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Local Evaluation and Calibration of Faulting Performance Model

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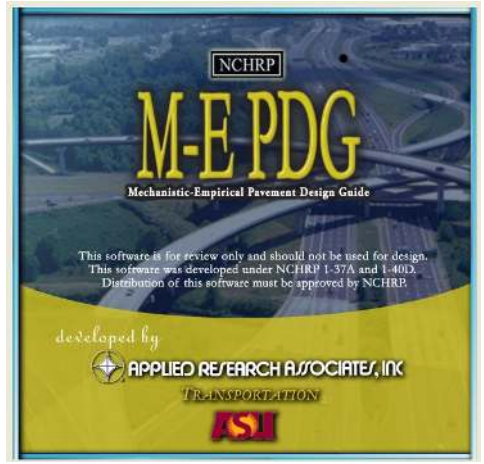
CENTER FOR Sustainable Transportation INFRASTRUCTURE

Rigid Pavement Design

- The current Pennsylvania design method for rigid pavements is outdated
  - AASHTO 93-based procedure (1960-s technology)
  - Not cost-effective
- Pennsylvania is transitioning to AASHTO ME design, which requires to calibrate the performance models for local conditions
- The faulting model is an important part of the AASHTO ME design procedure

History of AASHTO ME Design

- 2004: NCHRP Project 1-37A: Development of the Guide for Design of New and Rehabilitated Pavement Structures
- 2007: NCHRP Project 1-40B – Manual of Practice
- 2007: NCHRP Project 1-40D – Local Calibration Guide
- 2008: Balloted by AASHTO
- 2014: NCHRP Project 20-07 – Major national recalibration
- 2017: ARA Local calibration for PA conditions



DARWin ME™
Mechanistic Empirical Pavement Design

PvD AASHTOWare Pavement ME Design AASHTO

- 2020: PittRigid – simplified AASHTO ME-based procedure for PA conditions

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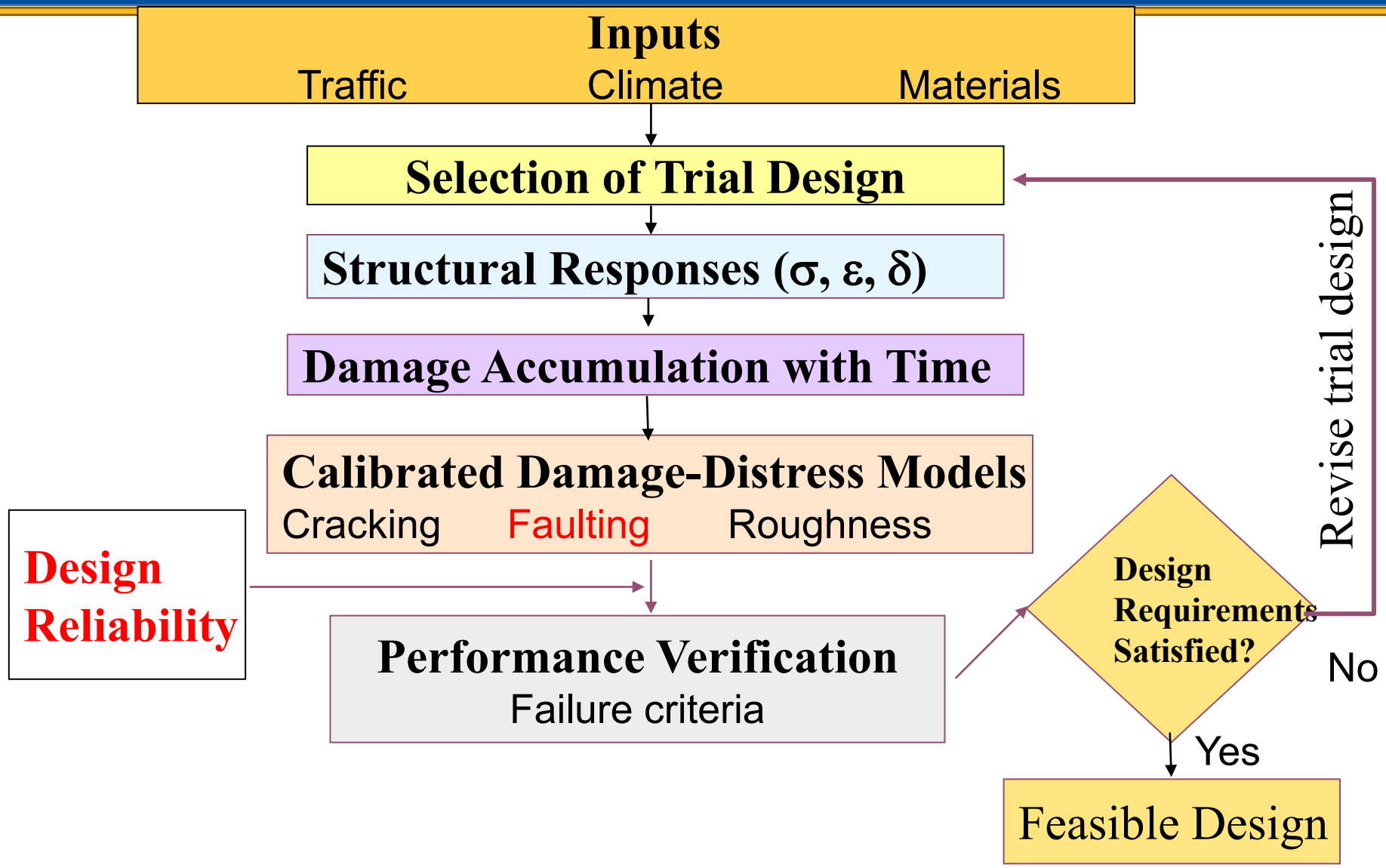
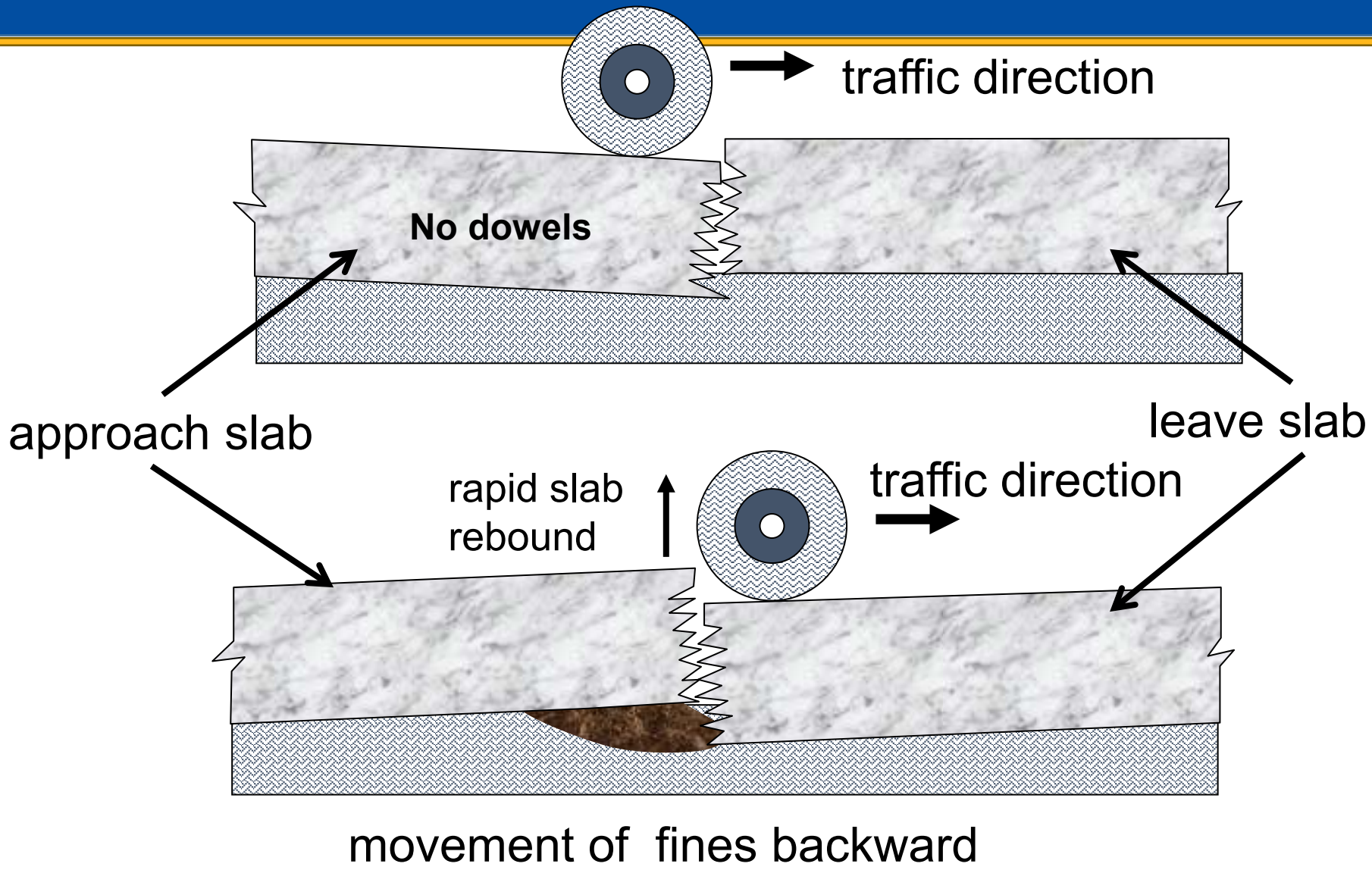
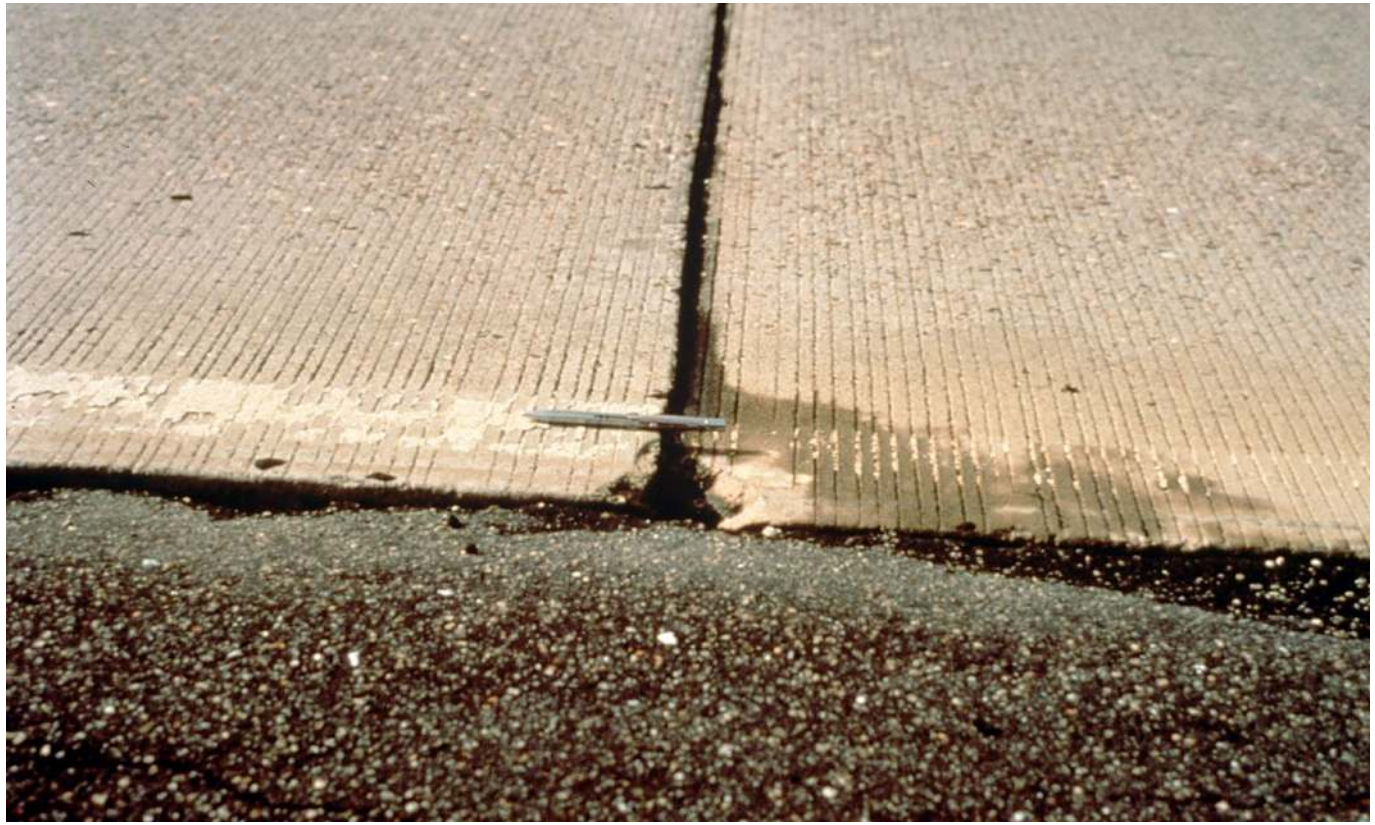
AASHTO ME Design



Joint Faulting



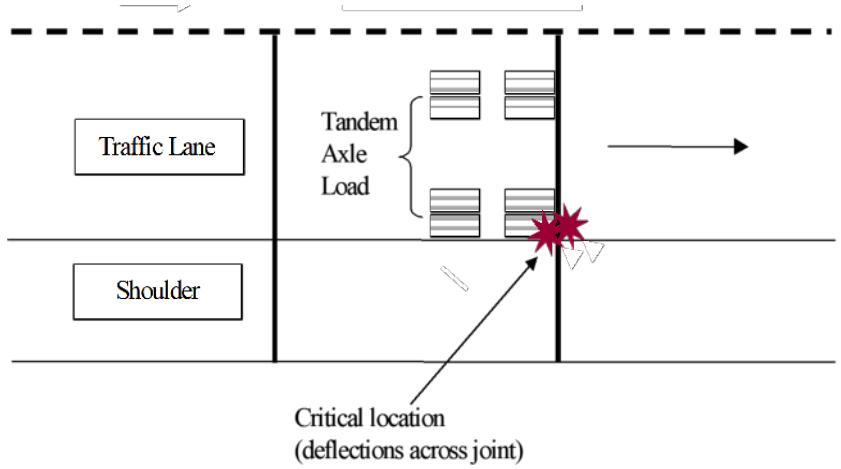
Joint Faulting



Conditions for faulting development:

- **High corner deflections**
- **High differential deflections**

PavementME Faulting Model



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

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

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

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

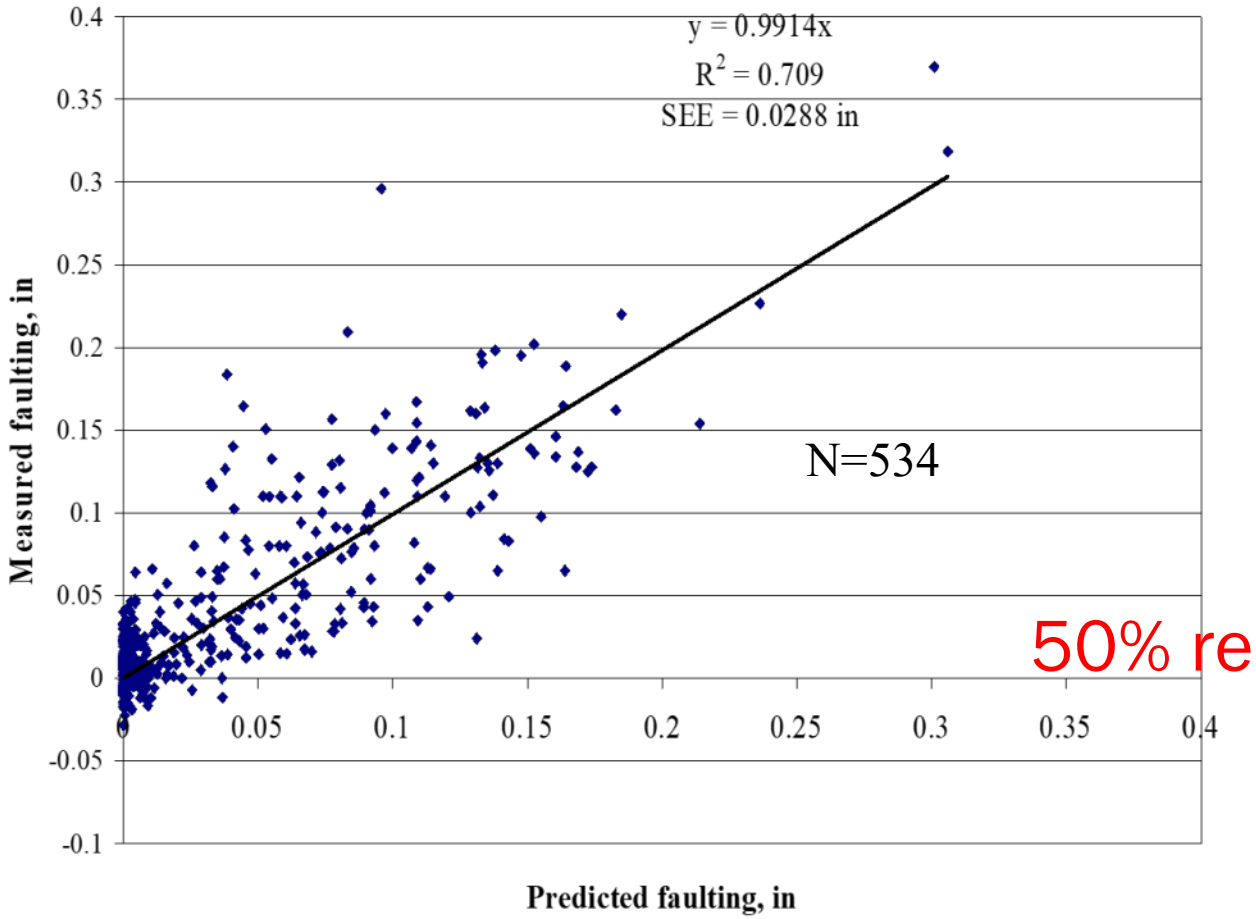
Calibrate predictions to observed field performance to eliminate prediction bias

Adjust predictions to account for the variability in the performance prediction

(Khazanovich et al. 2004)

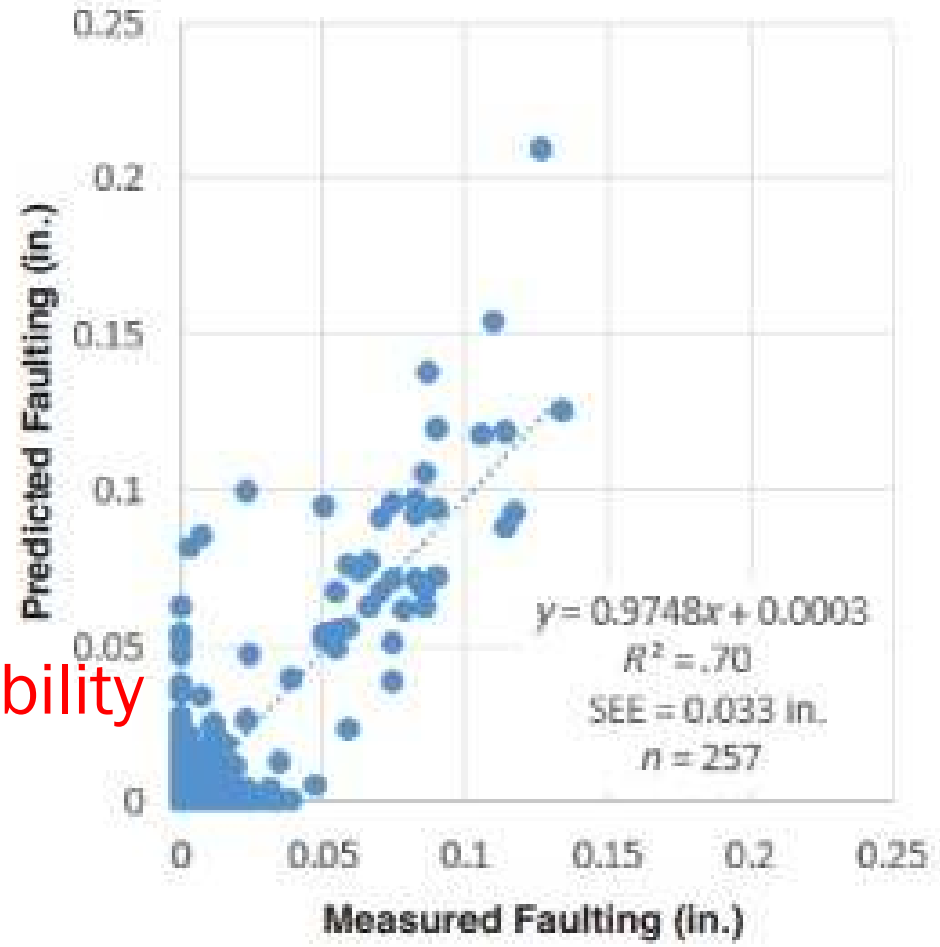
PavementME Faulting Model Calibrations

NCHRP 1-40D calibration (Khazanovich et al. 2004)

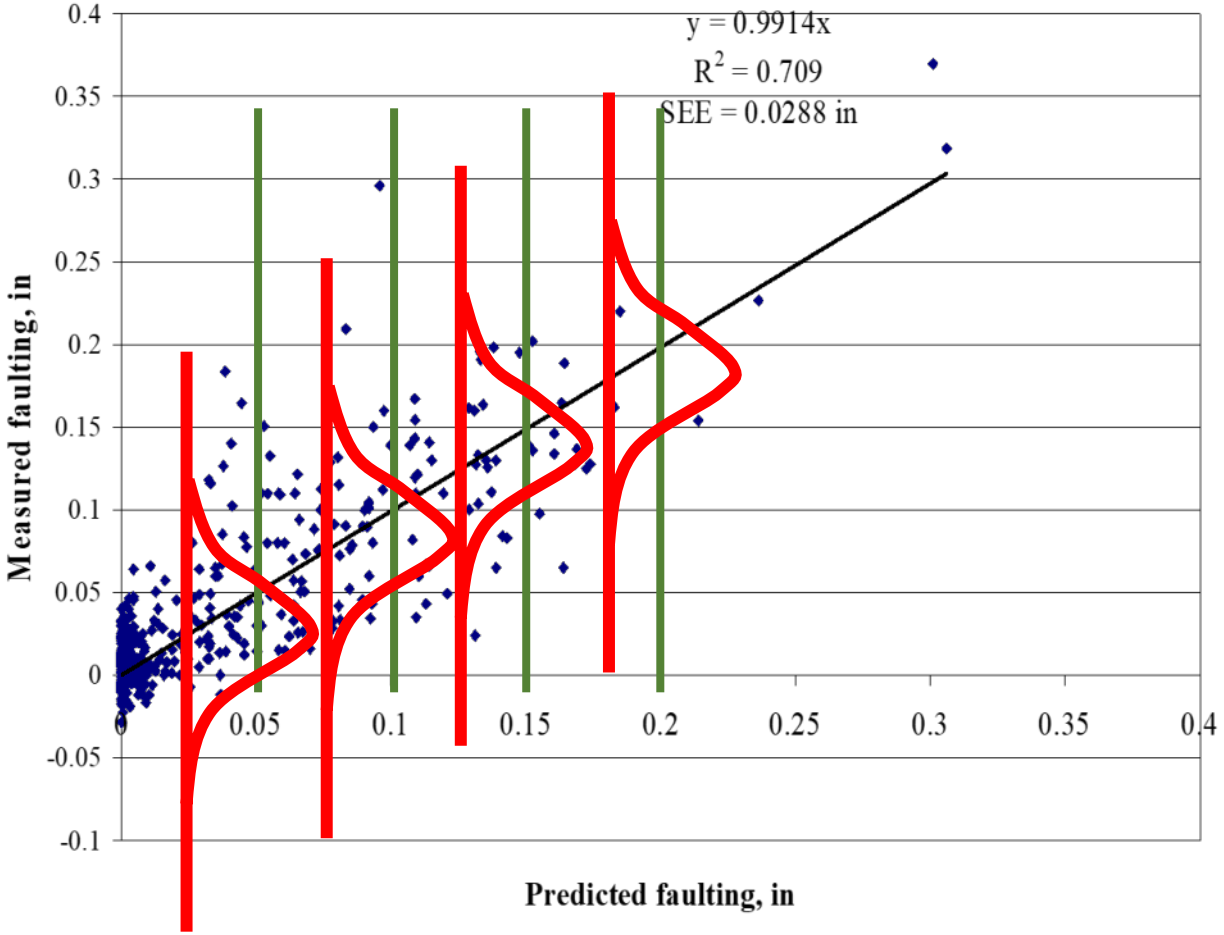


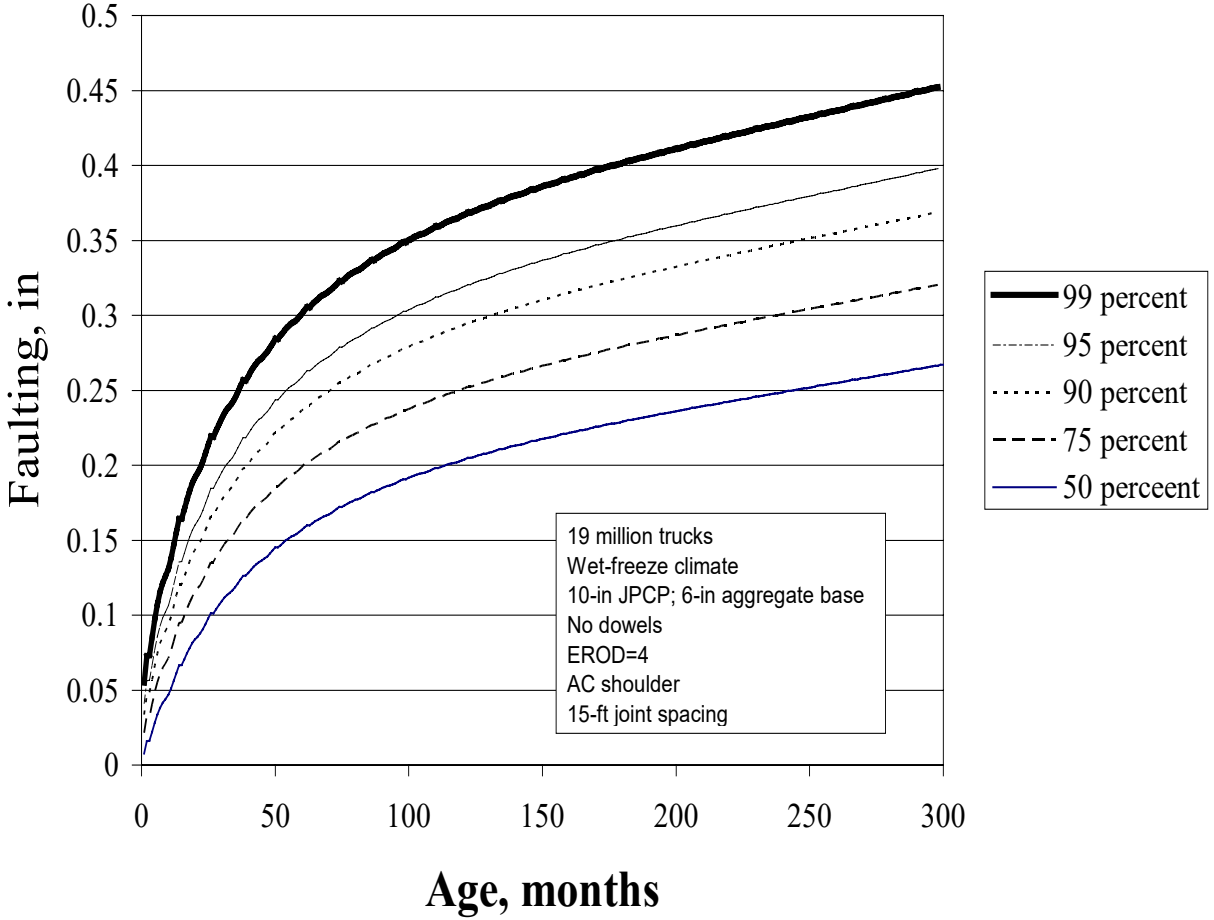
50% reliability

NCHRP 20-07 calibration (Vandenbossche et al. 2015)



PavementME Faulting Relaibility Analysis

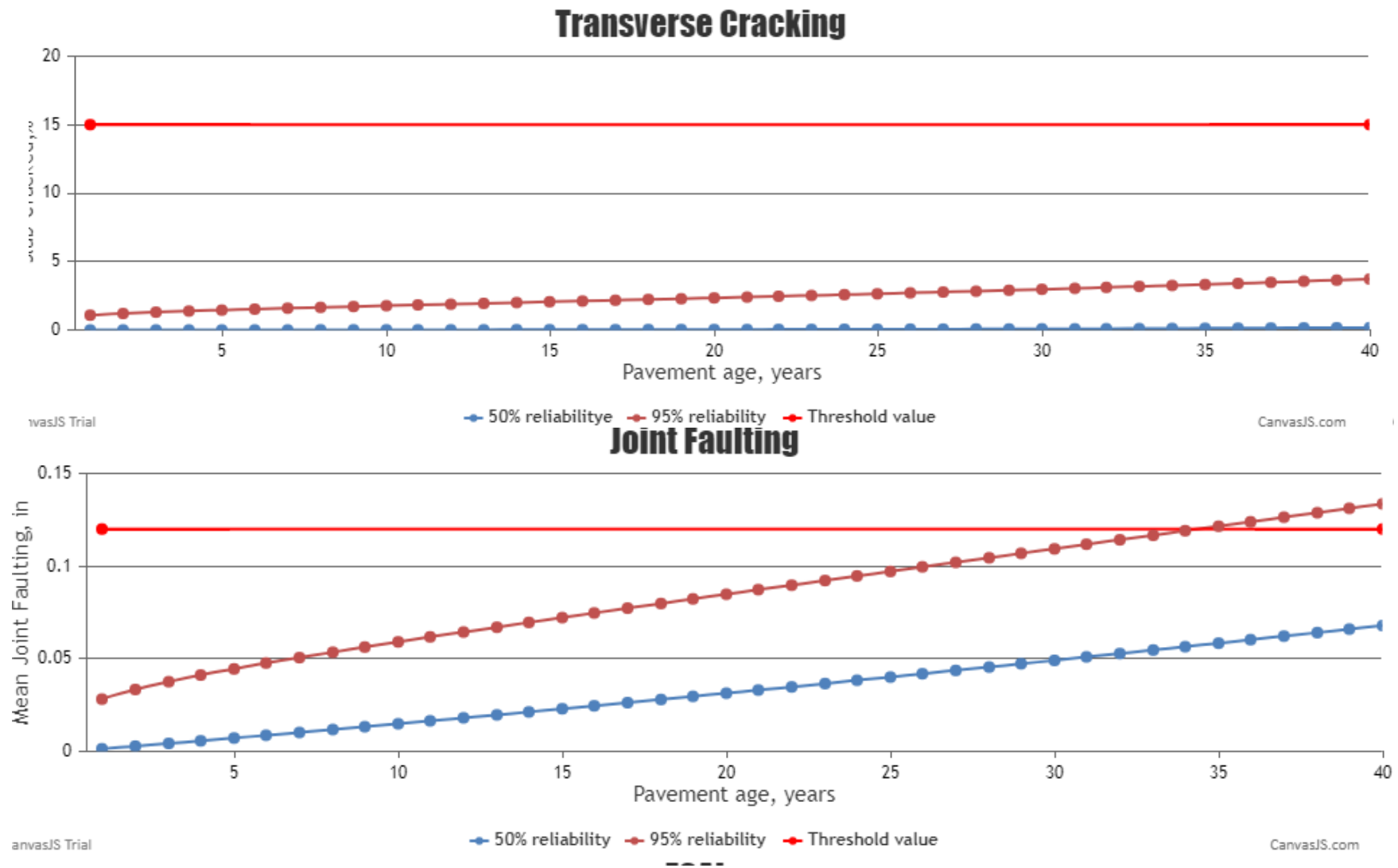




$$Fault_{R\%} = Fault_{50\%} + a\, Fault_{50\%}^{\,b} \cdot Z_R$$

(Darter et al. 2005)

Evaluation of PavementME/PittRigid Predictions



Location: Pittsburgh
46 million ESALs
PCC thickness: 11 in
15 ft joint spacing
1.5-in dowels

Problems with the Conventional Calibration

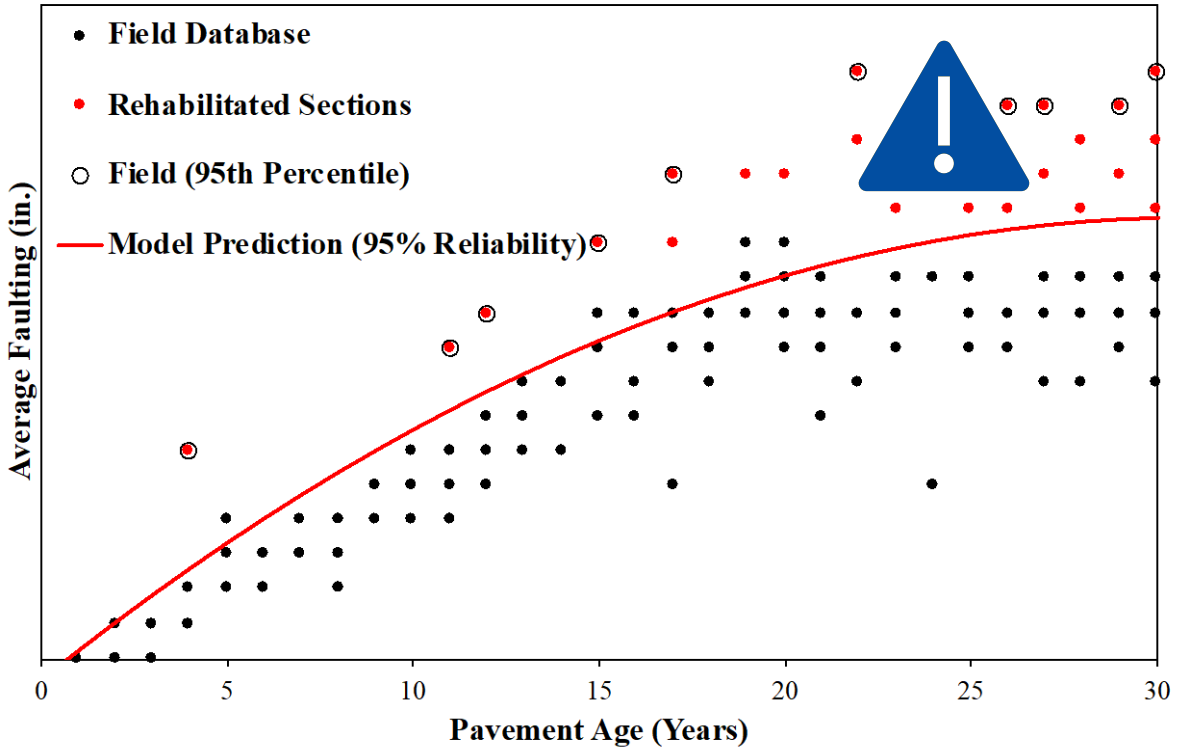
- Requires high quality data for each pavement sections
  - Site conditions (traffic, climate, subgrade)
  - Design and material properties
  - Pavement performance
- Overemphasizes 50% reliability predictions
- Cannot account for performance of the sections removed from service

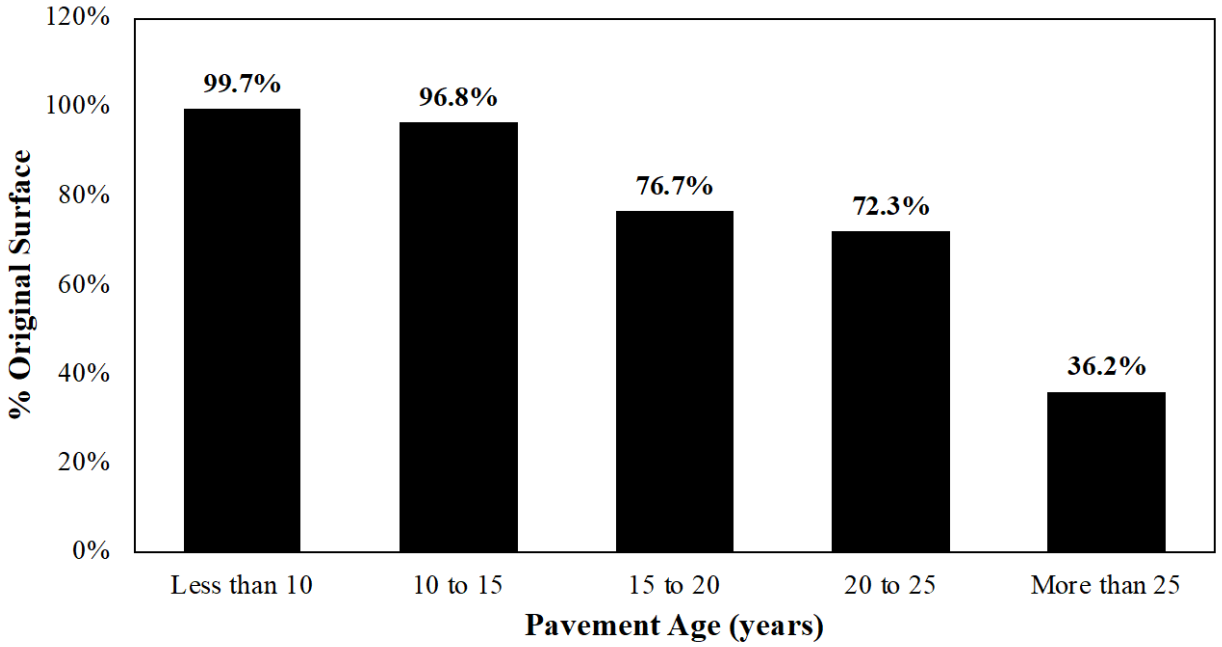
PA LTPP JPCP sections:
8 faulting observations

Most pavements are designed for 90 - 95% reliability

The "Survival" Issue

Missing Performance Data from RMS database



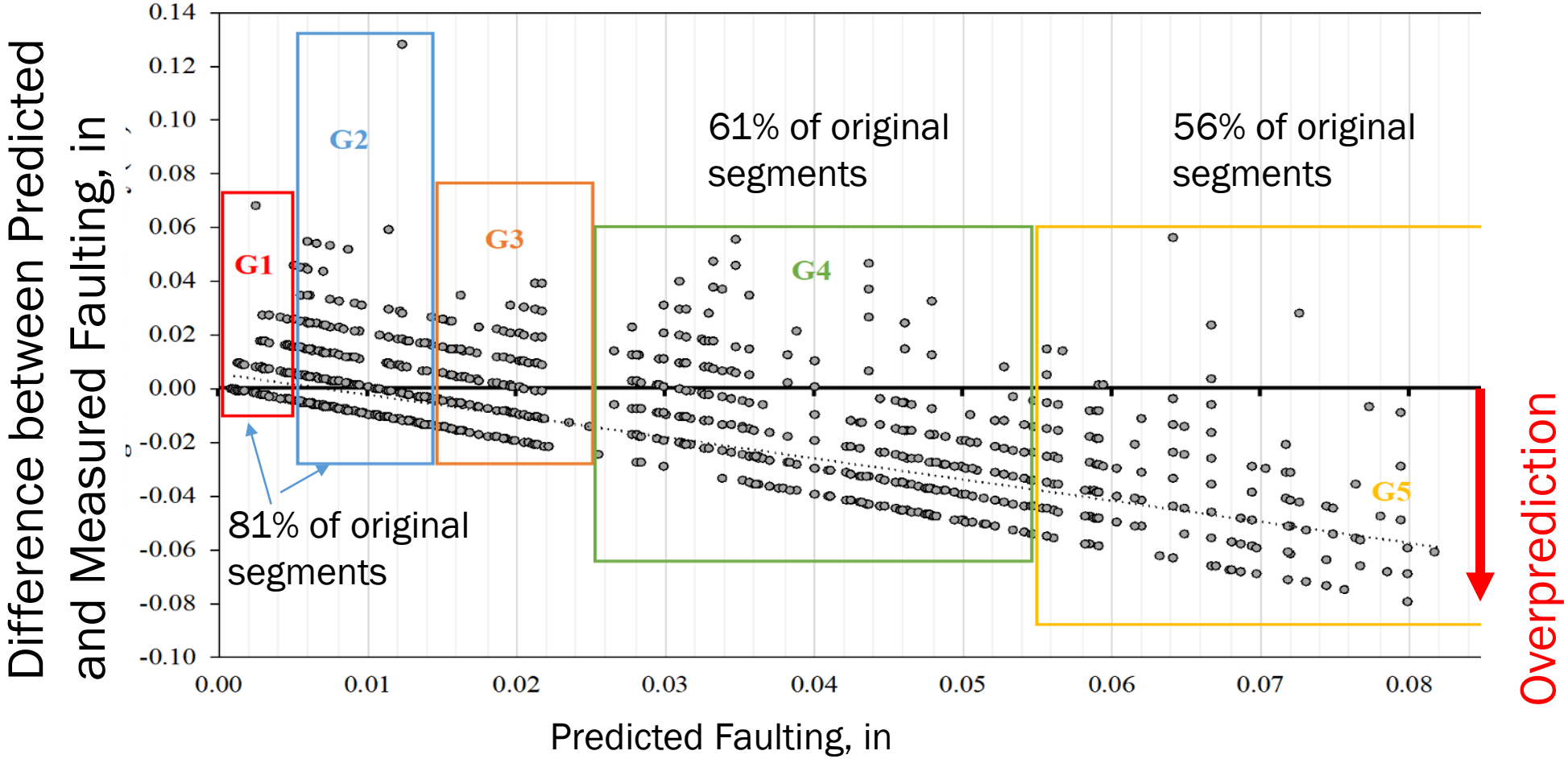


Developed Calibration Approach

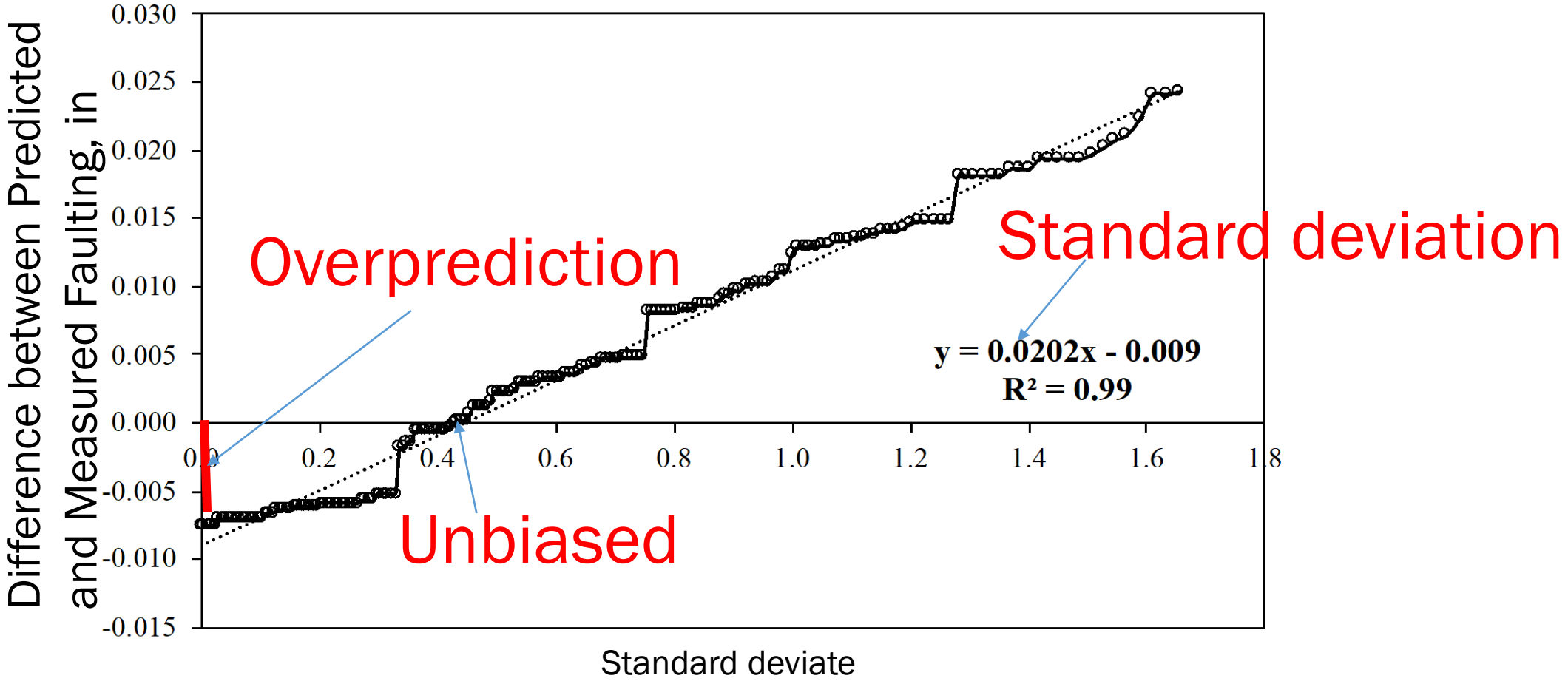
- Use PennDOT Road Management System (RMS) data
  - Over 4,000 observations
- Estimate performance of removed sections
- Evaluate performance prediction of the current model for high reliability levels
- Emphasize high reliability level predictions
  - Calibrate the reliability model first
  - Adjust the 50% reliability predictions

Modifying Reliability Model Accounting for Missing Data

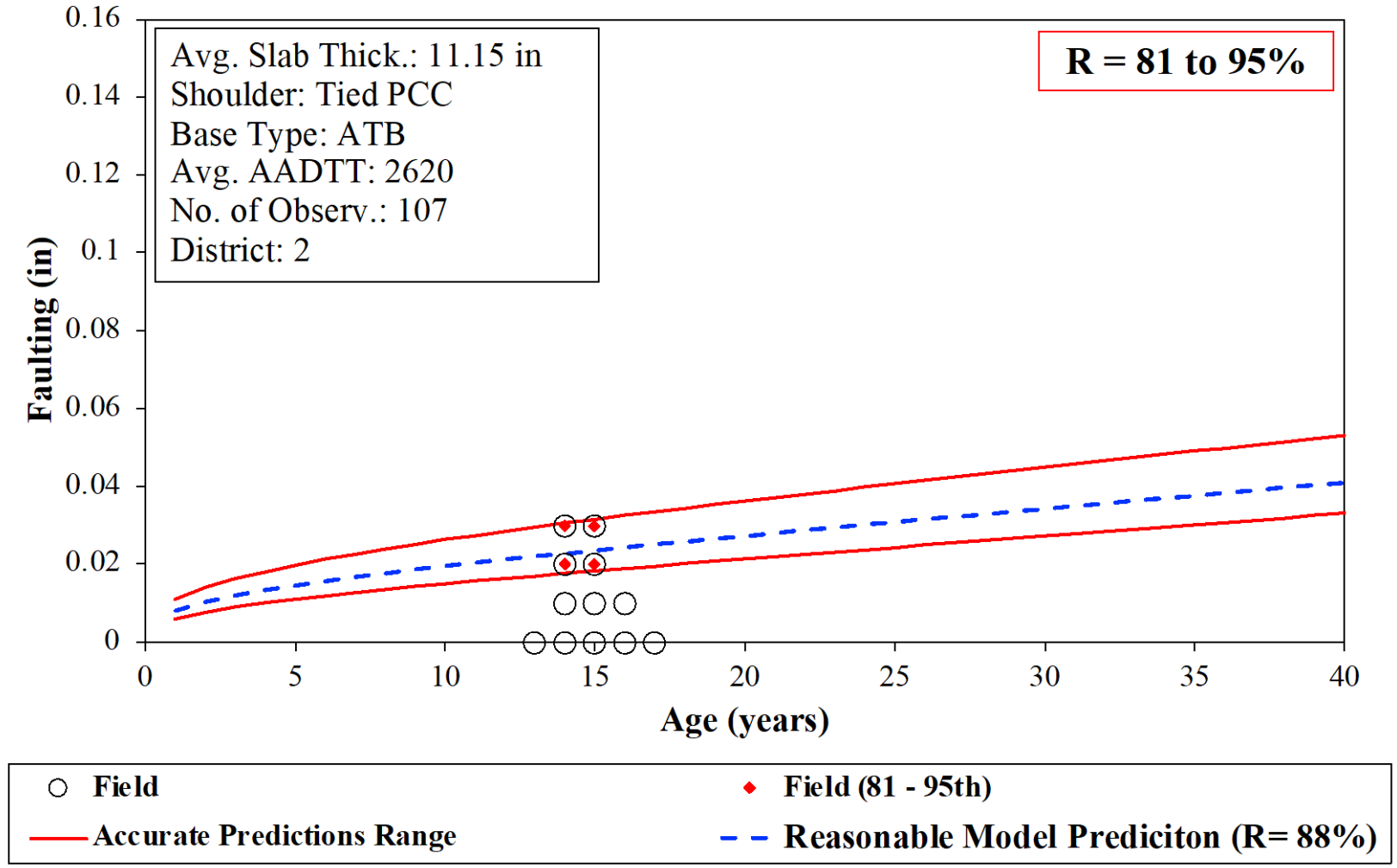
- **Perform PavementME simulation**
- **Compare predicted and measured responses**



New Reliability Model Development



Accounting for Missing Data



Faulting Model Modification

New term and coefficient to account for base drainage

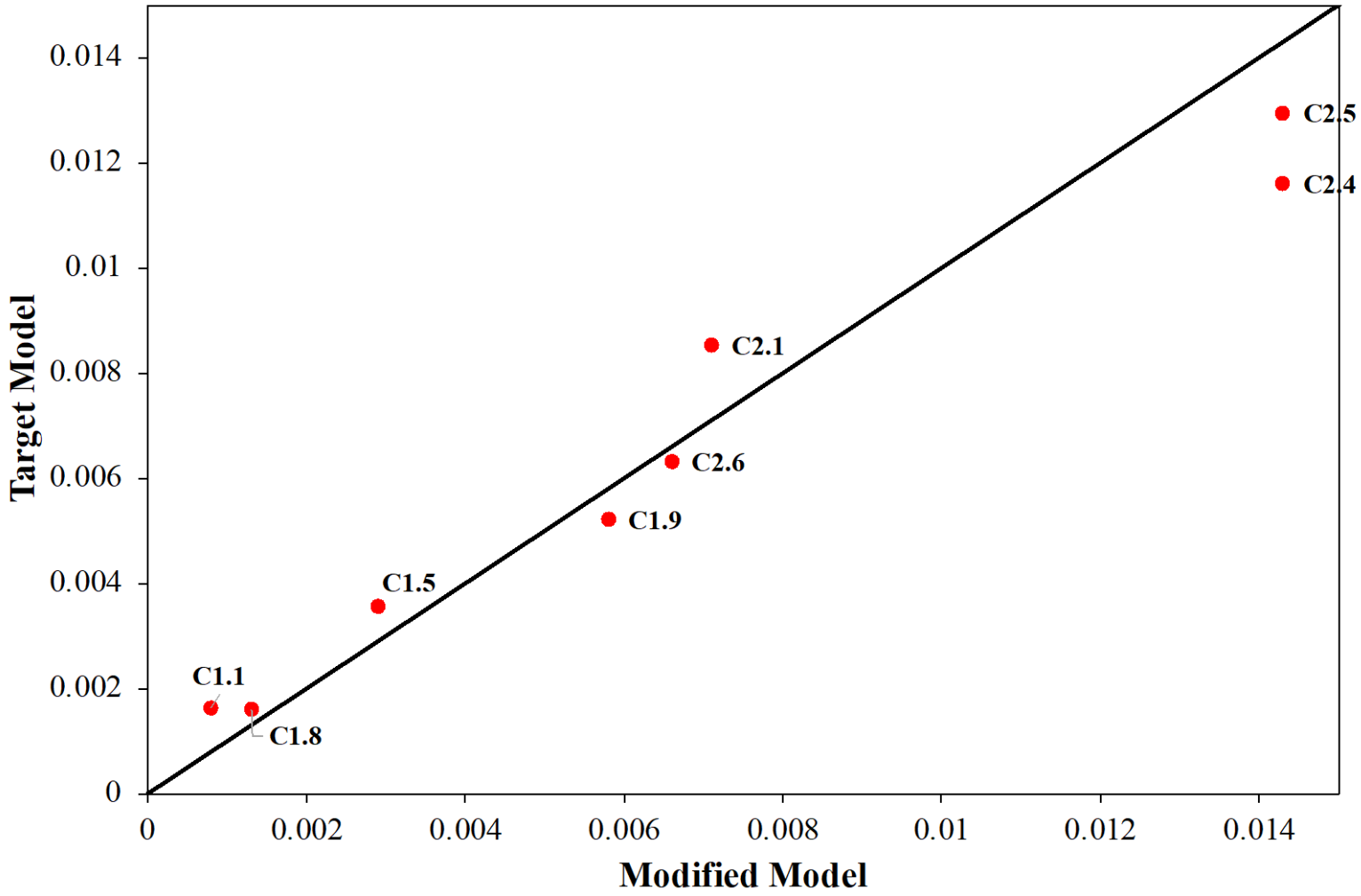
$$Fault_m = \sum_{i=1}^{m} \Delta Fault_i$$

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

$$FAULTMAX_i = FAULTMAX_0 + C_7 \times \sum_{j=1}^{m} DE_j \times Log\left(1 + C_5 \times 5.0^{EROD}\right)^{C_6} \times \left[Log\left(1 + C_5 \times 5.0^{EROD}\right) \times Log\left(\frac{P_{200}(C_9\, WetDays)}{P_s}\right)\right]^{C_6}$$

$$FAULTMAX_0 = C_{12} \cdot \delta_{curling} \cdot \left[Log\left(1 + C_5 \times 5.0^{EROD}\right) \times Log\left(\frac{P_{200}(C_9\, WetDays)}{P_s}\right)\right]^{C_6}$$

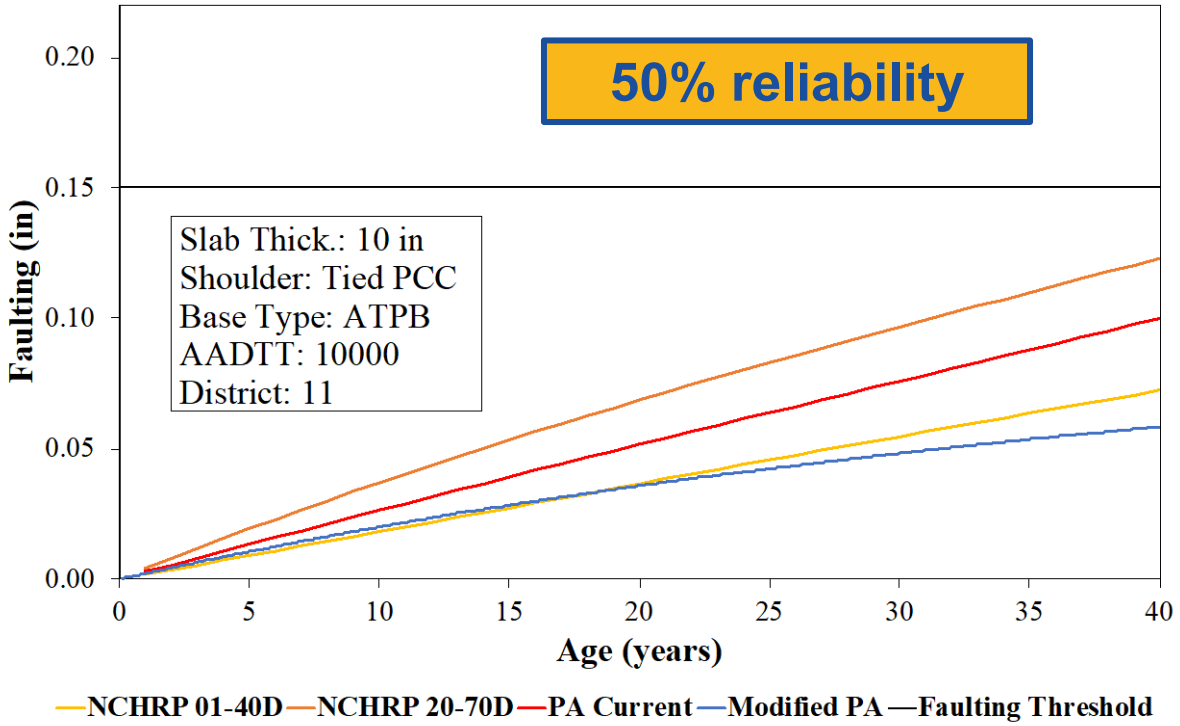
Faulting Model Calibration

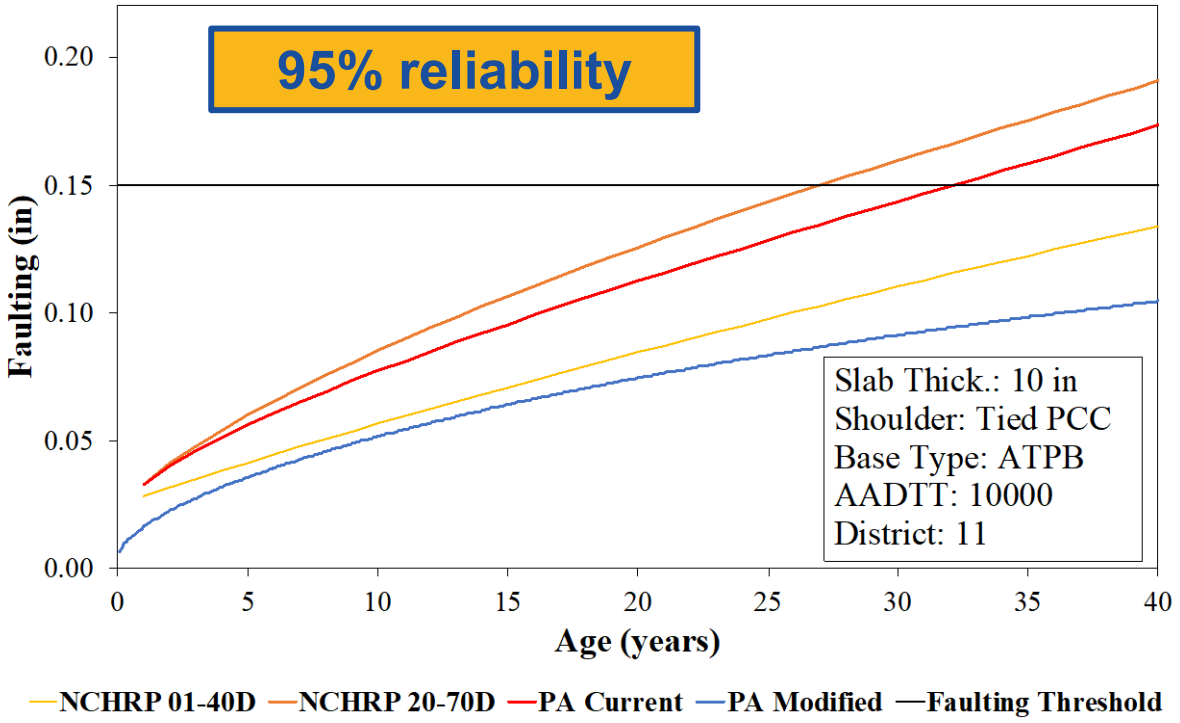


Calibration Coefficients

	NCHRP 01-40D	NCHRP 20-07	PA Current	PA Modified
Software Version	MEPDG 1.0	Pavement ME 2.3.1	Pavement ME 2.3.1	Pavement ME 2.3.1
C1	1.0184	0.595	0.595	0.4
C2	0.9165	1.636	1.636	1.1
C3	0.002185	0.00217	0.00147	0.0035
C4	0.000884	0.00444	0.00444	0.015
C5	250	250	250	250
C6	0.4	0.47	0.4	0.4
C7	1.83312	7.3	7.3	2
C8	400	400	400	400
C9	N/A	N/A	N/A	ATPB = 0.3 CTPB = 0.3 AGG = 1.0

Comparison of Performance Predictions





Performance Model Validation

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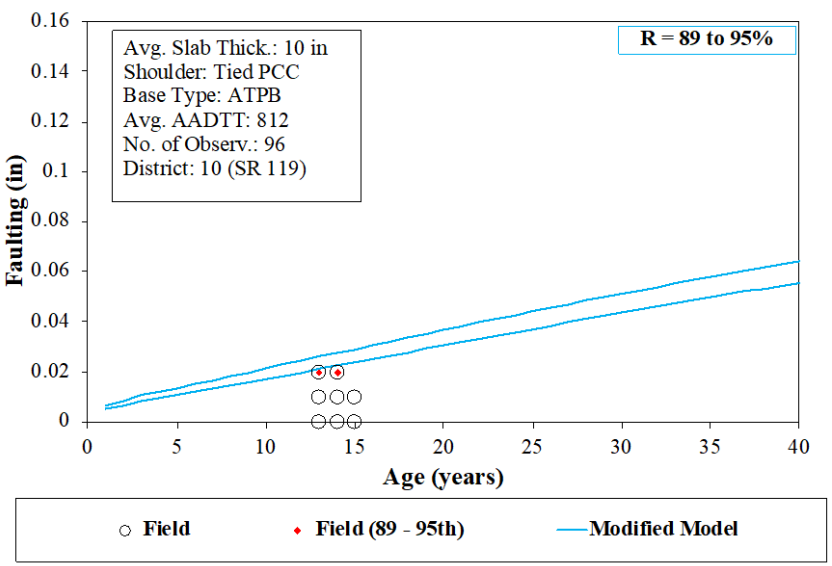

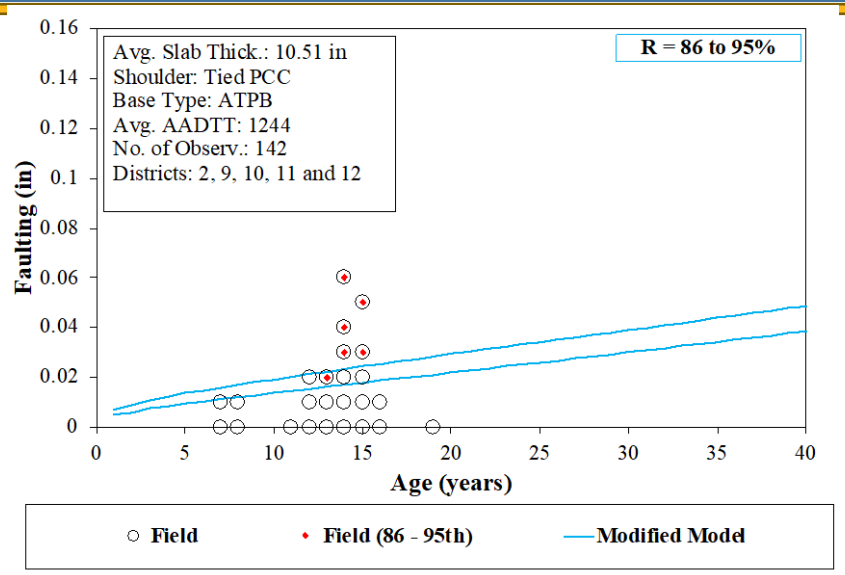

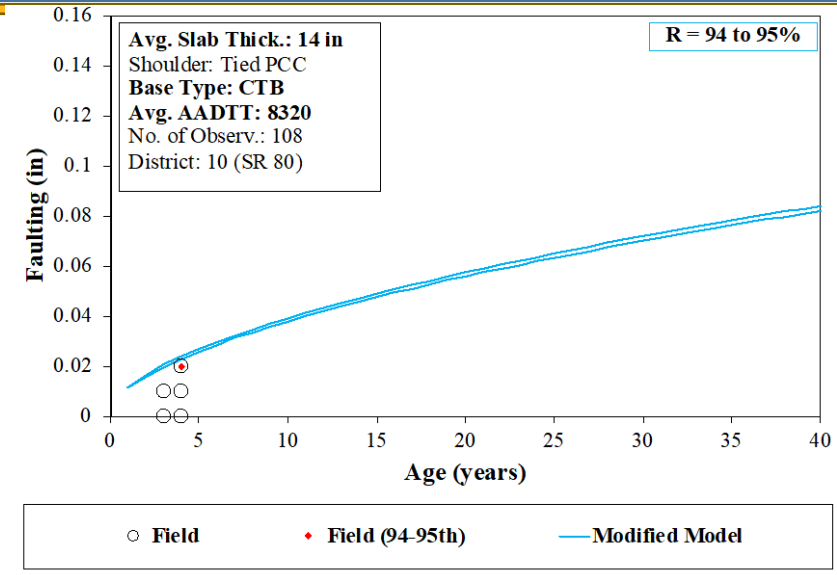

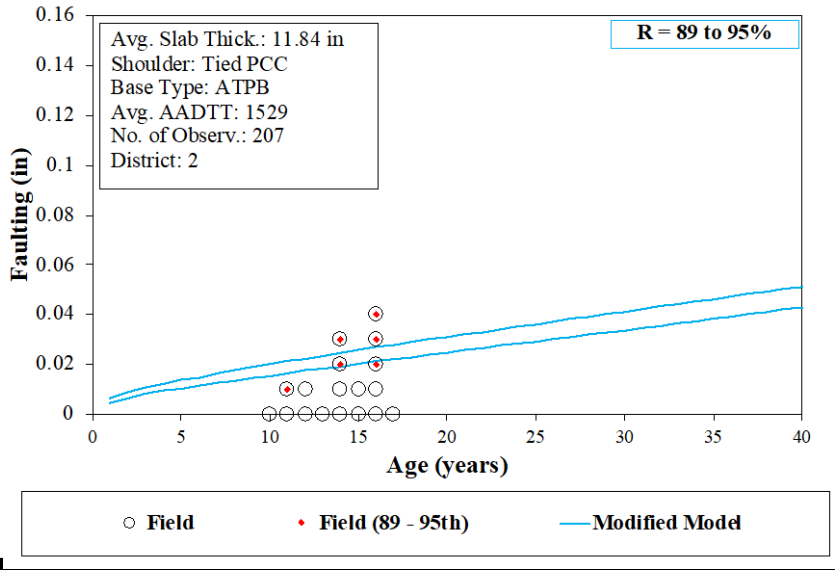

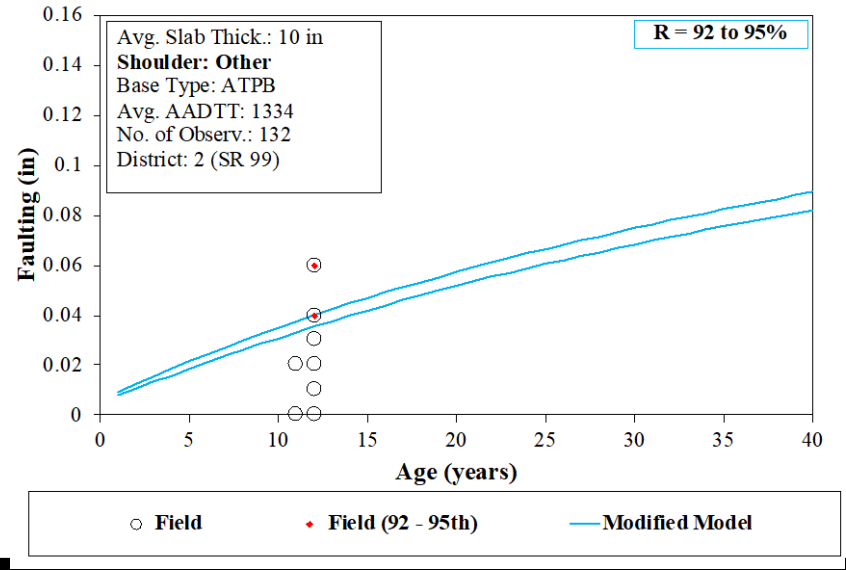

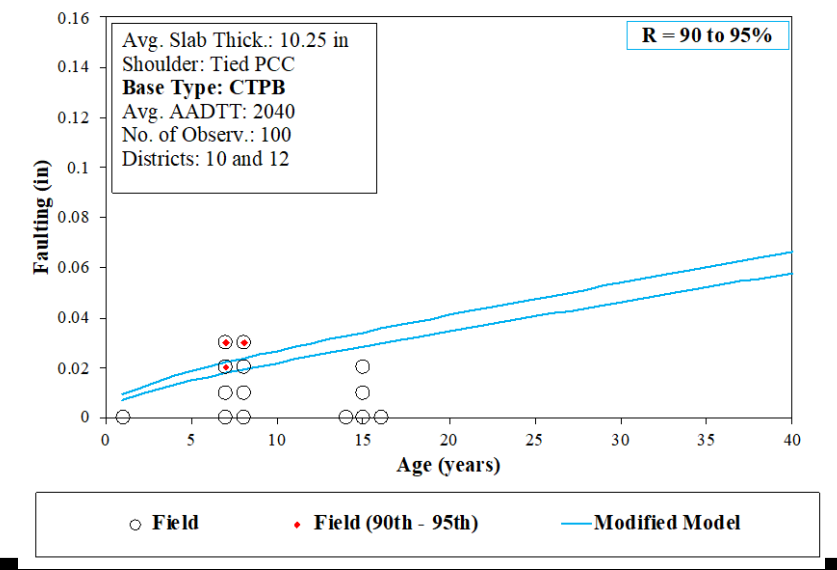

Evaluation of the Modified PittRigid Predictions

Conclusions

- The *faulting model* is an important part of the AASHTO ME design procedure
- The faulting model was improved and re-calibrated for PA conditions
  - PennDOT's Road Management System (RMS) data
  - Emphasis on high reliability predictions
  - Accounting for the "survivor" effect
- The improved model has been incorporated into a web-based program, PittRIGID

https://pittrigid.azurewebsites.net/

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Questions?