The Development of a Large Diameter Sampler

Développement d'un échantillonneur de large diamètre

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ABSTRACT: A large diameter sampler, *DLDS*, has been developed. This sampler can retrieve undisturbed samples with 0.4 m in diameter and 0.5 or 1.0 m in height. The large sampler has two purposes. First it facilitates laboratory testing on large volumes; for fibrous peats it is shown that size effects play a role in laboratory testing. A large triaxial device and a large direct simple shear device have been developed to study the behaviour of large samples in comparison to conventional sized samples. The sampler is developed to facilitate these large scale tests. Second, the sampler can be used to retrieve high quality samples in soft, organic clay and peat for conventional laboratory testing as an alternative for block sampling. In establishing the quality of the samples a comparison is made to samples retrieved with the well-known Sherbrooke sampler.

RÉSUMÉ : Un échantillonneur de large diamètre a été développé. Cet échantillonneur permet de prélever des échantillons de sol intact de 0.4 m de diamètre et de 0.5 ou 1 m de hauteur.
Ce large échantillonneur a deux propos. Premièrement, il facilite les essais sur de larges volumes ; pour les tourbes fibreuses, il a été montré que les effets d'échelle jouent un rôle dans les essais de laboratoire. Deuxièmement, l'échantillonneur permet d'obtenir des échantillons d'argile organique molle et de tourbe de grande qualité pour des essais en laboratoire de taille conventionnelle. La qualité des échantillons prélevés a été comparée à celle d'échantillons obtenus avec un échantillonneur Sherbrooke.

KEYWORDS: Soil sampling, laboratory testing, organic soil.

1 INTRODUCTION.

The mechanical behaviour of peat is complex. One of the issues when dealing with peats is its fibrous nature. In conventional laboratory testing, the test results are usually interpreted by an approach based on continuum mechanics. Such an approach is only allowed when the dimensions of individual particles are smaller than the dimensions of the tested specimen. As a rule of thumb it is assumed that the largest dimensions of the individual particles are at least 10-times smaller than the smallest dimension of the specimen. Most conventional laboratory tests are axial symmetric with a diameter of 3.8, 5.0 or 6.5 cm. This is in the same order of magnitude as the length of peat fibres. As a consequence size effects are to be expected when testing peat samples.

Zwanenburg & Van (2015) show results of large diameter triaxial tests on peat. Sample size effects are found for failure and post failure behaviour. Failure of the fibres either by slippage or rupture occur after some displacement. Although the strain levels in conventional and large sized samples are the same, the actual displacement is different, leading to different failure behaviour.

In order to test this behaviour undisturbed peat samples, with large dimensions are required. To facilitate large sized testing a large sized sampler is required. This paper discusses the development of *Deltares Large Diameter Sampler*, DLDS, which is capable of retrieving samples with a diameter of 0.40 m and a height of 0.50 or 1.00 m. Besides the use for retrieving large diameter samples, the sampler can be used as an alternative for block sampling of soft clays. Then the large diameter sample can be trimmed in the laboratory to the required dimensions.

2 LITERATURE STUDY

The design of the large diameter sampler is started with a literature study. The study aims for finding the state of the art in understanding sample disturbance. The available literature can be roughly divided into two groups. One group discusses numerical studies on sampling and sample disturbance (a.o. Mohsen et al 1987, Clayton 1998). This group studies the disturbance of an idealized material behaviour by an idealized sampling method. A second group discusses field experiences (a.o. Long et al 2009, Santagata et al 2006, Tanaka 1996). In this group often the total disturbance, due to sampling, transportation and laboratory handling is discussed by comparing laboratory test results. Literature specific on sampling peat is limited (a.o. Helenelund et al 1972, Long 2006, Mathijssen et al 2008). For sampling peats, a sharp cutting edge, to make clear cuts through the fibres is important. Dragging fibres down with the sampler should be avoided.

Lunne et al (1997, 2006) presents a sample disturbance index for clays based on the void ratio change by reloading the sample to field stress conditions. A low void ratio change during reloading indicates little disturbance. It is questionable if this index can be used for peats. Due to the high compressibility of peat in combination due to high permeability the sample easily compresses during sampling and a low void ratio change during reloading to field stress conditions might not necessarily indicate little sample disturbance.

3 SAMPLER DESIGN.

3.1 *Basic design*

The sampler is especially designed for sampling peat and soft clays. This means that the sample strength is low and might be too low to carry its own weight after sampling. Without lateral support the sample might bulge when bringing the sample from sampling depth to ground level. For this reason it was decided to design the new sampler as a tube sampler. During lifting of the sample, transportation and further handling of the sample, the tube provides the required lateral support.

The sampler is also designed as a down-hole sampler, meaning that first a boring is realized to the desired sampling depth. Collapse of the borehole walls is prevented by a casing. From this basic idea, a down-hole tube sampler, a design is made containing the following items:

- cutting shoe
- knives, to cut the sample after the required depth is reached.
- the tube, to collect the sample
- top cap which includes a suction valve and the connection to the plunger
- a plunger that pushes the sampler down.

The following sections will discuss the individual components. Figure 1 shows a photo of the complete sampler. The samples are taken from a pre-drilled borehole. At two elevations along the plunger, three struts, six in total, can be pushed against the casing, fixing the position of the sampler.

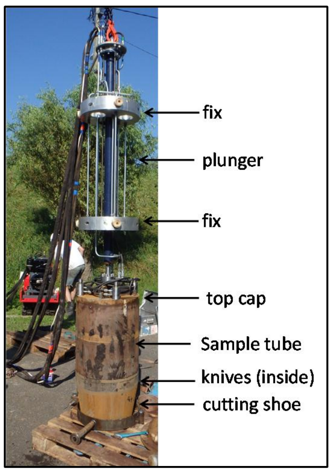

Figure 1. Components of the DLDS

3 .2 *cutting shoe*

The literature review shows the importance of the cutting edge of the cutting shoe. Preferably, the angle of the cutting edge should be as low as possible. Since the top of the cutting shoe is aligned with the rings for the knives, the thickness of the top of the cutting shoe is 0.05m. The angle of the cutting edge is 10°, leading to a cutting shoe height of 0.37 m

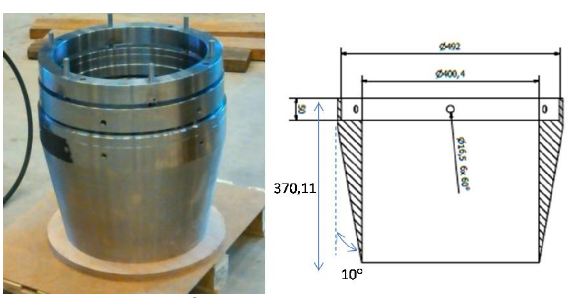

Figure 2. Cutting shoe

3 .3 *knives*

Before lifting the sample, the sample should be cut free from the lower soil. A set of six knives is present between the cutting shoe and the sampling tube. During sampling, the knives are inside a ring placed on the cutting shoe. The knives can be activated from ground level. During activation, the knives move simultaneously inside while cutting the soil, see Figure 3.

During lifting the sample to ground level the knives stay in the position as shown by Figure 3. In this way they carry a part of the sample weight. It should be noted that the knives do not cut the sample center. This part should break free during lifting of the sample.

Figure 3. Ring with cutting knives; red rings are for transportation purpose only.

3 .4 *sampling tube*

The sampling tube is placed directly on the ring with the knives. The sample tube is made of stainless steel. It has a thickness of 3 mm and a diameter of 0.40 m. Tubes with a height of 0.5 to 1.0 m can be used. Around the sample tube a protection tube is placed, see Figure 4. The outer diameter of the protection tube is aligned with the outer diameter of the ring with knives. The inside diameter of the tube, ring with knives and the cutting shoe is aligned such that the inside clearance ratio $C_i = 0$.

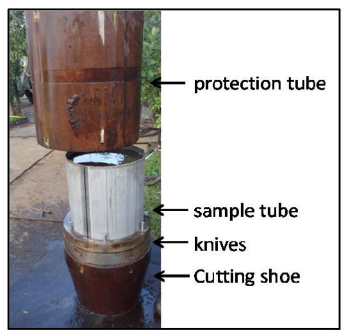

Figure 4. Sample tube

3 .5 *top cap*

A top cap, see Figure 5, is placed on the protection tube. The top cap encloses the sampler at the top. It contains equipment to activate the knives, a connection to the plunger and a valve. The valve controls the free air above the sample. During pushing the sample into the soil, the valve is open and air or water above the sample freely leaves the sampling tube. When extracting the sample tube, the valve is closed, which causes some suction when the sample has the tendency to slide down. The suction and the closed knives together carry the sample when bringing it to ground level.

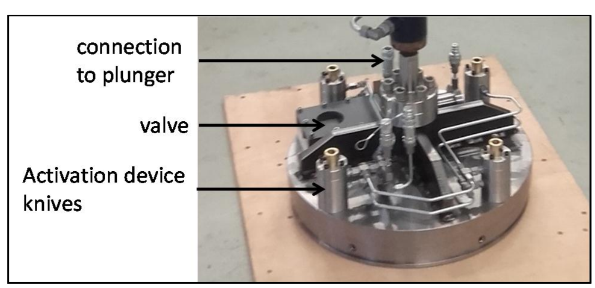

Figure 5. Top cap

3 .6 *plunger*

The plunger, see Figure 6, pushes the sampler into the soil. Six struts divided over two levels are pushed against the casing. This fixes the plunger in vertical direction and gives a firm basis from which the soil can be sampled. The plunger can be set such that it pushes the sampler exactly 0.50 m or 1.00 m. In this way it is avoided that the sample gets disturbed by hitting the top cap.

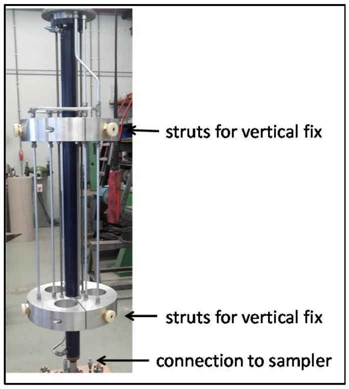

Figure 6. Plunger

4 SAMPLE HANDLING

Due to its dimensions and weight, the large samples are not easy to handle by manpower without disturbing the sample. Therefore, a special procedure and required tools are developed for further sample handling.

After the sampler is pushed into the soil, the suction valve is closed. The struts, for vertical fix, are released and the sampler is lifted to ground level. Experience shows that for soft soils the cutting shoe is empty, no soil is stuck inside. The sample rests on the knives. In case of an empty cutting shoe a pedestal is constructed. The sampler and cutting shoe are placed over the pedestal, such that after releasing the suction valve the soft sample is supported by the pedestal. Then the plunger and top cap are removed and the top of the sample is inspected. The recovery ratio is measured and the space between the top of the sample and top of the sample tube is filled with soft light weight material. The top of the sampling tube is carefully, water tight, closed by a lid.

The sampler is lifted again and carefully turned upside down, see Figure 7. To make lifting possible, lifting rings can be screwed onto the sides of the sampler. Next the cutting shoe and ring with knives are removed. A lid is placed at the, new, top. Finally, the sample can be transported to the laboratory for further handling and testing.

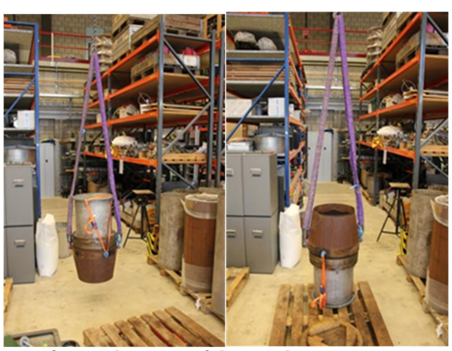

Figure 7. Lifting and rotating of the sampler

5 APPLICATION IN THE FIELD

To test the sampler, samples are retrieved from the Uitdam test site. At the Uitdam test site a series of field trials are conducted to test the operational shear strength of peat, for details see Zwanenburg & Jardine, (2015). At the site also Sherbrooke samples were retrieved which gives the option to compare the quality of the samples obtained by both methods.

The subsoil at the Uitdam site consists of a 4 to 5 m thick peat layer which overlays a 4 to 5 m thick clay deposit followed by a Pleistocene sand layer. The samples were taken from the peat layer at a depth, top sample, of 1.39 m below ground level.

The peat comprises mainly Phragmites (with sedge and sphagnum inclusions) with minor vegetal decomposition. The peat is characterized with a von Post classification of H2 to H3, indicating minor decomposition, a water content ranging between 650 and 1250 %, an organic content ranging from 75 to 92% and a particle density of 1.53 ± 1.6% Mg/m^3. The undrained shear strength, s_u ranges between 5 to 10 kPa.

Figure 7 shows one of the samples after releasing it from the sample tube. Careful inspection shows the following:

- The colour of the samples changes over its height from black at the top to reddish brown at the bottom. This indicates that, due to entrance of oxygen, some humification took place at the top.
- At the outer radius a very thin, less than 1 mm thick, smear zone was found.
- The fibres at the outer radius of the sample were clear cut by the sampler
- No indication that fibres were dragged through sample during sampling was found.

The first observation has led to an improvement of the seals of the lids. For future samples this will further prevent dewatering of the sample. The other three observations indicated that the core of the sample is not affected by sampling. With a very thin smear zone and no damage caused when cutting fibres, the sampler provides high quality peat samples.

Figure 7. Peat sample taken by DLDS

Figure 8. Impression of fibre structure

6 LABORATORY TESTING

To further study sample quality a series of oedometer tests is conducted on specimen taken from the *DLDS* samples and compared to results from tests on specimen from samples taken by the Sherbrooke sampler. This study is still ongoing and final results cannot be presented yet. Figure 9 shows preliminary results comparing classical oedometer tests on 4 specimen from *DLDS* samples and 2 specimen from Sherbrooke samples.

The oedometer curves, Figure 9, show good agreement. The differences between the different sampled specimens seem small. Table 1 gives further details on water content, *w*, dry density, γ_d, pre-consolidation stress, σ'_{vy}, stiffness parameter *CR* and ratio between reloading and normally consolidated stiffness, *CR/RR*. Although it should be noted that the number of tests are too small to draw final conclusions, there seems to be a difference between the DLDS and the Sherbrooke samples. The DLDS specimens have a higher water content, lower density a lower normally consolidated stiffness and larger CR/RR ratio. There seems no clear difference in pre-consolidation stress.

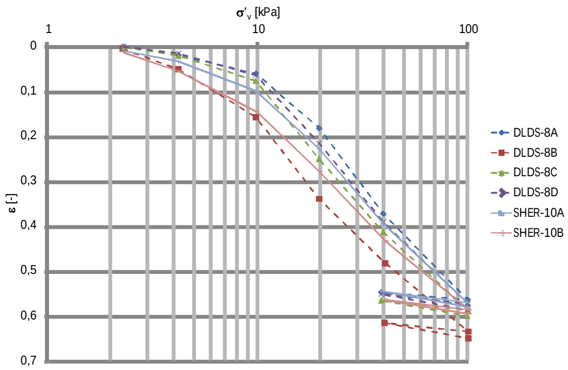

Figure 9. Comparison between classical oedometer test results for tests on DLDS and Sherbrooke specimen

Table 1. Comparison between the *DLDS* and Sherbrooke samples

test ID	*w* [%]	γ_d [kN/m^3]	σ'_{vy} [kN/m^2]	*CR* [-]	*CR/RR* [-]
DLDS 8a	1164	0,74	12,71	0,65	12,45
DLDS-8b	1186	0,73	7,49	0,56	9,19
DLDS-8c	1130	0,79	8,68	0,57	9,12
DLDS-8d	1154	0,75	10,48	0,61	9,76
Sher-10a	950	0,89	9,77	0,54	7,40
Sher-10b	976	0,87	8,69	0,49	7,07

Differences in *w*, γ_d and ratio *CR/RR* can be explained by differences in sampling techniques in which some compression of the peat samples might have occurred. During sampling and bringing the Sherbrooke samples to ground level, the samples are not supported and water from the large pores can leave the samples easily. Some of the Sherbrooke samples showed some deformation, bulging or bending directly after sampling. However, the differences in *CR* and the lack of difference in σ'_{vy} cannot be explained by sample disturbance. Alternatively, heterogeneity in the peat layer might also explain the differences between the test results. It should be noted that the samples were taken at close distance, centre to centre distance between the borings is 8.6 m. From visual inspection there was no indication for geological or biological differences in the peat layer. More test results are needed for final conclusions.

7 CONCLUSIONS

A large diameter sampler is designed and built successfully. The purpose of the sampler is twofold. First it aims to retrieve undisturbed samples for large volume testing. Second, the sampler forms an alternative for block sampling.

The sampler is applied at the Uitdam test field. Visual inspection shows that the sampler makes clear cuts through the fibres, which makes the sampler well suited for sampling peat. Based on the first results the connection between the sample tube and lids were improved to prevent loss of pore water. An ongoing study on the comparison with Sherbrooke samples shows promising results.

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