Porous Asphalt

Scot Schwandt
Executive Director of WAPA
Presentation Outline

• Concept
• Applications
• Design
• Construction
• Operation
• Costs
• Examples
Porous Asphalt

- Concept
Porous Pavements are Unique

- Conventional pavement philosophy is to build a roof over the pavement
  - Keep the water out
  - Drain water to the edges
- Porous Pavements intentionally allow the water to drain through and be stored below
Porous Pavements are Unique

- **Porous Asphalt Pavement**
  - An open-graded asphalt surface over a stone recharge bed where stormwater is stored.
What are Porous Pavements?
Why are they needed?

- New stormwater regulations
  - Reduce volumes
  - Limit the impervious area
  - Stormwater tax
- Sustainability
- LEED Credit
Stormwater Management

- Decreases runoff and increases infiltration
Undeveloped Site

- Rainfall: 45" (1143 mm)
- Evapotranspiration: 22" (558.8 mm)
- Infiltration
- Runoff: 8" (203.2 mm)
- Aquifer
- Baseflow: 15" or 1,120 gpd/acre
After Development

Rainfall: 45"/yr

Evaporative Loss from Impervious Surfaces: 2"

Reduced Infiltration through Regraded and Compacted Soils in Grasses

0" of Infiltration under Impervious Surfaces

Reduction in base flow by 15"/yr under Impervious Surfaces

43" Runoff from Impervious Cover
Challenges

• More Development
  – More Impervious Area
  – More Runoff
• Detention Basins and Retention Ponds
• Flash Flooding
• Suspended solids and chemicals entering our streams
Water Quality Benefits

Average Removal Efficiency

- TSS
- Metals
- Zn
- Bacteria
- Ammonia
Water Quality Benefits

### Median Pollutant Removal (%) of Stormwater Treatment Practices

<table>
<thead>
<tr>
<th>POLLUTANT</th>
<th>INFILTRATION PRACTICES</th>
<th>Stormwater Wetlands</th>
<th>Stormwater Ponds Wet</th>
<th>Filtering Practices</th>
<th>Water Quality Swales</th>
<th>Stormwater Dry Ponds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Phosphorus</td>
<td>70</td>
<td>49</td>
<td>51</td>
<td>59</td>
<td>34</td>
<td>19</td>
</tr>
<tr>
<td>Soluble Phosphorus</td>
<td>85</td>
<td>35</td>
<td>66</td>
<td>3</td>
<td>38</td>
<td>-6</td>
</tr>
<tr>
<td>Total Nitrogen</td>
<td>51</td>
<td>30</td>
<td>33</td>
<td>38</td>
<td>84</td>
<td>25</td>
</tr>
<tr>
<td>Nitrate</td>
<td>82</td>
<td>67</td>
<td>43</td>
<td>-14</td>
<td>31</td>
<td>4</td>
</tr>
<tr>
<td>Copper</td>
<td>N/A</td>
<td>40</td>
<td>57</td>
<td>49</td>
<td>51</td>
<td>26</td>
</tr>
<tr>
<td>Zinc</td>
<td>99</td>
<td>44</td>
<td>66</td>
<td>88</td>
<td>71</td>
<td>26</td>
</tr>
<tr>
<td>TSS</td>
<td>95</td>
<td>76</td>
<td>80</td>
<td>86</td>
<td>81</td>
<td>47</td>
</tr>
</tbody>
</table>

Porous Asphalt

• Applications
Parking Lots
Recreational Facilities
# Streets and Roads

<table>
<thead>
<tr>
<th>Layer</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5” Porous Surface Course</td>
<td>Porous Asphalt Cement Concrete</td>
</tr>
<tr>
<td>3.0” ATPB Choker Course</td>
<td>1-2” Provides working surface for construction</td>
</tr>
</tbody>
</table>
| 10.0” Reservoir Course | Clean uniformly
  Graded Crushed Aggregate
  Approximately 40% voids                                                   |
| 8.0” Pit Run Subbase   | 4” - 0 Clean                                                                 |
| Uncompacted Subgrade   | Uncompacted to retain permeability                                           |

*WAPA* (Wisconsin Asphalt Pavement Association)
Porous Asphalt Applications

Non-Desirable:

- Anywhere there’s a significant risk of groundwater contamination
  - Truck stops
  - Heavy industrial areas
- Heavy traffic loading situations
- Where smooth surfaces are necessary
  - Roller blading/skating areas
  - Skateboard/Scooter parks
Porous Asphalt

• Design
  – Reservoir
  – Porous Asphalt
    ▪ Thickness
    ▪ Mixture
    ▪ Ancillary Features
Drainable Pavement Structure

The Components:

- Porous Asphalt Pavement
- Paving Platform Layer
- Reservoir Layer
- Filter Layer
- Filter Fabric
Overall Design Concept

• To build a permeable structure that passes water vertically faster than it is supplied to the surface (which eliminates ponding), and has sufficient storage capacity to accommodate the water supplied through the pavement.
Design Methodology

System Functionality

• Site De-watering
• Reduction in impervious area while providing ground water recharge
• Reduction in impervious area & peak rainfall inflow to stormwater systems
• Combinations
Design Methodology

The Steps:

• Determine water inflow
• Determine soil capacities
• Determine structure type
• Determine structure layer thicknesses
• Determine optional drainage feature requirements
Design Methodology

**Water Flow**

- Calculate rainfall inflow
  - Design Storm event
  - Stormwater inflow calculation method
- Identify site requirements and capabilities
  - Test soil permeability
  - Environmental constraints
  - Land usage

\[
\text{Porous Pavement System}
\]

\[ Q_{in} \]

\[ Q_{out} \]
Soil Design Parameters

<table>
<thead>
<tr>
<th>Soil Group</th>
<th>Infiltration Rate (in/hr)</th>
<th>Water Storage Capacity (inch of water)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand, open-structured</td>
<td>8.27</td>
<td>0.35</td>
</tr>
<tr>
<td>Loamy sand</td>
<td>2.41</td>
<td>0.31</td>
</tr>
<tr>
<td>Sandy Loam</td>
<td>1.02</td>
<td>0.25</td>
</tr>
<tr>
<td>Loam</td>
<td>0.52</td>
<td>0.19</td>
</tr>
<tr>
<td>Silty Loam</td>
<td>0.27</td>
<td></td>
</tr>
<tr>
<td>Sandy clay loam</td>
<td>0.17</td>
<td><strong>0.17</strong></td>
</tr>
<tr>
<td>Clay loam</td>
<td>0.09</td>
<td></td>
</tr>
<tr>
<td>Silty clay loam</td>
<td>0.06</td>
<td></td>
</tr>
<tr>
<td>Clay</td>
<td>0.02</td>
<td></td>
</tr>
</tbody>
</table>

Infiltration rates less than 0.2 in/hr are not suitable for infiltration practices. Typically these soils have ~25% or more clay. Soils with a poor drainage capacity are also susceptible to frost heaving and swelling expansion which may cause possible structural instability.
Design Methodology

Structure Type Selection

• If project site soils provide > 0.2 in/hr
  – Total Ground Water recharge is possible (no additional drainage features are needed)

• If project site soils provide < 0.2 in/hr
  – Additional drainage features are required to accommodate rainfall flow (storage tanks, ponds and/or piping systems)
Design Methodology

Pavement Structure Thickness

- Calculate drainage system layer thicknesses
  - HMA: structural capacity
  - Reservoir: system’s functionality
Design Methodology

Asphalt Structure Thickness

• Recreational Facilities:
  • 3” HMA

• Parking Stall areas:
  • 4” HMA

• Access Roads:
  • 6” HMA (2 Lifts)

(Design based on the WAPA Design Guide)
Design Methodology

Reservoir Structure Thickness

• The type of soil dictates how much volume is needed to “hold” the water before it can leach back into the surrounding soils
  – Layer thickness ranges from 16” to 48”
  – The key is to properly design the structure by knowing the infiltration rates of the soils, the design storm event, and level of expectation
Design Methodology

Reservoir Structure Thickness

• Design Considerations:
  - Rainfall storm intensity, \( i \) (in/hr)
  - Soil permeability, \( k \) (in/hr)
  - Additional drainage feature outflow, \( q \) (in/hr)
  - Rainfall storm duration, \( d \) (hr)
  - Reservoir aggregate storage capacity (~40% air voids)
  - Frost expansion (~10% increase)

\[
t = \frac{[(i - k - q)(d)(1.1)]}{(0.4)}
\]

16” min (Includes filter layers)
Design Methodology

Reservoir Structure Thickness

• The recommended air void content is 40%
  – To find it we ran tests on local 2” & 3” clear stone compacted/uncompacted

<table>
<thead>
<tr>
<th></th>
<th>Uncompacted</th>
<th>Compacted</th>
</tr>
</thead>
<tbody>
<tr>
<td>2” Clear</td>
<td>50.8%</td>
<td>42.4%</td>
</tr>
<tr>
<td>3” Clear</td>
<td>52.3%</td>
<td>45.6%</td>
</tr>
</tbody>
</table>

*Compacted level done in lab by rodding, not using compaction equipment*
Additional Considerations

• Average frost level for reservoir depth
  – Approximately 4 feet for this area

• Environmental restrictions
  – Remain 3’ above water table
  – Remain 2’ above bedrock
# WAPA Porous Asphalt Mix Design

## Mix Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>12.5 mm Mix</th>
<th>9.5 mm Mix</th>
<th>Test Standard</th>
<th>Footnote</th>
</tr>
</thead>
<tbody>
<tr>
<td>Binder Content</td>
<td>6.5% min</td>
<td>6.5% min</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Binder Grade</td>
<td>PG 64-22</td>
<td>PG 64-22</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>% Air Voids (N&lt;sub&gt;v&lt;/sub&gt; @ 50 gyrations)</td>
<td>18 - 20</td>
<td>18 - 20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tensile Strength Ratio (TSR @ 5 cycles freeze/thaw)</td>
<td>69% min</td>
<td>90% min</td>
<td>ASTM D4967</td>
<td>3</td>
</tr>
<tr>
<td>Draindown at Production Temperature</td>
<td>0.3% max</td>
<td>0.3% max</td>
<td></td>
<td>4</td>
</tr>
</tbody>
</table>

## Aggregate Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>100 Revolutions</th>
<th>500 Revolutions</th>
<th>Test Standard</th>
<th>Footnote</th>
</tr>
</thead>
<tbody>
<tr>
<td>LA Abrasion (% Loss)</td>
<td>13 max</td>
<td>13 max</td>
<td>AASHTO T 96</td>
<td></td>
</tr>
<tr>
<td>Soundness (% Loss) using sodium sulfate</td>
<td>45 max</td>
<td>45 max</td>
<td>AASHTO T 104</td>
<td></td>
</tr>
<tr>
<td>Freeze/Thaw (% Loss)</td>
<td>12 max</td>
<td>12 max</td>
<td>AASHTO T 103</td>
<td></td>
</tr>
<tr>
<td>Fractured Faces</td>
<td>18 max</td>
<td>18 max</td>
<td>ASTM D5821</td>
<td></td>
</tr>
<tr>
<td>2 Faces</td>
<td>90% min</td>
<td>90% min</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Face</td>
<td>100% min</td>
<td>100% min</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thin or Elongated</td>
<td>5% max 6:1 ratio</td>
<td>5% max 6:1 ratio</td>
<td>ASTM D4701</td>
<td></td>
</tr>
</tbody>
</table>

## Mixture Gradation

<table>
<thead>
<tr>
<th>Sieve</th>
<th>3/4&quot;</th>
<th>1/2&quot;</th>
<th>3/8&quot;</th>
<th>#4</th>
<th>#8</th>
<th>#16</th>
<th>#30</th>
<th>#200</th>
<th>VMA (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100</td>
<td>-</td>
<td>85 - 100</td>
<td>90</td>
<td>90</td>
<td>5 - 12</td>
<td>5 - 15</td>
<td>3 - 10</td>
<td>1 - 4</td>
</tr>
</tbody>
</table>

## Footnotes

1. 5.75 - 0.0% Recommended
2. min. high temperature of 94°C Recommended
3. following National guidance, we are not including the Cantabro Abrasion test in the mix design guidelines
4. effective measures to reduce draindown include the use of washed manufactured sand in lieu of crusher screenings and fibers. Also a slight reduction in production temperature may also be considered
Unpaved Edges
Porous Asphalt

• Construction
Construction Guidelines

Pre-Construction

• Test materials
  – Measure air voids of reservoir course & compare to design.

• View other projects
  – View examples of existing projects to choose gradation of asphalt.
Construction Guidelines

**Site Preparations**

- Regulating area during development.
  - Compaction of soils is a large concern
  - Fence off/control traffic
- Construct near the end of the project.
  - Make detailed list of construction sequence
  - Accomplish as many items as possible prior to installation of porous system
Construction Guidelines

**Site Preparations**

- Final cut to finished grade.
  - It is OK to do rough grading earlier in project, but leave final cut of 6”+ for end of job.
- If equipment must be in affected areas, use tracked vehicles.
  - Do not take for granted, should be few reasons to have any traffic on final subgrade.
- Consider re-testing permeability of soil.
- Bedding area should be as level as possible.
Construction Guidelines
Construction Guidelines

System Placement

- Install Geotextile Non-Woven Fabric
  - Place immediately after excavation.
  - Overlap fabric rolls (1.5’ minimum).
  - Pin to eliminate movement.
  - Excess Fabric (4’ minimum) should be left on edges of area to prevent contamination (much like silt fence).
Construction Guidelines
Construction Guidelines

System Placement

• Place Protective Filter Layer
  – 2 to 3 inch depth of ½” clear stone.
  – Trucks are to dump from the edge and tracked equipment will place the material.
  – Used to protect fabric from larger aggregates.

• Place Reservoir Layer
  – Depth as needed using 1” – 3” clear stone.
Construction Guidelines

System Placement

• Place Reservoir Layer
  - Place in minimum 8” lifts.
  - No trucks allowed to drive on insufficiently thick stone areas.
  - Test material for air voids.
  - Use a lightweight roller or plate compactor.
  - All equipment must be tracked in order to prevent subsurface compaction (except for finish grading operations)
Construction Guidelines

System Placement

• Place Paving Platform
  – 1 to 2 inch depth of 1/2” clear stone.
  – Installation identical to the filter layer.
  – Used to stabilize the larger aggregates and allow for the paving equipment to get on site.
Construction Guidelines
Construction Guidelines
Construction Guidelines
Construction Guidelines

System Placement

- Place HMA Porous Pavement
  - Track paver.
  - Hand work.
  - One Layer.
Construction Guidelines

System Placement

• Place HMA Porous Pavement
  – Rolling techniques:
    ▪ Let pavement cool to 200 F before rolling.
    ▪ Use in static mode only 1-2 passes.
    ▪ Roll just enough to “set” the mix.
    ▪ Let cool further to 150 F, final roll 1-2 passes.
Construction Guidelines

System Placement

• HMA Porous Pavement
  – Keep traffic off for as long as possible (one week minimum).
  – If striping with epoxy, plan to do it several months later, using cold paint in interim.
Construction Guidelines

Post Construction

• Protect from runoff of unstabilized areas.
  – Confirm vegetation is established before removing temporary storm water measures (filter fabric on edges).

• Inspect for design compliance during storm events.

• Signage for maintenance staff.
Porous Asphalt

- Operation
Maintenance Plan

- Inspect the pavement:
  - Once per quarter in year 1
  - Once a year for the pavement life
  - Check for ponding or clogging

- Pavement should be vacuum swept 2 – 4 times a year.

- Patching can be done with conventional HMA up to 10% of the surface area without affecting the pavement infiltration.
Maintenance Plan

• Use liquid de-icing if possible or very light salting, do not use sand.

• Make sure maintenance staff is aware of the “differences” regarding this pavement structure. Keep debris off surface.
  – This would include the selection of adjacent vegetation.

• Do not seal coat pavement or it will no longer be porous.
Educational Signs

These parking areas are paved with porous pavement that leaks since 1977, it has raised the local water table while reducing erosion, pollution, and the need for storm drains or road salt. A brochure is available. A demonstration project by Mass. D.E.P. & Mass. Dem.

Permeable Asphalt

The parking lot is full of holes. The asphalt covering this section of the parking lot is permeable, allowing water to drain through it. Some of the particles usually mixed into asphalt were left out, so that small holes remain in the asphalt pavement. Rain and melting snow drain through these holes down into a layer of gravel.

Why is it better than regular asphalt?
In a regular parking lot, rainwater runs off the pavement, empties into storm sewers, and ends up in creeks, carrying impurities along with it. Permeable asphalt allows that rainwater to drain directly below the parking lot. This filters particles and slows the flow of water, reducing the flooding of sewers and creeks. Another benefit of permeable asphalt is that it lessens the amount of standing water and ice on a parking lot, making it safer for drivers.
Porous Asphalt

• Costs
Porous Asphalt Pavement Costs

- HMA Mix ~40% more than conventional
  - Porous Asphalt (FOB) ~$60/ton
  - WisDOT E-1 (FOB) ~$42/ton
    - Add ~$10/ton if using a polymer modified asphalt
- Reservoir Material ~50% more than CABC
  - Reservoir Base (installed) ~$15 – 18/ton
  - Standard CABC (installed) ~$10 – 12/ton
- Fabric (same as standard usage)
- Additional drainage features ??? (as needed)
Porous Asphalt Pavement Cost Savings

- Reduced usage of sewer fixtures
- Reduced usage of curb and gutters
- Reduced real estate usage
- Reduced environmental effects (fines)
Porous Asphalt

- Examples
Hart Park
Hart Park – 2006

- Environmental Constraints:
  - Soil permeability is wide ranging.
    ▪ Unpredictable from design criteria.
  - 50% of the site is in a flood plane.
    ▪ Backup and clogging of pavement structure hazard.
  - Adjoining facility is used by local senior citizens and there are several walking paths
    ▪ Walking hazards must be eliminated.
  - Site topography is not ideal.
    ▪ Terracing was not going to be utilized.
  - Frost depth in area is approximately 2-3’.
    ▪ Stone design will not exceed frost depth.
Hart Park – 2006

- 21” of Uniformly Graded 1” Base
- 2-3” paving platform layer
- 4” (one-lift) of 9.5mm porous asphalt
- Dense grade used for curb base (constructability).
Hart Park – 2006

- Redundant storm water system
  - Full storm sewer system
  - Attention to grading plan.
  - Backup system was to mill & overlay with standard asphalt.
  - Drain tile system into storm water system at various locations for overflow from stone bed.
Mitchell International Airport
Mitchell International Airport

- Demonstration project July 2004
- Paved shoulder (25’X300’)
  - Fabric
  - 6” perforated underdrain
  - 6” open grade filter layer
  - 12” of ¾” clear stone reservoir
  - 6” of open grade paving platform
  - 6” 12.5mm porous asphalt pavement
    - 2 3” lifts
Mitchell International Airport

- Existing slope of 1.5-5.0%
- PG 64-22 at 4.0% ac
- Air voids of 17%
- Very tight clays with little infiltration (hence the perforated piping)
• Constructed August 2005
• 2/3 of job is porous asphalt with 1/3 porous concrete
  – Fabric
  – 12” of 3” clear stone reservoir layer
  – 6” of 2” clear stone reservoir layer
  – 2” of 1½” TB paving platform
  – 4” Porous HMA asphalt
• Existing slope of 4-6%
• PG 64-22
• Very good soil, practically beach sand
Robert Anderson Municipal Building
Robert Anderson Municipal Building
Performance

Porous Asphalt Pavement Photos:
Wauwatosa Fire Station Parking Lot [April 13, 2011]
Performance

MSOE Porous Pavement Parking Lot (City of Milwaukee)
Age: ~5 years old
Mixture Gradation: 9.5 mm

Covenant Hill Housing (City of Milwaukee)
Age: ~5 years old
Mixture Gradation: 12.5 mm
Middleton Lexus Dealership
Middleton Lexus Dealership
Middleton Lexus Dealership
Middleton Lexus Dealership
Sauk Trail School
Sauk Trail School
Sauk Trail School
Sauk Trail School
Performance