Rigid Pavement Climatic Effects in Illinois

Jeffery Roesler, Ph.D., P.E.
Associate Professor
Department of Civil and Environmental Engineering
University of Illinois

North Central M-EPDG User's Group Meeting
Ames, IA
February 19-20, 2008

ILLINOIS CENTER FOR TRANSPORTATION

Acknowledgements

- ICT R57 – Technical Review Panel (2005-08)
  - Illinois Department of Transportation
    - Amy Schutzbach et al.

- UIUC Students
  - Jake Hiller
  - Dong Wang
  - Victor Cervantes
  - Matt Beyer
  - Amanda Bordelon

ILLINOIS CENTER FOR TRANSPORTATION

Overview

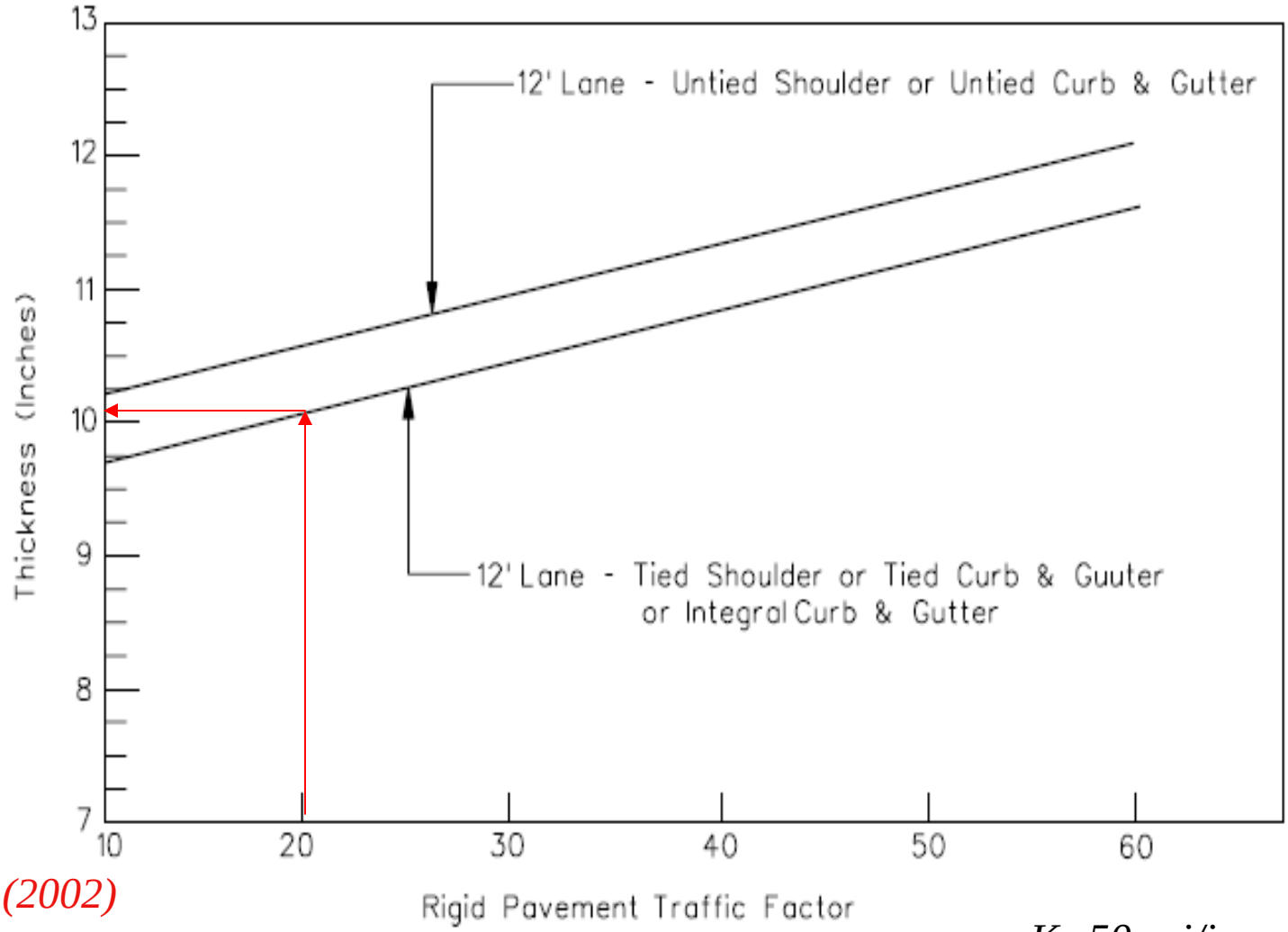
- Illinois has existing M-E JPCP method by Zollinger and Barenberg (1989)
  - No direct climate consideration
- IDOT has an semi-empirical method to determine CRCP thickness
  - No direct climate consideration
- Update/refine existing JPCP procedure and develop M-E CRCP design method

Existing IDOT JPCP Method

- Traffic = ESALs
- MOR = 703 psi *(?)*
- k-value = 50, 100, 200 psi/in
- Temperature curling (k=100 psi/in)
- Joint Spacing = 15ft
- Shoulder Type = AC or Tied [widen]
- Reliability (95% curves)
- Failure = 20% slabs cracked – TF>10
- COPES data calibration

ILLINOIS CENTER FOR TRANSPORTATION

IDOT M-E JPCP Method



IDOT (2002)

K=50 psi/in

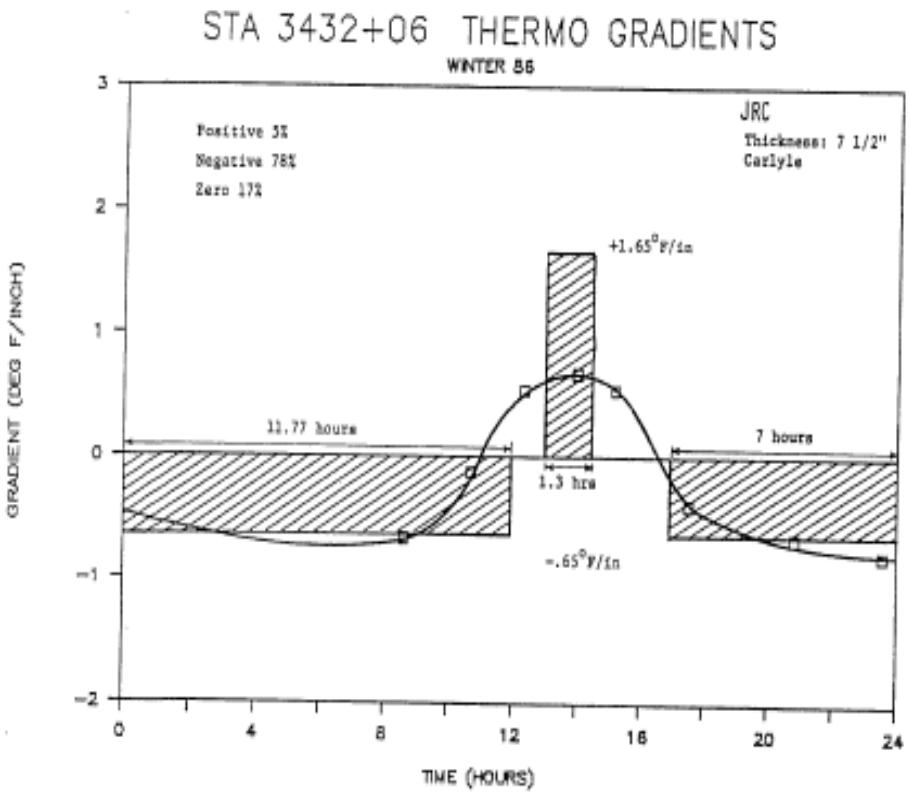
ILLINOIS CENTER FOR TRANSPORTATION

IDOT assumed Thermal Gradients

35% Night (-0.65°F/in)

25% Day (+1.65°F/in)

40% Zero (0°F/in)



ILLINOIS CENTER FOR TRANSPORTATION

M-EPDG Evaluation

- Objective
  - Evaluate version 0.91 vs. 1.0
  - Determine effect of Climate on PCC thickness in Illinois
  - Is there a need for a geography / climate-based design method in Illinois?

ILLINOIS CENTER FOR TRANSPORTATION

Concrete Coefficient of Thermal Expansion (COTE)

- Illinois SHRP Test Sites
  - 84 total cores

- $AVERAGE_{80\%} = 5.7x10^{-6}/°F$ (69 cores)
- $STD\ DEV_{80\%} = 0.33x10^{-6}/°F$
- COV = 6%

SHRP Test Site cores in Illinois

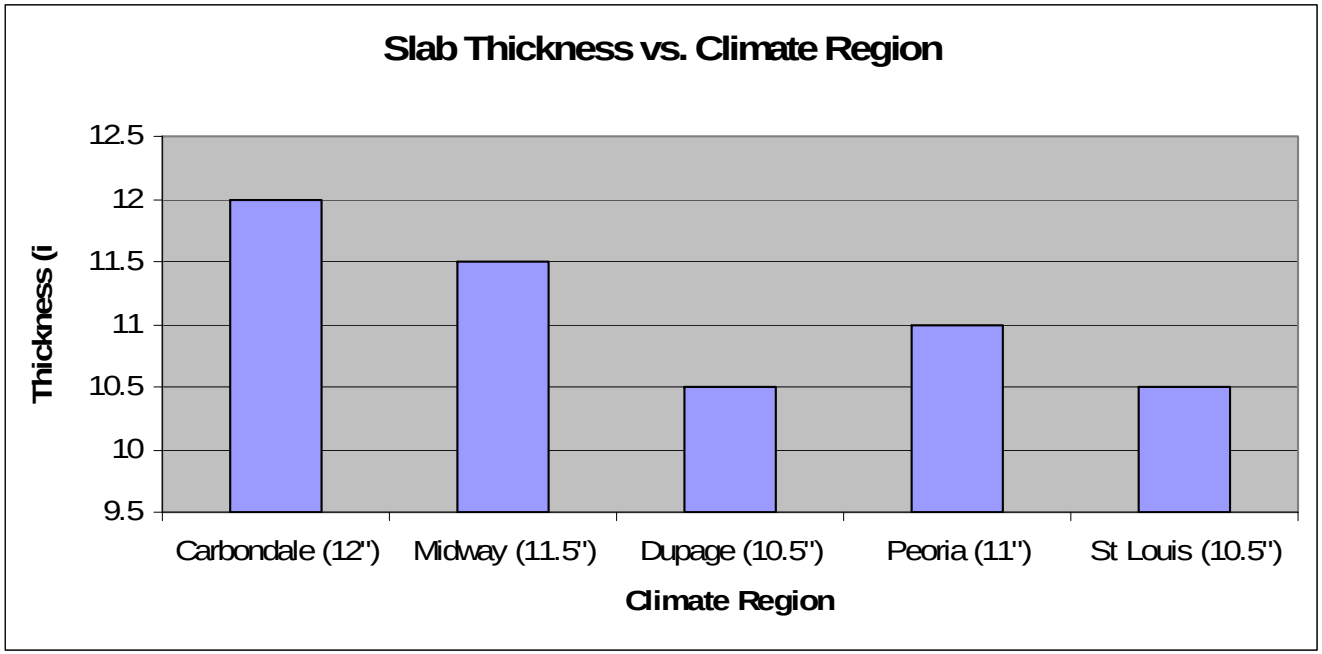
ILLINOIS CENTER FOR TRANSPORTATION

Climate Effect Inputs

- Changes in Climatic Effects
  - Climate data for several Illinois cities ran with E-ICM

- Concrete thickness was changed to ensure less than 20% slab cracking for each climate
  - *No faulting or IRI criteria limit!*

Climatic Effects (v. 0.91)



- Five regions in Illinois
- Range of slab thickness – 10.5” to 12”
- Pavement at all sites had less than 20% cracking at 30 yrs

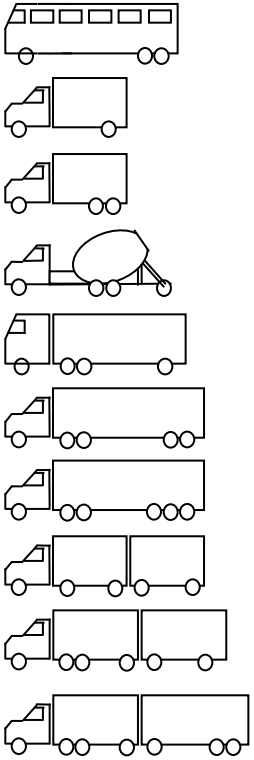
ILLINOIS CENTER FOR TRANSPORTATION

V.1.0 MEPDG / IDOT Inputs

- MEPDG (v1.0) default load spectra (TTC1)
- Illinois Vehicle Class Distribution
- Variables
  - Shoulder type (AC, tied, widen lane)
  - slab length (12, 15, 18 ft)
  - fatigue algorithm (MEPDG)
  - temperature profile (linear, nonlinear)
  - built-in curl (-10°F)

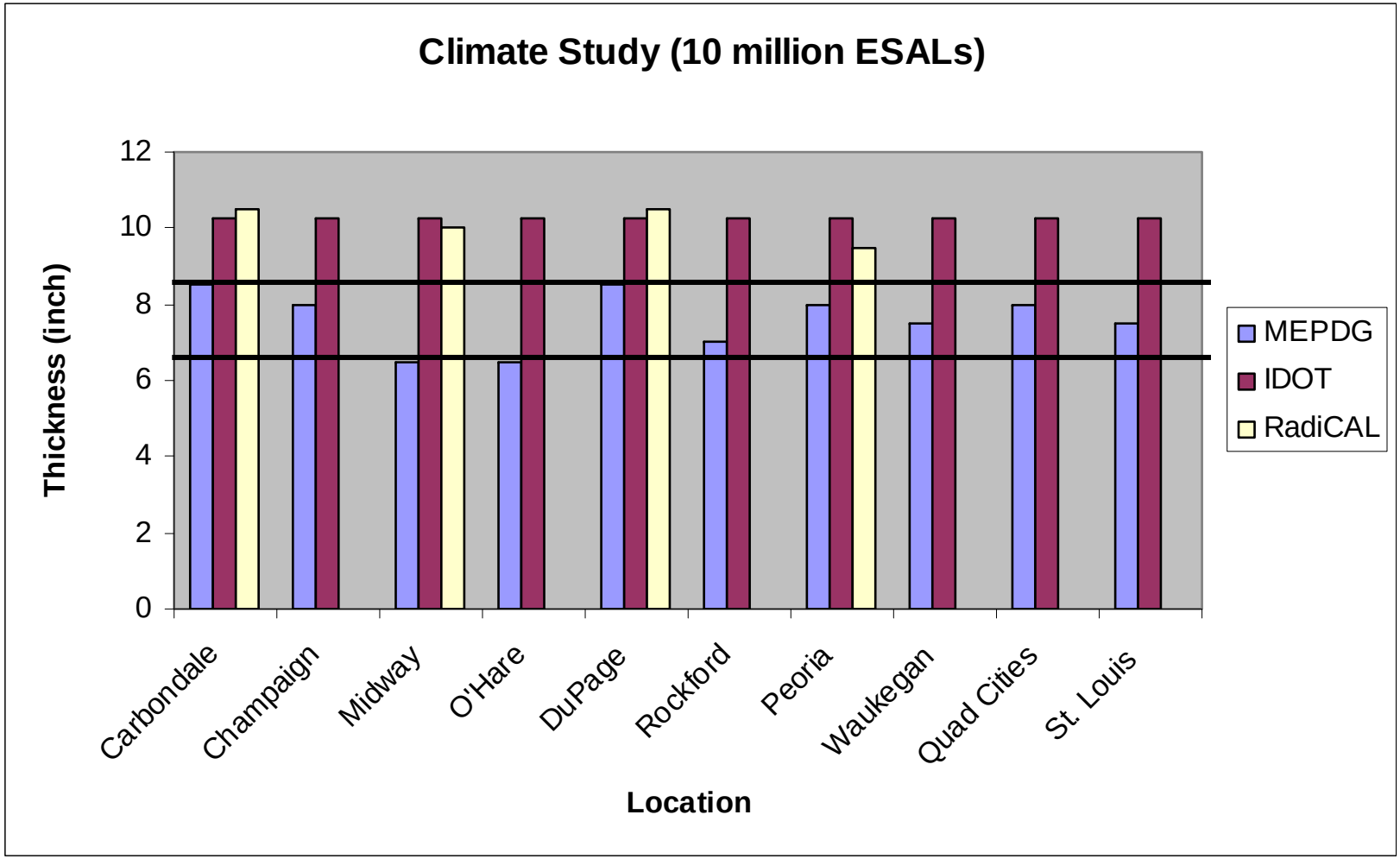
Vehicle Class distribution

Class	*Illinois*	*California*	*M-EPDG*
Class 4	1.4%	1.1%	1.8%
Class 5	3.8%	23.0%	24.6%
Class 6	2.3%	5.2%	7.6%
Class 7	0.0%	0.3%	0.5%
Class 8	3.8%	6.7%	5.0%
Class 9	84.4%	50.6%	31.3%
Class 10	0.5%	0.6%	9.8%
Class 11	2.8%	8.8%	0.8%
Class 12	0.3%	1.1%	3.3%
Class 13	0.3%	0.1%	15.3%



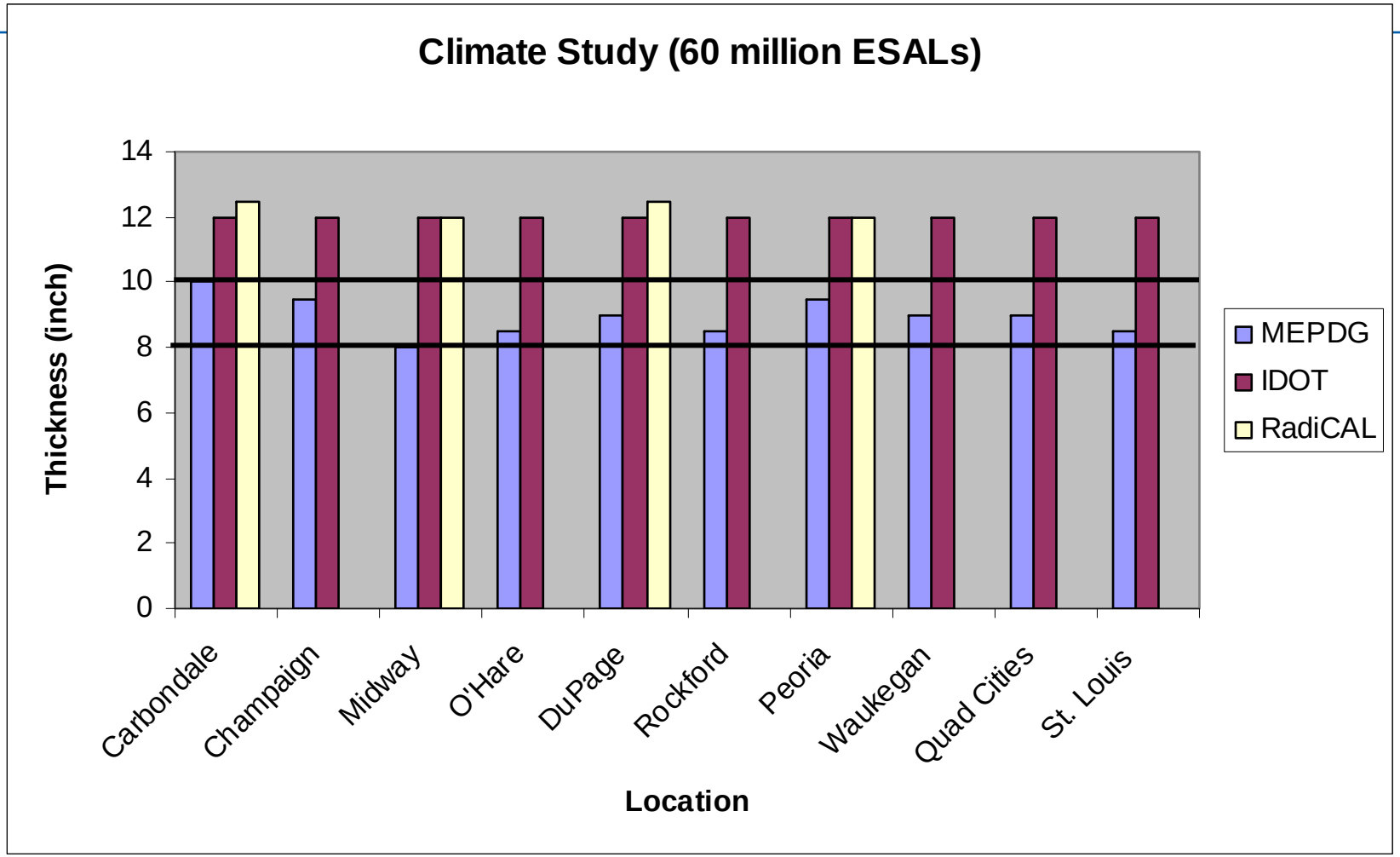
ILLINOIS CENTER FOR TRANSPORTATION

Climate Study – $10x10^6$ ESALs



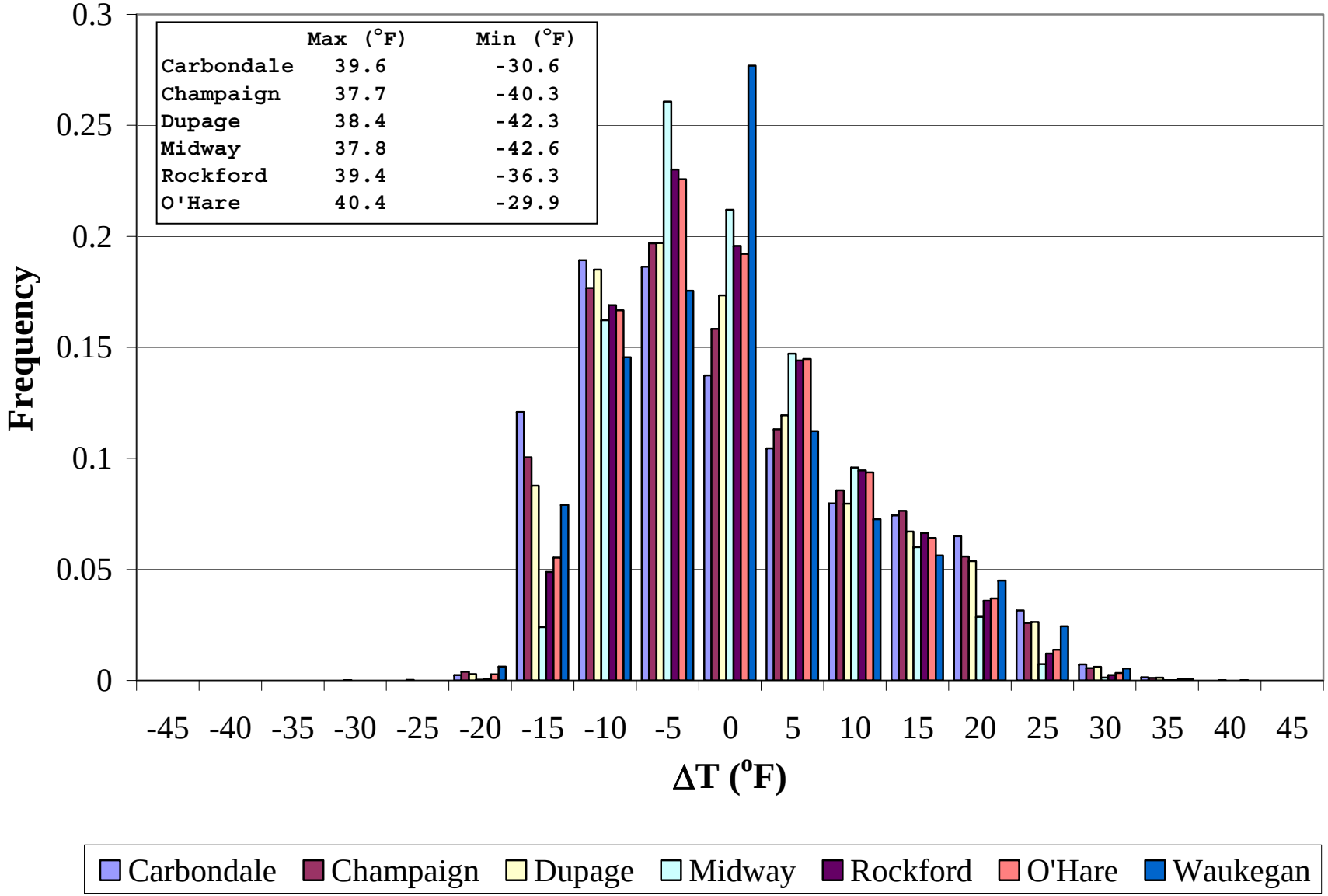
ILLINOIS CENTER FOR TRANSPORTATION

Climate Study – 60×10^6 ESALs

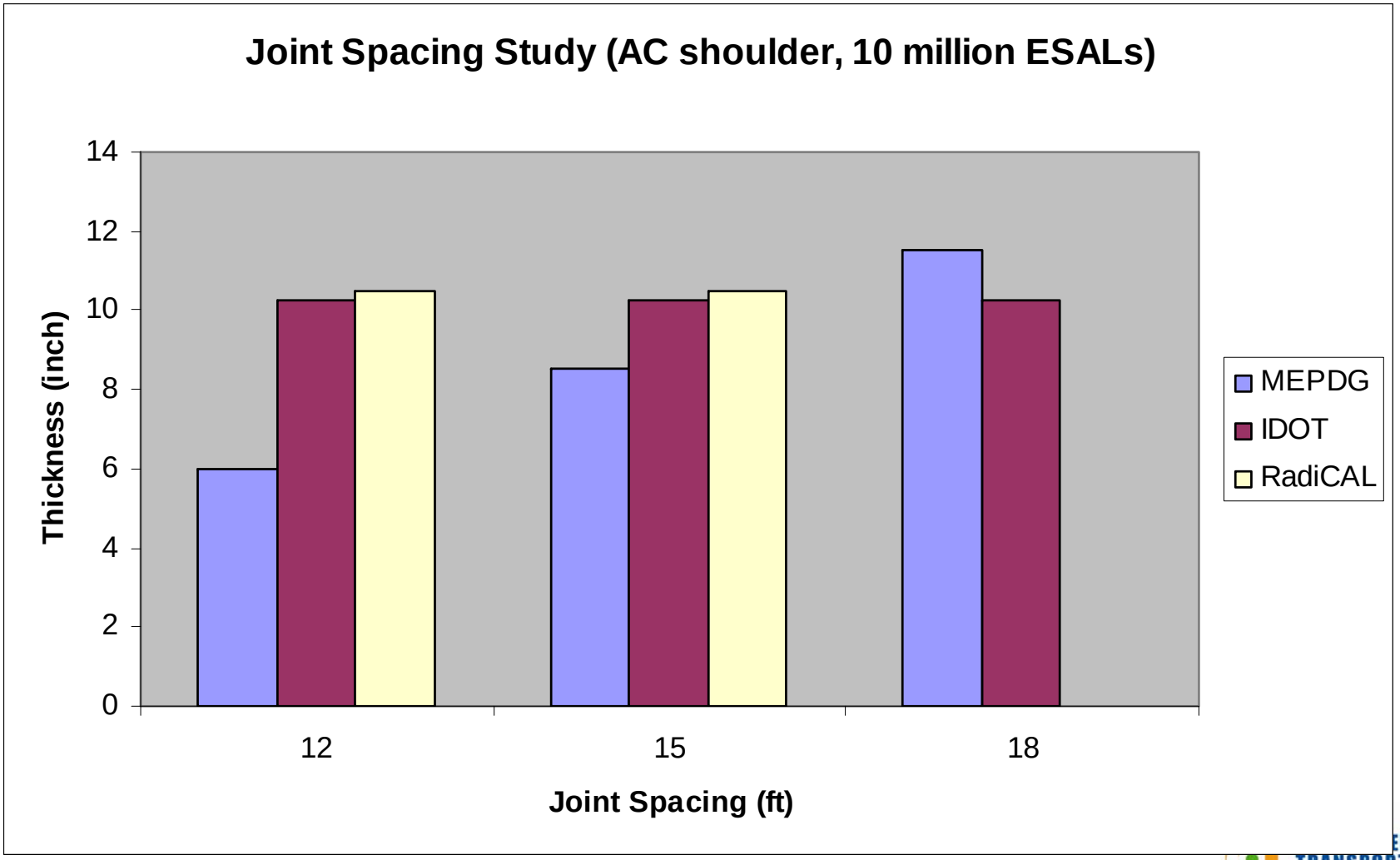


ILLINOIS CENTER FOR TRANSPORTATION

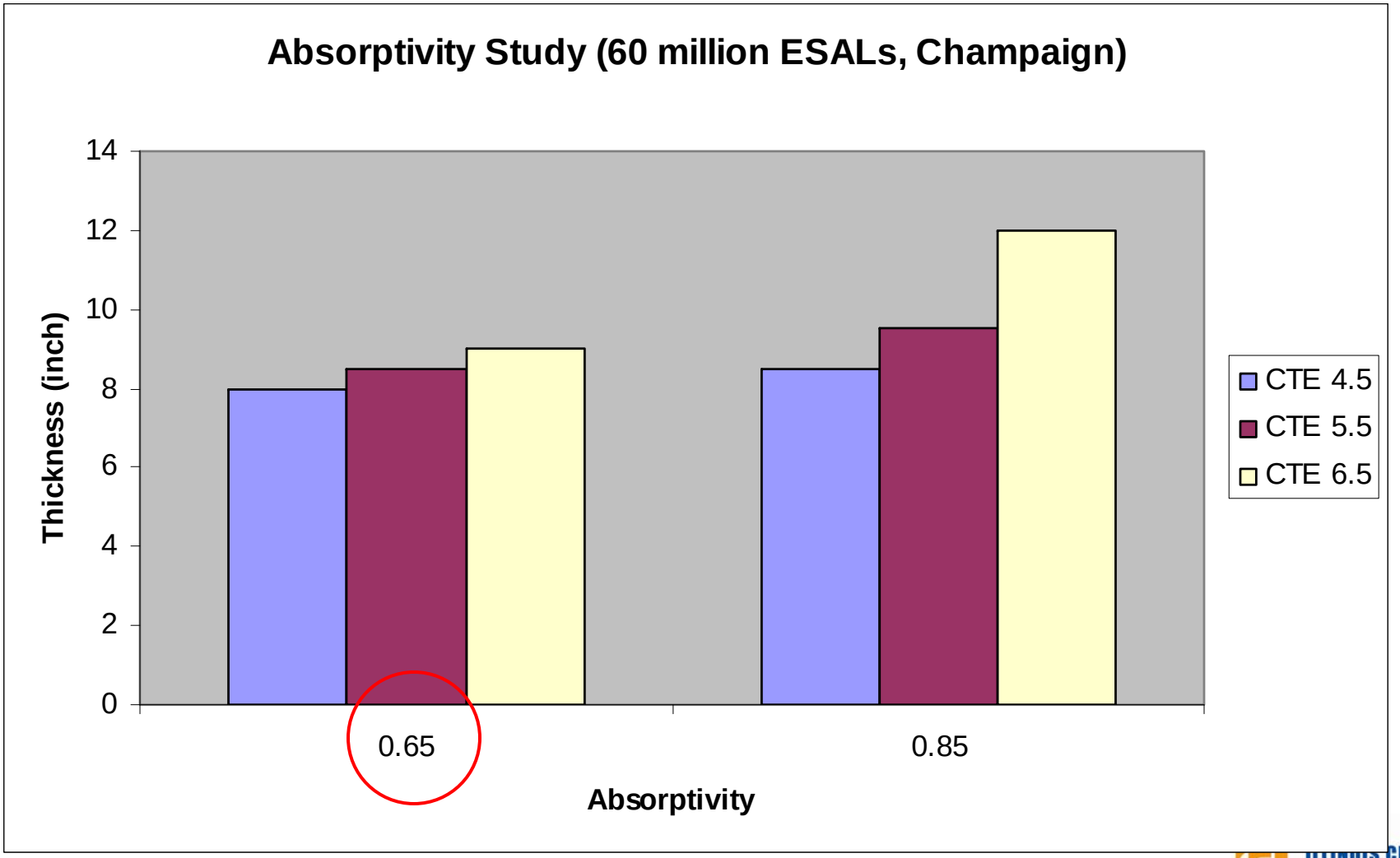
Temperature Differential Freq.



Joint Spacing – 10M ESALs and AC Shoulder



Thermal Properties



ILLINOIS CENTER FOR TRANSPORTATION

Findings – CLIMATE -JPCP

Climate

- Sensitive (1.5” to 2”)
- How to accommodate?

- Temperature Curling
  - Nonlinear is more representative

ILLINOIS CENTER FOR TRANSPORTATION

(IL) Climatic Zone Consideration

- Separate CHART for state zones (?)

<u>Design Feature limitations</u> (h>10 inches)

- ≤15’ south of I-80?
- 18’ use structural fibers or higher specified strength

- For h ≤ 10 inches
- 12’ south of I-80?

DRAFT

Initial MEPDG (v1.0) CRCP Analysis

- Concrete Materials
  - MOR = 585 psi at 28 days (3rd point bending)
  - Cement content: 550 lbs/cy (w/c=0.42)
  - COTE = 5.5 x 10^{-6} /°F ***(absorbtivity=0.85)***

- Reinforcement
  - 20-year: 0.7% steel, #6 bars
  - 30-year: 0.8% steel, #7 bars
  - steel depth:
    - 3.5” for 10, 60 million ESALs
    - 4.5” for 230 million ESALs

- -10°F Built-in Curl

ILLINOIS CENTER FOR TRANSPORTATION

Traffic Inputs

- Bolingbrook Data
  - vehicle class distribution
- M-EPDG Default Values
  - hourly adjustment
  - axle load distribution
  - # of axle types/truck class
- Tire pressure = 80 psi

Vehicle Class	Bolingbrook (NB)
4	1.6%
5	4.6%
6	3.7%
7	0.0%
8	6.7%
9	79.0%
10	0.9%
11	3.5%
12	0.0%
13	0.0%

ILLINOIS CENTER FOR TRANSPORTATION

CRCP Traffic Assumptions

AADTT values for MEPDG v1.0

<u>20-year design</u>

10 million ESALs = 1,657 AADTT
60 million ESALs = 9,918 AADTT
230 million ESAls = 38,021 AADTT

<u>30-year design</u>

10 million ESALs = 1,105 AADTT
60 million ESALs = 6,612 AADTT
230 million ESAls = 25,347 AADTT

AADTT = Average Annual Daily Truck Traffic

ILLINOIS CENTER FOR TRANSPORTATION

Design Features

- *PCC thickness is design variable*
- Asphalt concrete base = 4 inch
- A-7-6 soil (E = 7,500 psi)

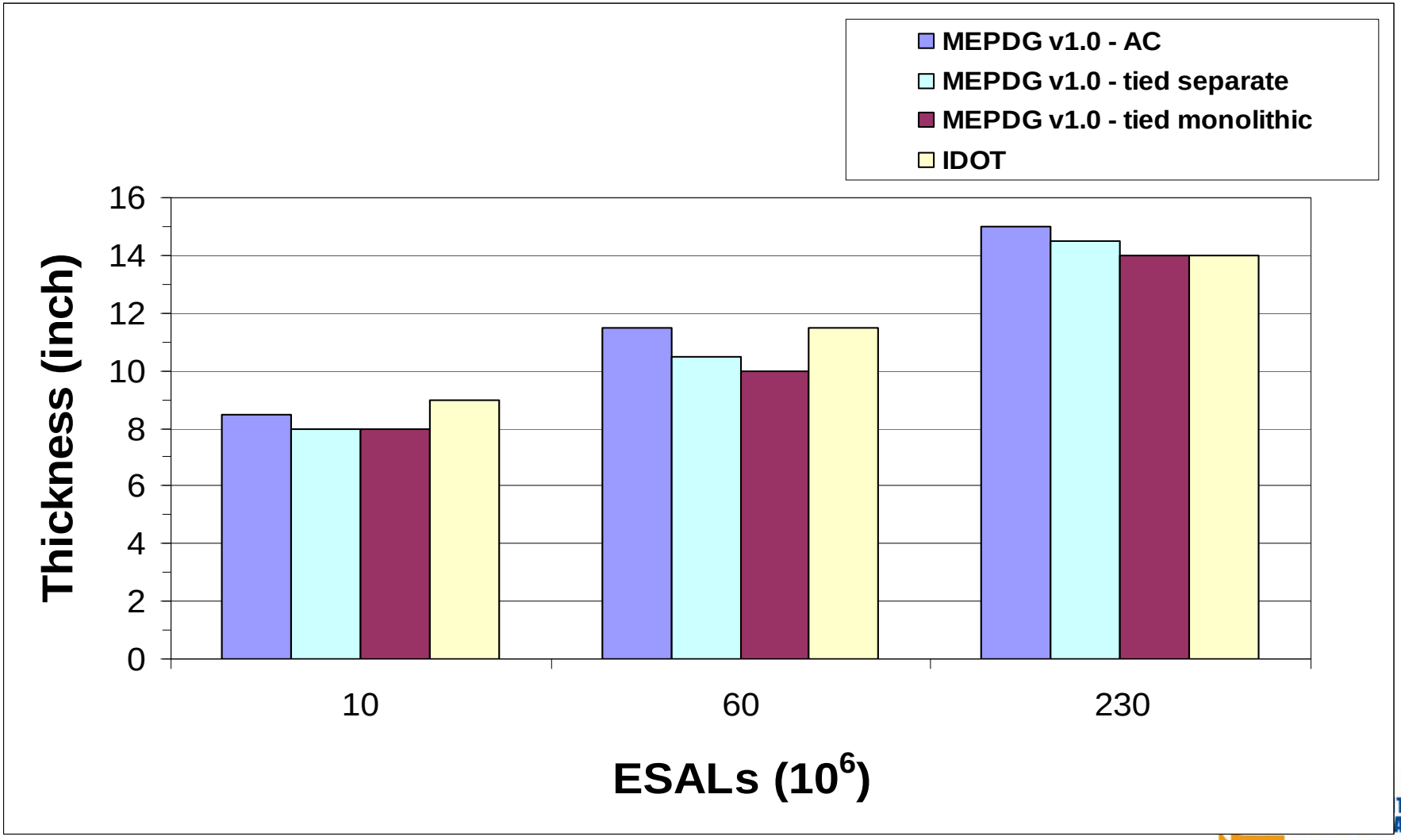
- Crack spacing = calculate

- Construction month = August

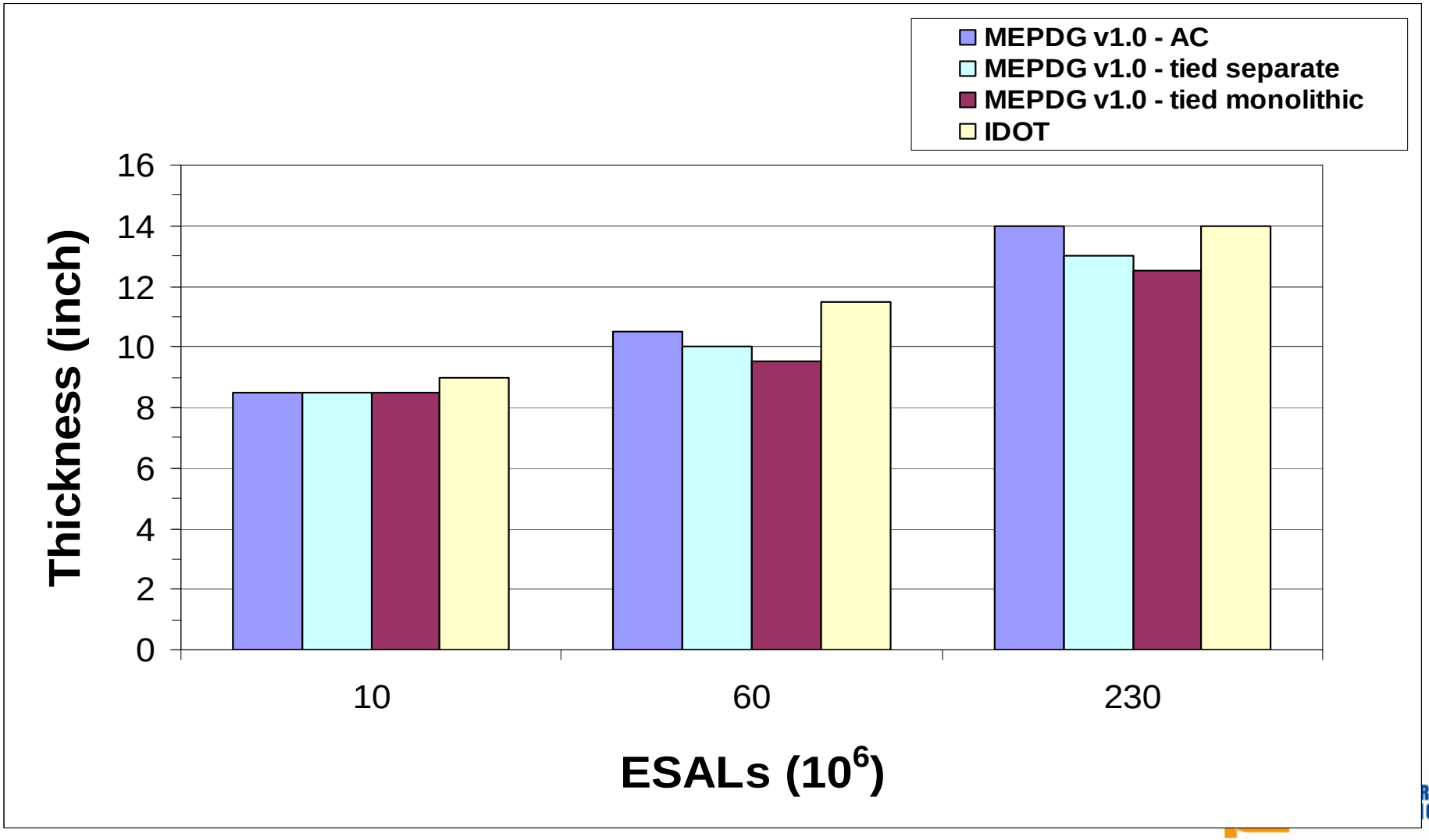
Failure Criteria

- Punchout = 10/mile @ 95% reliability
- IRI = ignore this failure criteria

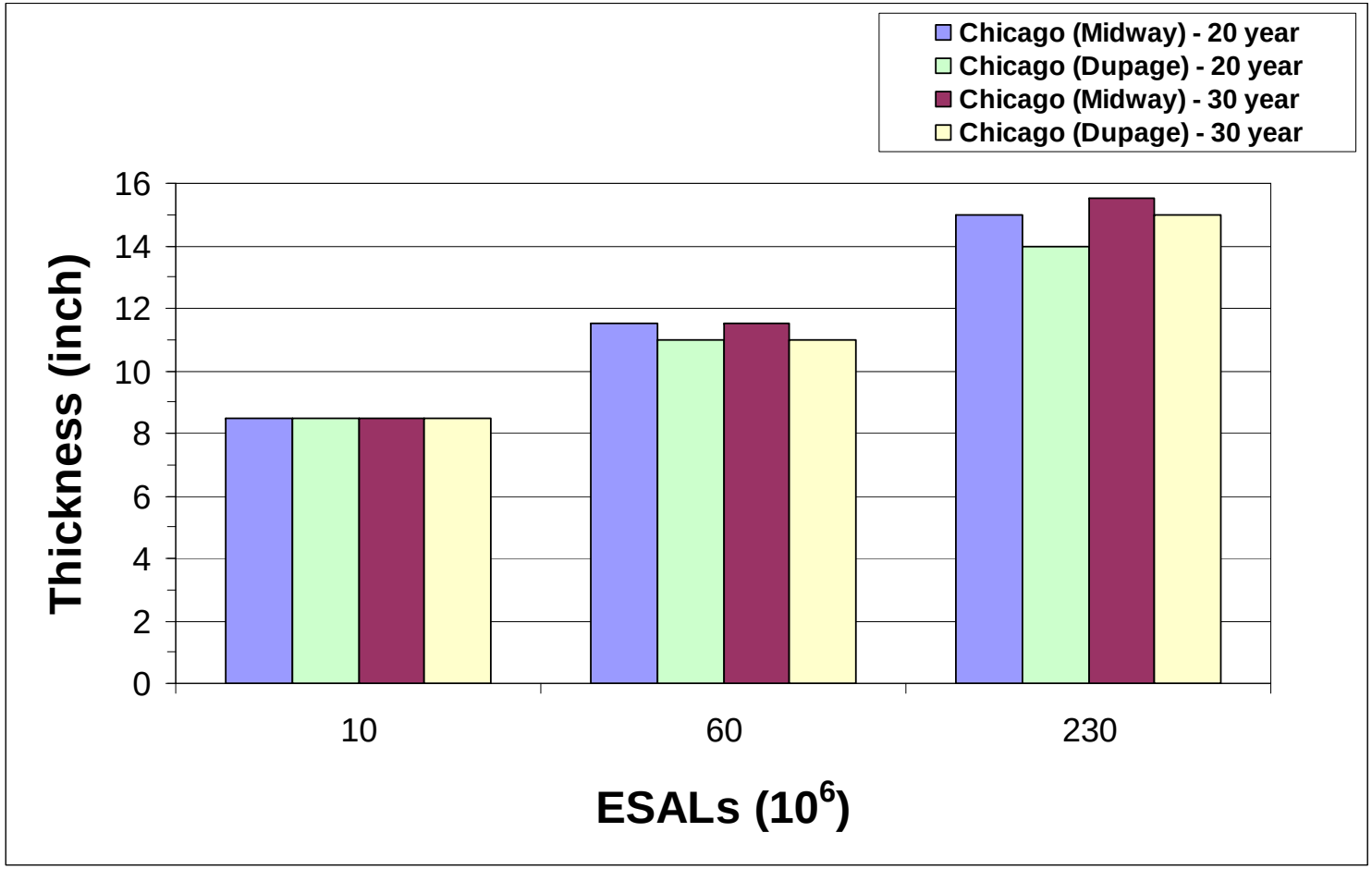
Chicago (Midway) [20 year]



Carbondale [20 year]



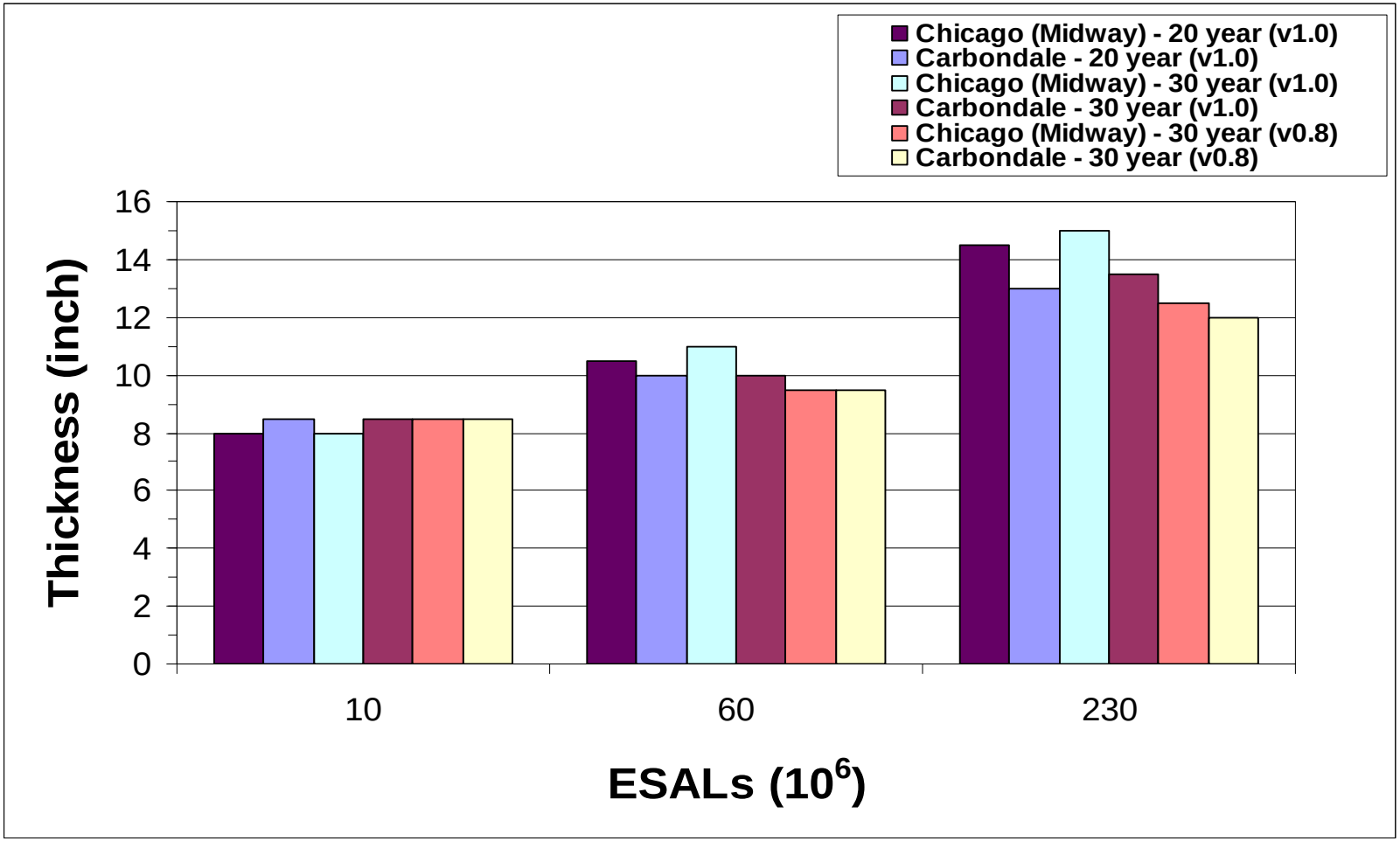
CRCP with AC shoulder (M-EPDG)



DUPAGE vs. Midway

ILLINOIS CENTER FOR TRANSPORTATION

CRCP with tied shoulder (separate)



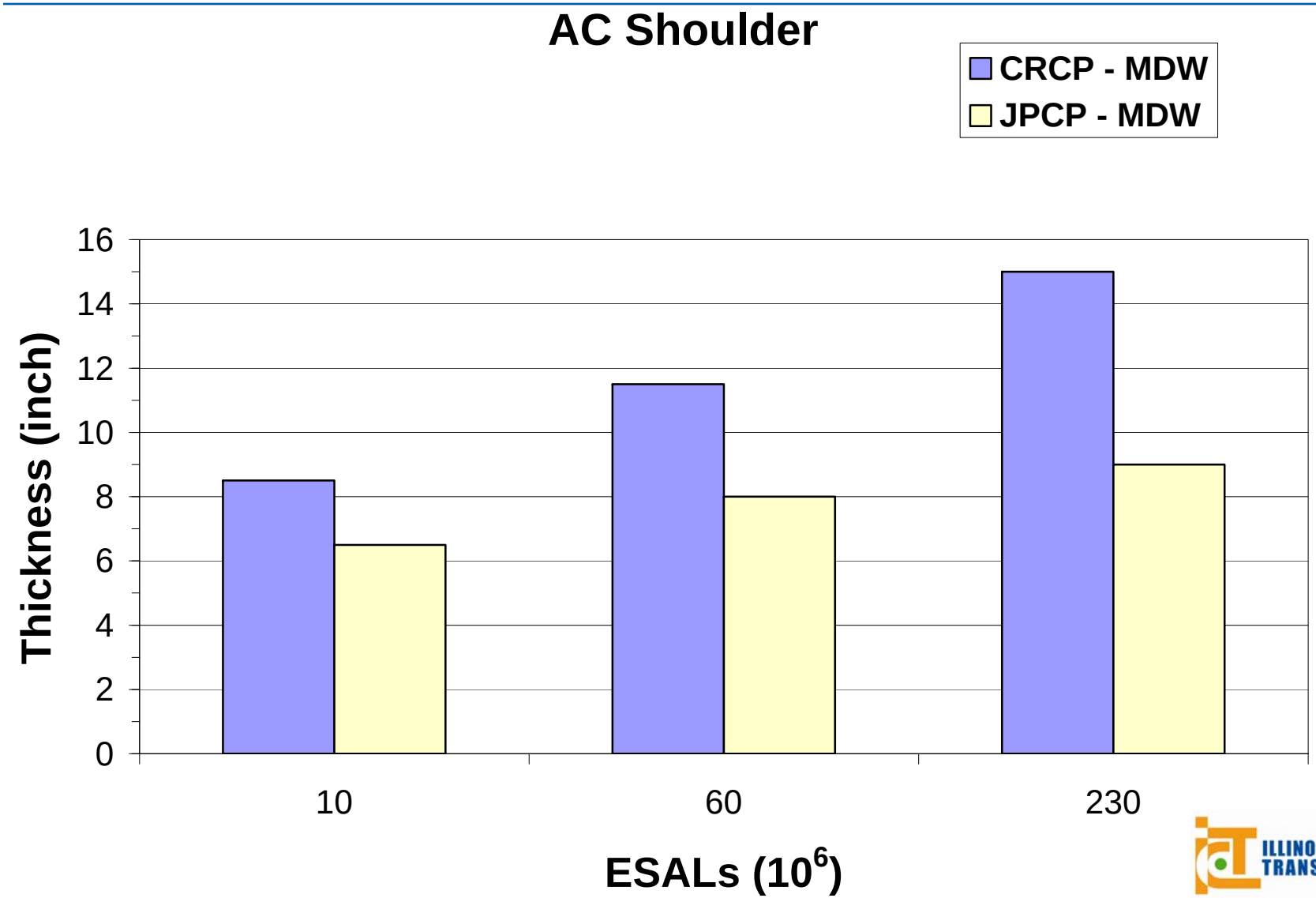
ILLINOIS CENTER FOR TRANSPORTATION

CRCP Summary

- CRCP MEPDG w/ AC shoulder most similar to IDOT method
- Climate thickness effects
  - Midway > Dupage = Carbondale
- 30 year design gives greater thickness than 20 year design @ constant ESAL
  - Different steel content

v_1.0

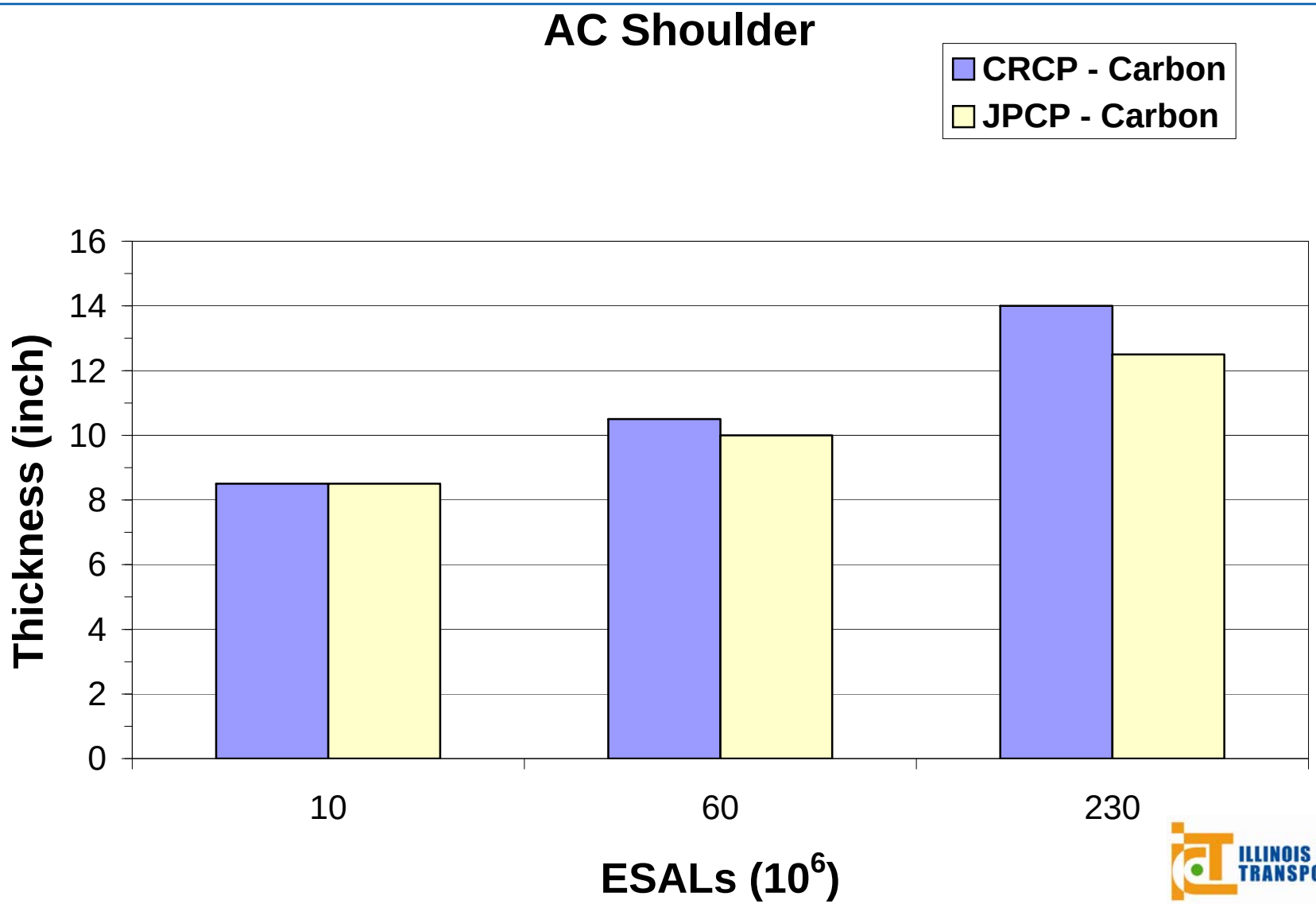
JPCP vs. CRCP (MDW)



ILLINOIS CENTER FOR TRANSPORTATION

v_1.0

JPCP vs. CRCP (Carbondale)



ILLINOIS CENTER FOR TRANSPORTATION

Summary

- There is a temperature effect but difficult to make it into a ***simple*** statewide design method.

- For JPCP
  - use joint spacing specifications to account for climate changes

- For CRCP: initial construction temperatures very important!

ILLINOIS CENTER FOR TRANSPORTATION

Potential - JPCP Calibration Data

- Appendix FF – MEPDG
  - JPCP and CRCP
  - Traffic, % cracking, load spectra
  - SHRP Sections, RPRR, COPES
  - 516 JPCP observations

- IDOT video surveys

MEPDG CRCP Calibration

- 22 States w/ 4 climatic regions

- 58 CRCP sections
  - 10 sections from Illinois
  - Vandalia (US40), I-80, I-94 Edens – Heavy traffic

Acknowledgements

The Illinois Center for Transportation (ICT) is an innovative partnership between the Illinois Department of Transportation (IDOT) and the University of Illinois at Urbana-Champaign (UIUC).

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Illinois Department of Transportation

ILLINOIS CENTER FOR TRANSPORTATION