy, activity, the specific surface area of soil particle, and so on. When clay was contaminated by diesel, surface properties of soil particle were changed, resulted in the change of soil Atterberg Limits. In this paper, Atterberg Limits of the soil were measured according to Standard for soil test method (GB/T 50123-1999), by Liquid Limit and Plastic Limit combine tester.

Fig. 4 shows the results of Atterberg Limits change with different diesel concentrations. The liquid limits and plastic limits of the contaminated soil all decrease with increase of diesel concentration, they have a similar trend, therefore, the content of diesel in soil has few effect on soil plastic index. When clay was contaminated by diesel, interaction between soil particles was weakened, and adsorbed water layers got thinner, so the plastic limit and liquid limit decrease.

![Fig. 5 soil resistivity versus water content at different oil content](image)

3.4 Electrical resistivity test

Put the prepared contaminated soil in the Miller Soil Box, the soil was compacted to designed density by layers. Connect the circuit, use 50 Hz electric current as measure current, voltage and current were measured respectively. Soil resistivity were calculated by equation 1. In this study, direct current were used as power supply, different states of contaminated soil such as water content, density, water saturation were controlled, resistivity at different states were measured, results were analyzed as following.

1) Water content versus resistivity

It can be seen from the Fig. 5 that at a fixed oil content, resistivity decrease in power function with the increase of water content. When water content is low, resistivity decrease quickly, when water content greater than 16%, resistivity decrease slowly. At a given water content, resistivity increase with oil content. When diesel content increase, the pore fluid of the contaminated soil composed of more diesel, diesel is non-conductivity, its resistivity is higher than water, so resistivity increase with the increase of diesel content.

2) Soil resistivity versus density

Fig. 6 illustrates the relationship of resistivity and density of 8% diesel contaminated soil. It can be seen from Fig. 6 that at different water content, soil
resistivity decrease in power function with the increase of density. The change scope of the resistivity is wider when density is lower, when density is denser the change scope is limited. It also can be seen that at a fixed density, resistivity decrease with the increase of water content.

\[ \rho_s (\Omega \cdot m) \]

Fig. 6 soil resistivity versus density at different water content

3) Soil resistivity versus saturation

![Graph showing soil resistivity versus saturation](image)

Fig. 7 soil resistivity versus saturation at different water content

Fig. 7 illustrates the relationship of resistivity and degree of saturation of 8% diesel contaminated soil. It can be seen from Fig. 7, at different water content, soil resistivity decrease with increase of saturation. When the saturation is lower, resistivity decrease quickly, when saturation is higher, resistivity decrease slowly. It can deduce that when water content and saturation is big enough, the change line should have a very limit vary scope.

4 CONCLUSIONS

Laboratory tests were done on diesel contaminated soil, conclusions can be reached as following, which can be helpful in continue research.

1) Diesel contamination has effects on soil particle distribution, with curing time increasing, both clay content and silt content of contaminated soil increase; at the same curing time, clay content increase with diesel content increase.

2) Diesel contamination can decrease the pH of soil, with curing time increase, pH of the contaminated soil decrease in a small scale.

3) Diesel contamination has little influence on soil Atterberg limit. Liquid limit and plastic limit all decrease with the increase of diesel concentration, and diesel has little influence on index of plastic.

4) Resistivity of contaminated soil decrease in power function with the increase of water content, density, degree of saturation.

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