

Long Term Monitoring of the Environmental Impact of Winter Maintenance Practices on Permeable Interlocking Concrete Pavements

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Abstract :

Increases in imperviousness is an undisputable outcome of urbanization. Converting as little as 10% of a catchments surface area to impervious cover generates significant changes in runoff quality and quantity [1].Sustainable stormwater systems such as Permeable Interlocking Concrete Pavements (PICP) that follow the principles of Low Impact Development (LID) have been effective in reducing the concentration of many urban pollutants including suspended solids, dissolved solids, nutrients, hydrocarbons and heavy metals [2]. Thus, municipalities across the world are supportive of the use of permeable paver blocks for source control of urban pollutants. In cold climates, hardscape surfaces are subjected to a variety of winter operation and maintenance practices. Salting, plowing, sanding and freeze-thaw cycles lead to gradual degradation of all pavements [3]. In Canada, approximately 5 million tonnes of road salt are applied each winter. Chloride from the road salt has high mobility in water and soil. It passes through the pavement reservoir to storm sewers and subsequently to streams, rivers and groundwater. Researchers [4]have observed that the average chloride concentration in parking lot runoff exceeded 5,000 mg/L, well above the recommended short and long term environmental limits by the US Environmental Protection Agency (EPA). Studies [5], [6] have observed chloride concentration in the permeable pavements effluent during spring and summer suggesting a possible delay in its release and containment of peak concentration in comparison to traditional asphalt surfaces. The specific conductivity of the effluent is an important indicator and can be used to estimate the chloride concentration. This research at the parking lot of Lake Street Service Center (LSSC), City of St. Catharines, Ontario, Canada monitors the specific conductivity of the PICP effluent over multiple years. Water samples were collected to develop a relationship curve between specific conductivity and chloride. This curve is used to quantify the chloride released in different seasons and to evaluate the chloride release delay provided by PICP in comparison to traditional asphalt. Application of de-icers pose a huge environmental challenge and this research provides the necessary evidence to study modifications in winter operational practices.

Key Words : chloride; concrete blocks; conductivity; permeable interlocking concrete pavements; permeable pavements; road salt; stormwater management

06_ Evalauation and Road Bearing Capacity

1. Introduction

Urbanization and increased impervious area drastically change the flow regime in watercourses by creating additional runoff volumes and larger peak flows. This causes stress on a city's stormwater infrastructure, resulting in a higher frequency of flooding, severe river bank erosions and water quality degradation, which negatively impacts the aquatic life in urban waterways. Permeable pavements (PPs) have proved to be an excellent tool for on-site stormwater management. There is an increasing support around the world for the use permeable pavements reflected by initiatives like China's Sponge City program and the 46% increase in pervious paver sales in North America between 2010 and 2015 [5]. The hydrologic benefits derived from PPs have been well established in the last two decades by researchers in North America [2], [7][9] which observed volume reductions of PP effluent ranging from 2575% in comparison to a control surface (i.e. traditional asphalt). Volume reductions provided by zero- infiltration PPs is smaller but large attenuation of peak flows is possible. Crookes et al. (2017) monitored a zero exfiltration Hydromedia® pervious concrete parking lot at the Lake Street Service Center (LSSC), St. Catharines and observed a total volume reduction of 46% from summer into the fall [10].

In cold climates, PPs are subjected to a variety of winter operation and maintenance practices. Salting, plowing, sanding and freeze-thaw cycles lead to gradual degradation of all pavements [3]. Winter operations like sanding lead to sand accumulation in the PP void space, resulting in a rapid degradation in the infiltration capacity of PPs over a single season [2]. Additionally, Drake et al. (2014) and Roseen et al. (2014) have observed that the winter stormwater quality differs from the water quality in spring, fall and summer months. Winter maintenance practices, like road salting and sanding, introduce a large amount of pollutants in the pavements which are ultimately collected by stormwater systems.

Chloride is introduced to a PP system through the high quantity of road salt applied throughout the winter. Once dissolved, the salt passes through the pavement reservoir and storm sewers into streams, rivers and groundwater. Houle (2008) observed chloride concentration in runoff from regular parking lots at the University of New Hampshire exceeding 5,000 mg/L. Since PPs infiltrate meltwater rapidly, they present an opportunity to reduce the amount of winter road salt applied to parking lot surfaces. Houle (2008) noted that an average annual reduction of 75% in salt use was possible for porous asphalt. Pavement color and shading were found to affect the salt usage. Drake et al. (2014) and Roseen et al. (2014) observed that PPs provide a temporary storage and buffering of chloride but do not provide a permanent removal of chloride from the infiltrated stormwater. The research presented in this paper attempts to bridge the gap between seasonal observations of chloride concentration and motivations to reduce application of road salts by monitoring the chloride released through different seasons and quantifying the buffering effect of chloride.

The objective of this study is to monitor and compare the long-term chloride released from Permeable Interlocking Concrete Pavement (PICP) in comparison to traditional asphalt in a zero-exfiltration system and quantify the chloride attenuation effect of PICP. This study is expected to lay the foundation of future research into reduction of regular road salts and testing of environmentally friendly de-icers to reduce the chloride concentration due to winter maintenance practices.

2. Method

The University of Toronto, in partnership with the Ontario Ministry of Transportation (MTO) and the City of St. Catharines, conducted a study to monitor the long-term chloride concentration between different PP effluent and traditional asphalt runoff. The experimental setup for this project is a seven-year-old parking lot at the Lake St. Service Centre of the City of St. Catharines (Figure 1 and Figure 2). The site consists of Porous Asphalt (PA), Pervious Concrete (PC) and PICP plots alongside an impervious asphalt plot that acts as control. The parking lot is built as a zero or no exfiltration site (i.e. the infiltrated stormwater for each PP is separately released from the outlet into a monitoring vault). The site has a very high traffic load during all times of the day, and no sediment removal maintenance is performed at the site. The results of long-term chloride monitoring and seasonal comparison between PICP and asphalt are presented in this paper.



Figure 1. Project location
(Mapping Source: Google Maps 2018)



Figure 2. Aerial view of parking lot site
(Mapping Source: Google Earth 2016)

2.1 Data Collection

The underdrain from the PICP area drains into a sampling catch basin, whereas surface flow from the asphalt area is conveyed to its catch basin through a short swale. Both catch basins are fitted with V-notch weirs (Figure 3). INW CT2X® smart sensors (Figure 3) are installed inside the weir box with the sensor head below the notch in the permanent pool of effluent water. CT2X® has a pressure transducer to measure water level upstream of the weir and a conductivity sensor, both of which are configured to collect measurements at 15-minute intervals. Grab water samples were collected from the PICP and asphalt effluent to develop a relationship between conductivity and chloride for each pavement. This relationship is used to interpret and analyze seasonal release of chloride.



Figure 3. V-notch weir (left) and INW CT2X conductivity sensor (right)

3. Results

Data was collected between January 12th, 2016 and June 12th, 2017. Specific conductivity values are used as a surrogate for chloride concentration. Thirty-seven water samples were collected from the effluent of each cell and laboratory analyses of the chloride and conductivity were performed at the Environmental Lab at the University of Toronto to derive a linear relationship between specific conductivity and chloride for each pavement (Figure 4). Due to the closure of a downstream valve from the asphalt catch basin during the monitoring period, there was a build-up of water and pollutants that lasted until Feb 5th, 2016 resulting high conductivity from the asphalt effluent. This was subsequently mitigated by opening the valve. Thus, only the conductivity results after Feb 22nd, 2016, which was after a precipitation event, were used for this analysis.

$$Asphalt(ASH): \quad [Cl^-] = 242.49\,[SC] \quad R^2 = 0.9288$$
$$Permeable\ Interlocking\ Concrete\ Pavement\ (PICP): \quad [Cl^-] = 315.27\,[SC] \quad R^2 = 0.9619$$

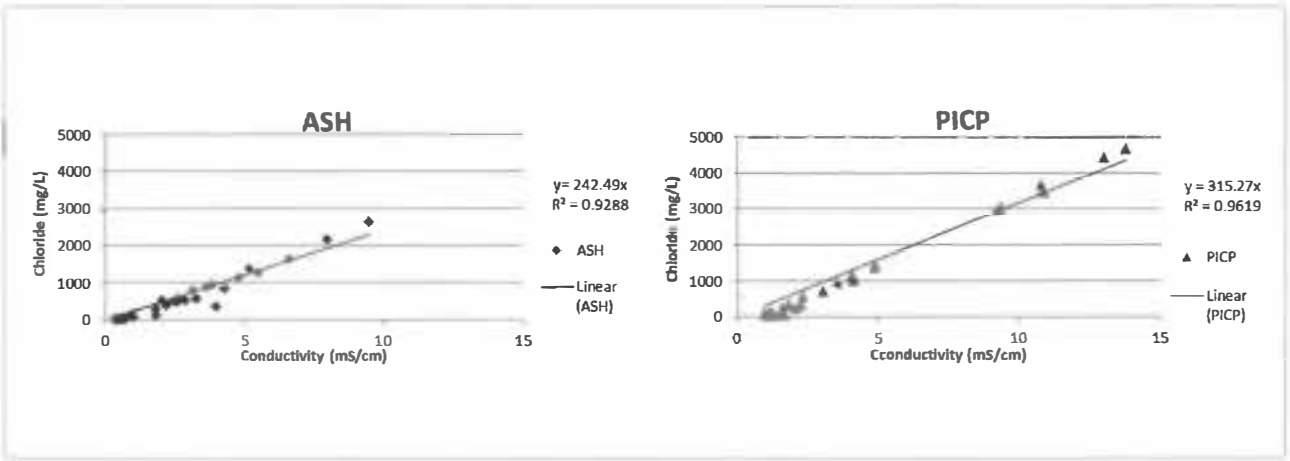

Figure 4. Chloride and conductivity relationship

3.1 Seasonal Analysis of Chloride Concentration

The United States Environmental Protection Agency (USEPA) has set forth the acute and chronic chloride concentration limits for drinking water as 830 mg/L and 250 mg/L. From the seasonal chloride concentration graphs and boxplots (Figure 5 and Figure 6) it can be observed that the winter chloride concentration (2015/2016 and 2016/2017) from asphalt was higher than PICP. Asphalt effluent had several high peak chloride concentrations, whereas PICP exhibited a muted response. Both the asphalt and PICP concentrations were higher than the regulatory limits however, PICP provided a buffering effect to the peak winter concentrations. It can be observed that PICP, unlike asphalt, continued to release chloride in spring, summer and fall seasons. The lowest chloride concentration was observed in September 2016 when PICP was still releasing chloride in the range of 400-500 mg/L and asphalt showed chloride concentration of ⟨100 mg/L. The year-long monitoring was suggestive that PICP did provide a buffering effect to chloride concentrations and released them throughout the year, whereas asphalt effluent showed peak chloride concentration of approximately 19,000mg/L (winter 2016-2017).

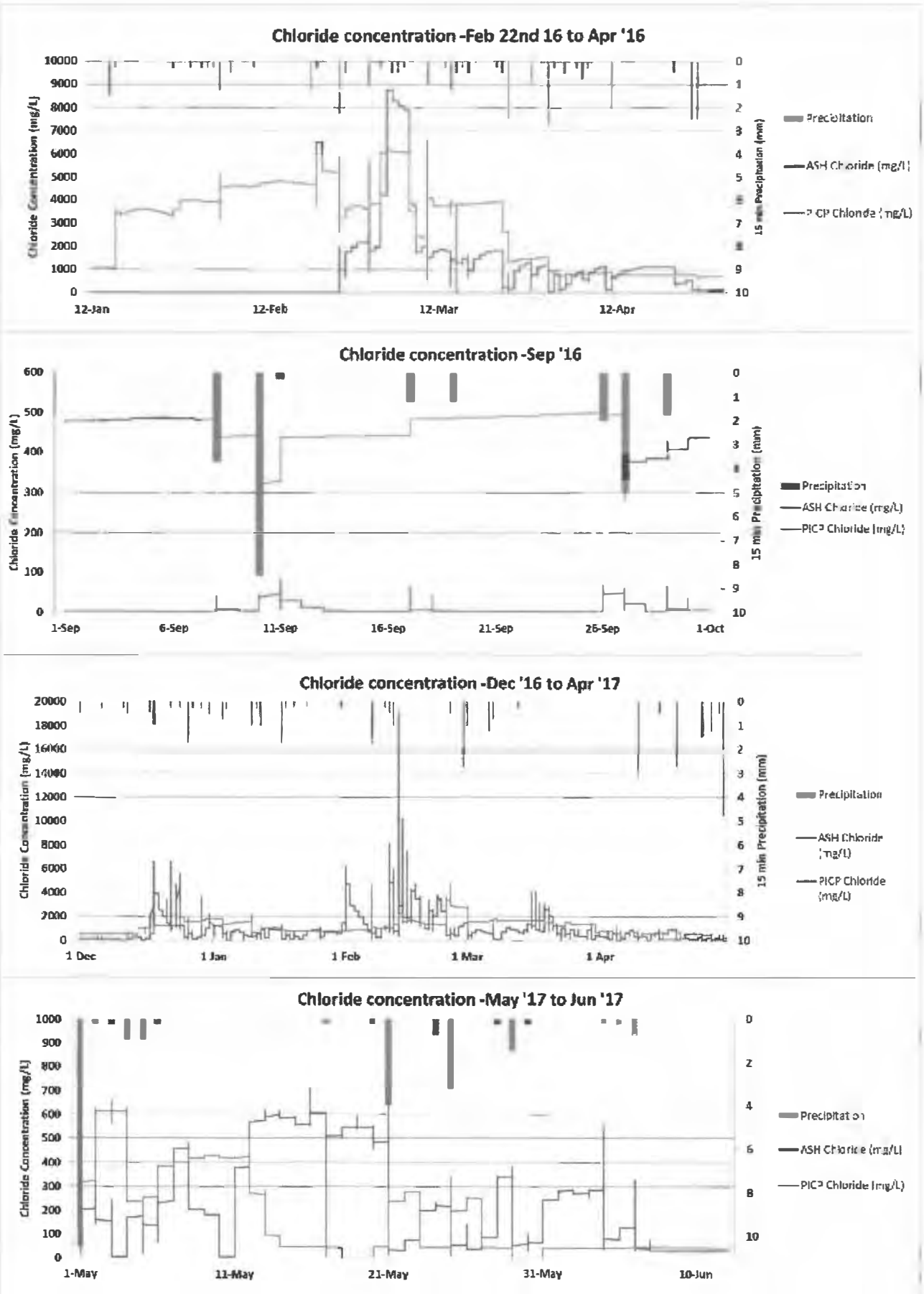

Figure 4. Chloride concentrations discharged throughout the year from PICP and asphalt

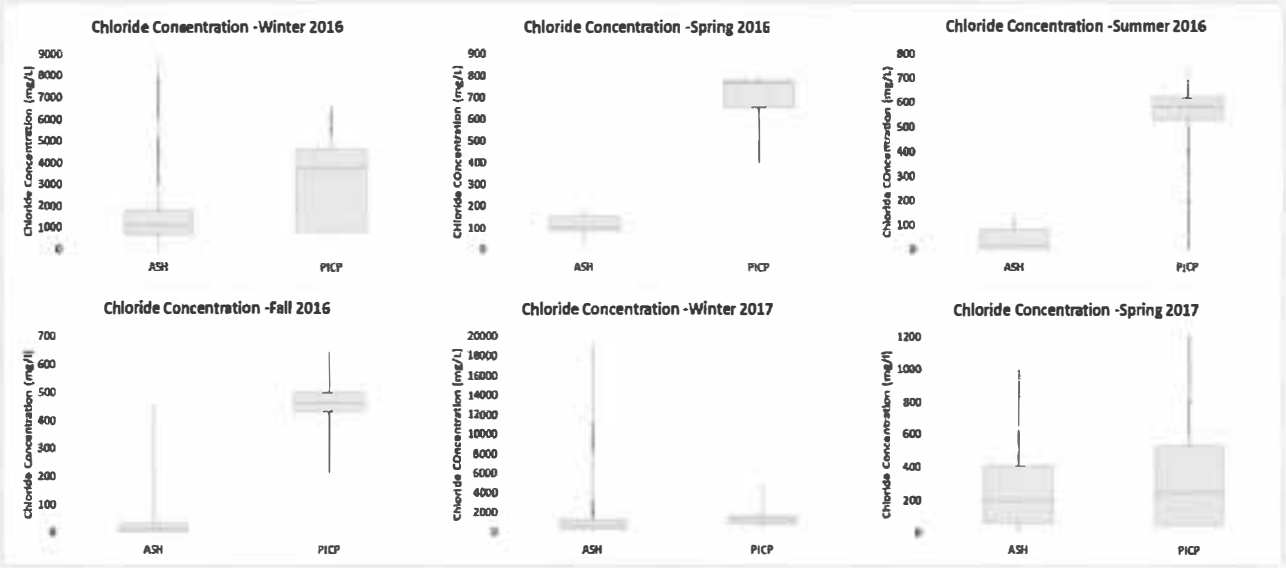

Figure 5. Seasonal comparison of PICP and asphalt

4. Conclusion

Paved surfaces include a large part of our urban environment, and LID based stormwater control measures are becoming popular across municipalities around the world. With the increase in impervious cover, safety concerns mandate the use of road salts against black ice formations. These salts ultimately enter our streams and rivers causing immense harm to freshwater ecosystems, soil, vegetation, aquatic life and wildlife. It is evident through this study that road salts contributed to a large concentration of chloride released to the environment, often above the recommended limits for both permeable pavement and impervious asphalt. Asphalt demonstrated very high peak concentrations during the winter thaw when chloride from the PICP was shown to demonstrate a buffering effect. Due to the non-reactive nature of chloride, there is no effective way to remove road salt from stormwater. Thus, the only reliable way to reduce chloride it to minimize the use of road by use of environmentally friendly de-icers and sustainable pavements like PICP that minimize the buildup of surface ice.

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Structural Evaluation of Block Pavements using Light Weight Deflectometer

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Abstract :

The block pavement has been widely used in urban area of Korea to mitigate the heat island effect, enhance the drainage function, and improve the aesthetic feature of city. Recently, the local government is willing to extend the application of block pavement to the roadway. For this purpose, the structural capacity of block pavement should be considered in design and construction stage for better performance and longer life. This study is intended to evaluate the structural capacity of block pavements using light weight deflectometer (LWD). The seasonal variation of surface deflection in block pavement hasbeen assessed using the field LWD testing results. Test results indicate that the deflections measured in block pavement 15 times higher than those in asphalt pavement. The structural capacity of subbase and subgrade in block pavement is generally low because of lack of compaction effort and low quality of materials. It is also found that the seasonal variation of LWD deflection in block pavement seems to be very high compared to asphalt pavement. This fact is because the materials used in subbase and subgrade is sensitive to seasonal change, the water can easily infiltrate into unbound layer through the block gap, and temperature change inside block pavement is very high.

Key Words : Block Pavement Structural Capacity Light Weight Deflectometer; Deflection

1. Introduction

The block pavement has been widely utilized in the sidewalk to mitigate the heat island effect, enhance the drainage function, and improve the aesthetic feature of city. Recently, the local government is willing to extensively apply block pavement to the roadway. Since a heavy loading of vehicle is applied in the block pavement, it is necessary to improve the strength of block and support of base and subgrade layer. For this purpose, the structural capacity of block pavement should be considered in design and construction stage for better performance and longer life. The objective of this study is to compare the deflection characteristics and seasonal variation of block and asphalt pavements using the Light Weight Deflectormeter (LWD) and Falling Weight Deflectometer (FWD).

2. Falling Weigth Deflectometer (FWD) and Light Weight Deflectometer (LWD)

FWD and LWD are the field testing equipments that can assess the structural integrity of pavement by applying a load to the pavement surface and measuring the resulting deflections. These equipments are normally used to determine the stiffness of pavement materials and evaluate the structural condition. Since the LWD is easy to operate and small enough to be used at any place, it is used to evaluate the structural capacity of block pavement in this study.A load can be applied up to 15kN using falling weights and deflections can be measured using geophones. It requires no reference and can be tested on both bound and unbound layers.