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A technology for the standpipe in flat roof of green building community

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ABSTRACT

Considering the characteristics of frequent occurrence and serious losses, a technology for the standpipe in flat roof of green building community was designed to alleviate the urban waterlogging, and a test was carried out to find out the influence of the concrete height, underlying surface and return period on reduction rate of peak discharge and rainwater pipe diameter. Results showed that the reduction rate of peak discharge increased with the increase of concrete height, and the reduction rate kept constant as 36.98% when the concrete height was 5 cm or more. The reduction rate of peak discharge increased with the increase of roof area proportion, while the reduction rate of peak discharge decreased with the increase of return period. At the same time, these results can be used to guide practical engineering.

1. Introduction

Recently, with the rapid urbanization in China, many cities such as Wuhan, Beijing, Nanjing, and Hangzhou have been suffered from flood disaster. Urbanization is typically accompanied by the increase of impervious surface such as roads and roofs (Elliott and Trowsdale, 2007). This phenomenon results in a series of water environment and ecological problems including the decrease of infiltration and increase of runoff (Gottschalka and Weingartner, 1998; Lee et al., 2002). The increasing impermeable surface leads to water contamination due to the first flush and overflow pollution of combined flow system which contains suspended matter, heavy metals, nutrient and pathogens (Deletic, 1998; Lee et al., 2004; Lee and Bang, 2000; Montalto et al., 2007).

In the last two decades, new urban water management approaches have been developed to control rainwater problems such as Low Impact Development (LID), Best Management Practices (BMP), Sustainable Urban Drainage Systems (SUDS) and Water Sensitive Urban Design (WSUD) (Davis et al., 2009; Morison and Brown, 2011; Scholz, 2013; Wang et al., 2009). LID is a sustainable design that does not rely on the conventional end-of-pipe or pipe structural method. The management measures of LID include rain garden, green roof, vegetative filter strips, vegetation swales, permeable pavement and reservoir (Dietz, 2007; van Roon, 2007; Carlson et al., 2015). Now, LID has been widely used by many developed countries, while the research of LID in China is in its infancy stage. For example, the entire rainwater is collected by sunken lawn or glassed swale, and then flow into the landscape pond in Beijing Oriental Sun City program (Dong et al., 2007).

Given the huge amount of unused roof area, green roof may be of use in urban areas. Recently, a large amount of papers have been carried out on the reduction of rainwater runoff for different types of green roof (Gregoire and Clausen, 2011; Mentens et al., 2006; Zhang et al., 2014). VanWoert et al. (2005) studied the influence of roof surface, slope and media depth on green roof rainwater. The results showed that vegetated green roof systems not only reduced the amount of rainwater runoff, but also extended its duration time beyond the actual rain event. Carter and Rasmussen (2006) found the retention rate of green roof decreased with precipitation depth, ranging from just under 90% for small storms to slightly less than 50% for larger storms. Meanwhile, average runoff lag times increased from 17.0 min for the black roof to 34.9 min for the green roof. Getter et al. (2007) found that the rain category and slope as

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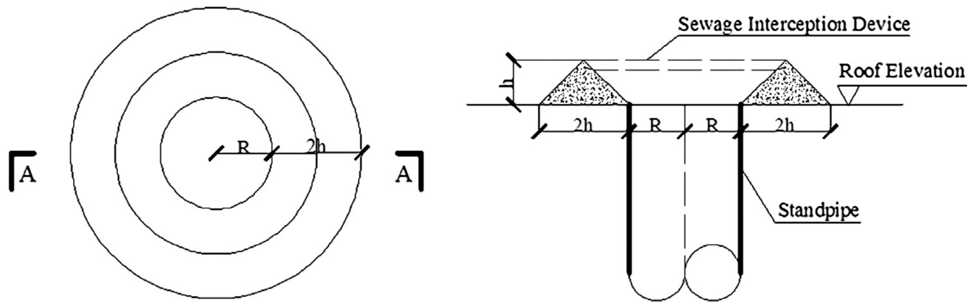

Fig. 1. A-A planar graph and profile of the design.

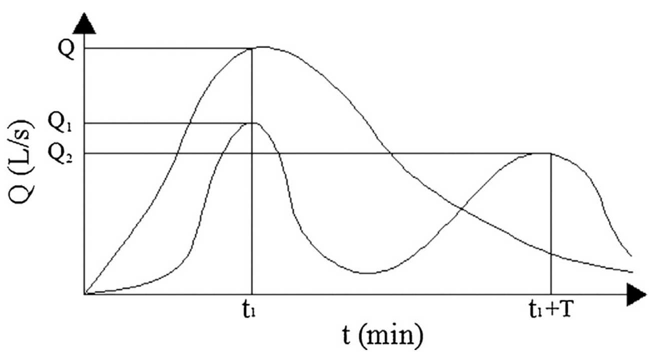

Fig. 2. Correlation between the flow rate and rain duration.

well as interaction of them are important for the water retention. Carter and Jackson (2007) concluded that the green roofs may be an effective tool for managing small storms in highly developed areas.

In order to provide a greater reduction on total runoff, green roof should be accompanied by other design technologies. Based on the source control concept of LID, a designed method for the standpipe in flat roof of building community was developed. The aim of this study is to elaborate and investigate the influence of the concrete height, underlying surface and return period on the reduction rate of peak discharge and rainwater pipe diameter.

2. Material and methods

2.1. Construction of standpipe

The technology mentioned above mainly included two steps. Firstly, the juncture of the standpipe and flat roof was used as an inner loop, and pouring of an isosceles triangle concrete. Secondly, a sewage interception device was set at the top of the concrete. The planar graph and profile of the design are shown in Fig. 1.

2.2. Computation of design hydrology

Correlation between the flow rate and rain duration is shown in Fig. 2. The single peak curve is the flow rate of the district prior to construction, while the double peak curve is the flow rate of the district after construction. Q represents peak discharge of original district; Q_1 represents peak discharge excluding roof runoff at the initial stage of rainfall; Q_2 represents peak discharge including roof runoff at the middle-later stage of rainfall; t_1 represents the local catchment time; T represents retention time of roof rainwater.

The formula of peak discharge of original district is as follows (Qi et al., 2009):

$$Q = \Psi F q \quad (1)$$

where Ψ represents mean runoff coefficient of the district; F represents drainage area (ha); q represents rainfall intensity ($\mathrm{L\,s^{-1}\,ha^{-1}}$).

Table 1
Runoff coefficient and area proportion of different underlying surface.

	Water	Green land	Road	Building	Permeable surface
Ψi	1	0.15	0.9	0.8	0.2
Area proportion	11%	27%	9%	21%	32%

The formula of rainfall intensity is determined as (Froehlich, 2010):

$$q = \frac{167A_1(1 + c\lg P)}{(t_1 + b)^n} \quad (2)$$

where t_1 represents the local catchment time (min); A_1, c, b, n represent the locally constant parameters; P represents return period (years).

During rainfall period, the retention volume of roof rainwater is equal to roof runoff, so retention time of roof rainwater can be calculated (Li et al., 2010):

$$T = \left[\frac{9.98h(1-n)}{A_1\Psi_1(1 + c\lg P)} + b^{1-n}\right]^{1/(1-n)} - b \quad (3)$$

where h represents the height of concrete (cm), Ψ_1 represents roof runoff coefficient.

In order to analysis the reduction rate of peak discharge, calculate peak discharge of the district after construction:

$$Q_1 = \Psi_2(F - A)\frac{167A_1(1 + c\lg P)}{(t_1 + b)^n} \quad (4)$$

$$Q_2 = \Psi F \frac{167A_1(1 + c\lg P)}{(t_1 + T + b)^n} \quad (5)$$

$$Q^* = \mathrm{Max}\left\{Q_1, Q_2\right\} \quad (6)$$

$$\Delta Q = Q - Q^* \quad (7)$$

where Ψ_2 represents mean runoff coefficient of the district excluding roof area; A represents roof area (ha); Q^* represents the larger value of Q_1 and Q_2; $\Delta Q/Q$ represents the reduction rate of peak discharge (%).

According to Q and Q^*, calculate the corresponding rainwater pipe diameter DN and DN*, then calculate the decrement of rainwater pipe diameter as ΔDN = DN – DN*.

2.3. Simulation site

The community is a green building community of Chongqing, which covers a total area of 6.39 ha. Table 1 represents runoff coefficient and area proportion of different underlying surface.

The formula of rainfall intensity of this green building community is as follows:

$$q = \frac{2509 \times (1 + 0.845\lg P)}{(5 + 14.095)^{0.753}} \quad (8)$$