Evolution of Whitetopping Design in Minnesota

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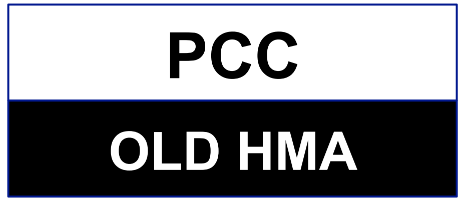
Outline

- 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

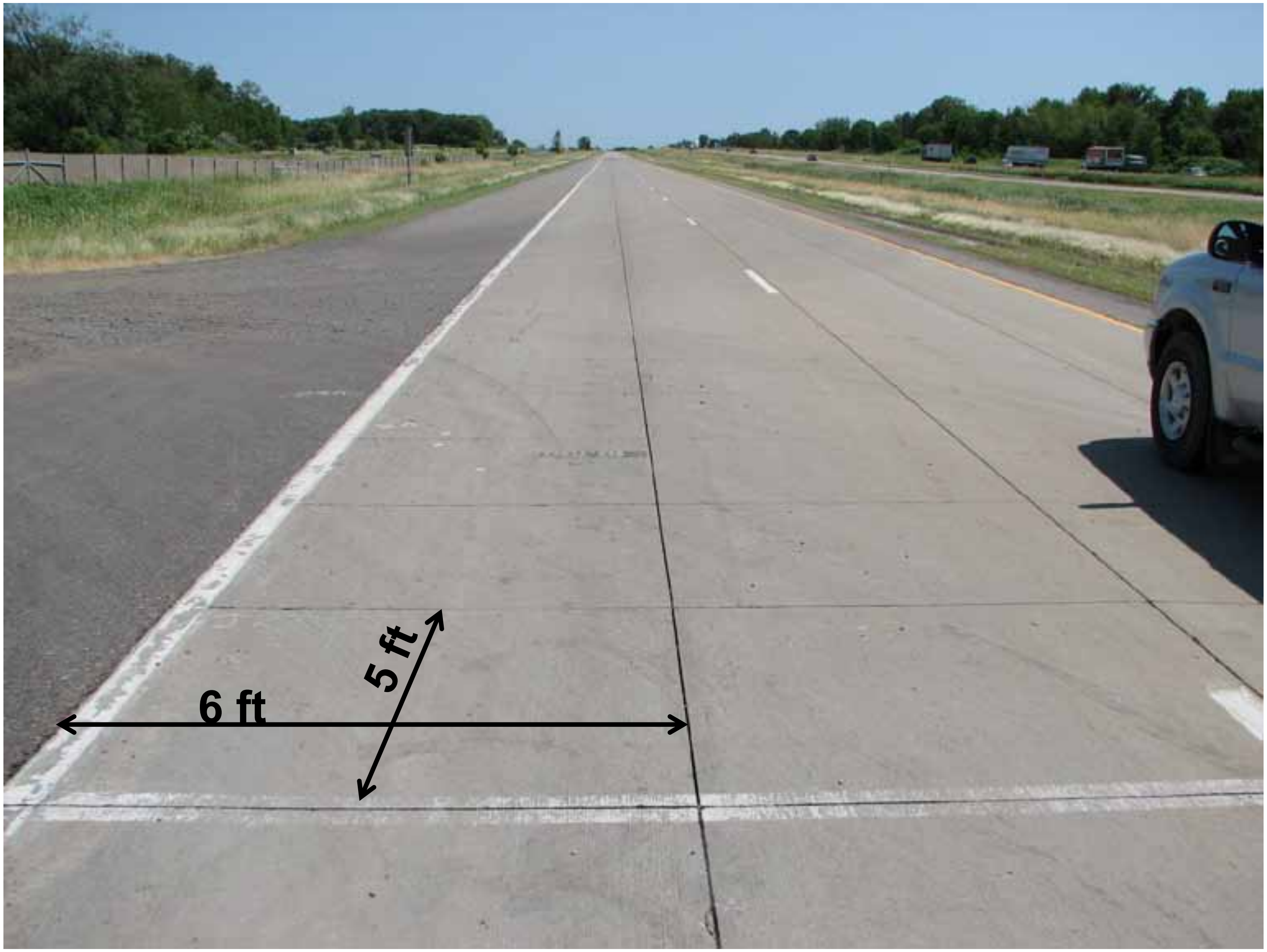
PCC

OLD HMA

<u>Typical terms</u>

- Ultrathin Whitetopping (UTW) = 3" to 4.5" [Requires bond]
- Thin Whitetopping (TWT) = 5" to 7.5" [Bond adds life]
- Bonded Concrete Overlays of Asphalt Pavements (BCOA) = UTW
- Unbonded Concrete Overlays of Asphalt Pavements (UBCOA) = TWT

MnROAD Cell 61



History in Minnesota

- First “modern” project
  - Olmsted County CSAH 10 (1982) [6” TWT]
- First Mn/DOT project (included test sections)
  - TH30 Amboy (1993) [6” TWT]
- Test Sections
  - MnROAD UTW & TWT (1997) [3”, 4”, 6”]
  - MnROAD TWT (2004) [4” to 5”]
  - MnROAD TWT (2008) [6”]
- First Mn/DOT “production” project
  - I-35 North Branch (2009) [6” TWT]

History in Minnesota

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

Many others currently under consideration as option in Alternate Bid projects

MnROAD Test Cells

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

Mainline = I-94 traffic

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

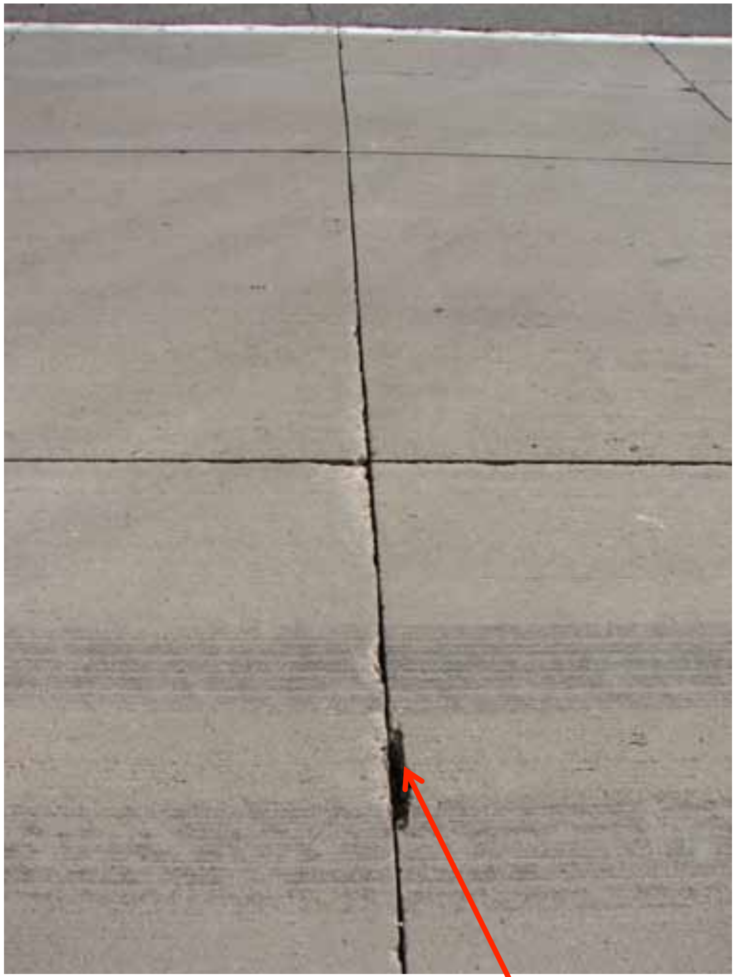
Sealed Joints

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
  - 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

Project Number
Designer
Date

20-year Design Lane BESALs = 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

20-year Design Lane BESALs = Traffic From ESAL Forecast

In-situ soil R-value =

Approximate GE Required for new construction = in. (from FlexPave)

Thickness of in-place Asphalt = in.

Condition of in-place Asphalt (@ cracks) good (GE Factor = 1.75)

Thickness of in-place Aggregate Base (GE Factor = 1.0) = in.
Thickness of in-place Granular Material (GE Factor = 0.5) = in.

In-place GE =

Effective R-value =

35 Year Design CESALS #VALUE! Design Life: 35 Design Year 35

Modulus of Subgrade Reaction, k = psi/in
Terminal Serviceability, P_t = 2.5
Load Transfer, J = 3.2 (standard)
Modulus of Rupture, S'_c = 500 psi
Modulus of Elasticity, E_c = 4,200,000 psi

DESIGN RECOMMENDATIONS

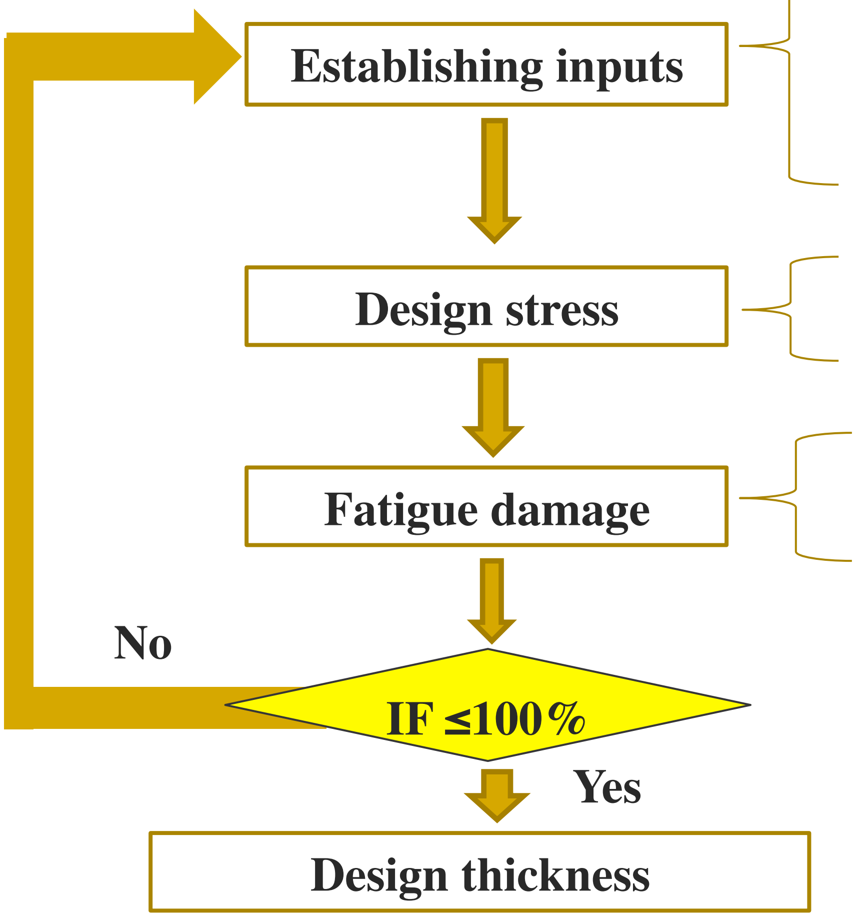
PCC Thickness Calculated: #VALUE! in. (from RigidPave)

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 <u>structural</u> fibers (future version)

- Stand alone design spreadsheet
  - *Designed to be easily adopted into DARWin ME in future*

2. Design philosophy



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

- Structural response models

- PCC performance models

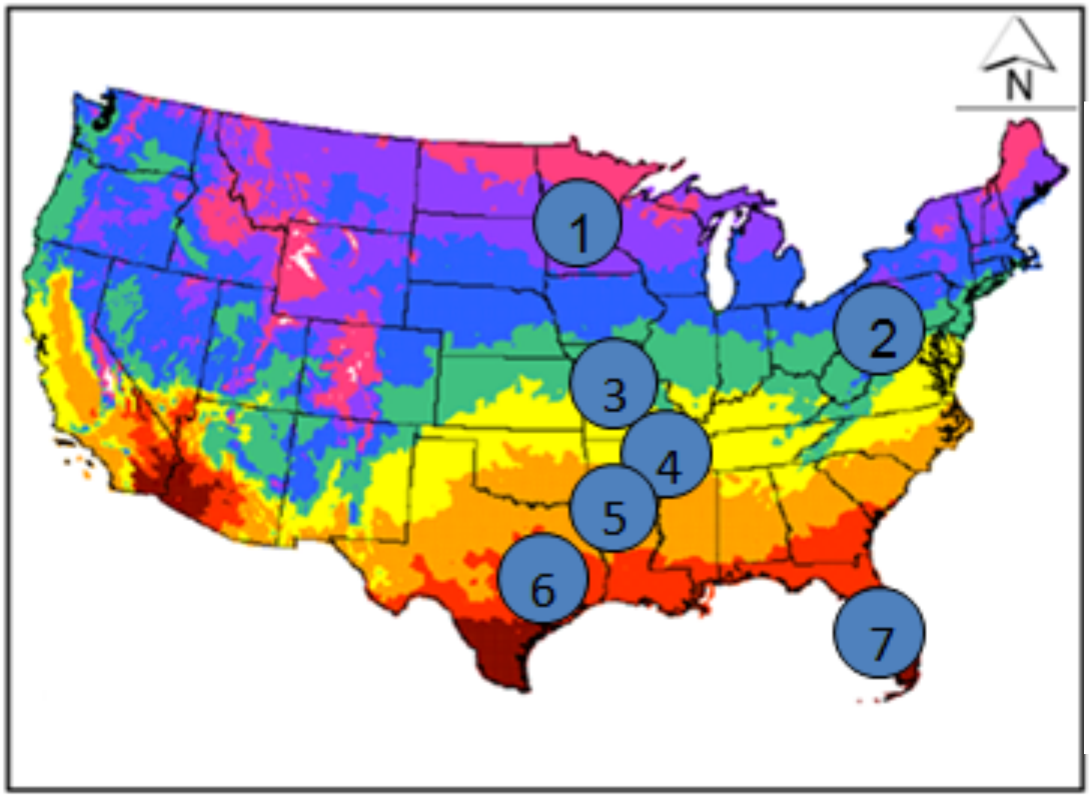
Factors affecting HMA temp.

HMA temperature is a function of

1. ~~Pavement structure~~
2. ~~Sunshine~~
3. ~~Humidity~~
4. ~~Wind speed~~
5. Ambient temperature

Seven zones based on AMDAT

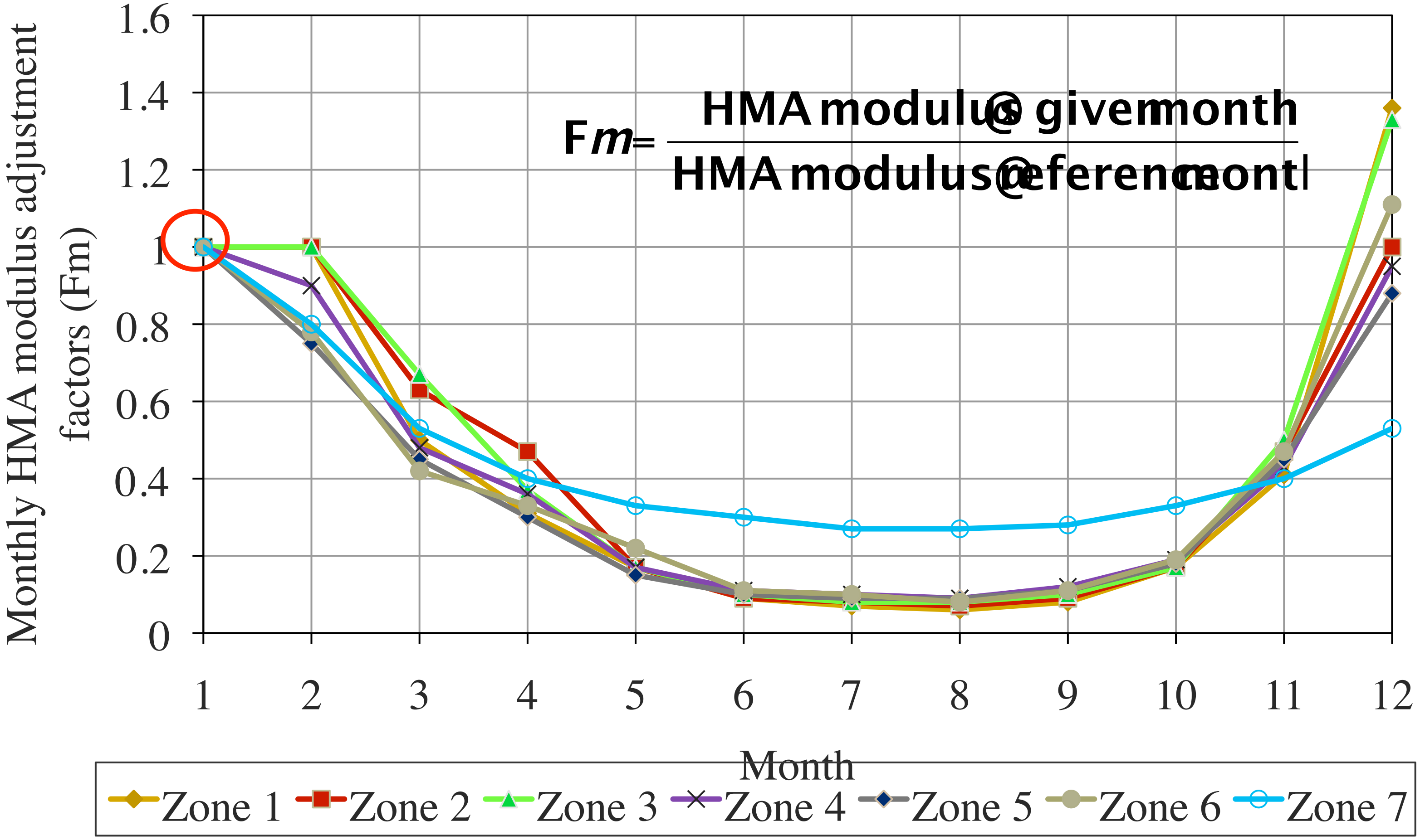
AMDAT = Annual mean daily average temp.



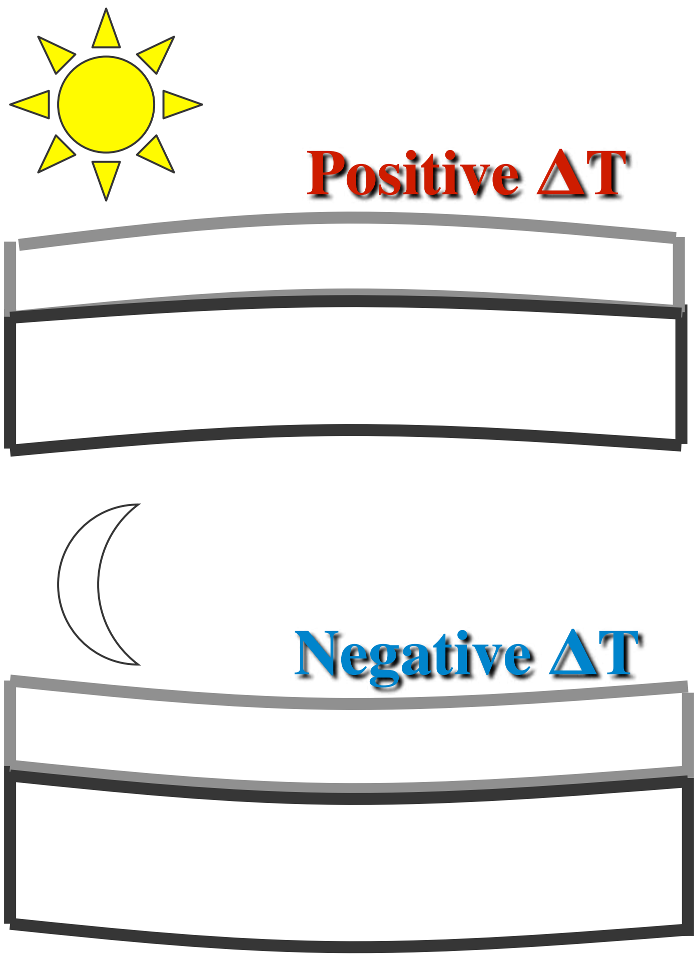
Region ID	Color code	AMDAT (ºF)
1		32.0-45.0
2		45.1-50.0
3		50.1-55.0
4		55.1-60.0
5		60.1-65.0
6		65.1-70.0
7		>70.0

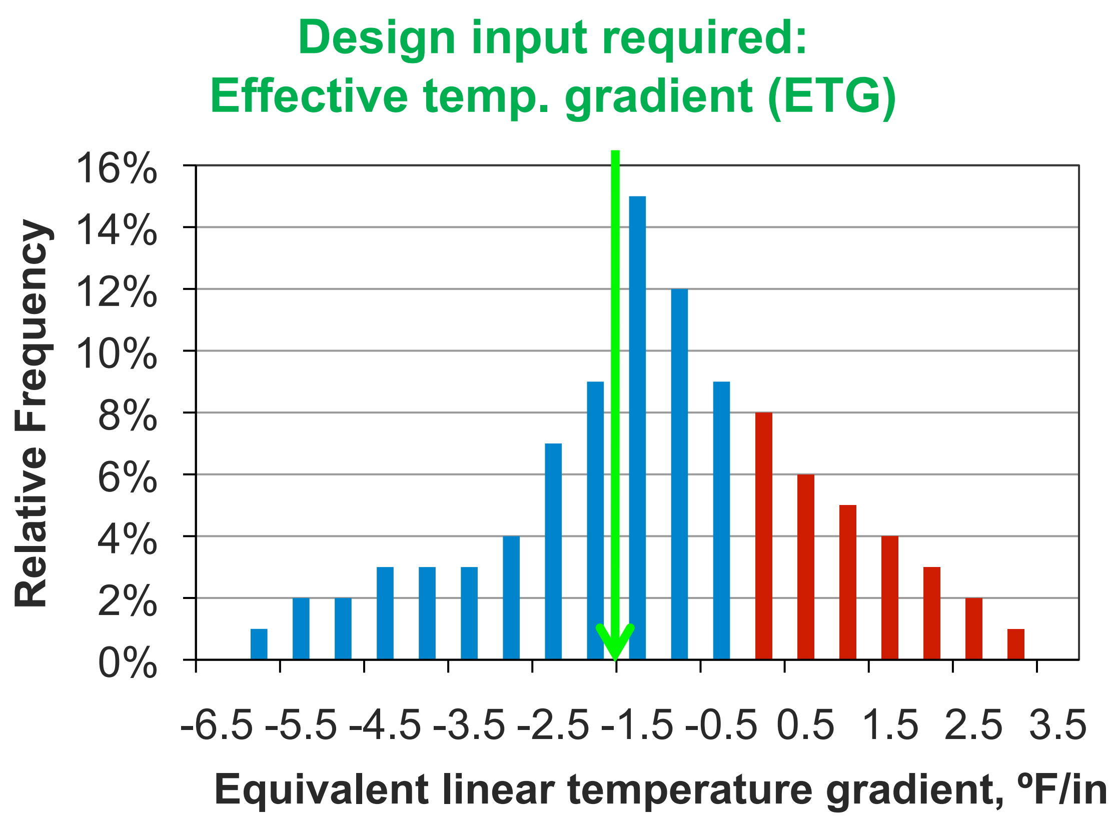
(http://cdo.ncdc.noaa.gov/climaps/temp0313.pdf, accessed on January, 2010).

Monthly HMA modulus adjustment factor

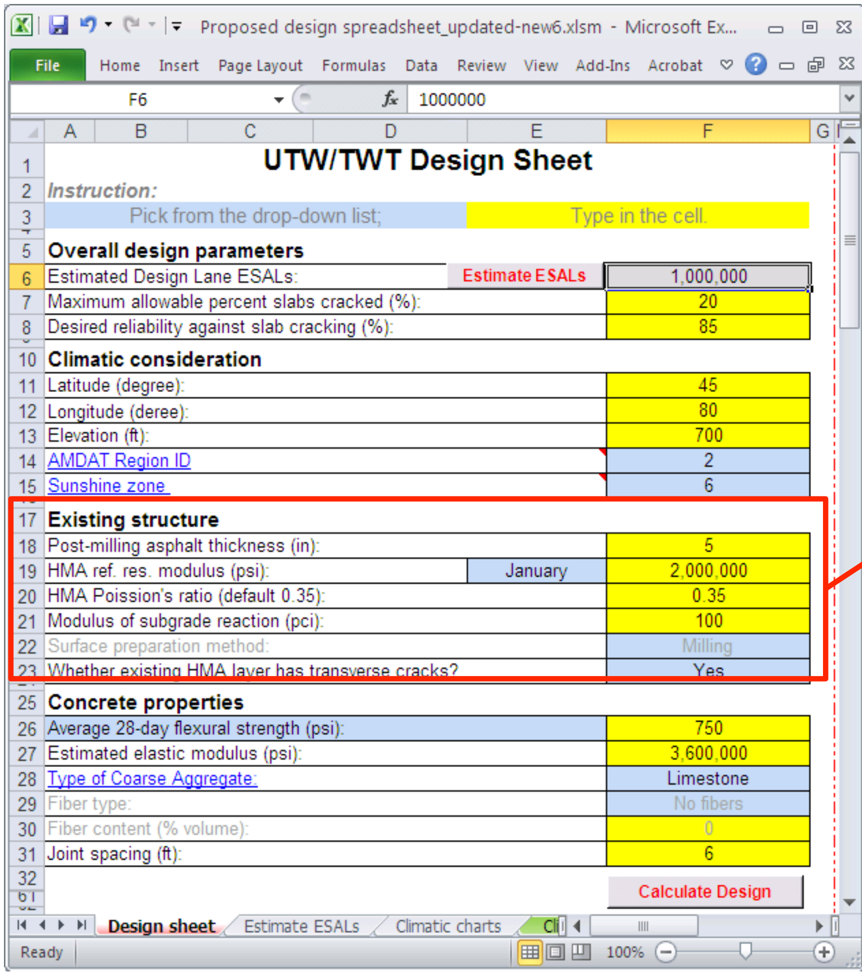


Climate: Effective temp. gradient





Existing structure in spreadsheet



Proposed design spreadsheet_updated-new6.xlsm - Microsoft Ex...

File Home Insert Page Layout Formulas Data Review View Add-Ins Acrobat

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UTW/TWT Design Sheet

Instruction:

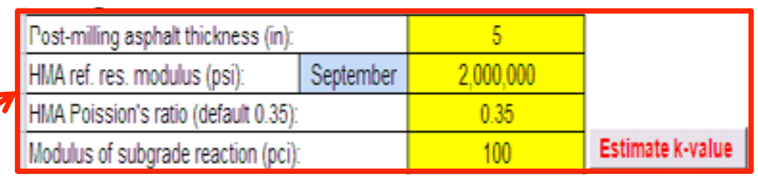
Pick from the drop-down list; Type in the cell.

5	**Overall design parameters**		
6	Estimated Design Lane ESALs:	Estimate ESALs	1,000,000
7	Maximum allowable percent slabs cracked (%):		20
8	Desired reliability against slab cracking (%):		85
10	**Climatic consideration**		
11	Latitude (degree):		45
12	Longitude (deree):		80
13	Elevation (ft):		700
14	AMDAT Region ID		2
15	Sunshine zone		6
17	**Existing structure**		
18	Post-milling asphalt thickness (in):		5
19	HMA ref. res. modulus (psi):	January	2,000,000
20	HMA Poission's ratio (default 0.35):		0.35
21	Modulus of subgrade reaction (pci):		100
22	Surface preparation method:		Milling
23	Whether existing HMA layer has transverse cracks?		Yes
25	**Concrete properties**		
26	Average 28-day flexural strength (psi):		750
27	Estimated elastic modulus (psi):		3,600,000
28	Type of Coarse Aggregate:		Limestone
29	Fiber type:		No fibers
30	Fiber content (% volume):		0
31	Joint spacing (ft):		6

Calculate Design

Design sheet | Estimate ESALs | Climatic charts

Ready 100%

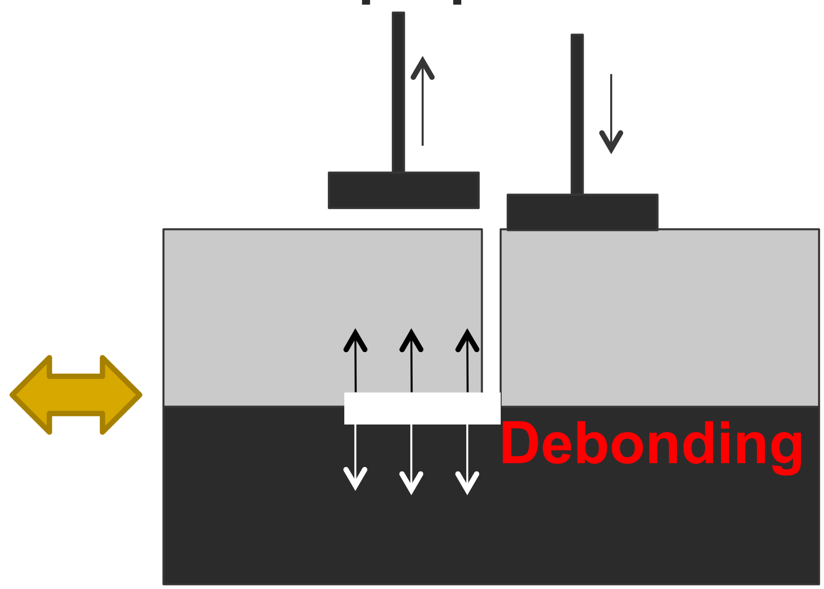


Post-milling asphalt thickness (in):		5	
HMA ref. res. modulus (psi):	September	2,000,000	
HMA Poission's ratio (default 0.35):		0.35	
Modulus of subgrade reaction (pci):		100	Estimate k-value

Accelerated load testing

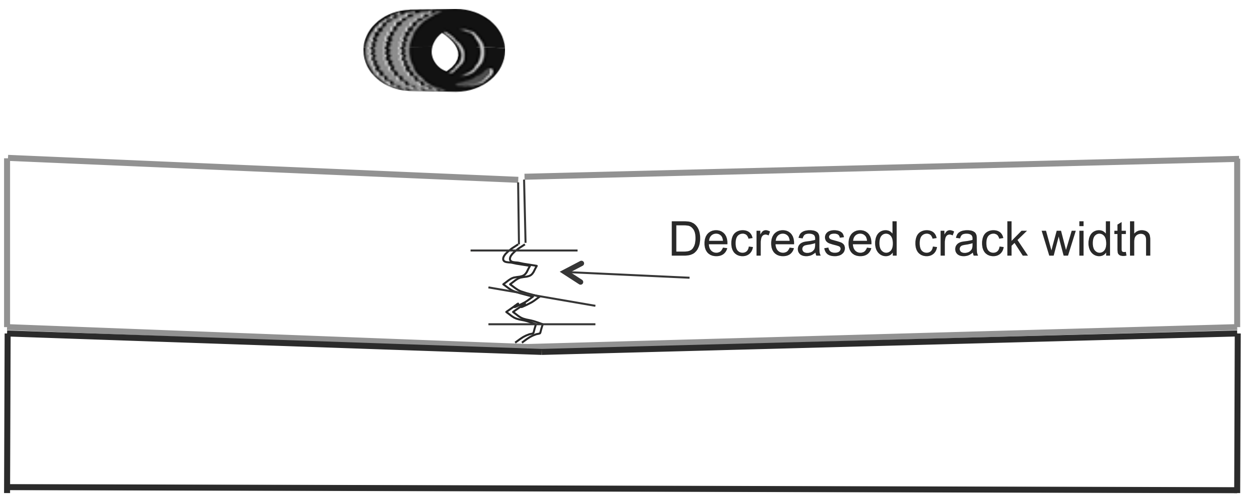
Fatigue of the interface due to:

- Repetitive loading
- Moisture
- Temperature
- Surface preparation



Load transfer

Contribution of Structural Fibers?



$$LTE_{Total} = LTE_{Agg} + LTE_{base} + LTE_{Fiber}$$

- Potentially increase shear transfer at joints/cracks

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:
  - *"Guide to Concrete Overlays"*
  - *"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?