INVITATION

Prediction of Pile Load-Movement Response and Assessment of Pile Capacity

at the ISSMGE TC212 Bolivian Experimental Site for Testing (B.E.S.T.)

Organized in connection with

the Third Bolivian International Conference on Deep Foundations

Registration

Please register your intent to submit a prediction at the below link or inform Bengt H. Fellenius directly at e-address: <bengt@Fellenius.net>. You will then receive all information on soil and piles as well as template for submitting a prediction:

{ http://www.cfpbolivia.com/web/page.aspx?refid=160 }

All submitted predictions will be kept confidential and only known to Dr. Fellenius, who in reciprocal confidence will share his prediction with the participants in due course, i.e., on the dead line date before the static tests are carried out.

Introduction

The Third Bolivian International Conference on Deep Foundations (C.F.P.B), scheduled for April 27 through April 29, 2017, in Santa Cruz, Bolivia, is building on the success of the First and Second Bolivian Conferences of 2013 and 2015. In connection with 3rd C.F.P.B., the first research results from the ISSMGE TC212 Bolivian Experimental Site for Testing (B.E.S.T.) will be presented. The research site is located in Santa Cruz, Bolivia, where an extensive site investigation program is being carried out, comprising different types of geotechnical and seismic methods. The forthcoming first-phase research programme concentrates on testing same-length (9.5 m) piles having different diameter and constructed using different methods. Static loading tests will be carried out on single piles and on a pile group. Dynamic tests will be performed on several of the piles and integrity tests will be carried out on all piles.

Figure 1 shows the pile locations. The head-down tests will use four reaction piles placed in a square configuration with a 5 m center to center distance with the test pile in the center (the distance between test pile and anchor pile is 3.5 m). The piles intended for static testing will be installed to a depth of 9.5 m, i.e., about 1.5 m above the about 1 m thick soft clay layer. (The length of the piles intended for integrity testing demonstration will not be disclosed).

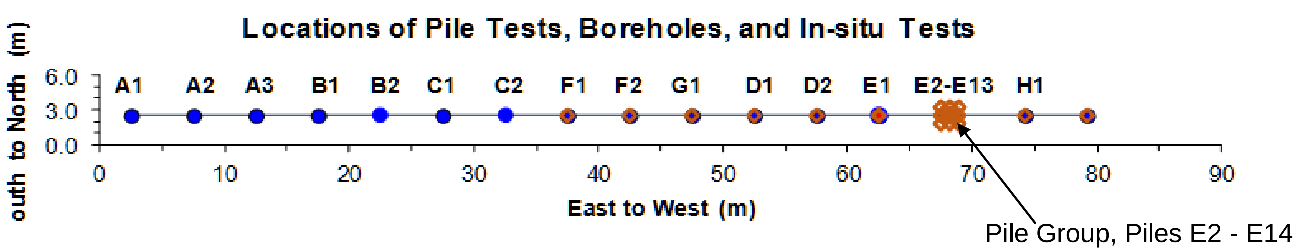


Figure 1. Test pile locations.

Four single piles have been chosen for a prediction event that intends to provide the opportunity for trying out one's ability to predict the response of a pile in a well-defined geotechnical setting with the consequence of being wrong affecting nothing but personal pride. It is expected to be a highly entertaining, enlightening, and revealing affair. However, the test results will also enhance the understanding of load and deformation response of individual piles and pile groups and the comparison of predictions will be an indication of the current state-of-practice of analysis of static response.

Participants in the prediction event will have the opportunity to see how their own experiences and approaches correlate to the conditions at Santa Cruz, Bolivia, and to those of their colleagues and friends. The predictors who attend the conference will be able to exchange points of view with other “experts".

The prediction event is coordinated by Dr. Bengt H. Fellenius and consists of evaluating the response of four single test piles of different types **and** a group of 13 piles constructed in a relatively homogenous alluvial fine sand deposit in Santa Cruz, Bolivia. Dr. Fellenius (<bengt@Fellenius.net>) will send a link for obtaining all necessary pile and soil records to everyone registering intent to submit a prediction.

Pile Types

The piles will be installed to 9.5 m depth and the following piles are included in the prediction event:

Pile A3: a 620-mm diameter Bored pile with retrievable casing.

Pile B2: a 450-mm diameter Continuous Flight Auger (CFA) pile.

Pile C2: a 450-mm diameter Full-Displacement-Pile (FDP).

Pile E1: a 220-mm diameter Full-Displacement-Pile (FDP) pile.

Piles E2-E14:a group of piles same as E1. Bidirectional tests will be simultaneous on all piles.

The piles will be instrumented with sister-bar strain-gages and telltales and constructed during February 2017 and tested in early March 2017. The prediction effort does not include the results of the instrumentation measurements.

The layout in plan of the E-pile group is shown in Figure 2.

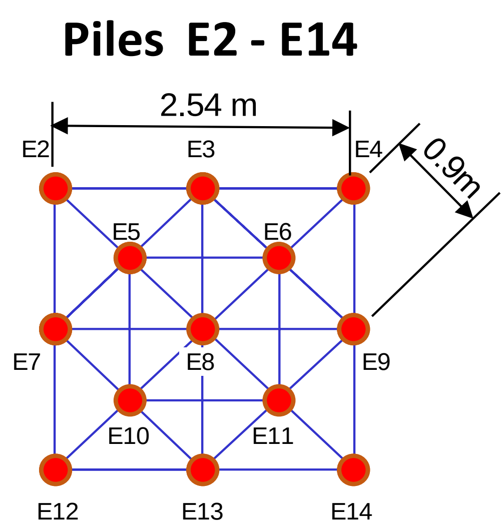


Figure 2. Layout of E-Piles in plan.

All persons interested in predicting the pile-head and pile toe load-movement curves, and the capacities determined from the predicted load-movement response are invited to participate by submitting a prediction per the prescribed format (an Excel template is included with the detailed soil information in the prediction package). A contribution will be accepted and included with the compilation of the test results if it at least includes a prediction of the pile-head load-movement response and capacities of Piles A3, B2, and C2. The identity of the persons submitting a prediction will be kept confidential and only known to Dr. Fellenius.

Naturally, all predictions must be submitted before the start of the loading tests. Thus, and to allow the results to be compiled so they can be presented to the conference, the dead line for receipt is March 6, 2017. The intent is to have the dead line coincide with the start of the static loading tests.

Pile Construction Details

The cylinder strength of concrete and mortar is designed to be 30 MPa (≈4,300 psi). The reinforcement cage consists of six 12-mm bars in Piles A3, B2, and C1 and four 12-mm bars in Piles E. All reinforcement cages have a 6-mm spiral with a 250-mm pitch. All test piles are intended to be constructed to 9.5 m depth. All reinforcement cages are instrumented with strain-gages and, for the E-piles, a bidirectional cell at the bottom end.

Test Pile A3 is a bored pile constructed with a 620-mm diameter casing that is retrieved on concreting the pile. Once the final depth is reached, the 500-mm reinforcement cage is placed in the casing. Thereafter, the concrete is pumped into the shaft starting at the toe of the pile and the casing is gradually withdrawn.

Test Pile B2 is a CFA pile constructed by drilling a hole with a 450 mm O.D. auger having a 250-mm (O.D.) central stem. After reaching the predetermined depth below ground surface, mortar is placed by injecting it through the central stem during the withdrawal of the casing. The 300-mm diameter reinforcement cage then inserted in the shaft.

Test C2 is a FDP pile constructed without removing any soil (but for nearest the ground surface on starting the pile). The equipment consists of a 440-mm O.D. displacement body (pipe) with a 800 mm long bulb attached to a 1.15 m long auger with a 350-mm diameter. The auger rotation pulls down the displacement body. The auger has a short conical tip that is left in the hole upon completion (“lost bit”). On reaching the predetermined depth below ground surface, the 200-mm O.D. reinforcement cage is placed in the ecasing. The concrete is then pumped through pipe and auger to exit at the auger tip while the FDP pipe and auger are withdrawn.

Test Piles E1 and E2-E13 are FDP piles constructed similar to the Pile C2, but using a 300-mm O.D. displacement body (pipe) with a 500 mm long bulb attached to a 0.22 m long auger with a 300-mm diameter. Over the lowest 1.0 m length, the diameter of the displacement body is 150 mm. On reaching the predetermined depth below ground surface, mortar is injected through the central stem, while the FDP pipe and auger are withdrawn. A 150-mm O.D. reinforcement cage is then lowered into the fresh mortar through the pipe, displacement body, and auger. No lost bit is used.

Each E-pile will be equipped with an Expander Body (EB) attached to the reinforcement cage to ensure a toe resistance larger than the shaft resistance. The EB is constructed by expanding a folded steel cylinder by injecting grout. The 9.5-m installation depth is the depth of the EB end before inflation.

For the E-piles, a 260-mm (OD) bidirectional cell (BD) will be placed above the EB with the BD bottom plate at 8.3-m depth, as shown in Figure 3. At installation, the EB width is 110 mm which is expanded to 300-mm width by means of pressure grouting after the shaft is concreted. The soil below the EB is thereafter pressure grouted. The 9.5-m pile toe depth is defined as the depth to the EB bottom end before inflation. The static loading test will be carried out by activating the bidirectional cell to generate upward and downward pile movement. The test on the group piles (E2-E13) will be carried out by simultaneous (equal load/pressure) action from the BDs while measuring the upward and downward movements of each pile.

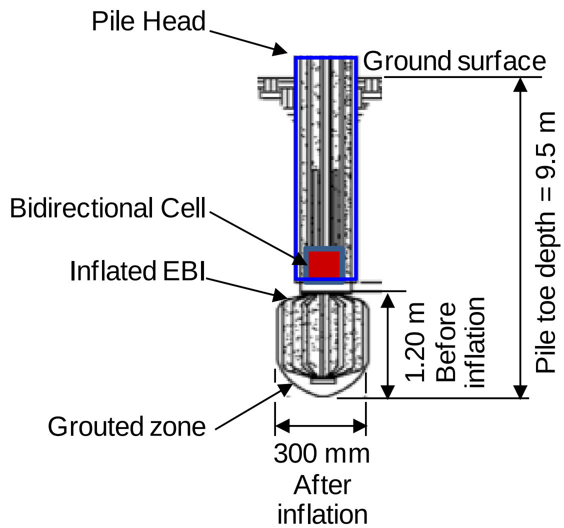


Figure 3. Sketch showing the E-Pile arrangement (not to scale).

Site Geology

The geology of the Santa Cruz area is a Paleozoic (250 million years old) sedimentary basin. The soils of interest to civil engineering construction, the surficial soils, are quaternary with the dominant minerals being calcite, silica, and feldspar. The main agent is the Piray River and its tributaries, which meandering over the area has resulted in a sedimentation-erosion-sedimentation process and a profile dominated by fine to medium sands with intermittent layers of clay or clayey sand. The geology in and around the city is such that even light buildings need to be supported on piles.

The geotechnical conditions of the site has been investigated using conventional in-situ and laboratory methods. All who have registered intent to submit a prediction will receive a zip file will all available soil information (or a link to from where it can be downloaded).

Experience from pile driving and testing in the area of the test field as well as the results of the prediction events of the first two conferences is available in the following three references:

337. Terceros, B.H. and Fellenius, B.H., 2014. Piling practice in the sedimentary granular soils of Santa Cruz, Bolivia. Proceedings of the DFI-EFFC International Conference on Piling and Deep Foundations, Stockholm, May 21-23, pp. 379 386.

338. Fellenius, B.H. and Terceros, B.H. 2014. Response to load for four different bored piles. Proceedings of the DFI-EFFC International Conference on Piling and Deep Foundations, Stockholm, May 21-23, pp. 99 120.

348. Fellenius, B.H., 2015. Field Test and Predictions. Segundo Congress International de Foundations Prefunds de Bolivia, Santa Cruz May 12-15, Lecture, 22 p.

Copies of the papers can be downloaded from {www.fellenius.net} "download papers". The numbers refer to the sequence number of the papers available for downloading at the web site.

Instrumentation

The pile head movement will be measured against two reference beams supported on the ground at a 2.5 m distance from the test pile and placed parallel to the pile center line. The toe response of the piles will be measured by means of telltales. The E-piles will have four telltales, two measuring between the pile head and the bottom of BD plate and two measuring the between the pile head and the upper BD plate. Subtracting one from the other will give the opening of the BD cell.

Pile Test Methods and Procedures

The test procedure will be according to the "quick method" consisting of a series of equal load increments. The load increments will be about 5 % of estimated maximum load (organizers' prediction). The loads will be applied at precisely 15-minute intervals and held constant during each interval until either a load is reached that produces excessive movement requiring continuous supply of hydraulic fluid, the 100-mm maximum jack or BD opening has developed, or the maximum available jack or BD load is reached, whereupon the pile is unloaded (the hydraulic pressure is released with no pumping or attempt to maintain pressure) in five or six about equal decrements, each maintained for 5 minutes.

The test will continue until either the pile plunges or the limit of available force, or the limit of expansion of the jack or BD is reached.

Soil Exploration Records

At each single pile location and at the location of two piles of the group (E-piles), the following tests have been performed:

- SPT (standard penetration test). Dynamic measurements were made to determine the transferred energy ratio (ETR). The data include torque measurements.
- CPTU (piezocone penetration test)
- PMT (pressuremeter tests)
- SDMT (seismic dilatometer test)
- SASW and REMI geophysical tests

Each borehole and field test is identified with the letter of its designated test pile and located at 0.80-m radial distance from the test pile. The first four in-situ tests are placed in the corners of a square inscribed in an octagon with it sides parallel with the line between the test piles. Any additional in-situ tests will be placed in the opposite corners of the octagon.

All test records will be provided in a Prediction package which will be provided to all who register intent to submit a prediction. The geophysical test records are not yet available but will be added to the package at a later date as they become available.

Each borehole, CPTU sounding, etc, is labeled with the letter of its designated test pile and located at a 0.80-m radial distance from the test pile.

The water content and grain size distribution will be determined for all samples and the samples will be classified for soil type per the Unified Soil Classification System (USCS). For cohesive samples, consistency limits (LP and LL) will also be performed.

The SPT weight was 62.5 kg and the free-fall height was 760 mm. Nominal energy is 466 J. Dynamic tests were carried out on the SPT equipment at BH-B2 Depths from 6 through 9.5 m. The transferred energy ratio (ETR) for the test are shown in Figure 4. The mean value was 44 %.

Appendix 1 contains a set of graphs compiling the Borehole and CPTU exploration records at locations A3, B2, C1, E1, and E2.

Visit www.cfpbolivia.com for information on the conference.

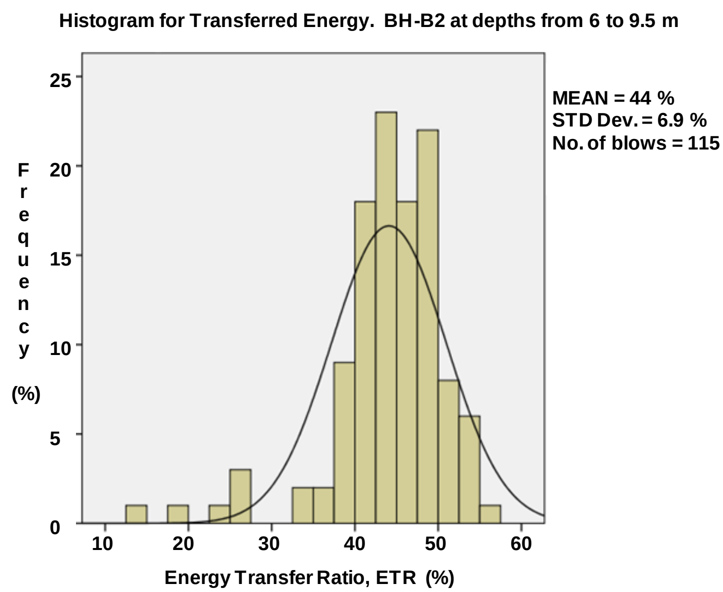


Figure 4. Histogram of transferred energy at BH-B2, depths 6 m through 9.5 m

Prediction Submission

Each participants is requested to:

(1) Predict the pile-head load-movement curves for each of the head-down static loading tests on Piles A3, B2, and C2.

(2) Assess the capacity of Piles A3, B2, and C2, respectively, from the head-down load-movement curves.

(3) Show the predicted axial load versus depth for a pile head load equal to the assessed value of capacity of Piles A3, B2, and C2, respectively.

(4) Predict the the upward and downward load-movement response (Phase 1) of the bidirectional static loading test on Pile E1.

(5) Predict the the downward pile-head load-movement response (Phase 2) of the head-down static loading test on Pile E1 following the Phase-1 test. N.B., the BD will be closed in Phase 2.

(6) Combine Phases 1 and 2 for Pile E1 to predict an equivalent head-down load-movement curve (intended for comparison to the Phase-2 test).

(7) Predict the load-movement response of the bidirectional tests on Piles E2 and E8 in the pile group similar to Step 4. Submitting this part of the effort is optional.

All predictions must be submitted using the designated Excel template and be accompanied with an explanation as to how the load-movement responses were determined and how the assessed pile capacities were defined. Add pertinent explanations and references to source material, such as software used, if any, and method of analysis (effective stress, total stress, or in-situ records, etc.)

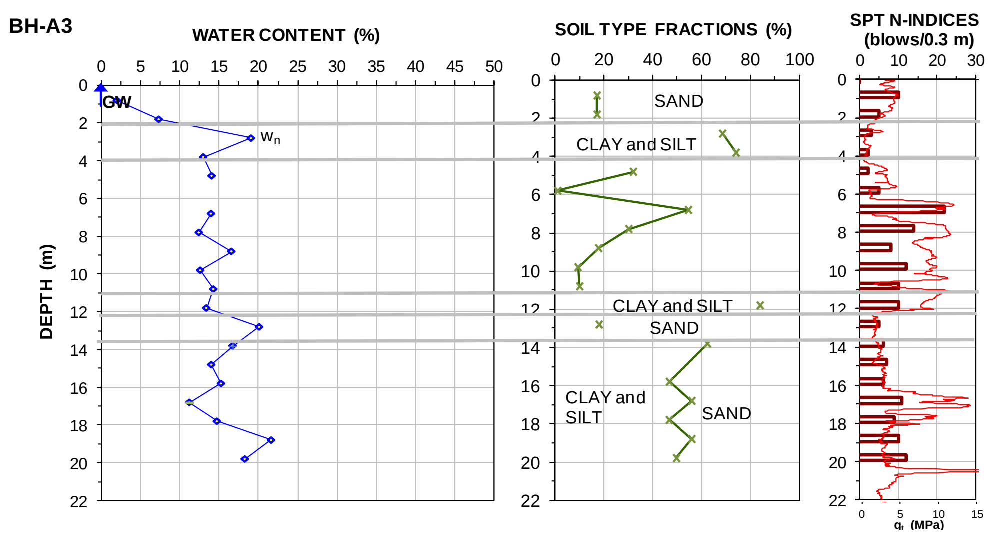
All predictors are encouraged to predict also the pile-shaft and pile-toe load-movement of the test piles as indicated in the Excel template (optional effort). Come April, all predictors will receive the final compilation of all submitted predictions.

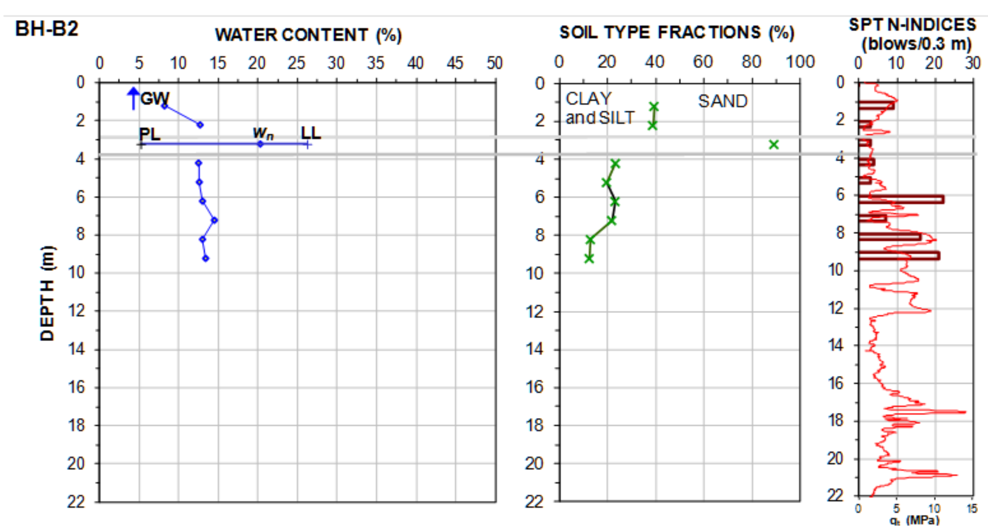
APPENDIX 1

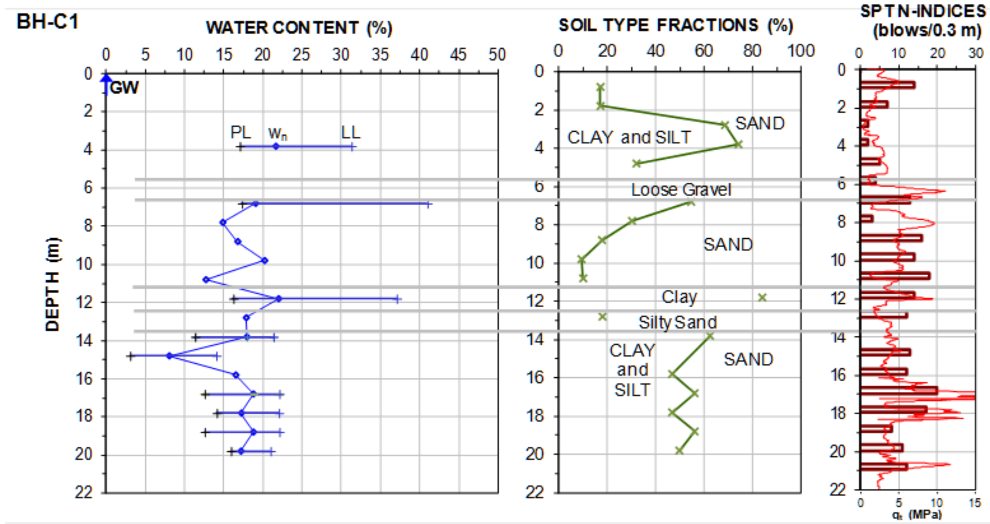
Compiled Borehole Records

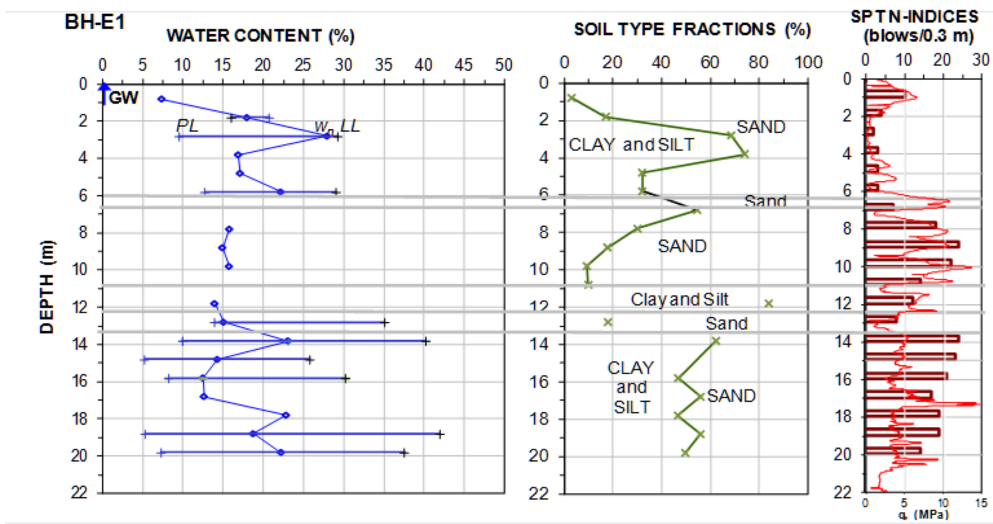
The "Soil Type Fraction" indicates the amount of fines in percent of total sample (Sieve #200). No gravel was found in the samples.

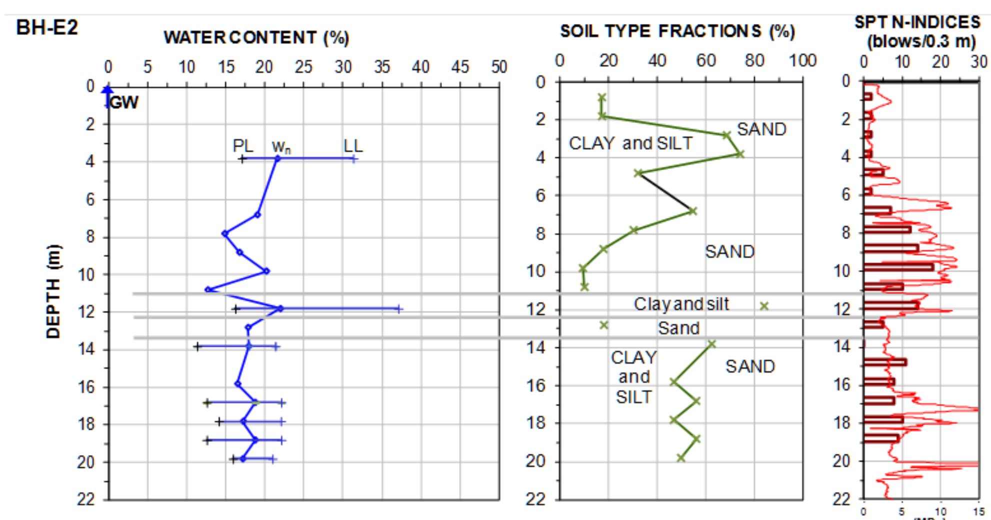
The as-recorded SPT N-indices are shown in bars and the CPTU q_t-curve is overlaid the N-index diagram. Note, as the boreholes and the CPTU soundings (15 in total) are about 1 to 2 m apart, the soil boundary depths indicated by the N-index bar and water content curve do not always agree with boundary depth suggested by the q_t-curve. BH-C1 and CPTU C1 are about 5 m away from Pile C2.





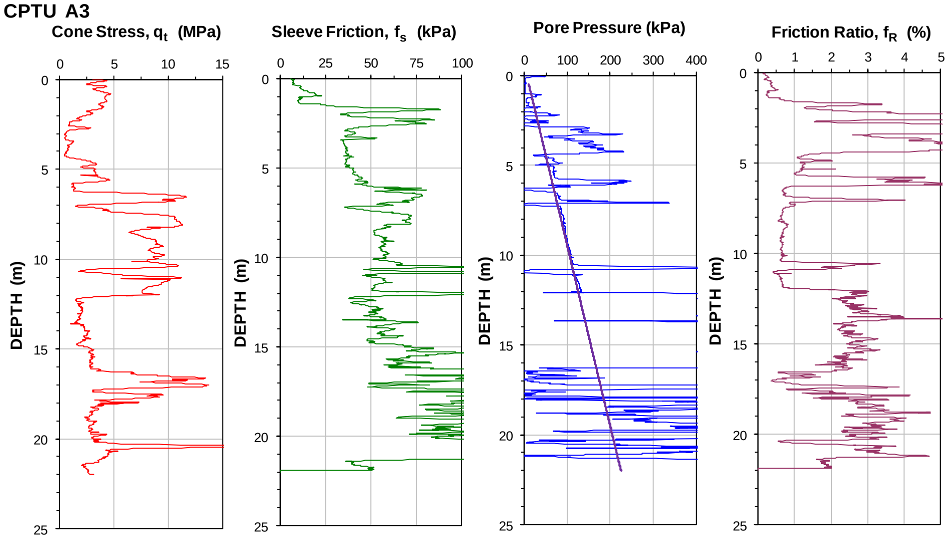

BH-C1
WATER CONTENT (%)
SOIL TYPE FRACTIONS (%)
SPT N-INDICES
(blows/0.3 m)
DEPTH (m)
GW
PL
w_n
LL
CLAY and SILT
SAND
Loose Gravel
SAND
Clay
Silty Sand
CLAY
and
SILT
SAND
q_t (MPa)


BH-E1
WATER CONTENT (%)
SOIL TYPE FRACTIONS (%)
SPT N-INDICES
(blows/0.3 m)
DEPTH (m)
GW
PL
w_n
LL
CLAY and SILT
SAND
Sand
SAND
Clay and Silt
Sand
CLAY
and
SILT
SAND
q_t (MPa)

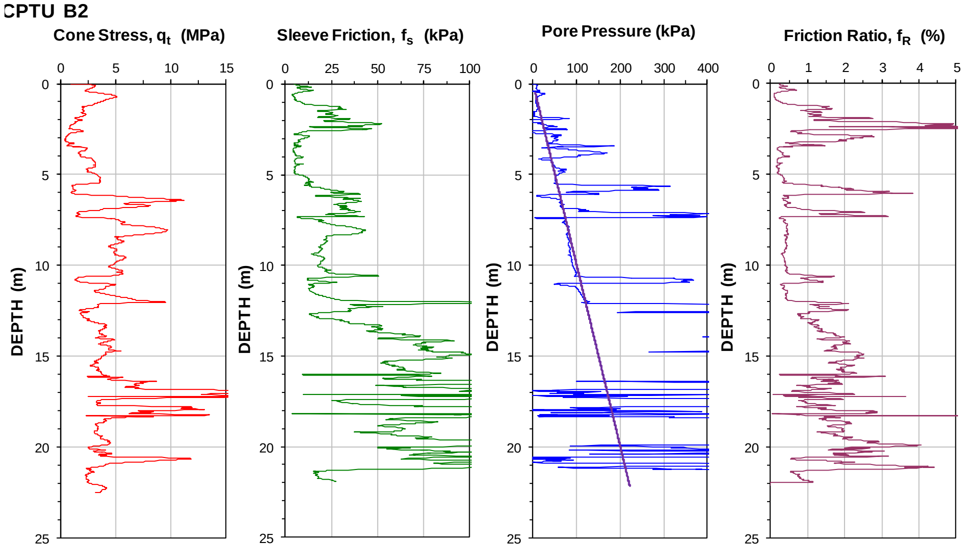

BH-E2
WATER CONTENT (%)
SOIL TYPE FRACTIONS (%)
SPT N-INDICES
(blows/0.3 m)
DEPTH (m)
GW
PL
w_n
LL
CLAY and SILT
SAND
SAND
Clay and silt
Sand
CLAY
and
SILT
SAND
q_t (MPa)

CPTU Diagrams

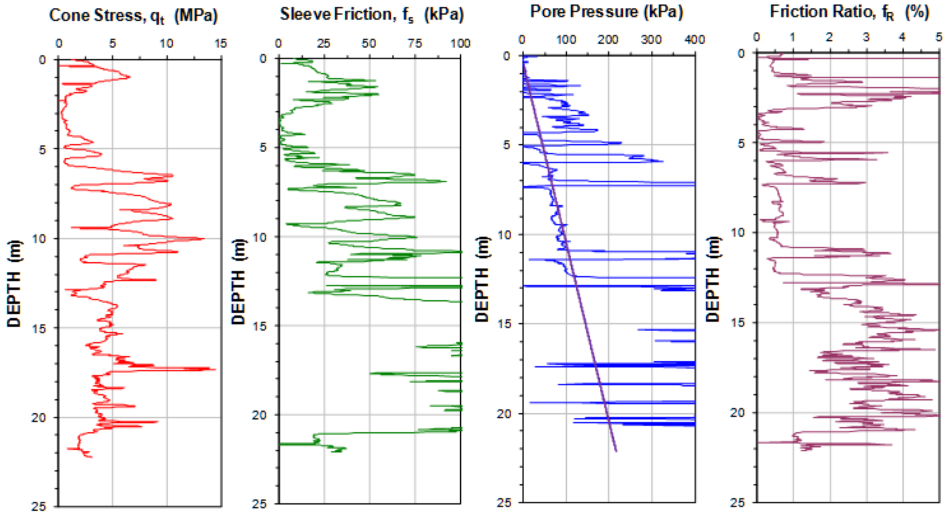
CPTU A3



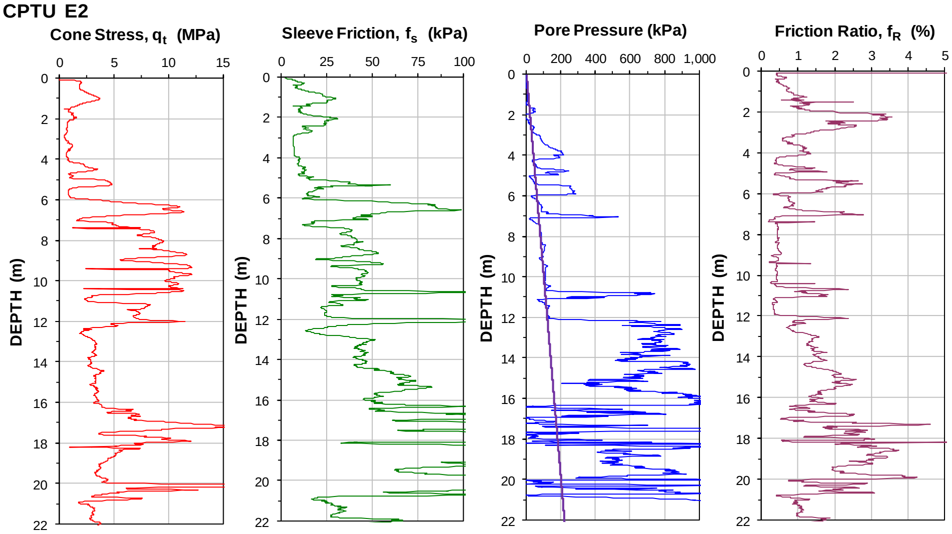
CPTU B2



CPTU E1



CPTU E2



CPTU C1