TECHNICAL NOTE

BS EN ISO 22475-1: Implications for geotechnical sampling in the UK

By Norwest Holst soil engineering technical director Matthew Baldwin and Soil Mechanics technical manager Dick Gosling

General guidance on geotechnical sampling has been part of BS 5930, both in its 1981 and 1999 editions. Within this standard, the UK geotechnical community has been able to find information on sampling methods and sample types. BS EN ISO 22475-1, which was first published in 2006, is titled *Geotechnical investigation and testing – sampling methods and groundwater measurements.* Together with other standards, it is a normative reference cited in BS EN 1997-2, that is, Eurocode 7 Part 2 (EC7-2), published in 2007.

Unlike the existing BS 5930, which is a code of practice, 22475-1 has the full status of a British Standard. Implementation of 22475-1 into UK practice should be in progress and could be complete during 2009. While much of 22475-1 describes the various methods for the sampling of the ground, it also reiterates the quality classes defined in EC7-2 that relate to each sampling type. It is this issue of quality that is likely to be problematic for the UK geotechnical industry.

This paper compares the general philosophy of BS 5930 with 22475-1 and makes comment on how geotechnical sampling in the UK may be affected in the near future. Some recommendations are also made as to possible solutions to help address the potential problems that the new standard has thrown up.

Document content

BS EN ISO 22475-1 addresses the sampling of soil and rock. It also deals with measurements of groundwater for geotechnical purposes, although this aspect is not discussed in the current paper. The environmental sampling of soil, water and gas is not covered by 22475-1.

The mandatory part of 22475-1 (approximately the first half of the whole document) covers the technical principles for obtaining samples and for groundwater measurements. The remainder of the document is a series of informative annexes providing information about various types of drilling and sampling equipment.

In the mandatory part of 22475-1 sections 1, 2 and 3, as is invariably the case in European Standards, deal with the scope, normative references and definitions respectively. Section 4 gives a very brief outline of drilling rigs and equipment. It should be noted that in 22475-1 the term "drilling" applies to all the various types of techniques used to form exploratory holes; it is not limited to rotary techniques, as distinct from boring, as is sometimes the case in the UK.

The general requirements prior to sampling are given in section 5 of 22475-1. The techniques used for sampling soil and rock form sections 6 and 7 respectively; this differentiation is worth noting in comparison to BS 5930 where techniques are discussed irrespective of whether the ground is soil or rock. Sections 8 to 10 deal with groundwater while sections 11 and 12 cover sample handling and reporting respectively.

Requirements prior to sampling

Section 5 of 22475-1 essentially deals with scoping and design of work which will be done in the field.

Clause 5.1 states that "the type and extent of sample recovery and groundwater measurements shall be specified according to the purpose of the project, the geological and hydrogeological conditions and the anticipated field and laboratory testing". This requires the designer of the investigation to consider the relationship between sampling method and laboratory testing.

Within Clause 5.2 on the selection of techniques and methods, the standard requires that the "sampling techniques… shall be selected on the basis of sample quality class, sample mass and sample diameter". There are five quality classes and the designer is required to specify the sampling regime that is appropriate for the likely laboratory testing requirements. It should be noted that the definition of quality classes is to all intents and purposes the same as that given in BS 5930, Section 3, Paragraph 22.2.

Soil sampling methods

Section 6 of 22475-1 defines three groups of techniques for the sampling of soil and these are:

- **Sampling by drilling**
- **Sampling using samplers**
- **Block sampling**

This is important insofar as this grouping recognises the difference between samples obtained direct from the drilling equipment (for example, clay cutter, shell) and those obtained from dedicated samplers (for example, U100, piston). Since sampling by drilling includes rotary core drilling this threefold grouping is compatible with the four main techniques identified in BS 5930, which are:

- **taking samples from drill tools/excavation equipment**
- **drive sampling**
- **rotary sampling**
- **block sampling.**

Soil sampling quality classes are defined in EC7-2 in terms of the soil properties that can be obtained from the samples. Soil sampling categories are also defined in 22475-1/EC7-2. The category of sample is linked to the quality class of soil sample. This is relevant to laboratory testing in the sense that different tests require different soil quality classes. Clearly the person specifying the site investigation will be required to fully understand this linkage. The relationship between soil quality class and sampling category is shown in Table 1, which is reproduced from EC7-2.

TABLE 1: QUALITY CLASSES OF SOIL SAMPLES AND SAMPLING CATEGORIES

Soil properties / Quality classes	1	2	3	4	5
Unchanged soil properties					
particle size	•	•	•	•	
water content	•	•	•		
density, density index, permeability	•	•			
compressibility, shear strength	•	•			
	•				
Properties that can be determined					
sequence of layers	•	•	•	•	•
boundaries of strata – broad	•	•	•	•	
boundaries of layers – fine	•	•			
Atterberg limits, particle density, organic content,	•	•	•	•	
water content	•	•	•		
density, density index, porosity, permeability	•	•			
compressibility, shear strength	•				
Sampling categories	A				
		B			
					C

Table 1 shows that if laboratory testing requiring soil samples of quality class 1 and 2 is to be scheduled, sampling category A must be specified. Arguably, the sampling category is a superfluous layer of classification; it is sample quality class which is critical. Notably if strength and stiffness tests are to be undertaken in the laboratory then by definition a quality class 1 sample is required. While this requirement is mandatory in EC7-2/22475-1 it is not new; exactly the same requirement occurs in BS 5930.

Sampling by drilling

The different sampling by drilling techniques used in Europe are discussed in Clauses 6.3.1 to 6.3.8 and summarised in Table 2 of 22475-1. There is potential for confusion here in that this table includes "cable percussion drilling" with either a "shell auger" or a "valve auger" in rows 12 and 13 of the table respectively. The authors contend that neither of these corresponds to the UK practice of cable percussion drilling using suspended tools which is, however, described explicitly in Clause 6.3.4 of the text. It is clear from Clause 6.3.2.5 that the "shell auger" is not what is understood in the UK by the commonly used misnomer "shell and auger". There is also no associated text to clarify the "valve auger".

Of those techniques listed in Table 2 of 22475-1 only a limited number are used in the UK and these are shown as Table 2 in this article. Given the discussion in the foregoing paragraph the authors have added cable percussion boring using suspended tools into the table contained within this paper, since this remains one of the main drilling techniques for "soils" in the UK.

Sampling using samplers

The different sampling by sampler techniques used in Europe are discussed in Clauses 6.4.1 to 6.4.4 and summarised in Table 3 of 22475-1. This table is presented in modified form within this article, giving some commentary on the individual techniques.

This table is mainly populated by tube samplers of one form or another and these are subdivided into thin and thick wall varieties. The key definitions in 22475-1 for a thin wall sampler are that it should have an edge taper angle of not exceeding 5º, an area ratio of less than 15% and an inside clearance ratio of less than 0.5%. It should be noted that the area ratio criterion is a relaxation of BS 5930 where it is given as "about 10% or less". Tube samplers not meeting the thin wall requirements in 22475-1 are by implication thick walled; this includes the U100 sampler and the implications for UK practice are discussed in greater detail later in this article.

Interestingly window sampling is included in the 22475-1 Table 3 Sampling by Sampler table whereas it might more properly be placed in the Sampling by Drilling table. The authors believe that the intention of 22475-1 Table 2 was to include "windowless" sampling in this table on the basis that a liner or tube is used for sampling. As noted above, this would mean that window sampling in the "open mode", that is, without liner, would indeed belong in the Sampling by Drilling table. For this reason, the authors have added a designation of "Percussion Boring" to Table 2 to include window sampling and all other similar techniques where an exploratory hole is formed by drilling tools, which are pushed into the ground using percussive methods.

The sample quality class for window sampling is given as 5 in 22475-1. The authors believe that this is incorrect since samples obtained from such sampling techniques may be used for certain laboratory classification testing and not merely strata identification as is implied from a quality class of 5. However, in any event, the samples are not suitable for strength testing and it is the authors' contention that specifying hand vane tests on window samples is an unacceptable practice.

Block sampling

The third type of sampling recognised in 22475-1, is that of block sampling. This covers both conventional block sampling from excavations as well as that from boreholes. In the latter case the standard recognises that the "large sampler" may be advanced by means of static thrust and or rotation. In the UK most block samples are obtained from trial pits or natural exposures and a sample quality class of 1 can normally be achieved.

Rock sampling methods

Rock sampling is covered in Section 7 of 22475-1. Clause 7.1 recognises three groups of techniques (as for soil sampling) which for rocks are:

- sampling by drilling
- block sampling
- integral sampling.

Of these three groups, the first two are recognised in the UK, with the first being by far the most common.

Clause 7.1 goes on to divide rock samples into three types as follows:

- cores (complete and incomplete)
- cuttings and retained returns
- block samples.

It is worth noting that contrary to what is stated in Clause 7.1, the quality of rock recovery is not "achieved" by applying the parameters of the total core recovery (TCR), solid core recovery (SCR) and rock qualiity designation (RQD). Quality of rock recovery is "achieved" by employing British Drilling Association accredited drillers and using well maintained and appropriate drill rigs and drilling equipment. The authors believe that the standard should state that the quality of the rock can be "measured" by applying TCR, SCR and RQD.

Clause 7.2 gives three categories of sampling methods for rocks although without any reference to sample quality class. This clause provides full definitions of the three categories. Category A sampling methods represent the least disturbance to the rock fabric and structure, whilst Category C sampling methods cause the most and can be equated to the "cuttings" sample type (as is confirmed in Table 5 of 22475-1). The definition of Category B is somewhat confused and appears to the authors to contradict itself.

In Clause 7.3, "Sampling by Drilling", the standard unhelpfully talks about 'soft rocks' in relation to the type of core-barrel to be used. The authors believe it would be more useful to relate the type of core-barrel to the strength, degree of weathering and even type of rock. In other words one would expect to see the use of large diameter double or triple tube core-barrels in rocks of low strength / significant weathering. However, other factors such as the type of flushing medium and core run length can also affect quality.

It should be noted that in the description of rotary core drilling within the soil sampling section, the fitting of a plastic liner to a double tube core barrel is deemed to generally be equivalent to a triple tube barrel.

Table 5 in 22475-1 provides a summary of rotary sampling techniques in rock which are described in Clause 7.3. Unfortunately, the table appears to be wrongly headed as "Soil sampling using samplers" in the standard, although its major thrust is that Category A samples can be recovered in all rocks with triple tube core-barrels (either conventional or wireline) and in stronger rocks with a double tube core-barrel.

Although quality classes are not applied to rocks in the same way as to soils in 22475-1, the definitions attached to the three sampling categories do have clear implications for the subsequent laboratory testing of rock samples. Any rock test that is designed to measure strength, such as the uniaxial compression and direct shear tests, will require samples of the highest quality. It is reasonable to assume that only sampling techniques that conform to sampling category A will yield suitable samples. Similarly some of the material reuse tests (slake durability, aggregate crushing value ACV and 10% fines etc) can be carried on "as received samples".

UK sampling in the future

Much of 22475-1 should give no cause for concern to the UK geotechnical industry. Whilst the document places considerable importance on quality in the design and selection of sampling techniques for individual investigations, the authors believe that this should be welcomed. In this respect 22475-1 builds on what is contained in BS 5930.

There is however a major problem. This occurs with obtaining samples of cohesive soil for strength and compressibility testing in the laboratory. Both 22475-1 and BS 5930 require samples of quality class 1 for this purpose. According to 22475-1, quality class 1 samples can only be achieved with a thin wall tube sampler (either open tube or piston) or with a triple tube core-barrel whereas in the UK it has been common practice to use a thick wall tube sampler, that is, the U100, for this purpose.

UK practice hitherto has at best been questionable. BS 5930 states that only in favourable circumstances, ie non-sensitive cohesive soils of stiff or lower consistency, will U100 samplers sometimes give class 1 samples but more often class 2. In sensitive clay, brittle or fissured materials, hard clay and stony materials the quality from this form of sampler would at best be class 2. Furthermore BS 5930 presupposes an area ratio not exceeding 30% which is less stringent than the 25% required by its predecessor, CP 2001, way back in 1957. Currently U100 samplers on the market that incorporate a liner can have area ratios approaching 50 % and even those without a liner barely meet the BS 5930 criterion. Space precludes an extended discussion here of the other features which influence sample quality: the main aspects are sampler design (notably the inside clearance ratio, the use of a liner and the liner material) and sampling methodology (means of cleaning the hole bottom before sampling and then of driving the tube). In the authors' opinion changes over the past 30 years or so to each of these features has been to the detriment of sample quality. The UK industry has by and large ignored the problem and continued to use

TABLE 2: Guidance on sampling by drilling in soils for use in the UK (column and line numbers as 22475-1)

Col	1	4	5	6	7	8	9	10	
Line	Drilling Method		Equipment		Guideline for Application & Limitations		Achievable Sample Categories	Achievable Quality Class	Author's Remarks
	Soil Cutting Technique	Designation	Tool	Likely hole dia (mm)	Unsuitable for	Preferred method for			
1	Rotary drilling	Rotary Dry Core Drilling	Single tube core-barrel	100 to 200	coarse gravel, cobbles, boulders	clay, silt, fine sand	B (A)	4 (2-3)	Relatively undisturbed interior, but outside dried by heat generated during drilling
			Hollow stem auger (***)	100 to 300		clay, silt, sand, organic soils	C (B)	4 (3)	Seldom used in the UK today. Difficult to ensure sample depth can be determined reliably
2		Rotary Core Drilling	Single tube core-barrel	100 to 200	non-cohesive soils	clay, clayey and cemented composite soils, boulders	B (A)	4 (2–3)	Only the use of a triple tube system can provide the basis for obtaining Class 1 samples. It should be noted however that other factors such as flushing medium and core run length can affect the quality class.
			Double tube core-barrel				B (A)	3 (1–2)	
			Triple tube core-barrel				A	1	
11	Vibration Drilling with an optional slow rotation	Resonance Drilling	Thick wall sampler or single tube core barrel with optional plastic lining tube	80 to 200	sand, gravel and cobbles and most cohesive soils	Some cohesive materials. The lack of dedicated sampling equipment makes the collection of undisturbed samples virtually impossible.	Cohesive soil: C	4	Trials to assess the quality of samples obtained using this technique have taken place in the UK. These trials indicate that samples exhibit significant disturbance and have margins dried by heat generated during drilling.
							Non cohesive: D(C)	5	
Additional (*)	Percussion	Cable Percussion Drilling	Cable percussion with shell	150 to 300	cohesive soils	sand, and/or gravel	B	4	In the UK cable percussion boring using a shell is the most common method of advancing boreholes in granular soils
			Cable percussion with clay cutter	150 to 300	sand and/or gravel	cohesive soils	B	4 (3)	Where cable percussion boring is used in cohesive soils, the clay cutter is used to advance the borehole.
		Percussion Drilling (**)	Various	30 to 150	dense sand, gravel	clay, silt, sand	B	4 (3)	The drilling tools associated with the various hybrid percussive rigs cause a high degree of material disturbance

NOTE The sampling categories and quality classes given in parentheses are only achievable in particularly favourable ground conditions.

KEY

(*) The authors have added the various percussion methods of forming exploratory holes in the UK. These include cable percussion drilling as well as the various techniques that are available for hole formation using a percussive system that essentially hammers the drilling tool into the ground.

(*) The authors have placed window sampling in the 'open mode' (ie without liner) within this category.

(*) The authors have amended Columns 9 and 10 for the hollow stem auger tool to reflect the achievable category / class in the sampling by drilling mode, ie sample recovered from the auger flights.

the U100. This is partially because much of the industry has remained wedded to cable percussion boring as a routine technique for drilling boreholes which in turn requires a sampler robust enough to be driven by a hammer/jarring link.

In the light of the discussion in the foregoing paragraph it is the authors' opinion that the downgrading of the quality class obtainable by the U100 in 22475-1 is fully justified. Given that this standard precludes its use in obtaining samples suitable for strength and compressibility testing, what options are there for the UK industry? The following are already available and their increased use should be considered by those who scope and specify investigations and aim to comply with the requirements of 22475-1 Section 5.

- **Thin wall (including piston) tube samplers: for use in low strength cohesive deposits, eg alluvium and some other Quaternary deposits.**

TABLE 3: SOIL SAMPLING USING 'TUBE' SAMPLING TECHNIQUES (column and line numbers as 22475-1)

col	1	2	3	4	5	6	7	8	Additional
Line	Type of sampler	Preferred sample dimension		Technique used	Guideline for application and limitations (***)		Achievable Sample Categories	Achievable Quality Class	Authors Remarks
		Diam-eter	Length		Unsuitable for	Recommended for use in			
1	Open sample thin walled (OS – T/W)	70 to 120	250 to 1000	static or dynamic driving	gravel, loose sand below water surface, cohesive soils containing coarse particles	soft to firm cohesive or organic soils	A	1	General purpose thin walled open tube samplers (OS-T/W) can provide Class 1 samples in soft materials, but may cause sample disturbance in stiff cohesive soils.
						(medium) dense sand below water surface	B (A)	3 (2)	
						stiff cohesive or organic soils	A	2 (1)	
2	Thick walled (OS– TK/W)	>100	250 to 1000	dynamic driving	gravel, sand, soft cohesive soils	firm to stiff cohesive soils, some organic soils (depending on % organic matter), cohesive soils containing coarse particles	B (A)	3 (2)	Open Sample thick walled (OS-TK/W) – commonly known as the U100 sample. Without modification can only give a Class 2 sample, which will have implications for laboratory testing.
3	Thin walled (PS – T/W)	50 to 300	600 to 1000	static driving	gravel, dense sands, firm to stiff cohesive soils and cohesive soils containing coarse particles	soft cohesive or organic soils and sensitive soils	A	1	The thin piston walled (PS-T/W) sample is the definitive method for sampling soft organic soils or soils that are sensitive to sampling.
						sand above/below groundwater (****)	B	3	
6	Cylinder (S-SPT) (*)	35	450	dynamic driving	coarse gravel, blocks	sand, silt, clays	B	4	The material recovered from a standard penetration test split spoon (S-SPT) is heavily disturbed and of low quality
7	Windowless (**)	30 to 100	1000 to 2000	static or dynamic driving	sand, gravel	silt, clay	B	4 (3)	Laboratory testing should be limited to classification testing.

NOTE The sampling categories and quality classes given in parentheses are only achievable in particularly favourable ground conditions

KEY

(*) It is not standard practice in the UK to insert any kind of liner into the SPT spilt spoon for sampling purposes. For the purposes of this paper, the presence of Cylinder (S-SPT) in the above table is taken to mean a standard SPT split spoon sample obtained without the use of a liner.

(**) The authors have interpreted the term 'window' in Table 3 of 22475-1 to actually mean windowless in the context of the table which covers sampling using 'tube' samplers. Window sampling in the 'open mode' has been moved by the authors into Table 2 where it is covered by the general term 'percussive drilling'.

(***) The authors have revised the ranges of soils in Columns 5 and 6 to what is in their opinion more realistic and to remove the inconsistencies in Table 3 of 2475-1.

(***) May recover samples of fine or medium sand particularly where there is a significant fines content.

Hydraulically powered piston samplers should be capable of sampling clays with a consistency of up to about the lower part of the firm range.

● Rotary core drilling: for use in higher strength cohesive deposits, say from firm through to hard consistencies. This technique is already frequently used on the more prestigious projects in the south-east of England, for example, in the London Clay and other tertiary deposits or some Jurassic formations such as the Oxford, Kimmeridge and Lias. There is significant scope for the technique to be used in glacial tills particularly where they are matrix dominant, that is, the stone content is not too high.

Consideration should also be given to the increased use of in situ testing to determine strength and compressibility. Again it is a question of selecting techniques which are appropriate for the anticipated ground conditions but there is considerable scope for using cone penetration testing to determine strength, albeit indirectly (that is, relying on correlations with laboratory results which will often have been on samples not of Class 1), or pressuremeter testing.

The authors believe that in order for something akin to the U100 to survive as a sampling tool capable of delivering samples for laboratory machine testing, a radical rethink of proprietary tube sampler designs will be required. Based on a preliminary exploration of the possibilities with a leading sampling equipment manufacturer it appears to be almost inconceivable that a tube sample incorporating a plastic liner would ever remotely approach the criteria for a class 1 sample. However, given advances in material science and manufacturing capabilities there could be potential for developing non-liner tube samplers which can provide improved sample quality class and still be robust enough to be driven into stronger cohesive materials including those containing coarse particles.