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Bearing Capacity of Unsaturated Oil-Contaminated Sand

Eun Chul Shin*
University of Inchon, Inchon, Korea

Braja M. Das*
California State University, Sacramento, California, USA

ABSTRACT

Onshore and offshore oil spills contaminate soil. In addition to environmental concerns about ground water pollution and other possible effects, the geotechnical properties of the contaminated soil such as the shear strength and the hydraulic conductivity are also altered. This paper presents the results of research to evaluate the variation of the shear strength of a sand contaminated by 3 different types of oil with varying kinematic viscosities and thus the ultimate bearing capacity of shallow foundations. The results of the tests reported here relate to only 1 type of sand and 3 types of oil. The oil contents varied from zero to 6%. Results of direct shear tests for determining the soil friction angles are given. Additionally presented are laboratory model test results to determine the ultimate bearing capacity of a surface strip foundation supported by oil-contaminated sand. Based on these test results, the effect of oil contamination in drastically reducing the bearing capacity is discussed.

INTRODUCTION

Every year, several onshore and offshore oil spills occur around the world, and these oil spills contaminate the soil. The physical properties of the oil-contaminated soil will also control the stability of slopes as well as the bearing capacity of foundations and other structures. During the last decade, the results of a number of studies related to the physical properties and behavior of oil- and petroleum constituent-contaminated soil have been published (e.g., Cook et al., 1992; Evgin and Das, 1992; Al-Sanad et al., 1995, 1997; Puri et al., 1994; Fan et al., 1994; Tuncan and Pamukcu, 1992). It does appear, however, that further studies are necessary to quantify several parameters of interest to geotechnical engineers. Although limited in quantity, the present published test results show that the total stress friction angle of sand undergoes a reduction when the sand becomes contaminated with oil. Most oil spills contaminate soil for a limited depth below the ground surface. A shallow foundation supported by sand will probably undergo a reduction in ultimate bearing capacity when the sand becomes contaminated with oil as the bearing capacity is a function of the soil friction angle. The purpose of this paper is to present the variation of the shear strength parameters of 3 types of oil-contaminated sand and also the effect of oil contamination on the ultimate bearing capacity of a surface strip foundation supported by the sand. The bearing capacity tests were conducted with small-scale models in the laboratory.

SAND AND OIL USED FOR TESTS

The present tests were conducted with Jumoonjin sand, a poorly graded silica sand found in South Korea. The physical properties of the sand are given in Table 1. Three different types of oil (Oman crude oil, engine oil, lamp oil) with varying degrees of viscosity were used as contaminants. The kinematic viscosities (v) for these oils at various temperatures were measured for each oil using the procedure described in ASTM test designation D-445, and these values are shown in Fig. 1 along with the standard variation of v with temperature for water. All laboratory tests reported here were conducted at a temperature of 22° ± 2C°. The specific gravities of the oil (G_o) at 20°C were: Oman crude oil, 0.879; engine oil, 0.852; and lamp oil, 0.798.

SHEAR STRENGTH OF SAND

Because the ultimate bearing capacity of shallow foundations is highly dependent on the friction angle of granular soil, a number of direct shear tests was conducted with both dry and oil-contaminated sand at relative densities of compaction (D_r) of 45% and 75%. Table 2 gives the details of the oil content and the degree of saturation at which the tests were conducted. The oil content, w, is defined as:

$$w = \frac{W_o}{W_s} \tag{1}$$

where W_o = weight of oil, and W_s = weight of dry sand.

Item	Quantity
Effective size, D_{10}	0.375 mm
Uniformity coefficient, C_u	1.53
Coefficient of gradation, C_z	1.10
Maximum dry unit weight	17.5 kN/m^3
Minimum dry unit weight	13.6 kN/m^3
Specific gravity of soil solids, G_s	2.65
Unified soil classification	SP

Table 1 Physical properties of sand

*ISOPE Member.
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KEY WORDS: Direct shear test, friction angle, oil contamination, sand, ultimate bearing capacity.