Pervious Pavement
Guidance Document
October 5, 2011

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Pervious Pavement

Source: Flexible Pavements of Ohio (2008)
Pervious Pavement
Why a Document?

- Promote the Use of Pervious Pavement

Goals

- Runoff Reduction
- Enhance BMP Toolbox
- Consistency/Reviewability
- Minimize Failures

Acknowledgments
Presentation Outline

- Overview
- Condition Where Practice Applies and Does Not Apply
- Planning Considerations
- Pavement Options
Presentation Outline

- Design Criteria – Stormwater
  - WQv
  - Peak Discharge
- Design Criteria – Structural
- Construction
- Maintenance
Presentation Outline

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  - WQv
  - Peak Discharge
- Design Criteria – Structural
- Construction
- Maintenance

**Draft available for public comment**
Condition Where Practice Applies

- Most settings where traditional pavements are used
- Especially suited to parking lots, parking lanes, sidewalks, playgrounds, plazas
- Sites where space is limited for use of traditional detention basins
Condition Where Practice Typically Does Not Apply

- Heavy Traffic Areas
- Potential Groundwater Contamination
  - Industrial & Chemical Storage Areas
  - Fueling Stations
- Sites with Sediment Source Areas (e.g., vehicle wash areas, bare soils, spoil piles, sand storage, certain landscaped areas, …)
- Unstable Slope Areas
- Pavement Slopes Greater than 5%
Pavement Slopes

Figure 10a. A "check dam" approach may be useful in long, sloped pavements.

Figure 10b. Terraces in pervious concrete pavement system with long slopes.

Source: Leming et al. (2007)

Source: PaDEP (2009)
Planning Considerations

- Preliminary Site Evaluation
- Soils
- Subgrade Compaction
- Grading
- Separation Distances
- Groundwater Concerns
- Karst Areas
Planning Considerations

- Freeze-Thaw & Frost Heave
- Drainage from Adjacent Areas
- Use of Liners
- Stormwater Detention
- Construction Sequencing
- Maintenance
- Cost
- Life Cycle Savings
Frost Depth

- Recommended Thickness of Pavement System

Pavement + Stone Layer = 0.65 * Frost Depth

(based on UNH Stormwater Center, 2009)

<table>
<thead>
<tr>
<th>Located North of Latitude</th>
<th>Max. Frost Depth (in)</th>
<th>Min. Recommended Thickness (0.65 x Frost Depth) (in)</th>
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<td>41.7 Ashtabula</td>
<td>44</td>
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</table>

* Tentative 6/10

Source: Floyd (1978)
Pavement Types

- Porous Asphalt
- Pervious Concrete
- Permeable Interlocking Concrete Pavement
- Clay Pavers
- Grid Pavers

Source: NC State Extension (2008)
Porous Asphalt

- Very Similar to an Asphalt Mix
- Expensive Binder for Small Batches
- Reduced Fines
- Historical Use as Surface Course on Highways to Reduce Spray
- NAPA or UNH Specifications
Porous Asphalt

Source: NAPA (2008)

Source: Adams (2005)

Source: Cornell UHI (2007)
Pervious Concrete

- Special Concrete Mix and Installation Guidelines, see Ohio Ready Mix Association Website
- Primarily Used in Parking Stalls
- Certified Installer Recommended
- 6” Pavement Thickness Recommended
Pervious Concrete
Pervious Concrete

Source: Colorado RMCA (2009)

NRMCA Pervious Concrete Contractor Certification Course

Program Summary

This program is designed to educate, train and certify concrete finishers in pervious concrete placement. Ohio Concrete engineers will provide a half-day classroom training necessary for the knowledge in pervious concrete materials and proper placement procedures in preparation for the written "Technician" examination following this training. NRMCA can provide certification on the following three (3) levels:

A Pervious Concrete Technician is a person who has demonstrated knowledge about proper procedures to place, compact, finish, edge, joint, cure, and protect pervious concrete pavements, but who lacks the required field experience to qualify as a pervious concrete Installer or Craftsman.

A Pervious Concrete Installer is a person who has demonstrated the ability to place, compact, finish, edge, joint, cure and protect pervious concrete pavements and has documented a limited project-based field experience in placing pervious concrete. Ohio Concrete must certify that the contractor has successfully installed a minimum of three projects with a total area exceeding 10,000 SF of Pervious Concrete. The Installer must possess a current ACI Flatwork Finisher Technician or Craftsman certification at the time of application.

A Pervious Concrete Craftsman is a person who has demonstrated the ability to place, compact, finish, edge, joint, cure and protect pervious concrete pavements and has documented a higher level of field experience in placing pervious concrete. In addition to the above Installer requirements, the Craftsman must either provide documentation of 3000 hours of pervious concrete experience or complete the performance evaluation and document 1500 hours of experience.

Certification Requirements

The "closed book" written examination is allotted two hours to complete and consists of approximately 50 multiple-choice questions. The passing grade for the written examination is 75%.

During the performance evaluation, each examinee must demonstrate procedures for placing, compacting, finishing, edging, jointing, and beginning curing a pervious concrete slab. The examiner will observe and evaluate the techniques used and record passing or failing grades on the various procedures. A passing grade is defined as "no significant variation from proper procedure and no more than two variations from proper technique in the use of the tools."

Recertification is required every five years and requires successful completion of a written examination.

ACI Requirements

The Contractor shall employ no less than 5 NRMCA certified Pervious Concrete Technicians or 3 NRMCA certified Pervious Concrete Installers or 1 NRMCA certified Pervious Concrete Craftsman - as members of each placement crew.
Permeable Interlocking Concrete Pavement

- Solid Concrete Blocks
- Can Be Machine Installed
- Can Be Used on Low Volume Streets
- Traffic Calming
- Aesthetic Value
- Life Cycle Cost Savings
Pervious Interlocking Concrete Pavement
Permeable Interlocking Concrete Pavement

Source: McIntyre (2007)

Source: ICPI (2008)
Clay Pervious Pavers

- Good Durability
- Less Likely to Fade
- Installed by Hand Due to Inconsistent Shape
- Aesthetic Value
Clay Pavers
Grid Pavers

- Mostly Used in Overflow Parking Situations
- Some Consider Less Aesthetically Appealing
- Inexpensive
Grid Pavers
Structural Considerations

Source: ICPI

Source: NC State Extension (2008)
Structural Considerations

- Must be Evaluated by Design Engineer on Case-by-Case Basis
- Structural Recommendations Based on Industry Research and Guidance
Structural Considerations
Design Criteria - Stormwater

- WQv
- Peak Discharge
Permeable pavement designs may be one of three types:

- Full Infiltration.
- Partial Infiltration.
- Partial Infiltration with flow restrictor.

**Full Infiltration**

Where rainfall is intended to infiltrate into the underlying subsoil. Candidate in sites with subsoil permeability > 15mm/hr.

**Partial Infiltration**

Designed so that most water may infiltrate into the underlying soil while the surplus overflow is drained by perforated pipes that are placed near the top of the drain rock reservoir. Suitable for subsoil permeability = 1 and ~ 10mm/hr.

**Partial Infiltration with Flow Restrictor**

Where subsoil permeability is < 1mm/hr, water is removed at a controlled rate through a bottom pipe system and flow restrictor assembly. Systems are essentially underground detention systems, used where the underlying soil has very low permeability or in areas with high water table. Also provides water quality benefits.

1. Permeable Pavers (Min. 80mm thickness)
2. Aggregate Bedding Course - not sand (50mm depth)
3. Open Graded Base (depth varies by design application)
4. Open Graded Cub base (depth varies by design application)
5. Subsoil - flat and scarified in infiltration designs
6. Geotextile on All Sides of Reservoir
7. Optional Reinforcing Grid for Heavy Loads
8. Perforated Drain Pipe 150mm Dia. Min.
9. Geotextile Adhered to Drain at Opening
10. Flow Restrictor Assembly
11. Secondary Overflow Inlet at Catch Basin
12. Outlet Pipe to Storm Drain or Swale System. Locate Gravel of Pipe Below Open Graded Base (no. 3) to Prevent Heaving During Freeze/Thaw Cycle
13. Trench Dams at All Utility Crossings

Source: GVRD (2005)
Water Quality Volume (WQv)

- Full Infiltration of WQv – no pre-approval from Ohio EPA
- No Infiltration of WQv (lined system or compacted subgrade) – case-by-case, prior approval required
- Partial Infiltration of WQv – case-by-case, prior approval required
- Redevelopment Projects
Drainage from Adjacent Areas

- Recommend limiting vegetated areas tributary to pavement to reduce fines
- Pretreatment required for all sediment source areas
- Maximum ratio of 2:1
  - 2 parts impervious area tributary to 1 part pervious pavement
Drainage from Adjacent Areas

\[ A_{\text{impervious}} < 2A_{\text{pervious}} \]
Full Infiltration of WQv

- WQv Determination
  - 20% Addition for Sediment Not Required
- Determine Volumetric Runoff Coefficient, C
- Subgrade Infiltration Capacity
- Determine Thickness of Aggregate Layer to Meet WQv
Subgrade Infiltration Capacity

- Estimates for Planning
- Field Determination
  - Pre-design Ring Infiltrometer Test
  - In-situ Test During Construction
Infiltration Estimates

<table>
<thead>
<tr>
<th>Subgrade Soil Texture</th>
<th>Clay Content (%)</th>
<th>Clay + Silt Content (%)</th>
<th>Compaction Factor = 1.00</th>
<th>Compaction Factor = 1.05</th>
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Note: For silt, silt loam and loam subgrade textures, check for the presence of a fragipan which can severely limit permeability.
Soils Investigation

- Borings and/or test pits
  - Test permeability
  - Determine depth to high water table
  - Determine depth to bedrock
Subgrade Infiltration Capacity

1. The subsurface infiltration bed located beneath the porous pavement must be excavated without heavy equipment compacting the bed bottom.
   (Cahill Associates Photo)
Maximizing the Infiltration Bed Surface

- The infiltrative surface can be extended under traditional pavement as long as the aggregate reservoir is fully connected and subgrade is not compacted.
Subsurface Extended Detention of WQv

- WQv Determination
- Determine Volumetric Runoff Coefficient, C
- Follow Wet Pond Standards – Drain P=0.75” in 24 hr (<1/2 WQv in 1/3 Td)
- Determine Thickness of Aggregate Layer and Outlet to Meet WQv
- Install Orifice Invert at Bottom of ED Storage Layer
WQv Example
WQv Example

Drive – 1.0 Ac

Walkway – 0.5 Ac

Roof – 3.0 Ac

Parking Lot – 4.5 Ac

Lawn – 1.0 Ac
WQv Example

- WQv = C*P*A
- i = 0.90
- C = 0.858(0.9)^3 - 0.78(0.9)^2 + 0.774(0.9) + 0.04
  = 0.73
- P = 0.75 in
- A = 10 Ac
- WQv = 0.73*(0.75 in)*(10 Ac) = 5.48 Ac-in
  = 0.46 Ac-ft = 19,900 cu ft
Chili series

The Chili series consists of deep, well drained, moderately rapidly permeable soils on stream terraces, cut-off wash plains, and knolls. These soils form in loamy material over sandy and gravelly stratified cut-off deposits. Slopes range from 0 to 18 percent and from 25 to 50 percent.

Chili soils are commonly adjacent to Bogart and Oshtemo soils and are similar to Bogart and Wooster soils. Bogart soils are moderately well drained and have gray mottles in the subsoil. Oshtemo soils have less clay and gravel in the subsoil. Wooster soils formed in glacial till and have a fragipan.

Typical pedon of Chili loam, 2 to 6 percent slopes, 1.5 miles south-southwest of Auburn Corners, in Auburn Township, 930 yards west along Bartholomew Road, from its intersection with State Route 44, then 365 yards north.

Ap—0 to 6 inches; dark grayish brown (10YR 4/2) loam; moderate medium granular structure; friable; many roots; 3 percent coarse fragments; slightly acid; abrupt smooth boundary.

B1—6 to 12 inches; dark yellowish brown (10YR 4/4) loam; moderate medium subangular blocky structure; firm; common roots; 2 percent coarse fragments; strongly acid; clear smooth boundary.

B2t—12 to 16 inches; brown (7.5YR 4/4) loam; moderate medium subangular blocky structure; firm; few roots; thin patchy brown (7.5YR 4/4) clay films on faces of peds; 8 percent coarse fragments; strongly acid; clear smooth boundary.

B2t—16 to 25 inches; yellowish red (5YR 5/6) gravelly clay loam; moderate medium and coarse subangular blocky structure; firm; few roots; thin patchy dark brown (7.5YR 4/4) clay films on faces of peds; 25 percent coarse fragments; medium acid; gradual smooth boundary.

B2t—25 to 32 inches; reddish brown (5YR 4/4) gravelly sandy clay loam; firm; few medium distinct strong brown (7.5YR 5/3) mottles; moderate medium subangular blocky structure; firm; thin patchy dark brown (7.5YR 4/4) clay films on faces of peds; 30 percent coarse fragments; medium acid; gradual smooth boundary.

B2t—32 to 37 inches; brown (7.5YR 4/4) gravelly sandy clay loam; moderate medium subangular blocky structure; firm; thin very patchy brown (7.5YR 4/4) clay films on faces of peds; 20 percent coarse fragments; medium acid; gradual smooth boundary.

B3—37 to 43 inches; reddish brown (5YR 4/4) gravelly sandy loam; massive; very friable; thin very patchy brown (7.5YR 4/4) clay films bridging pebbles and sand grains; 35 percent coarse fragments; slightly acid; gradual wavy boundary.

B3—43 to 61 inches; brown (7.5YR 4/4) gravelly loamy sand; single grained; loose; thin very patchy dark brown (7.5YR 4/4) clay films bridging pebbles and sand grains; 55 percent coarse fragments; slightly acid; abrupt wavy boundary.

C—61 to 64 inches; yellowish brown (5YR 6/4) gravelly sand; single grained; loose; 35 percent coarse fragments; slight effervescence; mildly alkaline.

The column is 40 to 70 inches thick. Content of gravel usually increases with depth and ranges from 2 to 23 percent by volume in the A horizon and upper part of the B horizon to 25 to 60 percent in the B2 and C horizons.

The Ap horizon has hue of 10YR or 7.5YR, value of 4, and chroma of 2 or 3. Some pedons have an A1 horizon 2 to 6 inches thick and an A2 horizon as much as 4 inches thick. The A horizon is commonly loamy or gravelly loam. It is less commonly silt loam. It is very strongly acid to slightly acid, except where lime has been added.

The B2 horizon has hue of 10YR to 5YR, value of 4 or 5, and chroma of 3 to 6. It is loam, clay loam, sandy clay loam, or a gravelly analog. Some pedons have thin subhorizons of sandy loam, gravelly sandy loam, or silty clay loam. Reaction is strongly acid to medium acid. The B2 horizon has hue of 10YR to 5YR, value of 4 or 5, and chroma of 3 to 6. It is gravelly or very gravelly sandy loam, loamy sand, or loam. Reaction is medium acid or slightly acid. The C horizon typically has hue of 10YR, value of 4 or 5, and chroma of 2 to 4. It is medium acid to mildly alkaline.
## Infiltration Estimates

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Note: For silt, silt loam and loam subgrade textures, check for the presence of a fragipan which can severely limit permeability.
WQv Example – Full Infiltration

Drive – 1.0 Ac
Walkway – 0.5 Ac
Parking Lot – 4.5 Ac
Lawn – 1.0 Ac
Roof – 3.0 Ac

\[ A_{\text{inf}} = 4.5 \text{ Ac} \]
\[ d_{\text{agg}} = \frac{\text{WQv}}{A_{\text{inf}}/\Phi} \]
\[ = \frac{5.48 \text{ Ac-in}}{4.5 \text{ Ac}/0.30} \]
\[ = 4.1 \text{ in} \]
\[ T_d = \frac{\text{WQv}/A_{\text{inf}}}{f_{\text{est}}} \]
\[ = \frac{5.48 \text{ Ac-in}}{4.5 \text{ Ac}/0.08 \text{ in/hr}^{-1}} \]
\[ = 15.2 \text{ hr} \]

\[ A_{\text{inf}} = 3.0 \text{ Ac} \]
\[ d_{\text{agg}} = \frac{\text{WQv}}{A_{\text{inf}}/\Phi} \]
\[ = \frac{5.48 \text{ Ac-in}}{3.0 \text{ Ac}/0.30} \]
\[ = 6.1 \text{ in} \]
\[ T_d = \frac{\text{WQv}/A_{\text{inf}}}{f_{\text{est}}} \]
\[ = \frac{5.48 \text{ Ac-in}}{3.0 \text{ Ac}/0.08 \text{ in/hr}^{-1}} \]
\[ = 22.9 \text{ hr} \]

\[ f_{\text{est}} = 0.08 \text{ in/hr} \] (est. final infilt rate)
\[ \Phi = 0.30 \] (effective porosity)
Full Infiltration of WQv

$A_{\text{inf}} = 4.5 \text{ Ac}$
$d_{\text{agg}} = \frac{WQv}{A_{\text{inf}}/\Phi}$
$= 5.48 \text{ Ac-in}/4.5 \text{ Ac}/0.30$
$= 4.1 \text{ in}$
Critical Storm “Credit”

- At discretion of MS4
- ODNR recommendation - Reduced CN based on “open space in poor condition”
- Requires full infiltration of WQv

<table>
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<tr>
<th>Soil HSG</th>
<th>Measured Infiltration Rate (in/hr)</th>
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<td>B</td>
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<td>D</td>
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* Tentative 6/10
Critical Storm Example

Hydrology Summary

Pre-dev
CN = 75 (Agr SR+CR)
Tc = 35 min
$q_{peak, 1-yr} = 2.7$ cfs

Post-dev (no perv pave)
All Imp (9 Ac) CN = 98
Open (1 Ac) CN = 74
Q increases 302%
Critical Storm = 50-yr

Auburn Twp, Geauga County
Chili Loam (HSG-B)
Lat 41.38 N
Critical Storm Example

Pre-dev
CN = 75 (Agr SR+CR)
Tc = 35 min
$q_{peak, 1-yr} = 2.7$ cfs

Post-dev (no perv pave)
All Imp (9 Ac) CN = 98
Open (1 Ac) CN = 74
Q increases 302%
Critical Storm = 50-yr

Dry Basin to Meet CSM Criteria:
8 ft total depth
5 ft above WQv outlet
@ 100-yr
- Storage = 2.6 Ac-ft
- Pool Area = 0.85 Ac

Auburn Twp, Geauga County
Chili Loam (HSG-B)
Lat 41.38 N
Critical Storm Example

Hydrology Summary

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Post-dev (no perv pave)
All Imp (9 Ac) CN = 98
Open (1 Ac) CN = 74
Q increases 302%
Critical Storm = 50-yr

Post-dev (w/perv pave)
Imp (4.5 Ac) CN = 98
Infilt (4.5 Ac) CN = 86
Open (1 Ac) CN = 74
Q increases 202%
Critical Storm = 25-yr

Auburn Twp, Geauga County
Chili Loam (HSG-B)
Lat 41.38 N
Peak Discharge

- Model as Typical Detention Basin w/Effective Porosity (use 0.30)
- Exfiltration (if applicable)
- WQ Outlet (if applicable)
- Secondary Outlet May Be Required
- Keep 10-yr Within Aggregate Layer (minimum standard)
- Check Routing of 100-yr Event
Critical Storm – Pervious Pavement w/Infiltration

- Aggregate Reservoir
  - \( \Phi = 0.30 \) (effective porosity)

- Subgrade
  - \( f_{\text{design}} = 0.15 \text{ in/hr} \)

- Pavement – 4"
- Choker Course – 4"

- \( D_{\text{total}} \geq 27 \text{ in} \)
- \( f_{\text{meas}} = 0.30 \text{ in/hr} \)
- \( f_{\text{design}} = 0.5 \times f_{\text{meas}} \)
- \( f_{\text{design}} = 0.15 \text{ in/hr} \)
- \( \Phi = 0.30 \)
Critical Storm – Pervious Pavement w/Infiltration

D_{total} \geq 27 \text{ in}

f_{meas} = 0.30 \text{ in/hr}

f_{design} = 0.5 \times f_{meas}

f_{design} = 0.15 \text{ in/hr}

\Phi = 0.30

Aggregate Reservoir

Subgrade

Pavement – 4”

Choker Course – 4”

D > 27”

WQv - 4.1”

Add Tile for Insurance?
Construction & Oversight

- All Infiltrative BMPs Require Higher Level of Oversight During Construction
- Critical to Have a Stabilized Tributary Area to Pavement System Before Installation of Aggregate Layer and Pavement Surface
Maintenance

- Good Housekeeping
- Routine Inspections Recommended
- In Areas with Organic Debris (leaves, etc.) Bi-annual Cleaning Recommended
Maintenance

Vacuum Trucks

Regenerative Air

Direct Vacuum

Source: UNH (2008)
Winter Maintenance

Source: UNH SC (2009)
# Winter Maintenance

## Winter Maintenance Guidelines for Porous Pavements

**Maintenance Guidelines**
- Road surfaces, porous and non-porous, are commonly not treated and plowed until 2 or more inches of snow accumulation.
- Plow after every storm. If possible plow with a slightly raised blade while not necessary, this will help prevent pavement scarring.
- Up to ~75% salt reduction for porous asphalt can be achieved. Salt reduction, amounts are site specific and are affected by degree of shading.
- **USE SALT REDUCTION NUMBERS WITH CAUTION!!!**
- Porous concrete salt reduction will vary and is heavily dependent upon shading. For shaded areas, porous concrete may not achieve salt reduction.
- Apply anti-icing treatments prior to storms. Anti-icing has the potential to provide the benefit of increased traffic safety at the lowest cost and with less environmental impact.
- Deicing is NOT required for black ice development. Meltwater readily drains through porous surfaces thereby preventing black ice.
- Apply deicing treatments during, and after storms as necessary to control compact snow and ice not removed by plowing.
- Sand application should be limited since its use will increase the need for warming.
- Vacuum porous areas a minimum of 2-4 times per year, especially after winter and fall seasons when debris accumulation and deposition is greatest.
- If ponding water is observed during precipitation cleaning is recommended.

## Winter Maintenance Challenges

- Mixed precipitation and compact snow or ice is problematic for all paved surfaces, but is particularly problematic for porous surfaces. This is corrected by application of excess deicing chemicals.
- De-icing chemicals work by lowering the freezing point of water. Generally, the longer a de-icing chemical has to react, the greater the amount of melting. Meltwater readily drains through porous surfaces thereby reducing chemical contact time. This is corrected by excess salt application.
- Excess salt application in these instances is offset by the overall reduced salt during routine winter maintenance and salt reduction.

## Additional Resources
- The UNH Stormwater Center: [http://www.unh.edu/org/cster/](http://www.unh.edu/org/cster/)

Source: UNH Stormwater Center
For Additional Information

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