New dedicated CPT rig expands exploration and analytical capabilities

In September, Braun Intertec took possession of a new, dedicated cone penetration test (CPT) rig by Applied Research Associates, Inc., (ARA) Vertek. This new rig expands the range of subsurface geologic conditions that we can explore with CPT technology. While Braun Intertec’s truck, flotation-tire and track rigs by Central Mine Equipment Co. (CME) have been equipped for cone penetration testing for years, we only had the capability to push about six tons. The new CPT rig, meanwhile, can penetrate much deeper and into much denser soils. It also can push up to 20 tons. Another benefit of the CPT rig is that it is track-supported and fitted with a temperature-controlled operations cabin, which allows for around-the-clock, year-round access and exploration at difficult sites.

The CPT Advantage

The cone penetration test, developed in the 1950s, is one of the most popular and accepted in-situ test methods worldwide. The test is performed by pushing a cone (1.44 or 1.75 inches in diameter) into the ground at a uniform rate of just under one inch per second. Most modern cones are equipped with tip and sleeve load cells, one or more pore pressure transducers, inclinometers and seismic geophones. The load cells measure tip stress, sleeve resistance and local pore water pressure generated during the push. It sends that information to an on-board computer about once per second, where it is displayed graphically in real time. With this information, a subsurface geologic profile is characterized on a near-continuous basis as the cone is pushed.

Because most cones are not equipped to retrieve soil samples, soil classifications are typically inferred. With limited exceptions (fill of variable composition and/or compaction, for example), soil classification is of secondary importance. This is because structure performance is governed by soil strength, which is measured directly, and soil behavior, which can be determined from the data. However, sample collection is not a critical limitation with our Vertek equipment.

See DRILLING - Continued on page 2
Braun Intertec can retrieve soil samples from CPT locations by using a soil sampler specifically adapted for CPT equipment. Used in conjunction with the CPT cone, this device helps our engineers validate and refine CPT data and better determine soil type as the cone is advanced.

The constant, near-continuous collection and real-time display of data is invaluable. Thin layers of suspect soils can be revealed through CPT and marked for further evaluation by other methods. The push can be stopped and the soils subjected to additional tests using the cone. For example:

- **Pore water pressures in fine-grained soils** that are detected during the push can be allowed to dissipate. This provides the means to estimate hydraulic conductivity and, in turn, evaluate time-dependent embankment stability and settlement. The fact that the pore water filter is oriented horizontally within the cone is also strategic in that the results of the dissipation test can be combined with the results of laboratory hydraulic conductivity testing to evaluate soil anisotropy.

- **Seismic shear wave velocity** can be used to refine a number of soil properties. In seismic zones and where soil performance under vibratory loads is suspect, the cone can help estimate the speed of seismic shear waves generated by a seismic impact test. In addition to applicants in seismic and vibration loading areas, seismic shear wave velocity can also be used to estimate the stress-strain relationship of the soil. This is crucial in the estimation of deformation and settlement of soils under load.

Pore water pressure response during a push can also be interpreted to estimate the depth to groundwater and the presence of perched groundwater deposits. These conditions may require a significant investment in time and materials with other exploration methods (or in conjunction with CPTs, depending on the importance of the information).

**CPT versus SPT**

The CPT method provides more data from which the engineering characteristics of the subsurface geologic profile can be evaluated than the standard penetration test (SPT) method. It is also faster. While 80 to 120 feet of production is common using the SPT method of exploration, between 200 and 500 feet of production can be anticipated with the CPT method. The quality and reliability of CPT data is also considered superior. The Minnesota Department of Transportation has steadily added CPT to its fleet and it now has several dedicated CPT rigs. Still, SPT borings are more commonly performed for geotechnical evaluations, and there are a number of arguments for continuing to rely on the SPT method.

The SPT method involves advancing a hollow-stem auger into the ground, through which a split-spoon sampler is periodically lowered to retrieve soil samples for classification and possible laboratory testing. In the absence of laboratory tests, soil behavior is evaluated based on the penetration resistance or “N” value, which amounts to the number of blows required of a 140-pound hammer to advance the sampler one foot below the bottom of the advancing borehole.
DRILLING - Continued from page 2

In general, SPT borings can also be advanced to greater depths and through coarser, denser or stiffer materials (such as cobbly or bouldery soils or weathered bedrock) than can a CPT cone. SPT borings thus remain a valuable component of geotechnical evaluations to evaluate deep foundations or characterize shallow bedrock, among other things.

Sample collection is also important for evaluating both soil behavior and origin: A deposit of relative compact fill, for example, may have properties similar to those of naturally deposited soil but may contain or conceal compressible debris or decomposing organic material. Standard penetration testing, however, is typically performed at 2½- to 5-foot intervals, thus still leaving portions of the geologic profile unseen and uncharacterized.

Balancing Technologies

CPT technology has the potential to reduce engineering costs by accelerating the exploration process and gaining better data from which more targeted, economical designs can be provided. CPT technology is considered particularly advantageous for:

- large sites, roadway or utility alignments and multiple-structure sites or “corridors” (ex: wind farms, transmission lines) that require multiple day evaluations;
- embankments, general fills and other structures built on soft foundations where construction stability and the time-rate of structure settlement are critical; and for
- projects where groundwater and the flow of groundwater through the subsurface geologic profile is important.

If logs of SPT borings are already available, consideration can be given to completing an exploration program solely with CPTs. If no SPT data is available, however, consider performing some SPT borings to confirm soil classifications and origins inferred from the CPTs. The number and depth of SPT borings should be consistent with the project’s structural requirements.

But wait, there’s more!

Whether your primary exploration method is CPT or SPT, we’ve got another versatile tool capable of improving the quality of your data: the Geoprobe®. Purchased during the spring of 2009, the Geoprobe® is a tracked, remote-controlled, direct push rig that advances steel casing with a hydraulic hammer rather than by rotation. However, the Geoprobe® has the ability to switch over to perform auger borings and SPT borings with an automatic hammer accessory. The rig is compact and able to navigate confined spaces and terrain that larger CPT and SPT rigs cannot. Rubber tracks allow the rig to run and work on pavement. The casing is fitted with a plastic sleeve that collects soils penetrated by the casing. The sleeve extends the length of the casing so sampling is continuous.

This rig’s direct push method does not produce data from which the engineering properties of soils can be inferred. Instead, the main purpose of the method is to characterize subsurface geologic conditions thoroughly and quickly. Between 150 and 180 feet of production is not uncommon. Sleeves can be extruded and stored or cut open immediately for evaluation by an engineer or geologist, allowing suspect soils to be identified and targeted for possible further evaluation by other methods.

The Geoprobe® is a valuable companion to the CPT and SPT methods. The Geoprobe® can be fitted with an auto-hammer for SPT testing if N values are desired or if there are access issues with heavier, conventional truck or tracked rigs. Used strategically, the Geoprobe® can enhance the overall breadth of an exploration program. The continuous sampling from the Geoprobe® also lends itself well to confirming the soil classifications and origins inferred from CPTs, and to filling in stratigraphic gaps between CPT and SPT borings. It can do so both efficiently and cost effectively.

braunintertec.com
Using extensometers for good measure

An extensometer measures changes in an object’s length. Invented more than 100 years ago by Dr. Charles Huston, these devices can be very sophisticated with measuring accuracies in microns (millionth of a meter), to less sophisticated with accuracies to 1/100th of a foot, depending on a project’s needs. Braun Intertec uses extensometers for ASTM test applications where the strain associated with an applied load needs to be measured.

Extensometers can measure movement in soil and rock in geotechnical settings. The mining industry uses this technology to measure movement in rock faces or soil masses. This can provide engineers with valuable information regarding the potential failure of a rock face or soil mass due to pressure release associated with changes in slope or excavation geometry.

Recently, Braun Intertec installed extensometers for the NOvA project in northern Minnesota (see story on page 5). For this project, extensometers were installed horizontally into granite bedrock to measure movement in the rock face. However, the devices can also be installed vertically.

Sample extensometer data:

<table>
<thead>
<tr>
<th>Date</th>
<th>Gage 1</th>
<th>Gage 2</th>
<th>Gage 3</th>
<th>Temperature</th>
<th>Micrometer Readings</th>
</tr>
</thead>
<tbody>
<tr>
<td>16-Oct-09</td>
<td></td>
<td></td>
<td>5782.1</td>
<td>5782.7</td>
<td>2.6</td>
</tr>
<tr>
<td>19-Oct-09</td>
<td>5811.5</td>
<td>5795.2</td>
<td>5795.8</td>
<td></td>
<td>0.745</td>
</tr>
<tr>
<td>23-Oct-09</td>
<td>5806.3</td>
<td>5782.1</td>
<td>5782.7</td>
<td></td>
<td>0.943</td>
</tr>
<tr>
<td>30-Oct-09</td>
<td>5802.9</td>
<td>5788.9</td>
<td>5793</td>
<td></td>
<td>0.717</td>
</tr>
<tr>
<td>6-Nov-09</td>
<td>5802.9</td>
<td>5788.9</td>
<td>5788.1</td>
<td></td>
<td>0.956</td>
</tr>
<tr>
<td>12-Nov-09</td>
<td>5803.1</td>
<td>5789.4</td>
<td>5783.2</td>
<td></td>
<td>0.943</td>
</tr>
<tr>
<td>19-Nov-09</td>
<td>5813.6</td>
<td>5800.5</td>
<td>5791.8</td>
<td></td>
<td>0.798</td>
</tr>
<tr>
<td>24-Nov-09</td>
<td>5811.5</td>
<td>5794.6</td>
<td>5782.1</td>
<td></td>
<td>0.936</td>
</tr>
</tbody>
</table>

Note: 0.700

On another recent project for a tunnel in Excelsior, MN, Braun Intertec installed vertical extensometers. The extensometers were installed in the soils above the centerline of a force main tunnel to monitor soil displacement or settlement above the tunnel during and after construction. The extensometers were similar to those installed in the bedrock at the NOvA site. We have used two types of extensometers: Stainless steel rods that are connected together and fiberglass rods encased in flexible PVC casing as the connection between the stainless steel anchor points and the surface monitoring head.

* Congratulations to Jim Samuelson on his recent retirement from Braun Intertec. Jim worked for Braun Intertec for more than 30 years and we wish him well in this next phase of his life.

braunintertec.com
The NOvA Project
By Michael Heuer, PE and James Samuelson

The University of Minnesota NuMI Off-Axis Electron Neutrino Appearance (NOvA) detector facility is being constructed in northern Minnesota as part of a scientific project designed to learn more about the role of subatomic particles called neutrinos in the origin of the universe. Braun Intertec was contracted by the general contractor, Adolfson & Peterson, to install and monitor extensometers during construction of the facility to measure movement of the rock face during and after construction.

The detector construction required an excavation into granite bedrock approximately 50 feet deep, 65 feet wide and 350 feet long. The first of 16 extensometers was installed after the initial 20 to 25 feet of rock was removed. To install the extensometer, a 4-inch diameter hole was cored at an angle of 5 degrees or less from horizontal about 53 feet behind the face of the excavation.

The pre-assembled extensometer consisted of a reference head at the rock face and three anchor points set at about 10, 20 and 50 feet into the bedrock. The deepest anchor point in rock excavations is typically placed at a depth where it can be assumed that no movement will occur, resulting in a stationary reference point. The anchor points consisted of 3/4 inch stainless steel deformed bars about 8 inches long that were grouted in place. A 1/4 inch stainless steel rod, encased in 1/4 inch ID schedule 40 PVC pipe, was attached to the anchor point and extended to the head assembly at the face of the excavation. The PVC casing was weak enough that it would snap under tension so anchors would always follow movement of the adjacent rock and allow free movement of the stainless steel rods. Stainless steel rods extended to the surface and were used as measuring points. The PVC pipes were also compressible compared to the surrounding rock so they could accommodate a limited amount of compression as well.

The entire length of the assembly was grouted in place along with the head assembly. After the grout cured for at least three hours, the head assembly, which houses the electronic displacement transducers, was installed. After three days of grout cure the initial gage readings were made. Measurements can be taken either mechanically with a micrometer or with an electronic displacement transducer. The range of this particular extensometer was 50 mm with an accuracy of +- .01 mm (.000394 inches).
This issue’s questions reinforce the idea that the world we live in will always be changing, and that adversity is sometimes more readily overcome by leaning into rather than backing away from it.

Dear Professor:
A client of ours has a parking lot, about three years old, which was built over an old dump. The dump was supposedly cleaned out and backfilled prior to paving. Nonetheless, the pavement has settled several inches over the deepest portion of the backfill. Unfortunately there is no catch basin to collect the surface drainage that now ponds there. We’d like to develop a plan to restore grades, improve surface drainage control and reduce pavement maintenance costs, but don’t know how much more settlement to anticipate. How should we proceed?

To you and others dealing with civil unrest:
Settlement (and the rate at which it occurs) is driven by several variables, including:
1. The magnitude of the applied load,
2. The rate at which the load is applied,
3. The compressibility of the bearing materials supporting the load,
4. The degree to which the bearing materials are saturated, and
5. The hydraulic conductivity of the bearing materials.

When the applied load consists of fill (rather than a foundation, for example), the compressibility of the fill (a function of compaction) is also of interest. In most situations, variables are evaluated prior to construction. This is so the project can be designed to accommodate a certain amount of settlement, built to reduce the risk of settlement occurring, or both. In some situations (like yours), however, such variables are used to reconstruct a project “stress history” and determine how/why settlement occurred, and if settlement is likely to continue. This will help in developing appropriate mitigation plans.

From the information you provided, all we know is that the dump was cleaned out and backfilled about three years ago and that the pavement has subsequently settled “several inches.” To get any sense of what happened and what you might still be in for, we’d need to know a little more about the backfill, such as:

- How much was placed?
- What did it consist of, and to what extent was it compacted?
- What did the materials that the backfill was placed upon consist of, and were they loose, dense, soft or stiff?
- Where is/was the groundwater?

Logs of exploratory borings taken prior to construction would be a good place to start, since knowing what was there to begin with would at least allow some of the undefined variables to be inferred. Reports of conditions observed prior to placement of the backfill, and the results of compaction tests, would also help evaluate the contribution of the backfill to the problem. In the absence of this and other data (such as laboratory consolidation and hydraulic conductivity testing), and to some extent even with all this data, it is difficult to verify and weigh the contribution of each variable to the observed settlement. This also makes it difficult to estimate how much more settlement is likely to occur.

At a minimum, you should consider advancing some borings through the backfill and into the underlying bearing materials so the composition and consistency of the backfill and bearing materials can be determined. Some laboratory tests should also be performed to allow the compression characteristics of both materials to be characterized. Finally, if there is time, the parking lot should be surveyed periodically so the magnitude and rate of any on-going settlement can be determined in real-time. With this, the excavation/backfill process and post-construction performance of the parking lot could be replicated analytically and the appropriateness and effectiveness of one or more mitigation plans demonstrated.

See PROFESSOR - Continued on page 7
Dear Professor:

I’m trying to better understand the geotechnical states of stress and strength parameters that apply under sustained and transient loading conditions. I understand how a sustained load is more or less a “permanent” load, having been in place long enough for drained, effective stress conditions to exist, and soil strength to be governed by internal friction. But why is the state of stress different in the case of transient loads? If a structure has already been in place for a long time, how do transient loads change the state of stress and strength parameters used for analysis?

To better negotiate the winds of change:

Sustained loads are permanent (dead and live) loads. They are, as you say, in place “long enough” so that soil/structure interaction is governed by long-term, drained, effective stress conditions (and internal friction). Meanwhile, transient loads, like wind and seismic loads, are periodic and of sufficiently brief duration so that soil/structure interaction is initially governed by undrained, total stress conditions (and cohesion). But, as time passes (depending on the duration of the load and soil type), partially drained or drained effective stress conditions apply. For example:

- For sands, un-drained conditions may last only momentarily, as the soil may be sufficiently permeable to dissipate load-induced pore water pressures very quickly, and soil/structure interaction over the duration of the transient load may be largely governed by partially drained and/or drained, effective stress conditions.

- For clays, the transient load may be sufficiently brief for undrained total stress conditions to govern over the duration of the transient load. We need to apply appropriate parameters to different loading conditions, based on load duration and soil type, to demonstrate that structure stability is not being compromised under any state of stress.

One consequence of misunderstanding the nature of transient loads is excessive deformation. We typically recommend, for example, a net allowable bearing capacity for sands that includes all transient loads. This is because sands drain relatively freely and are apt to experience permanent deformation under even short-term transient loads. In not allowing a temporary increase in bearing capacity for sands, we assume that structures supported on the sands will be appropriately over-designed so that, when exposed to transient loads, the resulting deformation does not exceed the desired or required tolerance. For clays and other fine-grained soils that are not free-draining, we can offer a temporary increase in bearing capacity because the transient loads will initially be resisted by pore water pressure. Also, permanent deformation will not occur if pore water pressures cannot drain before the load subsides.

Another consequence is failure. If we understand the relationship between load application and a soil’s hydraulic response (hydraulic conductivity and pore water pressure dissipation versus load duration), we can make a more appropriate determination of soil/structure stability. Excavations in clays and other fine-grained soils (a transient or short-term un-load) can be analyzed assuming that undrained, total stress conditions (and cohesion) apply if the time over which the excavation is unsupported is short relative to drainage. Over time, however, suction (negative pore water pressure) induced by the un-load diminishes, pore water pressures gradually return to pre-excavation levels, and excavation stability is governed by drained, effective stress conditions (and friction), often leading to a reduction in excavation stability.
Don’t let contaminated sediment thickness measurements leave you all wet

From a customized boat for testing over water to our all-terrain drill rigs, we have the right equipment for your sediment testing needs. Our capabilities include:

- Sample collection of sediments
- Chemical testing of sediments
- Gradation (sieve) testing
- Environmental evaluation of commercial/industrial activities within a watershed
- Data evaluation, reporting, and material disposition recommendations
- Dredging permitting

For more information, contact Mark Ciampone at 651.487.7015.