HOSTED BY
ELSEVIER

Available online at www.sciencedirect.com

ScienceDirect

Soils and Foundations xxx (2017) xxx–xxx

SOILS AND FOUNDATIONS

www.elsevier.com/locate/sandf

Mechanism of sample disturbance caused by tube penetration: Model tests on Toyoura sand

Takaharu Shogaki

National Defense Academy, 1-10-20 Hashirimizu, Yokosuka 239-8686, Japan

Received 17 November 2015; received in revised form 5 February 2017; accepted 23 March 2017

Abstract

The mechanism by which samples are disturbed as the sampling device penetrates the soil during sample collection was examined based on pore water pressure behavior, void ratio (e), and the movement of soil particles in model tests on Toyoura sand. Samplers with tubes with inner diameters of 35, 45, and 75 mm and cutting edge angles of 6° and 90° were used for the tests. The penetration speed (S_p) was in the range of 0.6–5.8 cm/s, while the relative density (D_r) was in the range of 6%–83%.

All the soil particles inside the tubes, with the exception of those close to the tube wall, shifted simultaneously due to local disturbance, which caused a lubricating effect. The distance from the tube wall (D_w) to which the soil was affected by wall friction during tube penetration was about 0.35–1.35 mm, similar to that of clayey material, which is nominally less than 2 mm. Moreover, the results were consistent with those for the tube sampling of Niigata sand deposits, for which D_w was unrelated to the tube diameter and D_r. This is contrary to the common belief that the movement of sand particles and changes in e are small for a 90° cutting edge angle in a tube 45 mm in diameter. However, this phenomenon can be explained by the existence of an area of disturbance. For Toyoura sand, this area of disturbance was formed more easily by a 90° cutting edge angle than by a 6° cutting edge angle.

Keywords: Sand; Sample disturbance; Tube sampling; Model test; Relative density; Cutting edge; Penetration speed; (IGC: C6, D7)

1. Introduction

The quality of soil samples is directly determined by their behavior when the material is subjected to changes in pore water pressure and the rearrangement of soil particles caused by the penetration of the tube during sampling. Up to now, there has been no sufficiently demonstrative research on these issues despite the existence of information that elucidates the nature of sample disturbance.

Using the test results of Kallstenius (1958), Okumura (1974) examined the influence of penetration speed (S_p) and the tube edge cutting angle on sample disturbance for Kinkai clay deposits. He employed a fixed piston sampler with an inner diameter of 75 mm. The results of this examination are reflected in the standards of the Japanese Geotechnical Society (JGS 2015a, 2015b, 2015c) and in ISO 22475-1 (2006). However, the mechanism by which samples are disturbed by the penetration of the sampling tube were not clarified. Using scanning electron microscopy (Shogaki and Matsuo, 1985) and color laser 3D profile microscopy (Shogaki, 2006a), as well as strength tests (Shogaki, 2006b, 2012), researchers have shown that the influence of the tube wall for Ariake, Amagasaki, and Urayasu clays takes place within a range of 2 mm from the wall even for a fixed piston sampler with an inner diameter of 45 mm. Their results brought about the development of a small-diameter sampler with a two-chamber hydraulic piston and the establishment of a new sampling standard (JGS, 2015a).

Peer review under responsibility of The Japanese Geotechnical Society.
E-mail address: shogaki@nda.ac.jp

http://dx.doi.org/10.1016/j.sandf.2017.06.004

Notations

CD_v	vertical displacement from the target at the cutting edge
D_r	relative density
D_c	distance of the arc from the X-X axis, as shown in Fig. 4
D_e	distance from the cutting edge
D_s	vertical deformation of ground surface
D_v	vertical displacement of target
$\overline{D}_v$	mean value of D_v
$D_{v(45)}$	D_v obtained from the 45-mm tube
D_w	distance from inside tube wall
e	void ratio
$\bar{e}$	mean value of e
e_0	initial void ratio
F_p	penetration force
FS	frozen sampling
G_0	initial modulus of rigidity obtained from cyclic triaxial test
N_c	number of uniform stress cycles
P_p	penetration pressure
R_e	ratio of $\bar{e}$ to e_0
R_{L20}	cyclic stress ratio at $N_c = 20$
$\overline{R}_r$	mean value of sample recovery ratio
S_p	tube penetration speed
45-mm	tube with an inner diameter of 45 mm
TS	tube sampling
u	pore water pressure
u_{max}	maximum value of u
$u_{(circular)}$	u for the circular tube
$u_{(semicircular)}$	u for the semicircular tube
ε_a	maximum axial strain
U_c	uniformity coefficient
U'_c	curvature coefficient
ρ_d	dry density

Baligh et al. (1987) and Clayton et al. (1998) used numerical analysis to study how the angle of the tube's cutting edge and the tube diameter affect sample quality via sample disturbance. They pointed out that sample quality decreases with decreasing tube diameter. However, these results cannot explain the quality of samples obtained using 45-mm and 75-mm samplers, since samples obtained using 45-mm samplers are of similar or higher quality than samples obtained with 75-mm samplers (Shogaki and Sakamoto, 2004; Shogaki et al., 2006; Shogaki and Nakano, 2010). One reason given for 45-mm samplers' higher quality samples is their higher penetration speed (Shogaki and Nakano, 2010). However, the reasoning behind this opinion is inadequate, since it is based on field sampling and the factors that control sample quality had not been examined quantitatively.

Sample disturbance occurring during soil sampling is a very complex phenomenon with potential changes during drilling, tube penetration, extraction, sealing, transport, storage, specimen preparation, and testing. Numerous researchers have investigated the extent and nature of disturbance occurring during sampling and laboratory testing for clayey soil (Skempton and Sowa, 1963; Adams and Radakrishna, 1971; Lefebvre and Poulin, 1979; La Rochelle et al., 1981; Kirkpatrick and Khan, 1984; Height et al., 1985; Graham and Lau, 1988; Clayton et al., 1992; Tanaka, 2000; Horng et al., 2010; Pineda et al., 2014). Hight and Georgiannou (1995) investigated the effects of sampling on the undrained behavior of clayey sands (5–15% clay) by conducting laboratory tests on soil reconsolidated to its *in situ* stress state. There has, however, been no quantitative evaluation of the main factors that influence sample disturbance in sand sampling. The effects of sample disturbance on the undrained shear strength of cohesive soil have been clarified by analyzing the responses to questionnaires given to senior engineers and researchers with a wealth of practical experience, and through laboratory and field investigations (Matsuo and Shogaki, 1988). However, there has not been sufficient analysis for a quantitative evaluation of what factors affect sample disturbance in each stage from *in situ* sand sampling to laboratory tests. Drilling, tube penetration, and tube extraction are the main opportunities for sample disturbance in sand, since the sand is frozen at the site and transported to the laboratory in a frozen condition in Japan. A similar technique was used in the CANLEX project (Robertson et al., 2000), but it is not practiced in many other countries and has not been widely used in well-known projects. Sampling in sands also frequently requires the use of a core catcher, which can also cause sample disturbance. This technique has not been included in the JGS standards (2015a) as suitable for undisturbed sand sampling. For aged sands where there may be bonds between some of the particles, breaking these bonds can also influence the quality of the sample.

Yoshimi et al. (1989) showed that the liquefaction strength of samples obtained by tube sampling is overestimated by something less than 20 blows in standard penetration tests (N_1), and that the effective overburden pressure caused by the increased density induced when the sampling tube penetrates a sand deposit should be considered.

In practice, simpler and more economical sampling methods for natural sand deposits, such as the single, double, and triple tube sampling methods (JGS (2015a, 2015b, 2015c), respectively, and ISO 22475-1, 2006) can be used.

Please cite this article in press as: Shogaki, T., Mechanism of sample disturbance caused by tube penetration: Model tests on Toyoura sand, Soils Found. (2017), http://dx.doi.org/10.1016/j.sandf.2017.06.004