Development of a New Soil-Core Sampler

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In experimental researches on various problems which are related to soils, it is necessary to know the actual condition of soils. The soil condition consists of water content, soil density and three (solid, liquid and gaseous) phase distribution apart from physical and chemical properties of soils. To measure these items of soil condition, soil samples of constant volume are usually taken.

Plate 1 shows a sampling aid and a soil sampler, which are generally used in Japan. The sampling aid is a tool which pushes a sample can (100 cm^3 in volume, 50.0 mm in inner diameter and 51.0 mm in height) into ground and the soil sampler is a tool which holds a sample can inside and has a role to lead soil core into the can. These tools are convenient to take many samples at a certain depth. However, they have the following problems. First, they can not take continuous samples along the direction of soil depth. Second, they need to dig a relatively big hole for sampling so that the sampling of relatively hard or deep soils is difficult and moreover disturbs fields.

Importance of reasonable soil management has come to be more widely emphasized in recent years. The authors also have come to work more often than before to test the performance of tilling machines. Accordingly, the authors conducted a research to develop a new soil-core sampler with an aim of solving the above-mentioned problems in taking soil samples.

Plate 1. Conventional tools for sampling soil cores
From right to left: Soil sampler, attachment for it, and sampling aid

Progress of research

It is not so easy to take a soil-core sample into a certain vessel without compression or loosening of it under various field conditions.

Many studies on the soil sampling device have been done[1-7]. Fundamentally, any core sampler developed in the past was composed of an outer cylinder and an inner cylinder. An outer cylinder rotates, digs the earth in the form of a doughnut and discharges the dug soil. An inner cylinder which is inserted into the outer cylinder guides the soil core to the sample can or tube. Hayden and Heinemann, Jr. (1968)[3] developed a core sampler which was oper-

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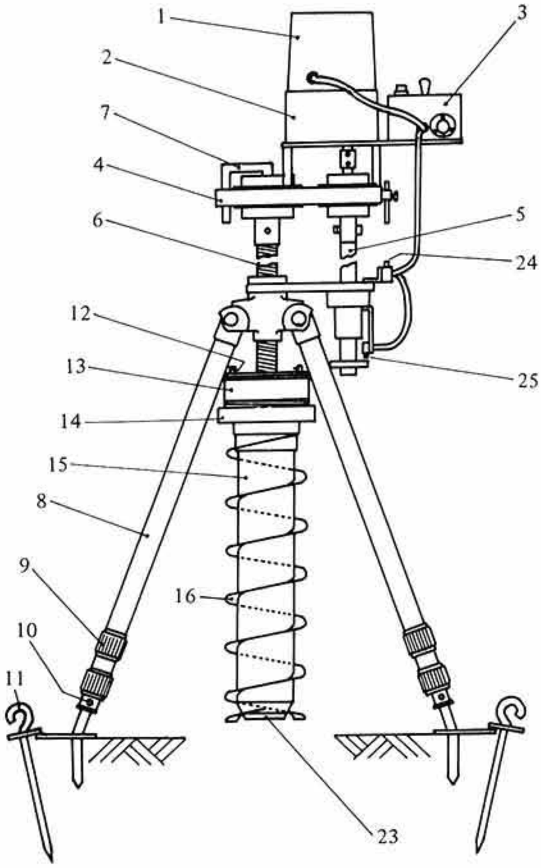
ated as follows; a man holds a handle to fix the inner cylinder in the standing posture and the other man rotates the handle fixed to the outer cylinder by both hands. In Japan, Naganoma and Moroyu (1981)[5] developed a motor-driven core sampling device mounted on a four-wheel-drive vehicle. By taking these two devices as useful references, the present authors developed a prototype soil-core sampler in 1984. Thereafter the authors improved it to reach the final model which may meet the requirements of many researchers. Now (1986),there is a plan to manufacture it for the market.



1. Motor
2. Reduction gear
3. Switch box
4. Gear case
5. Guide rod
6. Outer cylinder with screw
7. Stopper for preventing the rotation of inner cylinder
8. Tripod
9. Adjusting screw of tripod
10. Pin
11. Stake
12. Pin
13. Boss for connecting the holder of outer cylinder
14. Holder of outer cylinder
15. Outer cylinder
16. Screw plate
17. Holder of inner cylinder
18. Snap ring
19. Outer cylinder for extension
20. Inner cylinder for extension
21. Snap ring
22. Inner cylinder for containing sample cans
23. Sampling shoe
24. Limit switch to descent
25. Limit switch to asent

17 ~ 22 : Shown in Fig. 2

Fig. 1. The newly developed soil-core sampler (electric motor type)

Structure and operating procedure

By taking into consideration the working depth of usual plows, the size and weight of the soil-core sampler to be deviced, and so on, this research started from developing a portable device for taking a core sample (in the form of soil column) of 30 cm in length (or depth) with one or two persons. After then it was known that there is a strong demand for taking a core sample down to the depth of about 50 cm in case of vegetable cultivation including root vegetables. To sample soil-cores by conventional methods down to this depth, much labor is needed to

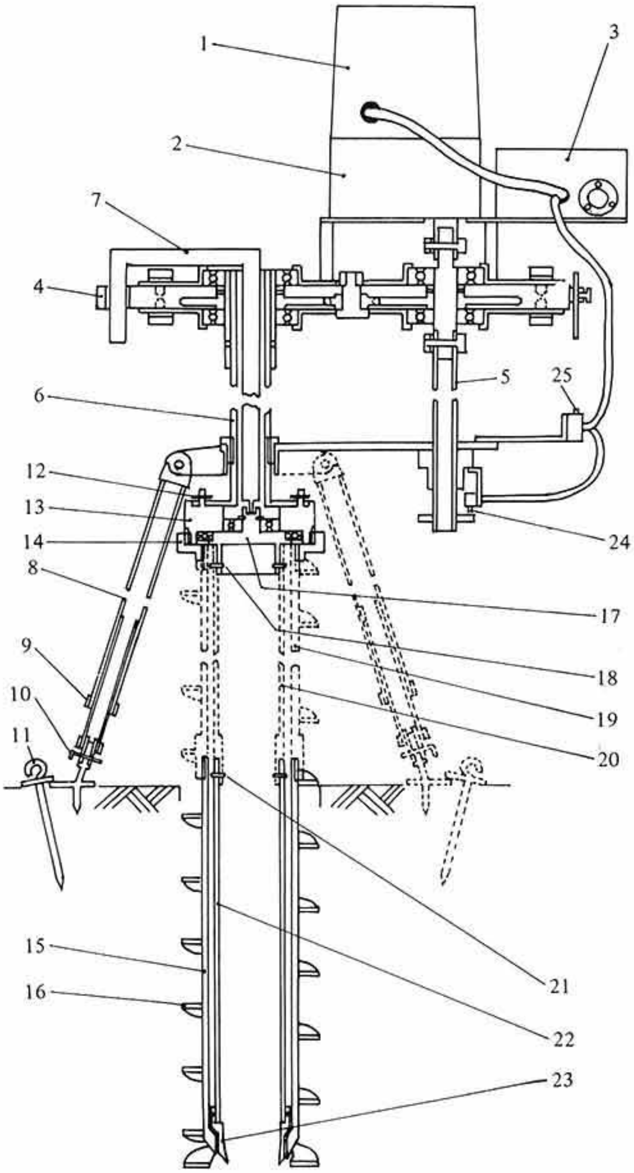


Fig. 2. Structure of the newly developed soil-core sampler which is just prepared for taking soil column from 30 to 60 cm of soil depth
1~25: Shown in Fig. 1.

dig a hole with shovels. Accordingly, the authors modified the device to take a core-sample of 60 cm in length (or depth) by connecting two 30 cm-long cylinders and to be driven by an electric motor for easy sampling, although the problems of weight and cost occurred.

The structure of the developed core sampler is shown in Fig. 1 and Fig. 2 and its main specifications are shown in Table 1. The state of sampling work is shown in Plate 2. The bottom part of this sampler which influences the sampling performance is shown in Plate 3. Regarding the shape of this part, the following fact was made clear. The height by which the tip of sampling shoe (resting blade) stood out by less than 1 mm from the lower edges of screw plates (rotating blades) was adequate, while when it was 3 mm the resistance force to the penetration of the sampler into the soil increased significantly. To

Table 1. Main specifications of the newly-developed soil-core sampler

Item	Specification
Electric motor	AC 100 V, 60 W, 1300 rpm/1.3 A
Reduction gear ratio	1/50
Total height (cm)	138* when working and 101 during transporting
Weight (kg)	Tripod and equipment for drive: 16.2**, outer and inner cylinders: 5.7, outer and inner cylinders for extension: 3.8, other tools: 5.4, portable case: 3.3, the total weight (without an AC generator): 34.4.
Outer diameter (mm)	Screw plate: 100, outer cylinder: 70

Note: 1) For the hand-operated type, *118, **10.2.
2) The pitch of screw: 60 mm.
3) Size of the sample can used: 100 cm^3 in volume, 50.0 mm in inner diameter, and 51.0 mm in height.

Plate 2. The newly-developed soil-core sampler in operation

Plate 3. The sampling shoe and double screw plates at the bottom of the coring cylinder

Plate 4. Connecting additional outer and inner cylinders in preparation of sampling soil column from 30 cm down to 60 cm of soil depth

lead the core smoothly into sample cans (without top and bottom) contained one above another in the inner cylinder and to make the diameter of core as close as inner diameter of the sample cans, the sampling shoe (3 cm in height) has a tapered hole with the diameter of 49.5–49.6 mm at the entrance side and 50.0 mm at the exit side (which is at the entrance of a sample can).

This device can be changed to a hand-operated type by attaching a handle instead of the electric motor unit.

Regarding the electric motor type, the motor is automatically stopped by two limit switches for the descent (sampling) and the ascent (idling to return the outer cylinder with screw to the position of starting sampling). Therefore, a man can do the works of cutting the core, cleaning the sampler, inserting 6 empty sample cans into the inner cylinder and so on while working by the electric motor. As a result, the difference in the total time required for a sampling work between the electric motor type and the hand-operated type was a little, although the rotating speed of the outer cylinder in the former was a little slower than in the latter.

The lift of the device caused by the reaction force of penetration resistance while digging is eliminated by the use of a tripod fixed to the ground surface. To obtain soil samples from the soil depth of 30 cm down to 60 cm, after soil samples from soil surface to the depth of 30 cm were taken, the following procedure is employed (Plate 4); 1) move the tripod aside, after

Plate 5. Separating sample cans each other by cutting a soil column contained in the sample cans with a stainless steel wire of the cutting tool
The sample cans taken out from the cylinder are placed on a receiving stand.

pulling out three stakes, 2) connect the extension outer cylinder to the outer cylinder left in the ground, 3) insert the inner cylinder connected with the extension inner cylinder into the outer cylinder, and 4) set the tripod.

The soil column taken into cans contained in the inner cylinder is pushed out on a soil column receiving stand, and each sample can was separated by cutting the soil column, using a tool with a stainless steel wire (Plate 5).

Performance of the sampler

1) Sampling accuracy

There are two problems affecting the sampling accuracy. One is compaction in the axial direction occurring while the soil is pushed up into the sample cans. The other is that the cross sectional area of soil column is smaller than that of the sample can, because the entering hole of sampling shoe should be smaller than the inner diameter of sample cans in order to assure smooth ascending of soil column in the inner cylinder.

However, the authors have experienced compaction of soil samples only in special cases such as extremely porous soil condition and the peat soil. Fig. 3 shows the result of measurement of the soil compaction on a lowland soil (Gray Lowland soil) and an upland soil (Ando soil). The result showed no soil compaction although the sampler used was not the final one, but in the course of improvement.

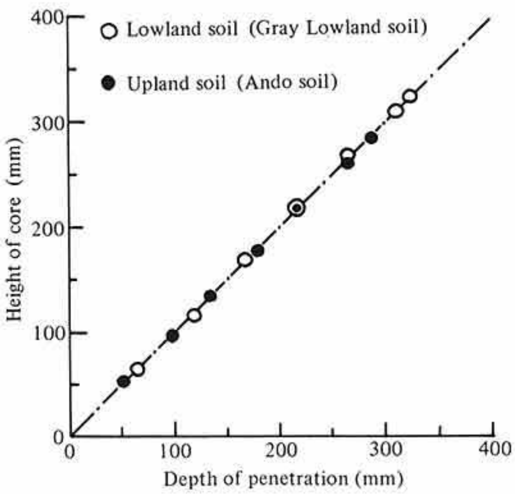


Fig. 3. Accuracy of sampling in terms of core compaction in axial direction

Next, the cross sectional area of the soil columns was calculated to be less than that of sample cans by about 4% and about 2%, when the diameter of the hole at the tip of sampling shoe was 49.0 and 49.5 mm respectively. It can be considered that the difference in the cross sectional area less than 2% is negligible in practical application. When the sampling shoe having the diameter of the hole of 49.5 to 49.6 mm at the tip was used, the sample cans were filled by the soil column leaving only a slight gap between the inner wall of the sample cans and the soil column. Therefore, when the cross sectional area of soil column is larger than that, a trouble may occur in entering the soil column into the sample cans.

Although the accurate comparison is difficult because soil condition such as water content sometimes varies among places very near each other, soil condition measured with soil cores obtained by different sampling methods shown below is given in Table 2.

1. The newly developed soil-core sampler.
2. The sampling aid shown in Plate 1.
3. The soil sampler shown in Plate 1.
4. Taking out soil column (with diameter a little larger than that of the inner diameter of the sample can) by using a knife, and then the sample can is placed on the top of the column. By pushing down the sample can carefully, the core portion of the column is contained into the can, while the outer portion of the column is shaved away. The core samples thus obtained were regarded to represent the real soil density.

When the last method is taken as the control, and values of soil samples with water content similar to that of the control plot are compared with those of the control plot, it is obvious that the core sampler can get the high sampling accuracy. It is also observed from Table 2 that the sampling aid has a tendency to cause soil compaction, and the soil sampler has a tendency of taking the core loosely by causing cracks and so on.

2) Efficiency of sampling work

Under the soil condition relatively good for the sampling work, it took about 15 to 16 min to sample soil core from the surface to the depth of 30 cm by one

Table 2. Soil condition measured with soil cores obtained by different sampling methods

Kind of soil	Depth (cm)	Sampling method	Water content (%)	Density (g/cm³)		Three phase distribution (%)		
				Wet weight	Dry weight	Solid ratio	Water ratio	Air ratio
Volcanic ash soil	5—10	A	101	1.31	0.65	25	66	9
		B	106	1.37	0.67	26	71	3
		C	99.7	1.28	0.64	25	64	11
		D	99.6	1.35	0.68	26	68	6
		D	106	1.27	0.62	24	65	11
		D	97.5	1.35	0.68	27	67	6
Gray Lowland soil	15—20	A	47.9	1.69	1.14	44	54	2
		B*	45.3	1.73	1.19	46	54	0
		B**	45.7	1.70	1.16	45	53	2
		C***	45.3	1.63	1.12	43	51	6
		C	43.6	1.69	1.18	45	51	4
		D	46.2	1.66	1.14	44	52	4
		D	44.0	1.70	1.18	45	52	3

Note: 1) Sampling method A: The newly developed soil-core sampler.
B: Sampling aid.
C: Soil sampler.
D: Taking out soil column by using a knife, and the sample can placed on the top of the column was pushed down to sample the core of the column.
2) *The grease ran short owing to the repeated use of sample cans (considerable compaction observed).
**Sample cans with their inside thickly coated by grease were used (slight compaction observed).
***Cracks took place strongly in the core.

man with a hand-operated device. In case of hard soils and clay soils of relatively high water content, the force required for turning the handle fairly increased. As a result the sampling time increased to about 17 to 18 min. The sampling time is only about a half that of the conventional soil sampling method. An example of the total time required for taking core samples down to 60 cm with the electric motor type was 42 min.

It was experienced sometimes that the electric motor was overloaded for an instant due to a very hard soil layer (30 kgf/cm² of the penetration resistance was observed with the cone of 2 cm² bottom area). Such a hard soil condition may inhibit the use of the hand-operated type.

With soil samplers of this type or similar types , it happens sometimes that the soil column already contained in the inner cylinder remains unraised in the soil when the sampler is lifted from the soil. However, this newly-developed sampler has a device to prevent completely the occurrence of such a trouble. The procedure is as follows: Before lifting the outer and inner cylinders from the soil, take off the stopper for inner cylinder rotation (No. 7 in Fig. 1), insert its point into a groove of the holder of inner cylinder (No. 17 in Fig. 2) and then rotate strongly the inner cylinder 2–3 times. By doing so, the bottom of the soil column is separated from the soil below it.

The largest problem of the core sampler is that it cannot be used for stony fields.

Acknowledgement

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