

2005 Southeastern States Pavement  
Management and Design Conference

# Mechanistic-Empirical Pavement Design Guide *- Flexible Pavements -*

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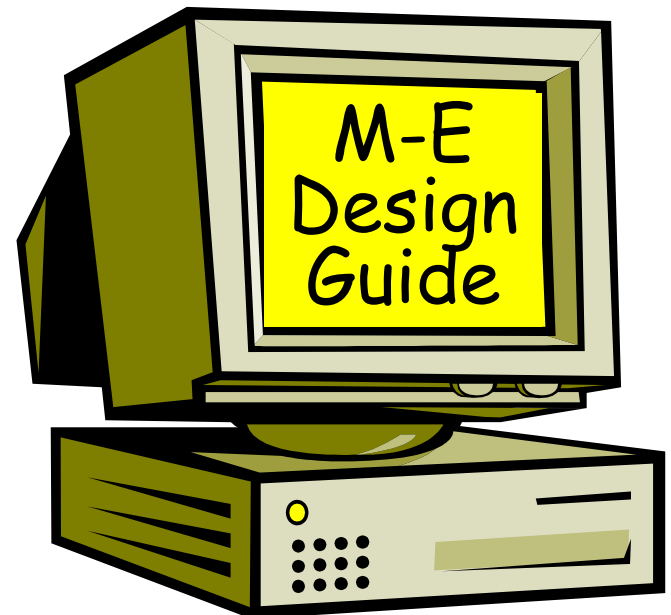
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# *Presentation Overview*

1. Introductory Comments
2. *Global Calibration*
3. *Local Calibration & Pre-Implementation Studies*
4. Sensitivity – Effect of Mix Properties
5. *Summary Comments on Implementation*

# *My Goals!*

1. Increase confidence in use of M-E PDG for flexible pavements.
2. Note areas of caution in its use.



*Remember,  
where we are  
coming from!*



- Assumptions used in the 1993 Design Guide.
- What is the error in the service life of the 1993 AASHTO Design Guide designs????

# Global Calibration of Distress Prediction Models



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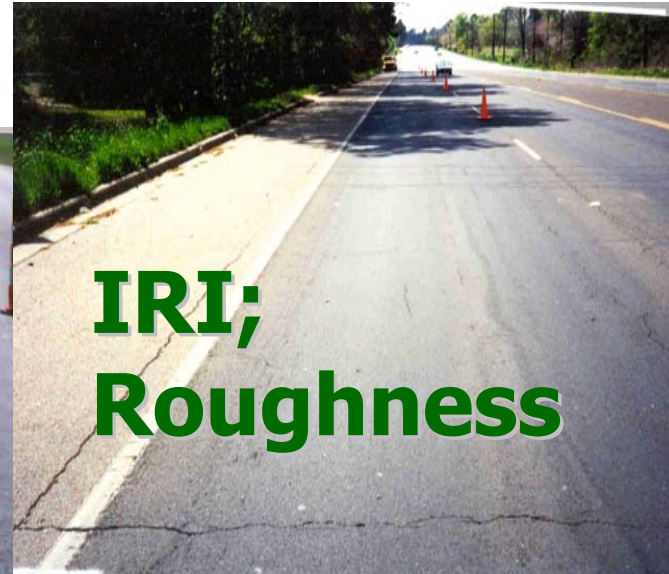
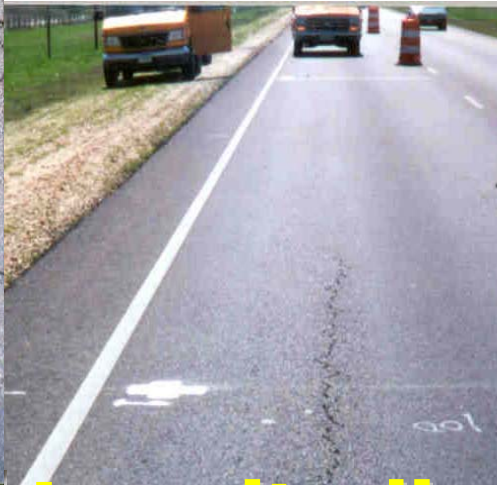
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# *Predicted Distresses of Flexible Pavements:*




**Fatigue  
Cracking;  
Bottom Initiated**



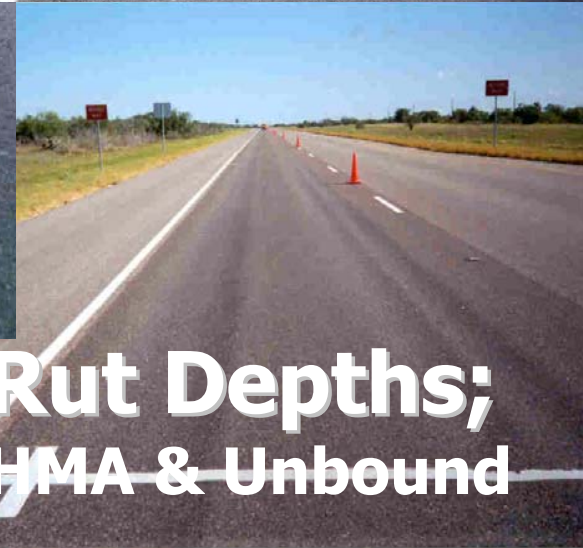
**IRI;  
Roughness**



**Thermal  
Cracking**

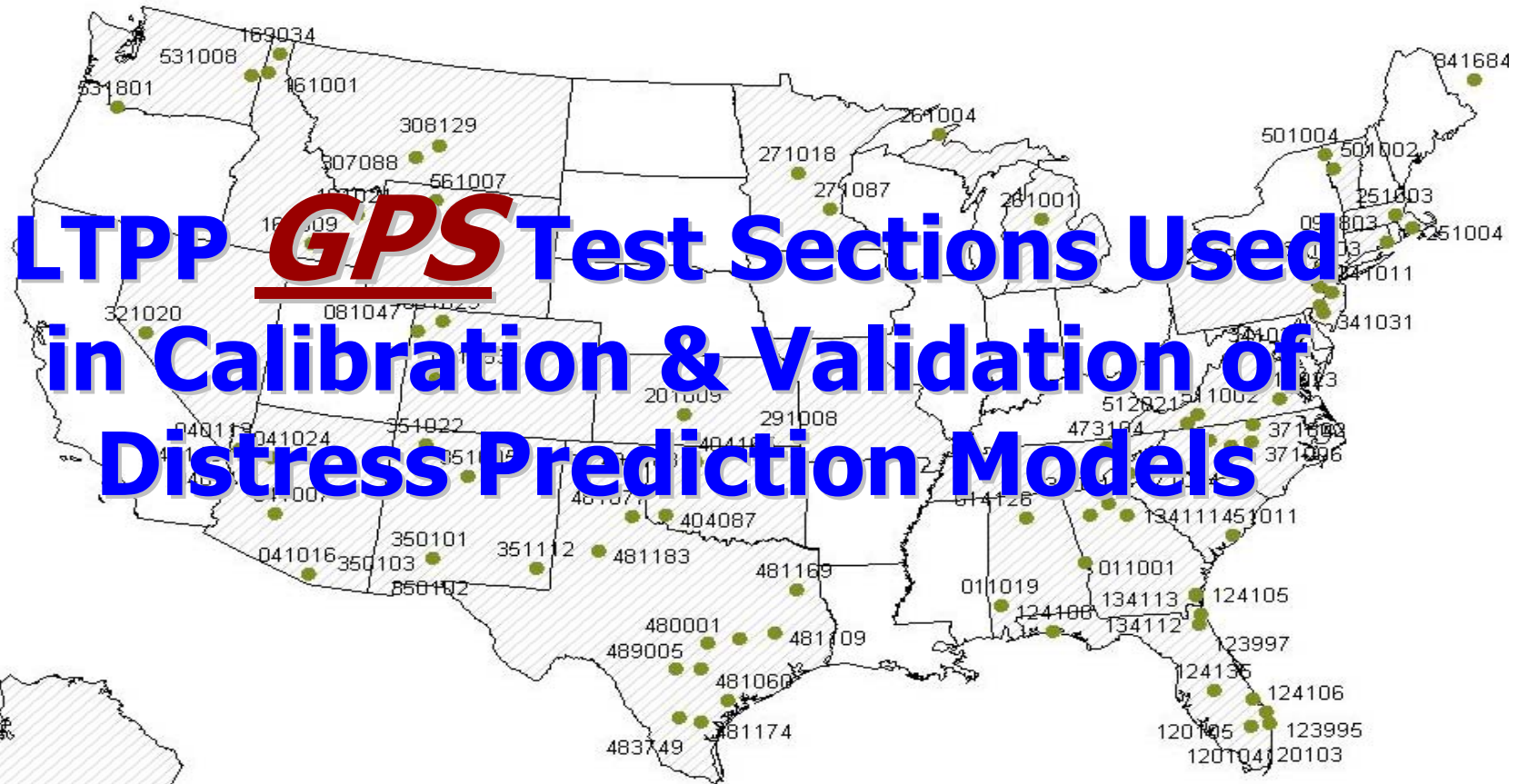


**Longitudinal  
Cracking;  
Surface Initiated**



**Rut Depths;  
HMA & Unbound**

# Global Calibration



- ✿ Many assumptions used.
- ✿ Many guessed values included.

# NCHRP 1-37A Calibration-Validation Process

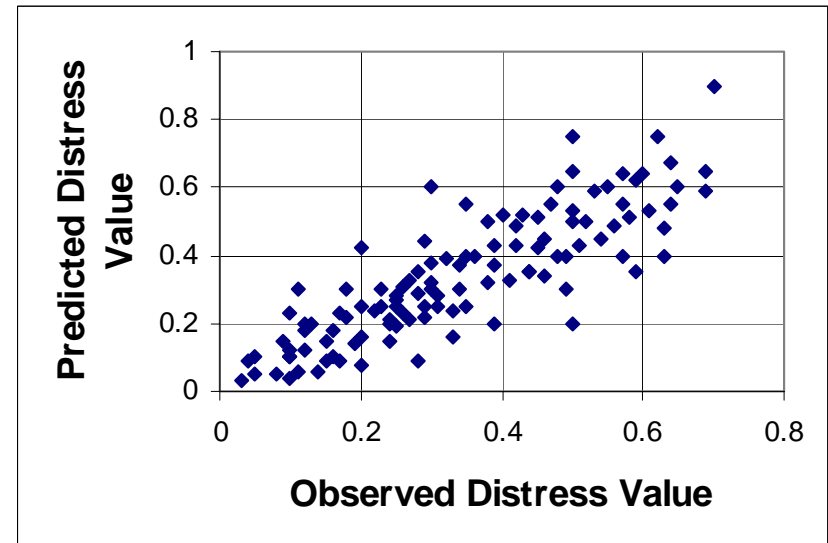
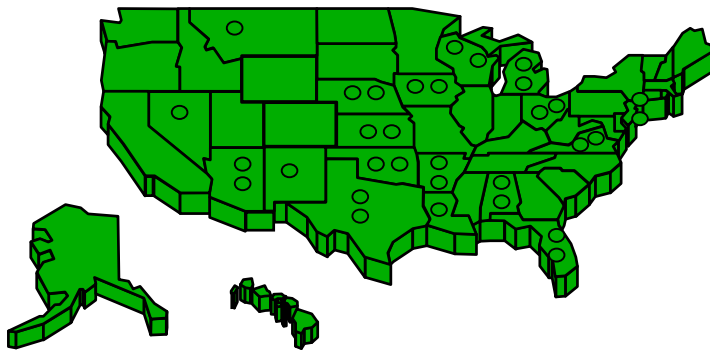
- ✿ Used **BEST** Available Data.
- ✿ No Materials Testing – Relied on existing databases for all inputs – LTPP.

Input Element	Input Level		
	1	2	3
Material Properties	Lab Testing	<i>Equations</i>	<i>"Guessed" Value</i>



# Global Calibration of Distress Prediction Models

- ★ LTPP database used to determine global calibration factors – ***No Forensic Studies.***
- ★ Variability in distress observations is high.
- ★ Errors between predictions & observations are high but no bias.



# Pre-Implementation Studies & Local Calibration



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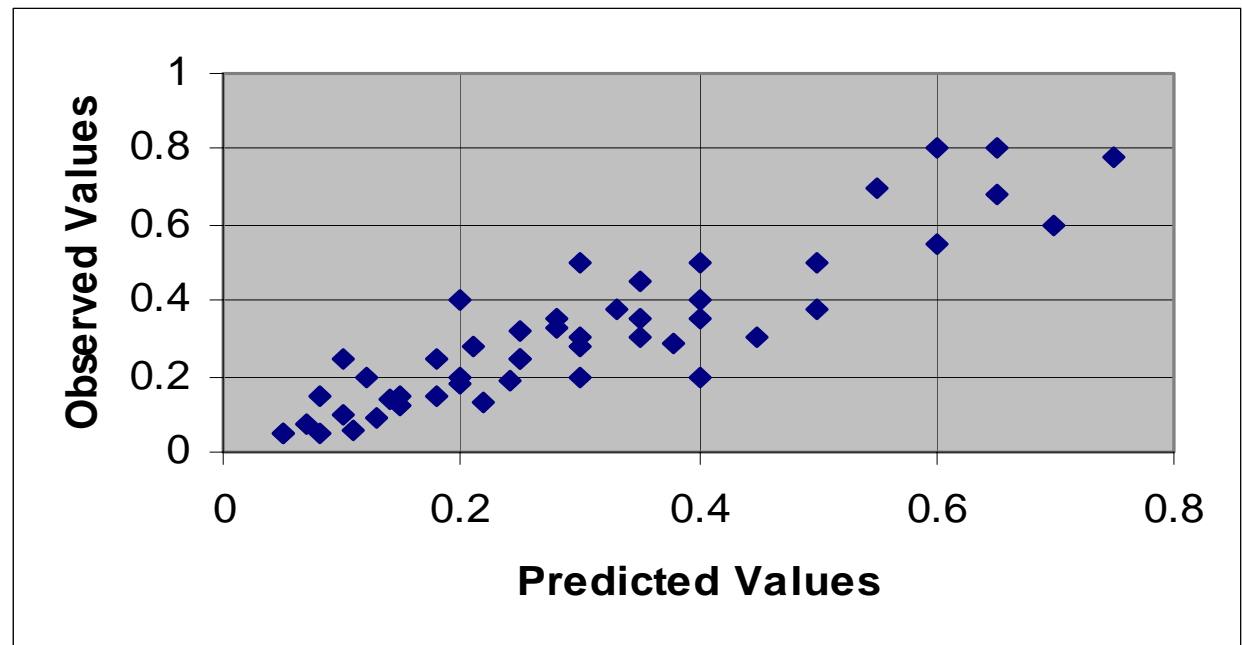
# Quantifying the Prediction Error

$$e_{Total} = e_{Lack-of-Fit}$$

$$+ e_{Measurement}$$

$$+ e_{Input}$$

$$+ e_{Pure}$$



# *Pre-Implementation Studies*

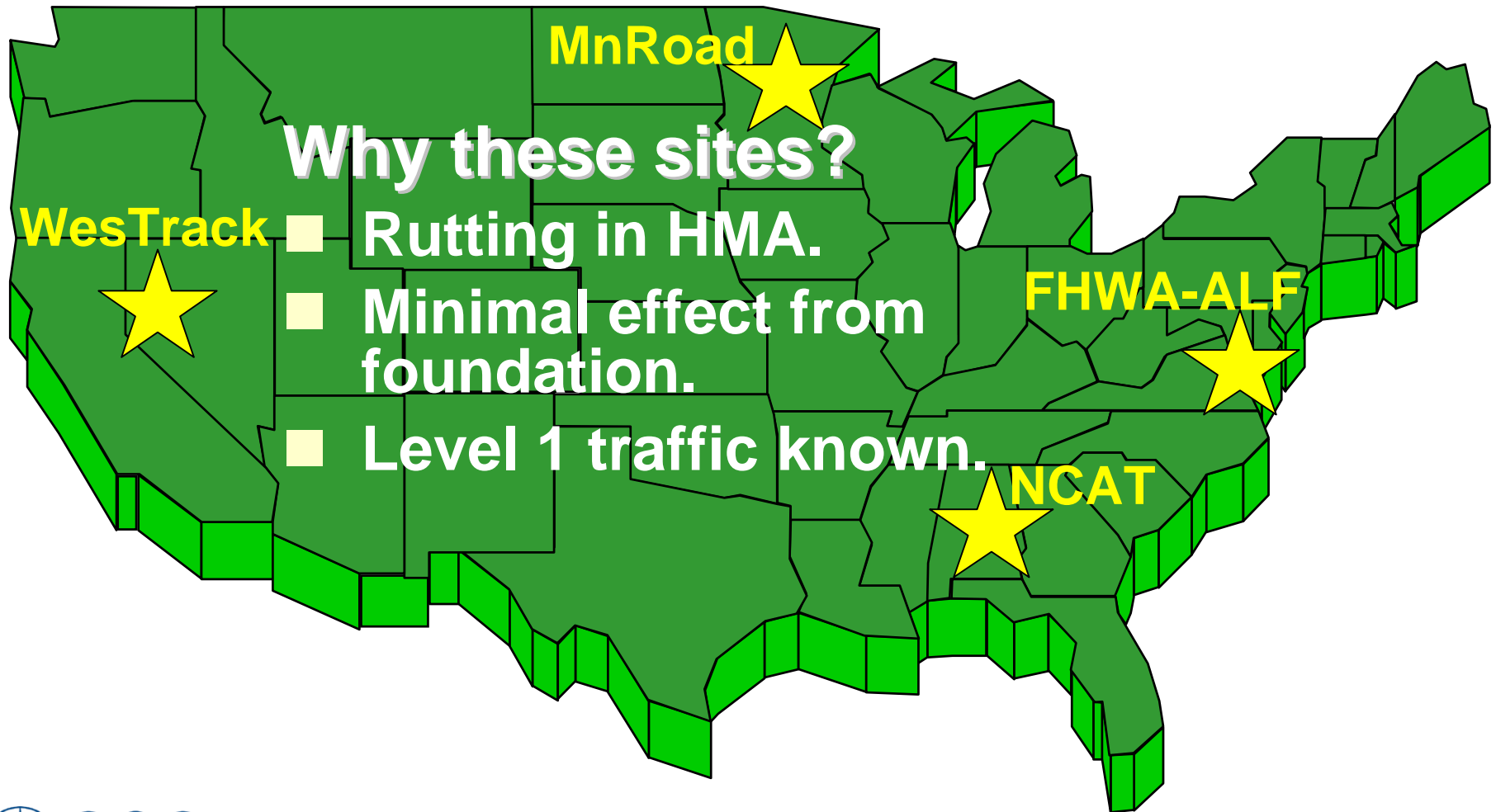
- 1. NCHRP 9-30** – Experimental Plan for Calibration & Validation of HMA Performance Models for Mix & Structural Design
- 2. NCHRP 1-40B** – Local Calibration for the M-E PDG for New & Rehabilitated Pavement Structures

# *Pre-Implementation Studies*

- ★ **Use independent data set from global calibration effort.**
  - WesTrack
  - MnRoad
  - NCAT
  - ALF - FHWA, Florida, Iowa
  - LTPP SPS Projects
- ★ **Are the residual errors different and what affects the residual error?**



# Quantifying Residual Error HMA Materials

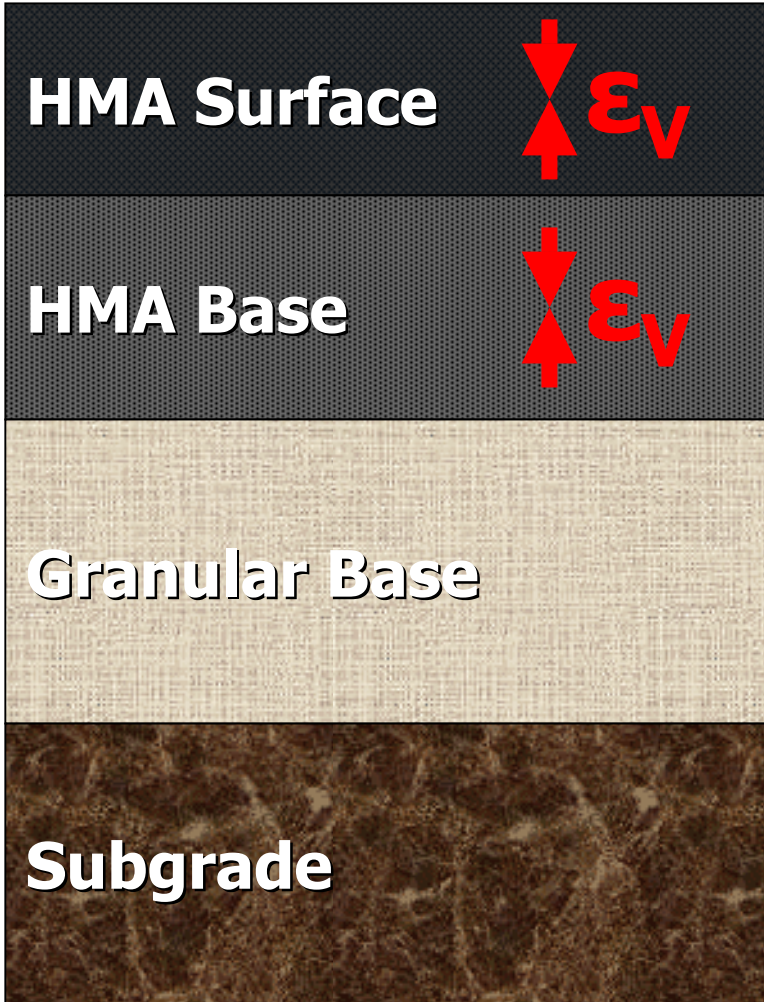


# *Rutting*

## *Observations Vs. Predictions*



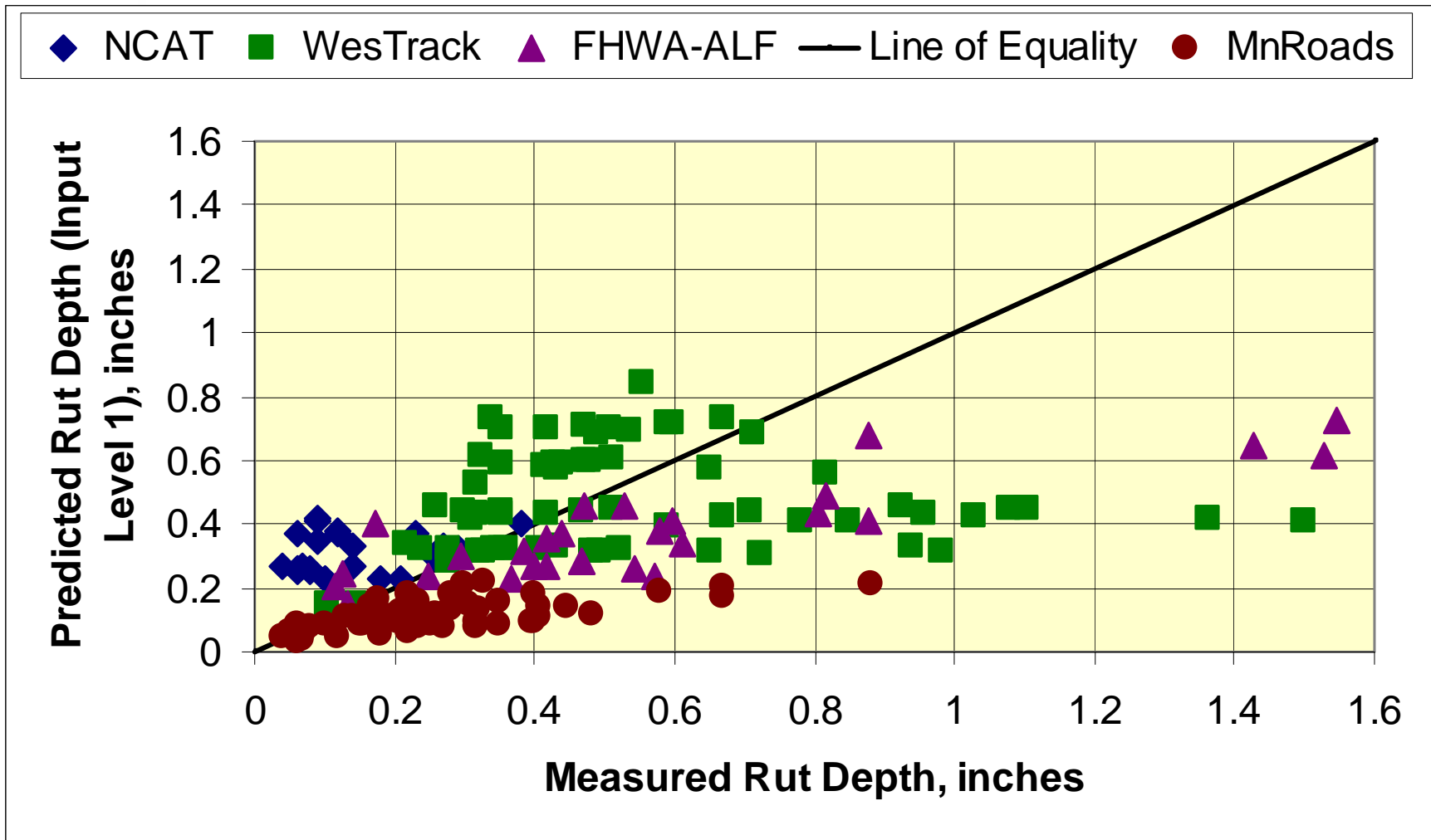
# Distortion Analysis



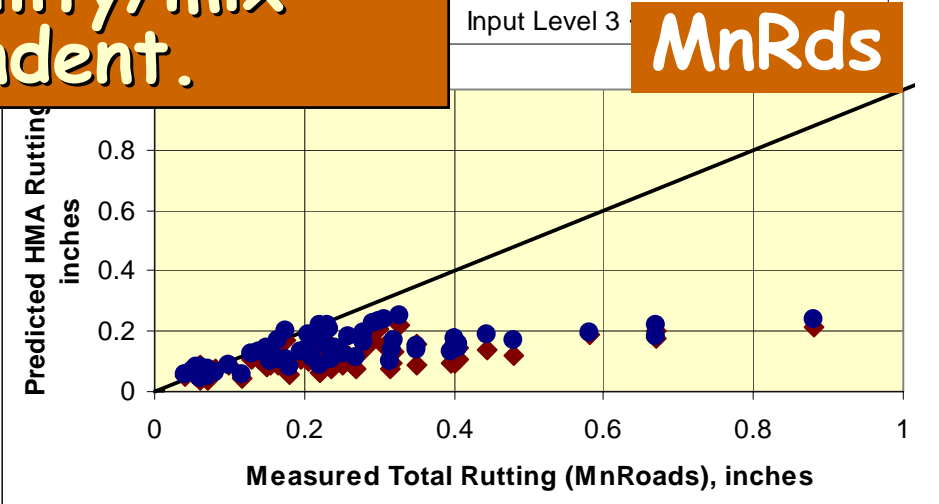
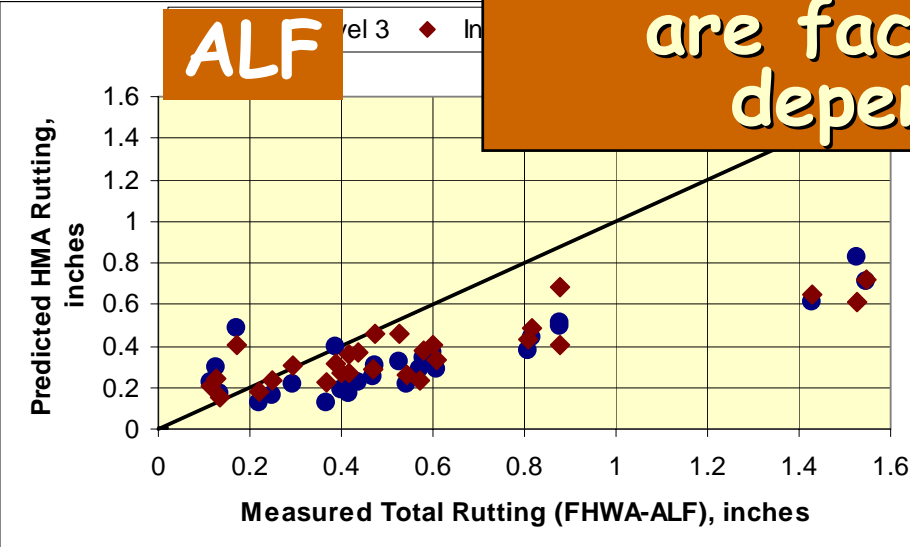
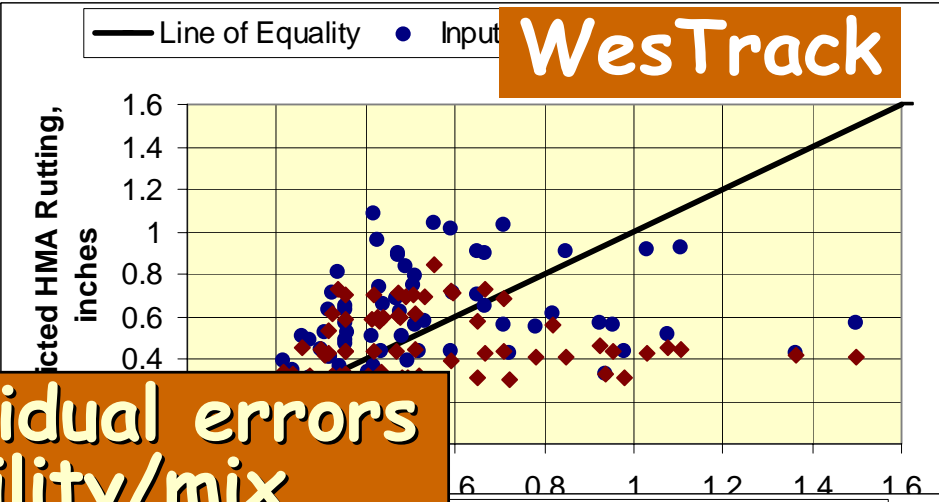
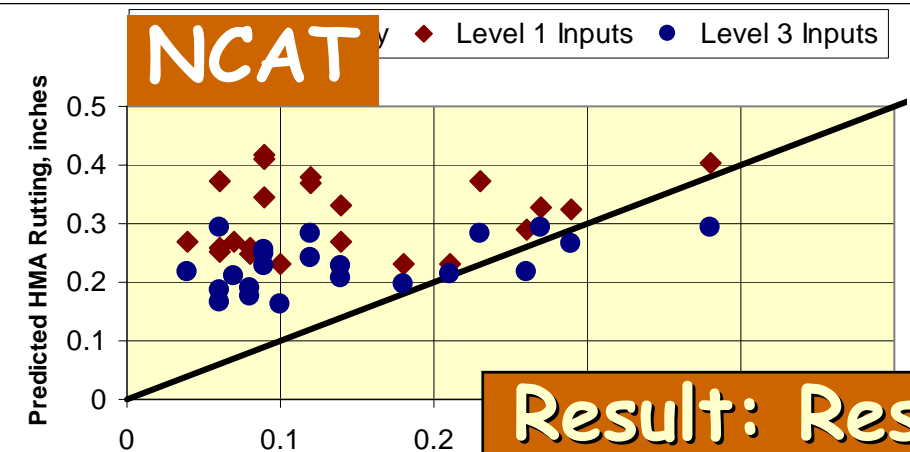
- Vertical strain at specific depths
- Used only sites where all measurable rutting occurred in HMA layers.

$$RD = \sum_{i=1}^n \left( \frac{5.37 \times 10^{-7} (C_{r1}) (N)^{0.4289(C_{r2})}}{(T)^{2.5896} (C_3) (\epsilon_r) (t)} \right)_i$$

# Rut Depth Predictions: Measured Versus Predicted



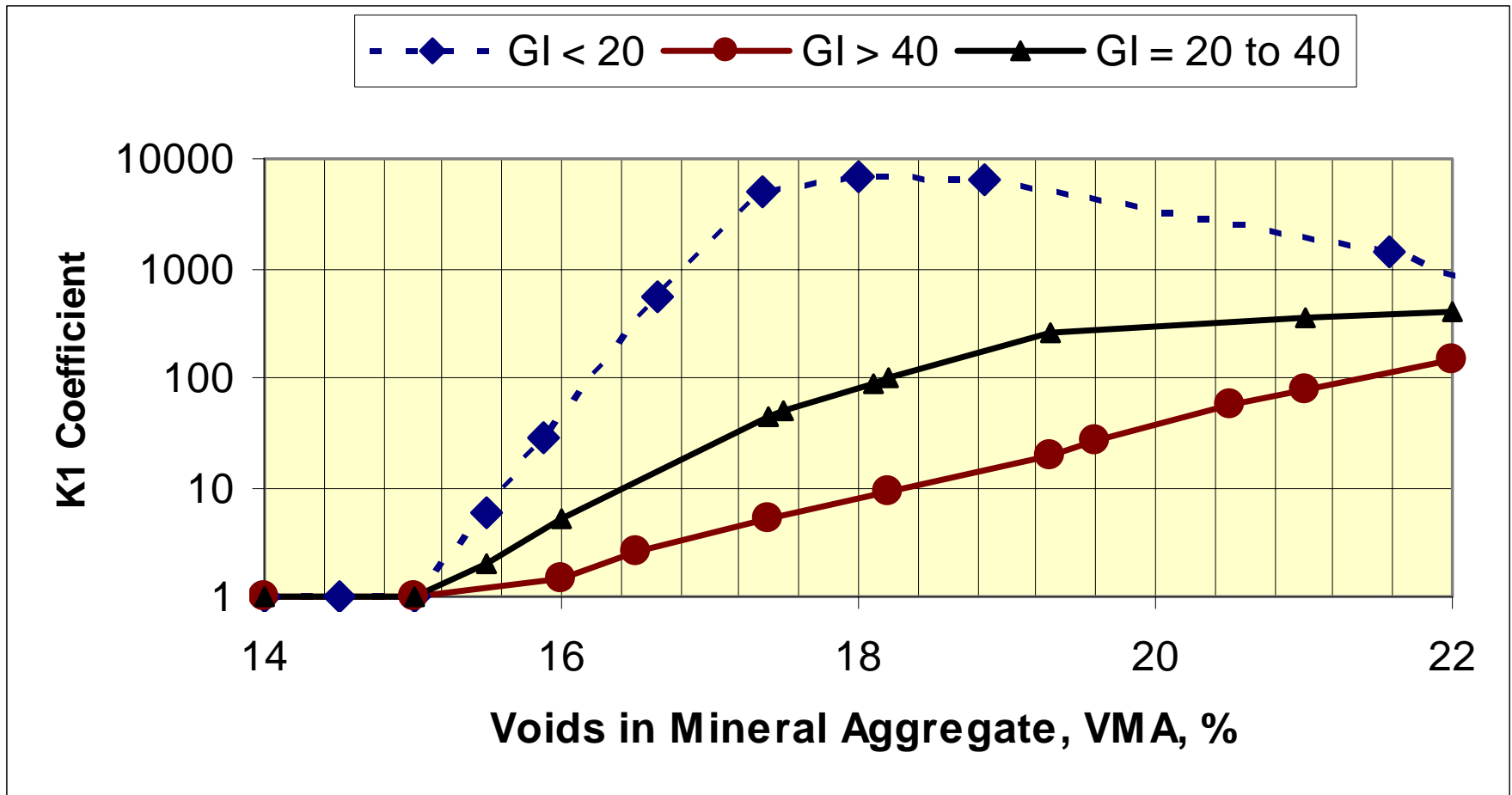
# Rut Depths Predictions Measured Versus Predicted



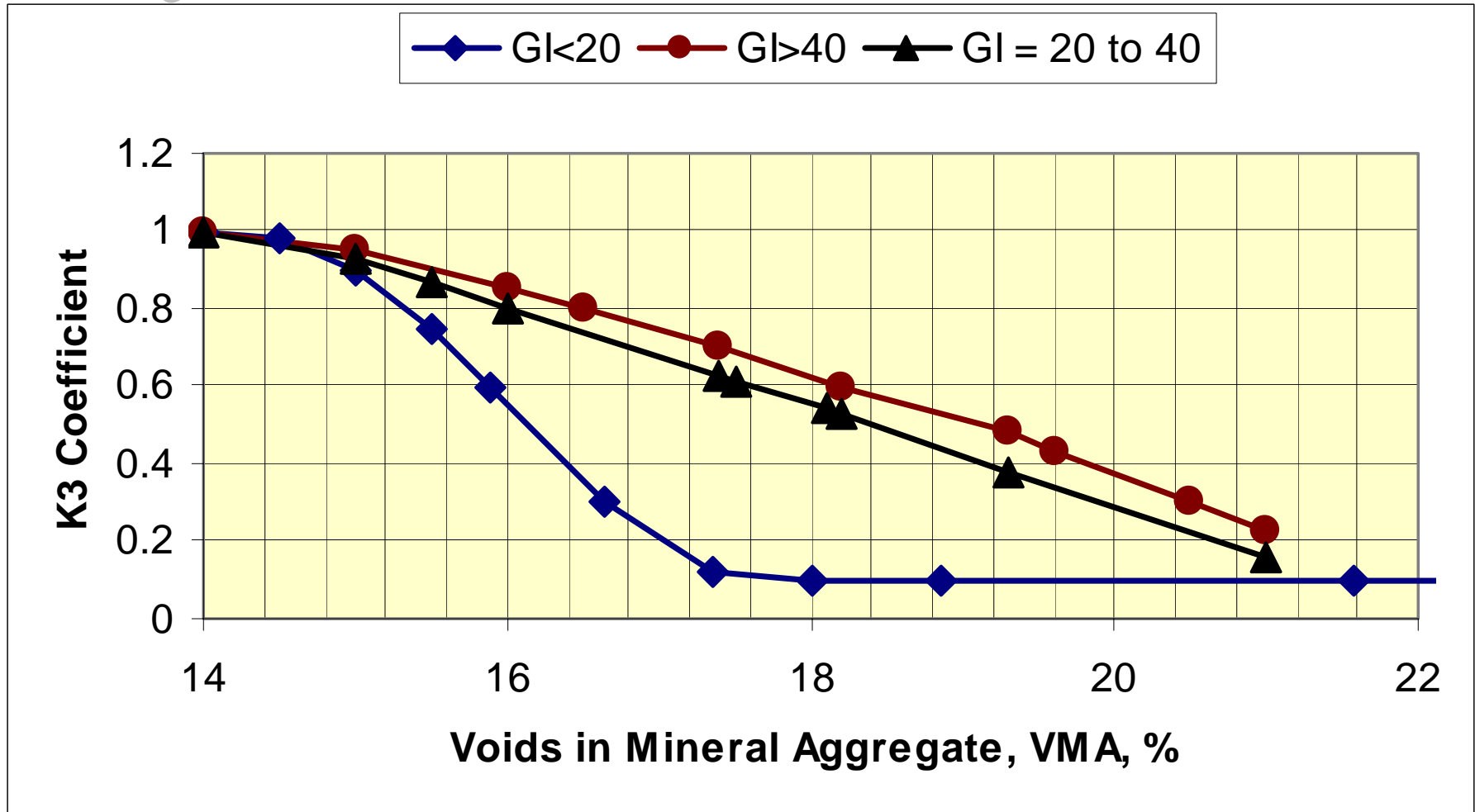
**Result: Residual errors are facility/mix dependent.**



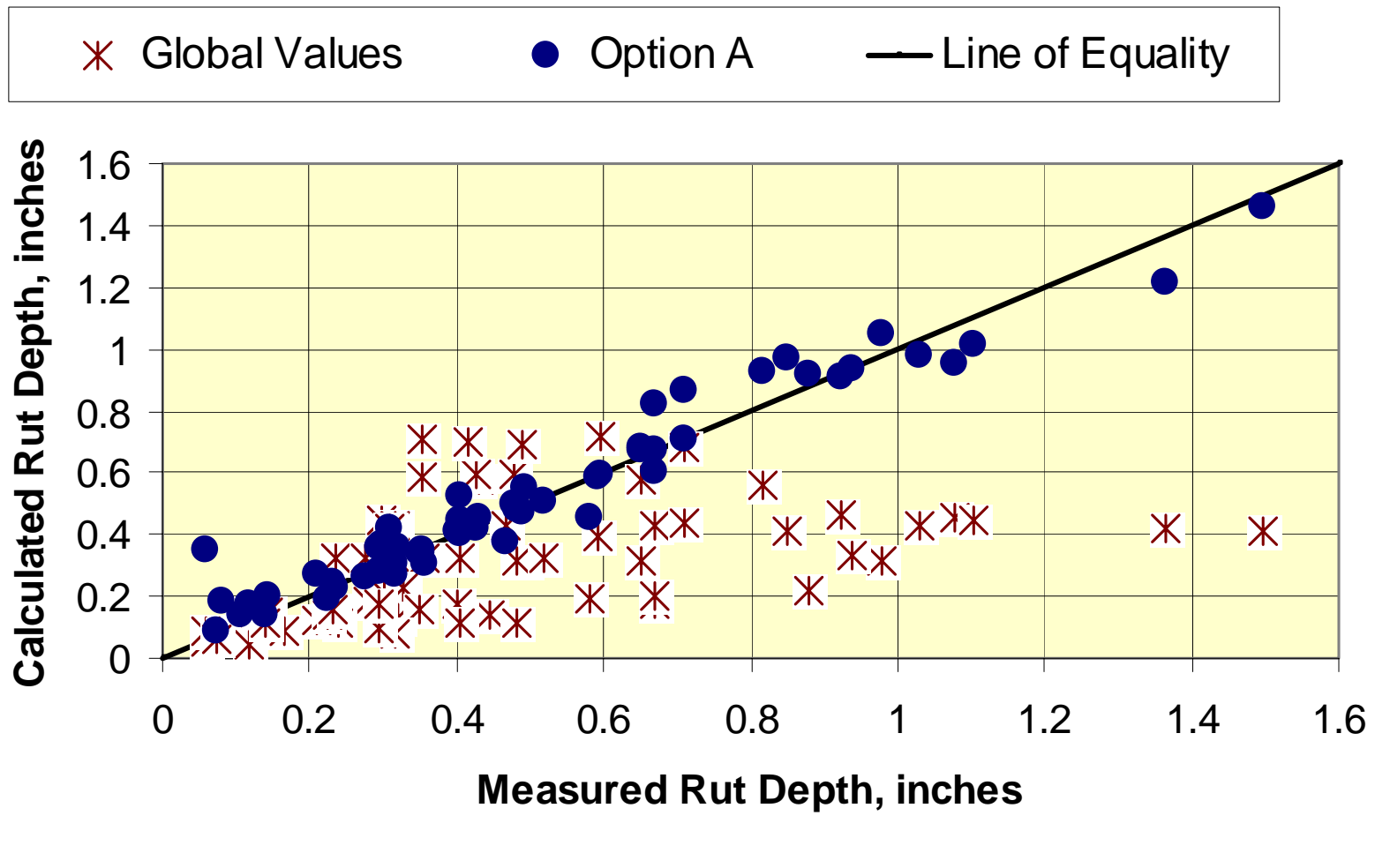
# Local Calibration Factor or Adjustments Based on Mix



# Local Calibration Factor or Adjustments Based on Mix



# HMA Rutting Predictions Using Local Calibration Factors

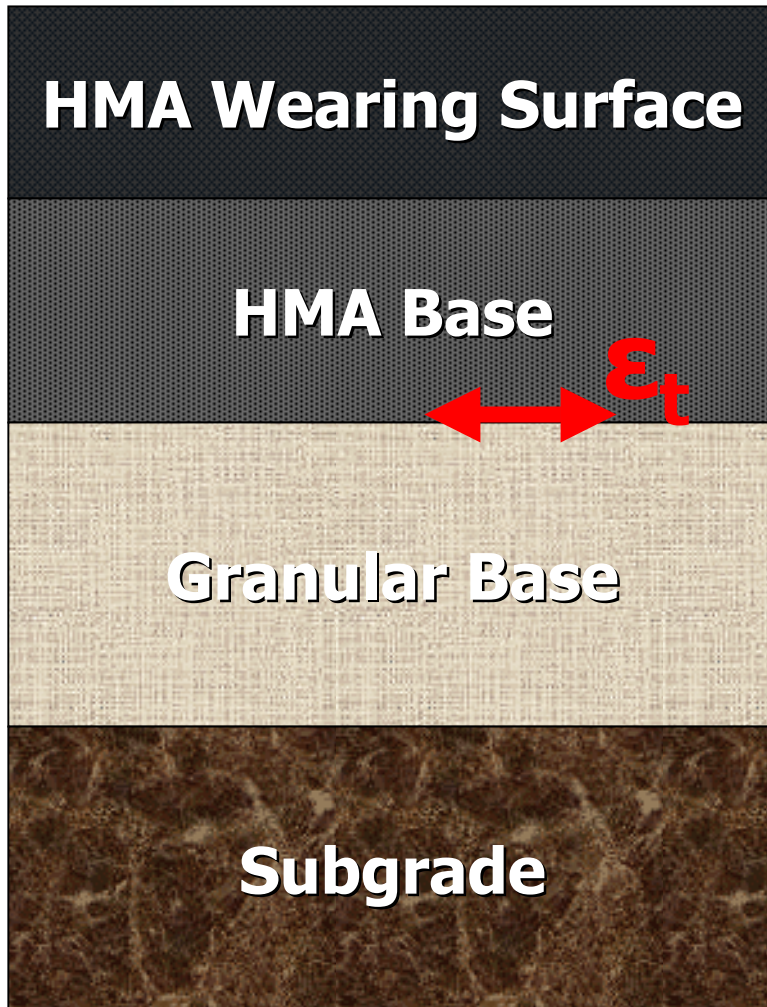




# *Load Related Cracking Observations Vs. Predictions*



# Fracture Damage Analysis



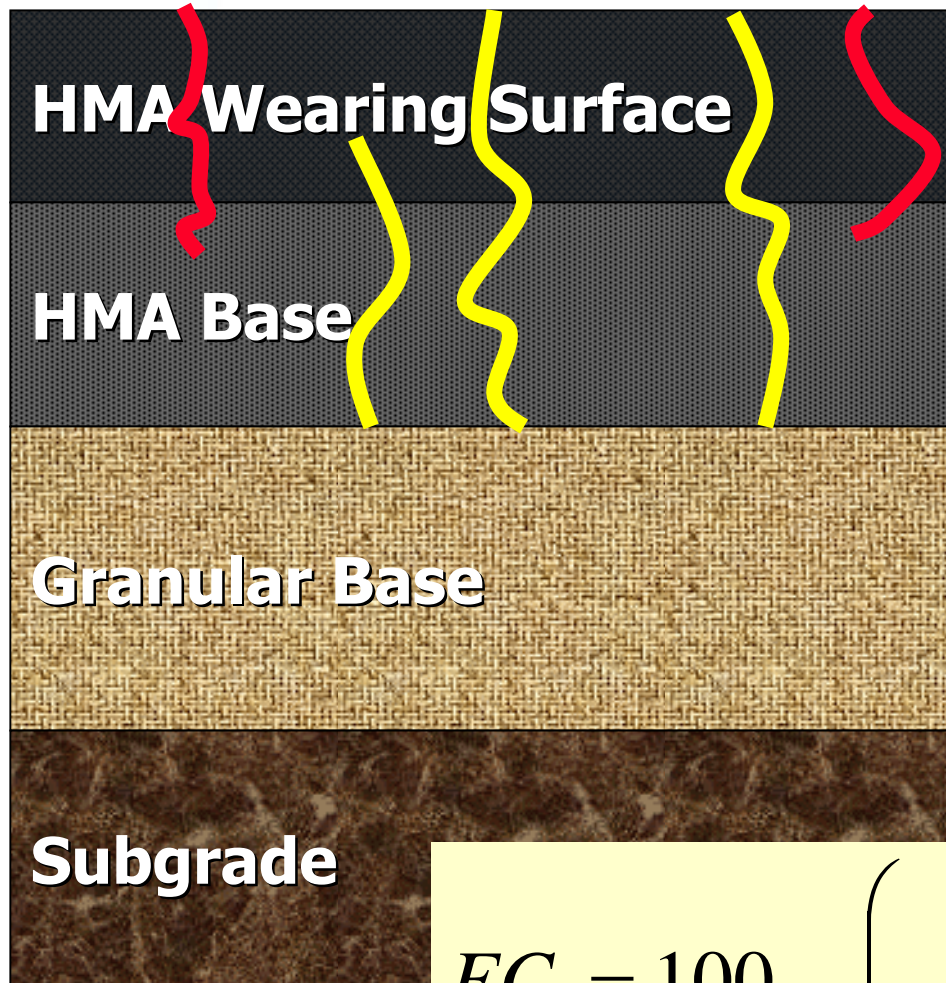
- Tensile strain at bottom of HMA layer

$$N_f = 0.00432(C_{f1})(10)^M (\epsilon_t)^{-3.291} (E)^{-0.854}$$

$$M = 4.84 \left( \frac{V_{beff}}{V_a + V_{beff}} - 0.69 \right)$$



# Fracture Analysis

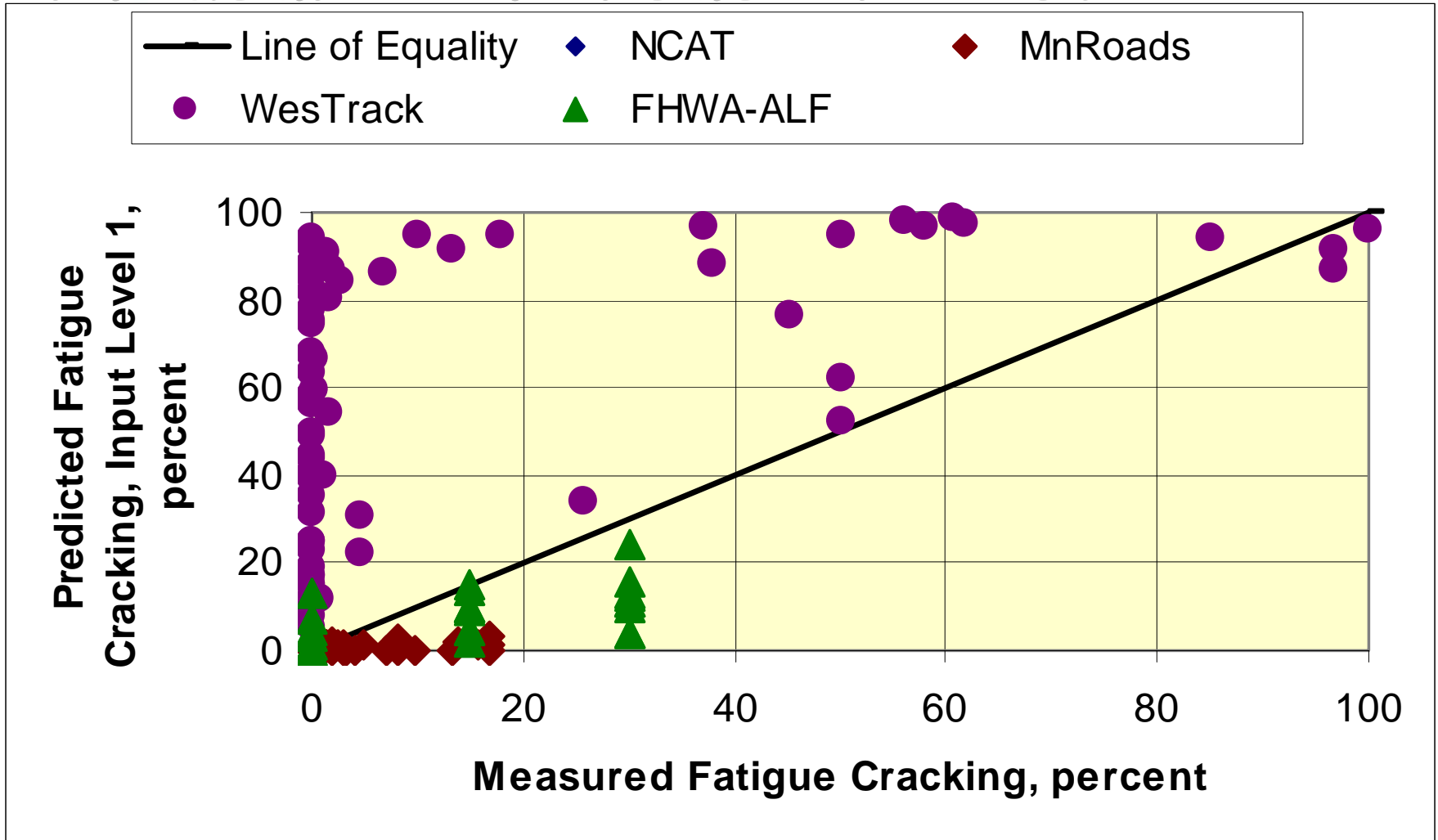


- Cracks initiated at the bottom of the HMA.

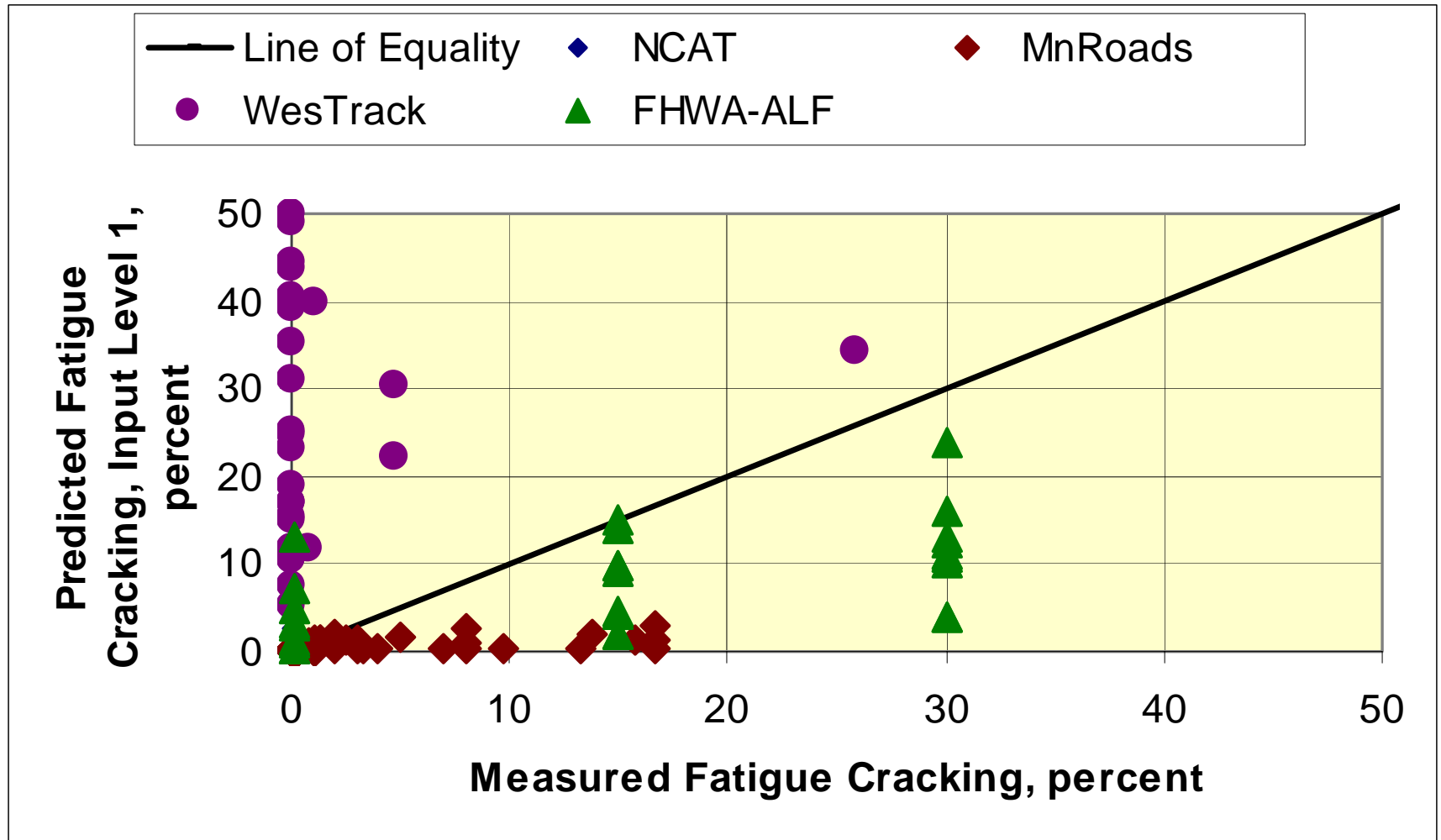
$$DI = \frac{n}{N_f}$$

$$FC = 100 - \left( \frac{100}{5.43656 (C_{f2})^{0.15} (C_{f3})(DI)} \right)$$

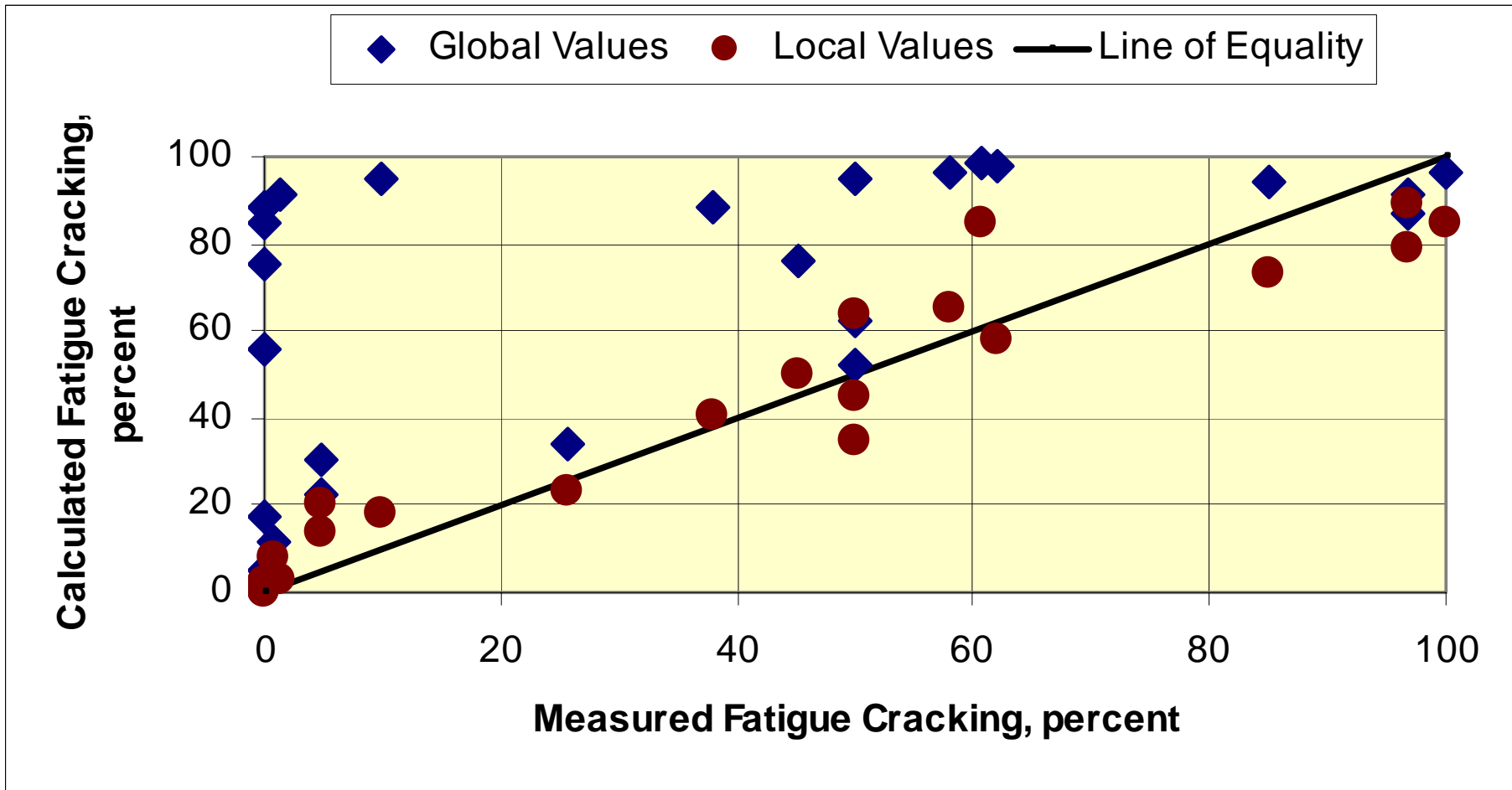
# Fatigue Cracking Predictions Measured Versus Predicted



# Fatigue Cracking Predictions Measured Versus Predicted



# Fatigue Cracking Predictions Using Local Calibration Factors



# Summary Comments Relative to Implementation



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# *What have we learned?*

- ✿ Global standard error is high, especially for fracture.
  - **BUT**, residual errors & bias are still smaller than errors and prediction anomalies reported for 1993 AASHTO Design Guide.
- ✿ Over predicts rutting in unbound layers.
- ✿ Over predicts fatigue cracking.
- ✿ Surface initiated cracks – accuracy not well defined.

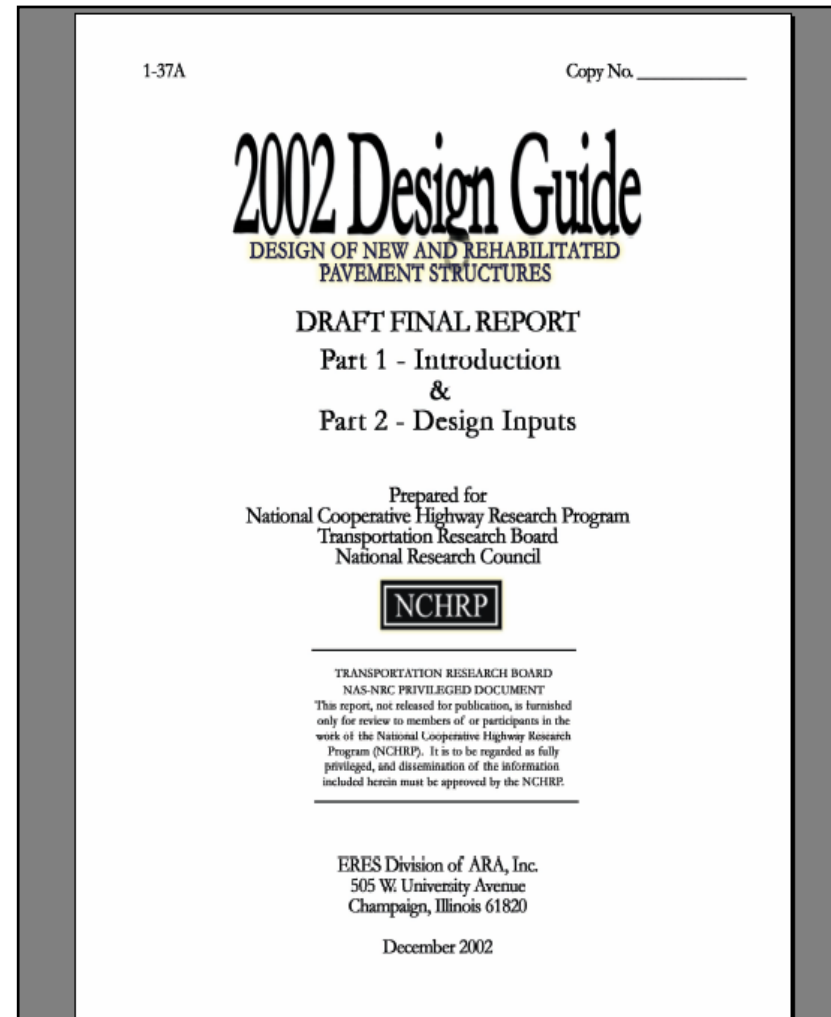
# *What have we learned?*

With local calibration:

- ★ Standard error & bias significantly reduced between mixes & facilities.
- ★ Input error is small relative to measurement error.
- ★ Lack-of-fit error is small relative to measurement error.

# Remember:

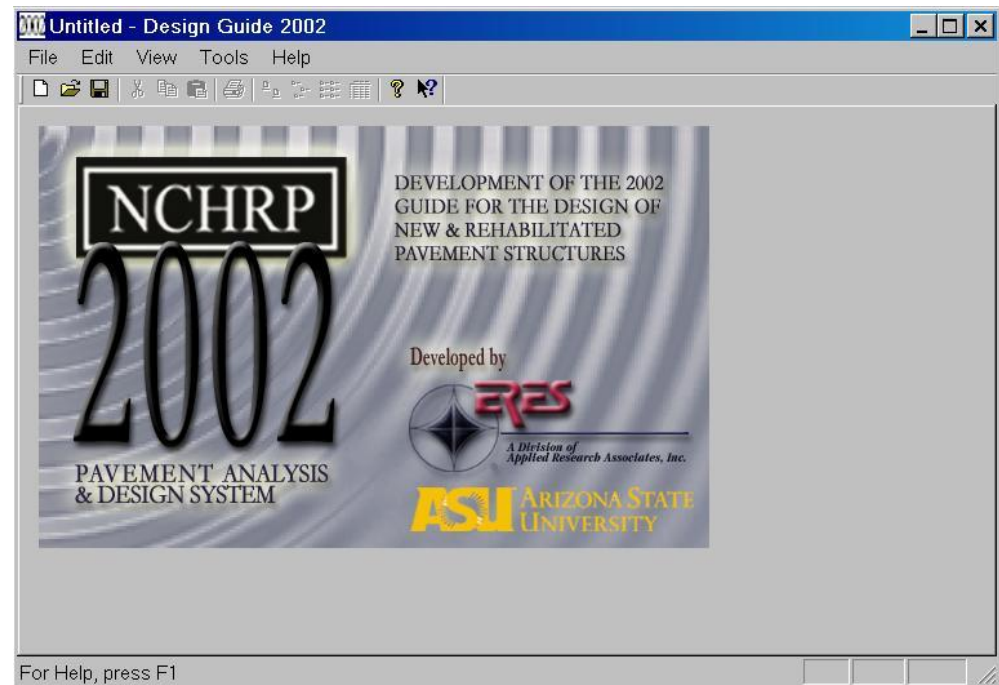
The hierarchical input procedure allows a user to use the Guide with a minimal investment.



# Remember:

It's a pavement design-analysis procedure with **Global**:

- ✱ Correlations to estimate selected inputs.
- ✱ Default values.
- ✱ Calibration factors - **LTPP**.



# *Implementation*

Remember point 1, no major investment is needed for Level 3 inputs, **BUT** you are going to get out of the program based on what you put into it!

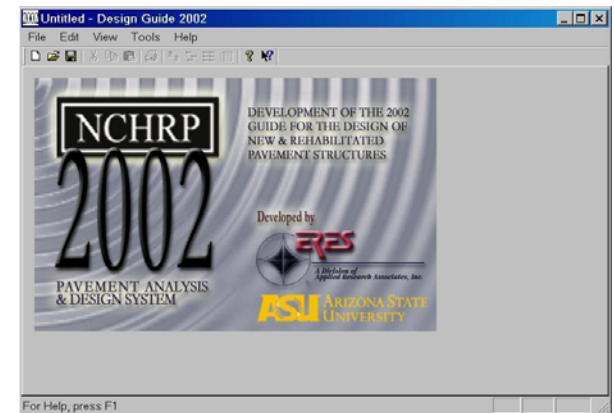




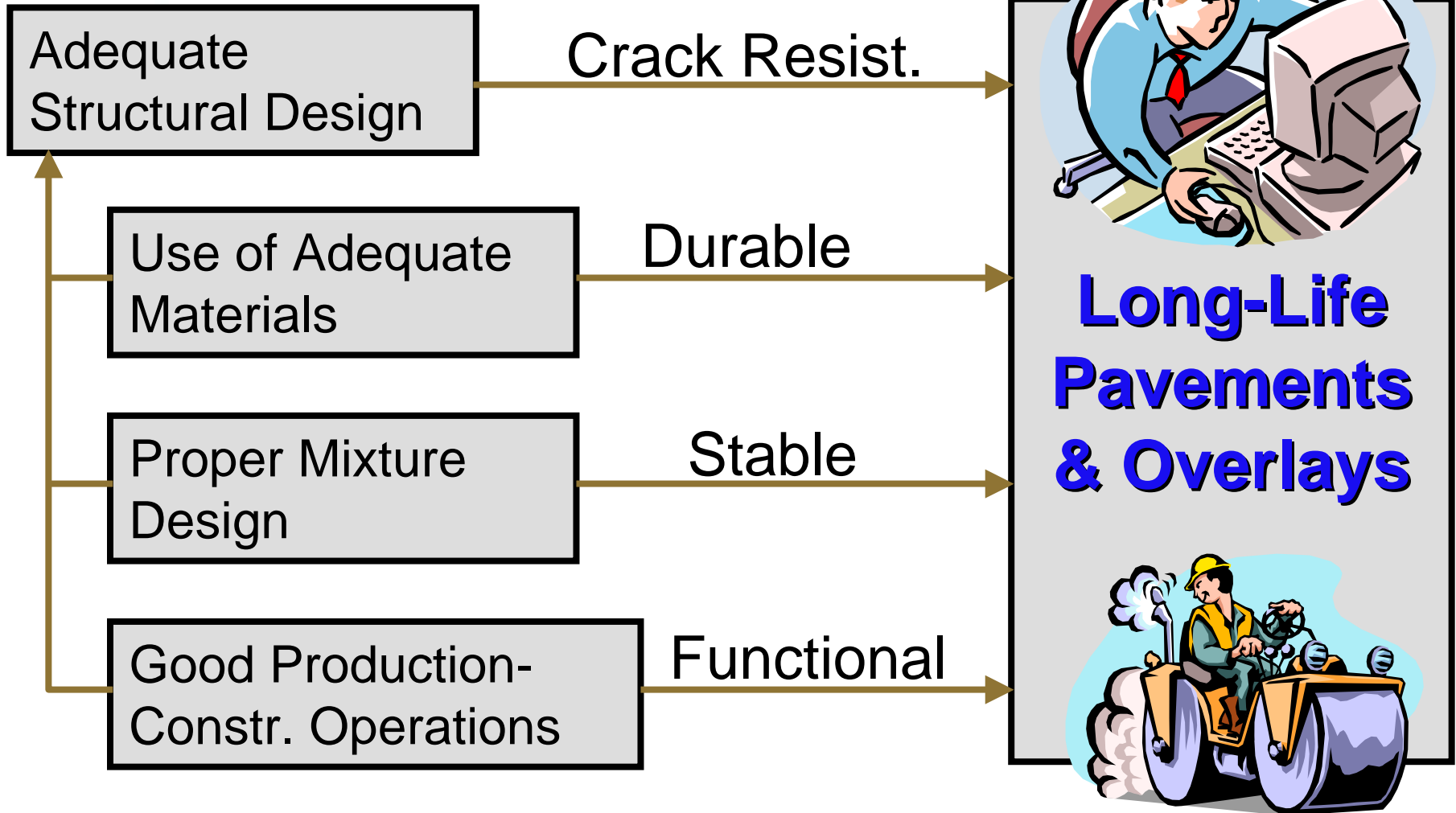
# Summary:

## The M-E PDG Will:

- ✿ Improve distress specific designs.
- ✿ Customize designs for regions & materials.
- ✿ Provide logic for considering materials/features beyond the infra-space of development.



# Summary of M-E PDG



Thank you for your attention  
- Any questions?

