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Laboratory Study on Dielectric Properties of Contaminated Soil Using CPT Deployed Probe

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ABSTRACT

Over the past decade, direct-push geotechnical sensors or penetration probes have earned widespread acceptance in the geoenvironmental fields of study as a more viable and cost-effective solution for the assessment of soil and groundwater contamination. Of these, cone penetrometer test devices equipped with resistivity sensors have been successful in qualitatively locating contaminated areas. The rationale in making electrical measurements is that the electrical properties of the soil will be changed by the presence of contaminants. Field scale studies have indicated that resistivity cone penetrometer tests (RCPT) are able to minimize laborious and iterative processes involved in the conventional method of site assessment.

The electrical resistivity of soil is a complex function of porosity, degree of saturation, ionic content of pore fluids, and clay content. Thus, qualitative analysis of measured resistivity data requires careful consideration on the compositional and structural heterogeneities of soil in-situ. However, this process can be greatly simplified when the soil medium is completely saturated, because the differences that arise in the bulk resistivity of soil from contamination is magnified when soil is fully saturated. This rationale is based on the Archie's law (1942) which states that the resistivity of soil is directly proportional to the pore fluid resistivity. On this account, most of the studies reported in literature have focused on interpreting RCPT measurements made below the groundwater level. Although the electrical resistivity of soil has proved to be a reliable measure in determining the presence of various contaminants in the saturated zone, measurements made in the vadose zone have not been considered of significant importance.

Transport of contaminant in the subsurface level occurs mainly through the flow of groundwater. However, contaminants must penetrate through layers of soil which are predominantly unsaturated before reaching the groundwater level. It is known that a relatively dry vadose zone acts like a sponge, holding contaminants in pore spaces. Delineating such retardation of contaminant in the vadose zone is important for its environmental consequences may be of remedial concern. The objective of this research is therefore focused on developing a RCPT module and investigating possibilities of extending its applicability in detecting contaminants in the vadose zone. In addition to electrical resistivity

measurements, capacitance measurements were made in the low frequency range (1kHz - 1MHz) in order to aid contaminant delineation in unsaturated soil medium.

Capacitance is a property which represents the dielectric properties of a material. Measurement of dielectric constant, which is directly proportional to capacitance, has long been used as a parameter to estimate the moisture content of soils in-situ. More recently, many studies have evaluated the potential of dielectric measurements as a method of contaminant delineation. Advantage of using such dielectric properties of soil is that it can aid overcoming inherent ambiguities in using resistivity measurements. While electrical resistivity measurements may give only qualitative information about the changes in the chemical composition of the soil-pore fluid, dielectric constant is a parameter which is almost independent of chemical composition and particle shape, and is considerably lower than that of most liquids (Kaya and fang, 1997). However, little is known about the development of electric sensors to utilize dielectric properties of soils as a method to characterize subsurface contamination.

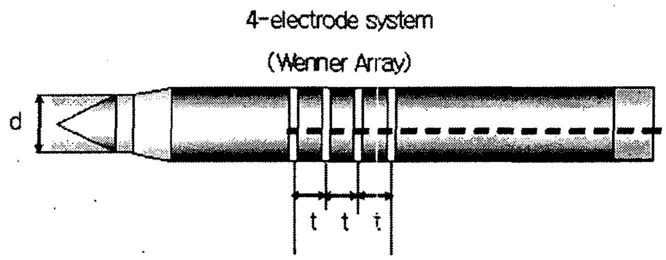

Fig. 1 Diagram of the CPT module with electric sensors capable of resistance and capacitance measurements

Figure 1 shows a schematic diagram of the CPT module developed in this study. Electrical resistivity measurements were made using the 4-electrode system which had identical configurations to the Wenner array. Both direct current resistivity was measured using the SAS 300C (ABEM) at an input current of 1mA, while alternating current resistivity and capacitance were measured using the LCR meters (Agilent) in the frequency range of 100Hz – 1 MHz. Experimental study was conducted in 30 cm diameter by 50 cm height chamber filled with Jumunjin sand contaminated by lead (Pb) solutions and diesel fuel at various concentrations. Results from laboratory study indicated that capacitance measurements in the low frequency range may be used as a complement to electrical resistivity measurements in delineating contaminants in the vadose zone.