

EFFECT OF SPECIMEN SIZE ON UNCONFINED COMPRESSIVE STRENGTH PROPERTIES OF NATURAL DEPOSITS

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ABSTRACT

In order to use the advantages of unconfined compression tests, a new testing procedure using S (or Small size) specimens (15 mm in diameter and 35 mm in height) is proposed and a new portable unconfined compression test apparatus with suction measurement is outlined. The effect of specimen size on unconfined compressive strength properties of natural deposits is discussed from laboratory tests. The standard deviations of the ratios of q_u and E_{50} values of the S specimens to O (or Ordinary size) specimens (35 mm d and 80 mm h) were in the range of 0.09 to 0.16. The 10% variation from the mean value reflects the homogeneity of soils since the coefficient of variations of the undrained shear strength for the undisturbed and reconstituted soils were 8% to 17% (Matsuo and Shogaki, 1988). In an engineering sense, there was no difference in shear strength and deformation characteristics between the S and O specimens for soils having plasticity indexes ranging from 10 to 370 and unconfined compressive strengths of 18 kPa to 1000 kPa, that were taken from 26 different sites in the United Kingdom, Korea and Japan. These soils consisted of Holocene and Pleistocene clays plus diatomaceous mudstone and highly organic soils.

Key words: clay, organic soil, specimen size, strength properties, suction, unconfined compression test (IGC: C6/D5)

INTRODUCTION

The unconfined compressive strength (q_u) is widely used in Japan for stability analysis of clay foundations under undrained conditions. This is mainly because the mean value of $q_u/2$ clearly describes the undrained shear strength on the failure surface in a specific area (Nakase, 1967; Matsuo and Asaoka, 1976; Shogaki et al., 1997), and in addition to this, the testing procedure for the q_u -value is simple and economical. The specimen size usually used in Japan for unconfined compression tests (UCT) is the O (or Ordinary size) specimen, 35 mm in diameter and 80 mm in height.

The thin-walled tube sampler normally used in Japan for obtaining undisturbed soil samples is the 75-mm (JGS 1221–2003) and double tube (JGS 1222–2003) samplers having an inner diameter of 75 mm and a length of 1 meter. The reasons for using O specimens in Japan are that two specimens can be taken from a sample 75 mm in diameter and 100 mm in height and the stress calculation is easy because the cross sectional area of the specimen is about 10 cm². However, for O specimens, the number of specimens is limited and their preparation for testing is difficult due to latent cracks or homogeneity. In addition, undisturbed sampling for hard soils like Pleistocene is difficult. Therefore, the small size specimen is better for effective use of samples because its size facilitates stress calculations and it is not necessary to retain the sample since calculations and measurements can be done

automatically via electronic instruments.

A small diameter (45-mm) and a cone sampler with a two-chambered hydraulic piston have been developed and their applicability for natural Holocene and Pleistocene clays, organic and sand deposits were shown by Shogaki, 1997a; Shogaki and Sakamoto, 2004; Shogaki et al., 2004a, 2004b, 2006. The effect of specimen size on the unconfined compressive strength properties is necessary for the examination of strength properties of a sample obtained from the 45-mm and cone samplers.

In this paper, an outline of the portable unconfined compression apparatus (PUCA) for measuring the suction and q_u is shown and the effect of specimen size on unconfined compressive strength properties of natural clay, organic and diatomaceous mudstone deposits is discussed based on laboratory tests.

REVIEW OF STUDIES FOR THE EFFECT OF SPECIMEN SIZE ON UNDRAINED STRENGTH PROPERTIES

In the studies for the effect of specimen size on unconfined compressive strength properties, Yoshinaka (1976) and Lo (1970) mentioned that the strength properties are influenced by the specimen size for rock materials and fissured clays respectively. Kamei and Tokida (1991) performed the UCT with specimen sizes of 10 mm, 20 mm, 35 mm and 50 mm in diameter and 10–100 mm in height for reconstituted clays having plasticity indexes

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The manuscript for this paper was received for review on August 24, 2005; approved on October 2, 2006.

Written discussions on this paper should be submitted before September 1, 2007 to the Japanese Geotechnical Society, 4-38-2, Sengoku, Bunkyo-ku, Tokyo 112-0011, Japan. Upon request the closing date may be extended one month.

from 19 to 36. They showed that there is no effect of specimen size on strength and deformation characteristics if the ratio of specimen height to diameter is 2.0 for diameters greater than 20 mm. However the q_u and secant modulus (E_{50}) values increase greatly if the diameter is 10 mm under $h/d=2$. They made the specimens by using small size sampling tubes of 10 mm and 20 mm in diameter and then by a trimmer only for 35 mm and 50 mm diameter specimens. Shogaki and Maruyama (1995) pointed out from the test results of reconstituted Kawasaki clay that the q_u and E_{50} values increase as the diameter decreases is caused by the problems in specimen taking, concerning Kamei and Tokida's test (1991).

Matsui et al. (1994) developed a triaxial apparatus using a small size specimen, 22.5 mm in diameter and 45 mm in height and discussed its applicability for undisturbed clay in Osaka city. They showed from the triaxial compression test on Holocene and Pleistocene clay deposits that specimen size has no effect on the shear strength. From these tests, they found that drainage time becomes shorter during the consolidation process.

The effect of friction between specimen and pedestal cap on strength properties differs by specimen size (e.g. JGS 0530–2000). Many researchers reported that there is no effect of specimen size on strength properties under $h/d \approx 2$. However, there are no systematic studies for the effect of specimen size on strength properties for the wide range of strength and plasticity in various soils, including organic and diatomaceous mudstone deposits.

The S (or Small size) specimen (15 mm in diameter and 35 mm in height) can be used for measuring the undrained strength anisotropy with a different angle of inclination to the vertical (Shogaki et al., 1997) and also K_0 -consolidated triaxial compression (CK_0UC) and extension (CK_0UE) tests (Shogaki and Nochikawa, 2004) for samples taken from the 75-mm sampler. Using the 45-mm and cone samplers having an inner tube diameter of 45 mm produces a smaller specimen, which is more advantageous for measuring mechanical and statistical properties. Therefore, the strength and deformation properties of the O and S specimens are discussed from the effect of specimen size in this study.

PORTABLE UNCONFINED COMPRESSION APPARATUS

The PUCA and its specifications for measuring the suction and the q_u values are shown in Fig. 1. In this apparatus, the load is applied by the linear head and is transmitted through an AC/DC motor. This equipment has a height of about 20 cm and a mass of about 7 kg. Therefore, since the equipment is portable, it is practical for field use. The UCT was performed on specimens 15–35 mm in diameter and 35–80 mm in height at a strain rate of 1%/min, after specimen suction was measured using a ceramic disk plate. The air entry value of a ceramic disc is about 200 kPa. The PUCA is equipped with a Perspex cylinder to measure the suction over one atmospheric pressure and also the q_u value for

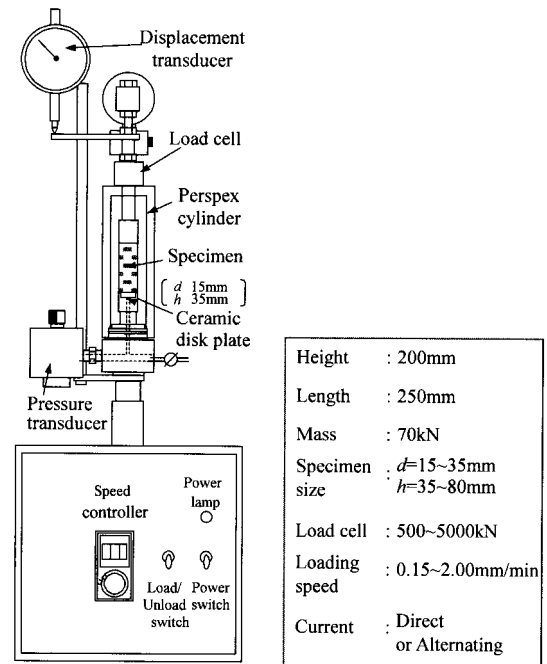


Fig. 1. Layout of the portable unconfined compression apparatus

hard soil with latent hair cracks (Shogaki, 1997b). The value of q_u was determined to be the maximum stress corresponding to axial strain of 15% or less. The E_{50} is given by Eq. (1), in which ϵ_{50} is the strain at the value of $q_u/2$.

$$E_{50} = \frac{(q_u/2)}{\epsilon_{50}} \quad (1)$$

SOIL SAMPLES AND TEST PROCEDURES

The undisturbed soil samples used in this study are shown in Fig. 2. The 75-mm rotary double-tube sampler identified as 75R, in accordance with the Japanese Geotechnical Standard (JGS 1222–2003), was used instead of the 75-mm sampler normally used in Japan in the Pleistocene clay deposits of Nagoya, Izumi, Osaka and Iwai soft clays and organic soil. The 84T sampler (JGS-1223, 2003) was used for Iwai Pleistocene clay. The method of core sampling (Core) used for the diatomaceous mudstone of Nanao was double tube core sampling using water pressure for drilling to minimize sample disturbance.

The water content (w_n), liquid limit (w_L), plastic limit (w_p), I_p , clay composition of less than $5\mu\text{m}$ (CC), effective overburden pressure (σ'_{v0}), overconsolidated ratio (OCR) (defined as the ratio of preconsolidation pressure (σ'_p) to (σ'_{v0})) and q_u together with samplers used in this study are summarized in Table 1. The I_p and q_u values range from 10 to 370 and 18 kPa to 1000 kPa respectively, which are very wide ranges. The Holocene clays are classified as from normally consolidated to slightly overconsolidated clays since the OCR values are in the range of 1.0 to 3.09, except for Busan New Port

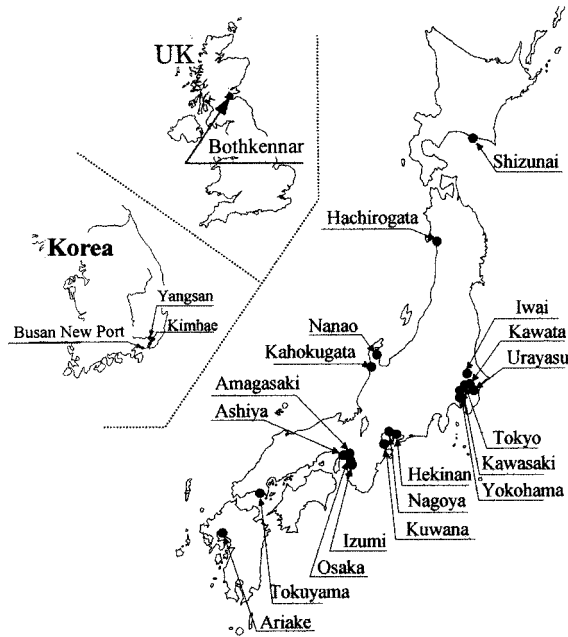


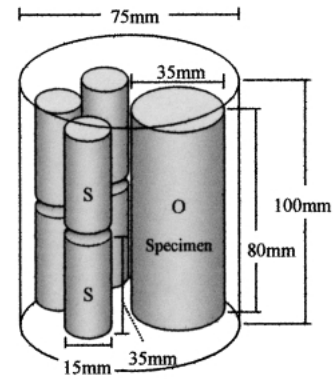
Fig. 2. Sampling sites

clay, which has OCR values ranging from 0.79 to 2.20. Busan New Port clays were disturbed under soil sampling (Shogaki et al., 2005a). The OCR values of Pleistocene clay, highly organic soil and diatomaceous mudstone range from 1.01 to 78.1 and classified as from normally consolidated to heavily overconsolidated clays.

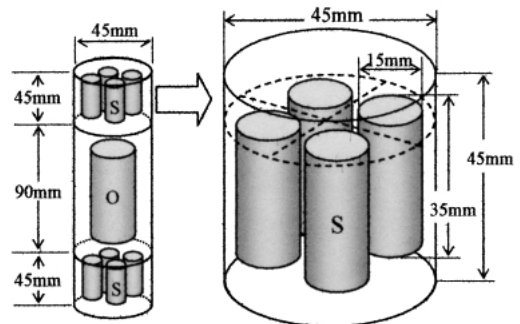
Figure 3 shows the location of specimens, for samples 75 mm in diameter and 100 mm in height and 45 mm in diameter and 180 mm in height, from the sampling tube of the 75-mm and 75R samplers and 45-mm sampler. Six S specimens and one O specimen can be obtained from the samples of the 75-mm and 75R samplers and eight S specimens and one O specimen from the 45-mm sampler, as shown in Fig. 3. Shogaki et al. (1995a) shows that the strength and deformation properties of ten S specimens obtained from a sample 75 mm in diameter and 45 mm in height are similar in an engineering sense. The specimen site, as shown in Fig. 3, is not influenced by the sample disturbance caused by tube penetration and friction between soil and tube during sample extrusion. This was confirmed by using a Scanning Electron Microscope (Shogaki and Matsuo, 1985) and a color laser three dimensional profile microscope (Shogaki, 2006a). Each specimen was sheared at 1%/min after suction measurement using PUCA in accordance with the Japanese Industrial Standard for unconfined compression tests of soils (JIS A1216-1993).

The procedure for measuring the suction is similar to that reported in other literature (Shogaki et al., 1995b; Shogaki and Maruyama, 1998). It is important that the suction be measured quickly to minimize stress condition changes, which directly affect the undrained shear strength and secant modulus values. The specimen suction was measured using a larger piezometer point value, based on the author's experience, as follows:

- 1) The suction (S_0) of a specimen, in which the suction



(a) A sample obtained from 75-mm and 75R samplers



(b) A sample obtained from 45-mm samplers

Fig. 3. Location of specimens for a sample

becomes constant, can be measured quickly when the piezometer measurement indicates a similar value to the expected specimen suction.

- 2) However, the possibility exists that suction greater than that of the piezometer measurement cannot be accurately measured if all air is not removed from the pressure transducer pipe.
- 3) If the air in the pressure transducer pipe is removed and the piezometer sensitivity is high, the measured S_0 values are unrelated when the specimen is put on the ceramic disc plate to get piezometer measurements.
- 4) However, the time in which suction becomes constant is less when the suction drops from a larger value to specimen suction.

The maximum time for measuring suction was six minutes. For the effect of measuring suction before and after shear on strength and deformation properties of specimens, it was confirmed by Shogaki et al. (1995b) that there was no effect for natural deposits. Namely, the decreases in water content of specimens during suction measurement and shear were less than 1%. It was considered that this small change in water content does not affect the strength and deformation properties.

EFFECT OF SPECIMEN SIZE ON SUCTION, RELATIONSHIP BETWEEN STRESS AND STRAIN AND EFFECTIVE STRESS PATHS

Figures 4(a), (b), (c), (d), (e), (f) and (g) show the

Table 1. Geotechnical properties of soil samples used in this study

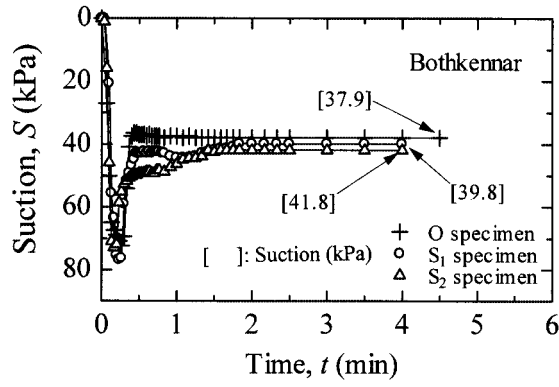
No.	Site	w_n (%)	w_L (%)	w_p (%)	I_p	CC* (%)	σ'_{vo} (kPa)	OCR	q_u (kPa)	Sampler
(Holocene)										
1	Shizunai	50	62	29	33	41	292	1.20	107	75-mm
2	Hachirogata	136	209	59	150	61	36	1.23	25	
3	Urayasu	81 ~ 85	104 ~ 114	44 ~ 49	60 ~ 65	50 ~ 52	232 ~ 457	1.23 ~ 1.19	127 ~ 177	
4	Kawata	48	36	26	10	15	77	1.95	59	
5	Tokyo	46	49	32	17	21	245	2.10	108 ~ 320	
6	Kawasaki	105 ~ 108	113 ~ 120	46 ~ 48	64 ~ 73	47 ~ 54	160 ~ 223	1.00 ~ 1.08	66 ~ 189	
7	Yokohama	57 ~ 61	73 ~ 74	33 ~ 36	38 ~ 41	16 ~ 26	195 ~ 211	1.06 ~ 2.02	100 ~ 197	
8	Hekinan	60 ~ 93	74 ~ 107	31 ~ 38	45 ~ 72	25 ~ 43	6 ~ 124	0.99 ~ 1.32	60 ~ 145	
9	Kuwana	34 ~ 71	51 ~ 95	25 ~ 38	26 ~ 57	3 ~ 30	99 ~ 205	1.17 ~ 2.94	92 ~ 220	
10	Amagasaki	47 ~ 72	59 ~ 105	26 ~ 41	33 ~ 69	30 ~ 54	191 ~ 241	1.02 ~ 1.36	130 ~ 138	
11	Ashiya	68 ~ 89	96 ~ 107	29 ~ 34	59 ~ 71	32 ~ 42	51 ~ 92	1.01 ~ 1.12	23 ~ 77	
12	Tokuyama	68 ~ 130	82 ~ 150	29 ~ 48	19 ~ 102	36 ~ 42	8 ~ 57	1.05 ~ 3.09	15 ~ 273	
13	Ariake	120	90 ~ 115	44 ~ 47	46 ~ 68	55 ~ 64	39 ~ 46	1.03 ~ 1.13	26 ~ 32	
14	Kahokugata	98 ~ 109	138	50	88	34	174	1.26	135	
15	Bothkennar (UK)	60	80	30	50	44	102	1.96	121	
16	Kimhae (Kr)	39 ~ 66	57 ~ 75	31 ~ 35	26 ~ 40	30 ~ 35	95 ~ 154	1.02 ~ 1.51	91 ~ 107	
17	Busan New Port (Kr)	53 ~ 70	60 ~ 86	28 ~ 32	32 ~ 54	36 ~ 60	59 ~ 175	0.79 ~ 2.20	48 ~ 129	
18	Yangsan (Kr)	64	61	27	34	65	86	1.03	54	
19	Iwai	358 ~ 592	67 ~ 118	33 ~ 44	34 ~ 74	34 ~ 63	18 ~ 23	1.01 ~ 2.04	16 ~ 20	
(Pleistocene clay)										
20	Nagoya	34 ~ 73	63 ~ 78	25 ~ 40	33 ~ 47	8 ~ 26	195 ~ 241	2.44 ~ 4.25	158 ~ 762	75R
21	Izumi	28 ~ 60	49 ~ 96	22 ~ 28	27 ~ 68	5 ~ 28	8 ~ 13	64.5 ~ 78.1	347 ~ 578	
22	Osaka (Bay area)	40	60	27	33	48	730	1.16	442	
23	Osaka (Ma12: Inland area)	63 ~ 73	75 ~ 118	31 ~ 44	44 ~ 78	39 ~ 66	324 ~ 346	1.83 ~ 2.08	362 ~ 585	45-mm, Cone
24	Iwai	74 ~ 83	101 ~ 111	41 ~ 51	58 ~ 74	40 ~ 66	66 ~ 68	1.01 ~ 1.90	25 ~ 35	84T
(Highly organic soil)										
25	Iwai	393 ~ 592	380 ~ 655	164 ~ 285	199 ~ 370	23 ~ 35	14 ~ 15	8.03 ~ 11.42	25 ~ 33	75-mm
(Diatomaceous mudstone)										
26	Nanao	87 ~ 182	143	91	52	42	135	22.32	335 ~ 1070	Core

*: Clay composition of less than 5 μm

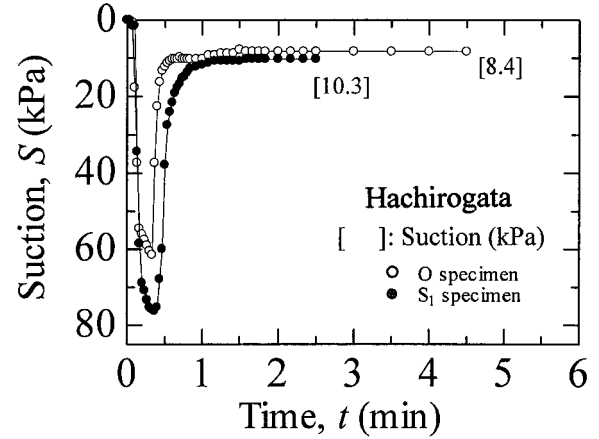
results of the suction measurement for Bothkennar, Kimhae, Busan New Port, Yangsan, Hachirogata, Iwai organic and Holocene clays respectively. These specimens were put on the ceramic disc plate when the piezometer point indicated about 80 kPa, dependent on type of soil tested. The time, in which the specimen suction became constant, varied slightly for each specimen and this time was independent of specimen size. The suction value decreased with sample disturbance (Shogaki, 1995). The effect of specimen trimming on suction is unrelated to specimen size since the S_0 values of both specimen sizes are similar, as shown in Fig. 4. The suction values of Iwai

organic and Holocene clays, as shown in Figs. 4(f) and (g) respectively, are as small as 3 ~ 5 kPa since the σ'_{vo} values are as small as 14 ~ 23 kPa.

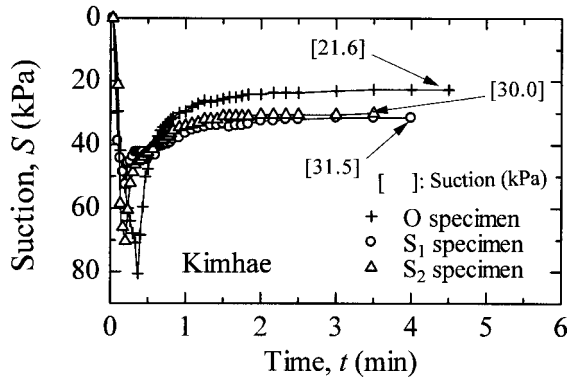
Figures 5(a), (b), (c), (d), (e), (f) and (g) show the relationships between the pore water pressure measured at the base of the specimen, the axial stress and the axial strain (ϵ_a) for the same specimen, as shown in Fig. 4. The suction under shear is represented as the pore water pressure (u) in Fig. 5 since the suction under shear becomes zero to plus for an O specimen and a small S_0 value for the S specimens. Therefore, the u values at the $\epsilon_a = 0\%$ are S_0 values. The w_n , q_u , E_{50} and axial strain at



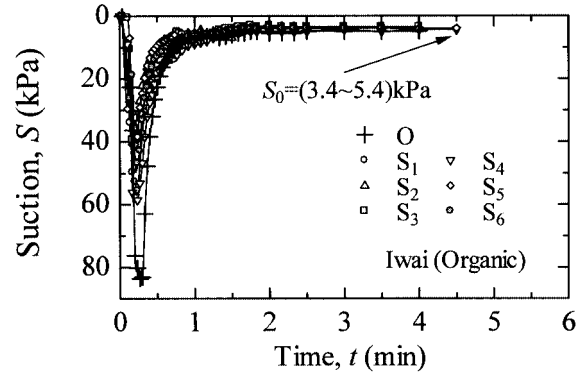
(a) Bothkennar clay



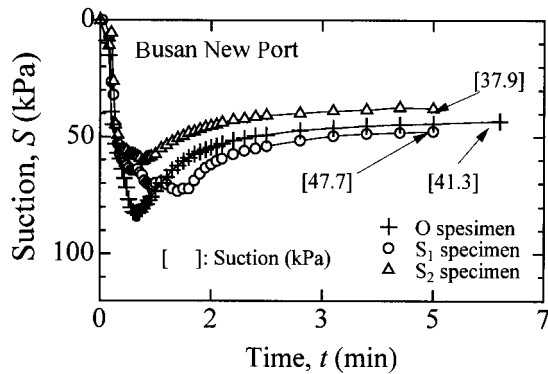
(e) Hachirogata clay



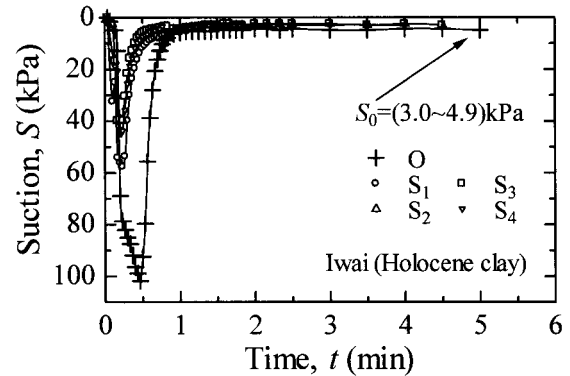
(b) Kimhae clay



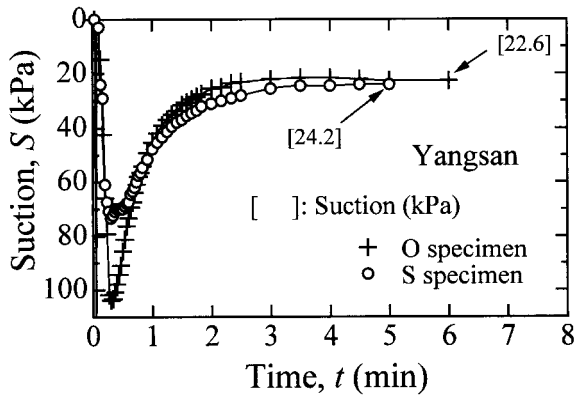
(f) Iwai organic soil



(c) Busan New Port clay



(g) Iwai (Holocene clay)

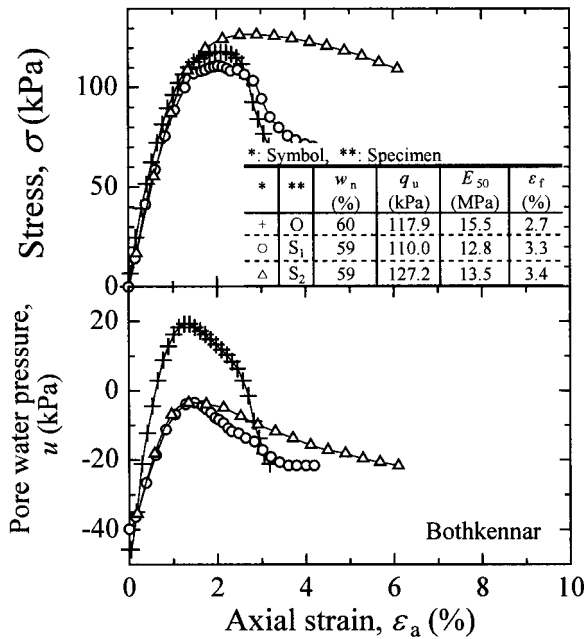


(d) Yangsan clay

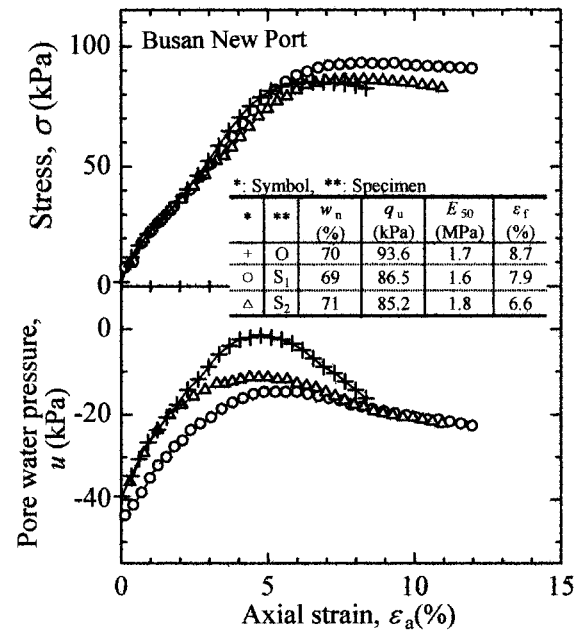
Fig. 4. Relationships between suction and time

failure values of each specimen are also given in Fig. 5.

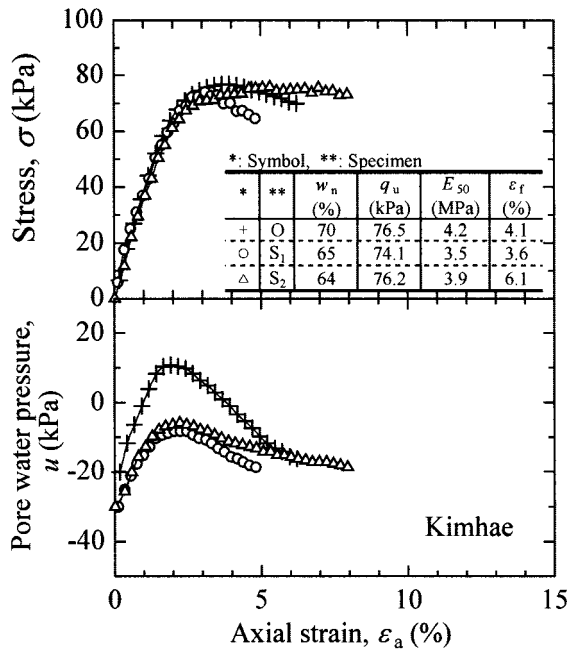
The q_u and E_{50} values and the relationships between stress and axial strain for each soil are almost the same, unrelated to specimen size. However, pore water pressure under shearing differs by specimen size, namely the pore water pressure of O specimens changed from minus to plus under an axial strain of from 0.5% to 1% before maximum axial stress and the amount of change of pore water pressure was greater than that of S specimens. As described in the previous chapter, the strain rate of both specimens was 1%/min. The pore water pressure values measured at the specimen bottom are smaller than those around the shear band and caused by the delayed



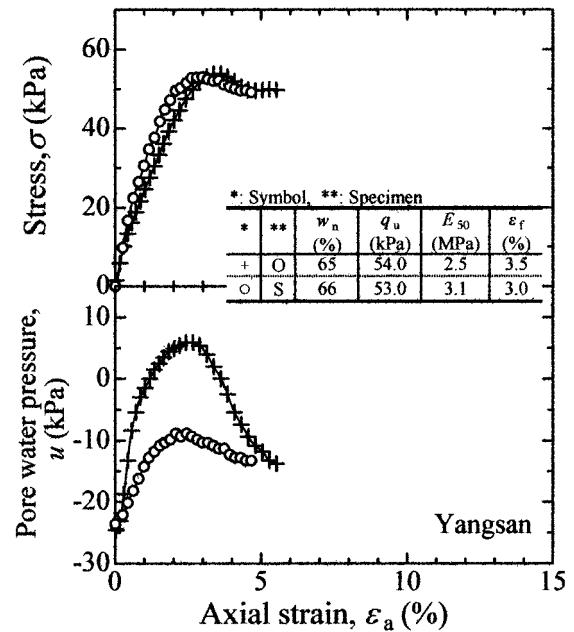
(a) Bothkennar clay



(c) Busan New Port clay



(b) Kimhae clay

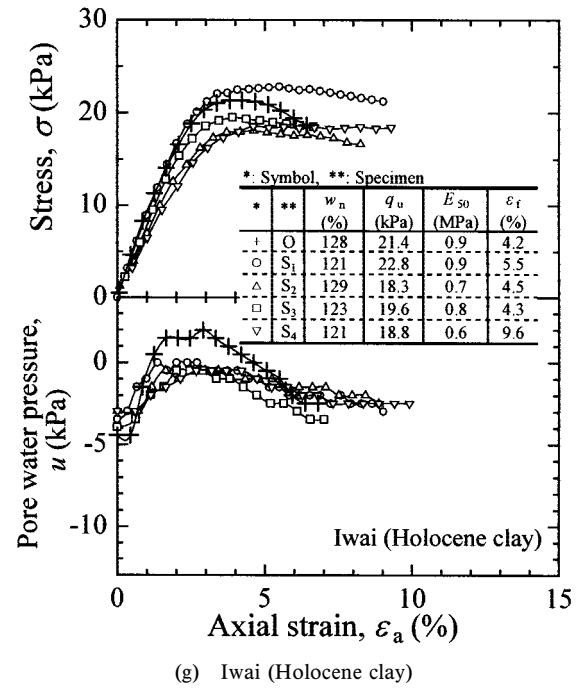
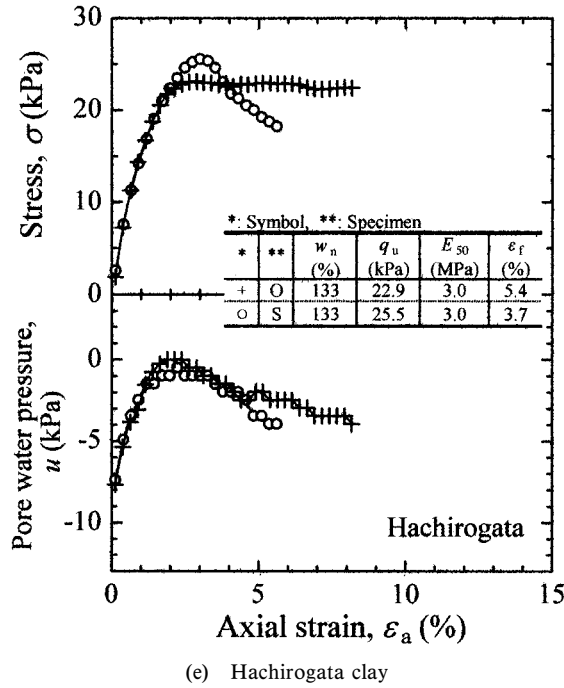
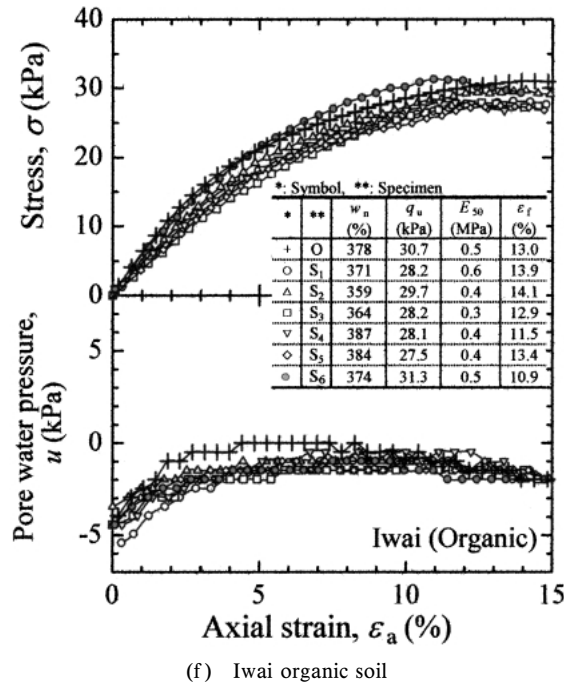


(d) Yangsan clay

migration of pore water pressure, as shown in Fig. 6. The undrained condition under shear for both specimen sizes was sufficient since the decrease of water content was less than 1% by calculating specimen weight before and after shear for both sizes. For Iwai organic soil and soft clay deposits, the effective stress paths of UCT using S specimens are consistent with those of the CK_0UC except the difference in the initial stress condition (Shogaki, 2006b). Therefore, the UCT with suction measurement using S specimens is suitable for the measurement of effective stress paths under undrained conditions.

The effective stress paths concerning Fig. 5 are shown in Fig. 7. From the relationships between axial stress and axial strain, as shown in Fig. 5, the deviation stresses are

almost similar for the O and S specimens. However, there is a large difference in the effective stress paths between the O and S specimens of Bothkennar, Kimhae, Yangsan and Iwai Holocene clays which is caused by the delayed migration of water content. In Hachirogata clay and Iwai organic soil, the plasticity index and natural water content are as high as 150~370% and 136~592% respectively and the q_u value is as small as 25~33 kPa. Hachirogata clay had many diatoms and the samples were saturated by water (Tanaka and Locat, 1998) and Iwai organic soil had a high water content of 370%. The delayed migration of pore water pressure for Hachirogata clay and Iwai organic soil is so minor that it can be ignored.

Fig. 5. Relationships between u , σ and ε_a 

The relationship between axial stress and axial strain for Osaka and Iwai Pleistocene clays is shown in Figs. 8 (a) and (b). The UCT using S specimens is applicable under JIS A1212-1993, as well as the triaxial test using S specimens (Shogaki and Nochikawa, 2004) since the relationship between axial stress and axial strain is unrelated to soils, as shown in Figs. 5 and 8.

EFFECT OF SPECIMEN SIZE ON q_u AND E_{50} VALUES

The ratios (Rq_u) of the mean value ($q_{u(S)}$) of q_u values of S specimens to those of O specimens are plotted

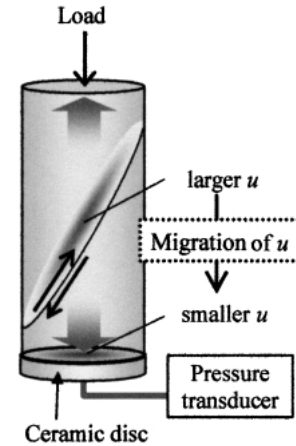
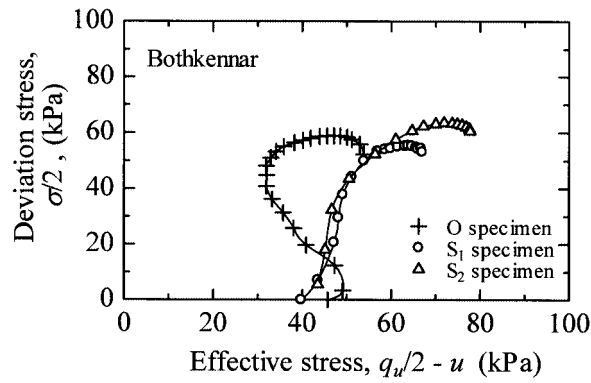
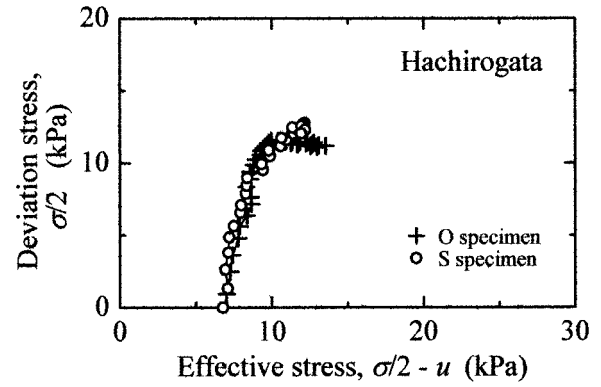


Fig. 6. Concept on migration of pore water pressure under shear

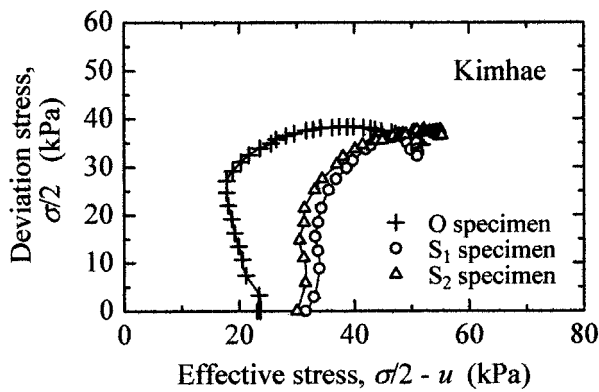
against I_p and q_u in Figs. 9 and 10 respectively. The ratios (RE_{50}) of E_{50} values are also shown in Figs. 11 and 12. The plot symbols are classified for Bothkennar, Kimhae, Busan New Port and Yangsan clays in order to distinguish from Osaka Ma12, Iwai Holocene and Pleistocene clays and organic soil and other Japanese Holocene and Pleistocene clays and diatomaceous mudstone. The Rq_u values are in the range of 0.91 to 1.25, unrelated to the $I_p = 10 \sim 370$ and $q_u = 18 \sim 1000$ kPa values, and the mean value is 1.02. The RE_{50} values are also in the range of 0.77 to 1.24 and the mean value is 0.99. The q_u and E_{50} values obtained from the O and S specimens are almost similar, unrelated to twenty-six different sites in the United Kingdom, Korea and Japan and also Holocene and Pleistocene clays, organic soils and diatomaceous mudstone. However, the RE_{50} of Iwai organic soils were



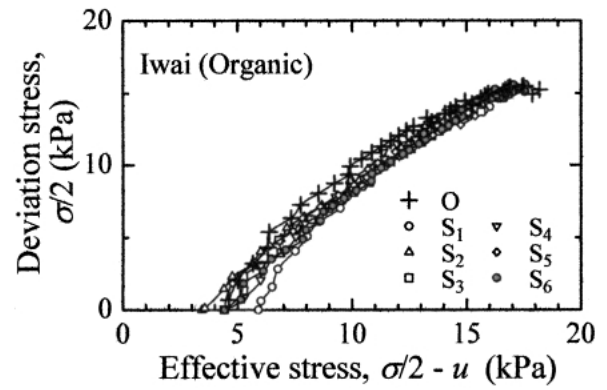
(a) Bothkennar clay



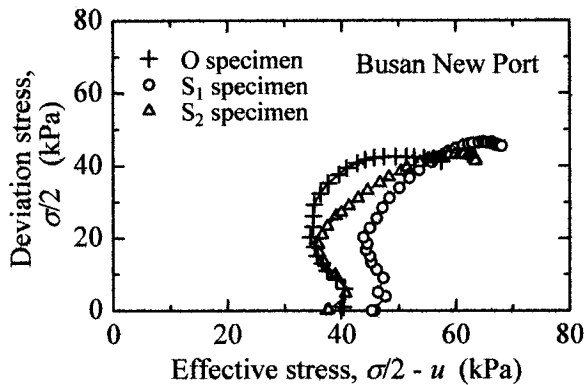
(e) Hachirogata clay



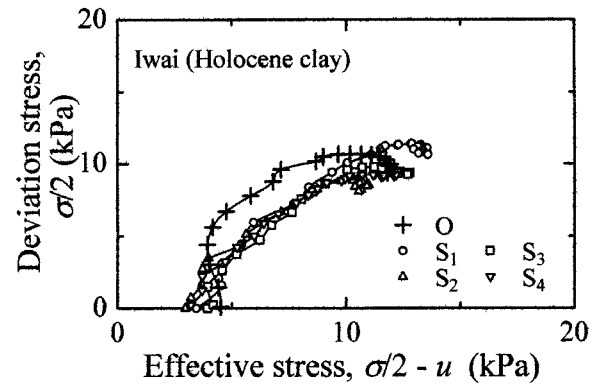
(b) Kimhae clay



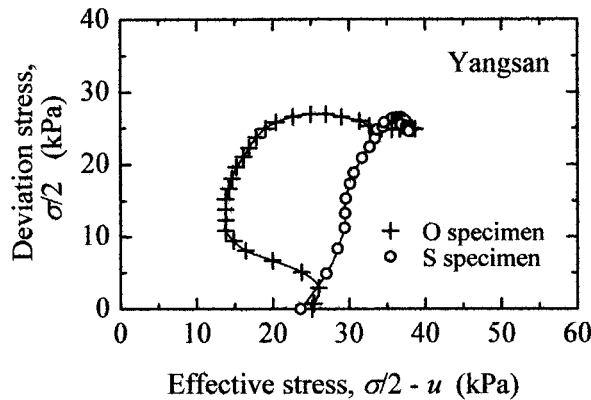
(f) Iwai organic soil



(c) Busan New Port clay



(g) Iwai (Holocene clay)

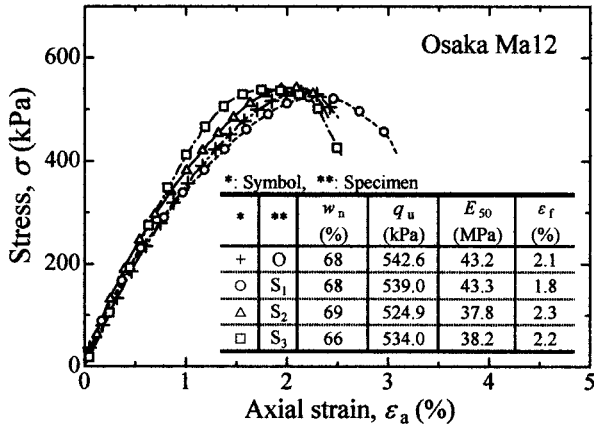


(d) Yangsan clay

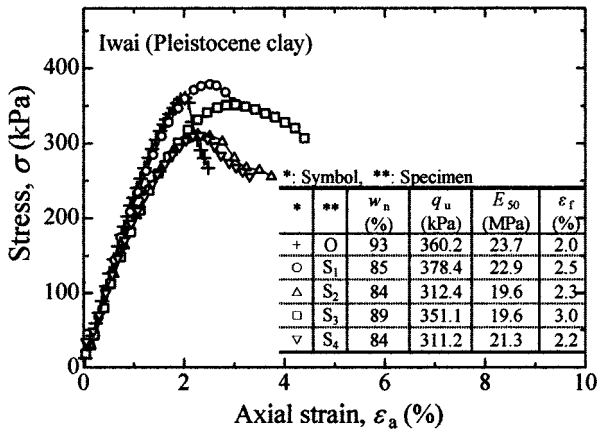
Fig. 7. The effective stress paths

in the range of 0.67 to 0.91 and the mean value was 0.76. This is caused by soil homogeneity, as shown in Fig. 5(f). Namely, the q_u and E_{50} values of the O, S₁ and S₆ specimens under similar w_n values are similar. The UCT test for highly organic soils is very difficult since the undrained condition under shear cannot always be confirmed. However, it was judged from the effective stress behavior for the UCT and K_0 consolidated-undrained triaxial compression tests (Shogaki et al., 2004b) that the UCT test for Iwai organic soils could be accurately performed.

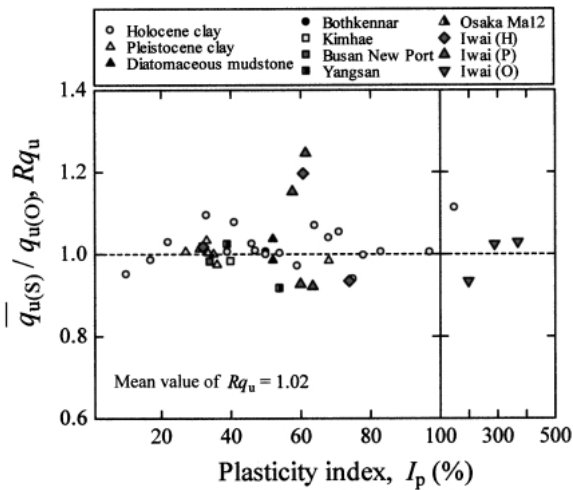
It was shown in Figs. 9 to 12 that the q_u and E_{50} values obtained from O and S specimens are unrelated to sampling sites and various soils. Based on this fact, Figs. 13



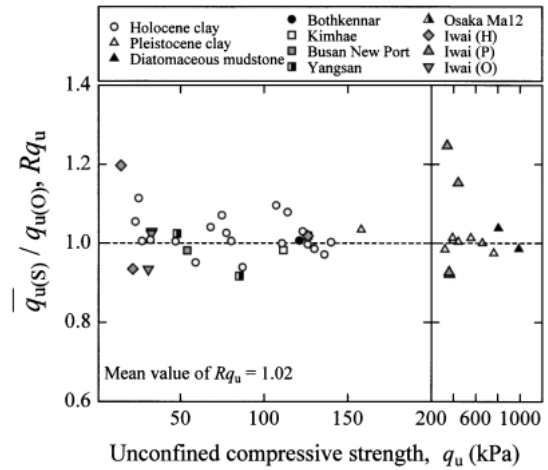
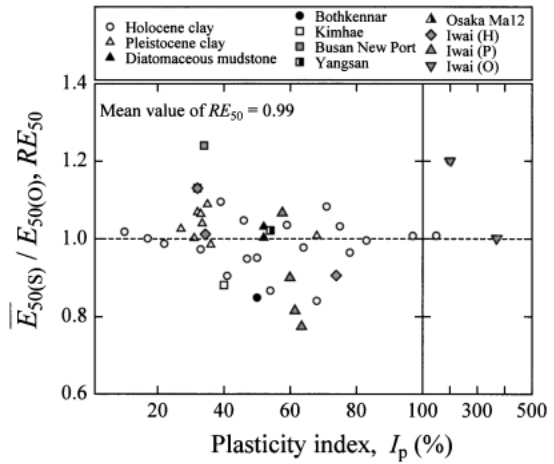
(a) Osaka Pleistocene (Ma12) clay



(b) Iwai Pleistocene clay

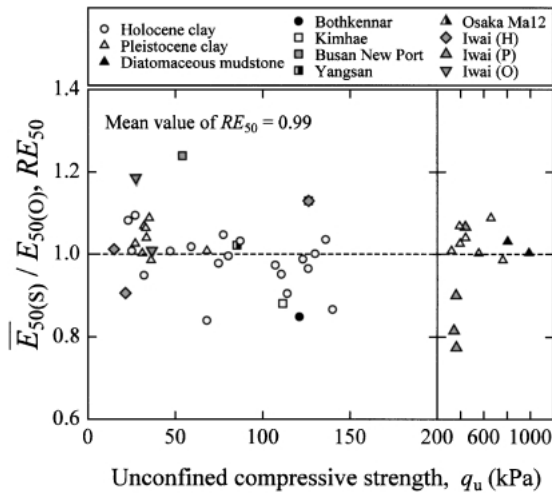
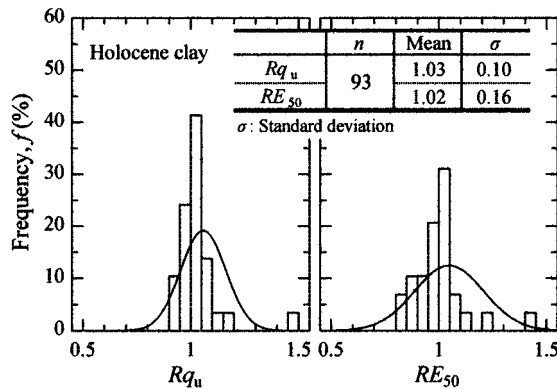
Fig. 8. Relationships between σ and ε_a Fig. 9. Relationships between R_{q_u} and I_p

and 14 show the histograms and their normal distribution curves for the R_{q_u} and RE_{50} for Holocene and Pleistocene clays respectively. The number (n) of S specimens in Figs. 13 and 14 are 93 for Holocene and 37 for Pleistocene clays for specimens having similar wet densities and w_n values since the $q_{u(s)}$ and $E_{50(s)}$ for each plot in

Fig. 10. Relationships between R_{q_u} and q_u Fig. 11. Relationships between RE_{50} and I_p

Figs. 9 to 12 are the mean value for several specimens. The mean values of the R_{q_u} and RE_{50} values using these specimens were similar to those of Figs. 13 and 14. The mean values of the R_{q_u} and RE_{50} are in the range of 0.99 to 1.03, unrelated to Holocene and Pleistocene clays. The standard deviations (s) of R_{q_u} and RE_{50} are in the range of 0.09 to 0.16. The 10% variation from the mean value reflects the soil homogeneity since the coefficient of variations of the undrained shear strength for the undisturbed and reconstituted soils, excluding soil strength, stiffness and sampling methods, were 8~17% (Matsuo and Shogaki, 1988). Therefore, the strength and deformation properties of the O and S specimens are similar for undisturbed clay and organic soil deposits and diatomaceous mudstone having plasticity indexes from 10 to 370 and the unconfined compressive strengths are 18~1000 kPa. The undrained strength properties between the ordinary and small specimens are also similar since the effects of specimen proportions on the strength properties are similar.

The unconfined compression test using the S specimen with suction measurement is better for effective use of samples and measuring strength properties and determin-

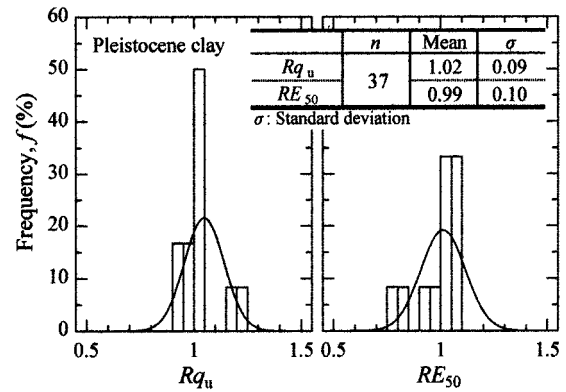
Fig. 12. Relationships between RE_{50} and q_u Fig. 13. The statistical properties of Rq_u and RE_{50} (Holocene clay)

ing statistical properties.

CONCLUSIONS

The conclusions obtained from this test are summarized as follows:

- 1) The unconfined compression test using S (or Small size) specimens of 15 mm in diameter and 35 mm in height with suction measurement is better for measuring strength properties and determining statistical properties.
- 2) The standard deviations of the ratios of q_u and E_{50} values of the S specimens to O (or Ordinary size) specimens ($d35$ mm and $h80$ mm) were in the range of 0.09 to 0.16. The 10% variation from the mean value reflects the soil homogeneity since the coefficients of variations of the undrained shear strength for the undisturbed and reconstituted soils were 8~17% (Matsuo and Shogaki, 1988).
- 3) In an engineering sense, there was no difference in shear strength and deformation characteristics between the S specimens and O specimens from soils having plasticity indexes ranging from 10 to 370 and unconfined compressive strengths of 18~1000 kPa

Fig. 14. The statistical properties of Rq_u and RE_{50} (Pleistocene clay)

that were taken from 26 different sites in the United Kingdom, Korea and Japan. These soils consisted of Holocene and Pleistocene clays plus diatomaceous mudstone and highly organic soils.

ACKNOWLEDGEMENT

The author wishes to express his sincere gratitude to Mr. Yoshikazu Maruyama, Syuji Shirakawa and Ryo Sakamoto, who were graduate students of the National Defense Academy, for their cooperation in experimental works and also to the Geotechnical Survey Laboratory of the Port and Airport Research Institute for the use of their Bothkennar and Yangsan clay samples in his research.

NOTATION

- CC: clay composition of less than 5 μ m
 E_{50} : secant modulus
 I_p : plasticity index
 OCR: overconsolidated ratios defined as the ratio of effective overburden pressure (σ'_{v0}) to preconsolidation pressure (σ'_p)
 q_u : unconfined compressive strength
 S_0 : specimen suction before shear
 u : pore water pressure
 w_L : liquid limit
 w_n : natural water content
 w_p : plasticity limit
 ε_a : axial strain
 ε_f : strain at failure
 σ : axial stress
 σ'_{v0} : effective overburden pressure

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