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Comparative Analysis of Sponge City Drainage System Schemes Based on SWMM

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Abstract:

In this paper, the drainage system schemes of sponge city are compared and analyzed based on Storm Water Management Model (SWMM). First, this paper builds a model in SWMM to explore the effect of green roof, rain garden and reservoir on solving the excessive pressure of urban drainage system during rainstorm, and analyzes the results of the model. Through comparative analysis, the best scheme is obtained. The results show that the green roof has the best effect among the three schemes, which can reduce the flow of the pipeline, increase the drainage cycle and thus reduce the pressure of the drainage system. Second, limited by the size of the area, it can only reduce the flow of the drainage system. The reservoir has the worst effect, mainly because the intensity is not large enough, and if it encounters greater rainfall, the reservoir can play a key role in regulating and storing. Through the analysis of the model results, an effective scheme can be obtained to relieve the pressure of urban drainage system in rainstorm, so as to reduce the drainage pipe flow and reduce the risk of urban waterlogging. The purpose of this paper is to provide effective reference for the construction of sponge city, relieve the pressure of drainage system and reduce the hidden danger of urban waterlogging.

Keywords: sponge city; Urban drainage system; SWMM.

1. Introduction

The city's drainage system plays a particularly important role when a rainstorm occurs once in many years. Continuous widening and building of drainage pipes can effectively avoid waterlogging, but such a method will cost a lot of manpower and material resources. This problem can be effectively avoided by building green roofs, rain gardens, cisterns, etc. These methods can not only relieve the pressure of urban drainage system, but also play a role in beautifying the environment and protecting the ecology.

Chen et al. [1] Verification of sponge city design of an industrial park in Chongqing based on SWMM model. Wei et al. [2] successfully solved the problem of low drainage efficiency of urban multistage drainage system based on Storm Water Management Model (SWMM) and Finite Volume Coastal Ocean Model (FVCOM). Taking Ruihu Renovation of Jiangsu Food and Drug Vocational Technical College as an example, Shi [3] analyzed the design points of rain garden application in sponge city at small and medium scale, and pointed out the application and advantages of rain garden in daily life. Jiang [4] studied the application of sponge city theory in road greening landscape design, indicating that these schemes can not only relieve the pressure of drainage system, but also beautify the environment. Deng [5] studied the application of sponge city in the renovation design of municipal road rainwater system, indicating that urban drainage system can be successfully combined with streets in blocks. Studies have shown that green roofs, rain gardens and reservoir are effective in relieving pressure on drainage systems.

Based on the SWMM model, this paper compares and analyzes the effects of green roof, rain garden and reservoir on relieving the pressure of drainage system through the data obtained in the model. Through comparative analysis, the best scheme of sponge city drainage system is discussed, which provides some theoretical reference for sponge city construction.

2. Case Analysis

2.1 Case Background

The neighborhood suffered the heaviest rainfall in 30 years. The area of this block is 120 acres, with 3 streets on the x and y axes. Each street in the X-axis direction has an area of 0.24 mu and a slope of 1.5. The three streets are S6, S4 and S2 in Fig. 1. In the Y-axis direction, each street has an area of 0.24 mu and the slope is 1. The three streets are S1, S3 and S5 in Fig. 1. The overall topography of this area is high in the southwest and low in the northeast, so the drainage outlets of the entire system are set in the southeast corner of the entire block. There are 4 main catchment areas in this area: house roofs (H1), two car parks (P1, P2) and streets. The total area of all the roofs is 1.6 mu, and the area of both parking lots is 0.1 mu. The rest of the area is permeable and the water does not flow into the drainage system. In the SWMM model, green roof, rain garden and water reservoir are added to slow down the flow rate so as to reduce the pressure on the drainage system.

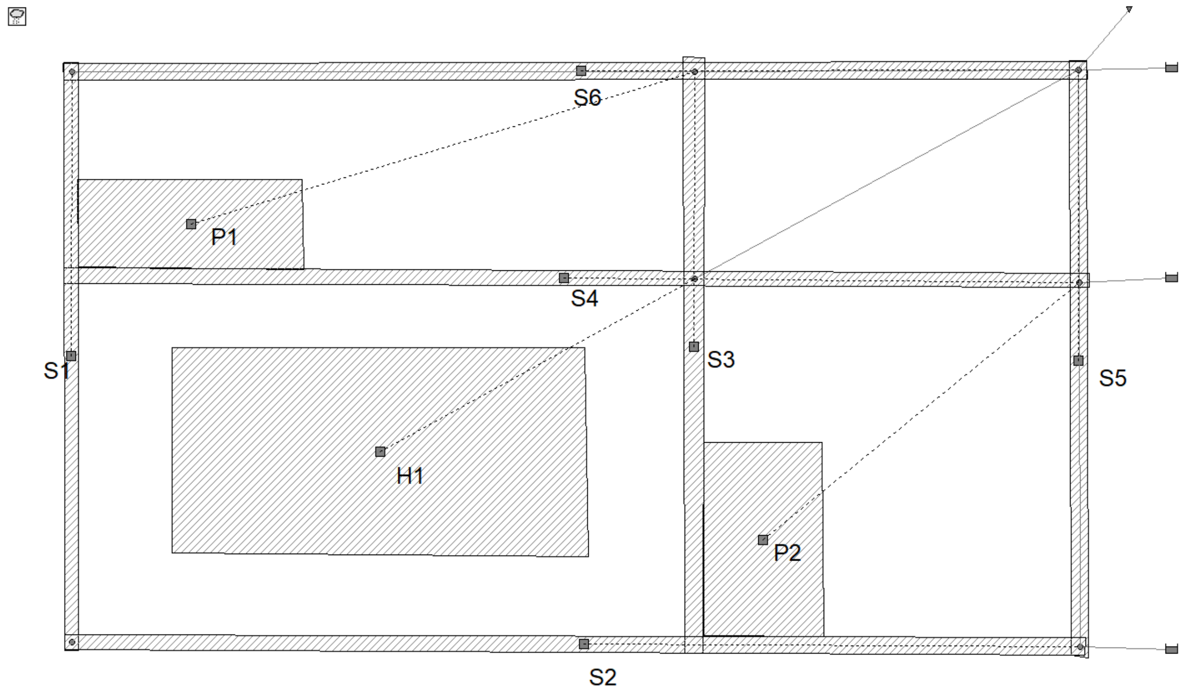

Fig. 1 Drainage pipe diagram of block

2.2 Analysis Methods and Results

2.2.1 Analysis of influence of green roof on water quantity in drainage pipe

The study of roof drainage is very important because the total area of the roof is the largest of all the catchment areas. According to the comparison between Fig. 2 and Fig. 3, it can be found that after the addition of green roof, the flow velocity produces three groups of changes: the time of water flow, the highest flow rate and the duration of drainage. First, the time for water to appear was delayed from 0.1 to 0.3 hours, which means that green roofs can retain water on the roof for a longer period of time. This extended period of time will give people more time to cope with the arrival of heavy rain. Second, the maximum flow rate was reduced from approximately 42 LPS to 0.25 LPS. The change was significant, with the maximum flow rate reduced by approximately 41.75 LPS, which means that the drainage system did not have to endure too much drainage pressure in a short period of time. Third, the duration of drainage. The change in the duration of drainage is also significant, as shown in Fig. 2 at around 2 hours the displacement is already close to 0 LPS, but in Fig. 3 with the green roof, the flow is about 0.2 LPS at 2 hours. This means that the water on the roof does not flow into the pipes in a short period of time, but slowly over a long period of time. From the above analysis of the line chart with and without green roofs, it can be concluded that green roofs can greatly relieve the pressure on drainage systems.

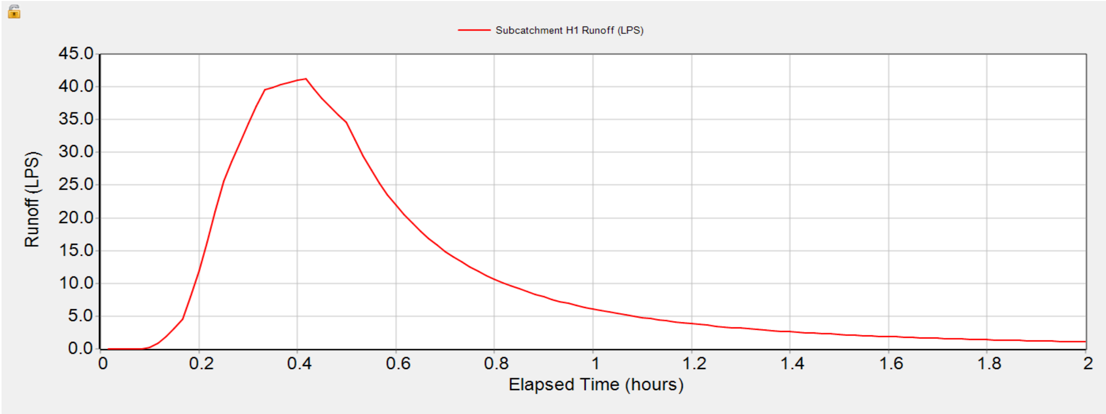

Fig. 2 Pipeline flow diagram before connecting the green roof

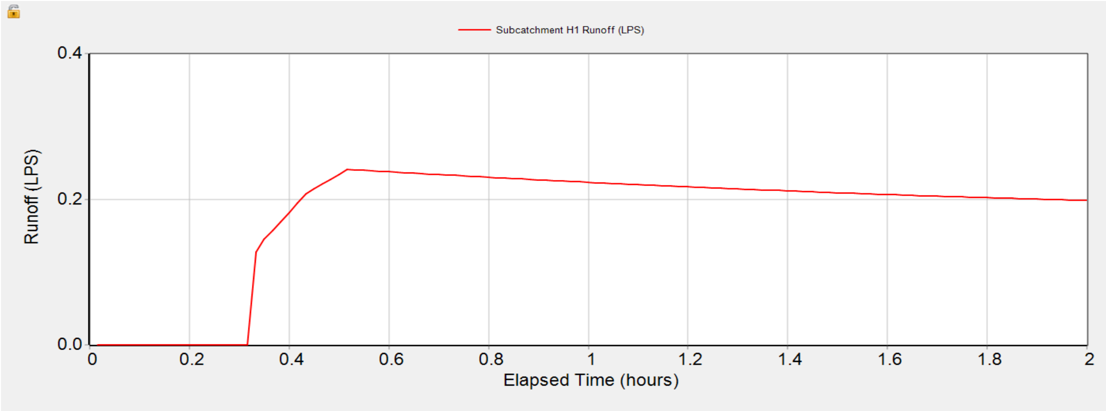

Fig. 3 Pipeline flow diagram after connecting the green roof

2.2.2 Analysis of the influence of rain garden on the amount of water in drainage pipe

By comparing Fig.4 and Fig. 5, it can be found that the addition of rain garden mainly reduces the maximum water flow significantly, from 4.7 LPS to 3.4 LPS. Although the effect is not as obvious as that of green roof, in view of the fact that only one roadside rain garden is built in the model, and the area is very small. Rain gardens can reduce maximum flow by 1.3 LPS. Rain gardens have been shown to slow the flow of water into drainage pipes and thus relieve pressure on drainage systems during storms.

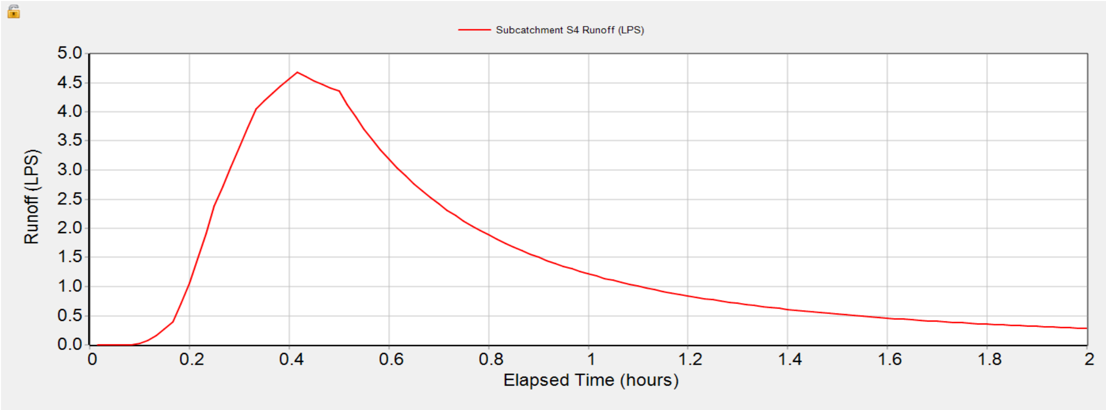

Fig. 4 Flow diagram of pipe before connecting rain garden

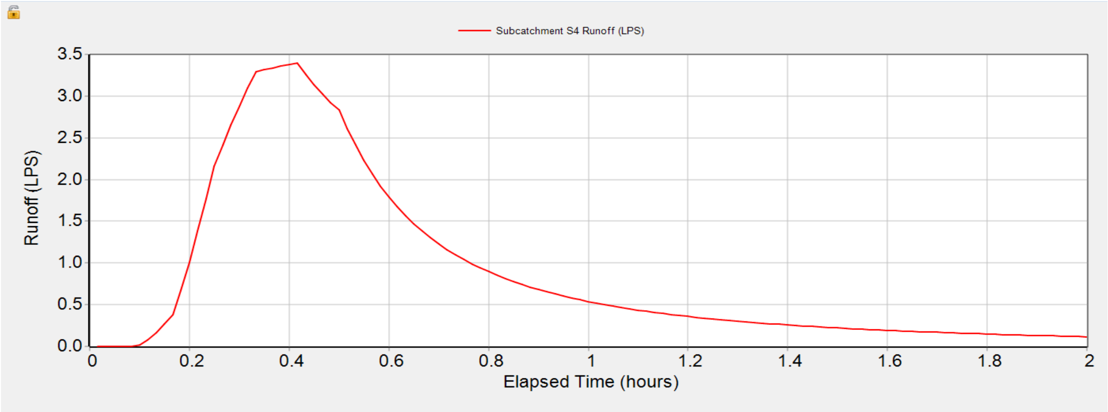

Fig. 5 Pipeline flow diagram after connecting rain garden

2.2.3 Analysis of the influence of reservoir on the flow in drainage pipe

The comparison between Fig. 6 and Fig. 7 shows that the reservoir has no significant effect on the flow rate. The analysis found that the reason for this is that the rainfall intensity is not large enough. When the intensity of the rainfall is increased to three times, the discharge is almost zero. Therefore, it can be concluded that the reservoir can only regulate the rain in extreme conditions, and not show much effect when the intensity of the rainfall is not strong enough.

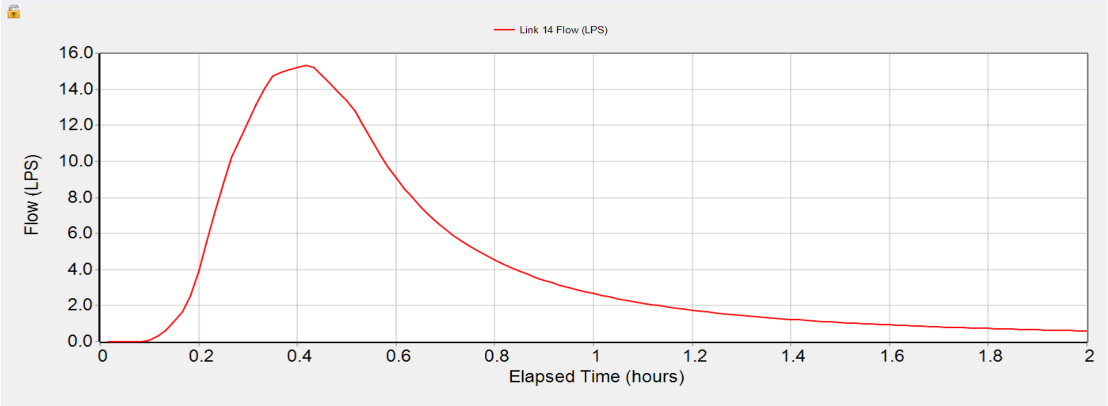

Fig. 6 Pipeline flow diagram prior to reservoir connection

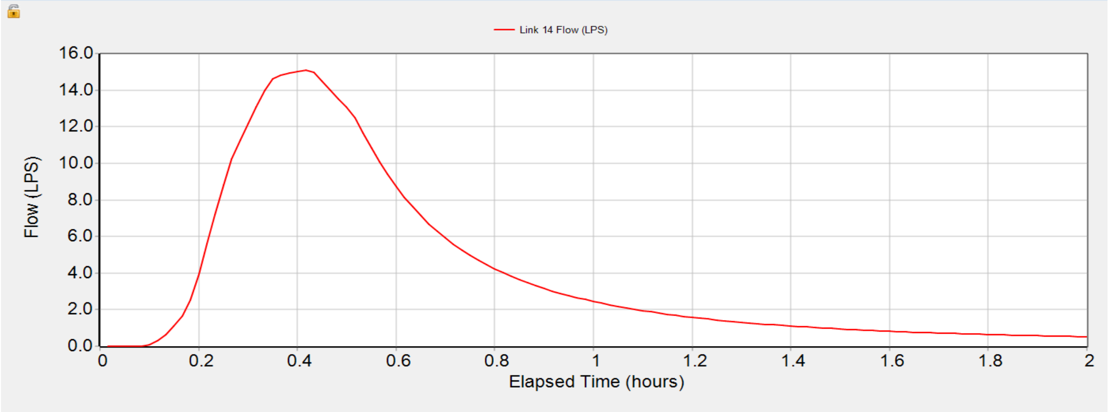

Fig. 7 Pipeline flow diagram after connecting reservoir

2.3 Discussion

Finally, Sankey diagram, as shown in Fig.8, is used to summarize the effect of these three methods on alleviating drainage system. Based on the analysis of the experiment, it is concluded that the green roof has the greatest impact on the three data: the time of water flow, the highest discharge and the duration of drainage. The cisterns, although of little use at this intensity, can play an important role in heavier rainfall. Finally, rain gardens can only be built on a small part of the road, so the impact will not be very large. From these three conclusions, it can be concluded that green roofs and cistern play the most important role, and rain gardens play the least role.

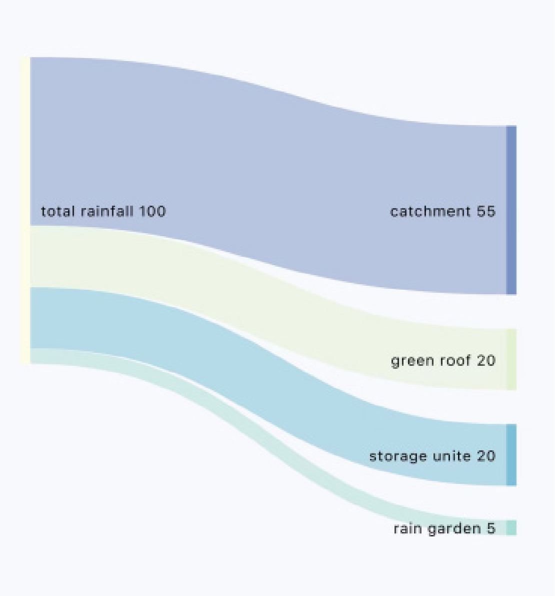

Fig. 8 Sankey diagram

3. Conclusion

This paper analyzes the data obtained by SWMM model by using comparative method, and draws the following main conclusions:

(1) Roof greening, rain garden and water reservoir have different relieving effects on drainage system pressure, among which roof greening has the best effect, followed by rain garden and water reservoir.

(2) The effect of the rain garden is limited by the size of the rain garden, and the reservoir has little effect on this rainfall level. However, if the rainfall intensity continues to increase, the reservoir can play the role of emergency water storage. When designing the model data, the key data affecting the experimental results should be taken into account. In future studies, the advantages of these three methods can be more comprehensively analyzed and compared.

(3) In the current research field, experiments mainly focus on model analysis. Since there is no large-scale practical application, the conclusions drawn may be biased.

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