Permeable Pavements in Cold Climates: Lessons Learned from Practice and Research

Peter T. Weiss, Valparaiso University
John Gulliver, University of Minnesota
Masoud Kayhanian, University of California-Davis
Lev Khazanovich, University of Pittsburgh

Ohio Water Environment Association
2018 Watershed Workshop
October 30, 2018
Porous pavements developed as early as the 1930s.
Full Depth Permeable Pavement X-Section

- Water infiltrates through permeable pavement surface and other layers
- Stored in gravel layer (~40% voids)
- Water infiltrates into soil or is collected by drain tile

Image: CAHILL Associates 2003
Project Scope

• Full depth permeable pavement:
  – Literature review
    • Structural design
    • Hydrologic design/performance
    • Water quality impact
    • Maintenance requirements
  – Cold climate case studies
  – Research needs
  – Software to determine feasibility of permeable pavement

• Does not include permeable friction course
Project Scope

- Full depth permeable pavement:
  - Literature review
    - Structural design
    - Hydrologic design/performances
    - Water quality impact
    - Maintenance requirements
  - Cold climate case studies
  - Research needs
  - Software to determine feasibility of permeable pavement
- Does not include permeable friction course

Image: www.epa.gov
Benefits of Permeable Pavement

- Volume Reduction
- Improved water quality
- Hydroplaning resistance
- Spray reduction
  - Increased visibility
- Smoother riding surface
- Noise reduction
- Less winter salt application

Photos: Barrett 2008
Permeable Pavement Types

- Porous Asphalt
- Pervious Concrete
- Permeable Pavers
- Permeable Articulated Concrete Blocks
Keys for Success

- Proper Construction
  - Mix design
  - Compaction
  - Void ratio
  - Curing
- Proper & regular maintenance

Photo courtesy of M. Maloney, Shoreview, MN
Summary of Hydraulic Performance

• Surface infiltration rates decrease but are not rate limiting

• Method needed to determine permeability of sub-base before design

• Geotextile fabrics can reduce/eliminate infiltration

• Infiltration rates are maintained through winter
Summary of Water Quality Impact

• Removes solids & solid-bound contaminants
• Mass load reduction often through infiltration
• Nitrification may occur (ammonium to nitrate), but total N removal is low
• Dissolved phosphorus removal is minimal
Summary of Maintenance

- Surface cleaning is effective but variable
- Particle removal (top ¼ inch) is major issue
- Pressure washing (45°) and/or vacuuming with regenerative air sweepers is most effective
- Brushes can push material farther into voids
- Clean multiple times per year
Summary of Maintenance

• Major cause of clogging is reduction of surface pavement void space:
  – Heavy loads
  – Particles
  – Lack of maintenance

• No standard to measure or evaluate clogging

Open voids

Partially clogged voids
Impact of Vacuuming

Permeable articulated concrete blocks/mats before (A) and after (B) cleaning with a Vac Head.

(Photo courtesy of University of Louisville and D. Buch, PaveDrain, LLC).
Porous Asphalt Paired Intersections - Robbinsdale

Constructed 2009-2010

Construction in September 2010 (Wenck 2014)
Paired Intersection Study

• Objective was to evaluate possible reductions in salt loads on porous asphalt pavements
• Also durability, maintenance, and water quality
Paired Intersection Study

- Two porous asphalt pavement intersections were constructed: one over a sand sub-base and the other over a clay sub-base.
- Designed to store the 2-yr storm
- Each porous asphalt section was approximately 150 feet long and 28 feet wide for a total area of about 4200 square feet.
- The porous asphalt sections were not salted during the winter.
- Conventional asphalt sections were salted.
Paired Intersection Study

Results

- Reservoir temperatures in both PP systems during winter was consistently warmer than the pavement temperature.
- Attributed to the air within the voids of the reservoir layer insulating the reservoir.
- Insulation minimizes winter freezing and keeps reservoir temperatures cooler in spring.
- Suggests winter infiltration into subgrade is possible.
Paired Intersection Study

Results

• Conventional pavement sites were slushier than the porous asphalt sites due to infiltration into PP

• Bare pavement on the porous test sections was comparable to that on conventional asphalt sections but had a lag of 2 to several hours
Paired Intersection Study

Slush gathering and refreezing on the traditional asphalt at Site 1 on January 17, 2010

Slush free porous asphalt on January 17, 2010
Paired Intersection Study

Site 1 Test Section looking south
Paired Intersection Study

Lessons Learned

• The unsalted, porous asphalt sections had a similar amount of bare pavement compared to salted, conventional asphalt sections.

• The porous pavement over sand subgrade was more effective for ice control compared to the porous pavement on clay subgrade.

• Porous asphalt sections have been durable without any special snow plow equipment or adjustments.
Paired Intersection Study
Lessons Learned

- Effective maintenance on the porous asphalt sections appears to be vacuuming (regenerative) twice per year and patching with traditional asphalt, as necessary

- Porous asphalt intersections have potential as an ice-control management practice in certain situations
Woodbridge Neighborhood-Shoreview, MN

Pervious Concrete, constructed in 2009.
Photo courtesy of M. Maloney
Woodbridge Neighborhood

Initially:

• 38 ac, fully developed
• 9000 yd² of asphalt
• Storm drainage concerns

Needed to:

• Replace road, upgrade utility, improve stormwater management

• Total cost = $15M

Photo courtesy of M. Maloney
Lessons Learned

- Construction & curing very important
- Saturated curing blankets have been successful
- Saw cut joints have been successful
- Snow plowed with regular plow
- Vacuum w/ regenerative air every 6 weeks
- Infiltration maintained at 300-500 in/hr in most areas

Image: Saw cut joint.
Photo courtesy of M. Maloney
• After 5 years, 20% of traverse joints were spalled & 15% surface raveled
• Deicing salt section most raveled
• Hydraulic conductivity is decreasing but still at functional level
• Sound adsorption is decreasing
• Including maintenance costs and anticipated surface grinding, pervious concrete is more cost effective than alternatives
Overall Conclusions

- Permeable pavements can result in less winter salt application
- Permeable pavements can reduce runoff volume and improve water quality (with other benefits)
- Permeable pavements are more expensive to construct
- Construction & maintenance are critical to success
Overall Conclusions (Cont’d)

• Maintenance: pressure washing and/or vacuuming
• Permeable pavements can withstand harsh winters
• Permeable pavements can maintain infiltration rates throughout the winter
• Advances are being made continuously
Thank you for your attention!

Questions?

Peter.Weiss@valpo.edu
Research Needs

- Structural/Construction: long-term performance, aggregate grading, geotextiles, compaction energy, in-situ tests, life-cycle cost analysis…
- Hydraulic/WQ: mix design as pollution source, hydraulics w/ heavy loads, raised drain tile, long-term WQ, N/P fate..
- Maintenance: quantify clogging, cleaning methods, frequency, optimal pavement design…

http://www.vaasphalt.org