Cone Penetration Test

The cone penetration test (CPT) is an in-situ sounding that pushes an electronic penetrometer into soil and records multiple measurements continuously with depth. Compared with rotary drilling and SPT, the CPT is rapid, cost-effective, reliable and repeatable (i.e. the influence of the equipment operator is minimized), produces continuous profiles, and generates no spoil. CPT results are available immediately in the field for assessment by the Design Office geoprofessional. CPT is performed in accordance with ASTM D5778 "*Standard Test Method for Electronic Friction Cone and Piezocone Penetration Testing of Soils*".

CPT data is most commonly used to determine the vertical distribution of soil behavioral types. A model of the vertical and lateral distribution of soil types can be determined when the data from several CPT soundings and boreholes are combined. CPT data can also be used to estimate common soil engineering properties, as well as soil liquefaction susceptibility.

CPT cannot be performed in rock or cemented soils. The test also cannot be used in gravel and gravelly sand. If you have questions about using CPT in a given formation, contact the Geotechnical Instrumentation Branch (GIB). With some exceptions related to stratigraphy, the CPT can be performed in very loose to medium dense cohesionless soil, and very soft to stiff cohesive soil. It is sometimes possible to penetrate dense cohesionless soil or very stiff cohesive soil if they are located within 60 feet of the ground surface. The CPT may not be successful where dense cohesionless soil and very stiff cohesive soil are overlain by a thickness of more than 10 feet of weak soil.

The cone penetrometer tip cannot penetrate asphalt or concrete pavement. It is necessary to remove the pavement by pre-drilling or coring prior to attempting a Cone Penetration Test.

The GIB provides CPT services with a truck-mounted penetrometer. GIB normal work schedule is 0700 hrs – 1630 hrs, Monday through Friday (9/80 schedule). An alternate work schedule may be requested when CPT hours are subject to external constraints (e.g. to accommodate a traffic management plan or permit constraints). In consultation with the geoprofessional, GIB management will determine the most appropriate schedule based on safety, efficiency, maximizing drilling time, Bargaining Unit 11 contract rules, commercial driver's regulations, and minimizing overtime. Drilling priorities will be set by project schedule needs and job readiness.

Requesting CPT Services

All Geotechnical Services employees are responsible to comply with the following CPT request process to ensure compliance with GS-01, California State Law, and applicable Local Enforcement Agency (LEA) requirements. More specifically, GS Managers and Supervisors are responsible to consistently monitor and actively manage this Drilling Request Process.

The process for requesting CPT work includes the following steps:

1) The geoprofessional must obtain a LEA determination document and LEA permits/conditions. (see Geotechnical Manual – Supplement A (GMSA))
2) The geoprofessional must complete the CPT work request (a-k below)
    a. CPT Request Form
    b. Layout Plan Sheet
    c. Site Assessment Questionnaire
    d. Allowable Lane Closure Times (if applicable)
    e. Site Vicinity Map
    f. LEA C-57 determination document (see GMSA)
    g. LEA requirements including but not limited to special conditions and required grout mixes (see GMSA)
    h. Site Safety Plan
    i. All applicable permits (encroachment, environmental, R/W, etc.) (See Geotechnical Investigations).
    j. Coring and/or other field support activities identified and coordinated
    k. A valid USA ticket number (needed prior to start of CPT field work)
3) The geoprofessional provides the work request to the design branch chief.
4) The design branch chief performs a quality check on the work request to ensure it contains all of the required documents, is legible and completed in a quality manner.
5) If the design branch chief identifies any errors or problems, the geoprofessional will be instructed and notified in writing to ensure all corrections are resolved.
6) The geoprofessional submits the approved work request to the Geotechnical Instrumentation Branch Chief (GIBC). Documents must be submitted to the GIBC by email at Gem-Yeu_Ma@dot.ca.gov (hard copies will not be accepted).

Upon GIB receipt of the final work request:

1) The GIBC will notify (by email) the geoprofessional and design branch chief if the work request is incomplete identifying item(s) requiring correction. The geoprofessional and design branch chief must correct and re-submit the work request to the GIBC at Gem-Yeu_Ma@dot.ca.gov.
2) The GIBC will distribute the work request to the CPT Technician responsible for the CPT activities.

3) The GIBC will review the work request and instruct the CPT Technician to ensure a complete understanding of the requested work.
4) The GIBC and CPT Technician will initial the work request confirming the review and acceptance of the planned work and any LEA permit/conditions by the CPT Technician.
5) The GIBC retains the documents in the GIB File Retention Center.

Cone Penetration Test (CPT) Request Form

Complete the *Cone Penetration Test (CPT) Request Form* and obtain a supervisor's approval signature. Include preliminary information on traffic control, pavement and/or slab coring, permits, and constraints on when the CPT can be conducted.

Site Preview Meeting

The geoprofessional must schedule a meeting with the CPT crew to review the work request utilizing project site plans, Caltrans Earth, and/or other pertinent information to evaluate site accessibility, the need for traffic control, and/or pre-testing coring. A site visit will be required if either the geoprofessional or CPT crew determines it is necessary in order to address concerns raised in the initial meeting. The goals of the Site Preview Meeting are similar to those of the same meeting described in the Geotechnical Drilling section of the Geotechnical Manual.

Site Safety Plan

Follow the instructions to complete the Site Safety Plan as described in the Geotechnical Drilling section of the Geotechnical Manual.

Site Assessment Questionnaire

Follow the instructions to complete the Site Assessment Questionnaire as described in the Geotechnical Drilling section of the Geotechnical Manual.

Layout Plan Sheet

The layout plan sheet presents the requested boreholes on a plan sheet (aerial photo, general plan, etc.) so that a reviewer can understand where the boreholes will be located relative to pertinent existing site features, such as a bridge, building, or stream. The layout plan sheet must include:

- Planned boreholes, including for each hole:
  - Type(s) of drilling (rotary, coring, etc.)
  - Depth
  - Instrumentation (piezometer, SI)
  - Estimated depth to groundwater

- Pertinent existing features (bridge, stream, highway, etc.)
- Access routes

Roles and Responsibilities

The geoprofessional is responsible to direct the CPT work, both in the office and the field, to meet project requirements which include the location and depth of soundings, frequency and duration of dissipation test(s), and depth interval of shear wave velocity measurements. The geoprofessional is responsible for identifying and obtaining permits, traffic control services, pavement coring services, and other site preparations such as equipment access. The geoprofessional is responsible for interpretation of the test results presented in the CPT Report.

The CPT crew is responsible to conduct the testing in accordance with ASTM D5778, and to conduct reliable and repeatable tests. The GIB engineers are responsible for performing a quality review of the CPT data, reporting the data to the geoprofessional, and archival of the raw test data.

Description of Caltrans CPT Equipment

The Geotechnical Instrumentation Branch has a 20-ton CPT truck with VTK Series Heavy CPT Platforms manufactured by Vertek. The CPT truck is capable of pushing the rods to a maximum capacity of 20 tons or to a maximum depth of 160 feet.

Several 15 cm^2 digital cones (standard (CPT), piezocone (CPTu) and seismic (SCPTu)) are available for use according to geoprofessionals needs. A standard cone contains tip and sleeve transducers. A piezocone contains tip, sleeve and pore water pressure transducers. A seismic cone consists of tip, sleeve, and pore water pressure transducers, and seismic tri-axial geophones.

Field Testing Procedures

Caltrans CPT testing procedure follows ASTM D5778 “Standard Test Method for Electronic Friction Cone and Piezocone Penetration Testing of Soils.”

Pre-drilling and Coring

For a CPT sounding to be conducted at a site covered with asphalt concrete, concrete, or near-surface gravel/cemented soil, pre-drilling or coring with a minimum diameter of six (6) inches must be completed prior to the sounding. The work should be coordinated by the geoprofessional through Drilling Services, District Materials or Maintenance.

Data Collected

The CPT cone is pushed into the ground at a constant rate of 20 mm/sec (approximately 1 inch per second), and continuous measurements of tip resistance and sleeve resistance are

recorded in the data acquisition system (Datapack 2000) at intervals of 30 mm (0.1 ft.). In a piezocone (CPTu) or a seismic cone (SCPTu), pore water pressures are also recorded.

A pore water dissipation test can be performed at any depth using a piezocone or a seismic cone. The CPTu test with a pore pressure transducer has the potential of providing estimates of the in situ coefficient of consolidation from a dissipation test.

The geoprofessional should consider piezocones to obtain measurements of pore water pressure to correct the cone tip resistance for pore water pressure effects, especially in soft clays and silts. The rate of pore water pressure dissipation also provides valuable information on soil behavioral type. In cohesionless soils, excess pore water pressures will dissipate rapidly, but take hours in cohesive soils.

The SCPTu provides quick and efficient measurements of shear and compression wave velocity profiles while performing a CPTu test (tip, sleeve, and pore pressure) at specified depth(s) of interest. Seismic waves generated on the surface are detected down-hole by three geophones mounted inside the seismic cone (true-interval method). Data gathered down-hole goes directly to the data acquisition system. The CPTu test is paused briefly to conduct the seismic tests at specific depths. Individual seismic tests include the recording of two opposing shear waves (S-Wave) and one compression wave (P-Wave).

Field Operations

Prior to performing the field investigation work, the geoprofessional must preside over the initial tailgate safety meeting. Subsequent tailgate safety meetings may be conducted by the CPT operator. Refer to the Code of Safe Drilling Practices for procedures.

During Cone Penetration Test (CPT) operations the geoprofessional is responsible for the following:

- Showing the drillers all USA markings, overhead utilities, marked utilities close to proposed boring locations, environmental constraints and safely positioning the borehole.
- Maintaining communication with support personnel (e.g., Maintenance, Consultants, District or Structures P.E.).
- Determining the sequence of work and exact location of the CPT sounding. However, the geoprofessional must be aware that due to equipment and access limitations, the CPT crew may not be able to set up on the exact spot. If exact locations are required it should be noted on the CPT request and discussed with the CPT crew during the site preview.

  Whenever practicable, the sequence of CPT operation should take into account the possibility of eliminating sounding locations if the site conditions are predictable

or uniform. Typically it is better to alternate sounding location ends and sides at a site rather than starting at one end and drilling consecutive holes. Efficiency relating to access restrictions need also be considered. A CPT sounding program should always be flexible and consider information as it is obtained.

- Directing the CPT crew when and where to conduct tests (dissipation, shear wave velocity) and when to end dissipation tests in cohesive soils. The geoprofessional is advised to discuss the goals of the CPT sounding with the CPT operator (e.g., geotechnical features being explored, foundation types, subsurface expectations). The CPT crew will be more inclined to communicate back to the geoprofessional the subtle information that they note while conducting tests if they know the goals of the investigation.
- Informing the CPT crew (and if necessary halting CPT operations) if standards are not being met. Examples include: not carefully checking "zero-load readings", not checking dimensions of cones (wear and tear), not providing current calibration sheet, not properly saturating the piezocone filter, etc.
- Communicating modifications to the sounding plan to the CPT crew. Encountering unexpected conditions, either favorable or unfavorable, may necessitate modifications by the CPT crew.

During CPT operation the CPT crew is responsible for the following:

- Carrying out functional checks during the field works and routine/as-needed calibrations before and after the field works
- Performing sounding according to the accepted test standards
- Acquiring and maintaining of CPT sounding data throughout the entire field works, and reporting all test data to GIB engineers for quality review and report preparation. Upon request, preliminary raw data may be provided to geoprofessional in the field
- Grouting or sealing the test holes after the sounding is completed according to the requirements established by the local enforcement agencies.

Borehole Backfill

A Borehole Backfill Data Sheet (BBDS) is required for all CPT soundings (see GMSA).

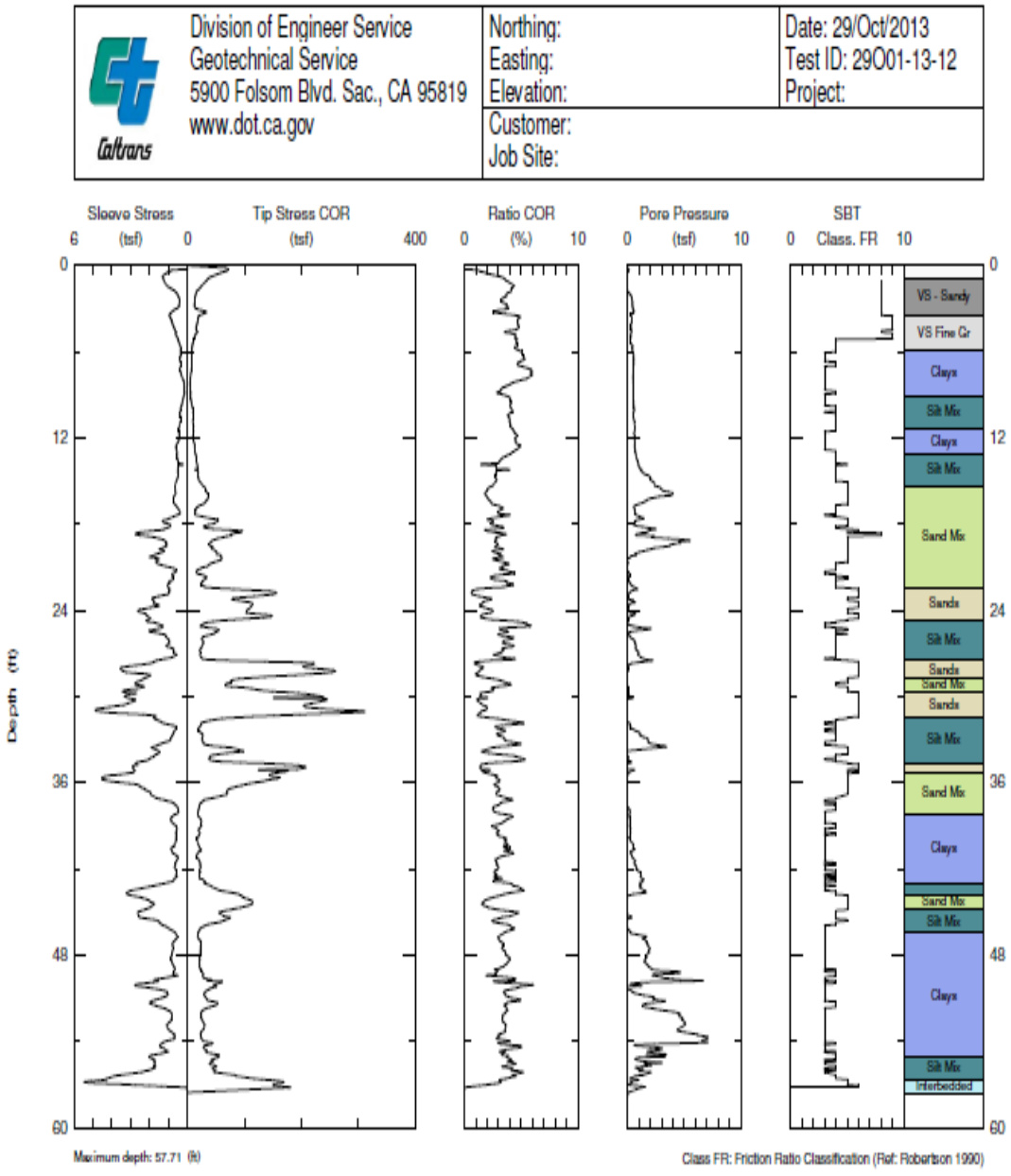
CPT Sounding Report

An electronic copy of the draft CPT sounding report (excluding shear wave velocity tests) is available at the completion of each sounding in the field upon request. The final CPT sounding results will be reported to the client within one week of the completion of all CPT work.

As shown on Figure 1, the CPT reports present sleeve stresses, corrected tip stresses, and corrected friction ratio vs. depth in side-by-side graphics. Pore water pressures are reported for tests using piezocones and seismic cones. Shear wave velocities are reported for seismic tests using the seismic cone. The CPT report provides un-interpreted test results for use in determining soil behavioral types and profiles.

The CPT report provides a general prediction of soil behavioral types based on the method developed by Robertson et al (1990). The CPT soil parameters used in the Robertson (1990) chart require normalization for overburden stress. Robertson divided soils into nine-zone soil behavioral type (SBT) as a guide to determine soil types. Prediction of soil types based on CPT is referred to as SBT. The SBT zones may be somewhat overlapped and need some adjustments based on local experience.

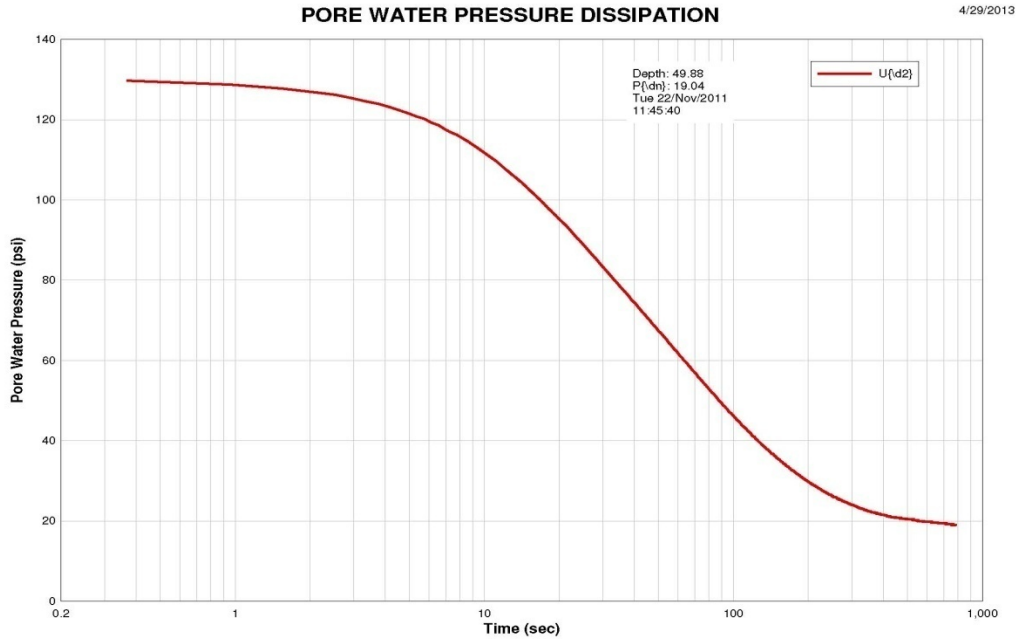
Figure 1 – CPT Sounding Report



Pore Water Pressure Dissipation

Dissipation tests are reported in semi-log plots of pore water pressure vs. time (Figure 2). Duration of the pore water pressure dissipation test typically continues to the point where 50% dissipation of pore water pressure can be determined, or continue until no obvious dissipation is noted.

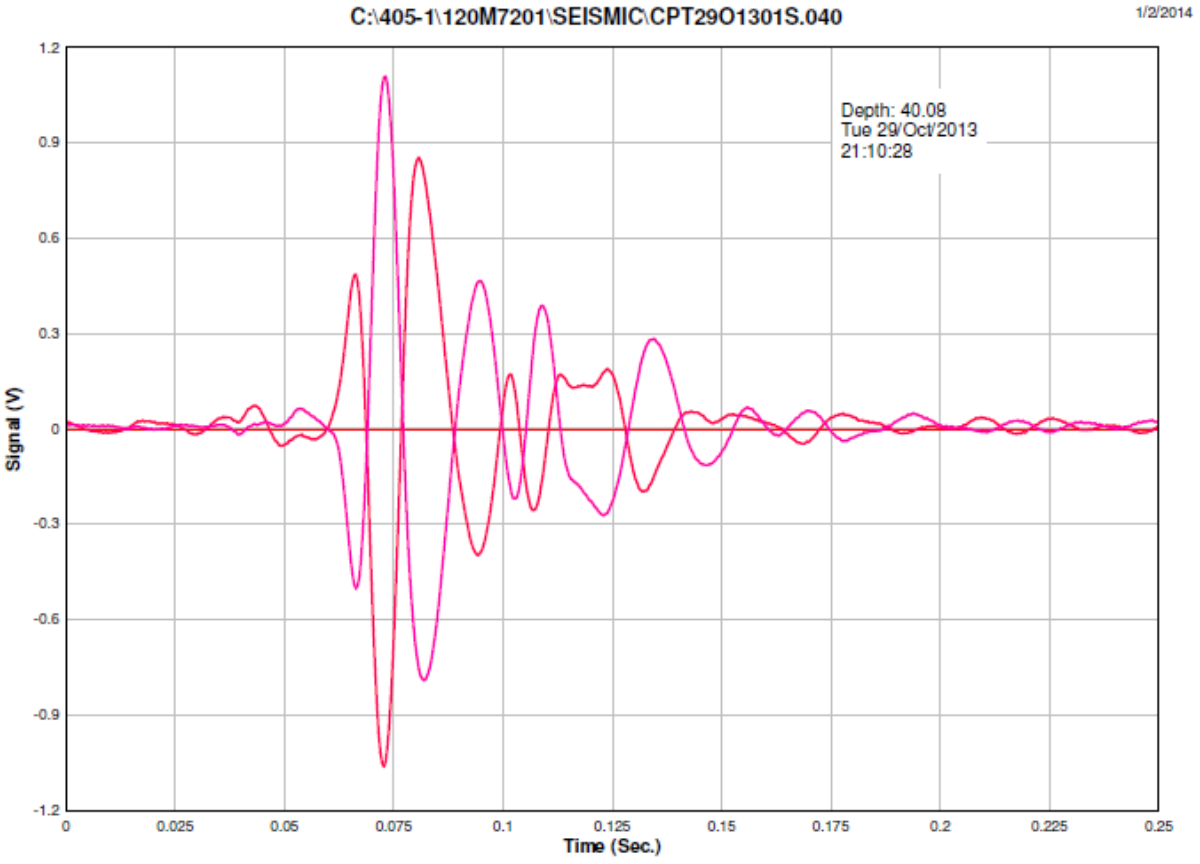
Figure 2 – Pore Water Pressure Dissipation Test



Shear Wave Velocity

The shear wave velocity is determined by SCPTu. Individual seismic tests include the recording of two opposing shear waves (S-Wave) that are reported as shown in Figure 3. The geoprofessional will calculate the shear wave velocity by determining what signal arrival time is to be used from the test results provided. The seismic test data are then analyzed by the geoprofessional to create a profile for seismic wave velocities, damping characteristics, and soil strength parameters.

Figure 3-Shear Wave Velocity Measurement

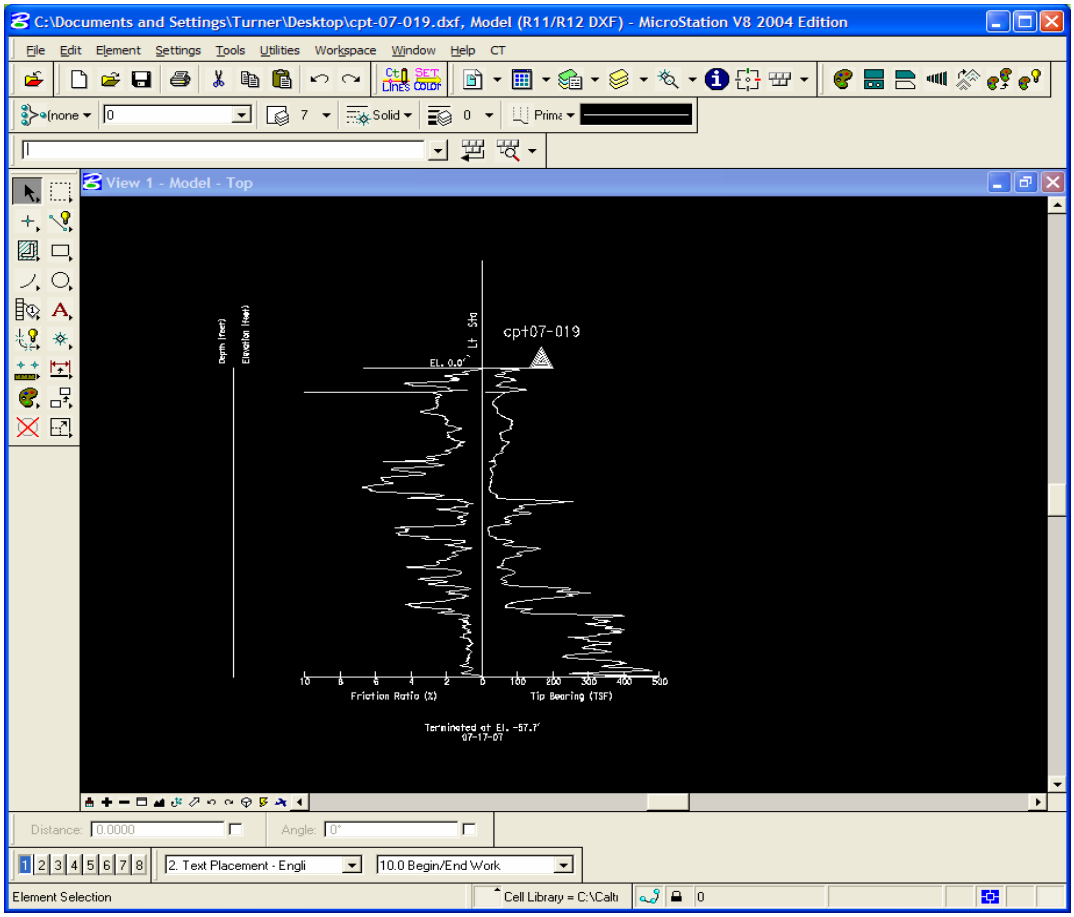


Report Formats

The CPT reports are presented in four different formats:

- The CPT data graph and soil behavioral type in pdf format (Figure 1)
- An un-interpreted data file (cvs) in Excel spreadsheets
- A gINT data file (gIN) generated by Vertek CPT to be used in gINT program
- A dxf file exported by gINT that can be used for Caltrans LOTB plotting in Microstation (Figure 4)

Figure 4- CPT results presented in Caltrans LOTB (Microstation)



References

1. ASTM D5778, "*Standard Test Method for Electronic Friction Cone and Piezocone Penetration Testing of Soils*"
2. FHWA-SA-91-043, "*The Cone Penetrometer Test*", 1992
3. NCHRP Synthesis 368, "*Cone Penetration Testing*", 2007
4. Caltrans CPT Class Notes, 2011

Revisions

- Supersedes "Cone Penetration Test", Caltrans Geotechnical Manual, May 2014