Perpetual Pavements

- **Max Tensile Strain**
- **Flexible Fatigue Resistant Material 75 - 100 mm**
- **100 mm to 150 mm Zone Of High Compression**
- **High Modulus Rut Resistant Material (Varies As Needed)**
- **40-75 mm SMA, OGFC or Superpave**

Pavement Foundation
Value

Quality in a product or service is not what the supplier puts in. It is what the customer gets out and is willing to pay for. A product is not quality because it is hard to make and costs a lot of money, as manufacturers typically believe. This is incompetence. Customers pay only for what is of use to them and gives them value. Nothing else constitutes quality.

Peter Drucker
Perpetual Pavements

Economics

Total Costs

Time

Option A

Option B

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Perpetual Pavements

Why are Perpetual Pavements Important?

• Lower Life Cycle Cost
  – Better Use of Resources
  – Low Incremental Costs for Surface Renewal

• Lower User Delay Cost
  – Shorter Work Zone Periods
  – Off-Peak Period Construction
Perpetual Pavements

Perpetual Pavement versus Conventional Design

- **HMA Thickness, in.**
  - Range: 0 to 25
- **Traffic, ESAL**
  - Range: 0.1 to 1000

**Graph Legend**
- **AASHTO**
- **PerRoad**
Perpetual Pavements

Mechanistic-Based Design

Material Properties (modulus values) → Pavement Model → Pavement Responses (strains, stresses, etc.) → Transfer Function → Pavement Life OK?

Minimize likelihood of tensile strains > 100 µε, comp. strains > 200 µε → Final Design

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Mechanistic Performance Criteria

Under ESAL

Limit Bending to < 100 με (NCHRP 9-38)

Thick HMA (> 200 mm)

Base (as required)

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

Subgrade
Perpetual Pavements

Thickness vs. Tensile Strain

HMA Tensile Strain vs. HMA Thickness

HMA Tensile Strain

HMA Thickness

Layer 1

HMA

E₁

Tensile Strain (ε₁)

h₁
Perpetual Pavements

Modulus vs. Tensile Strain

HMA Tensile Strain

HMA Modulus

Layer 1
HMA
E₁

Tensile Strain (ε₁)

h₁
Perpetual Pavements

Thickness vs. Compressive Strain

Subgrade Compressive Strain vs. HMA Thickness

HMA Thickness

Compressive Strain \((\varepsilon_v)\)

\(E_1\)

\(E_2\)

\(E_3\)

\(h_1\)

\(h_2\)
Perpetual Pavements

Normal Fatigue Testing Results Versus Endurance Limit Testing

Normal Range for Fatigue Testing

Endurance Limit
Perpetual Pavements

![Graph showing the relationship between strain and number of loads to failure. The graph indicates a region of damage accumulation and a normal range for fatigue testing.](image-url)
Perpetual Pavements

Does the Endurance Limit Exist?

- University of Illinois Study
  - 70 με reasonable
- NCHRP Project 9-38
  - 100 με for unmodified asphalt
  - 250 με for modified asphalt
- NCHRP Project 9-44 – Validating the Endurance Limit
  - Endurance Limit Workshop
- In the new MEPDG to be adopted by AASHTO
Significance of Fatigue Endurance Limit

“…such a limit would provide a thickness limit for the pavement. Increasing the thickness beyond the limiting thickness… would provide no increased structural resistance to fatigue damage and represent an unneeded expense.”

Prof. Carpenter
Perpetual Pavements
Perpetual Pavements

70 Micro Strain Test

University of Illinois

Failure @ Stiffness < 50%
Perpetual Pavements
Perpetual Pavements

Analysis

– Program uses Monte Carlo simulation to model input distributions
  • Load, Materials, thickness
– A distribution of pavement response is determined
– Reliability = probability that response(s) below threshold, OR
– Damage/Million ESAL, OR
– Time to Damage = 0.1
Perpetual Pavements

% Below Threshold

- Design should have high % below threshold
‘Damage Computation’

• For responses exceeding threshold, compute N using transfer function
  – User defined
• Calculate damage accumulation rate
  – Damage / MESAL
Perpetual Pavements

Estimated Long Life

• Convert damage rate into an estimated life
  – Use traffic volume and growth
  – Calculate when damage = 0.1
• Use for Low Vol. Roads (t ~30 yrs.)

Low Volume Traffic

10 - 20/wk  3 - 5/wk  10 - 20/wk
Perpetual Pavements

Key Components

• Based on fully functional M-E design software
• Layered elastic analysis
• Incorporates
  – Seasonal effects
  – Thickness variability
  – Material property variability
  – Load Spectra or Traffic Count
  – Probabilistic analyses
**Perpetual Pavements**

### Structural and Seasonal Information

<table>
<thead>
<tr>
<th># of Layers</th>
<th>Seasonal Information</th>
<th>Current Season</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td></td>
<td>Summer</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Duration (weeks)</th>
<th>Mean Air Temperature, F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer</td>
<td>26</td>
</tr>
<tr>
<td>Fall</td>
<td>0</td>
</tr>
<tr>
<td>Winter</td>
<td>12</td>
</tr>
<tr>
<td>Spring</td>
<td>6</td>
</tr>
<tr>
<td>Spring2</td>
<td>0</td>
</tr>
<tr>
<td>Temperature Correction</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Material Type</th>
<th>PG Grade</th>
<th>Min Modulus (psi)</th>
<th>Modulus (psi)</th>
<th>Max Modulus (psi)</th>
<th>Poisson's Ratio</th>
<th>Min - Max</th>
<th>Thickness (in)</th>
<th>Slip Condition Between Layers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Layer 1</td>
<td>AC</td>
<td>70, -22</td>
<td>50000</td>
<td>522958</td>
<td>0.35</td>
<td>0.15 - 0.4</td>
<td>10</td>
<td>Full Bond</td>
</tr>
<tr>
<td>Layer 2</td>
<td>Soil</td>
<td>3000</td>
<td>12000</td>
<td>40000</td>
<td>0.45</td>
<td>0.2 - 0.5</td>
<td>939</td>
<td>Full Bond</td>
</tr>
<tr>
<td>Layer 3</td>
<td>Soil</td>
<td>3000</td>
<td>12000</td>
<td>40000</td>
<td>0.45</td>
<td>0.2 - 0.5</td>
<td>939</td>
<td>Full Bond</td>
</tr>
<tr>
<td>Layer 4</td>
<td>Soil</td>
<td>3000</td>
<td>12000</td>
<td>40000</td>
<td>0.45</td>
<td>0.2 - 0.5</td>
<td>939</td>
<td>Full Bond</td>
</tr>
<tr>
<td>Layer 5</td>
<td>Soil</td>
<td>3000</td>
<td>12000</td>
<td>40000</td>
<td>0.45</td>
<td>0.2 - 0.5</td>
<td>Infinite</td>
<td>Full Bond</td>
</tr>
</tbody>
</table>

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**Perpetual Pavements**

**Perpetual Pavement Performance Criteria**
- Designer selects location(s) in layer
- Type of criteria (stress, strain, deflection)
- Threshold value and transfer function

![Layer Performance Criteria](Layer.png)

Layer Performance Criteria (Press F1 for Help)

<table>
<thead>
<tr>
<th>Layer</th>
<th>Position</th>
<th>Criteria</th>
<th>Threshold</th>
<th>Transfer Function</th>
<th>k1</th>
<th>k2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bottom</td>
<td>Horizontal Strain</td>
<td>-70</td>
<td>microstrain</td>
<td>2.83e-006</td>
<td>3.15</td>
</tr>
</tbody>
</table>

Note: The following sign convention is used...
Negative = Tension  
Positive = Compression  
Deflection is Positive Downward

Note: The transfer functions are for strain only.
## Perpetual Pavements

### Traffic

![Vehicle Type Distribution](Vehicle_Type_Distribution.png)

**Roadway Functional Classification**

<table>
<thead>
<tr>
<th>Vehicle Classification</th>
<th>% AADTT</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>1.2</td>
</tr>
<tr>
<td>5</td>
<td>9.4</td>
</tr>
<tr>
<td>6</td>
<td>3.3</td>
</tr>
<tr>
<td>7</td>
<td>0.5</td>
</tr>
<tr>
<td>8</td>
<td>7.4</td>
</tr>
<tr>
<td>9</td>
<td>68.9</td>
</tr>
<tr>
<td>10</td>
<td>1.2</td>
</tr>
<tr>
<td>11</td>
<td>6.1</td>
</tr>
<tr>
<td>12</td>
<td>0.8</td>
</tr>
<tr>
<td>13</td>
<td>1.2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>100</td>
</tr>
</tbody>
</table>

**Rural Interstate**

| Urban Interstate | 1 | 0.26 | 0.03 |
| Urban Arterial   |   |      |      |
| Rural Collector  |   |      |      |
| Urban Collector  |   |      |      |
| Urban Expressway |   |      |      |

**Rural Interstate**

| Urban Interstate | 2.36 | 0.67 | 0 |
| Urban Arterial   |   |      |      |
| Rural Collector  |   |      |      |
| Urban Collector  |   |      |      |
| Urban Expressway |   |      |      |

**Urban Interstate**

| Urban Interstate | 1.13 | 1.93 | 0 |
| Urban Arterial   |   |      |      |
| Rural Collector  |   |      |      |
| Urban Collector  |   |      |      |
| Urban Expressway |   |      |      |

**Urban Arterial**

| Urban Interstate | 1.13 | 1.09 | 0.89 |
| Urban Arterial   |   |      |      |
| Rural Collector  |   |      |      |
| Urban Collector  |   |      |      |
| Urban Expressway |   |      |      |

**Urban Collector**

| Urban Interstate | 4.29 | 0.26 | 0.06 |
| Urban Arterial   |   |      |      |
| Rural Collector  |   |      |      |
| Urban Collector  |   |      |      |
| Urban Expressway |   |      |      |

**Urban Expressway**

| Urban Interstate | 3.52 | 1.14 | 0.06 |
| Urban Arterial   |   |      |      |
| Rural Collector  |   |      |      |
| Urban Collector  |   |      |      |
| Urban Expressway |   |      |      |

**Rural Principal Arterial**

| Urban Interstate |   |      |      |
| Urban Arterial   |   |      |      |
| Rural Collector  |   |      |      |
| Urban Collector  |   |      |      |
| Urban Expressway |   |      |      |

**Rural Minor Arterial**

| Urban Interstate |   |      |      |
| Urban Arterial   |   |      |      |
| Rural Collector  |   |      |      |
| Urban Collector  |   |      |      |
| Urban Expressway |   |      |      |

**Rural Major Collector**

| Urban Interstate |   |      |      |
| Urban Arterial   |   |      |      |
| Rural Collector  |   |      |      |
| Urban Collector  |   |      |      |
| Urban Expressway |   |      |      |

**Rural Minor Collector**

| Urban Interstate |   |      |      |
| Urban Arterial   |   |      |      |
| Rural Collector  |   |      |      |
| Urban Collector  |   |      |      |
| Urban Expressway |   |      |      |

**Rural Local Collector**

| Urban Interstate |   |      |      |
| Urban Arterial   |   |      |      |
| Rural Collector  |   |      |      |
| Urban Collector  |   |      |      |
| Urban Expressway |   |      |      |

**Urban Other Freeways and Expressways**

| Urban Interstate |   |      |      |
| Urban Arterial   |   |      |      |
| Rural Collector  |   |      |      |
| Urban Collector  |   |      |      |
| Urban Expressway |   |      |      |

**Urban Principal Arterial**

| Urban Interstate |   |      |      |
| Urban Arterial   |   |      |      |
| Rural Collector  |   |      |      |
| Urban Collector  |   |      |      |
| Urban Expressway |   |      |      |

**Urban Minor Arterial**

| Urban Interstate |   |      |      |
| Urban Arterial   |   |      |      |
| Rural Collector  |   |      |      |
| Urban Collector  |   |      |      |
| Urban Expressway |   |      |      |

**Urban Collector**

| Urban Interstate |   |      |      |
| Urban Arterial   |   |      |      |
| Rural Collector  |   |      |      |
| Urban Collector  |   |      |      |
| Urban Expressway |   |      |      |
Perpetual Pavements

Performance Goals - Avoid These

- Repeated Bending Leads to Fatigue Cracking
- Repeated Deformation Leads to Rutting
Perpetual Pavements

Foundation - Illinois

Required Thickness Above Subgrade, inches

Remedial procedure required

Remedial procedure optional

No remedial procedure required

CBR

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SMOOTH | DURABLE | SAFE | QUIET
Perpetual Pavements

› Fatigue Resistant Asphalt Base
  » Minimize Tensile Strain with Pavement Thickness
  » Thicker Asphalt Pavement = **Lower Strain**
  » Strain Below Fatigue Limit = **Indefinite Life**
Perpetual Pavements

**TRL Design Chart**

- **DBM**
- **DBM50**
- **HDM**

**Design life (msa)**

**Thickness of asphalt layers (mm)**

---

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**SMOOTH | DURABLE | SAFE | QUIET**
Perpetual Pavements

- Rut Resistant Upper Layers
  - Aggregate Interlock
    - Crushed Particles
    - Stone-on-Stone Contact
  - Binder
    - High Temperature PG
    - Polymers
    - Fibers
  - Air Voids
    - Avg. 4% to 6% In-Place
  - Surface
    - Renewable
    - Tailored for Specific Use
Perpetual Pavements

RATE OF RUTTING vs ASPHALT THICKNESS

Rate of rutting (mm/msa)

0 100 200 300 400

Thickness of bituminous layer (mm)

0 100 200 300 400

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SMOOTH | DURABLE | SAFE | QUIET
Perpetual Pavements

Performance of Washington Interstate Flexible Pavements (based on 284 km)

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Time Since Original Construction (years)</th>
<th>Thickness of Original AC (mm (in.))</th>
<th>Time from Original Construction to First Resurfacing (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>31.6</td>
<td>230 (9.2)</td>
<td>12.4</td>
</tr>
<tr>
<td>Range</td>
<td>23 to 39</td>
<td>100 to 345</td>
<td>2 to 25</td>
</tr>
</tbody>
</table>
Perpetual Pavements

Ohio Study of Flexible Pavements

• Examined Performance on 4 Interstate Routes
  – HMA Pavements - Up to 34 Years without Rehabilitation or Reconstruction
  – “No significant quantity of work . . . for structural repair or to maintain drainage of the flexible pavements.”
  – Only small incremental increases in Present Cost for HMA pavements.
Perpetual Pavements

FHWA - Data from Long-Term Pavement Performance Study

- Data from GPS-6 (FHWA-RD-00-165)
- Conclusions
  - **Most AC Overlays ≥ 15 years before Rehab**
  - **Many AC Overlays > 20 years before Significant Distress**
  - Thicker overlays mean less:
    - Fatigue Cracking
    - Transverse Cracking
    - Longitudinal Cracking
Perpetual Pavements

SURFACE CRACKING

WHEEL LOAD

Crack
(surface initiated)

TRL
Perpetual Pavements

New Jersey I-287
Surface Cracking
Perpetual Pavements

Study of Kansas Interstates

THE NEW ASPHALT, ABSOLUTELY!

SMOOTH | DURABLE | SAFE | QUIET
Current Perpetual Pavement Efforts

- Europe
- California
- Colorado
- Illinois
- Kentucky
- Michigan
- Ohio
- Oregon
- Texas
- Wisconsin
Rehabilitation

Possible Distresses
› *Top-Down Fatigue*
› *Thermal Cracking*
› *Raveling*

Solutions
› *Mill & Fill*
› *Thin Overlay*

50 - 100 mm
Structure Remains Intact

High Quality SMA, OGFC or Superpave

20+ Years Later
Perpetual Pavements

Perpetual Pavement

› Structure Lasts 50+ years.
  » Bottom-Up Design and Construction
  » Indefinite Fatigue Life

› Renewable Pavement Surface.
  » High Rutting Resistance
  » Tailored for Specific Application

› Consistent, Smooth and Safe Driving Surface.

› Environmentally Friendly

› Avoids Costly Reconstruction.

www.AsphaltAlliance.com
References

- Int’l Conferences on Perpetual Pavements
  - Int’l Soc. for Asphalt Pavements – 2004
  - Ohio – 2006

THE NEW ASPHALT, ABSOLUTELY!
The price is what you pay; the value is what you receive.

Author Unknown