POROUS ASPHALT: DESIGN AND CONSTRUCTION

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POROUS ASPHALT: DESIGN AND CONSTRUCTION
• Materials and Specifications
• Performance of Permeable Asphalt
• Emerging Green Technologies for Asphalt
• Questions

1. Properly integrated into site design
2. Permeable wearing course
3. Flexible Pavement Section designed for saturated subgrade conditions
4. Pavement designed to infiltrate 100% of rainfall
5. Pavement depth sufficient to eliminate frost heave
6. Durable, long-lasting wearing course
7. Constructible Design (materials, sequencing)
8. Prevents or accounts for surface water run-on
9. Provides drainage redundancy (inlet, outlet)
10. Addresses potential storm water flows in subgrade/trenches
6. POROUS ASPHALT IS A GOOD PRODUCT FOR LOCAL ROADS, PARKING LOTS AND TRAILS.

Conclusions of Final Report for SR-87 project:

• “The porous pavement test section has performed satisfactorily for five years. Although a slight decrease in both infiltration rate and the storage capacity are above the design values.”

• “Visual observation during rain storms has shown that the surface of the porous pavement section does not include sheet flow. This provides a marked difference in strip delineation and pavement glare during nighttime driving weather allowing improved visibility.”

POROUS ASPHALT: CONSIDERATION FOR USE

6. Porous asphalt is a good product for local roads, parking lots and trails.

• Parking lots are tough test-low speed turning motions

• Resist temptation to mix porous with impermeable pavements in same section

• Depth of section can be an issue on high volume roads consider pervious concrete to avoid existing utilities and for life cycle cost advantages. Geogrid and/or porous asphalt treated base can help thin section.

POROUS ASPHALT: CONSIDERATION FOR USE

• Porous Asphalt vs. Pervious Concrete

  - Porous asphalt does not require certified installer-normal pavers can compact
  - Porous asphalt cannot be made in small batches
  - For high volume roads, pervious concrete may be more cost effective, both short term and life cycle cost
  - Porous asphalt can be used almost immediately vs. 7 days for concrete
  - Porous asphalt requires thicker section for higher volume or poor soils
Committee is working on a WSDOT format specification for porous asphalt (Jessica Knickerbocker, City of Tacoma lead).

Interesting developments, particularly in trying to establish optimum compaction effort.

Final product is not yet ready for publication.

Asphalt materials will comply with WSDOT specifications for Class ½ HMA PG 70-22 (Polymer modified) with the following modifications:

- Asphalt cement shall be between 6.0% and 7.0% by total weight. Test for drain down and void content at 75 gyrations at 6, 6.5 and 7.0, use highest percentage that passes both tests. Use of fibers MAY allow for higher asphalt content.

- NAPA IS-115 is good starting point for aggregate specification.

<table>
<thead>
<tr>
<th>Sieve</th>
<th>Percent Passing</th>
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<tbody>
<tr>
<td>¾&quot;</td>
<td>100</td>
</tr>
<tr>
<td>½&quot;</td>
<td>105-100</td>
</tr>
<tr>
<td>3/8&quot;</td>
<td>55-75</td>
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<tr>
<td>No. 4</td>
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<tr>
<td>No. 8</td>
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</tr>
<tr>
<td>No. 40</td>
<td></td>
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<tr>
<td>No. 200</td>
<td>2-4</td>
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</table>

NAPA IS-155 GRADATION
- Good, general purpose aggregate specification for porous pavement
- Other aggregates can be acceptable, both larger and smaller
- Consider requiring two face fracture requirement for better binding offsets lack of fines
- Some amount of fines is good for absorbing asphalt (get higher %) and thickening binder
- Good spec for choker course if being used
ALTERNATE GRADATION

- Good, general purpose aggregate specification for porous pavement
- Other aggregates can be acceptable, both larger and smaller.
- Consider requiring two face fracture requirement for better binding—offsets lack of fines.
- Some amount of fines is good for absorbing asphalt (get higher %) and thickening binder

Supplied material smaller than spec, but met voids ratio easily

GRADATION MISCUES

- Nearly 50% of material between ½” and 3/8”

GRADATION MISCUES

- Watch for too much aggregate of one size (poorly graded)
- Not enough fracture face
- Too little voids (too much fines)

Nearly 50% of material between ½” and 3/8”

GRADATION MISCUES

- Result of gradation miscalculation (poorly graded), on choker course
- Rutting, lack of interlocking
GRADATION CORRECTION
- Correction added correctly graded material to existing poorly graded material.
- Rutting greatly reduced
- Subsequent areas with strictly correct mix were even better.

AGGREGATE SPECIFICATION CHART
- Good way to see visually how gradation should look
- Original, poorly graded aggregate is near vertical line
- Replacement material has curve that emulates specification curve

POROUS ASPHALT MIX DESIGN
- Air Voids 16-25% (ASTM D3203)
- Drain Down-ASTM D6390-05, 0.3% maximum @ 15° above design mix temperature
- ODOT has alternate ODOT TM 318 Drain Down Test-subjective
  - Consider adding fiber to mix design
- All requirements should be provided with mix design from supplier.
ASTM D6390-05
DRAIN DOWN TEST
- Constituents mixed by hand per mix design
- Placed in basket with no compaction
- Cooked in oven at prescribed temperature
- Material that drops to plate weighed and compared to 0.3% standard
- Not necessarily representative of field conditions
- Look for asphalt in the bottom of dump trucks during construction

ODOT TM 318
DRAIN DOWN TEST
- Process similar to ASTM test - but places paper directly under sample
- Tester interprets between several example percentages of drain down pictures (see picture this page)
- Like ASTM test, not likely representative of field conditions, also subjective

POROUS ASPHALT MIX DESIGN
- Anti-stripping agent should be used if supplier normally uses anti-stripping in their HMA mixes.
- Should not exceed 1% by weight of aggregates
- If having difficulty meeting minimum 6% asphalt in mix design due to drain down:
  - Consider increasing fines in aggregate but watch void ratio
  - Consider adding fiber to mix design
- Intent of minimum asphalt content, polymer modified PG 70-22 is to provide full and durable coating of aggregate (design goal #6)
HAMBURG ANTI-STRIPPING TEST

- Replaces previous tests used by WSDOT for HMA
- Validity on PHMA yet to be determined
- Single test run by City of Puyallup indicated failure at 6,750 passes—less than 10,000 required for HMA
- Failure did not appear to be stripping but rather shear

HAMBURG ANTI-STRIPPING TEST

- 3-D profile of test area

HAMBURG ANTI-STRIPPING TEST

- Graph of rut depth vs. passes
- No inflection point indicates stripping is not failure cause
- Could try to add more fines to stiffen mix, see if that performs better
- Could do more field tests with different compaction efforts, take cores, evaluate density, asphalt content and consistency through core
- HMA standard varies based on asphalt grade but is generally 10,000 passes before 12.5 mm rutting

Rut depth, mm vs. wheel passes

12.5 mm rut depth, mm

Graph of rut depth vs. passes
POROUS ASPHALT SECTION DESIGN

- Starting from bottom of pavement section up:
  - Non-woven geotextile fabric—mixed opinions on this option
  - Non-woven geotextile fabric has been shown to provide surface for microbes which will decompose hydrocarbons—however, needs more study
  - Not likely to clog—Apparent Opening Size (AOS) should be similar to soils underneath, and most particles are captured in first couple of millimeters of pavement—dirty aggregate could be a problem though
  - Not a requirement for structural section—does not provide significant strength
  - Need structural strength or want reduced section, consider geo-grid in mid-point or higher of reservoir section.

GEOGRID

- Check manufacturer’s recommendations for placement
- Can reduce overall section thickness
- Section shown is proposed WSU-Puyallup LID Frontage Phase 1 section
- Porous asphalt treated base also helps reduce section thickness

GEOTEXTILE

Reference:
Section 9-23.2(1) of WSDOT 2012 Standard Specifications
POROUS ASPHALT SECTION DESIGN

- Reservoir Section
  - Same as other permeable pavements
  - Looking for 30-40% void space to allow infiltration
  - Want readily available rock with few fines
  - Want rock that is angular, of varying sizes to maximize interlock—provides a stable working surface for construction

9-03.9(2) Permeable Ballast
Permeable ballast shall meet the requirements of Section 9-03.9(1) for ballast except for the following special requirements. The grading and quality requirements are:

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Percent Passing</th>
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</thead>
<tbody>
<tr>
<td>2½&quot;</td>
<td>100</td>
</tr>
<tr>
<td>2&quot;</td>
<td>65-100</td>
</tr>
<tr>
<td>¾&quot;</td>
<td>40-80</td>
</tr>
<tr>
<td>No. 4</td>
<td>5 max.</td>
</tr>
<tr>
<td>No. 100</td>
<td>0-2</td>
</tr>
<tr>
<td>Fracture</td>
<td>75 min.</td>
</tr>
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</table>

All percentages are by weight. The sand equivalent value and dust ratio requirements do not apply. The fracture requirement shall be at least one fractured face and will apply the combined aggregate retained on the No. 4 sieve in accordance with FOP for AASHO TP 61.

RESERVOIR COURSE

Reference: Section 9-03.9(2) of WSDOT 2012 Standard Specifications

- Should be clean, less than 2% passing #100 as shown is good.
- 60-80% between 2" to ¾" allows for large void space.
- 75% fracture requirement is good for interlock, but requiring 2 face fractures, if available is better.

RESERVOIR COURSE

- Material in picture passed 75% fracture requirements, but was difficult to work with.
### Alternate Reservoir Course

- Mix used by City of Puyallup is blend developed by PW Streets. Uses a standard 1-1/4” CSBC rock blended with #57 rock.
- CSBC had void content of 12.5%
- #57 rock had void content of 41.3%
- Staff mixes the rock manually at 1:1 ratio
- Used as reservoir course and for porous gravel alleys, shoulders
- Can be used as single rock under porous asphalt, no choker course required—workable surface for pavers

### Choker Course

- If using larger diameter permeable ballast for reservoir course, there is a need for another layer to provide a working surface for paving machines.
- Use 1” to 1-1/2” layer of same aggregate as in asphalt mix design
- Or use porous asphalt treated base (recommended)
- Porous asphalt treated base can reduce overall pavement section thickness for structural design
- Can also provide a more stable surface for construction than aggregate alone.
- Standard WSDOT specification for aggregate for ATB may need to be modified to allow more permeability.

### Pavement Section Design

- Pavement section thickness needs to address:
  - Frost heave depth—lower Puget Sound basin around 1’
  - Hydrology—allow water to infiltrate before next storm
  - Structural—design flexible pavement thick enough to distribute load over assumed poor, saturated soils.
  - Frost heave only concern if fine grained, poor soils=>hydrology and structural will over ride in these cases
  - Hydrology and Structural generally will follow each other based on soils.
WSDOT has pavement design software which can be used for this purpose (EverStress), requires some expertise to use.

WSDOT also has design recommendations which are functional for designing pavement thickness.

Choose the appropriate table based on traffic, soils, and subgrade condition for all porous pavements.

There are also some locally developed pavement design programs that may be available.

<table>
<thead>
<tr>
<th>Design Period (ESALs)</th>
<th>Flexible Pavement Layer Thickness, ft</th>
<th>Rigid Pavement Base Type and Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 5,000,000</td>
<td>HMA: 0.50</td>
<td>PCC: 0.50</td>
</tr>
<tr>
<td>5,000,000 to 10,000,000</td>
<td>HMA: 0.50</td>
<td>PCC: 0.50</td>
</tr>
<tr>
<td>10,000,000 to 20,000,000</td>
<td>HMA: 0.50</td>
<td>PCC: 0.50</td>
</tr>
<tr>
<td>20,000,000 to 50,000,000</td>
<td>HMA: 0.50</td>
<td>PCC: 0.50</td>
</tr>
<tr>
<td>&gt; 50,000,000</td>
<td>HMA: 0.50</td>
<td>PCC: 0.50</td>
</tr>
</tbody>
</table>

Higher volume roads will require greater pavement section thickness.

Multiple lifts of porous asphalt can be a problem, can't lack coat.

WSDOT does not recommend porous pavement for high volume roads.
STRUCTURAL DESIGN

- Section used at the WSU LID Center
- Note, choker course was not used, aggregate for reservoir course was deemed adequate for working surface
- Would not recommend compaction of subgrade as shown here.

CONSTRUCTION

- Sequencing Important:
  - Plan site work to keep construction traffic off subgrade
  - Example: excavate to subgrade as moving out, back fill with aggregate from opposite end
  - Once geotextile and reservoir rock is down, can compact that and allow traffic on rock.
  - For anything but asphalt treated base, will likely need rollers around to fix/compact rock as pavers are working

- Watch materials and placement:
  - Look for aggregate to be porous, no sheen or sealed off areas
  - Make sure subgrade has not been compacted by construction traffic, if it has, scarify before geotextile and rock are placed.
  - Watch for asphalt in the beds of delivery trucks—indicates drain down issue
  - Make sure rollers are on the asphalt in the correct temperature range (by mix design)
  - Make sure rollers are using vibratory compaction (assuming test were passed during mix design) (Design goal #6)
CONSTRUCTION OBSERVATION KEYS

- Check that subgrade is not compacted or sealed off
- Should be loose, open graded.
- Pavement has been designed for poor subgrade, only soft, yielding subgrade should be concern.

COMPACTED SUBGRADE

Loose, open subgrade

CONSTRUCTION SEQUENCE

- Back dump rock onto geotextile
- Spread aggregate with dozer to design depth
- Compact aggregate at full design depth.

CONSTRUCTION OBSERVATION KEYS

- Note clean, interlocking look of rock.

SHOULDER BALLAST - CLEAN, FRACURED LOOSE IN PLACE
CONSTRUCTION OBSERVATION KEYS

• Compare and contrast:
  • Left cell is porous reservoir core/rock
  • Right cell is dense graded CSTC

CONSTRUCTION OBSERVATION KEYS

• Compare and contrast:
  • Left picture is standard CSBC
  • Right picture is good choker course

CONSTRUCTION OBSERVATION KEYS

• Test Time!!!
  • Which of the two choker courses shown would be acceptable?
  • Why is the other not acceptable?
CONSTRUCTION OBSERVATION KEYS

- Make sure compaction starts within the compaction range specified by the mix design
  - Too Early (too hot) - final mix may not have desired properties
  - Too Late (too cold) - final mix will not compact to desired density causing areas for rutting and eventual rutting

CONSTRUCTION TESTING KEYS

- Working on compaction/density specification
- Just now comparing data between Tacoma and Puyallup projects
- Stay tuned for more information
CONSTRUCTION OBSERVATION KEYS

- Porous asphalt will not look much different than dense graded HMA
- Left cell is porous
- Right cell is control dense graded HMA.
- Fun Fact: dense graded HMA was so porous, had to add dirt to it to clog it enough to provide run off.

CONSTRUCTION

- Placement and Acceptance:
  - Test for infiltration rate using modified ASTM test
  - Initial tests should average over 200”/hour
  - Remember that 1”/hour would still be adequate
  - Cities of Puyallup and Tacoma will be testing existing densities of porous asphalt pavements to see if density range can be established for porous asphalt.
  - If range can be established, will help inspectors with controlling compaction to desire range
  - Look for sealed off areas in pavement. Again, only if extensive areas closed off would remedial action be required.

POST CONSTRUCTION

Several owners late, porous asphalt driveway is seal coated
POST CONSTRUCTION

- Consider installing signage advising unique nature of pavement
- Covenants or other instruments tied to land/title for private developments

MAINTENANCE

- Sweep regularly with regenerative air or vacuum sweepers
  - TOP: Tymco Model 600 Regenerative Sweeper also available with Alternative Fuel option
  - Bottom: Elgin Crosswind Regenerative Sweeper also available with Alternative Fuel option

POST CONSTRUCTION

- Other Concerns/Issues
  - Protection of pavement during building construction.
  - Homeowner/End User care of pavement.
  - Education of maintenance personnel.
  - Utility installations and road way repairs.
Myth #1 - Porous asphalt (and other types of porous pavements) will clog over time and is not durable.

- **Truth** - While some caution is needed to prevent careless transport of sediments and fines on to pavements, many pavements have been operating for decades with little maintenance and others that have become clogged have been successfully rehabilitated.
- Clogging has occurred from asphalt draining down from the surface and settling lower in the asphalt pavement. Use of polymer modified asphalt, stiffer asphalts and sometimes the use of fibers mitigates this effect.
- Initial installation of porous asphalt at Walden Pond completed in 1977 still functioning.
- Arizona SB-87 still in use after 30 years (checking if still in place)
- "Several dozen large, successful porous pavement installations, including some that are now 20 years old, have been developed by Cahill Associates of West Chester, PA, mainly in Mid-Atlantic states."
- Use of regenerative vacuums periodically can restore pavements to installation infiltration rates or higher.

Myth #2 - Porous asphalt will rut under traffic loads.

- **Truth** -
  - The structural strength of flexible pavements comes primarily from the supporting roadway section, not the asphalt.
  - Cahill Associates experience confirms that the deeper pavement sections generally result in a more durable pavement.
  - Further, a Caltrans study performed in 1989 on the structural value of open graded asphalt treated base and open graded asphalt concrete pavement concluded that these materials would be assigned the same structural strength value as their dense graded counter parts.
  - ODOT has also concluded in their design guidelines that open graded asphalt will be given the same structural value as dense graded asphalt.
Myth #3 - Porous asphalt will lead to pollution of the ground water.

- Truth -
  - Intuitively, porous asphalt decreases pollution risk by keeping stormwater dispersed. Not a pollution generating surface.
  - Several studies have looked at the water quality treatment that occurs at the geotextile soil interface and concluded that removal of most pollutants is very good.
  - Other studies have shown that the porous pavement itself traps many of the heavy metals with fine sediments, and adsorption occurs to neutralize them. More study is needed in this area, but so far the results are positive.

Myth #4 - Porous asphalt is prohibitively expensive.

- Truth -
  - Porous asphalt costs about 20% more than HMA.
  - On a 20,000 square foot parking lot, 3" porous asphalt over 2" choker course at 2010 prices would be $43,000 ($2.15/sq ft) vs. $36,000 ($1.85/sq ft) for 3" Class ½ HMA over 2" CSTC.
  - The cost differential above represents about 1 ea. 2-cartridge StormFilter®
  - There is more depth of ballast and geotextiles for porous asphalt vs. HMA.
  - Porous asphalt may replace and eliminate catch basins, pipes, water quality treatment devices and storm ponds which may actually SAVE money.
City of Puyallup 8th Ave NW project information:

- Cost of top 2 layers (asphalt and binder/leveling course) = $8.98/sf (4" asphalt and 2" permeable crushed surfacing).
- Prices are based on the following:
  - Asphalt thickness: 4"
  - Asphalt/ton: $102.00/ton
  - 2" choker coarse/ton: $41.00/ton
- Overall project cost/SF: $23.49/sf (note this includes EVERYTHING the City installed on the project)
- Overall project cost/LF: $587.46
- Cost of project as bid: $408,561
- Final cost of project: $369,514
- SF of roadway: 15,725
- Length of road: 629 LF
- Width of road: 25 LF

Breakdown of various items:
Porous asphalt: 400 tons
Pervious concrete sidewalk: 344 SY
Permeable paver sidewalks: 287 SY
Raingarden: 10,000 SF, located in 6 different cells.

Other Benefits of Porous Asphalt Pavement
- Reductions of spray on higher speed roads.
- Infiltration helps recharge groundwater; helps control stream flows.
- Reduction of spray on higher speed roads.
- Reduction of hydroplaning.
- Reduction of glare.
- Less area required for stormwater control features.
- Reduced tire noise.
- May be less costly than standard road system; site dependent.
- Reduction in salt application.
- Above all, pollution prevention by eliminating surface runoff.
Warm Mix Porous Asphalt

- Warm mix asphalt is the generic term for a variety of technologies that allow the producers of hot mix asphalt pavement material to lower the temperatures at which the material is mixed and placed on the road.
- Reductions of 50 to 100 degrees Fahrenheit have been documented. Such drastic reductions have the obvious benefits of cutting fuel consumption and decreasing the production of greenhouse gases.
- In addition, potential engineering benefits include better compaction on the road, the ability to haul paving mix for longer distances, the ability to pave at lower temperatures, better asphalt coverage of aggregate, and safer conditions for workers.

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Department of Ecology Materials 101 Training Program

October 20, 2014
CITY OF PUYALLUP PROJECTS

8th Ave NW LID Retrofit
- Converted 100% impervious => 100% pervious
- Porous Asphalt Street
- Pervious concrete sidewalk (south side)
- Permeable Paver sidewalk (north side)
- ROW rain gardens

CITY OF PUYALLUP PROJECTS

Wilson Loop (Porous Alley Initiative)
- Replaced HMA section with pervious asphalt section
- Street had failed, frequent complaints
- Frequent ponding on roadway
- Utilized pervious rock shoulders
CITY OF PUYALLUP PROJECTS

6th Ave SW (Porous Alley Initiative)
- Water main replacement drove project
- Frequent street flooding events, adverse grade, no storm drainage
- Replaced HMA section with pervious asphalt section
- Utilized pervious rock shoulders

CITY OF PUYALLUP PROJECTS

Riverwalk Trail JEB III Link
- Pervious asphalt trail
- Connects to Foothills Trail
- Allows East Pioneer Way storm flows to pass laterally

CITY OF PUYALLUP PROJECTS

CLARKS CREEK: PARK RIFARIAN HABITAT & POROUS MAINTENANCE ROAD

Department of Ecology Statewide LID Training Program

October 20, 2014
CITY OF PUYALLUP PROJECTS
Corporate Yards South Entrance
- Pervious concrete entrance, 24' wide
- Heavy equipment access needed because of sight distance restriction on 39th Ave SE
- Utilized pervious alley mix of 1-1/4” blended with #57 rock for reservoir course
- Conservative 12” thick section

POROUS GRAVEL ALLEYS
- Using mix of 1-1/4” and #57 rock
- Allows 2-3 years between maintenance vs. one – two times/year with dense graded
- Inexpensively addresses ponding issues

COMING SOON
Department of Ecology Statewide LID Training Program
October 20, 2014
CITY OF PUYALLUP PROJECTS
39TH AVE SW 11TH ST SW TO 17TH ST SW

- Pervious concrete roadway & sidewalks
- Standard concrete for intersections
- Overall less cost than HMA
- Construction 2015

CITY OF PUYALLUP PROJECTS
WSU LID FRONTAGE IMPROVEMENT

- Pervious concrete and porous asphalt roadways
- Testing built into design
- Standard concrete for intersections
- Phased Construction starting 2015

CITY OF PUYALLUP PROJECTS
SHAW ROAD, 34TH AVE SE TO MANORWOOD DRIVE

- Pervious concrete roadways and bike track, sidewalks
- Construction projected for 2016