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Experimental Studies on the Measuring Soil Moisture Tension by the Use of the Pressure Membrane Method and the Centrifuging Method

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Abstract

Soil matric potential is necessary to be measured with undisturbed core samples taken from the field as possible. And also, to measure soil matric potential in laboratory, soil structure should not be distroyed under the experiments as possible, because the soil moisture retension properties are much influenced by the change of soil structure. Then, the study was carried out to make clear the difference of the results obtained from the pressure membrane method and the centrifuging method. Their differences were made clear to be about 1-2 % at pF 2.5-3.0 and to be about 2-5 % at pF 3.0-4.2.

Introduction

The pressure membrane method which was applied to the soil science field was developped by L. A. Richards (1941) at the beginning to collect the soil solution. After that, it was applied to measure the movement rate of soil moisture under the unsaturated conditions by R. F. Reitmever and L. A. Richards (1943), L. A. Richards and L. A. Weaver (1944), and L. A. Richards (1947). Furthermore, the relationship between soil moisture content and soil moisture tension was measured by Kollis George (1952), B. Heining (1963), A. Klute (1965), and A. M. Globus (1971). On the other hand, in Japan, the mechanism of the desiccation by the use of the pressure membrane method was reasonably investigated by H. Fukuda (1959) and that apparatus of the same type which was investigated by L. A. Richards was introduced by K. Otsuka (1961). Then the relationship between soil moisture tension and soil moisture content was investigated by S. Terasawa (1963) at the beginning and after that, the measurements of soil moisture tension were investigated by T. Maeda (1972) and I. Hashimoto and T. Kanou (1975). Nevertheless soil matric potential has not been almost measured with undisturbed soil core samples taken directly from the field untill now. Then, the core sample size of 100 ml was used and filled it with soil. And the relationship between soil moisture tension and content was directly measured by the improved pressure membrane apparatus under constant conditions. That is, the soil depth, the equilibrium time, initial soil moisture content, the manner of the desccation and the others were investigated in this study. At the same time, the results obtained were compared with the results which were measured by the centrifuging method. Consequently, above mentioned problems were clearified by the improved pressure membrane apparatus.

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Experimental Method

Experiments were carried out to measure the relationship of moisture tension and soil moiture content by use of the pressure membrane apparatus and the super centrifugal separator. In case of the pressure membrane method, the equilibrium time, the effects of the different soil depth, initial soil moisture content, and the others were ivestigated. The pressure membrane apparatus was improved so as to set the 100 ml sampler as shown in Fig. 1. The part improved is the cylinder height. Its height was improved from

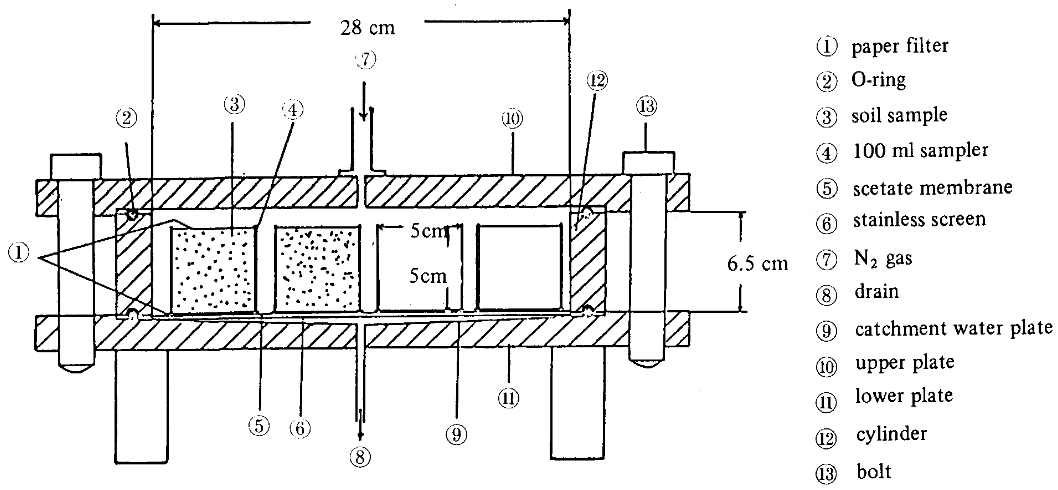

Fig. 1 Schematic cross section of pressure membrane apparatus

5cm to 6.5 cm in order to set the 100 ml sampler which its height is 5 cm. On the other hand, the mechanism of the super centrifugal separator which is the horizontal rotation model and can set the free water table was used to measure the relationship of tension and moisture content. The undisturbed soil core samples taken directly from Oizumi green park and Osaka Fudai Field were used to each experiment. The physical properties of their soil samples are shown in Table 1, and the distribution of soil particle size are shown in Fig. 2. In the measurement of the relationship of tension and moisture content, the undisturbed core samples taken directly from field were saturated by the use of the capillary phenomena from the bottom of the soil sampler. After then, the core samples were delt with the suction plate method from pF 1.0 to pF 2.0. The core samples which were attained to pF 2.0 were applied to the pressure membrane apparatus and the super centrifugal separator respectively in order to measure the relation of tension and soil moisture content. Its relations which were measured were investigated against the situa-

Table 1. Physical properties of soil samples

Soil name \ Item	Specific gravity (g/cm)	Apparent specific gravity (g/cm)	Porosity (%)	Grainsize (%)			Soil texture (international system)
				2.0> (mm)	0.02> (mm)	0.002 (mm)	
Oizumi soil	2.71	1.57 1.39	42.1 48.7	90	5	5	LS
Fudai surface soil	2.59	1.24	51.0	52	32	16	L
Fudai subsoil	2.64	1.55	41.3	37	35	28	LiC

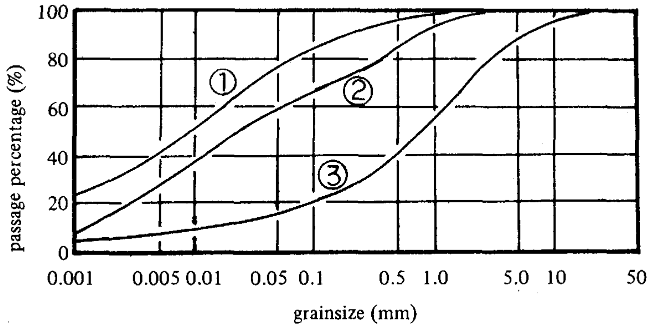

Fig. 2 Grainsize accumulation curves of soil samples
(①: Fudai subsoil, ②: Fudai surface soil, ③: Oizumi soil).

tions of pF 3.0, 3.5, and 4.2 respectively. That is, in case of the pressure membrane method, the pressure setted in container were 1 bar, 3 bars, and 16 bars. The order of the pressure setted was 1 bar at the beginning. After then, 3 bars was setted secondly, and lastly 16 bars. And the equilibrium of soil moisture content was confirmed by the rate of drainage in the burette which was connected with the vinyl hose. Vinyl hose was attached to the bottom of the pressure membrane apparatus. At the same time, soil moisture content was weighed after the core samples were taken out and the fluctuation extent of soil mositure was confirmed.

On the other hand, in case of the centrifuging method, the rotor of the super centrifugal separator was rotated from 3 hours to 7 hours under the predicted revolution numbers. Their values were pre-investigated to decide the approximate equilibrium time of soil moisture against the different soil texture respectively.

Results and Consideration

1. *Equilibrium time of soil moisture content by the pressure membrane method*

(1) Effects caused by the difference of soil texture

The results on the difference of soil texture were shown in Fig. 3. Fudai field subsoil

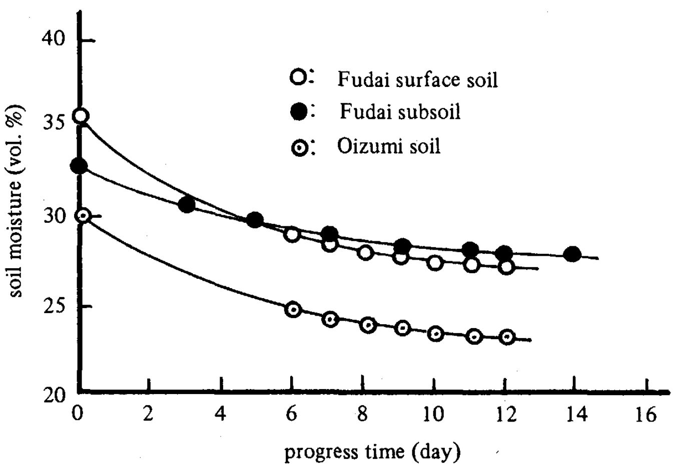

Fig. 3-1 Relation between soil moisture content and the progress time under 1 bar.

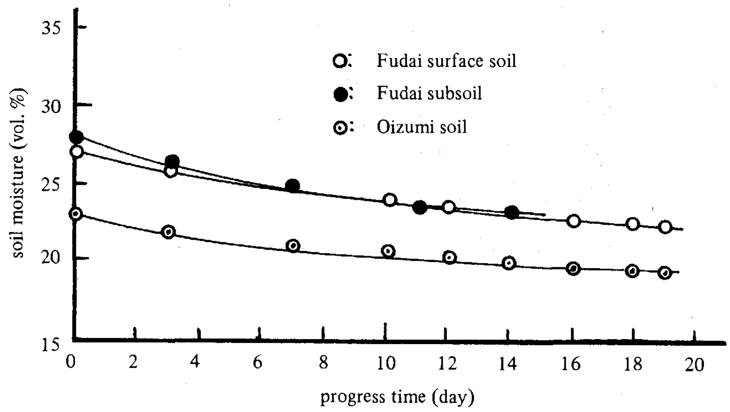

Fig. 3-2 Relation between soil moisture content and the progress time under 3 bars.

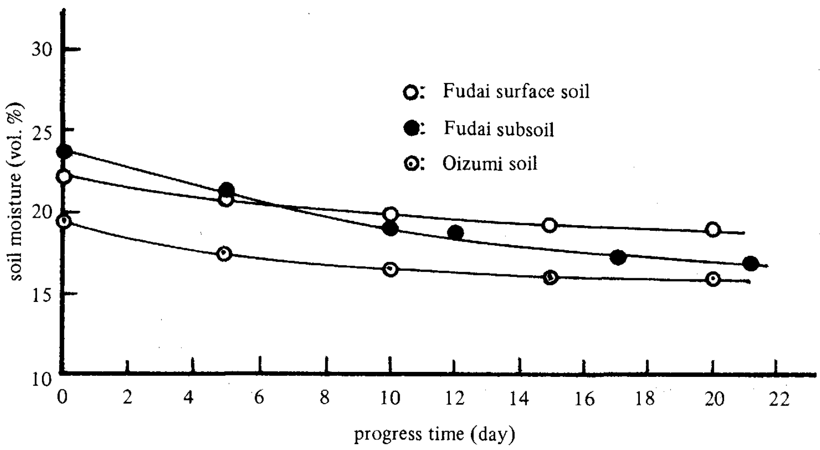

Fig. 3-3 Relation between soil moisture and the progress time under 16 bars.

is clay soil, so the disccation from soil is considered to be difficult when setting pressure is low. Therefore, the equilibrium time of soil moisture content is presumed to be progressed much hours on its subsoil. But apparently the equilibrium time is looked like short in order not to drain when the lower pressure is setted. Judging from the Fig. 3, the equilibrium time of soil moisture content is looked like shorter to the subsoil than the other soils in case of one bar or 3 bars setted. But in 16 bars, its time is recognized to be longer to the subsoil than other soils. As this reason, the disccation from the subsoil is not considered to be advanced so much in case of low pressure setted, and rested soil moisture was discated by high pressure setted, so the equilibrium time is considered to be progressed much hours.

(2) Effects caused by the difference of soil depth

The results on Oizumi soil obtained by the pressure membrane method on the difference of soil depth are shown in Fig. 4. It is usually said that the more soil column is deeper, the more the equilibrium time progresses much hours. But the satisfactory results how much the equilibrium time is influenced by the difference of soil depth is not reported untill now. In Japan, it is said that the equilibrium time is progressed about 2 days against the 1 cm soil depth in case of 2 bars setted. But the equilibrium

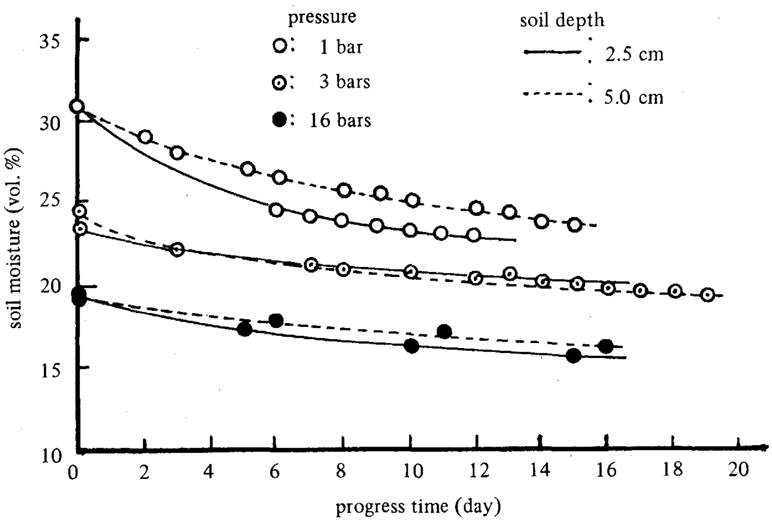

Fig. 4 Relation between soil moisture content and the progress time with regard to the difference of soil depth.

time of soil moisture content on the difference of soil depth is not investigated satisfactory untill now. From above mentioned reports, if the soil depth increases, the equilibrium time of soil moisture content progresses much hours. Then, seeing from Fig. 4, it is recognized that the equilibrium time in 2.5 cm soil depth is shorter than 5 cm soil depth. Therefore, the soil depth should be made thinner in order to shorten the equilibrium time of soil moisture content as possible. But in case of measuring by the use of the undisturbed soil sample, the soil depth should be needed 5 cm though its depth is made a small size sample.

(3) Effects caused by the difference of apparent specific gravity

The results in Oizumi soil obtained by the pressure membrane method on the difference of apparent specific gravity are shown in Fig. 5. If apparent specific gravity is

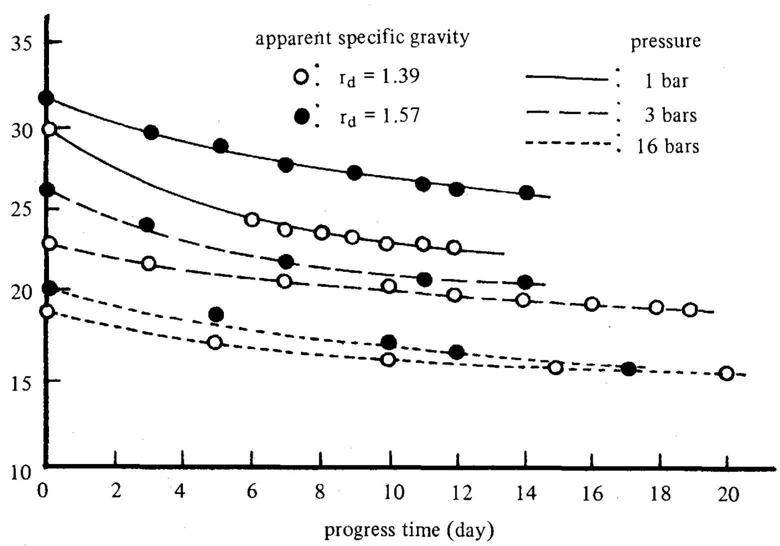

Fig. 5 Relation between soil moisture content and the progress time with regard to the difference of apparent specific gravity by the use of Oizumi soil.

smaller, the soil structure would be more rough. Therefore, it is presumed more easy to drain from soil on small apparent specific gravity than on big. Then, comparing with two kinds of soil in Fig. 5, it is clearly understood more rapid to drain on small apparent specific gravity than on big. Judging from these results, when apparent specific gravity is high, the equilibrium time of soil moisture content is lengthened so that the soil depth should be thinner in order to drain easily from soil.

(4) Effects caused by the difference of initial soil moisture

The results in surface soil of Fudai field obtained by the pressure membrane method on the difference of initial soil moisture content are shown in Fig. 6. The initial soil

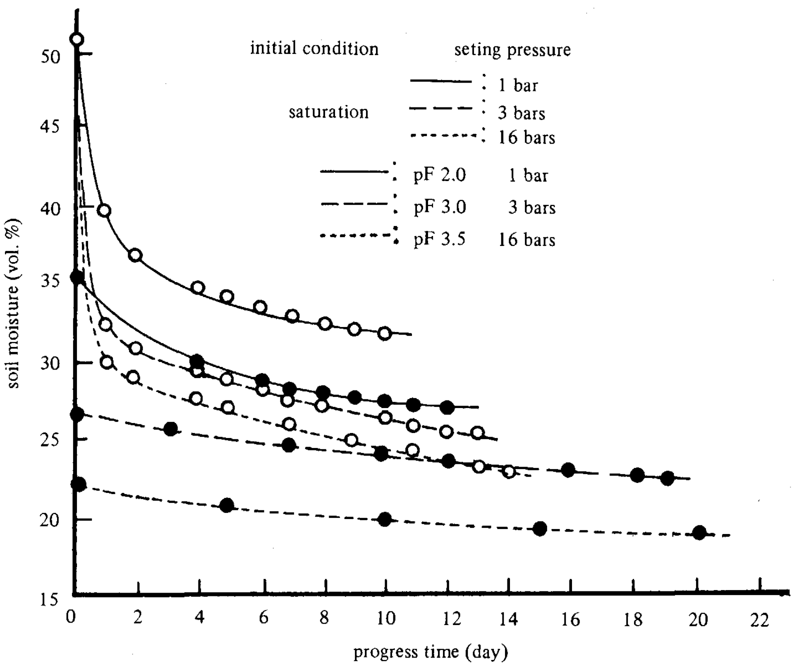

Fig. 6 Relation between soil moisture content and the progress time with regard to the difference of initial condition setted.

moisture conditions were decided at the saturated state or pF 2.0 in case of 1 bar setted, the saturated state or pF 3.0 in case of 3 bars, and the saturated state or pF 3.5 in case of 16 bars. If initial soil moisture content is high, it is presumed that water in soil is easy drained and the equilibrium time is shortened. But, according to the results obtained from Fig. 6, the difference of the equilibrium time was not recognized so much, and the difference of soil moisture content was recognized so much. That is, soil moisture content was less at low initial unsaturated conditions than at high. As the reason of these results, it is considered that water in soil was not easy to drain from the saturated condition in order to produce the abrupt pressure addition into pore and break with the continuous state of capillary water conditons.

2. *Soil moisture characteristics curves influenced by the centrifugal consolidation*

(1) Compression quantity and compression stress at each moisture tension measurement

Soil sample is compressed by the centrifugal force when the soil moisture tension measurement is carried out by the centrifuging method. Its compression quantity to the 5 cm soil depth is measured at each tension and the results obtained are shown in Table 2. When apparent specific gravity is small, the compression quantity is considered to record the big value. By means of the results obtained, the compression quantity is clearly understood to be small when apparent specific gravity is big value. But its tendency in high clay (subsoil) was understood to be smaller than in light sand (Oizumi soil). These results were considered in order to be extermely condensed from the beginning of the experiment in Fudai subsoil.

Table 2. Compression quantity (mm)

Soil name \ pF value		2.5	3.0	3.5	4.2
Oizumi soil	(= 1.57)	0	3	5	7
	(= 1.39)	2	5	7	12
Fudai surface soil	(= 1.24)	2	5	7	10
Fudai subsoil	(= 1.55)	0	1	2	5

(2) Relationship between the porosity and the compression stress

At the beginning, let consider the compression stress in the centrifuging method, the compression stress at each soil moiture tension is calculated by the following equation.

$$f_v = \int_{r_1}^{r_2} \frac{\gamma\omega^2}{g}\, dr = \frac{\gamma\omega^2}{g}\,(\, r_1^2 - r_2^2 \,)$$

where f_v is the compression stress (g/cm^2), γ the wet density in the soil soil sample, r_1 the radius of rotation to the bottom of the soil sample, r_2 the radius of rotation to the upper side of the soil sample, and ω the angular acceleration. The results of the compression stress at each tension which was calculated by the sbove equation was shown in Table 3. Judging from their results in Table 3, soil which the compression quantity

Table 3 Compression stress (Kg/cm)

Soil name \ pF value		2.5	3.0	3.5	4.2
Oizumi soil	(= 1.57)	0.9	2.8	8.7	42
	(= 1.39)	0.8	2.5	7.7	37
Fudai surface soil	(= 1.24)	0.8	2.3	7.1	34
Fudai subsoil	(= 1.55)	0.9	2.8	8.7	42

is small was understood to be influenced by the compression stress. On the other hand, the relationship of the compression stress and the porosity is shown in Fig. 7. Judging from the results in Fig. 7, the compression phenomena are understood to finish nearly before the compression is come up to 10 Kg/cm^2. Therefore, the centrifugal compression is not only the more compression quantity, bu also the relationship of the compression stress and the porosity is influenced by it.

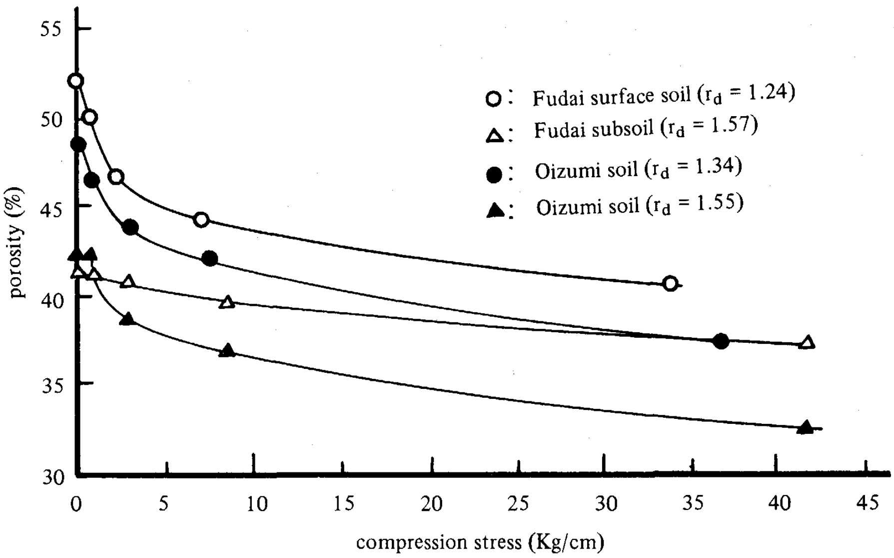

Fig. 7. Relation between the porosity and the compression stress.

3. *Comparison of soil moisture characteristics curves obtained from the pressure membrane method and the centrifuging method*

Soil moisture characteristics curves are shown in Fig. 8. Compare the results obtained from the pressure membrane method with that from the centrifuging method in Fudai

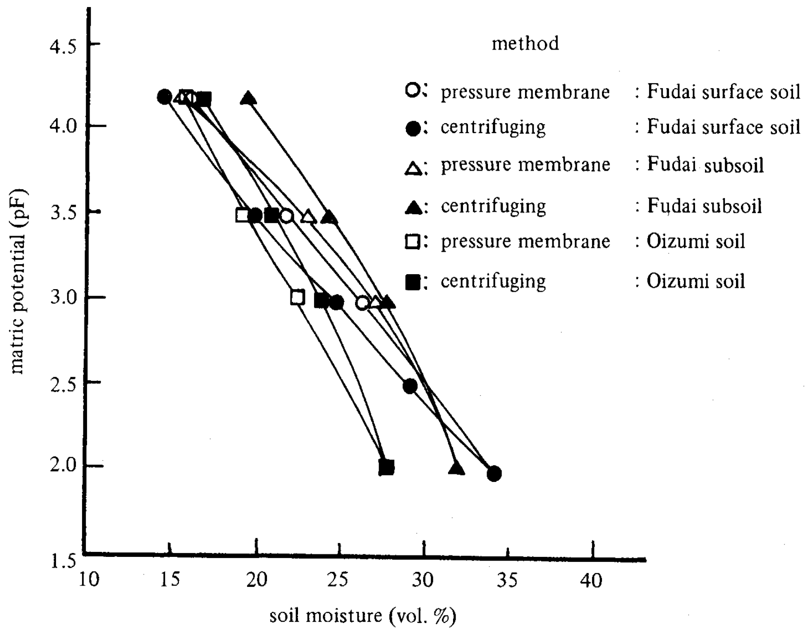

Fig. 8 Comparison of the pressure membrane method and the centrifuging method under 5 cm soil depth.

surface soil, the results from the pressure membrane method are undestood to be shown much more soil moisture content to the same tension than that from the centrifuging method. On the other hand, in Fudai subsoil and Oizumi soil, the results obtained from the pressure mebrane method are understood to be shown less soil moisture content to the same tension value than from the centrifuging method. This tendency is not considered to be compressed so much by the centrifugal force. Because it is considered that the pores are compressed at the low tension value and the water is difficult to be drained at the high. Therefore, strictly speaking, the more correct relationships between the soil moisture content and the tension are considerd to be obtained from the pressure membrane method.

Conclusion

The relationship of the soil moisture content and the tension were investigated by the pressure membrane method and the centifuging method. Consequently, in case of the pressure membrane method, the equilibrium time of soil moistue content was much progressed comparing with the centrifuging method, but in the experiments, the pores of soil are not compressed so that the results obtained are considered to be correct. On the other hand, in case of the centrifuging method, the reationships of the tension and the moisture content are obtained for short time. But the results obtained from the centrifuging method are not so much correct because the pores of soil are compressed by the centrifugal force. Therefore, to obtain the relationships between the tension and the soil moisture content, the selection of the tension measurement method should be decided in obedience to the object.

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