

Application of the Decentralized Rainwater Management to Eco-Village

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ABSTRACT: This study has recently established a decentralized Rainwater Management plan in order to provide an hydrology cycle system to the eco-village being planned by Seocheon-gun. Hydraulic conductivity of the subject area is measured at 10-7~10-10m/sec, and a flowerbed-type rainwater Infiltration system capable of controlling a non-point pollution source has been applied

The significance of this study is that it offers appropriate rainwater management planning based on the analysis of the current situation of the subject area. Decentralized Rainwater Management is a valuable measure both economically and ecologically that reduces the burdens on local underground water cultivation as well as rain water pipe lines or purification systems, and sewage pipes.

Keywords: Decentralized rainwater management, Eco-Village, flowerbed-type rainwater infiltration system, non-point pollution

1. INTRODUCTION

1.1 Background and Purpose of the Study

In the current development of lands for housing and complex projects, environmentality is being enhanced and sustainable development is being planned. Even if it is necessary, however, to proceed with environment-friendly development, in the case of private projects, the application of new ecological technologies is limited. Meanwhile, a variety of environment-friendly planning technologies are being applied to promote environment-friendly and ecological eco-villages.

The establishment of Sanneoul, a rural ecological community, on Seocheon-gun, Chungcheongnam-do, the target land in this study, is currently in progress in 2008. Thus, in this study, which focuses on Seocheon-gun Eco-Village, a plan for decentralized

rainwater management was formulated so that the ecological eco-village can be maintained even after the completion of its development. Decentralized rainwater management is effective for the improvement of water circulation, through infiltration and detentioning using rainwater.

1.2 Scope and Method of the Study

Sanneoul Eco-Village was selected as the scope of this study. It is being constructed on 28 Deongo-ri, Pankyo-myeon, Seocheon-gun, Chungcheongnam-do, a 29,749-m² area.

A rainwater infiltration and detention system was selected as the main content of this study, and was planned. Towards this end, the characteristics of the planned facility were determined, and the facility scope was calculated and established after a review of the circumstances surrounding the target land. In addition, the expected effect of the selected facilities was also reviewed.

2. ANALYSIS OF THE GIVEN CONDITIONS AND DEDUTION OF THE PLAN DIRECTION

2.1 Review of the Given Conditions

1) Pavement Area

Before the development, Sixty-five percent of the whole 29,749-m² area consists of rice fields. After the completion of the development, the pavement area is expected to be approximately 50% of the whole area. A building area, a road, a parking lot, and a sidewalk will also be included. In this case, the roof area is envisioned as a surface where rainwater will be collected for use, and the parking lot and road area will be used in the calculation of the capacity of the detention facility for infiltrating rainwater.

Table 1: Pavement Area by Kind

Kinds	Area (m ²)
Building Area	10,452
Entry Road	1,105
Parking Lot	1,338
Footpath (3 m)	957
Footpath (1.5 m)	173

2) Underground Water Level and Permeability Coefficient

The underground water level and permeability coefficient will be the main factors for the selection of the planned facilities. In general, if the soil hydraulic conduction k_f reaches the scope of $10^{-3} \sim 10^{-6}$ m/s, the infiltration facility can be installed (Ministrium fuer Umwelt und Verkehr Baden-Wuerttemberg, 2001). In the case of the infiltration facility, to ensure the proper operation of its infiltration function, the distance from the bottom of the facility

to the underground water level should be at least more than 1 m (Ministrium fuer Landwirtschaft, Umweltschutz und Raumordnung des Landes Brandenburg, 2001).

For the measurement of the underground water level, boring was performed on 13 places on the target land, and the underground water level was measured. As a result, it was determined that the infiltration facility could be installed in the area 1.0~13 m from the ground's surface, except for some sections. In the case of the permeability coefficient, however, almost all the samplings that had been collected from each boring hole were argillaceous, and the soil hydraulic conduction reached $10^{-7} \sim 10^{-10}$ m/sec, showing very low permeability. This value suggests that there is a limitation to the installation of the infiltration facility.

3) Slope

When installing the detention facility for infiltrating rainwater, it is necessary to consider the slope of the target land (Bandermann, 1996; Sieker, 1998). This target land has a 10% slope on average, but it is fostered on steps. Thus, the place where the structures are planned to be constructed was found to have a 3% slope.

Table 2 : Application of the Decentralized Rainwater Infiltration Facility according to Slope Degree

Slope Degree (%)	Application of the Decentralized Rainwater Infiltration Facility
0 ~ 2%	No limitation
2 ~ 6%	When the facility is installed in the slope direction, the length is limited to 3 ~ 10 m
6 ~ 12%	To be installed at a right angle from the slope
>12%	Special methods must be employed for the construction

Source: Bandermann, 1996; Sieker, 1998, p.58

2.2 Review of the Existing Plan in Relation to Water

The rainwater disposal plan under the basic plan for Seocheon Eco-Village is designed to induce an open-type waterway, such as a stream or an eco-pond, inside the complex(E-Jang Co. Ltd, 2006). The general rainwater disposal facility that is planned to be constructed on the target land is as follows:

Table 3 : Planned Facility for Rainwater Disposal

Facility	Applied Section	Features
Mole Drainage	Small playground	Underground drainage
Crossing Channel	Roads inside the complex, external area of the parking lot, south of the small playground	Drainage of the surface runoff
U -shaped Crossing Channel	South, outside the complex	Drainage of the surface runoff
Sump, Manhole	Outside the complex	Collection of rainwater and induction to the sewer
Rainwater Pipeline	Outside the complex	Induction to the public sewer

2.3 Induction of the Planned Direction

The purpose of fostering Seocheon Eco-Village is to minimize the circulation system of the water that is generated due to the development of the complex. Thus, the following specific goals and the means of attaining these were drawn:

First, to prevent an increase in the outflow, the pre-development quantity must be maintained by applying a rainwater infiltration and detention system.

Second, the non-point pollution in the field must be disposed of by applying the natural purification method using soil or vegetation.

Third, the planned direction must be

applied; focusing on the open-type facility so that it can be harmonized with the existing rainwater management plan. Then, the quantity of evapotranspiration that will be generated due to the change in the land cover after the development must be reduced, and the changes in the microclimate must be minimized(Eco-Arche,2007).



Figure 1 : The existing scheme drawing for the target land

3. BASIC EMBODIMENT OF DECENTRALIZED RAINWATER MANAGEMENT

3.1 Selection of the Facility and Installation

Based on the results of the analysis of the given regional conditions of the target land, the following standards for the selection of facilities were drawn:

First, as the soil permeability coefficient for the target land reaches the scope of $10^{-7} \sim 10^{-9}$ m/sec, the planned facility should be selected by focusing on the detention facility. In this case, however, some infiltration functions should be added. Second, the facility should be selected so that the outflowing water inside the complex and around the parking lot can be naturally purified. Third, as regards the planning of an evapotranspiration function, when rainwater infiltrates and is induced into the detention facility, the open-type waterway must be applied like a grass waterway.

Under the building circumstances based on the standards above, a flowerbed-type rainwater system, which could be naturally purified, infiltrated, and under-retained, was

selected.

When the decentralized rainwater management system is installed, it must be designed considering the following conditions: Distance Length in Cut Ground and Fill Dirt and Distance from the Building.

It is impossible to install the infiltration facility at the place where a rice field originally stood or where the underground water reaches a high level. If the infiltration facility is installed on the telocentric-sloping area of cut ground, the infiltration facility must not be installed within the distance where the slope reaches 30 degree and the slope height reaches twice its usual height. And in consideration of the safety of buildings, the infiltration facility must be installed at a discrete distance of more than 1.5 m.

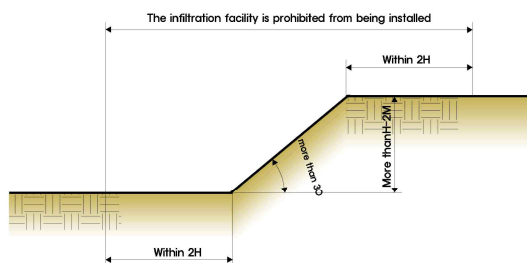


Figure 3 : The area within the slope area where the infiltration facility cannot be installed.

Source: Landscape World Co., Kr, 2000

3.2 Features of the Planned Facility

The flowerbed-type infiltration and detention system is composed of three parts: the planting soil part, where plants are planted; the detention part, composed of the pebble layer and the detention box; and the drainage-pipe net part, which makes it possible to connect to the sewer system (Han.Y.H. et al. 2006).

In the planting and soil part, soil with a permeability coefficient of $10^{-4} \sim 10^{-6}$ m/s must be installed, and plants must be planted, which will carry out the natural purification function. If a pebble layer and pored pipes are placed on the bottom, rainwater will

temporarily be under-retained on the pebble layer and will slowly infiltrate the natural ground. The drainage-pipe net part contains an overflow container, where the overflowing water will temporarily gather, and a pored pipe inside the pebble layer, which will connect to the said water.

The detention system was installed in the parking lot and in the access road to the complex.

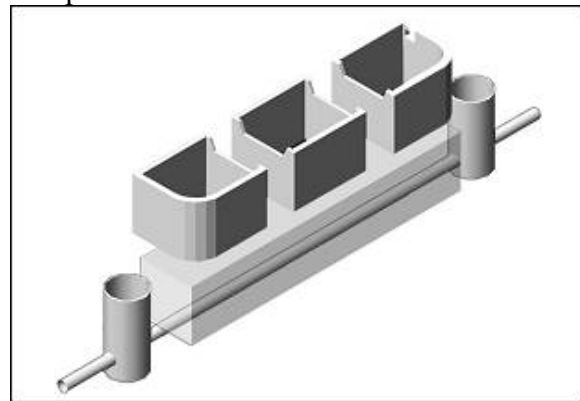


Figure 4 : The basic composition of the flowerbed-type infiltration and detention system.

4. CALCULATION OF THE CAPACITY OF THE SYSTEM

4.1 How to Calculate the Capacity

The capacity of the flowerbed-type rainwater infiltration and detention system was calculated so that the initial rainwater that falls on the impervious area could be disposed of. In general, according to the present study, the initial rainwater on the water collection surface amounts to 7.4 mm (E.H.Kim, 2007). For the ratio of the collection water, 0.7 was applied. In case of the quantity of the initial rainfall, it evaporates or lost on the ground surface, 0.7 was applied as the ratio of the collection water.

The target land was classified into three parking lots and the water collection surface of the access road, and the disposed quality through the use of the system (Q_s) was calculated. Then, the size of the system and the capacity of the inner pebble layer were decided.

$$Q_s = 10^{-3} \times A_c \times c \quad \text{Equation (1)}$$

(Qs: system-disposing quantity (m³); Ac: parking lot area (m²); c: 7.4 (mm); e: water collection ratio (0.7))

4.2 Capacity of the Flowerbed-Type Infiltration and Detention System

① Parking Lot

The parking lot was classified into P1, P2, and P3. When the initial rainwater on an area of a parking lot reaches 7 mm, the system-disposing capacity of the parking lot (Qs) is as seen in Table 4.

To dispose of this target (Qs), the flowerbed-type rainwater and detention system was installed in each parking lot. For the area of the system that was installed in each parking lot, the length and width were decided according to the neighboring conditions. The system area (As) and the depth of the pebble layer (h) were calculated according to the following equation:

$$h = \frac{A_s \times 0.3}{Q_s} \quad \text{(Equation 2)}$$

(h: pebble layer depth (m); Qs: system-disposing quantity (m³); As: system area (m²); pored ratio of the pebble layer: 0.3)

Table 4 : Capacity of the Flowerbed-Type Rainwater Infiltration and Detention System in the Parking Lot Area

P	Ac (m ²)	Qs (m ³)	As (m ²)	h (m)
P1	435	2.175	11	0.66
P2	254	1.270	7.5	0.56
P3	372	1.860	10.5	0.59

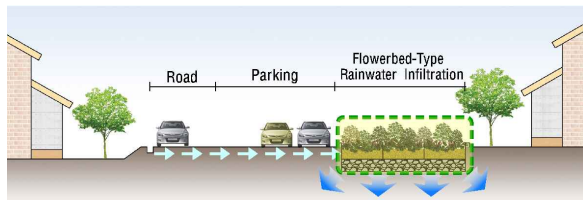


Figure 6 : Cross-sectional view of parking lot P1

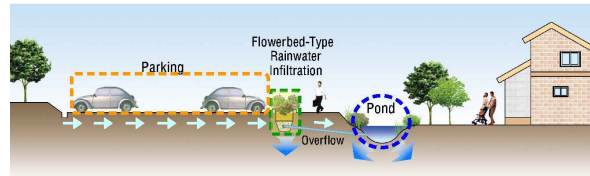


Figure 7 : Longitudinal view of parking lot P1.

② The Access Road inside the Complex

In the access road inside the complex, the installment spot was designated considering the slope and length of the access road and the location of the crossing channel. The access road was classified into two water collection surfaces, and it was installed between the entrance to the access road and the central area. Considering the alignment of the road, the width of the system and the depth of the pebble layer were regularly designated, and the length of the system was calculated.

$$Q_s = 10^{-3} \times R_c \times c \times e \quad \text{(Equation 3)}$$

(Qs: system-disposing quantity (m³); Rc: area of each access road (m²); c: 7 (mm); e: water collection ratio (0.7))

The access road was classified into R1 and R2. Using the quantity when the initial 7-mm rainfall was generated, the quantity (Qs_{R1}) to be disposed of in access road R1 and that (Qs_{R2}) to be disposed of in access road R2 are shown in Table. 5.

For the length (Ls) of the flowerbed-type rainwater infiltration and detention system, the width of the system was regularly decided as 1 m, and the depth of the pebble layer as 0.7 m. Then, the required system length was calculated.

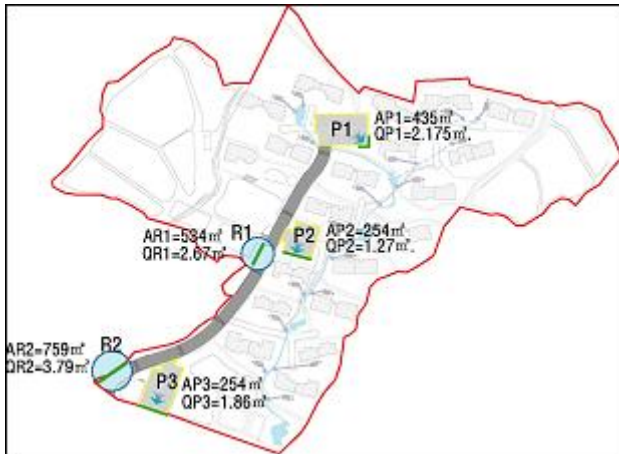
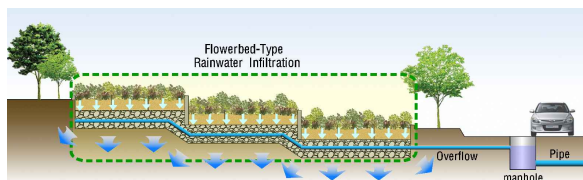
$$L = \frac{w \times h \times 0.3}{Q_s} \quad \text{(Equation 4)}$$

The system length (Ls1) that was installed in access road R1, and the system length (Ls2) that was installed in access road R2, are shown in Table 5.

(L: system length (m); Qs: system-disposing quantity (m³); w: system width (m); h: pebble layer depth (m); pored ratio of the pebble layer: 0.3)

Table 5. Capacity area of the flowerbed-type rainwater infiltration and detention system in an access area.

R	Ac (m ²)	Qs (m ³)	System Specifications		
			W(m)	H(m)	L(m)
R1	534	2.67	1.0	0.7	12.7
R2	759	3.79	1.0	0.7	18.0

**Figure 8 :** Location and area of the flowerbed-type infiltration and detention system.**Figure 9 :** The flowerbed-type rainwater infiltration and detention system installed in R2.

4.3 Expected Effect of the System

According to the results of the analysis that was conducted in this study, in the case of the installation of the flowerbed-type rainwater and detention system, the quantity that is circulated in nature reaches 1,417 ton. In other words, less than 7 mm of the annual rainfall is collected and retained. Of the 1,232-mm annual rainfall in Seochon-gun, 668.9 mm is transported through evapotranspiration, is infiltrated, and detentions.

5. CONCLUSION

In this study, a decentralized rainwater management plan was formulated for the purpose of maintaining ecological sustainability even after the completion of the development of a rural ecological community in Seochon-gun. The purpose of the decentralized rainwater management system for Seochon-gun Eco-Village is to minimize the damage to the water circulation system that was established as part of the development of the complex, and to dispose of the pollutants in the field.

The purpose of this study was to formulate a suitable rainwater management system by comparing the existing rainwater management plan limited to urban areas and diagnosing the status of the target areas in the village.

REFERENCES

- [1] Kim, E. H. 2007. The status of non-point pollution and the calculation of the initial rainfall standards for calculating the proper capacity. Journal of Korea Society of Road Engineering, 2nd Ed., 9. S. Korea.
- [2] E-Jang Co., Ltd. 2006. Master Plan for SanNeoUI Eco-Village in Seo-Chon, Seochon-gun. Korea
- [3] Eco-Arche Institute of Ecological Urban Design & Architecture. 2007, Plan for Hydrologic Cycle in Seo-Chon SanNeoUI Eco-Village, SHINHWA ENGINEERING & ARCHITECTS CO.,LTD. Korea
- [4] Han, Y.H, Lee, T.G, Hwang, H.Y.2006. Development of Flowerbed-type Infiltration System for Hydrologic Cycle in Urban Areas, Journal of the Korea Institute of Ecological Architecture and Environment. Korea.
- [5] Bandermaun, Stecker, A.1996, Auswahl und Klassifizierung relevanter Einflussfaktoren auf die dezentrale Regenwasserbewirtschaftung und Anwendung des GIS als Planungshilfe.

Zeitschrift fuer Stadtentwawsserung und
Gewaesserschutz. H.37. Germany.

- [6] Ministerium fuer Umwelt und Verkehr
Baden-Wuerttemberg(2001).

Naturvertraegliche
Regenwasserbewirtschaftung, Leitfaden
fuer Planer, Ingenierure, Architrkten,
Kommunen und Behoerden. Germany.

- [7] Ministerium fuer Landwirtschaft,
Umweltschutz und Raumordnung des
Landes Brandenburg(2001), Leitfaden zur
umweltvertraeglichen und
kostenguenstigen
Regenwasserbewirtschaftung in
Brandenburg. Germany.

- [8] Sieker, (1998), Naturnahe
Regenwasser bewirtschaftung,
Stadoekologie; Bd.1. Germany.