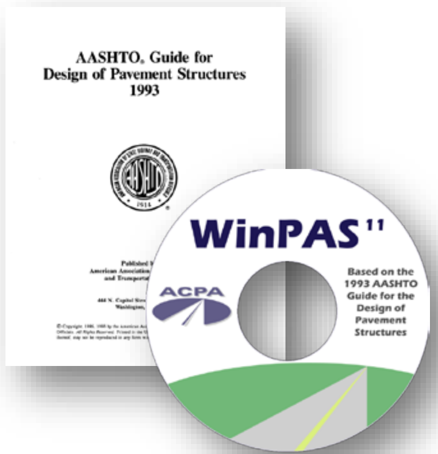
Pavement Thickness Design Methods



BCOA ME
University of Pittsburgh

Municipal Streets Seminar
November 12, 2014
Ames, Iowa

CP Tech Center

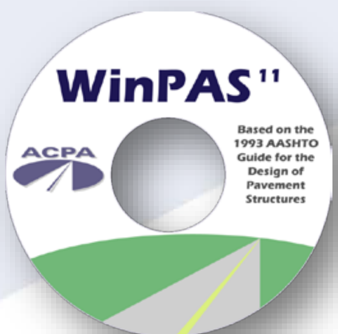
Eric Ferrebee - ACPA

U.S. JPCP Roadway Design Methods

AASHTOWare Pavement ME
(previously known as DARWin-ME and MEPDG)

ACPA StreetPave

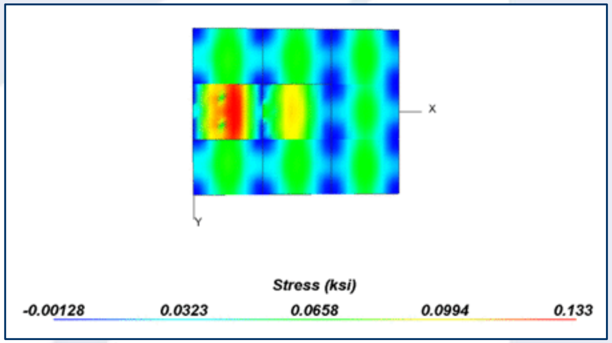
325 & 330



AASHTO 93
(software as ACPA WinPAS)

Design Method Basis

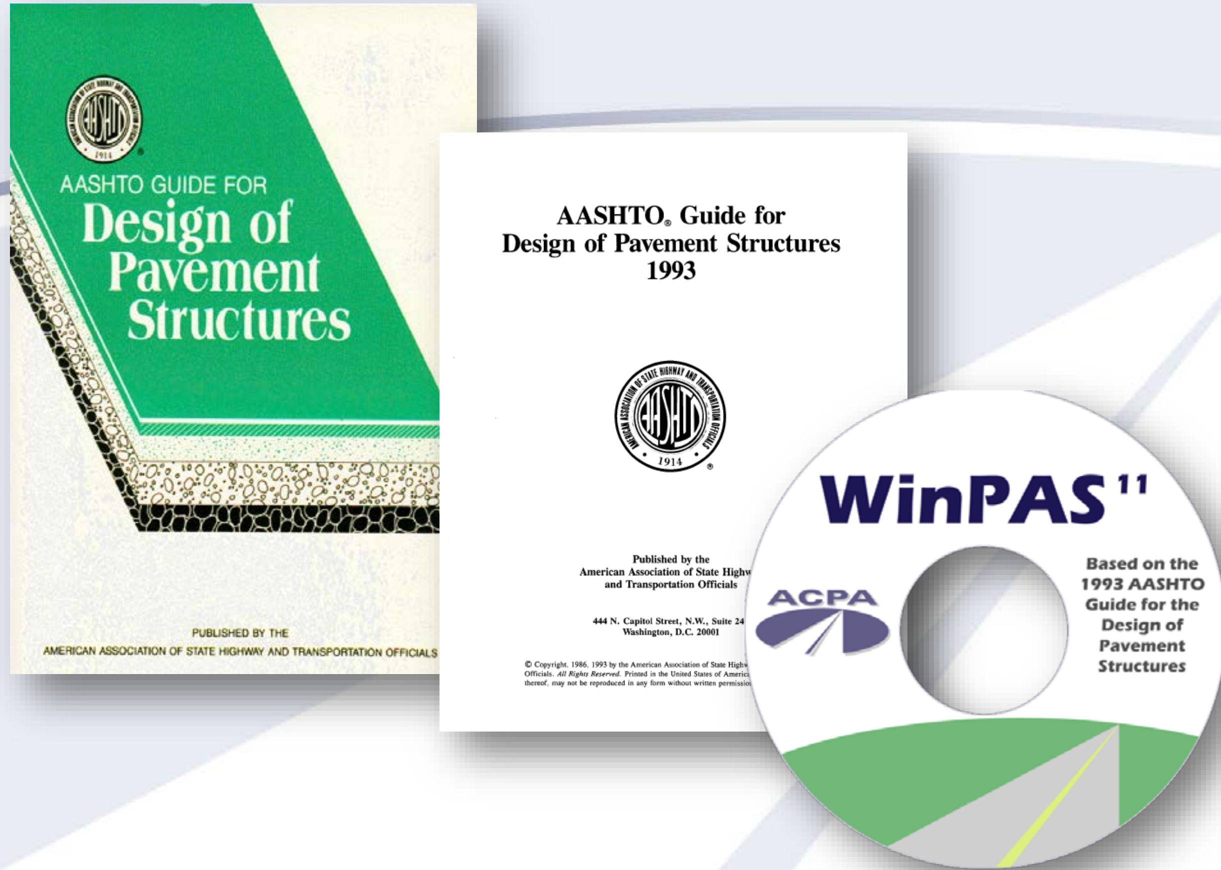
- **Mechanistic** – Purely scientific and based on measured, defendable scientific rules and laws



$$\epsilon = \sigma/E \qquad \Delta L = \alpha * \Delta T * L_o$$

- **Empirical** – Based on observations or experimentation and requires a lot of tests to connect all the relationships

$$\boldsymbol{Cracking = loads + environment + material}$$

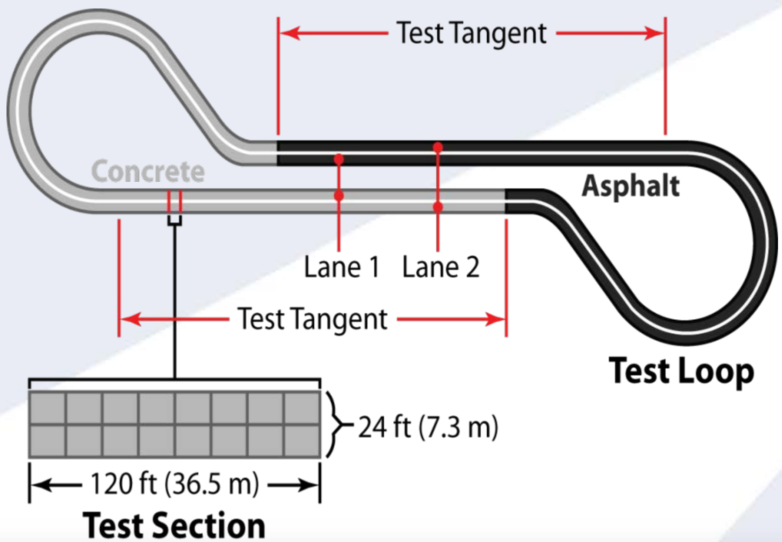


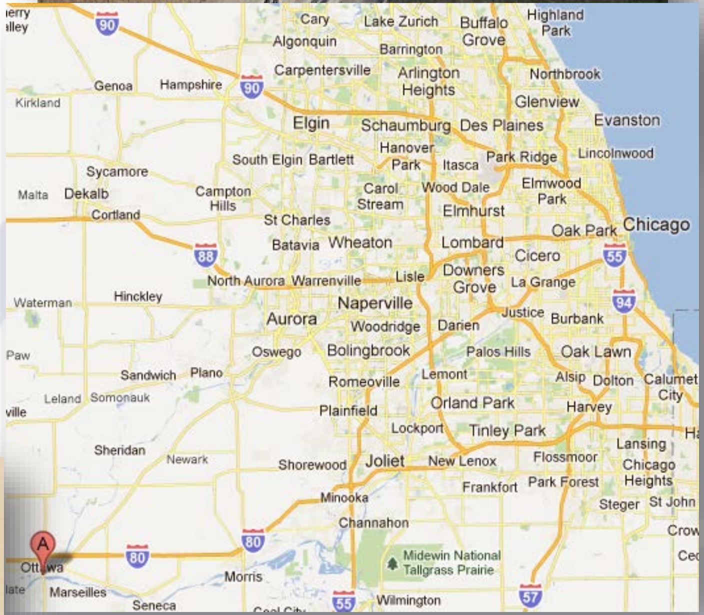
AASHTO 93 / ACPA WinPAS

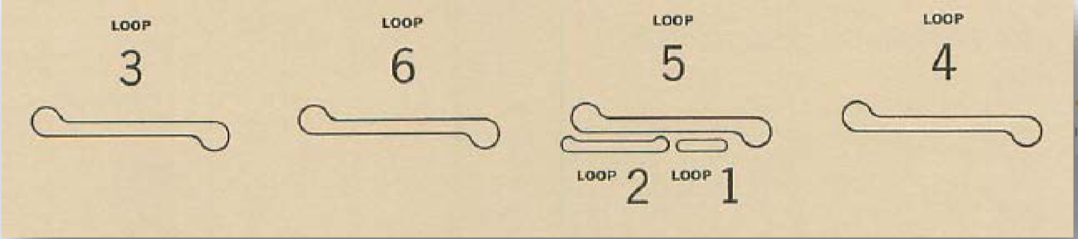
acpa.org / winpas

AASHO Road Test (1958-1960)

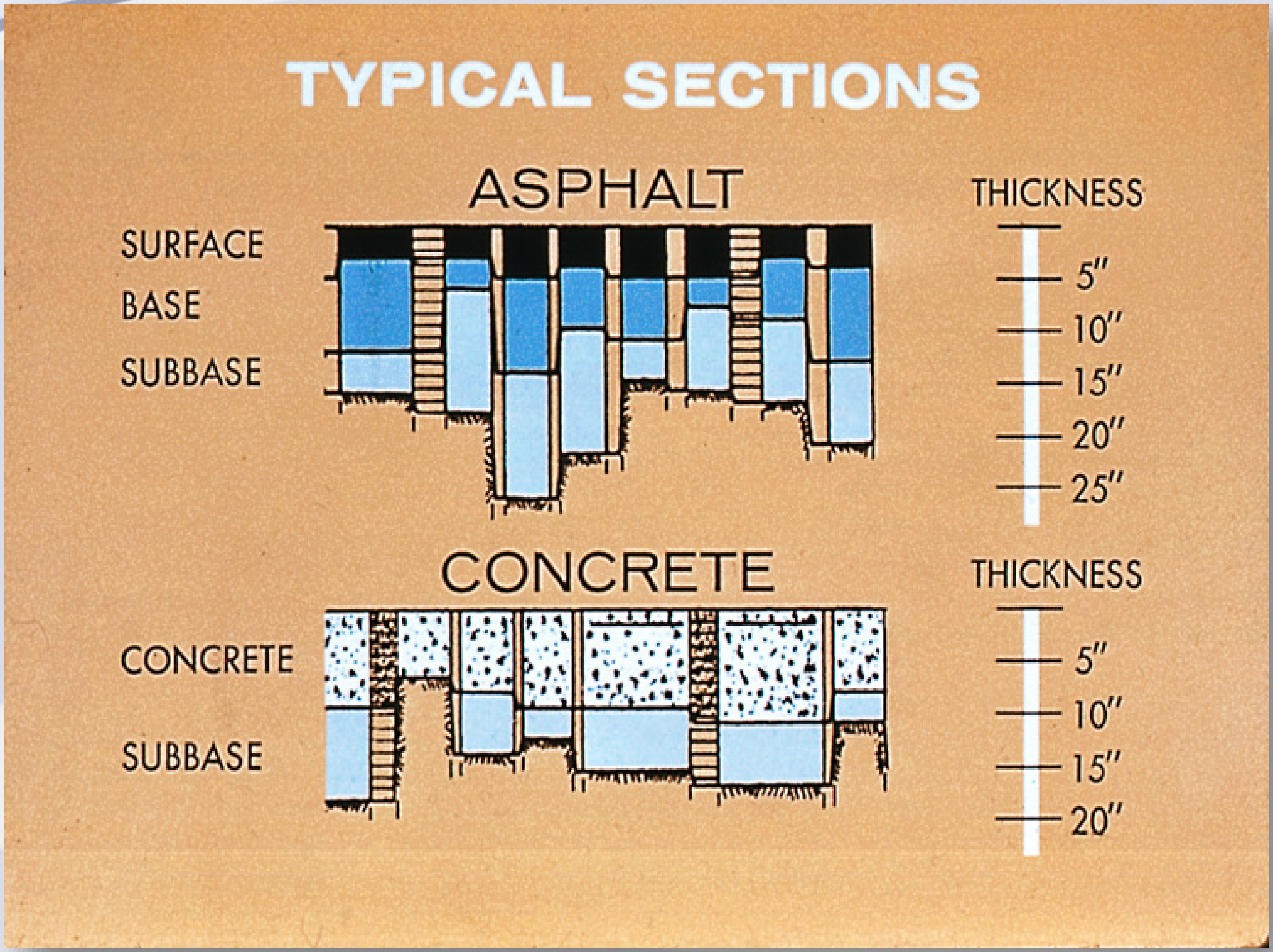
- Wholly empirical
- Included 368 concrete and 468 asphalt sections | focus was highway pavement







Necessary Thickness was Guessed!



<u>Subgrade = Clay Soil</u>

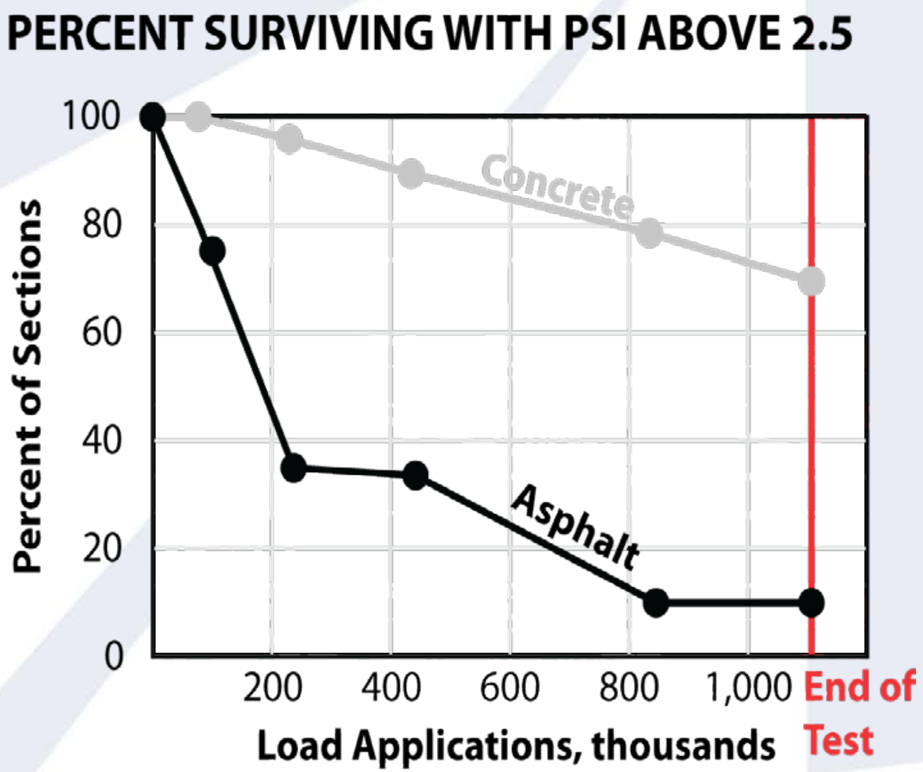
Sections Loaded for 2 Yrs | 1.1 Mil Reps

Max Single Axle

Max Tandem Axle

Performance Estimated Subjectively

- Present Serviceability Index (PSI)
  - 4.0 – 5.0 = Very Good
  - 3.0 – 4.0 = Good
  - 2.0 – 3.0 = Fair
  - 1.0 – 2.0 = Poor
  - 0.0 – 1.0 = Very Poor
- "Failure" at the Road Test considered @ 1.5
- Typical U.S. state agency terminal serviceability in practice = 2.5



Note on Inference Space of '93

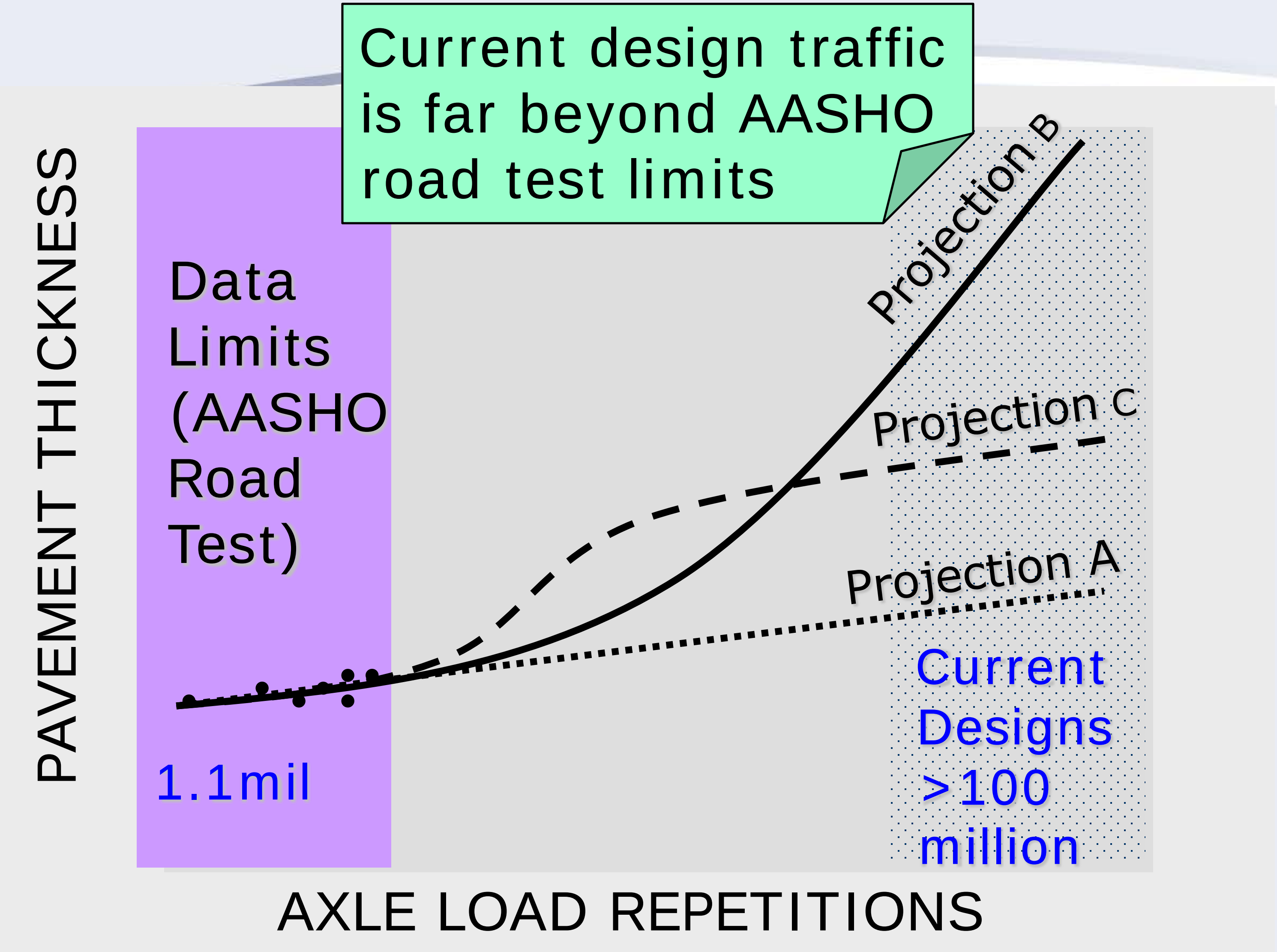
The experimental design at the AASHO Road Test included a wide range of loads as previously discussed (Section 1.4.1); however, the applied loads were limited to a maximum of 1,114,000 axle applications for those sections which survived the full trafficking period. Thus, the maximum number of 18-kip equivalent single axle loads (ESAL's) applied to any test section was approximately one million. However, by applying the concept of equivalent loads to test sections subjected to only 30-kip single axle loads, for example, it

is possible to extend the findings to 8×10^6 ESAL's. Use of any design ESAL's above 8×10^6 requires extrapolation beyond the equations developed from the Road Test results. Such extrapolations have, how-

AASHTO® Guide for
Design of Pavement Structures
1993

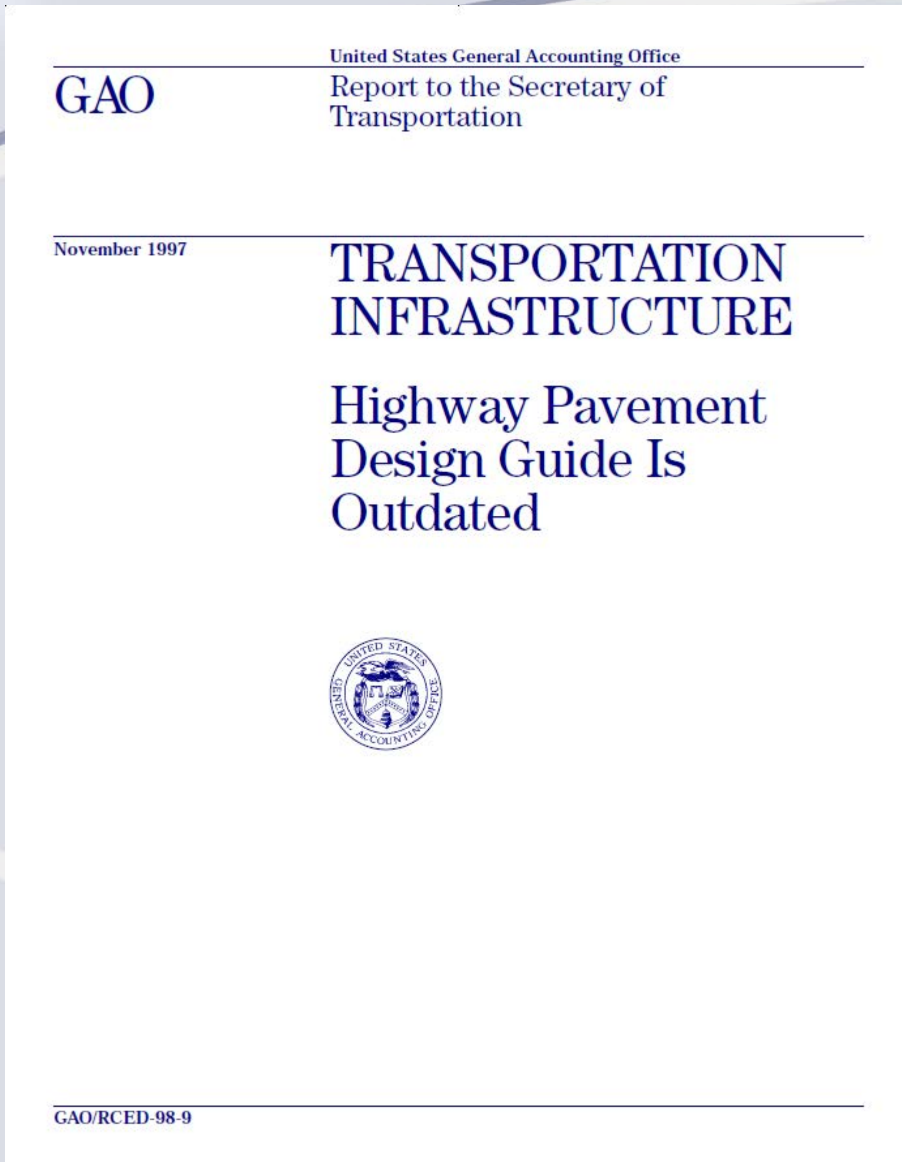
Published by the
American Association of State Highway
and Transportation Officials

444 N. Capitol Street, N.W., Suite 249
Washington, D.C. 20001



Current design traffic is far beyond AASHO road test limits
PAVEMENT THICKNESS
Data Limits (AASHO Road Test)
1.1mil
Projection B
Projection C
Projection A
Current Designs >100 million
AXLE LOAD REPETITIONS

Don't Just Take My Word…



United States General Accounting Office

GAO

Report to the Secretary of Transportation

November 1997

TRANSPORTATION INFRASTRUCTURE

Highway Pavement Design Guide Is Outdated

GAO/RCED-98-9

"The current design guide and its predecessors were largely based on design equations empirically derived from the observations AASHTO's predecessor made during road performance tests completed in 1959-60. Several transportation experts have criticized the empirical data thus derived as outdated and inadequate for today's highway system. In addition, a March 1994 DOT Office of Inspector General report concluded that the design guide was outdated and that pavement design information it relied on could not be supported and validated with systematic comparisons to actual experience or research."

…this is why Pavement ME exists!

1986-93 JPCP AASHTO 93 Equation

$$Log(ESAL) = Z_R * s_o + 7.35 * Log(D+1) - 0.06 + \left[\frac{Log\left[\frac{\Delta PSI}{4.5-1.5}\right]}{1+\frac{1.624*10^7}{(D+1)^{8.46}}} \right]$$

$$+ (4.22 - 0.32 * p_t) * Log \left[\frac{S_c^{'} * C_d * (D^{0.75} - 1.132)}{215.63 * J * \left[D^{0.75} - \frac{18.42}{(E_c / k)^{0.25}} \right]} \right]$$

Traffic

Standard Normal Deviate

Overall Standard Deviation

Thickness

Change in Serviceability

Terminal Serviceability

Modulus of Rupture

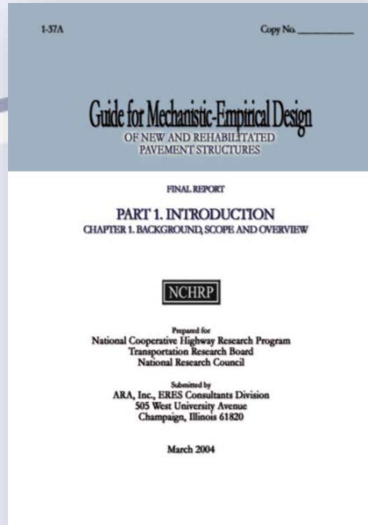
Drainage Coefficient

Load Transfer

Modulus of Elasticity

Modulus of Subgrade Reaction

WHAT DO DESIGNERS FOCUS ON?



1-37A

Copy No. ____________

Guide for Mechanistic-Empirical Design
OF NEW AND REHABILITATED PAVEMENT STRUCTURES

FINAL REPORT

PART 1. INTRODUCTION
CHAPTER 1. BACKGROUND, SCOPE AND OVERVIEW

NCHRP

Prepared for
National Cooperative Highway Research Program
Transportation Research Board
National Research Council

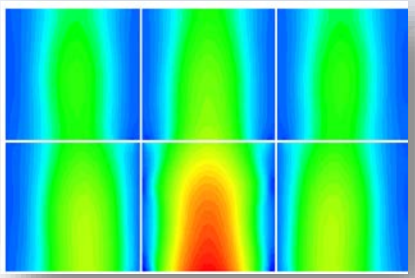
Submitted by
ARA, Inc., ERES Consultants Division
505 West University Avenue
Champaign, Illinois 61820

March 2004

MEPDG / DARWin-ME / AASHTOWare Pavement ME

Pavement ME Design

- Not "perfect" & not intended to be a "final" product
- Complex and relatively costly
- For highways and NOT street, road, parking lot, etc.



Mechanistic Calculation of Responses

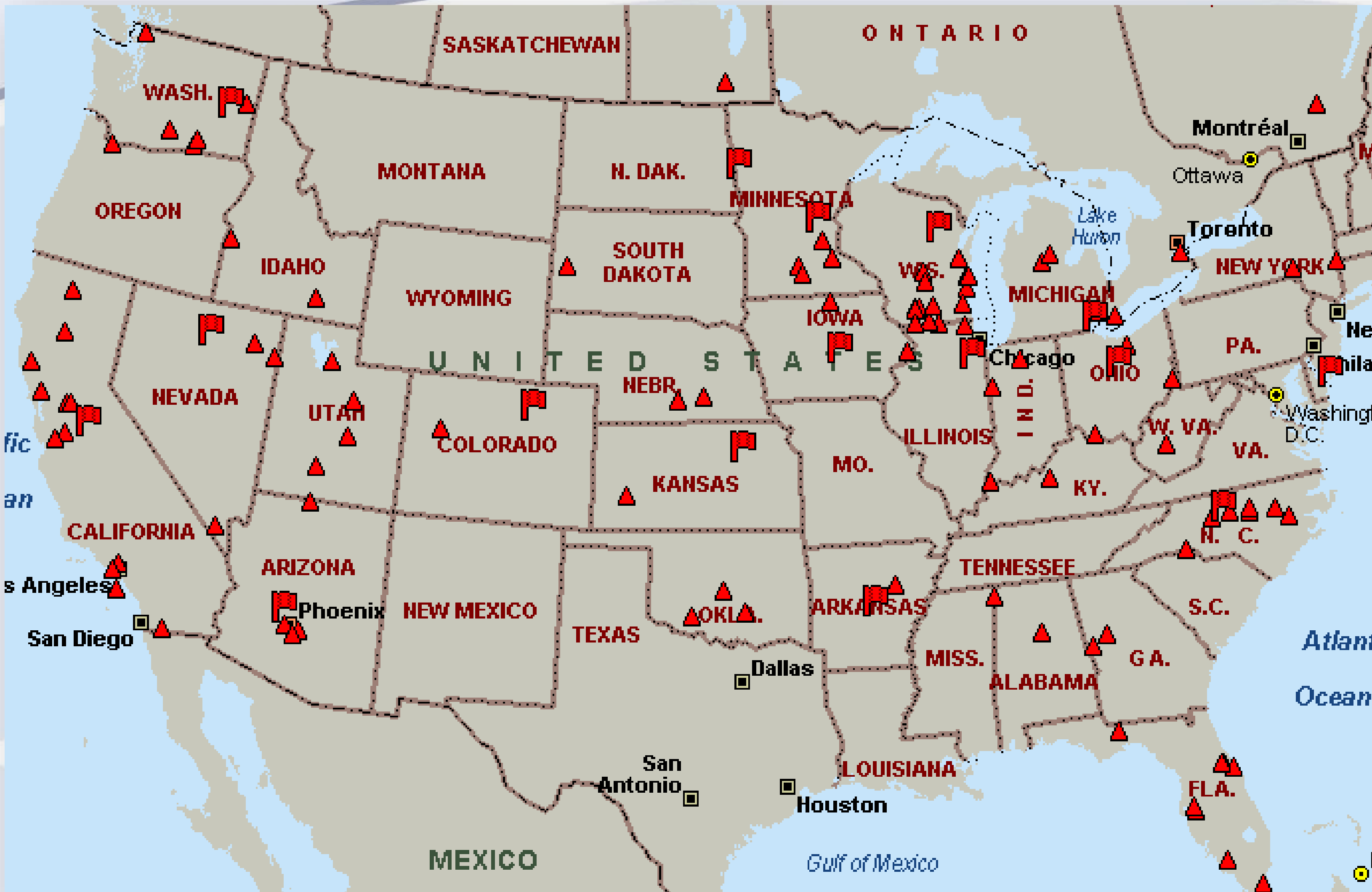
+

Empirical Tie to Ground

=

Pavement Performance Prediction

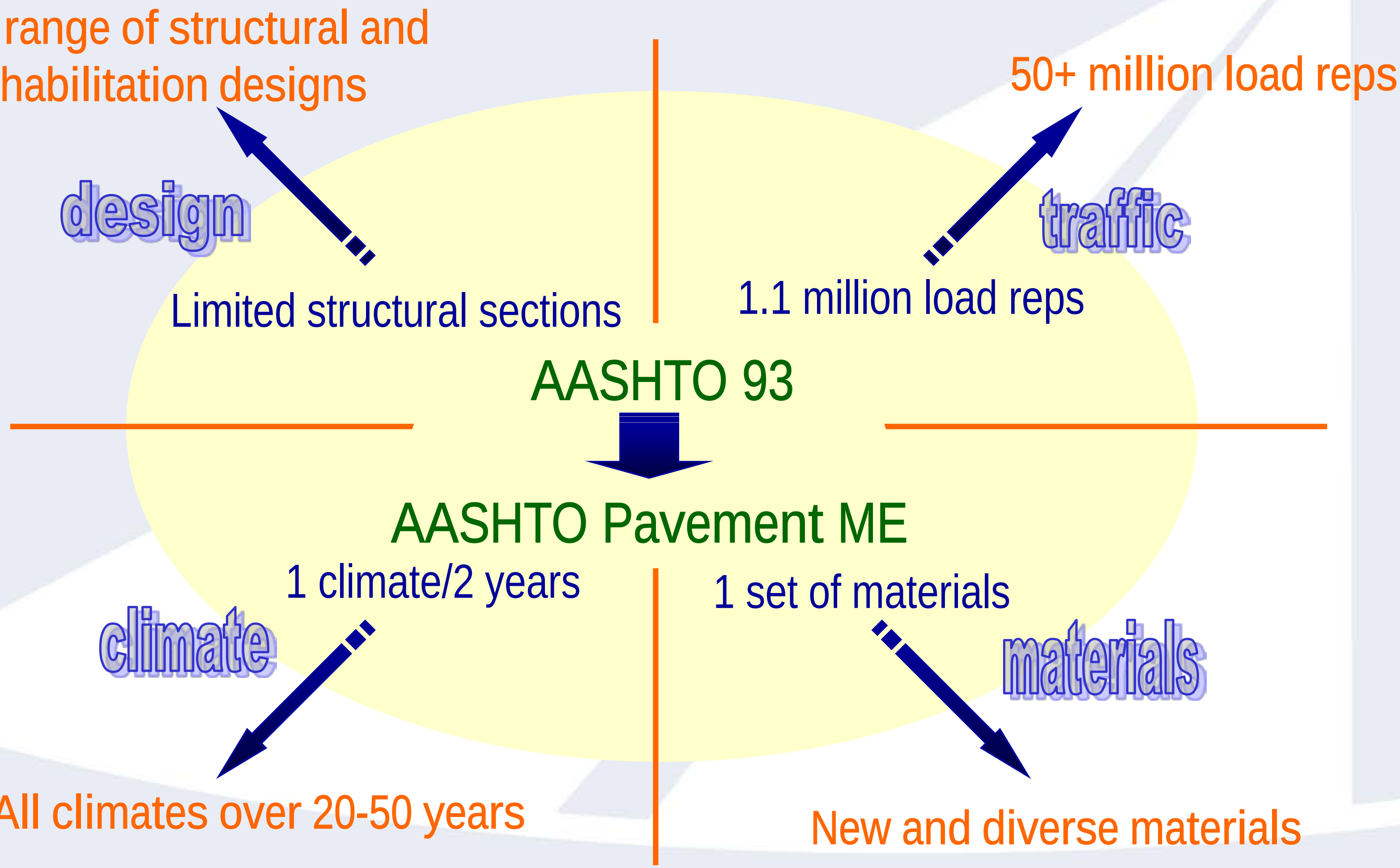
JPCP Calibration – BIG INF. SPACE!



LTPP GPS-3 & RPPR JPCP Sections

LTPP SPS-2, MnROAD, & AASHO JPCP Sections

AASHTO 93 vs. ME



Sounds Easy Enough, Right?

$$Fault_m = \sum_{i=1}^{m} \Delta Fault_i$$

$$\Delta Fault_i = C_{34} * (FAULTMAX_{i-1} - Fault_{i-1})^2 * DE_i$$

$$FAULTMAX_i = FAULTMAX_0 + C_7 * \sum_{j=1}^{m} DE_j * Log(1 + C_5 * 5.0^{EROD})^{C_6}$$

$$FAULTMAX_0 = C_{12} * \delta_{curling} * \left[Log(1 + C_5 * 5.0^{EROD}) * Log\left(\frac{P_{200} * WetDays}{p_s}\right) \right]^{C_6}$$

$$\sigma_0 = \frac{E_{PCC} \Delta \varepsilon_{tot}}{2(1 - \mu_{PCC})}$$

n = traffic path.

he damage increments were discussed previously in this section.

he applied number of load applications ($n_{i,j,k,l,m,n}$) is the actual number of axle type k of load vel l that passed through traffic path n under each condition (age, season, and temperature ifference). The allowable number of load applications is the number of load cycles at which tigue failure is expected (corresponding to 50 percent slab cracking) and is a function of the pplied stress and PCC strength. The allowable number of load applications is determined using e following fatigue model:

$$\log(N_{i,j,k,l,m,n}) = C_1 \cdot \left(\frac{MR_i}{\sigma_{i,j,k,l,m,n}} \right)^{C_2} + 0.4371 \qquad (3.4.10)$$

here,

- $N_{i,j,k,...}$ = allowable number of load applications at condition i, j, k, l, m, n
- MR_i = PCC modulus of rupture at age i, psi
- $\sigma_{i,j,k,...}$ = applied stress at condition i, j, k, l, m, n
- C_1 = calibration constant = 2.0
- C_2 = calibration constant = 1.22

The fatigue damage calculation is a simple process of summing damage from each damage increment, except that a numerical integration scheme is used to accurately determine the effects of traffic wander. The fatigue damage at the critical damage location caused by an axle load placed at any random distance away from the pavement edge (point j) is given by the following:

$$FD_{ij}^{*} = P(COV_j) \cdot FD_{ij} \qquad (3.4.11)$$

$$IRI = IRI_I + C1*CRK + C2*SPALL + C3*TFAULT + C4*SF$$

The probability of coverage is determined assuming normal distribution.

$$NORMDIST = \frac{1}{SD_{traf}\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2} \qquad (3.4.12)$$

= normal distribution density function.

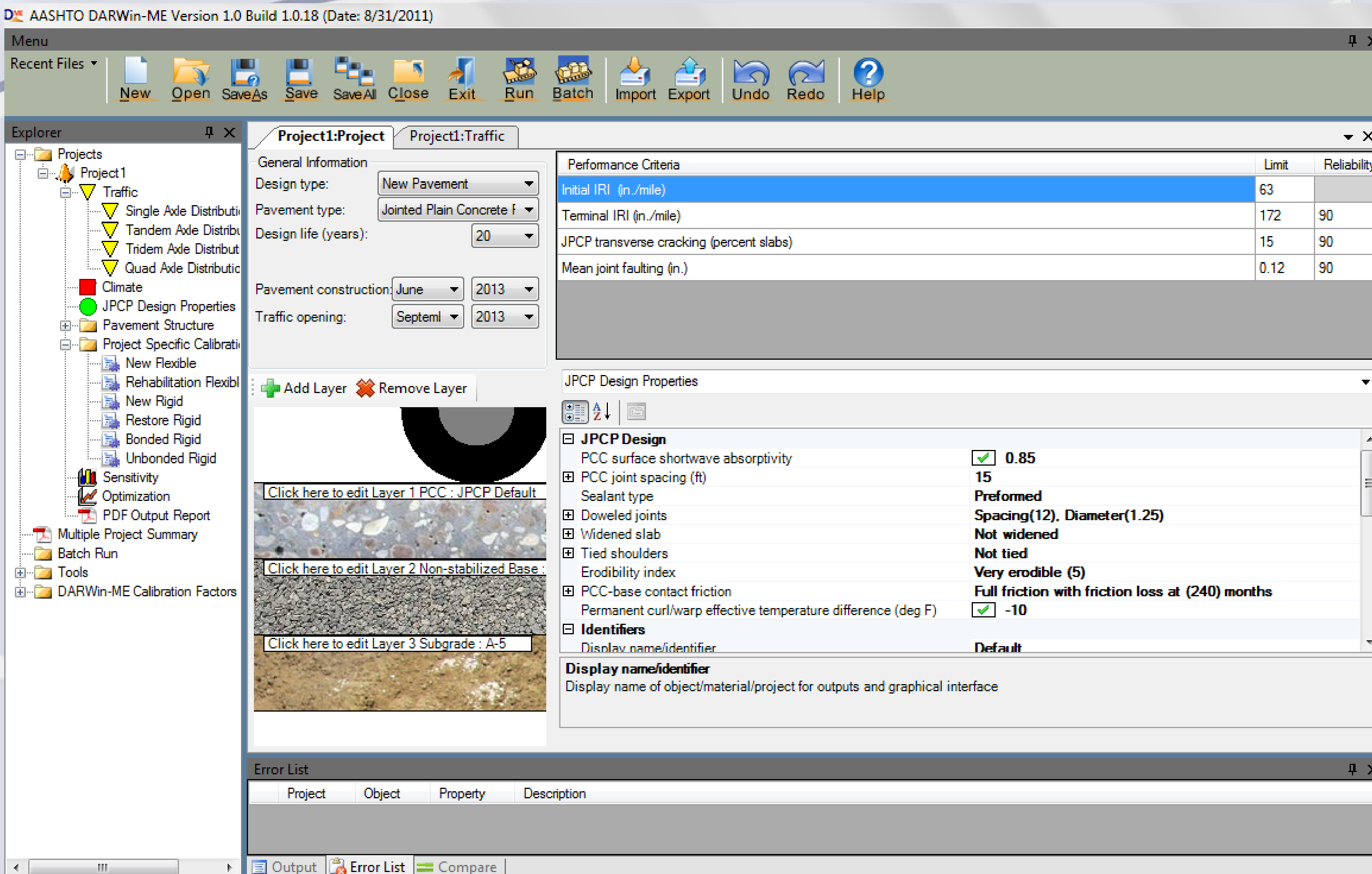
= wheel location – distance from pavement edge (or outside of the paint stripe for widened slab) to the outer edge of outermost wheel, in.

3.4.64

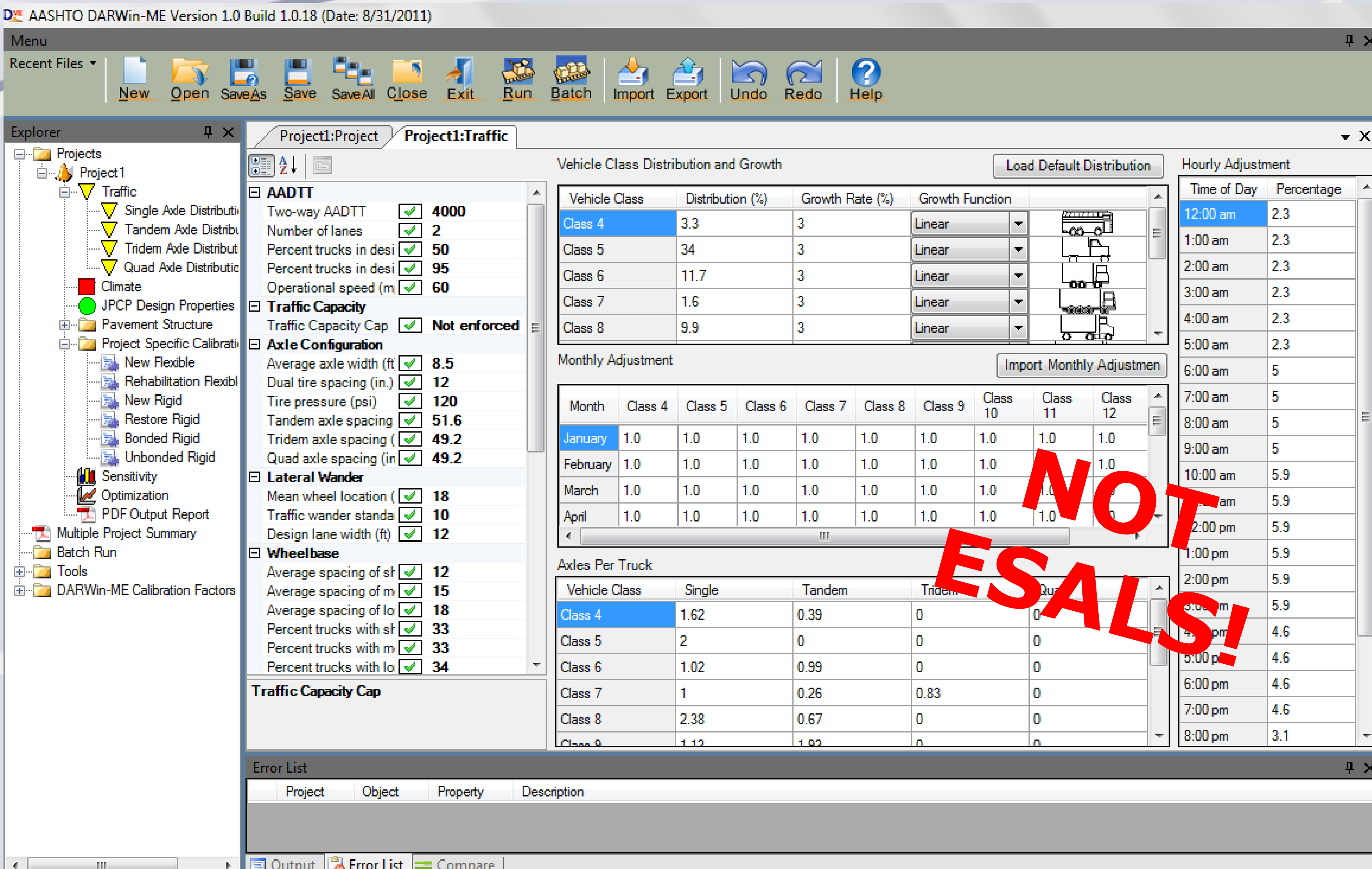
$$SCF = -1400 + 350 \cdot AIR\% \cdot (0.5 + PREFORM) + 3.4 f'c \cdot 0.4 - 0.2\,(FTCYC \cdot AGE) + 43\, h_{PCC} - 536\, WC\_Ratio$$

$$cw = Max\left(L \cdot \left(\varepsilon_{shr} + \alpha_{PCC} \Delta T_{\zeta} - \frac{c_2 f_{\sigma}}{E_{PCC}} \right) \cdot 1000 \cdot CC,\ 0.001 \right)$$

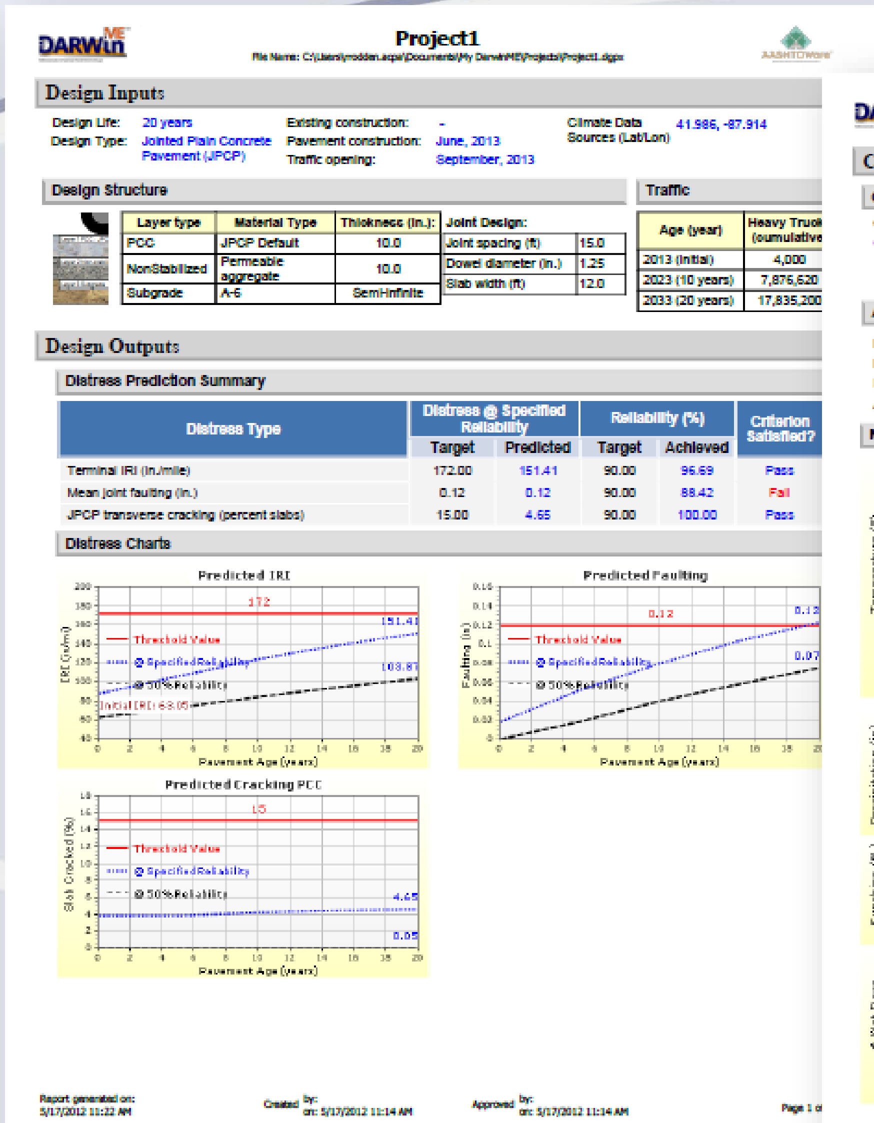
INPUTS, INPUTS, INPUTS!!!!



INPUTS, INPUTS, INPUTS!!!!



OUTPUTS, OUTPUTS, OUTPUTS!!!



Project1

File Name: C:\Users\rodden.acpa\Documents\My DarwinME\Projects\Project1.dgpx

Design Inputs

Design Life: 20 years
Design Type: Jointed Plain Concrete Pavement (JPCP)
Existing construction: -
Pavement construction: June, 2013
Traffic opening: September, 2013
Climate Data Sources (Lat/Lon): 41.986, -87.914

Design Structure

Layer type	Material Type	Thickness (in.):
PCC	JPCP Default	10.0
NonStabilized	Permeable aggregate	10.0
Subgrade	A-6	Semi-infinite

Joint Design:	
Joint spacing (ft)	15.0
Dowel diameter (in.)	1.25
Slab width (ft)	12.0

Traffic

Age (year)	Heavy Truck (cumulative
2013 (initial)	4,000
2023 (10 years)	7,876,620
2033 (20 years)	17,835,200

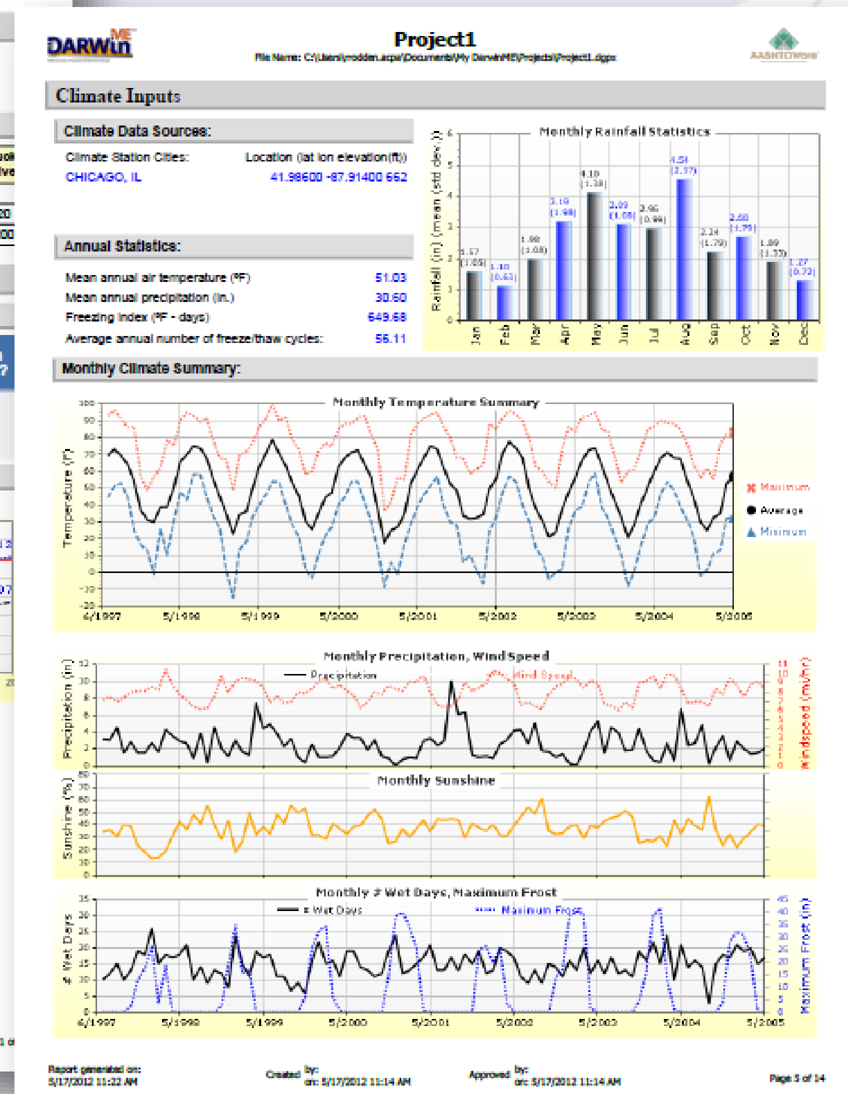
Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	172.00	151.41	90.00	96.69	Pass
Mean joint faulting (in.)	0.12	0.12	90.00	88.42	Fail
JPCP transverse cracking (percent slabs)	15.00	4.65	90.00	100.00	Pass

Distress Charts

Report generated on: 5/17/2012 11:22 AM
Created by: on: 5/17/2012 11:14 AM
Approved by: on: 5/17/2012 11:14 AM
Page 1 of



Project1

File Name: C:\Users\rodden.acpa\Documents\My DarwinME\Projects\Project1.dgpx

Climate Inputs

Climate Data Sources:

Climate Station Cities: CHICAGO, IL
Location (lat lon elevation(ft)): 41.98600 -87.91400 662

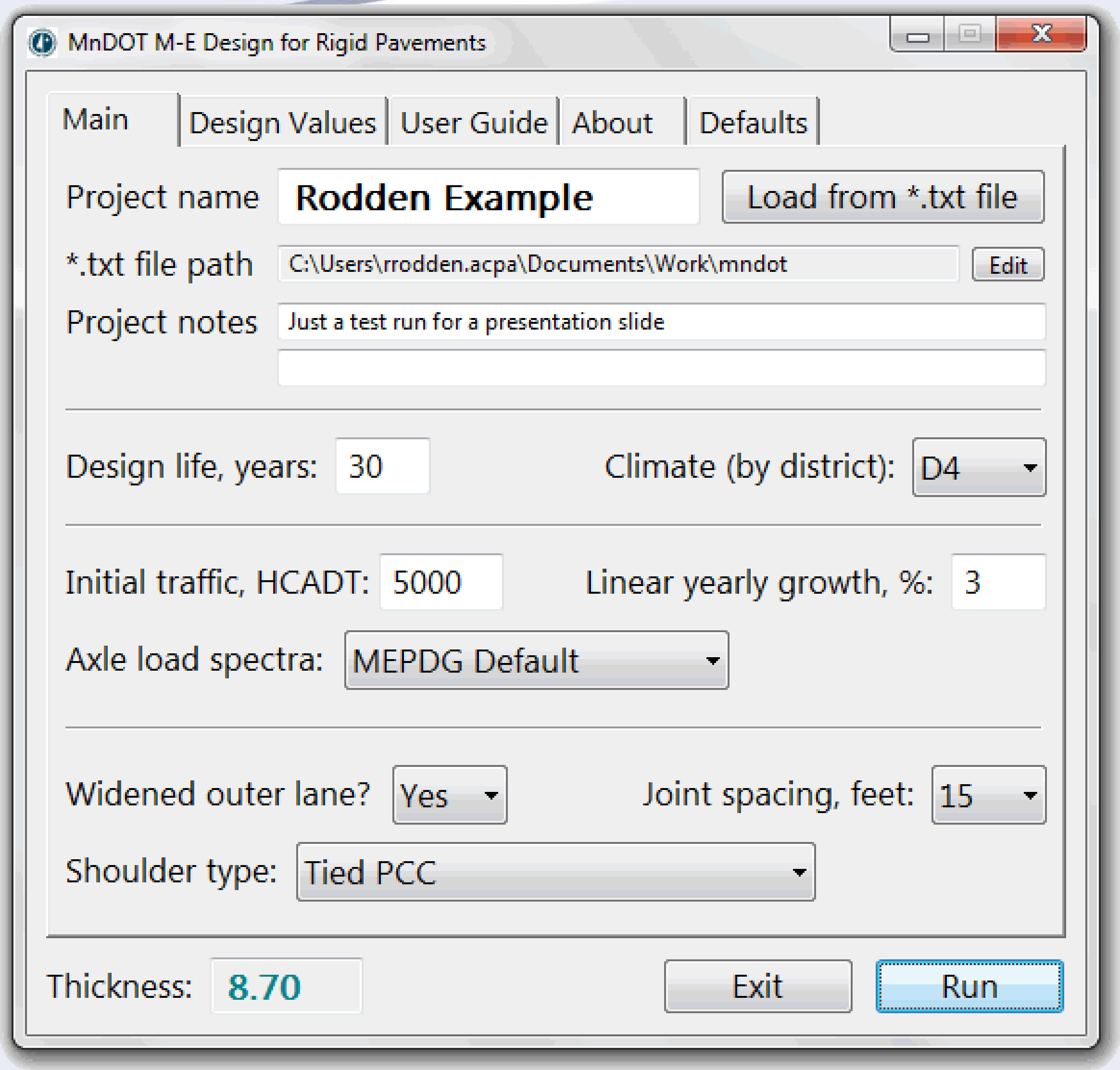
Annual Statistics:

Mean annual air temperature (ºF)	51.03
Mean annual precipitation (in.)	30.60
Freezing index (ºF - days)	649.68
Average annual number of freeze/thaw cycles:	56.11

Monthly Climate Summary:

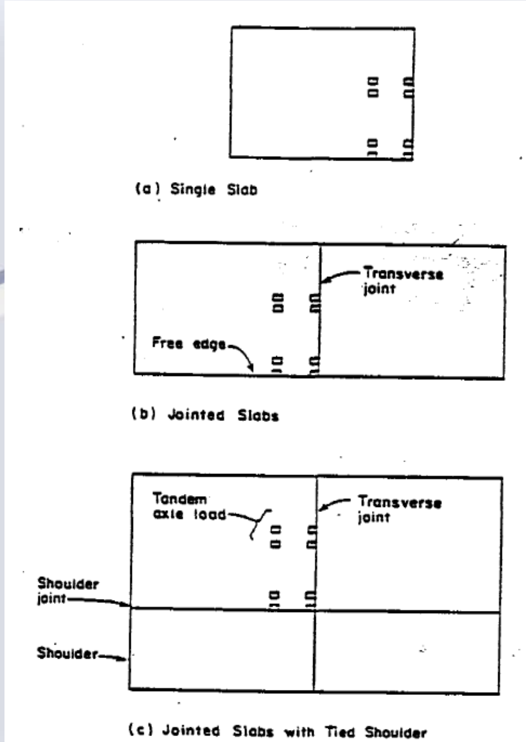
Report generated on: 5/17/2012 11:22 AM
Created by: on: 5/17/2012 11:14 AM
Approved by: on: 5/17/2012 11:14 AM
Page 5 of 14

Some Agencies Trying to Simplify



Note the inputs that have been deemed worth varying…

…<u>designers have a new idea of "what matters"!</u>



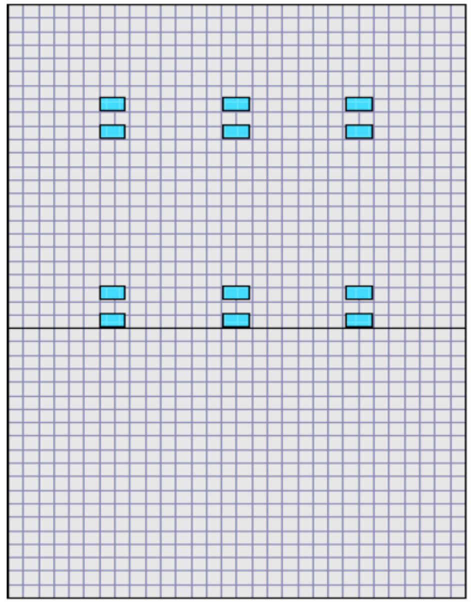


Figure 7. FE model of tridem axle edge loading (lane with tried concrete shoulders).

ACPA StreetPave

acpa.org/streetpave

ACPA StreetPave

- Roots date back to the 1960s PCA Method
- Tailored for streets and roads
- Failure modes are cracking and faulting

Traffic Spectrum + Counts

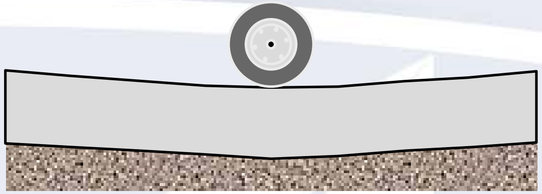
Single Axles	
Axle Load (kip)	Axles/1,000 Trucks
34	0.19
32	0.54
30	0.63
28	1.78
26	3.52
24	4.16
22	9.69
20	41.82
18	68.27
16	57.07

Tandem Axles	
Axle Load (kip)	Axles/1,000 Trucks
60	0.57
56	1.07
52	1.79
48	3.03
44	3.52
40	20.31
36	78.19
32	109.54
28	95.79
24	71.16

- Total trucks in design lane over the design life…

  calculated from trucks/day (2-way), traffic growth rate (%/yr), design life (yrs), directional distribution (%) and design lane distribution (%)

Traffic Loads Generate Stresses



- Equivalent stress at the slab edge:

$$\sigma_{eq} = \frac{6 * M_e}{{h_c}^2} * f_1 * f_2 * f_3 * f_4$$

M_e = equivalent moment, psi; different for single, tandem, and tridem axles, with and without edge support - func on radius of relative stiffness, which depends on concrete modulus, Poisson's ratio, and thickness and the k-value

h_c = pavement thickness, in.

f_1 = adjustment for the effect of axle loads and contact area

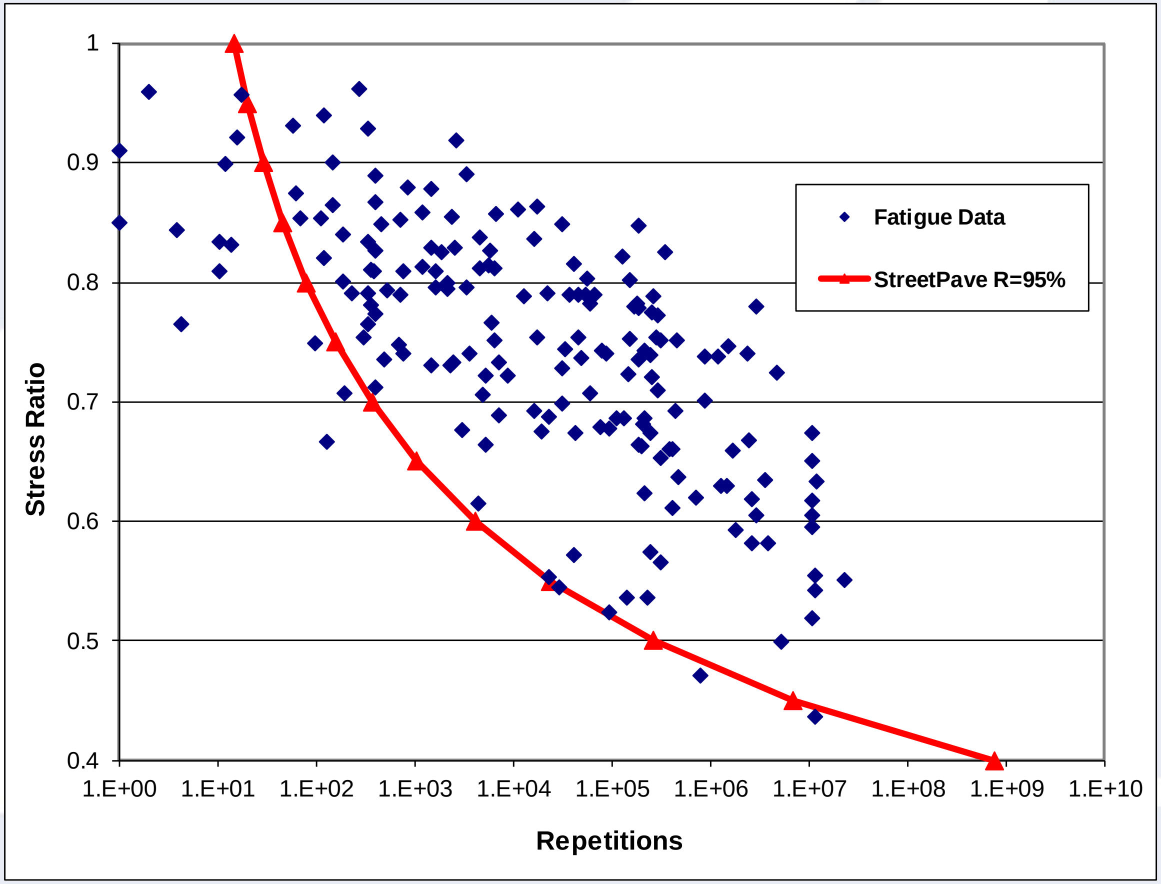
f_2 = adjustment for a slab with no concrete shoulder

f_3 = adjustment to account for the effect of truck (wheel) placement at the slab edge

f_4 = adjustment to account for approximately 23.5% increase in concrete strength with age after the 28th day and reduction of one coefficient of variation (COV) to account for materials variability

Limit Stress Ratio to Allow Design Reps

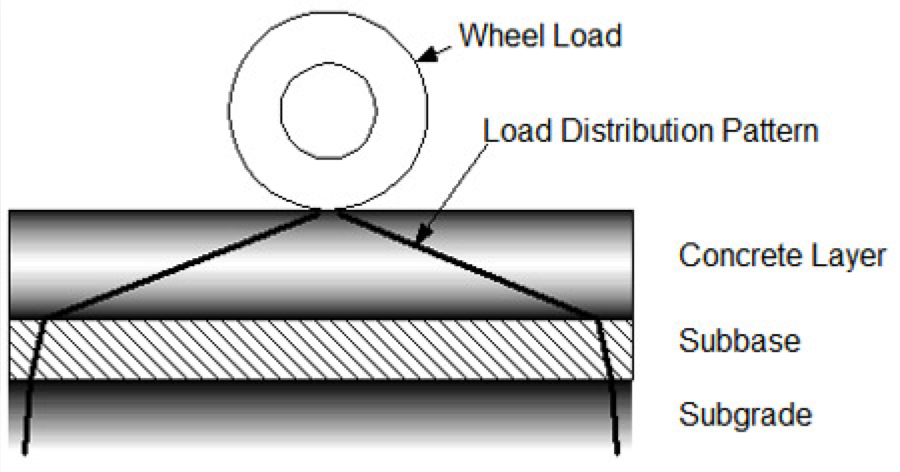
- Stress Ratio (SR) = Stress / Concrete Strength
- StreetPave makes slab thicker to limit stress ratio low enough to achieve the design traffic repetitions



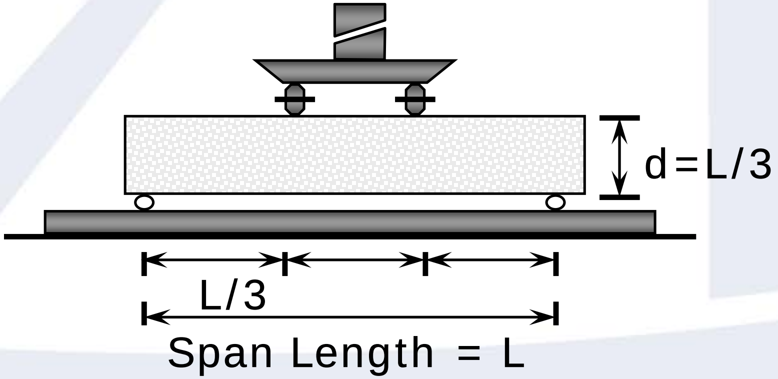
Inference space normalized to SR

A Conservative Approach!

- StreetPave fatigue calculation should be conservative relative to ME Design because:
  - **Size Effects** – Slabs have a greater fatigue capacity than beams
  - **Support** – The beam test has a k-value for support of 0 psi/in.!



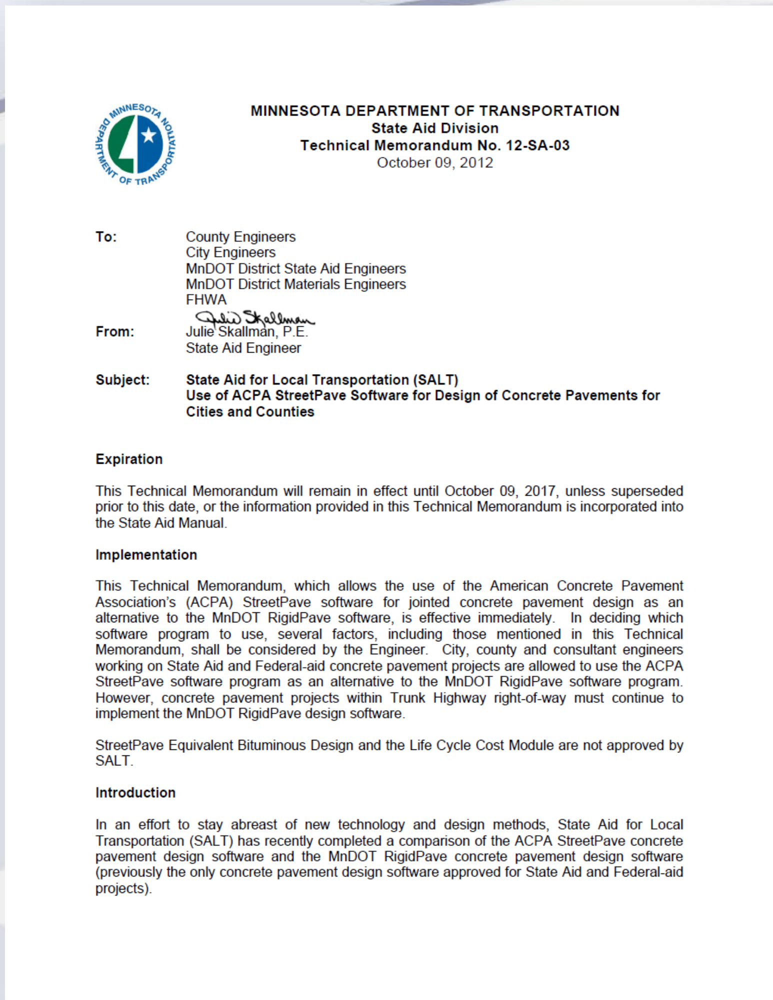
...versus...



Faulting Design in StreetPave

- If dowels used, faulting mitigated & fails by cracks
- No faulting data collected at the AASHO road test so model developed in 1980s using field performance data from WI, MN, ND, GA, and CA
- Similar to cracking models, the pavement is made thicker, as necessary, until faulting model predicts that the pavement will not fail by faulting during the design life
- StreetPave's weak point

StreetPave Accepted in MN



MINNESOTA DEPARTMENT OF TRANSPORTATION
State Aid Division
Technical Memorandum No. 12-SA-03
October 09, 2012

To: County Engineers
City Engineers
MnDOT District State Aid Engineers
MnDOT District Materials Engineers
FHWA

From: Julie Skallman, P.E.
State Aid Engineer

Subject: **State Aid for Local Transportation (SALT)**
Use of ACPA StreetPave Software for Design of Concrete Pavements for Cities and Counties

Expiration

This Technical Memorandum will remain in effect until October 09, 2017, unless superseded prior to this date, or the information provided in this Technical Memorandum is incorporated into the State Aid Manual.

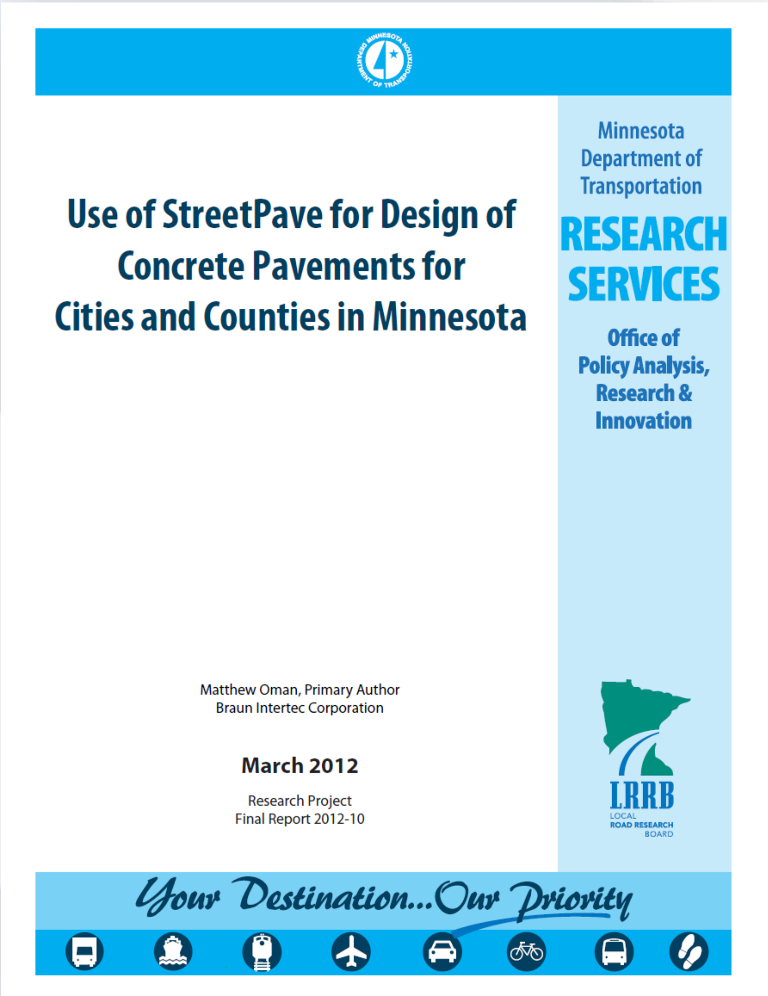
Implementation

This Technical Memorandum, which allows the use of the American Concrete Pavement Association's (ACPA) StreetPave software for jointed concrete pavement design as an alternative to the MnDOT RigidPave software, is effective immediately. In deciding which software program to use, several factors, including those mentioned in this Technical Memorandum, shall be considered by the Engineer. City, county and consultant engineers working on State Aid and Federal-aid concrete pavement projects are allowed to use the ACPA StreetPave software program as an alternative to the MnDOT RigidPave software program. However, concrete pavement projects within Trunk Highway right-of-way must continue to implement the MnDOT RigidPave design software.

StreetPave Equivalent Bituminous Design and the Life Cycle Cost Module are not approved by SALT.

Introduction

In an effort to stay abreast of new technology and design methods, State Aid for Local Transportation (SALT) has recently completed a comparison of the ACPA StreetPave concrete pavement design software and the MnDOT RigidPave concrete pavement design software (previously the only concrete pavement design software approved for State Aid and Federal-aid projects).



Use of StreetPave for Design of Concrete Pavements for Cities and Counties in Minnesota

Minnesota Department of Transportation
RESEARCH SERVICES
Office of Policy Analysis, Research & Innovation

Matthew Oman, Primary Author
Braun Intertec Corporation

March 2012

Research Project
Final Report 2012-10

LRRB
LOCAL ROAD RESEARCH BOARD

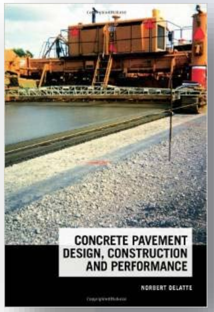
Your Destination...Our Priority

http://www.dot.state.mn.us/stateaid/admin/memos/12-sa-03.pdf

http://www.dot.state.mn.us/research/documents/201210.pdf

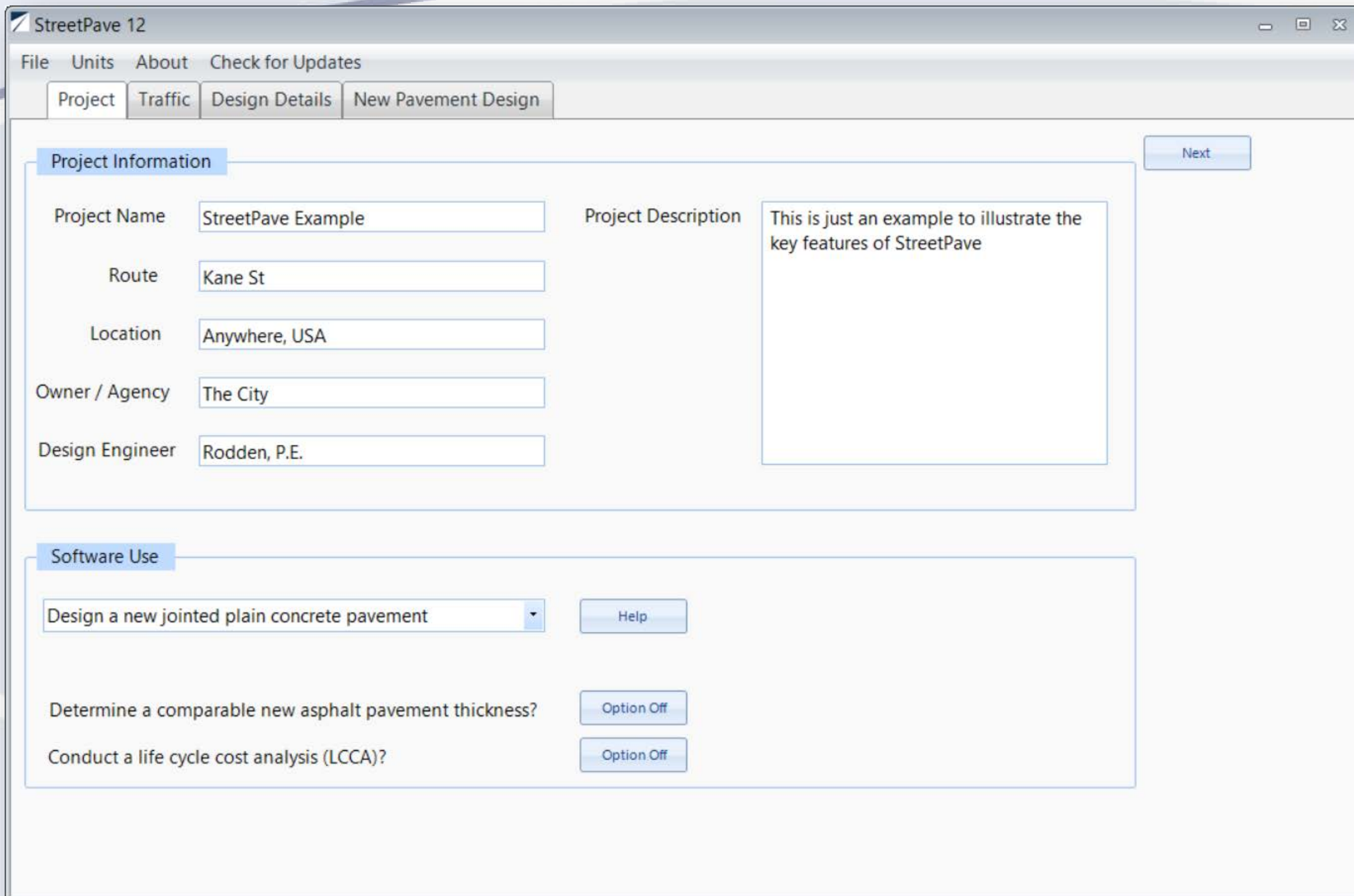
And Its Use is Growing!

- Also “approved” in VA and many other state, city, and county engineers are using it in the U.S.
- StreetPave used in design tables in:
  - ACI 325 and 330 documents
  - Dr. Norb Delatte’s textbook *Concrete Pavement Design, Construction, and Performance*

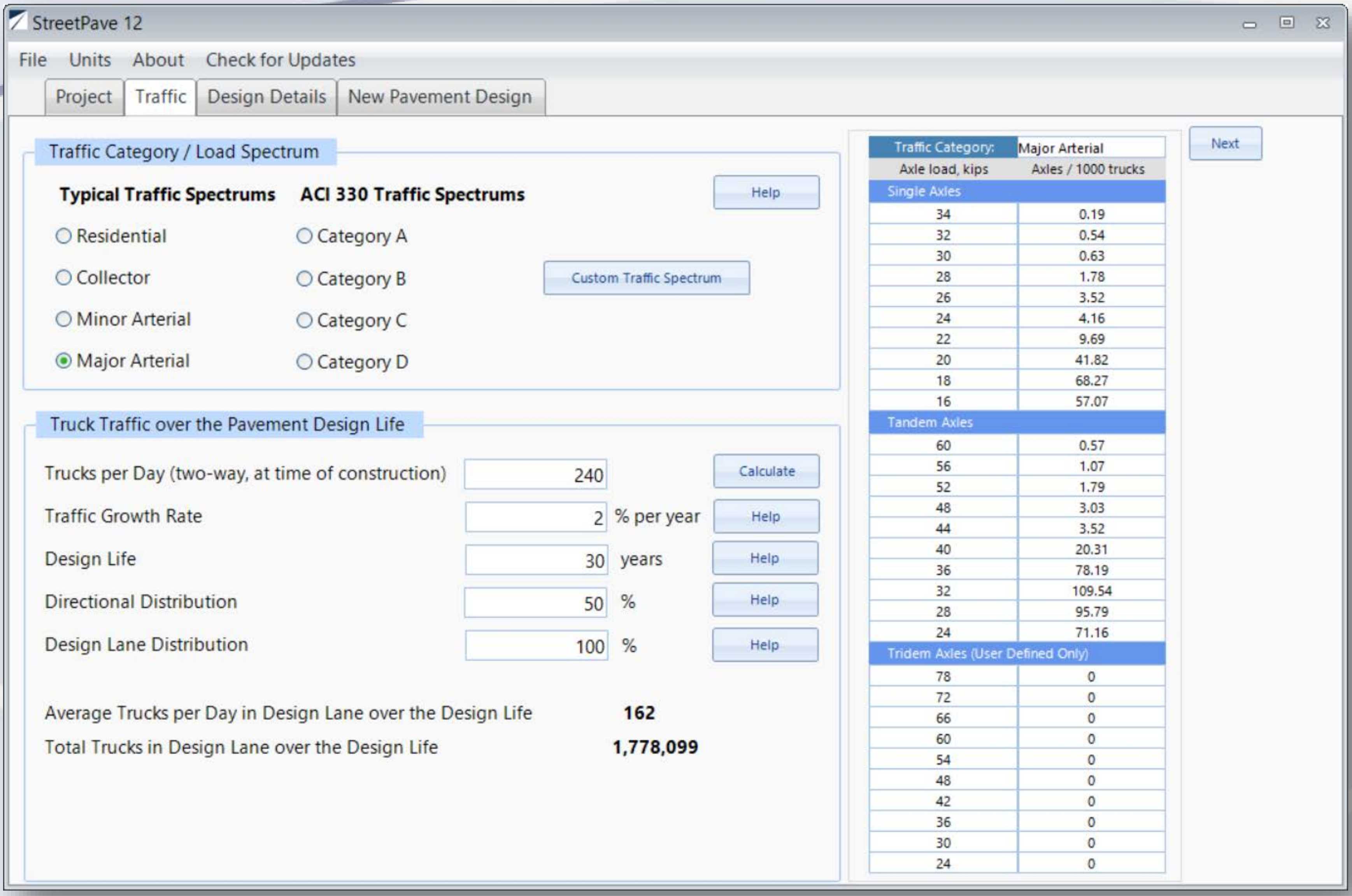


- Internationally, used in Australia, Portugal, Mexico, Uruguay, Argentina, Chile, etc.

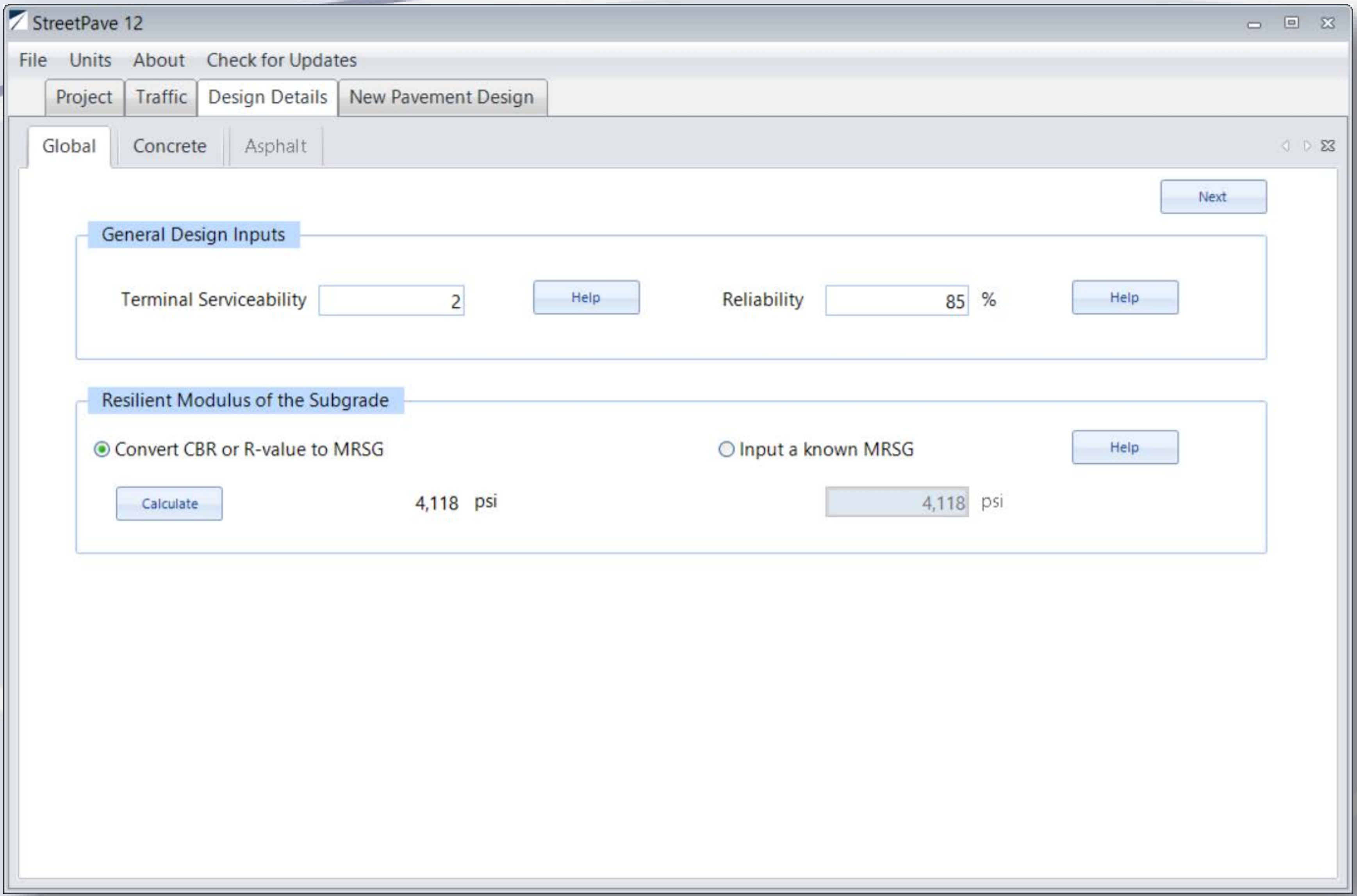
StreetPave | Project Details



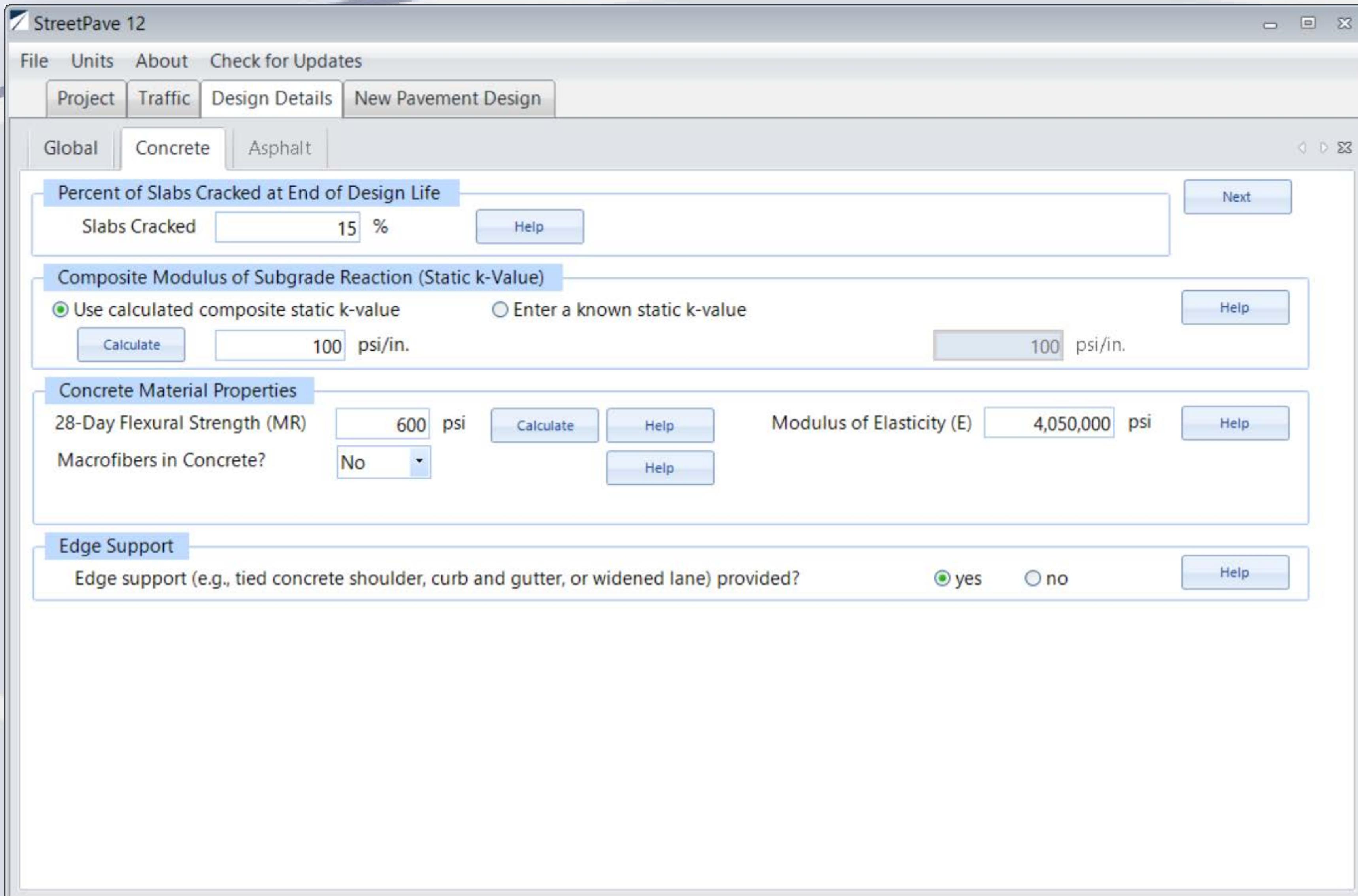
StreetPave | Traffic Details



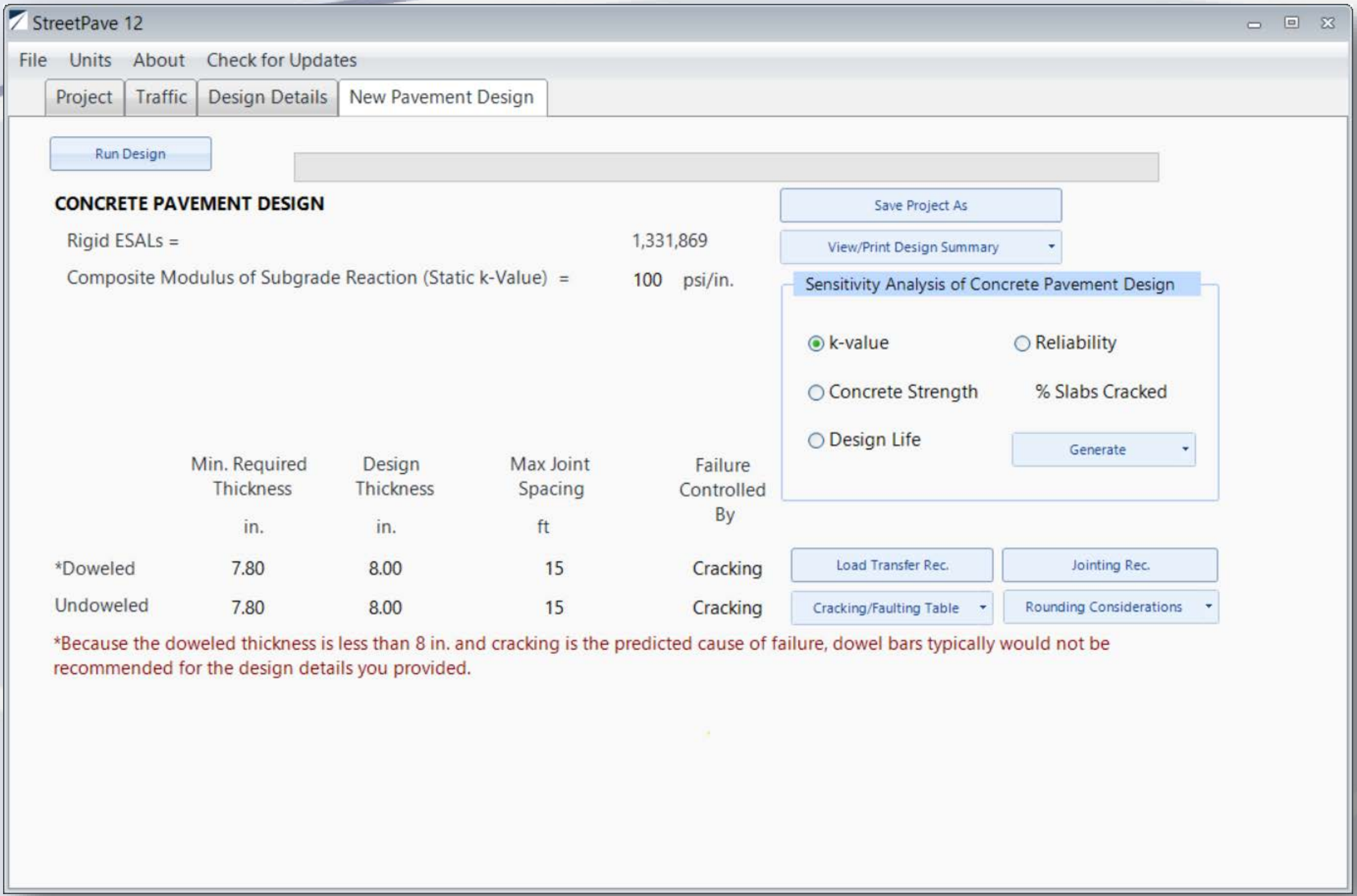
StreetPave | Design Details | General



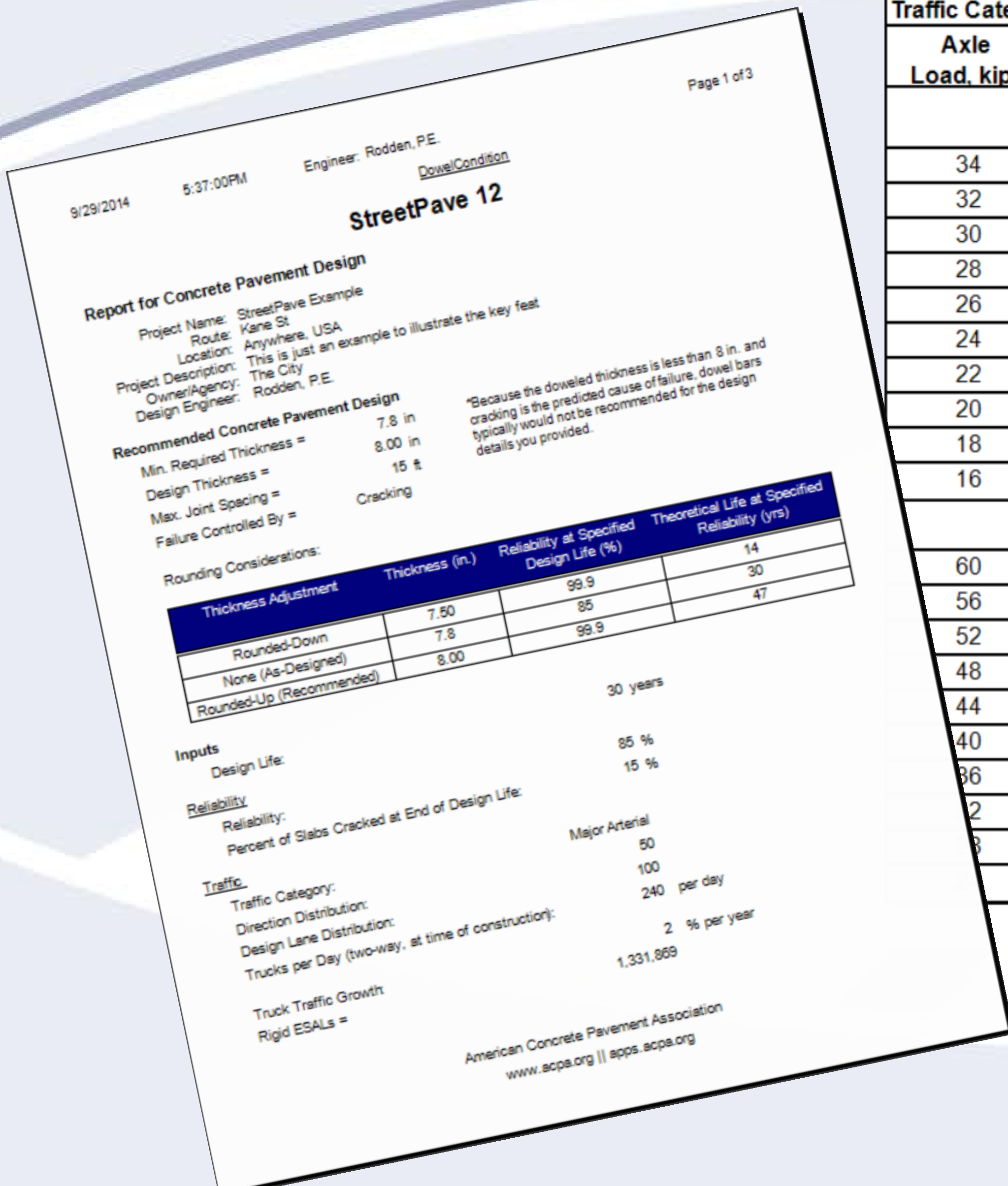
StreetPave | Design Details | Concrete



StreetPave | Design Results



StreetPave | Design Report


Page 1 of 3

9/29/2014 5:37:00PM Engineer: Rodden, P.E.

DowelCondition

StreetPave 12

Report for Concrete Pavement Design

Project Name: StreetPave Example
Route: Kane St
Location: Anywhere, USA
Project Description: This is just an example to illustrate the key feat
Owner/Agency: The City
Design Engineer: Rodden, P.E.

Recommended Concrete Pavement Design

Min. Required Thickness = 7.8 in
Design Thickness = 8.00 in
Max. Joint Spacing = 15 ft
Failure Controlled By = Cracking

*Because the doweled thickness is less than 8 in. and cracking is the predicted cause of failure, dowel bars typically would not be recommended for the design details you provided.

Rounding Considerations:

Thickness Adjustment	Thickness (in.)	Reliability at Specified Design Life (%)	Theoretical Life at Specified Reliability (yrs)
Rounded-Down	7.50	99.9	14
None (As-Designed)	7.8	85	30
Rounded-Up (Recommended)	8.00	99.9	47

Inputs

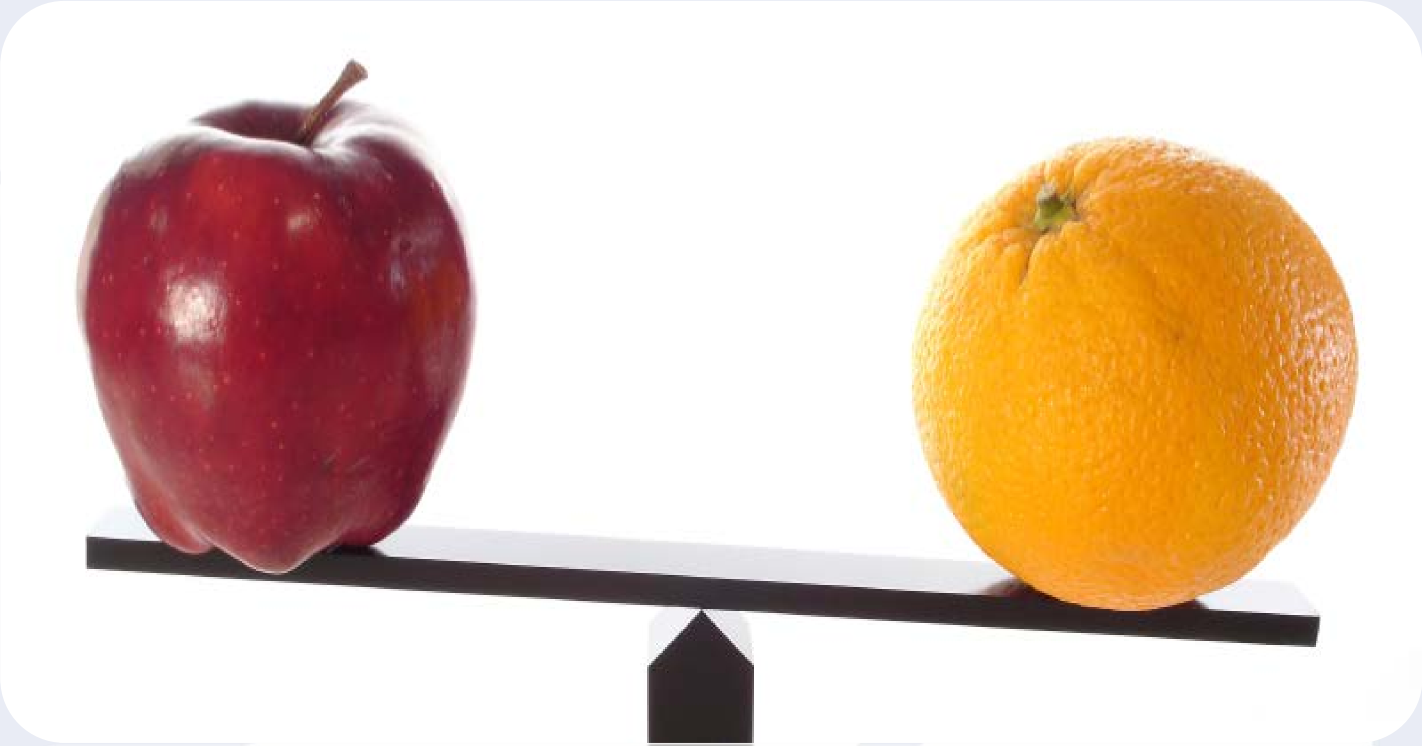
Design Life: 30 years

Reliability
Reliability: 85 %
Percent of Slabs Cracked at End of Design Life: 15 %

Traffic
Traffic Category: Major Arterial
Direction Distribution: 50
Design Lane Distribution: 100
Trucks per Day (two-way, at time of construction): 240 per day
Truck Traffic Growth: 2 % per year
Rigid ESALs = 1,331,869

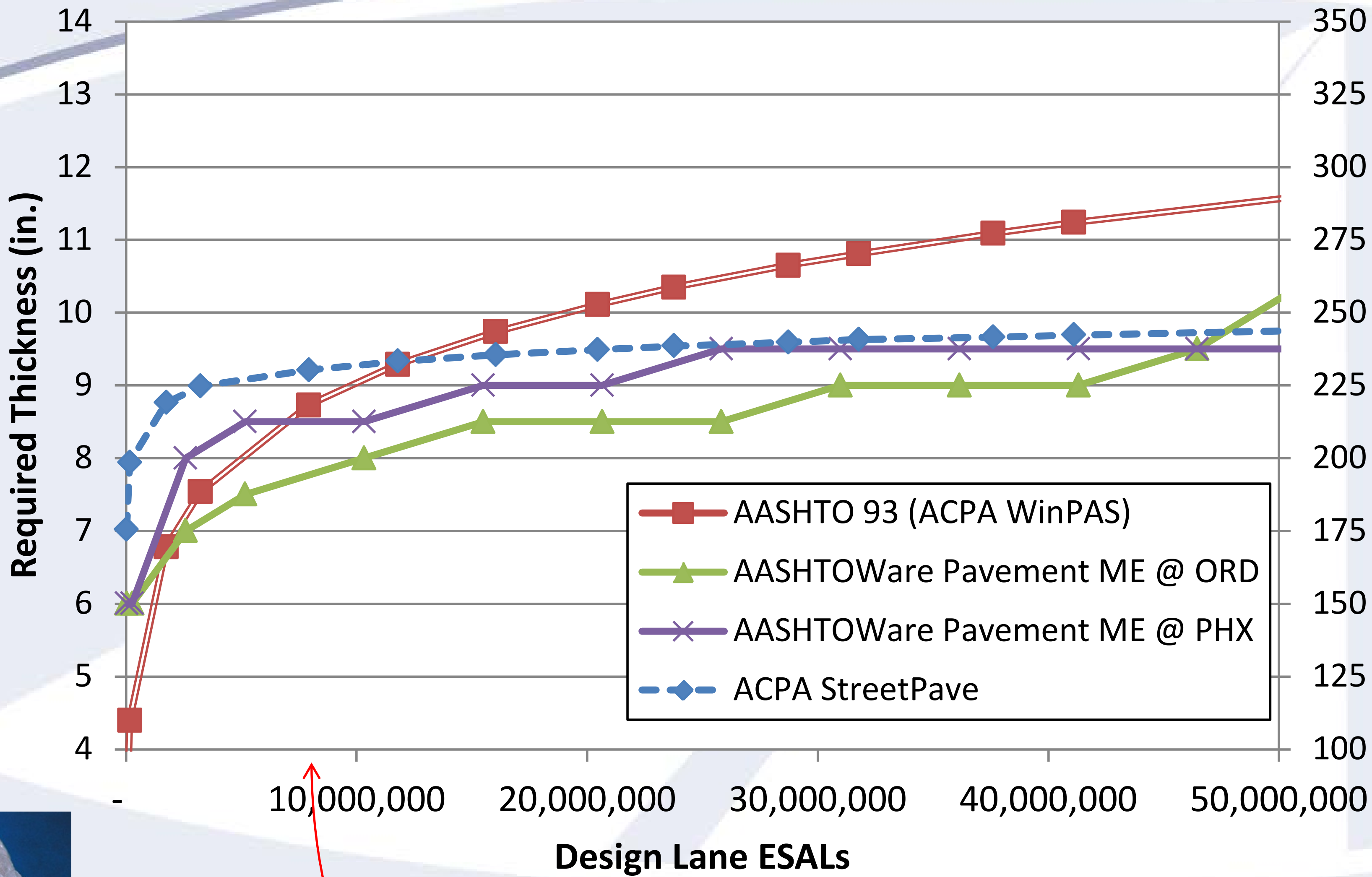
American Concrete Pavement Association
www.acpa.org || apps.acpa.org

Traffic Category: Major Arterial			Cracking Analysis		
Axle Load, kips	Axles per 1000 Trucks	Expected Repetitions	Stress Ratio	Allowable Repetitions	Fatigue Consumed
				Single Axles	
34	0.19	338	0.699	1018	33.18
32	0.54	960	0.661	2593	37.02
30	0.63	1120	0.622	8064	13.89
28	1.78	3165	0.583	32514	9.73
26	3.52	6259	0.544	185111	3.38
24	4.16	7397	0.504	1682478	0.44
22	9.69	17230	0.465	29293913	0.06
20	41.82	74360	0.425	unlimited	0.01
18	68.27	121391	0.385	unlimited	0
16	57.07	101476	0.344	unlimited	0
				Tandem Axles	
60	0.57	1014	0.546	167538	0.6
56	1.07	1903	0.511	1081193	0.18
52	1.79	3183	0.477	11068268	0.03
48	3.03	5388	0.442	211811503	0
44	3.52	6259	0.408	unlimited	0
40	20.31	36113	0.373	unlimited	0
[illegible]	78.19	139030	0.338	unlimited	0
[illegible]	109.54	194773	0.302	unlimited	0
[illegible]	95.79	170324	0.266	unlimited	0
[illegible]	71.16	126530	0.231	unlimited	0
				Total Fatigue Used %:	**98.53**



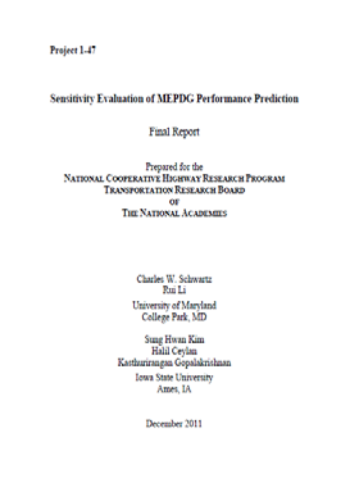
Comparison of Results and U.S. Trends

Doweled JPCP Thickness Comparison



remember AASHTO 93 limit?

Top 10 ME Design Most Sensitive


Project 1-47

Sensitivity Evaluation of MEPDG Performance Prediction

Final Report

Prepared for the
NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
TRANSPORTATION RESEARCH BOARD
OF
THE NATIONAL ACADEMIES

Charles W. Schwartz
Rui Li
University of Maryland
College Park, MD

Sung Hwan Kim
Halil Ceylan
Kasthurirangan Gopalakrishnan
Iowa State University
Ames, IA

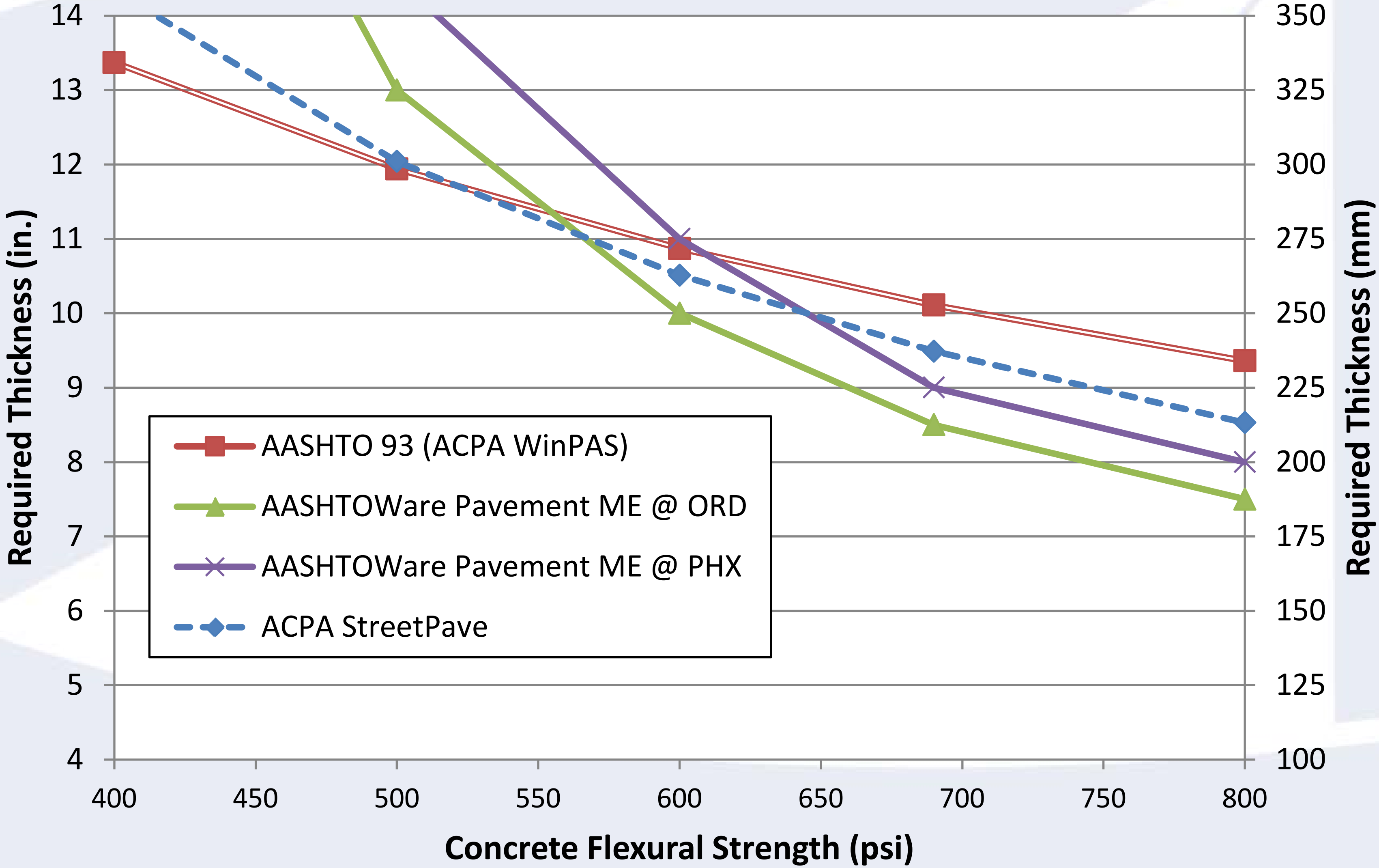
December 2011

1. **Concrete Flexural Strength at 28-Days**
2. Concrete Thickness
3. Surface Shortwave Absorptivity (SSA)
4. Joint Spacing
5. **Concrete Modulus of Elasticity at 28-Days**
6. Design Lane Width with a 14 ft (4.3 m) Widened Slab
7. **Edge Support via Widened Slab**
8. Concrete Thermal Conductivity
9. Concrete Coefficient of Thermal Expansion (CTE)
10. Concrete Unit Weight

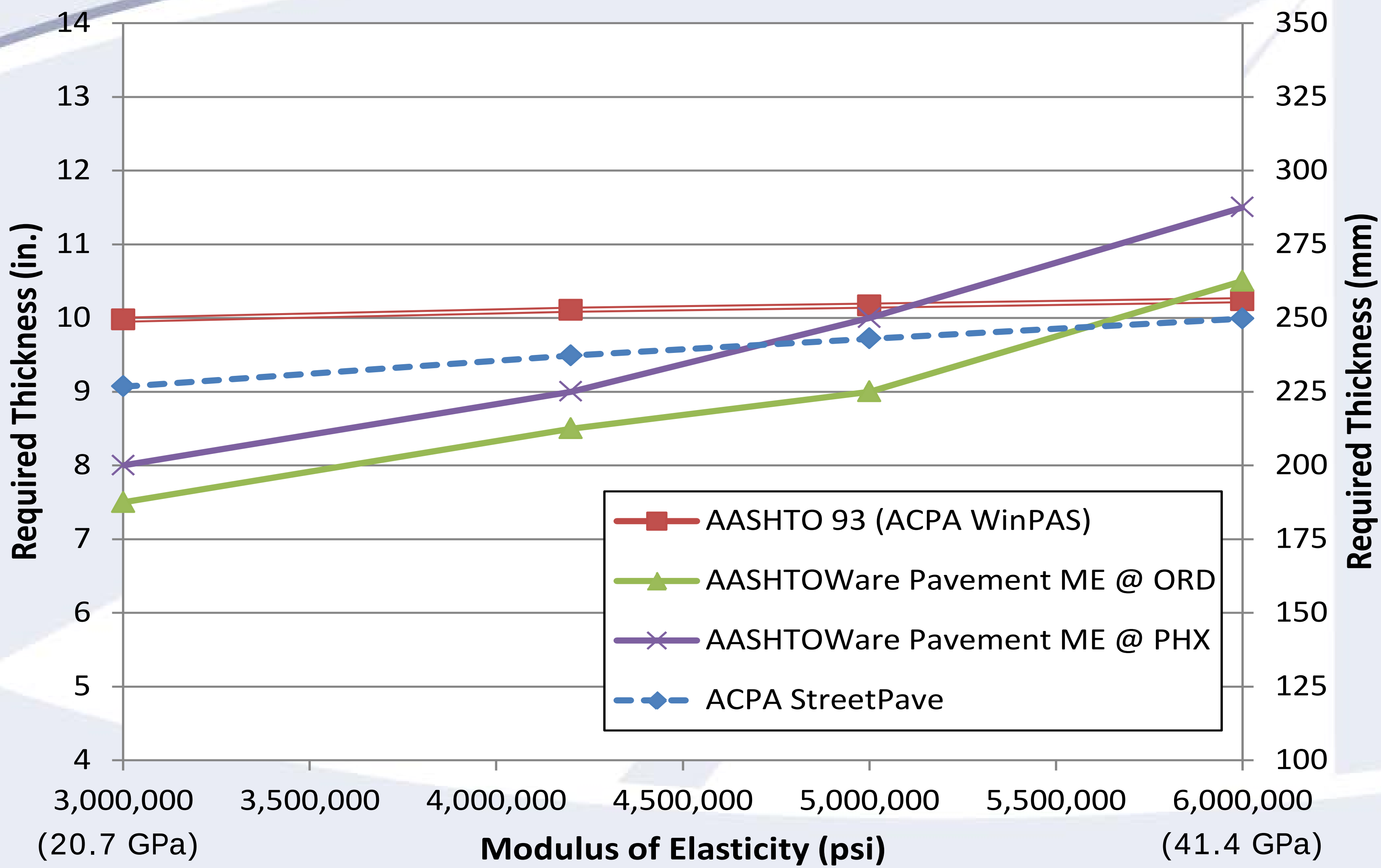
Red = only ME Design input… the **VALUE** of the software!

Blue + Bold = common for all

Flexural Strength Sensitivity

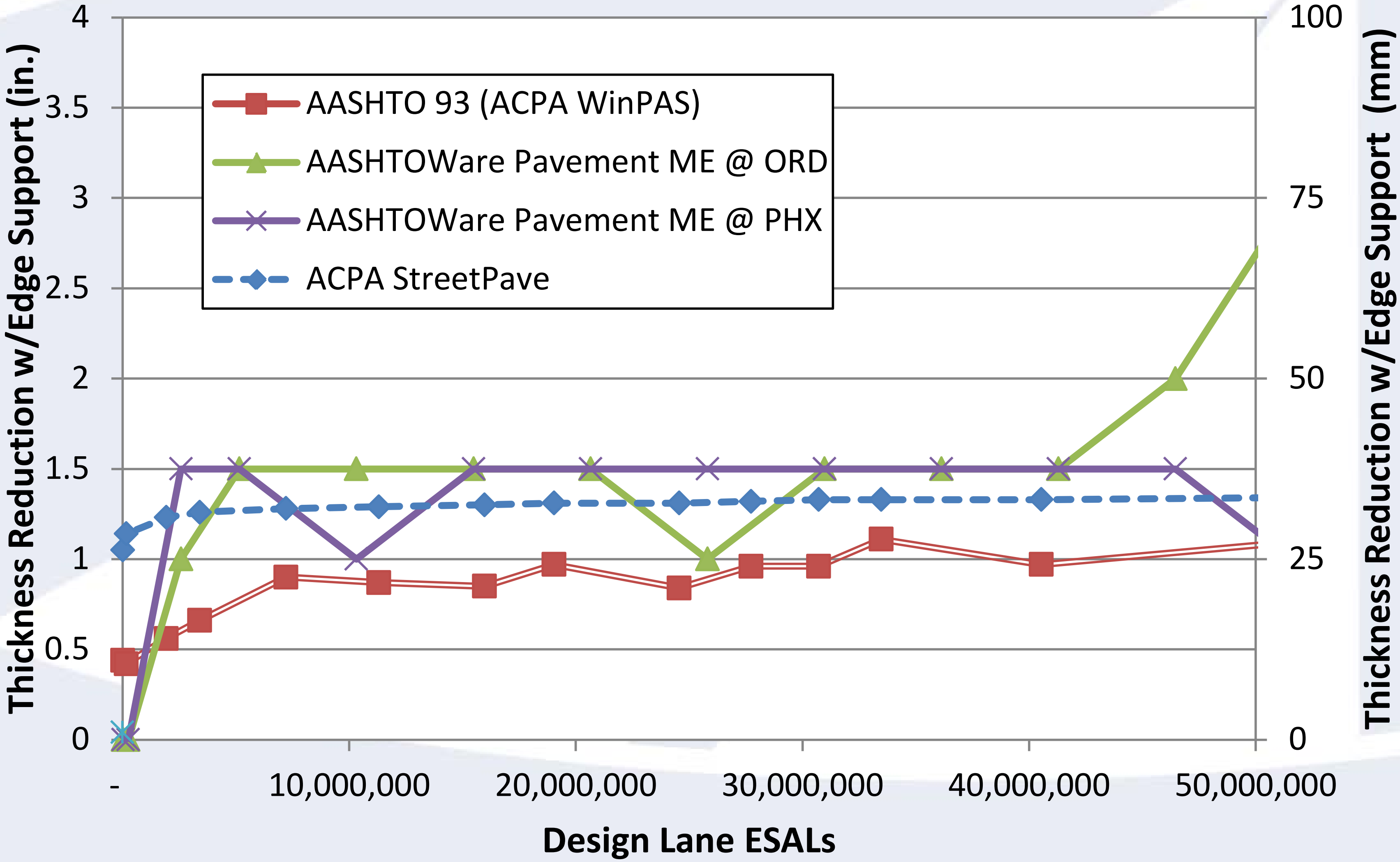


Modulus of Elasticity Sensitivity

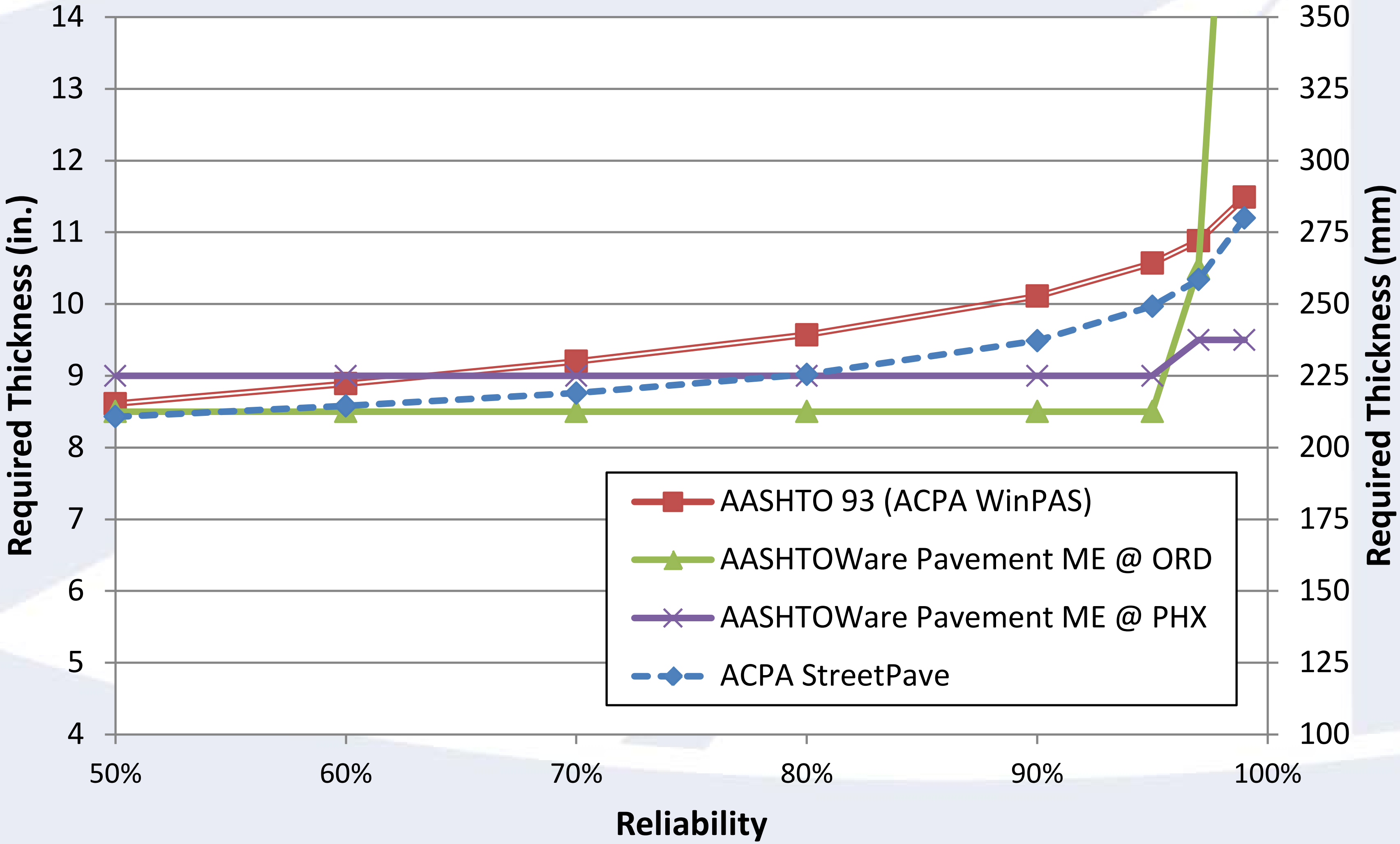


… in reality, need to change strength too…

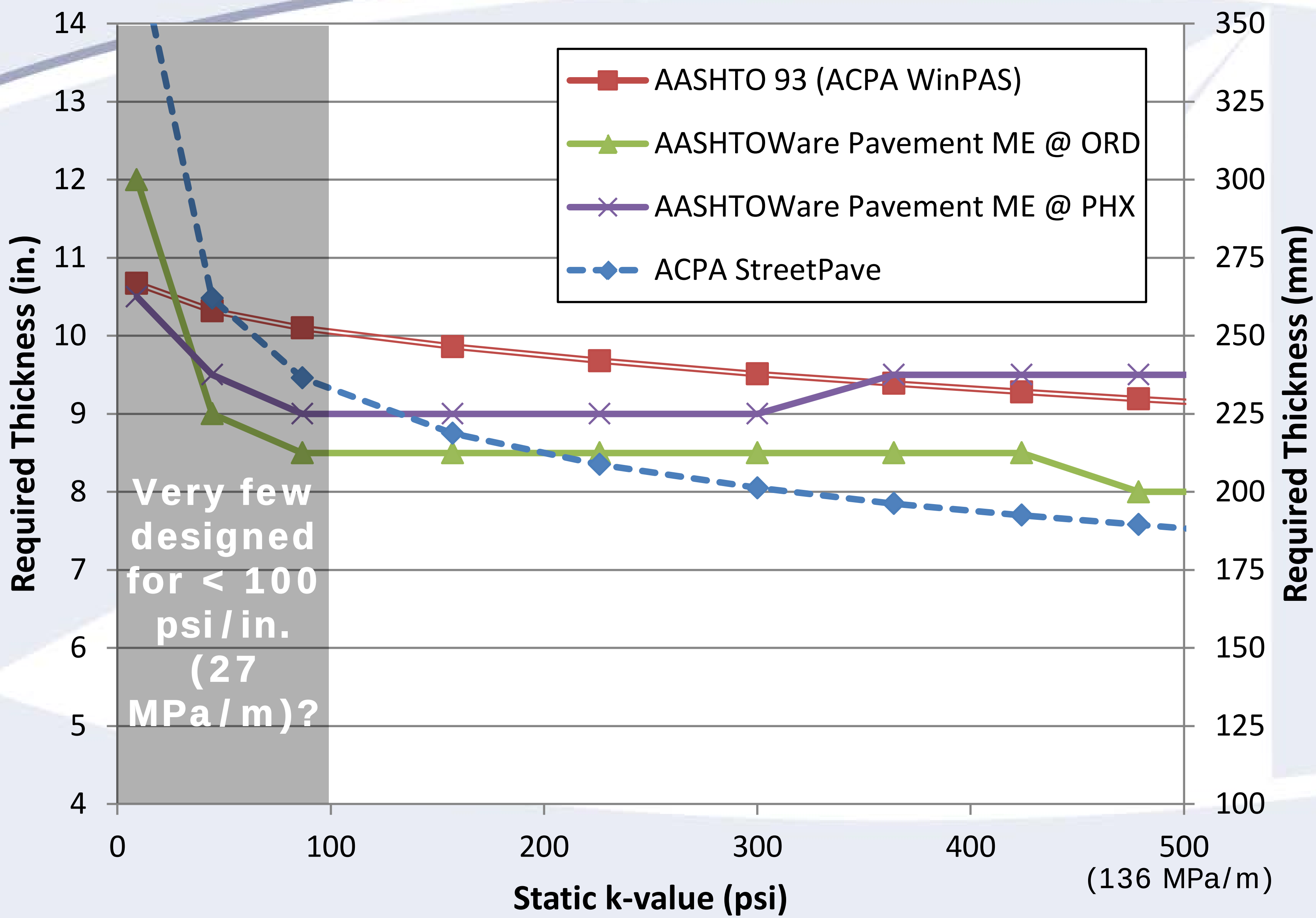
Thickness Reduction w/ Edge Support



Reliability Sensitivity



k-value Sensitivity



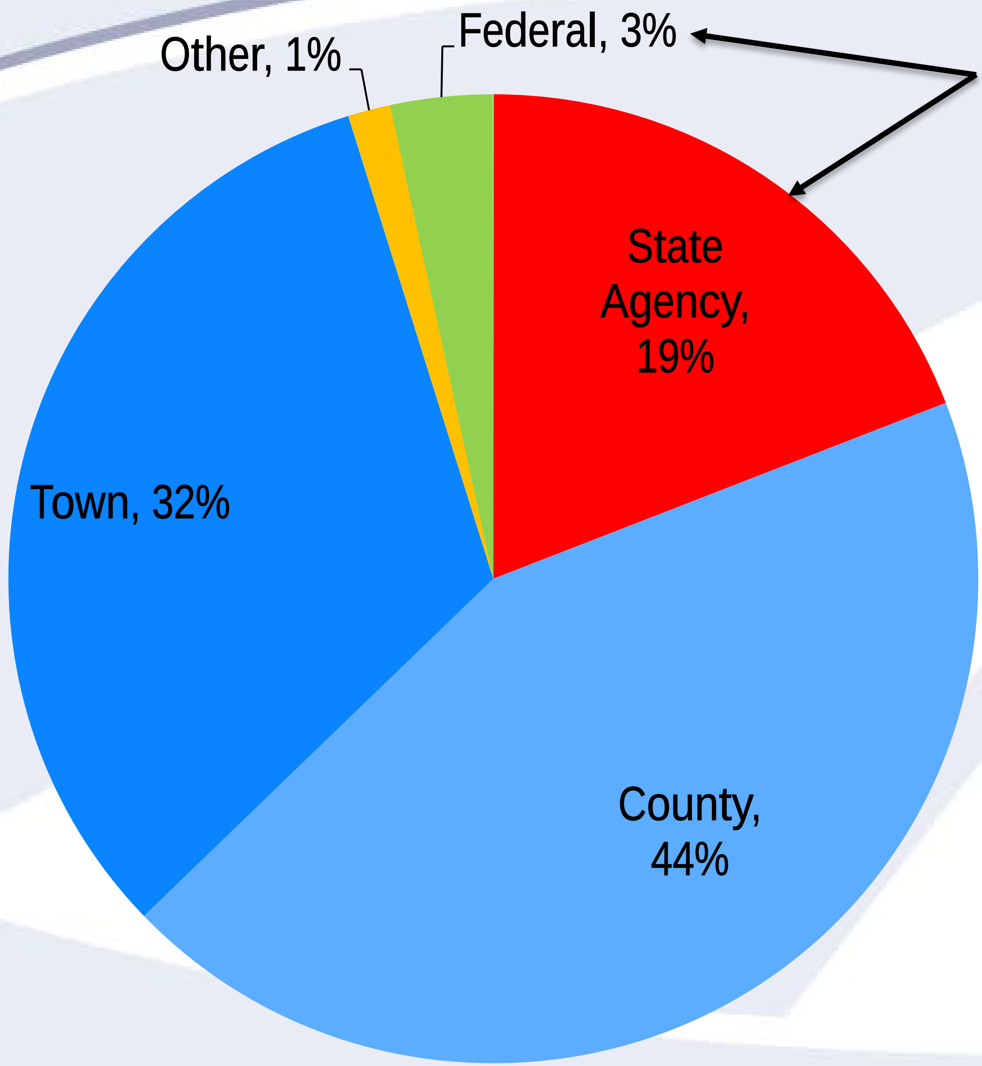
U.S. Agencies Quickly Changing

- Summary of State Agency practice in 2005:

Design Method Used	Percent of Responding Agencies	State Agency
AASHTO 72/86/93	85%	AR, AZ, DE, FL, ID, IN, IA, KS, MD, MI, NV, NC, OH, OK, SC, SD, TN, UT, VA, WA, WV, WI, WY
AASHTO MEPDG	4%	MO
PCA Method	11%	HI, IN, IA
State-Developed	7%	IL, MT

- At the end of 2013, 41 state agencies had performed ME Design calibration and implementation efforts, indicating a relatively quick shift from AASHTO 93.

U.S. Roadway Length (lane miles)



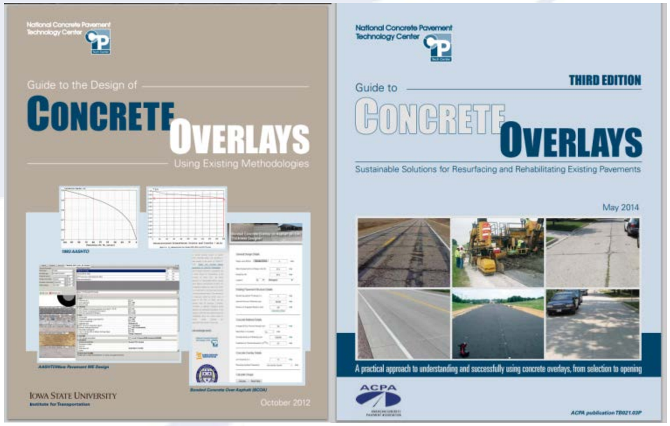
AASHTO tools are being developed for these owners…

City, county, and other local engineers need to decide what to use locally because Pavement ME will not trickle down due to its cost and complexity!

Source: HM-10, 2012 FHWA Highway Statistics

Overlay Design – Bonded Concrete on Asphalt

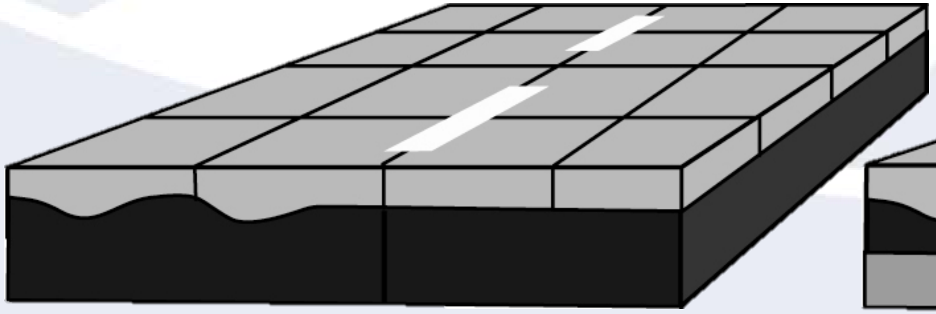
BCOA ME
University of Pittsburgh

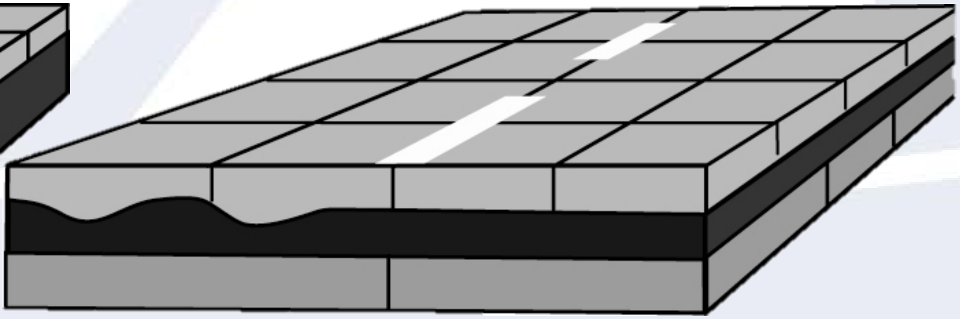


ACPA

Bonded over Asphalt/Composite

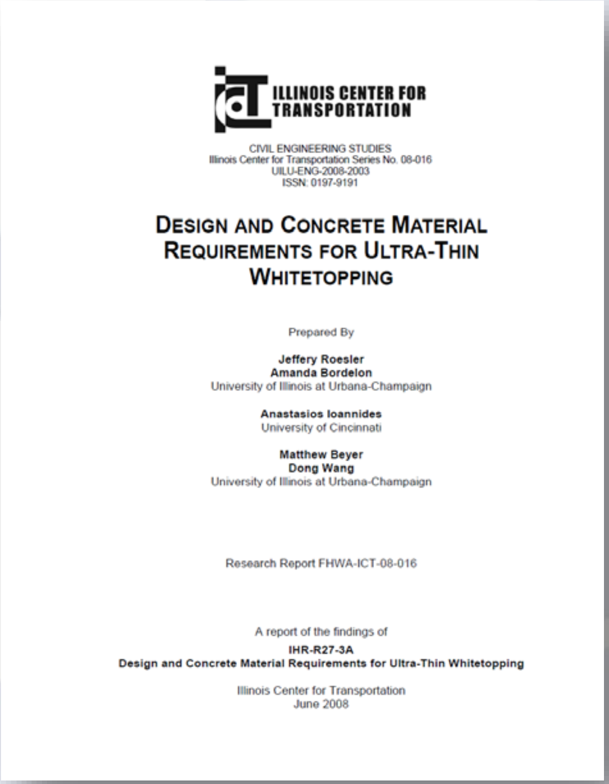
- AASHTO 93: not applicable
- AASHTO ME: limited to a joint spacing > 10 ft (3 m) and not applicable to thinner (2-6 in. [50-150 mm]) concrete overlays; refers people to ACPA
- ACPA BCOA and StreetPave: account for bond to asphalt and short slab size, fibers, etc.





Bonded over Asphalt/Composite

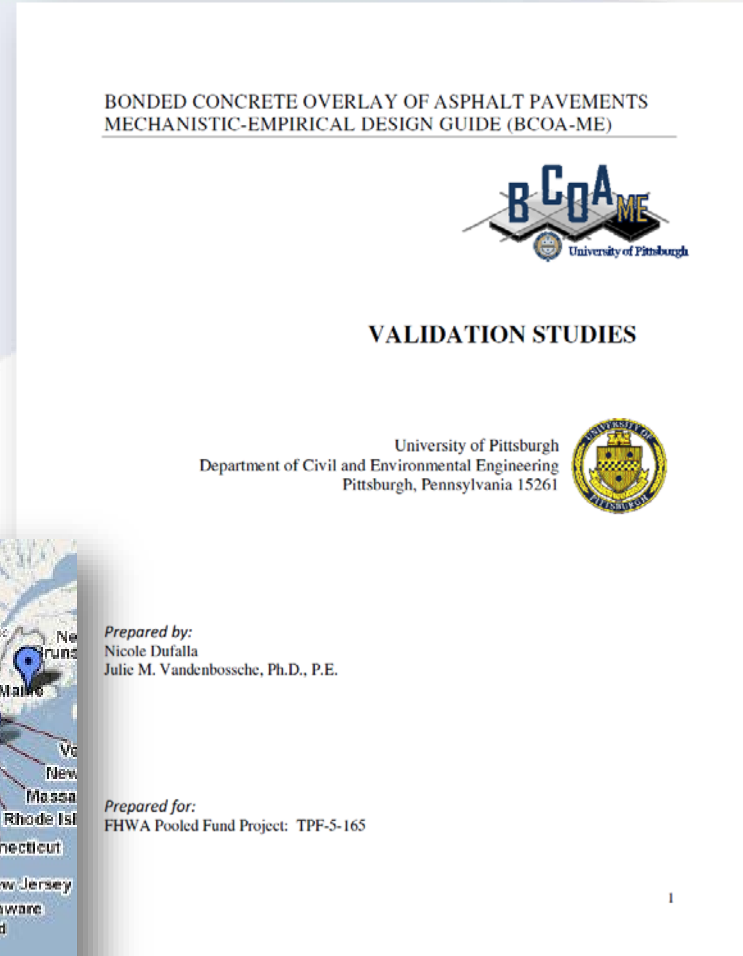
- Not an extension of an existing design method; a completely custom-built design method
- For ACPA BCOA and StreetPave based primarily on FHWA-ICT-08-016
- Other methods include CDOT 6x6x6 and recently released FHWA pooled fund TPF-5(165)



FHWA pooled fund TPF-5(165)

BCOA ME

University of Pittsburgh


BONDED CONCRETE OVERLAY OF ASPHALT PAVEMENTS MECHANISTIC-EMPIRICAL DESIGN GUIDE (BCOA-ME)

VALIDATION STUDIES

University of Pittsburgh
Department of Civil and Environmental Engineering
Pittsburgh, Pennsylvania 15261

Prepared by:
Nicole Dufalla
Julie M. Vandenbossche, Ph.D., P.E.

Prepared for:
FHWA Pooled Fund Project: TPF-5-165

1

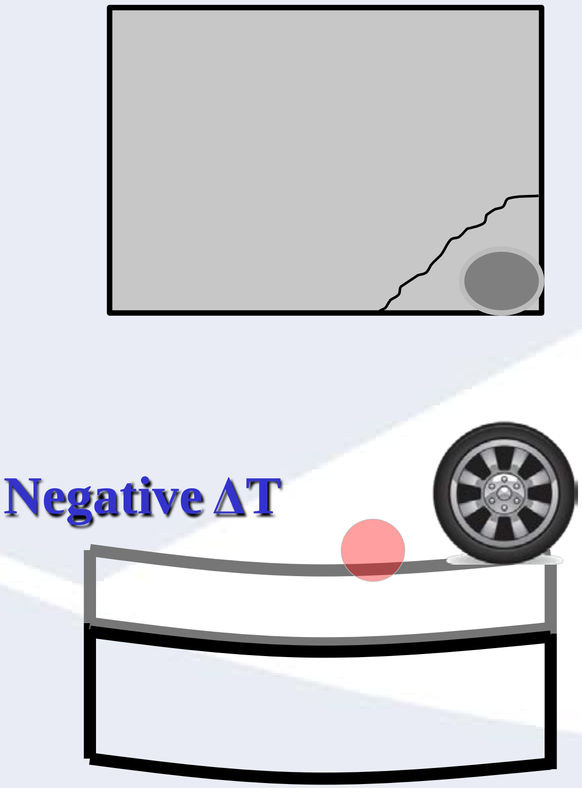
Pitt BCOA ME

- FHWA Pooled Fund Study TPF 5-165

BCOA ME failure modes

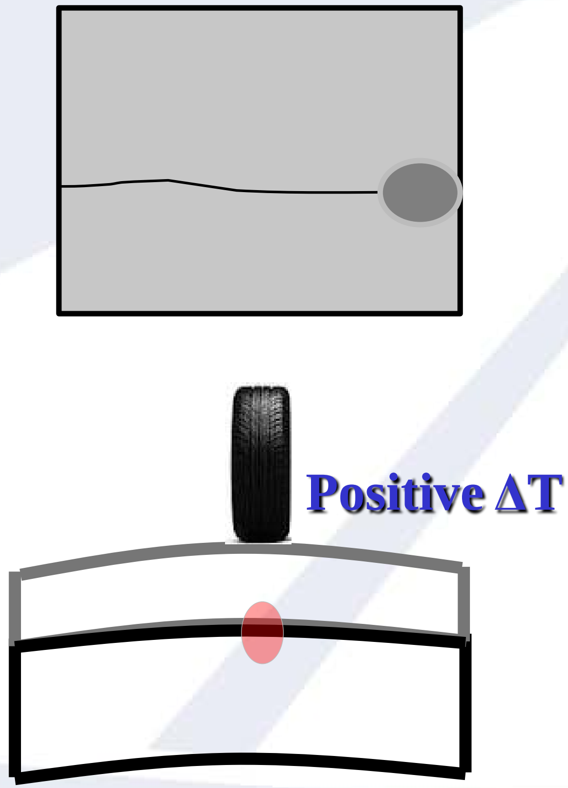
≤ 4.5 ft

Corner Break



5 to 7 ft

Long. & Diag Crack

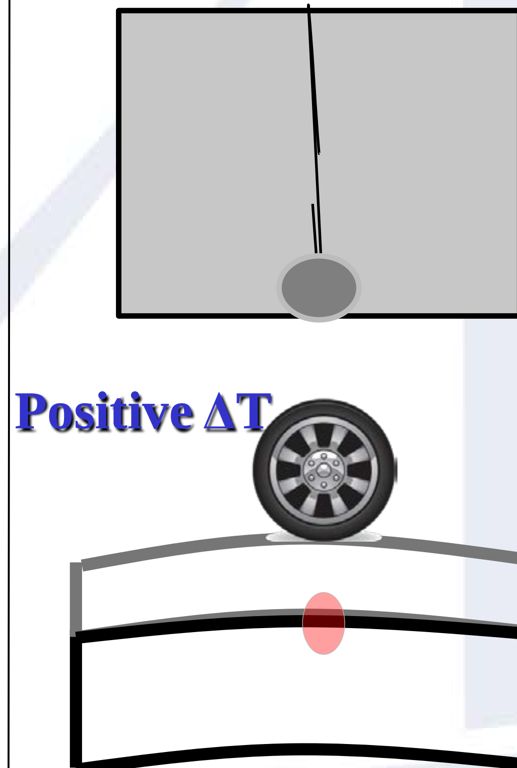


10 x 12 ft

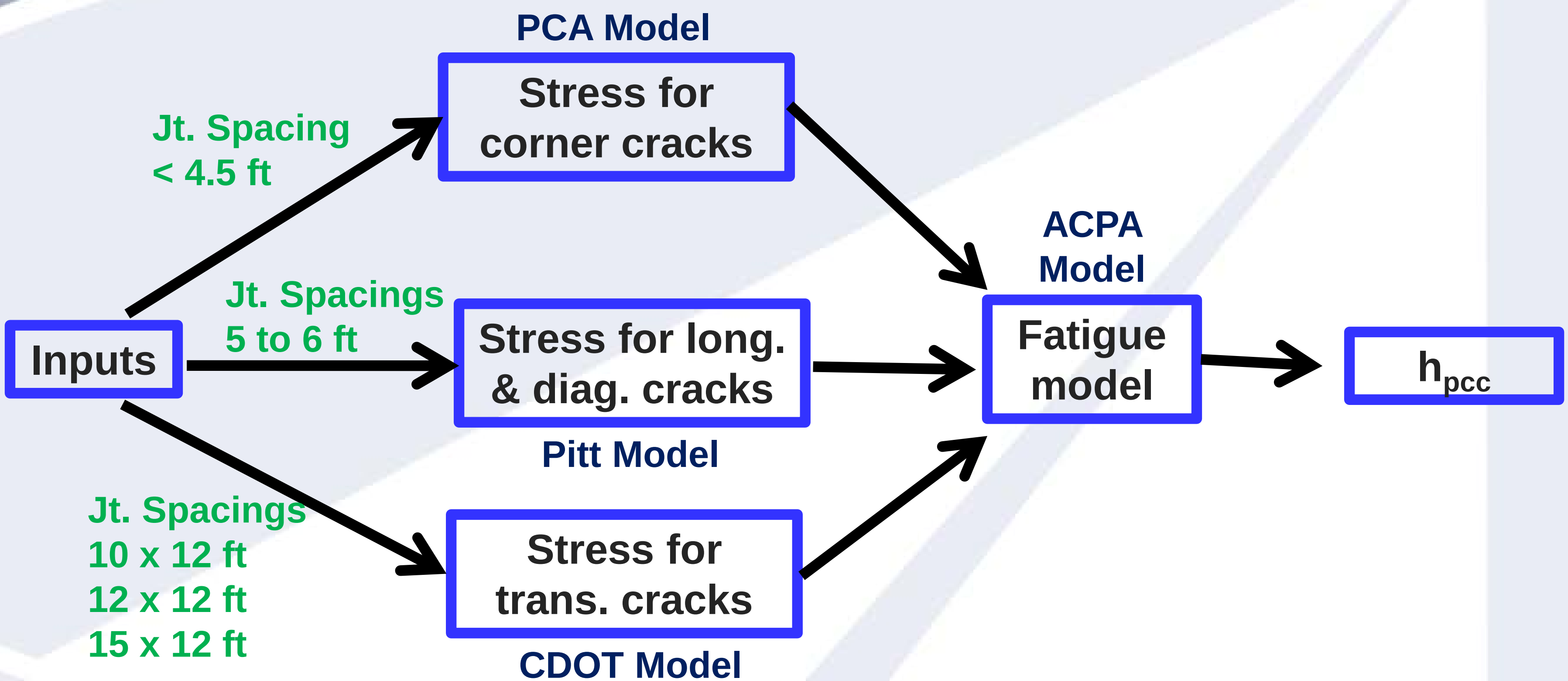
12 x 12 ft

12 x 15 ft

Trans. Crack

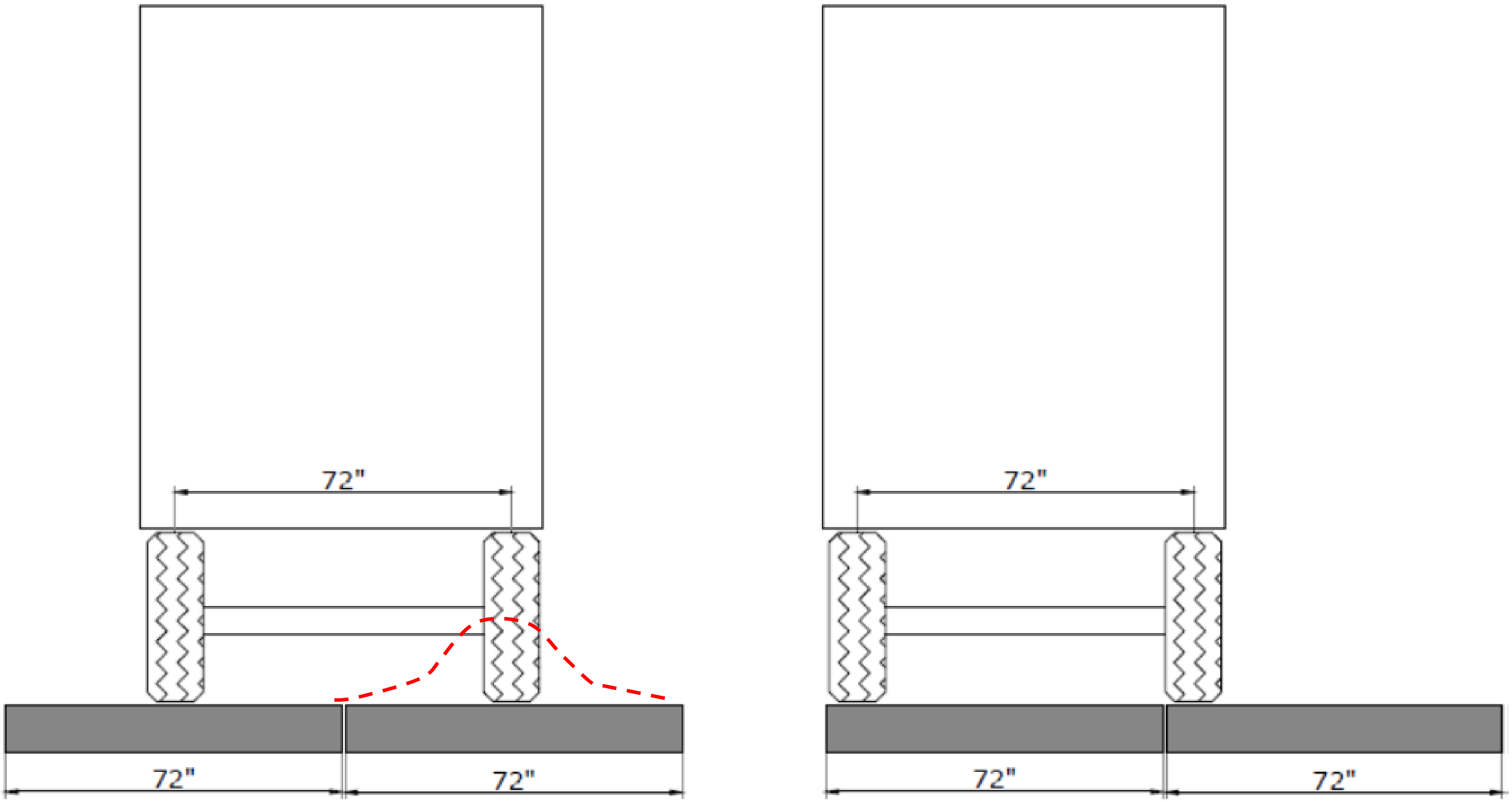


BCOA-ME



PCA Model
Stress for corner cracks
Jt. Spacing
< 4.5 ft
ACPA Model
Jt. Spacings
5 to 6 ft
Inputs
Stress for long. & diag. cracks
Fatigue model
h_{pcc}
Pitt Model
Jt. Spacings
10 x 12 ft
12 x 12 ft
15 x 12 ft
Stress for trans. cracks
CDOT Model

Wheel wander considered



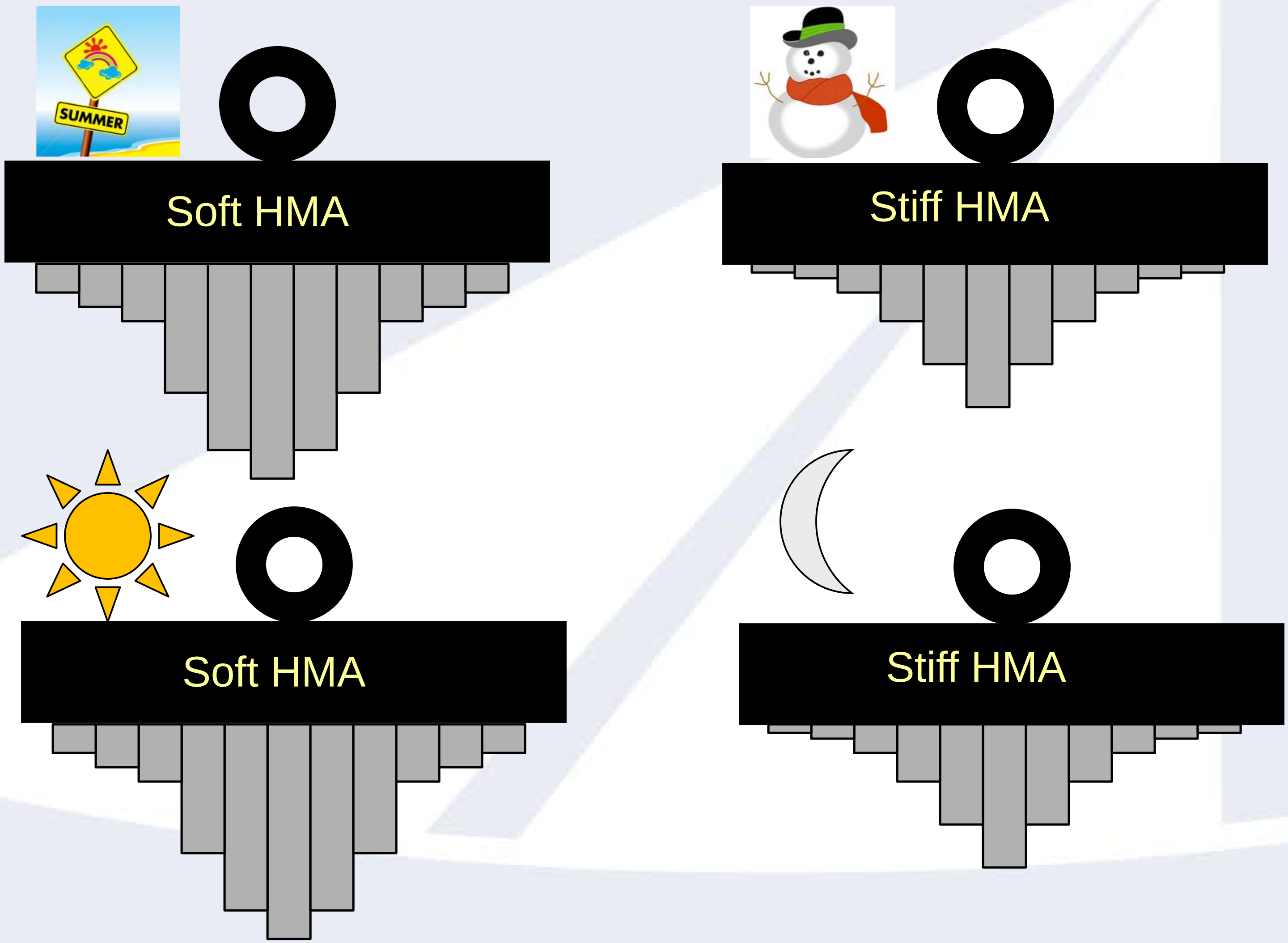
(a) Real Situation in the Road

(b) Critical condition

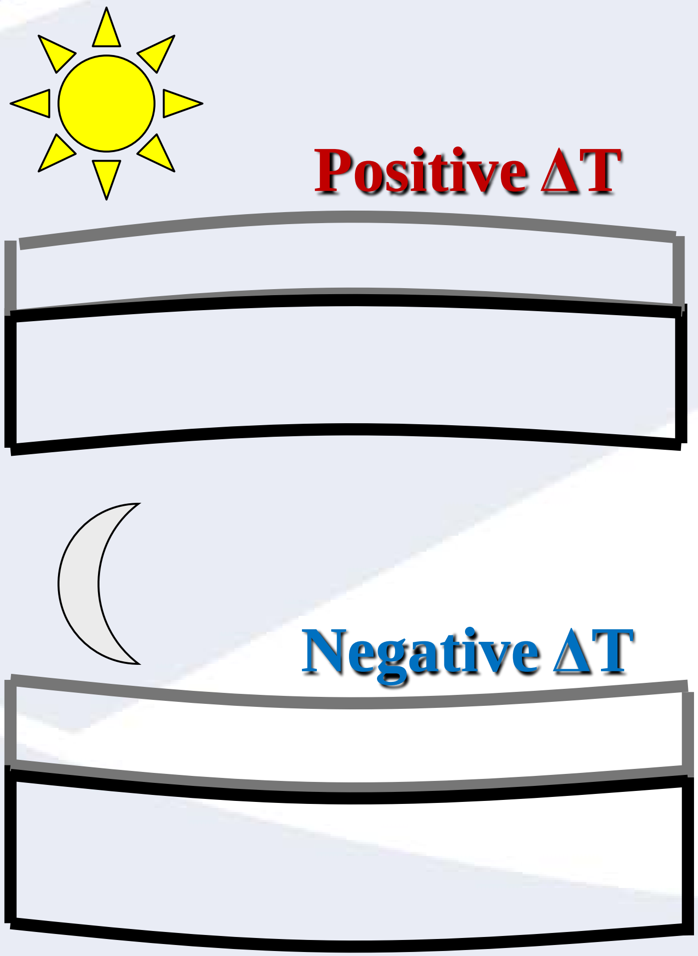
Variation in HMA stiffness

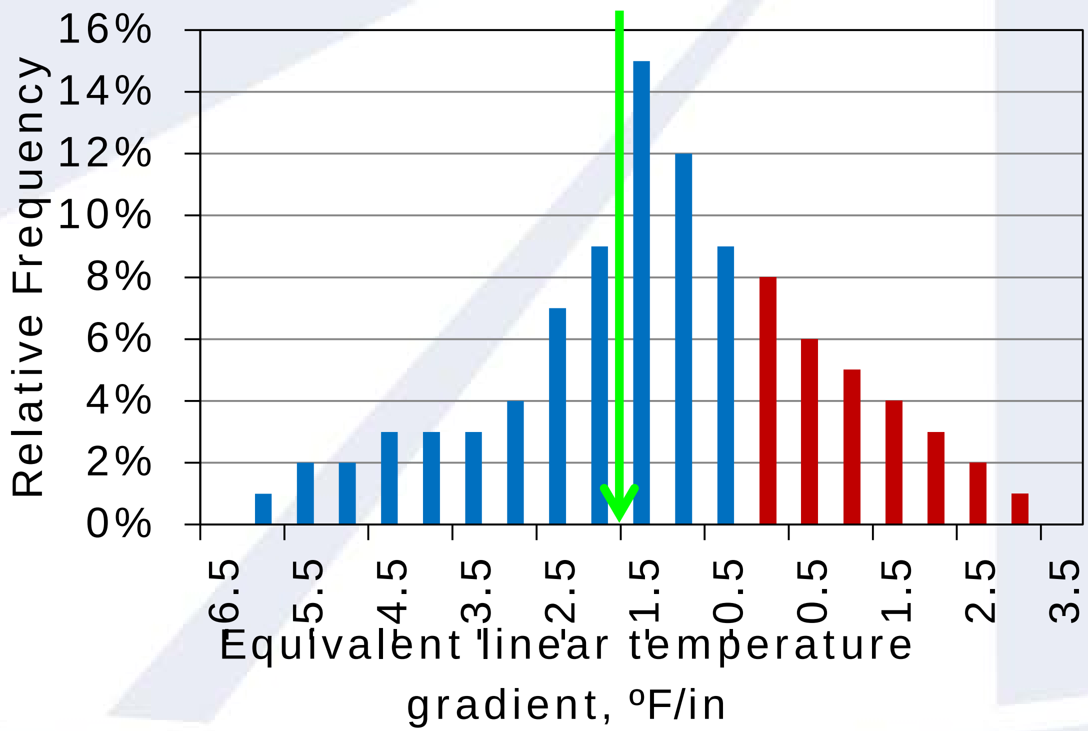
Seasonal variation

Daily variation

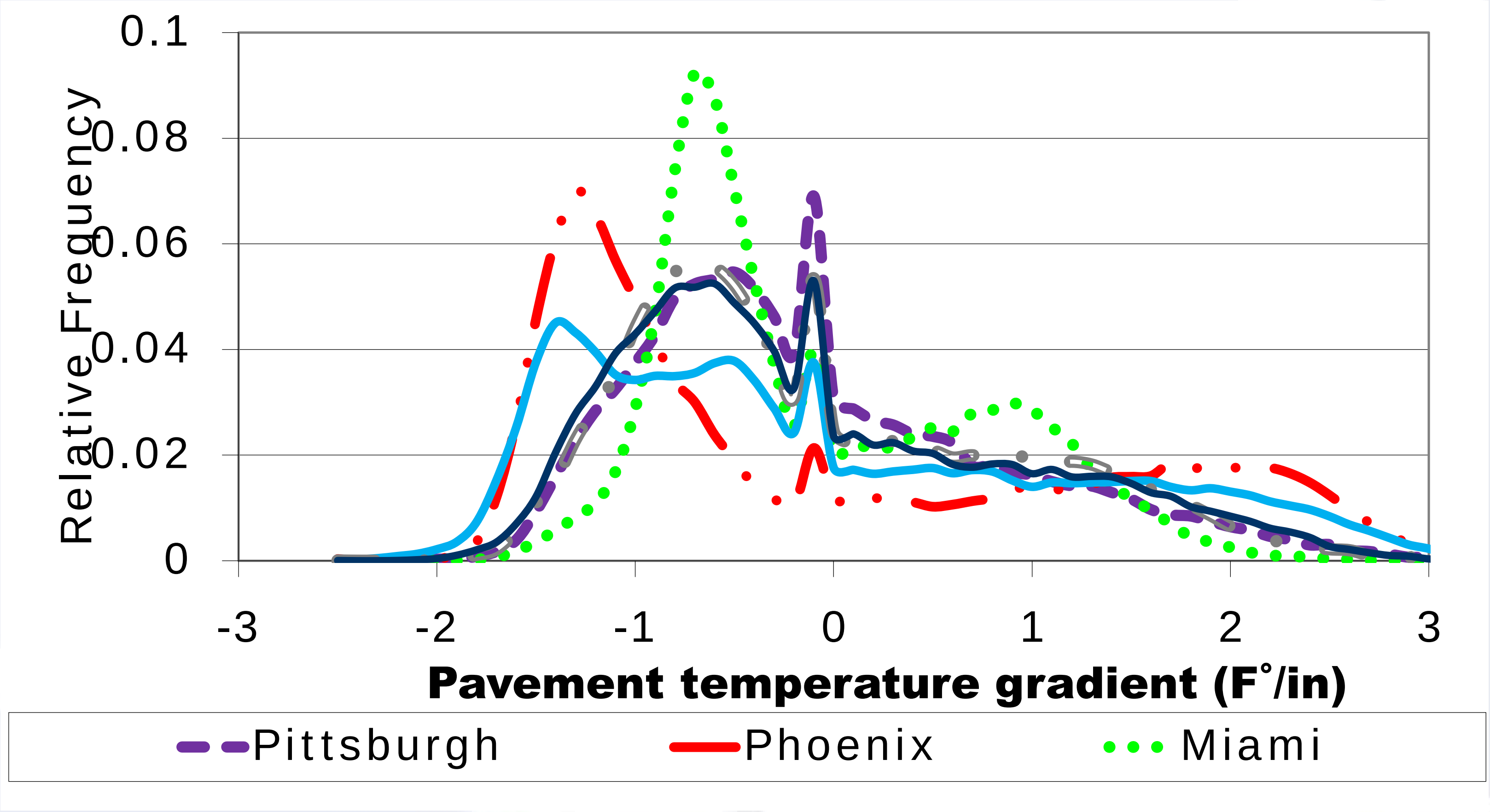


Effective temp. gradient



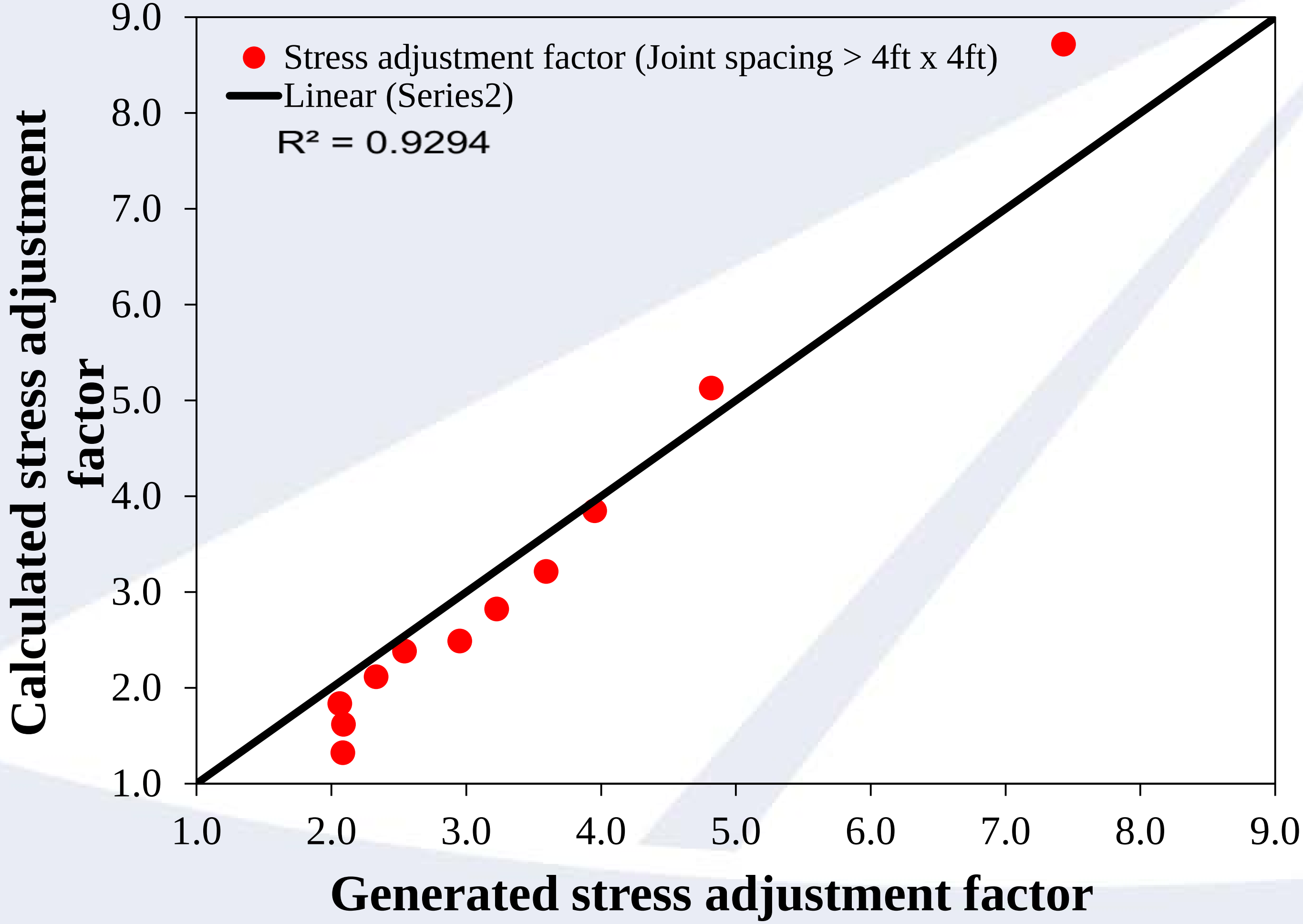


Regional variation in temp. grad.



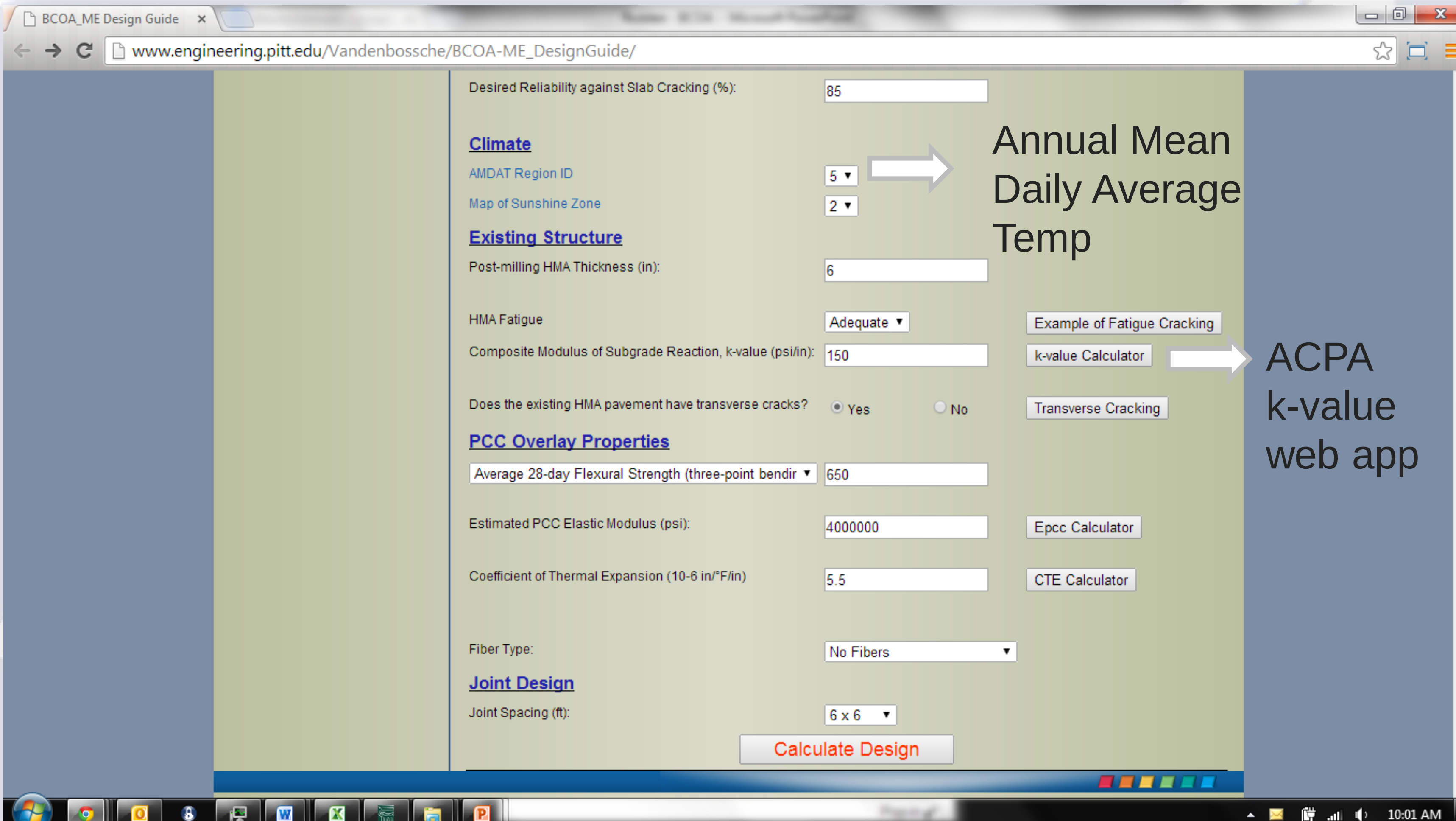
Vandenbossche and Mu (2010)

Calibration - Stress Adj. Factors



Pitt BCOA-ME Web App

Pitt BCOA-ME Web App



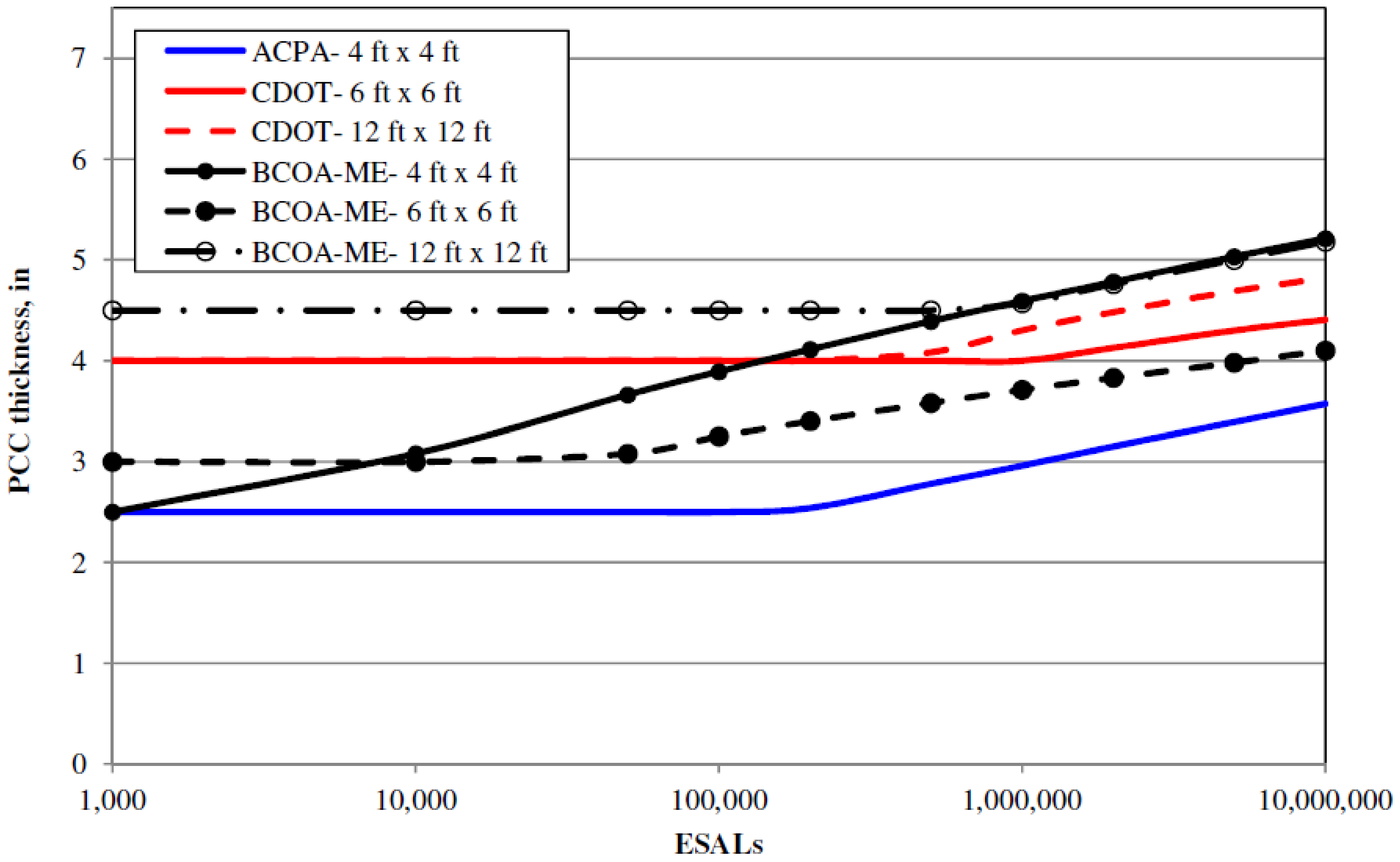
Annual Mean Daily Average Temp

ACPA k-value web app

Results of the BCOA-ME

- BCOA ME is <1/3 ACPA BCOA app, <1/3 CDOT procedure and the remainder was developed at Pitt
- Comparison to ACPA BCOA app:
  - JS ≤ 4.5 ft, the model is similar but thicknesses possibly greater because BCOA ME was calibrated to field performance, accounting for loading directly in the wheel path
  - JS > 4.5 ft, it will not compare because failure mode changes (e.g., no longer corner cracking); BCOA ME will almost always be thinner than ACPA BCOA for a 6’ x 6’ JS
- Comparison to CDOT design procedure:
  - Depends on failure mode

Bonded over Asphalt/Composite



Design considerations

PCC = 4 in or less
HMA

PCC = 5 in or more
PCC

Load carrying layer

Overlay thickness

PCC = 4 in or less → **HMA** → Bond is essential

PCC = 5 in or more → **PCC** → Bond enhances performance

Design considerations

Design considerations

Critical Stress for 6ft x 6ft slab, psi			
PCC Thickness	**3 in**	**4 in**	**6 in**
HMA Thickness			
4 in	352	339	274
6 in	246	234	211
8 in	198	191	177

Thank you.

Questions? FEEDBACK!

Download StreetPave:

www.acpa.org/streetpave

Eric Ferrebee

Technical Services Engineer

American Concrete Pavement Association

eferrebee@acpa.org | 847.423.8709

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