Fiber Optic Relative Humidity and TDR Sensors for the Cone Penetrometer

Technology Need

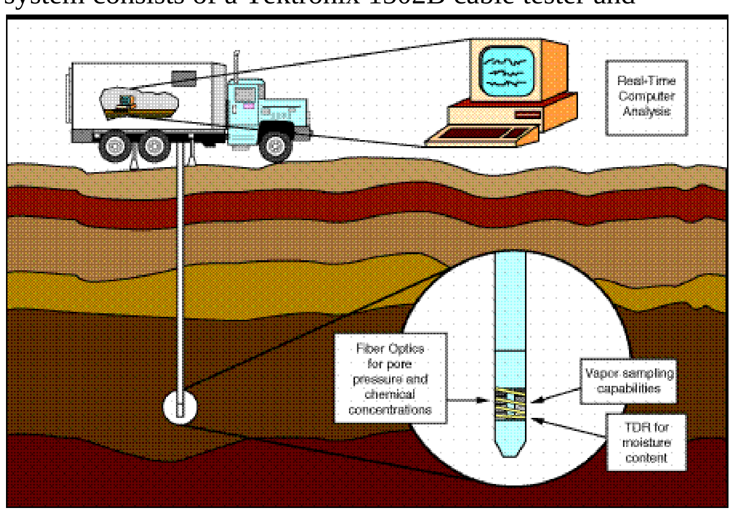
Accurate hydrogeologic characterization, along with the nature and extent of contamination of a site, must be determined in order to perform risk assessments, create contaminant transport models, and optimize remedial alternatives such as soil venting and bioremediation. Moisture content and pore pressure are critical parameters for flow and transport modeling that can be used with stratigraphic information to correlate geologic units. Two sensor packages, developed at Sandia National Laboratories, have been engineered into a cone-penetrometer-push technology; they also work as stand-alone units. The Time Domain Reflectometry (TDR) sensor quantifies volumetric soil moisture content. The Fiber Optic Relative Humidity (RH) sensor quantifies capillary pore pressure in unsaturated soils. Both sensors allow for real-time, continuous measurement.

Objective

The objective of this project is to characterize hydrogeologic parameters for waste-site and geotechnical investigations using Fiber Optic RH and TDR sensor packages developed for the cone penetrometer.

Project Description

The TDR sensor employs an electromagnetic pulse technique that quantifies moisture content. TDR measurement of volumetric moisture content is based on the contrast between the dielectric constant of soil and fresh water. As the moisture content of a soil increases, the dielectric constant of the soil will increase in a functional manner. The TDR system consists of a Tektronix 1502B cable tester and cable/probe assembly. The Tektronix 1502B generates a fast rise time electromagnetic pulse (200 ps), which propagates along the coaxial transmission line until it reaches an impedance change. A portion of the signal is reflected back to the Tektronix 1502B and displayed as a change in amplitude on the oscilloscope. The Tektronix 1502B measures the time for a pulse to travel between the beginning and end points of the probe and converts this transit time to a distance.



Fiber Optic System

The Fiber Optic RH pore pressure sensor is a porous-polymer fiber optic probe. It measures soil-water potential in unsaturated dry soils without dew-point estimates or temperature compensation methods, making it less problematic than the baseline technology. The optrodes are made of porous polymer chemical sensing material located between two standard optical fibers. One optical fiber introduces optical energy to the sensing element at two distinct wavelengths. The second fiber transmits the light that passes through the sensing element back to the opto-electronic interface. When water vapor reacts with the optrode chemical sensing material, the optical absorption rate at 660 nm changes. The optical transmission at 565 nm is minimally affected by the presence of water vapor and serves as a reference signal. The Fiber Optic RH is calibrated to measure relative humidity at very high sensitivities between 98% and 100% from which pore pressure is calculated for arid soils.

The Fiber Optic RH and TDR sensors are incorporated into the cone penetrometer and pushed into the subsurface for a minimally intrusive characterization hole. A 486-based computer with a graphics monitor analyzes and displays data in real-time. Data are stored on the hard disk and manipulated for plotting hard copies within ten minutes of completing the push. The sleeve friction and tip stress data are used to predict lithologic features like sands, silts, and clays. Lithology information and moisture content data obtained in real-time helps investigators predict the movement of water and solutes during a site investigation.

Advantages

Adding real-time measurement capabilities of hydrogeologic parameters to a cone penetrometer system could result in substantial time and cost savings. It could also improve worker safety for site assessments and remedial monitoring relative to conventional drilling and sampling methods because no soil cuttings or investigation-derived wastes are generated, and all the operations take place in the cone penetrometer truck. Real-time data collection also allows field personnel to decide whether additional locations should be investigated or if planned locations for subsurface investigations should be relocated.

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