Ontario Ministry of Transportation Carpool Parking Lot (Campbellville)

Location: Campbellville
Constructed: 2007

Case Study

Public Lands

Project Objectives, Design and Performance

- Construct a green carpool parking lot in accordance with the Ministry of Transportation's (MTO) Strategic Direction to have the "greenest highways in North America."
- Carpool lot has an area of 1,800 m² pervious concrete parking surface which helps to manage stormwater on-site.
- First pervious concrete lot designed and constructed by the MTO, intended as a demonstration site to identify best practices for construction and operation and maintenance of the material.

Overcoming Barriers and Lessons Learned

- Portions of the parking lot surface experienced raveling (dislodging of surface aggregate) following construction. Raveling was attributed to material specifications used at the time (since updated) and placement of mix during cold weather.
- Lessons learned from the project were used to update Ontario Provincial Standard Specifications for pervious concrete to increase the durability of future pervious concrete installations.
- Performance monitoring at the site, identified that pervious concrete requires specific operating and maintenance conditions to ensure it continues to provide stormwater control. Vaccuming the pervious surface improves permeability, and a scheduled sweeping plan is recommended.

Practices Implemented

Permeable Pavement

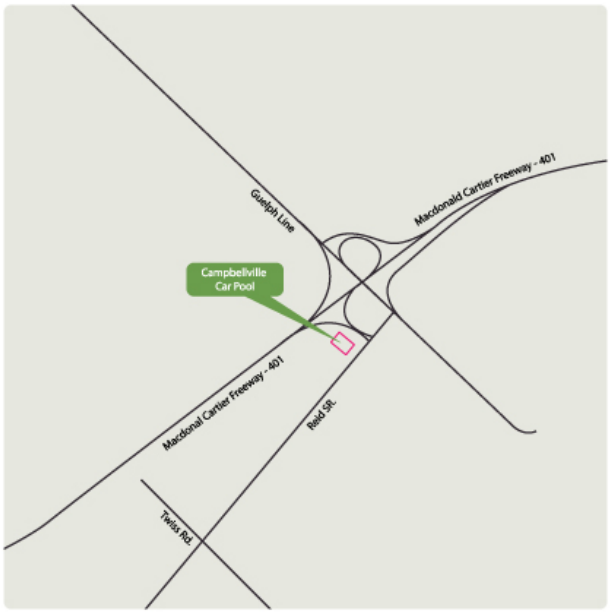
Barriers and Issues Encountered

Construction & Comissioning

Operation & Maintenance

Overview

The site consists of a pervious concrete carpool parking lot constructed in Campbellville adjacent to Guelph Line and Highway 401 in the fall of 2007.



Location of MTO Carpool Parking Lot, Campbellville, ON

The site was selected by the MTO as an ideal location to test the use of pervious concrete mix as a substitute for conventional asphalt or (impervious) concrete for the parking surface. Pervious concrete is a mixture of Portland cement, additives, and course aggregate with little or no fines. The high void content and interconnected pores allow for high infiltration rates through the concrete layer and into the sub-grade. Given these properties pervious concrete can provide both a parking surface and a means to manage stormwater on-site.

As this was the MTO's first pervious concrete project, the ministry partnered with the University of Waterloo and the Ready Mix Concrete Association of Ontario to assess the functionality and performance of the pervious concrete at the site. Construction materials and techniques were evaluated to assess infiltration performance, evaluate maintenance practices, and quantify durability. Lessons learned from the demonstration project will be applied to future pervious concrete projects.

Goals and Drivers

The Campbellville Carpool Parking Lot was constructed to meet several of the MTO's goals and drivers. These include:

- Encouraging carpooling in the Greater Toronto and Hamilton area
- Implementing MTO's *Strategic Direction* to have the "greenest highways in North America"
- Decreasing heat island impacts by directly infiltrating stormwater rather than conveying heated runoff from parking lot surface to a downstream watercourse
- Testing various installation methods for pervious concrete and monitoring performance and maintenance requirements of the material

Successes

First MTO pervious concrete installation – lessons learned at this site have been incorporated at other sites including a car pool lot at the Williams Parkway Interchange at Hwy 410 in Brampton.

Infiltration rate exceed maximum expected rainfall rate – the long-term infiltration rate of the pervious concrete was found to be higher than the expected maximum rainfall intensity after 22 months of monitoring.

***Ontario Provincial Standard Specification* for pervious concrete** – Lessons learned at this site have been incorporated into a specification, OPSS 356 November 2010, to promote the success of future pervious concrete projects.

Overcoming Barriers and Lessons Learned

Some of the issues and barriers encountered with this project include:

- Following construction the pavement has experienced raveling (dislodging/crumbing of the aggregate at the surface)
- Raveling has been attributed to a variety of issues, including; material specifications, placement techniques, and in cold weather concrete placement

Lessons learned:

- To prevent raveling, viscosity modifiers have been added to the concrete mix specifications
- Control joints (typically required to interrupt potential cracks) are both unnecessary and counter-productive with pervious concrete as raveling would often start at the joints at this site.
- Strict placement temperature limits are encouraged with pervious concrete to ensure proper curing
- Course aggregate component of concrete mix is now required to have a maximum nominal aggregate size less than or equal to 13.2 mm. This smaller size improves the mix stability and the surface texture for pedestrians.
- As pervious concrete is designed for light vehicle loads, a height restriction to the entrance of the parking lot should be used to prevent heavy trucks from entering.
- All other construction and landscaping should be completed prior to concrete placement so potential sediments do not plug the concrete pores.
- Updates have been incorporated into the *Ontario Provincial Standard Specification OPS 356 Construction Specification for Pervious Concrete Pavement for Low-Volume Traffic Applications, November 2010.*

Planning and Regulations

The Highway 401 Guelph Line carpool lot was part of a detailed design study for interchange improvements at Highway 401 and Guelph Line. The purpose of this study was to identify a solution to address the narrow lane widths across the Guelph Line underpass structure, the un-signalized intersection at Guelph Line and Reid Sideroad, associated geometric improvements, and the informal nature of the existing car pool lot and entrance onto Guelph Line. It was determined that the existing carpool lot would be relocated and expanded. This study was carried out in accordance with the requirements of the *Class Environmental Assessment (EA) for Provincial Transportation Facilities* (2000), a process that has been accepted and approved under the Environmental Assessment Act.

A "Notice of Study Commencement" outlining the project as a Group 'C' undertaking was advertised in April 2006. Group C projects involve *Minor* improvements to existing facilities. However, the study team evaluated the option of relocating the southbound Guelph Line to eastbound Highway 401 on ramp access onto Reid Sideroad and moving the existing informal carpool lot to a new location, west of the existing eastbound off-ramp along Reid Sideroad. The project was then reclassified as a Group 'B' project, projects involving *Major* improvements to an existing facility, in the fall of 2006.

Upon further consideration, due to minimal environmental impacts, the absence of significant property issues and high level of public support, the project was suitable to be 'stepped-down' back to the Group 'C' designation. A Notice of Project Step-Down was issued on April 19, 2007 and a 30-day period provided affected parties the opportunity to request that MTO reconsider the decision to step down the project. No requests for reconsideration were received and the project was stepped-down to a Group 'C' project on May 21, 2007.

Design

The parking lot is approximately 1800 m^2 in area. The pervious concrete layer is 240 mm over 100 mm of clear stone and 200 mm of dense graded granular base over sandy sub-grade material. A geotextile-wrapped clear stone with perforated sub-drain is located immediately below the top of the sub-grade. Infiltrated water is directed to a catchbasin for testing purposes.

A concrete thickness of 217 mm was determined following the *StreetPave* software guidelines distributed by the American Concrete Paving Association. However, this thickness was increased to 240 mm to match the top of pavement height originally tendered when the project had originally specified hot mix pavement. A 30-year design life with 85% reliability, low traffic, and a flexural strength of 1.7 MPa was used for the pervious concrete. A cross section photograph of the permeable pavement is provided below and highlights the low fines present within the material.

Pervious concrete cross section, showcasing the porosity of the material

Material specifications for the pervious concrete included:

- Maximum nominal aggregate size less than or equal to 20 mm
- Void content between 15 and 25% based on ASTM C138. The new OSPD now calls for LS-443.
- Fine aggregate could not exceed 0.11 m^3/m^3 of concrete. No fines were used in this sites mix.
- Total cementitious range to be between 325 and 425 kg/m^3.
- The paste is to be adequately air entrained to provide freeze-thaw resistance.
- Core samples could not be less than 13 mm of the design thickness.
- Unit weight of 1680-2080 kg/m^3 as determined using ASTM C29
- Core density within of 80 kg/m^3 of the design unit weight determined using ASTM C140.

Based upon issues encountered with the pervious concrete following construction, some of these specifications were modified in updated Ontario Standard Specifications. Updated recommended specifications include:

- Maximum nominal aggregate size less than or equal to 13.2 mm *(smaller to improve comfort of pedestrians walking on the pavement surface)*
- Void content to adhere to Ontario Test Method LS-433

The hydrological design followed the guidelines of the *Pervious Concrete Hydrological Analysis Program* software distributed by the Portland Cement Association and is based on a 10-year storm event lasting 24 hrs totaling 120 mm. The granular base material was estimated to have a porosity value of 30%. The exfiltration rate of 1.2 mm/hr used was based on the hydrological properties of the native silty sand soil.

The granular base thickness of 300 mm was sized to provide adequate storage and depth to prevent infiltrated water from freezing in the pervious concrete layer. Although not accounted for, the sandy sub-grade would also provide additional capacity to reduce the amount of water available which provides an additional level of comfort in the design.

Construction and Commissioning

Concrete placement was completed in November 2007 over the course of four days. The lot was poured in four sections each taking one day to complete. Cold weather was experienced during the entire pour. A plastic sheet was used to cover the concrete to assist with curing.

Specifications stated the longitudinal and transverse joints were to be formed using a joint roller while the concrete was still plastic. This was originally accomplished using a steel roller with a beveled fin. However, this equipment could not produce clear vertical cuts and also delayed placement of the protective plastic cover intended to help cure the concrete. This practice was abandoned in favor of saw cutting dry joints to ensure proper curing. Care was taken to remove dust following cutting to prevent clogging pores.

To evaluate the best construction technique for placing pervious concrete three sections were placed using a Bid-well Bridge Deck Paver and one section was placed with a Razorback Paver.

Bid-well deck paver tested for pervious concrete placement

Based upon the experiences of the construction crew and the performance of the material following construction, the use of the bridge deck finishing machines are not generally recommended for placing the pervious concrete. A hydraulically actuated rotating tube (roller) screed has become the preferred screed of choice for slab thicknesses up to 2000 mm using the new mix specifications. A photograph showing this technique follows.

Installation of pervious concrete by hydraulic roller screed

For further information on issues and lessons learned associated with pervious concrete, including construction lessons learned, see the *Operation & Maintenance* section.

Economics

For comparison purposes the average cost from the three lowest bidders is shown below for both the pervious pavement design and a conventional hot mix design.

Pervious Concrete Design	**Cost**
Supply and Construction of pervious concrete (1876 m^2 at \$154/m^2)	\$289,091
300 mm Granular "O" (2792 tonnes at \$30/tonne)	\$83,844
Additional cost of SSM material over fill typically required for conventional Hot Mix	\$20 000
Total	**\$393,000**
Conventional Hot Mix Asphalt Design	
90mm hot mix 150 mm granular base 300 mm granular sub base **Total**	**\$152,000**

It should be noted that, although not calculated for this project, the use of permeable surface often reduces the cost of other stormwater control infrastructure such as piping, oil grit separators, or other controls.

Operation and Maintenance

Raveling

Shortly following construction one of the issues identified with the pervious concrete was raveling, a process whereby the surface aggregate is dislodged from the cured concrete. Raveling began in the slabs and the joints. In spring 2008, ongoing performance monitoring at the site estimated that approximately 20% of the pervious concrete surface was experiencing slight, moderate or severe levels of surface abrasion. It is thought that winter maintenance exacerbated additional raveling in the parking lot. Snow was removed using the same plow equipment used for highway maintenance. A photograph showing an example of pervious concrete is provided below.

Example of pervious concrete raveling (note the loose aggregate near the curb)

Raveling issues persisted over time, with a majority of the parking lot experiencing moderate to severe raveling both in the slabs and at the joints.

One of the main drawbacks associated with raveling is that it negatively impacts the aesthetics of the LID practice. It tends to give the parking lot surface a messy look, sometimes making the lot look like an unpaved gravel parking lot. At this site, this issue was addressed by a sweeper truck. The truck removed much of this aggregate, sand and other debris that accumulated on the parking lot surface. Using sweeper trucks to remove debris is highly recommended for permeable pavements to ensure continued permeability of the surface.

Winter maintenance

During the winter, a pre-determined quantity of sand was applied to one side of the parking lot as part of long-term performance monitoring of the pervious concrete. Salt was only used during severe events for safety. The parking lot was plowed using highway maintenance equipment.

Pervious concrete lessons learned and parking lot rehabilitation

Given the large amount of raveling at the Campbellville demonstration lot, within five years construction it was necessary to rehabilitate the parking lot to maintain an acceptable level of service. In order to meet a tight deadline ahead of winter conditions, it was necessary to overlay the pervious concrete pavement with asphalt.

Although the permeable pavement is no longer exposed at the site, there were numerous lessons learned from constructing and observing performance of the pervious concrete parking lot in Campbellville. Many of these lessons have been used to improve material specifications in the MTO *Ontario Provincial Standard Specification OPS 356 Construction Specification for Pervious Concrete Pavement for Low-Volume Traffic Applications, November 2010.* Another important lesson was installation – that pervious concrete must be placed under strict conditions, particularly not in cold weather, to ensure long performance. Other MTO pervious concrete projects are providing additional lessons to further refine material and construction guidelines for continued success.

Key Facts

Issues

- Raveling, or surface aggregate loss, can become prominent without suitable concrete mix or placement techniques. Material specifications and construction techniques have been adapted to prevent raveling.
- Proper installation is imperative or the product will suffer. Proper equipment, material quality control, weather conditions, and skilled installers are required for successful placement.
- Maintenance is important. Pores can become clogged and prevent the pervious concrete from working properly.

Solutions and Lessons Learned

- Concrete placement should occur in warm weather using equipment and techniques as described in OPSS 356 November 2010.
- Finished concrete should be protected from sediment to maintain permeability.
- Traffic usage impacts long term permeability more than sanding during the winter months.

Long-term Performance

Permeability monitoring was conducted for 22 months following construction.

At this site sand use did not significantly reduce permeability of the concrete; however, the amount of traffic did. High use traffic lanes decreased permeability compared to parking spaces. It is presumed that the additional loading compacts debris into pore spaces.

Permeability of the pervious concrete decreased over time at the site. Maintenance techniques (annual sweeping) improved permeability, but did not restore the permeability to installation levels. It is important to note that even after 22 months of monitoring, permeability was still higher than 299 mm/hr (the maximum rainfall rate expected at the site). So even with some loss in permeability, the site would still have performed well during intense rainfall events.

Acknowledgements

Credit Valley Conservation would like to sincerely thank the following companies, organizations and individuals for their support in developing this case study:

- Ontario Ministry of Transportation
- University of Waterloo
- Ready Mix Concrete Association of Ontario
- Vimy Henderson & Susan Tighe
- Region of Peel
- Ontario Ministry of the Environment

Version 1.0, Released February 2014

This case study was developed through funding support from the Government of Ontario's Showcasing Water Innovation program. Such support does not indicate endorsement by the Government of Ontario of the contents of this material.