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A Peak Runoff Reduction Analysis of Drainage-Linked Permeable Pavement

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Abstract: Extreme rainfall events are increasing due to climate change, and the expansion of impervious surfaces caused by rapid urbanization is significantly increasing surface runoff, becoming a key cause of flooding and flash flooding in urban watersheds. Consequently, low-impact development (LID) technologies are being actively adopted as a means to restore healthy urban water cycles.Permeable pavement, in particular, is a technology that effectively manages stormwater runoff by reducing impervious surfaces while simultaneously performing road functions. It is widely applied in new towns and developing areas. However, performance evaluations to date have primarily focused on the permeability coefficient of the pavement material itself, and comprehensive water cycle performance evaluations of the entire permeable pavement system, including its integration with catchment wells, remain lacking.In this study, we conducted a simulated rainfall experiment to compare the runoff characteristics of two types of permeable pavement: Type A, which is a storage type that drains rainwater through surface runoff when fully saturated because runoff from the subbase is impossible, and Type B, which is a permeable pavement connected to a collection well that allows drainage through infiltration from the subbase and also allows drainage to the collection well through surface runoff.The experimental results showed that the on-site surface infiltration rate met the Seoul Metropolitan Government's permeable block permeability management standards for Grade 3 infiltration rates of 0.1–0.5 mm/s after contamination. This suggests that permeable pavement with integrated catchment wells could be applied in flood-prone areas in the future.

Keywords: Extreme Events, Climate Change, LID, Permeable Block, Sustainability

I. Introduction

Climate change is increasing impervious surfaces, reducing the natural infiltration of rainwater and negatively impacting urban water cycles. These changes increase surface water runoff, leading to increased peak runoff and faster runoff times, exacerbating the risk of urban flooding and flash flooding and contributing to water resource depletion [1-3]. Furthermore, the high imperviousness of roads and pavement surfaces and the resulting increased runoff coefficients allow pollutants to flow directly into rivers, deteriorating river water quality [4,5]. Existing urban rainwater management facilities, excluding new towns, were built to design standards prior to climate change and urbanization. Consequently, new urban development and redevelopment areas require rainwater management techniques capable of managing heavy rainfall during climate change-related events. Low-Impact Development (LID) is emerging as a promising approach. LID is a development technique that maintains urban functions while minimizing impacts on natural water cycles by maintaining infrastructure. Key technologies include green roofs and permeable pavement, which increase rainwater infiltration and retention, thereby reducing peak flow and runoff and enhancing the integrity of urban water cycles. Permeable pavement effectively improves water cycles by allowing rainwater to infiltrate the ground through pores in the material, reducing runoff and promoting ground infiltration. In particular, retention-type permeable block pavement creates a retention layer within or beneath the block, temporarily storing rainwater before gradually allowing it to infiltrate into the subsurface. This technology is gaining attention as a way to overcome the limitations of conventional impermeable pavement, which is surface runoff. This method effectively reduces runoff in urban areas during heavy rainfall by storing rainwater and allowing it to infiltrate underground.Korean studies have primarily focused on total runoff reduction and peak runoff reduction compared to impervious surfaces, and hydrological analyses using SWMM models for permeable blocks and pavements. International studies have primarily analyzed changes in permeability and storage capacity according to the characteristics of permeable blocks. While these studies have contributed to elucidating the individual performance factors of permeable pavements, there is a dearth of quantitative comparative analyses of the water circulation improvement effects of LID technologies or their integration with stormwater management facilities. Therefore, this study aims to analyze the effects of permeable pavements and permeable pavements integrated with catchment wells, which allow rainwater to infiltrate from the subbase to the catchment well, on water circulation improvement.

II. Experimental Section

Permeable pavement Type A and Type B were constructed at two locations at the outdoor parking lot-type permeability performance verification facility of the Korea Green Infrastructure Low Impact Development Center located on the Yangsan Campus of Pusan National University. As shown in Fig. 1, the two permeability performance evaluation facilities consist of concrete boxes measuring 10.85 m in length and 0.9 m in height, and the surface slope of the pavement is 1%. Permeable pavement Types A and B consist of an impermeable surface on top of which 5 cm of sand (medium sand), a 40 cm layer of crushed stone, and identical permeable blocks are installed. Type A does not allow for bottom runoff and is drained through surface runoff, while Type B is installed with a structure that allows infiltration through a subbase layer connected to a sump.

Figure 1: Size of the LID parking experiment

Figure 2: Photographs of type A and B

III. Results

In this study, we conducted a simulation experiment to compare the runoff characteristics of two types of permeable pavements: Type A, which is a storage type that drains rainwater through surface runoff when fully saturated because runoff from the subbase is impossible, and Type B, which is a permeable pavement connected to a sump that allows drainage through infiltration from the subbase to a sump and also allows drainage to the sump through surface runoff. The areas of permeable pavements A and B are 2.3 m wide, 10.85 m long, and 24.955 cm in area, and the same type of blocks were used, with the specifications being square blocks with width, length, and height of 200 mm X 200 mm X 80 mm, and joints were constructed between the blocks.

Table 1: Information of Type A and B

Properties	Type A	Type B
Size (mm)	200 × 200	200 × 200
Depth (mm)	80	80
Material void Raitio	0.22	0.22
Surface Permeablility Coefficient (mm/s)	6.4	6.4

The void ratio of the constructed block was measured to be 0.22, and the absorption rate per product, derived by measuring the air-dry weight, water weight, surface dry weight, and absolute dry weight, was measured to be 6.4 mm/s. In addition, using the ASTM C 1701 shingling method (Fig. 4), 3.6 L of water was added to 1, 2, and 4 joint intersections as a pre-wetting process. If the time for the water to disappear from the surface is less than 30 seconds, the test is conducted with 18.0 L, and if it is more than 30 seconds, the test is conducted with 3.6 L. The test is conducted twice and the average value of the two values is measured, and Test 2 is conducted within 5 minutes after completing Test 1. The measured field surface infiltration rates were 0.1727 mm/s for Type A and 0.1793 mm/s for Type B, which satisfies the regulation of 0.1–0.5 mm/s after contamination, which is the 3rd grade infiltration rate of the Seoul Metropolitan Government's permeable block permeability performance management standards [4]. Tables 1 and 2 below show the physical characteristics of the permeable blocks and the results of the field surface infiltration rate experiment, respectively.

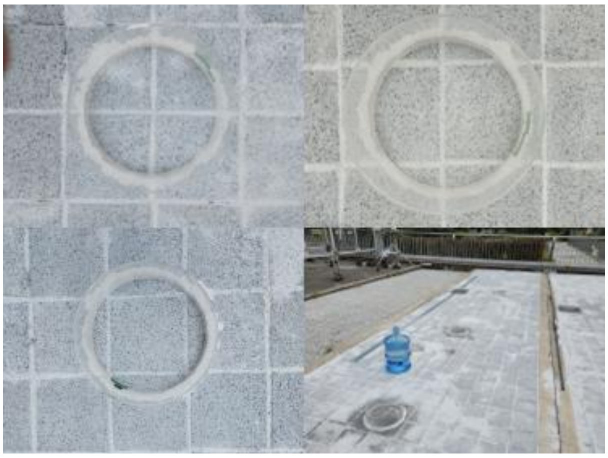

Figure 3: ASTM C 1701 Single Ring Test

Table 2: Results of field test

Test-bed Type	Joint Count	Pre-wetting (sec)	Test1 (sec)	Test2 (sec)	Average (sec)	Surface Permeability Coefficient (mm/s)	Average Surface Permeability Coefficient (mm/s)
Type A	1	370	507	579	543	0.116	0.1727
	2	175	211	265	238	0.268	
	4	251	401	567	484	0.134	
Type B	1	170	216	257	236.5	0.268	0.1793
	2	335	424	535	479.5	0.133	
	4	288	512	512	463.5	0.137	

IV. Conclusion

The increase in impervious surfaces due to accelerating urbanization is increasing surface runoff, becoming a major cause of flooding and flash flooding in urban watersheds. To address this issue, low-impact development (LID) technologies are being applied to urban watersheds to improve water circulation and reduce flood damage. Among various LID technologies, permeable pavement can reduce impervious surfaces while maintaining the functionality of existing roads, making it a key measure for preventing urban flooding in new towns and developing areas. However, current performance evaluations of permeable pavement have primarily focused on single-site performance evaluations and SWMM models. Empirical research on the runoff reduction effects of integration with other facilities is lacking.The experimental results showed that the on-site surface infiltration rate met the Seoul Metropolitan Government's permeable block permeability management standards for Grade 3 infiltration rates of 0.1–0.5 mm/s after contamination. This suggests that permeable pavement with integrated catchment wells could be applied in flood-prone areas in the future.

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