Middle Aged Deck Preservation
When to overlay or replace?

By Bruce Thill
Washington State DOT (WSDOT)
Bridge Asset Manager
May 2013
WBPP

Mission Statement

• Provide a platform ... to exchange, promote, and advance best practices, new technologies, and innovation ...
Deck Preservation Agenda

- WSDOT Deck History and Data
- Deck Theory & Management
  - Concrete Overlays vs. Deck Replacement
  - WSDOT Data triggers for optimum timing.
- Calibration Examples and Field conditions
- Forecasting /Managing the Deck Inventory
Washington State’s Concrete Bridge Deck Program

2,962 Bridges with Concrete Decks

<table>
<thead>
<tr>
<th>Deck Area (SF)</th>
<th>Bare Conc</th>
<th>Bare Conc-ECR</th>
<th>Conc Overlays</th>
<th>Asphalt</th>
<th>Polyester</th>
<th>Polymer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>11 MSF 24.3%</td>
<td>10 MSF 22.9%</td>
<td>13 MSF 29.2%</td>
<td>9 MSF 20.5%</td>
<td>0.8 MSF 1.9%</td>
<td>0.5 MSF 1.1%</td>
</tr>
<tr>
<td></td>
<td>628 21.2%</td>
<td>672 22.6%</td>
<td>567 19.1%</td>
<td>1035 34.9%</td>
<td>23 brgs 0.8%</td>
<td>25 brgs 0.8%</td>
</tr>
</tbody>
</table>
WSDOT Concrete Overlay History

Expected Life = 25-30 years

Total Overlays = 580
Overlay Area = 14.1 MSF

> 30 yrs | 25–30 yrs | 20 – 25 yrs | < 20 yrs
25 brgs | 140 brgs | 189 brgs | 226 brgs
$0.6M | $375M | $440M | $440M
4.3% | 24.1% | 32.5% | 38.9%

2nd Gen. Overlays = 13 or 2%
WSDOT Deck & Overlay Elements

Concrete Overlay Element # 803

Concrete Deck Element # 12

Deck Soffit Element # 35
WSDOT Deck Data Definitions

Deck & Overlay

Condition State 1
Good

Condition State 2
Patches

Condition State 3
Spalling

Soffit

Condition State 1
Good

Condition State 2
Patches

Condition State 3
Structural
Deck CS2 = Patches

Deck CS3 = Spalls

Deck CS4 = Delams

Soffit CS2 = Patches

Soffit CS3 = Any sign of Capacity loss
### Raw Data: Sorted on % Patching (CS2)

<table>
<thead>
<tr>
<th>Bridge Nu</th>
<th>Bridge Name</th>
<th>Patch SF</th>
<th>Spall SF</th>
<th>Delam SF</th>
<th>Patch %</th>
<th>Spall %</th>
<th>Delam %</th>
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<tbody>
<tr>
<td>142/9</td>
<td>Klickitat R</td>
<td>1568</td>
<td>581</td>
<td>985</td>
<td>37.05%</td>
<td>62.82%</td>
<td>0.13%</td>
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<tr>
<td>2/215</td>
<td>Wenatchee R</td>
<td>6312</td>
<td>1649</td>
<td>2240</td>
<td>26.12%</td>
<td>35.49%</td>
<td>0.00%</td>
</tr>
<tr>
<td>90/316N</td>
<td>I-90 Over Paha Packard</td>
<td>3990</td>
<td>2762</td>
<td>1053</td>
<td>69.22%</td>
<td>26.39%</td>
<td>0.30%</td>
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<tr>
<td>261/120</td>
<td>Tucannon R</td>
<td>5486</td>
<td>4204</td>
<td>1222</td>
<td>76.63%</td>
<td>22.27%</td>
<td>0.49%</td>
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<tr>
<td>90/316S</td>
<td>I-90 Over N Paha Packard</td>
<td>3990</td>
<td>3040</td>
<td>864</td>
<td>76.19%</td>
<td>21.65%</td>
<td>0.08%</td>
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<tr>
<td>2/212</td>
<td>Chiwaukum CR</td>
<td>3384</td>
<td>2798</td>
<td>586</td>
<td>82.68%</td>
<td>17.32%</td>
<td>0.00%</td>
</tr>
<tr>
<td>90/156S</td>
<td>Dry CR</td>
<td>11700</td>
<td>6811</td>
<td>1900</td>
<td>58.21%</td>
<td>16.24%</td>
<td>4.15%</td>
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<tr>
<td>290/2W-W</td>
<td>W-W Ramp Over 2nd Ave</td>
<td>6600</td>
<td>3501</td>
<td>1036</td>
<td>53.05%</td>
<td>15.70%</td>
<td>0.00%</td>
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<tr>
<td>101/44</td>
<td>Bone R</td>
<td>7128</td>
<td>6428</td>
<td>650</td>
<td>90.18%</td>
<td>9.12%</td>
<td>0.70%</td>
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<tr>
<td>90/150S</td>
<td>Taneum CR</td>
<td>3942</td>
<td>2880</td>
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<td>73.06%</td>
<td>9.01%</td>
<td>0.25%</td>
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<tr>
<td>195/52</td>
<td>US 195 Ovr John Wayne Tr</td>
<td>5680</td>
<td>5207</td>
<td>473</td>
<td>91.67%</td>
<td>8.33%</td>
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<td>90/120N</td>
<td>Yakima R</td>
<td>12458</td>
<td>11341</td>
<td>1006</td>
<td>91.03%</td>
<td>8.08%</td>
<td>0.00%</td>
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<tr>
<td>90/156N</td>
<td>Dry CR</td>
<td>11700</td>
<td>9064</td>
<td>893</td>
<td>77.47%</td>
<td>7.63%</td>
<td>0.00%</td>
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<tr>
<td>900/30</td>
<td>SR 900 Over I-90</td>
<td>17424</td>
<td>16126</td>
<td>1298</td>
<td>92.55%</td>
<td>7.45%</td>
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<tr>
<td>97/534</td>
<td>Okanogan R</td>
<td>11704</td>
<td>10881</td>
<td>819</td>
<td>92.97%</td>
<td>7.00%</td>
<td>0.03%</td>
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</tbody>
</table>

- Rank by SF patching for highest maintenance investment
- Rank by % patching for prioritization
- Rank bridges by spalling to indicate need and budget
  - WSDOT Maintenance Performance Grading (ABCDF)
# Deck Condition Summary

<table>
<thead>
<tr>
<th></th>
<th>No Defects</th>
<th>Patches</th>
<th>Spalls</th>
<th>Delams</th>
<th>Totals</th>
<th>State 1</th>
<th>State 2</th>
<th>State 3</th>
<th>State 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Num =</td>
<td>950 brgs</td>
<td>387 brgs</td>
<td>289 brgs</td>
<td>254 brgs</td>
<td>1703 brgs</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Area =</td>
<td>26.2 MSF</td>
<td>52,368 SF</td>
<td>9,332 SF</td>
<td>50,310 SF</td>
<td>26.3 MSF</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>% SF =</td>
<td>(99.57%)</td>
<td>(0.20%)</td>
<td>(0.04%)</td>
<td>(0.19%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Cost =</td>
<td>$5.2 M</td>
<td>$0.9 M</td>
<td></td>
<td></td>
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<td></td>
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</table>

**Patch Distribution**
- 312 brgs @ 0% - 1%
- 25 brgs @ 1% - 2%
- 26 brgs @ 2% - 5%
- 24 brgs > 5%
Distribution of CS2 - Top 400

950 Patch = 0
312 Patch @ 0% - 1%
25 Patch @ 1% - 2%
26 Patch @ 2% - 5%
24 Patch > 5%

387 Bridges with Patches in Deck Element 12
WSDOT *Soffit Elem (SF)*

Deck CS2 = Patches

Soffit CS2 = Patches

Deck CS3 = Spalls

Soffit CS3 = Any sign of Capacity loss

Deck CS4 = Delams

Soffit CS4 = Delams
## WSDOT Soffit Element Summaries

<table>
<thead>
<tr>
<th>No Defects</th>
<th>Patches</th>
<th>Structural</th>
</tr>
</thead>
<tbody>
<tr>
<td>39.9 MSF (99.94%)</td>
<td>10,362 SF (0.03%)</td>
<td>12,464 SF (0.03%)</td>
</tr>
<tr>
<td>1705 brgs 73%</td>
<td>16 brgs &gt; 2%</td>
<td>13 brgs &gt;2%</td>
</tr>
</tbody>
</table>

- State 1: 311 brgs
- State 2: 516 brgs

2349 Bridges @ 40.0 mil SF
12/309 Deck Repair – 5 SF?
Soffit – CS2=10 SF, CS3=70 SF
Localized or Systemic
Soffit Stalactites & Rebar

• White stalactites are salts from the top.
• Not calcium from the concrete matrix.
• Brown = rust, asphalt or dirt.
Structural Problem in Soffit?

Delaminated area in Span 1 between Girders 1A and 1B east half. The concrete can easily be removed as between Girders 1B and 1C.
Exposed with little effort
Historical Deck Replacements = 13

10/143 Bristol Fill
Completed Nov 2012

<table>
<thead>
<tr>
<th>Br Num</th>
<th>Yr</th>
<th>Length</th>
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<tbody>
<tr>
<td>9/130</td>
<td>1991</td>
<td>344</td>
</tr>
<tr>
<td>12/512N</td>
<td>1987</td>
<td>1,270</td>
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<tr>
<td>82/280S</td>
<td>1988</td>
<td>1,471</td>
</tr>
<tr>
<td>97/1</td>
<td>2009</td>
<td>2,567</td>
</tr>
<tr>
<td>240/32W</td>
<td>1989</td>
<td>244</td>
</tr>
<tr>
<td>281/1</td>
<td>1990</td>
<td>196</td>
</tr>
<tr>
<td>395/16</td>
<td>1988</td>
<td>72</td>
</tr>
<tr>
<td>395/40</td>
<td>1986</td>
<td>2,451</td>
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<tr>
<td>397/10</td>
<td>1995</td>
<td>261</td>
</tr>
<tr>
<td>433/1</td>
<td>2004</td>
<td>5,478</td>
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<tr>
<td>509/101</td>
<td>1995</td>
<td>562</td>
</tr>
<tr>
<td>509/103</td>
<td>1995</td>
<td>264</td>
</tr>
<tr>
<td>529/10E</td>
<td>1994</td>
<td>1,544</td>
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</tbody>
</table>

14 bridges (588,536 sq ft) or 1.3% of total Statewide Deck Area
Deck Management Theory Based on Data

• Historically concrete overlays last 25-30 years?
• When to do a concrete overlay?
• When to Replace the Deck?
General Deck & Overlay Theory

- **Original Deck**
- **Preservation Limit**
- **Overlay Condition**
- **Rehabilitated Deck Condition**

**Deck Condition**

- **GOOD**
- **FAIR**
- **Poor**

**Overlay Trigger**

**Optimal Timing for Overlay Rehabilitation**

**Bare Deck Condition**

**Replace Deck**

**Deterioration** Above

**Deck Replacement Trigger**

**Below Top Mat: Rebar**

**Time - Years**

- 10
- 20
- 30
- 40
- 50
- 60
- 70
- 80
- 90
- 100
Distribution of CS2 - Top 400

WSDOT adopted FHWA Item 58
Deck Evaluation in 1979

950 No Patches
312 brgs @ 0% - 1%
25 brgs @ 1% - 2%
26 brgs @ 2% - 5%
24 brgs @ more than 5%

387 Bridges with Patches in Deck Element 12
### WSDOT Deck Assessment

#### Deck – Top Surface

<table>
<thead>
<tr>
<th>Deck Assessment For Concrete Overlay</th>
<th>Percent of Deck Patches &amp; Spalls (CS2 + CS3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good Deck Condition</td>
<td>&lt; 1%</td>
</tr>
<tr>
<td>Monitor for Overlay</td>
<td>1% - 2%</td>
</tr>
<tr>
<td>Prioritize for Overlay</td>
<td>2% - 5%</td>
</tr>
<tr>
<td>Prioritize for Replacement</td>
<td>&gt; 10 %</td>
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</tbody>
</table>

#### Soffit – Bottom Surface

<table>
<thead>
<tr>
<th>Deck Assessment For Replacement</th>
<th>Percent of Soffit in Distress (CS3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good Structural Condition</td>
<td>&lt; 2%</td>
</tr>
<tr>
<td>Monitor for Replacement</td>
<td>2% - 5%</td>
</tr>
<tr>
<td>Prioritize for Replacement</td>
<td>5% - 10%</td>
</tr>
</tbody>
</table>
WSDOT Data Triggers for Management

- Original Deck = 0%
- Monitor Deck Element @ 1%
- Prioritize Project @ 2%
- Overlay Trigger @ 5%
- Monitor Soffit @ 2%
- Prioritize New Deck Soffit @ 5%
- Replace Deck Soffit @ 10%

Deck Condition:
- GOOD
- FAIR
- Poor

Time - Years
10 20 30 40 50 60 70 80 90 100
Alternate Theories - NBI Data?
TRB 2013: Journal No.2313

- How to Prioritize or Forecast NBI Deck 3, 4, & 5?
- How to decipher overlay from replacements?
Field Calibration

- What does 1%, 2%, 5% Patching look like?
395/212N-W Monitor @ 1.24%

1.24% = 125 SF

LMC 1984
2012 BIR = 2.1%
2009 Chain Drag = 14.8%
90/336S – Prioritize @ 2%

- 2008 = 1.1%
- 2009 Patches Shown = 3.0%
<table>
<thead>
<tr>
<th>Bridge Nu</th>
<th>Bridge Name</th>
<th>Duration</th>
<th>Total</th>
<th>qty_1</th>
<th>qty_2</th>
<th>qty_3</th>
<th>qty_4</th>
<th>%CES</th>
<th>%CS2</th>
<th>%CS3</th>
<th>%CS4</th>
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<tbody>
<tr>
<td>142/9</td>
<td>KLICKITAT</td>
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<td>1568</td>
<td>581</td>
<td>988</td>
<td>2</td>
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<td>62.82</td>
<td>0.13</td>
<td>0.00</td>
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<td>2/215</td>
<td>WENATCHEE</td>
<td>12</td>
<td>6312</td>
<td>1649</td>
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<td>2423</td>
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<td>35.49</td>
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<td>38.39</td>
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<tr>
<td>90/316N</td>
<td>I-90 OVER PAHA PACKARD</td>
<td>12</td>
<td>3990</td>
<td>2762</td>
<td>1055</td>
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<td>163</td>
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<td>26.39</td>
<td>0.30</td>
<td>4.09</td>
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<td>0.60</td>
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<td>3990</td>
<td>3040</td>
<td>804</td>
<td>3</td>
<td>83</td>
<td>76.19</td>
<td>21.05</td>
<td>0.08</td>
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<td>2/212</td>
<td>CHIWAUKA CR</td>
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<td>3394</td>
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<td>0</td>
<td>82.68</td>
<td>17.32</td>
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<td>0.00</td>
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<tr>
<td>90/156S</td>
<td>DRY CR</td>
<td>12</td>
<td>11700</td>
<td>6811</td>
<td>1900</td>
<td>485</td>
<td>2504</td>
<td>58.21</td>
<td>16.24</td>
<td>4.13</td>
<td>21.40</td>
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<td>W-W RAMP OVER 2ND AVE</td>
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<td>5680</td>
<td>5207</td>
<td>473</td>
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<td>0</td>
<td>91.57</td>
<td>8.33</td>
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<td>0.00</td>
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<tr>
<td>90/120N</td>
<td>YAKIMA R</td>
<td>12</td>
<td>12458</td>
<td>11241</td>
<td>1006</td>
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<td>111</td>
<td>91.08</td>
<td>8.08</td>
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<td>0.89</td>
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<td>90/156N</td>
<td>DRY CR</td>
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<td>11700</td>
<td>5064</td>
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<td>1743</td>
<td>77.47</td>
<td>7.63</td>
<td>0.00</td>
<td>14.90</td>
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<td>SR 900 OVER I-90</td>
<td>12</td>
<td>17424</td>
<td>16126</td>
<td>1298</td>
<td>0</td>
<td>0</td>
<td>92.55</td>
<td>7.45</td>
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<td>10881</td>
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<td>4</td>
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<td>92.97</td>
<td>7.03</td>
<td>0.03</td>
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<td>11200</td>
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<td>162/22</td>
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<td>12</td>
<td>4882</td>
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<td>18/31N</td>
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<td>96.12</td>
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**Highlighted Row:** Bridge Nu 18/31N, Bridge Name SR 38 OVER HOBART RD/CRK
Duration 12, Total 12251, qty_1 11776, qty_2 435, qty_3 40, %CES 96.12, %CS2 3.85, %CS3 0.33, %CS4 0.00
18/31N Prioritized @ 2%

Polyester Overlay 1989: 435 SF = 3.55%
18/31N Deck View @ 3.55%
90/78N  Contract @ 5%

• 2011 @ 5.1%
90/140N  Contract @ 5%

90/140N = 5.33%
Contract

90/140S = 2.2%
Prioritize
90/154N Contract @ 5%

90/154N = 5.99%
Contract

90/154S = 2.44%
Prioritize
290/2W-W @ 15.7%
In Depth Examples

- Were these the right decisions?
- Kettle Falls 395/545: Overlay vs Replace Deck
- Paha 90/316N: No Action/Overlay/Replace
Distribution of Deck Patching (CS2)

Kettle Falls 395/545 @ 5.4%

I-90 Paha 90/316 N & S @ more than 20%
Kettle Falls 398/545
(Foreground)
Calibration of Deck Trigger - Monitor

**Deck Deterioration Curve - 395/545**

**INSPECTION YEAR**

**DETERIORATION - PERCENT OF DECK AREA**

Verify 0.194% in 2002
Kettle Falls 395/545 - 2002

- Two truss panels: 60 SF patching = 0.194%
- Not on the Radar
- Built 1941    Length = 1267 ft. Area = 30,408 SF
Calibration of Deck Trigger - Prioritize

Verify 1.8% in 2007
Kettle Falls 395/545 – 2007

- Same two truss panels: (2002 @ 60 SF)
- 2007: Five Panels & other patching, 536 SF = 1.8%
Verify 5.4% in 2011
Delams by Chain Drag
Pattern in the Patches?
Kettle Falls 395/545 – 2010

• 2010 Chain Drag Results = 5.4% Deterioration
  • Patch = 1159 SF, Spall = 156 SF, Delam = 324 SF

• New deteriorated truss panels

• Raised the priority in 2010
395/545 - Soffit Element

- Deck Replacement or Overlay?
Sofft

• With patching this bad, can the deck be saved?
• Deck replacement ruled out based on soffit quantity @ 0.35% or 105 SF and cost.
• Additional $20,000 provided for full depth deck repairs.
Deck Replacement Considerations

- In depth inspection suggested.
- Accurate Deck and Soffit quantities
  - Quality assessment
  - Quality prioritization
Hydromill 1.5” & Overlay 1.5”
Element Quantities useful for Contract

- **2012 Bridge Inspection Patching** was 337 SF and used for Contract.
  - Deep or Full depth Asphalt patching + Bad Deck
- **2012 Constructed quantity** was 345 sf
• Patch 1053 SF = 26.4%
• Spall 12 SF = 0.3%
• Delam 163 SF = 4.0%
• Soffit @ 0%

• Patch 864 SF = 21.7%
• Spall 3 SF = 0.08%
• Delam 83 SF = 2.1%
• Soffit = 1 SF
Bridge Deck Preservation Options

Maintain Only?
Bridge Deck Decisions for 90/316N

To overlay or Not to overlay. What to do?

Maintain only $

Deck Rehab and Concrete Overlay $$$

Deck Replacement $$$$$

<table>
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<tr>
<th>Elem</th>
<th>Description</th>
<th>Total</th>
<th>Unit</th>
<th>State1</th>
<th>State2</th>
<th>State3</th>
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<tr>
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<td>3,990</td>
<td>SF</td>
<td>2,774</td>
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<td>35</td>
<td>Soffit</td>
<td>3,990</td>
<td>SF</td>
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<td>0</td>
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<td>376</td>
<td>Delam Testing</td>
<td>3,990</td>
<td>SF</td>
<td>3,827</td>
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Delam Test - October 2001

(26%) (4%)
Bridge Deck Preservation Economics

Bridge 90/316N
Length: 105ft
Width: 38ft
Deck Area: 3,990 sq. ft.
Year Built: 1972
Deck Thickness: 7”
Top Conc. Cover: 2”

Continue Maintenance Deck Repair
Patch Avg. 5% per year = 220 sq. ft.
Cost to repair = $100 / sq. ft.
Continue deck deterioration
Annual cost of $22,000 per year

Contract Overlay
Overlay Cost = $80 per sq. ft.
Deck Area = 3,990 sq. ft.
Overlay life = 30 years
Annual cost of $10,640 per year

Contract Deck Replacement
Deck Cost = $250 per sq. ft.
Deck Area = 3,990 sq. ft.
Deck life = 50 years
Annual cost of $19,950 per year
In Depth Examples

• Were these the right decisions?
• Kettle Falls 395/545: Overlay vs Replace Deck?
  – Contract confirmed assumptions.
• Paha 90/316N: No Action/Overlay/Replace
  – Overlay construction 2013
Managing the Deck Inventory

Forecasting for the Future
WSDOT Bridge Asset Management?

Identify Bridge Problem (Need)

Prioritize Need

Budget and Secure Funding for Need

Fix the Problem
Distribution of CS2 - Top 400

950 Patch = 0
312 Patch @ 0% - 1%

Forecast Overlays with this group: 25 Patch @ 1% - 2%

26 Patch @ 2% - 5%
24 Patch > 5%

387 Bridges with Patches in Deck Element 12
Washington State’s Bridge Deck Preservation Needs

- Bare Conc: $50.5M
- Bare Conc-ECR: $104.6M
- Polyester: $0.9M
- Asphalt: $156M

Bar graph showing the preservation needs for different materials:

- Bare Conc: 628
- Bare Conc-ECR: 672
- Conc Overlays: 567
- Asphalt: 1035
- Polyester: 23
- Polymer: 25
## Summary of 10-year WSDOT bridge funding needs

*Dollars in millions*

<table>
<thead>
<tr>
<th>Category</th>
<th>Allocated for 2011 - 2013 biennium</th>
<th>Projected needs for fiscal years 2013 - 2023</th>
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<tbody>
<tr>
<td>Bridge replacement/rehabilitation</td>
<td>$101.1</td>
<td>$285</td>
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<tr>
<td>Bridge repairs, movable bridges</td>
<td>$17.4</td>
<td>$100</td>
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<td>Steel bridge painting</td>
<td>$39.1</td>
<td>$566</td>
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<td>Concrete deck rehabilitation</td>
<td>$13.4</td>
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<td>Seismic retrofit</td>
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<td>Scour mitigation</td>
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<td><strong>Total</strong></td>
<td><strong>$196.6</strong></td>
<td><strong>$1,274</strong></td>
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Data source: WSDOT Bridge and Structures Office.
Bridge Deck Decisions Summary

- History, Engineering Practice, & Useful Data
- Theory based in maintenance
- Theory supported by Data
- Calibrate data and triggers
Bridge Deck Decisions

When to overlay or replace?

By Bruce Thill
Washington State DOT (WSDOT)
Bridge Asset Manager
May 2013