Engineering Analysis and PMS
Washington State Experience

National Pavement Management Conference
Norfolk, Virginia
May 6-9, 2007
Presentation Outline

• Introduction
• HMA life
• PG binders
• Studded tires
• PCC deterioration
• Forensic Studies
• Economic analysis
• Bituminous surface treatments
• Experimental features
Questions

• How is Superpave performing? How does it compare to traditional methods?
Questions

• What caused the failure of this road? Design? Construction? Materials?
Questions

• What design factors will help ensure a long lasting pavement?
Need a Pavement Management System that will bring together...

- Materials
- Construction quality
- Traffic
- Surface condition / performance
- Rehabilitation / maintenance
- Etc.
Overview of WSPMS

- WSDOT maintains ~ 18,000 lane miles
- Annual pavement condition survey
  - 100 percent of pavement surface in the survey lane (~10,000 lane miles)
  - Rut/wear, IRI, faulting
  - Cracking, patching, raveling, spalling, etc.
    - Pavement Structural Condition (PSC)
- Skid resistance
- Performance equations
  - PSC determined using a best fit curve
  - IRI and rutting, at this time, determined using a straight line regression
HMA Pavement Life

• Life extension has occurred due to better management of roadways

• However, pavement life is also a function of improvements in:
  - Construction practices
  - Specification changes
  - Material selection process

• Over the last 10 years, pavement life has increased
  - Eastern: 5%
  - Western: 15%
  - Statewide: 16%

<table>
<thead>
<tr>
<th>Year</th>
<th>East</th>
<th>West</th>
<th>Statewide</th>
</tr>
</thead>
<tbody>
<tr>
<td>1997</td>
<td>10.7</td>
<td>14.6</td>
<td>12.9</td>
</tr>
<tr>
<td>2000</td>
<td>10.8</td>
<td>15.8</td>
<td>14.1</td>
</tr>
<tr>
<td>2003</td>
<td>11.3</td>
<td>16.5</td>
<td>14.7</td>
</tr>
<tr>
<td>2006</td>
<td>11.2</td>
<td>16.8</td>
<td>14.9</td>
</tr>
</tbody>
</table>
Are Performance Grade Binders Impacting Pavement Performance?
Performance Grade Binders

PG 58–22

PG 64–28
WSPMS Binder Selection
Intersection Rutting

- Eight projects
  - 1 to 7 intersections per project
- Three binder grades
  - PG 76
  - PG 70
  - PG 64
Low Temperature Cracking

- Overlay projects
- High probability that cracks are reflective cracks from underlying HMA
- Low severity
  - Width < 6 mm
- Medium severity
  - Width > 6 mm
- High severity
  - Width > 6 mm and spalled

<table>
<thead>
<tr>
<th>Binder</th>
<th>Low (%)</th>
<th>Medium (%)</th>
<th>High (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PG</td>
<td>5.0</td>
<td>4.0</td>
<td>0.0</td>
</tr>
<tr>
<td>AR4000W</td>
<td>12.0</td>
<td>12.0</td>
<td>3.0</td>
</tr>
</tbody>
</table>
Studded Tire Damage
Studded Tire Damage

- 1972 Legislation allowed use of studded tires
- November 1 to March 31
- Damage seen primarily on highways with
  - Higher speeds
  - Higher volumes
  - HMA and PCC
Studded Tire Damage

I-5 Northbound, Milepost 112.23 (Lane 2) - Lacey
Portland Cement Concrete Pavement

Rut (inch)
-0.30
-0.20
-0.10
0.00
0.10
0.20
0.30

Transverse Distance (ft)
0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0

I-5, Southbound, Milepost 63.00 - Toledo Vicinity
Hot-Mix Asphalt Pavement

Rut (inch)
-0.30
-0.20
-0.10
0.00
0.10
0.20
0.30

Transverse Distance (ft)
0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0

4.6 feet
5.3 feet
7.4 feet
shoving
pavement surface

shoving
PCCP Wear

Note - Lane 1 is the leftmost lane
## Studded Tire Wear on PCC

<table>
<thead>
<tr>
<th>Rut Depth (mm)</th>
<th>Number of Lane Miles</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 - 4</td>
<td>285</td>
</tr>
<tr>
<td>4 - 6</td>
<td>507</td>
</tr>
<tr>
<td>6 - 8</td>
<td>374</td>
</tr>
<tr>
<td>8 - 10</td>
<td>200</td>
</tr>
<tr>
<td>10 - 12</td>
<td>135</td>
</tr>
<tr>
<td>12 - 14</td>
<td>60</td>
</tr>
<tr>
<td>14 - 16</td>
<td>24</td>
</tr>
<tr>
<td>16 - 18</td>
<td>12</td>
</tr>
<tr>
<td>18 - 20</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1600</strong></td>
</tr>
</tbody>
</table>

234 In-mi with more than 10 mm of wear

$18.2$ million in damage

(estimate for diamond grinding only)
PCC Deterioration
I-5 Deterioration Study

• Scope
  - Understand the condition of PCCP in King County (greater Seattle area)
  - Application to the remainder of state

• Rehabilitated and non-rehabilitated sections

• Varying construction dates

• Performance of different sections
I-5 Deterioration Study

- The data and resources used
  - Construction dates
  - Traffic volumes, percent trucks, ESAL
  - Rehabilitation treatments
  - Pavement structure
    - 9 inch non-doweled slabs on varying base type and thickness
  - Distress summaries
    - Slab cracking, faulting, IRI and wear
  - Video imaging of pavement condition
I-5 Deterioration Study

• Construction occurred from 1962-1970
• Identified three “states”
  - Non-rehabilitated
  - Diamond grinding
  - Dowel bar retrofit and diamond grinding
## I-5 Deterioration Study

<table>
<thead>
<tr>
<th>Section</th>
<th>Avg IRI (in/mi)</th>
<th>Wear (inch)</th>
<th>% slabs &gt; 1/8” faulting</th>
<th>% slabs cracked</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-rehabilitated</td>
<td>157</td>
<td>0.34</td>
<td>29</td>
<td>14</td>
</tr>
<tr>
<td>Diamond Grinding</td>
<td>70</td>
<td>0.18</td>
<td>18</td>
<td>12</td>
</tr>
<tr>
<td>DBR and Diamond Grinding</td>
<td>52</td>
<td>0.26</td>
<td>3.4</td>
<td>4.4</td>
</tr>
</tbody>
</table>
# I-5 Deterioration Study

<table>
<thead>
<tr>
<th>Faulting (in)</th>
<th>Cracking</th>
<th>Assigned Value</th>
<th>Color</th>
<th>Pavement Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 1/8</td>
<td>0 - 5%</td>
<td>1</td>
<td>green</td>
<td>Good</td>
</tr>
<tr>
<td>1/8 – 1/4</td>
<td>5% - 10%</td>
<td>2</td>
<td>yellow</td>
<td>Poor</td>
</tr>
<tr>
<td>1/4 +</td>
<td>10%+</td>
<td>3</td>
<td>red</td>
<td>Extremely Poor</td>
</tr>
</tbody>
</table>
I-5 Deterioration Study

Legend

- **Good**
- **Poor**
- **Extremely Poor**
Forensic Studies
PMS Provides...

• Construction data
  - Construction year
  - Pavement type
  - Pavement thickness
  - QA/QC data
    • Data exists in separate data base
    • Automatic electronic link is still under development

• Condition data
  - PSC
  - Rutting
  - IRI
## Example of Condition Data

### Pavement distresses comparison

<table>
<thead>
<tr>
<th>Distress</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alligator Cracking</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.4</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Patching</td>
<td>0.0</td>
<td>0.1</td>
<td>0.0</td>
<td>0.0</td>
<td>1.6</td>
<td>0.0</td>
</tr>
<tr>
<td>Raveling</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Longitudinal Cracking</td>
<td>0.3</td>
<td>0.0</td>
<td>0.0</td>
<td>1.4</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Transverse Cracking</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.3</td>
<td>0.1</td>
<td>0.0</td>
</tr>
<tr>
<td>Flushing</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>
Example of Condition Data

![Graphs showing data for PSC, Rut, and IRI over Accumulated Route Miles (ARM) for years 1999 and 2004.](image)
Video Imaging

~3 feet

~6 feet

~3 feet
Pavement Management Needs

• WSPMS has ability to determine pavement performance on standard treatments
  – mill and fill, overlay, chip seal, etc.
• Currently lacks the ability to estimate how a funding cut (or increase) effects short and long-term pavement performance
• Potential applications
  – Highway Economic Requirements System (HERS)
  – Highway Development and Management System (HDM-4)
HDM-4 Calibration

- Highway Development and Management System (HDM-4) provides
  - Road performance prediction
  - Road treatment programming
  - Funding estimates
  - Budget allocation
  - Project appraisal
  - Policy impact studies

- Effectiveness is dependant on ability to accurately model and predict pavement performance
HDM-4 Calibration

- Effectiveness to model is dependant on
  - Structural design
  - Materials
  - Construction variability
  - Traffic
  - Vehicle operating costs
  - Environmental considerations
  - Maintenance and rehabilitation practices
## WSDOT Budget Scenarios for HMA

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Description</th>
<th>Budget Distribution</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>A</td>
<td>Cut $30 M from the current WSDOT HMA budget in FY 2004-2005, then use the unconstrained budget for the last 38 years</td>
<td>$144 ($72/year)</td>
<td>$4,013 ($105.6/year)</td>
</tr>
<tr>
<td>B</td>
<td>Cut $30 M from the current WSDOT HMA budget in FY 2004-2005, then use the current WSDOT budget for the last 38 years</td>
<td>$144 ($72/year)</td>
<td>$870 ($87/year)</td>
</tr>
<tr>
<td>C</td>
<td>Cut $30 M from the current WSDOT HMA budget in FY 2004-2005, then bring the network back to the same condition as scenario D in 10 years</td>
<td>$144 ($72/year)</td>
<td>$1,050 ($105/year)</td>
</tr>
<tr>
<td>D</td>
<td>Current WSDOT budget for HMAs</td>
<td>$3,482 ($87/year)</td>
<td></td>
</tr>
</tbody>
</table>

(All costs are in millions of dollars)
Predicted Roughness

Annual Average Roughness of AC Surfaced WSDOT Highways

A = cut + unconstrained
B = cut + current WSDOT budget
C = cut + bring back to D condition in 10 years
D = current WSDOT budget

Note:
Scenario C costs $150 million more than scenario D
Bituminous Surface Treatment Analysis
2005-2007 Biennium

- WSPMS staff identified a potential $15 million in savings if current bituminous surface treatment (BST) protocol was implemented
  - ADT < 2000 vehicles
  - ESAL < 50,000 per year
  - HMA through cities and towns

- Legislative direction
  - Reduce pavement preservation program by $10 million for next three biennium's
  - Monies given to Partnership Projects
Potential HMA to BST Routes
BST Protocol Refinement Study

• University of Washington study
  - What is the appropriate ADT level?
  - Is there a limit for truck volumes?
  - Other factors (noise, speed, grade, etc.)?
  - Are there combinations of BST to HMA cycles to obtain optimal performance?
BST Protocol Refinement Study

• Increasing number of BST surfaces will impact pavement performance
  – How do we quantify this impact?
    • Structural analysis
    • Economic analysis (HDM-4)
      – Performance prediction
      – Impact of rehabilitation cycle on user delay during construction and pavement roughness
    • WSDOT Pavement Management System
      – Traffic
      – Performance
### WSDOT Lane Miles

<table>
<thead>
<tr>
<th>Pavement Type</th>
<th>Lane-miles</th>
<th>% of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>HMA</td>
<td>10,776</td>
<td>60</td>
</tr>
<tr>
<td>BST</td>
<td>4,843</td>
<td>27</td>
</tr>
<tr>
<td>PCC</td>
<td>2,262</td>
<td>13</td>
</tr>
<tr>
<td>Totals</td>
<td>17,881</td>
<td>100</td>
</tr>
</tbody>
</table>
# WSDOT Lane-Miles by ADT

<table>
<thead>
<tr>
<th>AADT</th>
<th>BST</th>
<th>HMA</th>
<th>Flexible</th>
<th>All Types</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-2,000</td>
<td>3,157</td>
<td>1,834</td>
<td>4,991</td>
<td>4,993</td>
</tr>
<tr>
<td>2,000 - 4,000</td>
<td>819</td>
<td>1,645</td>
<td>2,464</td>
<td>2,486</td>
</tr>
<tr>
<td>4,000 – 6,000</td>
<td>190</td>
<td>1,423</td>
<td>1,613</td>
<td>1,631</td>
</tr>
<tr>
<td>6,000 – 8,000</td>
<td>8</td>
<td>840</td>
<td>848</td>
<td>934</td>
</tr>
<tr>
<td>8,000 – 10,000</td>
<td>1</td>
<td>567</td>
<td>568</td>
<td>660</td>
</tr>
<tr>
<td>10,000 – 20,000</td>
<td>4</td>
<td>2,094</td>
<td>2,098</td>
<td>2,572</td>
</tr>
<tr>
<td>20,000 – 40,000</td>
<td>0</td>
<td>1,610</td>
<td>1,610</td>
<td>2,029</td>
</tr>
<tr>
<td>40,000 – 80,000</td>
<td>0</td>
<td>1,032</td>
<td>1,032</td>
<td>1,360</td>
</tr>
<tr>
<td>80,000 – 160,000</td>
<td>0</td>
<td>436</td>
<td>436</td>
<td>640</td>
</tr>
<tr>
<td>&gt;160,000</td>
<td>0</td>
<td>132</td>
<td>132</td>
<td>360</td>
</tr>
</tbody>
</table>
Preliminary Findings

• ADT < 2000
  - Apply BST
  - Exemptions for cities, towns

• ADT 2000 to 4000
  - Combination of BST and HMA
  - Exemptions for cities, towns, difficult traffic conditions, intersections, etc.

• ADT > 4000
  - HMA
Experimental Features
Experimental Features

• New technologies and innovative ideas
• Construction practices
• Specification development
• Pavement performance
  - Ride
  - Pavement condition
  - Rutting/wear
  - Faulting
• Equal or better extension of performance life?
SR-395 SPS-2 Pavement Wear

Flexural Strength
Questions?