Advance on Rotary Core Samplers

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Abstract

As an increasing number of large civil engineering structures are constructed on and in sedimentary soft rock, a more accurate estimation of stiffness of soft rock will be required. Laboratory testing results of in situ soil properties are essentially dependent on the quality of the sample species obtained commonly by core sampling in a borehole. A recent study (Tatsuoka et al, 1995) showed that rotary core boring samples may be significantly disturbed. This paper reviews outlines of current core samplers and introduces an improved core sampler named "Planet sampler". Comparing the quality of core samples obtained by the planet sampler and by current samplers from three different sites, it was concluded that the planet sampler is more effective in obtaining high quality core samples. Also, it is shown that this sampler is a very useful tool for investigating sloping lands with a potential to landslide.

1. Introduction

In order to estimate the mechanical properties of stiff ground in nature or ground improved by artificial cement-mixed procedure, laboratory tests on species obtained by rotary boring core samplers are commonly used. There have been many kinds of core samplers developed so far. Most of these were designed for mining surveys which put emphasis on gaining an entire core sample, no matter how disturbed it is, rather than on obtaining an undisturbed sample. Recently Tatsuoka et al(1994), on the basis of comparative studies of deformation modulus data obtained from specific triaxial testing results, suggested that there is a high probability that core boring samples will be disturbed during boring, even if they are cemented rocks or cement-mixed soils. Also, they advised that in order to examine the deformation modulus and strength of subsoils by laboratory testing, it would be worth while to develop a new core sampler which gives good samples with minimum disturbance.

2. General Review of Current Core Samplers and their Additional Parts

With reference mainly to Hvorslev M.J.(1948), the following general review primarily concerns samplers of rotary core boring. The samplers used in core boring are generally called core drills, core barrels or core samplers and samples obtained are called core whether they consist of soil or rock. In core boring, the material is ground up by rotating the core tube and its coring bit, and by circulating water or drilling fluid.

The principal types of rotary core samplers commonly used in site investigation are shown in Fig.1.

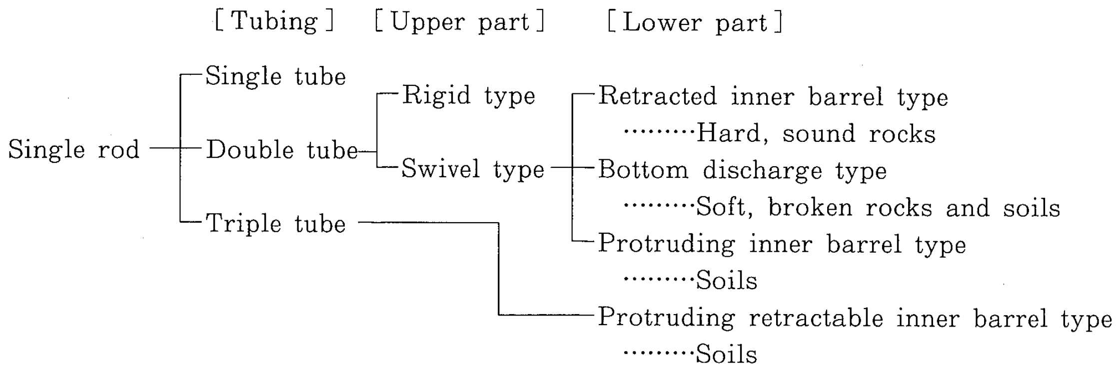


Fig.1 General review of core samplers

1) Single tube core sampler

The simplest type of rotary core sampler consists of a single tube with a coring bit (Fig.2a). The core is exposed, over its full length, to contact with the circulating fluid. The single tube core sampler is primarily used in materials which are not subject to erosion, slaking or excess swelling.

2) Double tube core sampler

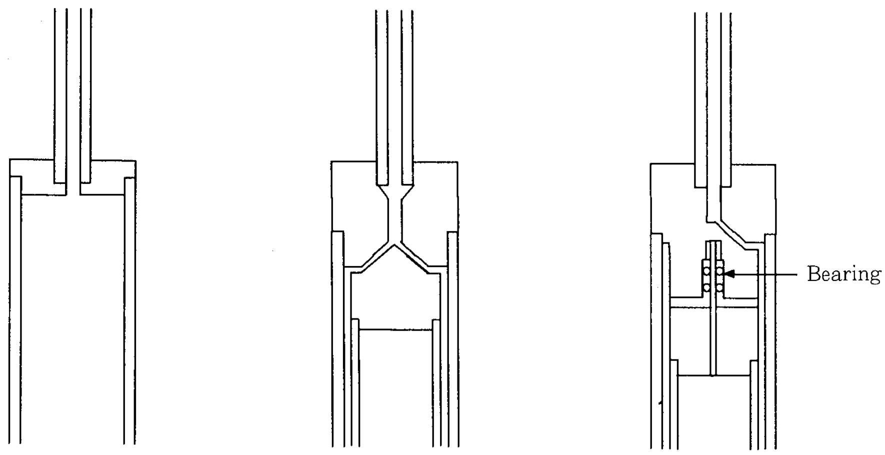
To protect the core against the action of the circulating fluid, double tube core sampler are commonly used in the sampling of soil, non-uniform, fissured, friable, and soft rock. Double tube core sampler are mainly classified into two groups: rigid type (Fig.2b) and swivel type (Fig.2c). The former has the inner tube rigidly connected to the core barrel head. Therefore the inner tube rotates with the outer tube and merely serves to protect the core against erosion and to keep the passage of fluid open.

The latter has been commonly used since the inner tube does not rotate during the actual coring, and therefore torsion transmitted to the core and dangers of breaking the core are decreased.

3) Triple tube core sampler (Mazier, G. 1974)

The triple tube core sampler consists of a liner (innermost tube), an inner tube and outer tube shown in Fig.3. Two types triple tube core samplers are presently available on market: the non-retractable type and the retractable type.

The non-retractable type is for high quality cores in weathered or moderate weathered rock while the retractable type are particularly suited for weaker, highly weathered rock, i. e. friable unconso-



a) Single tube core sampler

b) Rigid type core sampler

c) Swivel type Double tube

Fig.2 Sampler head of Single and Double tube core sampler

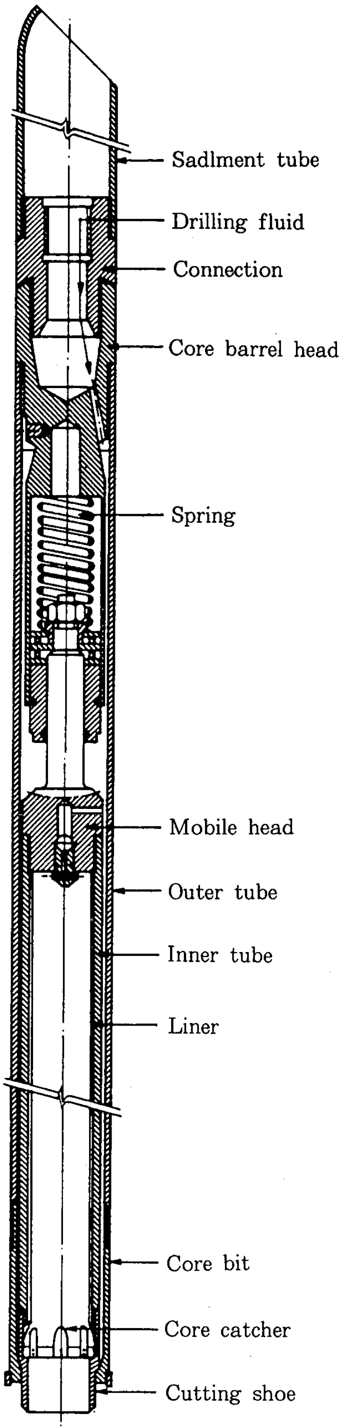


Fig. 3 Mazier triple tube core sampler (named after Mazier, 1974)

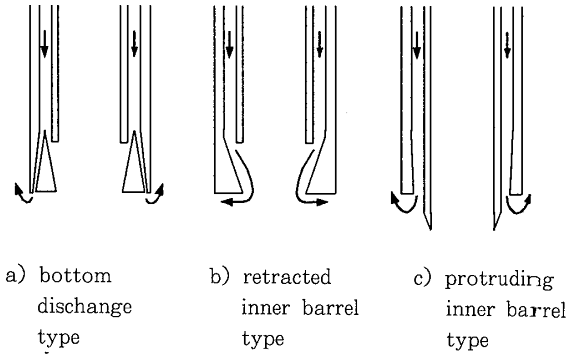


Fig. 4 The structures of core bit, parts of swivel type double core tube sampler

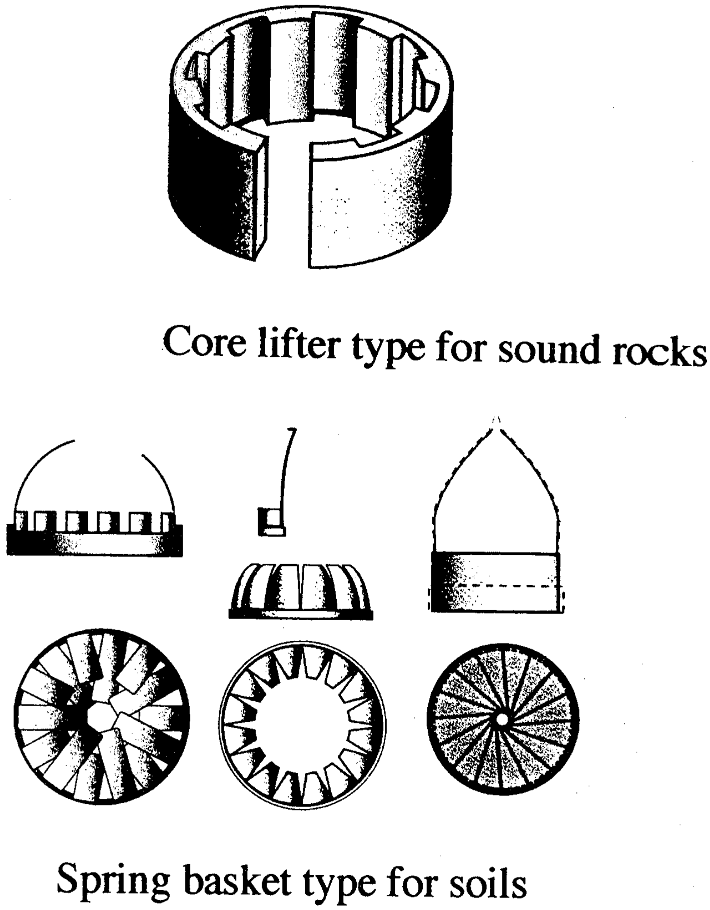


Fig. 5 Core retainers

lidated formations. The retractable core type has an inner tube and cutting shoe which is spring-loaded and when passing through soft strata projects ahead of the bit face, thus protecting the core from the drilling fluid. When encountering harder materials, the tube retracts. This retractable mechanics is therefore particularly useful when drilling through layers of varying stiffness. Also, the liner is detachable and thus the sample is well protected when extruded from the inner tube and during the subsequent transportation to the laboratory.

4) Additional Parts of Core Barrels for High Quality Sampling

In addition to the main structure of core sampler, some essential parts for obtaining good core are the following:

4-1) Core bits

The actual grinding or cutting medium may be diamonds, tungsten-carbide inserts, steel teeth, or bladed or roller cutters. The shape of bits and the type and arrangement of the cutting media vary with the type and diameter of core sampler and with the character of the material to be sampled.

A simple straight or beveled bit is used in many single and double tube core sampler. In terms of the structure on the core bit parts, the swivel type core sampler are grouped into three types: the bottom discharge type (Fig.4a), the retracted inner barrel type (Fig.4b) and the protruding inner barrel type (Fig.4c).

The bottom discharge bit is used in soft and broken rock and often in soils. The fluid passes is carried through the bit proper. But the fluid passage at the bottom of the bits may often be closed by cuttings if sufficient care of circulating fluid rate and feeding power is not taken. The retracted inner tube core sampler as well as the bottom discharge type has an extension or shoe with a core catcher unit reaching nearly the edge of the coring bit. The core is then nearly, but not completely, protected against erosion and torsion.

Further protection can be obtained by providing the inner tube with a shoe and sharp cutting edge which extends to or a little beyond the edge of the coring bit. This is called a protruding inner barrel type, but this type can be used only in soils.

4-2) Core Retainers

All double core tube sampler are provided with core retainers (Fig.5), also called core catchers or core lifters, which are placed in the coring bit or in the shoe of the inner tube. A tapered and fluted split ring, which grips the core after a short downward movement, is generally used to retain cores of sound rock. Core spring or a basket type core lifter or flap valves are used to retain core of soft and broken rock and of soils.

4-3) Vents and Check Valves

Modern core sampler are generally provided with vents and check valves (Fig.6) in order to permit the circulating fluid to drain from the drill rod. This prevents formation of excess hydrostatic pressure over the core during the withdrawal, and avoids splashing the fluid over equipment and drilling platform when uncoupling the drill rods. Also, the fluid over the core must be forced out between the core and the inner tube as the core enters the tube. The inside vents may have the function of preventing such improper excess fluid pressure.

3. The Requirements of Current Samplers for Obtaining Good Core Samples

From the basis of current core samplers, the requirements for obtaining good core samples are summarized as follows:

① To protect the core against erosion
② To keep fluid passages open
③ To retain the core
④ To prevent formation of excess hydrostatic pressure over the core during withdrawal
⑤ To provide an escape for fluid over the core as the core enters the inner tube
⑥ To provide convenient access to extrude core from the inner tube.
⑦ To provide safe transportion of the samples to the laboratory.

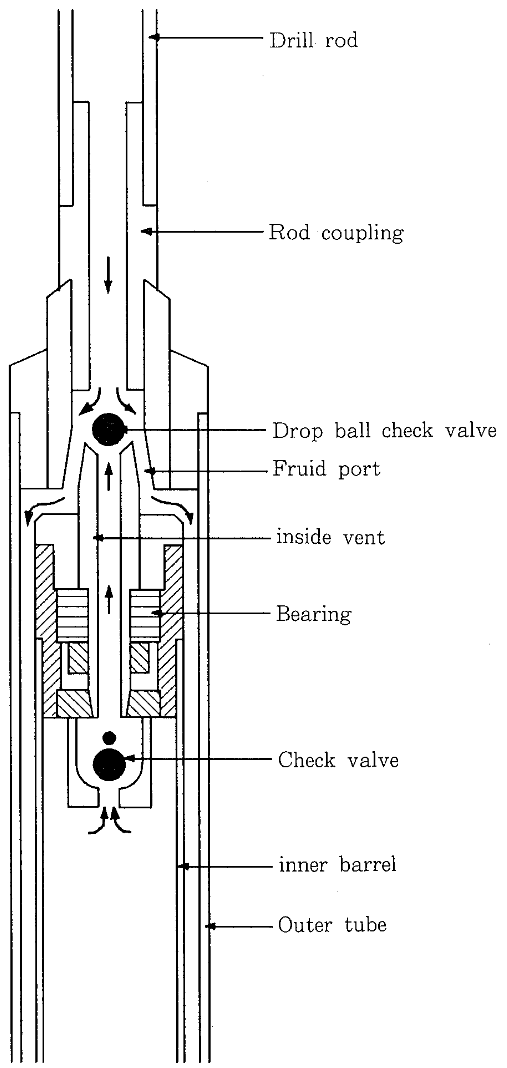


Fig.6 An example of vents and check valve

⑧ Proper coring bits, considering their shape, their type and arrangement of the cutting media.
However, successful sampling, even using the triple tube core sampler, requires a certain amount of skill from the drilling operator in that drilling should be done with drilling fluid circulation reduced to a minimum corresponding to the amount of cuttings produced by the drilling.

4. The Proposal from Tatsuoka et al (1995)

Tatsuoka et al (1995) conducted the following research: a comparison of the elastic Young's moduli, pre-peak sress-strain relations and compressive strength. These characteristics were evaluated by triaxial compression tests (TC Test) performed with a Local Deformation Transducer. Core samples were obtained by rotary core boring sampling and by block sampling or direct coring.

At Tsunashima, Just west of Tokyo, core samples of 7cm in diameter were obtained using a triple-tube sampler prior to the ground excavation for a high-rise building. Then 7.0cm in diameter and 17cm high triaxial compression test species were then prepared. These samples will herein be called RTC samples. Samples of 5.5cm in diameter were obtained from excavated ground by direct coring

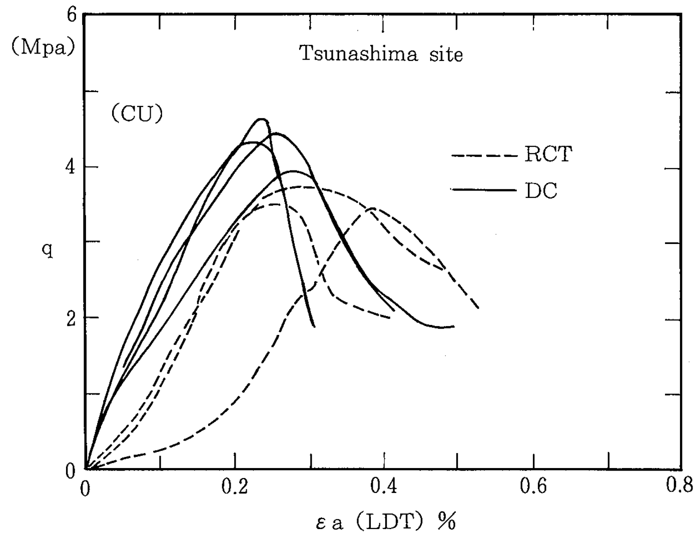


Fig.7 Comparison of q-local ε_1 relations, on CU TC tests using RCT and DC samples (After Tatsuoka et al 1995)

using a well-fixed core barrel having a diamond bit rotating 900rpm and using water as the drill fluid. In such a direct coring detrimental rocking motion of the core barrel during coring was unlikely. These samples will herein be called DC samples.

A series of CD and CU TC tests were performed on RCT and DC samples reconsolidated isotropically.

It can be seen in Fig.7 that the S-shape of the stress-strain curves of the RCT samples cannot be seen for those of DC samples. And also, the RCT samples exhibited generally lower maximum Young's moduli E_{max}, lower compressive strengths q_{max} and larger axial strain ε_{1f} at peak stress state when compared with those of DC samples. Fig.8 shows the relationships between the "tangent Young's modulus $E_{tan} = dq/d\varepsilon_a/E_{max}$ and the shear stress level q/q_{max} for the RCT and DC samples. The difference in E_{tan}/E_{max} between the RCT and the DC samples is largest when q/q_{max} is around 0.1.

Tatsuoka et al (1995) performed the same comparison TC tests in another sites as mentioned above, and presented the following suggestions:

"The behavior of the RCT samples different from that of the DC samples should be due to sampling disturbance resulting from rotation and rocking motion of the inner tube during rotary coring. Although the inner tube is designed not to rotate together with the outer tube, it can rotate when in contact with the outer tube. In that case, the cored sample is twisted, which may result into cracking in the direction inclined from the axial direction of sampler. Although the bottom of the outer tube is fixed against lateral movement being fixed against the ground, the other parts of the outer tube are not, and the axis of rotation and the sampler axis may not be co-axial.

Therefore, rocking motion of the sample is quite possible, particularly when drill rod and borehole are long and they are not straight."

Hvorslev (1948) also suggested the same problems of the RCT sampling as follows: "Vibration and whip of drill rod and core barrel are difficult to eliminate entirely and may cause disturbance of the sample."

5. Additional Functions of Core Samplers for Better Core Sampling

Most natural ground, and even artificial ground, can be assumed to be heterogeneous including

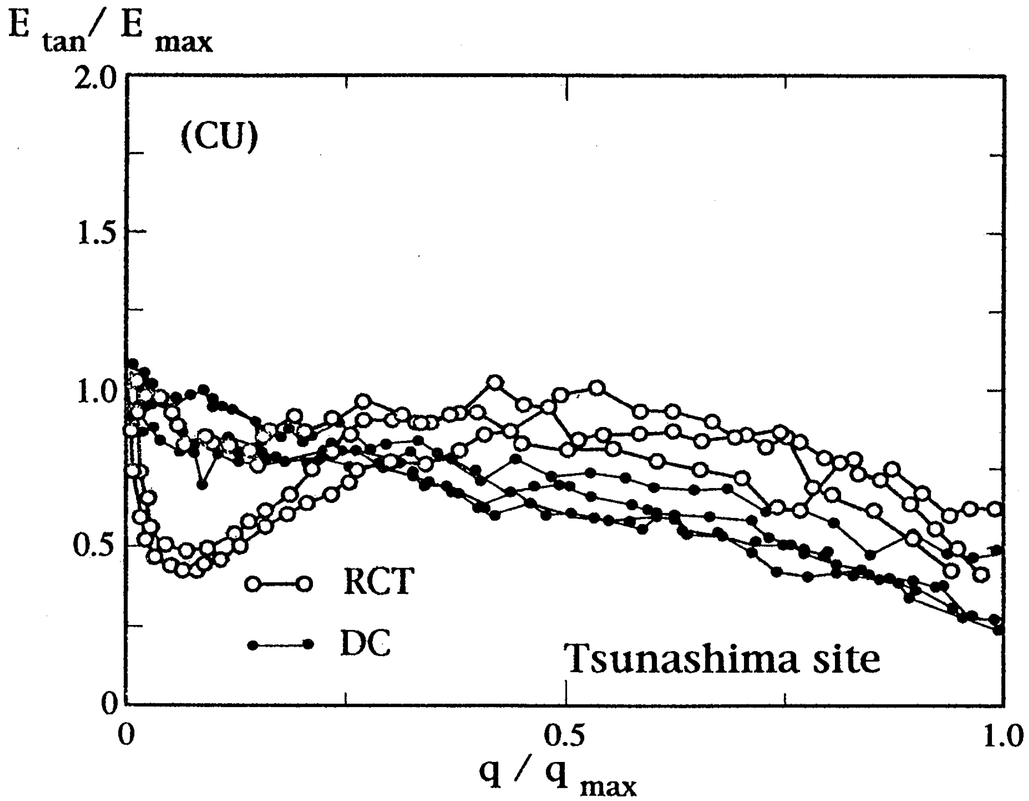


Fig. 8 E_{tan}/E_{max} (based on local strains) - q/q_{max} relations of RCT and DC samples (After Tatsuoka et al 1995)

stiff and soft portions. This generally leads to difficulties in obtaining undisturbed samples. In current core samplers, a single rod rotates while thrust is applied. In this condition the single rod may bend which will result in the sampler head being beaten as shown in Fig.9, and this may disturb the core sample.

The inner tube housed within the outer tube is retained with bearings, which are intended to free it from rotation during coring. However, this retaining mechanism may still allow the inner tube to rotate together with outer tube, resulting in ring shear of the core.

Commonly, there are no confined stresses around the core being taken into the inner tube resulting in swelling and vibrating of the core underneath the bits during the coring process. Especially when the ground includes both stiff and soft parts, such as landslide areas, stress relief on soft parts, such as the old slip plane, underneath coring bits introduces a decrease in shear strength and makes it possible for soft parts to rotate due to rotational shear stress by coring process as shown in Fig.10. In order to take good samples by the rotary core boring method, the following functions, in addition to those of current core samplers, are required:

① Prevention of the sampler head from shaking or rotating.
② Prevention of any movement of the sample housed in the inner tube during coring.
③ Prevention of stress relief of the core at the bottom of the borehole.
④ Reduction of friction stress between the core and the wall of the inner tube to prevent disturbing the core as it enters the tube.

6. Outline of New Core Sampler Developed

As compared with current samplers, the new sampler has the following additional elements in the

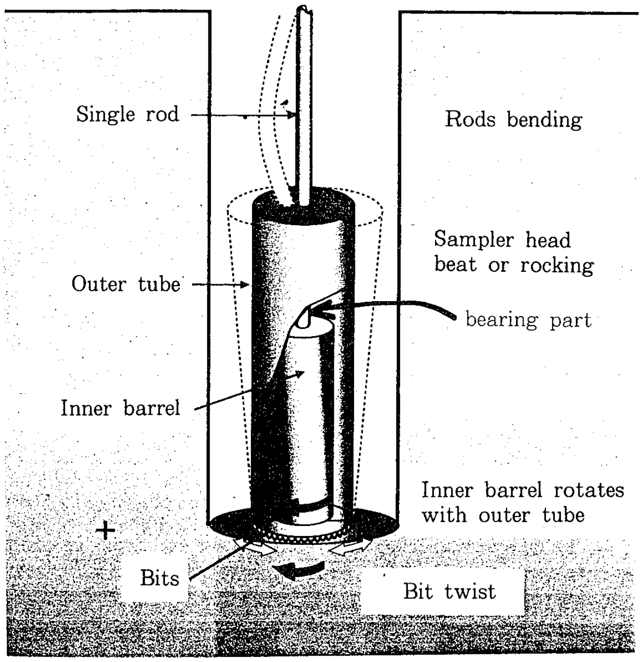


Fig. 9 The problems of the current core sampler with single rod

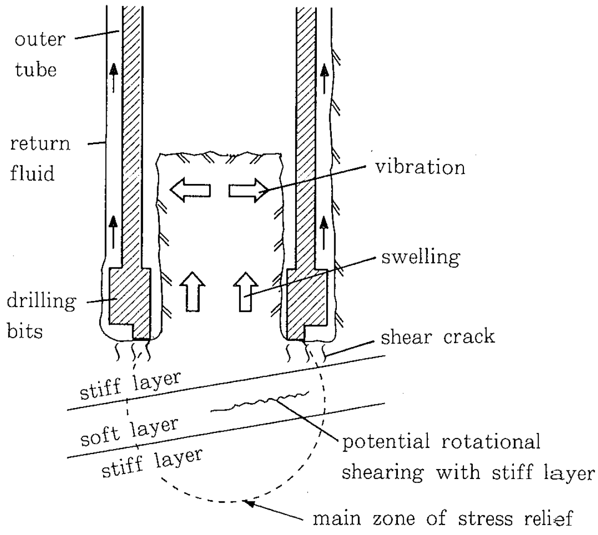


Fig. 10 Mechanism of disturbance on soft layer during core sampling

case of site investigation in shallow depths less than about 50m as shown in Fig.11.

(1) Twin rods

As when installing self-boring pressuremeter probes, a twin rod system is used. For a 65mm core sampler rods with outside diameters of 28 and 50mm are used. The smaller diameter rod is for rotating the outer tube of sampler, the bigger rod is for pressing down the core bits.

(2) Twin rod chuck

The rod chuck is attached to the bottom of a 40.5mm rod that is fixed to the drilling machine. The top of twin rods are connected with the bottom of the twin rod chuck. This transmits thrust to 50mm rod and torsion to 28 mm rod separately.

(3) Centering joint (Fig.12)

To prevent the sampler head from beating or whipping during coring, the rotational axis of the inner rod should be kept in a fixed condition. The inner rod may bend considerably under its own weight as its length increases. The centering joint is set for keeping the rotational axis of the inner rod fixed and transmitting total weight of the inner rod above the centering joint onto the outer rod. Using this centering joint, vibration and whipping of the sampler head is expected to decrease and this will contribute to acquiring undisturbed core during coring.

(4) Planet gear system (Fig.13)

The planet gear system consists of solar gear, planet gear and internal gear. The system is set in the top of the sampler. The Torque of the 28mm rod is transmitted to the outer tube, while the inner tube is fixed to the 50mm rod by the planet gear system to insure that the inner tube is left free of rotation.

(5) Core pressure piston

The objective of this device is mainly to prevent shaking and stress relief of core which lead to sample disturbance. If the effective overburden at a sampling depth is estimated to be σ_0', then the pressure on the surface of the core can be adjusted to be 0.5 ~1.0 σ_0' using the core pressure piston. The piston's force can be set by using a torque wrench to adjust compression force on the side

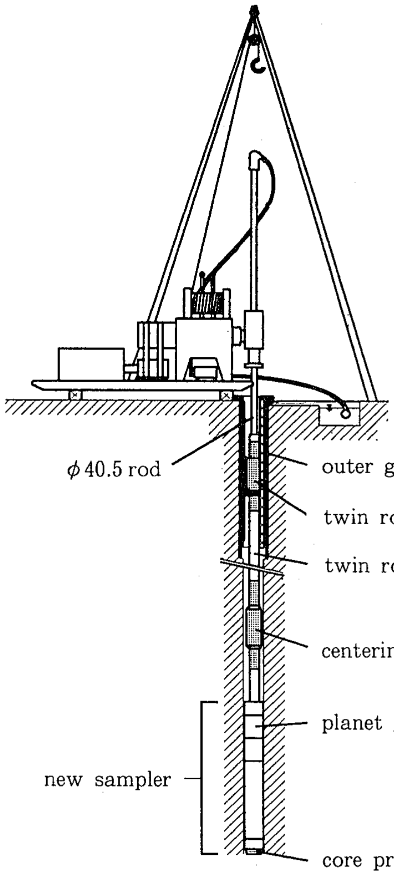


Fig.11 New sampling system drilling machine, sampler and its additional devices

friction rubber (see Fig.13).

In the case of site investigation of deep depth of more than about 50m, the twin rod method is too laborious to perform. In such a case, the mud-mortar drilling system can be applied in stead of twin rod method. By setting mud-mortar immediately behind new sampler, only singlerods from drilling machine to mud-mortar is available for core sampling as shown in Fig.14. As mater of course, the twin rod chuck and the centering joint are unnecessary to use.

7. Comparative Studies of Sampling Quality Between the New Sampler and Current Samplers

The sampling Committee of Japanese Society of SMFE standardized "Methods for Sampling of Soil using Double Tube Sampler with Sleeve" (JGS 1224-1993) and "Rotary Triple Tube Sampler" (JGS 1223-1993) are currently commonly used core samplers in Japan. Both standard samplers are used with single rods. In this study, these samplers represented current samplers.

7.1 The Test Site of Cement Soil Mortar Embankment

(1) Conditions of test site

Off-shore of Kawasaki in about 18m of sea water, cement soil mortar was poured out of the hopper of ships in order to construct an embankment. The embankment was built as part of a big size shield tunnel into the bottom of the sea. In order to confirm the shear strength of embankment materials, core sampling was carried out. Three types of core samplers were used: the retractable triple tube sampler (T-Sampler), the retractable double tube core sampler with sleeve (C-sampler)

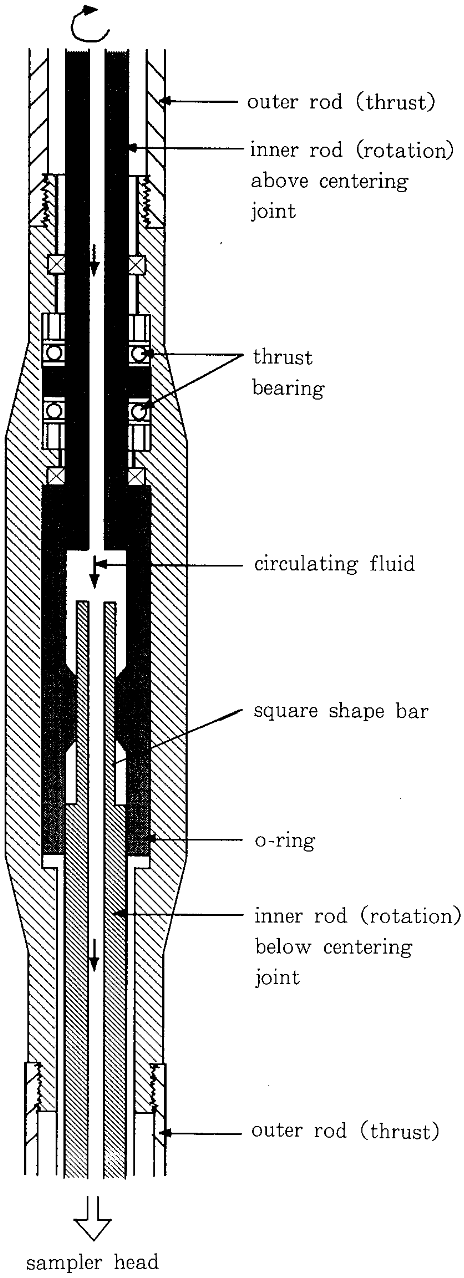


Fig. 12 Design of centering joint

and the planet sampler (P-sampler).

(2) Comparison of length on non-cracked core

The core profiles obtained by the C-sampler and the P-sampler are shown in Fig.15. It is considered that most of the cracks included in the core were made during core drilling because the sampling material is supposed to be relatively homogeneous consisting of artificial mortar. A distinct difference in the number of cracks in the cores produced by the samplers can be seen. The core produced by the P-sampler has less cracks than the core produced by the C-sampler.

Fig.16 shows the maximum core length per one meter against R.Q.D. between the three types of samplers. It can be seen that the maximum core length of the C- and the T-sampler are mostly shorter than that of the P-sampler.

(3) Comparison of unconfined strength of core

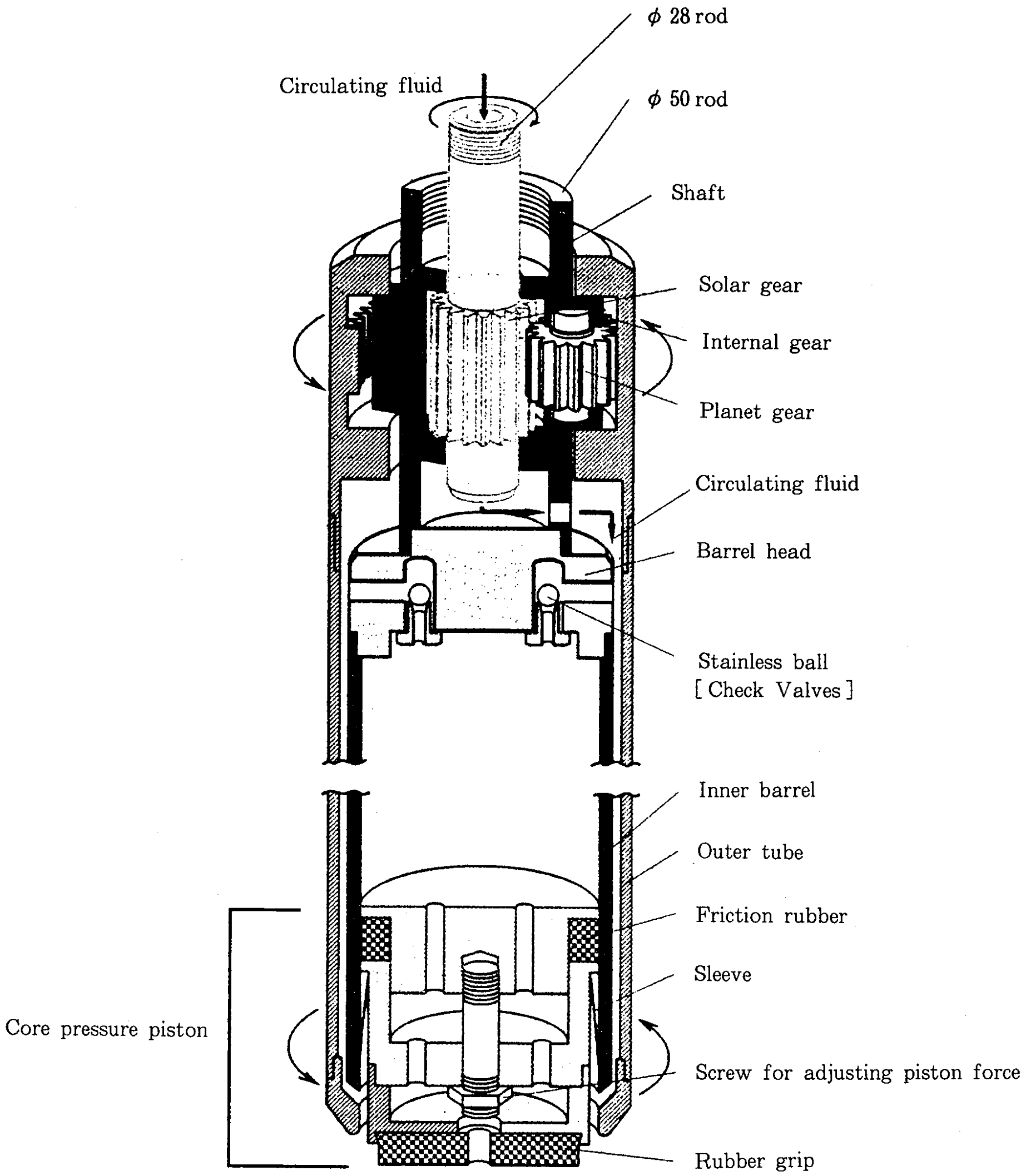


Fig. 13 The planet gear system and core pressure piston

Selecting good quality species from each meter of core, unconfined compression tests were carried out on the C-sampler and the P-sampler. The test results show, in Fig.17, that the unconfined strength of the artificial embankment soil of mortar mostly increases with depth but in some places distinct low values were observed. Comparing the maximum strength of each one meter depth, there are only slight differences in maximum values between the two samplers, however there are obviously many lower values obtained by the C-sampler.

7.2 The Test Site of Soft Ground Improved by Mixed In-Place Piles

(1) Condition of test site

The test site for this study was located at the alluvial plain of the Yodo river in Osaka, Japan. The soil at the site consists of lightly over consolidated clay and loose sand, which needed to be improved for the construction of an embankment dike. Ground improvement works involving sand

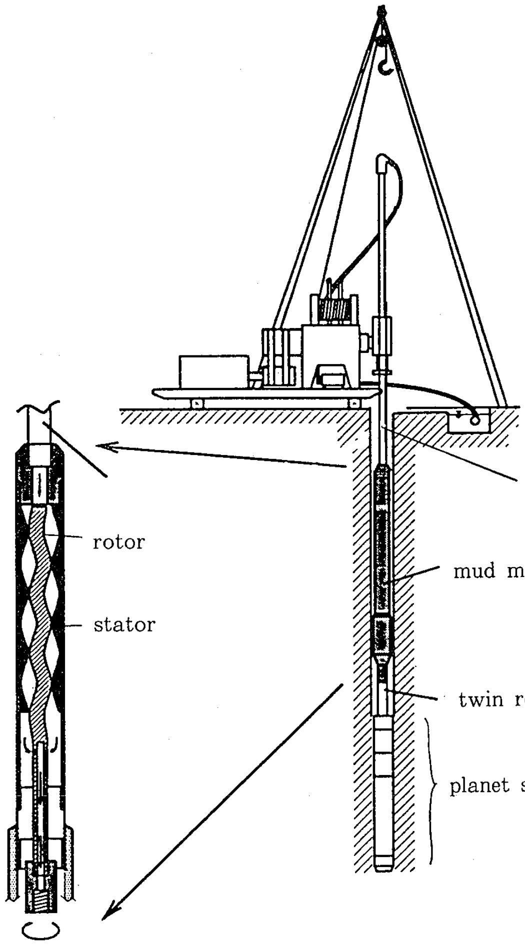


Fig.14 Drilling system for core sampling using mud-motor in the case of deep drilling

compaction piles, sand drains and two types of cement-mixed-in-place piles namely dry cement mixing method (DJM) and slurry cement mixing method (CDM), were carried out in an area about 85m × 125m. The mixed-in-place pile was 100cm in diameter with a cement content of 130kg per 1.0m^3 for sand and 110kg for clay.

(2) Core sampling, seismic logging and laboratory test

Core samples of the two types of mixed-in-place piles were taken by both the C-sampler and the P-sampler. After borehole drilling, the S-wave velocity of each borehole was measured by seismic down-hole method at intervals of 20cm in depth. The core samples were sketched, and taken for unconfined compression tests at intervals of about 1m in depth. The density of samples was also measured.

(3) Quality of samples and strength of core

The condition of core taken by each sampler are shown in Fig.18. It can be clearly seen that the cores obtained by the C-sampler have more cracks and shorter length than those taken by the P-sampler. The test data on unconfined compression strength, q_u, of core samples and S-wave velocity, V_s, at each location are shown in Table-1, and those values plotted against depth are shown in Fig.19.

The distribution of S-wave velocity shows that the stiffness of all four piles is significantly different at each depth. Therefore, it seems to be unreasonable to directly compare the qu values at the same depth.

Fig.15 Core profiles obtained by C-Sampler (a) and P-Sampler (b)

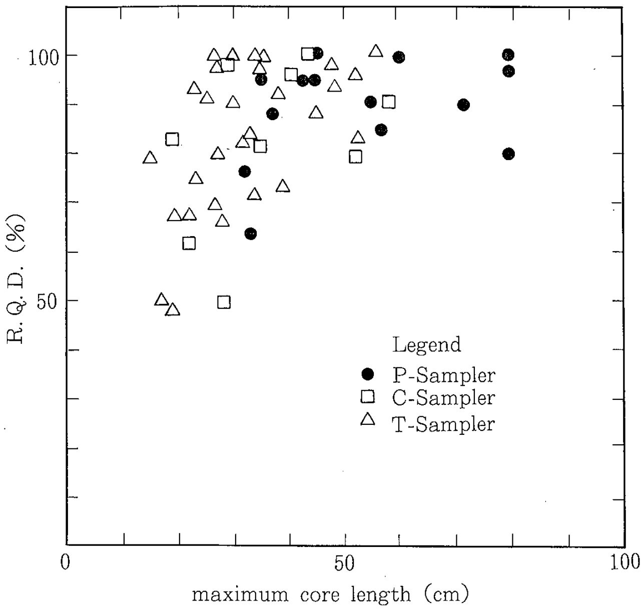


Fig. 16 Maximum core length against R.Q.D.

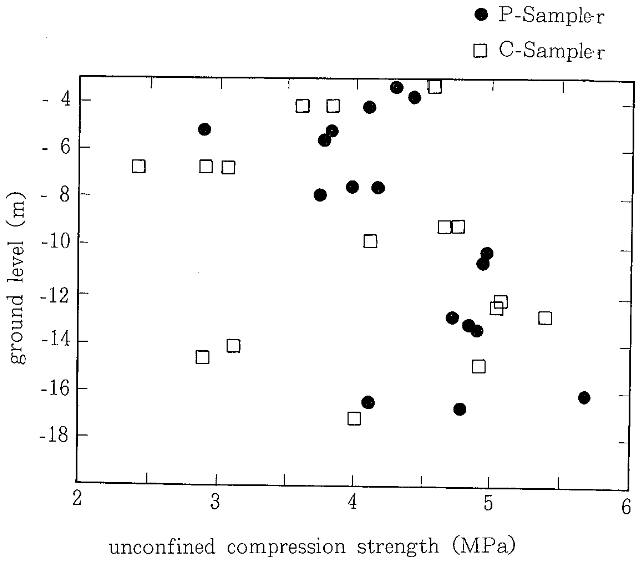


Fig. 17 Unconfined compression strength against ground level

(4) Interpretation of sampling quality

As mentioned above, the q_u and V_s parameters of mixed-in-place piles are considerably variable at each depth, and therefore some specific parameters should be required to undergo comparative study of sampling quality between two samplers. The normalized $q_u{}^*$ parameter has been used for the analysis and the $q_u{}^*$ is defined as follows:

Elastic theory shows that maximum value of shear modulus at small strains, G_{max} can be determined as follows:

$$G_{max} = \rho V_s{}^2$$

Where V_s is the S-wave velocity, ρ is the mass density. It is generally expected that in-situ shear strength of soil is approximately proportional to G_{max}. Then the normalijed parameter $q_u{}^*$ is defined by the ratio of $q_u{}^*$ to G_{max}. The relationships between G_{max} and $q_u{}^*$ are shown in Fig.20. Then 7 points marked × are located below the line of $q_u{}^* = 1.0 \times 10^{-3}$ and all points marked ○ are located above that line.

As shown in Table-1, the normalized $q_u{}^*$ parameters using the C-sampler include many values below $q_u{}^* = 1.0 \times 10^{-3}$.

It is suggested from Fig.20 that laboratory tests on core samples taken by the C-sampler often predict ground strengths that are too small and underestimate the shear strength of cement mixed in-place piles.

7.3 Core Sampling Results in a Landslide Area.

(1) Introduction

Landslides frequently occur in sloping areas consisting of a continuous plane of such weak layers as an old sliding plane or a tectonic shear folding slip layer. One of the most important aspects of site investigations in landslide areas is to locate such weak zone. One of the most reliable methods for finding such potential slip planes is direct observations of core samples obtained by rotary core boring methods.

Identification of a very weak zone in core samples, originating from old landslide movement or

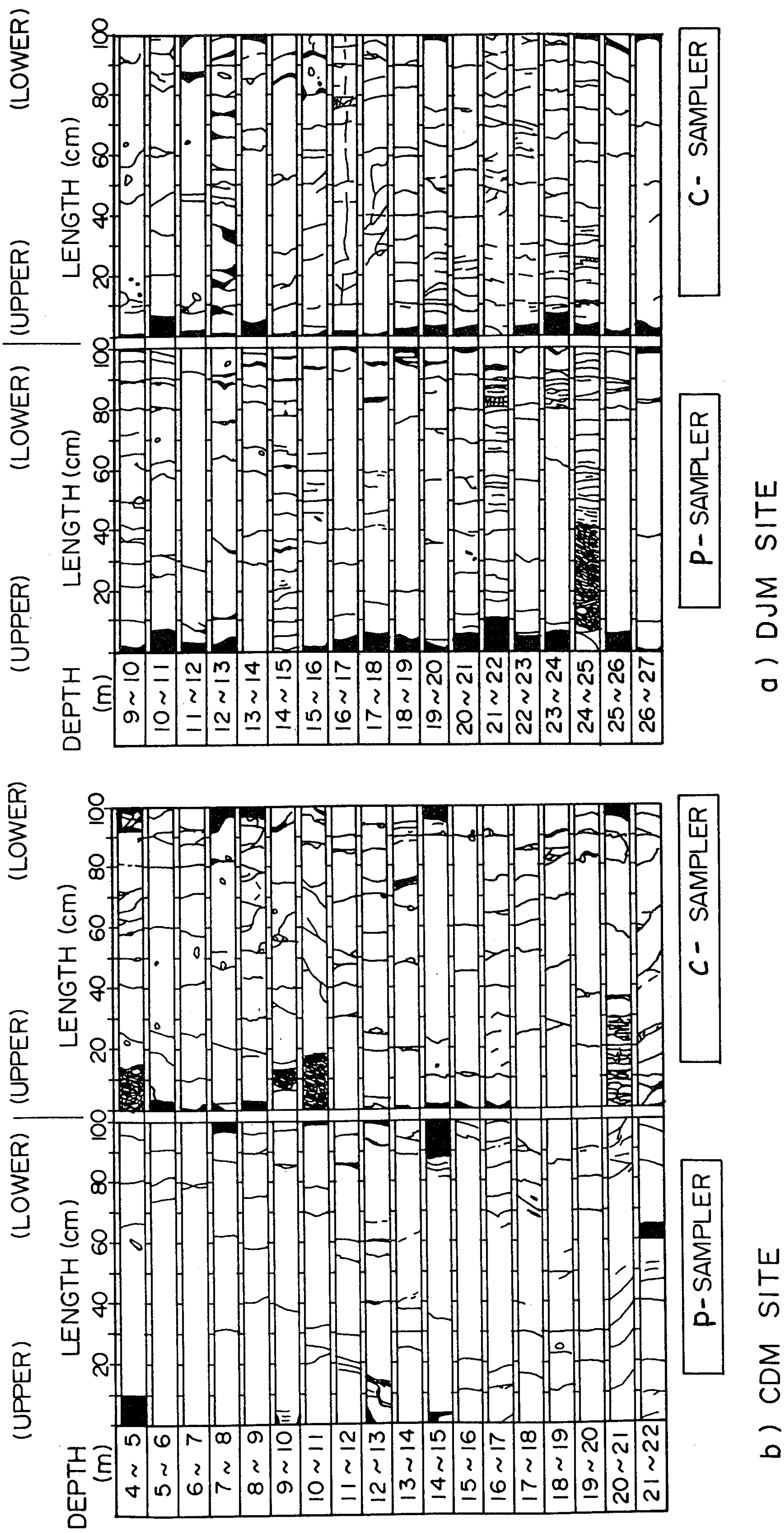


Fig.18 Core profiles taken by P-Sampler and C-Sampler

Table-1 Test results unconfined compression strength and seismic S-wave velocity

a) In the bore hole of DJM−mixed in place pile

using P-sampler					using C-sampler				
DEPTH m	q_u MPa	ρ KN/m³	V_s m/s	q_u/G_{max} ×10⁻³	DEPTH m	q_u MPa	ρ KN/m³	V_s m/s	q_u/G_{max} ×10⁻³
9.52～ 9.65	6.27	18.2	928	4.0	9.30～ 9.45	2.87	18.4	1052	1.4
10.32～10.58	4.82	17.80	903	3.3	10.40～10.58	3.68	18.0	1045	1.8
11.06～11.29	3.07	17.7	849	2.3	11.62～11.83	0.27	17.3	796	2.4
12.09～12.36	2.60	17.2	474	6.7	12.24～12.37	0.097	16.0	703	0.12
13.39～13.62	1.75	16.4	953	1.1	13.70～13.90	0.53	16.1	607	0.89
14.37～14.45	4.24	16.5	1210	1.7	14.35～14.54	1.39	15.7	666	2.0
15.05～15.31	1.82	15.5	524	4.3	15.36～15.50	1.02	16.2	734	1.2
16.09～16.29	1.32	15.5	913	1.0	16.78～16.90	2.52	15.8	727	3.0
17.55～17.83	1.01	15.8	699	1.3	17.63～17.80	0.91	15.7	565	1.8
18.75～18.90	1.42	15.9	957	1.0	18.45～18.65	3.44	15.7	669	4.9
19.56～19.72	3.56	15.9	893	2.8	19.62～19.76	1.66	15.7	723	2.0
20.54～20.72	3.69	15.9	876	3.0	20.76～20.88	0.064	16.5	791	0.062
22.30～22.55	5.44	17.0	1235	2.1	21.16～21.28	0.47	16.6	1146	0.22
23.60～23.80	7.87	18.4	911	5.1	22.70～22.88	3.82	17.9	1144	0.16
24.65～24.73	4.53	19.3	858	3.2	23.47～23.52	2.77	18.1	1046	1.4
25.15～25.36	4.80	19.1	997	2.5	24.42～24.57	5.73	19.2	1278	1.8
					25.42～25.60	4.20	19.2	1329	1.2

b) In the bore hole of CDM−mixed in place pile

using P-sampler					using C-sampler				
DEPTH m	q_u MPa	ρ KN/m³	V_s m/s	q_u/G_{max} ×10⁻³	DEPTH m	q_u MPa	ρ KN/m³	V_s m/s	q_u/G_{max} ×10⁻³
4.10 ～ 4.50	2.19	18.6	852	1.6	4.15 ～ 4.32	2.90	18.3	846	2.2
5.50 ～ 5.75	2.49	18.7	881	1.7	5.62 ～ 5.82	3.18	18.3	1129	1.4
6.50 ～ 6.80	2.94	18.5	993	1.6	6.42 ～ 6.58	5.17	18.1	1040	2.6
7.33 ～ 7.65	2.84	18.5	1042	1.4	7.22 ～ 7.48	4.24	17.6	1084	2.1
8.42 ～ 8.58	2.61	18.0	947	1.6	8.22 ～ 8.33	5.93	17.1	1218	2.3
9.40 ～ 9.70	2.88	17.8	834	2.3	9.45 ～ 9.59	1.49	16.7	1010	0.87
10.40 ～10.72	1.67	17.0	846	1.4	10.20 ～10.45	1.57	15.9	1022	0.95
11.00 ～11.18	1.40	16.9	698	1.7	11.53 ～11.71	2.49	15.6	975	1.7
12.15 ～12.35	1.14	16.5	602	1.9	12.59 ～12.74	2.15	15.1	1038	1.3
13.00 ～13.15	1.14	16.2	635	1.7	13.45 ～13.68	3.06	15.5	941	2.2
13.70 ～13.88	1.35	16.4	525	3.0	14.55 ～14.75	3.34	15.4	968	2.3
14.05 ～14.15	0.49	15.5	536	1.1	15.46 ～15.60	1.55	15.5	1099	0.83
14.45 ～14.53	0.67	15.5	601	1.2	16.52 ～16.65	3.29	15.6	989	2.2
15.20 ～15.40	1.27	15.7	542	2.7	17.40 ～17.57	4.19	15.8	1050	2.4
16.20 ～16.40	1.33	15.8	686	1.8	18.28 ～18.48	4.26	16.0	1040	2.5
17.16 ～17.28	0.61	15.8	497	1.6	19.22 ～19.38	2.54	15.9	1122	1.3
18.50 ～18.65	1.04	15.9	729	1.2	20.35 ～20.60	1.74	16.1	1098	0.9
19.30 ～19.45	0.74	15.1	612	1.3					
20.60 ～20.80	1.05	16.5	592	1.8					

* Underline shows the part of lower value of normalized q_u-parameter, q_u^* than 1.0.

from weathering along fissures, is dependent on the quality of the core sample. If high quality core samples at old slide planes are obtained, strength parameters of potential slip planes can be

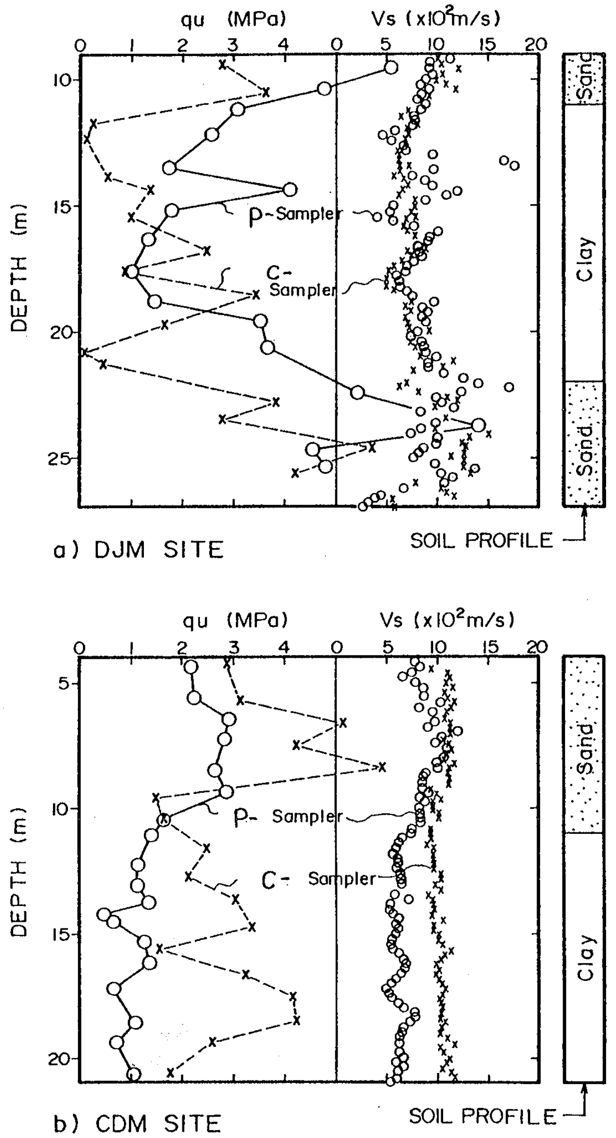


Fig.19 Unconfined compression strength, q_u and seismic velocity, V_s, against depth

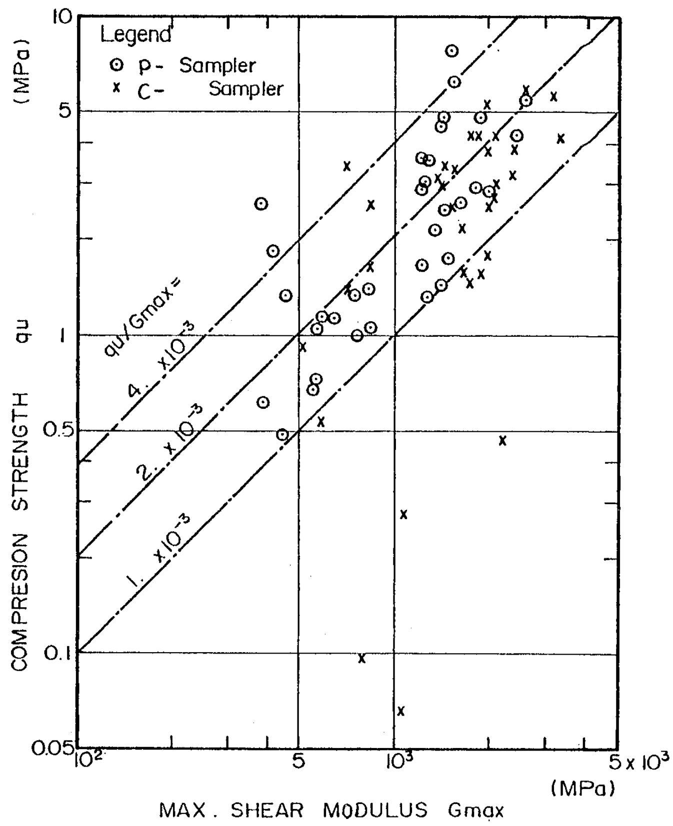


Fig.20 Relationship between unconfined compression strength, q_u and maximum shear modulus G_{max}

estimated by such laboratory testings as shear box test with multiple reversals.

(2) Examples of core sampling

Fig.21 shows an example of a core profile obtained by the P-sampler in a land slide area which consisted of mainly sedimentary rocks. It can be seen from this figure that highly weathered and fissure-rich rock have developed above about 16m in depth and is laying on unweathered rock. Also the thin soft white clay is supposed to be an old slide plane, which has the potential to fail.

Fig.22 shows an example of a short piece of core from an area near the presently active slide plane, confirmed by inclinometer instrumentation. It can be seen that the short piece of core includes a thin soft clay layer with a slickenside surface. Debris is located above the clay layer and highly weathered mud and sandy rock mixed with slightly sheared faces lie below the layer.

The P- sampler presented here gives us high quality core samples from which we are able to estimate slip-planes with the potential to fail.

Fig. 21 A core profile obtained using P-sampler

8. Summary

Reviewing the requirements of samplers for obtaining good quality core samples, the new core sampler called "planet sampler" was developed. Main design improvements of this sampler is to provide such new mechanics as a twin rod system, a planet gear, a centering joint and a core pressure piston. These mechanics are intended to make a more similar condition during core sampling close to block sampling or direct core sampling as suggested by Tatsuoka et al. (1995) as possible.

The planet sampler has major advantages such as to prevent co-rotation of inner barrel with outer tube, to prevent stress relief on the top of the core during drilling and to keep rotation of the rod centralized.

Comparative studies of unconfined compression strength of core samples using the planet sampler and a current sampler was carried out at two sites. From this study, it is concluded as follows:

1. The current core samplers using single rod have shortcomings that often cause core disturbance.
2. Using a current sampler, mechanical properties of cement mixed soils were underestimated.

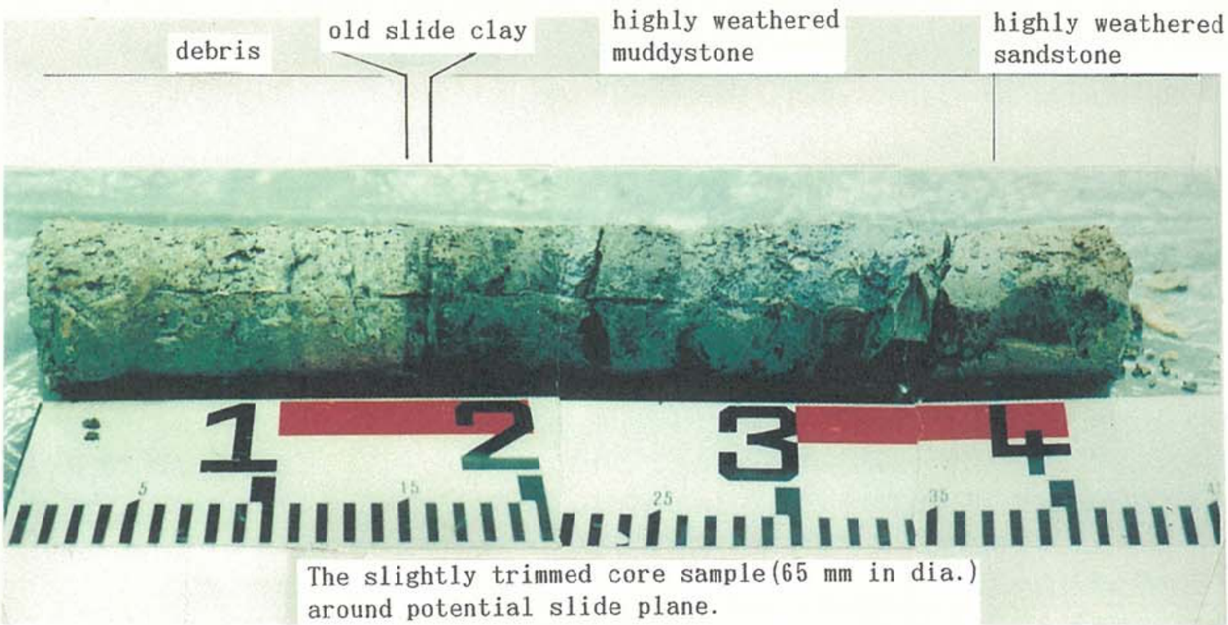


Fig.22 A short piece of core from the area near a presently active slide plane obtained using the P-sampler

3. The planet sampler with planet gear using twin rod gives better quality samples for laboratory testing.

Lastly, some examples of core obtained by the new sampler in a land slide area were presented. They indicated that the new P-sampler is useful for site investigations in landslide areas.

9. Acknowledgment

The development of the new sampler was started after attending the 13th International Conference on Soil Mechanics & Foundation Engineering, held in New Delhi in January, 1994. At this conference Dr.Fumio Tatsuoka suggested to me that in rotary boring disturbed core samples may be due to beating of the single rod.

The performance of field investigations, including core sampling, were successful due to the assistance of members of the Tokyo Bay Across Road Company, Mr.Goro Yasuda of the Yodo River Work Office of Kinki Regional Construction Bureau, Ministry of Construction of Japan, and members of Iwaki work office of Japan High Way Public Corporation and Sakata work office of the Ministry of Construction.

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要 旨

軟岩などの比較的固結した地盤の地盤調査においては，コアボーリングによって試料を採取し，その試料の観察および室内試験による物性の把握が行われる。この場合，乱れの少ないコア試料を採取することが基本的に重要である。従来のコアサンプラーは次の条件を満たす機能を備えて設計されている。① 泥水の浸食防止 ② 循環泥水の流路の確保 ③ コアの落下防止 ④ サンプラー引き上げ時のコアに作用する過剰泥水圧発生防止 ⑤ サンプラーよりのコア引き出しを容易にし，その運搬をしやすくする ⑥ 掘削地盤に適したコアリングビット。

しかしながら，龍岡（1995）の最近の研究によると，これまでのサンプラーによって採取した試料は著しく乱れていることが指摘されている。従来のサンプラーは押しつけによって撓んだシングルロッドの回転によってサンプラーヘッドが揺動し，コアリングビットが揺れながら切削する事からコア試料が乱れる可能性を持っている。同時に，コアを循環泥水の浸食から保護するための内管が外管とともに回転し，コアを切断する可能性を持っている。より乱れの少ないコア試料を採取するための追加必要条件は，⑦ サンプラーヘッドの揺動を押さえる ⑧ 内管が絶対に外管とともに回転しない ⑨ 孔底のコア上面の応力解放を許さない ⑩ コアの外壁と内管の内壁との摩擦に伴う練り返しがを生じないようにする，が考えられる。

上記の必要条件を持った新しいコアサンプラーを開発した。その特徴は，従来のサンプラーの性能に加えて，ツインロッドを使用し，センタリングジョイントを装備してロッドの揺動を最小限に抑える。コアサンプラーの内管と外管の共回りを完全に防止するためにプラネットギアを取り付ける。孔底のコア上面の応力解放を少なくするためにコアプレッシャーピストンを内装する，である。これらの特徴を持ったサンプラーをプラネットサンプラーと呼ぶ。

プラネットサンプラーを使用して，セメントモルタル地盤，セメント深層混合杭のサンプリングを行い，従来のサンプラーによるコア試料と品質の比較を行った。その結果，従来のサンプラーで採取した試料には乱れの著しい試料が多く含まれることが多く，一方，プラネットサンプラーで採取された試料には著しく乱れた試料は含まれず，その品質は比較的良好であることが確かめられた。また，風化泥岩の地すべり地帯において，プラネットサンプラーで採取したコア試料によって，明確な鏡肌をもった地すべり粘土を持った状態を確認できた。このような地盤は従来のサンプラーでは採取が非常に困難な地盤であった。