Implementation Process of

# Pavement ME Design in Maricopa County


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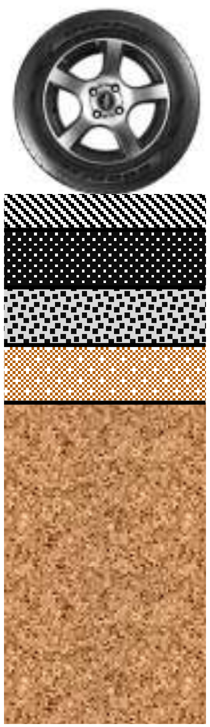
# Main Objective of this Study

- ❑ Explore the new pavement design software program
- ❑ Find suitable local calibration factors for County conditions
- ❑ Implement the new design method at Maricopa County in the future

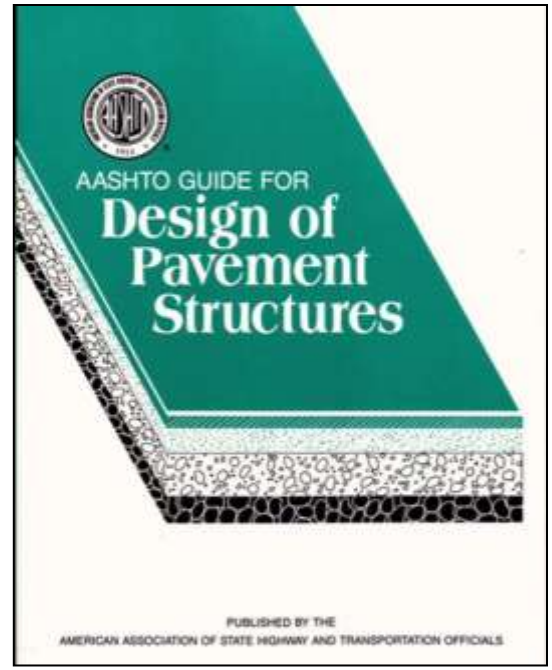
# Current MCDOT Pavement Design Procedure



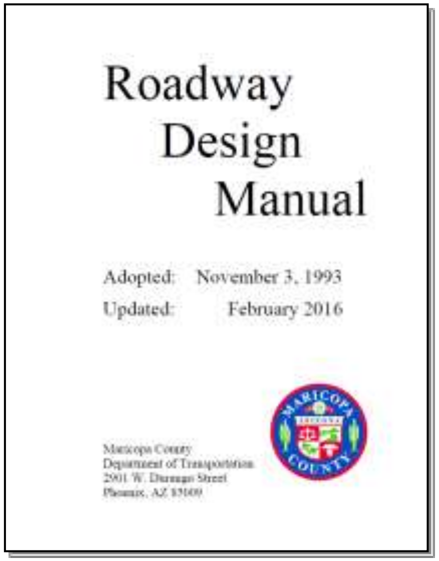
Traffic: **AADT** & **% Trucks** converted to **ESALs**

AC and AB:
***a*$_i$** and **E**

Subgrade:
**R-Value**, **Sieve** and **PI** correlated to **$M_R$**




# Current Pavement Design: Pros and Cons


Roadway Design Manual

Adopted: November 3, 1993
Updated: February 2016

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2901 W. Durango Street
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## Chapter 10

MCDOT Pavement Design Guide

## PROS

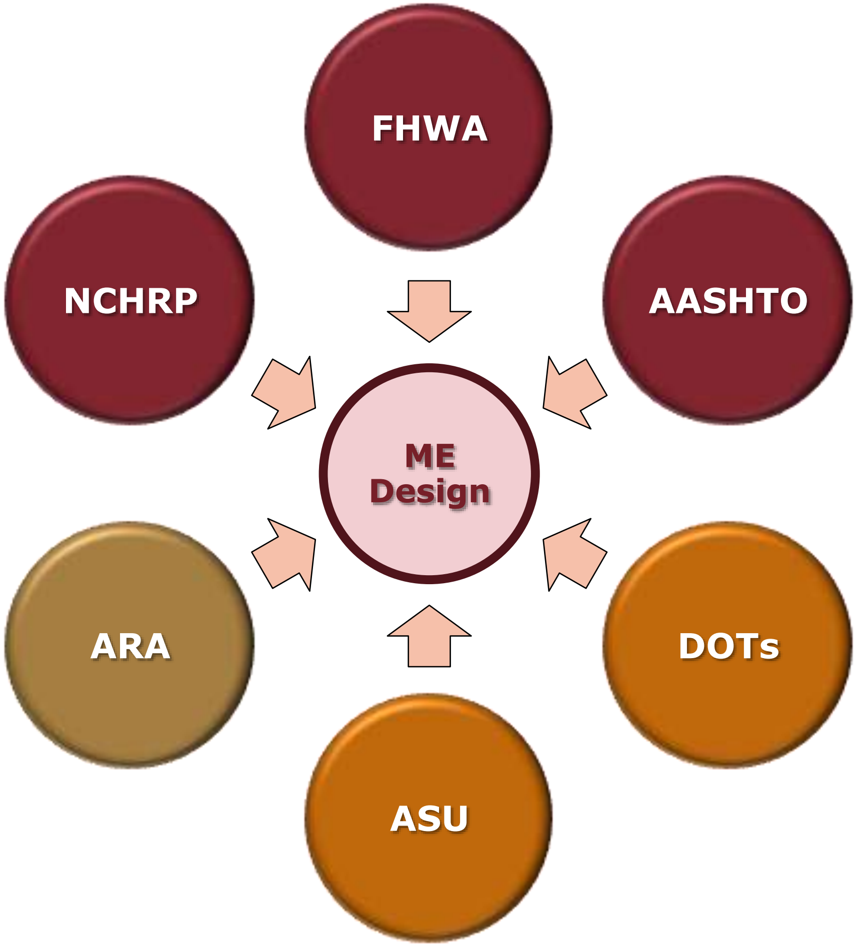
- ❑ Inexpensive testing
- ❑ Simple design
- ❑ layer thicknesses

## CONS

- ❑ Based on one AASHO Road Test conducted in the late 1950s
- ❑ The latest update was in 1993
- ❑ Uses empirical relations

# New Pavement ME Design

- Pavement ME Design is built upon Mechanistic-Empirical Pavement Design Guide (MEPDG)
- Reflects eight years of research and development by ASU and others
- Continuous improvement under NCHRP, the FHWA and State Agencies



# New Pavement ME Design: Pros and Cons

## PROS

- Mechanistic behavior of structure is modeled
- Based on extensive research effort over many years
- Predicts pavement performance
- Hierarchical input levels available
- Possible to carry out local calibrations

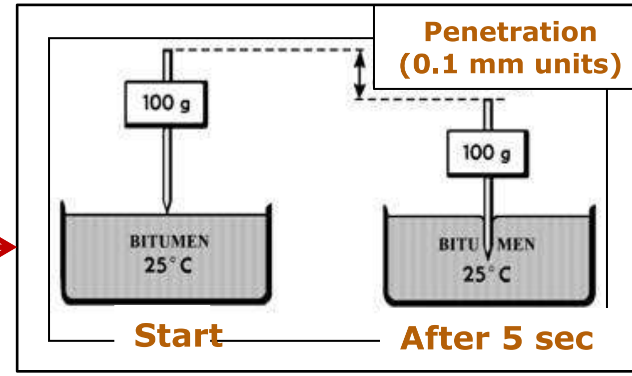
## CONS

- Expensive testing is required
- The design process is not very simple
- The software is expensive to maintain
- Users should gain good knowledge to input data, interpret analyses, and make reasonable decisions

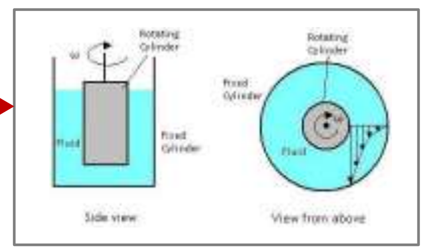
# New Pavement ME Design Laboratory Testing

## Binder Viscosity Testing

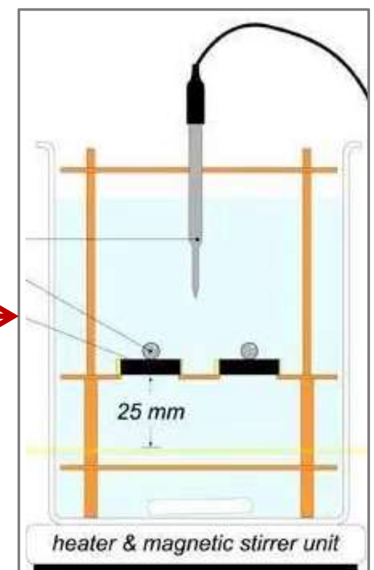
- ❑ **Penetration** at 77 $^{o}$F



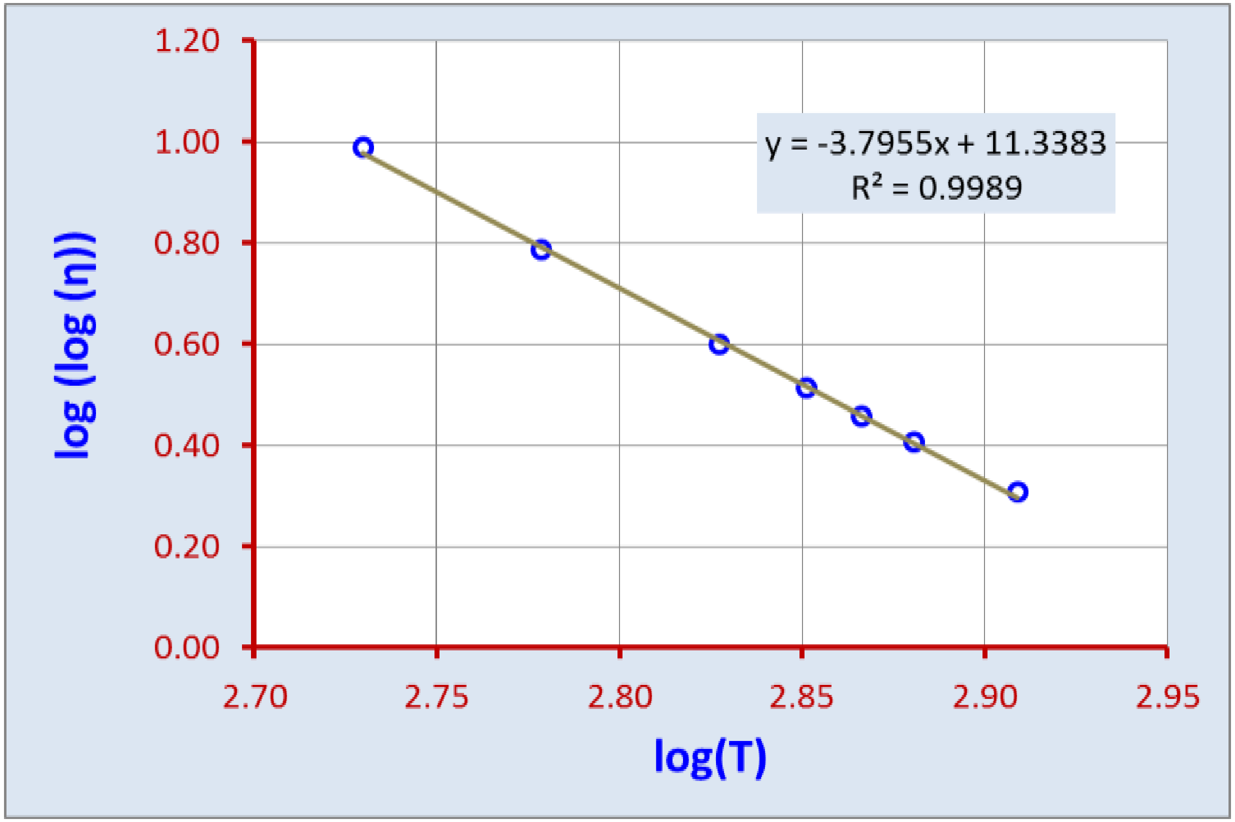

- ❑ **Brookfield Viscosity** at 212, 250, 275, 300, and 351 $^{o}$F




- ❑ **Softening Point**



# Viscosity-Temperature Susceptibility (VTS)




Regression parameters **Ai** (intercept) & **VTSi** (slope) describe the Viscosity-Temperature relationship

**For the plot shown:**

**Ai = 11.3383**

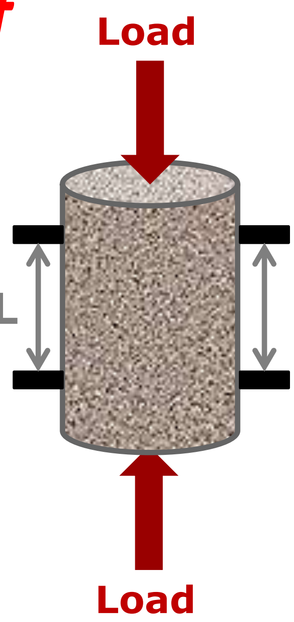
**VTSi = — 3.7955**

# Dynamic Modulus Test

**Control:**

Temperature **T**

Load Frequency ***f***

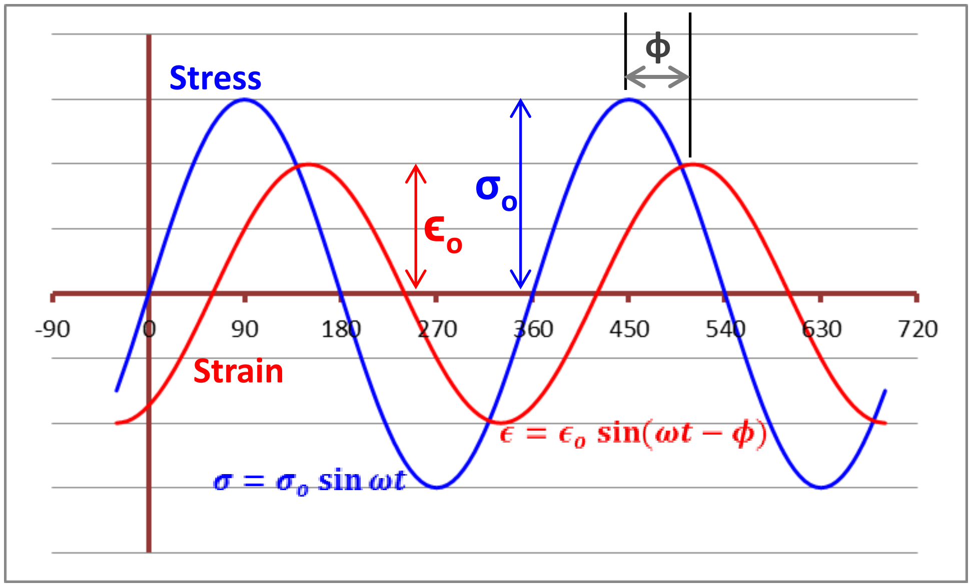


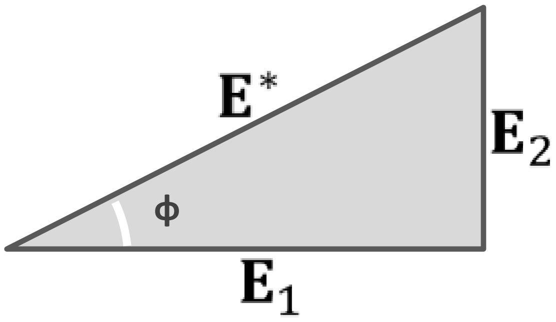

**Measure:**

Stress **σ**

Strain **ϵ**

# Dynamic Modulus, E* of Visco-Elastic Material




$$|E^*| = \frac{\sigma_o}{\epsilon_o}$$

# E* in kips/in$^2$ Obtained after Testing

| EG | Frequency (Hz) / Time (sec) | | | | | |
|---|---|---|---|---|---|---|
| Temp (°F) | 0.1 | 0.5 | 1 | 5 | 10 | 25 |
| | 10 | 2 | 1 | 0.2 | 0.1 | 0.04 |
| 14 | 2,854 | 3,276 | 3,470 | 3,829 | 3,947 | 3,952 |
| 40 | 1,258 | 1,749 | 2,004 | 2,614 | 2,850 | 3,030 |
| 70 | 497 | 743 | 872 | 1,256 | 1,445 | 1,670 |
| 100 | 152 | 209 | 250 | 412 | 508 | 665 |
| 130 | 119 | 130 | 141 | 184 | 219 | 300 |

Max

Min

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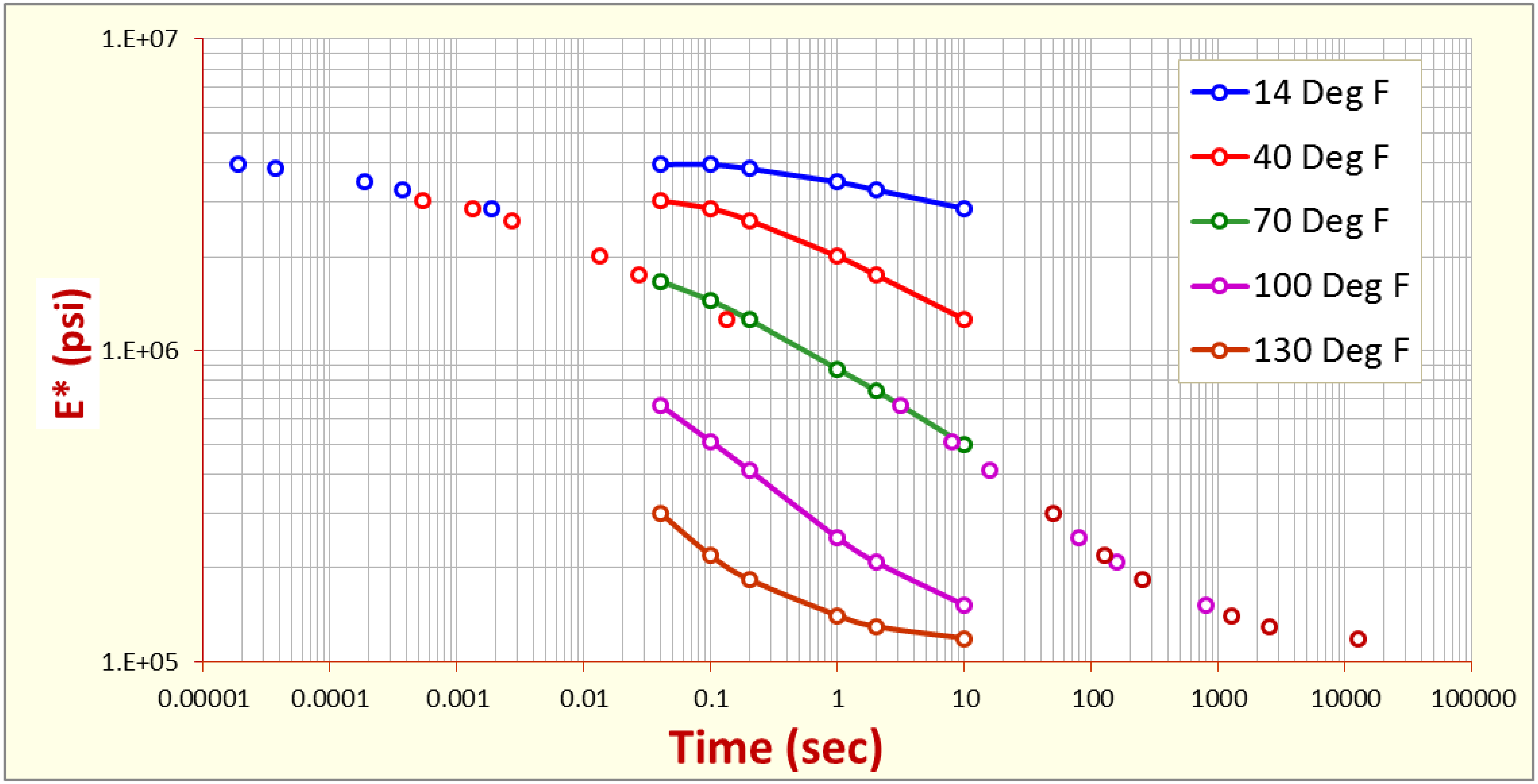
# Plotting E* and Master Curve

## Principal of Time-Temperature Superposition

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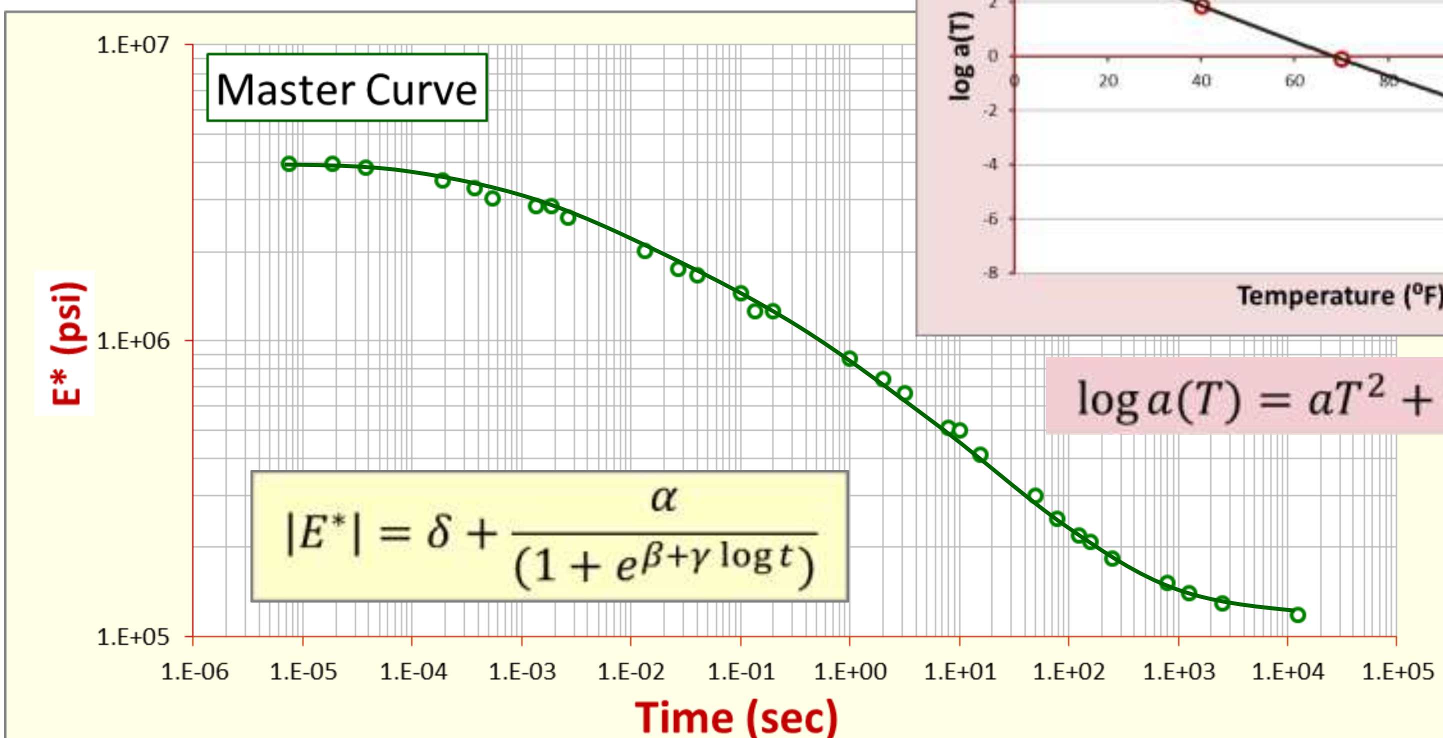
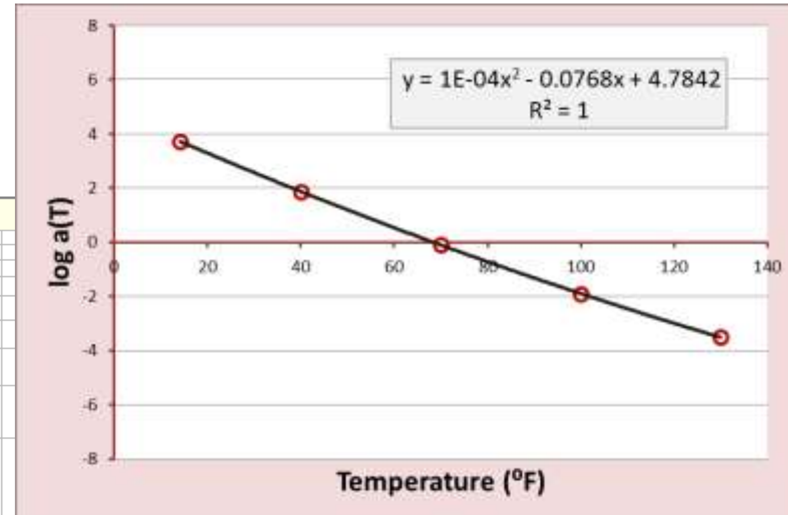
# Master Curve Function & Shift Factor Function




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




$$\log a(T) = aT^2 + \mathrm{bT} + \mathrm{c}$$

# Maricopa County Research 2006 to 2009

- ASU conducted a research program for Maricopa County from 2006 to 2009
- All pavements were flexible pavements
- Binder, AC mix, AB, and soil samples from 15 road construction projects were collected for testing

# Material Characterization under The Research Program

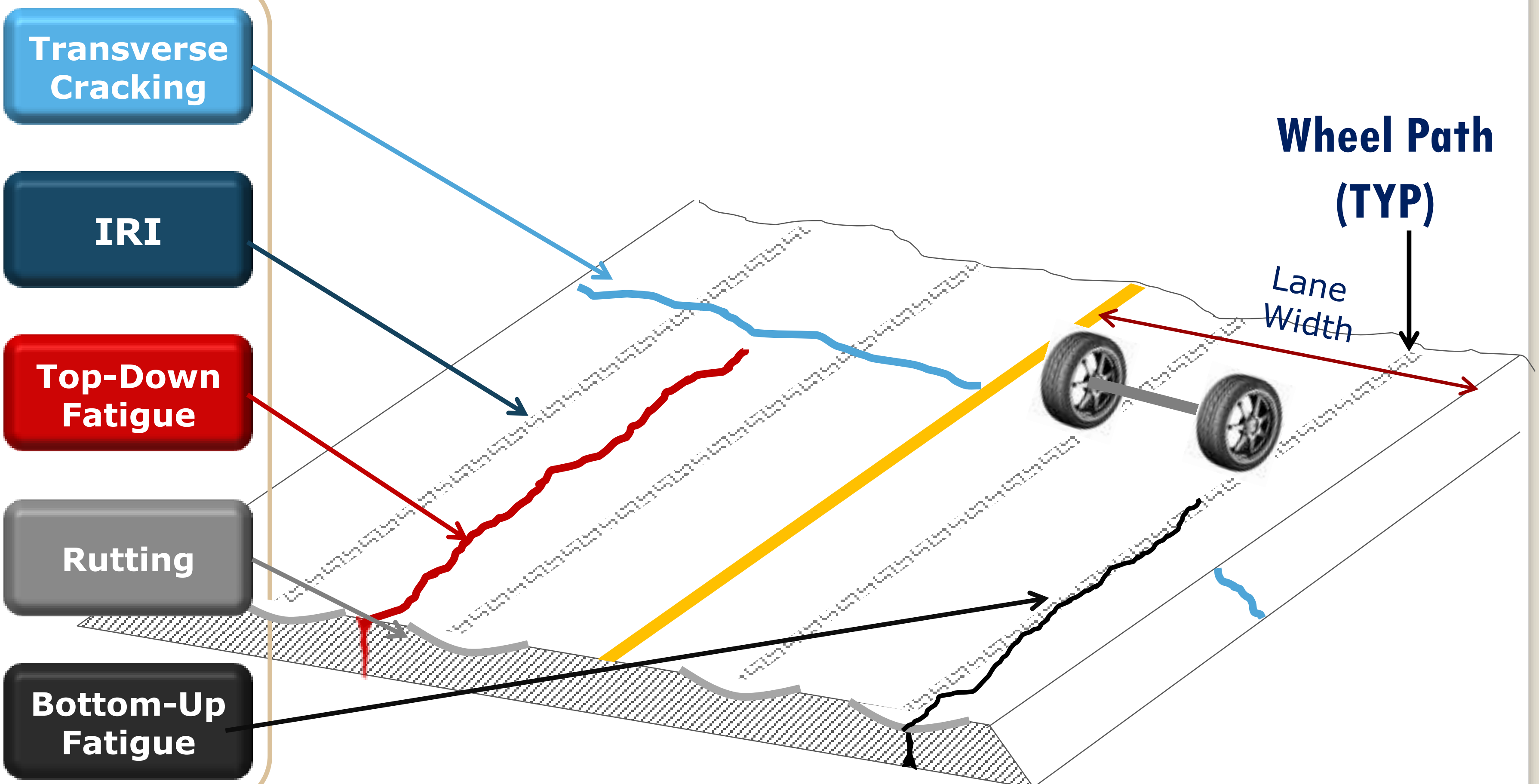
| | |
|---|---|
| AC/AR Surface Course<br>AC Base Course | Viscosity tests on asphalt binder<br>Dynamic modulus on mixes<br>Ignition tests on mixes |
| AB Aggregate Base | Sieve, PI, Proctor<br>Resilient Modulus |
| Subgrade Compacted/Treated<br>Subgrade | Sieve, Hydrometer, PI<br>Specific Gravity, Proctor<br>Resilient Modulus<br>Soil-Water Characteristic Curve (SWCC) |

# MCDOT Test Roads

| No. | Site ID | Project Name | Project Termini | | Road Align. | Traffic On Date |
|---|---|---|---|---|---|---|
| | | | Start | End | | |
| 1 | EG | Ellsworth Road | Germann Rd | Pecos Rd | NS | Jan-07 |
| 2 | HH | Hawes Road | Hunt Hwy | Stacey Rd | NS | Mar-07 |
| 3 | TQ | Tuthill Road | Queen Creek Rd | Pecos Rd | NS | Aug-07 |
| 4 | IO | Indian School Road | Old Litchfield Rd | Dysart Rd | EW | May-08 |
| 5 | CM | Cotton Lane | Cotton Ln Bridge | MC 85 | NS | Nov-07 |
| 6 | CS | Chandler Heights | Sossaman Rd | Hawes Rd | EW | Mar-08 |
| 7 | MT | MC 85 | Turner Rd | SR 85 | EW | May-08 |
| 8 | ED | El Mirage Road | Deer Valley Rd | Loop 303 | NS | Mar-09 |
| 9 | GC | Gavilan Peak Parkway | Cloud Rd | Daisy Mtn Rd | NS | May-09 |

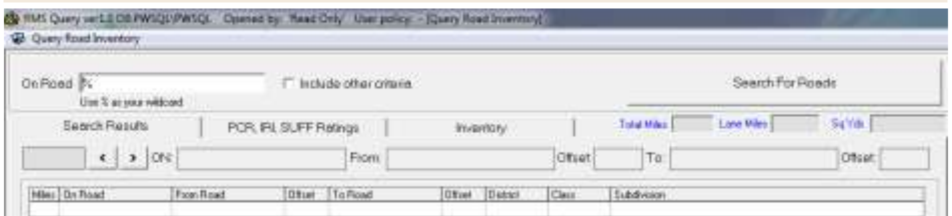
# MCDOT Test Road Locations with 2016 Photos

# Field Measurements
# Distresses on Flexible Pavements

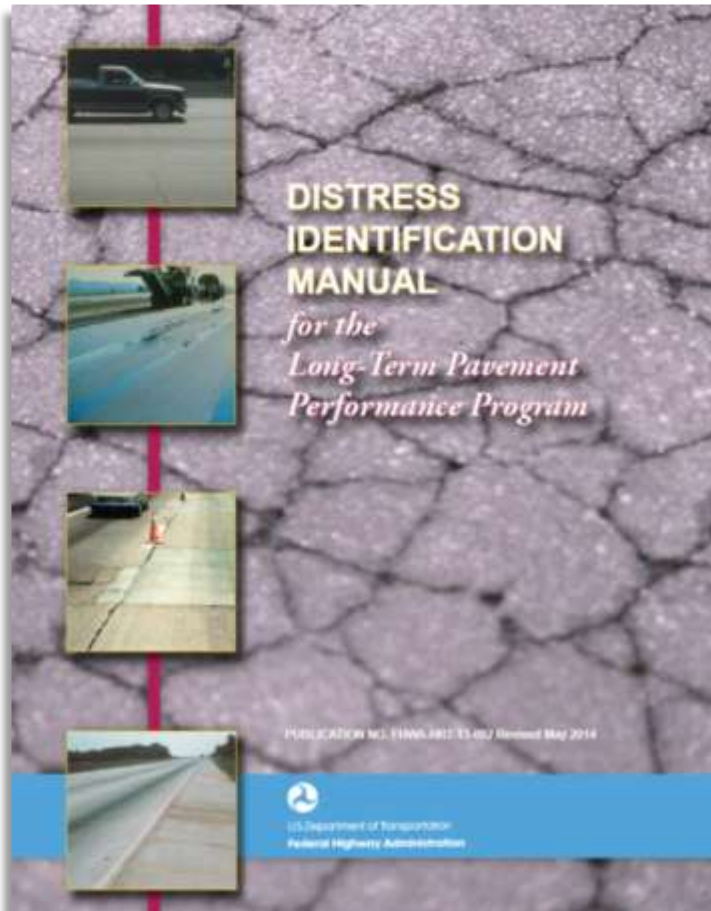


# MCDOT Distress Evaluation & Database

- ❑ MCDOT distress evaluations based on **LTPP Distress Identification Manual**
- ❑ **MCDOT Roadway Management System** (RMS) Database




- IRI (International Roughness Index)
- Pavement Condition Rating (PCR)
- Sufficiency Rating
- Traffic Data
- Pavement Structure
- Work History



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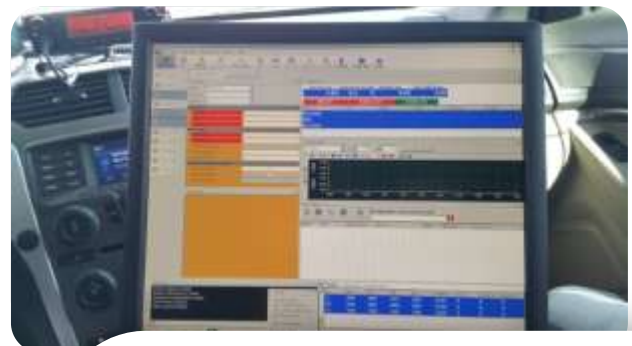
# IRI Field Measurements

## Laser Truck

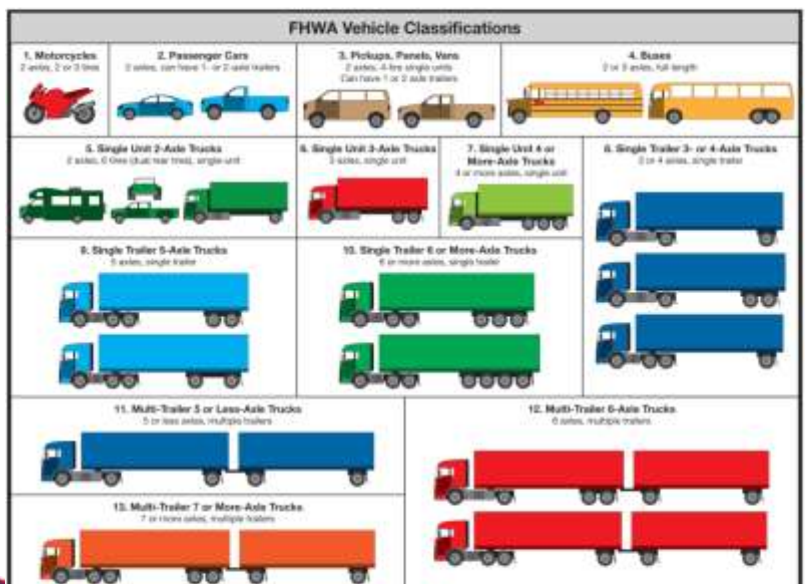

## IRI Software Program

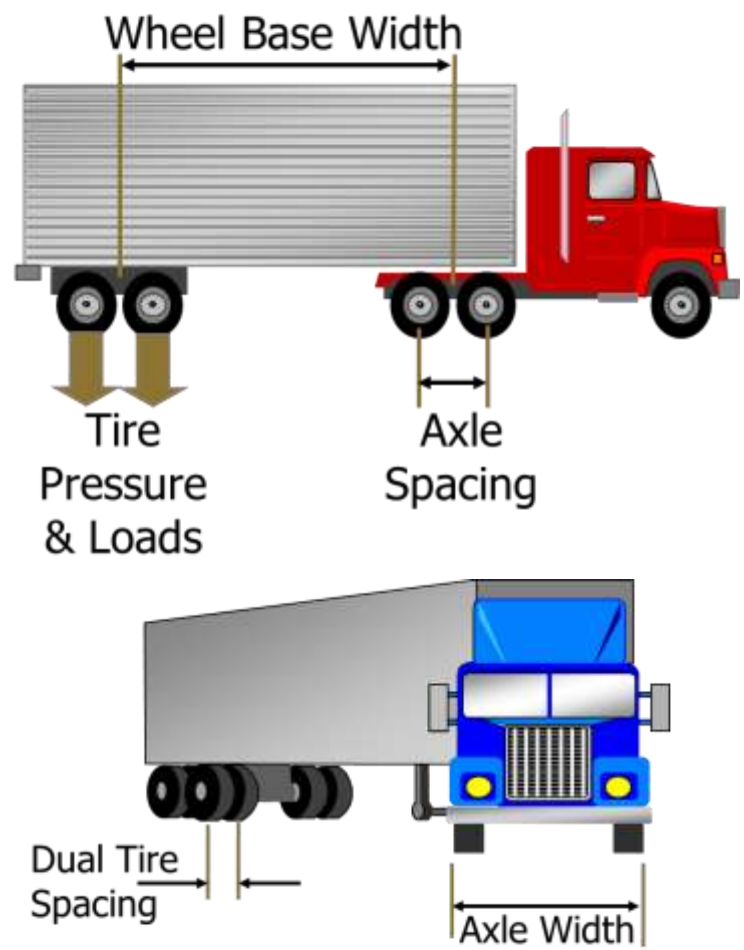


# MCDOT Traffic Data & Axle Configuration Inputs

## Traffic data from MCDOT Traffic Management group:

1. ADT counts over the past years
2. Vehicle class distribution
3. Operational speed



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# Data Entry for Pavement ME Design Program


- Weather data over 20 year period
- Latitude, Longitude, and Elevation
- Depth to Groundwater Table


- AADTT (Average Annual Daily Truck Traffic)
- Class Distribution (Class 4 thru 13)
- Axle Distribution (Single, Tandem, Tridem, & Quad)


- Binder Viscosity
- Asphalt Mix (E*, binder content, air voids)
- Base material (Gradation, PI)
- Subgrade (Gradation, PI, R-Value, Resilient Modulus, SWCC)

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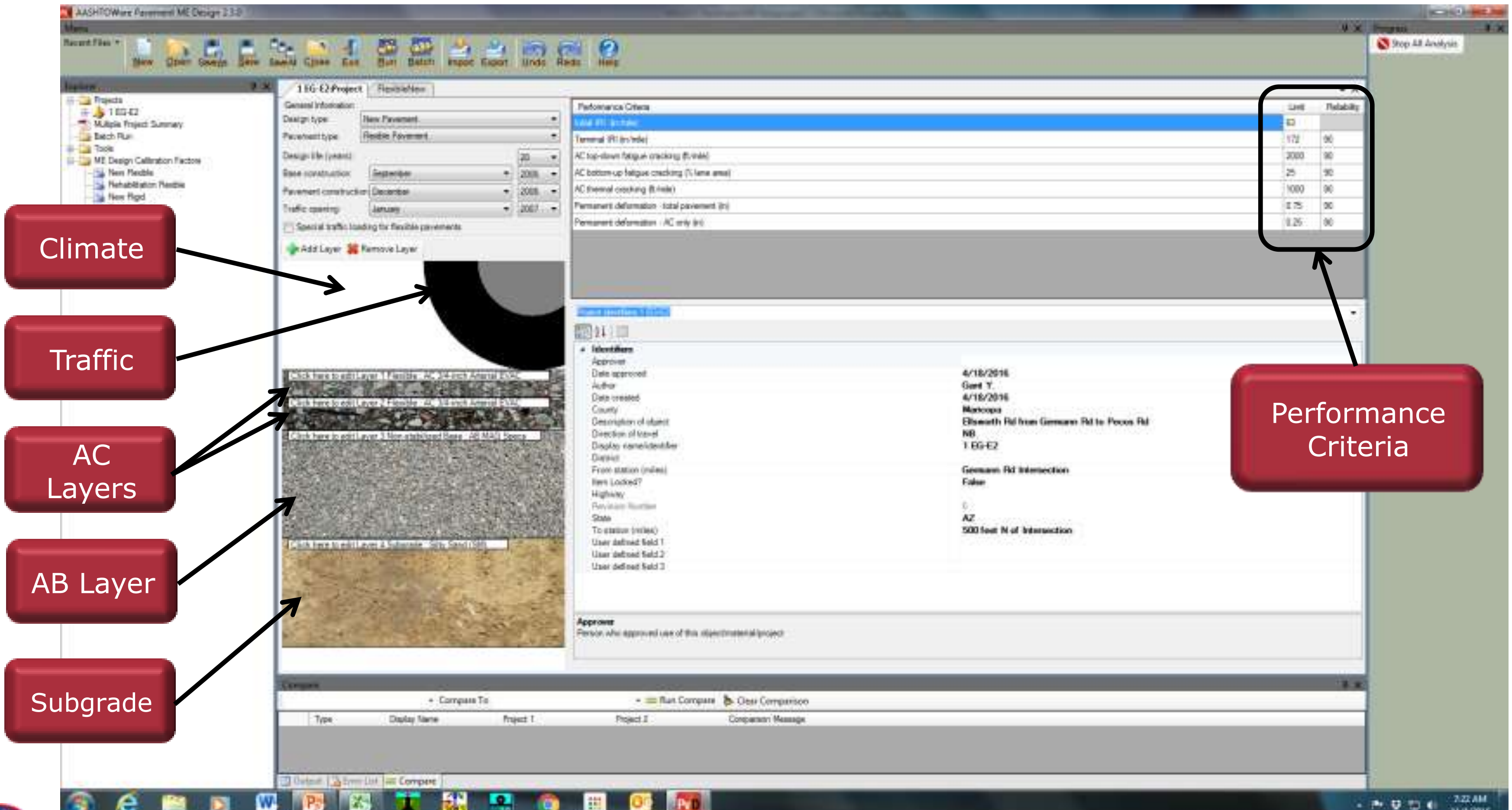
# New Pavement ME Design Material Data



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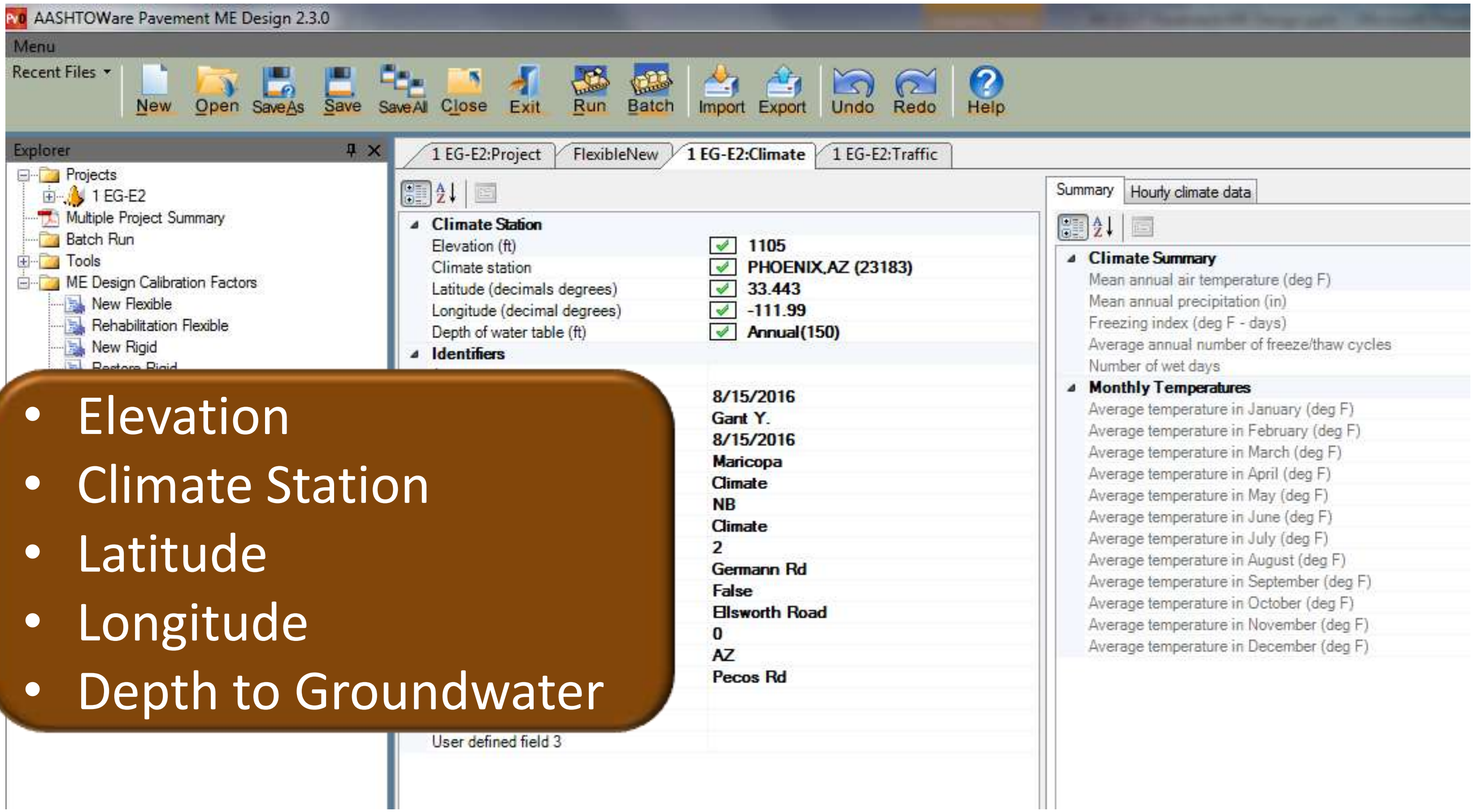
# New Pavement ME Design Climate Data




- Elevation
- Climate Station
- Latitude
- Longitude
- Depth to Groundwater

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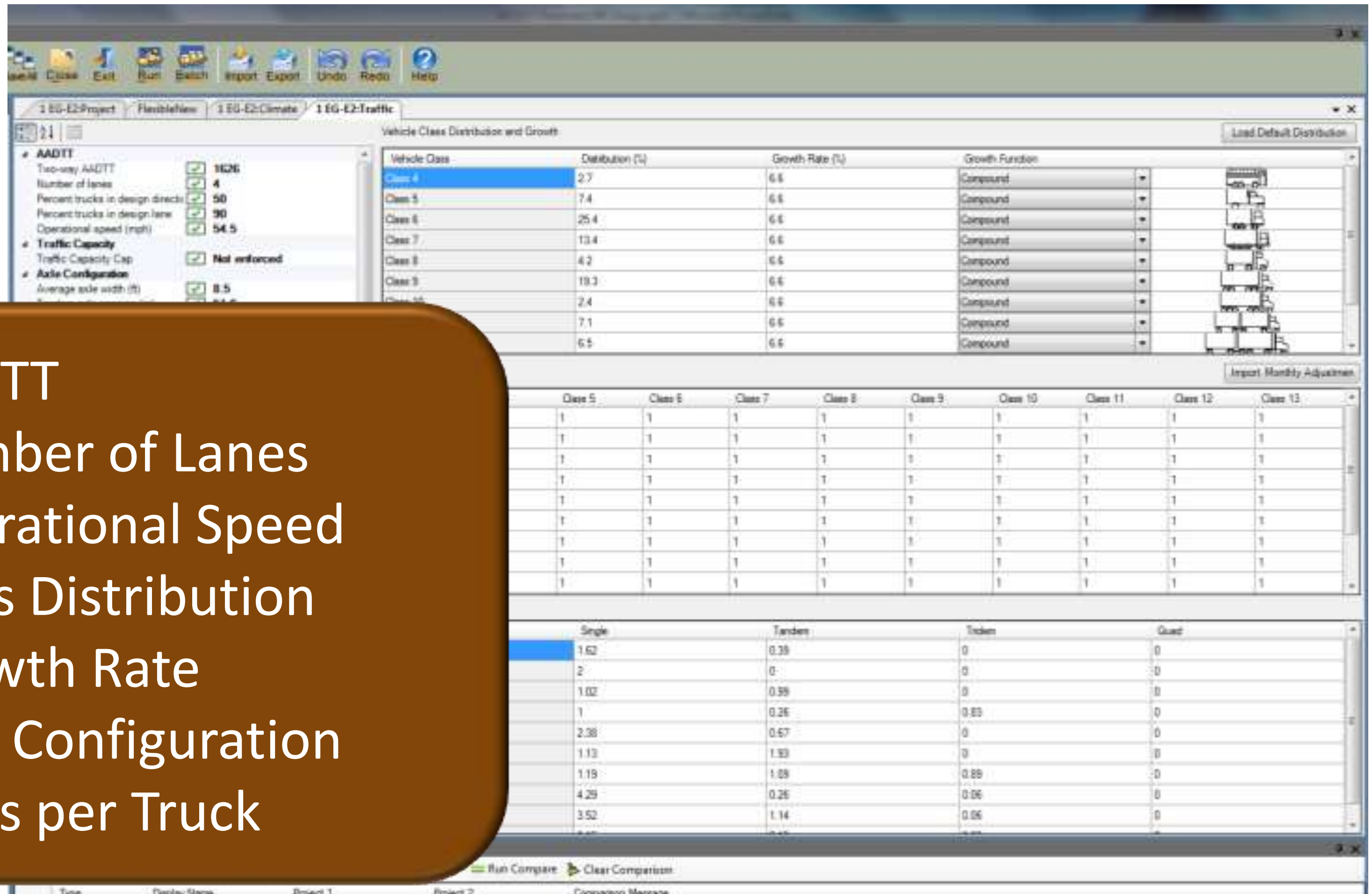
# New Pavement ME Design Traffic Data



- AADTT
- Number of Lanes
- Operational Speed
- Class Distribution
- Growth Rate
- Axle Configuration
- Axles per Truck

# New Pavement ME Design Calibration Screen

AC Cracking

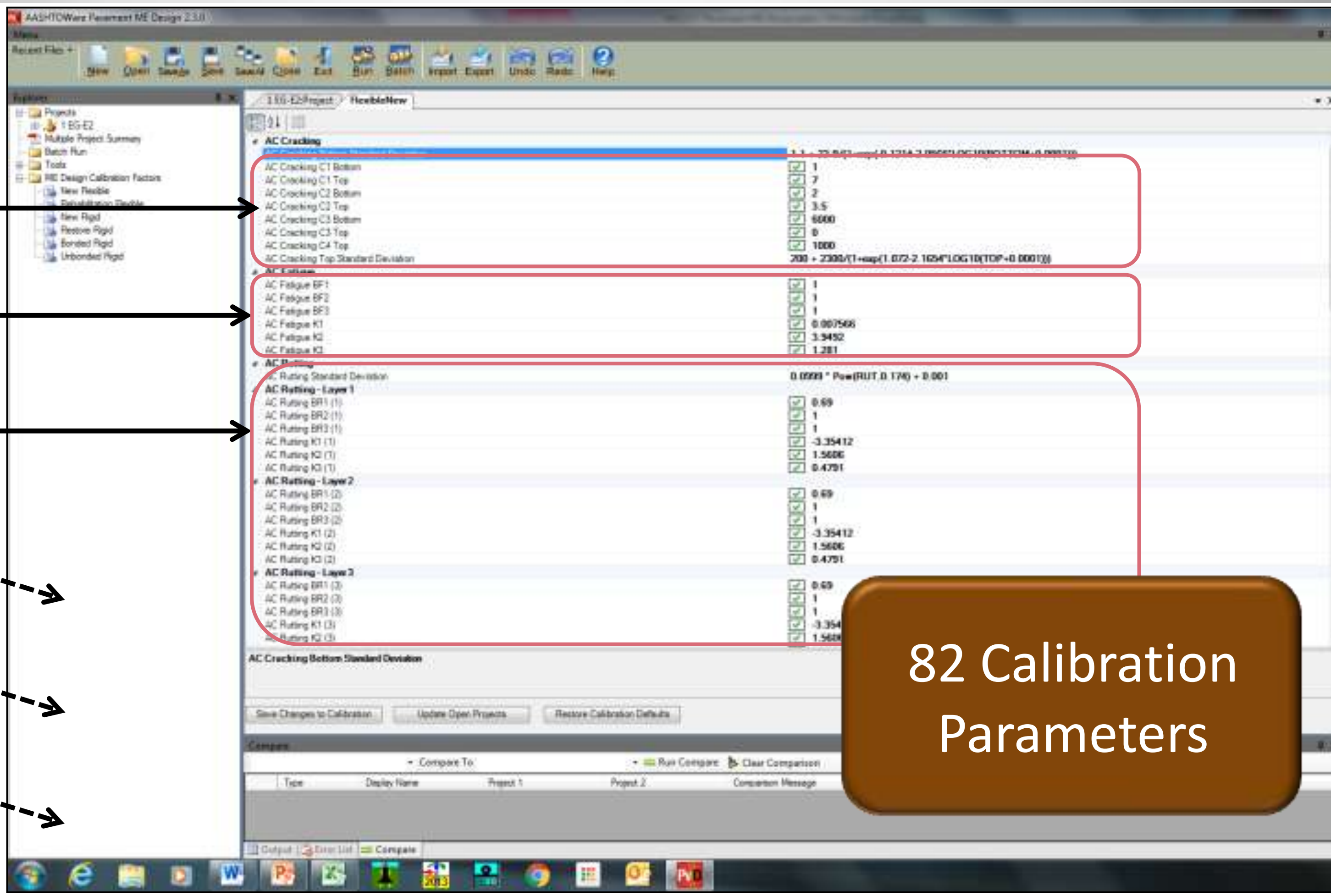
AC Fatigue

AC Rutting

AB & Subgrade Rutting

IRI

Thermal Fracture



82 Calibration Parameters

# Pavement ME Design Computation Process

- Integrated Climatic Model
- Thermal Cracking
- Asphalt Damage
- Asphalt Rutting & Fatigue
- Asphalt IRI

# Pavement ME Design Input & Output

## 1 EG-E2

File Name: C:\Users\yasanayakeg\Desktop\1 EG-E2.dgpx

### Design Inputs

Design Life: 20 years
Design Type: FLEXIBLE

Base construction: September, 2006
Pavement construction: December, 2006
Traffic opening: January, 2007

Climate Data Sources (Lat/Lon): 33.443, -111.99

#### Design Structure

| Layer type | Material Type | Thickness (in) |
|---|---|---|
| Flexible | AC 3/4-inch Arterial EVAC | 2.5 |
| Flexible | AC 3/4-inch Arterial EVAC | 3.0 |
| NonStabilized | AB MAG Specs | 10.0 |
| Subgrade | Silty Sand (SM) | Semi-infinite |

| Volumetric at Construction: | |
|---|---|
| Effective binder content (%) | 14.3 |
| Air voids (%) | 5.8 |

#### Traffic

| Age (year) | Heavy Trucks (cumulative) |
|---|---|
| 2007 (initial) | 1,626 |
| 2017 (10 years) | 3,623,460 |
| 2027 (20 years) | 10,489,300 |

### Design Outputs

#### Distress Prediction Summary

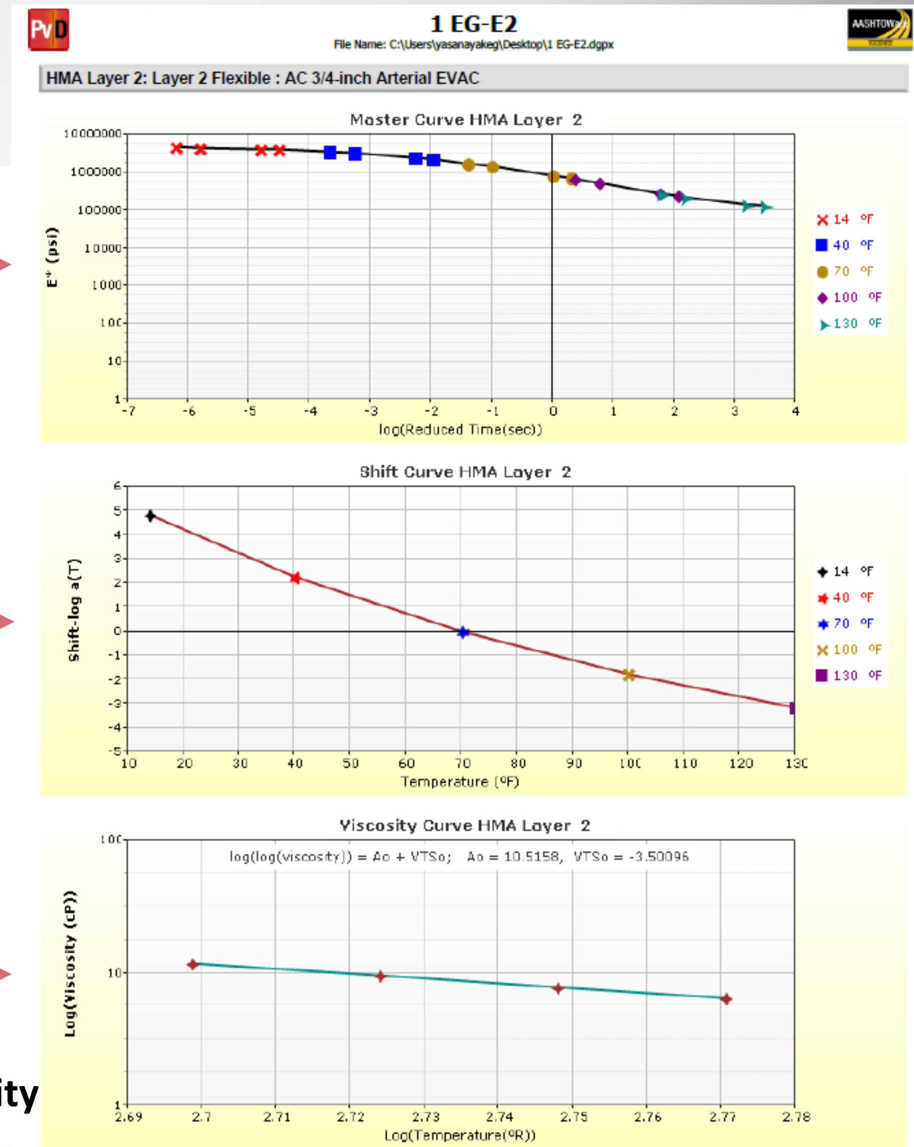
| Distress Type | Distress @ Specified Reliability | | Reliability (%) | | Criterion Satisfied? |
|---|---|---|---|---|---|
| | Target | Predicted | Target | Achieved | |
| Terminal IRI (in/mile) | 172.00 | 168.82 | 90.00 | 91.54 | Pass |
| Permanent deformation - total pavement (in) | 0.75 | 0.82 | 90.00 | 72.67 | Fail |
| AC bottom-up fatigue cracking (% lane area) | 25.00 | 22.47 | 90.00 | 92.49 | Pass |
| AC thermal cracking (ft/mile) | 1000.00 | 27.17 | 90.00 | 100.00 | Pass |
| AC top-down fatigue cracking (ft/mile) | 2000.00 | 3406.60 | 90.00 | 73.15 | Fail |
| Permanent deformation - AC only (in) | 0.25 | 0.52 | 90.00 | 3.29 | Fail |

# Pavement ME Design Input: Master Curve & VTS

Master Curve

Shift Curve

Viscosity Curve




**VTS = Viscosity-Temperature Susceptibility**

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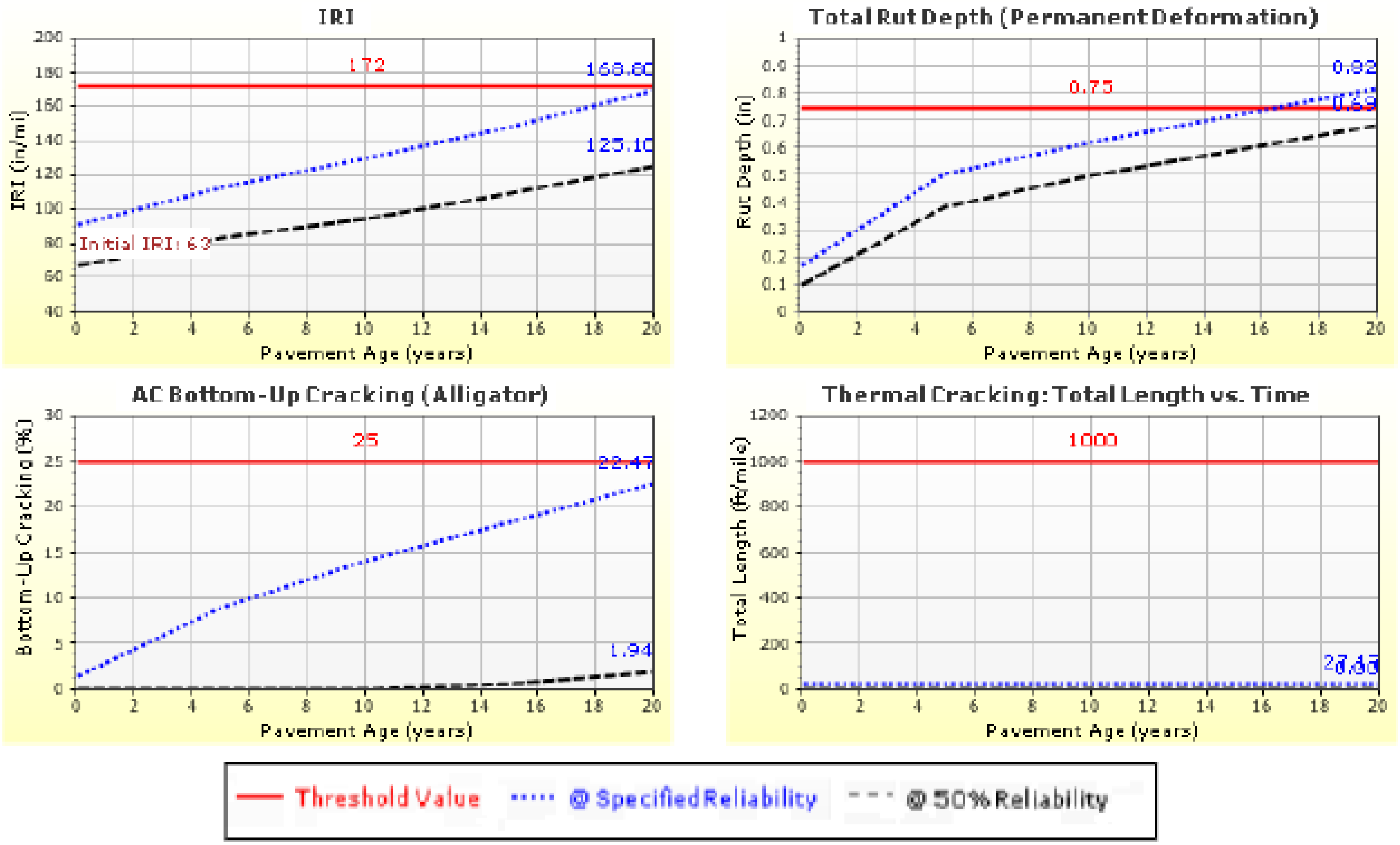
# Pavement ME Design Output: Distress Charts

## 1 EG-E2

File Name: C:\Users\yasanayakeg\Desktop\1 EG-E2.dgpx

### Distress Charts



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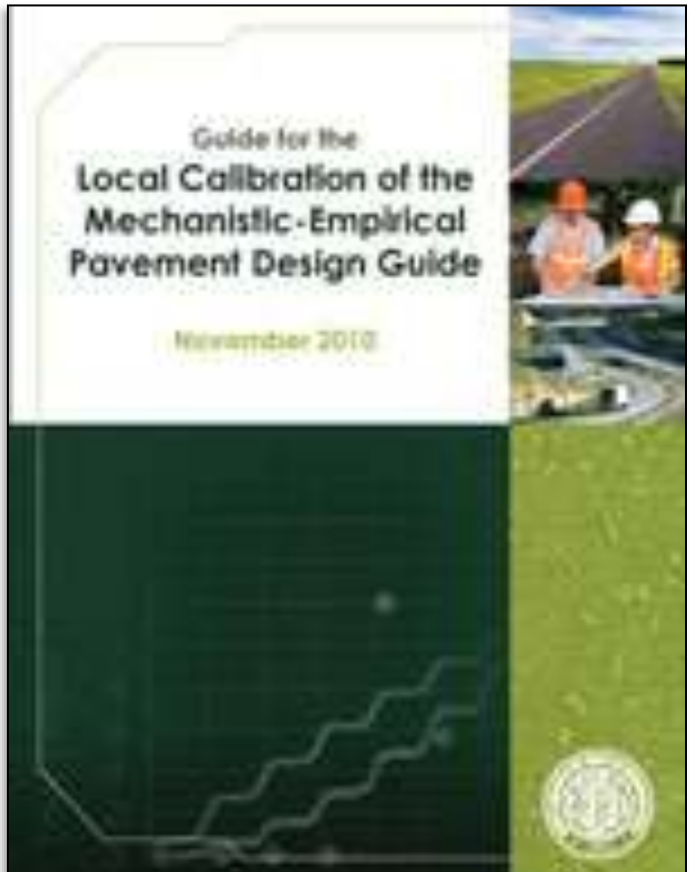
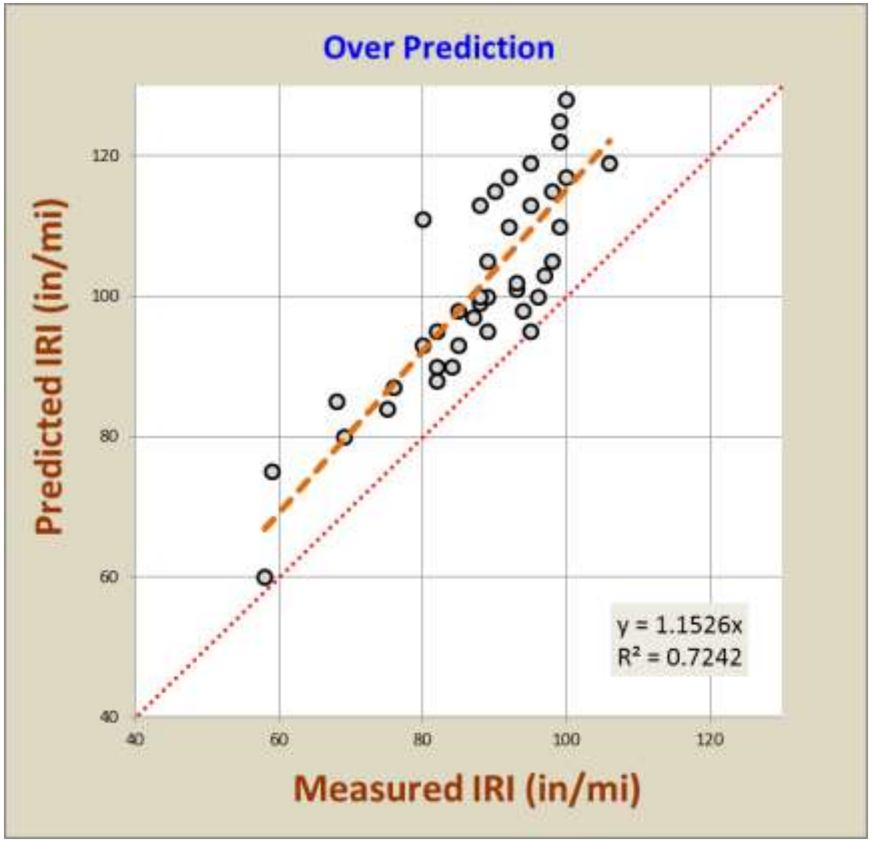
# Local Calibration & Validation Procedure


Guide for the
Local Calibration of the Mechanistic-Empirical Pavement Design Guide
November 2010

- Material Characterization
- ⇩
- Prediction of Distresses
- ⇩
- Field Monitoring
- ⇩
- Predicted vs Measured
- ⇩
- Modify parameters to eliminate any bias

# Local Calibration: Bias and Goodness of Fit

- Reduce **bias** (avoid **over-designed** and **under-designed** pavements)
- **Goodness-of-fit** criteria is used to find the best set of calibration parameters
- **Method of least squares** using **linear regression analysis** is adopted



# Approach to Local Calibration and Validation

| | |
|---|---|
| Traditional Split-Sample | Use split-sample approach if the sample size is **large** |
| Jack-Knifing | Use jack-knife approach if the sample size is **small** |

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# Model Validation Jack-Knife Method

- For **"n-1 Jack-Knife"** validation, remove one set of data and calibrate the model with remaining **n-1** data sets
- **n = 9** for this study
- The **9** sites were grouped into nine **1 | 8** groups as shown on the table
- The final calibration was checked with each data set

| Site> | EG | HH | TQ | IO | CM | CS | MT | ED | GC |
|---|---|---|---|---|---|---|---|---|---|
| 1 | C | C | C | C | C | C | C | C | V |
| 2 | C | C | C | C | C | C | C | V | C |
| 3 | C | C | C | C | C | C | V | C | C |
| 4 | C | C | C | C | C | V | C | C | C |
| 5 | C | C | C | C | V | C | C | C | C |
| 6 | C | C | C | V | C | C | C | C | C |
| 7 | C | C | V | C | C | C | C | C | C |
| 8 | C | V | C | C | C | C | C | C | C |
| 9 | V | C | C | C | C | C | C | C | C |

# Field Measurements and Calibration and Validation

Trivial Data to Analyze

- ❑ Rutting—no or little rutting

Trivial Data to Analyze

- ❑ Fatigue Cracking—no or little fatigue

Currently no predictions available

- ❑ Transverse Cracking—light to moderate thermal cracking

Main distress used in the calibration

- ❑ IRI—measured data available for all the test sites

# Statistical Parameters

**$b \rightarrow 0$**

**$m \rightarrow 1$**

When b = 0 and m = 1: Predicted =Measured

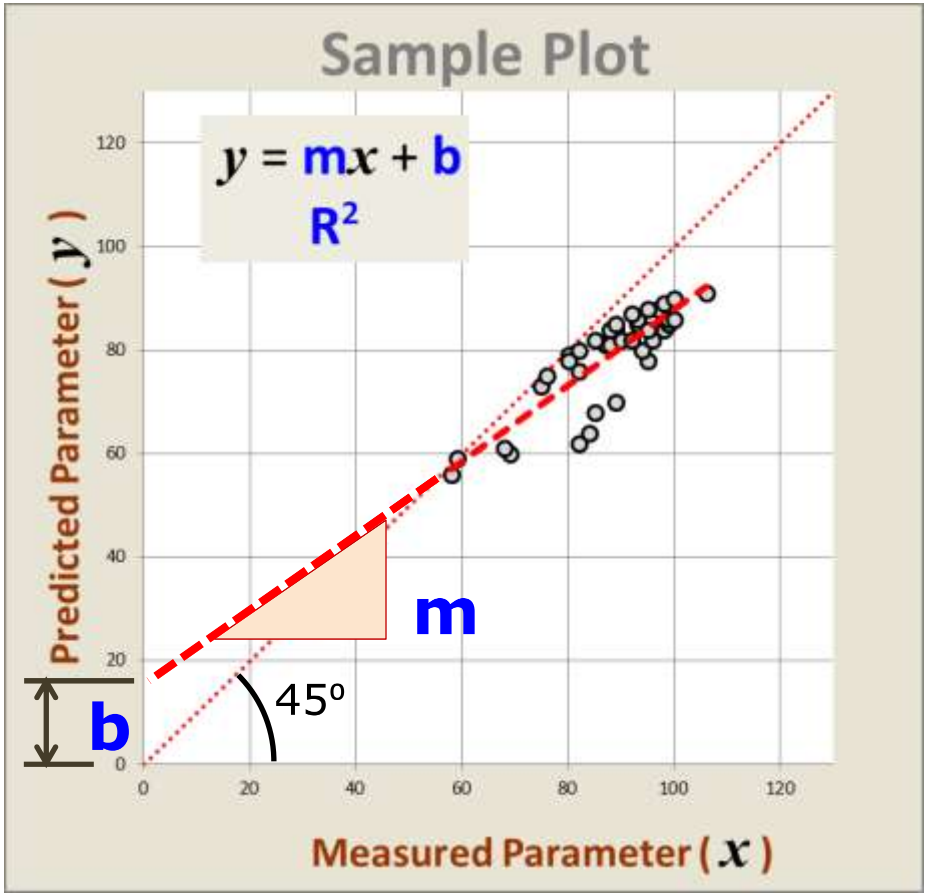
**$R^2 \rightarrow 1$**

$R^2$ = 1 gives best goodness of fit

**$S_e \rightarrow$ Min**

$S_e$ = Standard Error

$$S_e = \sqrt{\frac{\sum_{i=1}^{n}(e-\bar{e})^2}{n-1}}$$



# Calibrated Parameters

| | Parameter | | | | |
|---|---|---|---|---|---|
| | C2 | C4 | BR1 | BS1 | BS1 |
| | Bottom Up Cracking | IRI | Asphalt Rutting | Base Rutting | Subgrade Rutting |
| NAT'L | 1.0 | 0.015 | 1.00 | 1.00 | 1.00 |
| ADOT | 4.5 | 0.028 | 0.69 | 0.14 | 0.37 |
| MCDOT | 2.0 | 0.033 | 0.69 | 1.00 | 1.00 |

# IRI Data Plot Three Calibrations

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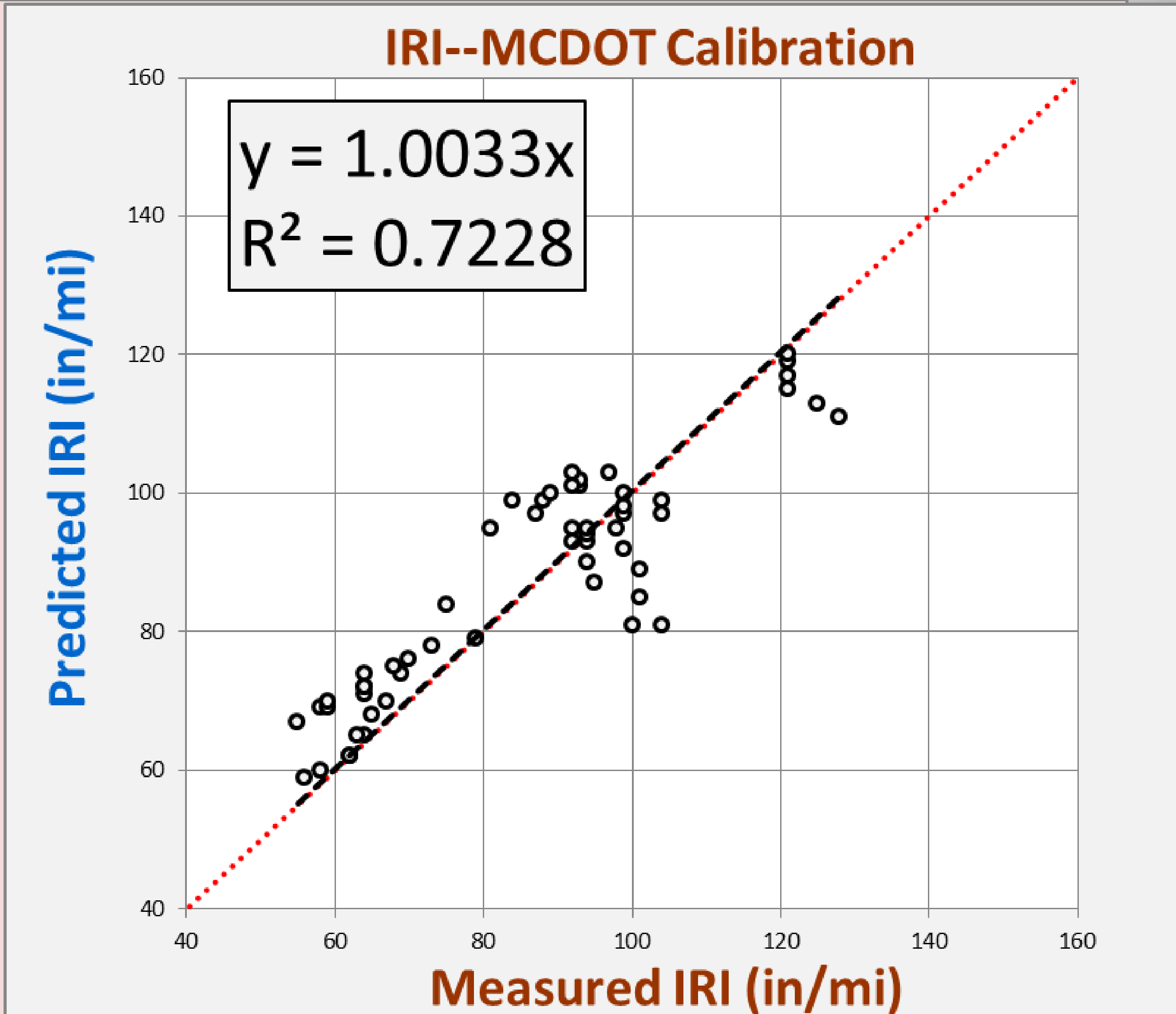


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# Model Validation: Three Independent Sites

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Other Sites | 10 | GS | Gilbert Road | South of Salt River | North of Salt River | NS | Jul-11 |
| | 11 | ST | 7th Street | Tanya Road | Desert Hills Dr | NS | May-11 |
| | 12 | EU | Ellsworth Road | University Dr | Adobe Road | NS | Feb-06 |

- Data from 3 additional roadway projects were used for validation
- These three sites were never used in the calibration process

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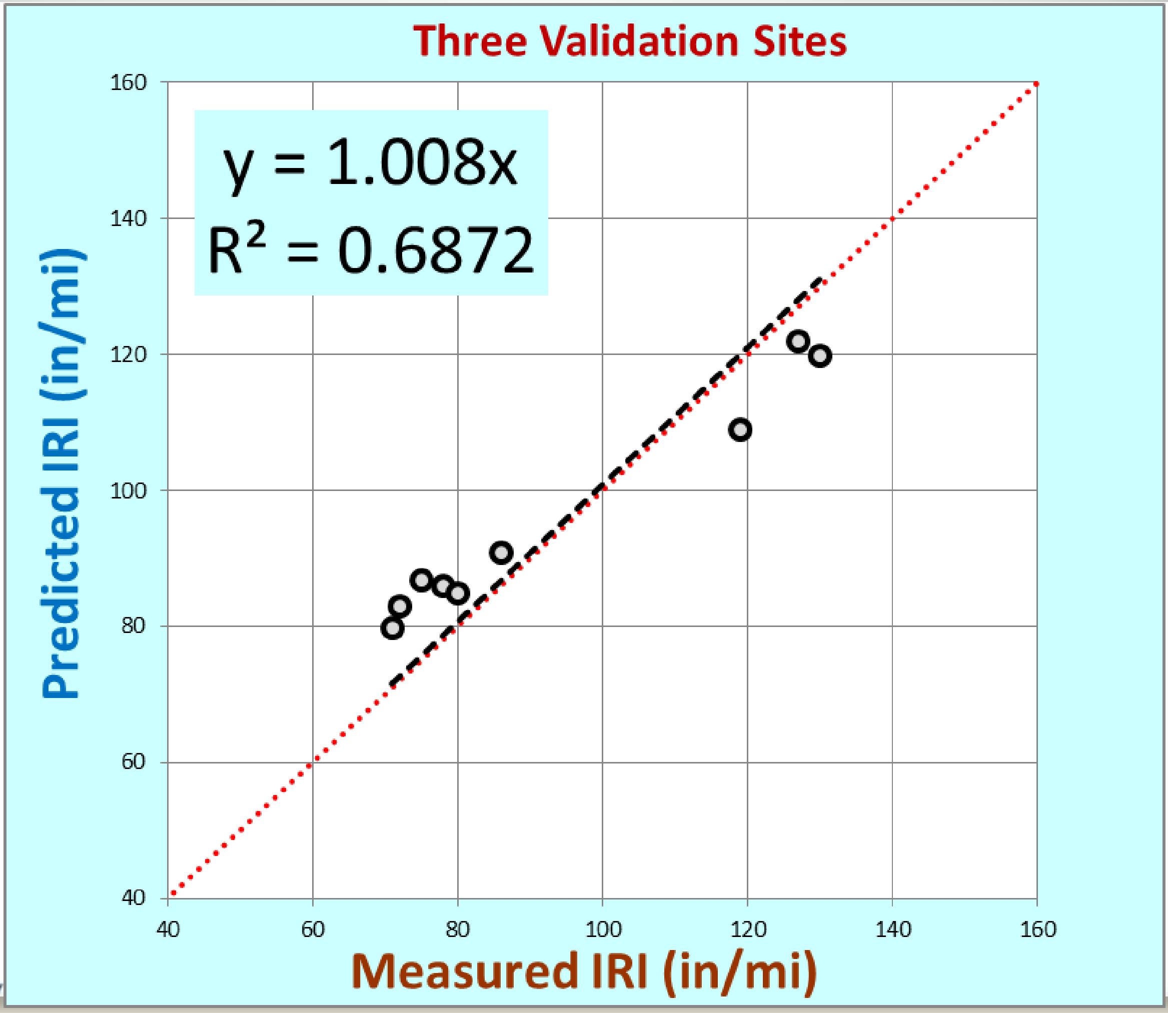
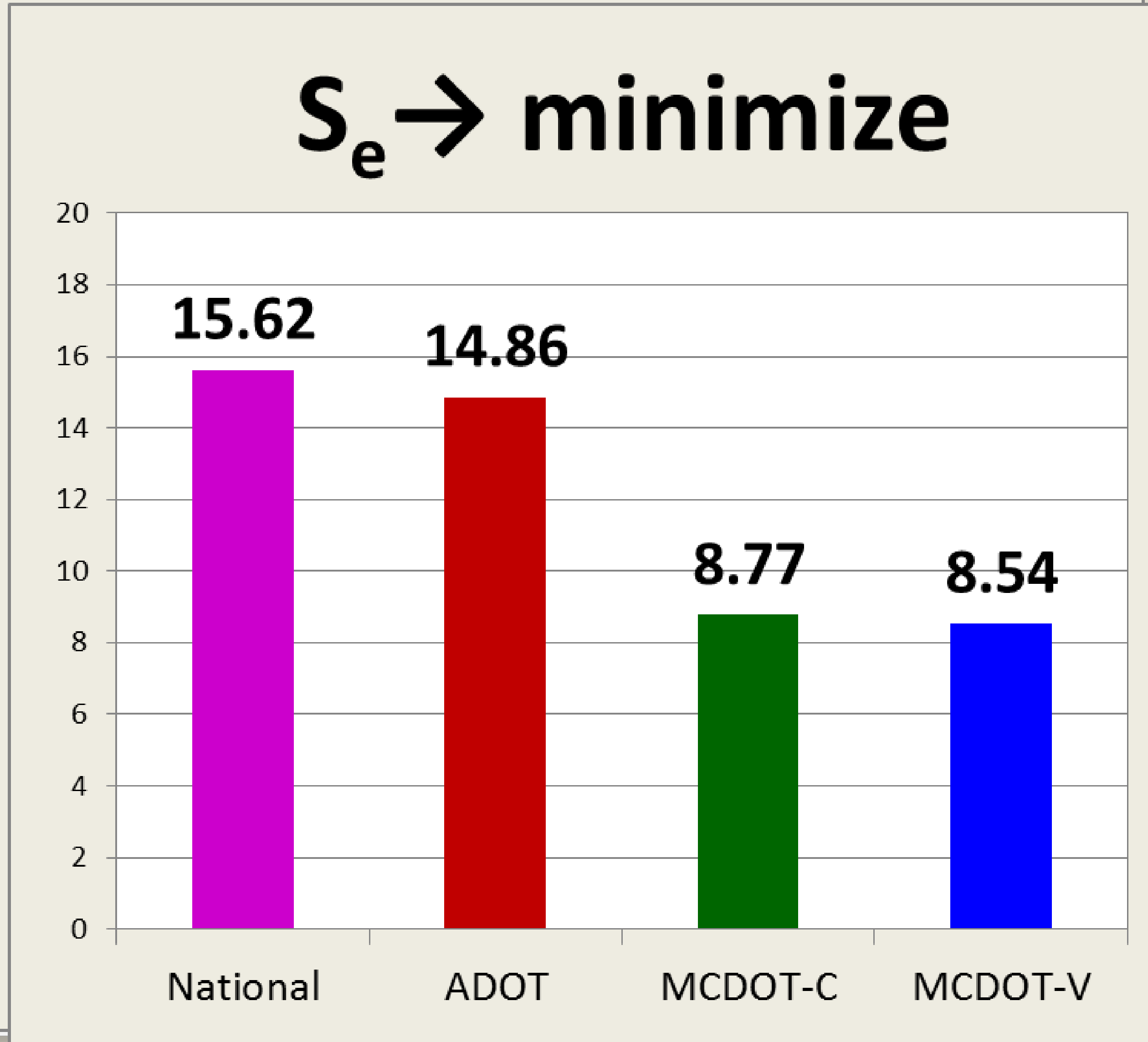
# Validation: IRI Data Plot with MCDOT Calibrations



# Calibration and Validation — Summary

Legend:

- National
- ADOT
- MCDOT-Calibration
- MCDOT-Validation

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# Future Work

- Continue monitoring the test sites and the implementation process of Pavement ME Design
- Prepare an interim MCDOT Pavement Design Guide and start designing MCDOT pavements using it
- Investigate the possibilities of modeling transverse cracking
- Provide useful suggestions to AASHTO and ARA to solve the problems encontered while using the software

# Acknowledgements


- ASU
- ADOT
- ARA
- AASHTO
- Terracon
- MCDOT Traffic Group
- MCDOT Materials Lab
- MCDOT Pavement Management Group

# Thank You!