Asphalt Pavements: Perpetual to Porous

Gary L. Fitts, P.E.
Sr. Regional Engineer
Asphalt Institute
Topics

• Perpetual (long-life) asphalt pavements:
  – Background, observations, design requirements

• Porous asphalt pavements
  – Design requirements, limitations
International association of petroleum asphalt producers, manufacturers, and affiliated businesses, established in 1919

Promotes the use, benefits and quality performance of petroleum asphalt through engineering, research and educational activities.

HQ office-Lexington, KY, local office-San Antonio area

www.asphaltinstitute.org
Background

- Many “long life” asphalt pavements have been observed in the U.S. and elsewhere
  - Pavements lasting much longer/receiving much more traffic than they were designed for
  - Led to forensic studies and analyses to find out why these pavements performed so well
- With increases in truck traffic, it is necessary to identify efficient, long-term asphalt pavement strategies for “heavy-duty” applications
  - Empirical design procedures consistently overdesign asphalt pavements for high truck traffic volumes
1993 AASHTO Guide

Increasing ESAL results in increased SN, i.e., thicker pavement
Mechanistic-based methods allow consideration of anticipated axle loads.
Concept of a Perpetual, or Long Life Asphalt Pavement

• Reduce load-induced strain under traffic loads to levels that do not damage the foundation or the structural asphalt layers

• Select HMA materials and mixture qualities that resist:
  – Shear deformation (rutting within the asphalt layer)
  – Moisture damage
  – Low temperature/thermal cracking

• Provide the highest level of functional performance available to highway users
  – Smooth, safe and quiet
Perpetual Pavements

- Designed so the pavement structural layers perform without significant damage
  - For light-duty pavements, “limited” damage per loaded axle application
  - For heavy-duty pavements, minimal damage per loaded axle
- Surface/wearing course replaced periodically
  - Replacement interval depends on mixture/materials type, traffic conditions, etc.
These loads cause damage
These loads don’t

Damage (decreasing)
Thicker, Stiffer pavement

Minimal damage, extended pavement life
Design Strategy - Fatigue

- Strain below fatigue limit = Indefinite Fatigue Life
- Reduce tensile strain by increasing pavement thickness and/or increasing stiffness

![Diagram showing compression, tension, thick/stiff HMA, and strain-fatigue life relationship]
Mechanistic Criteria

Limit Bending to < 70με* (Monismith, Von Quintus, Nunn, Thompson)

Limit Vertical Compression to < 200με (Monismith, Nunn)

Thick HMA (> 8”)

Subbase

Subgrade

* New research suggests a fatigue higher endurance limit
Can we prove the hypothesis?

Observations:
- Performance of thick HMA pavements in the developed world
  - US Interstate Highways, UK Motorways
- Forensic evaluations suggested no structural damage

Laboratory verification:
- Endurance limit concept well-recognized
- Does it apply to HMA?
United Kingdom

• Changed design period from 20 to 40 years in the 1990’s

• TRL investigated the performance of existing heavily trafficked motorways
  – “…failed to detect evidence of deterioration in the main structural layers of the thicker, more heavily trafficked pavements”
Rate of Rutting vs. Total Asphalt Thickness

Subgrade deformation

Rate of rutting (mm/msa)

Thickness of bituminous layer (mm)
• 40 year design period, strong emphasis on pavement foundation

• French example:
  – Constructed in 1993
  – 40 mm porous surface over 220 mm “high modulus” HMA

• German example:
  – Constructed in 1977
  – Gußasphalt surface, over 200 mm HMA over stabilized subbase
European Observations

• Ways to realize “long life” bituminous pavements:
  – Increase the stiffness of the HMA layers
    • 2X increase in stiffness increases projected life 2-5X
  – Increasing the thickness of the HMA base layer
    • 10% increase doubles the projected life
• Observed excellent performance of thick asphalt pavements built on the Interstate system and other major routes

• Interest resulted in TRB Circular No. 503, “Perpetual Bituminous Pavements,” published in 2001

• “Perpetual Pavement” awards highlighted the performance of some of these pavements around the country
  – 39 projects awarded since 2002
Beam Fatigue Testing of HMA

- AASHTO T-321
- Temperature: 20°C
- Controlled strain
  - Test @ various levels
- Constantly monitor load (force)
- Failure defined as $\frac{1}{2} S_{initial}$
Repeated Loading @ 800με

Stiffness vs #Cycles @ 800με

~6500 cycles
Repeated Loading @ 400\(\mu\varepsilon\)

Stiffness vs #Cycles @ 400\(\mu\varepsilon\)

- X-axis: Cycles (0 to 120,000)
- Y-axis: Stiffness (Mpa) (0 to 4500)

Graph showing the decrease in stiffness with increasing cycles at 400\(\mu\varepsilon\).
Repeated Loading @ 200με

Stiffness vs. #Cycles @ 200με

Note: Reducing strain by half extends fatigue life ~8-10X
Repeated Loading @ 100με

Stiffness vs. #Cycles @ 100με

- Y-axis: Stiffness (Mpa)
- X-axis: Cycles

Graph showing the decrease in stiffness with increasing cycles at 100με.
A strain limit was observed for all mixtures, but the limit differed between mixes. All exceeded 70με.
“Endurance Limit” Research

- NCHRP 9-38, “Endurance Limit of HMA to Prevent Fatigue Cracking in Flexible Pavements”
  - Awarded to NCAT
    - Dr. E. Ray Brown, Principal Investigator
  - Final report currently (2/08) being prepared
  - Project not yet awarded
NCHRP 9-38

- Test the hypothesis that an endurance limit exists for fatigue behavior in HMA and measure its value for a representative range of HMA mixtures
- Suggest how to incorporate an endurance limit into mechanistic pavement design methods

★ Version 1.0 of MEPDG allows for including a fatigue endurance limit as an input for asphalt mixtures
“Structural” rutting is accumulated subgrade permanent deformation
  – If the subgrade deforms, the pavement above it conforms to the shape of the underlying foundation
  – Related to the vertical compressive strain at the top of the subgrade

Rutting in the asphalt layer is addressed through mixture/materials selection
  – Particularly for upper 4-6 inches of pavement
Rate of Rutting vs. Total Asphalt Thickness

- Thickness of bituminous layer (mm)
- Rate of rutting (mm/msa)

Subgrade deformation

TRL

We're driven. www.asphaltinstitute.org
Shear Stress Within an Asphalt Pavement

**$E_{HMA} = 500$ ksi**

**$E_{SG} = 10$ ksi**

- $120$ psi
- $>35$ psi
- $>30$ psi
- $>25$ psi

3” — 6”
Stiff, Rut Resistant Upper Layers

• Particularly important in upper 4-6 inches of pavement
• Use polymer-modified asphalt binders, mixtures that develop aggregate interlock
How do you design a perpetual pavement?

• Develop a trial pavement design
  – Using AASHTO, AI, or other pavement design procedure
  – Download PerRoad software (www.asphaltalliance.com)

• Identify key inputs for elastic layer theory/PerRoad
  – Modulus, Poisson’s ratio for each pavement layer and subgrade, thickness for each pavement layer
    • Layer stiffness values may vary according to season
  – Damage function constants (k-values) for HMA, subgrade
  – Traffic load spectra
TRL Design Chart

- DBM
- DBM50
- HDM

Thickness of asphalt layers (mm)

Design Life (Millions of Standard Axles)

TRL
PerRoad 3.2

- Sponsored by APA
- Developed at Auburn University / NCAT
- M-E Pavement Analysis Tool

Software is available
www.asphaltalliance.com
PerRoad Input-Structure & Materials
PerRoad Input-Traffic Load Spectra
Reliability Analysis

Perform Analysis

Perpetual Pavilion Design Results

<table>
<thead>
<tr>
<th>Layer</th>
<th>Location</th>
<th>Criteria</th>
<th>Thres...</th>
<th>Units</th>
<th>Percent Be...</th>
<th>Damage/Million A...</th>
<th>Years to D=0.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Top</td>
<td>Vertical Defl...</td>
<td>20.</td>
<td>mill-in</td>
<td>90.62</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>1</td>
<td>Bottom</td>
<td>Horizontal Str...</td>
<td>-100.</td>
<td>micr...</td>
<td>97.74</td>
<td>4.1794e-003</td>
<td>28.1</td>
</tr>
<tr>
<td>4</td>
<td>Bottom</td>
<td>Vertical Strain</td>
<td>200.</td>
<td>micr...</td>
<td>99.14</td>
<td>2.6952e-003</td>
<td>37.253</td>
</tr>
</tbody>
</table>

Thickness Design Studio

Number of Pavement Layers: 4

<table>
<thead>
<tr>
<th>Material</th>
<th>Layer 1</th>
<th>Layer 2</th>
<th>Layer 3</th>
<th>Layer 4</th>
<th>Layer 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC</td>
<td></td>
<td>Gran Base</td>
<td>Other</td>
<td>Soil</td>
<td>Soil</td>
</tr>
<tr>
<td>Thickness, in.</td>
<td>12</td>
<td>8</td>
<td>8</td>
<td>999</td>
<td>Infinite</td>
</tr>
</tbody>
</table>

Disclaimer | Cost Analysis | Export Data | Leave Module
I-49 Extension, Caddo Parish, Louisiana

- New Interstate highway construction, Shreveport to Arkansas state line
- Preliminary designs performed for asphalt and concrete pavements
Project Location

Denver

INTERSTATE 49 CORRIDOR
I-220 to Louisiana / Arkansas Line
Input data sources

- Obtained inputs used for AASHTO design from LaDOTD pavement design office
- Used FWD data from similar projects to estimate layer stiffnesses to be used as input in the pavement analysis
Traffic data

• AADT: 10,000
• % trucks: 21.2%
• Growth rate: 2.9%
<table>
<thead>
<tr>
<th>Roadway Functional Classification</th>
<th>Rural Interstate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rural Principal Arterial</td>
<td></td>
</tr>
<tr>
<td>Rural Minor Arterial</td>
<td></td>
</tr>
<tr>
<td>Rural Major Collector</td>
<td></td>
</tr>
<tr>
<td>Rural Minor Collector</td>
<td></td>
</tr>
<tr>
<td>Rural Local Collector</td>
<td></td>
</tr>
<tr>
<td>Urban Interstate</td>
<td></td>
</tr>
<tr>
<td>Urban Other Freeways and Expressways</td>
<td></td>
</tr>
<tr>
<td>Urban Principal Arterial</td>
<td></td>
</tr>
<tr>
<td>Urban Minor Arterial</td>
<td></td>
</tr>
<tr>
<td>Urban Collector</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Vehicle Classification</th>
<th>% AADTT</th>
<th>1</th>
<th>0.26</th>
<th>0.83</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>1.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>9.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>3.3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>0.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>7.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>68.9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>1.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>6.1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>0.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>1.2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total: 100
### Materials data inputs

<table>
<thead>
<tr>
<th>Season</th>
<th>Avg. air temperature, F</th>
<th>Estimated pavement temperature, F</th>
<th>Duration</th>
<th>E*, ksi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter</td>
<td>50</td>
<td>58</td>
<td>17 weeks</td>
<td>1600</td>
</tr>
<tr>
<td>Spring/fall</td>
<td>68</td>
<td>76</td>
<td>21 weeks</td>
<td>1250</td>
</tr>
<tr>
<td>Summer</td>
<td>82</td>
<td>91</td>
<td>14 weeks</td>
<td>1100</td>
</tr>
</tbody>
</table>

**Other layer stiffnesses:**

\[
E_{\text{base}} = 45,000 \text{ psi} \\
E_{\text{subbase}} = 25,000 \text{ psi} \\
E_{\text{subgrade}} = 10,000 \text{ psi}
\]
## Materials data inputs-conservative “design” values

<table>
<thead>
<tr>
<th>Season</th>
<th>Avg. air temperature, F</th>
<th>Estimated pavement temperature, F</th>
<th>Duration</th>
<th>E*, ksi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter</td>
<td>50</td>
<td>58</td>
<td>17 weeks</td>
<td>800</td>
</tr>
<tr>
<td>Spring/fall</td>
<td>68</td>
<td>76</td>
<td>21 weeks</td>
<td>625</td>
</tr>
<tr>
<td>Summer</td>
<td>82</td>
<td>91</td>
<td>14 weeks</td>
<td>550</td>
</tr>
</tbody>
</table>

Other layer stiffnesses:

\[
E_{\text{base}} = 30,000 \text{ psi} \\
E_{\text{subbase}} = 15,000 \text{ psi} \\
E_{\text{subgrade}} = 7,000 \text{ psi}
\]
### Summary of results

<table>
<thead>
<tr>
<th>THMA, in</th>
<th>Probabilistic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fatigue</td>
</tr>
<tr>
<td></td>
<td>% below limit$^2$</td>
</tr>
<tr>
<td>10</td>
<td>76.1</td>
</tr>
<tr>
<td>12</td>
<td>90.2</td>
</tr>
<tr>
<td>14</td>
<td>96.8</td>
</tr>
<tr>
<td>16</td>
<td>99.0</td>
</tr>
</tbody>
</table>

1. Monte Carlo simulation, 5000 cycles
2. Fatigue Threshold = -70 $\mu\varepsilon$
3. Deformation Threshold = 200 $\mu\varepsilon$

What if we raised our requirements for subgrade/subbase/base?
Summary of results, revised

Probabilistic Fatigue Permanent Deformation

<table>
<thead>
<tr>
<th>$T_{HMA}'$ in</th>
<th>Fatigue</th>
<th>Permanent Deformation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% below limit$^2$</td>
<td>Estimated life, years</td>
</tr>
<tr>
<td>10</td>
<td>82.1</td>
<td>7.2</td>
</tr>
<tr>
<td>12</td>
<td>93.6</td>
<td>21.9</td>
</tr>
<tr>
<td>14</td>
<td>98.4</td>
<td>54.8</td>
</tr>
<tr>
<td>16</td>
<td>99.5</td>
<td>93.4</td>
</tr>
</tbody>
</table>

Other layer stiffnesses:

$E_{\text{base}} = 35,000$ psi
$E_{\text{subbase}} = 20,000$ psi
$E_{\text{subgrade}} = 10,000$ psi
Fatigue & Deformation

Time to Damage = 0.1

HMA Thickness

- Fatigue
- Deformation
- Fatigue+
- Deformation+
Observations

• Improvement to poor foundation materials can significantly reduce the HMA thickness necessary
  – Proof rolling criterion
  – Consider stiffness/modulus as an acceptance requirement for pavement foundation
    • Intelligent compaction equipment, FWD, LWD, DCP

• Need to collect and analyze FWD data to develop ranges of values to expect seasonally for local climate and materials
Texas Perpetual Pavement Project

Locations

- I-35, Waco District
  - McLennan County
  - Hill County, under construction
- I-35, Laredo District
  - LaSalle County, (S. of Cotulla)
  - LaSalle County, NBL (N. of Cotulla)
  - LaSalle County, (S. of first project)
  - Webb County, under construction
- I-35, San Antonio District
  - Comal County (New Braunfels)
Considerations for All Layers

• Initial compaction is critically important
  – HMA must be compacted to a nonporous condition for optimal performance

• Support conditions and lift thicknesses must allow compaction to be achievable
  – Design the pavement foundation!
  – Fine-graded mixtures, ≥ 3X NMS
  – Coarse-graded mixtures, ≥ 4X NMS
  – Consider including loaded wheel test requirements (APA or HWT) for premium mixtures

• Many agencies are reducing $N_{des}$ levels when using asphalt binders that require polymer modification
Summary

• PerRoad is available and easy to use for evaluating pavement designs with respect to mechanistic “perpetual pavement” criteria

• Input data are similar to what are needed when using the “ME Design Guide” developed in NCHRP 1-37A

• www.asphaltalliance.com
Perpetual Pavement Resources

• Check APA website (www.asphaltalliance.com) for references, software, etc.

• Keep alert for articles in trade literature, research reports, etc.
Porous Asphalt Pavements
Resources

• Cahill Associates
  – http://www.forester.net/sw_0305_porous.html

• Newt Jackson
  – Nichols Consulting Engineers

• Kent Hansen
  – Director of Engineering, National Asphalt Pavement Association

• Environmental Protection Agency (EPA), EPA 832-F-99-023, Storm Water Technology Fact Sheet: Porous Pavement

• University of New Hampshire
  http://www.unh.edu/erg/cstev/porous_asphalt/porous_asphalt-spec_mar_05.pdf

• Numerous articles available online
What are Porous Pavements?

Open-Graded HMA ~ 2 ½”

½” Agg. (#7) ~ 1 – 2” Thick

Clean Uniformly Graded 2”-3” Crushed Agg. (#2) – 40% Voids

Non-Woven Geotextile

Uncompacted Subgrade
Rainfall 45"/yr

2" evaporative loss from impervious surfaces

Reduced infiltration through regraded and compacted soils in grasses

0" of infiltration under impervious surfaces

Reduction in base flow by 15"/yr under impervious surfaces

43" runoff from impervious cover
Typical Porous Pavement Installation

From: Storm Water Technology Fact Sheet, USEPA, 09/99
Comparison of Detention vs. Infiltration Design Systems

- Post Development
- Post Development w/ Detention
- Post Development w/ Recharge
- Predevelopment

Discharge (cfs)

Time interval (hrs)
Water Quality

- Infiltration
- Wetlands
- Wet Ponds
- Filtering
- Swales
- Dry Ponds
Porous Asphalt Pavements - Background

- Early 1970’s
  - USEPA Study, Franklin Institute
  - Pilot projects: Delaware, Pennsylvania, The Woodlands

- Current design approach has been used since 1980
  - Development of geotextiles in 1970’s
  - Hundreds of projects built

- Porous surfacing mixtures (PFC, OGFC) have become much more widely used since the early 1990’s
  - Modified asphalts, fibers, GTR
Typical Applications

• Lightly vehicle loads
  – Passenger vehicle parking lots
  – Low volume roads (limited truck use)
  – Recreational areas
    • Cartpaths, hike & bike trails
  – Pedestrian walkways

• Roadways?
Roadways

• Challenges
  – Variable conditions
  – Cuts and fills
  – Slope
  – Soils
  – Designing for heavy vehicles
  – Utilities

• More likely to see the use of porous wearing surfaces or permeable base/subbase instead of porous pavements
Site Conditions

• Soil permeability/infiltration rate
  – EPA recommends minimum 0.5 in/hr, 3 ft below the bottom of the stone reservoir
    • May consider lower percolation rate (to 0.1 in/hr) depending on site conditions
    • If okay for septic tank dispersion, usually okay for porous pavement
  – Near wetlands, consider using to filter/slow runoff & recharge
• Ideally, 4 ft minimum clearance from the bottom of the system to bedrock or the water table
• Fill – not recommended
• Frost
  – Pavement section should exceed frost depth
Montgomery County, Texas

- Black-shaded areas do not appear to be suitable
- ~ 2/3 of soil types appear to be suitable
- Exceptions exist both ways
# Physical Properties of Soils

<table>
<thead>
<tr>
<th>Map symbol and soil name</th>
<th>Depth</th>
<th>Clay Pct</th>
<th>Moist bulk density</th>
<th>Permeability (Ksat)</th>
<th>Available water capacity</th>
<th>Linear extensibility</th>
<th>Organic matter</th>
<th>Erosion factors Kg, Kf, T</th>
<th>Wind erodibility group</th>
<th>Wind erodibility index</th>
</tr>
</thead>
<tbody>
<tr>
<td>AhpA: Ashport</td>
<td>0-5</td>
<td>27-35</td>
<td>1.30-1.60</td>
<td>0.60-2.00</td>
<td>0.15-0.22</td>
<td>3.0-5.9</td>
<td>1.0-3.0</td>
<td>.32 .32 5</td>
<td>7</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>5-14</td>
<td>27-35</td>
<td>1.30-1.60</td>
<td>0.60-2.00</td>
<td>0.15-0.22</td>
<td>3.0-5.9</td>
<td>1.0-3.0</td>
<td>.32 .32</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>14-36</td>
<td>18-35</td>
<td>1.40-1.70</td>
<td>0.60-2.00</td>
<td>0.15-0.24</td>
<td>3.0-5.9</td>
<td>0.5-1.0</td>
<td>.37 .37</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>36-96</td>
<td>18-35</td>
<td>1.40-1.70</td>
<td>0.60-2.00</td>
<td>0.15-0.24</td>
<td>3.0-5.9</td>
<td>0.5-1.0</td>
<td>.37 .37</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AmbE: Amber</td>
<td>0-9</td>
<td>10-18</td>
<td>1.30-1.55</td>
<td>0.60-2.00</td>
<td>0.13-0.20</td>
<td>0.0-2.9</td>
<td>0.5-1.0</td>
<td>.37 .37 5</td>
<td>3</td>
<td>86</td>
</tr>
<tr>
<td></td>
<td>9-11</td>
<td>10-18</td>
<td>1.30-1.55</td>
<td>0.60-2.00</td>
<td>0.13-0.20</td>
<td>0.0-2.9</td>
<td>0.5-1.0</td>
<td>.37 .37</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>11-22</td>
<td>10-18</td>
<td>1.30-1.60</td>
<td>0.60-2.00</td>
<td>0.13-0.20</td>
<td>0.0-2.9</td>
<td>0.5-1.0</td>
<td>.37 .37</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>22-38</td>
<td>5-18</td>
<td>1.30-1.60</td>
<td>0.60-2.00</td>
<td>0.13-0.24</td>
<td>0.0-2.9</td>
<td>0.5-1.0</td>
<td>.37 .37</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>38-84</td>
<td>5-35</td>
<td>1.30-1.70</td>
<td>0.00-2.00</td>
<td>0.13-0.22</td>
<td>0.0-2.9</td>
<td>0.0-0.8</td>
<td>.37 .37</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AshA: Asher</td>
<td>0-8</td>
<td>27-40</td>
<td>1.30-1.60</td>
<td>0.06-0.20</td>
<td>0.18-0.22</td>
<td>3.0-5.9</td>
<td>1.0-3.0</td>
<td>.37 .37 5</td>
<td>7</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>8-14</td>
<td>27-40</td>
<td>1.30-1.60</td>
<td>0.06-0.20</td>
<td>0.18-0.22</td>
<td>3.0-5.9</td>
<td>1.0-3.0</td>
<td>.37 .37</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>14-31</td>
<td>27-40</td>
<td>1.45-1.70</td>
<td>0.06-0.20</td>
<td>0.18-0.22</td>
<td>3.0-5.9</td>
<td>0.5-2.0</td>
<td>.37 .37</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>31-88</td>
<td>8-18</td>
<td>1.40-1.65</td>
<td>0.60-2.00</td>
<td>0.07-0.24</td>
<td>0.0-2.9</td>
<td>0.0-1.0</td>
<td>.37 .37</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Soils Investigation

• Excavate 6-8 ft deep test pits/trenches
  – Percolation tests
  – Observe soil horizons

• Drilling
  – Depth to bedrock/claypan
  – Depth to water table
Design Considerations

• Slope – as flat as possible
  – Terrace where necessary
  – Use conventional HMA for steep slopes

• Spread infiltration over largest area possible
  – 5:1 ratio: Impervious area: Infiltration area

• Setbacks:
  – Building foundations:
    • 10 ft downgradient
    • 100 ft upgradient
  – Water supply wells: >100 ft
Terraced Parking Lots
Draining Rooftop to Parking Area
Bottom Must Be Flat

Recharge Bed

Recharge Bed
Rainfall
- Typical design event: 6 month/24 hr storm
  • 1 yr, 24 hr intensity ~ 4 in/hr
- Conservative design event: 25 year/24 hr storm
  • Intensities range from 1.4 to 15 in./24 hr
  • ~9-10.5 in/24 hr in SE Texas
- 24 hour drainage time (rec’d by USEPA)

Meet local & state wastewater mitigation requirements
25-year, 24 hour Rainfall from National Climatic Data Center

http://lwf.ncdc.noaa.gov/oa/documentlibrary/rainfall.html#atlas14
Materials Requirements

Reservoir: (unbound crushed stone):
  - AASHTO #2 (large aggregate)
  - AASHTO #5 (smaller aggregate)
    • TxDOT Item 302, Grades 1 or 2

Choke Stone:
  - AASHTO Size 7, 78
  - TxDOT Item 302, Grade 4, 4S or 5 (cover stone for chip seal)

Drainable ATB: (streets, walkways, cartpaths)
  • TxDOT Special Specification Item 3077, “Drainable Asphalt Treated Base”
- Lab Molded Density: 78.0 - 82.0%
- Binder Content 6.0 - 6.5%
- PG 76-22 + Fibers
  - 5.5 - 7.0% asphalt binder (polymer modified)
  - 0.2 - 0.5% cellulose fibers
  - ≥ 1% hydrated lime
- Asphalt-Rubber
  - 8.0 - 10.0% asphalt-rubber (min. 15% CRM)
  - Fibers, lime not used
Typical Porous HMA Surface Gradations - TxDOT Item 342

TxDOT Item 342, PG 76 midband gradation

TxDOT Item 342, A-R midband gradation
Construction Practices

• Build porous pavement last
  – Protect from construction debris
  – Protect from soil laden runoff

• Avoid compacting the subgrade
  – Protect site from heavy equipment
  – When necessary, use tracked or high flotation tires

• Excavate to subgrade

• Place filter fabric
  – Some have placed a sand bedding/leveling course before
Construction Practices

• Place reservoir course 1.5 to 3 in. stone (min. 95% with two fractured faces)
• Place 1-2 in layer of ½ in stone to stabilize the surface of the reservoir course
• Place porous asphalt course (2 to 4 in.) usually rolled with 2-3 passes with 10 ton steel-wheeled roller operated in STATIC mode
  – Consider requiring the use of a tracked paver
Construction Practices

• Restrict traffic for 24 hrs.
  – May not be as important when using modified asphalt binders

• Protect porous pavement from contamination
  – Runoff sediment
  – Construction debris/tracking
  – Keep sediment controls in place until after vegetation is established or areas are well-mulched
• Sign for maintenance and landscaping personnel
• Do not sand or ash for snow or ice, liquid de-icing compounds may be used
• Inspect annually
• Pavement surface may be periodically flushed or power-washed, or vacuumed
• Damaged pavement (<10% area) can be repaired using conventional HMA
Cost

- Pavement structure is more expensive than a traditional parking lot, BUT

- Increased costs may be offset by reduced drainage costs
  - Initially - reduce or eliminate need for separate detention basin
  - Future – reduce mowing/landscape maintenance costs, no need for pesticide/mosquito control
Diagram of infiltration bed at Morris Arboretum

SECTION THROUGH PARKING LOT AND STORMWATER RECHARGE BED
Conclusions

• Porous pavements may offer an alternative to conventional stormwater mitigation
• Site conditions must be right
• Need to protect pavement from contamination during and after construction
• Properly designed and constructed will last more than 20 years
Resources, References

- NAPA IS-131, *Porous Asphalt Pavements*
- EPA