The paper was published in the proceedings of the 6th International Conference on Geotechnical and Geophysical Site Characterization and was edited by Tamás Huszák, András Mahler and Edina Koch. The conference was originally scheduled to be held in Budapest, Hungary in 2020, but due to the COVID-19 pandemic, it was held online from September 26th to September 29th 2021.

A+ sampler for natural fine soils

P. Reiffsteck
Univ. Gustave Eiffel, IFSTTAR, Marne-la-Vallée, IdF, France, Philippe.reiffsteck@ifsttar.fr

F. Pilnière[1], F. Jadé[2], G. Desanneaux[3]
CEREMA, Angers[1&2], Saint-Brieuc[3], France, franck.pilniere@cerema.fr [1], fabrice.jade@cerema.fr[2], gilles.desanneaux@cerema.fr [3]

ABSTRACT: This paper will present a new sampler designed to sample almost undisturbed soil specimens. The objectives of this sampler are to collect natural fine soils that are coherent or not, normally to medium coverage for depths up to 10 m. We would like to be able to preserve the saturation state of the specimen. An inner diameter of 150mm core barrel allow with the size of a ball valve used to close the sampler to remain relatively compact. Tests on sandy and clayey sites are presented showing the efficiency of the sampler.

Keywords: Equipment, Measuring Techniques, Sampling / Drilling & sampling methods for soils and rock / Sample quality

1. Introduction

In 1969, at the special session "soil sampling" of the International Congress of Soil Mechanics of Mexico, Idel et al. (1969) proposed a practical classification of samples. There are five sampling quality classes defined according to the parameters that can be obtained from the soil taken. This classification appears in the DIN 4021 standard, the English standard BS 5930, the Dutch standard NEN 5119, the French standard NF P94220 the Canadian Engineering Manual and finally the European standard: EN ISO 22475-1 "Recognition and geotechnical testing - Method of sampling by drilling and piezometric measurements - Part 1: Technical principles ".

1.1. Class for sampler

The method of classifying the samples was defined according to the final class of the sample and the tests that we will be able to carry out:

- if, after sampling, the sample is recovered with all its particles, all its water, the same arrangement and the same links between all the particles of the soil, one will be able to make tests of resistance and deformability,
- if, on the other hand, the sample is remodeled with all the particles and all the water of the pores of the soil in place but whose structure has been completely modified, one will limit oneself to carry out tests of identification.

For these purposes, five classes of soil samples for laboratory testing have been defined in Eurocode 7 Part 2.

Table 1 defines the classes of samples according to Eurocode 7 part 2 (CEN, 1997) and the european standard dedicated to sampling EN ISO 22475-1, corresponding to the properties of soils that can be determined from the samples taken.

Table 1. Sampling classes definition

Soil properties	Sampling 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 strata – fine	✓	✓			
Atterberg limits, particle density, organic content	✓	✓	✓	✓	
water content	✓	✓	✓		
density, density index, porosity, permeability	✓	✓			
compressibility, shear strength	✓				

Now that we have define the sample classes Determination of the required class of sample according to the planned tests.

Historically, three categories of sampling methods ranging from A to C have been defined based on the best quality class that can be obtained for soil samples for laboratory testing.

Table 2. Sampler categories definition

Quality	Category	Tests achievable
Precautions at all stages	A	samples enable to be used for all physical and chemical tests and determination of mechanical parameters
No precautions at one stage	B	samples enable to be used for all tests except mechanical
Without special precautions	C	samples can be used for identification tests but not state parameters determination

1.2. Fitting classes and categories

The required specific sampling category (A to C as defined in Table 3) is defined by the geotechnician responsible for the project and must be selected in order to obtain the required sample quality class according to EN 1997-2 and EN ISO 22475-1 (from 1 to 5 as defined in Table 1).

Table 3. Correspondence between sample class and sampler category to be used

	Sample class				
	1	2	3	4	5
Sampler categories	A	A	A	A	A
			B	B	B
					C

Thus for the most demanding category A, the properties of soils and rocks are assumed to remain unchanged during sample collection, handling, transport and storage. However, the picking categories do not correspond exactly to a hierarchy of value or quality because they overlap.

Several types of A sampler exists for soft soils.

2. Sampler for soft soils belonging to class A

2.1. Stationary piston sampler

The CPS is a Stationary Piston Corer with holster. It is a thin-walled corer sheathed inside by a plastic case. Inside this core tube slides a piston. The piston is double adjustable thick seal to ensure tightness. It is held by a central rod carrying two ball lock mechanisms remote from the corer stroke. The holster once removed from the corer serves for transport and storage of the sample. The elements described are shown in Fig. 1 and 2.

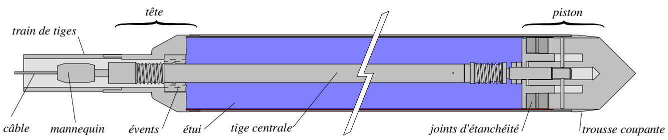


Figure 1. Drawing of stationary sampler

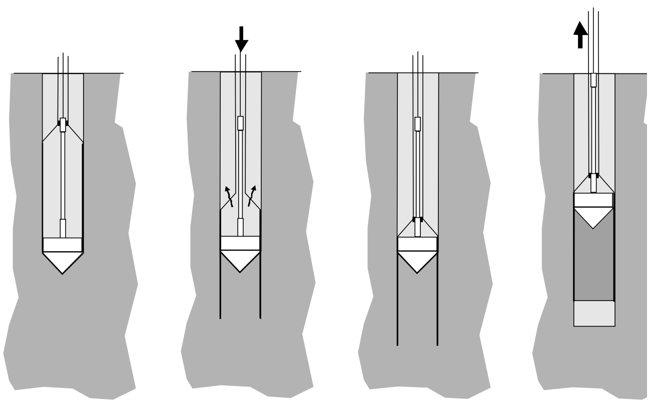


Figure 2. Operation phases of of stationary piston sampler

The main advantages of stationnary piston sampler is is weigth, it's simplicity of action but sample size over 80 mm usually are not retrieved correctly from borehole. The Osterberg version is however a good compromise.

2.2. Laval university sampler

The university Laval sampler (Fig. 3) has a geometry of 200 mm in diameter and 600 mm in height [7]. The corer consists of two tubes: an inner tube terminated at its bottom by a tapered cutting shoe without internal clearance, which constitutes the sampling tool, and an outer tube equipped at its lower part with a ring gear, which can be made integral with the inner tube during the descent of the corer at the sampling and during the ascent of the sample to the surface (Fig 3).

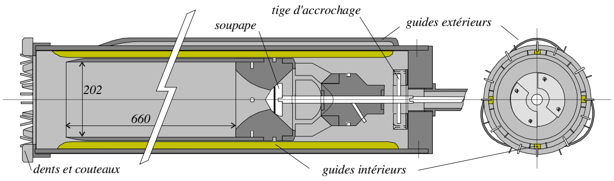


Figure 3. Schematic view of Laval university sampler

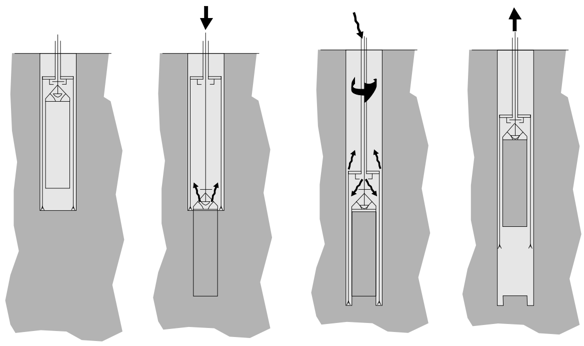
The sampling operations (Fig. 4) using this corer are carried out as follows from pilot holes augered to the desired depth:

a) lowering the corer in the borehole to the sampling level;

b) disconnection of the inner and outer tubes and jacking of the inner tube only on the height of the sample to be taken;

c) lowering the outer tube driven in rotation with mud injection between the latter and the inner tube, and this in order to disintegrate the clay surrounding it, until the base of the crown exceeds the end of the cutting bag about 2 cm;

d) relocking the corer and raising the sample to the surface.



a b c d

Figure 4. Differents phase of operation of Laval sampler

3. Proposed design for a A+ sampler

A A+ sampler is mainly intended for research. The objectives of such a sampler are to collect natural fine soils that are cohesive or not, normally to moderately overconsolidated for depths up to 10 m without casing. These soils will be at most of a firm consistency (in the sense of [6] standard), that is to say having a cohesion of 50kPa (for higher values of cohesion the traditional sampler work well and are less sensitive to the sampling). We would like to be able to preserve the interstitial pore water and the level of saturation of the sample, which means keeping the pore water pressure at its initial value.

The techniques for closing a sampler are numerous, we may use:
- mechanical systems to close,
  - core catchers composed of spring blades, shells, knives,
  - sphincter with an inflated membrane,
  - ball valve,
- chemicals to seal,
  - two-component epoxy resin,
  - freezing or gel.

The core catchers have the defect of not being waterproof (for example: it would be possible to place on the Laval sampler, Sherbrooke type knives that would fold under the holster, but this solution would not allow the sampling of poorly coherent soils.) the sphincters will have trouble shearing slightly overconsolidated soils, so the ball valve remains alone. Freezing is long and expensive, the epoxy resin used mainly in the oil industry requires a setting time. There remains the ball valve.

This sampler must be adaptable to most drilling machines used in Public Works laboratories and companies. This implies a simplicity in the drill rods and a diameter not exceeding the capacity of the drilling rods clamps.

The first request made of an inner diameter of 200 to 250 mm is therefore reduced to 150mm. An inner diameter of 150mm core barrel would allow with the size of the ball valve to remain relatively compact.

Finally it was decided to develop a sampler which would have the following characteristics:
- strict compliance and even higher requirement than the Hvorslev index values indicated in the French standard and the Eurocodes,
- use of the proven CPS locking technique,
- sampling stage close to Laval, decoupling the rotation and pushing function,
- complete filling of the corer to preserve an intact sample with interstitial fluid and pressure of this one.

These choices lead to the concept illustrated in Fig. 5, the sampler consists of a body with an internal case of about 150 mm internal diameter complemented by a rotary outer tool provided with a ring gear to bore the borehole and a a ball valve closing system.

3.1. Working principle

The following procedure has been developped to realized the sampling with this new sampler:

1. downward phase. The outer body is attached to the drill rods, so that the drill head supports friction along the walls of the borehole and descends without blocking. This requires an additional locking system (outer shell - "inner" rod) which will be locked in the downward phase and must be unlocked at the beginning of the sinking. The borehole walls must be maintained using bentonite mud as for the Laval sampler to avoid the maximum wall collapse that would hinder the descent.

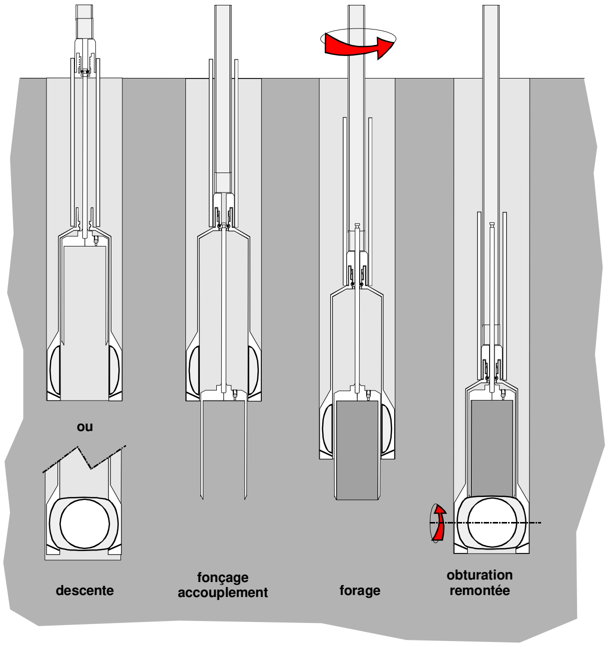


Figure 5. Possible sampling stages

2. pushing phase. The presence of valve type vent will evacuate the drilling fluid and cuttings of the sampler and maintain the pressure during the recovery phase.

3. down phase of the outer case rotated. During this phase, the corer is not rotated. The drilling fluid (water or air injected through the drill string) rises along the body of the sampler.

4. closing phase of the shutter. This closure is triggered by the docking of the case in the outer casing.

5. recovery phase.

3.2. Construction

Fig. 6 and 7 show the final design of the sampler: the ball valve closing system, the inner casing and the compressed air reservoir needed to feed the various pneumatic jack actionning the closing system.

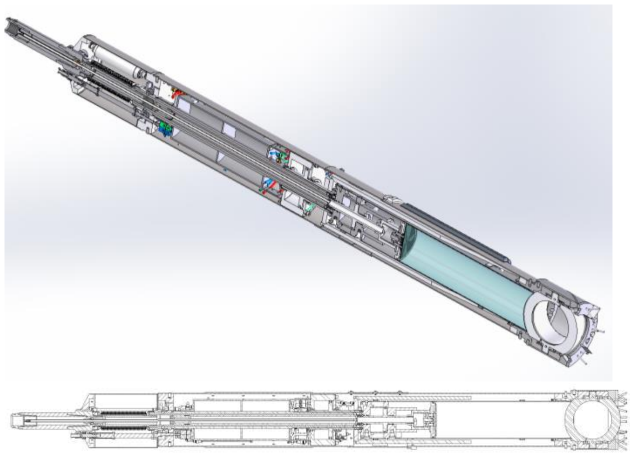


Figure 6. Cross section of A+ sampler

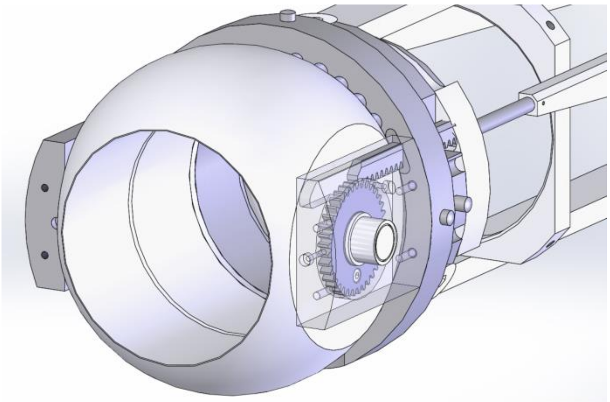


Figure 7. Ball valve arrangement of A+ sampler

A specific trailer has be designed and built to help handle the sampler and attached it to the drill rig (Fig. 7).

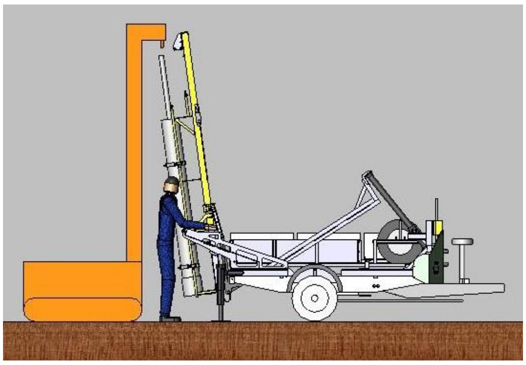


Figure 8. Trailer used to handle the sampler

4. Tests on sites

The sampler has been tested in sandy soils (Fig. 9) and clayey soils (Fig. 10).

Figure 9. Trailer used to raise the sampler

The first test performed in sand have shown that ball valve closing system work well even with the particle incoming and the pressure needed to made the ball to rotate was correctly designed.

A second test campaign was performed in le Pont de Cran experimental test site in a soft organic clay (Fig. 10).

Figure 10. First tests of A+ sampler

Fig. 11 shows the quality of the cutting created by the teeth of the cutting shoe. This last one design was ispired by the university Laval sampler.

Figure 11. Quality of the cuttings

Figure 12. First tests of A+ sampler

Once retreived from the borehole the cutting shoe is unscrewed and access to the ball valveallow to start the dismountling phase.

A mettallic door is taken away and an hydraulic system is connected to the sampler. The sample is moved in the liner and two plugs fitted with a gasket are fixed at each end of the liner.

Figure 13. Sample container

5. Conclusions

During this research, a new sampler has been developped and tested showing the same ability than Laval sampler to retrieve high quality samples of fine soils. Tests on site have shown that some improvement of the operating principle have to be made.

A comparative study with IFSTTAR 's Laval sampler and stationary piston sampler is under current developpement.

The study of the effect sampling will be based on oedometric test procedures on the compressibility parameters that take into account the disturbance encountered.

Acknowledgement

The authors thank the Ministry of Ecological and Solidarity Transition for funding this research project as well as their colleagues R. Benot, G. Desanneaux, J. Rebours and J. Mauxion for assisting in this project..

References

[1] Idel K.H., Muhs H., Von Soos P., Proposal for quality classes in soil sampling in relation to boring methods and sampling equipment, Proc. Of the Specialty Session 1, Soil Sampling, 7th ICSMFE, Mexico city, 1969, 11-14

[2] Hvorslev J.,Subsurface exploration and sampling of soils for civil engineering purposes, Rapport ASCE, 1949521 pages

[3] AFNOR, Sols Reconnaissance et Essais - Prélèvement des sols et des roches - Méthodologie et procédures. (Soil, ground investigation and testing, Soil and rock sampling, Methodology and procedure) French standard XP P 94-202, 1995, 42 pages (in French)

[4] CEN, EN ISO 22475-1 Geotechnical investigation and testing — Sampling of soil, rock and groundwater, 2007, 109 pages

[5] CEN, EN 1997-2, Eurocode 7 - Geotechnical design - Part 2: Ground investigation and testing, 2007, 145 pages

[6] ISO, Geotechnical investigation and testing — Identification and classification of soil — Part 1: Identification and description, ISO 14688-1, 2002,18 pages

[7] La Rochelle P., Sarrailh J., Tavenas F., Roy M., Leroueil S. Causes of sampling disturbance and design of a new sampler for sensitive soils, Can. Geotech. J., 1981, 18, 52-66

[8] Lefebvre G., Poulin C. A new method of sampling in sensitive clay, Revue Canadienne de Géotechnique, 1979, 16 (1), 226-233

[9] Lunne T., Berre T., Andersen K.H., Strandvik S., Sjursen M. Effects of sample disturbance and consolidation procedures on measured shear strength of soft marine Norwegian clays. Can. Geotech. J. 2006, 43 pp. 726–750.

[10] Bat A., Blivet J.-C., Levacher D., Incidence de la procédure de prélèvement des sols fins sur les caractéristiques géotechniques mesurées en laboratoire, (Impact of sampling procedure on the geotechnical characteristics of fine soil measured in the laboratory) RFG 91, 2000, 3-12 (in French)