Subsurface Exploration with the Cone Penetration Testing Truck

The U.S. Geological Survey Cone Penetration Testing (CPT) truck is a fast and inexpensive way to conduct shallow subsurface exploration. Detailed data are available immediately, permitting on-the-fly mapping of stratigraphy and other subsurface features. CPT is a useful tool in geologic-hazard, hydrologic and environmental studies. This rapid and cost-effective approach is particularly advantageous in urban environments because no drill spoils are produced. The CPT truck is available on a reimbursable basis to all USGS staff and cooperators.

Cone penetration testing (CPT) permits rapid exploration of shallow (less than 30 meters) subsurface conditions while minimizing retrieval of subsurface materials, an inconvenient and occasionally expensive byproduct of conventional drilling. This exploration method employs sensors that are pushed into the ground to infer the properties of both soils and pore fluids. Known as direct-push technology, this method can map out the vertical and lateral extent of stratigraphic layers, as well as the distribution of subsurface contaminants. By using standard engineering correlations, the geotechnical properties of stratigraphic layers can also be inferred.

In 1997, the Pacific Gas and Electric Co. (PG&E), under the PG&E–U.S. Geological Survey (USGS) Cooperative Research and Development Agreement (CRADA), contributed funds for the CPT truck. The PG&E–USGS CRADA was created to conduct earthquake-hazard investigations and improve earthquake notifications needed for reducing earthquake risks in the San Francisco Bay Region. Since 1998, the USGS CPT truck has provided data for a broad variety of USGS earthquake-hazard, geologic, and hydrologic investigations that require detailed subsurface information.

A CPT sounding is made by pushing a small probe into the ground. Typically, a 3.6-centimeter-diameter probe (cone) is pushed into the ground to depths ranging from 15 to 30 meters. The CPT log of friction ratio and relative tip resistance with inferred geologic units and their shear-wave velocities is shown in the table below.

<table>
<thead>
<tr>
<th>Soil type</th>
<th>Friction ratio</th>
<th>Relative tip resistance</th>
<th>Shear-wave velocity (in meters per second)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Artificial fill</td>
<td>-1</td>
<td>118</td>
<td></td>
</tr>
<tr>
<td>Mud</td>
<td>-3</td>
<td>103</td>
<td></td>
</tr>
<tr>
<td>Silty sand</td>
<td>-4</td>
<td>225</td>
<td></td>
</tr>
<tr>
<td>Dense sand</td>
<td>-5</td>
<td>419</td>
<td></td>
</tr>
</tbody>
</table>

CPT log of friction ratio and relative tip resistance with inferred geologic units and their shear-wave velocities.
CPT applications are numerous and wide ranging. CPT measures the thicknesses and quantifies the physical properties, including shear-wave velocity, of individual geologic units. In combination with maps of surficial geology, this method permits mapping of regional liquefaction hazards and National Earthquake Hazards Reduction Program (NEHRP) site-amplification soil classes used for seismic design. CPT is well suited for mapping the elevations of buried stratigraphic horizons, as well as for reconnaissance of paleoseismic sites, the locations where sedimentary deposits may record evidence of prehistoric earthquakes. For example, CPT can be used to identify areas suitable for trenching of active faults, as well as excluding less desirable trench sites. Closely spaced CPT soundings aligned along a profile provide detailed cross-sectional information, including lateral variation in composition and elevation changes of units. Recent advances in sensor technology have led to the use of CPT to install electrical-resistivity-tomography (ERT) electrodes and provide access for ground-penetrating-radar (GPR) antennas. ERT monitors and detects such subsurface processes as contaminant-plume migration. GPR uses high-frequency radio waves transmitted from one subsurface location and received at a second location. The radar traveltimes image soil-horizon boundaries, buried objects, or faults. CPT is useful to ground-water studies by measuring pore pressure, measuring in-place permeability, and sampling ground water and soil gas. For environmental site investigations, volatile-organic-compound (VOC) sensors in the cone can identify the composition of contaminant plumes and map their distribution and extent. Subsurface video imagery obtained with a cone-mounted camera can measure grain size, using a 20x magnifying lens and fiber-optic light source.

The U.S. Geological Survey CPT truck is available on a reimbursable basis for all research investigations by USGS staff and cooperators. The CPT truck provides a fast and inexpensive way to conduct shallow subsurface exploration. Detailed data are available immediately, permitting rapid mapping of subsurface features. CPT can expedite geologic-hazard, hydrologic, and environmental studies. This rapid and cost-effective approach is well suited for urban environments because no drill spoils are produced.

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