Design and Construction Guidelines for Thermally Insulated Concrete Pavements

Lev Khazanovich
Associate Professor
Civil Engineering Department
University of Minnesota – Twin Cities

TPF-5(149) Acknowledgements

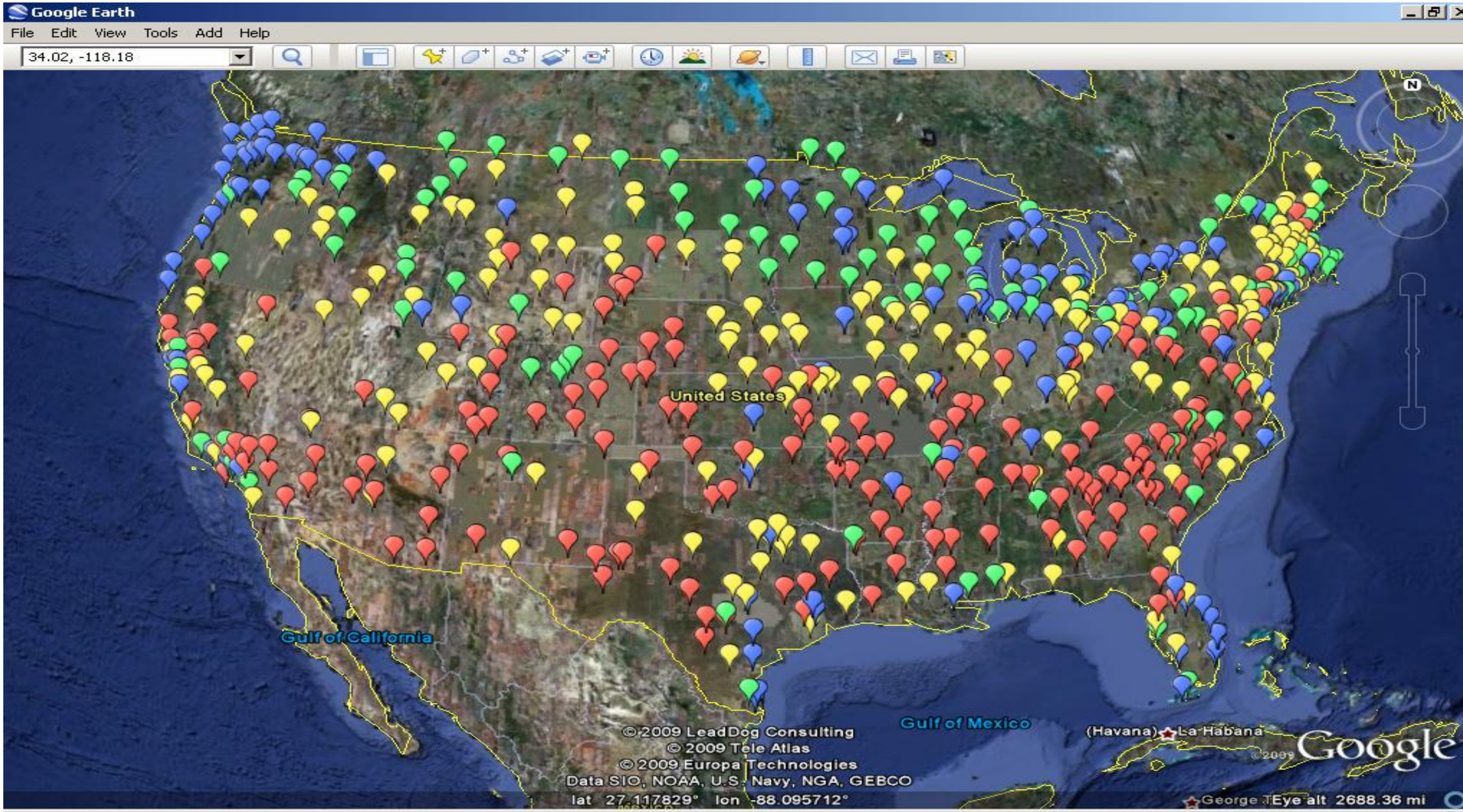
- MnDOT, LRRB, Caltrans, WsDOT
- FHWA
- TL: Tim Clyne
- Former and current students
- John Harvey (UC Davis), Nick Santero (MIT), Jim Signore (UC Berkeley)

- Literature Review
- LCCA
- **EICM Validation and Analysis**
- Evaluation of Response Models
- Development of Design Guidelines
- Development of Construction Guidelines
- Development of Synthesis

EICM Evaluation (1)

- A comprehensive sensitivity of the effect of climate on pavement performance predictions was conducted
  - Over 600 stations
- Environment has a significant impact on predicted pavement performance
- Many trends were reasonable
- However, differences in stations with similar climates were greater than expected
- Illustrated the need for high-quality climatic data

EICM Evaluation (2)

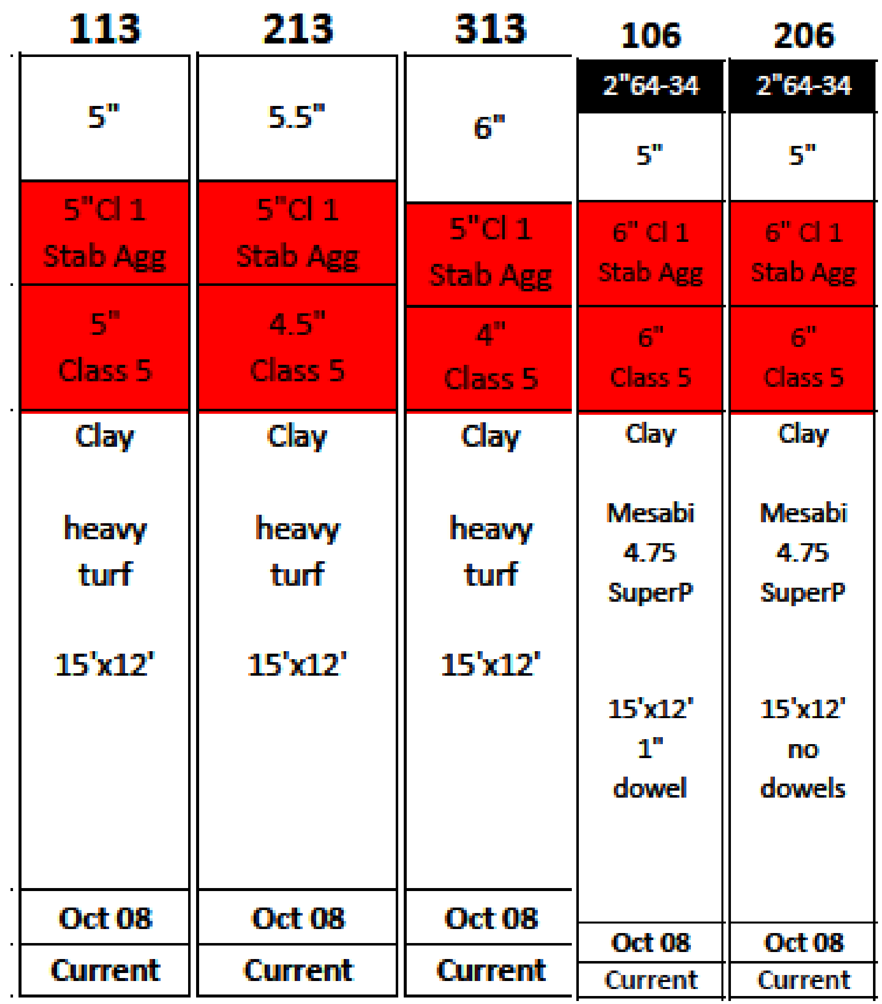


Blue < 16% Green 16-25% Yellow 26-40% Red > 40%

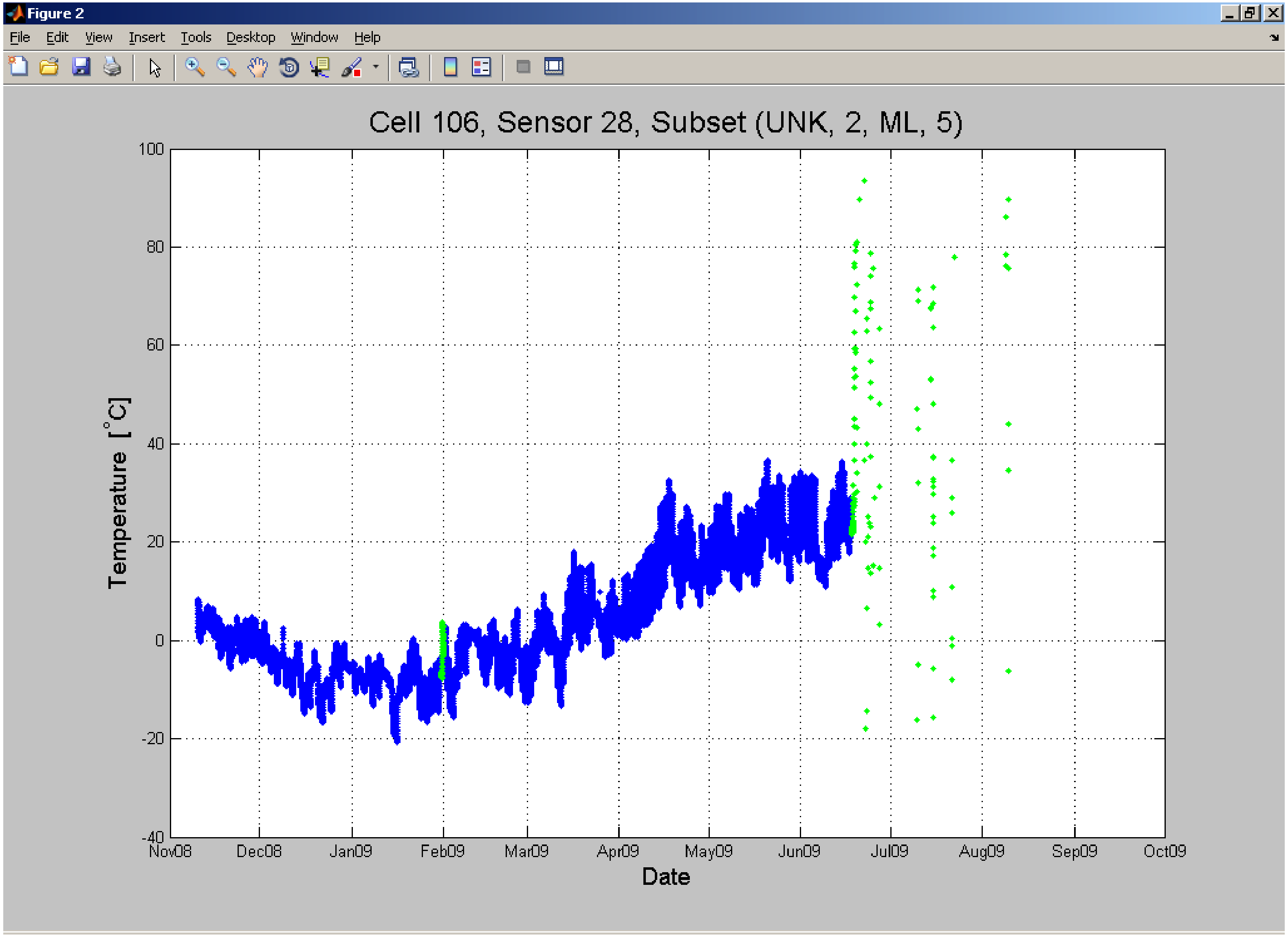
- Trends are visible, but anomalies are present

MnROAD Data & Data Analysis

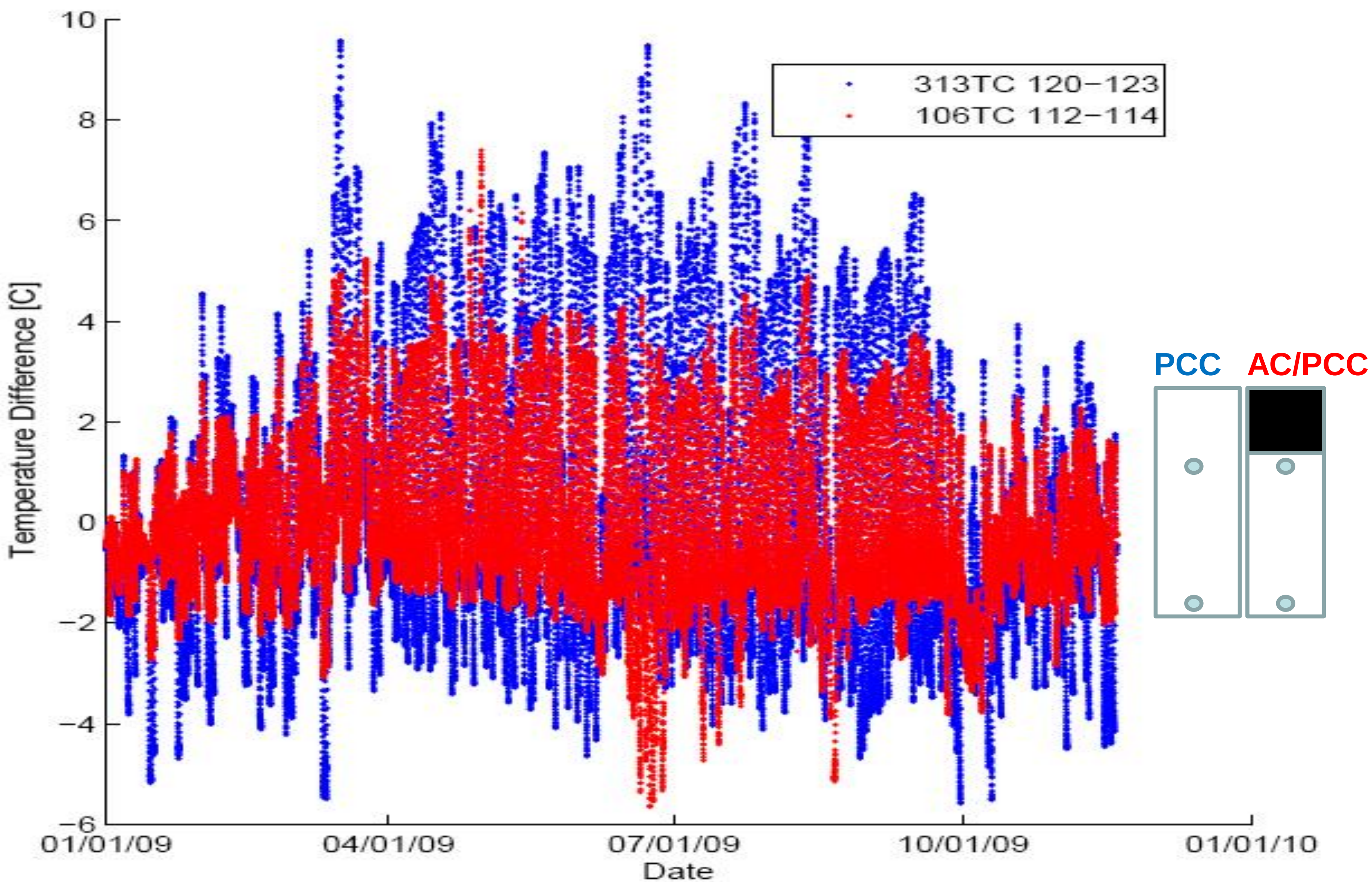
- More than 10 million temperature measurements from PCC and AC/PCC
- Data was filtered using a program developed by Dr. Randal Barnes, UMN
- Subjected field data to 14 different tests to identify missing and insufficient data, sensors outliers, subset outliers
- Suspect data were flagged



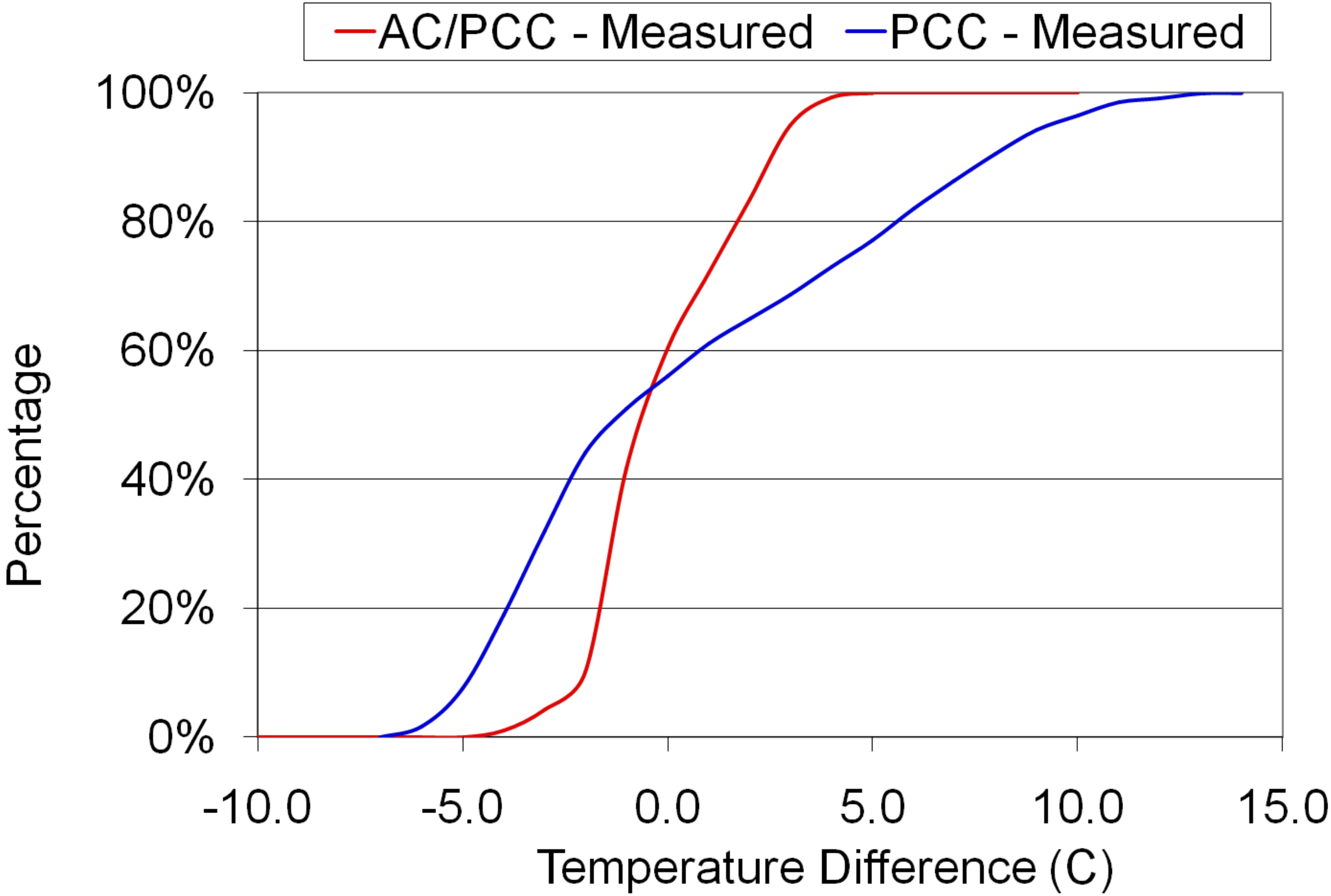
MnROAD Data Screening Example



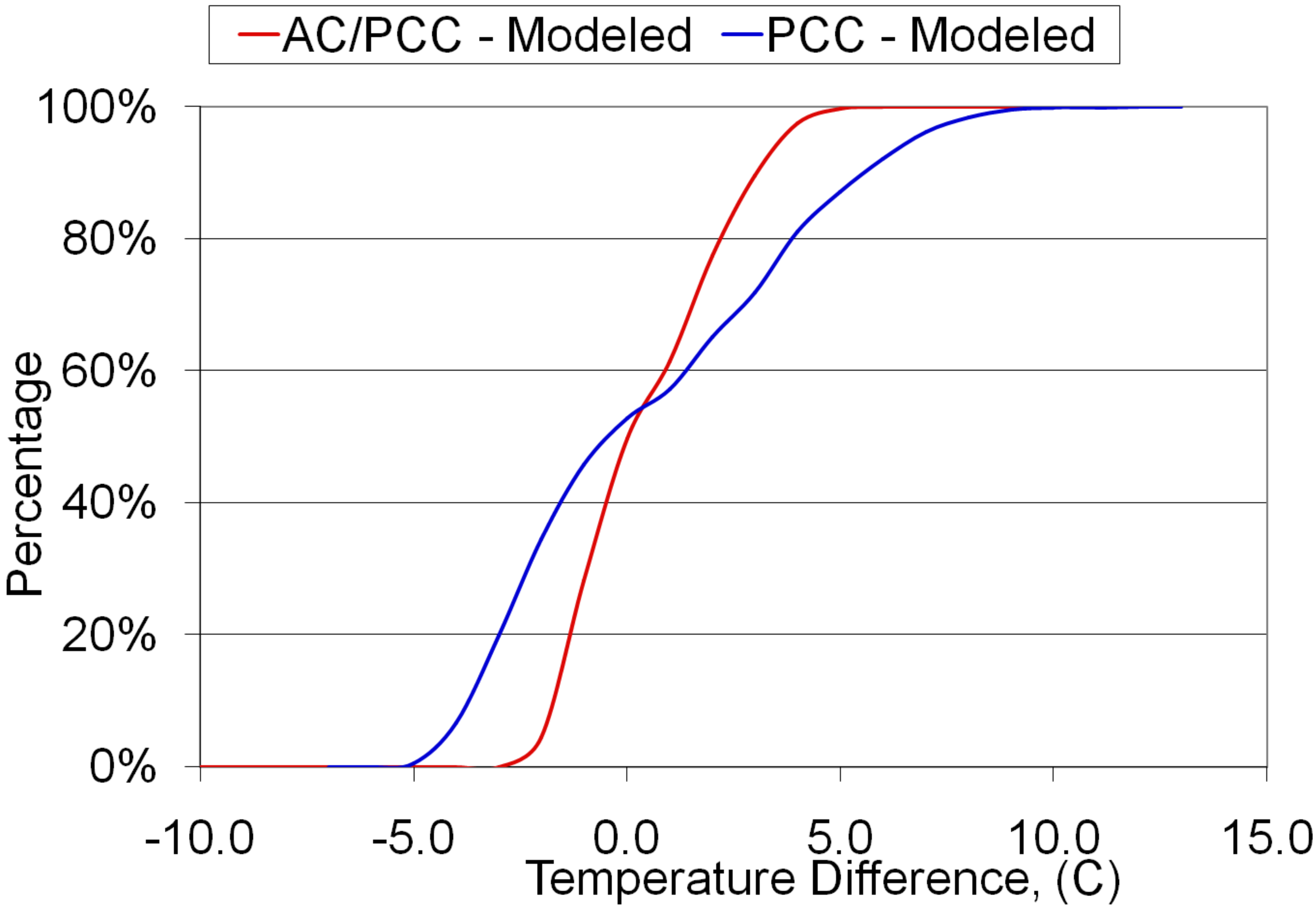
MnROAD Data: Thermal Gradients in PCC



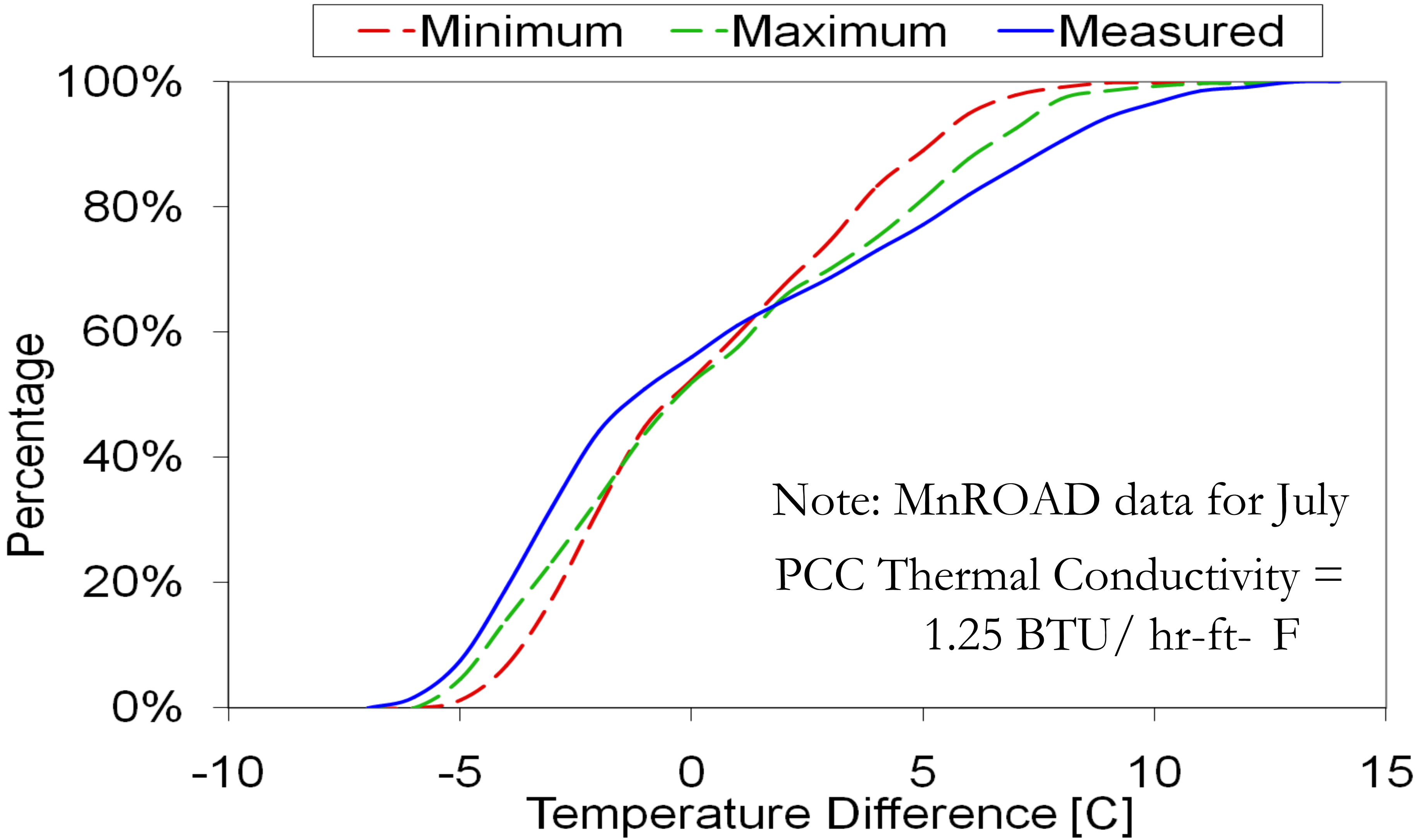
MnROAD Data and EICM (1)



MnROAD Data and EICM (2)



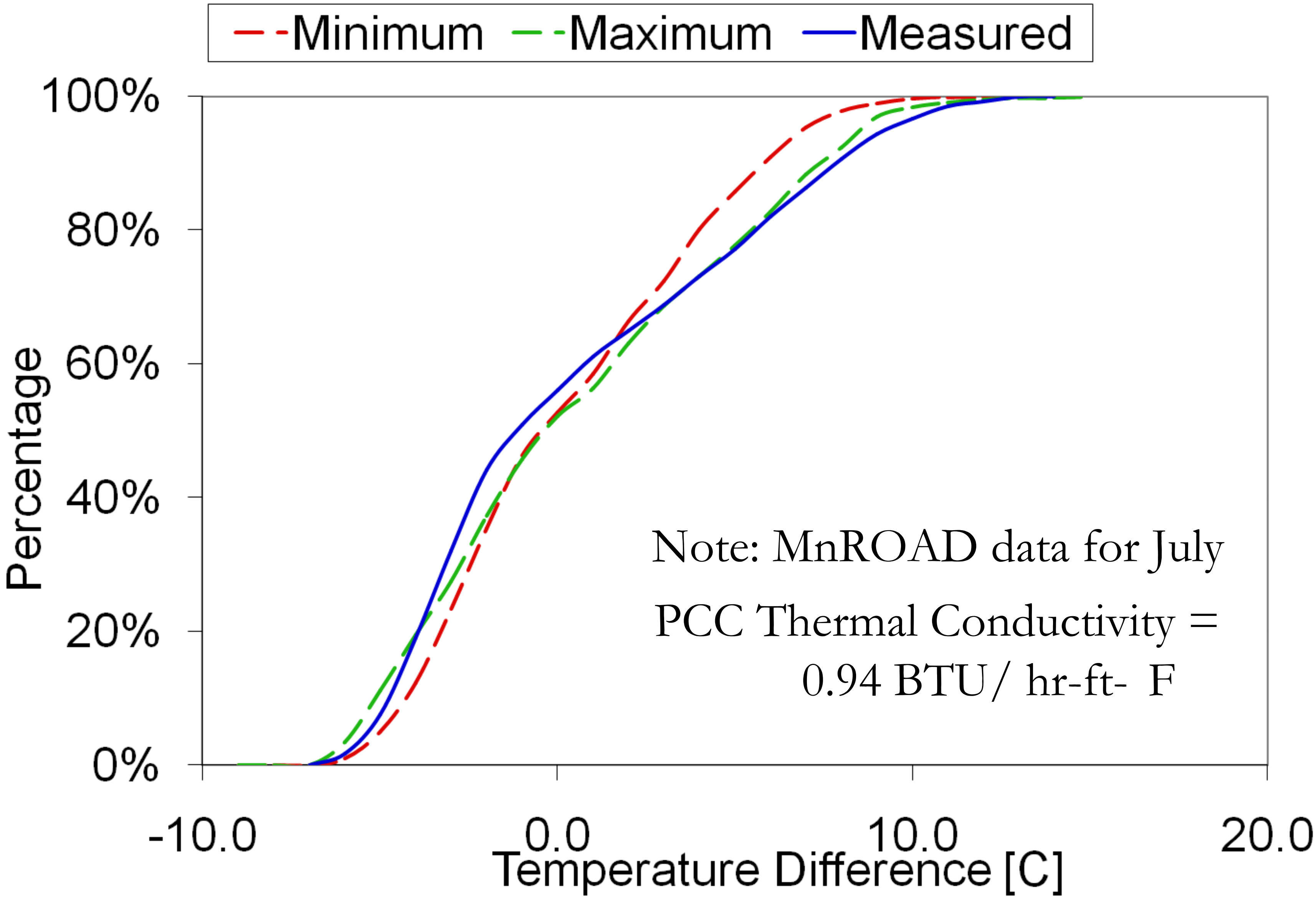
MnROAD Data vs. MEPDG Default



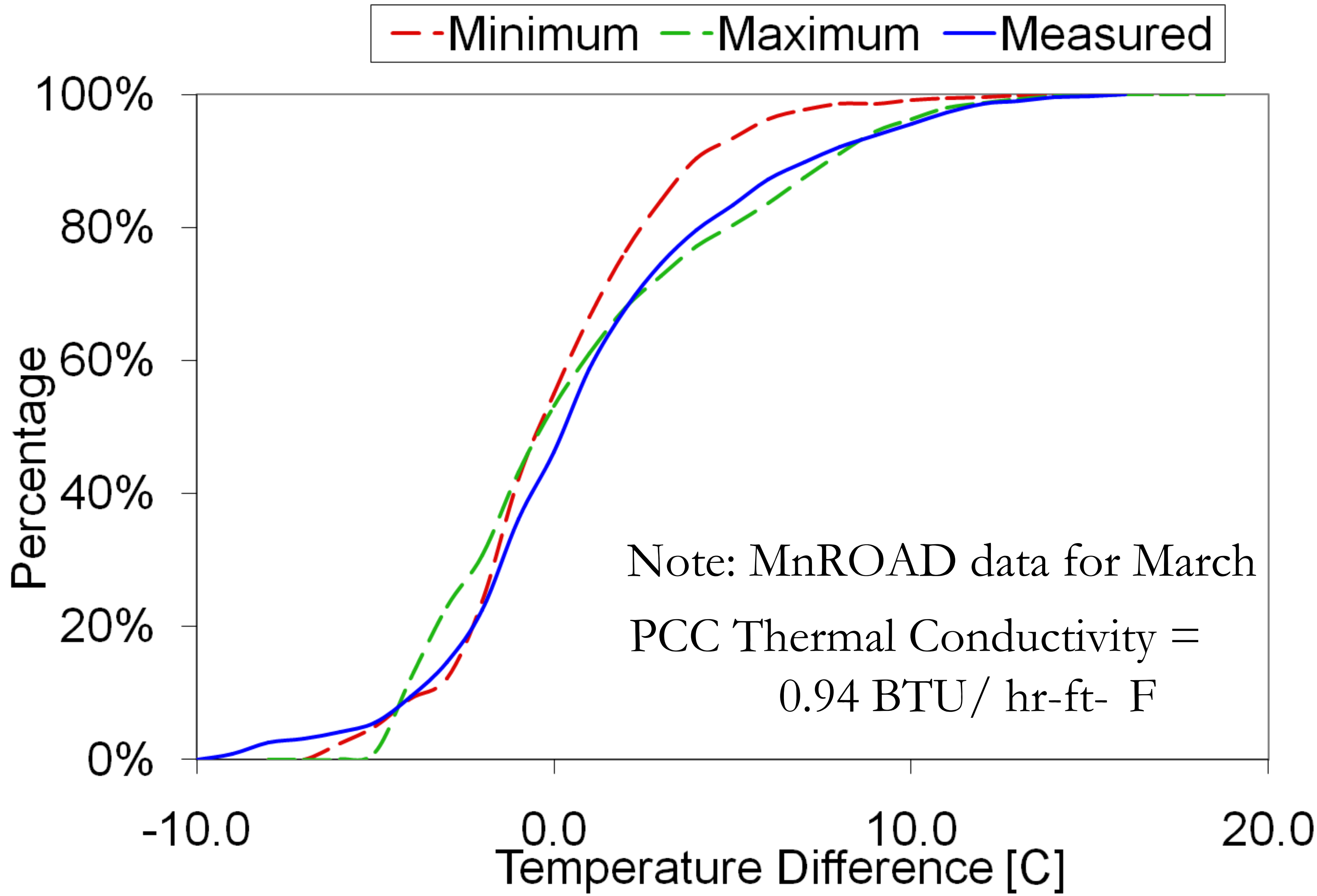
Model Predictions vs. Measured Data

- Good qualitative agreement, but the MEPDG underestimates frequencies of positive and negative temperature gradients
- Possible explanation is the MEPDG default thermal conductivity value is too high
- Action:
  - Adjust thermal conductivity to minimize the discrepancy for July
  - Verify the model for other months

MnROAD Data and EICM, Pt. 2 (1)



MnROAD Data and EICM, Pt. 2 (2)



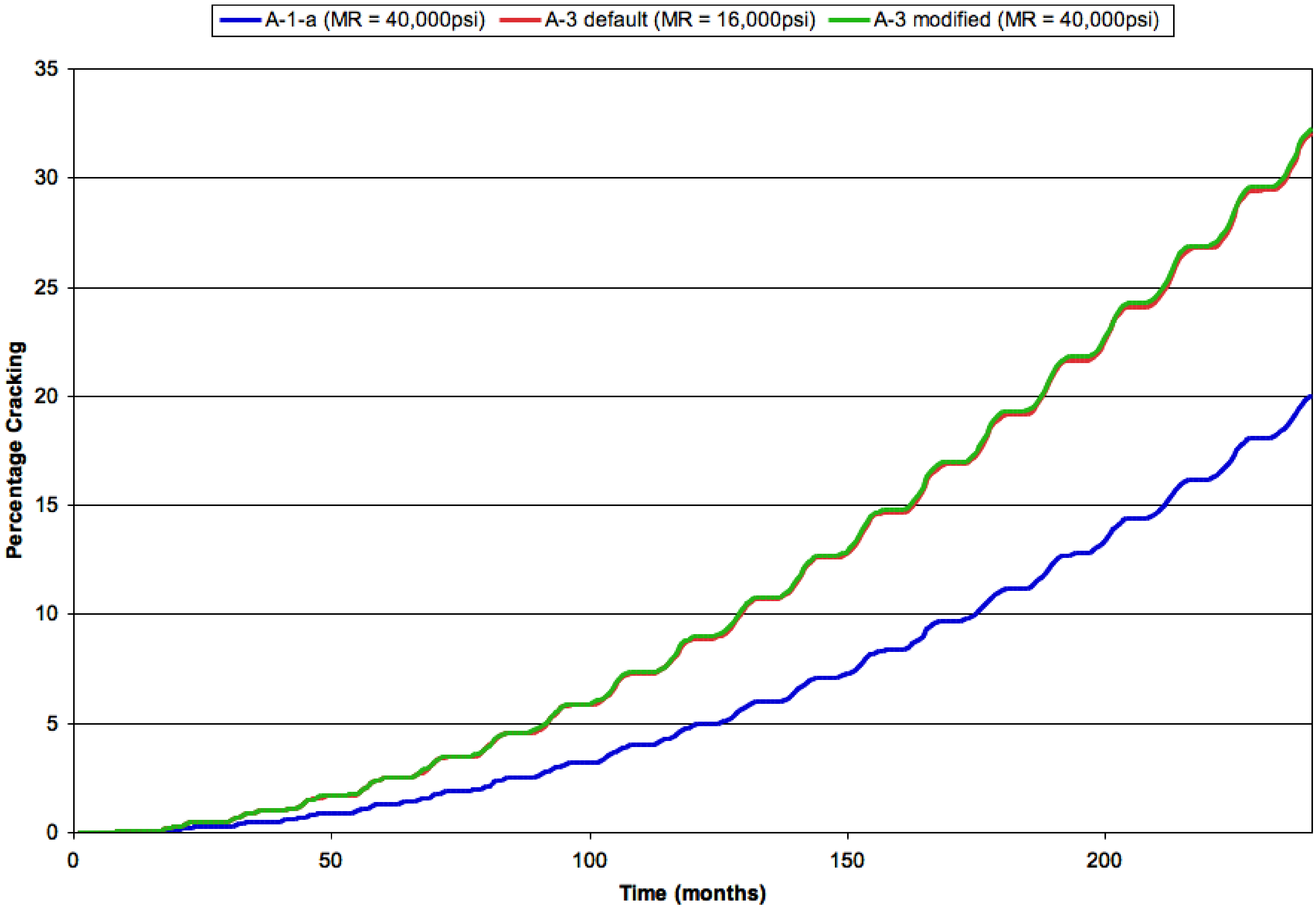
EICM Evaluation Conclusions

- MnROAD data confirmed thermal insulating effect of AC over PCC
- Quantitatively the EICM model accounts for this effect
- Calibration of thermal conductivity value gave better agreement between measured and modeled data
- Environmental effects should be considered with equal importance as traffic, design features and material properties

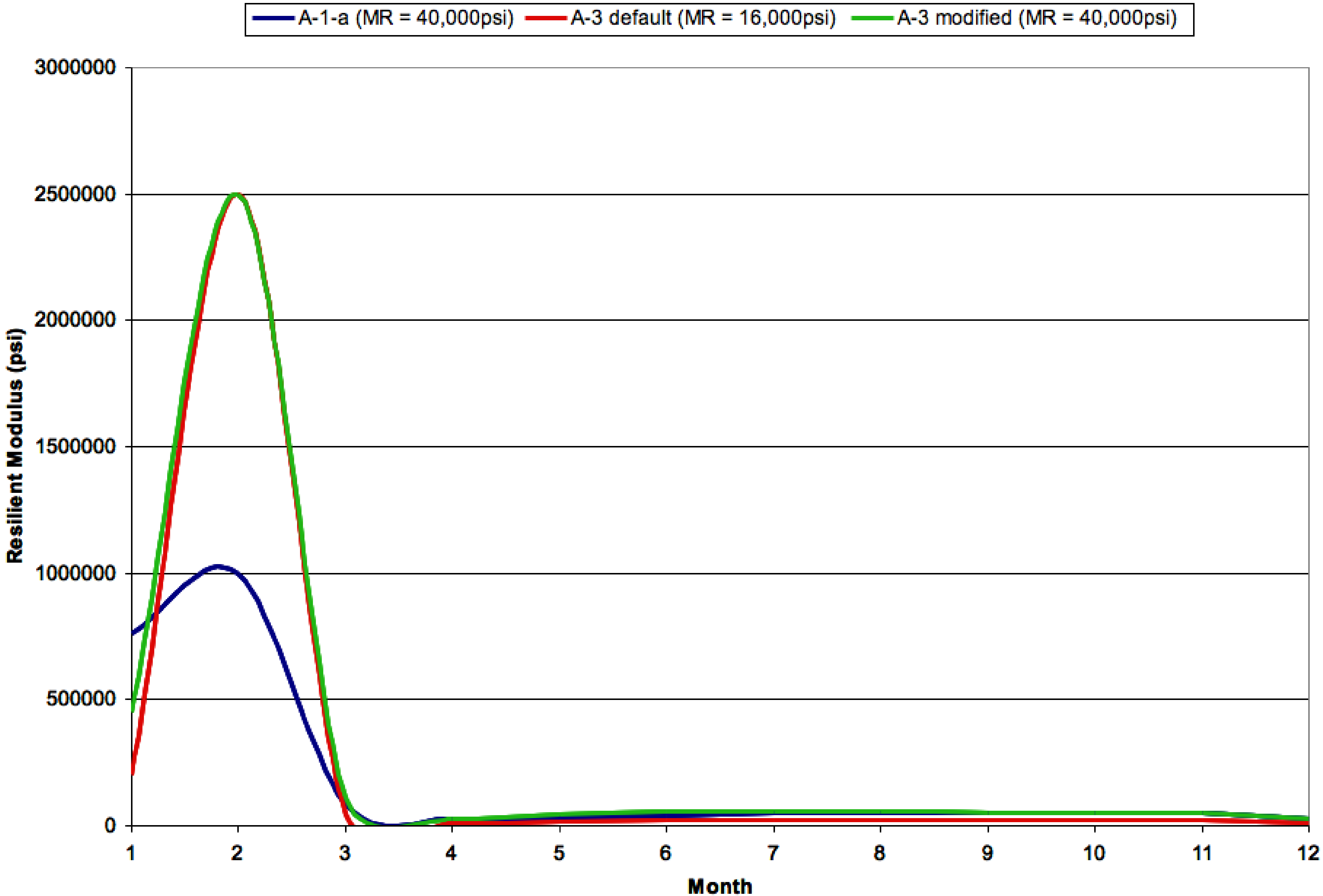
Effect of Base Gradation in MEPDG

Sieve	Percent Passing	
	A-1-a	A-3
#200	8.7	5.2
#80	12.9	33
#40	20	76.8
#10	33.8	94.3
#4	44.7	95.3
3/8"	57.2	96.6
1/2"	63.1	97.1
3/4"	72.7	98
1"	78.8	98.6
1 1/2"	85.8	99.2
2"	91.6	99.7
3 1/2"	97.6	99.9

Base Gradation: Predicted Trans Cracking



Base Gradation: Modeled Res Modulus



MEPDG: AC and PCC Thicknesses

- The sensitivity to PCC layer thickness was evaluated for two different AC thicknesses
  - 2” AC over 7” PCC
  - 3” AC over 6” PCC
- AADTT was adjusted to meet a target of 20% cracking
- All other inputs were identical
- PCC was adjusted ± 2” at 1” increments

MEPDG AC/PCC: Thickness and Cracking

Traffic: 7420 AADTT

AC Thickness	PCC Thickness	% Cracking
2	5	99.8
2	6	89.3
2	7	20.0
2	8	0.2
2	9	0.0

Traffic: 4325 AADTT

AC Thickness	PCC Thickness	% Cracking
3	4	99.9
3	5	96.9
3	6	20.0
3	7	0.3
3	8	0.0

- 2"AC / 7" PCC structure will support over 3000 AADTT more than 3" AC/ 6" PCC structure

-

Width	% Cracking	
	AC/PCC	PCC
12'	20.0	20.0
12.5'	2.3	3.0
13'	0.1	0.3
13.5'	0.1	0.3
14'	0.1	0.3

Length	% Cracking	
	AC/PCC	PCC
12'	0.0	0.8
15'	20.0	20.0
17'	68.1	75.3
19'	91.1	98.4

MEPDG/EICM Conclusions (1)

- EICM/MEPDG very sensitive to climate data and erroneous climate files can undermine analysis entirely
- EICM/MEPDG models sensitive to thermal conductivity
- MEPDG pavement performance models very sensitive to PCC layer thickness in AC-PCC projects

MEPDG/EICM Conclusions (2)

Two papers submitted on MEPDG climate sensitivity

- TRB 2010
  - Accepted for presentation and publication
  - Award: Geology and Properties of Earth Materials Section 2010 Best Paper Award
- TRB 2011
  - Accepted for presentation and publication

- Literature Review
- **LCCA**
- EICM Validation and Analysis
- Evaluation of Response Models
- Development of Design Guidelines
- Development of Construction Guidelines
- Development of Synthesis

California LCCA Case Studies

- Case 1: Lane replacement of truck lanes in Southern California as TICP instead of JPCP.
- Case 2: Convert multi-lane highway in Northern California into divided highway by adding new direction with TICP instead of JPCP.

CA LCCA Decision Metrics

- Thickness of the PCC in the TICP pavement that resulted in same NPV for the TICP as for the JPCP
- The reduction in cost of the TICP PCC as a percentage of the cost of JPCP PCC that resulted in the same NPV for TICP and JPCP
- The increase of PCC life in the TICP pavement beyond the normal PCC service life

Minnesota LCCA Case Study

- New two-lane, high-volume road
- MN LCCA decision metrics
  - When is the NPV of TICP and JPCP construction comparable?
  - Cost of initial construction
  - Cost of minor and major maintenance
  - Cost of rehabilitation regimens

Minnesota LCCA Case Study (2)

For ESALs > 7 million…

JPCP Maintenance Schedule

Pavement Age	Treatment
0	initial construction
17	minor re-seal and minor CPR (partial depth repairs)
27	Minor CPR (partial depth repairs) and some full depth repairs
40	major CPR (Full depth repair and diamond grind)
50	end of analysis period (no residual value)

TICP Maintenance Schedule

Pavement Age	Treatment
0	initial construction
7	crack fill
15	mill and overlay
20	crack fill
27	mill and overlay
32	crack fill
40	mill and overlay
45	crack fill
50	end of analysis period (no residual value)

Minnesota LCCA Case Study (3)

- Three levels of concrete and asphalt costs
- Cost of TICP concrete could be 25%, 50%, 75%, or 100% the cost of the JPCP concrete

Concrete or Asphalt $ per yd^3 (m^3)	Price designation
38 (50)	Low
115 (150)	Medium
230 (300)	High

Minnesota LCCA Case Study (4)

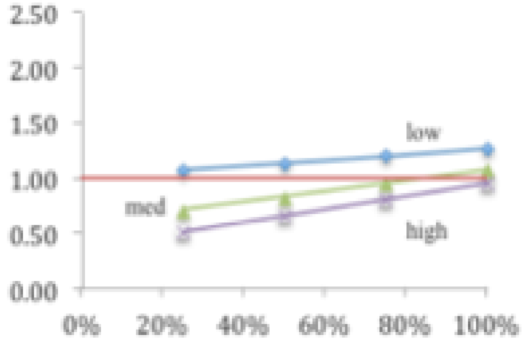
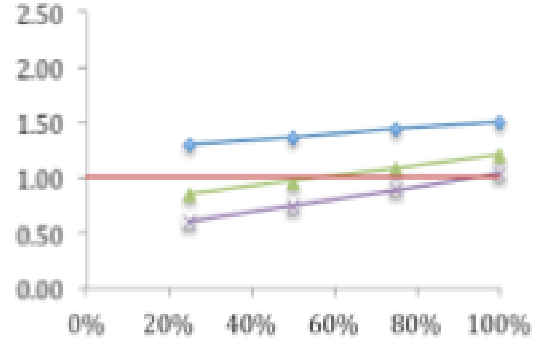
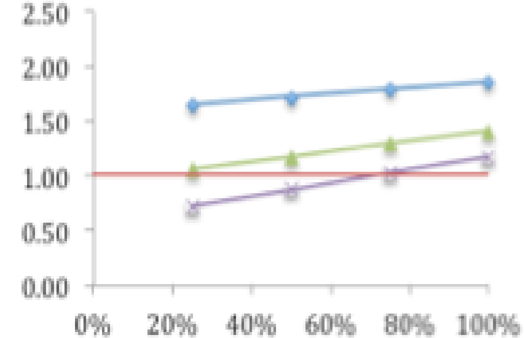
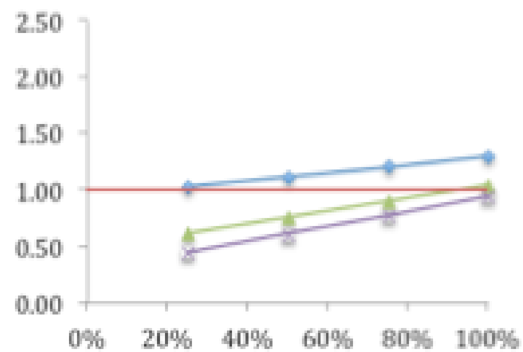
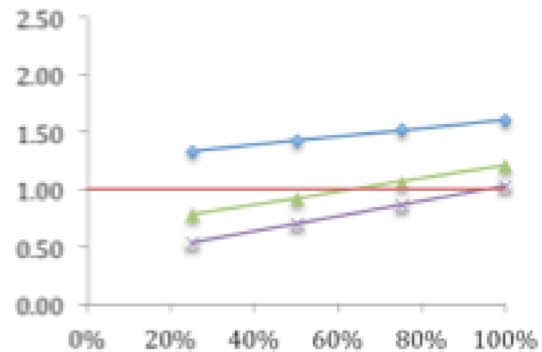
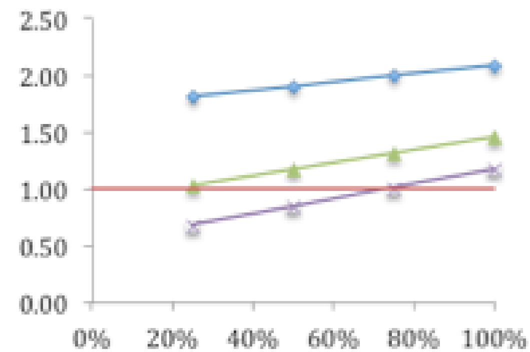
- A reduction in cost of the TICP PCC layer could be accomplished by
  - Increasing the percentage of supplementary cementitious materials
  - Substituting recycled concrete aggregates for conventional coarse aggregates
  - Allowing a higher percentage of fine, soft, spall, or slate in the coarse aggregate.
  - Decreasing the cost of concrete is not limited to these examples

MN LCCA: Primary Variable Inputs

- Cost of concrete (H, M, L)
- Cost of asphalt (H, M, L)
- Cost of concrete in TICP relative to the cost of concrete in JPCP (0%, 25%, 75%, 100%)
- Discount rate (2.5% & 5.0%)

MN LCCA: Influence of AC Cost

University of Minnesota
Driven to Discover℠

	Asphalt Cost: Low	Asphalt Cost: Medium	Asphalt Cost: High
DR = 2.8			
DR=5.0			

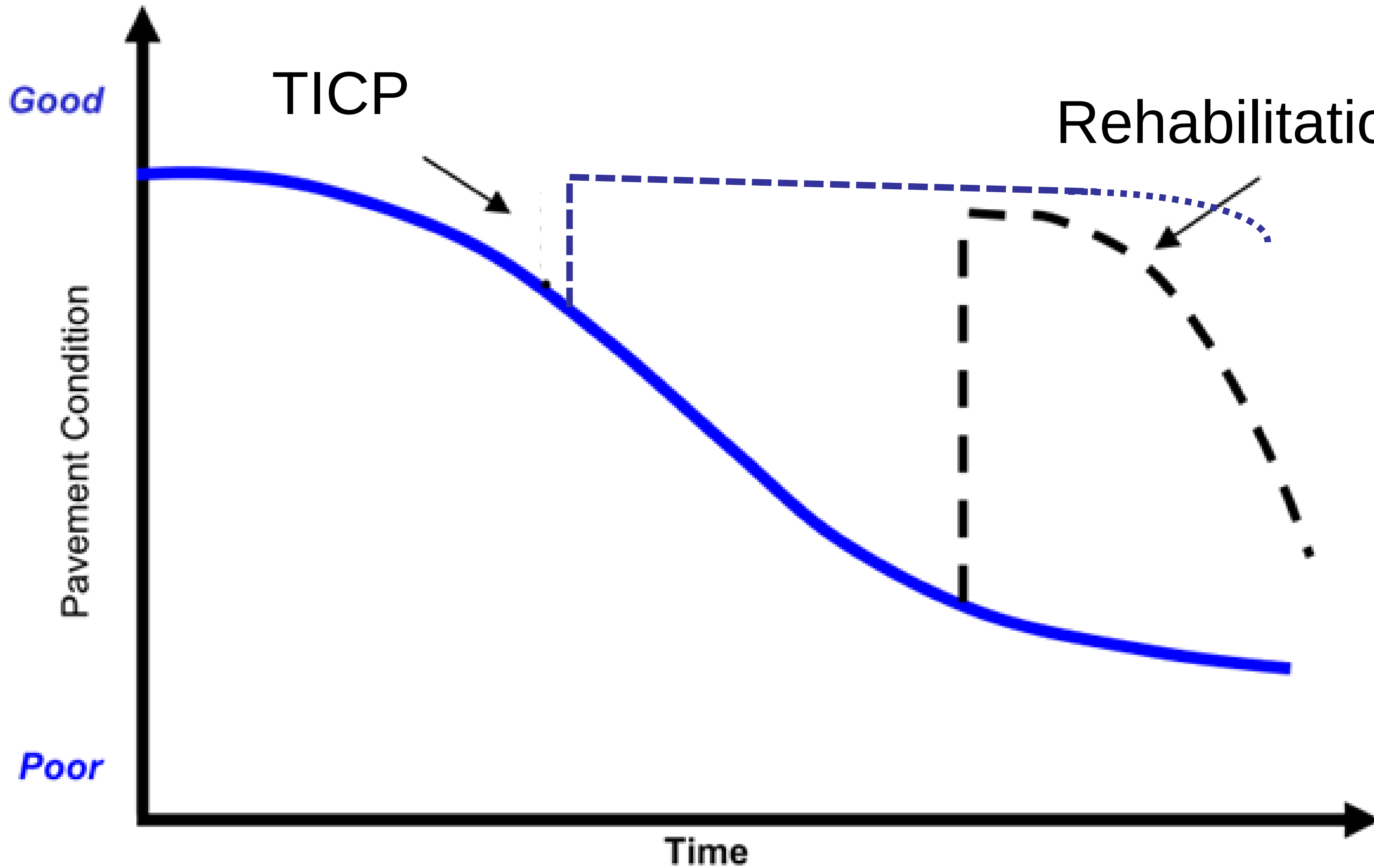
MN LCCA Conclusions

- TICP becomes more cost competitive with JPCP when/as . . .
  - The cost of concrete increases
  - The cost of asphalt is low and the cost of concrete is high or medium
  - The cost of concrete for TICPs decrease relative to the cost of JPCP concrete
  - The discount rate increases

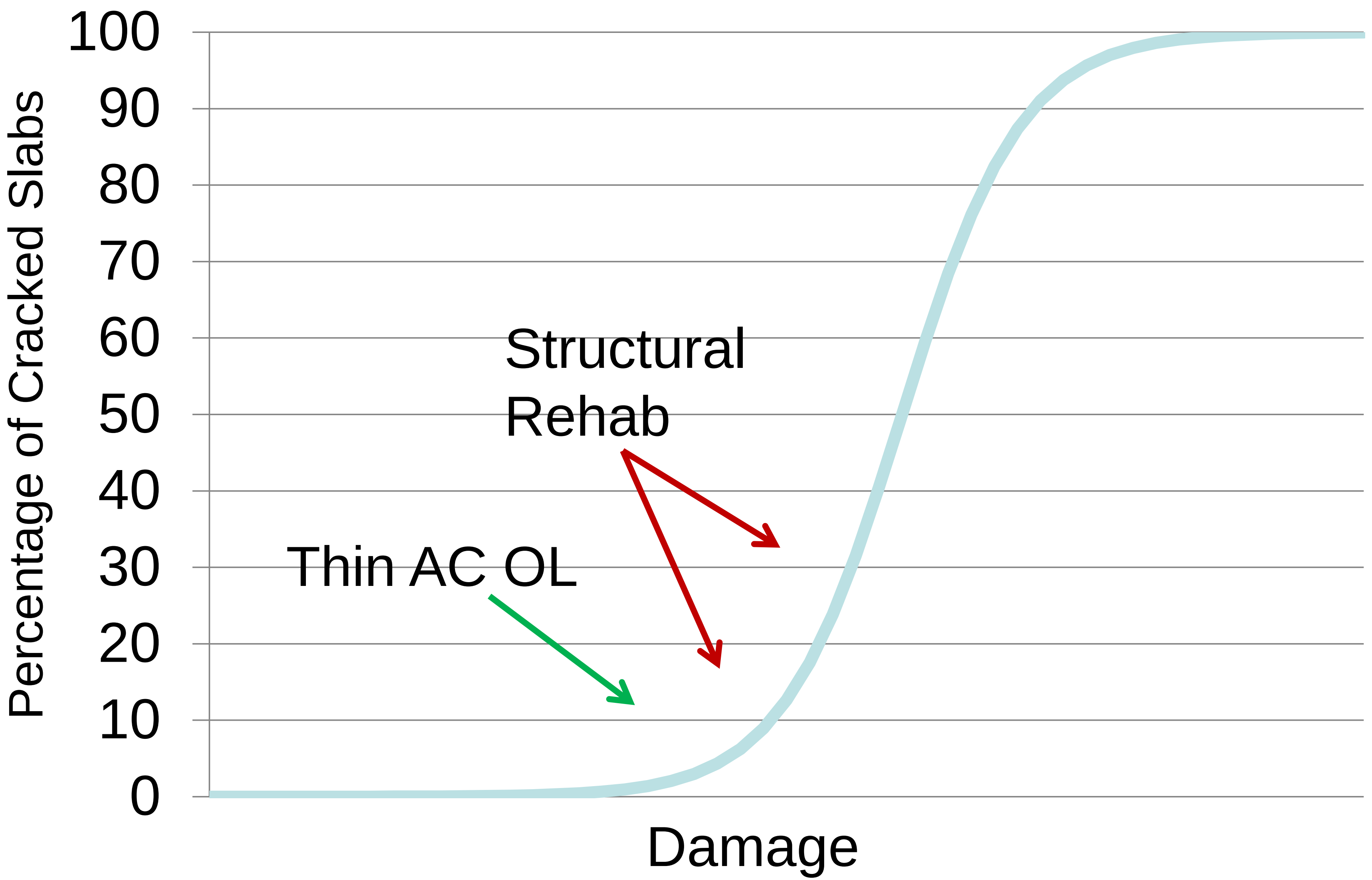
LCCA: Other Applications

- Stage Construction
- Preventive Maintenance

TICP vs. Structural Overlay



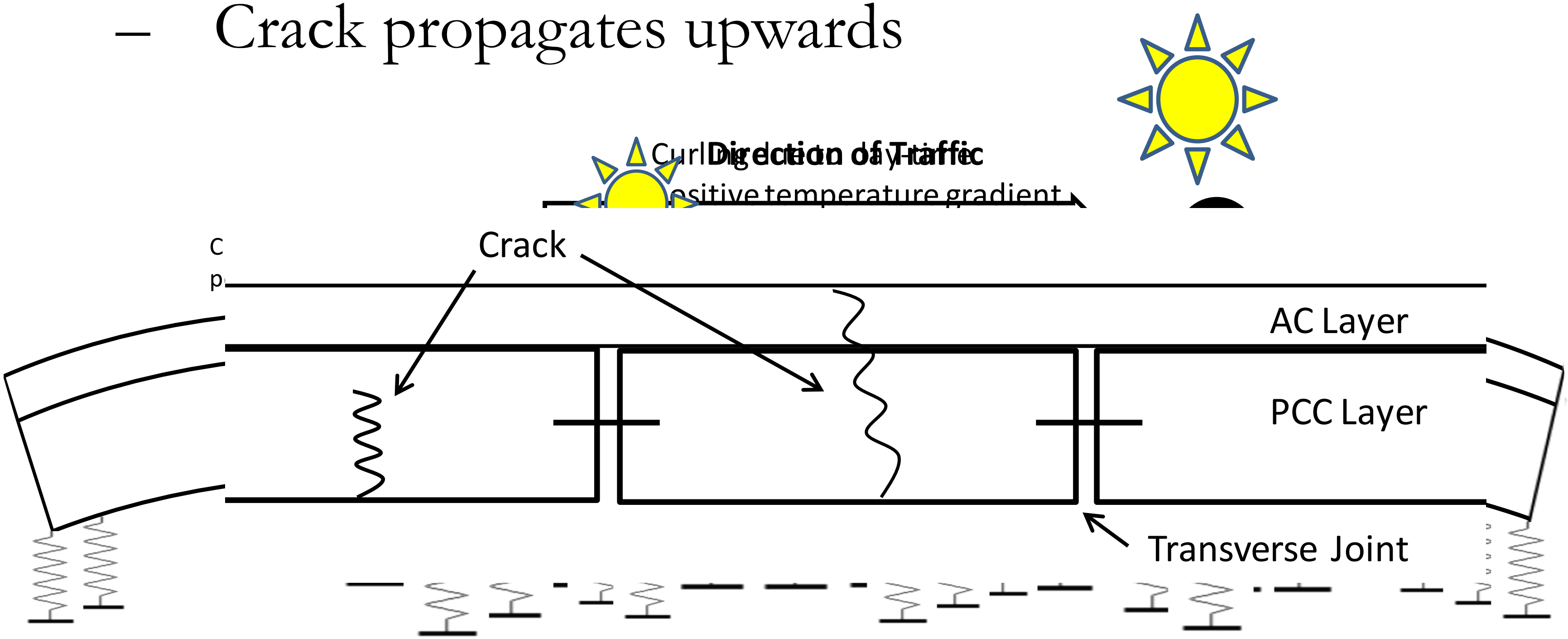
Stage Construction/ Preventive Maintenance



- Literature Review
- LCCA
- EICM Validation and Analysis
- **Evaluation of Response Models**
- Development of Design Guidelines
- Development of Construction Guidelines
- Development of Synthesis

Structural Modeling

- Composite pavement is subjected to
  - Positive temperature gradient
  - Traffic load
- PCC layer cracks at the bottom
  - Crack propagates upwards



Bottom-up Cracking Model

$$CRK = \frac{100}{1 + FD^{-1.68}} \qquad FD = \sum \frac{n_{t,j,k,l,m,p}}{N_{t,j,k,l,m,p}}$$

- *CRK* is the percentage of bottom up PCC cracking
- *FD* is the fatigue damage
- *n* is the applied number of load applications at conditions *t, j, k, l, m, p*
- *N* is the allowable number of load applications at conditions *t, j, k, l, m, p*
- *t, j, k, l, m, p* are conditions relating to the age, month, axle type, load level, temperature difference, and traffic path, respectively

$$\log(N_{t,j,k,l,m,p}) = C_1 \cdot \left(\frac{MR}{\sigma_{t,j,k,l,m,p}} \right)^{C_2}$$

- *MR* is the modulus of rupture of PCC
- *σ* is the applied stress at conditions *t, j, k, l, m, p*
- C_1, C_2 are calibration constants ($C_1 = 2.0$, $C_2 = 1.22$)

Limitations due to the adaptation

- Stiffness of the AC layer is dependent on loading time
  - Traffic loading: approx. 0.01 sec. to 0.05 sec.
  - Temperature loading: 1 hour (3600 sec)
- Fatigue cracking considers combined temperature and traffic loading
- MEPDG AC dynamic modulus does not capture VE response

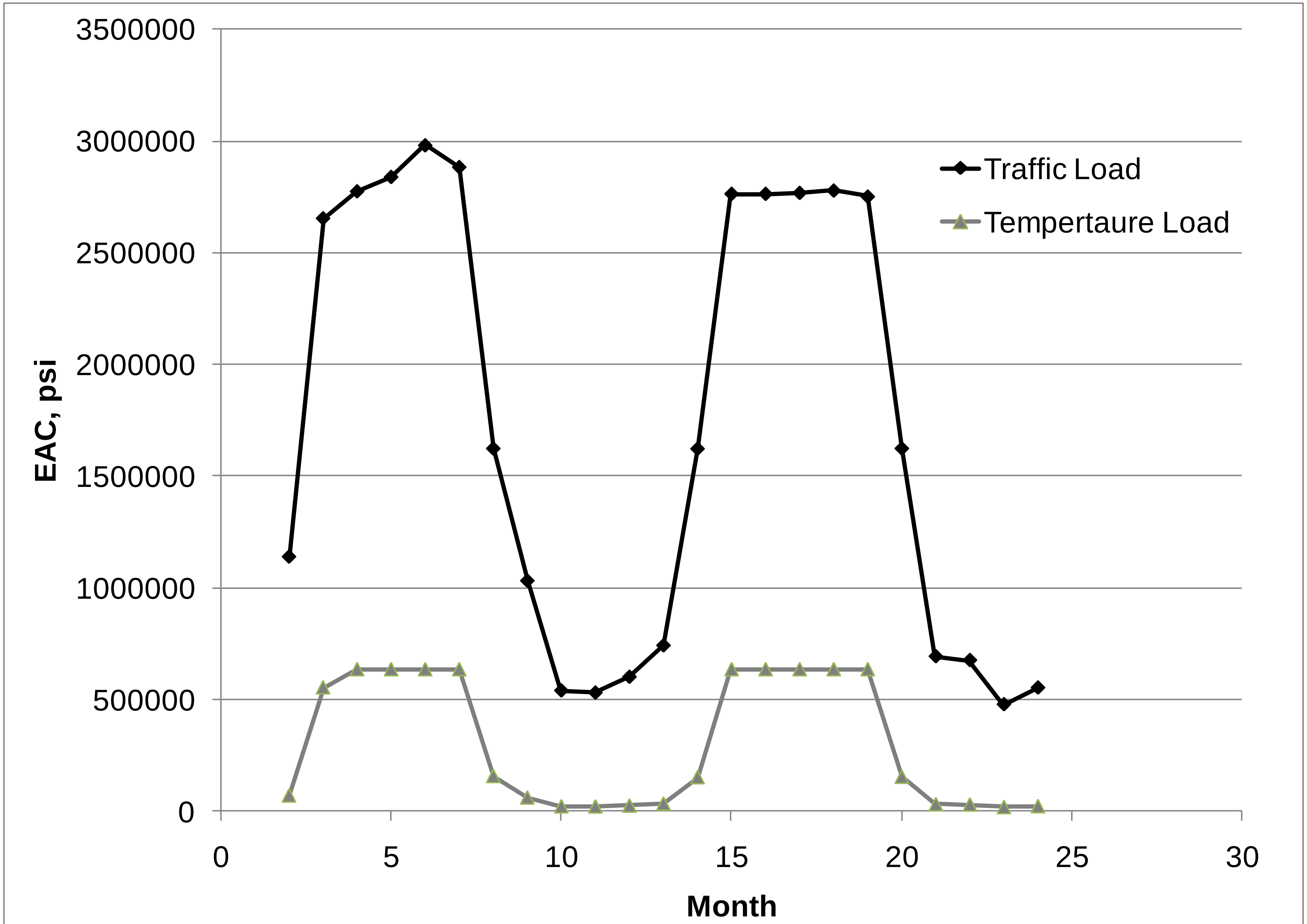
AC/PCC Case for Analysis

- Composite pavement
- Location: Minneapolis, MN
- Structure: AC (4 in.) over PCC (6 in.) over A-1-a base (8 in.) over A-6 subgrade (semi-infinite)
- All other inputs: MEPDG defaults
- Dynamic modulus – mid-depth of AC layer
  - traffic load
  - temperature load

$$\log(E^*) = \delta + \frac{\alpha}{1 + e^{\beta + \gamma(\log(t_r))}}$$

$$\log(t_r) = \log(\underbrace{t}_{\textbf{Loading Time}}) - \underbrace{c\left(\log(\eta) - \log(\eta_{T_r})\right)}_{\textbf{Shift Factor}}$$

Asphalt stiffness versus pavement age



Two Alternative Approaches

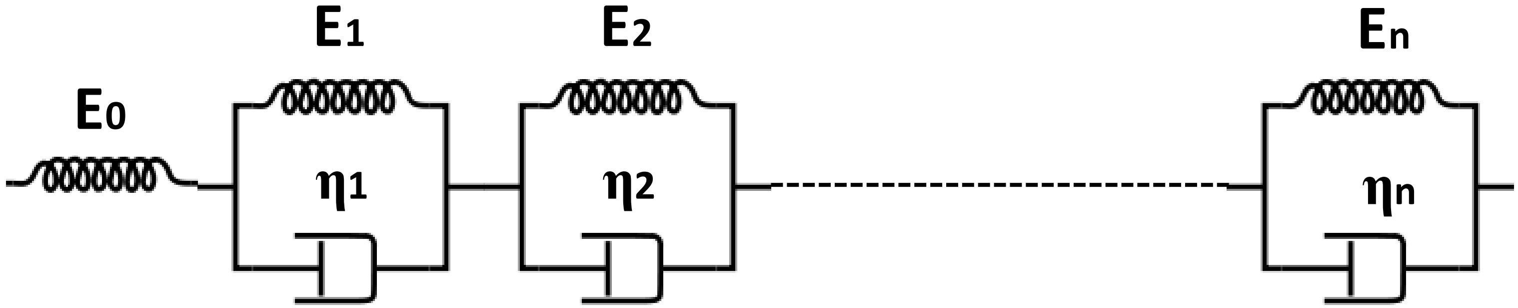
- Visco-elastic analysis
  - Rigorous
  - Computationally expensive
- Two-moduli approach
  - Compatible with the MEPDG
  - Fast and inexpensive

Viscoelastic Characterization of AC

- Creep compliance function – Prony series (Park et al. 1999, Bendetto et al. 2004, Zofka et al. 2008)

$$J(t) = \frac{1}{E_0} + \sum_{i=1}^{N} \frac{1}{E_i}\left(1 - e^{\frac{-E_i t}{\eta_i}}\right)$$

- Generalized Kelvin-Voigt model



VE Characterization of AC (2)

- Consider that the material is stress-free for time $t < 0$
- Differential form

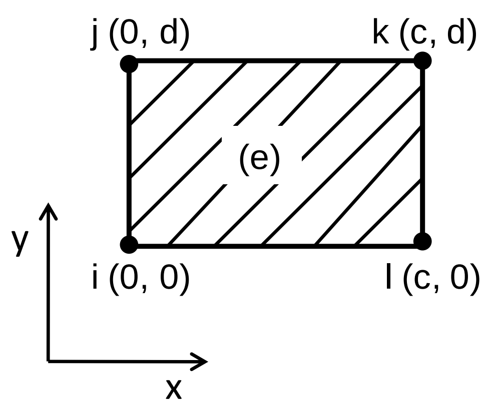
$$\sum_{i=1}^{N} \dot{\varepsilon}_i^{cr}(t) = \sum_{i=1}^{N} \left(\frac{1}{\eta_i} \sigma(t) - \frac{E_i}{\eta_i} \varepsilon_i^{cr}(t) \right)$$

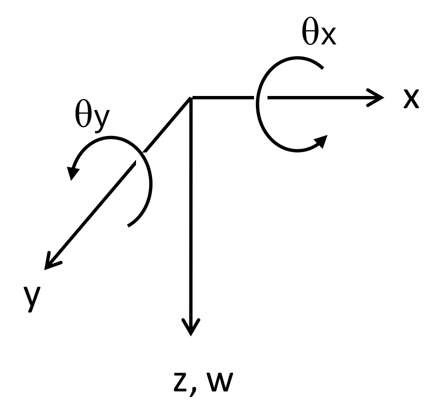
  - Implemented in FE algorithms (Lesieutre and Govindswamy 1996, Johnson et al. 1997)
  - Creep strain approximated using time-discretization

$$\Delta\varepsilon^{cr}(t) \cong \sum_{i=1}^{n} \left[\left(\sigma(t) - E_i \varepsilon_i^{cr}(t) \right) \frac{\Delta t}{\eta_i} \right] \qquad \varepsilon(t_{j+1}) = \varepsilon(t_j) + \Delta\varepsilon^{cr}(t_j)$$

Development of VE Model (1)

- FE model incorporating viscoelastic/elastic layers
- Kirchhoff-Love plate theory for bending of isotropic and homogenous medium-thick plates
- Similar to ISLAB2000
  - four-noded rectangular plate element with three degrees of freedom at each node





Development of VE Model (2)

- Time-discretized process
  - Total time to develop creep behavior is discretized into sufficiently small time intervals
- At any time t, the plate is subjected to
  - Axle loads at time t
  - Fictitious forces due to
    - Temperature distribution at time t
    - Creep strains at the start of time interval Δt

$$[K]\{\delta(t_j)\} = \{F(t_j)\} + \{F_{therm}(t_j)\} + \{F_{creep}(t_j)\}$$

Development of VE Model (3)

- Compute stress at any time t (Hooke's law)

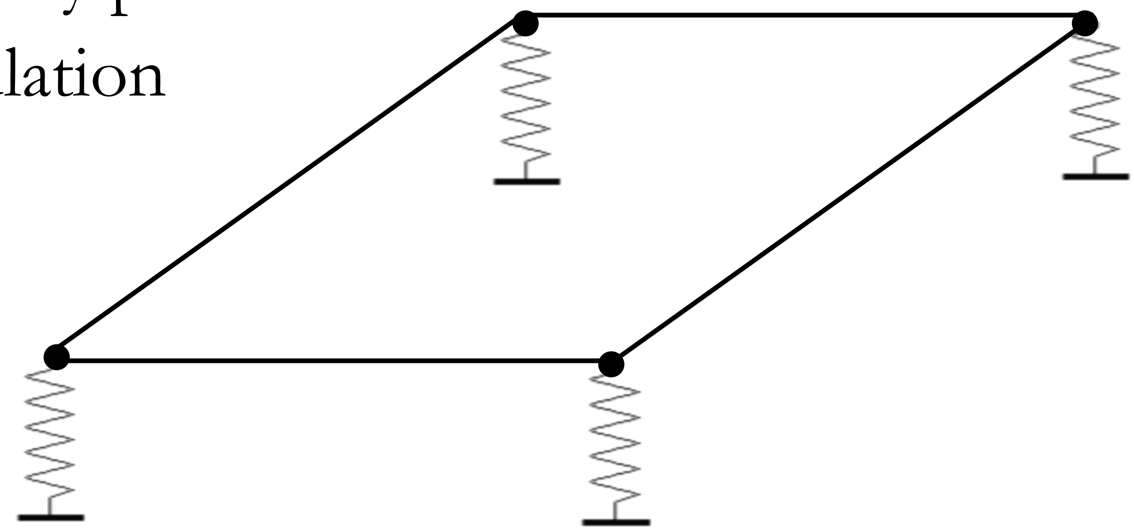
$$\{\sigma(t_j)\}_e = [D]\left(\{\varepsilon(t_j)\} - \{\varepsilon_{therm}(t_j)\} - \{\varepsilon^{cr}_{tot}(t_j)\}\right)_e$$

- Update creep strain at the end of time interval Δt

$$\varepsilon(t_{j+1}) = \varepsilon(t_j) + \Delta\varepsilon^{cr}(t_j)$$

Development of VE Model (4)

- Elastic / VE Plate
- Elastic / VE Winkler foundation
- Winkler foundation
  - Proportionality of applied pressure and plate deflection at any point
  - Spring formulation



Thermal loads

Any temperature distribution can be split into the following 3 components:

1. Constant-strain-causing temperature component
   - Does not cause stress
2. Linear-strain-causing temperature component
   - Bending stresses computed using FE analysis
3. Nonlinear-strain-causing temperature component
   - Self equilibrating stress calculated using analytical solutions (Khazanovich 1994)

Total stress

- Bending stress in the equivalent single layer slab
- Stress due to nonlinear-strain-causing temperature component $$\sigma_{NL}(z) = -\frac{E(z)\alpha(z)}{(1-\mu)}\left(T_{NL}(z) - T_o(z)\right)$$
- Stress due to nonlinear-strain-causing creep component $$\left\{\sigma_{NL}^{cr}(z)\right\} = -[\bar{D}]\left(\left\{\varepsilon_{NL}^{cr}(z)\right\} - \left\{\varepsilon_0^{cr}(z)\right\}\right)$$

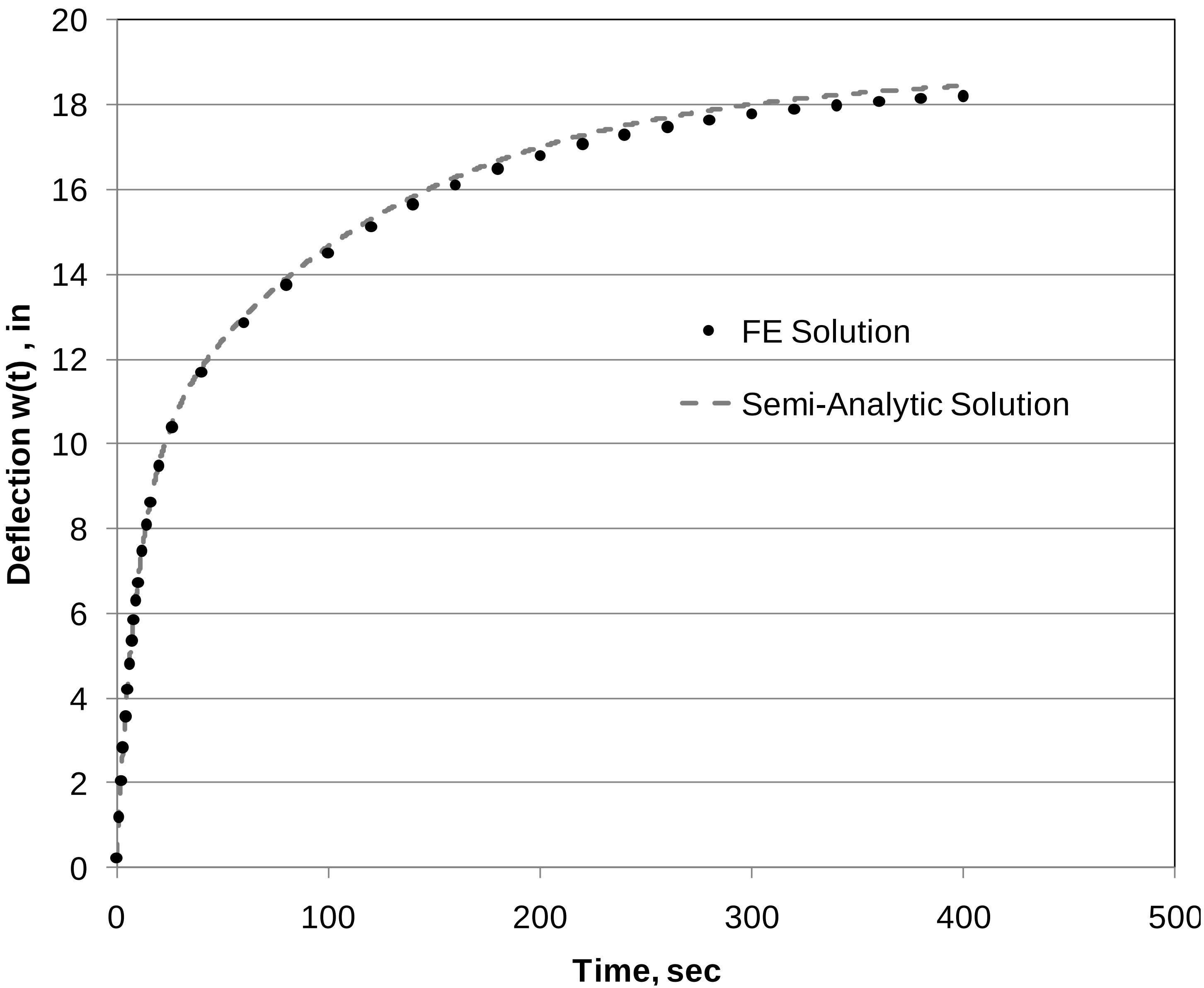
$$\sigma(x,y,z,t) = \beta(z) * \sigma_{eq}(x,y,t) + \sigma_{NL}(z) + \sigma_{NL}^{cr}(x,y,z,t)$$

$$\beta(z) = \frac{2z}{h_{eq}} \frac{E(z)}{E_{eq}}$$

Model Verification Examples

1. Viscoelastic plate on viscoelastic Winkler foundation
2. Viscoelastic plate with simply supported corners
3. Sensitivity to internal parameters

VE Plate on VE Foundation



Two-Moduli Approach

- Why ?
  - Compatibility with the existing MEPDG framework
- EACL & EACT
- Combined stress procedure
- Verification examples
- Comparison with the existing MEPDG stress computation procedure

Two-Moduli Approach (2)

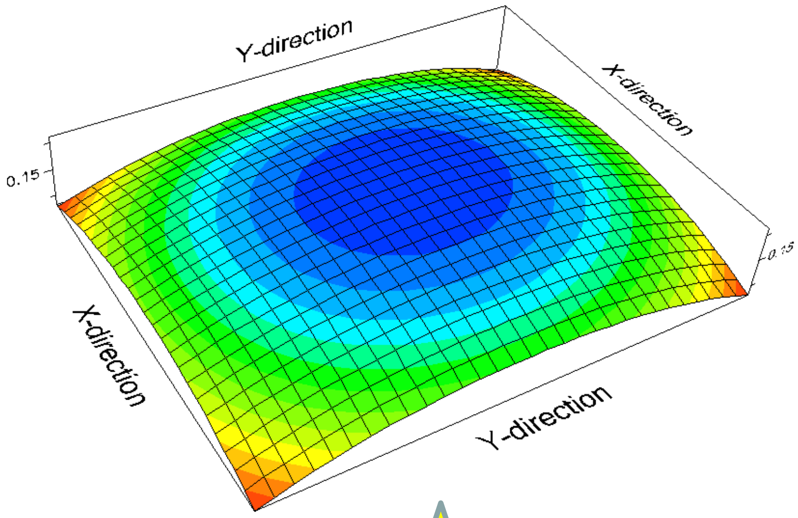
1. EACL

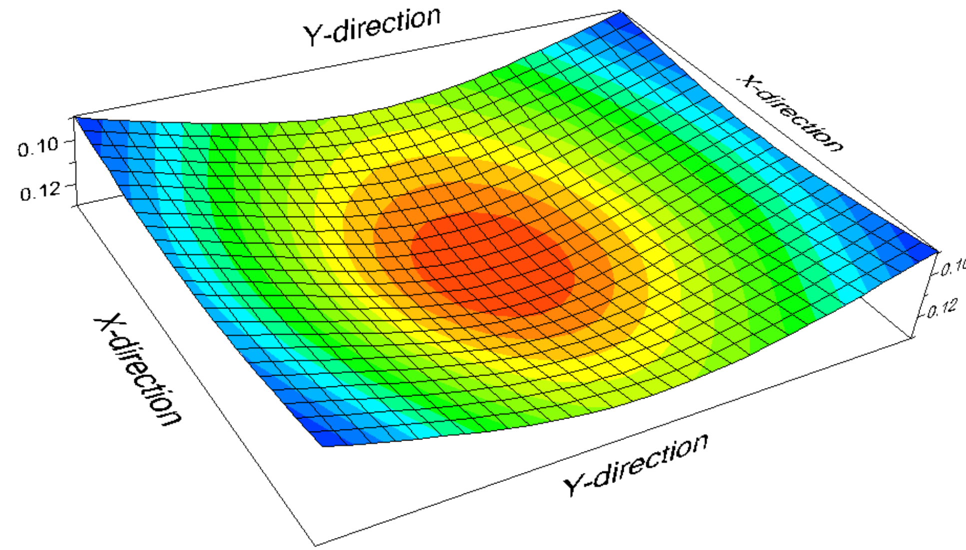
   Traffic-duration-dependent AC dynamic modulus to characterize the pavement response under typical traffic loads, and

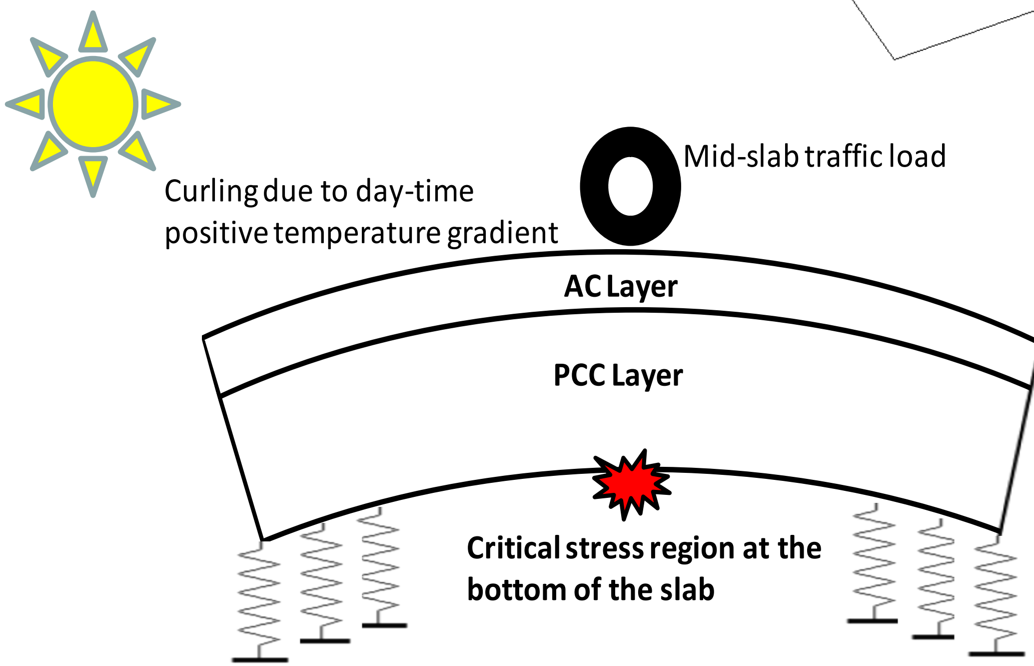
2. EACT

   Temperature-duration-dependent AC dynamic modulus to characterize the pavement response for the duration of temperature loads, t_T.

Non-linear Slab-Foundation Interaction





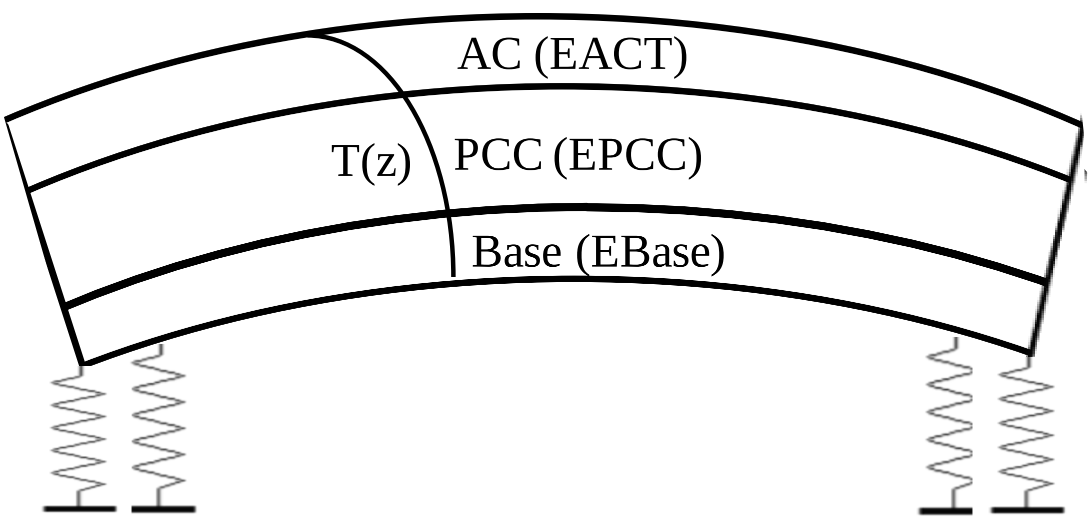


Three Systems to Model

- System 1
  - Temperature curling only
  - AC layer characterized by long-term modulus
- System 2
  - AC layer characterized by short-term modulus
  - Determine fictitious loading that produces the same deflection profile as in System 1
- System 3
  - AC layer characterized by short-term modulus
  - Subjected to traffic and fictitious loading

Boundary Value Problem # 1

- System 1: AC layer characterized with EACT
- Subjected to temperature distribution T(z) only



$$[K_1]\{\delta_1\} = \{R_{therm}\}$$

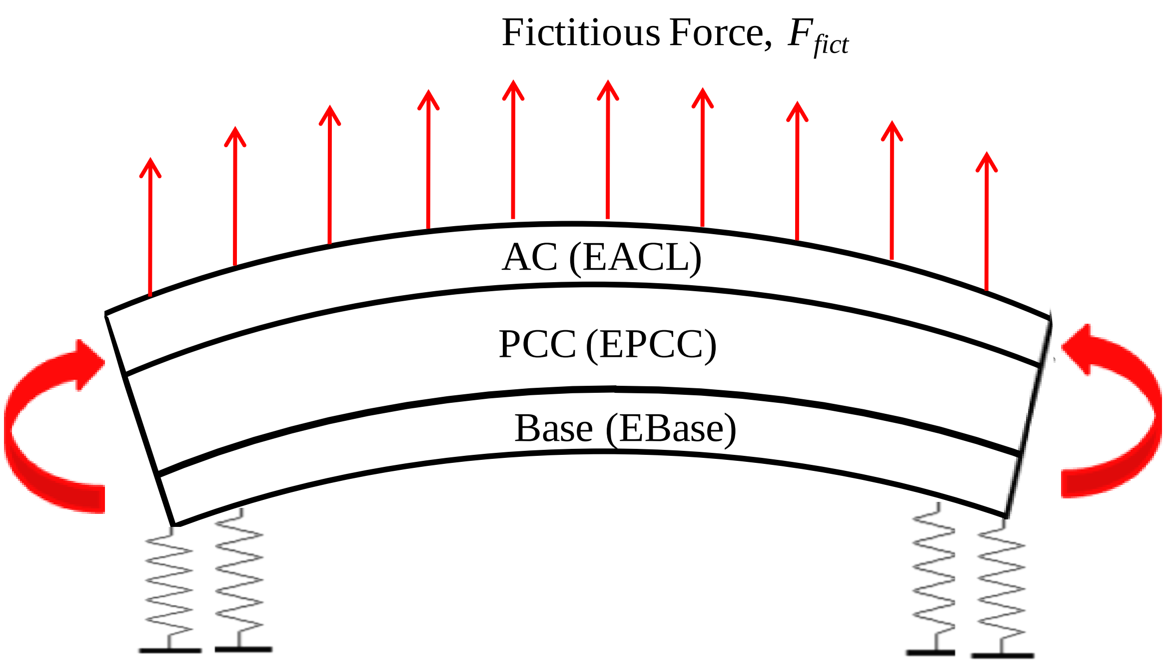
$$\{\delta_1\} = [K_1]^{-1}\{R_{therm}\}$$

$$\{\sigma_1\}_e = [D_T](\{\varepsilon_1\} - \{\varepsilon_{therm}\})_e$$

Boundary Value Problem # 2

UNIVERSITY OF MINNESOTA
Driven to Discover℠

- System 2: AC layer characterized with EACL
- Deflection profile of system 2 = deflection profile of system 1

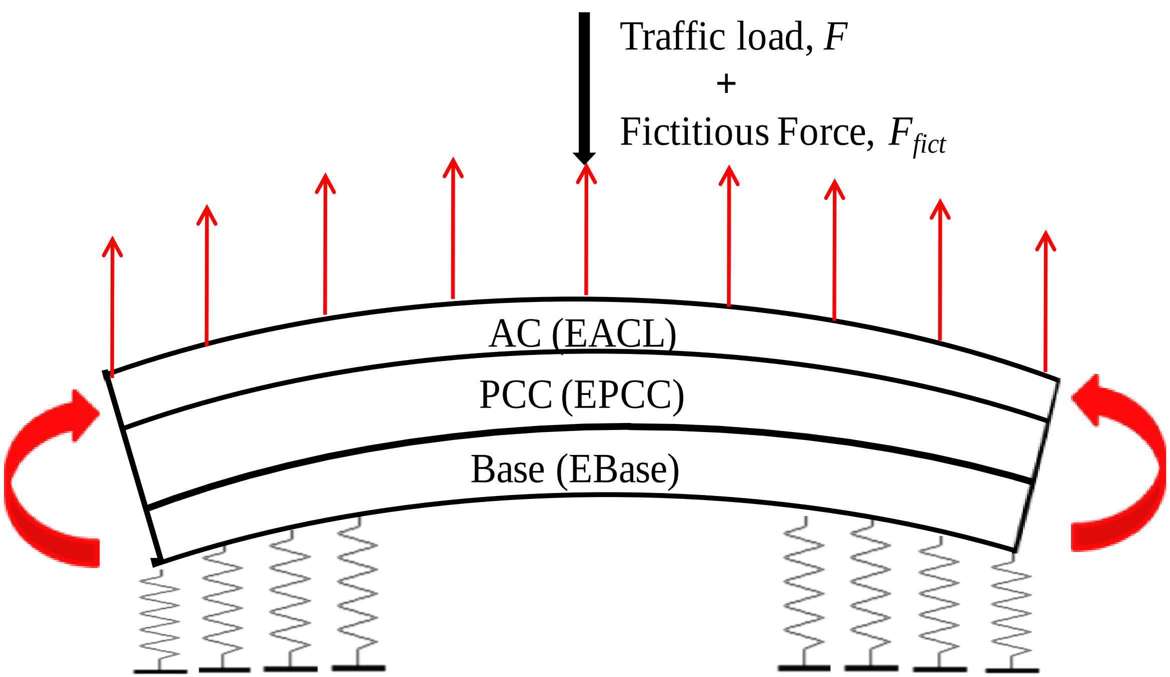


$$\{F_{fict}\} = [K_2]\{\delta_1\}$$

$$\{\sigma_2\}_e = [D_L]\{\varepsilon_1\}_e$$

Boundary Value Problem # 3

- System 3: AC layer characterized with EACL
- Subjected to traffic load F and fictitious load F_{fict}



$$\{\delta\} = [K_2]^{-1}\left(\{F\} + \{F_{fict}\}\right)$$

$$\{\sigma_3\}_e = [D_L]\{\varepsilon_T\}_e$$

Two-Moduli Stress Calculation

- Total stress due to combined loading

$$\sigma_{2M} = \sigma_1 + (\sigma_3 - \sigma_2)$$

- Advantages
  - Accounts for the duration of loading
  - 2-moduli approach permits using existing MEPDG procedure for AC dynamic modulus
  - Accounts for non-linearity of slab-foundation interaction
  - Substitutes viscoelastic analysis

Comparison with Simple Addition of the Stresses

	Location, in		Deflection, in	Rotation		Longitudinal Stress, psi
	X	Y		θy	θx	
Three elastic solution						
# 1	90	0	-0.0077	0.00	0.00	108.74
# 2	90	0	-0.0077	0.00	0.00	-138.36
# 3	90	0	0.0038	0.00	0.00	204.06
Combined stress						451.17
Viscoelastic FE solution	90	0	0.0038	0.00	0.00	451.12
EACT, temperature load only	90	0	-0.0077	0.00	0.00	108.74
EACL, traffic load only	90	0	0.0033	0.00	0.00	284.05
						392.79
% Difference						14.86%

Comparison with VE FE Solution

	Location, in		Deflection, in	Rotation		Longitudinal Stress, psi
	X	Y		Θy	θx	
Three elastic solution						
# 1	90	72	-0.0054	0.00	0.00	78.65
# 2	90	72	-0.0054	0.00	0.00	-96.61
# 3	90	72	0.2401	0.00	0.00	1947.8
Combined stress						2123.06
Viscoelastic FE solution	90	72	0.2401	0.00	0.00	2122.84
% Error						-0.01%

Center node

	Location, in					
	X	Y				
Three elastic solution						
# 1	90	0				
# 2	90	0				
# 3	90	0				
Combined stress						891.462
Viscoelastic FE solution	90	0	0.1220	0.0015	0.00	891.461
% Error						-0.00015%

Edge node

Comparison with VE FE Solution (2)

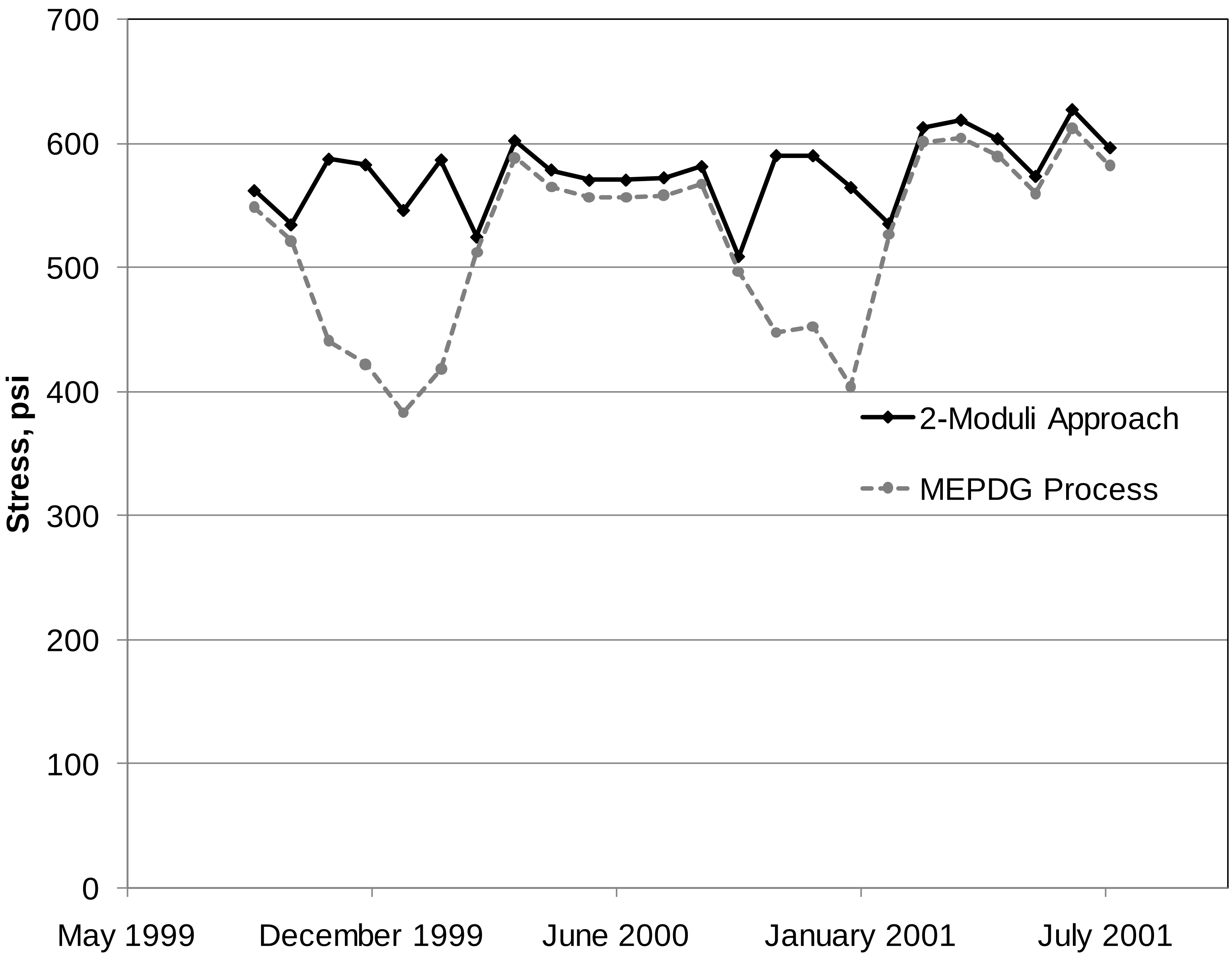
	Location, in		Deflection, in	Rotation		Longitudinal Stress, psi
	X	Y		θy	θx	
Three elastic solution						
# 1	90	0	0.0188	-0.0007	0.00	74.35
# 2	90	0	0.0188	-0.0007	0.00	-101.04
# 3	90	0	0.0466	-0.0011	0.00	268.11
Combined stress						443.5
Viscoelastic FE solution	90	0	0.0466	-0.0011	0.00	443.3
% Error						-0.046%

Edge node

Three elastic solut						
# 1						
# 2						
# 3	72	54	0.0106	-0.00026	-0.00004	-21.31
Combined stress						154.02
Viscoelastic FE solution	72	54	0.0106	-0.00026	-0.00004	153.76
% Error						-0.169%

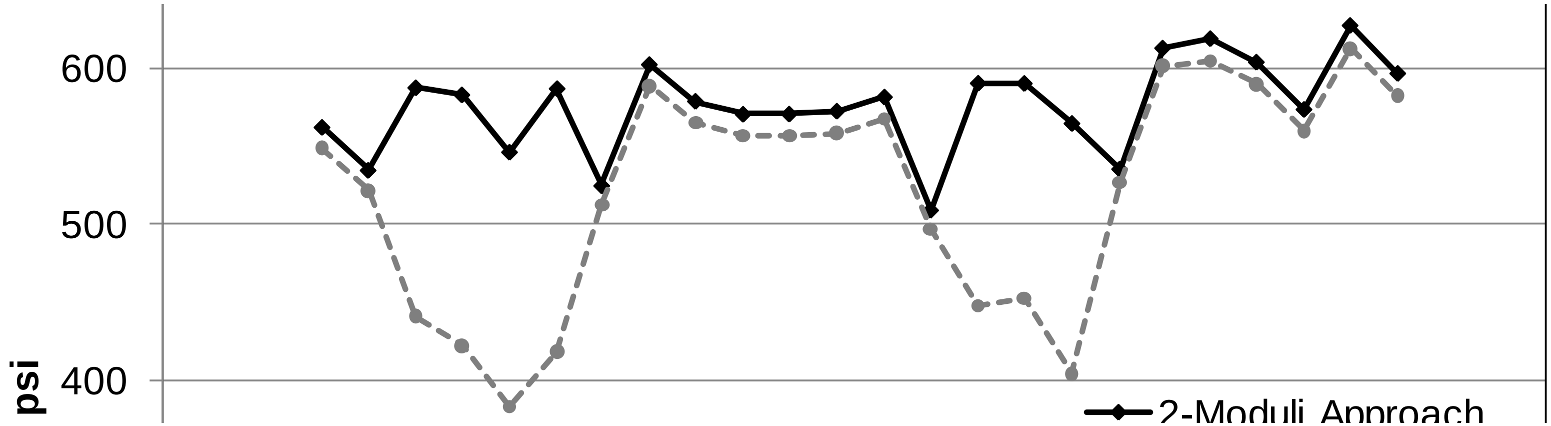
Interior node

MEPDG Stress Comparison

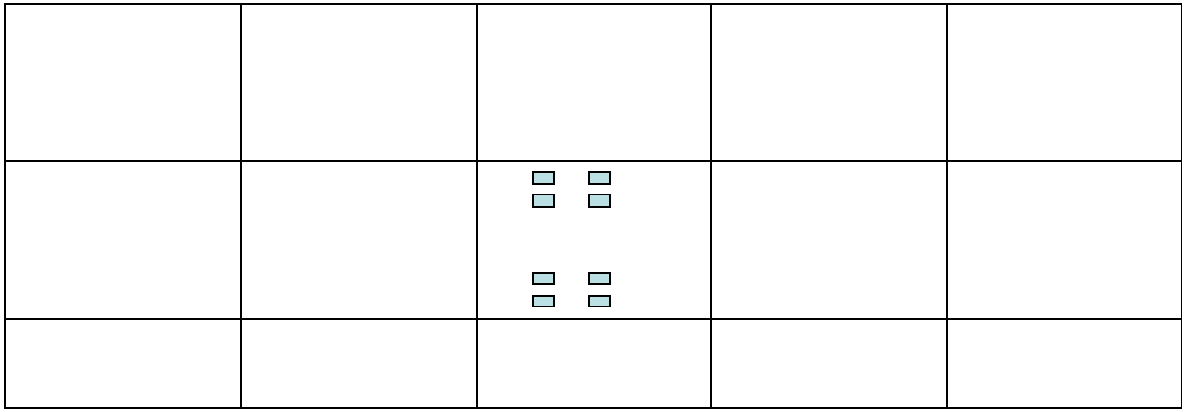


MEPDG Stress Comparison (2)

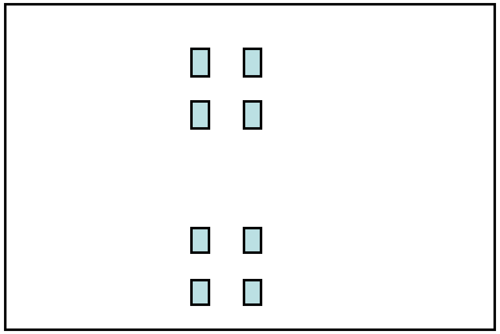
- Why is there a significant difference?
  - Self-equilibrating stresses are based on EACT instead of EACL as in the MEPDG
  - Reference temperature follows existing MEPDG guidelines



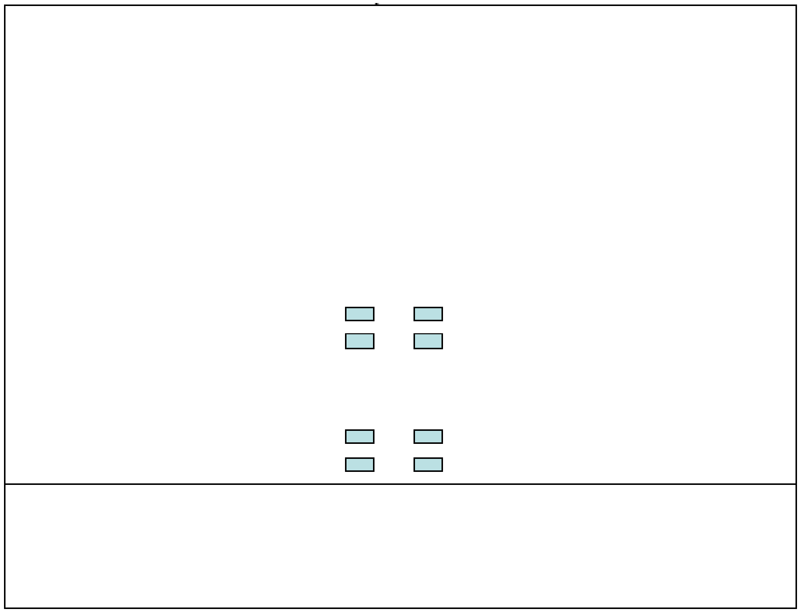
Simplification of the Structural System in the MEPDG



(a) original multi-layered system



(b) single slab system A



(c) two-slab system B

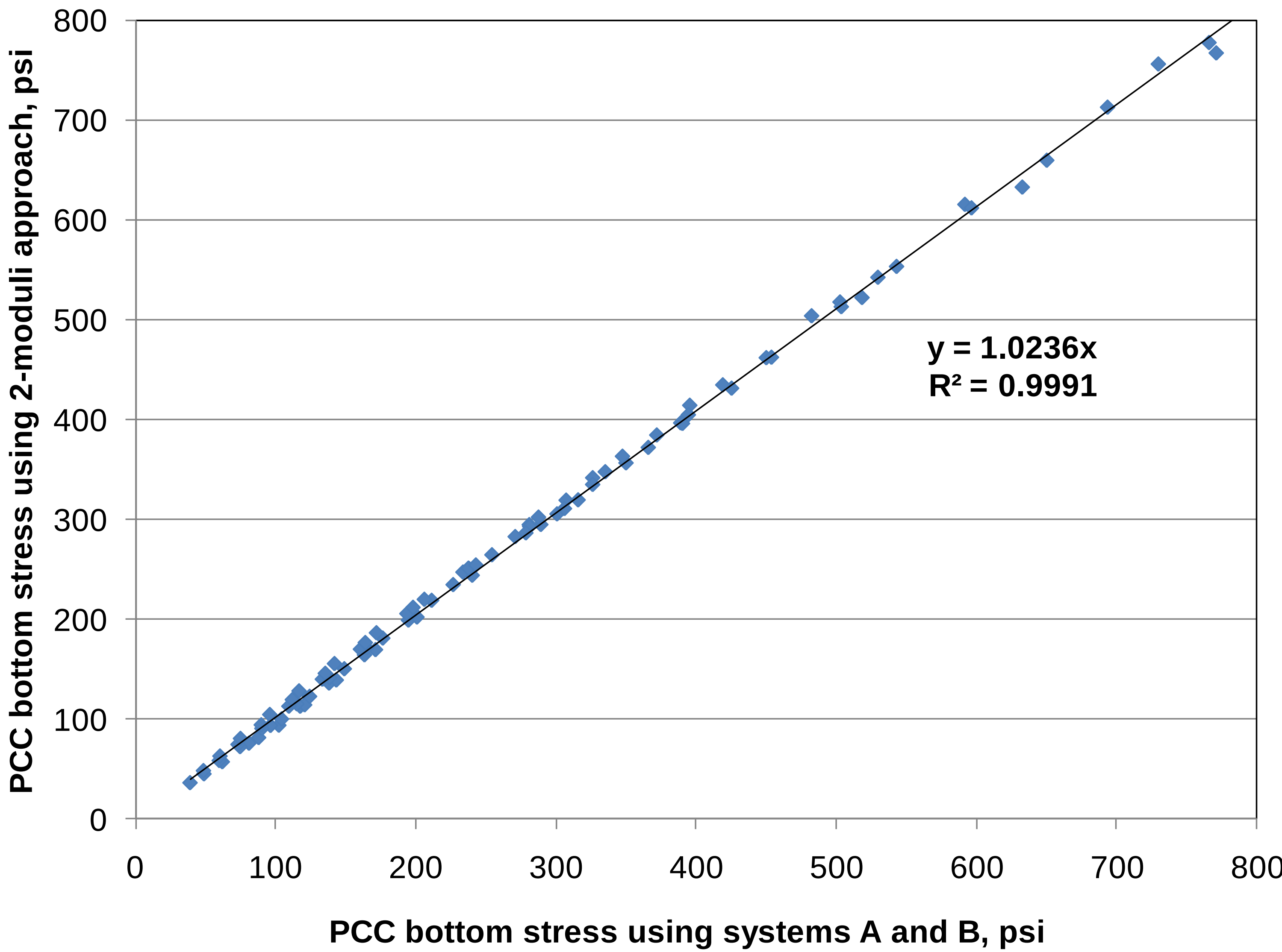
- System A
  - Case I: temperature loading only, $\sigma_1^A(0,T)$
  - Case II: combined traffic and temperature loading, $\sigma_2^A(0,T^*)$ $\sigma_3^A(P,T^*)$
  - Case III: traffic loading only, $\sigma^A(P,0)$

- System B
  - Case I: no load transfer between the slabs, $\sigma^B(0)$
  - Case II: load transfer efficiency between two slabs is equal to shoulder LTE, $\sigma^B(LTE)$

$$\sigma_{Tot} = \sigma_1^A(0,T) + LTE * \left[\left(\sigma_3^A(P,T^*) - \sigma_2^A(0,T^*) \right) - \sigma^A(P,0) + \sigma^B(0) \right]$$

Simplification of the Structural System in the MEPDG (3)

- Factorial of 98 cases
- Wheel offset
  - 0, 2, 4, 6, 12, 18, and 24
- PCC thickness
  - 2-15" in 1" incr



Equivalency Techniques

- Simplify multi-layered pavement in terms of single layer slab
- If the following are valid (AASHTO 2008)…
  - Equality of slab stiffness, $$D = \frac{E\ h^3}{12(1-\mu^2)}$$
  - Equality of Korenev's non-dimensional temperature gradient, $$\phi = \frac{2\alpha(1+\mu)l^2}{h^2}\frac{k}{\gamma}\Delta T$$
  - Equivalency of radius of relative stiffness, $$l = \sqrt[4]{\frac{D}{k}}$$
  - Equivalency of normalized load ratio, $$q^* = \frac{P}{LW\gamma h}$$

Equivalency Techniques (2)

If (above) valid, then…

– Deflections are related as:

$$w_1 = \frac{\gamma_1 h_1 k_2}{\gamma_2 h_2 k_1} w_2$$

– Stresses are related as:

$$\sigma_1 = \frac{h_2 \gamma_1}{h_1 \gamma_2} \sigma_2$$

Equivalency Techniques (3)

	Location, in		Deflection, in	Bending stress, psi		
	X	Y		σ_{SL}	β	σ_{3LS}
Three elastic solution – Three-layered composite pavement						
# 1	90	0	0.0188			136.19
# 2	90	0	0.0188			-101.04
# 3	90	0	0.0424			180.99
Combined stress						418.22
Three elastic solution – Equivalent single layer slabs SL1 and SL2						
SL1: # 1	90	0	0.0188	136.73	0.996	136.191
SL2: # 2	90	0	0.0188	-102.73	0.914	-101.038
SL2: # 3	90	0	0.0424	184.03	0.914	180.993
Combined stress						418.221
% Difference						0.000%

Conclusions on Two-Moduli Approach and MEPDG Stress Comparison

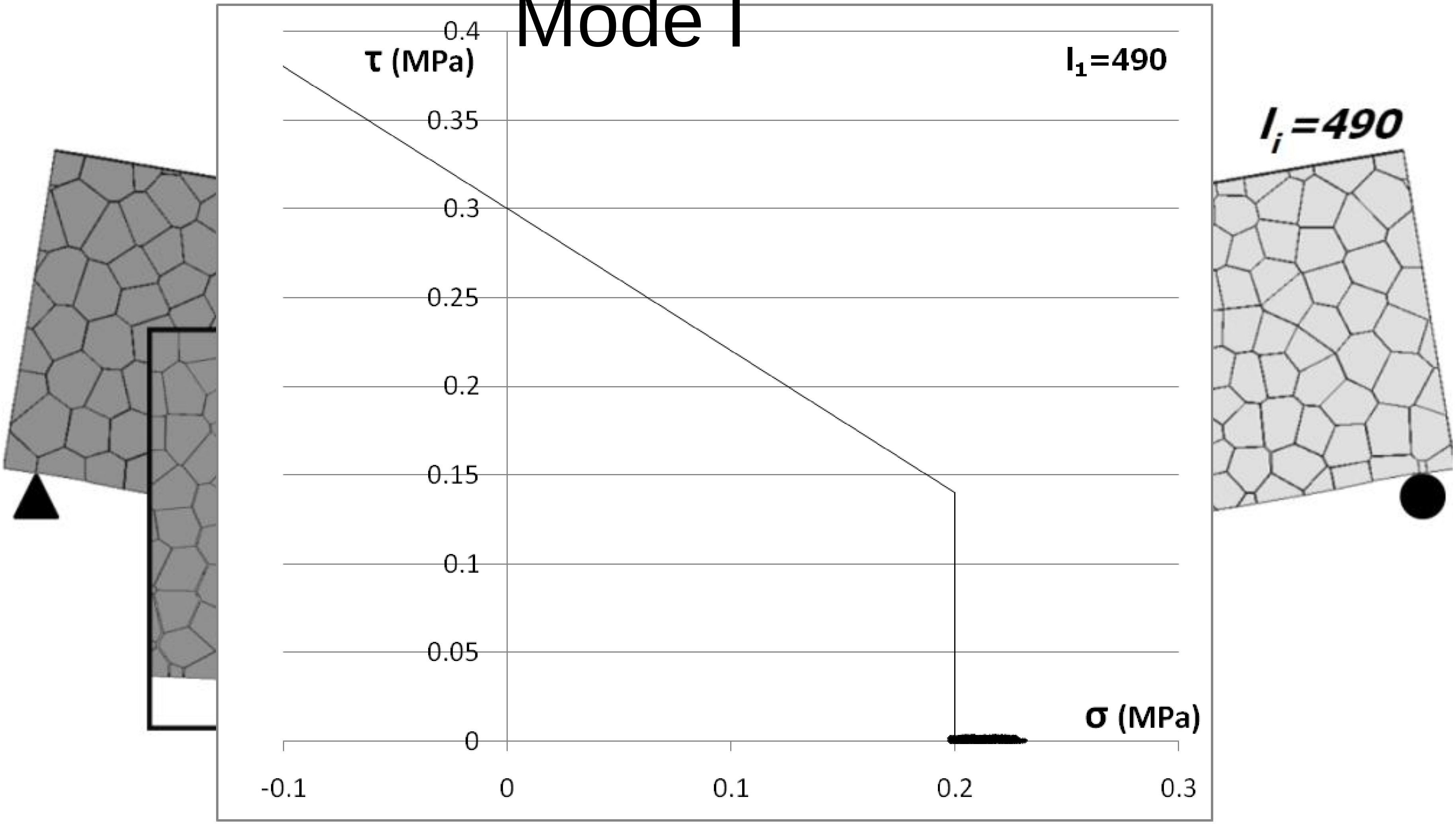
- A novel stress computation procedure was developed
  - Uses different moduli for curling and axle load analysis
  - Verified with viscoelastic finite element solutions
- A framework for the implementation of the proposed stress procedure into the MEPDG was developed
  - Minimum modifications to the existing MEPDG framework are required to be implemented into the MEPDG for predicting fatigue cracking

Reflection Cracking Modeling

- Lattice 3D model
  - Developed at UC-Davis by Prof. John Bolander
  - Modified under R21 project to account for mixed mode failure
- Coupling with ISLAB (FEM) completed, currently being validated for additional beam and slab problems

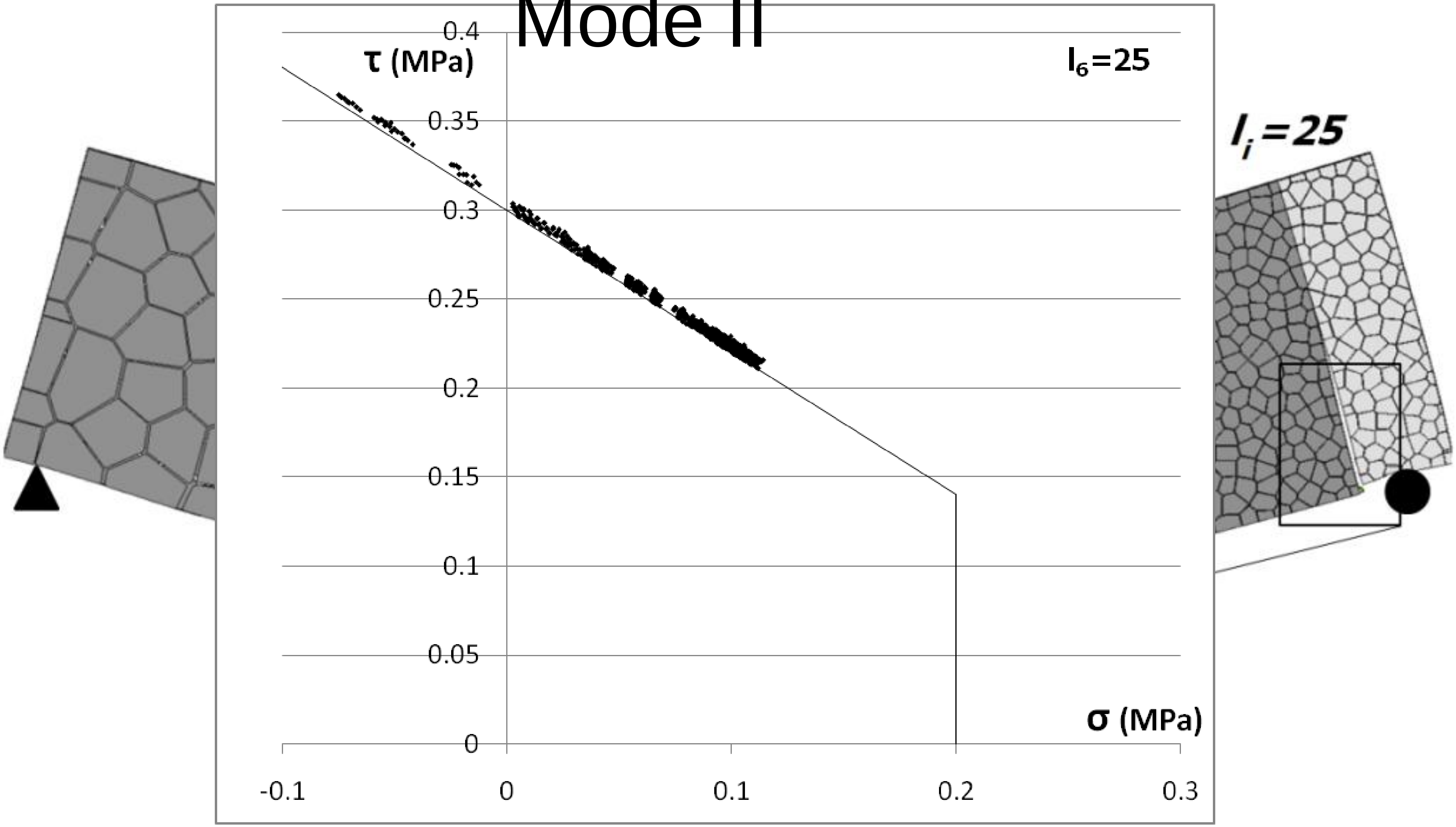
Reflection Cracking Modeling

Mode I



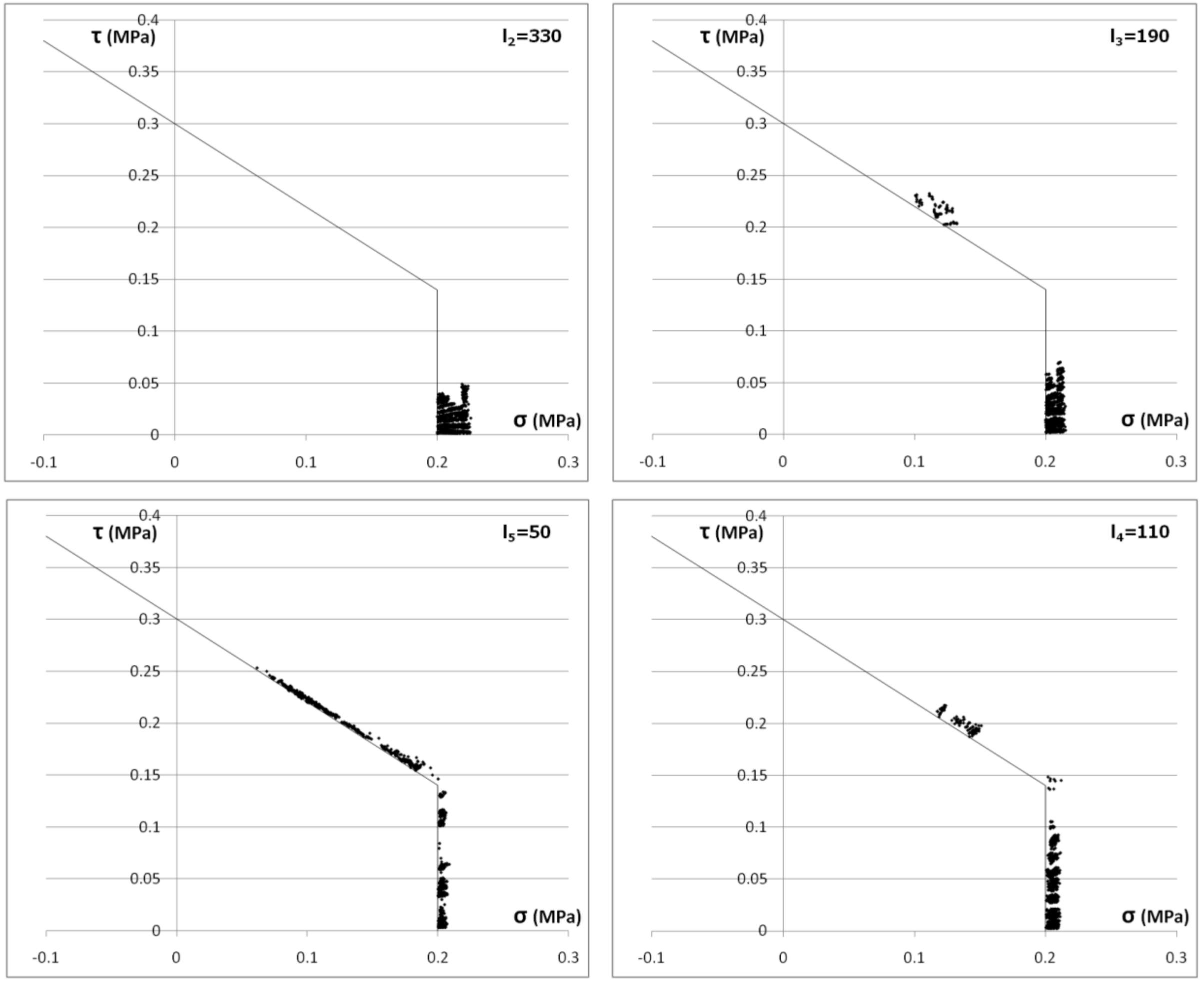
Reflection Cracking Modeling

Mode II



Modeling Mixed Mode Fracture

- Weakened interface moves away from mid-span
- Effect near support is an “unzipping,” with shear initiating fracture then tensile events increasing in number



- Literature Review
- LCCA
- EICM Validation and Analysis
- Evaluation of Response Models
- Development of Design Guidelines
- Development of Construction Guidelines
- **Development of Synthesis**

Synthesis

- TICP focuses on new construction
  - Life-cycle cost analysis
  - EICM/MEPDG revisions/enhancements
  - CalME/MEPDG merging
  - Construction guidelines
- Scope of synthesis should include conventional AC overlays (rehabilitation)

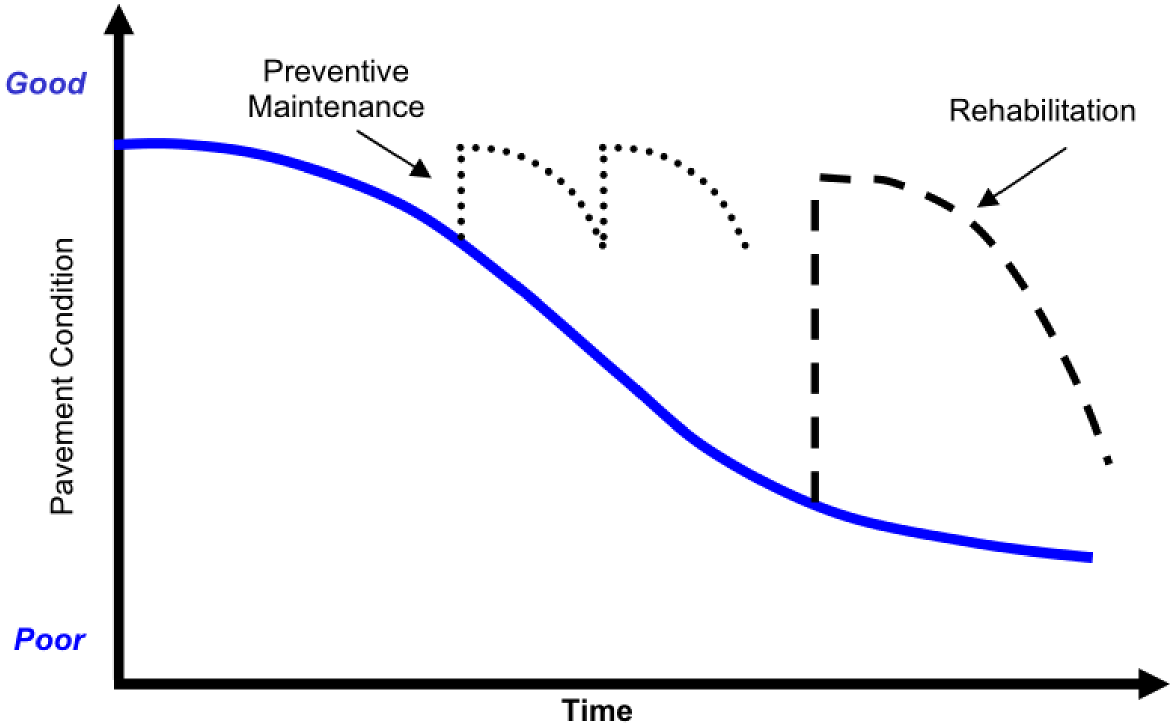
AC-PCC Guidelines Overview (1)

1. Introduction
   – **AC-over-PCC (AC-PCC)** as pavement preservation
   – Benefits of AC-PCC
2. Evaluation of existing PCC
   – Structural and Functional Evaluations
3. Repair and preparation of existing PCC
   – Slab support, Full- and partial-depth repair, edge drains, restoring LTE, cleaning
4. AC overlay mix design
   – Overlay mix guidelines TBD

AC-PCC Guidelines Overview (2)

5. Geotextile interlayer
6. AC overlay structural design
   – MEPDG & CALME
7. AC-PCC performance evaluation
   – Includes extensive LTPP experience
8. AC overlay construction
   – Saw & seal technique and effectiveness
   – Construction guidelines TBD with UCD experience

AC-PCC Benefits

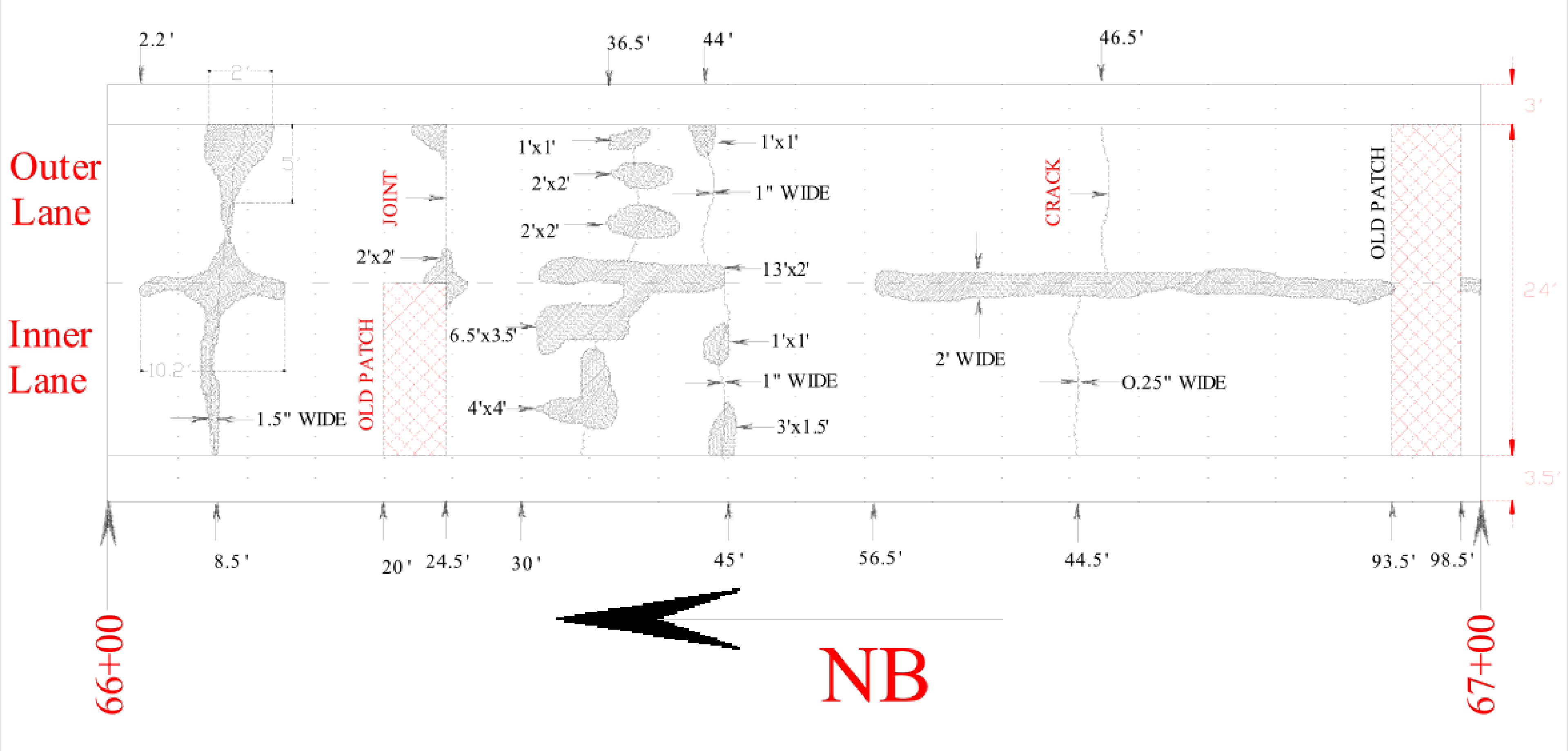


- AC overlay on PCC plays to both materials' strengths:
  - Long-term performance of PCC
  - Renewability and low noise performance of AC
- With some planning, best possible long-term performance can be achieved affordably

Evaluate existing PCC (1)

- Evaluation procedure
  - From office (historical records) to field (surveys and tests)
- Structural evaluation
  - Survey extent of damage and drainage
  - NDT for slab strength, subgrade reaction, etc.
- Functional evaluation
  - Assess friction, roughness, noise
- Decide on rehabilitation or maintenance

Evaluate existing PCC (2)



STH 38, Racine County, Wisconsin

from Wen et al 2005

Repair and prepare existing PCC (1)

University of Minnesota

- Restore PCC slab support
  - Alleviate pumping or loss of support
  - Use slab stabilization or slab jacking
- Partial-depth slab repair
  - Repair functional damage (i.e. not structural) such as shallow spalled joints or cracks
  - Define repair area, remove questionable material, use fill material (AC, PCC, or other alternatives)

STH 38, Racine County, Wisconsin

from Wen et al 2005

Repair and prepare existing PCC (2)

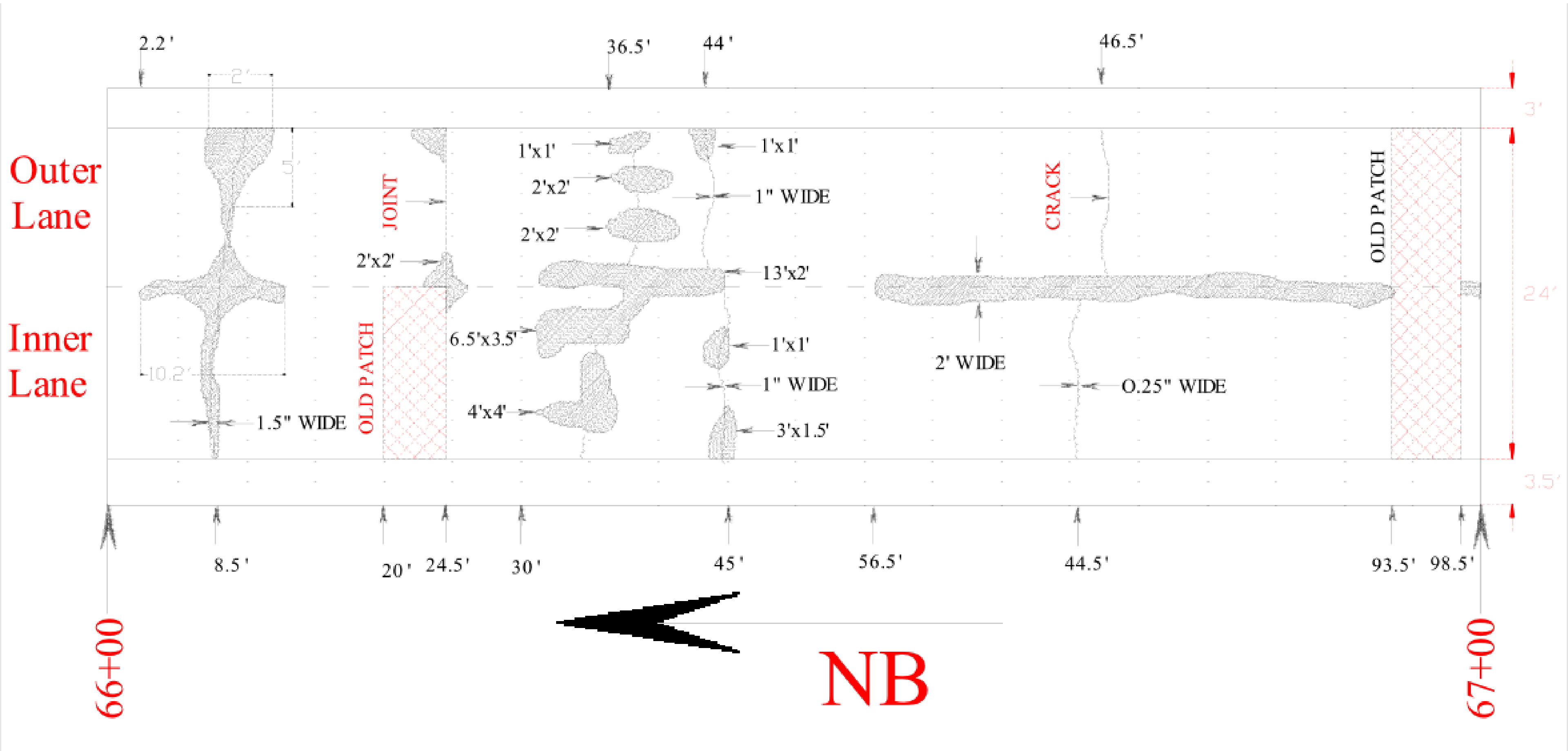
- Full-depth slab repair
  - Repair major structural damage, can include corner breaks, severe cracking, d-cracking, etc.
  - Ensure that repair area includes all deterioration through slab, use repair material based on lane closure time

Repair and prepare existing PCC (3)

- Install edge drains or reseal joints
  - Assess need for improved drainage, if required, retrofit edge drains or repair existing damage/blocked drains
- Improve LTE across joints
  - Restore LTE by replacing damaged dowels or retrofitting dowels to undoweled pavement
- Clean and prepare slab for overlay
  - Grinding and grooving to restore surface

Repair and prepare existing PCC (4)

UNIVERSITY OF MINNESOTA



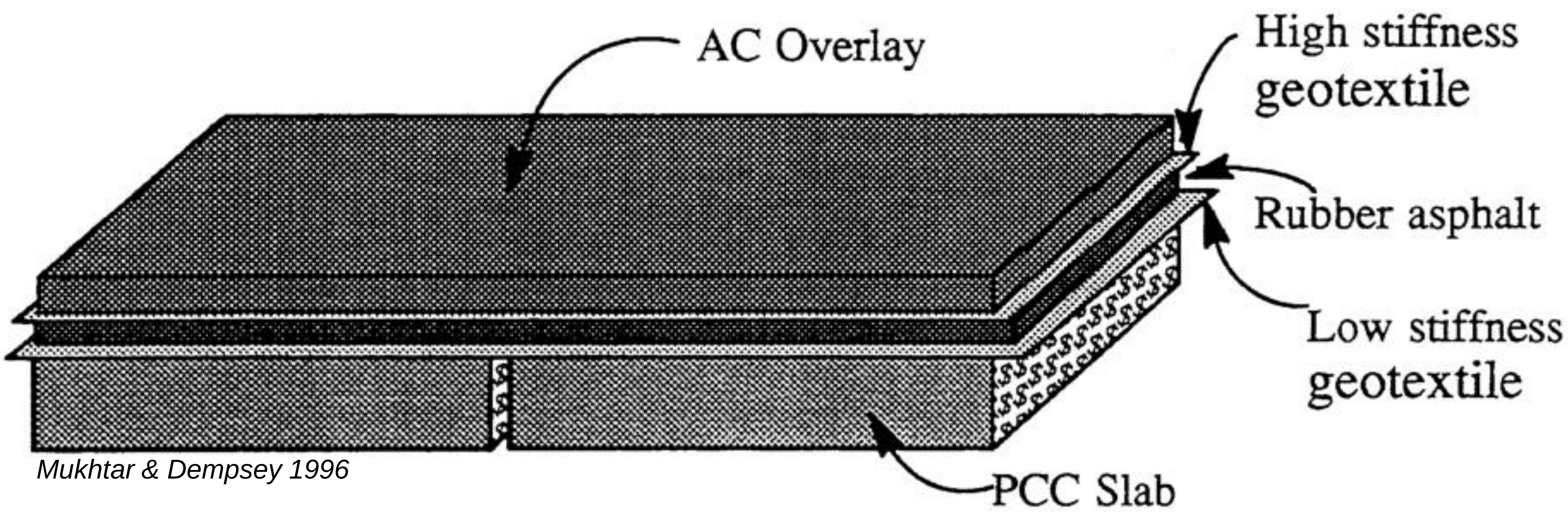
STH 38, Racine County, Wisconsin

from Wen et al 2005

AC overlay mix design

- AC overlay mix design to be determined
  - Prof. Marasteanu at UMN will be consulted for overlay mix design
- AC mix design will consider paving concerns (site conditions, etc.) for TPF(5)-149 member states

Geotextile interlayer



Mukhtar & Dempsey 1996

- Interlayer to arrest crack propagation from existing PCC into AC overlay
  - While it has been shown to be effective in reducing reflective cracking in thin overlays…
  - the cost of implementation may outweigh the benefits
- Guidelines will briefly detail interlayers in hope of informing user on both sides of existing research (**still in process**)

AC-PCC long-term performance (1)

- LTPP AC-PCC sections included:
  - GPS-7. AC Overlay of PCC Pavements
  - SPS-6. Rehab Using AC Overlays of PCC Pavements
  - These include 8-inch OL over crack-and-seat, 4-inch OL over crack-and-seat or intact pavement, and full-depth repair with/without grinding
- U. Mich. found that for Arizona SPS-6 pavements:
  - Reflective cracking was the greatest contributor to post-overlay roughness
  - A layered Asphalt Rubber AC (ARAC) and AC over reduced the development of post-overlay roughness better than a conventional AC overlay
- NCHRP 20-50 found… (cont.)

AC-PCC long-term performance (2)

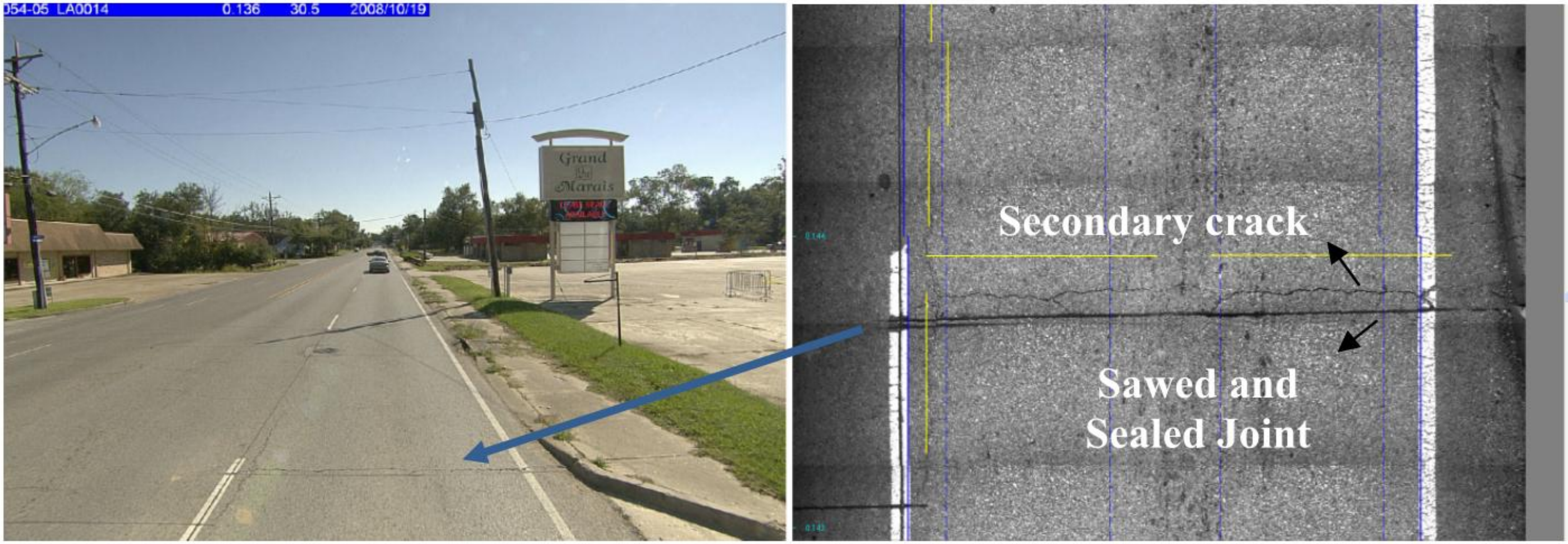
- NCHRP 20-50 found that for 4-inch asphalt overlays of intact slabs no significant mean differences in long-term roughness or cracking performance were detected between (cont.):
  - minimal versus intensive preoverlay preparation
  - sections without versus with sawing and sealing of transverse joints
  - overlays with sawed and sealed joints versus overlays of cracked/broken and seated slab
- NCHRP 20-50 ranked effectiveness of rehab as
  - 8-inch over crack and seat
  - 4-inch over crack and seat or intact
  - Non-overlay full-depth repair with diamond grind
  - Non-overlay full-depth repair without grind

AC-PCC construction

- AC overlay construction to be determined
  - UCD will be consulted for its AC overlay construction expertise
  - Earlier sections on existing PCC slab preparation will be revised to reflect UCD input
- Construction will include details on sawing and sealing, which was investigated for the SHRP2 R21 project and implemented at MnROAD

AC-PCC saw and sealing (1)

- Guidelines cite saw & seal spec developed for Illinois Tollway by SHRP2 R21
  - Saw cutting no longer than 48 hours after overlay paving, sawed joints to be ½ inch wide by 5/8 inch deep for 3-inch AC OL
  - Locating underlying JPCP joint is critical (*misidentified joint below*)
  - Joint cleanliness and site conditions emphasized



Elseifi et al 2011

AC-PCC saw and sealing (2)

- Saw and seal found to be effective in Louisiana DOT and SHRP2 R21 experience
  - SHRP2 R21 tour of EU countries that implemented saw and seal in AC-PCC (Austria, Germany, Netherlands

SHRP2 2010

Conclusions: TICP and AC Overlays

- Guidelines for AC overlays of existing PCC pavements in development
  - AC OL mix design and AC OL construction await expert input
- Inclusion of AC over existing PCC alongside new construction of TICP…
  - further expands definition of TICP and
  - expands possible user base for TICP products