Experience with lightweight pushing equipment and CPT in Lithuania

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ABSTRACT: *In situ* testing in geotechnical engineering has traditionally been carried out using relatively heavy equipment. Smaller soil exploration equipment allow the use of the cone penetration test (CPT) to be used for some geotechnical work with difficult or limited access.

Anchored soil probing units have been used to perform CPT in many areas of the Lithuania. Anchoring is straightforward and three well-placed anchors can provide up to eight tons of reaction force.

Soil probing machine have been used for geotechnical testing in many different soil types across the Lithuania. Lightweight soil probing unit will increasingly be used to push CPT probes because of their relatively low mobilization costs and because of the large number of units that are available to project planners.

1 INTRODUCTION

In situ testing in geotechnical engineering has traditionally been carried out using relatively heavy equipment. This can be conventional drilling rig or, more commonly, a dedicated CPT truck commonly weighting twenty to twenty-five tons. Smaller soil exploration rig, such as Geoprobe® Model 54LT soil probing unit (Figure 1), allow CPT to be used for some geotechnical work where access is either difficult or limited.

In some cases not always such heavy specialized equipment for CPT can be used. Modern direct push machines are rugged and compact designed for tight spaces and rough terrain.

The CPT is one of the most effective methods for determining sub-surface stratigraphy as well as obtaining many geotechnical parameters. The length and bearing capacity of driven piles for the pile foundation are determined from the results of CPT.

Figure 1. Geoprobe® Model 54LT track machine.

2 INTERPRETATION AND USE OF THE CPT RESULTS

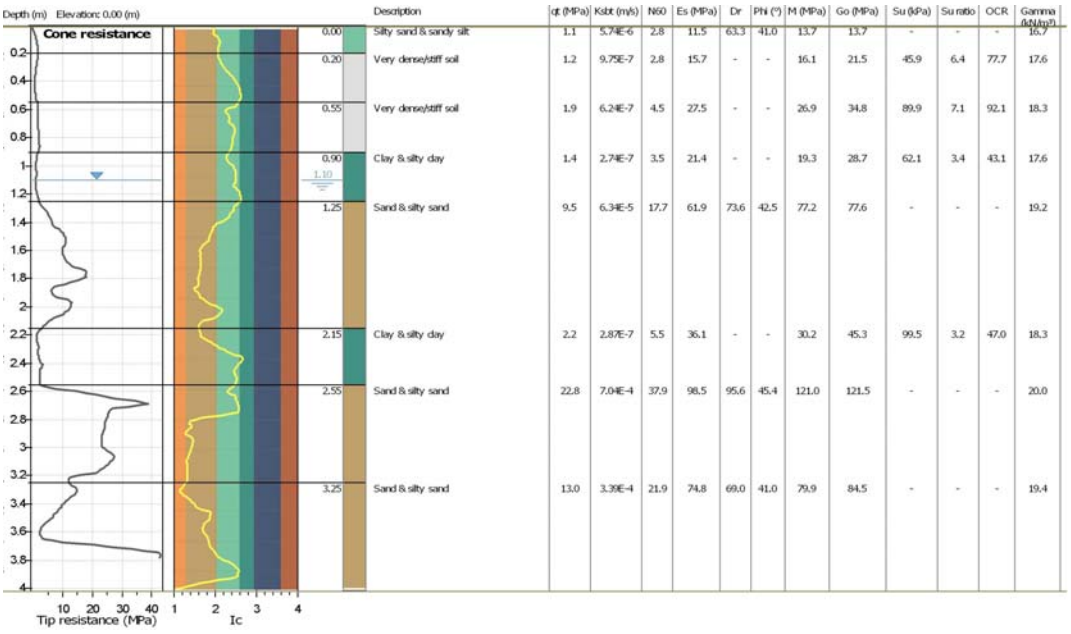
Cone penetration testing (CPT) is widely used in Lithuania since 1967. This is due to two factors. First, because of the extensive use of pile foundations it was necessary to have a fairly reliable method to determine the bearing capacity of piles. Secondly, in the country the constructions of new buildings and facilities increasingly had to be constructed on land that previously was considered unsuitable for construction due to weak soils.

CPT in combination with other types of engineering-geological studies of soils can be used to determine:

■ engineering-geological layers (distribution limits of soils of different composition and state);
■ homogeneity of soil area and depth;
■ depth of rock and coarse-grained soils;
■ approximate quantitative assessment of soil characteristics (density, angle of internal friction, modulus of deformation, etc.);
■ resistance of soil under the pile and for lateral loading;
■ degree of compaction and hardening over time of compacted (bulk and alluvial) soils, selecting the location of the experimental sites for detailed study of the physical and mechanical properties of soils.

The estimation of soil type using measurements of just cone and friction are based upon the variation of the friction ratio in respect to the cone end resistance (e.g. Robertson, 1990). The friction ratio varies depending upon whether the soil is cohesive or granular. Much has been published on the interpretation of soil type from the CPT. A popular method used in Lithuania is software for interpretation CPT data (CPeT-IT). Figure 2 shows an example of typical CPT profile with estimated mean soil parameters. Table 1 shows the detail geotechnical parameters with statistics for some soil types.

Figure 2. Example CPT interpretation data and mean geotechnical parameters



Description	qt (MPa)	Ksbt (m/s)	N60	Es (MPa)	Dr	Phi (°)	M (MPa)	Go (MPa)	Su (kPa)	Su ratio	OCR	Gamma (kN/m³)
Silty sand & sandy silt	1.1	5.74E-6	2.8	11.5	63.3	41.0	13.7	13.7	-	-	-	16.7
Very dense/stiff soil	1.2	9.75E-7	2.8	15.7	-	-	16.1	21.5	45.9	6.4	77.7	17.6
Very dense/stiff soil	1.9	6.24E-7	4.5	27.5	-	-	26.9	34.8	89.9	7.1	92.1	18.3
Clay & silty clay	1.4	2.74E-7	3.5	21.4	-	-	19.3	28.7	62.1	3.4	43.1	17.6
Sand & silty sand	9.5	6.34E-5	17.7	61.9	73.6	42.5	77.2	77.6	-	-	-	19.2
Clay & silty clay	2.2	2.87E-7	5.5	36.1	-	-	30.2	45.3	99.5	3.2	47.0	18.3
Sand & silty sand	22.8	7.04E-4	37.9	98.5	95.6	45.4	121.0	121.5	-	-	-	20.0
Sand & silty sand	13.0	3.39E-4	21.9	74.8	69.0	41.0	79.9	84.5	-	-	-	19.4

Table 1. Example summary of mean geotechnical parameters with statistics based on CPT

From depth To depth (m)	Thickness (m)	Permeability (m/s)	SPT_{N60} (blows/30cm)	E_s (MPa)	D_r	Friction angle	Constrained modulus, M (MPa)	Shear modulus, G_0 (MPa)	Undrained stregth, S_U (kPa)	Undrained stregth ratio	OCR	Unit weight (kN/m^3)
0.00	0.20	5.74E-06	2.8	11.5	63.3	41.0	13.7	13.7	0.0	0.0	0.0	16.7
0.20		(±2.72E-06)	(±1.1)	(±5.7)	(±12.0)	(±2.2)	(±7.7)	(±7.7)	(±0.0)	(±0.0)	(±0.0)	(±1.6)
0.20	0.35	9.75E-07	2.8	15.7	0.0	0.0	16.1	21.5	45.9	6.4	77.7	17.6
0.55		(±1.28E-06)	(±0.7)	(±4.4)	(±0.0)	(±0.0)	(±4.0)	(±1.9)	(±11.4)	(±1.8)	(±18.2)	(±0.1)
0.55	0.35	6.24E-07	4.5	27.5	0.0	0.0	26.9	34.8	89.9	7.1	92.1	18.3
0.90		(±3.04E-07)	(±0.5)	(±6.4)	(±0.0)	(±0.0)	(±2.6)	(±3.5)	(±20.9)	(±1.6)	(±20.4)	(±0.2)
0.90	0.35	2.74E-07	3.5	21.4	0.0	0.0	19.3	28.7	62.1	3.4	43.1	17.6
1.25		(±1.60E-07)	(±0.7)	(±4.7)	(±0.0)	(±0.0)	(±4.1)	(±3.3)	(±14.2)	(±0.8)	(±10.1)	(±0.2)
1.25	0.90	6.34E-05	17.7	61.9	73.6	42.5	77.2	77.6	0.0	0.0	0.0	19.2
2.15		(±5.65E-05)	(±6.6)	(±16.5)	(±13.1)	(±1.8)	(±21.4)	(±20.7)	(±0.0)	(±0.0)	(±0.0)	(±0.6)
2.15	0.40	2.87E-07	5.5	36.1	0.0	0.0	30.2	45.3	99.5	3.2	47.0	18.3
2.55		(±2.36E-07)	(±1.1)	(±5.7)	(±0.0)	(±0.0)	(±7.2)	(±7.3)	(±18.5)	(±0.5)	(±8.9)	(±0.4)
2.55	0.70	7.04E-04	37.9	98.5	95.6	45.4	121.0	121.5	0.0	0.0	0.0	20.0
3.25		(±6.32E-04)	(±10.4)	(±16.9)	(±9.4)	(±1.3)	(±25.3)	(±23.8)	(±0.0)	(±0.0)	(±0.0)	(±0.5)
3.25	0.75	3.39E-04	21.9	74.8	69.0	41.0	79.9	84.5	0.0	0.0	0.0	19.4
4.00		(±1.76E-03)	(±12.9)	(±18.4)	(±18.2)	(±7.0)	(±30.6)	(±25.4)	(±0.0)	(±0.0)	(±0.0)	(±0.4)

The CPT is used in obtaining preliminary survey data, allowing the design organization to identify the feasibility of pile foundations, and complete data necessary for the preparation of working drawings of pile foundations. Experience shows that using a CPT can accurately determine the bearing capacity of piles, which allows in many cases, do without expensive and time-consuming static load test piles.

The CPT test is valuable in many geotechnical designs, and the number of direct design procedures is increasing. The continuous, detailed nature of the CPT results is having a significant effect on the geotechnical industry in Lithuania.

3 CPT EQUIPMENT

Figure 3. Anchored Geoprobe® soil probing machine with CPT.

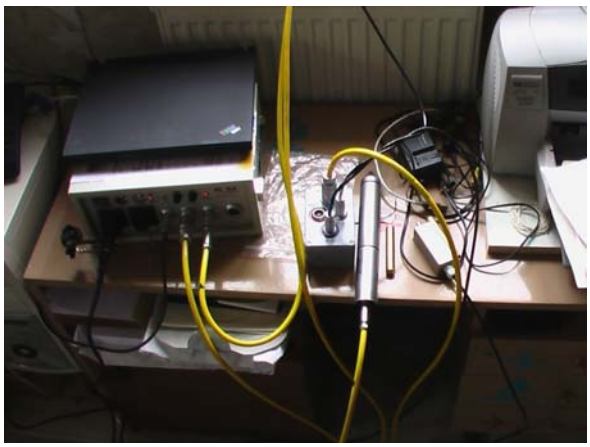
The CPT system that was used was manufactured by GeoMil Equipment B.V of Netherlands. A cone cable will run through the hollow\drill rods and attach to a data acquisition system at the ground surface. The data acquisition system will generally consist of an analog signal conditioner, an analog to digital (A-D) converter, and computer processor.

Figure 4 and 5. Electrical subtraction cone with 10 cm^2 cross sectional surface.

Electrical CPT probes make up the most advanced measuring method for Cone Penetration Testing. Since very sensitive load cells are used much more accurate readings than with mechanical CPT can be achieved. The electrical solution also allows for additional parameters to be measured in-situ, among others pore pressure, temperature, electrical conductivity, inclination etc. The cone specifications are according to the prEN ISO 22476-1.11, Application Class 1 and NEN 5140, Class 1.

The load cell signals are transmitted to the surface as an amplified analogue voltage signal via cable and converted to a 16 bit digital signal in the GME 500 data acquisition system.

Figure 6. Complete electrical CPT system.



Two probes used one with maximum tip resistance of 50 MPa, and another one with maximum tip resistance of 100 MPa. 100 MPa and 50 MPa are roughly equivalent to 10 and 5 tons, respectively. The 50 MPa cone is recommended mainly for use in softer soils, such as clays, silts and loose sands, while the 100 MPa cone can be used in denser and harder soils.

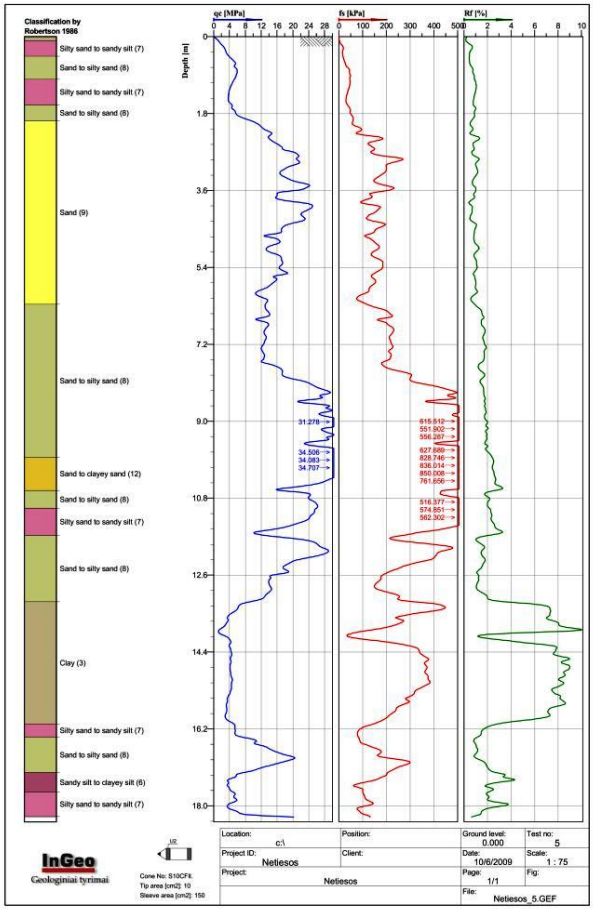
4 CPT LOGGING

CPT probing is generally limited to soils that do not contain much gravel. This limitation does not only apply to lightweight machines, as the same gravelly soil will limit the push of large CPT truck. The lightweight probing machine shown in Fig.1 has been successfully used to push the CPT in many areas of the Lithuania and in many different soil types. The following examples are logs that have been taken using this machine. These particular logs have been chosen with the idea of showing probing results in different soil types.

Alytus region, Netiesos village

The first example of a CPT log is from Alytus region, Netiesos village (Figure 7). The 100 MPa CPT probe was used during this test. A tracked soil probing unit was anchored with three screw anchors.

Figure 7. A CPT log from Alytus region, Netiesos village.

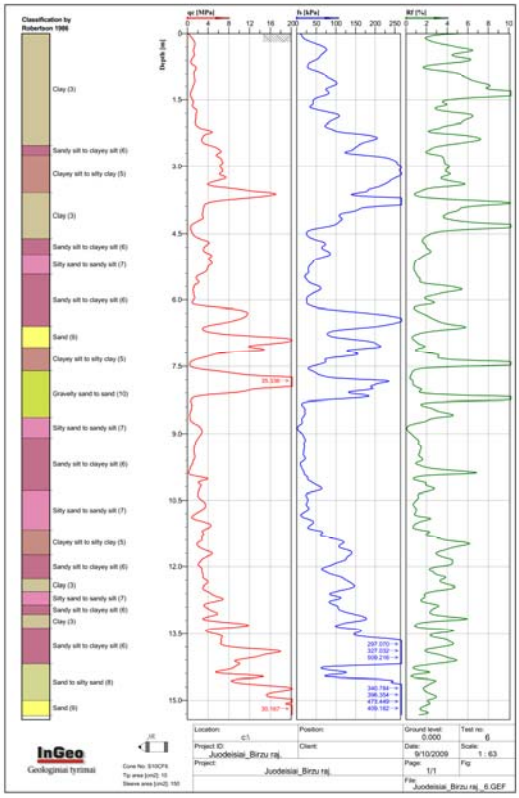


The area where the CPT test was run is a lake sediments area, and the soils are typical sandy lake sediments. The log shows approximately thirteen meters of mainly sandy to silty sand medium to very dense sands. Deepest part up to sixteen meters consists of gytija and peat. The probe met refusal at 18.5 meter when it encountered the glacial boulder. The soil types encountered at this site are classified according to behavior type based on the classification procedure of Robertson, et. al., (1986).

Birzai region, Juodeisiai village

The second CPT case was logged in Birzai region, Juodeisiai village (Figure 8), where specific investigations carried out in karst region include detailed engineering geological investigation.

Figure 8. CPT log number 2 Birzai region, Juodeisiai village. The graphs include soil behavior type, tip resistance, sleeve friction, and friction ratio.



The Lithuanian karst region covers about 1000 km^3 in the northern part of the country. This is the most vulnerable area from a pollution point of view where effective static probing makes it possible to assess existing vacant land.

The 50 MPa cone was used for this test, and refusal was met when tip resistance increased suddenly to more than 20 MPa at 6-8 meter and after decreased until 0.05 MPa. Soils encountered at this site were predominantly karst deposits and dolomite silts.

5 CONCLUSION

In situ geotechnical testing can easily and effectively be carried out using lightweight machine. CPT testing, usually performed using heavy trucks can be carried out using anchored lightweight unit. In many situations, lightweight rigs can push probes to the same depths as large CPT trucks. Lightweight rigs are easier to mobilize and much easier to maneuver on site, especially at undeveloped sites.

Soil probing machines have pushed CPT probes in many different soil types across the Lithuania. The data collected is a useful tool for geotechnical site characterization and geotechnical design. Lightweight soil probing units will increasingly be used to push cones because of their relatively low mobilization costs and because of the large number of units that are available to project planners.

Geotechnical work does not have to be performed with only drill rigs and CPT trucks. The advancements discussed in this paper will enable smaller, lightweight soil probing machine to find a niche within the geotechnical arena.

6 REFERENCES

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