A Study to Increase the Sensitivity of an Observation Pipe to Rapid Changes of Water-Table

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Introduction

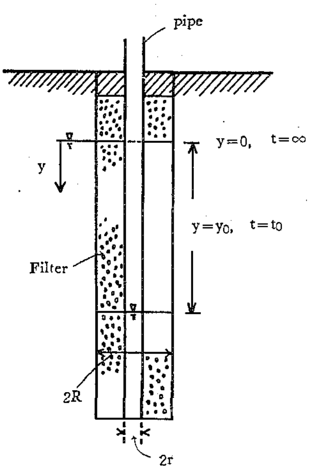
It seems to be a useful method to control the ground water table for the purpose of maintaining the soil moisture condition in an optimum condition or in an optimum quantity of percolation.

While, in reality, the problem remains such as increase in quantity of percolation in the environs of paddy field area of a lake, because of lowering water level of lake, then in order to analyze this problem, it is necessay to make observations of the ground water table.[1] In any case, it is essential for us to take an accurate measurement of the ground water table.

In practice, as a method of measuring ground water table, we generally take a measure of the water level in the pipe which was driven into the ground, and at this time, we usually pack filter around the pipe for the purpose of making the time lag of the water table in the pipe which corresponds with the ground water table to the minimum.[2),3] Here, however, it has been not made clear up to now how it responds to the size of the pipe and filter. In this paper, therefore, in order to make clear this point, we discussed about the relation between the pipe and filter, so that the water table may respond most sensitively, and we made some experiments about them, and then we reported some results of them.

Theoretical consideration

Fig. 1. Observation pipe



Now, in Fig. 1, considering discharge in the pipe through the soil, corresponding flow q is given by the equation,

$$q = K \cdot S \cdot y \cdots\cdots\cdots\cdots (1)$$

Where S is the shape or entry factor which depends on the cavity dimensions, K is the hydraulic conductivity, and Y is the active head.

The volume of flow during time dt is given by

$$dt \cdot q = -A dy \cdots\cdots\cdots (2)$$

Where A is the effective cross-sectional area of rise water level in the pipe and filter.

By introducing q from equation (1), the differential equation can be written as

$$K \cdot S \cdot y = -A \cdot \frac{dy}{dt} \cdots\cdots\cdots (3)$$

As initial condition,

$$y = y_0,\ t = 0 \cdots\cdots\cdots\cdots\cdots\cdots (4)$$

Considering (4), equation (3) becomes

$$y = y_0 e^{-\frac{K \cdot S}{A} \cdot t} \cdots\cdots\cdots\cdots (5)$$

While, S and A are determined by the diameter of the pipe, the section of strainer, or diameter and packed size of the filter, then if Z is written as below, it depends upon the method of setting the pipe.

$$Z = S/A \cdots\cdots\cdots\cdots\cdots\cdots\cdots (6)$$

Now, shape factor S is in proportion to the filter and the soil contact plane; then

$$S \propto R$$

It also can be written as $S = a \cdot R$

Moreover, $A = \pi\{(R^2 - r^2)P + r^2\}$

Where R: radius of the filter

r: radius of the pipe

p: effective porosity of the filter

Therefor, $Z = \frac{a \cdot R}{\pi\{(R^2 - r^2)P + r^2\}}$

Now, when it is $dZ/dR = 0$, the maximum $R = r\sqrt{(1/p) - 1}$ is given. This shows that the response of the water level in the pipe is shortest, when $R = r\sqrt{(1/p) - 1}$. For the convenience, showing this result by the relation between the best ratio of diameter R/r and the effective porosity p, it is as shown in Figs. 2 and 3.

Fig. 2. Curve showing relationship between R/r and P

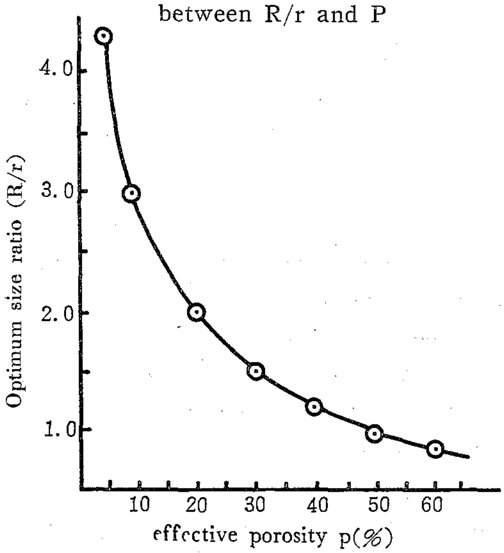


Fig. 3. Relationship between Radius of pipe and Radius of Filter for effective porosity of Filter

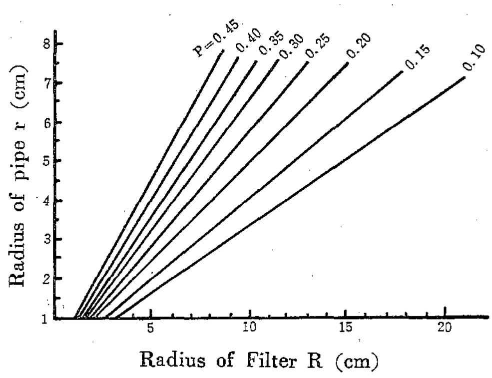
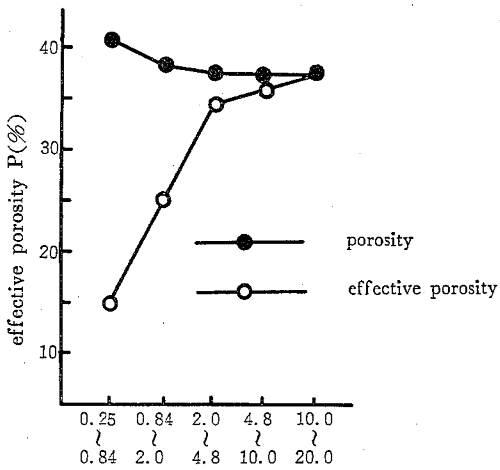


Fig. 4. Relationship between grain size and effective porosity



While, effective prosity is about 15% in the case of alluvial gravel layer, 15% in fine gravel layer, 20% in dune sand layer, 30% in sand layer, and 15~20% in diluvial sand gravel layer. Here, for the convenience, we made some experiments about the relation between the grain size in the filter and its effective porosity, and showed its results in Fig. 4. From this results, therefore, if the grain size of filter used is given, the effective porosity will be given. And if the effective porosity is given, the relation between the radious of the pipe r of the shortest response and the radious of the filter R will be determined by Figs. 2 and 3.

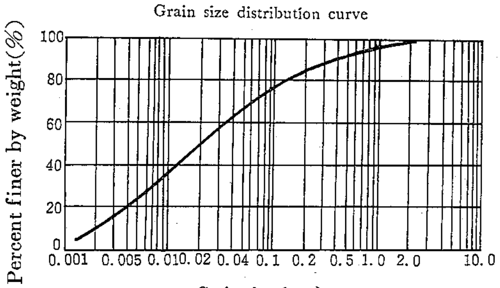
Experiments

The experiments were made on the border of the paddy field of Agricultural Department, Okayama University. The results of the physical experiments about the soil in the field and its soil texture are shown in Table 1.

The grain size analysis was based on JIS A 1204. As shown in Table 1, the soil belongs to silty clayey loam. The specific gravity was 2.65, and the coefficient of permeability of the field was $K=4.3\times10^{-4}$ cm/sec by Auger-Hole Method. [4),5)]

Table 1. Physical results of soil grain size distribution

gravel (%)	sand (%)	silt (%)	clay (%)	60% grain size (mm)	10% grain size (mm)	coefficient of uniformity	soil classification	specific gravity	k (cm/sec)
0	26	52	22	0.031	0.002	15.5	silty clayey loam	2.65	4.3×10^{-4}



For the observation of ground water level, the pipe of 4 cm in diameter and 50 cm in length was used, and over 40 cm of the strainer, small holes of 5 mm in diameter ran zigzag at intervals of 2 cm.

Sand in the filter was kept from running into the pipe by winding the strainer with gauze. The hole to insert the pipe was digged out to the depth of 50 cm with Post-Auger and the inner face of the hole was brushed to keep the coarse state as that of the natural soil structure, then the pipe was set in the center of the hole, around which the filter was packed a little longer than the strainer. About 7 cm of its top was packed with clayey soil.

The grain size of the filter was 0.84～2.0 mm in diameter, then its effective porosity can be obtained as $p=25\%$ by Fig. 4. Therefore, from Figs. 2 and 3, the best relation between the diameter of the filter and that of the pipe is $R/r=1.75$. Here, the diameter of the used pipe is 4 cm, that is $r=2$cm, therefore, $R=3.5$cm. Then, the best suitable filter to the pipe of 4cm is 7cm in diameter. On this method, therefore, we applied two conditions different in diameter, and made experiments about the best condition of the response between them, on the base of the time for measurement, within which the water level rised to 80%.

Results and Discussion

The pipe measuring the ground water was laid for 48 hours after setting. Confirming the stability of the ground water table in the pipe, we lowered the water table in the pipe, and recorded the recovering state of the water table in the process of the time. Showing the results of them, they are as Table 2.

Table 2. The relation between diameter of the filter and the recovery of the water table

Test	No. 1	No. 2	No. 3
Radius of the filter R (cm)	7.0	15.0	5.0
Time for the recovery of the water level t (sec)	540.0	1440.0	840.0
Note	The filter of the best suitable diameter	Filter of the diameter longer than it of the best suitable one	Filter of the diameter shorter than it of the best suitable one

The results of Table 2 show that the response time is shortest in case No. 1 which has the condition of the best ratio of diameter, and next in case No. 3 and last in No. 2. It is, therefore, concluded that the response of the pipe measuring the ground water table is sufficiently short in case No. 1 of the best ratio of diameter. We will prove that this theory is applied to the cases of various conditions by further experiments.

Conclusions

From the above results, we made clear the following points.

1) If the diameter of using filter is given, the effective porosity can be easily shown in Fig. 4.

2) When the grain size of the filter is larger than 2.0mm, there is no great differece between the porosity and the effective porosity.

3) If the diameter of the measuring pipe of the ground water table and the effective porosity of the filter are given, the radious of the filter of the best response will be shown by the equation $R=r\sqrt{(1/p)-1}$.

4) Considering two conditions, (best ratio and not in diameter), we made some experiments practically in the paddy field, and proved the validity of the best ratio of diameter.

5) From the above-mentioned, we made clear the method for setting the measuring pipe of ground water table, with which its response time is sufficiently short to the underground water level, when setting it.

References

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地下水位の急速な変化に対応する測水パイプの感度の増加に関する研究

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要　　約

土壌中の水分環境を最適な条件に保持する方法として，あるいは適正浸透量を与える方法として地下水位をコントロールする手法が有用とされている．一方地下水位を測定する方法としてはパイプを地中に打込んでパイプ内水位を測定するのが一般的であるが，その際，地下水位の変化に対応するパイプ内水位の Time lag をできる限り小さくする必要からパイプの周囲にフィルターをまくのが普通である．しかし，その場合のパイプとフィルターの大きさによっていかなる感度を示すかは従来あまり明確にされていない．そこで本論文ではこの点を明確にするためにパイプとフィルターの組合わせによって最も感度よく水位が応答する関係を明らかにするための実証的研究を行なった結果について報告している．それらの結果について要約すれば次の通りである．

1）使用するフィルターの粒径がわかれば Fig. 4 より有効間隙量が直ちに明らかとなる．

2）フィルターの粒径が 2 mm以上の場合には，間隙率と有効間隙率との間にはあまり大きな差違はみられない．

3）地下水位測定用パイプの径とフィルターの有効間隙がわかれば，$R=r\sqrt{\frac{1}{P}-1}$ より直ちに最も応答のよいフィルターの半径がわかる．

4）最適径比 R/r の条件とそうでない場合の 2 つの条件を与え，実際の圃場においてそれらの比較実験を行なった結果，理論的に導いた最適径比の妥当性が実証された．

5）以上によって地下水位の変動に対して，最も応答の良い地下水位測定用パイプの設置方法が明らかとなった．