Permeability Restoration of Permeable Interlocking Concrete Pavements

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Highlights

- Clogged PICP surface infiltration rates can be restored with selection of the right equipment.
- While not specifically measured, the most effective equipment in restoring infiltration was the least efficient.
- Prior to deciding on permeable pavement, be sure the owner is willing and able to clean it regularly.

Introduction

Permeable interlocking concrete pavement (PICP) expanded in Canada and the US at the start of the 21st century. Since then, millions of square feet (m2) in sidewalks, plazas, parking lots, alleys and roads reduce runoff and water pollution. PICP receiving no run-on from adjacent impervious surfaces typically renders high infiltration rates for years without cleaning. However, PICP and other types of permeable pavements accepting run-on from impervious surfaces requires routine cleaning to prevent clogging. Industry recommendations emphasize periodic, preventive surface cleaning to remove accumulated sediment and detritus from the joints well before compaction into them occurs. Successful routine cleaning can be achieved with a regenerative air machine. Unfortunately, many PICP owners were not willing or able to conduct periodic, routine cleaning. This results in reduced surface infiltration rates (aka a “clogged” condition) typically accompanied by ponding and the need for more powerful equipment to increase and restore infiltration.

Methodology

The objectives of this study were as follows:

- Test performance of various cleaning equipment.
- Investigate pre-cleaning practices (e.g. power washing) that might increase efficiency and effectiveness of various cleaning equipment technologies for restoring surface infiltration rates.
- Investigate cohesive vs non-cohesive sediments on their response to various cleaning equipment technologies and cleaning frequencies.

A PICP test pad was constructed in 2017 at the Toronto and Region Conservation Authority’s Kortright Centre for Conservation in Vaughan, Ontario. This pad consisted of seven 10 ft square PICP cells with an underdrain. Five test cells were clogged with street sweepings that matched sediments sampled from mature PICP parking lots within the Greater Toronto Area. The PICP joints were clogged using a controlled procedure developed by the University. This resulted in a consistent mix of materials used to clog the joints. In addition, a mix of cohesive, clay-based sediment was developed, typical to that found in existing PICP sites in the region. Removing cohesive soils from the joints typically required powerful vac or air pressure equipment.

ASTM C1781 was used to measure surface infiltration rates on new, progressively clogged, and cleaned PICP joints. Restorative maintenance was required when mean surface infiltration measurements approached 250 mm/hr (10 in./hr). Equipment was allowed one pass at normal operating speeds. Effectiveness could be increased by performing multiple passes in actual field applications. Five equipment types evaluated are shown below.

Key Findings

The regenerative air machine restored 20% of the surface permeability. This confirms the use of this equipment for routine cleaning to remove loose dirt, leaves, litter, etc. and not on clogged surfaces. The true vac produced the most variable results. On average, the PICP’s surface infiltration capacity was 295 in./hr or 70% of post-construction

Regenerative Air Machine

True Vac Machine

Waterless Mechanical Sweeper

Power Washing Before Applying a Shop Vac

High Pressure Air and Vacuum System

infiltration. Measurements ranged from 50 in./hr to 547 in./hr. Power washing and a Shop Vac improved surface infiltration by 25%. The waterless mechanical street sweeper restored the PICP's surface infiltration capacity to 35% of its original condition, or about 139 in./hr. The high pressurized-air and vacuum system fully restored the PICP to its baseline, post-construction surface infiltration. Average surface infiltration rates were 2 to 6 times higher than from other equipment, ~508 in./hr for cohesionless soil mixed with jointing stone.

Recommendations

The most effective equipment in raising infiltration rates was also the least efficient and may require multiple passes to regain some or most of the surface infiltration rate when new. This was demonstrated by Smith and Bowers (2018). Jointing stone material captures sediment thereby slowing accumulation on the soil subgrade while achieving pollution reduction as well as contribution to surface stability aka interlock. Therefore, the jointing material is essential to structural and pollutant reduction performance while requiring periodic cleaning. Equipment is expected to improve efficiencies as permeable pavements become the norm rather than the exception. Adjacent impervious surfaces contributing runoff should be vacuumed as well to minimize sediment deposition on permeable pavements.

References

Smith, D.R. and Bowers, R. 2018. Surface Infiltration Improvement of Highly Clogged Permeable Interlocking Concrete Pavements, Proceedings of the 12th International Conference on Concrete Block Paving, Seoul, South Korea. Available at http://www.sept.org/techpapers/1768.pdf.

A full report on this research is available [here]().

Permeable Pavement Case Study at Ursinus College

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Highlights

- Permeable Pavers were installed on a college campus as part of a green infrastructure initiative.
- Post-construction infiltration testing confirmed high surface infiltration two years after installation.
- An attractive, multi-purpose pavement surface can be successfully used as a stormwater control system.

Introduction

In 2020 Ursinus College completed construction of a new Student Commons building that included sustainable green infrastructure components including a permeable pavement multi-use campus access road with parking stalls that included electric vehicle charging stations. This presentation reviews how the permeable pavement system was designed and reviews post-construction surface infiltration rate testing.

Background

Ursinus College collects stormwater through an existing stormwater collection system that ultimately discharges into the nearby Perkiomen River. Over the last decade, the regional drainage area and river has been prone to severe flooding due to increased impervious land coverage in the growing suburban area. The Ursinus College administration desired to incorporate green infrastructure for a new Student Commons building, to limit any increased runoff and minimize local flooding. Permeable pavement was an ideal solution that provided a structural paving surface capable of supporting vehicular traffic and a green infrastructure solution for managing stormwater runoff.

A geotechnical investigation determined that the project's subgrade consisted of lean clay soil with a minimum hydraulic conductivity of 0.30 in/hr. based on results from multiple field measurements in accordance with ASTM D3385 *Standard Test Method for Infiltration Rate of Soils in Field Using Double-Ring Infiltrometer*. A design infiltration rate of 0.15 in/hr. was used based on Design Standard 68-18 *Permeable Interlocking Concrete Pavement (ASCE, 2018)*, which recommends a factor of safety of two for measured infiltration rates.

A cross-section that includes a 4" base layer and 12" subbase layer of open-graded aggregate (Figure 1) was designed for the 18,000 sf permeable pavement system. An underdrain within the subbase was incorporated with an outlet control structure to control the release of stormwater from the permeable pavement system when needed. Two flow dams were installed along the 300 ft. long drive lane to maximize vertical infiltration into the 2° sloping subgrade.

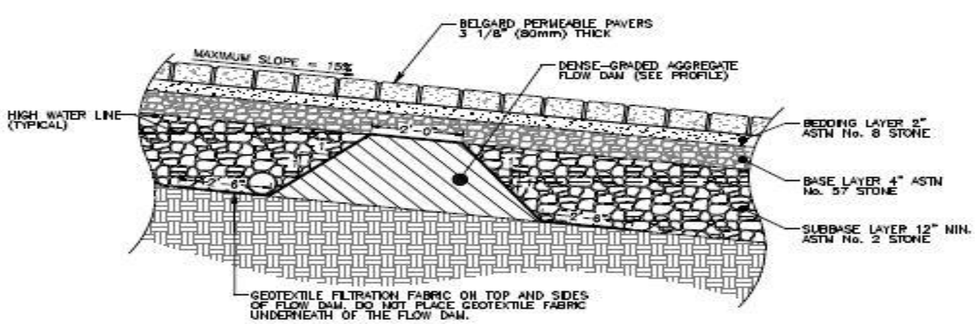

Figure 1. Permeable Pavement Cross Section, Ursinus College

Key Findings

In 2020, two months after construction was completed, infiltration testing a was performed in accordance with ASTM C 1781, *Standard Test Method for Surface Infiltration Rate of Permeable Unit Pavement Systems*. The constant head test was performed on top of the permeable pavers using a single infiltrometer ring and a known weight of water poured into the sealed ring. Time was kept from the first moment of contact between the surface and water until no visible water remained. An average surface infiltration rate for the site was determined to be 707 in/hr., which is typical for new permeable pavement using ASTM No. 89 filter stone in the joint openings.

To measure the ongoing infiltration performance over time, additional infiltration tests were performed 11-, 25- and 28-months post- construction. The average surface infiltration rate has decreased to 467 in/hr., a 34% reduction in surface flow rate capabilities.

Post-construction infiltration rates were found to be consistent with industry-recognized performance for permeable pavement systems. Research has shown that surface infiltration will decrease over time for all permeable pavement systems. However, long-term values exceeding 100 in/hr. is typical for properly designed and maintained systems and is an industry-recommended action level for acceptance. 10 in/hr.is a typical trigger for corrective restorative maintenance measures (Smith 2020).

The multi-purpose pavement is an example of a successful green infrastructure project that is operating as designed. The use of permeable interlocking concrete pavement has provided multiple benefits including: a stormwater control measure that is reducing surface runoff; infiltrating rainwater into the subgrade, providing volume retention; and functioning as a highly aesthetic structural pavement surface, all in one system (Figure 2).

Figure 2. Permeable Pavers at Ursinus College

Recommendations

This project demonstrated that permeable pavement is a viable stormwater management solution for campus applications. However, maintenance is critical for long-term performance. Ursinus College should continue to monitor surface infiltration performance and will incorporate surface joint cleaning based on evidence of surface ponding after normal rain events or when surface infiltration rates decrease below 10 in/hr.

References

American Society of Civil Engineers, Permeable Interlocking Concrete Pavement Committee, Design Standard 68-18 Permeable Interlocking Concrete Pavement (2018) https://sp360.asce.org/PersonifyEbusiness/Merchandise/Product-Details/productId/244074874

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Comparison of Winter Deicing Operations for Permeable Interlocking Concrete Pavements (PICP) Compared to Asphalt

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- Half as much deicer on PICP achieved similar pedestrian slip resistance compared to twice as much on asphalt.
- Half as much deicer on PICP achieved similar vehicular friction compared to twice as much on asphalt.
- The study demonstrates benefits of snowmelt infiltrating rather than refreezing on PICP in terms of lower deicer use.

Introduction

With increasing liability from winter slips and falls plus loss of vehicular control on snow and ice comes an increasing use of deicers. The increase in snowmelt and stormwater runoff results in environmental damage to lakes, streams and rivers. This results in economic damage to communities, i.e. lost revenue from recreational activities such as swimming, boating, and fishing. Additionally, there is the cost of deicers and their application.

Empirical/anecdotal information from PICP owners in cold climates have consistently noted snow melting faster compared to that on conventional impervious pavements especially after plowing. Other permeable pavements provide this benefit as well, and deicer reductions have been established through research (Houle et al. 2009). Quantifying reductions in deicer use for PICP was needed to add to existing maintenance guidelines promulgated by industry, public agencies and designers.

Methodology or Background

An outdoor pavement test pad was constructed in August 2017 at the Toronto and Region Conservation Authority's (TRCA) Kortright Centre for Conservation located in Vaughan, Ontario. The test pad shown below consisted of four 6.6 ft square, level PICP cells with underdrains and an asphalt control cell at a 2% slope to a catch basin. Each pavement cell was enclosed with concrete to prevent lateral subsurface flows between them. Installed in an open field, the cells received no pedestrian or vehicular traffic throughout the two-year study. Deicer types were sodium chloride (rock salt) and sodium chloride mixed with beet juice.

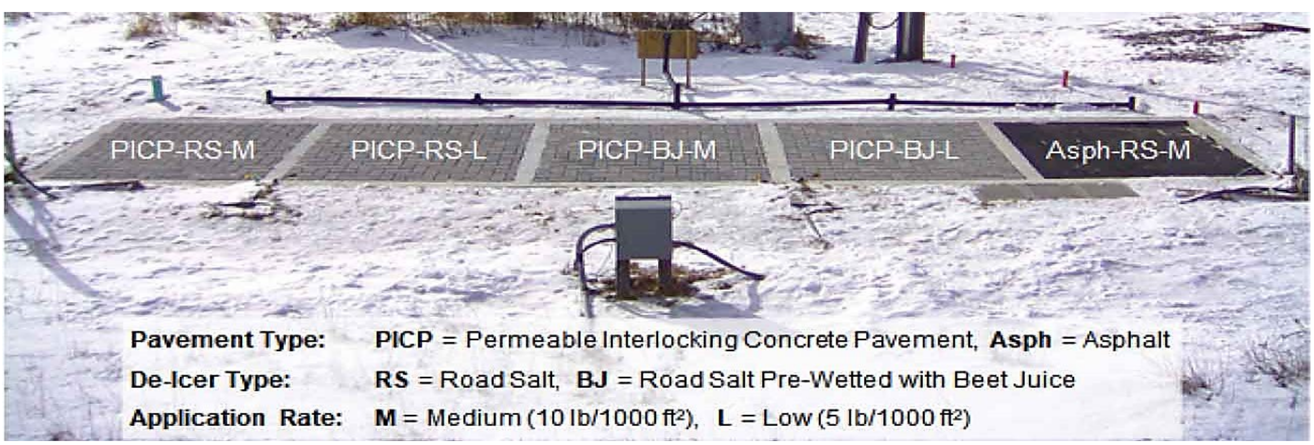

Figure 1. Pavement cells for deicer tests.

This research compared winter slip and skid resistance, time to melt/bare pavement, and re-freezing characteristics under various deicer loads and timing. In addition, deicer concentrations were measured in surface runoff from impervious and PICP and in underdrains exiting the latter. Surface friction was measured on the pavement cells using two devices, SlipAlert and Slip-Test Mark IIIB. SlipAlert is a British tribometer adopted by British Standards BS 8204 that measures the dynamic coefficient of friction (DCOF) by simulating the sliding action of a vehicle. Mark IIIB is an American tribometer certified to ASTM F2508 that measures the transitional coefficient of friction (TCOF) by simulating the biomechanical movement of a pedestrian when slipping on a surface. Table 1 indicates the results. DCOF and TCOF values below 0.20 indicate a high risk of slipping or skidding; between 0.20 and 0.40 indicate a medium risk; 0.4 and higher indicate a low risk.

Table 1. Coefficients of friction for pavements after snow shoveling and deicer application.

Pavement Type, Deicer type, Application rate	**Test 1 (n=4) Immediately after shoveling**		**Test 2 (n=3) 10 - 20 mins. after shoveling**		**Test 3 (n=2) 1 - 2 hours after salting**	
	Mean DCOF	**Mean TCOF**	**Mean DCOF**	**Mean TCOF**	**Mean DCOF**	**Mean TCOF**
PICP, Road Salt, Medium	0.22	0.23	0.42	0.46	0.52	0.61
PICP, Road Salt, Low	0.23	0.23	0.39	0.44	0.51	0.59
PICP, Road Salt & Beet Juice, Medium	0.24	0.20	0.43	0.49	0.55	0.63
PICP, Beet Juice & Road Salt, Low	0.23	0.25	0.42	0.52	0.52	0.63
Asphalt, Road Salt, Low	0.35	0.48	0.37	0.51	0.47	0.68

Notes: Road salt was pre-wetted with beet juice
Road salt application rates: Medium = 10 lb/1000 ft^2; Low = 5 lb/1000 ft^2

Key Findings

- PICP provides equivalent or higher levels of friction compared to asphalt when treated with 50% less deicers compared to asphalt pavement. While using less deicers, PICP can have a lower risk of slips and falls for pedestrians and lower risk of skidding for vehicles throughout the winter.

- Under icy conditions, the PICP and asphalt surfaces had similar levels of surface friction prior to salting. Asphalt and pavement surfaces receiving a medium application rate of road salt of 10 lb/1000 ft^2 provide similar levels of safety soon after snow begins to melt. Melting and drying of the PICP surfaces occurred more rapidly with the medium application rate or when using road salt pre-wetted with beet juice.

- However, PICP treated with a low application rate of road salt of 5 lb/1000 ft^2 provided similar levels of safety as PICP treated with a medium application rate of road salt of 10 lb/1000 ft^2. Pre-wetting road salt with beet juice did not provide any additional benefits under the tested conditions.

- Re-freezing of melted snow and ice after sunset was observed on the asphalt surface but could not occur on the PICP surface. The meltwater infiltrated into the PICP leaving the surface dry.

Recommendations

Like other permeable pavements, PICP holds the potential to reduce deicer use. This has broader economic and environmental benefits for preservation of recreational lakes. While this was a small scale experiment, it demonstrates the potential for safety levels on PICP similar to that on asphalt but achieved with a lower application of deicers. In addition, given adequate aggregates and mix designs, concrete paving units can survive degradation from concentrated deicers. Future studies should examine winter performance of PICP parking lots and streets.

References

Houle, K.M., Roseen, R.M., Ballestero, T.P., Briggs, J. F., and Houle, J.J. 2009. Examinations of Pervious Concrete and Porous Asphalt Pavements Performance for Stormwater Management in Northern Climates. World Environmental and Water Resource Congress, American Society of Civil Engineers, Reston, VA. Available from https://ascelibrary.org/doi/abs/10.1061/41036%28342%29111.

A full report on this research is available here.