PERMEABLE PAVEMENTS IN COLD REGIONS

5TH ANNUAL NEW HAMPSHIRE JOINT ENGINEERING SOCIETIES CONFERENCE
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Jon E. Zufelt, PhD, PE
ERDC-CRREL
Anchorage, Alaska
Outline

- Why am I here?
- What exactly am I going to talk about?
- Energy Independence and Security Act
- Permeable Pavements in Cold Regions White Paper for USARAK
- TCCRE Monograph

I would also like to acknowledge all the cited study authors, co-authors Rosa Affleck, Kelsey Gagnon
What am I talking about?

- Cold Regions – areas that experience at least one month per year with air temperatures below freezing
- Pavements that allow or increase the passage of storm water through their surfaces to the underlying base and sub-base material
  - Pervious Concrete
  - Porous Asphalt
  - Permeable Interlocking Pavers
Energy Independence and Security Act

- Passed in 2007, the EISA:
  - established new storm water design requirements
  - All Federal development and redevelopment projects
  - Federal facility projects over 5,000 square feet must
    - “maintain or restore, to the maximum extent technically feasible, the predevelopment hydrology of the property with regard to the temperature, rate, volume and duration of flow.”
- Federal agencies can comply using a variety of storm water management practices
  - "green infrastructure" or "low impact development" practices
  - includes reducing impervious surfaces, using vegetative practices, porous pavements, cisterns and green roofs
Permeable Pavements White Paper

- Began at the request of JBER Natural Resources Office
- Continued development of JBER
- Almost all projects over 5000 ft²
- Some typical treatments for reduction of storm water now not available
- Underground Injection Control wells no longer allowed (ADEC)
- Questions of water quality from storm runoff (roofs, roads, parking areas)
Example of Redevelopment
UIC’s
Permeable Pavements White Paper

- Literature review of past applications/studies in cold regions
- General description of permeable pavement types and their design
- Description of six studies utilizing different types of permeable pavements at six different locations and climates
- Comparison of climates to Alaska
Literature Review

- Identified 135 studies specifically mentioning pervious concrete, porous asphalt, or interlocking concrete pavers
- Of these, 31 were definitely looking at the impacts of cold
- Of these, 6 were chosen to provide a wide range of climate and to document the three types of pavements
General design characteristics

- Allow storm water to percolate through the voids in the surface layer, reducing runoff
- Permeable, pervious, porous
- Generally installed on gently sloping or flat ground, light traffic, limited heavy vehicle use
- Critical element is the porous layers of stone beneath the permeable surface to promote infiltration
- Typically used for sidewalks, parking areas, or low traffic density areas
Pervious Concrete Pavement

Pervious concrete surface layer with 15-25% voids to promote flow through the layer

Clean, coarse aggregate layer (20-40% voids) to act as temporary storage for runoff
Geotextile liner to prevent migration of fines

Native soil sub base

(Specifier’s Guide to Pervious Concrete Pavements in the Greater Kansas City Area)
Asphalt layer has minimal fines in mixture, laid in a single course
Thickness of storage layer (clean aggregate) depends on the storage volume required (design storm)
Permeable Interlocking Pavers (Permeable Interlocking Concrete Pavers)

Typical PICP configuration (after Smith, 2010)
Ground Temperature in Porous Pavement During Freezing and Thawing, Lulea Sweden

Groundwater temperatures ranged from 3°C in April to 8°C in October

First winter was warmer than average with much more snow

Second winter was colder than average with much less snow
Two test sections: 45mm thick porous asphalt layer with $d_{10} = 1\text{mm}$, 45mm thick conventional asphalt with $d_{10} = 0.125\text{mm}$.

Both over 1.0m aggregate base wrapped in geotextile.

Temperature and groundwater levels recorded.
Ground Temperature in Porous Pavement During Freezing and Thawing, Lulea Sweden

Water table levels higher under porous pavement (especially in thaw). Ground temperatures beneath the porous pavement were higher (less frost heave)
Deflection Basin Measurements And Seasonal Structural Behavior Of Interlocking Concrete Block Pavements In A Urban Northern Context, Québec City, Québec

Investigated interlocking concrete paver performance with variations in traffic volume, season, sub base thickness
Deflection Basin Measurements And Seasonal Structural Behavior Of Interlocking Concrete Block Pavements In A Urban Northern Context, Québec City, Québec

Table 1. Thickness layers of pavement structures. (after Pierre et al. 2009)

<table>
<thead>
<tr>
<th>Layer</th>
<th>Thickness (mm)</th>
<th>Layer</th>
<th>Thickness (mm)</th>
<th>Layer</th>
<th>Thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete block</td>
<td>100</td>
<td>Concrete block</td>
<td>100</td>
<td>Concrete block</td>
<td>100</td>
</tr>
<tr>
<td>Bedding sand</td>
<td>20</td>
<td>Bedding sand</td>
<td>15</td>
<td>Stabilized bedding sand</td>
<td>15</td>
</tr>
<tr>
<td>Granular base (0 – 20 mm)</td>
<td>400</td>
<td>Granular base (0 – 20 mm)</td>
<td>225</td>
<td>Bitumen stabilized granular base</td>
<td>125</td>
</tr>
<tr>
<td>Granular base (0 – 112 mm)</td>
<td>300</td>
<td>Granular base (0 – 56 mm)</td>
<td>275</td>
<td>Granular base (0 – 20 mm)</td>
<td>300</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Granular base (0 – 112 mm)</td>
<td>300</td>
<td>Granular base (0 – 112 mm)</td>
<td>600</td>
</tr>
</tbody>
</table>

Main street – average traffic loads, Principal avenue – high traffic volume, Industrial – heavy loads and high traffic volume
Deflection Basin Measurements And Seasonal Structural Behavior Of Interlocking Concrete Block Pavements In A Urban Northern Context, Québec City, Québec

Traffic loads simulated by a falling weight deflectometer at loading values of 40, 50, and 60 kN during fall, winter, and spring
Deflection Basin Measurements And Seasonal Structural Behavior Of Interlocking Concrete Block Pavements In A Urban Northern Context, Québec City, Québec

• Results analyzed Surface Curvature Index (SCI) and Base Curvature Index (BCI)
• SCI was lower in the bitumen stabilized granular base (thickness of the surface base course is important)
• No significant difference between types for the BCI
• Lowest deflections in winter when pavement frozen
• Highest deflections in spring during thaw
• Structural performance is a function of the thickness and type of the base layer
Performance Evaluation of Permeable Pavement and a Bioretention Swale Seneca College, King City, Ontario

Investigated the water quality associated with parking lot runoff: conventional asphalt surface, conventional surface leading to bioswale, interlocking concrete pavers

![Graph showing temperature over the months March to November.](image-url)
Seasonal high water table is more than 3 m beneath the surface.

Runoff collected at the pavement surface and as infiltrate 1.5 m beneath the bioswale and PCIP.
Performance Evaluation of Permeable Pavement and a Bioretention Swale Seneca College, King City, Ontario

Results indicated:
• Even during sub-zero air temperatures the PICP (and base course layer) functioned effectively
• Water quality testing showed significantly lower concentrations of pollutants in the PICP runoff and infiltrate as compared to the asphalt runoff
• Salt from winter maintenance could increase the mobility of metals in the groundwater
• Winter surface temperatures of the asphalt and PICP were very similar, but the PICP reduced local ponding and ice build-up (frozen puddles) because of its ability to infiltrate surface water
Examinations of Pervious Concrete and Porous Asphalt Pavements: Performance for Stormwater Management in Northern Climates, Durham, New Hampshire

- Study to compare winter performance of porous asphalt (PA) and pervious concrete (PC)
- Response to frost penetration
- Hydraulic performance measured by infiltration capacity
- Winter performance based on snow and ice cover
- Surface friction (slip and fall)
- Porous asphalt lot – hydraulically isolated 5,000 ft²
- Dense mix asphalt lot – hydraulically isolated
- Pervious concrete lot – 20,000 ft²
- Standard asphalt lot (control)
Examinations of Pervious Concrete and Porous Asphalt Pavements Performance for Stormwater Management in Northern Climates, Durham, New Hampshire

Average winter snowfall is 63 inches
Examinations of Pervious Concrete and Porous Asphalt Pavements Performance for Stormwater Management in Northern Climates, Durham, New Hampshire

• PA surface had 18-20% voids placed in single 4” lift
• PC surface had 15-25% voids placed in single 6” lift
• Both placed over choker stone course
• 12” or more filter course of bank run gravel (to improve water quality)
• Sub base filter layer of 14” for PC, 24” for PA
• Additional sub base crushed stone reservoir of 4” for PC and 21” for PA for water storage
• Temperature and groundwater level recorded
• Monthly surface infiltration capacity tests
• Visual observations, friction measurements, records of met data
Examinations of Pervious Concrete and Porous Asphalt Pavements Performance for Stormwater Management in Northern Climates, Durham, New Hampshire

Results:
- PA provided greater overall benefits but PC had strengths
- PA performed well throughout freeze-thaw structurally, visually, and hydraulically
- PA allowed salt load reduction of over 70% (water drainage and less buildup of ice)
- PC infiltration rates were higher than PA
- PC also had salt load reduction
- PC surface is lighter colored – less solar incidence
- Normal snow removal operations led to less overall salt load and snow and ice buildup
Examinations of Pervious Concrete and Porous Asphalt Pavements Performance for Stormwater Management in Northern Climates, Durham, New Hampshire

Changing pavement conditions with time. PA vs. DMA. PA at 11:20am top left vs PA at 1pm top right. DMA at 11:20am bottom left vs DMA at 1pm bottom right. (after Houle et al 2009)

Pervious concrete surface conditions with varying levels of shading (left: sun, center: partial sun, right: shade). (after Houle et al 2009)
TCCRE Monograph

- American Society of Civil Engineers – Technical Council on Cold Regions Engineering (TCCRE) produces a series of monographs

- *Permeable Pavements in Cold Regions* arose due to a lack of guidance on design techniques

- Goal is to provide some history, design recommendations, construction, and operations/maintenance options for the three major types of permeable pavements
Chapter 1. Introduction

A. Types of permeable pavements covered in the document
   i. Pervious Concrete
   ii. Porous Asphalt
   iii. Permeable Interlocking Pavers

B. Current applications
   i. Stormwater Management
   ii. Splash and Spray Reduction

C. Potential/Future applications
   i. Safety for Slip and Fall
   ii. Urban Heat Island Mitigation/Permafrost Preservation
   iii. Noise Reduction

D. Summary of current reference documents
   i. Pervious Concrete (ASCE, ACI, NRMCA, …)
   ii. Porous Asphalt (ASCE, AI, ….)
   iii. Permeable Interlocking Pavers (ASCE, ILPP, …)

E. Summary of current reference specifications
   i. (ACI, AI, UFGS 2009/2010, State DOTs)

Chapter 2. Permeable Pavement History in Cold Regions

A. Broad Applications and Purposes
B. Vehicular Pavement
C. Parking Areas
D. Non-Vehicular Pavement
E. Case Studies
F. Summary of Lessons Learned
Chapter 3. Design Considerations Consistent for All Pavement Types

A. Hydrologic
   i. Site Investigation

B. Hydraulic
   i. Section Design
   ii. Infiltration Considerations (especially for clogging from winter maintenance)
   iii. Stormwater Treatment

C. Heat Transfer
   i. (specifically looking at freeze behavior at soil interface and potential improved performance for permafrost)

D. Freezing and Thawing Base Behavior

Chapter 4. Pervious Concrete Design for Cold Climates

A. Structural Design
B. Mixture Proportioning
   i. Material Selection
   ii. Proportioning Guidelines
   iii. Sample Mixture Proportions

C. Construction
D. Curing
Chapter 5. Porous Asphalt Design for Cold Climates
   A. Structural Design
   B. Mixture Proportioning
      i. Material Selection
      ii. Proportioning Guidelines
      iii. Sample Mixture Proportions
   C. Construction

Chapter 6. Permeable Interlocking Paver Design for Cold Climates
   A. Structural Design
   B. Mixture Selection
   C. Construction

Chapter 7. Operation and Maintenance
   A. Routine and Expected Maintenance
      i. Ice and Snow Removal
      ii. Permeability Maintenance
   B. Unanticipated Maintenance Concerns
      i. Clogging Remediation
      ii. Pavement Distresses
Contributing Authors

- John Kevern - University of Missouri-Kansas City
- Liv Haselbach - Washington State University
- Spencer Guthrie - Brigham Young University
- Mary Vancura - University of Minnesota
- Rob Roseen - University of New Hampshire
- Bob Lisi - LHB Corporation
- Matt Lebens - Minnesota Department of Transportation
- Dave Smith - Interlocking Concrete Pavement Institute
- Hannele Zubeck – University of Alaska Anchorage
- Ben Worel – MnROAD
- Jon Zufelt - CRREL
Timeline

- Outline for chapters – September 2011
- Rough draft for chapters – January 2012
- Second draft complete – April 2012
- Final – July 2012
- Presentation of Monograph – August 2012 at the ASCE/CSCE Cold Regions Engineering Conference in Quebec City
- Publication of Monograph – October 2012
Questions??

Jon.e.zufelt@usace.army.mil