The State of the Practice and Common Pitfalls for Porous Asphalt for Stormwater Management and Transportation System in Northern Climates

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- Kelly Collins, CWP, Committee Vice Chair
- Joshua F. Briggs, Geosyntec
State of the Practice

- Significant advancements in PA strength, durability, and cost have been achieved.
- Large increase in significant PA installs for light duty, residential, commercial, and state road applications.
- However, a large number of installations STILL continue to be sub-standard.

WHY???
Why So Many Poor Installations?

Porous pavements are an filtration/infiltration system as well as a transportation surface.

Because of dual functionality:

- Greater site evaluation and design effort
- Strict engineering oversight and skilled personnel through all phases of the project
- Requires a comprehensive maintenance schedule
Common Pitfalls

- Inappropriate PA mix selection WRT to durability leads to raveling and low durability
- Poor subbase compaction—tendency to under-compact due to concerns regarding infiltration leads to rutting
- Poor asphalt compaction—tendency to under-compact due to weaker subbase leads to low pavement durability

All issues can be addressed through qualified engineering oversight
Porous Asphalt Design Overview

- Porous pavements for new and redevelopment are a watershed-based strategy that can both mitigate impacts for new development and reverse impacts in areas with redevelopment.

- Porous asphalt systems combine stormwater infiltration, storage, and structural pavement in a single system.

- PA consists of a pavement surface underlain by a stormwater storage bed. The bed is usually placed on uncompacted soil to facilitate infiltration.
Porous Asphalt Residential Lane, Pelham, NH 
(Source: UNHSC)

Parking Lot with Standard Aisle and Porous Asphalt Stalls, Morris Arboretum, Philadelphia, PA (Source: CH2M HILL)

Porous Asphalt Path, Grey Towers National Historic Site, PA  
(Source: CH2M HILL)

Porous Asphalt Commercial Parking Lot, Greenland Meadows, Greenland, NH  
(Source: UNHSC)

Porous Asphalt Section of State Highway, South Portland, ME (Source: ME DOT)

Porous Asphalt Basketball Court, Upper Darby, PA  
(Source: CH2M HILL)
Hydrologic Performance

2.96 in depth

D-Box Flow
Effluent Flow
Precip
Contaminant Removal Performance Efficiencies

### Porous Asphalt Performance

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>Summer</th>
<th>Winter</th>
<th>Annual</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSS</td>
<td>36 mg/L</td>
<td>711 µg/L</td>
<td>100%</td>
</tr>
<tr>
<td>TPH-D</td>
<td>0.24 mg/L</td>
<td>0.08 mg/L</td>
<td>90%</td>
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<tr>
<td>DIN</td>
<td>0.04 mg/L</td>
<td>0.05 mg/L</td>
<td>80%</td>
</tr>
<tr>
<td>Zn</td>
<td>0.09 mg/L</td>
<td>0.3 mg/L</td>
<td>70%</td>
</tr>
<tr>
<td>TP</td>
<td>0.08 mg/L</td>
<td>0.09 mg/L</td>
<td>60%</td>
</tr>
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</table>

### Retention Pond

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>Summer</th>
<th>Winter</th>
<th>Annual</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSS</td>
<td>45 mg/L</td>
<td>0.86 mg/L</td>
<td>100%</td>
</tr>
<tr>
<td>TPH-D</td>
<td>0.3 mg/L</td>
<td>0.05 mg/L</td>
<td>90%</td>
</tr>
<tr>
<td>DIN</td>
<td>0.05 mg/L</td>
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</tr>
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</table>
Typical Porous Asphalt System Sections

Section with Filter Course for Water Quality

- **Pervious pavement**: 4-6" (10 - 15 cm) of porous asphalt section with filter course for water quality
- **Typical section for storage and infiltration**: 4"-8" (10 – 20 cm) minimum thickness of subbase (aka. bank run gravel or modified 304.1)
- **Choker Course**: 4"-8" (10 – 20 cm) minimum thickness of subbase
- **Filter Course**: 8" - 12" (20 - 30 cm) minimum thickness of subbase (aka. bank run gravel or modified 304.1)
- **Filter Blanket**: intermediate setting bed: 3" (8 cm) thickness of \(\frac{3}{8}\)" (1 cm) pea gravel
- **Reservoir Course**: 4" (10 cm) minimum thickness of \(\frac{3}{4}\)" (2 cm) crushed stone for frost protection. 4-6" (10-15 cm) diameter perforated subdrains with 2" cover

Optional-Liner for land uses where infiltration is undesirable (e.g., hazardous materials handling, sole-source aquifer protection)

Native materials
Applications - Site Constraints

1. Minimum 2-foot separation from bedrock and seasonal high water table,

2. Measured soil infiltration rates typically between 0.25 and 12 inches per hour, <0.25 in/hr may require additional drainage and recharge beds

3. Appropriate separation from wells, septic systems, subsurface structures (basements), etc., and

4. Where risk of groundwater contamination exists, as with any LID filtration system, the system may be lined to prevent infiltration, thereby being limited to its filtration benefits
1. Pretreatment or avoidance of runoff from hot spots,

2. Locations of potential groundwater contamination from either high loading, high groundwater, or bedrock should employ liners.

3. Level, or nearly level stormwater bed bottoms; sloped installations will need to employ internal grade controls

4. A consideration of the loading ratio (ratio of drainage area to infiltration area),

5. Consideration of potential sediment, detritus, etc. sources that could lead to clogging,

6. Proper drainage
## Porous Asphalt Mixes

1. **LOW-MODERATE DURABILITY**: PG 64-28* with 5 pounds of fibers per ton of asphalt mix. This mix is recommended for smaller projects with lower traffic counts or loading potential. This mix is manageable at common batch plants.

2. **MODERATE DURABILITY**: Pre-Blended PG 64-28* SBS/SBR with 5 pounds of fibers per ton of asphalt mix. This mix is recommended for large projects > 1 acre where high durability pavements are needed.

3. **HIGH DURABILITY**: Pre-Blended PG 76-22** modified with SBS/SBR and 5 pounds of fibers per ton of asphalt mix. This mix is recommended for large sites anticipating high wheel load (H-20) and traffic counts for maximum durability.

*or PG binder typical to region; **PG binder 2 grades stiffer
## Porous Asphalt Mix Criteria

<table>
<thead>
<tr>
<th>Sieve Size (inch/mm)</th>
<th>Percent Passing (%)</th>
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<tbody>
<tr>
<td>0.75/19</td>
<td>100</td>
</tr>
<tr>
<td>0.50/12.5</td>
<td>85-100</td>
</tr>
<tr>
<td>0.375/9.5</td>
<td>55-75</td>
</tr>
<tr>
<td>No.4/4.75</td>
<td>10-25</td>
</tr>
<tr>
<td>No.8/2.36</td>
<td>5-10</td>
</tr>
<tr>
<td>No.200/0.075 (#200)</td>
<td>2-4</td>
</tr>
</tbody>
</table>

Binder Content (AASHTO T164) 6 - 6.5%
Fiber Content by Total Mixture Mass 0.3% cellulose or 0.4% mineral
Rubber Solids (SBR) Content by Weight of the Bitumen 1.5-3% or TBD
Air Void Content (ASTM D6752/AASHTO T275) 16.0-22.0%
Draindown (ASTM D6390)* ≤0.3 %
Retained Tensile Strength (AASHTO 283)** ≥ 80 %
Cantabro abrasion test on unaged samples (ASTM D7064-04) ≤ 20%
Cantabro abrasion test on 7 day aged samples ≤ 30%
Cold Climate Considerations

Thickness of sub-base materials is determined based on various factors

1. In cold climates / penetration of freezing Total system thickness $\geq 0.65 \times D_{\text{max}}$ frost depth (Ex. if $D_{\text{max}} = 48''$, sub-base depth = 32'')

2. The high voids content of the reservoir course creates a capillary barrier to prevent wicking of moisture in subbase minimizing winter freeze-thaw and heaving
Recommended Installation
Compaction and Rutting

- Install filter, choker, gravel, and stone base course aggregate in 8-inch maximum lifts to a MAXIMUM of 95% standard proctor compaction (ASTM D698 / AASHTO T99).

- The density of subbase courses shall be determined by AASHTO T 191 (Sand-Cone Method), AASHTO T 204 (Drive Cylinder Method), or AASHTO T 238 (Nuclear Methods), or other approved alternate.

- The infiltration rate (ASTM D3385 or approved alternate) shall be no less 5-30 ft/day or 50% of the hydraulic conductivity (D2434) at 95% standard proctor compaction.
Multiple lift installation

- PA can be installed as 1 or 2 lifts depending on site
- 2\textsuperscript{nd} lift improves pavement compaction
- Paving sequencing is important---plan to minimize traffic on completed lifts
- Should be up to the contractor. Small simple jobs may be easier in a single lift, larger jobs in two lifts.
- Two-lift scenario may require use of a light application of tackifier between the first and second lift.
- Enables installation of curbs and castings in typical fashion
- Simplifies use of “tacky” 64-28SBR/SBS or 76-22SBR/SBS as top layer and 64-28 with fibers as base course
Asphalt Compaction

- Immediately after the asphalt mixture has been spread, struck off, and surface irregularities adjusted, it shall be thoroughly and uniformly compacted by rolling. The compaction objective is 16% - 19% in place void content (Corelock).
- Breakdown rolling shall occur when the mix temperature is between 275 to 325°F.
- Intermediate rolling shall occur when the mix temperature is between 200 to 275°F.
- Finish rolling shall occur when the mix temperature is between 150 to 200°F.
- The cessation temperature occurs at approximately 175°F, at which point the mix becomes resistant to compaction and will not achieve adequate durability.
- Rolling should not cause undue displacement, cracking, or shoving.
Curing time needs are site specific but there should be at least 24-48 hrs of curing. Common sense clause may lead to lower threshold for small jobs with lighter loading such as when pavement surface is less than 100 F (one-time measurement). Problems occur when the surface temperature is greater than 120 F.
Repairs and Replacement

- Damage can occur to PA from non-design loads
- Repairs may be needed from cuts for utilities
- Repairs can be made with standard HMA for most damages up to 15% of surface area
- PA can be repaired by heating and rerolling at $2000/day at approximately 500’ of trench
- When pavement reaches end of life, it is replaced by milling to choker coarse.
Used for repairs around manholes, catch basins, and reworking rough pavement areas.

Asphalt in the repair area can be raked and rolled back into place and additional hot mix can be added when needed.

Repairs cost ~$2000.
Cost Information

- ~10-20% more for materials
- 2009, DMA $75-100/ton, PA $89-125/ton placed by machine for parking and residential road and driveways
- Complicated jobs with handwork are more expensive
- DMA $2.25/sf, PA $2.80/sf, not including subbase
- Costs offset by lack of stormwater infrastructure
- Cost break even is achieved when designing for quantity management ~Q10-Q25
Looking Forward

- The need for training and possible certification for designers and installers
- Installation checklist
- Increased availability of PA suppliers
- Greater availability of pavement cleaning
Example Sites in the Northeast
Greenland Meadows Commercial

- “Gold-Star” Commercial Development
- Cost of doing business near Impaired Waters/303D
- Saved $930,000 on total cost of SWM (26%), on drainage, and MTD
- Brownfields site, ideal location, 15yrs
- Proposed site >10,000 Average Daily Traffic count on >30 acres
28 ac site, initially >95% impervious, now <10%EIC, with all drainage through filtration, expected to have minimal WQ impact except thermal and chloride
Boulder Hills, Pelham, NH

- 2009 Installation of 900’ of first PA private residential road in Northeast
- Site will be nearly Zero discharge
- LID subdivision 55+ Active Adult Community
- Large sand deposit
- Cost 25% greater per ton installed
Avoided use of 1616’ of curbing, 785’ pipe, 8 catch-basins, 2 detention basins, 2 outlet control structures

Conventional SWM=$789,500 vs LID SWM=$740,300, $49,000 savings (6.2%)
Maine Mall, Long Creek Watershed
S. Portland, ME

- Surface Transportation ARRA Project
- First DOT PA road in the northeast - Sept 09
- 1500 feet of Highway Reconstruction
- 20,000 vehicles per day
Maine Mall

- Significant that DOT is even considering it
- DOT involvement in PA is crucial for success
- Rockstar Mix
  - PG76-24SBS with Fibers
- High durability
- RDA/TMDL was essential
Conclusions

- Porous pavements are not a silver bullet
- PP are a watershed-based strategy that can both mitigate impacts for new development and reverse impacts in areas with redevelopment.
- Successful installations will require
  - Greater site evaluation and design effort
  - Strict engineering oversight and skilled personnel through all phases of the project
  - Requires a comprehensive maintenance schedule
Questions?
7. Detailed Specifications

- Committee Report on Recommended Design Guidelines for Permeable Pavements—Late 2010
- University of New Hampshire Stormwater Center (UNHSC)
- ASTM WK-15789 (a committee is currently working on a specification for pervious asphalt)
- Some state Department of Transportation (DOT) specifications may also be partially applicable for pervious asphalt systems although they should be reviewed carefully before being used. Notable examples include:
  - Oregon DOT F-Mix
  - Georgia DOT Open-Graded Friction Course
## Structural Considerations

### Recommended Structural Layer Coefficients for Porous Asphalt

<table>
<thead>
<tr>
<th>Material</th>
<th>Layer Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Porous asphalt</td>
<td>0.40 – 0.42</td>
</tr>
<tr>
<td>Asphalt treated permeable base (ATPB)</td>
<td>0.30 – 0.35</td>
</tr>
<tr>
<td>Porous aggregate base (stone infiltration bed)</td>
<td>0.10 – 0.14</td>
</tr>
</tbody>
</table>

### Minimum Compacted Porous Asphalt Thickness

<table>
<thead>
<tr>
<th>Traffic Loading</th>
<th>Minimum Compacted Thickness (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parking – few or no trucks</td>
<td>2.5</td>
</tr>
<tr>
<td>– some trucks</td>
<td>4.0</td>
</tr>
<tr>
<td>Heavy trucks</td>
<td>6.0</td>
</tr>
</tbody>
</table>

Liners

- Federal guidelines regulate groundwater protection standards.
- Most states require 1-3 ft separation between the system and the seasonal high water table (or bedrock).
- Liners can be used for sites where the infiltration is not appropriate (e.g., high water table, bedrock karst sites and hot spots where hazardous materials may be handled).
- The use of Liners will preserve water quality through detention and filtration but limit any infiltration.
- Liners can be made from HSG 'D' soils, HDPE, or clay.
Geotextiles

- Recommendations vary on the usage of geotextiles in pervious pavement systems.

- At minimum, geotextiles should be used on soils with poor load bearing capacity, high fines content, and on the sides of the excavation to prevent in-migration of fines.

- Infiltration systems, such as pervious pavements, that are subject to soil movement and deposition should carefully consider the usage of geotextiles.
Subbase Materials

- A 1-4 inch layer choker course (often AASHTO #57)
- A filter course of poorly graded sand can be included for its water quality and hydrologic benefits at thicknesses of 8” to 12” minimum
- A stormwater infiltration bed AASHTO #57 to #3 with approximately 40% void space. The bed is typically 8 to 36 inches deep
I-93 Exit 5 Park and Ride

- 2007 Construction NHDOT Park and Ride and bus maintenance facility
- Infiltration required due to TMDL listing
- Rear parking lot, little usage
- Training wheels
- 2005 discussions