Designing and Specifying Pervious Concrete

Philip Kresge
Sr. Director, National Resources
This presentation has been prepared solely for information purposes. It is intended solely for the use of professional personnel, competent to evaluate the significance and limitations of its content, and who will accept full responsibility for the application of the material it contains. The National Ready Mixed Concrete Association and any other organizations cooperating in the preparation of this presentation strive for accuracy but disclaim any and all responsibility for application of the stated principles or for the accuracy of the content or sources and shall not be liable for any loss or damage arising from reliance on or use of any content or principles contained in this presentation. Unless otherwise indicated, all materials in this presentation are copyrighted to the National Ready Mixed Concrete Association. All rights reserved. Therefore reproduction, modification or retransmission in any form is strictly prohibited without the prior written permission of the National Ready Mixed Concrete Association. © 2009 National Ready Mixed Concrete Association.
Thank you to our 2010 Super Sponsors

- BASF
  The Chemical Company

- GRACE
  Construction Products

- Trimble
Announcement

- This program is registered with the AIA/CES for continuing professional education. As such, it does not include content that may be deemed or construed to be an approval or endorsement by the AIA of any material of construction or any method or manner of handling, using, distributing, or dealing in any material or product.
Designing & Specifying Pervious Concrete – Part One

Topics of Discussion
• Properties of Pervious Concrete
• Design Considerations
  • Structural
  • Hydrological
    • Passive/Active Mitigation
  • Soil Conditions
  • Freeze/Thaw
  • Heavy Traffic
What is Pervious Concrete?

• A No-Fines Concrete Mix
  • Coarse Aggregate
  • Portland Cement
  • Water
• Intended for use as an open-graded drainage material
Pervious Concrete Properties

- 15% to 35% air void content
  - Field studies show 20-25% average
- 100 to 120 lbs/ft$^3$ unit weight
- 2500 to 3500 psi strength\
  - Introduction of small amount of fine aggregate can increase strength to 4000 psi (+/-)
  - Compressive strength typically \textit{not} used as acceptance criteria. Air void structure and unit weight are used instead.
Pervious Concrete Properties

- Drainage rate = 3-5 gal/min/ft²
- Equivalent of 275” to 450” of rain per hour!
  - More than half of all rainfall is provided in rain events that total one inch or less.
Conventional Stormwater Management

Retention Pond (Wet Pond)

Permanent pool of water year round
Conventional Stormwater Management

Detention Pond (Dry Pond)

Detain stormwater for period of time to allow particles and pollutants to settle
Infiltration System

- Developed in 1970’s
  - Franklin Institute, Philadelphia, PA
  - Successfully used across the country for over 30 years
- Provide hard surface to detention pond

* Illustration courtesy of T Cahill Associates
• Pervious concrete: 4-8 inches typical
  • Thickness based on intended use
• Subgrade maximum compaction
  • 95% Standard Proctor
  • 90-92% Modified Proctor
• Open-graded stone subbase: determined by local hydrologic conditions
  • Filter Bed
  • Storage Bed
  • Detention Layer
• Typical detention layer thickness $\approx 6$ inches
• Thickness may be increased for certain conditions
  • Increased storage
  • Freeze/thaw
• No detention layer required in some cases
  • Well draining native soils
  • Minimize root damage
- Geotex prevents movement of fines into detention layer
- Can provide subgrade support
• Water drains through pavement into detention layer and infiltrates slowly into underlying soil mantle
  • 0.1 – 0.5 in/hr acceptable
  • Total drawdown time should not exceed 5 days
Designing Pervious Concrete

Structural Design
Strength vs. Thickness

Section strength – proportionate to:

• Material Strength
• Square of the thickness

For a stronger pavement,

• Use a stronger concrete
• Use a little more concrete
Flexural Strength vs. Compressive Strength

Ahmad & Shah Mean:
Flexural Strength = 2.3(Compressive Strength)^0.6067

Estimating Pervious PCC Pavement Design Inputs with Compressive Strength and Effective Void Content, Crouch, et al.
Compressive Strength vs. Unit Weight

Effect of Compaction on Pervious Concrete Properties, Suleiman, et al.
Compressive Strength vs. Void Ratio

Results - Compressive Strength

For regular compaction:
7-day strength (psi) = 4763.1 - 98.16 * void ratio (%)
$R^2 = 0.82$

For low compaction:
7-day strength (psi) = 4012.7 - 77.16 * void ratio (%)
$R^2 = 0.49$

Effect of Compaction on Pervious Concrete Properties, Suleiman, et al.
Strength vs. Thickness

Section strength – proportionate to:
  • Material Strength
  • Square of the thickness

For a stronger pavement,
  • Use a stronger concrete
  • Use a little more concrete

If the concrete has to be weaker (e.g., pervious)
  • You can make the section stronger by making it thicker
StreetPave ©

Uses PCAPAV engine
- Copyrighted 1985

Adds elements from AASHTO design guide
- Reliability
- $M_{rs}$ (Resilient Modulus of Subgrade Reaction)

Allows use of low MR/f’c values, to characterize pervious pavements
Structural Design – Example

- Design Life = 30 years
- Average Daily Traffic
  - 200 vehicles/day
  - 1% trucks
- Compare $f'_c$
  - 4000 psi
  - 2000 psi
- Assume 6” gravel base
  - CBR = 2
  - Resistance Value (R) = 10.625
f'c = 4000 psi
ADT = 200
1% Trucks

Composite Modulus of Subgrade Reaction (k) = 161 psi
Resilient Modulus of the Subgrade:
MRSG [user-entered] = 3120 psi
MRSG [design] = 1891.2 psi
Base =
Flexible ESALs =
Design Asphalt Thickness =

Design Concrete Thickness = 4.62 in.
Concrete Recommendations:
Concrete Thickness = 5.00 in.
Maximum Transverse Joint Spacing = 10 ft.
Dowel Bars: Dowel bars not chosen and not recommended.
f’c = 2000 psi
ADT = 200
1% Trucks

Composite Modulus of Subgrade Reaction (k) = 161 psi
Design Concrete Thickness = 5.98 in.

Concrete Recommendations:
Concrete Thickness = 6.00 in.
Maximum Transverse Joint Spacing = 12 ft.
Dowel Bars: Dowel bars not chosen and not recommended.
Structural Design – Experience

- 4” Sidewalks/Pathways
- 6” Parking Lots
- 6” Residential Driveways
- 8” Residential Streets
- 8-9” Commercial Driveways / HD Parking Lots
Designing Pervious Concrete

Hydrological Design
Two types of design

• Passive Mitigation

• Active Mitigation
Passive Mitigation

- Used to reduce quantity of impervious surface by replacing with pervious
- Can capture much, if not all, first flush
- Not intended to offset excess runoff from adjacent impervious surfaces
Active Mitigation

- Designed to maintain total runoff of a site at some specified level
- Must accommodate runoff from a much larger area
- Used when pervious concrete system is intended to capture a sizeable portion of the runoff from other areas
Hydrologic Analysis Software

- User inputs
  - Pervious pavement thickness
  - Pervious surface area
  - Detention layer thickness
  - Soil exfiltration rate
  - Stormwater volume
  - Desired (allowed) runoff
Data Input Sheet

Project Details
- Project: Home Depot
- Designer: MZ
- Date Run: 11/16/06

Pervious concrete
- Thickness: 6 in
- Surface area: 43,560 sq ft
- Porosity: 15%

Gravel base
- Thickness: 6 in
- Porosity: 40%

Ponding limit: 0 in

Soil infiltration rate: 0.010 in/hr

Impervious surface
- Surface area: 43,560 sq ft

Off-site drainage
- Area: 0 sq ft
- CN: 0

24-hr Precipitation: 3.5 in
- Location: Suwanee GA
- Return period: 2 yr

Design Aim
- Target CN: 72

After you have completed entering the above data, click the ‘Run’ button.
• Ponding limit allows for use of the area above the pavement surface, contained within the confines of curb, to be included in calculations of temporary storage capacity.
Project Details

Project: Home Depot
Designer: M2
Date Run: 11/16/05

Pervious concrete

<table>
<thead>
<tr>
<th>Thickness</th>
<th>6 in</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface area</td>
<td>43,560 sq ft</td>
</tr>
<tr>
<td>Porosity</td>
<td>15 %</td>
</tr>
</tbody>
</table>

Gravel base

<table>
<thead>
<tr>
<th>Thickness</th>
<th>6 in</th>
</tr>
</thead>
<tbody>
<tr>
<td>Porosity</td>
<td>40 %</td>
</tr>
</tbody>
</table>

Ponding limit

<table>
<thead>
<tr>
<th>Thickness</th>
<th>0 in</th>
</tr>
</thead>
<tbody>
<tr>
<td>Porosity</td>
<td>0 %</td>
</tr>
</tbody>
</table>

Exfiltration rate

| 0.016 in/hr |

Impervious surface

| Surface area | 43,560 sq ft |

Off-site drainage

| Area | 0 sq ft |
| CN | 0 |

24-hr Precipitation

| 3.5 in |

Location

Suwanee GA

Return period

2 yr

Design Aim

Target CN | 72 |

After you have completed entering the above data, click the Return button.
### Exfiltration - Design Values

<table>
<thead>
<tr>
<th>Material</th>
<th>Permeability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mm/sec</td>
</tr>
<tr>
<td>Sand</td>
<td>0.01</td>
</tr>
<tr>
<td>Silty sand</td>
<td>0.002 to 0.0004</td>
</tr>
<tr>
<td>Silt</td>
<td>$1 \times 10^{-4}$ to $1 \times 10^{-6}$</td>
</tr>
<tr>
<td>Clay</td>
<td>$&lt; 1 \times 10^{-6}$</td>
</tr>
<tr>
<td>Data Input Sheet</td>
<td></td>
</tr>
<tr>
<td>------------------</td>
<td></td>
</tr>
<tr>
<td><strong>Project Details</strong></td>
<td></td>
</tr>
<tr>
<td>Project: Home Depot</td>
<td></td>
</tr>
<tr>
<td>Designer: MZ</td>
<td></td>
</tr>
<tr>
<td>Date Run: 11/16/05</td>
<td></td>
</tr>
<tr>
<td><strong>Pervious concrete</strong></td>
<td></td>
</tr>
<tr>
<td>Thickness: 6 in</td>
<td></td>
</tr>
<tr>
<td>Surface area: 43,560 sq ft</td>
<td></td>
</tr>
<tr>
<td>Porosity: 15%</td>
<td></td>
</tr>
<tr>
<td><strong>Gravel base</strong></td>
<td></td>
</tr>
<tr>
<td>Thickness: 6 in</td>
<td></td>
</tr>
<tr>
<td>Porosity: 40%</td>
<td></td>
</tr>
<tr>
<td><strong>Ponding limit</strong></td>
<td></td>
</tr>
<tr>
<td>Thickness: 0 in</td>
<td></td>
</tr>
<tr>
<td><strong>Evaporation rate</strong></td>
<td></td>
</tr>
<tr>
<td>0.010 in/hr</td>
<td></td>
</tr>
<tr>
<td><strong>Impervious surface</strong></td>
<td></td>
</tr>
<tr>
<td>Surface area: 43,560 sq ft</td>
<td></td>
</tr>
<tr>
<td><strong>Off-site drainage</strong></td>
<td></td>
</tr>
<tr>
<td>Area: 0 sq ft</td>
<td></td>
</tr>
<tr>
<td>CN: 0</td>
<td></td>
</tr>
<tr>
<td><strong>24-hr Precipitation</strong></td>
<td></td>
</tr>
<tr>
<td>3.5 in</td>
<td></td>
</tr>
<tr>
<td>Location: Suwanee GA</td>
<td></td>
</tr>
<tr>
<td>Return period: 2 yr</td>
<td></td>
</tr>
<tr>
<td><strong>Design Aim</strong></td>
<td></td>
</tr>
<tr>
<td>Target CN: 72</td>
<td></td>
</tr>
</tbody>
</table>

After you have completed entering the above data, click the Run button.
<table>
<thead>
<tr>
<th>Cover Description</th>
<th>Hydrologic Soil Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td>Developed urban areas</td>
<td></td>
</tr>
<tr>
<td>Open space</td>
<td></td>
</tr>
<tr>
<td>Poor condition (&lt;50% grass)</td>
<td>63</td>
</tr>
<tr>
<td>Fair condition (50-75% grass)</td>
<td>49</td>
</tr>
<tr>
<td>Good condition (&gt;50% grass)</td>
<td>39</td>
</tr>
<tr>
<td>Impervious areas</td>
<td></td>
</tr>
<tr>
<td>Pavement, roofs</td>
<td>98</td>
</tr>
<tr>
<td>Gravel</td>
<td>75</td>
</tr>
<tr>
<td>Dirt</td>
<td>72</td>
</tr>
<tr>
<td>Urban districts</td>
<td></td>
</tr>
<tr>
<td>Commercial and business</td>
<td>89</td>
</tr>
<tr>
<td>Industrial</td>
<td>81</td>
</tr>
<tr>
<td>Residential areas</td>
<td></td>
</tr>
<tr>
<td>(by lot size)</td>
<td></td>
</tr>
<tr>
<td>1/8 acre (town houses, condos)</td>
<td>77</td>
</tr>
<tr>
<td>1/4 acre</td>
<td>61</td>
</tr>
<tr>
<td>1/3 acre</td>
<td>57</td>
</tr>
<tr>
<td>1/2 acre</td>
<td>54</td>
</tr>
<tr>
<td>1 acre</td>
<td>51</td>
</tr>
<tr>
<td>2 acres</td>
<td>46</td>
</tr>
<tr>
<td>Agricultural areas</td>
<td></td>
</tr>
<tr>
<td>Pasture, grassland</td>
<td></td>
</tr>
<tr>
<td>Poor</td>
<td>68</td>
</tr>
<tr>
<td>Fair</td>
<td>49</td>
</tr>
<tr>
<td>Good</td>
<td>30</td>
</tr>
<tr>
<td>Meadow (mowed) Brush</td>
<td></td>
</tr>
<tr>
<td>Poor</td>
<td>48</td>
</tr>
<tr>
<td>Fair</td>
<td>35</td>
</tr>
<tr>
<td>Good</td>
<td>30</td>
</tr>
<tr>
<td>Woods and grass (orchard)</td>
<td></td>
</tr>
<tr>
<td>Poor</td>
<td>57</td>
</tr>
<tr>
<td>Fair</td>
<td>43</td>
</tr>
<tr>
<td>Good</td>
<td>32</td>
</tr>
<tr>
<td>Woods</td>
<td></td>
</tr>
<tr>
<td>Poor</td>
<td>45</td>
</tr>
<tr>
<td>Fair</td>
<td>36</td>
</tr>
<tr>
<td>Good</td>
<td>30</td>
</tr>
<tr>
<td>Row crops, straight, good</td>
<td></td>
</tr>
<tr>
<td>Row crops, contoured, good</td>
<td></td>
</tr>
<tr>
<td>Small grain, good</td>
<td>63</td>
</tr>
<tr>
<td>Farmsteads</td>
<td>59</td>
</tr>
</tbody>
</table>
### Results Sheet

**Project:** Home Depot  
**Designer:** MP

---

**Configuration**
- **Previous concrete**
  - **Thickness:** 6 in  
  - **Surface area:** 4,560 sq ft  
  - **Porosity:** 40%

- **Gravel base**
  - **Thickness:** 4 in  
  - **Porosity:** 40%

- **Ponding limit:** 0 in  
- **Exfiltration rate:** 0.100 in/hr

- **Impervious surface**
  - **Surface area:** 4,560 sq ft

- **Off-site drainage**
  - **Area:** 0 sq ft  
  - **CN:** 0

---

**User Input**

**Summary of results**
- **Effective CN:** 72  
- **Estimated runoff (5 days):** 1.12 in  
- **Available storage used:** 100%  
- **Number of hours of ponding:** 0  
- **Max ponding depth:** 0.0 in  
- **Available storage after 24 hr:** 0%  
- **Available storage after 5 days:** 0.0 in  
- **Steps after 5 days:** 0  
- **Additional time to drain completely:** 0 hr

---

**Intermediate results**
- **Total drained surface area:** 87,120 sq ft  
- **Storage capacity, pervious concrete:** 3,267 cu ft  
- **Storage capacity, gravel base:** 5,806 cu ft  
- **Storage capacity, ponding:** 0 cu ft  
- **Total stormwater storage:** 9,075 cu ft

- **Total precip volume:** 55,410 cu ft  
- **5-day exfiltration volume:** 17,237 cu ft  
- **Total runoff (overflow):** 8,113 cu ft  
- **Water stored after 5 days:** 0 cu ft  
- **Water balance error:** 0.0 cu ft

---

**Program Calculations**

![Diagram of infiltration rates and soil subbase](Image)

---

**Copyright 2004 CRHCYA**  
All rights reserved. Permission is granted to use this material for its intended purpose, provided the origin is attributed to the copyright holder.

---

**Caution:** This spreadsheet is intended for study purposes to illustrate expected hydrologic behavior of pervious concrete. Designs must verify results for specific sites by independent means.
### Summary of results

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effective CN</td>
<td>72</td>
</tr>
<tr>
<td>Estimated runoff (5 days)</td>
<td>1.12 in</td>
</tr>
<tr>
<td>Available storage used</td>
<td>100 %</td>
</tr>
<tr>
<td>Number of hours of ponding</td>
<td>0</td>
</tr>
<tr>
<td>Max ponding depth</td>
<td>0.0 in</td>
</tr>
<tr>
<td>Available storage after 24 hr</td>
<td>3 %</td>
</tr>
<tr>
<td>Available storage after 5 days</td>
<td>100 %</td>
</tr>
<tr>
<td>Stage after 5 days</td>
<td>0.0 in</td>
</tr>
<tr>
<td>Additional time to drain completely</td>
<td>0 hr</td>
</tr>
</tbody>
</table>

### Intermediate results

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total drained surface area</td>
<td>87,120 sqft</td>
</tr>
<tr>
<td>Storage capacity, pervious concrete</td>
<td>3,267 cuft</td>
</tr>
<tr>
<td>Storage capacity, gravel base</td>
<td>5,808 cuft</td>
</tr>
<tr>
<td>Storage capacity, ponding</td>
<td>0 cuft</td>
</tr>
<tr>
<td>Total stormwater storage</td>
<td>9,075 cuft</td>
</tr>
<tr>
<td>Total precip volume</td>
<td>25,410 cuft</td>
</tr>
<tr>
<td>5-day exfiltration volume</td>
<td>17,237 cuft</td>
</tr>
<tr>
<td>Total runoff (overflow)</td>
<td>8,113 cuft</td>
</tr>
<tr>
<td>Water stored after 5-days</td>
<td>0 cuft</td>
</tr>
<tr>
<td>Water balance error</td>
<td>U.U cuft</td>
</tr>
</tbody>
</table>
Understanding *Pervious Concrete - Hydrological Design and Resources Software.*

Presented by Jason Wimberly, EI, MCE, director of technical services, Carolinas Ready Mixed Concrete Association

Starts 2 p.m. EST | hour duration | $50 Members | $100 Non-members

**Special Offer - Save $10:** Register for the Webinar and purchase save $10 on the software. [Click here](#) to purchase online, login and use the code PCHDWeb at checkout. Or contact Jacques Jenkins, 800-846-7622, x1165 or by [e-mail](mailto:). Email Jason Wimberly for other dates and information.

Download a [Fax back registration form](#)
Call 240-485-1152 or e-mail meetings@nrmca.org
Designing for Special Considerations

Pavement Grades
Pervious Concrete – On the Level
For sloped pavements, storage capacity calculations must consider depth of pavement, infiltration rate of subgrade, and desired runoff goals.
Designing for Special Considerations

Poor Soils
<table>
<thead>
<tr>
<th>Layer</th>
<th>Void/Solid Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pervious Concrete</td>
<td>20% +/- Void</td>
</tr>
<tr>
<td>Detention Layer</td>
<td>40% Void Stone</td>
</tr>
<tr>
<td>Non-woven Geo-textile</td>
<td></td>
</tr>
<tr>
<td>Well Draining Soil</td>
<td>1/2&quot; + per. hr.</td>
</tr>
</tbody>
</table>
Pervious Concrete (20% +/− Void)
Detention Layer (40% Void Stone)
Non-woven Geo-textile
Poorly Draining Soil
Pervious Concrete (20% ± Void)
Detention Layer (40% Void Stone)
\[w/ \text{ Stormwater Chambers (100\% Void)}\]

Non-woven Geo-textile

Poorly Draining Soil
Designing for Special Considerations

Water Harvesting
• Perforated pipe in detention layer can capture water for re-use on site
Water Harvesting

- Can utilize underground stormwater chambers
Finley Stadium

- Chattanooga, TN
- OCT, 1997
- Total parking lot approximately 6 acres
- Size of pervious area
  - 10,000 ft$^2$
  - 10 ½ ft width
• 6” stone subbase under entire parking lot
• 4” Pervious Concrete in parking areas
• 200,000 gal. holding capacity
• 400,000 gal catch basin
Designing for Special Considerations

Freeze-Thaw
Iowa State University

• In conjunction with:
  • Center for Transportation Research and Education
  • National Center for Concrete Pavement Technology
• Prepared mixes with varying aggregates, admixtures, etc.
3400 psi @ 7 days, 3800 psi @ 28 days for this mix
Permeability is over 300 gallons per hour
Samples have passed 300 cycles with approximately 2% loss of mass.
• Study conducted by Cleveland State University
• No deteriorations of Pervious Concrete due to cold weather cycling activity
Freeze-Thaw Resistance

- Depends on saturation level
- Avoid critical saturation
  - Design
    - Infiltration System
    - Secret of success is to provide the water a place to go
  - Maintenance
    - Cleaning, as needed, in severe climates
What About Clogging?

• Even if 100% clogged with dirt, pervious concrete will still be permeable
• Clean is key to F/T durability
• For maintenance, clean pervious pavement with power scrubber or power wash
• Conventional pavement sweeper/vacuum equipment can also be used
Cleaning can restore 90+% of original permeability
Designing for Special Considerations

Heavy Traffic
Transition to asphalt
Transition to asphalt
Prime Outlets – Williamsburg, VA

- 7.6 acres Pervious Concrete
- 3.5 acres Conventional Concrete
Shelter Systems Ltd.
Westminster, MD

- Pavement used as staging area for completed truss systems
- Required heavy duty pavement
  - 30 to 40 trucks per day
Shelter Systems Ltd.
Westminster, MD

- R/M adjusted mix
  - Added 600 lbs. fine agg. per CY
  - Mix of #8 and #57 stone
- Placed with ABG dual-compaction paver
- Rolled with small static roller
- Flexural strength avg. 650 psi (7 days)
Shelter Systems Ltd.
Westminster, MD

- Approximately 8 acres of pavement
- Mix design can accommodate 80” of rain per hour
- 10 times intensity of 100 year rainfall event!
Designing for Special Considerations

Adjacent Sites
Prevent Debris from Clogging Slab
Slope Grade Away from Pavement
Grade Pavement High
Resources
Pervious Concrete Pavements
• Engineering Properties
• Design
• Construction
• Inspection & Maintenance
Pervious concrete pavement is a unique and effective means to address important environmental issues and support sustainable growth. By capturing stormwater and allowing it to seep into the ground, pervious concrete is instrumental in recharging groundwater, reducing stormwater runoff, and meeting U.S. Environmental Protection Agency (EPA) stormwater regulations. In fact, the use of pervious concrete is among the Best Management Practices (BMPs) recommended by the EPA— and by other agencies and geotechnical engineers across the country— for the management of stormwater runoff on a regional and local basis. This pavement technology creates more efficient land use by eliminating the need for retention ponds, swales, and other stormwater management devices. In doing so, pervious concrete has the ability to lower overall project costs on a first-cost basis.
Part Two – Specifying Pervious Concrete
Designing & Specifying Pervious Concrete – Part Two

Topics of Discussion

- Why Specify Pervious Concrete?
  - Pervious Concrete and LEED Certification
- Guidelines for Specifying Pervious Concrete
  - ACI 522
  - Recommended Addendums
- Construction Practices
- Acceptance Testing
Why Specify Pervious Concrete?
Environmental Issues

- Water Quality
  - Groundwater Recharge
  - Flood Prevention / Management
  - First-Flush Pollution Mitigation
Treatment of Pollutants

• First Flush
  • First 1” of rain
  • Contains contaminants
    • EPA requires collection and treatment prior to release
• USGS study – Austin, TX
  • High concentration of polycyclic aromatic hydrocarbons (PAH)
  • Attributed to asphalt parking lot runoff
  • Runoff from asphalt-based sealants 10 times higher
  • Runoff from coal-tar based sealants 65 times higher
• Source:
  • http://water.usgs.gov/nawqa/asphalt_sealers.html
Treatment of Pollutants

• Pervious concrete pavement reduces runoff
  • Eliminates first flush
  • Captured by void structure
  • Minimization of PAH

• Soil chemistry and biology will naturally treat water
  • Oil drips and other automotive pollutants are “attacked” by naturally occurring soil microbes
Treatment of Pollutants

Porous pavement pollutant removal mechanisms include absorption, straining, and microbiological decomposition in the soil. Studies indicate removal efficiencies of between 82 and 95 percent for sediment, 65 percent for total phosphorus, and between 80 and 85 percent of total nitrogen. It also indicated high removal rates for zinc, lead, and chemical oxygen demand.

U.S. Geological Survey
Savings to Owners/Developers

• Eliminates need for detention ponds & other costly stormwater management practices
• Provides for more efficient use of land development
Savings to Owners/Developers

- 7 ½ Acre parking lot
- Saved $400,000 in underdrain construction
- Eliminated 1 ½ Acre detention pond

Shelter Systems Ltd.
Westminster, MD
More Efficient Land Use

- 0.8115 Acres or 35,651 SF
- Proposed Building 9,250 SF
- Parking Requirements 27 Spaces or 5,000 SF
- Detention Requirements 4,419 CF
- Maximum Impervious 37% or 13,190 SF

East Atlanta Library
How many cars can you park on a detention pond?
More Efficient Land Use

- 7.6 acres Pervious Concrete
- 3.5 acres Conventional Concrete

Prime Retail Outlets
Williamsburg, VA

© Copyright 2009 - NRMCA
- 448 new pervious concrete spaces
- 139 spaces converted from asphalt to pervious concrete
- 243 spaces converted from asphalt to pervious concrete
- 503 new pervious concrete spaces
- 16 new pervious concrete spaces
- 16 spaces converted from asphalt to pervious concrete
- 156 spaces converted from asphalt to pervious concrete
Closed existing detention pond
Paved with Pervious Concrete

Prime Retail Outlets
Williamsburg, VA
40% additional rental space available

Prime Retail Outlets
Williamsburg, VA
US EPA - Clean Water Act

EPA Storm Water Phase II Final Rule (EPA 2000)

- Reduce or eliminate runoff
- “Treatment” of Pollutants (Percolation)
- Groundwater and aquifer recharge
- Minimize Flooding
Sustainable Development
Potential Credit Contributions
LEED 2009 / Version 3

- Sustainable Sites
- Water Efficient Landscape
- Materials and Resources
- Regional Materials
- Innovation in Design
- Regional Bonus Credits
Sustainable Sites

Stormwater Design - Limit disruption and pollution of natural water flows by managing stormwater runoff

SS-6.1 1 Pt.
- Option 1: If existing imperviousness is less than 50% then maintain existing discharge rate
- Option 2: If existing imperviousness is more than 50% then decrease discharge rate by 25%

SS-6.2 1 Pt.
- Treat 90% of the avg. annual rainfall using BMPs
- Remove 80% TSS
Water Efficient Landscape

**Water Efficiency Credit 1** - Reduce/eliminate the use of potable water for landscape irrigation
- 50% Reduction 2 Pts.
- 100% Reduction 4 Pts.

**Water Efficiency Credit 2** - Reduce generation of wastewater and potable water demand 2 Pts.

**Water Efficiency Credit 3** - Further increase water efficiency to reduce burden on municipal water supply and wastewater systems
- 30% Reduction 2 Pts.
- 35% Reduction 3 Pts.
- 40% Reduction 4 Pts.
Additional Contributions

Materials and Resources
- Recycled content 1-2 pts.

Regional Materials
- Extracted, Processed & Manufactured Regionally 1-2 pts.

Innovation in Design 1-5 pts.

Regional Priority Credits 1-4 pts.
Total Points directly and/or indirectly related to utilizing Pervious Concrete:

12 - 26
Guidelines for Specifying Pervious Concrete
An Unnatural Act

- Making concrete that includes large voids.
- Intentionally reducing concrete density.
- Knowingly reducing concrete strength.
Typical Pervious Concrete Mix Design

- 550 – 650 lbs. Portland Cement
  - Fly Ash / Slag Cement substitute acceptable at standard rates
- 27 ft³ Coarse Aggregate
  - Aggregate size will affect drainage rate
- 0.25 – 0.35 W/C Ratio
  - Sufficient water to display a wet, metallic sheen on the aggregate
- Viscosity Modifier, Hydration Stabilizer, High Range Water Reducer
Supplementary Cementitious Materials

- **Fly Ash**
  - (up to 25%)
- **Slag Cement**
  - (up to 50%)
- Will increase set time
- Increase curing time
Water Reducer

- Acts as a Surfactant
  - Aids the wet metallic sheen on cement paste
- Aids Wet-Out
  - Causes negative ions on cement particles
  - Separates the cement particles
  - Water enters the space
- Water Reducer is used in moderate dose.
- Not used to reduce the water content
Viscosity Modifier (VMA)

- Counteracts the plasticity effects of water reducer
- Firmer Cement Paste
  - Cement paste clings to aggregate
  - Allows higher water content
  - Aids discharge
  - Aids the strike-off
  - Aids the compression
- Faster Placement
Hydration Stabilizer

• Maybe the most essential admixture for a manageable mix
• Differs from Normal Retarders
  • Temporarily stops hydration
• Dosed to maintain cement paste consistency for 90 minutes
  • According to ambient temperature
    • 80° F ≈ 8 oz/cwt
    • 90° F ≈ 11 oz/cwt
    • 100° F ≈ 14 oz/cwt
Pervious Concrete Properties

- 15% to 35% air void content
  - Field studies show 20-25% average
- 100 to 120 lbs/ft\(^3\) unit weight
- 2500 to 3500 psi strength*
  - Introduction of small amount of fine aggregate can increase strength to 4000 psi (+/-)
- compressive strength typically not used as acceptance criteria. Air void structure and unit weight are used instead.
ACI 522 – Pervious Concrete

• ACI 522R – 06
  • Provides technical information on pervious concrete’s application, properties, and construction methods

• ACI 522.1 – 08
  • Specification for Pervious Concrete Pavements
ACI 522.1 - 08: Specification for Pervious Concrete Pavements

- Performance specification
- Provides Guidelines for
  - Quality Assurance
    - Materials
    - Testing - Acceptance
    - Placement
- Does not provide recipe for pervious concrete mix design
Specification Recommendations

- Target void content of 16% to 24% as measured by ASTM C1688*
- Minimum void content of 15% as measured by ASTM C1688*
- Fresh density of pervious concrete shall be within 5 lbs. (+/-) of the fresh density of the specified fresh density (approved mix design)
- Suggested text - Not taken from ACI 522.1-08
Specification Recommendations

• Nominal maximum aggregate size shall not exceed 1/3 of the specified pavement thickness.
• Chemical admixtures that facilitate the production and placement of pervious concrete shall be permitted. The use of such admixtures shall be notified to the Architect/Engineer.
• The use of fibers in pervious concrete mixtures is permitted when approved by the Architect/Engineer.
NRMCA Recommended
Addendums to Specification
Section 1.6: Quality Assurance

1.6.1.1 **Contractor qualification** - Unless otherwise approved by Architect/Engineer, Contractor shall provide evidence of employment of one (1) NRMCA certified Pervious Concrete Craftsman who must be on site, overseeing each placement crew, during all concrete placement, or the contractor shall provide evidence of employment of three (3) NRMCA certified Pervious Concrete Installers or five (5) NRMCA certified Pervious Concrete Technicians, who have received hands-on training in the construction of pervious concrete pavements, and who must be on site, working as members of each placement crew, during all concrete placement, or, with the approval of Architect/Engineer, contractor may provide written evidence of project experience and proficiency in successfully completing pervious concrete pavement construction, and submit evidence of completion of a pervious concrete craftsman certification program.
Pervious Concrete Contractor Certification Program
Certification Levels

• Pervious Concrete Technician
  • Complete written exam – passing score 75%

• Pervious Concrete Installer
  • Prerequisite – ACI Flatwork Technician
  • Performance Exam
  • Minimum 3 projects @ 10,000 Sq. Ft.

• Pervious Concrete Craftsman
  • Prerequisite – ACI Flatwork Technician
  • 1500 hours work experience + performance exam
    or
  • 3000 hours of work experience

• Certifications valid for 5 years
1.6.1.2 Concrete Producer qualification – Unless otherwise approved by Architect/Engineer, ready mixed pervious concrete shall be produced and provided by an NRMCA Certified plant. If, rather than ready mixed pervious concrete, a volumetric mobile mixer is used to produce the pervious concrete, the mixer(s) must conform to the standards of the Volumetric Mixer Manufacturers Bureau (VMMB), to be verified by a current VMMB conformance plate affixed to the volumetric mixer equipment.
1.6.1.2 **Concrete Producer qualification** – Unless otherwise approved by Architect/Engineer, ready mixed pervious concrete shall be produced and provided by an NRMCA Certified plant. If, rather than ready mixed pervious concrete, a **volumetric mobile mixer** is used to produce the pervious concrete, the mixer(s) **must conform to the standards of the Volumetric Mixer Manufacturers Bureau (VMMB)**, to be verified by a current VMMB conformance plate affixed to the volumetric mixer equipment.
Section 1.5; Submittals

1.5.3.2 Pre-Placement Conference – A mandatory pre-placement conference will take place including at a minimum, the architect, engineer, general contractor, pervious concrete contractor, concrete supplier, and field testing agency. As a guide for the meeting, a copy of the document **Checklist for the Concrete Pre-Construction Conference** (co-published and available from the National Ready Mixed Concrete Association (NRMCA), 900 Spring Street, Silver Spring, MD, (301) 587-1400 or the American Society of Concrete Contractors (ASCC), 2025 South Brentwood Boulevard, St Louis, MO, (314) 962-0210), will be used to review all materials and personnel qualifications, concrete production, preparation, placing, curing, and testing procedures.
Pervious Concrete Placement

For fixed-form placement
  • Place and screed pervious concrete
Pervious Concrete Placement

• Specialized head available for Laser Screed application
Pervious Concrete Placement

- Can also use paving equipment
- May still require side forms
  - Material usually not stiff enough for edges to hold under pressure of compaction
- Conventional asphalt paver provides \( \approx 90\% \) compaction
- For denser surface, follow behind with small roller
Quality Control

• Water content of concrete must match contractor’s equipment
• Don’t be afraid to add water to get the right consistency
  • Be careful not to exceed maximum W/C ratio
Jointing

- Roughly ½ the shrinkage of normal concrete
- Joints are typically placed every 15 - 20’
- Best practice is to tool joints
  - Sawing can cause raveling
  - Sawing may require interruption of curing
Curing

- Curing pervious concrete is perhaps more important than curing conventional concrete
- Without curing, surface will dry out and deteriorate easily
- Moist cure (7 days preferred)

Curing pervious concrete is critical due to the porosity and low W/C ratio
Pervious Concrete
Acceptance Testing
Acceptance Testing

- Considered zero-slump
- Compressive strength typically *not* used as acceptance criteria.
- Air void structure and density are used instead.
  - Density of plastic concrete should be within 5 pcf +/- of mix design
  - Void content can be verified with ASTM C1688
Fresh Density

- The density is simply the weight of one cubic foot (unit weight)
- Critical in quality control
- Density should be +/- 5 pcf of design

ASTM C1688
Density vs. Void Ratio

Effect of Compaction on Pervious Concrete Properties, Suleiman, et al.
Pulling Cores

• ASTM C 42
• Larger projects might require cores
• Measure thickness
• Dry Density/Void
  • Standard not yet determined by ASTM
Acceptance Testing

• Cores used to conduct tests in hardened pervious concrete
  • Compressive strength
    • Not typically used as acceptance criteria
  • Void content
• Also can use infiltrometer to test infiltration rate
ASTM Task Groups

- Fresh Concrete Density and Voids Content
  - ASTM C1688 - Standard Test Method for Density and Void Content of Freshly Mixed Pervious Concrete

- Field Permeability (Infiltration Rate)
  - ASTM C1701 - Standard Test Method for Infiltration Rate of In-Place Pervious Concrete

- Hardened Concrete Density and Porosity
  - Being developed

- Compressive Strength
  - Working to reduce compressive strength variability
  - Outline of Standard

- Flexural Strength
  - Being developed
Resources
ACI 522-R & 522.1
Available through American Concrete Institute
www.concrete.org
Pervious Concrete Pavements
Available through Portland Cement Association
www.cement.org/bookstore
Pervious Concrete
Hydrological Design
and Resources
Software
Available through
Portland Cement
Association
www.cement.org/bookstore
Understanding *Pervious Concrete - Hydrological Design and Resources* Software.

Presented by [Jason Wimberly](#), EI, MCE, director of technical services, Carolinas Ready Mixed Concrete Association

Starts 2 p.m. EST | hour duration | $50 Members | $100 Non-members

**Special Offer - Save $10:** Register for the Webinar and purchase save $10 on the software. [Click here](#) to purchase online, login and use the code PCHDWeb at checkout. Or contact Jacques Jenkins, 800-846-7622, x1165 or by [e-mail](#). Email [Jason Wimberly](#) for other dates and information.

Download a [Fax back registration form](#)
Call 240-485-1152 or [e-mail](#) meetings@nrmca.org
www.PerviousPavement.org

- Engineering Properties
- Mix Design
  - Software available
- Structural Design
- Hydrological Design
- Construction Guidelines
- Inspection & Maintenance
- Resources
Now Available from NRMCA

Pervious Concrete: Guideline to Mixture Proportioning

2PE001
Version 1.0
Pervious Concrete Contractor Certification Program
Questions?
Thank You!

Philip Kresge
Sr. Director, National Resources
pkresge@nrmca.org