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Laboratory Study for the Maximum Storm Runoff of the Environmental Round-bottom Flume

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Abstract. There are many studies on the low impacted developments method that minimizes the effects of hydrological circulation system prevent from rapid urbanization. In this research, a maximum allowable precipitation of the environmental round-bottom flume to prevent non-point pollutant source were studied. The environmental round-bottom flume used in this research is consisted of double layered structures which are a cover layer and drainage hole layer whereas a conventional bench flumes is single layer with steel grating drainage covers. A drain cap which is made of recycled PVC scrap is applied on the drainage hole to drain of rainfall. The maximum allowable precipitation of the environmental round-bottom flume were calculated in conditions of crushed stone is covered on filter surfaces and same experiment were performed for the thickness of filter layer.

Keywords: Environmental round-bottom flume, Street inlet, Maximum storm runoff, Recycled PVC scrap

1 Introduction

Recently, the low impact development (LID) method is introduced globally for minimizing a rapid urbanization effects on the hydro-ecology and hydrological cycle. Rainfalls in urban area are discharged to streams through manhole or street inlet. The amount of rainfall collected by manhole is limited, so the local government installed street inlets to collect more rainfall than manholes to increase the efficiency to prevent an urban flooding. However, the conventional bench flume street inlets with steel grating cover were used to collect rainfall but it have fundamental problems of blockages by floating debris and sediments [1]. To prevent these phenomena, an environmental round-bottom flume (hereinafter, ERF) is newly developed. The ERF can overcome blockage and increase collection efficiency.

There are many studies concern street inlets dealt with collection efficiency and discharge rate [2,3]. Whiffin et al. [4] re-expressed a relationship of inlet size with a

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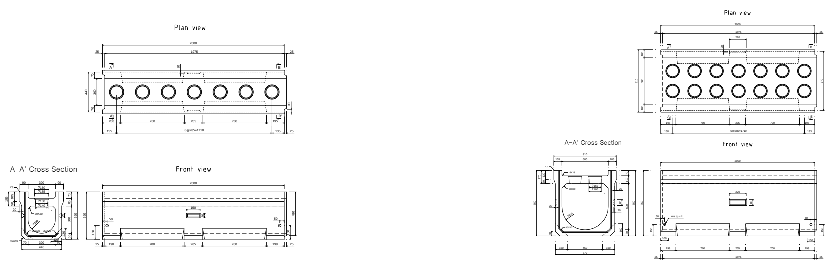
road width using rational method and Manning equation assuming all rainfalls flow into a street inlet. Wong et al. [5] performed hydraulic experiments and prove a collecting discharge rate is varied with road slopes and local coefficients.

In this study, we conducted a series of experiments to determine the hydraulic properties and calculate the maximum allowable precipitation of the ERF. A design compatibility and connectivity between the conventional bench flume street inlet with steel grating cover and the ERF with plastic cap is also verified.

2 Experimental

2.1 Specification of the environmental round-bottom flume

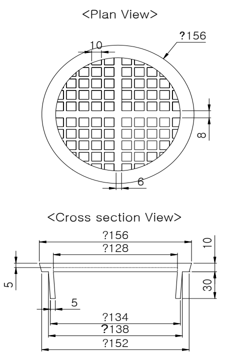
The ERF which is used in this research is a modified product of a conventional bench flume which was made of concrete. The ERF have a closed top with drain hole capped by recycled PVC cover cap prevent blockage from floating debris and sediments and it is the differences between the ERF and the conventional bench flume street inlet. Also finishing materials such as crush stones and landscaping cobble stones are put over the drainage hole cover cap to prevent the exposure of concrete surface for improving scenery and prevent the inflow of non-point pollutant sources into the channel directly. The lower part of ERF designed as to be semi-spherical concave shapes to secure optimal velocity of flow. There are 4 different sizes as 300A, 400A, 500A, 600A and the roundness of each bottom shapes are R150, R200, R250, R300 respectively. The round-bottom is designed as the best hydraulic cross section to achieve the less friction for draining the maximum rainfall. The specifications and dimensions of ERF are shown in Fig. 1.



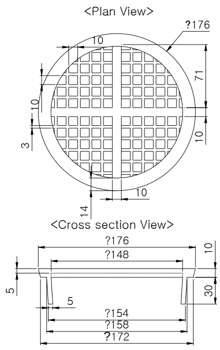
(a) 300A (b) 600A

Fig. 1. Specification and dimensions of the ERF.

Fig. 2 shows the specifications of PVC drain cap. The ERF uses two sizes of PVC drain caps which are D140 and D160. The drain caps have 10 mm square holes for discharging rainfall and simultaneously block the floating debris. Fig. 3 shows the appearance of the ERF with caps and with crush stones cover materials on the top.



(a) D140



(b) D160

Fig. 2. Specification and dimension of PVC drain cap for filter screen.


(a) General appearance


(b) Appearance with filter layer

Fig. 3. Appearances of environmental round-bottom flume.

2.2 Permeability test of the ERF

The rainfall has to be excluded to prevent urban flooding. So the precipitation collecting efficiency is the most important factor of the street inlet. To evaluate the collecting efficiency of the ERF, a permeability tests were performed with crush stone cover material. Rainwater draining performance tests of the ERF were performed to check the rainwater inflow delay phenomena with time as a function of filter layer thickness. Fig. 4 shows the experimental setups for drainage test. The crush stones of over 15 mm diameter are selected by sieving-analysis test for which it could not pass through drain cap screen filter. The thickness of filter layer were set up to 70, 140, 210 mm.

Acrylic cylinders with 450 cm height and diameter of 160 mm, 180 mm were built for experiments and the transit time of 0.0088 ㎥ inflow water (V_w) passing through the experimental setup were measured and averaged.

$$\frac{V_t}{t} = Q_t \qquad \textbf{(1)}$$

The total discharge rate(Q_t) through drain cap with crush stones were calculated by eq. (1), where V_t is volume of passing through water, t is transit time.

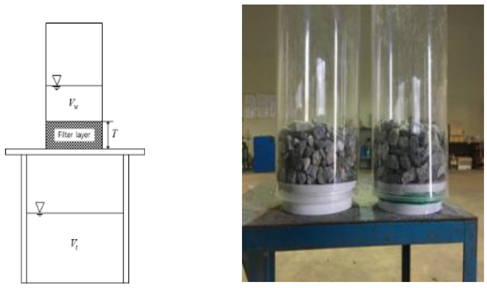


Fig. 4. Schematics of experimental setup.

3 Result and Discussion

As shown in Fig. 5 and Table 1, the permeability increases with diameter of drainage cap and decreases with increasing filter layer thickness. But as shown in Table 1, the drainage time differences as a function of thickness are less than 0.2 seconds and it assumed to be negligible. The cover stone size applied on the ERF shows no direct affection on the permeability of experiments.

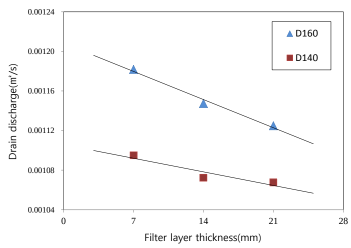


Fig. 5. Total drain discharge rate with filter thickness.

A rational method equation is applied to calculate the storm runoff discharge rate. The rational method is appropriate equation to estimate maximum design volume of rainfall for small drainage areas of up to 200 acres. The rational method used in this study is as follows,

$$Q = 0.2778CIA \quad \textbf{(2)}$$

where, Q is the maximum storm runoff discharge rate (m^3/s), C is runoff coefficient, I is rainfall intensity and A is area (km^2).

Table 1. Drainage discharge rate with thickness and cap size.

type	thickness (T, m)	discharge (㎥)	drainage time (sec)		average time (sec)		discharge rate (㎥/s)	
			D160	D140	D160	D140	D160	D140
crushed stone	0.07	0.0088	7.65	8.18	7.45	8.04	0.001182	0.001095
			7.48	7.98				
			7.21	7.95				
	0.14		7.81	8.42	7.67	8.21	0.001147	0.001072
			7.41	8.12				
			7.79	8.08				
	0.21		7.87	8.14	7.82	8.24	0.001125	0.001068
			7.79	8.31				
			7.81	8.28				

Fig. 6 shows the calculation result of runoff coefficient and area. The precipitation probability includes the shoulder of a road, and cultivated land (20.0 m) information from Ministry of Land, Infrastructure, and Transport of Korea[6] is applied to determine the runoff coefficient and area

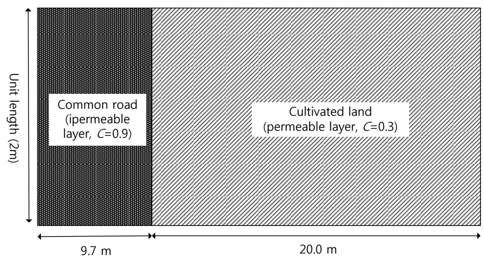


Fig. 6. Total runoff coefficients and areas.

The total precipitations by average recurrences interval and allowable maximum drain discharge of the ERF were calculated and the results were shown in Fig. 7. The total precipitations were calculated using the probability rainfall intensity data based on the long-term rainfall records of Seoul Metropolitan City[7]. The rainfall intensity of 60 minute and 2, 5, 10, 20, 50, 100 recurrence interval years were calculated and shown in Fig. 7 The dashed and straight line represent maximum allowable drain discharge rate of ERF. As a result, the ERF can drain every rainfall discharge within 20 years recurrence intervals precipitation. The 500A and 600A can drain over 100 year precipitation. The target planned year of Korea is 20 years, so the ERF can be applied in general conditions.

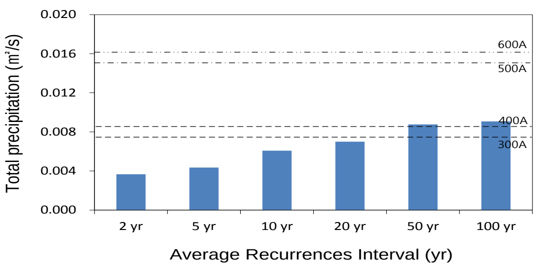


Fig. 7. Maximum allowable precipitation with average recurrences interval.

4 Conclusion

In this research, the drainage capability and allowable precipitation of the ERF developed for replacing a conventional street inlet were investigated. The allowable precipitation is calculated using rational method for small local region, also the allowable maximum drainage discharge rate of filter cap were calculated. As a result, the drainage cap can handle the precipitation intensity of 80 ㎜/hr, when the rainfall intensity increased to 100 ㎜/hr then drainage cap can accept whole precipitation except the smallest cap(300 A).

Also when we estimate the 20 years frequency of Seoul Metropolitan City's maximum rainfall using probability rainfall intensity, the result shows all sizes of cap will accept rainfall, and 500A and 600A will sustain 100 years precipitation frequency.

The conventional street inlet's steel grating upper cover part is opened in the air so it can collect large amount of rainfall, but the contaminant and outer suspended solids are blocked the flume as a result precipitation collecting is not smooth. So if we consider the problems of conventional steel grating top flume, the ERF developed in this research can enhance rainfall collection ability. Also the cap which is produced by recycled PVC scrap can reduce the CO_2 via waste material recycling.

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