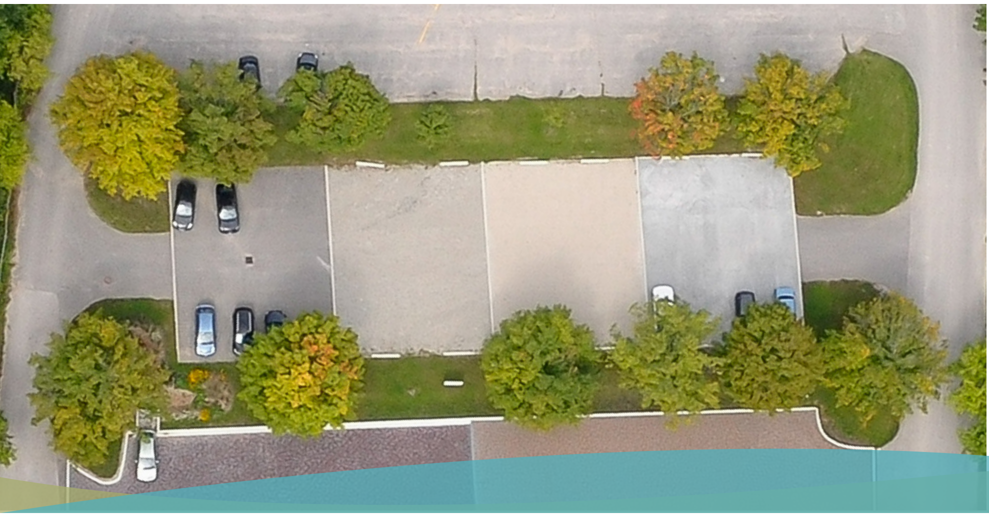
FIVE YEAR PERFORMANCE EVALUATION OF PERMEABLE PAVEMENTS

FINAL REPORT




Sustainable Technologies Evaluation Program
www.sustainabletechnologies.ca

Toronto and Region Conservation for The Living City
UNIVERSITY OF TORONTO

FIVE YEAR PERFORMANCE EVALUATION OF PERMEABLE PAVEMENTS – KORTRIGHT, VAUGHAN

Final Report

Prepared by:

Toronto and Region Conservation
and
University of Toronto

under the
Sustainable Technologies Evaluation Program

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PUBLICATION INFORMATION

This research was undertaken collaboratively between the Toronto and Region Conservation Authority's (TRCA) Sustainable Technologies Evaluation Program (project lead: Tim Van Seters, B.Sc, MES) and the University of Toronto, Department of Civil Engineering (project lead: Jennifer Drake, PhD). TRCA field and technical support was provided by Christy Graham, Kristina Delidjakova, Yuestas David, Matt Derro, Paul Greck, Amanda Slaght, Mark Hummel and Jacob Kloeze.

This project is an extension of a previous research project undertaken by the University of Guelph and STEP covering the first 22 months of monitoring at the Kortright permeable pavements research site. See the STEP web site for a copy of the earlier report entitled *Evaluation of Permeable Pavements in Cold Climates*.

Report citation: Van Seters, T, Drake, J. 2015. *Five year performance evaluation of permeable pavements*. Sustainable Technologies Evaluation Program, Toronto and Region Conservation Authority, Toronto, Ontario.

Reports conducted under the Sustainable Technologies Evaluation Program (STEP) are available at www.sustainabletechnologies.ca. For more information about this project or the STEP program, please contact:

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THE SUSTAINABLE TECHNOLOGIES EVALUATION PROGRAM

The Sustainable Technologies Evaluation Program (STEP) is a multi-agency program, led by the Toronto and Region Conservation Authority (TRCA). The program helps to provide the data and analytical tools necessary to support broader implementation of sustainable technologies and practices within a Canadian context. The main program objectives are to:

- monitor and evaluate clean water, air and energy technologies;
- assess barriers and opportunities to implementing technologies;
- develop tools, guidelines and policies, and
- promote broader use of effective technologies through research, education and advocacy.

Technologies evaluated under STEP are not limited to physical products or devices; they may also include preventative measures, alternative urban site designs, and other innovative practices that help create more sustainable and livable communities.

ACKNOWLEDGEMENTS

Financial support for the extended monitoring program, undertaken between July 2012 and December 2014, was generously provided by the Cement Association of Canada, the Interlocking Concrete Paving Institute and STEP program partners – Region of Peel, York Region and the City of Toronto. In-kind services for monitoring and research were provided by the University of Toronto.

The first phase of the project, undertaken between September 2010 and June 2012, was supported financially by the following organizations:

- Great Lakes Sustainability Fund
- Toronto and Region Remedial Action Plan
- Ontario Ministry of the Environment Best in Science Program
- Ontario Ministry of Transportation
- City of Toronto
- Region of Peel
- York Region
- Metrus Development Inc.
- Interlocking Concrete Paving Institute
- Aecon

In kind-donations of services and materials were generously provided by the following organizations.

- Urban Ecosystems Limited (Engineering consulting services)
- Brown's Concrete (Aquapave™)
- Unilock (Eco-Optiloc™)
- Lafarge (Ultra Pervious concrete)
- Hanson (sampling vault)
- Ontario Ministry of the Environment (laboratory services)
- Armtec (pipes)
- Condrain (construction services)
- Dufferin Aggregates (aggregate base)
- Layfield Plastics (liner)

EXECUTIVE SUMMARY

Permeable pavements treat pollutants from parking areas and low traffic roads by filtering runoff through voids in the pavement and base materials. The pavements may be designed for full, partial or no infiltration depending on the characteristics of the underlying native soils (*e.g.* permeability, soil quality). Poured pavements such as pervious concrete, allow water to infiltrate through the entire pavement matrix, while permeable interlocking concrete pavements (PICP) combine pre-cast pavers with open, gravel filled joints to promote infiltration.

This study of permeable pavements was conducted over a five year period at a custom designed field research facility constructed by Toronto and Region Conservation Authority (TRCA) in 2009 at the Kortright Center visitor's center parking lot in Vaughan, Ontario. The site consists of four 230–233 m^2 pavement cells. Two cells are constructed with permeable interlocking concrete pavers (AquaPave® and Eco-Optiloc®), one cell is constructed with Pervious Concrete (PC) and one cell is constructed with traditional asphalt. Each permeable pavement cell is drained by a perforated pipe. The asphalt cell is surface drained via a catchbasin in the center of the plot. Concrete curbs between cells prevent inter-mixing of flows.

The first phase of this study was conducted as part of a doctoral research study by researchers from the University of Guelph, in collaboration with the TRCA's Sustainable Technologies Evaluation Program. The overall objective of the initial research study, conducted between September 2010 and June 2012, was to evaluate the hydrologic, water quality and functional performance of different types of concrete permeable pavements under Ontario climate and geologic conditions. This initial study also examined the effectiveness of different types of permeable pavement cleaning equipment.

The second phase of the study, initiated in July 2012, extended the original study for another 2.5 years with the intent of documenting the direction and magnitude of changes in performance over time. The monitoring program included measurements of rainfall, outflow, water quality, water levels in the base and temperature. After nearly 5 years of monitoring, this project represents one of the longest continuous field monitoring data sets of permeable pavements in North America.

Study Findings

Results of this study indicate that permeable pavements are an effective practice for maintaining or restoring infiltration functions on parking lots and other low volume traffic areas, even in areas with low permeability soils. Key findings of the extended monitoring program include the following:

- ***Surface infiltration:*** The rate of infiltration through the surface of the three permeable pavements was initially very high but declined rapidly over the first two years as sediment accumulated in surface voids of the pavements. Vacuum cleaning in June 2012 partially restored permeability to the pavements. However, by December 2014, infiltration rates on the AquaPave® (AP) and Eco-Optiloc® (EO) pavements had declined below thresholds established to avoid surface runoff during intense rain events (15 cm/h). The PC had a surface infiltration rate over 30 times that of the AP and EO pavements after 4 years and one maintenance cycle. While this pavement continues to infiltrate well, it is not yet clear how effective vacuum maintenance will be in reversing clogging on this type of pavement.

- ***Runoff volume reduction***. The pavements were found to reduce runoff volumes consistently over the course of the study, despite the presence of fine grained native soils. Annual warm season volume reduction rates relative to asphalt ranged from 40 to 52 percent (45% over the study period). This finding suggests that native soils below the pavements retained their capacity to infiltrate and that the geotextile below the base layer did not inhibit the movement of water into the underlying soils. The first 5 mm of most events was almost completely retained and infiltrated despite location of the perforated pipe at the bottom of the pavement structure.

- ***Surface Water Quality***. The permeable pavement effluents had lower concentrations of most pollutants relative to asphalt runoff. Reductions in median total suspended solids event mean concentrations (EMCs) by the permeable pavements over the study period were between 88 and 89%. Mass load reductions of pollutants would be greater than concentration reductions because, as noted earlier, 45% less stormwater was discharged from the permeable pavement plots than from the asphalt pavement. The quality of outflows from the different permeable pavements was comparable, but the PC pavement showed higher levels of pH, phosphate and potassium than the pre-cast pavers. Concentrations of these constituents in PC outflows stabilized at levels similar to the AP and EO pavements after two to four years. Effluent quality from the AP and EO pavements were very similar despite differences in the size of joints, filler material and the presence of a geotextile below the bedding layer of the AP pavement.

- ***Groundwater Quality:*** Underdrains were placed in the base and below a 0.5 to 1.0 m layer of native soil to evaluate potential effects on groundwater in areas with high water tables. Results showed that effluent from the upper and lower underdrains had similar concentrations of pollutants and exhibited little change over time. With the exception of salt (NaCl), pollutant concentrations in the lower underdrain were rarely at concentrations that would pose a health threat to the use of groundwater for drinking water. Lead exceeded the guideline in 2% of samples from the lower underdrain, suggesting that a separation distance between the base and seasonally high water table would need to be greater than 0.5 m to prevent contamination from lead. Iron and total dissolved solids were also above the aesthetic objective for drinking water in up to 40% of samples.

- ***Thermal loads.*** Paved surfaces and some types of stormwater best practices can pose a threat to aquatic life in receiving waters by increasing the temperature of runoff. Results of this study showed that permeable pavement generated considerably lower thermal loads to receiving waters than the asphalt pavement during hot summer days, primarily due to lower outflow volumes. While the permeable pavement had lower maximum temperatures than asphalt, event mean temperatures (EMT) were higher than asphalt during two of the four events analyzed. During these two events, runoff from the asphalt occurred during the cool night hours, while the permeable pavement drained more gradually (up to 36 hours) and was therefore subject to greater daytime solar heating.

- ***Surface movement.*** Elevation surveys conducted annually over the course of the study showed that the permeable pavement surfaces have been relatively stable over time with no obvious signs of heaving or slumping.

Recommendations for further monitoring and research are provided on maintenance of permeable pavements, winter snow and ice management, and the fate and transport of sediment particles within permeable pavement systems.

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