Design and Construction Guidelines for Thermally Insulated Concrete Pavements

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Project Overview

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

Outline

- Introduction
  - What is a TICP?
  - When should it be used?
  - Why do we call it TICP?

- Example of EICM validation and analysis
- Example of evaluation of response models

What is TICP?

Thermally Insulated Concrete Pavement

=

asphalt layer over concrete pavement

- Newly constructed
- AC overlay over existing concrete pavement
  - Concrete layer is in good structural condition

When should a TICP be used?

- To achieve long life, premium ride and noise characteristics, rapid renewal - SHRP R21 project
- To achieve lower life cycle cost (LCC) - this study

Premium Pavement

Betonconstructie

50 mm ZOAB 0/16
Porous AC Friction Course

250 mm DGB
CRCP, 0.7% steel

60 mm GAB 0/32
AC Interlayer, Dense

250 mm AGRAC
Cement Bound Recycled Asphalt

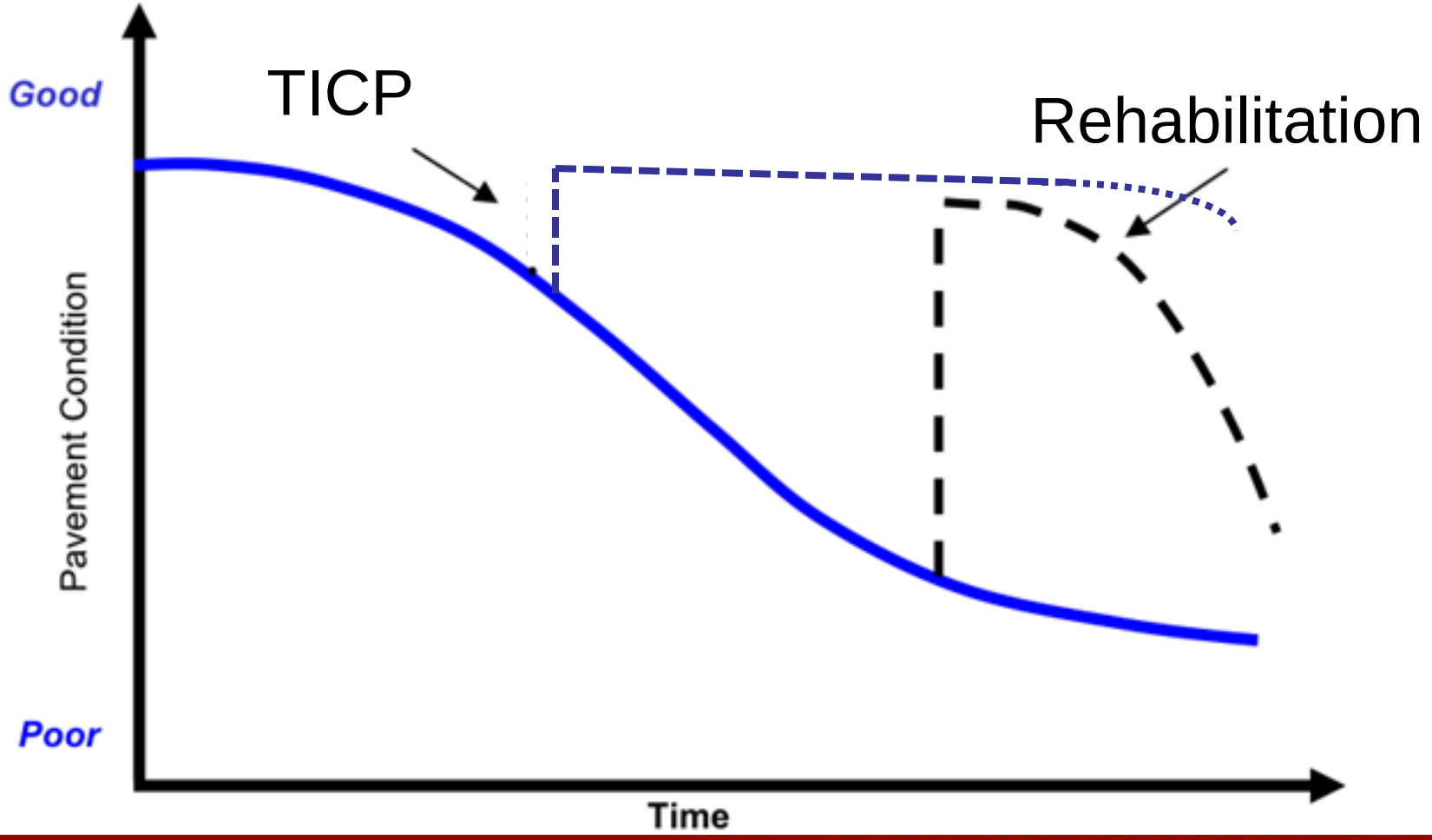
A50, Netherlands AC/CRCP Cores

Photo rotated to match cross-section at left

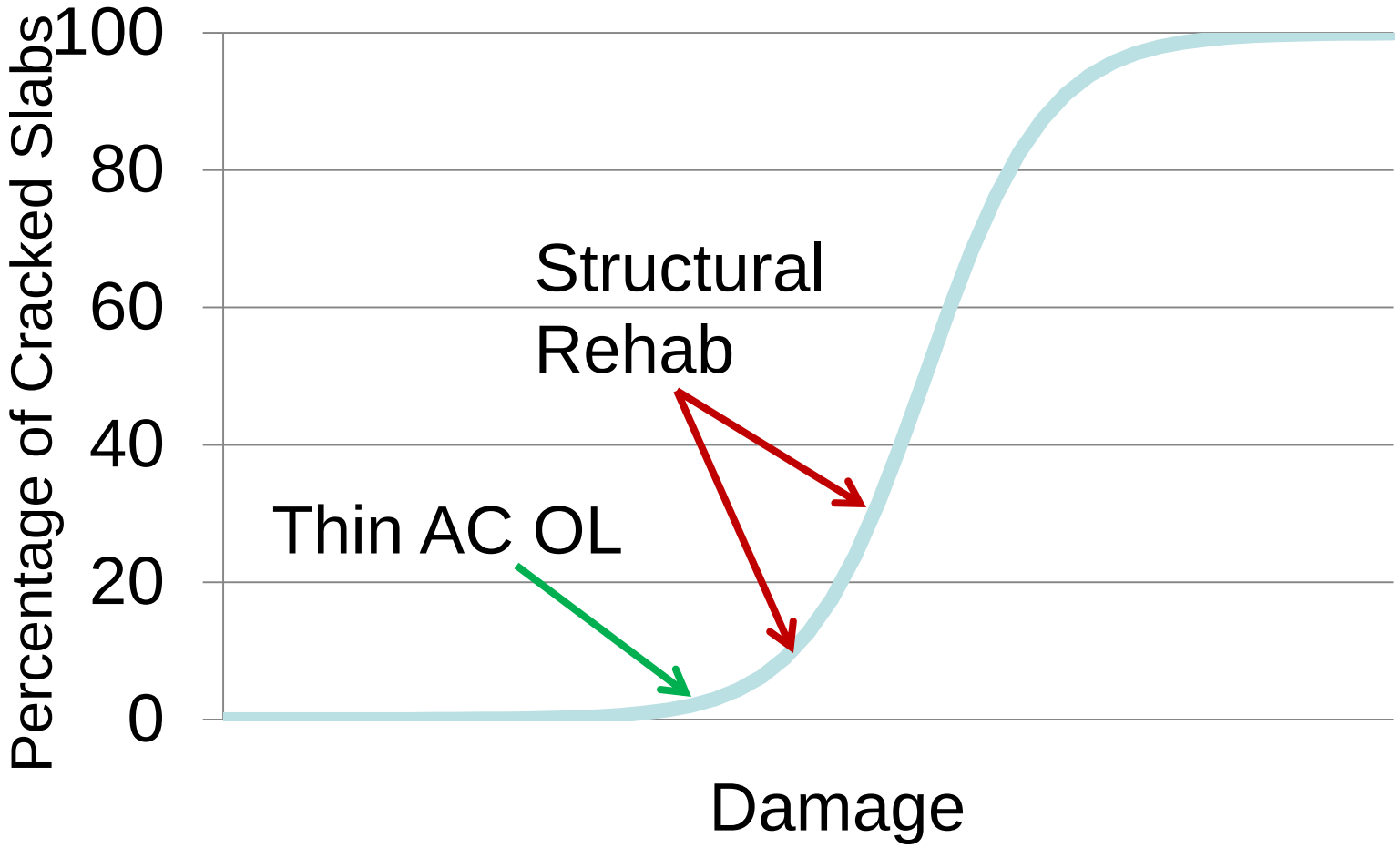
Lower LCC

- Thinner concrete thickness
- Low cost concrete
  - Low cost aggregates
  - Recycled concrete aggregates
  - High percentage of SCM
- Lower construction cost

TICP vs STRUCTUAL OVERLAY



Stage Construction/ Preventive Maintenance



Why do we call it TICP?

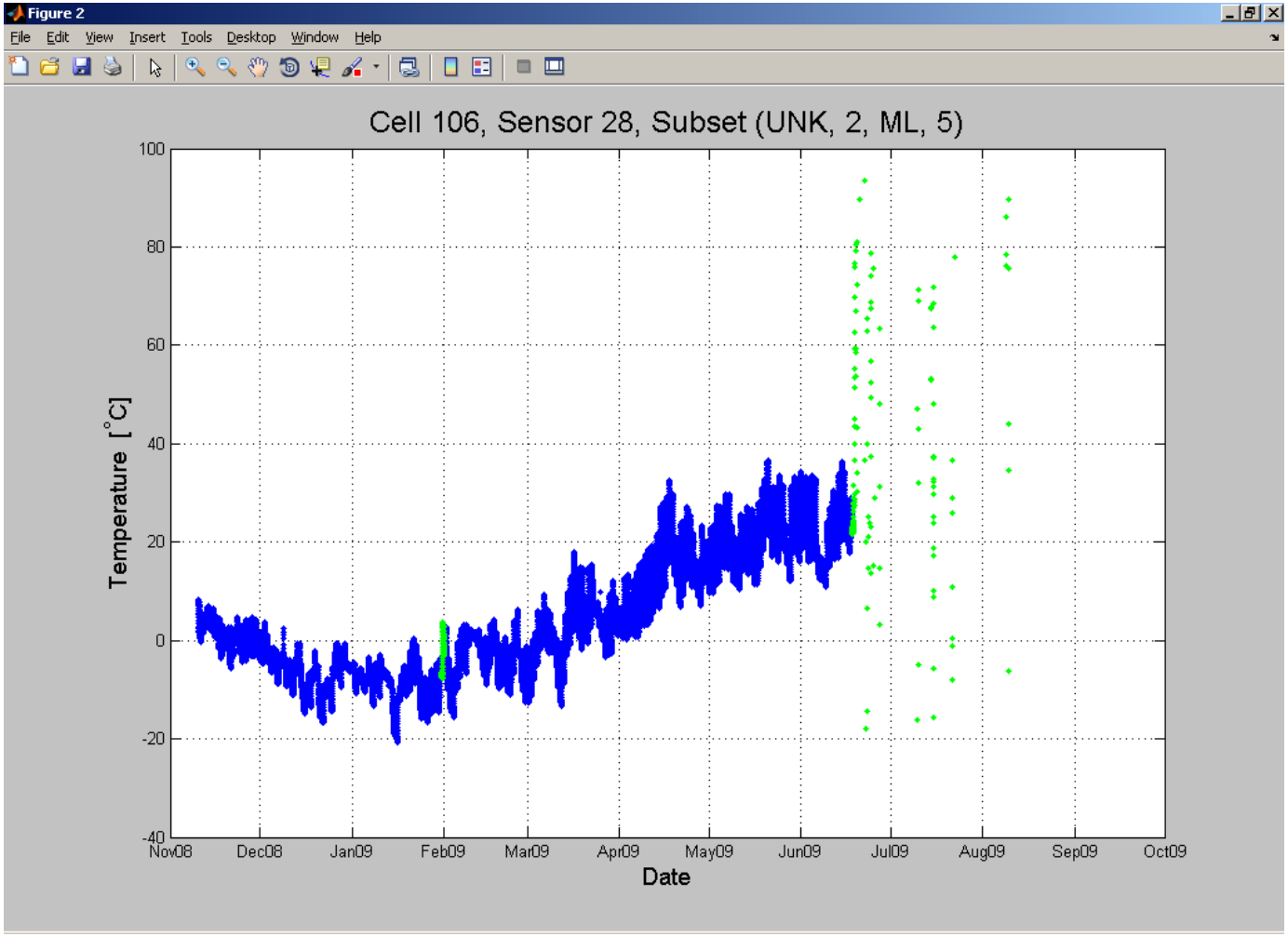
According to the Enhanced Integrated Climate Model (EICM), presence of the asphalt layer reduces temperature gradients in the concrete slab.

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

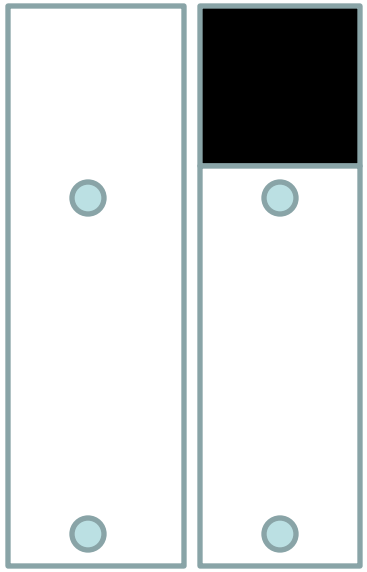
113	213	313	106	206
			2"64-34	2"64-34
5"	5.5"	6"	5"	5"
5"Cl 1 Stab Agg	5"Cl 1 Stab Agg	5"Cl 1 Stab Agg	6" Cl 1 Stab Agg	6" Cl 1 Stab Agg
5" Class 5	4.5" Class 5	4" Class 5	6" Class 5	6" Class 5
Clay	Clay	Clay	Clay	Clay
heavy turf	heavy turf	heavy turf	Mesabi 4.75 SuperP	Mesabi 4.75 SuperP
15'x12'	15'x12'	15'x12'	15'x12' 1" dowel	15'x12' no dowels
Oct 08	Oct 08	Oct 08	Oct 08	Oct 08
Current	Current	Current	Current	Current

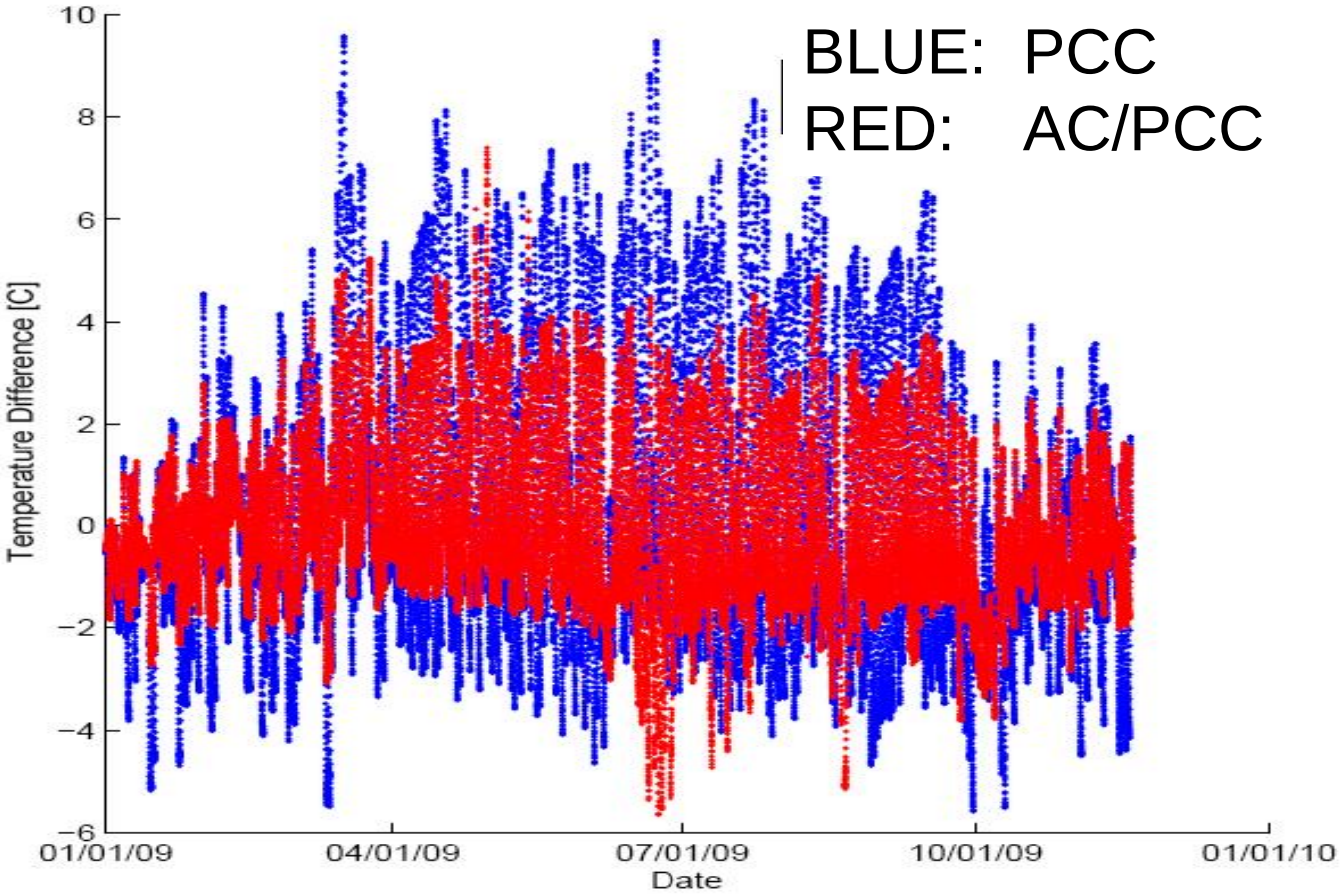
Example of Data Screening

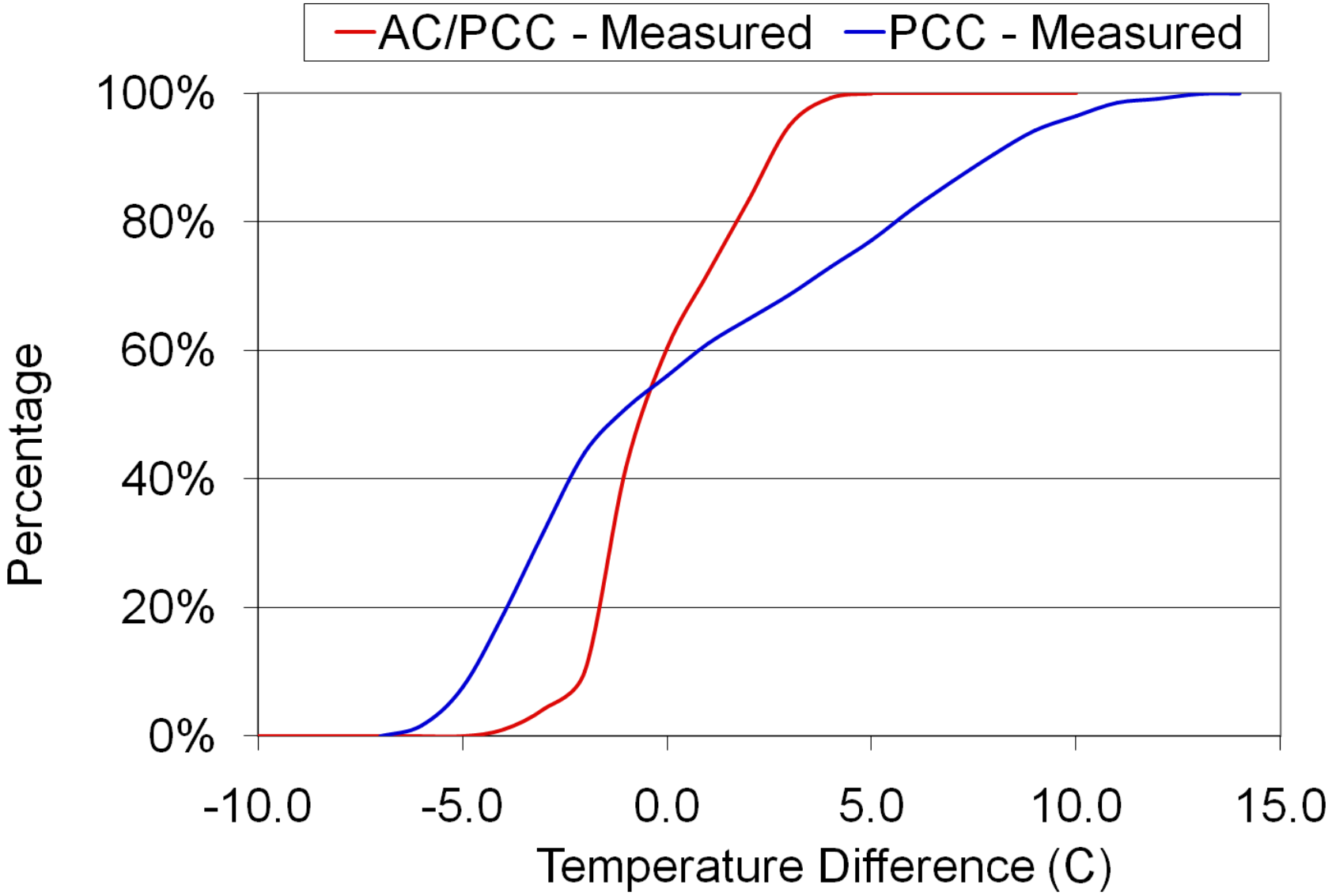


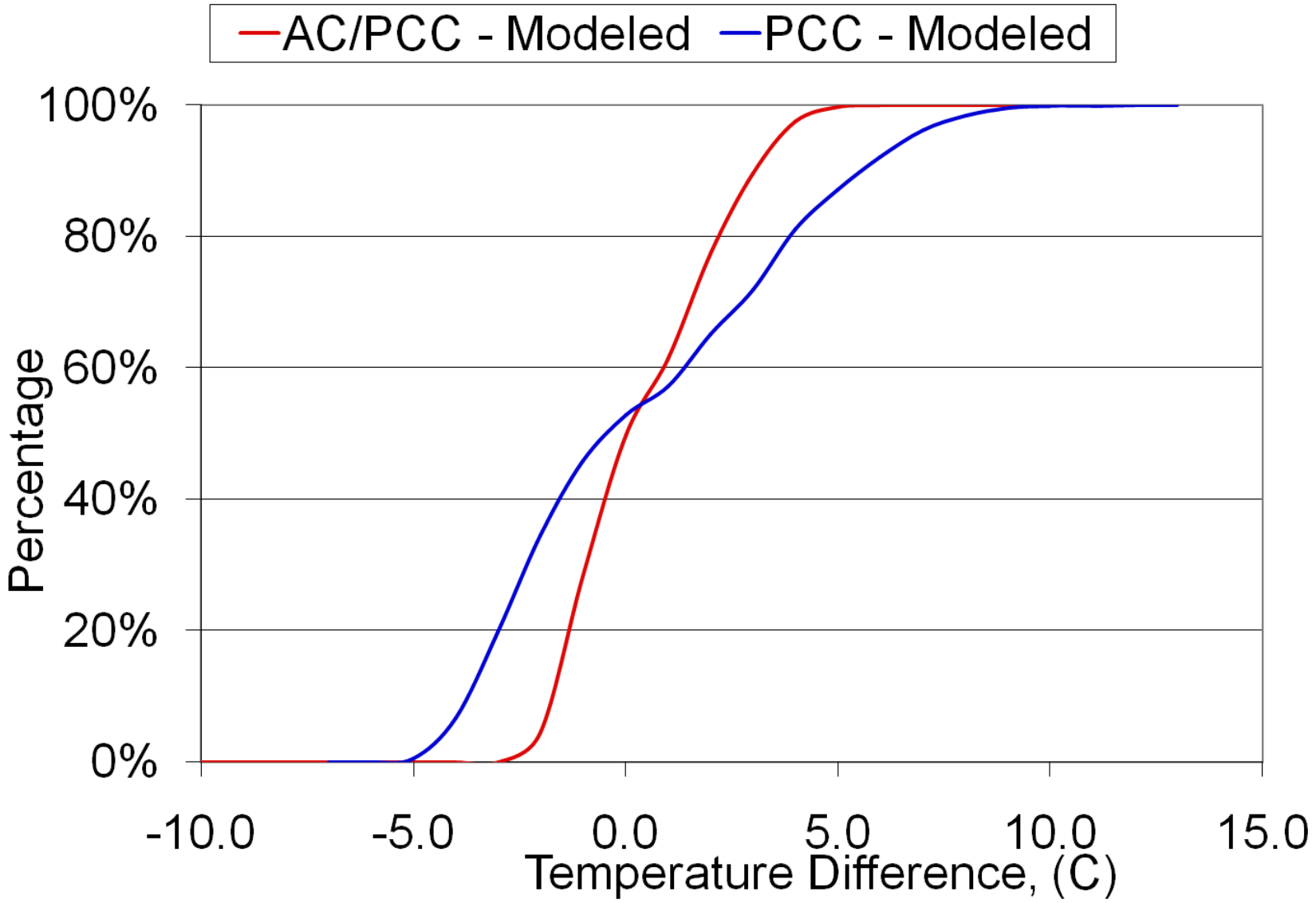
Thermal Gradients in PCC

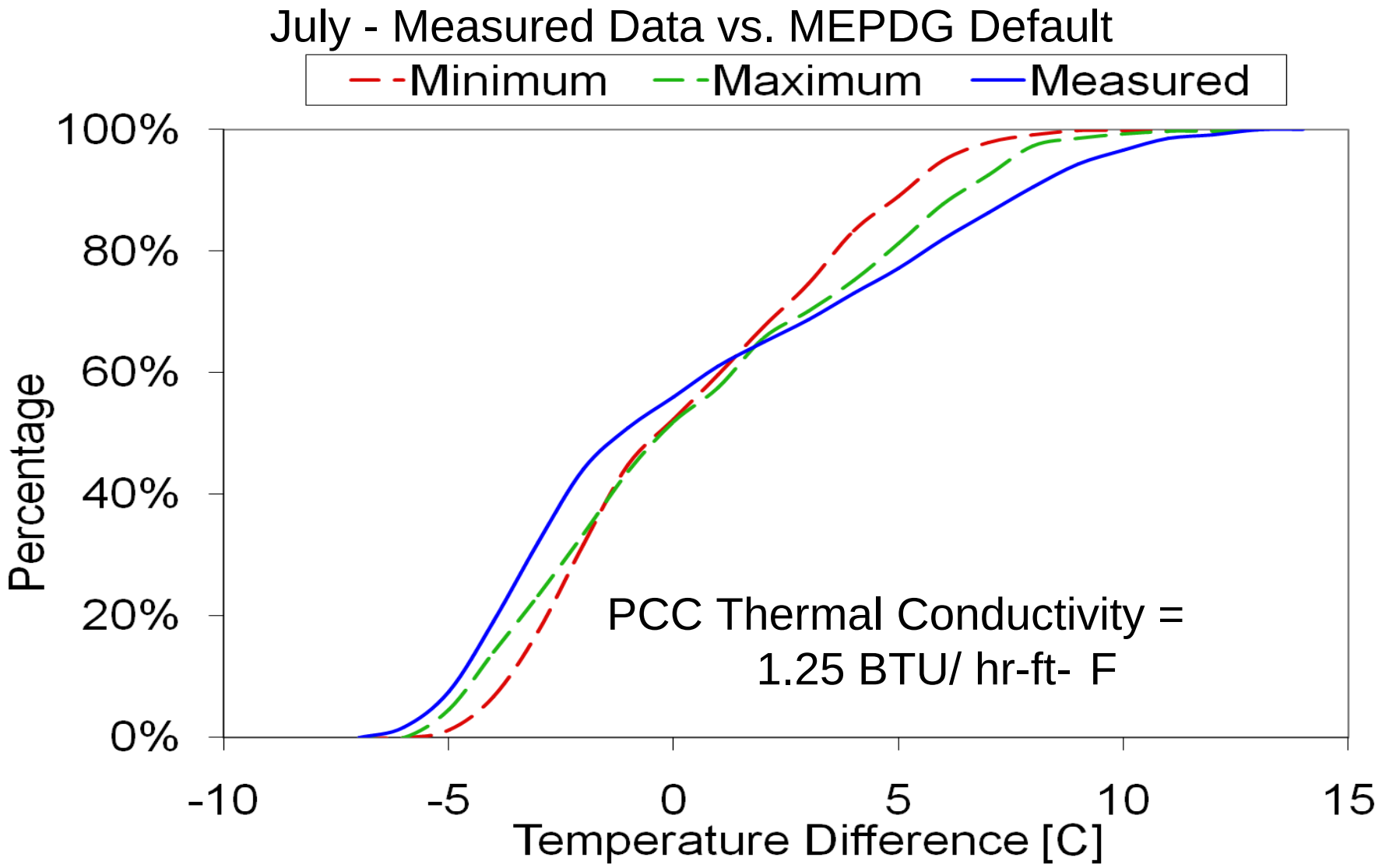
PCC AC/PCC





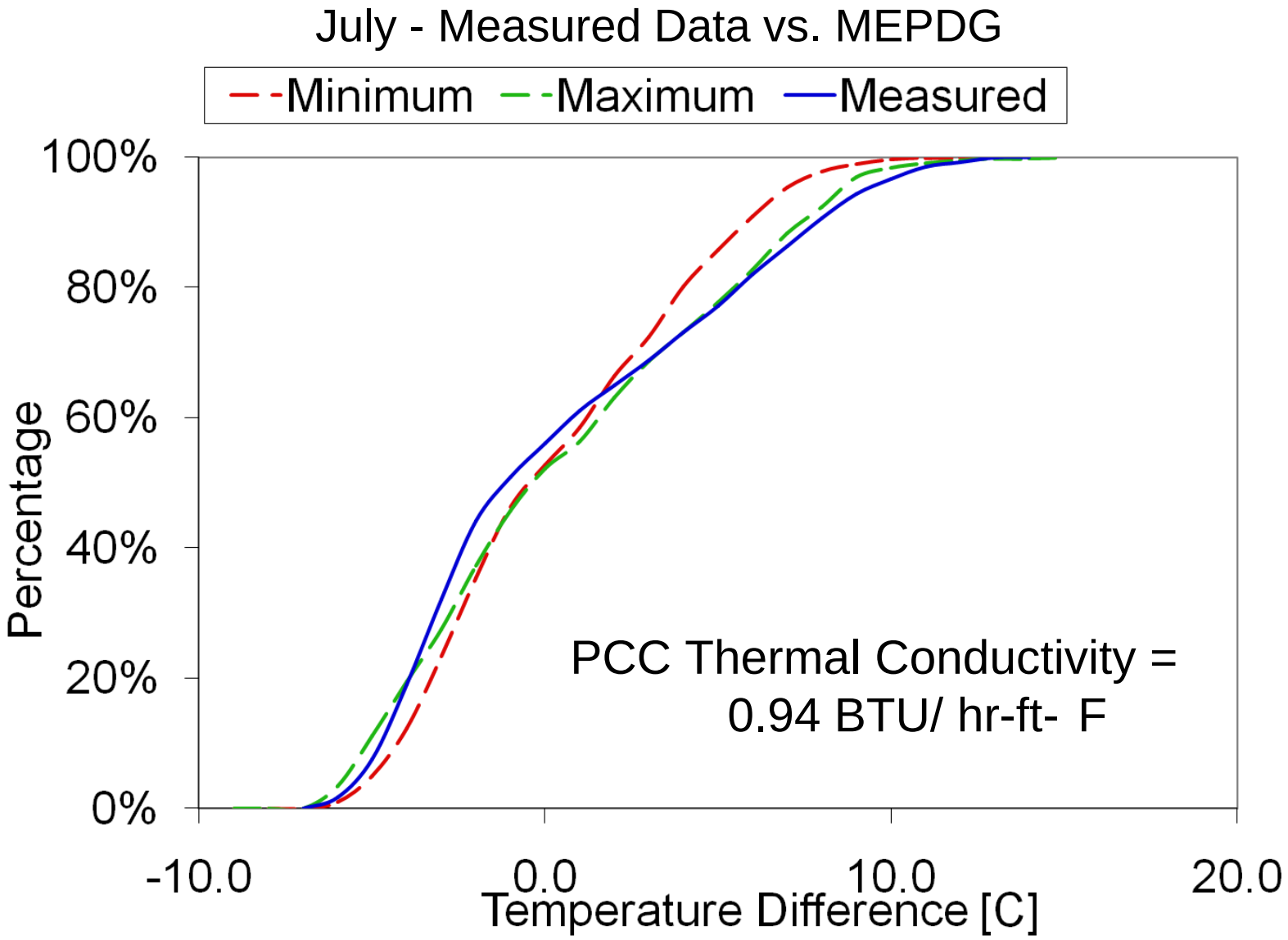

AC/PCC - Measured
PCC - Measured
100%
80%
60%
40%
20%
0%
Percentage
-10.0
-5.0
0.0
5.0
10.0
15.0
Temperature Difference (C)


AC/PCC - Modeled
PCC - Modeled
100%
80%
60%
40%
20%
0%
Percentage
-10.0
-5.0
0.0
5.0
10.0
15.0
Temperature Difference, (C)

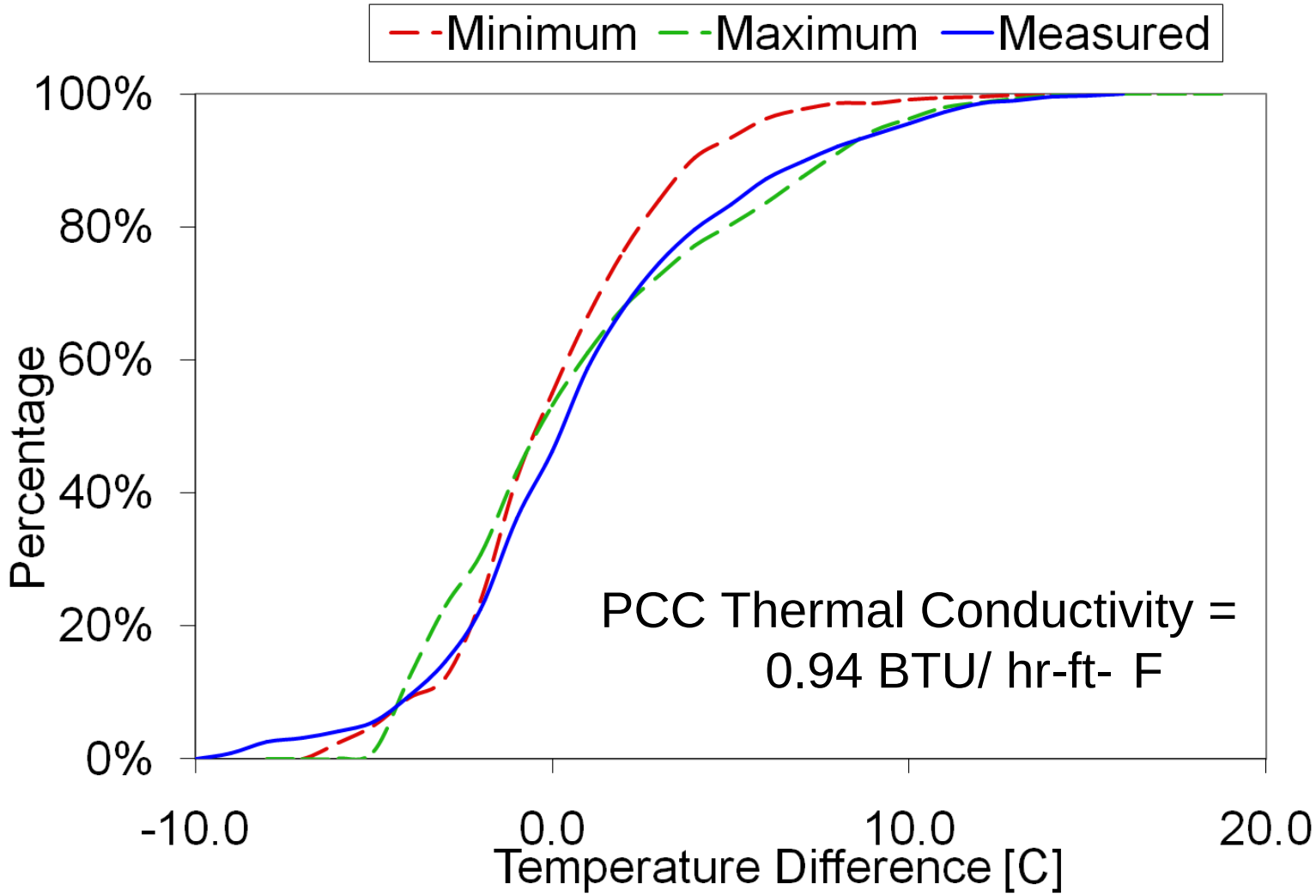

July - Measured Data vs. MEPDG Default
Minimum
Maximum
Measured
100%
80%
60%
40%
20%
0%
Percentage
PCC Thermal Conductivity =
1.25 BTU/ hr-ft- F
-10
-5
0
5
10
15
Temperature Difference [C]

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


July - Measured Data vs. MEPDG
Minimum
Maximum
Measured
100%
80%
60%
40%
20%
0%
Percentage
PCC Thermal Conductivity =
0.94 BTU/ hr-ft- F
-10.0
0.0
10.0
20.0
Temperature Difference [C]

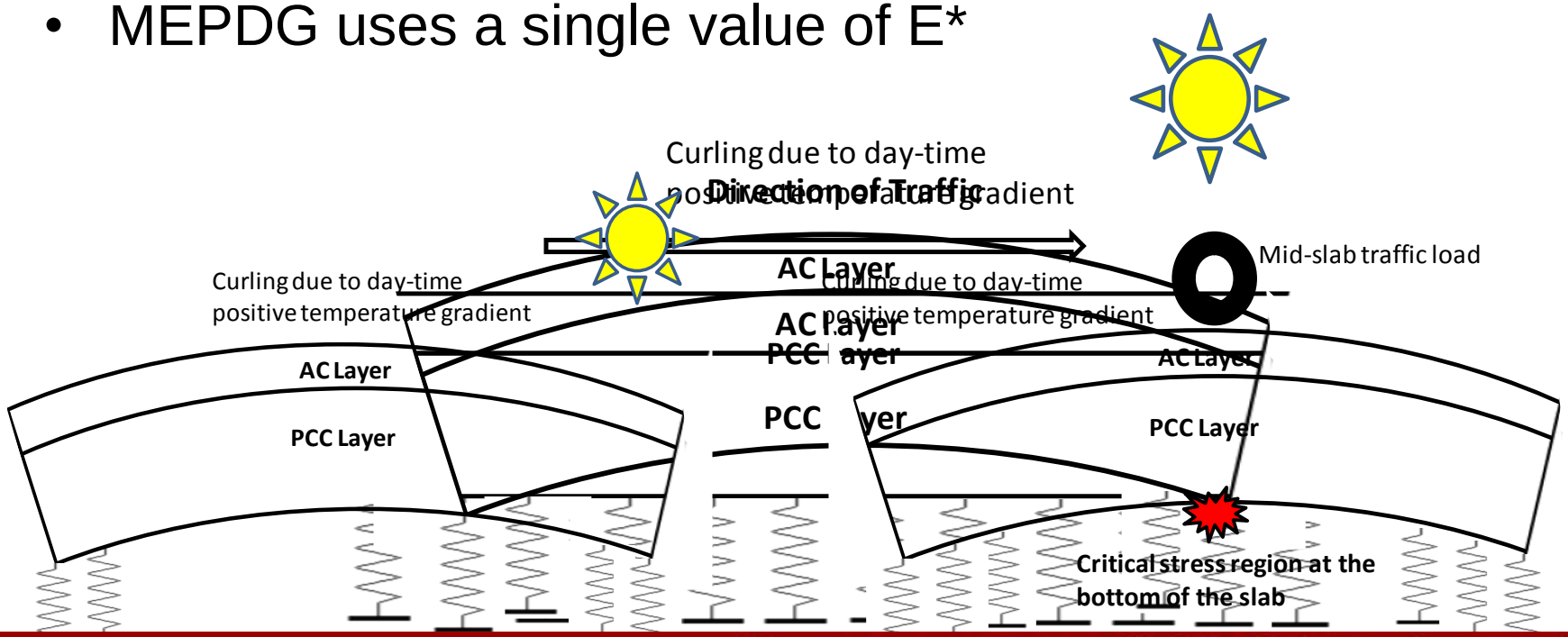
Independent Verification: March - Measured Data vs. MEPDG



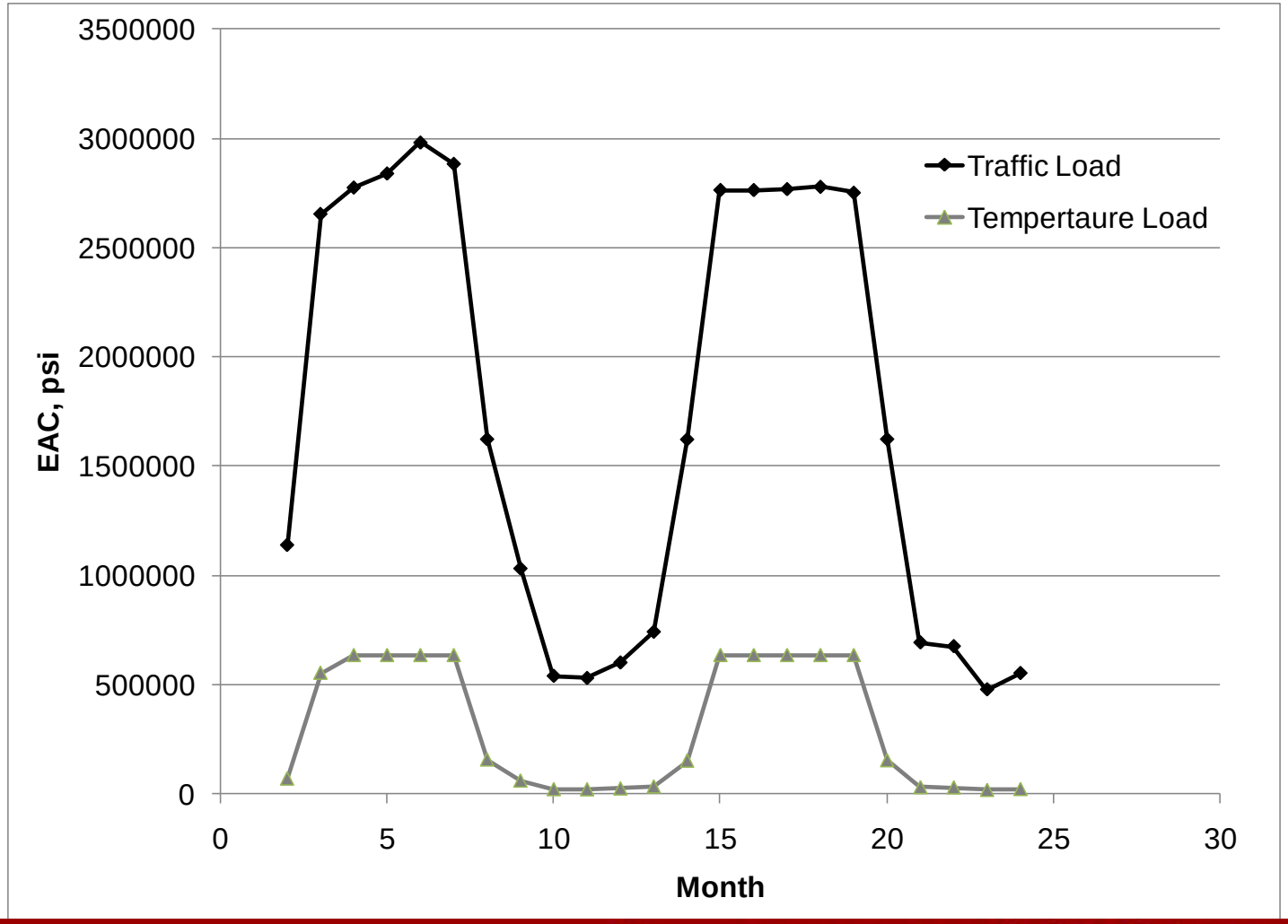
Conclusions

- Presence of an AC overlay reduces temperature gradients in the PCC layer
- EICM qualitatively captures this effect
- High quality MnROAD data provide an opportunity to calibrate and validate the EICM

- Composite pavement is subjected to
  - Temperature gradients (long duration)
  - Traffic loads (short duration)
- Asphalt properties are time-dependent
- MEPDG uses a single value of E*



Effect of Load Duration on MEPDG Asphalt E*



Two Alternatives

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

Two-moduli approach

- Different moduli for curling and axle load analysis
- Both moduli are determined using the MEPDG procedure
- Stress computation involves analysis of three elastic problems

- 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

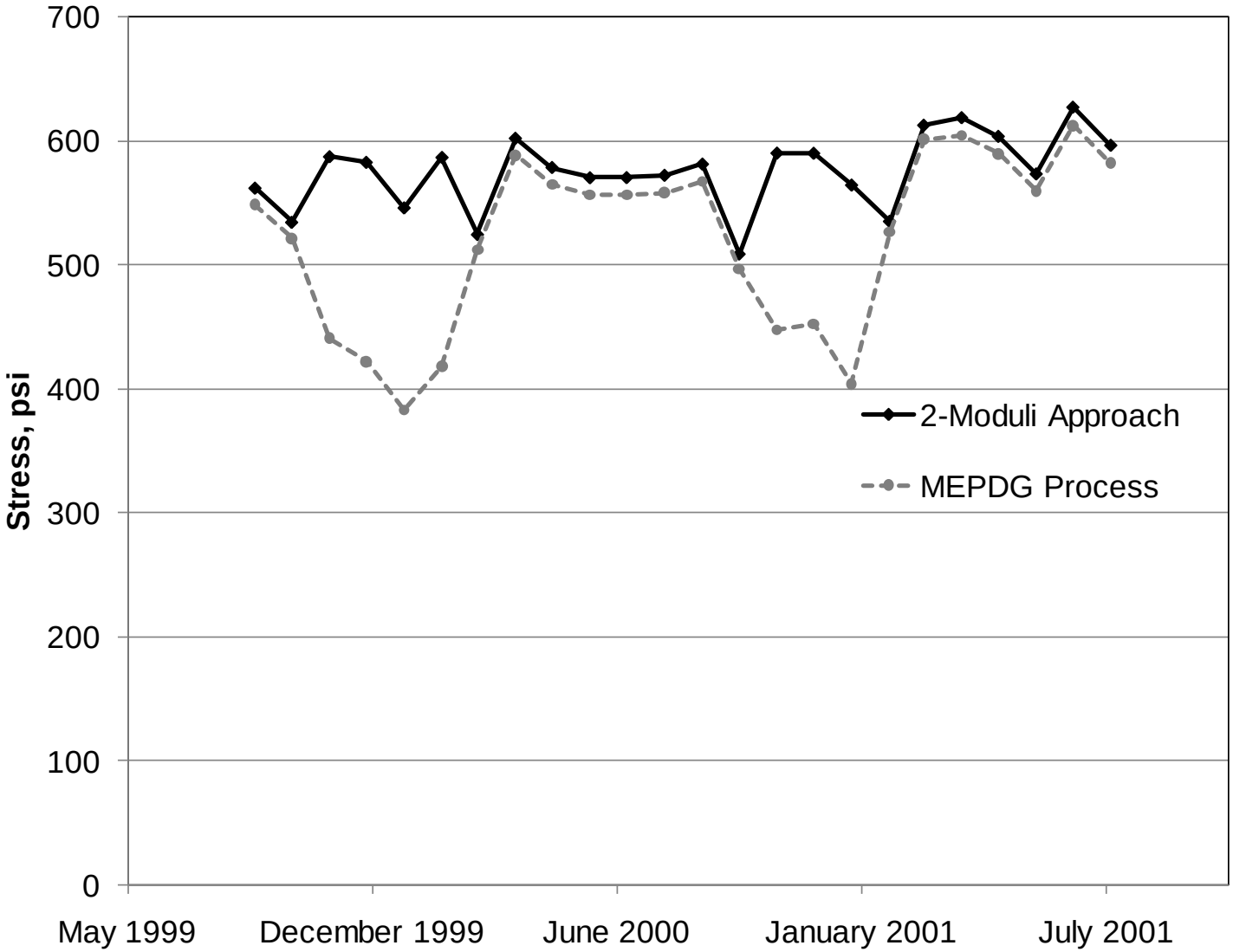
Evaluation of Response Models

- 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

Evaluation of Response Models



Conclusions

- 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

Ongoing Work

- Modification of the MEPDG cracking model
- Incorporation of CalME AC Rutting model (UC Davis) into the MEPDG framework
- Development of construction guidelines
- Synthesis