# Evaluation of Permeable Pavements in Cold Climates

## Kortright Centre, Vaughan


**Prepared by:** University of Guelph
Toronto and Region Conservation

**Final Report 2012**

# EVALUATION OF PERMEABLE PAVEMENTS IN COLD CLIMATES
## Kortright Centre, Vaughan

Final Report

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## NOTICE



## PUBLICATION INFORMATION

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Reports prepared under the Sustainable Technologies Evaluation Program (STEP) are available at www.sustainabletechnologies.ca. For more information about this project or STEP, 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 liveable communities.

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# EXECUTIVE SUMMARY

Permeable pavements (PP) are one of several Low Impact Development practices that are being used to treat runoff and help increase infiltration in an effort to reproduce the pre-development hydrologic regime. Since PPs replace conventional asphalt, they are ideally suited to older built-up areas that lack stormwater management and have little to no space for conventional stormwater facilities. They can also be cost effective in new development areas where runoff reductions from infiltration can reduce or eliminate the need for sewer infrastructure beneath the pavement.

This three year study advances knowledge about the performance of PPs under Ontario climatic and geologic conditions by evaluating the functional, hydraulic and water quality effectiveness of three types of PPs and conventional asphalt. In addition, the study assesses the benefits of using PPs in areas with low permeability native soils, identifies critical cold climate factors that may influence performance, and compares the effectiveness of alternative pavement cleaning practices.

The research primarily centres on a new PP lot designed and constructed in 2009/10 by TRCA on the Living City Campus at Kortright in Vaughan, Ontario. The Kortright PP research facility provides the unique opportunity to simultaneous study multiple pavements subjected to the same local effects. This is the first research project of this scope to be conducted in Canada and under typical winter conditions. An underground sampling vault was installed downstream of the site to facilitate monitoring and drainage controls were designed to enhance infiltration into the silty clay native soils.

In order to assess the impact maintenance practices and in-situ conditions have on pavement performance, experiments were conducted on older PP parking lots within the Greater Toronto Area (GTA). Multiple types of proprietary street cleaners as well as labour intensive vacuuming and pressure washing on different types of PPs were examined. In-situ conditions were characterized according to drainage patterns, traffic use, age, and adjacent vegetation to evaluate impacts to pavement performance.

## Study Findings

Results of this study show that PPs offer significant benefits for the treatment and management of stormwater over conventional asphalt-to-catchbasin collection systems. A key advantage of PPs is the capacity of these systems to reduce outflow volumes even when applied to areas with low permeability soils. The three evaluated PPs, AquaPave™ (AP), Eco-Optiloc™ (EO) and Hydromedia™ Pervious Concrete (PC), did not produce direct surface runoff throughout the 22 month monitoring period of this study. Overall, the PPs reduced the volume of stormwater outflow by 43% and were shown to be capable of completely capturing (i.e. infiltrating and evaporating) the stormwater produced from rainfall events up to 7 mm in depth. This reduction of stormwater volume mitigates the adverse impact of the urban landscape on receiving surface water systems.

In addition to reducing outflow volumes, the PPs delayed and reduced peak flows. Attenuation was observed throughout all seasons, including the winter, over the duration of the study. On average, PP peak flows were 91% smaller than peak runoff flows from the asphalt pavement. A median 14 hour attenuation (or 2.9 lag ratio) of outflow was observed from the PPs. The slower and more controlled outflow closely mimics natural interflow and reduces the risk of flooding and erosion in downstream receiving waters.

Winter data showed the PP systems to function well even during freezing temperatures. Elevation surveys indicated that freezing temperatures did not cause significant surface heaving or slumping. A substantial spring thaw was observed in March 2011, during which the PP delayed the outflow of melt water by three days and greatly reduced peak flows. Increases in outflow volume were occasionally observed during the winter and spring due to the delayed release of stormwater stored within the aggregate reservoir.

Surface infiltration measurements revealed substantial reductions in permeability over the course of the study, although even at reduced permeability levels, all of the pavements continued to maintain sufficient capacity to rapidly infiltrate all rainfall from the observed storms. Between June 2010 and May 2012, permeability reductions of the narrow jointed permeable interlocking concrete pavement (PICP) (AP), wide jointed PICP (EO) and PC were 87%, 70% and 43%, respectively. These results indicate that PPs with larger surface opening may sustain critical infiltration capacity longer without maintenance than PPs with small surface openings.

The PC pavement continued to have extremely high infiltration capacity even after two years, with median infiltrations rates of 1,072 cm/hr at the end of the study in 2012. By contrast, the median surface infiltration rate of the narrow jointed PICP was only 20 cm/hr after 2 years. Vacuum sweeping provided only partial restoration of surface permeability for the PICPs. No benefit was observed from vacuum sweeping for the PC at Kortright, although the pavement retained a high infiltration capacity. Vacuum sweeping on other PP parking lots produced highly variable results and did not provide consistent removal of embedded fines within PICP joints and PC pavements.

Over the monitoring period, median/mean concentrations of several pollutants in PP outflow were significantly lower than median/mean concentrations in asphalt runoff, including suspended solids, extractable solvents (oil & grease), ammonia-ammonium nitrogen ($NH_3$, $NH_4^+$), nitrite, total kjeldahl nitrogen (TKN), total phosphorus, copper, iron, manganese and zinc. The PPs also generated a net reduction in total pollutant mass for all of these constituents in addition to dissolved solids, chloride, sodium, phosphate, and nitrates. Seasonality was more pronounced in runoff than in PP outflow. In the winter the concentration of pollutants associated with road salting were considerably higher in runoff than in PP outflow. The reduction in concentration is attributed to the detention and dilution of winter stormwater provided by the PP systems. Water quality data collected below native soils indicated that sodium and chloride will migrate onwards to groundwater systems, although further investigation is needed to determine how the presence of these constituents may affect the mobility of other stormwater contaminants, such as metals.

The PICP and PC pavements introduced different constituents into stormwater outflow as a result of leaching of materials within the pavement system. In the case of the PC this led to a gradual improvement in water quality over the course of the study, as mobile pollutants were ultimately flushed from the pavement. Throughout the first year of monitoring the PC effluent contained elevated levels of phosphate and released highly alkaline stormwater, which are undesirable characteristics for aquatic ecosystems.

Further investigation is needed to explore the implications of pollutant leaching on stormwater quality from large newly constructed PP installations. The long term change in water quality of outflows from these PPs is being investigated in a second phase of this project.

## Recommendations

Results of this study indicate that PPs can be effective measures for maintaining or restoring infiltration functions on parking lots and other low volume traffic areas, even in areas with low permeability soils. The following recommendations are based on study findings and observations.

- Restricting outflow rates from partial infiltration PP systems through raised pipes or flow control valves is recommended to increase stormwater volume reductions through infiltration.
- Closed outlet valve tests suggested that raising the perforated outflow pipe in the cross section of the PP structure or elevating the discharge pipe downstream of the PP system is feasible on low permeability silty clay soils and may result in substantially larger outflow volume reductions than would occur from restricting outflow rates alone. Further investigation of this type of application on low permeability soils is recommended.
- Pollutant leaching of pavement and aggregate materials was observed, particularly for pervious concrete. Leaching was observed to decline as the pavement aged. For large pervious concrete installations, additional treatment may be required if outflows drain to ecologically sensitive streams. Further testing of the performance and leaching potential of different types of pervious concrete is recommended.
- PPs were observed to reduce the loads and concentrations of several stormwater contaminants. Additional investigations are needed to define the specific conditions (*e.g.* magnitude of load reductions, ecological sensitivity of receiving waters, maintenance guarantees) under which partial infiltration PP systems should be eligible for pollutant removal credits in Ontario jurisdictions.
- Vacuum cleaning of permeable interlocking concrete pavements was found to only partially restore surface permeability after 2 years of operation. Further tests of different techniques for loosening or dislodging compacted material in PP joints or pores prior to cleaning are needed to improve the effectiveness of regenerative air and vacuum sweeping trucks.
- Based on maintenance practices evaluated in this study, annual vacuum cleaning of permeable interlocking concrete pavements is recommended to increase the operational life of these pavements. The PC pavement maintained high surface permeability over the study period, and therefore maintenance is recommended less frequently (i.e. > 2 years).
- Further research on the long-term (*i.e.* > 3years) performance of PP systems is needed to assess how the hydrologic, water quality and functional characteristics of the pavements may change over time.
- In this study, the 2011/2012 winter was unseasonably warm with low amounts of snowfall. Additional monitoring of winter performance and behaviour is recommended.
- In 2011/2012 operational staff found that the PPs did not require salting as frequently as the asphalt pavement. Further research is needed to evaluate how and whether PPs can maintain safe conditions with lower salt use than conventional pavements.

- Elevation surveys of the pavements during this study showed no significant movement across the four pavement cells. Further testing of pavement movement under increased traffic frequencies and loading scenarios are needed to verify the range of functional conditions under which these pavements are suitable alternatives to asphalt.