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Undrained cyclic shear strength and post undrained cyclic shear volumetric strain behavior of high-quality undisturbed gravel

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ABSTRACT The undrained cyclic shear strength and the post-liquefaction volumetric strain behavior of in-situ gravel layers were studied by performing a series of cyclic undrained shear tests on two different kinds of high-quality undisturbed gravel samples using a large scale triaxial test apparatus. The high-quality undisturbed gravel samples were recovered by the in-situ freezing sampling method from two gravelly layers having a shear wave velocity of 560 and 330 m/sec, respectively.

INTRODUCTION

In the past decade, the in-situ properties of gravelly soils have been studied for the verification of their stability for supporting important structures such as nuclear power plants against earthquake motions. Though some data has been collected for the cyclic undisturbed strength and deformation characteristics (for example, Hatanaka et al (1988), Suzuki et al (1992)), the volumetric strain following the undrained cyclic shear has not yet been investigated for the in-situ gravelly soils. Obviously, the knowledge on the volumetric strain behavior of gravelly soils induced by earthquake motions is a very important factor for the aseismic design of structures founded on such soil layers.

The simplified procedure for evaluating the undrained cyclic shear strength by using penetration resistance obtained from large penetration test (LPT) or shear wave velocity measured in-situ (Vs) has been proposed by Suzuki et al (1993) and Hatanaka et al (1996), respectively. It is very important to verify such kind of simplified procedures by using new data for different kinds of gravels. Responding to these needs, a series of undrained cyclic shear tests were performed on the high-quality undisturbed gravel samples recovered by the in-situ freezing sampling method. The objectives of this study are to investigate the post undrained cyclic shear volumetric strain behavior and also to verify the proposed procedure for evaluation of the undrained cyclic shear strength of in-situ gravel from the penetration resistance and in-situ shear wave velocity.

SOIL PROFILE OF SAMPLING SITE AND FIELD TESTS

Figure 1 shows the soil profile of the sampling site for obtaining high-quality undisturbed gravel samples. There are two gravel layers (upper layer-KFU samples and lower layer-KFL samples) at the sampling site, at the depth between 5 m and 20 m from the ground surface. They are seperated by a thin sand layer located at a depth of about 8.3 to 9.5 m from the ground surface. The ground water table is about 2.0 m from the ground surface. Figure 2 indicates the plan showing the locations of the field tests and the in-situ freezing sampling performed on the site.

The standard penetration tests (SPT) were performed at boring holes No.1 and No.2 which are 4 m away from the sampling position, while the large-scale penetration tests (LPT) were performed at boring holes No. LB-1 and No. LB-2 which are 6 m away from the sampling position, respectively (Fig. 2). The blow counts both of SPT (N value) and LPT (N_L value) are also shown in Fig.1, while the specifications for both the SPT and LPT used in the present study are indicated in Table 1. The LPT was developed by Kaito et al (1971) for reducing the effects of large size gravel particles on the penetration resistance obtained from SPT. In the past decade, use of the LPT has been increased gradually in research projects for relating the undrained cyclic shear strength of gravelly soils. For the same reason, it was performed in the present study.

The shear wave velocity (Vs) was measured using a down hole method in hole No.1 after performing the SPT, by moving the two receivers connected at a distance of 2 m apart, from the ground surface to the bottom of the hole. With this method, the shear wave velocity can be measured every meter in the depth, continuously. As indicated in Fig.1, the shear wave velocity are 330 m/s and 560 m/s for the upper and lower gravel layers, respectively.

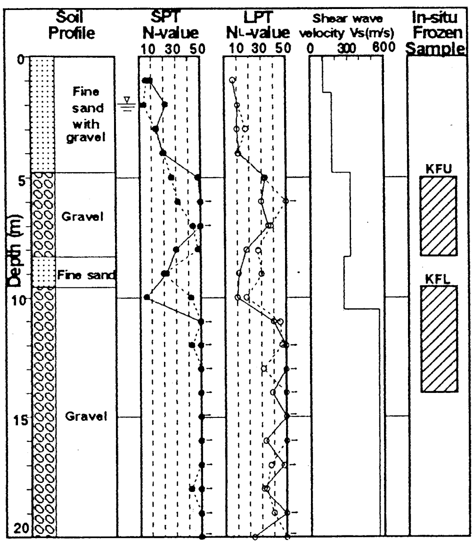

Fig.1 Soil profile of sampling site

Table 1 Specifications of penetration tests

	Item	LPT	SPT
Hammer	Weight (kgf)	100	63.5
	Drop height (cm)	150	75
Rod	Outer Diam. (mm)	60	40.5
Sampler	Outer Dia. (mm)	73	51
	Inner Dia. (mm)	50	35

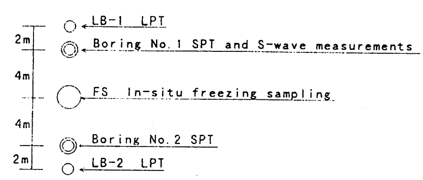

Fig.2 Plan of locations for field tests

IN-SITU FREEZING SAMPLING METHOD TO RECOVER HIGH-QUALITY UNDISTURBED GRAVEL SAMPLES

The in-situ freezing technique was used for obtaining high-quality undisturbed gravel samples for laboratory tests. Because this method of sampling is known to be the best in the present state-of-the-art technique, in order to obtain high quality undisturbed gravel samples as reported by Hatanaka et al (1988). Figure 3 shows the procedure of the in-situ freezing sampling for the recovery of gravel samples. The details are described below.

① A hole about 120 cm in diameter is excavated to a depth of one to two diameters (120 cm to 240 cm), above the top of the gravel stratum to be sampled. A steel casing about