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RHEOLOGICAL STUDY ON STRAINER STRUCTURE OF UNDER DRAIN PIPES FOR SLOPE PROTECTION

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ABSTRACT

Pipe drainage is one of the effective slope protection works that can be adopted practically. As fine soil particles are suspended in percolating water, the strainer structure of under drain pipes is necessary to prevent the immediate clogging by soil suspension flow. This study deals with the effective strainer structure of under drain pipes for slope protection.

The effective strainer structure of under drain pipes is the funneled strainer in which pore radius is enlarged toward flow direction. It is designed from the rheological properties of soil suspension flow which prevents the immediate clogging.

Experimental results showed that the pipe drain discharge through the funneled strainers was larger than that through the constant pore radius strainers. This theoretical and experimental results indicate that the strainer with enlarged pore radius toward flow direction, is more effective than the strainer with constant pore radius.

Key Words : Strainer, Under drain pipe, Slope protection, Rheology

INTRODUCTION

The occurrence of erosion disasters on agricultural lands and facilities in semi-mountainous regions is more frequent than that in flat regions. On agricultural lands in semi-mountainous regions, slope protection works with concrete or stone are few, and agricultural lands are normally close to mountainous forest with steep slopes. There are often many terraced fields on steep slopes, therefore, when the weather is abnormal such as heavy rainfall, agricultural lands in semi-mountainous regions are likely to suffer from the failure or gully erosion of paddy field levees, the scour and sedimentation in paddy fields, and the slope failure of agricultural canals. A great deal of effort has been made on the investigations of erosion mechanism and slope protection measures. What seems to be lacking, however, is the investigation of soil suspension effects on erosion processes.

Pipe drainage is one of the effective slope protection works. As fine soil particles are suspended in percolating water, the strainer of under drain pipes is often clogged by soil particles. This study deals with the effective strainer structure of under drain pipes for slope protection. The objectives of this paper are to analyse theoretically the effective strainer structure which prevent the immediate clogging by soil suspension flow, and to observe experimentally the difference between the pipe drain discharge through the funneled strainers in which pore radius is enlarged toward flow direction and that through the constant pore radius strainers.

THEORETICAL ANALYSIS

The immediate clogging mechanism by soil suspension flow has been recently brought to light by Mihara and Yasutomi[1]. The velocity distributions of Newtonian and Bingham liquid in pore are shown in Fig.1. Bingham liquid has plug flow in which the shearing stress is smaller than the yield value. The rheological behavior of soil suspension flow which causes the immediate clogging is pointed out in Eq.(1).

$$R \leqq r_o \; (= 2L\theta / \Delta P) \qquad -(1)$$

where R is the pore radius, r_o the radius of plug flow, L the pore-length, θ the Bingham yield value, and ΔP the difference in pressure. To prevent the immediate clogging by soil suspension flow, the radius of plug flow should at least be smaller than that of the pores.

The sketch of under drain pipe installed in the soil is shown in Fig.2. It is surrounded with gravel which serve as a filter to prevent the mechanical immediate clogging by coarse soil particles. The standard strainer structure of under drain pipes (Type I) is shown in Fig.3. The pore radius of Type I strainer is constant toward flow direction. It should be within the range between the radius of plug flow and the minimum radius of gravel, as pointed out in Eq.(2).

$$r_o < R_d < R_g \qquad -(2)$$

where R_d is the pore radius and R_g is the minimum radius of gravel. As pointed out in Eq.(1), the radius of plug flow increases with the increase in volume concentration. When the volume concentration of percolating water is high, the immediate clogging occurs in Type I strainer.

The effective strainer structure of under drain pipes (Type II) was suggested as shown in Fig.4. The pore radius of Type II strainer is enlarged toward flow direction. The structure of Type II strainer is designed from the rheological properties of soil suspension flow which prevents the immediate clogging. Rheological approach to calculate the optimum pore radius of strainer was indicated as follows.

With the increase in the pore radius of Type II strainer as $R_{d1}, R_{d2}, R_{d3}, \cdots, R_{dj}, \cdots, R_m$ ($R_{dj-1} < R_{dj}$), the pressure of soil suspension in each section decreased as $P_1, P_2, P_3, \cdots, P_j, \cdots, P_m$ ($P_{j-1} > P_j$). It is assumed that the relation between the pore radius and the pressure is pointed out in Eq.(3).

$$P_1 \pi R_{d1}^2 = P_2 \pi R_{d2}^2 = P_j \pi R_{dj}^2 = P_m \pi R_{dm}^2 \qquad - (3)$$

The pore radius R_{d1} is decided on the basis of the minimum radius of gravel. As pointed out in Eqs.(4) and (5), the pore radius R_{dj} should be calculated to make the radius of plug flow r_{oj-1} smaller than the pore radius R_{dj-1} to prevent the immediate clogging in section R_{dj-1}.

$$r_{oj-1} = \frac{2L_{dj-1}\theta}{\Delta P_{j-1}} = \frac{2L_{dj-1}\theta}{P_1(R_{d1}/R_{dj-1})^2[1-(R_{dj-1}/R_{dj})^2]} < R_{dj-1} \qquad - (4)$$

$$R_{dj} > \frac{R_{dj-1}}{[1-(2L_{dj-1}R_{dj-1}\theta/(P_1R_{d1}^2)]^{1/2}} \qquad - (5)$$

Theoretical considerations showed that Type II strainer in which pore radius is enlarged toward flow direction is more effective to prevent the immediate clogging by soil suspension flow than Type I strainer.

MATERIALS AND METHODS

Two types of under drain pipe were made, one has strainers with constant pore radius (Type I), the other has strainers with enlarged pore radius (Type II) as shown in Photo.1. The authors compared the pipe drain discharge through Type I strainers with that through Type

II strainers using a soil tank in a laboratory. Pore radius of Type I strainer is 0.5 mm, which was decided on the basis of the minimum radius of gravel as mentioned before. Also external pore radius of Type II strainer is 0.5 mm, and the radius is enlarged at an angle of 60° toward flow direction. Percolation water was supplied through a porous pipe in the soil. Difference in height between water surface in a Mariotte bottle and under drain pipes was 1 cm.

The decomposed granite soil was sampled from Yasaka of Shimane Prefecture in Japan, and filled in a soil tank. Several properties of soil sample are shown in Table 1. Soil texture is sandy loam (LS), and dispersion ratio is 10.4 %. Severe erosion disasters occurred on agricultural lands and facilities in Yasaka by heavy rainfall[2]. Further research is required to clarify the erosion mechanism and the slope protection measures.

EXPERIMENTAL RESULTS AND DISCUSSION

An experiment was carried out to compare the pipe drain discharge through Type I strainers with that through Type II strainers. Experimental result using a soil tank is shown in Fig.5. The pipe drain discharge through Type I strainers was larger than that through Type II strainers in the first stage. But after 8 hours, accumulative discharge through Type II strainers was larger than that through Type I strainers. It may be concluded that the funneled strainer with enlarged pore radius toward flow direction (Type II), is more effective than the strainer with constant pore radius (Type I). However, in the case when the volume concentration is low, the pipe drain discharge through Type I strainers was larger than that through Type II strainers. Further studies should clarify the relation between the discharge effects of Type II strainer and the volume concentration of percolating water.

CONCLUSIONS

Pipe drainage is one of the effective slope protection works that can be adopted practically. As fine soil particles are suspended in percolating water, the strainer of under drain pipes is often clogged by soil particles. It should be considered to prevent the immediate clogging by soil suspension flow. This study dealt with the effective strainer structure of under drain pipes for slope protection.

The effective strainer structure of under drain pipes is the funneled strainer in which pore radius is enlarged toward flow direction. It is designed from the rheological properties of soil suspension flow which prevents the immediate clogging.

Experimental results showed that the pipe drain discharge through the funneled strainers was larger than that through the constant pore radius strainers. This theoretical and experimental results may be taken to indicate that the strainer with enlarged pore radius toward flow direction, is more effective than the strainer with constant pore radius.

REFERENCE

1) Mihara,M., and R.Yasutomi. 1992. Changes in soil permeability with time and mechanism of pore clogging, Transactions of the Japanese Society of Irrigation, Drainage and Reclamation Engineering (JSIDRE) 162 : pp.67-75.

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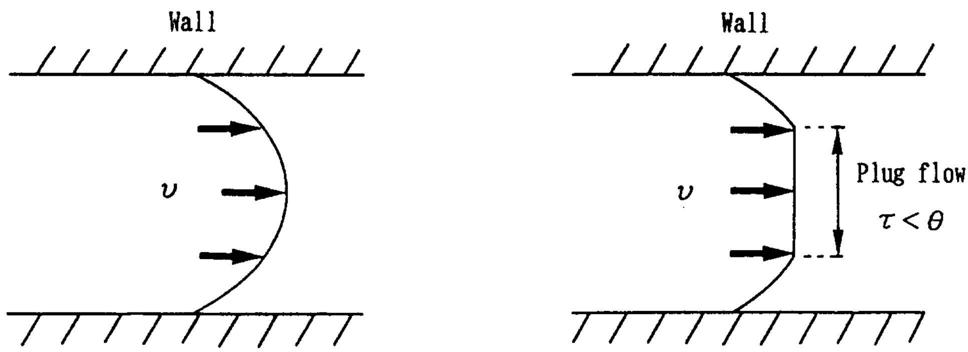
Table 1 Several properties of soil sample.

Soil sample	Specific gravity	Particle size distribution (%)				Dispersion ratio (%)
		Coarse sand	Fine sand	Silt	Clay	
Yasaka	2.68	54.5	17.0	14.2	14.3	10.4



Newtonian liquid

Bingham liquid

Fig.1 Velocity distributions in pore.

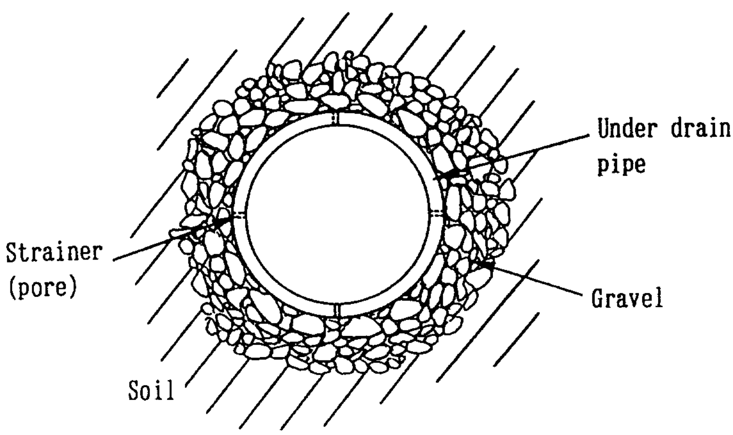


Fig.2 Outline of under drain pipe in the soil.

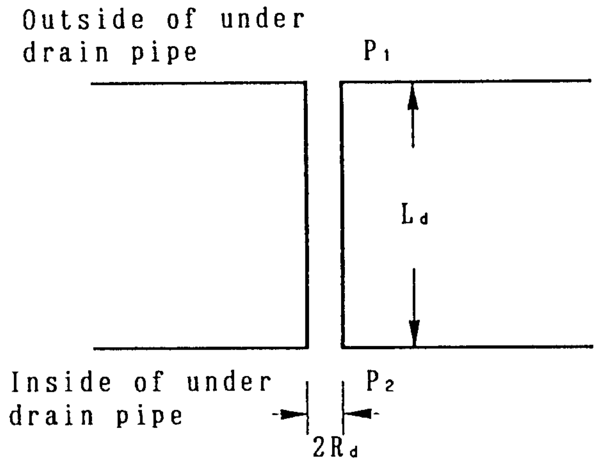


Fig.3 Cross-sectional view of Type I strainer.
(R_d is constant)

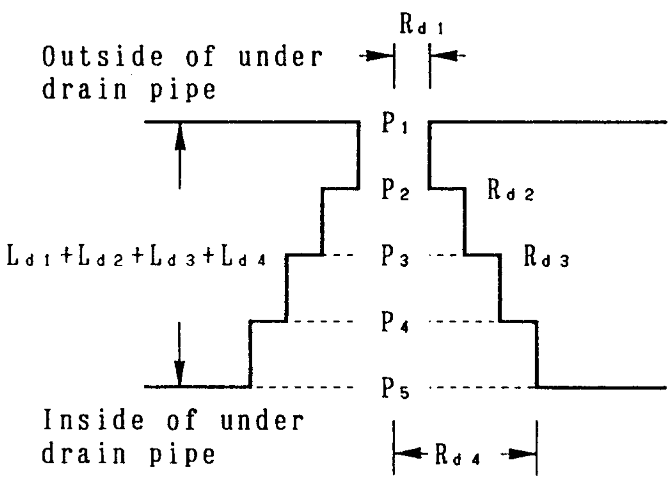


Fig.4 Cross-sectional view of Type II strainer.
(R_d is enlarged)

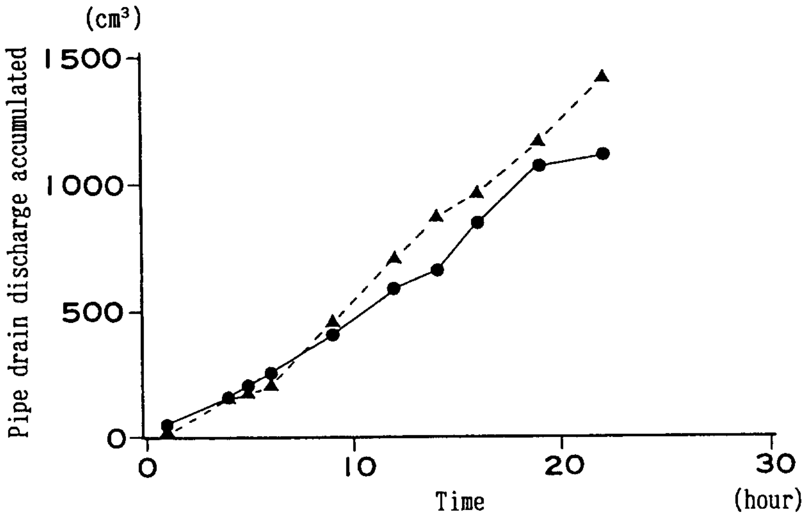


Fig.5 Changes in pipe drain discharge with time.
— Type I strainers ··· Type II strainers

Type I strainer (R_d is constant) Type II strainer (R_d is enlarged)

Photo.1 Strainer structure of under drain pipes.