Perpetual Pavement: Superior Performance & Sustainability

Kent R. Hansen, P.E.
Director of Engineering
National Asphalt Pavement Association
Outline

• Overview
• Advantages
• Sustainability
• Top 10
What is a Perpetual Pavement?

• No deep structural distress

Dave Timm 2012
Keep Deformation in Surface
Limit Cracking to top-down

Dave Timm 2012
New Jersey I-287
Surface Cracking
Goal of Perpetual Pavement Design

- Design so there are no deep structural distresses
  - Bottom up fatigue cracking
  - Structural rutting
- All distresses can be quickly remedied from surface
- Result in a structure with ‘Perpetual’ or ‘Long Life’
TRL Report 250
Nunn, Brown, Weston & Nicholls

Design of Long-Life Flexible Pavements for Heavy Traffic

http://www.trl.co.uk
Longitudinal crack in M1 TRL
TRL Design Chart

Design life (msa)

Thickness of asphalt layers (mm)

DBM
DBM50
HDM
Concept

Max Tensile Strain

Pavement Foundation

40-75 mm SMA, OGFC or Superpave

100 mm to 150 mm

Zone Of High Compression

High Modulus Rut Resistant Material (Varies As Needed)

Flexible Fatigue Resistant Material 75 - 100 mm

Pavement Foundation
M-E Perpetual Pavement Design

![Diagram of pavement layers and strain levels](image)

- $P$: Load
- $A$: Area
- $\varepsilon_t$: Total strain
- $\varepsilon_v$: Vertical strain
- $D_1$, $D_2$, $D_3$: Depth levels
- $E_1$, $E_2$, $E_3$: Young's modulus levels

Graph:
- $\log \varepsilon$ vs. $\log N$
- Threshold Strain
- No Damage Accumulation

Equations:
$$\log N$$

Legend:
- NAPA: National Asphalt Pavement Association
Endurance Limit

Normal Fatigue Testing Results Versus Endurance Limit Testing

Strain, (10E-06)

Number of Loads to Failure

Normal Range for Fatigue Testing
What is the Endurance Limit for HMA?

- 1972 – Monismith estimates about 70 \( \mu \varepsilon \)
- 2001 – I-710 designed at 70 \( \mu \varepsilon \)
- 2002 – 70 \( \mu \varepsilon \) used by APA
- 2007 – NCHRP 9-38 Lab Study
  - 100 \( \mu \varepsilon \) for unmod binders
  - 250 \( \mu \varepsilon \) for mod binders
  - More severe than field
- 2007 – MEPDG uses 100 to 250 \( \mu \varepsilon \)
- 2008 – Field measurements show higher strains
Perpetual Pavement Advantage

- Efficient Design – No Overdesign
- Avoid Reconstruction
- Reduce Rehabilitation
- Reduce Life Cycle Cost
- Reduce Energy Consumption
- Reduce Materials Use
Design Applications

- High Volume Pavements
  - MEPDG (DarWIN-ME)(Pavement ME Design)
  - PerRoad
- Low and Medium Volume Pavements
  - PerRoadXpress
Sustainability

- **Economic**
  - Lowest Life Cycle Cost
  - Lowest Initial Cost
  - Don’t spend money our children don’t have

- **Social**
  - Reduce Dependency on Outside
  - Save Resources
  - Make sure you leave something behind

- **Environmental**
  - Reduce Impact on Environment
  - Don’t leave your garbage behind
Perpetual Pavements

- Save Money
- Save Asphalt
- Save Aggregate
- Reduce Construction Pollution
- Reduce GHG
- Reduce Vehicle Pollution
Two Cases

• Conventional Design (AASHTO 1972) vs. Perpetual Pavement
• Concrete Rehab with PCC Remove and Replace vs. Perpetual Pavement
Perpetual Pavement versus Conventional Design
Conventional vs. Perpetual

- One Lane-Mile
- Compare Materials Usage
- Compare Costs
Assumed Economic Inputs

- **Materials**
  - Conventional -
    - 25% RAP All Layers
    - 8” Base - $60/ton
    - 4” Intermediate - $65/ton
    - 3” Surface - $70/ton (Mill & Replace Every 15 yrs)
  - Perpetual –
    - 25% RAP (Base & Intermediate) 10% in SMA
    - 8” Base - $60/ton
    - 2” Intermediate - $65/ton
    - 2” SMA Surface - $80/ton (Mill & Replace Every 20 yrs)

- **Discount Rate = 4%**
## Comparison of Structures

<table>
<thead>
<tr>
<th>Year</th>
<th>Activity</th>
<th>Year</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>15” HMA/6” Base</td>
<td>0</td>
<td>11” HMA/6” Base</td>
</tr>
<tr>
<td>15</td>
<td>Mill 3”/Overlay 3”</td>
<td>20</td>
<td>Mill 2”/Overlay 2”</td>
</tr>
<tr>
<td>30</td>
<td>Mill 3”/Overlay 3”</td>
<td>40</td>
<td>Mill 2”/Overlay 2”</td>
</tr>
<tr>
<td>45</td>
<td>Mill 3”/Overlay 3”</td>
<td>50</td>
<td>-----</td>
</tr>
<tr>
<td>50</td>
<td>-----</td>
<td>50</td>
<td>-----</td>
</tr>
<tr>
<td>Year</td>
<td>Conventional (tons/lane-mile)</td>
<td>Perpetual Pavement (tons/lane-mile)</td>
<td></td>
</tr>
<tr>
<td>------</td>
<td>-----------------------------</td>
<td>-------------------------------------</td>
<td></td>
</tr>
<tr>
<td></td>
<td>HMA*</td>
<td>HMA*</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>5,358</td>
<td>4,594</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>1,148</td>
<td>766</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>1,148</td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td></td>
<td>766</td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>1,148</td>
<td>766</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>----</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>8,802</td>
<td>4,594</td>
<td></td>
</tr>
<tr>
<td>RAP</td>
<td>2,205</td>
<td>1,187</td>
<td></td>
</tr>
<tr>
<td>Aggregate</td>
<td>6,069</td>
<td>3,203</td>
<td></td>
</tr>
<tr>
<td>Asphalt Binder**</td>
<td>396</td>
<td>204</td>
<td></td>
</tr>
</tbody>
</table>
Material Usage

- HMA, tons
  - Save 47%

- RAP, tons
  - Save 46%

- Aggregate, tons
  - Save 47%

- Binder, tons
  - Save 48%
Initial Costs

Save 16.5%
Costs

Save 25%
Rubbleization with Perpetual Pavement Overlay versus Remove/Replace PCC
First Cost Comparisons

• One Mile, Four Lanes (7040 SY)
• Case 1: Rubblization with Perpetual Pavement
• Case 2: Remove PCC and Replace with PCC
Case 1

- Perpetual Pavement with Rubblization
  - Rubblize 11” PCC
  - Overlay with 8” HMA

- Initial Cost:

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Edge Drains</td>
<td>5.00</td>
</tr>
<tr>
<td>Rubblize</td>
<td>1.50</td>
</tr>
<tr>
<td>HMA Overlay</td>
<td>60.00</td>
</tr>
</tbody>
</table>
Case 2

- Remove/Replace PCC
  - Remove PCC
  - Replace with 11” PCC

- Initial Cost:

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remove PCC</td>
<td>30.00</td>
</tr>
<tr>
<td>PCC Placement</td>
<td>43.00</td>
</tr>
</tbody>
</table>
General Experience

• First Cost: Rubblization ~ 32% less than remove/replace
• Speed of Construction: days vs. weeks
• Impact of User Costs?
Work Zone Assumptions

- 1 mile long
- 4 lanes
- One lane open each direction during work
- 40,000 ADT
Case 1

- Rubblization: One lane-mile/day production
- Paving: 2 lane-miles/day
  - Sequence
    - 3" bottom lift
    - 3" 2nd lift
    - 2" 3rd lift
  - 24 hour closure until 2nd asphalt lift
  - 12 hour closure for 3rd
Case 2

- Remove/Replace PCC
  - Removal: 2000 SY/day ~ 3.5 days/lane – 24 hr/day
  - Trim Base and Set Dowels – 12 hr
  - Paving: 0.75 mile/day – 11 hr
  - Curing: 7 days – 24 hr/day
User Costs

<table>
<thead>
<tr>
<th>User Costs, $/mile</th>
<th>Rubblize &amp; Overlay</th>
<th>Remove/Replace PCC</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>500,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1,000,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1,500,000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Life Cycle Costs

- **Asphalt**
  - Initial Construction
  - Overlay Every 15 years

- **Concrete**
  - Initial Construction
  - Grind at Year 15
  - Overlay at 25 years
  - Overlay at 35 years
Life Cycle Costs

- Rubblize & Overlay
- Remove/Replace PCC

Costs: $0 to $2,000,000 per mile.
Rubbilization Summary

• Economic Sustainability
  – Lower Initial Cost
  – Lower Life Cycle Cost
  – Lower User Cost

• Social Sustainability
  – Less User Inconvenience
  – Recycled both Concrete (as base) and Asphalt

• Environmental Sustainability
  – Lower GHG
  – Lower Pollution from Traffic Delays
Economic Sustainability

• Perpetual Pavement design is improving
  – More efficient pavements
  – More cost-effective
• Perpetual Pavement is Less Expensive
  – Initial Cost – 1/3 less
  – User Cost – 2/3 less
  – Life Cycle Cost -1/4 less
Social Sustainability

• Lower User Delay Costs
  – Lower Crash
  – Lower VOC
  – Lower Fuel Consumption

• Save Resources for Other Uses and Future Generations

• Maintain Smoothness/Quietness
Environmental Sustainability

- Completely Recycle Concrete In-Place
- Use Recycled Asphalt in Surface
- Lower GHG Emissions
This award honors asphalt pavements that were designed and built with outstanding care and exceptional quality. The result is a long-lasting pavement, one that serves the traveling public well, provides true value to the taxpayers and demonstrates both the convenience and the quality of asphalt pavement.
• 35+ years old
• 13+ years between overlays
• No increase >4”
Perpetual Pavement Awards from 2001 to 2012

Alabama - 4
Alaska - 1
Arizona – 1
Arkansas - 3
California - 2
Colorado - 1
Connecticut – 2
Florida - 3
Illinois - 1
Iowa - 2
Kentucky - 4
Maryland - 4
Michigan - 2
Minnesota - 11
Mississippi - 4
Missouri - 4
Montana - 3
Nebraska - 3
New Jersey - 2
Ohio - 3
Oklahoma – 3
Pennsylvania - 2
Rhode Island - 1
South Carolina - 4
Tennessee - 8
Texas - 2
Virginia - 1
Washington - 2
Wisconsin - 1
Toronto, Canada - 1

85 awards to date
Top 10

Nebraska 1934

Ohio 1937-40
Top 10

Alabama 1940  Tennessee 1948
Top 10

Toronto 1948

Maryland 1951
Top 10
New Jersey 1952  New Jersey 1954
Top 10
Michigan M-24, 1956
Summary

- Perpetual Pavement Design is Improving
- Perpetual Pavement is Less Expensive
- Perpetual Pavement is Sustainable