CETANZ Technical Guideline (TG)

TG6 – INDUSTRY BEST PRACTICE GUIDELINE FOR PERFORMING CONE PENETRATION TESTING (CPT) IN NEW ZEALAND

(in accordance with ISO 22476-1: 2012)

TG6

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TG6 – INDUSTRY BEST PRACTICE GUIDELINE FOR PERFORMING CONE PENETRATION TESTING (CPT) IN NEW ZEALAND

1.0 INTRODUCTION

1.1   This document covers the methodology for undertaking electric cone penetrometer testing (CPT) and piezocone cone penetration testing (CPTU) in New Zealand (NZ). CETANZ, as the group representing the NZ CPT industry, have adopted the International Standard ISO 22476-1:2012 as the standard to which CPT/CPTU testing should be undertaken. This document is a guideline for undertaking the testing in accordance with ISO 22476-1 and to clarify any areas of uncertainty in interpretation. This document has been prepared by the industry after extensive appraisals and consultation with CPT contractors. It is considered best practice for undertaking CPT/CPTU testing in NZ.

1.2   This document is not intended to replace ISO 22476-1, but is a supplementary guide to that standard. Some clauses have been amended, replaced, omitted or added. Where there is conflict between this document and ISO 22476-1, this document shall take precedence.

1.3   This document is primarily intended for CPT contractors to guide them in performing CPT/CPTU testing to industry best practice. The intention is to provide a consistent methodology and standard of quality across the industry to provide confidence in the test results to end users.

1.4   This document is also intended for the use of those that may undertake audits of contractors performing these tests.

1.5   This document may also be useful for engineers, clients, stakeholders or others who wish to understand the process of CPT/CPTU testing and NZ best practice.

2.0 OVERVIEW OF ISO 22476-1 AND APPLICATION CLASSES

2.1   The ISO 22476-1: 2012 standard is based around the concept of application classes. There are four defined application classes (Classes 1 to 4), which are given in Table 2 of ISO 22476-1 and described further in clause 5.2 of ISO 22476-1. The classes are determined by the type of soil being tested and the level of accuracy achieved during the test. Class 1 is intended only for soft to very soft soils and has the strictest requirements for accuracy. Only piezocone (CPTU) testing (TE2 type tests) can be done for Class 1. Classes 2 and 3 are for mixed bedded soil profiles and can be undertaken with either non-piezocone CPT (TE1) or piezocone CPTU (TE2). Class 4 applies to TE1 type testing only in mixed bedded soils and is the least strict in terms of accuracy.

2.2   The ISO standard provides guidance to an engineer or other end-user as to how reliable the data may be for characterising the ground and interpreting design parameters based on the application class and soil type. The concept is illustrated in Tables 1 and 2 below.

Table 1: Soil type definitions (*note: this is a modified interpretation from Table 2 of ISO 22476-1*)

Soil Type:	A	B	C	D
General description	Very soft to firm clays and silts, sensitive soils and peat/organic soils	Stiff to hard clays and loose to medium dense sandy silts or silty sands	Medium dense to dense sands and overconsolidated or weakly cemented soils	Dense to very dense sands and gravels or cemented weak rocks
CPT q_c criteria (MPa)	$q_c < 1$	$1 < q_c < 5$	$5 < q_c < 20$	$q_c > 20$

Table 2: Assumed level of uncertainty based on Application Class and soil type (from Table 2 of ISO 22476-1)

Application Class (classified by accuracy)	Soil Type	Profiling and material identification	Interpretation in terms of design
1	A (only)	Low uncertainty	Low uncertainty
2	A	Low uncertainty	High uncertainty
	B, C, D	Low uncertainty	Low uncertainty
3	A	Low uncertainty	n/a
	B	Low uncertainty	High uncertainty
	C, D	Low uncertainty	Low uncertainty
4	A, B, C, D	High uncertainty	n/a

2.3   The ISO standard places a large degree of weight on determining the accuracy of the test. On this basis, ISO 22476-1 is fundamentally a performance-based standard. In Clause 5.2, ISO 22476-1 requires '*all possible sources of error*' to be evaluated and this '*shall include internal friction, errors in the data acquisition, eccentric loading, temperature effects and dimensional errors*'. The terms 'accuracy' and 'error' are not defined. Annex E of the standard lists some potential sources of uncertainty, but the standard provides little guidance as to how errors can be quantified. In practice, identifying and quantifying '*all possible sources of error*' is near impossible and this presents a fundamental problem with demonstrating compliance of this performance-based standard.

3.0 PROCEDURAL APPROACH TO APPLICATION CLASSES

3.1   In practice, the performance-based accuracy criteria of the ISO standard cannot be achieved on the basis of evaluating '*all possible sources of error*'. The approach of this document is to maintain the concept of Application Class as defined by the standard, but rather than base acceptance criteria solely on accuracy, provide more prescriptive methodologies so that in following those methods it is more likely that the desired application class will be achieved. There is still the requirement to meet the accuracy criteria of the application class, but that is now limited to known and easily measurable errors or prescribed indicators, rather than the open-ended 'all possible sources of error'.

3.2   CPT contractors in NZ routinely use modern cone penetrometers and predominantly piezocones. As such there is already a baseline of good quality equipment in current use. By following good practice, a high level of accuracy can be achieved. Consequently, a high base standard methodology can be set that would be appropriate for all application classes, other

than Class 1. Tests in soft to very soft soils are potentially more erroneous as errors can be a much larger percentage of the very low measurements in these soils. Consequently, more stringent method-based requirements apply for Class 1 testing in order for errors to be minimised to levels that are likely to be acceptable for this class.

3.3   The approach is to have the same baseline methodology for Application Classes 2 to 4, with additional requirements for Class 1. There is no need to have reduced levels of methodology for Classes 3 and 4, as the same basic procedures for performing Class 2 tests will also apply to Class 3 and Class 4 testing. The tests will be designated Class 2, 3 or 4 depending on the accuracy criteria of Table 2 of ISO 22476-1. For these Classes, the zero drift during the test will be the main indicator by which the Application Class by accuracy is determined.

3.4   For Application Class 1, additional method-based procedures are specified. These add more stringent requirements to the basic procedures suitable for the other application classes. These include:

   a) More frequent and load range appropriate calibrations
   b) More frequent and more accurate measurements of probe dimensions
   c) More care in cone preparation and saturation
   d) More stringent requirements for temperature control
   e) Recording two sets of after zero readings

3.5   For the accuracy criteria of Application Class 1, the zero drift during the test is taken as the main indicator of test accuracy. However, if other factors are influencing accuracy, such as temperature changes during the test, and the errors associated with those are readily quantifiable, then they could also be taken into consideration.

4.0 MAINTENANCE ROUTINES

4.1   The following table (Table 3) outlines the schedule for checks and maintenance of the testing equipment. This table replaces Table A.1 of Annex A of the ISO standard.

Table 3: Schedule of Checks and Maintenance

Checks/maintenance	Start of project	Start of day	Start of test	End of test	Every 12 months[f]
Calibration[a]	x[1]	-	-	-	x[2]
Cleaning of cone penetrometer	-	-	x	x	-
Wear and condition of components and seals[b]	-	-	x	x	-
Cone dimension measurements[c]	-	x[2]	x[1]	x[1]	-
Filter element[d]	-	-	x	-	-
Verticality of thrust machine	-	-	x	-	-
Depth sensor	-	-	-	-	x
Straightness of push rods and penetrometer	-	-	x	-	x
Zero values[e]	-	-	x	x	-
Penetration rate	-	-	-	-	x
Safety functions	-	x	-	-	x

x[1] denotes for Class 1 only;   x[2] denotes for Classes 2 to 4;   x denotes all classes

Notes:

a. Refer to Section 5.0 for explanation of calibration requirements
b. A wear check indicator tool can be used at start of each test for Classes 2 to 4
c. Cone dimensions measured at the start of the day for Classes 2 to 4 with digital callipers. For Class 1, measurements at start and end of test with micrometer
d. A new porous filter element should be used for each test. If a slot filter is used, it may be reused provided it is in good conditions and meets dimensional tolerances
e. Zero readings to be taken before and after each test. For Class 1, additional after zero reading to be taken once penetrometer has been cleaned
f. More regular checks may be required

5.0 CALIBRATION

5.1   The calibration requirements of Section A.2 of Annex A of ISO 22476-1: 2012 apply with the following amendments, additions and clarifications.

5.2   A continuous record of zero readings (both before and after) with time should be maintained for each cone penetrometer starting with the baseline readings from the last calibration. The record should include the zero readings for the cone resistance, sleeve friction and pore pressure sensors.

5.3   Classes 2 to 4

5.3.1   A new calibration should be carried out:

a) Within 12 months from the first use of a calibrated cone penetrometer, or;
b) Within 24 months since last calibration of an unused cone penetrometer, or;
c) If the continuous record of zero readings shows a shift from the initial calibration baseline readings of more than 2.5% of the FSO of any of the sensors, or;
d) If the penetrometer is damaged or overloaded

5.4   Class 1

5.4.1   A new calibration should ideally be carried out at the start of a new project, otherwise:

a) Within 6 months from the first use of a calibrated cone penetrometer, or;
b) Within 24 months since last calibration of an unused cone penetrometer, or;
c) If the continuous record of zero readings shows a shift from the initial calibration baseline readings of more than 1% of the FSO of any of the sensors, or;
d) If the penetrometer is damaged or overloaded

5.4.2   The calibration should be focused on the low end of the load range with at least two increments of cone resistance and sleeve friction representing the range:

a) 0 to 1 MPa cone resistance
b) 0 to 10 kPa sleeve friction

5.4.3   The calibration factors should favour the low end of the load range (i.e. 0 – 2 MPa cone resistance). A second set of calibration factors may be appropriate for the higher range.

5.5   Cone Penetrometer Class

5.5.1   The calibration (for all classes) should include an uncertainty analysis by which the errors measured under laboratory conditions are quantified. This will indicate what Application Class is achievable with the equipment under laboratory conditions.

5.5.2   The uncertainty analysis should determine a combined uncertainty by considering the contributions of the following uncertainties:

a) Resolution
b) Repeatability
c) Reproducibility
d) Interpolation
e) Reversibility
f) Zero Drift

5.5.3   The Cone Penetrometer Class is determined from Table 4 below.

Table 4: Classification of cone penetrometers under laboratory conditions

Cone Penetrometer Class	Allowable maximum combined uncertainty*		Application Class(es) that penetrometer can be used for
1	Cone resistance	35 kPa or 5%	1, 2, 3, 4**
	Sleeve friction	5 kPa or 10%	
	Pore pressure	10 kPa or 2%	
2	Cone resistance	100 kPa or 5%	2, 3, 4
	Sleeve friction	15 kPa or 15%	
	Pore pressure	25 kPa or 3%	
3	Cone resistance	200 kPa or 5%	3, 4
	Sleeve friction	25 kPa or 15%	
	Pore pressure	50 kPa or 5%	

*the allowable maximum combined uncertainty is the larger of the two quoted. The relative uncertainty (%) applies to the measured value and not the FSO of the sensor
**Penetrometers that meet Cone Penetrometer Class 1 criteria would usually only be used for Application Class 1 conditions
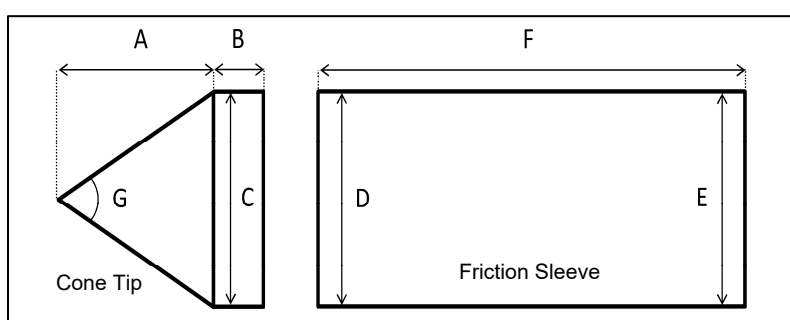
5.5.4   The Cone Penetration Class should be stated on the calibration report.

5.5.5   The Cone Penetration Class stated on the calibration report is an indication of the accuracy of the cone under laboratory conditions and does not represent the Application Class achieved by a test using that penetrometer. The Cone Penetrometer Class indicates that suitability of the penetrometer to be used for a particular Application Class as shown in Table 4. For example, for an Application Class 1 test, only a penetrometer that meets the requirements of Cone Penetrometer Class 1 can be used. The test will also need to meet the procedural and performance criteria of ISO 22476-1 and this best practice document in order to achieve a particular Application Class. Section 12.0 provides more information on how to assign Application Class to a completed test.

6.0 PENETROMETER DIMENSIONS

6.1   The physical dimensions and tolerances given in Sections 4.4 to 4.7 of ISO 22476-1: 2012 and associated Technical Corrigendum 1 shall apply with the following additions and clarifications.

6.2   Figure A below clarifies the acceptable dimensions of 10 cm^2 and 15 cm^2 cone penetrometers.

Dimension	Description	10 cm^2	15 cm^2
A	Height of conical section of tip	24.0 to 31.2 mm	29.4 to 38.2 mm
B	Height of cylindrical section of tip*	7.0 to 10.0 mm	8.6 to 12.2 mm
C	Diameter of cylindrical section of tip	35.3 to 36.0 mm	43.2 to 44.1 mm
D	Diameter at bottom of friction sleeve	C ≤ D ≤ (C + 0.35) mm	C ≤ D ≤ (C + 0.35) mm
E	Diameter at top of friction sleeve	D ≤ E ≤ 36.1	D ≤ E ≤ 44.2
F	Length of friction sleeve	132.5 to 135.0 mm	162.3 to 165.3 mm
G	Apex angle of cone tip	60^0 +/- 5^0	60^0 +/- 5^0

*includes the filter element and centring ring for TE2 penetrometer

Figure A: Cone Penetrometer dimensions and tolerances

6.3   Measurements at C, D and E should be taken at two orthogonal points around the penetrometer. The average of the two orthogonal readings should be used for comparison to the required dimensions and tolerances given in Figure A, above.

6.4   Measurements at D and E should be taken approximately 10mm in from the ends of the sleeve.

6.5 Dimensions C, D, E and F should be measured using Vernier or digital callipers accurate to two decimal places, or similar instrument that provides at least this level of accuracy (e.g. micrometer). These dimensions should be recorded in mm to one decimal place.

6.6 For good practice, dimensions A, B and G can be checked by using a wear check indicator tool.

6.7 A continuous record of the penetrometer dimensions should be maintained for each penetrometer. A standard template is provided in Appendix 1, which can be used to record the dimensions and checks done in the field.

6.8 Application Classes 2 to 4

6.8.1 Measurements of the cone penetrometer dimensions C, D, E and F and a check of dimensions A, B and G should be taken at least once daily. These should be taken at the time of the first use of the penetrometer for the day. More frequent measurements may be required when working in abrasive soils.

6.9 Application Class 1

6.9.1 Measurements of the cone penetrometer dimensions C, D, E and F and a check of dimensions A, B and G should be taken prior to the start of each test.

7.0 PENETROMETER PREPARATION

7.1 Cleaning and preparation of the penetrometer should be carried out as described in ISO 22476-1: 2012 with the following additions and clarifications.

7.2 The penetrometer should be fully dismantled, i.e. the cone tip, friction sleeve, dirt seals and O-rings removed. The dismantled cone and its components should be fully cleaned.

7.3 The penetrometer and its components should be checked for wear and surface imperfections, including rounded edges, uneven wear, convex or concave cone tip, broken or bent cone tip point and scratches or pitting on the surfaces of the cone tip or sleeve. If unacceptably worn or damaged, the affected components should be replaced with new components and this should be recorded on the dimension measurements form.

7.4 The dirt seals should be cleaned of all dirt and checked for damage. If damaged or deformed in any way, the affected seals should be replaced with new seals.

7.5 If the dismantled penetrometer is found to have moisture inside, e.g. condensation, then the penetrometer should be carefully dried.

7.6 When reassembling the penetrometer, the O-rings that seal the friction sleeve should be lightly lubricated so as to reduce frictional resistance provided by the O-ring. The type of lubrication used for this purpose should be that recommended by the manufacturer.

7.7 The cleaning and preparation of the penetrometer as described above should be carried out before and after each test. Where the penetrometer has been cleaned after a test and then reassembled, it can be considered ready for another test on the same day. If the penetrometer has not been used on the same day as previous tests but has previously been cleaned and reassembled, it should be dismantled (i.e the cone tip and friction sleeve removed) to check for any moisture or condensation inside.

8.0 PENETROMETER SATURATION

8.1   Saturation of the penetrometer as described in Section 5.4 and in Annex D of ISO 22476-1: 2012 shall apply with the following additions and clarifications.

8.2   Saturation fluid should be either glycerine or silicon oil. The grade of the saturation fluid should be such that it will perform to the minimum requirements of ISO 22476-1: 2012.

8.3   Porous filters should be placed in a container of the same saturation fluid that will be used in the cone preparation and treated under vacuum for a minimum period of approx. 24 hours to fully de-air the filters and fluid. Care should be taken to ensure there is plenty of fluid above the top of the filters.

8.4   Following vacuum treatment, the container should be topped up with de-aired fluid and sealed with an airtight lid. When transporting the containers, they should be kept vertical and carefully transported so that the filters are not exposed to the air above the fluid. A container that can hold a vacuum is preferred.

8.5   Methods of saturation/preparation of the penetrometer

8.5.1   Syringe method: The penetrometer is held upside down with the sleeve installed but the cone tip removed to expose the cavity for the pore pressure transducer. The cavity is filled with de-aired saturation fluid using a syringe by direct injection. A de-aired filter is removed from its container and quickly placed in position. De-aired saturation fluid is injected into the cone tip and then the cone tip placed in position on top of the penetrometer and tightened. As the cone tip is tightened, excess fluid and any air is displaced to ensure saturation of the cone.

8.5.2   Funnel method: The penetrometer is held upside down with the sleeve installed but the cone tip removed to expose the cavity for the pore pressure transducer. A funnel or cylindrical container is placed over the penetrometer. A hole with an O-ring seal at the base of the funnel or container creates a seal to the friction sleeve. The cone tip is placed at the bottom of the funnel/container and then de-aired saturation fluid poured into the funnel or container. This fills the pore pressure chamber of the penetrometer and fully covers the cone tip. A de-aired filter is removed from its container and quickly placed in the fluid in the funnel/container. The tip and filter are then installed on the end of the penetrometer entirely under the fluid. The fluid is then poured out of the funnel and the penetrometer removed from the funnel.

8.5.3   Secondary Saturation: In this method, the cone is first prepared and saturated in the one of the methods described in 8.5.1 or 8.5.2 and then the end of the penetrometer or otherwise the whole penetrometer is placed in a clear vacuum chamber under the de-aired saturation fluid and treated to full vacuum. This further ensures full saturation of the penetrometer. The vacuum is applied until no air can be seen coming out of the filter. This method allows any air that may have been introduced into the system during the initial preparation of the cone to be expelled so as to provide more certainty of the de-airing of the penetrometer. This treatment is referred to in this document as 'secondary saturation' as it is generally performed after an initial preparation of a saturated filter. However, this method can also be applied to a penetrometer with a dry filter. In that case the penetrometer is assembled without any saturation fluid and with a dry filter and then placed in the vacuum with de-aired fluid. This is also an acceptable method and may be required for some penetrometer types. It will take longer for the penetrometer to be fully de-aired in that case.

8.6   Once prepared and saturated in the manner described in 8.5, the end of the penetrometer can be covered with a rubber membrane to create a seal and hold the fluid in place. A rubber membrane should be used if the penetrometer is left in air for a period of time of more than 10 mins before starting the test.

8.7   Slot Filter: A slot filter can be used instead of a porous filter in which case silicon grease is usually used as the saturation fluid. Slot filters have the advantage of holding saturation better through dry surface crust soils, however, they can provide less dynamic pressure response than porous filters. As such they should generally not be used unless required under specific circumstances.

8.8   Application Class 1

8.8.1   For Application Class 1, a porous filter treated to secondary saturation as described in 8.5.3 is required. A slot filter should not be used for Class 1 testing.

8.9   Application Classes 2 to 4

8.9.1   For Application Classes 2 to 4, saturation can be by any of the methods described in 8.5.

8.9.2   If pore pressure measurements are particularly important, then secondary saturation should be specified regardless of application class.

8.9.3   In instances where the ground conditions are not favourable for maintaining saturation, a slot filter may be used. Pore pressure response is likely to be reduced.

8.10   A new porous filter should be used for each test.

9.0 TEMPERATURE CONDITIONING

9.1   Changes in temperature will affect the results of the test due as the sensors cannot readily compensate for transient temperature changes. The penetrometer should be brought to a stable temperature as close as possible to the expected ground temperature prior to testing. This is particularly important when the penetrometer is significantly higher or lower than the ground temperature.

9.2   Methods for Temperature Conditioning

9.2.1   Bucket of water: Place the prepared and saturated cone into a bucket of water and leave to stabilise to the temperature of the water. This will generally take about 10 mins. This can be monitored by the zero readings of the sensors and/or by a temperature sensor in the penetrometer, if installed.

9.2.2   Heating/cooling chamber: The penetrometer can be placed in a chamber or bath which is heated or cooled to a temperature equivalent to the expected ground temperature and left to stabilise.

9.2.3   In situ temperature conditioning: The penetrometer is pushed into the ground by a few meters and preferably below the water table and left until a stable temperature is achieved. This will generally take about 10 minutes. If the penetrometer includes a temperature sensor, this can be used to monitor the stability of the penetrometer temperature.

9.3.1   Any of the methods described in 9.2 can be used. The bucket of water method is likely to be the most convenient. If the penetrometer and air temperature are already close to the expected ground temperature, then temperature conditioning prior to the test is probably not necessary.

9.4   Application Class 1

9.4.1   The penetrometer should be conditioned to the ground temperature using the methods described in 9.2.2 and 9.2.3.

9.4.2   For Class 1 testing, the cone penetrometer should be equipped with a temperature sensor.

9.5   Temperature changes during testing are discussed in 11.8.

10.0 ZERO LOAD READINGS

10.1   The recording of zero load readings before and after the test should be carried out as described in ISO 22476-1: 2012 with the following additions and clarifications.

10.2   The zero load readings before the test should be undertaken with the rubber membrane removed.

10.3   The zero load readings should be monitored for at least 1 minute until they have stabilised to the extent that they fluctuate by no more than two times the resolution of the sensors over a 30 second period.

10.4   At the end of the test, an after set of zero load readings should be taken as soon as the penetrometer is extracted from the ground.

10.5   It is possible that the after zero readings will be affected by dirt in the gaps and partial blockage of the porous filter. It is acceptable to partially unscrew the cone tip to relieve this residual load in order to take the after zero readings. Similarly, it may also be necessary to loosen the friction sleeve if it is a screw-on type.

10.6   For Application Class 1, two sets of after zero readings shall be taken. One set with the penetrometer as it is when extracted from the ground and the other after cleaning.

10.7   The after zero load readings should be monitored for at least 1 minute before accepting them to ensure that they have stabilised to within two times the resolution of the sensors.

10.8   The zero load readings of each individual penetrometer (both before and after) should be recorded with time where the baseline readings from the last calibration are the zero readings form the first use of the penetrometer after last calibration.

10.9   A suggested template form for the monitoring of zero load readings is given in Appendix 2.

11.0 TESTING

11.1   The test is carried out by pushing the cone penetrometer into the ground as described in ISO 22476-1: 2012 with the following additions and clarifications.

11.2   The rods and penetrometer should be adequately straight so that the test remains within the allowable tolerances of the required application class for inclination. *Practice note: straightness can be checked by rolling the rods or penetrometer on a flat surface. Alternatively, the methods suggested in Annex A, Clause A.1.1 of the ISO 22476-1 can be used*.

11.3   Friction Reducer: If used, a friction reducer should be located at least 400 mm from the base of the cone tip for a 10 cm^2 penetrometer. A friction reducer is generally not required for a 15 cm^2 penetrometer, but if used should be at least 490 mm from the base of the cone tip.

11.4   The rods and/or penetrometer body should be the same diameter for a 15 cm^2 penetrometer for a distance of at least 490 mm from the base of the cone tip. A lesser distance can be used and is considered an acceptable deviation from the standard but should be noted in the records of the test.

11.5   The penetrometer should be pushed at a continuous rate of 20 mm/s +/- 5 mm/s. If the penetration is stopped for a period of more than 5 minutes (e.g. due to breakdown), a note should be made in the records to indicate reason and length of time of the stop.

11.6   Penetration length checks

11.6.1 Penetration length can be checked by measuring the distance from the top of a rod to a reference point on the push frame at the start of a test and then measuring to the top of the last rod from the same reference point at the end of the test. By knowing the number of rods used, the total length of rods pushed can be compared to the penetration length measured by the depth encoder. The penetration length error is the difference between the total rod length pushed and the measured penetration length. This error should be no more than the minimum accuracy values given in Table 2 of ISO 22476-1.

11.6.2 For Application Classes 2 to 4, the penetration length check described in 11.6.1 should be undertaken for each test.

11.6.3 For Application Class 1, the penetration length checks described in 11.6.1 should be done at least every 5 m.

11.6.4 Alternative methods for checking penetration length may also be used provided they can be shown to be at least as effective as that described in 11.6.1.

11.7   Temperature changes during testing

(Clauses 11.7.1 to 11.7.4 are advisory notes)

11.7.1 During testing, temperature changes may occur as the penetrometer goes through layers of harder and softer ground. This is mostly of concern when penetrating through dense sand into soft clay. The penetrometer will heat up as it goes through the sand and then cools as it enters the soft clay. The transient changes in temperature may affect the accuracy of the data in both the sand and the clay, but will have a greater effect in the clay.

11.7.2 If a temperature sensor is included in the penetrometer, then the information obtained from this sensor may help to assess the temperature effects.

11.7.3 If large transient temperature changes are anticipated from the ground conditions at the site, e.g. going from dense soil into soft clay, then it may be necessary to halt the penetration at the bottom of the dense soil layer until temperatures can dissipate. If the penetrometer is equipped with a temperature sensor, the temperature can be monitored until it returns to the expected ground conditions before continuing the push. Alternatively, the test can be repeated in a pre-drilled hole or larger diameter dummy probe hole that is taken through the dense layer into the top of the soft soil.

11.7.4 For Application Class 1, temperature should ideally be monitored and recorded during testing by using a temperature sensor in the penetrometer. If changes in temperature are recorded during the test, the results may need to be corrected. Otherwise the estimated error (if any) relating to temperature changes should be included in the uncertainty assessment of the test, if readily quantifiable.

11.8   Pore pressure problems during testing

11.8.1 It is sometimes difficult to maintain filter saturation during testing, particularly when pushing through a desiccated crust or through dilatant soils. In such cases, low porewater pressure response may occur. If the pore pressure response is poor, then the pore pressure information may be invalid, and the test is then considered to be equivalent to a non-piezocone TE1 test. A note in the records should indicate that the pore pressure results should be ignored in the processing and analysis of the data.

11.8.2 Where good porewater pressure response is important, but the ground conditions are unfavourable, it may be necessary to predrill or dummy probe to the water table, fill the hole with water, and then start a new test.

11.8.3 For Application Class 1, high quality pore pressure measurements are required. If bad pore pressure results are obtained despite utilising the method suggested in 11.8.2 or by other methods, the test results cannot be assigned Class 1 status.

11.8.4 Where ground conditions may be unfavourable for maintaining saturation, a grease filled slot filter can be used. The use of a slot filter should be noted in the records of the test. A slot filter cannot be used for Application Class 1 testing.

11.9   Dissipation testing

11.9.1 Dissipation testing should be carried out in accordance with Clause 5.9 of ISO 22476-1: 2012 with the following additions and clarifications.

11.9.2 Dissipation tests should be carried out with the rods unclamped and the force maintained. Alternatively, the force may be removed from the rods at the start of the test. If the rods start sinking, they may be clamped. The test record should show whether the force was maintained or removed, and if the rods were clamped or unclamped.

11.9.3 Dissipation tests are considered to start (i.e. time = 0) the instance the penetration has stopped. It is therefore important to start recording pore pressure dissipation as soon as possible after stopping.

12.0 ASSESSMENT OF APPLICATION CLASS

12.1   The first step in evaluating application class is to ensure that the Cone Penetrometer Class as determined by the laboratory calibration is suitable for the desired Application Class as per Table 4 of this document. For example, for the test to meet Application Class 1, the penetrometer must meet the criteria for Cone Penetrometer Class 1.

12.2   Provided that the tests have been performed in accordance with the procedural methods and performance criteria described in this document, then the test can be assigned as meeting a particular application class depending on the accuracy error being less than that shown in Table 2 of ISO 22476-1. The accuracy error of the test shall be taken as the absolute value of the zero drift during a test in kPa for cone resistance, sleeve friction and pore pressure.

12.3   For Application Class 1, the zero drift for the purposes of evaluating application class shall be determined from the difference between the second after zero readings (i.e. after cleaning) and the before zero readings at the start of the test.

12.4   The zero drift is compared to the absolute values given in Table 2 of ISO 22476-1. For example, if the zero drift is between 35 kPa and 100 kPa for cone resistance, then the test falls into Application Class 2 (for cone resistance).

12.5   The assessed errors of all sensors must meet all the corresponding accuracy criteria given in Table 2 of ISO 22476-1 in order for that test to meet a particular application class.

12.6   Where a piezocone test (TE2) has been affected by bad pore pressure readings, the test may be considered to be a TE1 type test and the u_2 error ignored from the evaluation of application class. This is only applicable to Application Classes 2 to 4 and not to Application Class 1. Although the zero drift values may meet the desired application class criteria, a test may need to be repeated if the pore pressure readings are not satisfactory for the Client's requirements.

12.7   For Application Class 1, any additional errors, such as those relating to temperature changes, if readily quantifiable, should also be considered in the evaluation of application class. Any such additional errors should be added to the in-test zero drift values to provide an estimate of the total accuracy error of the test.

12.8   Application Class 1 only applies to very soft to soft homogeneous soils (q_c < 1MPa). Class 1 cannot be assigned to any other soil type. If the sounding is mostly very soft to soft homogeneous soils but includes a layer of harder/denser soil, the sounding may still be classified as Class 1, provided that the accuracy levels measured within the other soils in the sounding also meet the Application Class 1 accuracy criteria. It may be necessary to predrill or dummy probe through harder/denser layers so that the CPT testing is only done in very soft to firm soils.

12.9   A template to help assign application class from test results is given in Appendix 5.

12.10   An optional alternative method of evaluating application class is to consider the zero drift error as a percentage of the measured values of the q_c, f_s and u_2 parameters. This will vary with each depth point and so is best presented in a graphical form, as illustrated in the example shown in Appendix 6 (after Peuchen and Terwindt 2014).

13.0 REPORTING

13.1 This section completely replaces ISO 22476-1, Section 7.

13.2 The reporting and presentation of the results shall comprise:

a) A test report that includes information recorded from the site, as prescribed in Section 13.4, below
b) Plots showing the measured or calculated parameters: q_c (or q_t), f_s, u_2 (if applicable) with penetration length or depth.
c) Plots showing results of dissipation tests, if applicable, as described in Section 13.6, below
d) Excel spreadsheet or similar electronic tabulated data covering relevant data from b) to d), as described in Section 13.7, below
e) AGS4 data (optional)
f) A calibration report for the laboratory calibration of the cone penetrometer, as per the requirements of Section 5.

13.3 Definition of information and data types

13.3.1 **Test Information** is defined as all information recorded in relation to the testing, other than the data obtained from the cone penetrometers sensors.

13.3.2 **Raw Data** is defined as the unaltered data obtained directly from the cone penetrometer sensors. These are usually electrical values with units of mV.

13.3.3 **Measured Parameters** are defined as raw data with the calibration factors applied, but no other correction, adjustment or calculation.

13.3.4 **Calculated Parameters** are defined as the measured parameters adjusted or corrected for such things as porewater pressure (to obtain q_t), sleeve offset, inclination, penetrometer dimensions. These are calculations or adjustments made using measured or known parameters, but do not include any interpreted information.

13.3.5 **Interpreted Parameters** are defined as additional calculations to the measured or calculated parameters using assumed values or using theoretical relationships or empirical correlations. For example, parameters that rely on in situ porewater pressure, u_0 or unit soil weight, γ. Correlations to geotechnical soil parameters, such as undrained shear strength, s_u, are also included in the definition of interpreted parameters. The determination and reporting of interpreted parameters are considered to be outside the standard. This is further discussed in section 14.

13.4 Test Report

13.4.1 The test report shall include the following information:

13.4.2 **Project Information**:

— Project name (if applicable)
— Project address
— Client name
— Client contact

13.4.3 **Test information** (for each sounding):

a) <u>Test number and location</u>:
— Test number
— Co-ordinates and reference system
— Elevation (if known) and reference datum

b) <u>Client test requirements</u>:
— Target depth (m) and/or stop criteria
— Any other client requirements or instructions (e.g. required Application Class, dissipation test requirements)

c) <u>Rig information</u>:
— Make and model or type of rig
— Maximum stated push capacity (kN)
— Anchored or non-anchored (ballasted)
— Any other information relating to the rig and its set up that deviate from a common set up.

d) <u>Cone penetrometer</u>:
— Cone penetrometer type (TE1 or TE2)
— Nominal size (e.g. 10 cm^2 or 15 cm^2)
— Manufacturer
— Compression or subtraction
— Serial or identification number
— Calibration report reference, date of last calibration and date of first use of penetrometer after last calibration
— Cone penetrometer class
— FSO of the sensors (q_c, f_s and u_2)
— Filter location (if not u_2)
— Net area ratio, a

e) <u>Test procedure</u>:
— Date of test
— Name of company and operator performing the test
— Depth of the start of penetration in relation to the ground surface
— Depth of predrilling in relation to the ground surface (if applicable)
— Temperature of the penetrometer at the start of the test, if known
— Details of temperature conditioning (e.g. bucket of water)
— Starting time of the test (clock time)
— Before zero readings of the penetrometer sensors
— Depths to which penetration was stopped for pore pressure dissipation tests
— Length of time for each dissipation test
— Observations during the test (e.g. buckling rods, noise during push, reasons for non-standard pauses in penetration)
— Reason for terminating the test (e.g. target depth reached or limit of cone tip sensor)
— After zero readings of the penetrometer sensors
— Second set of after zero readings after penetrometer has been cleaned, if applicable
— Drift in zero readings (difference between before and after) for each sensor
— Achieved Application Class
— Method of measuring groundwater in the CPT hole, if applicable (e.g. dipmeter)

— Measured depth to groundwater, if measured or estimated depth to groundwater if estimated

13.5 <u>Graphical presentation of measured or calculated parameters</u>

13.5.1 Plots of measured or calculated data against depth shall be provided for:

a) Cone resistance, q_c and/or corrected cone resistance, q_t (MPa)
b) Sleeve friction, f_s (kPa or MPa)
c) Pore pressure, u_2 (kPa or MPa), if applicable

13.5.2 Optional plots with depth may also be provided for:

a) Inclination, α (degrees from vertical)
b) Friction ratio, $R_f = f_s/q_c$ x 100%
c) Corrected friction ratio, $R_{ft} = f_s/q_t$ x 100%
d) Temperature, if applicable

13.5.3 Plots can be at any appropriate scale. Depth shall be plotted on the vertical axis with increasing values from top to bottom. The depth axis shall be at the same scale for all plots provided.

13.5.4 More than one parameter may be plotted on one axis of the same plot, e.g. q_c and f_s.

13.5.5 If the measured parameters have been altered to calculated parameters, any alterations or calculations (e.g. sleeve depth offset) should be clearly stated on the plot sheet or accompanying information sheet.

13.5.6 For plotting purposes, penetration depth can be assumed to equal penetration length for Application Classes 2 to 4, but this assumption should be clearly indicated on the plot sheet or accompanying information sheet.

13.5.7 For Class 1, the corrected penetration depth should be calculated from the measured penetration length and inclination using the method provided in ISO 22476-1 Annex B. This is optional for Classes 2 to 4. If such a correction has been made, it should be clearly stated on the plot sheet or accompanying information sheet.

13.6 <u>Presentation of Dissipation Tests</u>

13.6.1 A plot should be provided of measured pore pressure with either square root of time or time on a log scale.

13.6.2 For Application Class 1, q_c, f_s and temperature (if applicable) shall also be plotted with time (square root or log scale) along with the pore pressure.

13.6.3 For Application Classes 2 to 4, the additional plots of q_c, f_s and/or temperature are optional.

13.7 <u>Numerical Results</u>

13.7.1 The data relating to the measured and/or calculated parameters that are provided in graphical form (as described in 13.5 and 13.6) shall also be provided in an electronic tabular format such as Excel (or similar). The data provided in the tabular format should match that provided in the graphical plots using the same alterations or calculations to the measured data, if any.

13.7.2 The data can also be provided in AGS4 format. This is optional, but strongly encouraged.

13.8 <u>Calibration information</u>

The calibration report for the cone penetrometer used shall be provided.

13.9 <u>Test report template</u>

An example template for recording the required test information in accordance with Section 13.4 is provided in Appendix 3 as a guide.

14.0 INTERPRETED PARAMETERS (Informative)

14.1 The determination and reporting of interpreted parameters is considered to be outside the standard. These require geotechnical assumptions or correlations to be made beyond the measurements obtained from the test. Ideally only those with appropriate geotechnical qualifications, experience and skill should provide interpreted parameters. The interpreted parameters may inform design decisions and therefore can carry a liability risk. Care should be taken if these are to be provided.

14.2 Common interpreted parameters include, but are not limited to:

   a) In situ porewater pressure, u_o (assumes knowledge of the groundwater table and in situ pore pressure distribution in the ground)
   b) Soil unit weight, γ (may be estimated from laboratory soil testing or from correlations from CPT data)
   c) Overburden stress, σ_{vo} (dependant on γ)
   d) Effective overburden stress, σ'_{vo} (dependant on u_o and γ)
   e) Excess pore pressure, $\Delta u = u_2 - u_o$
   f) Net cone resistance, $q_n = q_t - \sigma_{vo}$
   g) Pore pressure ratio, $B_q = \Delta u / q_n$
   h) Normalised cone resistance, $Q_t = q_n / \sigma'_{vo}$
   i) Normalised friction ratio, $F_r = f_s / q_n \times 100\%$
   j) Soil Behaviour Type Index, $I_c = ((3.47 - \text{Log } Q_t)^2 + (\text{Log } F_r + 1.22)^2)^{0.5}$
   k) Soil Behaviour Type (a type of soil description dependant on Q_t and F_r)

14.3 Further interpretation can provide estimates of engineering parameters. These engineering parameters require an extra level of interpretation and usually involve the use of theoretical or empirical correlations. Extra caution is required if these engineering parameters are to be provided. Examples of typical engineering parameters that can be derived from CPT data are:

   a) Undrained shear strength, s_u
   b) Relative density, D_r
   c) Friction angle, ϕ'
   d) Equivalent SPT N_{60}

14.4 If the interpreted parameters described in 14.2 and 14.3 or any other interpreted parameters are to be provided, the assumptions made should be clearly stated and references provided for any theoretical or empirical relationships used. A note should also be included that these parameters are outside the standard.

15.0 AUDITING AND CERTIFICATION

15.1   CPT Contractors are to be audited to demonstrate compliance to ISO 22476-1:2012 and this best practice guideline (TG6). Audits will be done internally (within companies) and externally (using an external auditor) at periods determined appropriate by the CETANZ CPT Group.

15.2   External auditors will be suitably experienced CPT operators or otherwise experts in the industry that are approved by the CETANZ CPT Group. These auditors may be sourced from volunteers within the CETANZ CPT Group or from experts outside the group.

15.3   It will be up to the Auditor to determine how the audit shall be conducted and what elements of the standard are to be demonstrated. As a guide, a short audit checklist has been provided in Appendix 8. This is not a complete checklist of all elements of the standard but covers the main items that influence the quality and accuracy of the test and its results.

15.4   Contractors that pass an audit will be considered certified to TG6. A list of those contractors so certified will be provided on the CETANZ website. Only contractors that have representative membership of CETANZ can be certified.

APPENDICES

Appendix 1: Template for recording penetrometer dimensions and condition

Appendix 2: Template for zero readings

Appendix 3: Test report template

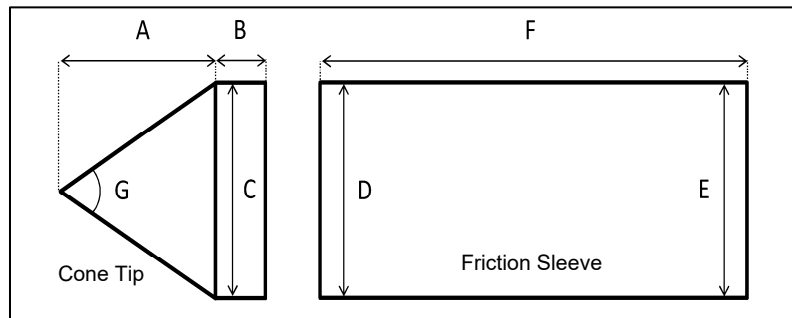Appendix 4: Dissipation test report template

Appendix 5: Template for application class assessment

Appendix 6: Example of graphical presentation of application class

Appendix 7: Flow chart for CPT test procedure

Appendix 8: Short audit checklist

APPENDIX 1: TEMPLATE FOR RECORDING PENETROMETER DIMENSIONS AND CONDITION

Dimension	Description	10 cm²	15 cm²
A	Height of conical section of tip	24.0 to 31.2 mm	29.4 to 38.2 mm
B	Height of cylindrical section of tip	7.0 to 10.0 mm	8.6 to 12.2 mm
C	Diameter of cylindrical section of tip	35.3 to 36.0 mm	43.2 to 44.1 mm
D	Diameter at bottom of friction sleeve	C ≤ D ≤ (C + 0.35) mm	C ≤ D ≤ (C + 0.35) mm
E	Diameter at top of friction sleeve	E ≥ D	E ≥ D
F	Length of friction sleeve	132.5 to 135.0 mm	162.3 to 165.3 mm
G	Apex angle of cone tip	60^0 +/- 5^0	60^0 +/- 5^0

Penetrometer:		☐ 10 cm²		☐ 15 cm²				Serial No.		
Date	Time	Dimensions						Dimensions OK?	Components Condition OK?	Remarks
		A	B	C	D	E	F	G		

Date	Time	A	B	C	D	E	F	G	Dimensions OK?	Components Condition OK?	Remarks
									☐ Y ☐ N	☐ Y ☐ N	
									☐ Y ☐ N	☐ Y ☐ N	
									☐ Y ☐ N	☐ Y ☐ N	
									☐ Y ☐ N	☐ Y ☐ N	
									☐ Y ☐ N	☐ Y ☐ N	
									☐ Y ☐ N	☐ Y ☐ N	
									☐ Y ☐ N	☐ Y ☐ N	
									☐ Y ☐ N	☐ Y ☐ N	

APPENDIX 2: TEMPLATE FOR ZERO READINGS

Penetrometer:													Serial No.

Date	Test No./ Calibration	q_c				f_s				u_2				Remarks
		Initial zero	Final zero	In-test Drift	Shift from Cal.	Initial zero	Final zero	In-test Drift	Shift from Cal.	Initial zero	Final zero	In-test Drift	Shift from Cal.	
	Calibration													

APPENDIX 3: TEST REPORT TEMPLATE

Project Details Project name:	
Project address:	Project Ref:
Client name:	Client contact:

Test Number and Location Test Number:	
Co-ordinates	Elevation:
Reference:	

Client's Test Requirements

☐ Target depth: m   or ☐ Continue to refusal (estimated depth: m)

Any other Client instructions:

Rig Information   Make and model or type:

Maximum push capacity: kN   ☐ Ballasted   or ☐ Anchored

Any deviations from common set up:

Cone Penetrometer Information Penetrometer type: ☐ TE1 ☐ TE2	
Nominal size ☐ 10 cm^2 ☐ 15 cm^2 ☐ Other:	
Type: ☐ Compression ☐ Subtraction	Filter location: ☐ u$_2$ ☐ Other:
Manufacturer:	Serial Number:
Calibration report ref:	Date of last calibration:
Full Scale Output of sensors: q$_c$: MPa f$_s$: kPa u$_2$: kPa	
Net cone area ratio, a:	Cone Penetrometer Class:
Saturation method: ☐ n/a ☐ syringe ☐ funnel ☐ secondary (vacuum) ☐ other	

Test Procedure: Date of test Test number:	
Testing contractor:	Name of operator:
Depth of predrill, if applicable:	
Temperature of penetrometer at start of test, if known: degC	
Temperature conditioning: ☐ none ☐ bucket of water ☐ pre-push into ground ☐ other:	
Depth at start of penetration in relation to ground surface: m ☐ AGL ☐ BGL	
Starting time of test (clock time):	
Before zero readings: q$_c$: f$_s$: u$_2$:	
Observations during the test:	
Pore pressure dissipation tests done: ☐ Yes (see separate sheet) ☐ No	
Reason(s) for terminating the test: ☐ target depth reached ☐ high cone resistance ☐ high sleeve friction ☐ high pore pressure ☐ excessive inclination ☐ high total load ☐ danger of buckling rods ☐ other:	
After zero readings: q$_c$: f$_s$: u$_2$:	
Second set of after zero readings (after cleaning): q$_c$: f$_s$: u$_2$	
Drift in zero readings: q$_c$: f$_s$: u$_2$:	
Achieved Application Class:	
Depth to groundwater: m ☐ estimated ☐ measured ☐ not known	
If estimated or measured, how:	

APPENDIX 4: DISSIPATION TEST REPORT TEMPLATE

Dissipation Tests:		Date of test			CPT Test number:		
Testing contractor:				Name of operator:			
Dissipation test No.	1	2	3	4	5	6	7
Depth (m):							
GW depth							
Insitu u_0							
Initial u_2							
Final u_2							
Load on?	☐y ☐n	☐y ☐n	☐y ☐n	☐y ☐n	☐y ☐n	☐y ☐n	☐y ☐n
Clamped?	☐y ☐n	☐y ☐n	☐y ☐n	☐y ☐n	☐y ☐n	☐y ☐n	☐y ☐n
Start Time							
Total time							
Achieved	☐ t_{50} ☐ t_{90} ☐ other:	☐ t_{50} ☐ t_{90} ☐ other:	☐ t_{50} ☐ t_{90} ☐ other:	☐ t_{50} ☐ t_{90} ☐ other:	☐ t_{50} ☐ t_{90} ☐ other:	☐ t_{50} ☐ t_{90} ☐ other:	☐ t_{50} ☐ t_{90} ☐ other:
Any other information or observations on dissipation tests:							
Plots of dissipation tests are provided separately							

APPENDIX 5: TEMPLATE FOR APPLICATION CLASS ASSESSMENT

Project name:	Project Ref.
Project address:	

Date of test:	Test Number:

Desired Application Class: ☐ Class 1 ☐ Class 2 ☐ Class 3 ☐ unknown

Cone penetrometer type: TE1 (CPT) ☐ application classes 2 to 4
TE2 (CPTU) ☐ application classes 1 to 4

Full Scale Output (FSO) of sensors: q_c: MPa f_s: kPa u_2: kPa

Temperature sensor in penetrometer? Yes ☐ No ☐ (preferable for Class 1)

Calibration report ref:	Date of last calibration:

Cone Penetrometer Class: 1 ☐ application classes 1 to 4
(from laboratory calibration) 2 ☐ application classes 2 to 4
3 ☐ application classes 3 to 4

Time since first use of penetrometer: < 6 months ☐ application classes 1 to 4
< 12 months ☐ application classes 2 to 4
Time since last calibration: < 24 months ☐ application classes 1 to 4
greater than these values ☐ outside standard

Continuous record of zero readings maintained? Yes ☐ classes 1 to 4
No ☐ outside standard
Maximum shift of zero readings from baseline calibration values:
    cone resistance: < 2.5% FSO ☐ classes 2 to 4, or: < 1% FSO ☐ class 1
    sleeve friction: < 2.5% FSO ☐ classes 2 to 4, or: < 1% FSO ☐ class 1
    pore pressure: < 2.5% FSO ☐ classes 2 to 4, or: < 1% FSO ☐ class 1
    greater than these values ☐ outside standard

Cone dimensions: within tolerances? Yes ☐ classes 1 to 4
No ☐ outside standard
    Measurement method: wear check indicator (each test) ☐ classes 2 to 4
callipers/micrometer (each day) ☐ classes 2 to 4
callipers/micrometer (each test) ☐ class 1 to 4
Difference in dimensions as percentage in relation to ideal areas*: q_c: _____% f_s: _____%
Test data corrected for dimension differences? Yes ☐ classes 1 to 4
No ☐ classes 2 to 4

*Ideal areas are q_c = 10 cm^2 and f_s = 150 cm^2 for 10 cm^2 cone penetrometer and q_c = 15 cm^2 and f_s = 225 cm^2 for 15 cm^2 cone penetrometer. Similarly determined for other sized cone penetrometers depending on nominal diameter.

Pore pressure filter type (if TE2): slot ☐ classes 2 to 4
porous ☐ classes 1 to 4
    Saturation method: grease filled slot filter ☐ classes 2 to 4
syringe or funnel without secondary saturation ☐ classes 2 to 4
secondary saturation ☐ classes 1 to 4

Pore pressure response in test. good ☐ classes 1 to 4
Poor/bad* ☐ classes 2 to 4
*if pore pressure response is bad then u_2 results to be ignored and test considered to be equivalent to TE1 test

Temperature conditioning of the penetrometer prior to testing?
    bucket of water ☐ classes 2 to 4
    heating/cooling chamber ☐ classes 1 to 4
    in situ temperature conditioning ☐ classes 1 to 4
    No temperature conditioning ☐ outside standard unless penetrometer
    already close to ground temperature (classes 2 to 4 only)

Comments:

Comments of temperature variations during testing:

Before zero readings:
Length of time that before zero readings were left to stabilise: > 1 min ☐ classes 1 to 4

After zero readings:
Length of time that after zero readings were left to stabilise: > 1 min ☐ classes 1 to 4
less than these values ☐ outside standard

Zero reading output stability:
q_c, f_s and u_2 < 2 x resolution of sensors ☐ classes 2 to 4
greater than these values ☐ outside standard

Penetration length checks:
completed at least every 5 m ☐ classes 1 to 4
at least once per test ☐ classes 2 to 4
penetration length tests not done ☐ outside standard
Error in penetration length: _____ m, _____%   < 0.1 m or 1% ☐ classes 1 to 2
< 0.2 m or 2% ☐ classes 3 to 4
Penetration error corrected in test results?   Yes ☐   No ☐

	Error in measurement		
	q_c	f_s	u_2
Zero reading drift during test (kPa) (difference in before and after zero readings)			
Application class criteria:			
Application class 1	≤ 35 kPa ☐	≤ 5 kPa ☐	≤ 10 kPa ☐
Application class 2	≤ 100 kPa ☐	≤ 15 kPa ☐	≤ 25 kPa ☐
Application class 3	≤ 200 kPa ☐	≤ 25 kPa ☐	≤ 50 kPa ☐
Application class 4	≤ 500 kPa ☐	≤ 50 kPa ☐	

Achieved Application Class:
☐ Application Class 1
☐ Application Class 2
☐ Application Class 3
☐ Application Class 4
☐ Application class not achieved or outside standard

Comments:

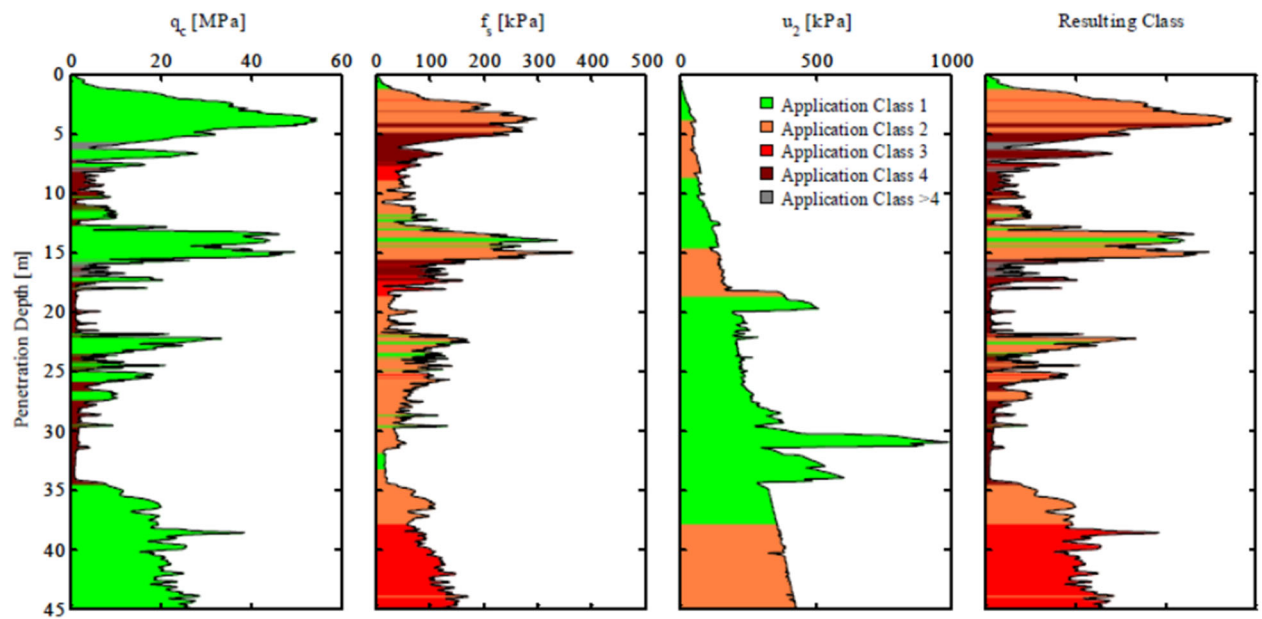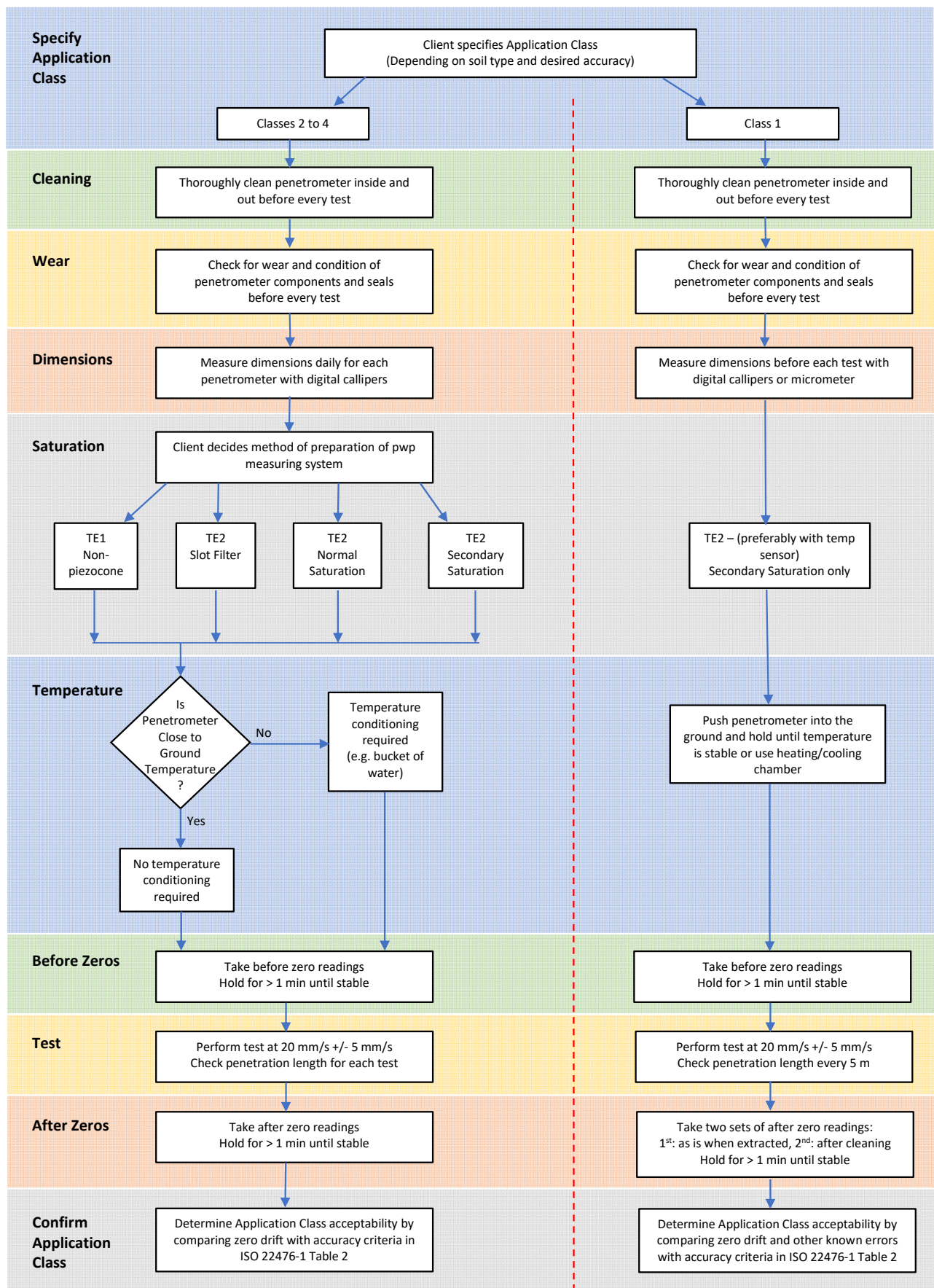**APPENDIX 6: EXAMPLE OF GRAPHICAL PRESENTATION OF APPLICATION CLASS**

Figure A6.1: Graphs illustrating application class determined as percentage of measured values (after Peuchen and Terwindt 2014).

APPENDIX 7: FLOW CHART FOR CPT TEST PROCEDURE

Specify Application Class

Client specifies Application Class
(Depending on soil type and desired accuracy)

→ Classes 2 to 4

→ Class 1

Cleaning

Thoroughly clean penetrometer inside and out before every test

Thoroughly clean penetrometer inside and out before every test

Wear

Check for wear and condition of penetrometer components and seals before every test

Check for wear and condition of penetrometer components and seals before every test

Dimensions

Measure dimensions daily for each penetrometer with digital callipers

Measure dimensions before each test with digital callipers or micrometer

Saturation

Client decides method of preparation of pwp measuring system

- TE1 Non-piezocone
- TE2 Slot Filter
- TE2 Normal Saturation
- TE2 Secondary Saturation

TE2 – (preferably with temp sensor) Secondary Saturation only

Temperature

Is Penetrometer Close to Ground Temperature?

— No → Temperature conditioning required (e.g. bucket of water)

— Yes → No temperature conditioning required

Push penetrometer into the ground and hold until temperature is stable or use heating/cooling chamber

Before Zeros

Take before zero readings
Hold for > 1 min until stable

Take before zero readings
Hold for > 1 min until stable

Test

Perform test at 20 mm/s +/- 5 mm/s
Check penetration length for each test

Perform test at 20 mm/s +/- 5 mm/s
Check penetration length every 5 m

After Zeros

Take after zero readings
Hold for > 1 min until stable

Take two sets of after zero readings:
1st: as is when extracted, 2nd: after cleaning
Hold for > 1 min until stable

Confirm Application Class

Determine Application Class acceptability by comparing zero drift with accuracy criteria in ISO 22476-1 Table 2

Determine Application Class acceptability by comparing zero drift and other known errors with accuracy criteria in ISO 22476-1 Table 2

APPENDIX 8: SHORT AUDIT CHECKLIST

Note: this form is intended as a guide for internal audits by CPT Contractors or for quality assurance audits by clients or engineers. It is not intended for a complete audit that might be required for certification or accreditation purposes.

Item	Pass	Fail	Comments
1. Operator(s) knowledge: Do they know what standard the test is being done to?	☐ Yes	☐ No	
Have they been trained to the standard and TG6?	☐ Yes	☐ No	
Are they aware of the desired application class for the test?	☐ Yes	☐ No	
2. Rig set up: Has the rig been set up as close to vertical as possible? (within 2°)?	☐ Yes	☐ No	
3. Calibration (TG6 Section 5.0): Is the calibration report available on site?	☐ Yes	☐ No	
Is the calibration up to date?	☐ Yes	☐ No	
Does the serial number of the penetrometer match the calibration?	☐ Yes	☐ No	
Is the Cone Penetrometer Class stated on the calibration report suitable for the desired application class?	☐ Yes	☐ No	
Has a continuous record of zero readings been maintained?	☐ Yes	☐ No	
4. Penetrometer dimensions (TG6 Section 6.0): Has the penetrometer been measured at the correct intervals?	☐ Yes	☐ No	
Has a continuous record of penetrometer dimensions been maintained?	☐ Yes	☐ No	
Are the components of the penetrometer within tolerances?	☐ Yes	☐ No	
5. Penetrometer preparation (TG6 Section 7.0): Has the penetrometer been fully dismantled and thoroughly cleaned prior to using?	☐ Yes	☐ No	
Are the components of the penetrometer in good condition?	☐ Yes	☐ No	
Are the dirt seals and O-rings in good condition?	☐ Yes	☐ No	
O-rings for the friction sleeve lightly greased prior to assembly?	☐ Yes	☐ No	
6. Penetrometer Saturation (TG6 Section 8.0) – as applicable: Is the method of saturation suitable for the desired application class and Client's requirements?	☐ Yes ☐ N/A	☐ No	
Has a new porous filter been used?	☐ Yes ☐ N/A	☐ No	
Has porous filters been pre-saturated in vacuum for approx. 24 hrs?	☐ Yes ☐ N/A	☐ No	
Have de-aired porous filters been stored in an airtight container under the saturation fluid?	☐ Yes ☐ N/A	☐ No	
Porous filter correctly assembled with penetrometer?	☐ Yes ☐ N/A	☐ No	
Secondary saturation undertaken? (assembled penetrometer put in vacuum chamber under sat. fluid)	☐ Yes ☐ N/A	☐ No	
Slot filter adequately assembled using suitable saturation grease (if applicable)?	☐ Yes ☐ N/A	☐ No	
7. Temperature conditioning (TG6 Section 9.0): Has the penetrometer been adequately conditioned so that it is close to the expected ground temperature? State method used.	☐ Yes	☐ No	
8. Zero load readings (TG6 Section 10.0): Before zero readings taken with penetrometer unloaded, not touching the ground and membrane removed?	☐ Yes	☐ No	
Before and after zero load readings held for adequate period of time to stabilise to adequate level?	☐ Yes	☐ No	
9. Testing (TG6 Section 11.0): Have the straightness of the rods been checked?	☐ Yes	☐ No	
Has the push rate been maintained at the correct speed?	☐ Yes	☐ No	
Has the penetration length been checked	☐ Yes	☐ No	
Has there been any loss in signal during the testing?	☐ No	☐ Yes	
Have any of the sensors been loaded beyond the manufacturer's safe levels?	☐ No	☐ Yes	
10. Reporting (TG6 Section 13.0): Has a test report been provided with all relevant information?	☐ Yes	☐ No	
Have plots of q_c, f_s and u_2 (if applicable) with depth been provided?	☐ Yes	☐ No	
Has an excel spreadsheet and/or AGS4 file been supplied?	☐ Yes	☐ No	
Do the plots and spreadsheet data clearly indicate whether they are measured, calculated or interpreted parameters and what, if any, adjustments or calculations have been undertaken from the measured parameters?	☐ Yes	☐ No	
Has the Application Class for the test been determined?	☐ Yes	☐ No	

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