# ANALYSES OF PERFORMED CPT TESTS ON SITE WITH RESPECT TO THE NEW STANDARD

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**KEYWORDS**

CPT, CPTU, Cone penetrometer, Cone resistance, Sleeve friction, Eurocode, Guidelines, Standards, Operator performance, Calibration

**ABSTRACT**

"*Quality of CPTU – Analysis and Comparison of data from Commercial Actors in Stockholm/Mälardalen"* was a study conducted by the Royal Institute of Technology during the autumn of 2014. The scope (aim) of the study was to evaluate the quality of CPTU with respect to SS-EN ISO 22476-1:2012 and mostly based on the choice of equipment since the equipment is different in design and functionality but also the execution and factors related to the performance of the operators.

The main purpose of this study is to evaluate the results from the conducted field test in the previous paper from 2014 with respect to the new guideline SS-EN ISO 22476-1:2023 and study the difference in the results of the classification of performed CPTUs.

## 1. INTRODUCTION

There are some other differences between the old guideline and the new one such as dimensional tolerances of cone penetrometer and minor updates to figures and text. Still, the more important changes are related to requirements for the calibration of cone penetrometers, introduction of temperature influence on measurement monitoring and requirements of internal temperature sensor for cone penetrometer class 0 and differences in classification of CPTUs.

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## 2. DIFFERENCES BETWEEN OLD AND NEW GUIDELINES

### Maintenance, checks and calibration

Maintenance, checks and calibration of the cone penetrometers have been described in Annex B in the new standard SS-EN ISO 22476-1:2023. The first part is maintenance and checks which is not significantly changed compared to the old standard and includes the aspects below:

- Linearity of pushrods.
  - Minor updates in the text have been made, updated with regards to Test Category instead of Application Class.
- Wear of cone penetrometers.
  - Updated with the procedure for determining cross-sectional area and sleeve friction using cone penetrometer class 0.
- Gaps and seals.
  - No updates in this section.
- Pore pressure measuring system.
  - No updates in this section.
- Maintenance procedure.
  - Minor updates in Table B1 (Table A1 in the old standard) regarding the control scheme for maintenance routines.

According to the new standards, the reference readings of the measured parameters should be taken twice. The first reading should be taken after the cleaning of the cone penetrometers and this reading is more useful for compression of cone resistance ($q_c$) and sleeve friction ($f_t$).

The second reference reading should be performed with the cone penetrometer unloaded under similar temperature conditions as close to the ground temperature as possible. The second reading is more useful for the correction of the pore pressure concerning instability in the output and for gathering long-term measurement series.

The section regarding calibration has been revised significantly. This section has been divided into 8 subsections.

The first subsection is about "*Environment and preparation*" which provides the reader with requirements regarding the range of temperature and standard uncertainty, time and cleaning of the cone penetrometer and that the cone penetrometer should be fully assembled during calibration.

The second subsection is about measuring intervals for calibration with general information about measuring intervals and typically selected intervals for calibration of inclination.

The other subsections (from B.2.3 to B.2.8) are listed below:

- Cone resistance and sleeve friction calibration
- Calibration of pore pressure sensor
- Determination of cone and friction sleeve dimensions
- Calibration of a cone penetrometer for inclination
- Verification of a cone penetrometer for temperature influence
- Verification of a cone penetrometer for bending influence

Each subsection has been divided into three parts:

- General
- Test method
- Assessment of calibration uncertainty
- Test results

In the "*General*" part for each subsection, there are some descriptions regarding how the test will be conducted, the devices needed to perform calibration and the environmental aspects such as air temperatures etc.

The "*Test method*" is the most important part of each subsection. In this part, there are some detailed descriptions regarding how the calibration needs to be done in a certain order. Each step is described with detailed instructions and every step needs to be performed for three different angles (ϴ = 0°; ϴ = 120°; ϴ = 240°) perpendicular to the axis of the cone.

The part regarding "*Assessment of calibration uncertainty*" is the calculation procedure with several mathematical equations to evaluate the uncertainties for each calibration phase.

The part "*Test results*" includes how the results should be documented. Besides the general information such as the serial number for the cone penetrometer, the manufacture of the cone penetrometer and so on, every moment of the calibration procedure should be documented with all the data for each rotational position (ϴ = 0°; ϴ = 120°; ϴ = 240°) and the results from each phase. Some results such as expanded measurement uncertainty for cone resistance or bending influence for all four major parameters ($q_{c.a}$; $f_{s.a}$; $u_a$; $T_a$) should also be illustrated graphically. An example of how a calibration report should be compiled is presented in Annex C in SS-EN ISO 22476-1:2023.

## Classification

The classification in the previous version of Standard SS-EN ISO 22476-1:2012 was based on the Application class in which test type, allowable minimum accuracy for the measured parameters, the maximum length between the measurements, the type of the soil and some instructions regarding interpretation and evaluation. The application classes from SS-EN ISO 22476-1:2012 are presented in Figure 1.

**Table 2 — Application classes**

| Application class | Test type | Measured parameter | Allowable minimum accuracy[a] | Maximum length between measurements | Use | |
|---|---|---|---|---|---|---|
| | | | | | Soil[b] | Interpretation / evaluation[c] |
| 1 | TE2 | Cone resistance | 35 kPa or 5 % | 20 mm | A | G, H |
| | | Sleeve friction | 5 kPa or 10 % | | | |
| | | Pore pressure | 10 kPa or 2 % | | | |
| | | Inclination | 2° | | | |
| | | Penetration length | 0,1 m or 1% | | | |
| 2 | TE1<br>TE2 | Cone resistance | 100 kPa or 5 % | 20 mm | A<br>B<br>C<br>D | G, H*<br>G, H<br>G, H<br>G, H |
| | | Sleeve friction | 15 kPa or 15 % | | | |
| | | Pore pressure[d] | 25 kPa or 3 % | | | |
| | | Inclination | 2° | | | |
| | | Penetration length | 0,1 m or 1 % | | | |
| 3 | TE1<br>TE2 | Cone resistance | 200 kPa or 5 % | 50 mm | A<br>B<br>C<br>D | G<br>G, H*<br>G, H<br>G, H |
| | | Sleeve friction | 25 kPa or 15 % | | | |
| | | Pore pressure[d] | 50 kPa or 5 % | | | |
| | | Inclination | 5° | | | |
| | | Penetration length | 0,2 m or 2 % | | | |
| 4 | TE1 | Cone resistance | 500 kPa or 5 % | 50 mm | A<br>B<br>C<br>D | G*<br>G*<br>G*<br>G* |
| | | Sleeve friction | 50 kPa or 20 % | | | |
| | | Penetration length | 0,2 m or 2 % | | | |

NOTE For extremely soft soils, even higher demands on the accuracy can be needed.

[a] The allowable minimum accuracy of the measured parameter is the larger value of the two quoted. The relative accuracy applies to the measured value and not the measuring range.

[b] According to ISO 14688-2 [1]:
- A homogeneously bedded soils with very soft to stiff clays and silts (typically $q_c$ < 3 MPa)
- B mixed bedded soils with soft to stiff clays (typically $q_c \leq$ 3 MPa) and medium dense sands (typically 5 MPa $\leq q_c$ < 10 MPa)
- C mixed bedded soils with stiff clays (typically 1,5 MPa $\leq q_c$ < 3 MPa) and very dense sands (typically $q_c$ > 20 MPa)
- D very stiff to hard clays (typically $q_c \geq$ 3 MPa) and very dense coarse soils ($q_c \geq$ 20 MPa)

[c]
- G profiling and material identification with low associated uncertainty level
- G* indicative profiling and material identification with high associated uncertainty level
- H interpretation in terms of design with low associated uncertainty level
- H* indicative interpretation in terms of design with high associated uncertainty level

[d] Pore pressure can only be measured if TE2 is used.

*Figure 1, Table 2 in SS-EN 22476-1:2023.*

However, the previous standard did not treat the relation between the cone penetrometer and the achieved cone resistance $q_c$. The new standard classification is based on the test category which is also related to the cone penetrometer class, see the relation between the test category and the cone penetrometer class in Figure 2.

**Table 3 — Test categories of CPT/CPTU**

| Test category | Cone penetrometer class | Reference reading checks | | |
|---|---|---|---|---|
| | | Parameter | Maximum allowable difference of reference values before and after test | Maximum variation in output stability |
| A | 0 | Cone resistance | 15 kPa | 1 kPa |
| | | Sleeve friction | 5 kPa | 0,5 kPa |
| | | Pore pressure | 3 kPa | 0,5 kPa |
| B | 0, 1 | Cone resistance | 35 kPa | 5 kPa |
| | | Sleeve friction | 5 kPa | 1,5 kPa |
| | | Pore pressure | 10 kPa | 3 kPa |
| C | 0, 1, 2 | Cone resistance | 100 kPa | 11 kPa |
| | | Sleeve friction | 15 kPa | 3 kPa |
| | | Pore pressure[a] | 25 kPa | 8 kPa |
| D | 0, 1, 2, 3 | Cone resistance | 200 kPa | 33 kPa |
| | | Sleeve friction | 25 kPa | 5 kPa |
| | | Pore pressure[a] | 50 kPa | 16 kPa |
| [a] Pore pressure applies only to CPTU. | | | | |

*Figure 2, Table 3 in SS-EN 22476-1:2023.*

In this system, cone penetrometers will be categorized during the calibration of them from class 0 up to class 3 where class 0 has the most accurate requirements and class 3 has the least accurate ones. Based on the results from achieved cone resistance $q_c$ from performed attempts in the field, each one of these classes will give a confidence level which can be high, medium, low or not applicable.

So basically, depending on the class of cone penetrometer and the achieved cone resistance qc the requirements for one category will be fulfilled. For example, to achieve test category A, the chosen cone penetrometer for the attempt has to be a class 0 penetrometer and the measured $q_c$ should be less than 1 MPa ($q_{c,max}$> 1 MPa). This means that the new standard is a planning tool as well as it can be used for evaluation. To achieve a certain test category, the choice of cone penetrometers should be right from the beginning.

The requirements for the confidence level with respect to cone penetrometer class and the result of cone resistance $q_c$ are presented in the SS-EN ISO 22476-1:2023 Appendix A and illustrated in Figure 3.

**Table A.1 — Confidence levels of measurements for the characterisation of geotechnical properties depending on the cone type and test category**

<table>
<tr><th rowspan="2">Application</th><th rowspan="2">Confidence level</th><th colspan="4">Cone penetrometer class</th></tr>
<tr><th>0</th><th>1</th><th>2</th><th>3</th></tr>
<tr><td rowspan="3">Characterisations of geotechnical proprieties of soil deposits with $q_{c;max} \leq 1$ MPa</td><td>High</td><td>A</td><td></td><td></td><td></td></tr>
<tr><td>Medium</td><td colspan="2">B</td><td></td><td></td></tr>
<tr><td>Low</td><td colspan="3">C</td><td></td></tr>
<tr><td rowspan="3">Characterisations of geotechnical proprieties of soil deposits with 1 MPa < $q_{c;max} \leq 3$ MPa</td><td>High</td><td colspan="2">B</td><td></td><td></td></tr>
<tr><td>Medium</td><td colspan="3">C</td><td></td></tr>
<tr><td>Low</td><td colspan="4">D</td></tr>
<tr><td rowspan="2">Characterisations of geotechnical proprieties of soil deposits with $q_{c;max} > 3$ MPa</td><td>High</td><td rowspan="2">Not recommended</td><td colspan="2">B and C</td><td></td></tr>
<tr><td>Medium</td><td colspan="3">D</td></tr>
<tr><td colspan="6">NOTE A, B, C and D are the test categories according to Table 3.</td></tr>
</table>

*Figure 3, Table A.1 in SS-EN 22476-1:2023.*

## Temperature influence

The new Standard SS-EN ISO 22476-1:2023 has been updated with requirements regarding the verification of cone penetrometers for temperature influence. The operation shall be conducted in two thermostat baths the first one being a bath with tap water or a mixture of water and antifreeze with the capability of maintaining a constant temperature of fluid at 30°C with a standard uncertainty of <0,5°C during the entire test. The second bath on the other hand has the capability of maintaining a constant temperature of fluid at 0°C with a standard uncertainty of <0,5°C.

The test method is generally based on recording the apparent cone resistance $q_{c;a}$, apparent sleeve friction $f_{s;a}$ and apparent pore pressure $u_a$ and also the temperature $T_a$ throughout the test at ≥1Hz to determine and record the temperature-corrected cone resistance $q_{c;ac}$, sleeve friction $f_{s;ac}$ pore pressure $u_{ac}$ by transferring the cone penetrometer several times between thermostat 1 and 2. The entire procedure of verification of a cone penetrometer for temperature influence and also reporting the results is described in SS-EN ISO 22476-1:2023 Annex B chapter B.2.7.

The results from the verification of CPTU with respect to temperature influence can be used to apply corrections to the measurements of $q_c$, $f_s$ and $u_2$.

Temperature sensors can be integrated into any cone class with the main purpose of monitoring the temperature changes that can affect the cell loads and pressure transducer. For the cone penetrometers with application class 0, the requirement is that the integrated sensor in the cone penetrometer has the range of -10°C to +50°C with a maximum allowable uncertainty of 0,5°C.

The temperature influence is an important aspect of achieving reliable results from CPTU. However, the gathered data historically from cone penetrometers in Nordic countries indicate suitable results and that the values fulfil requirements regarding the temperature aspect.

## 3. RESULTS & EVALUATION

The evaluation from the performed CPTU in the field in the previously mentioned study from 2014 has been performed based on the reference values (zero values) of each penetration before and after that penetration is performed (Calibration Drift) and with respect to both the old standard SS-EN ISO 22476-1:2012 and the new standard SS-EN ISO 22476-1:2023. The results from reference values are presented in the study under section 4.4.2 and Table 1.

*Table 1, The registered zero values for each borehole during penetration.*

| Penetration ID | Cone resistance (kPa) | | | Pore pressure (kPa) | | | Sleeve friction (kPa) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Before | After | Diff | Before | After | Diff | Before | After | Diff |
| **14C001** | 9660 | 9588 | -72 | 920.7 | 933.6 | 12.9 | 332.4 | 330.8 | -1.6 |
| **14C004** | 9654 | 9600 | -54 | 934.4 | 937 | 2.6 | 325.4 | 324.7 | -0.7 |
| **14A005** | 7196 | 7160 | -36 | 285.6 | 285.7 | 0.1 | 184.6 | 183.5 | -1.1 |
| **14A006** | 7306 | 7234 | -72 | 287.5 | 285.8 | -1.7 | 184.3 | 6553.5 | 6369.2 |
| **14A007** | 7148 | 7250 | 102 | 283.2 | 287 | 3.8 | 184.5 | 184.2 | -0.3 |
| **14A008** | 7262 | 7262 | 0 | 292.8 | 290 | -2.8 | 183.8 | 183.4 | -0.4 |
| **14A009** | 7236 | 7204 | -32 | 294.1 | 298.9 | 4.8 | 182.8 | 183.1 | 0.3 |
| **14A010** | 7232 | 7200 | -32 | 290.9 | 288 | -2.9 | 183.5 | 183.6 | 0.1 |
| **14A011** | 7136 | 7100 | -36 | 286 | 305.6 | 19.6 | 185.7 | 185.9 | 0.2 |
| **14A012** | 7244 | 7210 | -34 | 284.4 | 309.8 | 25.4 | 185.4 | 184.3 | -1.1 |
| **14A016** | 7218 | 7192 | -26 | 282.3 | 308.2 | 25.9 | 181.4 | 180.7 | -0.7 |
| **14D017** | 6456 | 6453.1 | -2.9 | 255.5 | 256.4 | 0.9 | 132.5 | 132.5 | 0 |
| **14D018** | 6453.7 | 6465.4 | 11.7 | 255.9 | 255 | -0.9 | 132.1 | 132.4 | 0.3 |
| **14D019** | 6452.5 | 6460.1 | 7.6 | 254.8 | 264.1 | 9.3 | 133.1 | 132.8 | -0.3 |
| **14SD20b** | 6461.3 | 6454.9 | -6.4 | 255.7 | 255.2 | -0.5 | 132.8 | 132.4 | -0.4 |
| **14B021** | 3170.6 | 3173.1 | 2.5 | 273.4 | 280.1 | 6.7 | 112.2 | 112.5 | 0.3 |
| **14B022** | 3204.9 | 3184.2 | -20.7 | 274.7 | 273.9 | -0.8 | 112.5 | 112.8 | 0.3 |
| **14B023** | 3212.7 | 3150 | -62.7 | 290.3 | 273.4 | -16.9 | 112.6 | 113 | 0.4 |
| **14B024** | 3174 | 3166.2 | -7.8 | 274.5 | 270.4 | -4.1 | 112.7 | 112.8 | 0.1 |
| **14B025** | 3204.9 | 3168.5 | -36.4 | 273.8 | 272.9 | -0.9 | 112.7 | 112.9 | 0.2 |
| **14B026** | 3171.2 | 3174.5 | 3.3 | 274.1 | 273.7 | -0.4 | 112.6 | 112.7 | 0.1 |
| **14E027** | 4612 | 4622 | 10 | 597.7 | 610.4 | 12.7 | 147.2 | 148.9 | 1.7 |
| **14E028** | 4598 | 4474 | -124 | 598.5 | 598.6 | 0.1 | 149 | 149 | 0 |
| **14E029** | 4480 | 4470 | -10 | 594.5 | 607.3 | 12.8 | 150.9 | 151.3 | 0.4 |

The results from the performed CPTU based on the reference values (zero values) in the previous Figure and with respect to the old standard SS-EN ISO 22476-1:2012 and the new standard SS-EN ISO 22476-1:2023 presented in Tabell 4-1. For the new standard, all the cases had measured cone resistances $q_c$ less than 1 MPa ($q_{c;max} > 1$ MPa) along the entire penetration which means that the criteria for the first case in Table A-1 in Appendix A is fulfilled.

The results from the performed CPTU based on the reference values (zero values) in the previous Figure and with respect to the new standard SS-EN ISO 22476-1:2023 are presented in Table 2. For all the cases are the measured cone resistance $q_c$ less than 1 MPa ($q_{c;max}$ > 1 MPa) which means that the criteria for the first case in Table A-1 in Appendix A are fulfilled.

*Table 2, The results from CPTU with respect to the old and new standards.*

| Penetration ID | Reference Values | | | SS-EN ISO 22476-1:2012 | SS-EN ISO 22476-1:2023 | |
|---|---|---|---|---|---|---|
| | $u_2$ [kPa] | $f_s$ [kPa] | $q_c$ [MPa] | Application Class | Test Category | Cone Penetrometer Class |
| 14C001 | 12,9 | 1,6 | 0,072 | 2 | C | 1 |
| 14C004 | 2,6 | 0,7 | 0,054 | 2 | C | 1 |
| 14A005** | 0,1 | 1,1 | 0,036 | - | - | 1 |
| 14A006** | 1,7 | 6369,2 | 0,072 | - | - | 1 |
| 14A007** | 3,8 | 0,3 | 0,102 | - | - | 1 |
| 14A008* | 2,8 | 0,4 | 0 | 4(1) | D(B) | 1 |
| 14A009* | 4,8 | 0,3 | 0,032 | 4(1) | D(B) | 1 |
| 14A010* | 2,9 | 0,1 | 0,032 | 4(1) | D(B) | 1 |
| 14A011* | 19,6 | 0,2 | 0,036 | 4(1) | D(C) | 1 |
| 14A012* | 25,4 | 1,1 | 0,034 | 4(3) | D | 1 |
| 14A016* | 25,9 | 0,7 | 0,026 | 4(3) | D | 1 |
| 14D017 | 0,9 | 0 | 0,0029 | 1 | B | 1 |
| 14D018 | 0,9 | 0,3 | 0,0117 | 1 | B | 1 |
| 14D019 | 9,3 | 0,3 | 0,0076 | 1 | B | 1 |
| 14D020b | 0,5 | 0,4 | 0,0064 | 1 | B | 1 |
| 14B021 | 6,7 | 0,3 | 0,0025 | 1 | B | 0 |
| 14B022 | 0,8 | 0,3 | 0,0207 | 1 | B | 0 |
| 14B023 | 16,9 | 0,4 | 0,0627 | 2 | C | 0 |
| 14B024 | 4,1 | 0,1 | 0,0078 | 1 | B | 0 |
| 14B025 | 0,9 | 0,2 | 0,0364 | 2 | C | 0 |
| 14B026 | 0,4 | 0,1 | 0,0033 | 1 | A | 0 |
| 14E027 | 12,7 | 1,7 | 0,01 | 2 | C | 1 |
| 14E028 | 0,1 | 0 | 0,124 | 3 | D | 1 |
| 14E029 | 12,8 | 0,4 | 0,01 | 2 | C | 1 |

*) The cone penetrometer was not equipped with an inclinometer. Since the target penetration was deeper than 5 meters, the performed CPTU cannot reach a higher test category than category D in the new standards or a higher application class than class 4 in the old one. Obtained test category/application class is indicated in parentheses if this requirement was disregarded.

**) The penetration was not valid since the criteria regarding the accuracy of the penetration rate was not fulfilled.

## 4. DISCUSSION & CONCLUSION

A comparison has been made between the old standard and the new one regarding the criteria for the reference values (zero values) for each Application Class/Category. It can be considered that there are similarities between some of the test categories in the new standard with some of the application classes in the old one, see Table 3.

The criteria for the reference values in Application Class 1, 2 and 3 in the old standard is the same as for the Test Category B, C and D in the new one. However, the new standard has been updated with the Test Category A which is higher requirements than Application Class 1 in the old standard. Also, there is no equivalent for Application Class 4 in the new standard. Based on these two aspects it can be stated that there are higher requirements in the new standard compared to the old one.

*Table 3, Comparison between criteria for reference values for old and new standards.*

| SS-EN ISO 22476-1:2012 | | | | SS-EN ISO 22476-1:2023 | | | |
|---|---|---|---|---|---|---|---|
| Application Class | Pore pressure $u_2$ [kPa] | Sleeve friction $f_s$ [kPa] | Cone resistance $q_c$ [MPa] | Test Category | Pore pressure $u_2$ [kPa] | Sleeve friction $f_s$ [kPa] | Cone resistance $q_c$ [MPa] |
| - | - | - | - | A | 3 | 5 | 0,015 |
| 1 | 10 | 5 | 0,035 | B | 10 | 5 | 0,035 |
| 2 | 25 | 15 | 0,100 | C | 25 | 15 | 0,100 |
| 3 | 50 | 25 | 0,200 | D | 50 | 25 | 0,200 |
| 4 | >50 | 50 | 0,500 | - | - | - | - |

Considering aspects above and other aspects such as compensation for the temperature influence and the new calibration procedure for cone penetrometers, it can also be stated that the level of accuracy in the performance, calibration, and evaluation of CPTU has been increased.

Based on the discussion above a comparison has been accomplished between the evaluation of the results from performed CPTU in the study from 2014 with respect to the old standard and the new one. The comparison is presented in Table 4.

*Table 4, Comparison between the evaluation of the results from performed CPTU in the study from 2014.*

| Penetration ID | SS-EN ISO 22476-1:2012 | SS-EN ISO 22476-1:2023 | |
|---|---|---|---|
| | Application Class | Test Category | Cone Penetrometer Class |
| **14C001** | 2 | C | 1 |
| **14C004** | 2 | C | 1 |
| **14A005(*** | - | - | 1 |
| **14A006(*** | - | - | 1 |
| **14A007(*** | - | - | 1 |
| **14A008(*** | 4(1) | D(B) | 1 |
| **14A009(*** | 4(1) | D(B) | 1 |
| **14A010(*** | 4(1) | D(B) | 1 |
| **14A011(*** | 4(1) | D(C) | 1 |
| **14A012(*** | 4(3) | D | 1 |
| **14A016(*** | 4(3) | D | 1 |
| **14D017** | 1 | B | 1 |
| **14D018** | 1 | B | 1 |
| **14D019** | 1 | B | 1 |
| **14D020b** | 1 | B | 1 |
| **14B021** | 1 | B | 0 |
| **14B022** | 1 | B | 0 |
| **14B023** | 2 | C | 0 |
| **14B024** | 1 | B | 0 |
| **14B025** | 2 | C | 0 |
| **14B026** | 1 | A | 0 |
| **14E027** | 2 | C | 1 |
| **14E028** | 3 | D | 1 |
| **14E029** | 2 | C | 1 |

It can be considered that the similarities that have been discussed earlier in this chapter can be identified in most of the attempts. The attempts that have been labelled as Application Class 1, 2 or 3 in the old system have got the equivalent Test category in the new one (B, C and D). However, one of the attempts differs from that matter, the evaluated result from the penetration in 14B026 has been labelled as Application Class 1 according to the old standard. This penetration should be categorized as a Test Category B in the new system, but it can be considered that this attempt has been categorized as a Test Category A. Based on that it can be stated that with higher accuracy in the performance of the CPTU, better results can be achieved. It should also be mentioned that the achievement of Test Category A in that attempt was not possible if the cone penetrometer was not classed as 0 in the Cone Penetrometer Class according to the new standard.

Although there was not so much of a difference in the other performed attempts in this study, it should be considered that all the attempts had a $q_c$ less than 1 MPa ($q_{c;max} \leq 1$ MPa) along the entire penetration. The case will be completely different if the $q_c$ was higher than 1 MPa, the Test category will remain the same, but the confidence level of each category will be different.

The conclusions from the study in this paper can be compiled as:

- ❖ The level of accuracy in the performance, calibration, and evaluation of CPTU has been increased in the new standard.
- ❖ New requirements regarding the correction of parameters with regard to temperature influence.
- ❖ New requirements regarding calibration of cone penetrometer.
- ❖ The relation between cone penetrometer class and confidence level with respect to $q_{c;max}$ in the evaluation of Test Category.
- ❖ Addition of Test Category A and removal of equivalent Test Category to Application Class 4 in the old standard.
- ❖ The new standard is a planning tool as well as a new evaluation method.

## REFERENCES

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