Porous Asphalt
for
Storm Water Management
“It’s Not Just for Parking Lots Anymore”

OHIO ASPHALT PAVING CONFERENCE
FEBRUARY, 2008

by
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Training Director
Preface

“ODOT” as referenced in this presentation refers to the Oregon Department of Transportation
History of Porous Asphalt in Oregon

Open-Graded Mixes:

• FHWA-RD 74-2 Technical Advisory on Friction Courses (1974)

• Oregon use of Open-graded cold mix since 1970s

• Oregon use of Open-graded hot mix (F-mix) since 1979
Typical Freeway Application in Oregon

- Wearing Course only
- Primarily to reduce splash spray and ponding
- Typically 3/4” Open-grade Mix in a 2” Lift
- Interconnected Voids allows water to drain laterally
History of Parking Lots in the U.S. Using Porous Pavements

- Developed by the Franklin Institute – 1972
- Some pilot projects tested during 1970’s
- Development of geotextiles in 1979
- *Cahill Associates* have constructed more than 100 projects since 1980 (all still performing well)
- Technology becoming popular around the country including Oregon
Advantages of Porous Asphalts for Parking Lot Applications

- Reduce impervious surface
- Improve water quality
- Recharge groundwater
- Eliminate need for detention basins
- Reduce the load on municipal stormwater collection systems
Typical Public Parking Lot Design

Cahill Associates
Commercial Application

Port of Portland
Commercial Application

Port of Portland

3" Porous Surface Course
Porous Asphalt Cement Concrete

1" Choker Course
Provides working surface for construction

10" Reservoir Course
Clean uniformly
Graded Crushed Aggregate
Approximately 40% voids

Non-woven Geotextile

Uncompacted Subgrade
Uncompacted to retain permeability
Placement Operations
*Port of Portland*
Permeability Check

*Port of Portland*
Progression to Residential Streets

- Municipalities placing more and more restrictions on Developers
- Higher housing densities
- Requirements to mitigate loss of pervious surfaces
Street Design Using Porous Pavements for Storm Water Management

- Finish Grade
- Pervious Paving - Surface Course 2 \( \frac{1}{2} \)"
- Choker Course: AASHTO No. 57 - 1" or more sufficient to fill large aggregate space
- Clean, uniformly graded coarse aggregate, AASHTO No. 2
- Non-woven geotextile
- Bed bottom elevation
- Uncompacted subgrade
Asphalt Thickness Design

For auto parking applications: (with little or no trucks)

- Can substitute dense mix w/porous inch for inch
- Cahill Assoc. has success with 2.5” for parking lots

For streets or commercial sites with trucks:

- Follow AASHTO design procedure
- Minimum recommended depth:
  - 4.0” on light street traffic
  - 6.0” with heavy trucks
Recommended Layer Coefficients for AASHTO Design Method

Open-Graded Mixes: 0.40 – 0.42
(per ODOT/Arizona)

Asphalt Treated Permeable Base: 0.30 – 0.35

Porous Aggregate Base: 0.10 - 0.14
## Porous Asphalt Mix Options

<table>
<thead>
<tr>
<th>Mix Size</th>
<th>Application</th>
<th>Layer Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/8” Open</td>
<td>Parking/Recreational Facilities</td>
<td>1.5 – 2.5 Inches</td>
</tr>
<tr>
<td>1/2” Open</td>
<td>Wearing Surface, Roads, Streets, Heavy Commercial</td>
<td>2.0 – 4.0 Inches</td>
</tr>
<tr>
<td>3/4” Open</td>
<td>Wearing Surface, Roads, Heavy Commercial</td>
<td>2.0 – 5.0 Inches</td>
</tr>
<tr>
<td>3/4” ATPB</td>
<td>Base Course</td>
<td>3.0 – 6.0 Inches</td>
</tr>
</tbody>
</table>
Materials for Porous Streets

- Geo-textile:
  - Non-woven

- Aggregate Bases:
  - Reservoir Course
  - Choker Course

- Hot Mixed Asphalt:
  - Asphalt Treated Permeable Base (ATPB)
  - Open-Graded Wearing Course
Geotextile

- Use non-woven material
- Place on uncompacted subgrade
# Aggregate Base Materials

<table>
<thead>
<tr>
<th>Sieve</th>
<th>Reservoir AASHTO No. 2</th>
<th>Choker AASHTO No. 57</th>
</tr>
</thead>
<tbody>
<tr>
<td>3”</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>2 ½”</td>
<td>90 – 100</td>
<td></td>
</tr>
<tr>
<td>2”</td>
<td>35 – 70</td>
<td></td>
</tr>
<tr>
<td>1 ½”</td>
<td>0 – 15</td>
<td>100</td>
</tr>
<tr>
<td>1”</td>
<td>-</td>
<td>95 – 100</td>
</tr>
<tr>
<td>3/4”</td>
<td>0 – 5</td>
<td>-</td>
</tr>
<tr>
<td>1/2”</td>
<td></td>
<td>25 – 60</td>
</tr>
<tr>
<td>No. 4</td>
<td></td>
<td>0 – 10</td>
</tr>
<tr>
<td>No. 8</td>
<td></td>
<td>0 – 5</td>
</tr>
</tbody>
</table>
Choker/Reservoir Aggregates
Hot Mixed Asphalt Materials

- Use Oregon Standard Specifications:
  - 3/4” Open-Graded Mixture
  - 1/2” Open-Graded Mixture
  - (3/8”* Open-Graded Mixture)
  - 3/4” Asphalt Treated Permeable Base

- Use PG 70-22 or PG 70-22ER binder
## Oregon Gradation “Control Points”

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>3/8”*</th>
<th>1/2”</th>
<th>3/4”</th>
<th>ATPB</th>
</tr>
</thead>
<tbody>
<tr>
<td>1”</td>
<td></td>
<td>-</td>
<td>99-100</td>
<td>99-100</td>
</tr>
<tr>
<td>3/4”</td>
<td>-</td>
<td>99-100</td>
<td>85-96</td>
<td>85-95</td>
</tr>
<tr>
<td>1/2”</td>
<td>99-100</td>
<td>90-98</td>
<td>55-71</td>
<td>35-68</td>
</tr>
<tr>
<td>3/8”</td>
<td>90-100</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>#4</td>
<td>22-40</td>
<td>18-32</td>
<td>10-24</td>
<td>2-10</td>
</tr>
<tr>
<td>#8</td>
<td>5-15</td>
<td>3-15</td>
<td>6-16</td>
<td>0-5</td>
</tr>
<tr>
<td>#200</td>
<td>1-5</td>
<td>1-5</td>
<td>1-6</td>
<td>0-2</td>
</tr>
</tbody>
</table>
HMAC Mix Design

- Require an ODOT Certified Mix Design Technician (CMDT)

- Use current version of the ODOT Contractor Mix Design Guidelines for Open-Graded mixtures
## Mix Design Criteria

<table>
<thead>
<tr>
<th></th>
<th>3/4”, 1/2”, &amp; 3/8”* Open-Graded</th>
<th>3/4” ATPB</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Air Voids, %</strong></td>
<td>13.5 – 16.0*</td>
<td>-</td>
</tr>
<tr>
<td><strong>Draindown, %</strong></td>
<td>70 - 80</td>
<td>-</td>
</tr>
<tr>
<td><strong>TSR, min</strong></td>
<td>80</td>
<td>-</td>
</tr>
<tr>
<td><strong>Coating, %</strong></td>
<td>-</td>
<td>90</td>
</tr>
<tr>
<td><strong>VFA, %</strong></td>
<td>40 - 50</td>
<td>-</td>
</tr>
<tr>
<td><strong>VIR, %</strong></td>
<td>14.0 – 15.5</td>
<td>-</td>
</tr>
</tbody>
</table>
Compacted Specimens
AASHTO T 167
Mix Design Criteria

- Voids in Mineral Aggregate (VMA) is not a specified criteria, however, VMA’s typically run in the 22 – 26 % range

- Design Asphalt contents typically range from 5.7% to 6.2% by dry mass of mix

- Tensile Strength Ratio (TSR) is run on a “surrogate dense-graded” mixture
Mix Design Criteria

- Draindown is a measure of the amount of binder that leaves the mixture and pools at the bottom of a sample

- In the lab, ODOT uses 9”x 9” glass pyrex baking dishes to measure draindown
Evaluation of Draindown
Evaluation of Draindown
Mix Design Criteria

- Volume Increase Ratio (VIR) is the volume of non-absorbed binder compared to the volume of aggregate.

- In layman’s terms; “How much does mix volume increase as binder is added”

\[
VIR = \left( \frac{P_{be}/G_b}{P_s/G_{sb}} \right) \times 100
\]
Mix Design Criteria

- VIR is used in conjunction with “Draindown” to determine if the thick coatings that are desired for Open-Graded mixtures are being achieved.

- If excessive Draindown occurs before VIR is achieved, then the binder lacks the required viscosity properties to construct the necessary thick coating.
Construction of Porous Asphalts

- Conventional Paving Equipment
- Lower mixing and placement temps. to mitigate draindown
Construction of Porous Asphalts

- A little more difficult to do “handwork”
- More so if polymer modified asphalt is used
Construction of Porous Asphalts

- Compaction Equip:
  - Steel wheel rollers only
  - Generally static mode
  - 8 ton minimum
  - 3-4 complete coverage's
Post Construction Guidelines

- Restrict traffic for 24 hrs.
- Protect porous pavement from contamination.
  - Run-off sediment
  - Construction debris
Maintenance/Snow Removal

- Inspect several time first few months during storm events.
- Inspect annually thereafter.
- Pavement surface may be flushed or jet washed.
- Damage pavement can be repaired using dense hot mix provided <10% area.
- Use liquid de-icing compounds as needed
- Do not use sand, ash, or salt for snow or ice
Porous Asphalt Costs

- Generally same as dense graded asphalt
- Mix Costs at the plant may be 3-5% higher than conventional mix
- No premium for placement
- Weighs less so yields are ~10% better
Porous Asphalt Benefits

- Low cost - same as conventional
- Easy to construct - same as conventional
- Proven performance:
  - 20 years common application
  - 30 years as highway wearing surfaces
  - Can handle heavy truck traffic
Pringle Creek Community – Porous Asphalt Streets

Community Plan

Pringle Creek Community will feature walkable neighborhoods, a meandering creek and wetlands, a vibrant community plaza of preserved and re-purposed historical buildings, community gardens and open green space for all to enjoy. This combination of preserving the natural environment while adding community amenities and a variety of housing options will create a unique opportunity for those seeking a livable community setting.

<table>
<thead>
<tr>
<th>Housing Types</th>
<th>AREA NO.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Family (SF)</td>
<td>1,2,4,6,7,8</td>
</tr>
<tr>
<td>SF Carbon Neutral</td>
<td>2</td>
</tr>
<tr>
<td>Cottage</td>
<td>1,2,4,7,8</td>
</tr>
<tr>
<td>Tall House</td>
<td>4</td>
</tr>
<tr>
<td>Row Houses</td>
<td>6,7,8</td>
</tr>
<tr>
<td>Townhouse</td>
<td>5,8</td>
</tr>
<tr>
<td>Live Work Studio Lofts</td>
<td>5</td>
</tr>
<tr>
<td>Duplexes</td>
<td>1,4,5,6,7,8</td>
</tr>
</tbody>
</table>
Pringle Creek Community – Porous Asphalt Streets

35 SUSTAINABLE THINGS TAKING PLACE AT PRINGLE CREEK:

CONSERVATION & PRESERVATION

1. Preserve open space (12 of 32 acres)
2. Save 80% of existing trees through efficient planning (150 Trees)
3. Capture, absorb and infiltrate 90% of all rainwater that falls on site
4. Use 100% FSC (Forest Stewardship Council) lumber for all construction
5. Save and renovate existing greenhouses for use in the community garden
6. Deconstruct two buildings from site and rebuild in Eugene, Oregon
7. Preserve and restore four existing buildings to U.S. Green Building Council LEED certification
8. Restore & revitalize Pringle Creek’s natural habitat and riparian zone

BUILDING FOR THE ENVIRONMENT

9. Build a community where every home will exceed both Earth Advantage™ and Energy Star™ standards
10. Build an entire neighborhood of Carbon Neutral homes (26 dwellings)
11. Build porous pavement Green Streets system that infiltrates stormwater, protects environment and enhances livability
12. Use on-site ground source Geothermal energy to heat & cool mixed-use residential structures

13. American Sustainability and Energy Foundation: provide the foundation for a sustainable community
14. Establish a safe and natural river corridor.
15. Establish a rainwater harvesting system.
16. Establish a rainwater harvesting and infiltration system.
17. Encourage contractors to use Bio-Diesel in construction and heavy equipment (and they are!)
18. Use reclaimed Concrete Bridge from state highway project to cross Pringle Creek

PLANNING FOR COMMUNITY

20. Enable income, age and lifestyle diversity by offering a variety of housing types
21. Rehabilitate Painters’ Hall into a community building available for community use
22. Create a community where every home is built for healthy indoor air quality and energy efficiency
23. Encourage walking with a system of safe streets, sidewalks, trails & paths
24. Create affordable housing by building small, energy efficient housing that keep the cost of living low
25. Create a vibrant Village Center with public space, work space, shops, housing & events pavilion
26. Create a mix of community gathering places (urban and natural, public and private)
27. Create economic growth by using local businesses, services & contractors
28. Build residential structures that encourage in-home offices, businesses & art studios
29. Create Community Gardens with plots available for residents to grow food & flowers
30. Provide high-speed LAN and wireless access throughout the Community
Pringle Creek Community – Porous Asphalt Streets

- Soils: med-stiff stiff silts with some sand, clay
- Infiltration rates: 2”-11”/hour
- Design storm: 1” rain 24 hours
- 3”- 4”/24 hours storage
Pringle Creek Community – Porous Asphalt Streets

TYPICAL STREET SECTION

SCALE: N.T.S.
Pringle Creek Community – Porous Asphalt Streets

1.5” Porous Surface Course
3/8” Porous Asphalt Cement Concrete
w/Polymer modified PG 70-22 binder

3.0” ATPB

1—2” Choker Course
AASHTO #57 stone

10.0” Reservoir Course
Clean, uniformly graded, AASHTO #2
stone, or equivalent
Crushed Aggregate
Approximately 40% voids

8.0” Pit Run Subbase
4” - 0 Clean

Uncompacted Subgrade
Uncompacted to retain permeability
- Late season paving required addition of 8” pit run
- Eliminated geotextile underneath the pit run
- Geotextile was still used to line the edges of the pit run
Pit Run:

- Very Clean 4” – 0 Quarry Rock Material
“Reservoir” Course:

- 100% fracture
  Clean 2½”- 1½”
  AASHTO No. 2
- 40% void space
- 10”-12” depth
“Choker” Course:

- Crushed Clean
  3/4” - 1/2”
  AASHTO No. 57

- 2” Layer
Pringle Creek Community – Porous Asphalt Streets

Choker Course:

- Allowed more accurate grading
- Smoother surface
- Filter between asphalt and coarse base
Choker Course:

- Rolling helps
- Choker course tends to be unstable
- Expensive
Pringle Creek Community – Porous Asphalt Streets

Completed Base Section:

- Choker ➔
- Reservoir ➔
- Pit Run ➔
Asphalt Treated Permeable Base (ATPB):

- 3” lift
- 3% asphalt
- 30%-35% voids
- Paved full width
- Crowned section 2.5%
- Tight Corners are a problem
- Choker course tends to move under turning action of trucks
Pringle Creek Community – Porous Asphalt Streets

- Required extra attention
- Contractor Repaired damage as they went
Close up of the ATPB

Very open!
Try to minimize hand work with ATPB

Some hand work is doable

Architects gone wild!!!
Pringle Creek Community – Porous Asphalt Streets

- Minimal compaction
- Static steel wheel (10 ton)
- 4 coverages
- Base paving was completed before utilities.
- Top lift delayed over the winter to allow installation of utilities.
- How do you keep it clean?
- Contractor had the idea to cover it all with a Geotextile.
- Winter 2006 came early
- November storms gave us record rainfall of more than 11”
- Lots of wind as well
Utilities were installed during winter weather

The ATPB provide a working platform for the utility crews
Rubber cleated excavator minimizes damage
Pringle Creek Community – Porous Asphalt Streets
- Proof rolling?

- ATPB
  Pavement held up exceedingly well under saturated conditions

- Not a single weak spot on the project
- April 2007
- Utility Work Completed
- Sidewalks and some landscaping complete
Landscaping crews also used the covered ATPB as a working platform.
Some localized surface damage of the ATPB layer occurred over the winter.
Contractor removed the geotextile cover and cleaned the ATPB surface to prepare for top lift.
Pringle Creek Community – Porous Asphalt Streets

- Ready to Pave
### Pringle Creek Community – Porous Asphalt Streets

<table>
<thead>
<tr>
<th>Top Lift</th>
<th>Sieve</th>
<th>% Pass</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1/2”</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>3/8”</td>
<td>97</td>
</tr>
<tr>
<td></td>
<td>1/4”</td>
<td>55</td>
</tr>
<tr>
<td></td>
<td>#4</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td>#8</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>#30</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>#200</td>
<td>2.1</td>
</tr>
<tr>
<td>Asphalt %</td>
<td>6.0</td>
<td></td>
</tr>
<tr>
<td>Binder</td>
<td>PG 70-22 ER</td>
<td>(Polymer Modified)</td>
</tr>
</tbody>
</table>
Pringle Creek Community – Porous Asphalt Streets

- Outstanding mix
- Uniform texture
- No draindown in haul vehicles
Polymer modified mix is sticky, and required attention to detail.
Pringle Creek Community – Porous Asphalt Streets

- Variable widths required 2 different pavers on the job
- Wide paver set to 25’ could not wing down to fit 12’ reductions and alleys
Had to bring out the little guy to finish the job
The completed project came out very nice

The owner is extremely happy
Pringle Creek Community – Porous Asphalt Streets

- Edge details
The owner wanted to verify the permeability of the street....

He couldn’t wait for the real thing so, he set up a simulated rain event......
Performance in wet weather has been outstanding.
Dense-graded city street compared to Pringle Creek’s porous asphalt
Residential construction requires protecting street surface from intrusion of construction debris.
Porous Pavement

Porous Concrete

- Spalling
- Cracked
- Will be repaired under warranty (~4,450 ft²)
- Ugly
Porous Pavement

Better

Porous Asphalt

- Proven performance
- Stage construction
- Multiple product/design options
- Standard practice
- Superior design/maintenance system
- Beautiful
Pringle Creek Community – Porous Asphalt Streets

FASTER

Asphalt
- 8,000 lineal feet - variable width, 2 lifts
- Total paving days = 6
- Prep between lifts = 2

Concrete
- 800 lineal feet
- Total paving days = 10
- Cure time = 28
Porous Pavement

LOWER COST

Asphalt
4-1/2 – 5” –
Base & Top
+ Prep + Geotexile =
$2.85/ft^2

Concrete
6” pervious =
$5.00/ft^2
Conclusions/Recommendations

- The key to performance of porous systems is a high quality stone base/reservoir course.
- For fine-grained soils reservoir course should be a minimum of 18”.
- For thicker, multiple lift asphalt sections, you can eliminate the choker course.
- Asphalt Base should be ATPB.
- Design so the percent voids and void size increase with depth.
- Consider PG70-22 ER binder in wearing course if project size allows. (This will add $5.00/ton)
Resources

- Asphalt Pavement Association of Oregon, Salem, OR  (APAO.org)

- Cahill Associates Environmental Consultants, West Chester, PA  (Porous@thcahill.com)

- NAPA / AI Pavement Alliance (Pavegreen.com)