การประเมินความรบกวนในการเก็บตัวอย่างดินแบบ Open Tube Sampler และ Rotary Core Drilling

Soil Disturbance Assessment in Soil Sampling of Open Tube Sampler and Rotary Core Drilling

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บทคัดย่อ

การรบกวนตัวอย่างดินในระหว่างการเก็บตัวอย่างดินมีความสำคัญต่อนักวิจัยและวิศวกรปฐพี โดยศึกษาดินเหนียวของประเทศเบลเยี่ยม (Belgian Boom clay) เปรียบเทียบการเก็บตัวอย่างดินจากสองวิธี โดยวิธีแรกเป็นการเก็บตัวอย่างดินโดย open-tube sampler จะใช้ thin-walled tube ในการเก็บตัวอย่างดินที่มีคุณภาพสูงในชั้น A ส่วนวิธีที่สองเป็นการเก็บตัวอย่างดินแบบ rotary core drilling ซึ่งเป็นวิธีใหม่และทำงานได้เร็วกว่าวิธีแรกสามารถเก็บตัวอย่างดินได้อย่างต่อเนื่องตลอดความลึก แต่การทำงานเร็วขึ้นนี้อาจจะส่งผลกระทบให้เกิดการรบกวนดินได้ จึงต้องศึกษาตัวอย่างดินที่เก็บมาจากทั้งสองวิธี โดยจากคุณสมบัติพื้นฐานของตัวอย่างดินและการทดสอบแรงอัดสามแกนร่วมกับอุปกรณ์เบ็นเดอร์อีลีเมนต์ ซึ่งเป็นวิธีใหม่ที่งานวิจัยนี้นำเสนอในการประเมินความรบกวนของดิน โดยคำนวณค่าอิลาสติกโมดูลัสเฉือนของตัวอย่างดินเหนียวโดยอาศัยความเร็วคลื่นเฉือนอิลาสติก ซึ่งจากการทดลองพบว่า วิธีเก็บตัวอย่างดินแบบใหม่สามารถเก็บตัวอย่างดินที่มีคุณภาพสูงเช่นเดียวกับวิธีเดิม

คำสำคัญ : การรบกวน, การเจาะแบบหมุน, การทดสอบในห้องปฏิบัติการ, ตัวแปรด้านปฐพีกลศาสตร์, เบนเดอร์อีลีเมนต์

Abstract

Soil disturbance due to soil sampling is of outmost importance for researchers and geotechnical engineers. This research studied on the Belgian Boom clay comparing of soil sample disturbance for two soil sampling techniques. Firstly, an open-tube sampler is a common soil sampling method used in Belgium. The open-tube sampler applied the thin-walled tube for soil sampling quality class A. Secondly, the rotary core drilling with triple tube wire line coring sampling system is a new technique and operates faster than the first technique continuing to the greater the depth. However, its fast operation might cause soil sample disturbance. Therefore, the research studied on samples from two sampling techniques using index tests and triaxial tests with bender elements technique which is a new technique to assess the soil disturbance calculating the initial shear modulus, G_0, from the elastic shear wave velocity. It is shown that the new sampling technique can obtain as high quality sample as the open-tube sampler.

Keywords : Sample disturbance, Rotary drilling, Laboratory tests, Soil parameters, Bender elements

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1. INTRODUCTION

Obtaining undisturbed soil samples is an important issue for soil research and geotechnical engineering. Generally in Belgium an undisturbed sample was taken from a borehole by pushing an open-tube sampler. This technique offers a very good quality sample. Alternately, there is a new soil sampling technique by rotary core drilling Geobor-S with triple tube wire line coring sampling system. The new technique can continuously sample undisturbed soil from the ground surface to very deep levels even in stiff soils. The rotary core drilling can operate faster than the borehole technique with open-tube samplers. However, this fast operation might cause disturbance effects on the undisturbed soil sample. Therefore, this research investigates the possible disturbance of the coring technique. From the research site at Sint-Katelijne-Waver (Belgium), samples from the two techniques at the same depth are evaluated by index tests and triaxial tests with bender elements in order to obtain comparable soil parameters. Several research studies at this site are available Haegeman [1] Haegeman and Mengé [2] and Mengé [3]. This technique offers a possibility to sample large depths up to 200 m. The sample can be continuously obtained along the drilling with the sampler remaining in the hole as a casing until the borehole is completed. Therefore there is no risk of the borehole collapsing during the drilling. The plastic sampling tube can be cut and opened without pushing force. Therefore it is claimed that this new technique also offers undisturbed samples in category A. Currently, within the framework of this research, additionally triaxial tests with bender elements are used allowing shear waves to propagate through the soil sample to obtain the shear wave velocity. This shear wave velocity has a direct relationship to the initial shear modulus, G_0, an important parameter for vibration analysis. It is known that this dynamics shear modulus is highly influenced by the structure of the soil material. Therefore, the difference in test results on samples from the two sampling techniques shows the existence of the soil disturbance.

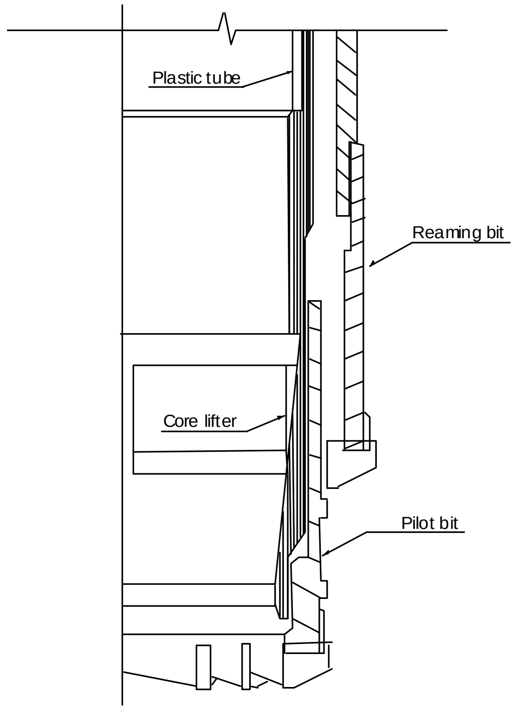

Figure 1 The triple tube wire line coring sampling system after [6]

2. SOIL SAMPLING TECHNIQUES

The important objective of soil sampling for this research is to obtain an undisturbed sample. For laboratory testing, samples in category A are required as described in European Standards [4]. In category A, the soil disturbance should not or slightly occur during the sampling procedure. The water content and the void ratio of the soil correspond to the in-situ values. In this research two sampling techniques of category A are used for sampling overconsolidated stiff clay. The first technique is the borehole drilling with thin-walled tube sampler (OS-T/W-PU) and the other technique is the rotary core drilling with triple tube wire line coring sampling system (CS-TT). The two sampling boreholes are located 3.2 meter away from each other assuming that the Boom clay samples have the same properties.

2.1 An open-tube sampler with thin-walled pushed tube

This technique has been used for soil sampling in Belgium by the Ministry of the Flemish Community, Department of Environment and Infrastructure, Geotechnics Division. A borehole is drilled and soil sampling is performed at the bottom of the predrilled hole. The borehole bottom is protected from collapse by casing and cleaned before sampling. At a desired depth, the thin-walled tube is pushed for sampling a 50 cm long sample. The thin-walled tube is manufactured according to the ASTM standards [5] and European Standards [4]. The sampling tubes are made from thin-walled seamless stainless steel with an inner diameter of 102 mm and a wall thickness of about 2 mm. These tubes are cut into lengths of 600 mm and at the lower end of the sampling tube a sharp edge is foreseen. The inside clearance ratio, C_i, one of the factors that determines the mechanical disturbance of the soil by friction on the inside wall of the sampling tube, is practicaliy 0 % and it is considered as category A sampling method.

2.2 Rotary core drilling with triple tube wire line coring sampling system

The rotary drilling technique is a Geobor S product and described in details in the manual of Atlas Copco [6]. As seen in Figure 1, the bit is two-parted, one pilot and one reaming bit. The flushing discharges between the pilot and the reamer, minimizing the contact between core and flushing media. The Geobor-S equipment can be used in stiff soils. During operation, it is possible to control and vary the drilling fluid and its pressure and flow, the applied torque and the speed of rotation. The drilled core has a diameter of 102 mm and is inserted into a plastic sampler tube with a length of 1.5 m. After drilling the core is drawn up inside the casing tube with aid of a wire which is first lowered inside the drill rods and hooked onto the sampling tube.

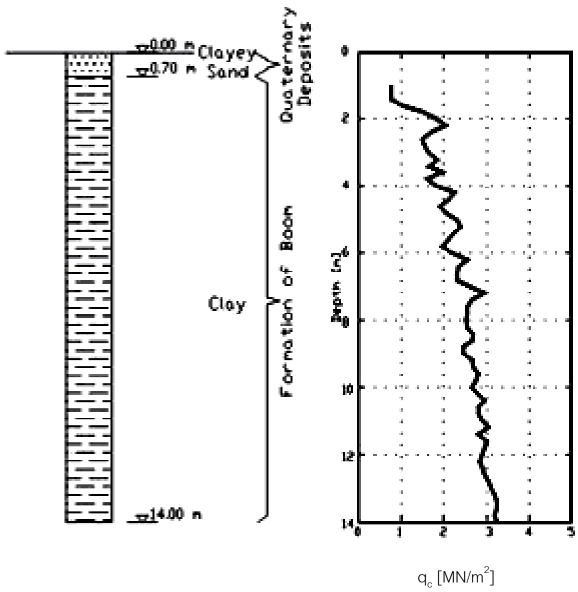

Figure 2 Research site at Sint-Katelijne-Waver (Belgium)

3. LABORATORY TESTS

Boom clay is sampled from the research site at Sint-Katelijn-Waver in Belgium with a geological profile as shown in Figure 2. The q_c is the bearing capacity of the cone tip showing that the Boom clay formation has higher stiffness in the deeper depth. The geological condition at the research site consists of a homogeneous layer of Boom clay to a large depth. Schittekat et al. [7] reported that the Boom clay belongs to the Oligocene series (Rupelien stage). At the beginning of the continental Pleistocene erosion, the Boom clay was covered by about 40 m of Neogene sand (Antwerpian). This load has acted on the Boom clay for 5-7 million years, while the unloading due to the Pleistocene erosion started about 500,000 years ago. According to the geological data the Boom clay should never have been subjected to larger loads than those corresponding to the 40 m of Neogene sand. In its upper part the Boom clay exhibits horizontal layering and has a medium to high degree of fissuring. Many of the fissures have a slickensided appearance. There-fore the Boom clay in its upper part has to be de-scribed as a “stiff, fissured, layered overconsolidated clay” as mention in Schittekat et al. [7]

Boom clay samples at depths of 8.0 m are used for index testing and triaxial testing with bender elements. A sample from the thin-walled tube and a sample from the triple tube wire line coring are tested. Samples are named C8 and D8 while C means the continuous rotary drilling technique and D means the discontinuous thin-walled pushed tube technique. The number indicates the depth of sampling.

3.1 Index tests

In order to determine the physical and mechanical behaviour of the Boom clay, index tests are carried out on all samples. Index test results such as water content, Atterberg's limits, soil density and specific gravity indicate the internal composition of the samples and are used for evaluating the test results.

3.2 Triaxial testing with bender elements

The triaxial cell accommodating a soil specimen of 38 mm in diameter is used. The cell consists of three main parts, a cell base, a top platen assembly and a removable Perspex cylinder. The cell base consists of a pedestal for the setup of the soil sample and three water passages; one is a cell water line and the other two are drainage lines. These drainage lines are linked to the top and the bottom of the soil specimen and connected to a burette to measure the volume change during consolidation. The pedestal and the top platen assembly are mounted with bender elements. The details of using bender element in triaxial cell are clearly described by Brignoli et al. [8]. The desired stress conditions are imposed on the soil specimen by a pressure panel. Effective stresses of 150, 300, and 600 kPa are used to consolidate the clay samples with a back pressure of 100 kPa. The Boom clay sample is consolidated until no volume change occurs anymore. At the end of consolidation, bender element tests are preformed to measure the shear wave velocity.

Figure 3 shows the triaxial apparatus with the piezoelectric bender elements setup. Bender element technique uses piezoceramic transducers for a direct measurement of shear wave velocity. The shear wave is generated and received by transducers placed at opposite sides of the soil sample. The propagation velocity is calculated from the distance between the two transducers and the time required by the wave to cover this distance. A personal computer generates a signal through a sound card with 5V peak to peak as suggested by Mohsin and Airey [9]. This signal is amplified to 40V peak to peak. A Hewlett-Packard dynamic signal analyzer model 3562A is used to measure the arrival time between a transmitted signal and a received signal. A voltage pulse is applied to the transmitter transducer, this causes it to produce a shear wave. When the shear wave reaches the other end of the soil specimen, distortion of the receiver transducer produces another voltage pulse. The receiver transducer is connected to the analyzer to analyze the difference in time between the transmitter and the receiver signal. The shear wave velocity measurements are usually performed with frequencies ranging between 2 to 10 kHz, at strains estimated to be less than 0.0001 %. In most cases, signals are averaged 20 times in order to get a clear signal.

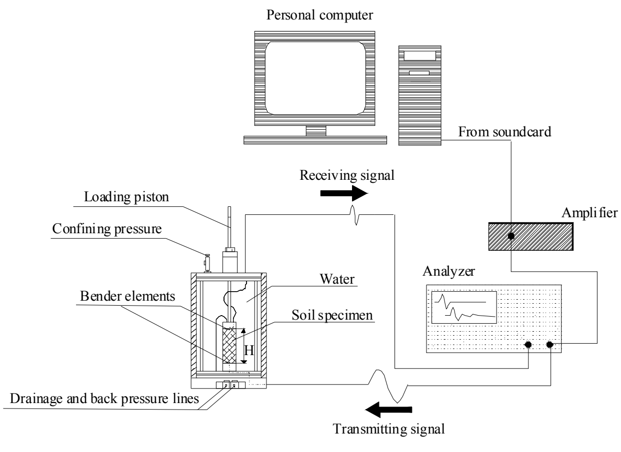

Figure 3 Triaxial cell with bender element setup

4. RESEARCH RESULTS

4.1 Results from index tests

In this research study, we analyzed the sample disturbed by comparing the water contents, liquid limit, plastic limit, specific gravity and mass density of the samples sampling by the OS-T/W-PU and CS-TT techniques. As seen in Table 1, the water content of the samples from CS-TT sampling technique is higher than the OS-T/W-PU sampling technique. This might be due to flushing process in CS-TT sampling technique.

Table 1 Index parameters of Boom clay

Parameter		C8	D8
w_{LL}	[%]	57.51	54.12
w_{PL}	[%]	21.02	22.89
I_p	[%]	36.49	31.23
G_s	[-]	2.70	2.71
w	[%]	28.25	23.32
ρ	[kg/m³]	2042	2034

where w_{LL} is the liquid limit, w_{PL} is the plastic limit, I_p is the plastic index, G_s is the specific gravity, w is the water content and ρ is the mass density.

4.2 Results from triaxial tests with bender elements

Figure 4 shows the bender element results measured on the Boom clay samples under different stress states. The figure shows the values of G_0/p_r against p'/p_r, both in a logarithmic scale, where p_r is a reference pressure of 1 kPa. The data points for the consolidated samples fall close to a straight line given by Equation (1)

$$\frac{G_0}{p_r} = A\left(\frac{p'}{p_r}\right)^n \qquad (1)$$

where A and n are non-dimensional soil parameters. Table 2 summarizes the A and n values of this research.

The A value of the sample C8 is 9.912 and for D8 is 11.975. These parameters show their fabric of Boom clay samples and both are similar. The n parameter is the stress exponent. The n value of sample C8 is 0.5024 and for D8 is 0.4693. The n values of sample C8 and D8 are about 0.5 confirming the finding of Roesler [10].

Table 2 Data of bender element tests on Boom clay

Sample	A	n
C8	9.912	0.5024
D8	11.975	0.4693

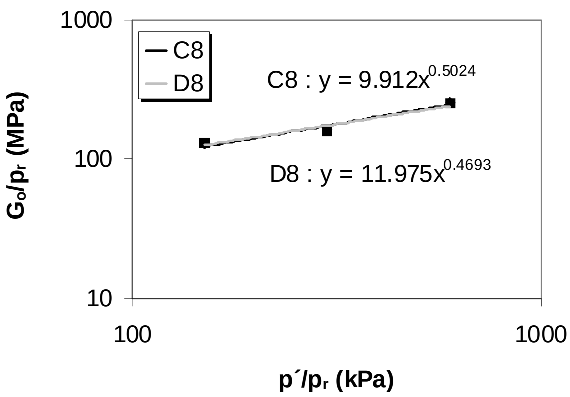

Figure 4 Bender element tests: G_0 versus isotropic consolidation stress

5. CONCLUSIONS

The conclusions from this research study, drawn from all testing data, are that both sampling techniques provide the high quality samples. Both sampling techniques are satisfied in category class A since the Boom clay material is stiff clay. Especially, the new technique is preferred because of its fast operation and the continuity of sampling. However, care is necessary due to the increase of the water content.

Bender elements technique is a high quality method which can apply to soil testing. The research purposes this technique in order to evaluate the soil disturbance.

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