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Evaluation of two road right-of-way stormwater control technologies

Évaluation de deux technologies de contrôle des eaux pluviales sur l'emprise routière

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RÉSUMÉ

Cette étude d'évaluation sur le terrain a évalué la réponse hydrologique d'une ruelle en béton à Toronto, Ontario, Canada modernisée avec (1) un nouveau système d'aménagement à faible impact au niveau de la rue appelé Cupolex®, une arcade de dômes en plastique recouverts de béton système de rétention des eaux pluviales qui fait partie du volume de chaussée en béton; et (2) un pavé en béton imbriquable perméable (PICP). Un protocole de surveillance spécial a été élaboré pour l'étude sur la base des lignes directrices recommandées localement. Sur la base de huit précipitations entre mai et juillet 2020, il a été constaté qu'un % de profondeur de ruissellement et un taux de ruissellement de pointe se réduisent entre 90,6 % et 100 % à 100 % respectivement pour Cupolex®. Les résultats du PICP ont révélé une réduction de la profondeur de ruissellement et du taux de ruissellement de pointe comprises entre 35 % et 67 % et entre 4 % et 85 % respectivement. Le rendement du PICP peut être attribué aux conditions de faible perméabilité du sol et aux caractéristiques de conception telles que l'absence d'un système de drainage souterrain. Dans l'ensemble, le contrôle du ruissellement de Cupolex® était excellent compte tenu des événements observés et a fourni une compréhension de base de son rendement pour une mise en œuvre future. D'autres recherches devraient être axées sur la surveillance à long terme et l'élaboration de modèles de gestion des eaux pluviales pour la prévision du rendement dans différentes conditions de conception.

ABSTRACT

This field assessment study focused on the hydrologic response of a concrete laneway in Toronto, Canada retrofitted with (1) a new street-level low impact development system called Cupolex®, an arcade of concrete-covered plastic domes stormwater detention/retention system which forms part of the concrete pavement; and (2) a permeable interlocking concrete pavers (PICP). A special monitoring protocol was developed for the study based on local recommended guidelines. Based on eight rainfall events between May to July in 2020, it was found that % runoff depth and peak runoff rate reductions were between 90.6% to 100%, and 94% to 100% respectively for Cupolex®. The monitoring results for PICP revealed % runoff depth and peak runoff rate reductions between 35% to 67%, and 4% to 85% respectively. The performance for PICP may be attributed to the low permeability soil conditions and design features such as absence of a underdrain system. Overall, the runoff control of Cupolex® was excellent under the events observed and provided a baseline understanding of its performance for future implementation. Further research should focus on long-term monitoring and further development of stormwater management models for performance prediction under different design conditions.

KEYWORDS

Stormwater management, runoff control performance, road right-of-way

1 INTRODUCTION

Decentralized stormwater systems such as low impact development (LID) manage urban runoff locally and create environmental benefits (Cadavid & Ando 2013). Stormwater management of highly urbanized areas is challenging due to limited space, complex underground utilities, and lack of effective technologies. To overcome these challenges, emerging low impact development (LID) technologies have been developed (Li *et al.* 2015, 2021) and tested in several highly urbanized areas in Canada. This extended abstract reports the field performance of two LIDs retrofitted to a highly urbanized laneways in Toronto, Canada.

The first LID, termed CUPOLEX[®], is a concrete forming system (plastic domes) that interlocks and connects to each other, creating an underground water detention/retention system over the entire space of the road pavement (Pontarolo Engineering 2017). It utilizes the subsurface space where road base would have been in a conventional concrete pavement. Once runoff enters the system, it disperses itself over the native soil layer beneath. Thus, it utilizes both the underground space and the soil beneath to detain and/or retain runoff while its above ground use can still function as a roadway for transportation.

The second LID is a permeable interlocking pavers (PICP), composed of 80 mm concrete pavers with joint spaces of 10 mm. The joints were filled with aggregate materials, which were also used for the 50 mm bedding below the pavers. A 450 mm clear stone base layer, called 'Granular A' was found below which provides both structural support and water storage. No underdrain was constructed beneath the PICP.

The following sections describe the methodology, monitoring results, and data analyses. Details of this study can be found in Maglalang (2022).

2 METHODOLOGY

The monitoring methodology was adapted from 'Lessons Learned : CVC Stormwater Management and Low Impact Development Monitoring and Performance Assessment Guide (CVC 2015). The objective of the field monitoring study was to evaluate the runoff quantity control performance of CUPOLEX[®] and PICP while the control being a conventional concrete pavement along a highly urbanized laneway in downstream Toronto. After reviewing background information (e.g., soil type, natural features and landscape and the retrofit design of the laneway), the monitoring locations, measurement parameters and equipment were determined. Collected data were processed for analyses and conclusions were drawn.

2.1 Site description

Fig. 1 shows the retrofit site and monitoring equipment locations. The drainage area of the PICP and the conventional pavement sections (i.e., runoff to CUPOLEX[®]) are 393.5 and 326 m² respectively. For the PICP section, the runoff flows into CB2 (which has a 250 mm overflow pipe leading to the main sewer). Runoff from the conventional pavement enters CUPOLEX[®] through CB3 and Isolator Row (pre-treatment entrance vault of CUPOLEX[®]). The calculated storage volume of CUPOLEX[®] and PICP were 38 and 10 m³ respectively

2.2 Monitoring locations and equipment

Monitoring took place between May and July 2020. In the PICP section, runoff was measured at CB2 using a HOBO U20 level logger paired with a 250 mm Thel-Mar volumetric weir. For the conventional pavement section, runoff entering CB3, and ultimately the isolator row, was measured using one Global Water WL16 level logger at CB3 and two HOBO U20 level loggers at the isolator row. Two 150 mm Thel-Mar volumetric weirs were installed in the transfer pipes connecting the isolator row and CUPOLEX[®] to measure inflow into CUPOLEX[®]. There was a subdrain perforated pipe beneath the domes which collects the dome outflow into MH3. From MH3, a 150 mm overflow pipe is connected to CB4 that leads to the main sewer flowing north. A HOBO U20 level logger and a 150 mm Thel-Mar volumetric weir were used to measure the CUPOLEX[®] overflow (i.e., the outflow from CUPOLEX[®]). At the southernmost end of the laneway, a HOBO RG3 tipping bucket rain gauge was installed to measure site precipitation. Logging intervals for all instruments were set to 1-minute intervals for consistency and post-processing of data. The three sections were separated by speed bumps to help isolating the runoff of each section according to its estimated drainage area.



Figure 1 : The retrofit site and the monitoring locations.

2.3 2.3 Data analyses

The PICP (i.e., CB1 to CB2), the control conventional pavement (i.e., CB2 to CB3), and the CUPOLEX® section (i.e., CB3 to CB4) of the laneway have different drainage areas. Thus, the measured runoff volumes and peak rates of PICP at CB2, the control conventional pavement sections at CB3, and the CUPOLEX® section at MH3 were normalized by each drainage area, resulting in per unit area basis (i.e., mm and mm/hr). Measured runoff values (i.e., volume and peak runoff rate) of PICP and CUPOLEX® (i.e., at CB2 and MH3) were compared to those of the conventional pavement section (i.e., at CB3) to analyze the runoff control performance of the PICP and CUPOLEX®.

3 RESULTS

Pre-construction soil analyses indicated that the underlying soil of the site was clayey-silty type with the average soil saturated hydraulic conductivity ranging from 0.045 to 1.365 cm/day. From May to July 2020 a total of 8 rainfall events (total 67.6 mm) were measured with rainfall depths and peak runoff rates ranging from 4.6 to 14 mm and 12 to 108 mm/hr respectively. Based on the Toronto's intensity-duration-frequency curves, all the monitored rainfall events were all under the 2-year return period.

Table 1 summarizes the % runoff control performance of PICP and CUPOLEX® of the 8 monitored events. It can be seen that the PICP reduced runoff depths and peak runoff rates from 35-67% and 32-85% respectively. On the other hand, the % runoff depth and peak runoff rate reduction of CUPOLEX® ranged from 91-100% and 94-100% respectively.

4 CONCLUSIONS

Conclusions drawn from these case studies are:

1. The runoff reductions of PICP were lower than those of previous studies with silty clay subsoil (TRCA 2015) due to the absence of an underdrain. Saturation of the pore space of the PICP during rainfall reduced the infiltration rate of PICP, resulting in low runoff control performance.
2. The runoff reductions of CUPOLEX® were excellent due to the ample storage capacity created by the plastic dome beneath the concrete top layer.

It is recommended that future monitoring of CUPOLEX® be extended to four seasons and at least 15 rainfall events. Additional hydrologic data are needed to support the development of runoff control models for system

performance prediction of different hydrologic conditions.

Table 1: Summary of system performance of PICP and CUPOLEX®.

Date	Duration of Rainfall Event (minutes)	Total Rainfall Depth (mm)	% Runoff Depth Reduction		% Runoff Rate Reduction	
			PICP	CUPOLEX®	PICP	CUPOLEX®
28-May	143	4.6	47	100	85.4	100
02-Jun	29	10	36.6	100	58	100
05-Jun	43	9.2	50.2	100	55	100
10-Jun	65	4.8	57.9	100	4.7	100
10-Jun	171	10.6	66.2	100	57.3	100
08-Jul	67	14	35.3	100	38.5	100
11-Jul	112	8.8	67.1	90.6	23.1	94
16-Jul	41	5	56.4	100	31.9	100
Median			53%	100%	47%	100%

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