Evolution of Whitetopping Design in Minnesota

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Minnesota Department of Transportation

Office of Materials and Road Research
Outline

• Definitions
• History of whitetopping in Minnesota
• Lessons Learned
• TPF 5-165 project status
Whitetopping

- A pavement rehabilitation technique
- Concrete over distressed asphalt pavement
- Asphalt milled to maintain grade and improve layer bonding
- More often an “inlay” than an “overlay”
- Typically concrete layer thicknesses range = 3” to 7.5”
- Smaller panel sizes for thinner overlays
Whitetopping

Typical terms

Ø Ultrathin Whitetopping (UTW) = 3” to 4.5” [Requires bond]

Ø Thin Whitetopping (TWT) = 5” to 7.5” [Bond adds life]

Ø Bonded Concrete Overlays of Asphalt Pavements (BCOA) = UTW

Ø Unbonded Concrete Overlays of Asphalt Pavements (UBCOA) = TWT
MnROAD Cell 61
History in Minnesota

§ First “modern” project
Ø Olmsted County CSAH 10 (1982) [6” TWT]

§ First Mn/DOT project (included test sections)
Ø TH30 Amboy (1993) [6” TWT]

§ Test Sections
Ø MnROAD UTW & TWT (1997) [3”, 4”, 6”]
Ø MnROAD TWT (2004) [4” to 5”]
Ø MnROAD TWT (2008) [6”]

§ First Mn/DOT “production” project
Ø I-35 North Branch (2009) [6” TWT]
History in Minnesota

§ Recent Minnesota projects

Ø CSAH 7 Hutchinson (2009)
Ø CSAH 46 Albert Lea (2009)
Ø TH23 Marshall (2009/10)
Ø CSAH 9 Harris (2010)
Ø TH 56 West Concord (2010)
Ø Olmsted County CSAH 22 (2011)
Ø Anoka County CSAH 22 & CSAH 18 (2011)
Ø McLeod County CSAH 2 & CSAH 25 (2011)

Many others currently under consideration as option in Alternate Bid projects
# MnROAD Test Cells

**Mainline = I-94 traffic**

<table>
<thead>
<tr>
<th>Cell #</th>
<th>Type</th>
<th>PCC thickness (in)</th>
<th>HMA thickness (in)</th>
<th>Panel size (ft)</th>
<th>Sealed joints</th>
<th>Fiber reinforcement type</th>
<th>Year Start-End</th>
</tr>
</thead>
<tbody>
<tr>
<td>93</td>
<td>UTW</td>
<td>4</td>
<td>9</td>
<td>4 x 4</td>
<td>Y</td>
<td>Polypropylene</td>
<td>1997-2004</td>
</tr>
<tr>
<td>94</td>
<td>UTW</td>
<td>3</td>
<td>10</td>
<td>4 x 4</td>
<td>Y</td>
<td>Polypropylene</td>
<td>1997-2004</td>
</tr>
<tr>
<td>95</td>
<td>UTW</td>
<td>3</td>
<td>10</td>
<td>5 x 6</td>
<td>Y</td>
<td>Polyolefin</td>
<td>1997-2004</td>
</tr>
<tr>
<td>96</td>
<td>TWT</td>
<td>6</td>
<td>7</td>
<td>5 x 6</td>
<td>Y</td>
<td>Polypropylene</td>
<td>1997-present</td>
</tr>
<tr>
<td>97</td>
<td>TWT</td>
<td>6</td>
<td>7</td>
<td>10 x 12</td>
<td>Y</td>
<td>Polypropylene</td>
<td>1997-2010</td>
</tr>
<tr>
<td>92</td>
<td>TWT</td>
<td>6</td>
<td>7</td>
<td>10 x 12 (dowels)</td>
<td>Y</td>
<td>Polypropylene</td>
<td>1997-2010</td>
</tr>
<tr>
<td>60</td>
<td>TWT</td>
<td>5</td>
<td>7</td>
<td>5 x 6</td>
<td>Y</td>
<td>None</td>
<td>2004-present</td>
</tr>
<tr>
<td>61</td>
<td>TWT</td>
<td>5</td>
<td>7</td>
<td>5 x 6</td>
<td>N</td>
<td>None</td>
<td>2004-present</td>
</tr>
<tr>
<td>62</td>
<td>TWT</td>
<td>4</td>
<td>8</td>
<td>5 x 6</td>
<td>Y</td>
<td>None</td>
<td>2004-present</td>
</tr>
<tr>
<td>63</td>
<td>TWT</td>
<td>4</td>
<td>8</td>
<td>5 x 6</td>
<td>N</td>
<td>None</td>
<td>2004-present</td>
</tr>
<tr>
<td>114-914</td>
<td>TWT</td>
<td>6</td>
<td>Var. (5-8)</td>
<td>6 x 6, 6Wx12L w/plate dowels</td>
<td>N</td>
<td>None</td>
<td>2008-present</td>
</tr>
</tbody>
</table>
Lessons Learned

§ Keep wheel loads away from corners in ultrathin (≤ 4” thick) whitetopping

§ Non-structural fibers do not prevent or hold cracks together well under heavy traffic
Lessons Learned

§ Large panels (10’Lx12’W) can develop joint faulting
§ Longitudinal cracking is a prominent distress in thin (4”-6”) whitetopping*

*Now thought to be for UTW also
Lessons Learned

Sections with sealed/filled joints perform better!
Panel Cracking (Fall 2010)

Unsealed Joints
4” PCC = 55% cracked panels
5” PCC = 8% cracked panels

Sealed Joints
4” PCC = 11% cracked panels
5” PCC = 11% cracked panels
Cell 61 (2010)

5 inch PCC with unsealed joints

Spalling

Unbonded, with some HMA deterioration
Lessons Learned

- 6”x5’Lx6’W can withstand over 10 million ESALs
- Minnesota’s climate can cause reflective cracking

I-35 North Branch
Improved Design Procedure

§ Goal= Mechanistic-Empirical design procedure
Ø Want to better predict long term performance and life cycle costs

§ Pooled Fund Project TPF 5-165: Development of Design Guide for Thin and Ultrathin Concrete Overlays of Existing Asphalt Pavements

Participating states:
Minnesota, Mississippi, Missouri, New York, Pennsylvania, Texas

Project began in Fall 2008. Completion Fall 2012.
Existing Design Procedures

Task 2 of TPF 5-165 project

§ Colorado DOT
  – More mechanistic than empirical

§ New Jersey DOT
  – Relies on engineer’s judgment of layer bonding

§ PCA (Portland Cement Association)
  – Temperature dependency of HMA stiffness and contribution of fibers not considered

§ ACPA/ICT (Illinois Center for Transportation)
  – More empirical
  – HMA stiffness and fatigue not considered
Existing Design Procedures

§ AASHTO 1993
  – Considers HMA as (gravel) base
  – Does not allow for smaller thicknesses or panel sizes

§ MEPDG (DARWin ME)
  – Analysis limited to panel sizes ≥ 10 feet
  – Refers to ACPA design method for thin whitetopping

§ Mn/DOT (Updated April 2011)
  – “Concrete pavement thickness is calculated using current Mn/DOT concrete thickness procedures with an adjusted R-Value, developed from bituminous design procedures, to account for the support of the existing pavement.”
## Whitetopping Design

<table>
<thead>
<tr>
<th>Project Number</th>
<th>Designer</th>
<th>Date</th>
</tr>
</thead>
</table>

| 20-year Design Lane BEASALs = | Use this section if a traffic forecast is available. |
| 20-year Design Lane CESALs = | Otherwise, use the ESAL Forecast to calculate ESALs from AADT. |
| 35-year Design Lane CESALs = | To go to ESAL Forecast, click [here](#). |

<table>
<thead>
<tr>
<th>20-year Design Lane BEASALs =</th>
<th>Traffic From ESAL Forecast</th>
</tr>
</thead>
<tbody>
<tr>
<td>In-situ soil R-value =</td>
<td></td>
</tr>
<tr>
<td>Approximate GE Required for new construction = in. (from FlexPave)</td>
<td></td>
</tr>
<tr>
<td>Thickness of in-place Asphalt = in.</td>
<td></td>
</tr>
<tr>
<td>Condition of in-place Asphalt (@ cracks) good (GE Factor = 1.75)</td>
<td></td>
</tr>
<tr>
<td>Thickness of in-place Aggregate Base (GE Factor = 1.0) = in.</td>
<td></td>
</tr>
<tr>
<td>Thickness of in-place Granular Material (GE Factor = 0.5) = in.</td>
<td></td>
</tr>
<tr>
<td>In-place GE =</td>
<td></td>
</tr>
<tr>
<td>Effective R-value =</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>35 Year Design CESALS</th>
<th>Design Life: 35</th>
<th>Design Year 35</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulus of Subgrade Reaction, k = psi/in</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Terminal Serviceability, P_t = 2.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Load Transfer, J = 3.2 (standard)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Modulus of Rupture, S_u = 500 psi</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Modulus of Elasticity, E_u = 4,200,000 psi</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**DESIGN RECOMMENDATIONS**

<table>
<thead>
<tr>
<th>PCC Thickness Calculated:</th>
<th>#VALUE!</th>
</tr>
</thead>
<tbody>
<tr>
<td>in. (from RigidPave)</td>
<td></td>
</tr>
</tbody>
</table>
TPF 5-165 Design Procedure

§ P.I. Julie Vandenbossche, University of Pittsburgh

§ Design breakthroughs

- Developed using long term field performance data from existing projects (throughout U.S.) and test facilities like MnROAD, FHWA (Turner Fairbanks), and Illinois ICT
- Time and temperature dependent HMA stiffness
- *Separate* fatigue models for thin and ultrathin whitetopping
- Accommodates smaller panel sizes
- Guidelines for pre-overlay repairs
- Time dependent layer bonding (future version)
- Design inputs for structural fibers (future version)

§ Stand alone design spreadsheet

- *Designed to be easily adopted into DARWin ME in future*
2. Design philosophy

Establishing inputs

Design stress

Fatigue damage

IF ≤100%

Yes

Design thickness

• Traffic
• Existing structure
• PCC properties & other design features
• Climate consideration

No

• Structural response models
• PCC performance models
Factors affecting HMA temp.

HMA temperature is a function of

1. Pavement structure
2. Sunshine
3. Humidity
4. Wind speed
5. Ambient temperature
Seven zones based on AMDAT

AMDAT = Annual mean daily average temp.

Monthly HMA modulus adjustment factor

\[ F_m = \frac{\text{HMA modulus at given month}}{\text{HMA modulus at reference month}} \]
Climate: Effective temp. gradient

Design input required:
Effective temp. gradient (ETG)

Positive $\Delta T$

Negative $\Delta T$

Equivalent linear temperature gradient, °F/in

Relative Frequency

0% 2% 4% 6% 8% 10% 12% 14% 16%

-6.5 -5.5 -4.5 -3.5 -2.5 -1.5 -0.5 0.5 1.5 2.5 3.5
## Existing structure in spreadsheet

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post-milling asphalt thickness (in)</td>
<td>5</td>
</tr>
<tr>
<td>HMA ref. res. modulus (psi)</td>
<td>2,000,000</td>
</tr>
<tr>
<td>HMA Poisson's ratio (default 0.35)</td>
<td>0.35</td>
</tr>
<tr>
<td>Modulus of subgrade reaction (pci)</td>
<td>100</td>
</tr>
</tbody>
</table>

### UTW/TWT Design Sheet

#### Overall design parameters

- Estimated Design Lane ESALs: 1,000,000
- Maximum allowable percent slabs cracked (%): 20
- Desired reliability against slab cracking (%): 85

#### Climatic consideration

- Latitude (degree): 45
- Longitude (degree): 80
- Elevation (ft): 700
- AODAT Region ID: 2
- Substrate zone: 6

#### Existing structure

- Post-milling asphalt thickness (in): 5
- HMA ref. res. modulus (psi): 2,000,000
- HMA Poisson's ratio (default 0.35): 0.35
- Modulus of subgrade reaction (pci): 100

#### Concrete properties

- Average 28-day flexural strength (psi): 750
- Estimated elastic modulus (psi): 3,600,000
- Type of coarse aggregate: Limestone
- Fiber type: No fibers
- Fiber content (% volume): 6
- Joint spacing (ft):
Accelerated load testing

Fatigue of the interface due to:
Ø Repetitive loading
Ø Moisture
Ø Temperature
Ø Surface preparation

Debonding
Contribution of Structural Fibers?

- Potentially increase shear transfer at joints/cracks

\[ \text{LTE}_{\text{Total}} = \text{LTE}_{\text{Agg}} + \text{LTE}_{\text{base}} + \text{LTE}_{\text{Fiber}} \]

- Decreased crack width
TPF 5-165 Timeline

- March 2012: First version of design procedure spreadsheet delivered to TAP for review.
- July 2012: Task 3 bond characterization and fiber contribution experiments to be completed.
- August 2012: Draft final report completed.
- December 2012: If approved by TAP, first release of design procedure, user manual, and final report.

- Spring 2012: Work on Phase “1B?” proposal to incorporate findings from Task 3 and other recommended updates into next version of design procedure. Requires additional time/funds.
TPF 5-165 Implementation

§ Expected to be implemented immediately by most participating states

§ Will complement ISU CP Tech Center’s publications:
  Ø “Guide to Concrete Overlays”
  Ø “Design of Concrete Overlays Using Existing Methodologies”
Acknowledgements

- Julie Vandenbossche – Univ of Pittsburgh (& Mn/DOT alumni)
- Julie’s students over the years
- States participating in TPF 5-165
Questions?