Sampling method and pore water pressure measurement in the great depth (-400m)

Méthode de mesure de pression interstitielle de l'eau d'échantillonnage en grande profondeur (– 400m)

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ABSTRACT: Pleistocene clay and sand layers are deposited in the great depth under Holocene soft clay layer at Kansai international airport area. Since the weight of the reclamation soil is heavy because of its depth of sea water which is reached -20m, it has become the very important issue that the characteristics of Pleistocene clays are investigated correctly. For this reason, the new type sampling method which has been called 'Koken wire line system' was developed and the undisturbed samples were obtained by this sampling system. Sample quality which obtained from great depth was estimated using the range of the strain which was re-consolidated to in-situ effective stress by constant strain rate consolidation test. As a result, it was confirmed that the sample quality of these samples had good quality. On the construction phase of reclamation, cone type measuring equipment of pore pressure for Pleistocene clay and new type measuring equipment of pore pressure for sand were developed and the excess pore water pressure was measured. As a result of the examination of these data, the measured value has been had high accuracy. Therefore, the consolidation characteristic of Pleistocene deposit of Kansai international airport area has been estimated more correct by these useful data.

RÉSUMÉ : L'argile Pléistocène et couches du sable sont déposées dans la grande profondeur sous Holocene couche de l'argile douce à Kansai région aéroportuaire internationale. Depuis le poids du sol de la réclamation est lourd à cause de sa profondeur d'eau de mer qui en est atteinte -20m, il est devenu la question très importante que les caractéristiques d'argiles Pléistocène sont enquêtées sur correctement. Pour cette raison, la nouvelle méthode de l'échantillonnage du type qui a été appelée 'Koken installent le système de la ligne' a été développé et les échantillons non dérangés ont été obtenus par ce système de l'échantillonnage. Goûtez la qualité qui a obtenu de grande profondeur a été estimée utiliser la gamme de la tension qui a été réconsolidée à in-situ stress efficace par épreuve de la consolidation du taux de la tension constante. En conséquence, il a été confirmé que la qualité de l'échantillon de ces échantillons avait la bonne qualité. Sur la phase de la construction de réclamation, matériel de la mesure du type du cône de pression du pore pour argile Pléistocène et nouveau matériel de la mesure du type de pression du pore pour le sable a été développé et la pression de l'eau du pore en excès a été mesurée. Par suite de l'examen de ces données, la valeur mesurée a été eue la haute exactitude. Par conséquent, la caractéristique de la consolidation de dépôt Pléistocène de Kansai que la région aéroportuaire internationale a été estimée plus correct par ces données utiles.

KEYWORDS: Pleistocene clay, Koken wire-line system, Pore water pressure measurement.

1 INTRODUCTION

Kansai international airport has constructed in the Osaka bay area. In this area, Pleistocene clay and sand layers are deposited into the great depth under a Holocene soft clay layer. Since the weight of the reclamation soil is heavy because of its depth of sea water which is reached 20m in depth, it has become the very important issue that the characteristics of Pleistocene clays are investigated correctly. Therefore, it has been required high quality sampling and high-precision consolidation test for the samples deposited such great depth of 400m in depth.

On the construction phase of reclamation, the measurement of pore water pressure for Pleistocene clay and sand layers has become a important issue to improve settlement analysis in addition to the measurement of settlement. As the target depth of the measurement of pore water pressure reaches 300m in depth, the piezometer and the permeability test equipment which are usually used in shallow depth can not use such great depth. The cone type measuring equipment of pore water pressure for Pleistocene clay named GD-CONE and the new type measuring equipment of pore water pressure for sand named H-MHT have been developed. We have been able to measure the pore water pressure in great depth using these new equipment.

2 SAMPLING FROM GREAT DEPTH USING KOKEN WIRE LINE METHOD

Port and Airport Research Institute has tried to improve wire line boring method for the investigation method at the port and harbor area (Matsumoto K., et al.1981). As a result, new wire line method called Koken wire line method has developed. The characteristic of this method is to be able to obtain undisturbed samples which are stiff clay and sand in great depth. Koken wire line method has applied for boring and sampling method of Kansai international reclamation project.

The system of Koken wire line method is shown in Figure 1 (Okumura T., et al.1982). Three types of specific samplers have made for Koken wire line method. The structure of these samplers is shown in Figure 2 and Table 1. Thin-walled tube sampler with fixed piston is used for soft and stiff clay whose unconfined compressive strength is under $2MN/m^2$. Denison sampler which is rotary double-tube sampler is used for more stiff clay whose unconfined compressive strength is over $2MN/m^2$. Rigid sampler which is double-tube sampler fixed outer tube and inner tube is used for stiff sand and gravel.

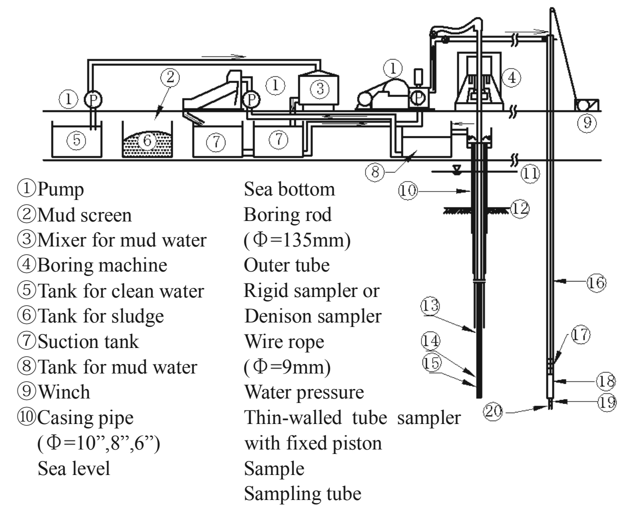

Figure 1. System of Koken wire line method.

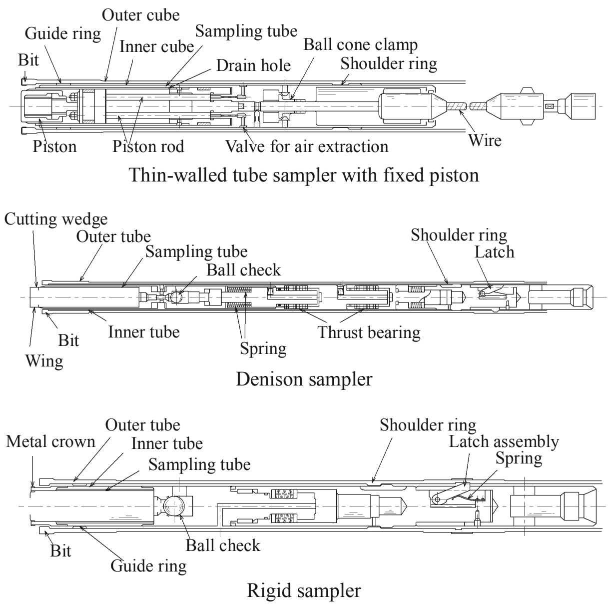

Figure 2. Samplers for Koken wire line method.

3 ESTIMATION OF SAMPLESQUALITY OBTAINED FROM GREAT DEPTH

The samples obtained from great depth which is up to 400m in depth are influenced not only mechanical disturbance but also stress release. As mechanical disturbance can avoid improving sampling technic, stress release cannot avoid even what kind of method. Therefore, the estimation of sample quality has to be examined quantitatively to interpret the results of constant strain rate consolidation test (CRS test).

The volumetric strain which is consolidated to the in-situ effective stress, ε_{v0}, can be used as an indication of sample quality. The relationship between change of ε_{v0} and quality of samples having various degree of sample disturbance is shown in Table 2 (Andersen A. and Kolstad P. 1979). The relationship between $\Delta e/e_0$ and sample quality, where Δe is change in void ratio in recompressing a sample to in-situ effective stress and e_0 is initial void ratio, is shown in Table 3 (Lunne T., et al. 1997). According to this figure, when the range of $\Delta e/e_0$ is within 0.07, the sample can regard good quality.

The change of ε_{v0} and$\Delta e/e_0$ profile of Pleistocene clay samples with recompression to the corresponding in-situ effective vertical stress is shown in Figure 3. With few exceptions, the range of ε_{v0} varies within 2% to 4%. It is apparent that the majority of samples of Pleistocene clay are good quality. The values of $\Delta e/e_0$ vary in a narrow band of 0.04 to 0.07, and are not sensitive with depth. It may be recalled that if $\Delta e/e_0$ is within 0.07, the soil samples can be considered to be good quality.

The relation between ε_{v0} and OCR, $\Delta e/e_0$ and OCR of Pleistocene clay samples is shown in Figure 4. It is obvious that OCR is almost constant with depth, and is independent of ε_{v0} and $\Delta e/e_0$. As the consequence, it is clear that the samples obtained from great depth in the Osaka bay have good and uniform quality.

Table 2. Relationship between volumetric strain (ε_{v0}) and sample quality.

ε_{v0}(%)	Sample quality
< 1	Very good
1 ~ 2	Good
2 ~ 4	Fair
4 ~ 10	Poor
> 10	Very poor

Table 3. Relationship between changing rate of void ratio ($\Delta e/e_0$) and sample quality.

Overconsolidation Ratio	$\Delta e/e_0$			
	Very good to excellent	Good to fair	Poor	Very poor
1-2	< 0.04	0.04-0.07	0.07-0.14	> 0.14
2-4	< 0.03	0.03-0.05	0.05-0.10	> 0.10

For particular clay multiply $\Delta e/e_0$ by $e_0/(1+e_0)$ to get the criteria in terms of ε_{v0}

Table 1. Specification of samplers.

Applicated soil property	Sampler				Sampling tube						
	Sampler Name	Outer diameter (mm)	Length (mm)	Remarks	Material	Inner diameter (mm)	Thickness (mm)	Angle of edge (°)	Ratio of inside diameter (%)	Length (mm)	Remarks
Soft clay	Thin-walled tube sampler with fixed piston	108	4358	Hydraulic type sampler	Stainless steel (SUS-304)	90	2	6	0	1250	-
Stiff clay	Thick-walled tube sampler with fixed piston	108	4358	Hydraulic type sampler	Same as the above	81.1	4	6	0	1170	Exchange of edge blade is possible
Stiff clay	Denison sampler	108	2850	Projection length of edge blade (20-50mm)	Same as the above	81.1	4	6	0.5	1000	Exchange of edge blade is possible
Stiff sand and gravel	Rigid sampler	108	2875	-	Same as the above	90	2	-	-	1000	-

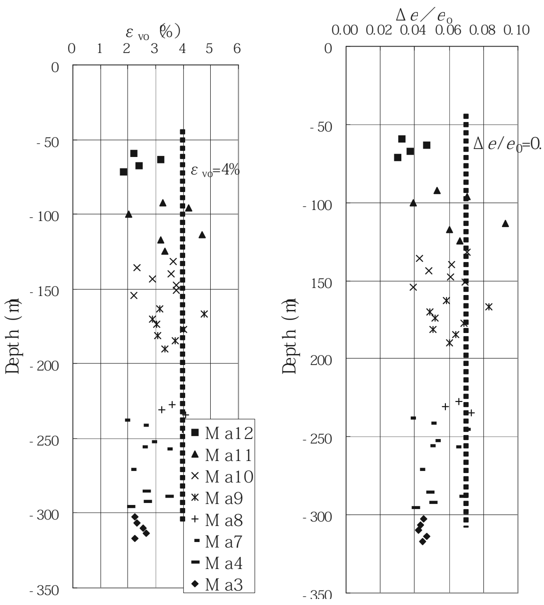

Figure 3. Result of ε_{v0} and $\Delta e/e_0$ obtained by CRS test.

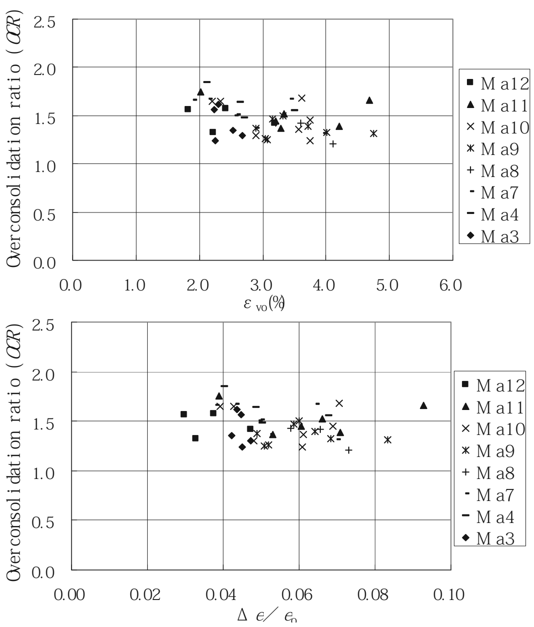

Figure 4. Relationship between OCR and ε_{v0}, $\Delta e/e_0$.

4 MEASURMENT OF PORE WATER PRESSURE IN GREAT DEPTH

4.1 Cone type measuring equipment of pore water pressure for Pleistocene clay (GD-CONE)

The measurement of pore water pressure for clay layer is used a push-in type piezometer (JGS 1313-2003) .This type of piezometer has a merit which can seal the measuring section completely and can measure a correct pore water pressure. Therefore, this is usually used in shallow depth and cannot use such great depth which is up to 350m in depth because of the capacity of sensor and the penetrating power of cone.

The cone type measuring equipment of pore water pressure for Pleistocene clay in great depth called GD-CONE has been developed. The structure of this equipment is shown in Figure 5. The characteristics of this cone are as follows:

The tip part which is the penetrating part is very thin in order to decrease the penetrating resistance and promote the dissipation of pore water pressure. Its diameter is only 15mm to 20mm.

The upper part of the tip becomes thicker gradually. Its diameter is 41mm to 56mm. This part is penetrated into the small borehole, which is drilled in advance, to seal the testing section completely.

GD-CONE is connected with AQ rod whose outer diameter is 44.5mm and installed into the borehole. During installation of GD-CONE, the center riser fixed to AQ rod is used in order to install into the pre-drilled small borehole correctly.

The pressure gauge of GD-CONE has used a crystal oscillation sensor which has wide pressure range and high sensibility. The maximum pressure range is 5MPa and the sensibility has 0.01%FS. The compensation of atmospheric pressure has been done by using another pressure gauge on the ground.

4.2 New type measuring equipment of pore water pressure for sand (H-MHT)

The measurement of pore water pressure for sand layer in great depth is used a new type measuring equipment of pore water pressure called H-MHT. The structure and test procedure of H-MHT is shown in Figure 6. The characteristic of H-MHT are as follows:

As the principle of measurement is simple, the reliable measurement is possible easily.

As the pressure gauge of H-MHT has used a crystal oscillation sensor too, the high pressure caused in the great depth can be measured highly precise.

H-MHT can obtain equilibrium water table in a short time because the specific air valve which is joined to the AQ rod can shut the test section in order to promote dissipation of pore water pressure rapidly.

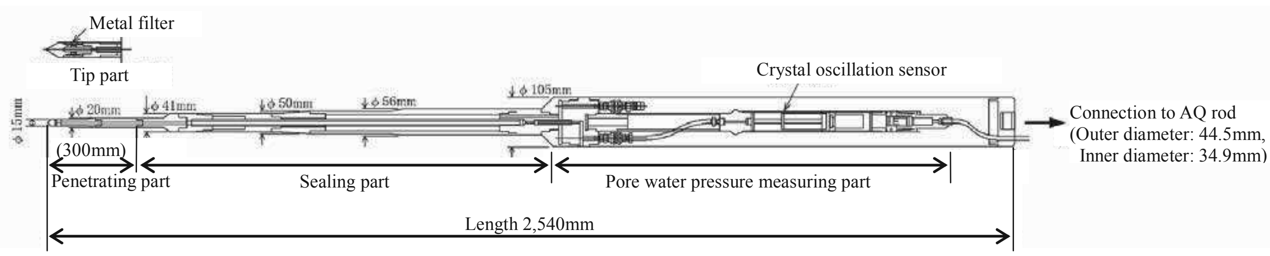

Figure 5. Structure of cone type measuring equipment of pore water pressure for Pleistocene clay (GD-CONE).

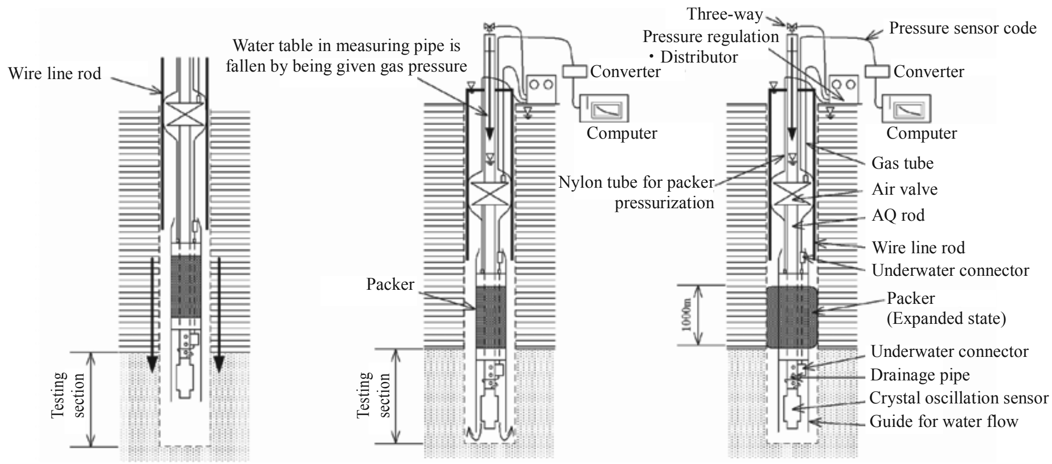

Figure 6. Structure of new type measuring equipment of pore water pressure for sand (H-MHT).

4.3 Results and discussion

4.3.1 Estimation of pore water pressure using hyperbolic method

The diameter of the tip part of GD-CONE is designed of thin size because pore water pressure is needed to dissipate rapidly. The standard method to GD-CONE continue to measure for three hours after penetrating. The adoption value of pore water pressure is calculated by hyperbolic method using the data measured after three hours from penetration. In order to accurate the adoption value, the long hour's measurement, 38 hours, has carried out. The results of these data are shown in Table 4. Since the results of the long hour's measurement and the adoption value by hyperbolic method using three hours' measurement are almost same, the accuracy of hyperbolic method has been confirmed.

Table 4. Application of hyperbola method for measuring result of pore water pressure.

No.	Altitude (CDL-m)	Investigation case	Measuring hours(sec)	Pore water pressure of last measuring time (kPa)	Pore water pressure by hyperbola method (kPa)
1	263.47	Standard measurement	11260	2760	2700
2	263.47		12110	2800	2702
3	264.02	Long measurement	138917	2700	2702

4.3.2 Reliability of sealing of measurement section of GD-CONE

Three patterns of penetration of GD-CONE, which is varied from 30cm, 60cm to 90cm length, have carried out. The results are shown in Figure 7. These data are almost same despite the penetrating length. In addition, since the result of pore water pressure is not same to the mud water pressure of the bore hole, the seal of measuring section is regarded completely.

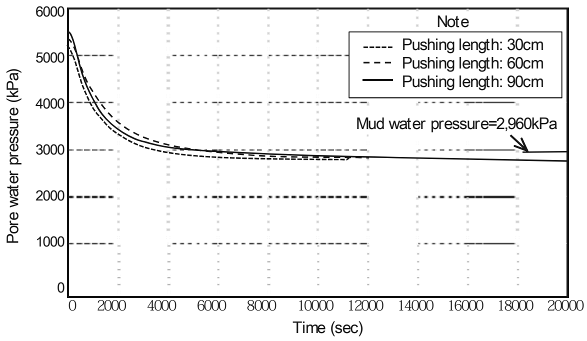

Figure 7. Difference of test result of pore water pressure by penetrating length.

4.3.3 Comparison examination of the results by GD-CONE and H-MHT for Pleistocene clay

The comparative experiments used both GD-CONE and H-MHT has been carried out in same depth, which is 170m in depth. The results are shown in Table 5. Since these data are almost same, the appropriate of GD-CONE and H-MHT method for measuring equipment for great depth can be confirmed.

Table 5. Comparison between measuring result of pore water pressure using GD-CONE and H-MHT.

Measuring method	Altitude (CDL-m)	Pore water pressure p (kPa)	Excess pore water pressure Δu (kPa)
GD-CONE	172.77	2006	256
H-MHT	169.12 ~ 172.77	1984	257

5 CONCLUSIONS

Kansai international airport which has been constructed in the Osaka bay far from 5km from the land area in order to solve noise pollution has been able to take off and landing of airplane using two runways whose length is about 4,000m. The consolidation settlement of 2nd runway, which is related to this paper, is almost the same like the consolidation analysis. For the future, the management of consolidation settlement shall be important for the operation of the airport while the consolidation settlement will continue for long times. It is important that the continuing study for the settlement of Pleistocene clays using the in-situ observation data.

6 REFFERENCES

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