Effect of Disturbance on the Compressibility of Marine Clay in Korea

L'Effet du Dérangement sur la Compressibilité de l'Argile Marine en Corée

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ABSTRACT

This study describes the compressibility of marine clays at southern and western coasts in Korea. In order to evaluate the effect of disturbance on the compressibility, a series of various laboratory consolidation tests are performed on the specimens obtained by large block sampling and piston sampler. It is observed that the volumetric strain of large block sample is smaller than that of piston samples and the compression index of large block sample is larger than that of piston sample. An empirical equation of compression index is suggested in this study, considering the effect of sampling. The usage of suggested empirical relation is expected to provide more reasonable prediction of settlement than using the compressibility obtained from the result of tests on piston samples.

RÉSUMÉ

Cette étude décrit la compressibilité de l'argile marine sur la côte méridionale et occidentale en Corée. Pour évaluer l'effet du dérangement sur la compressibilité, une collection de divers tests de la consolidation du laboratoire est exécutée sur le spécimen obtenu par l'échantillon du grand bloc et par le modèle du piston. Il est observé que la tension volumétrique du grand bloc est moins grande que celle de l'échantillon du piston et le taux de la compression du modèle du grand bloc est plus grand que celui de l'échantillon du piston. Une équation empirique du taux de la compression est suggérée dans cette étude, considérant l'éffet de l'échantillonnage. L'utilisation du rapport empirique et suggéré s'attend à fournir plus de prédictions raisonnables de l'accord que l'emploi de la compressibilité obtenue par le résultat des tests sur l'échantillon du piston.

Keywords : sampling disturbance, large block sample, compression index, marine clay

1 INTRODUCTION

When the laboratory test is performed on the natural specimen, the mechanical characteristics of the specimen depend on the degree of disturbance occurred during sampling process. Since the sampling disturbance affects the compressibility, the evaluation of reasonable design values is essential to the exact prediction of settlement. In this study, various types of laboratory consolidation tests are performed on the marine clay specimens obtained by block samples and piston sampler. The degree of disturbance is evaluated for each test specimen, based on the volumetric strain occurred during recompression up to in-situ stress level. Using the compression index obtained for the large block samples, the relationships with natural water content, liquid limit and plasticity index are reviewed and a new empirical relation is suggested.

2 TEST PROGRAM

2.1 *Physical Properties of Test Samples*

Figure 1 represents the locations at southern and western coasts in Korea, where the marine clays are obtained in this study. The west coast shows a relatively large difference between tidal high and low levels, and the ground is mainly composed of a silt or clay layer. The average N value of this soft stratum is 3~5 up to the depth 10~17m. The soft stratum of the southern coast is a high plastic silt or clay which extends more than 22m from the ground surface. The representative geotechnical properties for specimens of each location are shown in Table 1.

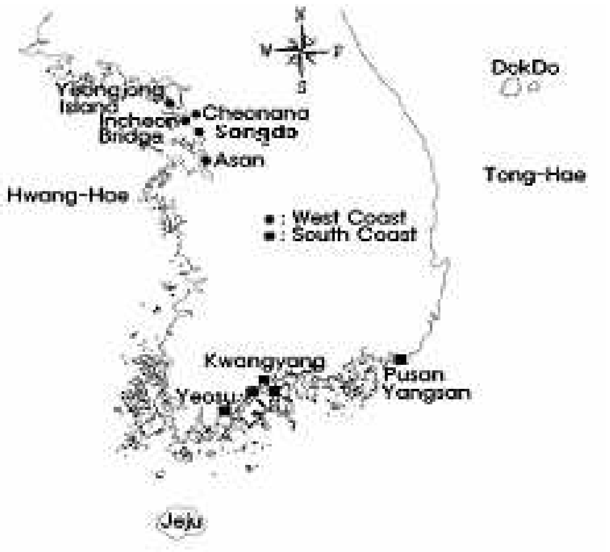

Figure 1. Natural sample extraction a location of characteristics of marine clay in Korea

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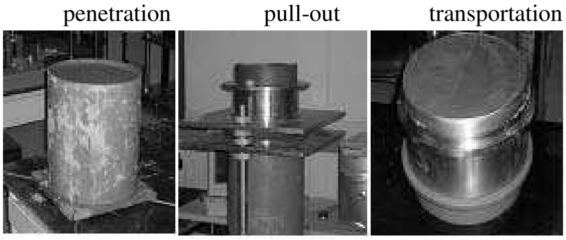
Table 1. Geotechnical properties of large block samples

Test site		w_n(%)	G_s	LL(%)	PI(%)	e_o	USCS
West coast	YI	32.4 ~49.4	2.65 ~2.69	28.4 ~53.7	9.5 ~28.3	0.94 ~1.31	CL
	IB	41.1 ~48.2	2.67 ~2.72	34.5 ~45.6	11.5 ~21.8	1.12 ~1.29	CL
	CL	35.5 ~57.1	2.70 ~2.73	31.1 ~55.0	6.2 ~29.5	0.96 ~1.55	CL
	SD	29.8 ~42.5	2.67 ~2.73	27.1 ~36.7	2.6 ~14.2	0.81 ~1.16	ML, CL
	AS	34.5 ~36.2	2.69 ~2.70	30.2 ~35.6	7.7 ~12.8	0.93 ~0.97	CL
South coast	KY-2A1	63.3 ~105.9	2.71 ~2.73	66.3 ~92.2	42.1 ~59.9	1.74 ~2.81	CH
	KY-2A2	47.2 ~64.8	2.72 ~2.72	40.5 ~57.4	16.1 ~30.9	1.28 ~1.76	CL, CH
	KY-2B	70.5 ~89.7	2.69 ~2.72	68.5 ~75.3	40.0 ~50.8	1.65 ~2.40	CH
	KY-2C	71.0 ~94.4	2.69 ~2.72	61.6 ~95.2	35.7 ~66.6	2.05 ~2.54	CH
	PS	53.6 ~88.9	2.71 ~2.74	53.6 ~88.3	26.9 ~46.2	1.48 ~2.54	CH

2.2 *Specimen Preparation and Laboratory Experiments*

The specimens used in this study are obtained by both large block and piston samplers. After excavating the hole using a 500mm diameter auger and removing the slime at the borehole bottom, a large block sampler of 400mm in diameter and 600mm in height is inserted and located at the bottom of the hole. Then sampler is pushed into the ground and a specially designed cutter cuts the specimen bottom to recover the block sample from the ground. Figure 2 shows the process of sampling, sealing, extrusion and specimen preparation. In this study, large natural block samples, whose diameter and height are 180~250mm and 350~800mm respectively, are obtained at 37 locations at south and east coasts in Korea. Also, the NX size natural samples are obtained using piston samplers at the same locations.

(a)sampler penetration (b)sampler pull-out (c)sealing up & transportation



(d)block Sample (e)sample extraction (f)sample molding

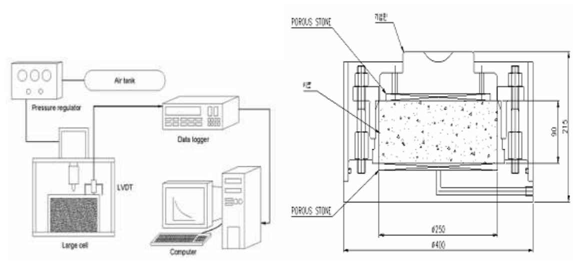
Figure 2. Large block sampling and specimen preparation

Table 2 is a summary of the laboratory consolidation test program, which shows the type of consolidation test, specimen dimension and samplers used to obtain the sample. A series of laboratory consolidation tests, such as incremental loading test on standard specimen (SC), constant rate of strain test (CRS), Rowe-cell test (Ro), and incremental loading test on large specimen (LSC).

Table 2 Experimental sample and test method

Test item	Sample size (mm)	Sampler
standards test (SC)	Ø=60, H=20	piston
Constant rate test (CRS)	Ø=60, H=20	piston
Rowe cell test (Ro)	Ø=150, H=50	block
large size test (LSC)	Ø=250, H=90	block

The schematic diagram of large size consolidation test equipment is shown in Figure 3. The large size consolidation specimen, whose diameter and height are 250mm and 90mm respectively, is loaded by air pressure up to 1000kPa. In this study, the load is increased incrementally in seven steps from 10kPa to 640kPa with a load increment ratio of 1.0. By analyzing the log t – ε_v relation at each load and the ε_v – log σ_v' relation, consolidation properties are evaluated.



(a) loading device (b) large consolidation ring

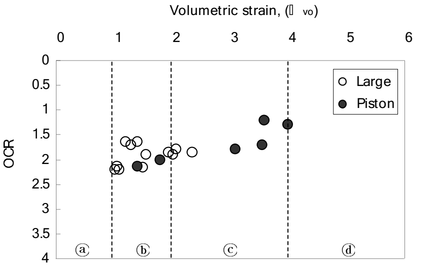
Figure 3. Schematic diagram of LSC equipment

3 TEST RESULT AND ANALYSIS

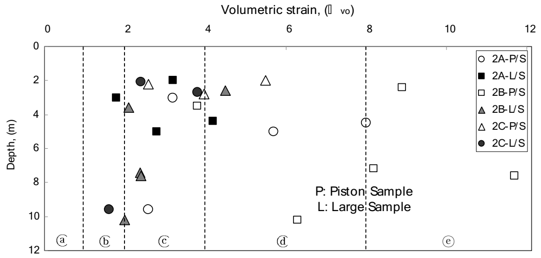
3.1 *Analysis of Sample Disturbance*

Shogaki (1996) provided the criteria evaluating the sample disturbance, based on the database of consolidation tests for specimens which are subjected to different degrees of disturbance. Andersen and Kolstad (1979) observed the increase in specimen deformation during the recompression to in-situ effective stress and suggested the sample quality designation (SQD). Lunne et al. (1997) also suggested four groups of sample quality, based on the $\Delta e/e_0$.

In order to evaluate the degree of disturbance for the specimen tested, consolidation test results are analyzed, considering the over-consolidation ratio and volumetric strain, and the results for both west and south coasts are presented in Figure 4. It is observed from Figure 4(a) that the large block samples with OCR of 1.65~2.22 shows only 1.0~2.4% volumetric strain, which can be categorized as very good ~ good sample quality. However, the piston samples with OCR of 1.23~2.13 shows 1.4~4.0% volumetric strain, which is described as good ~ poor sample quality. From the data of south coast in Figure 4(b), it is observed that the volumetric strain of large block samples ranges in 1.7~4.5% while that of piston samples is 2.5~11.7%. From above observations, it is concluded that the quality of large block samples is better than that of piston samples, regardless of the sampling location.



(a) west coast

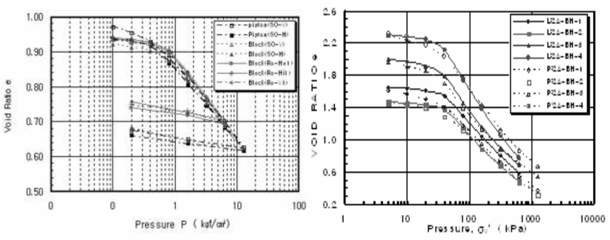


(b) south coast

Figure 4. Evaluation of sample disturbance using volumetric strain

3.2 *Effect of Test Method on Consolidation Curve*

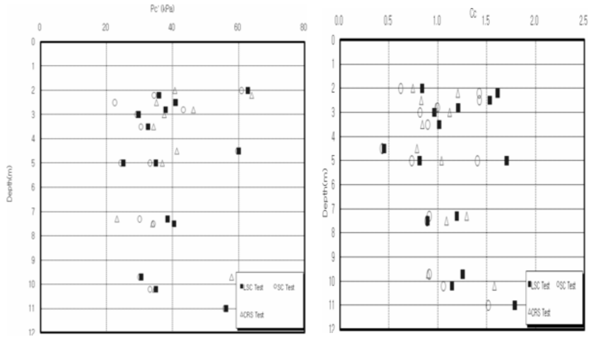
Figure 5 presents the e-log σ_v' curves obtained by various consolidation tests on the specimens sampled using different samplers. It can be observed that the curves of large block samples present the sharper curvature, larger pre-consolidation pressure, and larger compression index, compared with those of piston samples. From e-log σ_v' curves of Figure 5(a), it is shown that the pre-consolidation pressure obtained from Rowe-cell test on large block sample is about 1.3 times larger than that of piston sample. And the pre-consolidation pressure evaluated from the incremental loading consolidation tests on large block sample is 1.1 times larger than that of piston samples. From Figure 5(b), it is also shown that the pre-consolidation pressure is largest for LSC test, middle for CRS test and smallest for SC test. The slope of compression curve of the piston sample is relatively gentle, compared with that of the large block sample.



(a) west coast (b) south coast

Figure 5. Effect of test methods on e-log P curves

Figure 6 shows the variations of pre-consolidation pressure and compression index with depth for various tests. As shown in Figure 6(a), the pre-consolidation pressure obtained from SC tests on piston samples is 5% smaller than that of CRS test and is 9% smaller than that from LSC test on large block samples. Also shown in Figure 6(b) is that the compression index of SC tests is 9% smaller than that of CRS tests and is about 19% smaller than that of LSC test on large block samples.

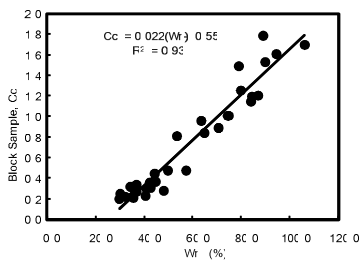


(a) P_c' (b) C_c

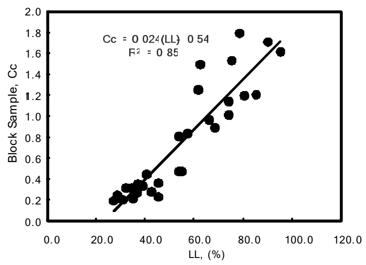
Figure 6. Effect of test method on pre-consolidation pressure and compression index

3.3 *Empirical Correlation of Compression Index*

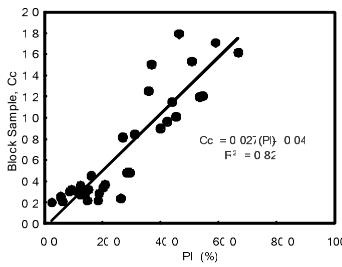
Figure 7 presents the correlations of compression index (C_c) with natural water content (w_n), liquid limit (LL), and plasticity index (PI) for large block samples. Although the linear relationship appears appropriate for all three relations suggested, the relationship between C_c and w_n has the largest R-square value. Three equations suggested in Figure 7 and their R-square values are given in Table 3.



(a) w_n & C_c



(b) LL & C_c



(c) PI & C_c

Figure 7. Relations of compression index with w_n, LL and PI for large block samples

Table 3. Suggested empirical correlations for compression index

Variables	Suggested correlation	Remark
Natural w/c (w_n)	$C_c = 0.022 \cdot (w_n) - 0.55$	R^2=0.93
Liquid limit (LL)	$C_c = 0.024 \cdot (LL) - 0.54$	R^2=0.85
Plastic index (PI)	$C_c = 0.027 \cdot (PI) - 0.04$	R^2=0.82

Table 4 is a summary of empirical correlations which have been suggested by previous researchers for domestic and foreign cases. Cases in Table 4 are plotted in Figure 8 with the correlations suggested in this study. It can be seen that the correlation by Kim et al. (2001) for Busan clay is in similar to that suggested in this study. However, a correlation developed by Song (1988) provides the significantly smaller compression index because it is based on test results on 554 piston samples from 14 southern and western coast areas. The correlation suggested by Koppula (1981) and Herrero (1983) appears to provide significant under-prediction of compression index.

Table 4. Empirical relations for compression index for domestic and foreign cases

Reference	Proposed relation	Remark
Song (1988)	C_c=0.016(w_n-22)	Korea (west & south coasts)
Kim et al. (2001)	C_c=0.0014(w_n-1.556)	
Koppula (1981)	C_c=0.01w_n	
Herrero (1983)	C_c=0.01(w_n-7.549)	

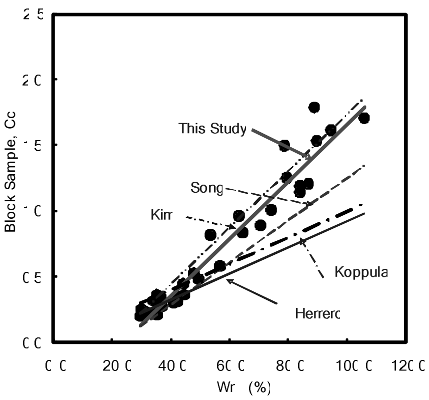


Figure 8. Comparison of empirical correlations for C_c

4 CONCLUSIONS

Various consolidation tests are performed on the specimens obtained using different types of sampling techniques. From the investigations on the compressibility of marine clay at south and west coasts in Korea, following conclusions are drawn.

Large block samples appear to have better quality than piston samples: the volumetric strains of large block samples range from 1.0 to 4.5% for the OCR of 1.65~2.22; that of piston samples range from 1.4 to 11.7% for the OCR of 1.23~2.13.

The magnitude of pre-consolidation pressures obtained from various consolidation tests on large block samples dependent on the types of sampler and test method. The pre-consolidation pressure obtained from Rowe-cell test on large block sample is about 1.3 times larger than that of piston sample. And the pre-consolidation pressure evaluated from the incremental loading consolidation tests on large block sample is 1.1 times larger than that of piston samples.

The correlations for compression index of large block samples are suggested considering the effect of disturbance during specimen preparation. It can be seen that the correlation obtained by Kim et al. (2001) is similar to that suggested in this study. The correlation suggested by Song (1988) and Koppula (1981) and Herrero (1983) appears to provide significant under-prediction of compression index.

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