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Research article

In-situ infiltration performance of different permeable pavements in a employee used parking lot – A four-year study

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ABSTRACT

Permeable pavements are being adopted as a green solution in many parts of the world to manage urban stormwater quantity and quality. This paper reports on the measured in-situ infiltration performance over a four-year period since construction and use of three permeable parking sections (permeable pavers, permeable concrete and permeable asphalt) of an employee car parking lot. There was only a marginal decline in infiltration rates of all three pavements after one year of use. However, between years two to four, the infiltration rates declined significantly due to clogging of pores either by dry deposition of particles and/or shear stress of vehicles driving and degrading the permeable surfaces; during the last two years, a greater decline was also observed in driving areas of the parking lots compared to parking slots, where minimal wear and tear are expected. Maintenance strategies were employed to reclaim some of the lost infiltration rate of the permeable pavements to limited success. Despite this decline, the infiltration rates were still four to five times higher than average rainstorm intensity in the region. Thus, these permeable pavement parking lots may have significant ecological importance due to their ability to infiltrate rainwater quickly, reduce the runoff in the catchment area, and also dampen runoff peak flows that could otherwise enter the collection system for treatment in a combined sewer area.

1. Introduction

Since the early 19th century, most urbanized areas capture and convey wastewater via a networked collection system. Many areas accommodate both stormwater and wastewater in combined sewer systems (Scholz and Grabowiecki, 2007). Population growth and urbanization have resulted in increases in impervious areas in the last three decades in many cities. This, along with changing weather patterns throughout the world, has led to tremendous impacts on local hydrology as urban areas shed more water as runoff, thereby rendering the old combined sewer systems inefficient and undersized. Additionally, many water reclamation plants (WRPs) that serve combined sewer systems need capacity expansions to treat this additional water. The upgrades needed to accept all the generated water, as well as treat the water in the centralized WRPs, are very costly.

In Chicago, Illinois, development and urbanization have altered the drainage system resulting in greater volumes of stormwater runoff and flashier storm peaks, which overwhelm the capacity of combined sewers and cause localized flooding, flow surge to the downstream WRPs, and combined sewer overflows to receiving waters. In order to minimize the impact of urban stormwater runoff pollution and the costs of control associated with wet-weather flows, stormwater runoff volumes and pollutant loads must be reduced through stormwater management. Recently, focus is shifting from 'end-of-pipe' traditional drainage systems to more sustainable drainage systems often referred to as 'Green infrastructure' (GI) for managing stormwater runoff. The impact of GI is most commonly evaluated in terms of its ability to reduce the total volume of stormwater and peak flow or delay the arrival of water that reaches the sewer system and subsequently the WRPs and receiving surface water bodies. Reducing the peak flow is also advantageous in terms of potential subsequent reduction in combined sewer overflows and localized flooding. A final benefit may also be realized by reducing pollutants being conveyed to surface water bodies via WRPs hence reducing the impact of the 'first flush' effect that is commonly associated with urban runoff (Rajapakse and Ives, 1990; Andersen et al., 1999; Drake et al., 2014; Mullaney and Lucke,

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2014). These GI technologies have shown reductions in the concentration of suspended solids, biochemical oxygen demand, ammonia, hydrocarbons, and mineral oil in stormwater (Baladès et al., 1995; Pratt et al., 1999; Bean et al., 2007; Drake et al., 2014).

The general principle behind the idea of GI technologies, and permeable pavements in particular, is simply "collect, treat, and freely infiltrate stormwater to recharge groundwater" such that the stormwater bypasses the collection system sewers. In comparison to traditional drainage systems, GI technologies are deemed sustainable and are often cost effective for urban areas.

Permeable pavements are one such GI technology that is being adopted to manage stormwater in many urban areas in both Europe and the United States (Baladès et al., 1995; Brattebo and Both, 2003; Bean et al., 2004; Scholz and Grabowiecki, 2007; Mullaney and Lucke, 2014). The infiltration performance throughout the service life of permeable pavement is of important significance as entrapment of fine particulate matter (both organic and inorganic) in the pores of the pavement surfaces may cause irreversible reduction of water permeability (Borgwardt, 2006; Scholz and Grabowiecki, 2007; Sansalone et al., 2012; Yong et al., 2013) and ultimately reduce their effectiveness. Nevertheless, these permeable pavement systems may have significant impact on the runoff process. Even if part of the rainfall is retained, this part is not added to the total runoff entering the collection system. A reduction in runoff peaks can also occur because of the pavement's delaying effects (Borgwardt, 2006). Lee et al. (2010) and Montalto et al. (2007) conducted a cost-effectiveness analysis on stormwater best management practices and showed that permeable pavements were most cost effective in managing runoff, reducing peak flows and delaying peak runoff time as compared to green roofs and traditional storage basins and traditional drainage systems.

The research reported herein involved the evaluation of three different kinds of permeable pavement installed into sections of a parking lot at the Stickney WRP of the Metropolitan Water Reclamation District of Greater Chicago (MWRDGC). The pavements used were (i) permeable asphalt, (ii) permeable concrete, and (iii) permeable pavers. This research reports the temporal changes in water infiltration into these respective permeable pavements since their construction and four years of use as well as spacial differences in infiltration rate changes that have occurred in different sections of the pavements that have undergone different degrees of use.

2. Site description and methods

2.1. Description of permeable pavements in parking lots of MWRDGC's Stickney WRP and site description

The permeable parking surfaces that were constructed on the existing employee parking facility measure approximately 245.8 m × 82.1 m in total (Picture 1). The existing parking facility had six sections. The easternmost section was divided into two with a ~6 m grassed median separating the two sections with a permeable pavers lot on the south side and a permeable concrete lot on the north side. The permeable asphalt lot was located on the southern half of the 3rd from the westernmost parking section. Each parking section is separated by a 6 m wide grassed median, with through traffic moving east-west between different sections at the north side of the parking sections. The actual sizes of the permeable parking lots and number of parking stalls in each lot are given in Table 1. There are 43, 38, and 23 parking slots in permeable pavers, permeable concrete, and permeable asphalt lots, respectively (Table 1). The permeable pavers' lot receives minimum traffic, as it is used to park the MWRDGC's pollution control full-size vans and small utility vehicles with, on average, only less than 40% of the slots filled and minimum in-out traffic during the day. However, these vehicles are bigger and heavier as compared to the passenger cars used by employees. On the other hand, all slots in the permeable concrete and permeable asphalt lots are always full throughout the working days during the year. In general, MWRDGC employees park their cars for the 8.5-h work day, and only ~10% of the cars may be moved in and out during the day with employees going out during lunch break. The permeable concrete and pavers lots do not have through traffic; cars enter and leave from the same direction. The permeable asphalt lot has regular asphalt on the north side without any physical barrier in between but is sloped in

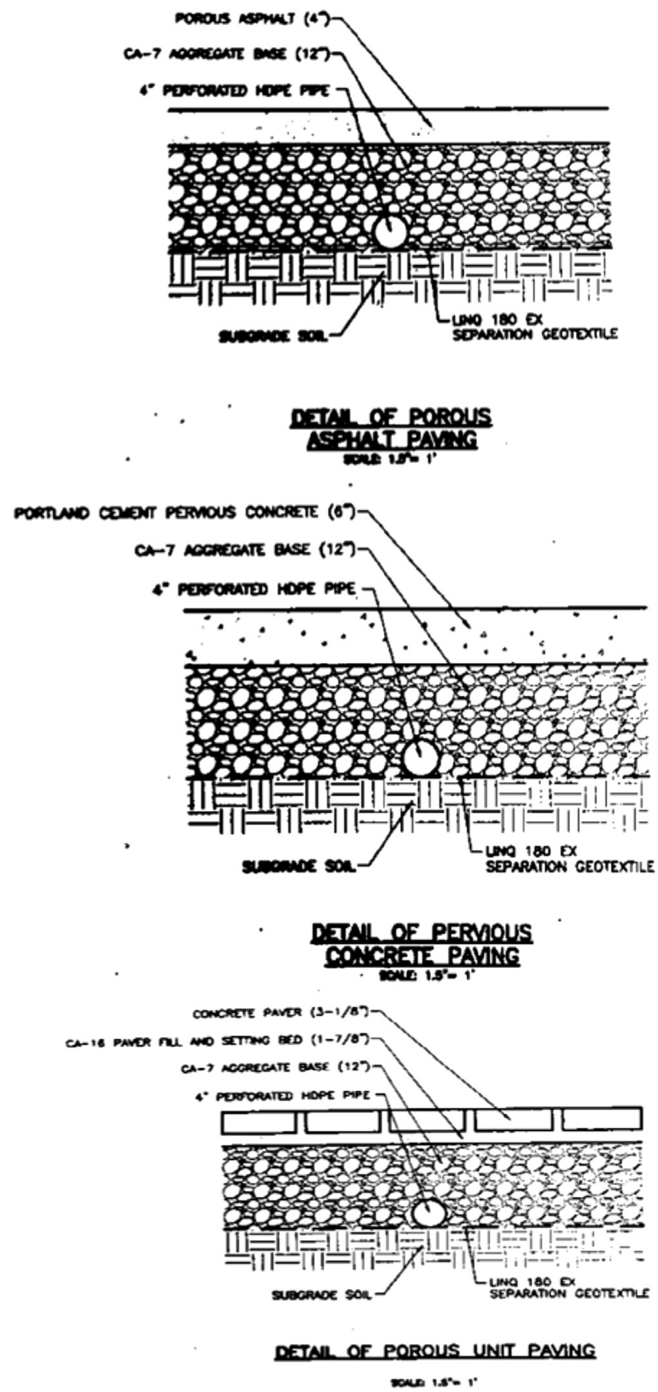

Fig. 1. Design details of the permeable pavers, permeable concrete and permeable asphalt lots of the parking lot at the Stickney Water Reclamation Plant.