Undisturbed sampling of non-cohesive soils by drilling

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ABSTRACT: In the past it was impossible to take undisturbed and representative samples by drilling from non-cohesive soils such as sand and gravel above und beneath the groundwater surface. A common sampling tool is the so-called valve auger but the sample quality of this method is poor as most of the in-situ soil properties like water content and grain size distribution are lost. Therefore, these samples are only of minor geotechnical use. Moreover, this method loosens the ground which contradicts geotechnical purposes as well. The new method was developed to take undisturbed samples by continuously cored drilling for the first time. Due to the grain size of sand and gravel the inner diameter is 200 mm to take representative samples up the diameter of coarse gravel. The method has been tested in various soils in different countries like France, Germany, Norway and Togo to proof the general application. Besides the representative and complete grain- size distribution this undisturbed sample enables laboratories to proof internal erosion and suffusion caused by flowing groundwater which is likely to produce liquefaction e.g. in dams and dikes as a product of aging. Furthermore, the samples show the layering and lamination of the soil in great detail.

Keywords: sampling, non-cohesive soil, liquefaction, internal erosion, suffusion

1. Introduction

1.1. Sampling techniques

The aim of sampling in the framework of ground investigation are the following:

a) to recover soil and rock samples of a quality sufficient to assess the general suitability of a site for geotechnical engineering purposes and to determine the required ground characteristics in the laboratory;
b) to obtain information on the sequence, thickness and orientation of strata and discontinuities;
c) to establish the type, composition and condition of strata;
d) to obtain information on groundwater conditions and recover water samples for assessment of the interaction of groundwater, soil, rock and construction material.

The type and extent of sample recovery will be usually specified in advance according to the purpose of the project, the geological and hydrogeological conditions and the anticipated field and laboratory testing.

The quality of a sample is influenced by the geological and hydrogeological conditions, the choice and execution of the drilling and/or the sampling method, handling, transport and storage of the samples.

The techniques and methods employed for sampling shall therefore be selected according to the purpose of the investigations in relation to the expected geological and hydrogeological conditions.

Different degrees of disturbance of the sample can be expected when using different sampling methods. The quality class of a sample taken with the same sampler can vary depending on e.g. the soil type to be sampled, the presence of groundwater and the sampling operation. The following types of sample disturbance can be generated by the drilling and sampling methods:

- mechanical sample disturbance due to compression, shearing, flushing or vibration during drilling or excavation;
- sample disturbance due to release of in-situ stresses and related rebound;
- changes in material and chemical constituents such as water content and gases.

The drilling and sampling equipment selected has to be of the appropriate size and type in order to meet the required sampling category.

1.2. Sampling categories

ISO 22475-1 [1] comprises various soil sampling methods by drilling. This standard divides these methods into 5 sampling categories. These categories represent the best practices that should be followed in order to match the five quality classes of soil samples for suitable laboratory testing (see Table 1).

The best practices that should be followed by drilling for each sampling category can never guarantee that a certain quality class is obtained as many factors can cause soil disturbance that are outside the influence of the drilling. This can cause a decrease in effective stress, a reduction in the inter-particle bonds, and a rearrangement of the soil particles, that determine the eventual quality class of a soil sample.

Table 1. Quality classes of soil samples for laboratory testing and sampling categories to be used according to ISO 22475-1 [1]

Soil properties	Quality classes of soil samples for laboratory testing				
Unchanged soil properties	**1**	**2**	**3**	**4**	**5**
soil type	*	*	*	*	*
particle size	*	*	*	*	
water content	*	*	*		
density, density index, permeability	*	*			
compressibility, shear strength, stiffness	*				
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, stiffness	*				
Sampling categories	**A**	**A**	**A**	**A**	**A**
		B	**B**	**B**	**B**
			C	**C**	**C**
				D	**D**
					E

The aim of category A sampling is to obtain samples in which structure, texture, consistency and in-situ stresses are intact. This would allow laboratory testing for strength, compressibility and stiffness.

As a practical matter, it should be recognized that no soil sample can be taken from the ground and be in a perfectly undisturbed state.

The aim of category B sampling is to obtain samples in which the structure, texture and consistency are intact. This would allow laboratory testing such as permeability, porosity and density of fine soils and detailed layer boundary analyses.

The aim of category C sampling is to obtain samples in which the structure and texture are intact. This would allow laboratory testing such as the determination of the water content.

The aim of category D sampling is to obtain samples in which the structure is intact. This would allow laboratory testing for particle size distribution and Atterberg limits as well as organic content.

The category E sampling only obtains samples where all initial soil properties have changed due to the drilling process. Based on these samples only a rough indication of strata type and thickness (approximately 0,5 m) can be determined.

2. Sampling of coarse soils

2.1. Valve auger sampling method

In the past no sampling method according to sampling category A was available to take samples from non-cohesive soils such as sand and gravel above und beneath the groundwater surface.

A common sampling tool for taking such samples by drilling is the so-called valve auger but the sample quality of this method is poor as most of the in-situ soil properties like water content and grain size distribution are lost. Therefore, this method represents sampling category E (or D in favorable soil conditions). It is totally unsuitable in gravel and sand underneath the groundwater level. Samples taken by this method are only of minor geotechnical use. Moreover, this method loosens the ground which contradicts geotechnical purposes as well.

2.2. New sampling method using the Stoelben sampler

The lack of drilling methods for obtaining undisturbed samples from non-cohesive, coarse grained soils was the reason to develop a method according to *sampling category A* of ISO 22475-1 [1] to take such samples.

2.2.1. Sampling tool

This new sampler (core barrel) has a inner diameter of 200 mm and a length of 1´000 mm (see Figure 1). These dimensions are necessary to incorporate the coarser grain sizes of gravels in a representative way as well. The length of the undisturbed sample is 500 mm in a stainless-steel liner.

The liner has to be made of stainless-steel to cope with the friction forces while penetrating the ground. Liners made from PVC coping with these forces would have a wall thickness that is too large to fit into the sampler. The wall of stainless-steel liner is mucher thinner and does not disturbes the sample.

Figure 1. Stoelben sampler made from stainless-steel with liner and window for extraction

At the bottom of the sampler is a double layered core catcher to hold the sample in the tool while it is withdrawn from the borehole (see Figure 2). The layers of the core catcher are staggered in reverse order to hold all coarse grain sizes.

Figure 2. Core catcher at the bottom of the Stoelben sampler

2.2.2. Sampling procedure

The sampling tool penetrates the soil by dynamic driving using the so-called *Düsterloh* hammer. This is a dry percussion drilling method with casing. It is made of a pneumatic down the hole hammer unit that is combined with a sampler holding the stainless steel liner of 200 mm inner diameter (Stoelben Sampler).

The procedure using the Stoelben Sampler is illustrated in Figure 3 step-by-step.

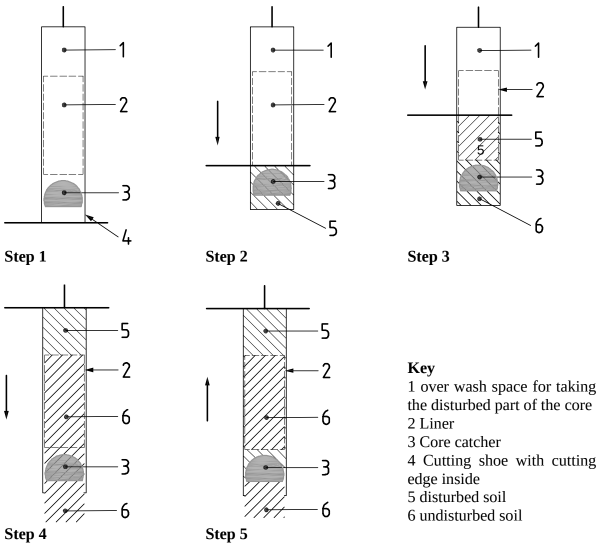

Figure 3. Sampling of coarse soils according to sampling category of ISO 22475-1 [1] using the Stoelben Sampler.

First the sampler is lowered into the borehole by means of a wireline (Step 1). The sampler is then hammered at a low frequency (1 to 2 shots per second) by the fall of a hammer of 150 kg or 250 kg. This dry drilling method avoids washing or disturbing the groundto be sampled. The low frequency also avoids liquefaction in contradiction to the so called sonic drilling method [2].

The core catcher opens while penetrating the ground and disturbes the soil entering the liner (Step 2)

Once the core catcher is open, the soil entering during further penetration is undisturbed (Step 3).

When the sampling tool is completely drilled into the ground, the soil disturbed by the core catcher lies above the liner (Step 4). The soil inside the liner is undisturbed.

The core catcher closes when the sampler is pulled out of the ground by the wireline (Step 5). This closing operation disturbes the soil below the liner.

The sampler has a window that can be opened when it is withdrawn from the borehole. The liner can then be extracted (see Figure 4)

Figure 4. Stoelben sampler with opened window to extract the stainless-steel liner

The sampler filled with soil is rather heavy due its larger dimensions. Therefore, a special holding device was developed that facilitates the handling and the extraction (see Figure 5).

Figure 5. Stoelben sampler in a special holding device to facilitate the handling and liner extraction

2.2.3. Sample quality

The quality of the non-cohesive samples obtained by using the Stoelben sampler from sediments deposited by a river are illustrated in Figures 6, 7 and 8.

Figure 6. Example of samples of non-cohesive soils taken by the Stoelben sampler in groundwater

Figure 7. Example of samples of non-cohesive soils taken by the Stoelben sampler in the unsaturated zone showing the in situ sedimentary structures

Figure 8. Example of samples of non-cohesive soils taken by the Stoelben sampler in groundwater

2.2.4. Transport and storage

The undisturbed samples shall be protected against vibration and shocks and be transported in a vertical position in order to preserve the in situ conditions of the sampled soil (see Figure 9) as laboratory testing for strength, settlement, deformation and water flow will be undertaken on the samples.

Figure 9. Transport of liner samples according to sampling category A of ISO 22475-1 [1]

For these tests no reduction of the quality is permitted following extraction from the ground. As such the samples and any subsamples that have been taken will require to be stored in an environment that protects the sample from physical disturbance as well as from the effects of temperature extremes.

3. Conclusions

The samples obtained by using the Stoelben sampler preserves the in situ conditions of non-cohesive soils perfectly. No grain size fractions up to 200 mm diameter are lost by the sampling process like with the valve auger sampling tool before. In the laboratory all soil meachnical parameters of these samples can be determined representing the in situ state.

Further, all sedimantary structure are conserved.

References

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