TECHNICAL NOTE

Development of a thin wall open drive tube sampler (UT100)

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Introduction
In a technical note published in the August 2009 issue of Ground Engineering (Vol 42, No 8) the authors summarised the implications for the UK geotechnical industry of sampling requirements contained in BS EN ISO 22475-1:2006. In particular, they drew attention to the UK's traditional open drive tube sampler (U100), which has been used extensively by the site investigation sector.

The U100 is a thick-wall open-tube (OS/TKW) sampler as defined in 22475-1, and as such it does not comply with the criteria in that standard for obtaining quality class 1 samples (of cohesive material). Thus, adherence to 22475-1 will preclude samples recovered with this equipment from being used for strength and compressibility testing in the laboratory.

In the previous article the authors raised the possibility of redesigning the U100 to meet the criteria for a thin wall open-tube sampler (OS/TW) and hence, according to 22475-1, be capable of obtaining a quality class 1 sample, while still being sufficiently robust to be driven into the ground. In this article the authors will describe progress with the development of this thin wall open-tube sampler (UT100).

The aim was to produce a sampler that resembled its predecessor both in terms of its method of operation and the components of the assembly, these being a drive head, a sample tube, a core catcher (optional) and a cutting shoe. The development has been carried out in conjunction with Archway Engineering, a leading manufacturer and supplier of drilling equipment to the site investigation industry in the UK. The proposed designation of UT100 indicates the parent sampler from which it was modified, the introduction of the letter T denoting that it is a thin wall version.

Feature	22475-1 criteria for thin wall sampler	U100** with plastic liner	U100** without liner	UT100
Edge taper angle (degrees)	should not exceed 5	7	10	5
Area ratio, Ca (%)	should be less than 15	47.1	29.4	14.97
Inside clearance ratio, Ci (%)	min* should be less than 0.5	1.27	1.34	0.19

*taking account of manufacturing tolerances
**U100 data are metricated values taken from Archway's design drawings

Table 1: Geometry of samplers

Sampler Geometry
According to 22475-1, for a tube sampler to be unambiguously designated as thin wall then the features in the first column of Table 1 must meet the criteria in the second column. The data in the third and fourth columns clearly demonstrate the non-compliance of the existing U100, either with or without a liner.

It should be noted that the 22475-1 area ratio requirement for a thin wall sampler is less stringent than that given in BS 5930 of "about 10% or less". This relaxation was a key factor in initially providing the authors with some encouragement to pursue the development.

Design and Manufacture
The starting point was to compare the existing non-liner U100 sampling equipment (see fourth column of Table 1) with the geometry requirements for a thin wall version. It can be seen that the area ratio is nearly double that required for a thin wall sampler. Even if a cutting edge was machined onto the sampling tube itself, the area ratio would only reduce to about 17%, and thus still be too large.

It follows from the preceding paragraph that the new sampler could not be based on the 4.5 inch 7 gauge tubing which has been used for the thick walled sampler. An alternative standard cold drawn seamless tube was identified, it being assumed that any special product would have been prohibitively expensive. The dimensions of the two tubes are given in Table 2.

Although the wall thickness is significantly reduced, it is similar to that used for windowless sample tubes, and thus there was reason to believe it would be capable of withstanding dynamic driving. However, the thinner tube cannot accommodate the 4-inch BSP thread used previously and an alternative had to be selected. The thread adopted has a square profile and is thus akin to the threads commonly used on drilling equipment. Although this change was enforced, it does have two advantages over the triangular profile BSP thread: it makes for easier coupling of the components forming the sampler assembly; and it is less susceptible to damage.

The thin wall sampling tube is the same length as the U100 (457mm) and, like its predecessor, has male threads at either end for coupling to the drive head and cutting shoe. The upper end of the drive head is unchanged, so it connects to existing jarring links, and there is no need to modify any of the "in-hole" tools. The cutting shoe is about »

A prototype UT100 has shown its manufacturability

Dimension (mm)	U100	UT100
Outside diameter	114.3	110.0
Inside diameter	105.7	104.0
Wall thickness	4.3	3.0

Table 2: Sampling tube dimensions

» 15mm longer than that used for the U100, and this is necessary to accommodate the reduced edge taper angle. The only "downstream" consequence of the revised design is the need for a simple thread adaptor for the laboratory extruder.

It can be seen from the fifth column in Table 1 that the UT100 design meets the 22475-1 criteria for a thin wall open-tube sampler. In the case of area ratio it only just complies and, as the authors contended in their previous article, there is no scope for devising a version of the sampler which would incorporate a liner (plastic or any other material) and still comply with the thin wall requirements.

Archway Engineering produced a prototype batch of the UT100 sampling equipment, as shown on the previous page, thereby demonstrating the manufacturability of the design.

Field trials

A series of field trials has been conducted by Norwest Holst Soil Engineering (NHSE) and Soil Mechanics (SM) to assess the performance of the prototype UT100. The programme was designed to test the sampler in a variety of soil types.

The initial trials were intended to prove, in particular, the robustness of the sampler. Boreholes were put down by NHSE into glacial till in the Manchester area and by SM into a mixed alluvial and glacial sequence in South Yorkshire. At the latter site the soils included a stratum with significant fabric, ie a laminated clay, while at both sites there were slightly sandy, slightly gravelly clays of firm through to stiff consistency. Samples of these heterogeneous soils were recovered successfully and there were no problems with the sampler crumpling or deforming. Some of the samples were extruded, split, photographed and described. Classification and unconsolidated undrained triaxial tests were carried out on the other samples.

NHSE also undertook limited trials with the UT100 sampler in the London clay formation and in more challenging glacial soils in Cumbria. In both cases the sampler performed well, and in the latter case stood up to the rigours of a cohesive soil with a high granular content.

A more comprehensive trial was then carried out in the homogeneous, albeit fissured, Gault clay in Bedfordshire. The site selected benefited from a previous investigation in 2001 in which a single borehole had been put down and which showed the consistency of the Gault to increase from firm at shallow levels to very stiff at depth. Both NHSE and SM rigs were involved in the trial, which comprised four adjacent boreholes.

Results of Gault clay trials

Two of the four boreholes at the Bedfordshire site were sampled with the UT100, the other two with the U100 (in one of these boreholes the sampler incorporated a plastic liner) to allow a comparative study. In all boreholes, including the previous investigation, there were alternate tube samples and standard penetration tests (SPTs). Sample recovery in the joint trial was 100% successful and, as with the initial trials, the sampler suffered no apparent distress.

Laboratory and insitu testing provide an insight to the nature of the clay from which the UT100 samples were recovered. This testing is summarised below, followed by comments on the more direct indicators of sample quality.

Samples of mixed alluvial and glacial sequence in South Yorkshire were recovered without the sampler crumpling or deforming

Laboratory index tests classify the Gault on this site to be a clay of high, becoming with depth very high, plasticity. A profile of the Atterberg limits and natural moisture content is presented as Figure 4. This shows the liquid limit to increase with depth while the plastic limit remains essentially constant. The natural moisture content determinations decline (relative to the corresponding plastic limits) with depth from a little above to more or less equal to the plastic limit.

A profile of the SPT N-values is presented as Figure 2, which includes data from both the NHSE and SM boreholes. It can be seen that the results generally lie within a narrow band. There is a clear trend of N-values increasing linearly with depth down to about 7m, below which, although the increase continues, it is at a reduced rate. However, between 7m and 9m there are a couple of N-values that are significantly greater than the general trend.

The number of blows required to drive the UT100 and the U100 (both with and without liners) is plotted against depth as Figure 1. To minimise the influence of the potential variables the data for this plot comes from the NHSE boreholes only, thus providing a comparison of blow count obtained by a single crew operating the same rig with identical downhole tools (jarring link and sinker bar assembly).

The plot does not reflect the

A comprehensive trial of Gault soil was conducted in Bedfordshire

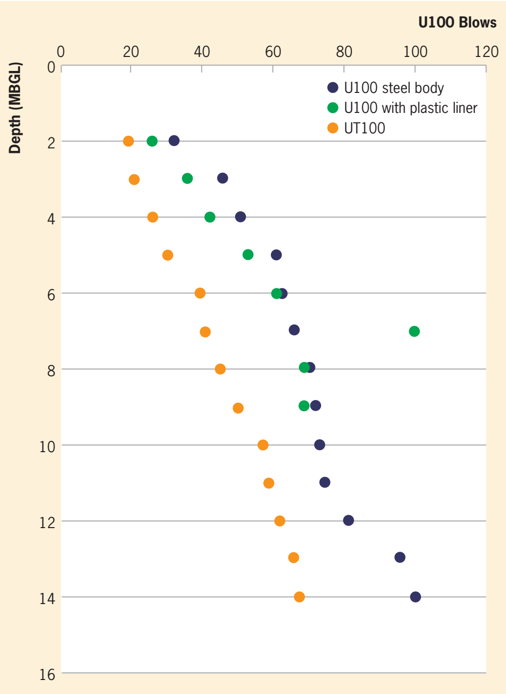

Fig 1: Number of blows measured against depth

Fig 2: Profile of the SPT N values

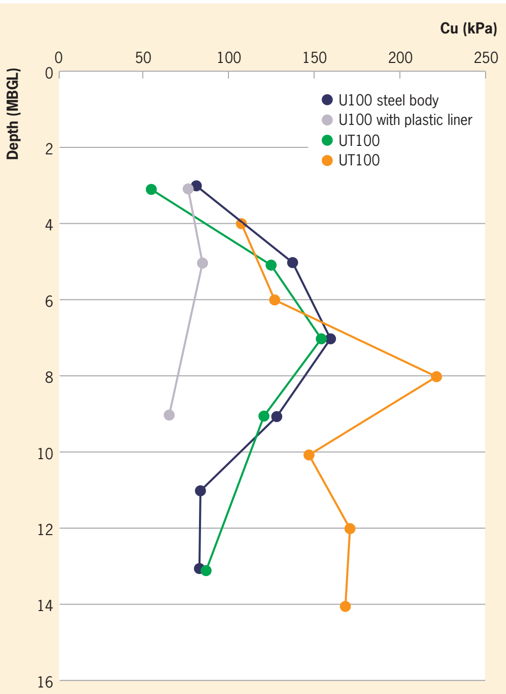

Fig 3: Results of triaxial tests against depth

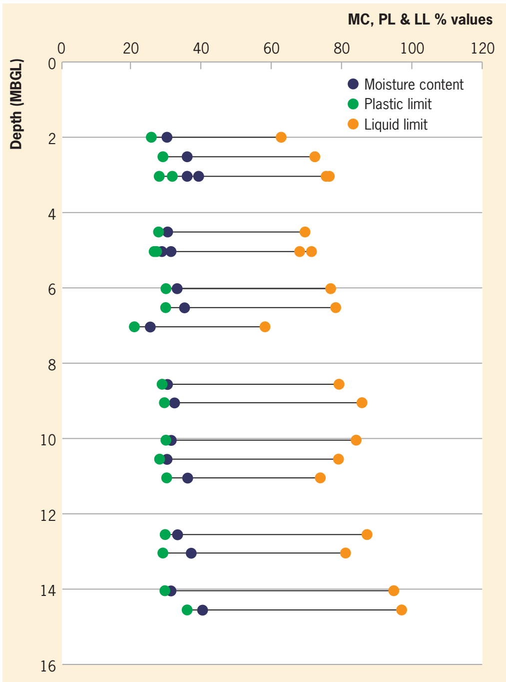

Fig 4: Profile of Atterberg limits and natural moisture

marked change in gradient of the trend line evident from the SPT results, although again there is an isolated high at 7m. However, it does show a significant difference in the number of blows required to drive the UT100 compared to the U100, the former consistently taking approximately 25 to 30% less. This will clearly benefit the quality of the samples recovered insofar as they should have experienced less material disturbance during sampling.

Unconsolidated undrained triaxial tests were carried out in the laboratories of both NHSE and SM on about half of the tube samples recovered, and the results, plotted against depth, are presented as Figure 3. Down to about 9m the undrained shear strengths determined from the UT100 and U100 without a liner are similar to each other, whereas those determined on the U100 with a liner are much lower. There is an isolated high result in the 7m to 9m range from a UT100 sample, which is consistent with the pattern of N-values and sample blow counts.

Below 9m, in the clay of higher consistency, the majority of strengths from the UT100 are significantly higher than those from the U100 without a liner.

From the above discussion it appears from the trials that the UT100 is meeting expectations. The thin wall sampler has a smaller area ratio and inside clearance ratio than its thick wall predecessor, which theoretically should result in less disturbance due to remoulding and volume change respectively.

The UT100 demonstrably requires less energy to drive in the same soil than the U100, as evidenced by the reduction in blow count, and thus reduces the potential for mechanical disturbance. The lesser disturbance is reflected in higher cohesion values generally being determined by triaxial testing, this being most noticeable in the very high strength range.

Concluding remarks

The UT100 is a thin wall open-tube sampler designed to comply with the requirements of 22475-1 for obtaining quality class 1 samples and to be capable of being driven by existing cable percussion drop tools. Its manufacturability has been proven and its functionality has been demonstrated in a series of successful field trials carried out in a variety of fine soils, including those with a high granular content.

Undrained shear strengths of between about 50kPa and 220kPa have been measured in the laboratory on the samples recovered with the UT100. These results cover the greater part of the strength range at which this sampler was targeted, there being existing alternatives, eg the piston sampler, for lower strength soils where pushing rather than driving is appropriate.

The trials included a comparative exercise with the driven thick wall sampler. The evidence from these suggests that the influence of sample disturbance, ie laboratory determinations under-measuring insitu shear strength, is less with the UT100 than the U100, particularly in higher strength clays. An incidental observation from the comparative trial is the grossly unsatisfactory consequences of using plastic liners in the thick walled sampler.

While the UT100 sampler is capable of taking a sample that meets the standard as being suitable for strength and compressibility testing in the laboratory, it does not obviate the need for care in the sampling process. As with its predecessor, any shortcomings in this will result in a reduction of sample quality.

The UT100 is available for use on a commercial basis and the industry will need to specify its use explicitly to ensure uptake if the technical benefits are to be realised.

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