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Network Level Structural Evaluation With Rolling Wheel Deflectometer

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1909-2009

VDOT
Virginia Department of Transportation

Presentation Outline

- **Structural Data for Network Level Pavement Management**
- **Methods of Pavement Structural Evaluation**
- **PennDOT- Case Study-3 Methods of Evaluation**
  - Falling Weight Deflectometer
  - Rolling Wheel Deflectometer
  - Algorithm Based on Pavement Composition & Age
- **Recommendations for Network Level Structural Evaluation**

Pavement Management Decision Making

- Goal- identify maintenance & rehab treatments, priorities & budgets
- Input- pavement surface condition, pavement history, geometric measurements (rut, profile)
- Pavement strength useful- often not available

Traditional Project Level Structural Evaluation

- Benkelman Beam Testing
- Falling Weight Deflectometer Testing

Benkelman Beam

- Beam deflection under truck load measured by dial gage
- Empirical correlations developed to determine overlay thickness required
  - Based on deflection & projected traffic loading

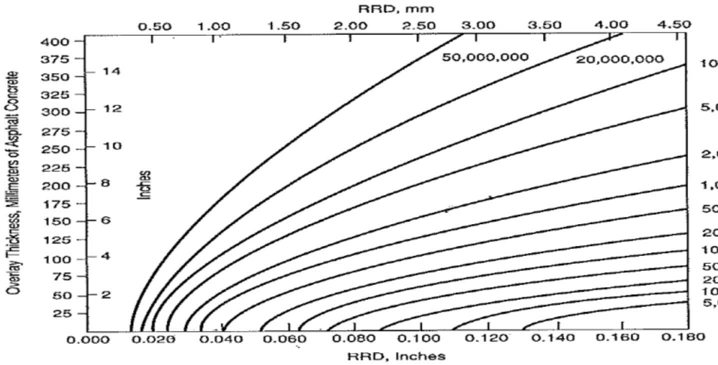
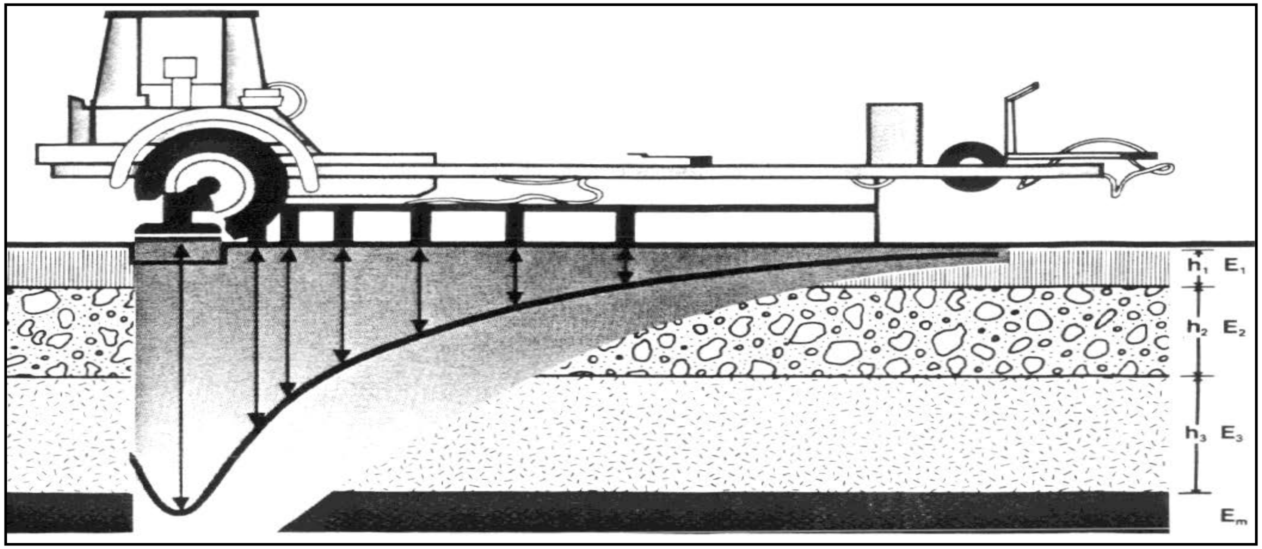


Figure 8-2 Asphalt Concrete Overlay Thickness Required to Reduce Pavement Deflections from a Measured to a Design Deflection Value (Rebound Test)

Asphalt Institute Manual Series-17

Falling Weight Deflectometer (FWD) Testing

- Weight dropped on load plate
- Deflection measured at series of sensors
- Model developed to determine strength of each layer (so that predicted deflections = actual)



Rolling Wheel Deflectometer

- FWD concept applied to tractor trailer
- Continuous deflection measured by laser

(under 8,164 kg single axle)

Reference beam and forward lasers

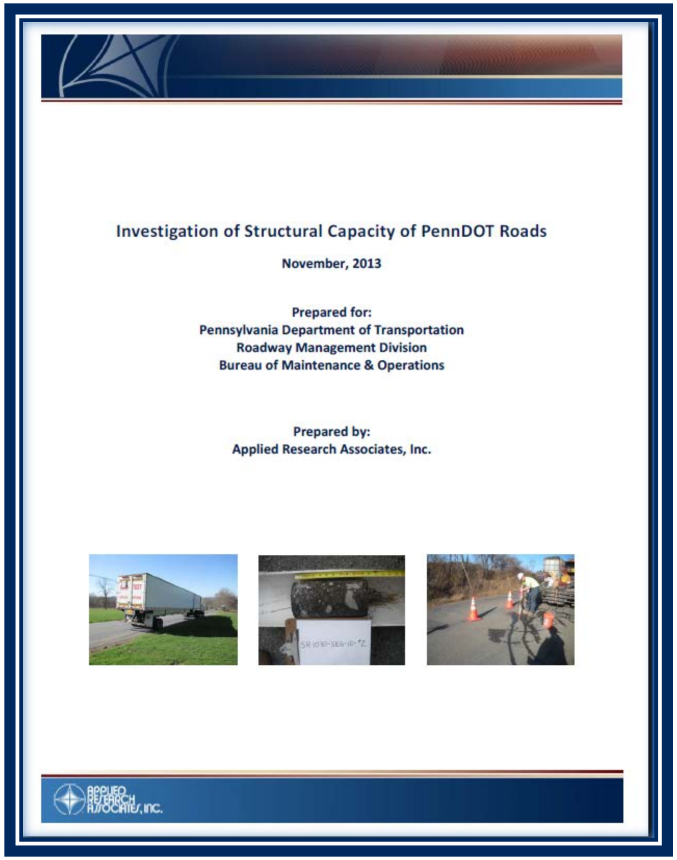
Laser between dual tires

How Can The RWD Be Used?

- Applications
  - Network-level evaluation (PMS)
  - Pre-screener for focusing project-level efforts (evaluation/design)
- Limitations
  - Currently, maximum deflection only
  - Lack of “deflection basin” limits analysis
  - Accuracy is suitable for network-level analysis, but not detailed engineering analysis

PennDOT Study - Compared 3 Methods of Structural Evaluation

- RWD testing of 463 kilometers
- FWD testing & pavement coring for 16 test segments
- Compared estimates of "structural number" based on RWD, FWD & RMS estimates


Investigation of Structural Capacity of PennDOT Roads

November, 2013

Prepared for:
Pennsylvania Department of Transportation
Roadway Management Division
Bureau of Maintenance & Operations

Prepared by:
Applied Research Associates, Inc.

Structural Capacity

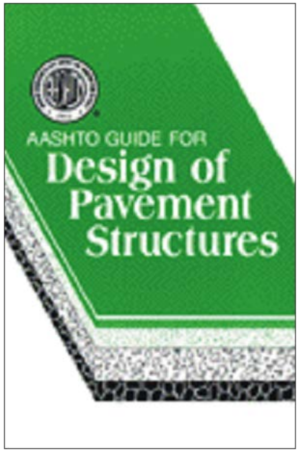
- Commonly expressed in terms of:
  - Structural number
  - Remaining life
- Study used both parameters

Review of Structural Number & Remaining Life Concepts

- SN used in 1993 AASHTO Pavement Design to quantify pavement strength required to support design traffic
- Select pavement layers to achieve required SN

AC Surface **AC Base** **Subbase**

- $\mathbf{SN = a_1 D_1 + a_2 D_2 + a_3 D_3 m_3}$



$\mathbf{a_i}$ = Layer coefficient of layer i
$\mathbf{D_i}$ = Thickness of layer i
$\mathbf{m_i}$ = Drainage coefficient of layer i

- SN existing pavement used to estimate structural capacity (remaining life, ESALs)

Structural Number (SN) Determinations

- FWD:
  - Direct output from model (backcalculations)
- RMS:
  - Algorithm based on layer thickness, type & age
  - Reduced structural coefficients if age > 9 yrs
- RWD:
  - Determined remaining pavement life (not SN directly)

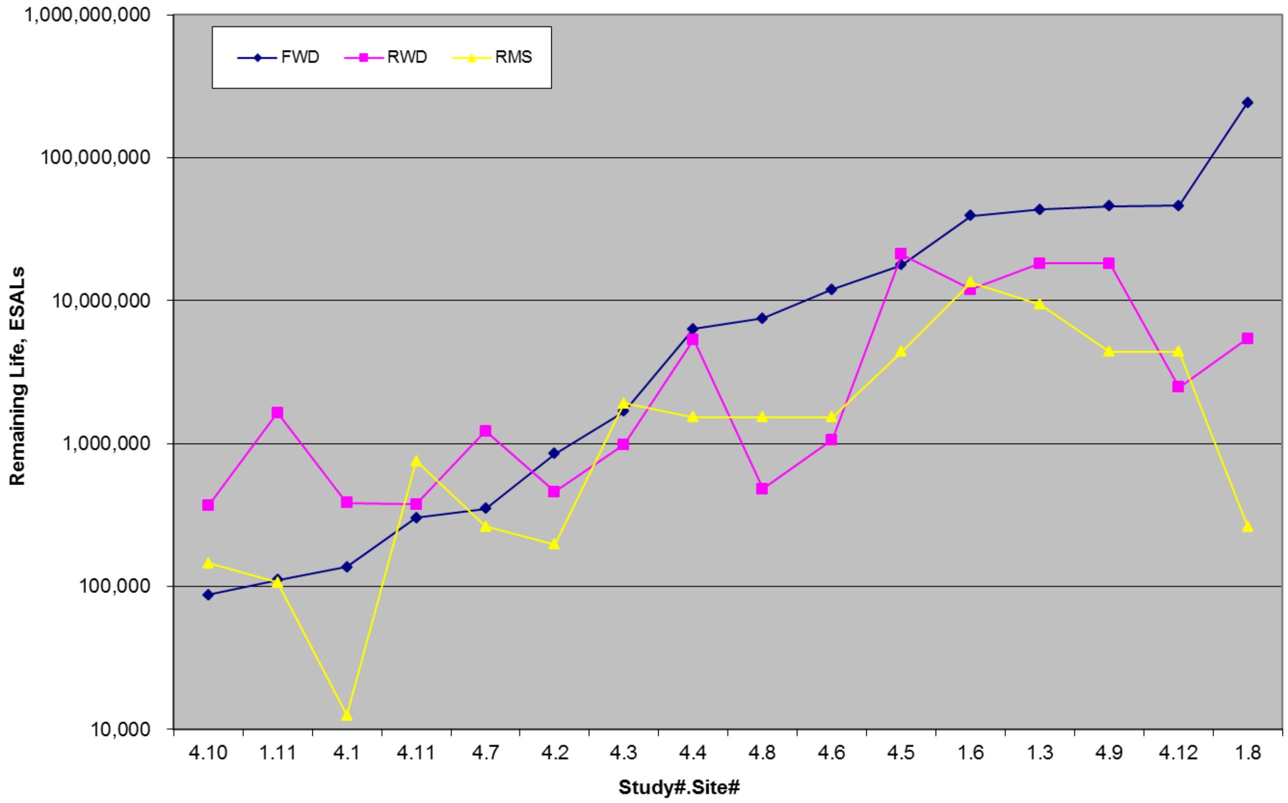
Remaining Life Determinations

- FWD:
  - AASHTO design equation
  - SN eff & subgrade Mr from FWD calcs
- RMS:
  - AASHTO design equation
  - SN eff from algorithm
  - Subgrade Mr= 52 MPa (CBR-5 default)
  - Subgrade Mr from FWD calcs
- RWD:
  - Asphalt Institute equation for Benkelman Beam
  - Determine ESALS corresponding to “zero overlay thickness”

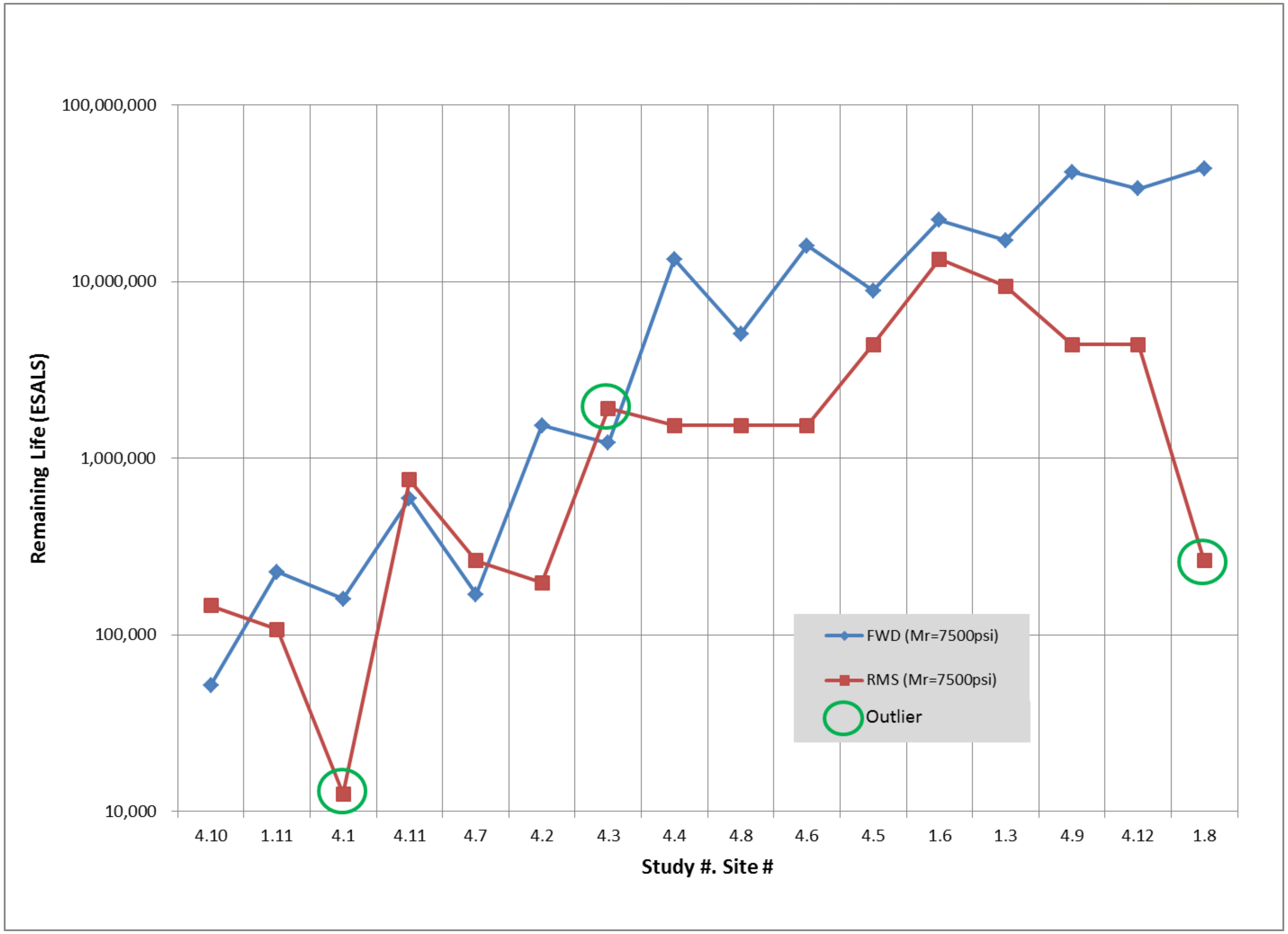
Analysis of PennDOT Study Data

- **2 Separate Evaluations:**
- 16 test sites -detailed data
  - cores, FWD, RWD, RMS pavement history & SN
- Broad network- 463 Km
  - RWD & RMS reported SN only
  - Remaining life estimates RWD & RMS compared

Remaining Life- 3 Methods

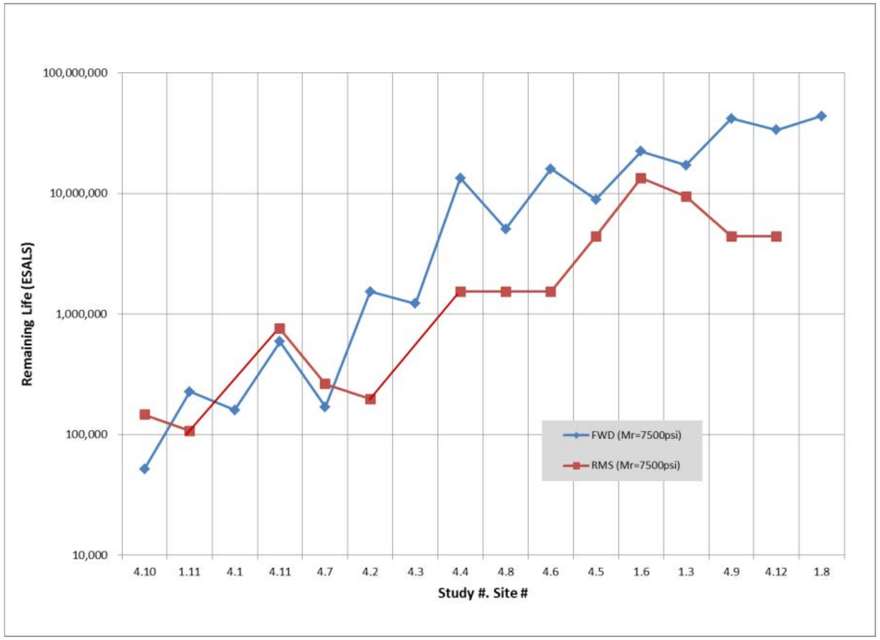


Remaining Life- FWD vs RMS Mr = 52 MPa (7500 psi) assumed



Evaluation of Remaining Life “Outliers”

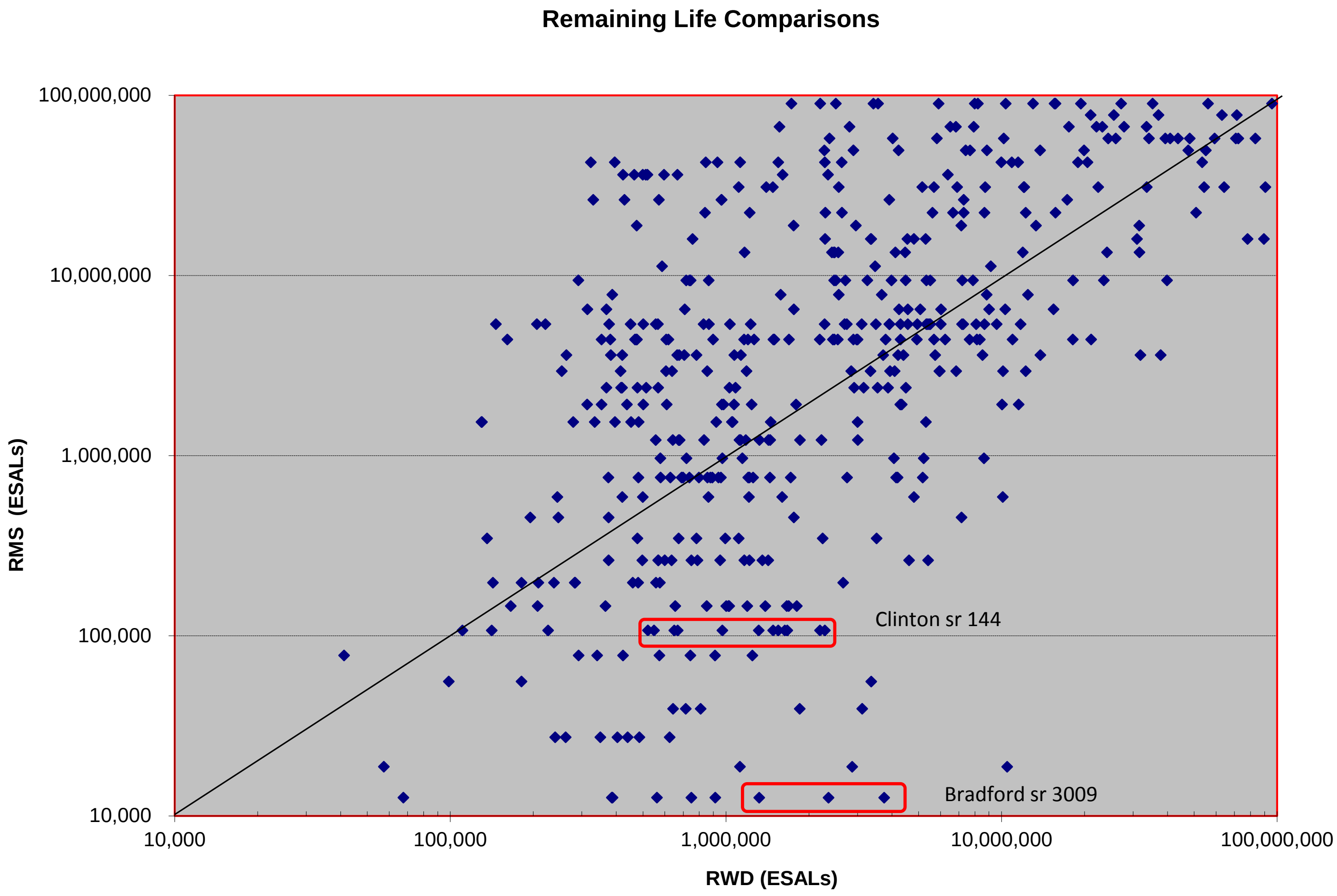
- 2 sites RMS << RWD & FWD
  - Bituminous thickness RMS< cores
- 1 site RMS > FWD
  - RMS bituminous thicker 3” > core
- 3 outliers removed- RMS better matches FWD & RWD



Assessment of Global Network (463 km)

- More data points, but less detailed info
- No FWD testing
- No detailed evaluation of RMS pavement sections

Remaining Life Comparisons (RWD vs. RMS)



Remaining Life by Business Plan

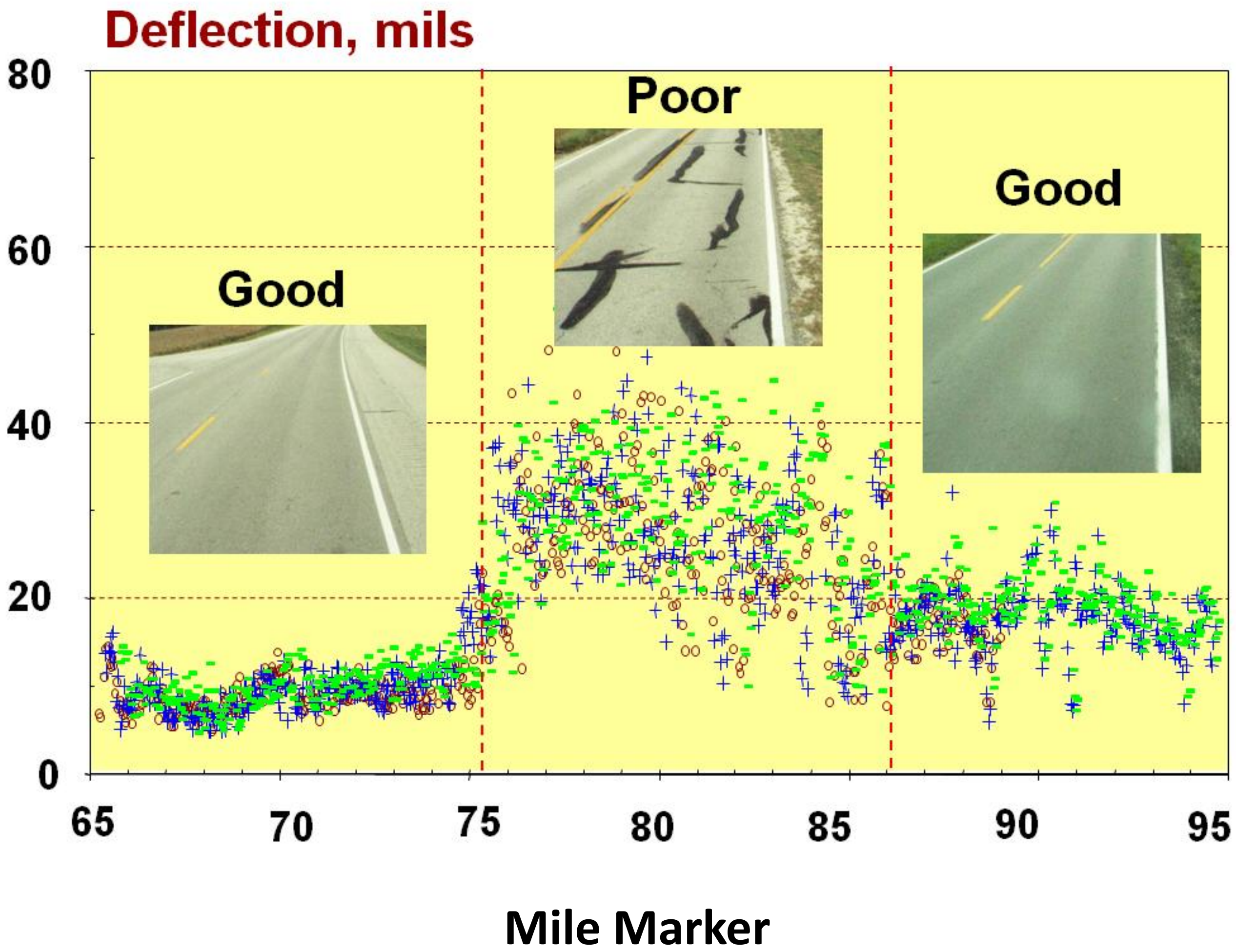
Business Plan Group	Remaining Pavement Life (ESALs)		
	RWD	RMS	Log RWD/Log RMS
2	225 million	287 million	0.99
3	63 million	198 million	0.93
4	14 million	25 million	0.97

- Both RWD & RMS clearly show strength increases from BP 4 to 3 to 2 (as expected)
- 70% of data from BP-4; good agreement RWD & RMS
- (log RWD/log RMS= 0.97)

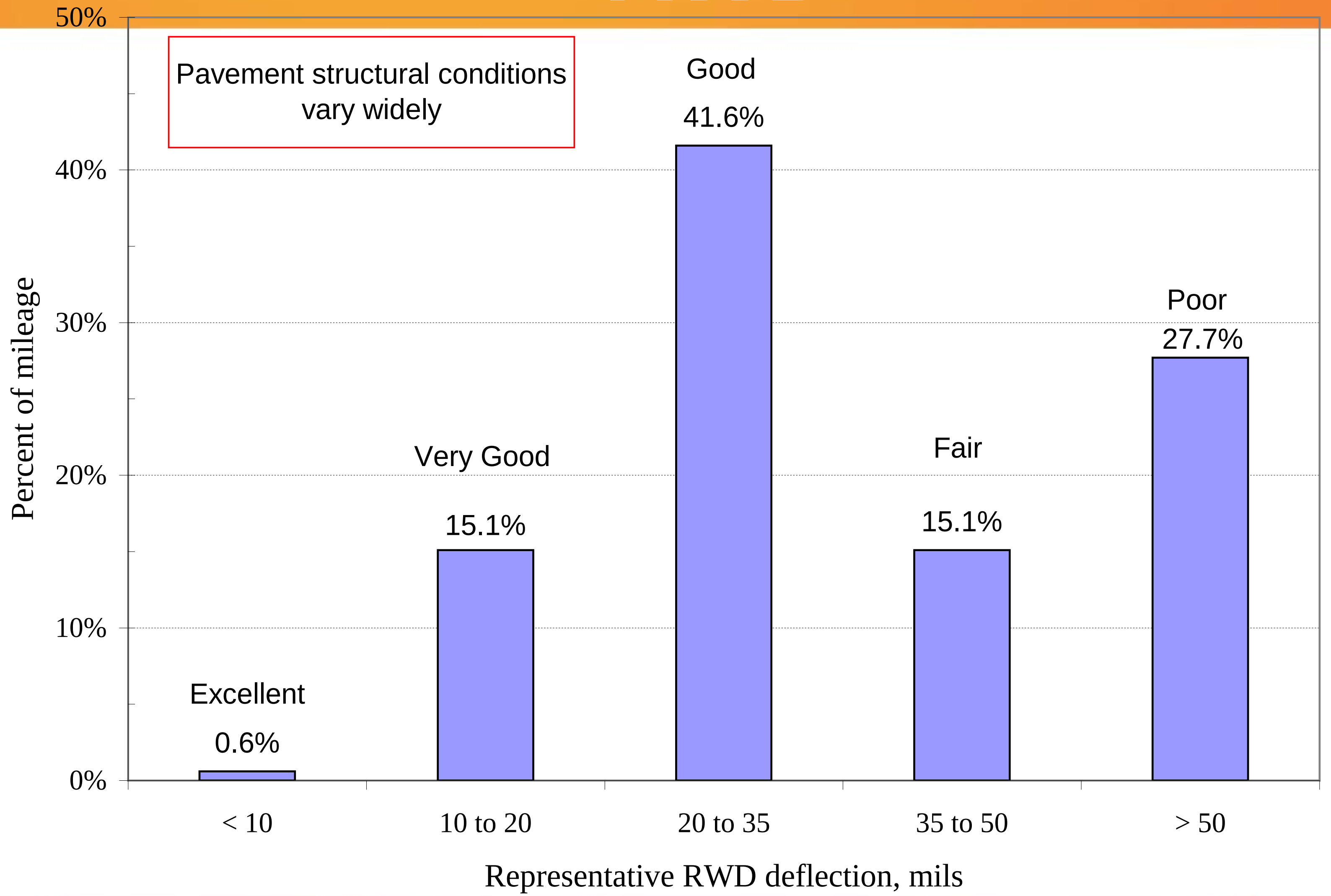
PennDOT Study Conclusions

- RMS provides reasonable estimate of SN & remaining life
- RMS & RWD provide comparable estimates of remaining life (log basis reasonable)
- RWD useful in categorizing groups of pavement for network evaluations
- Examples follow

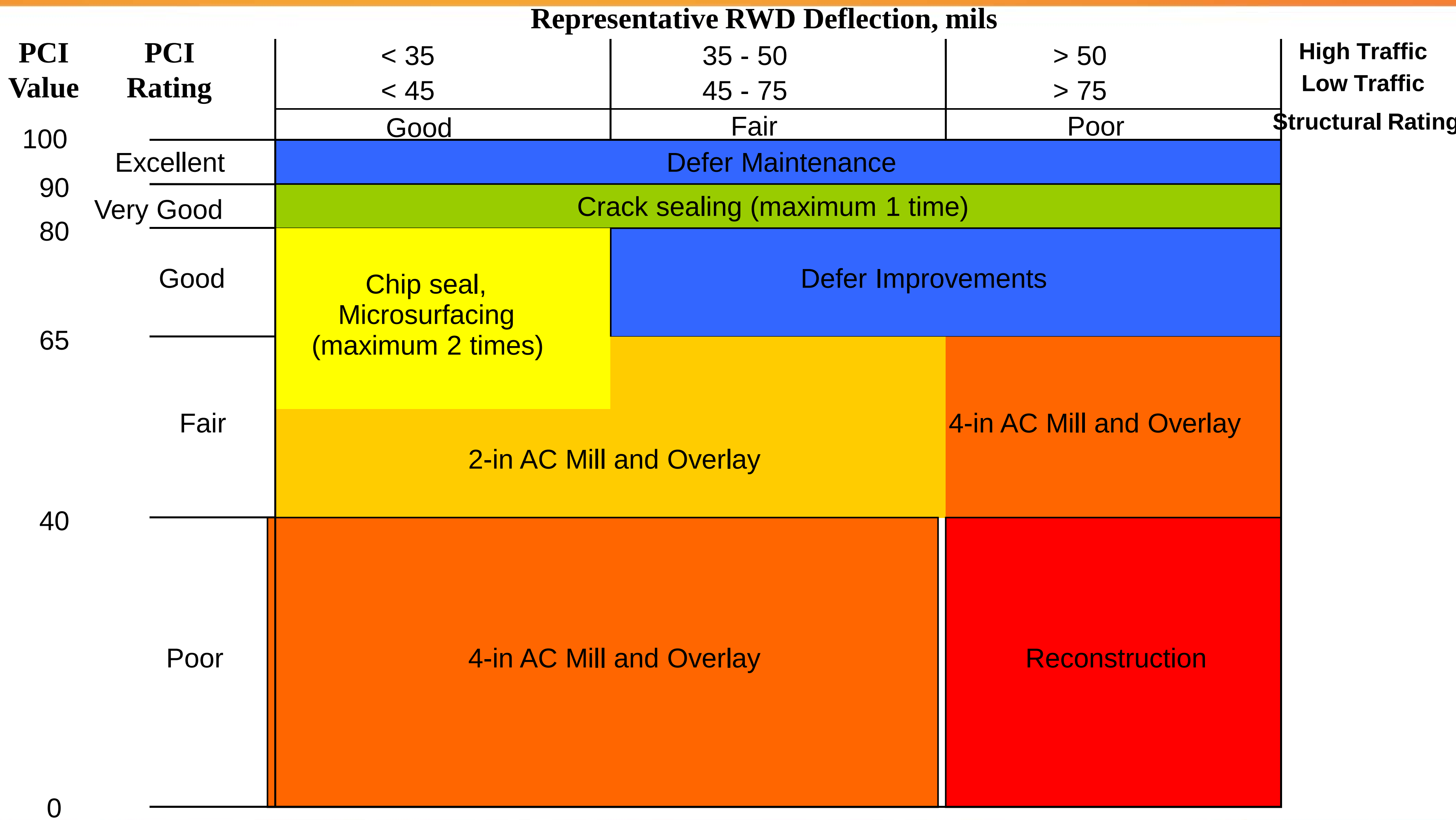
Network Level Strength Classification



Structural Condition Binning By RWD



Treatment Matrix Based on RWD & PCI



Louisiana DOT Study by LSU

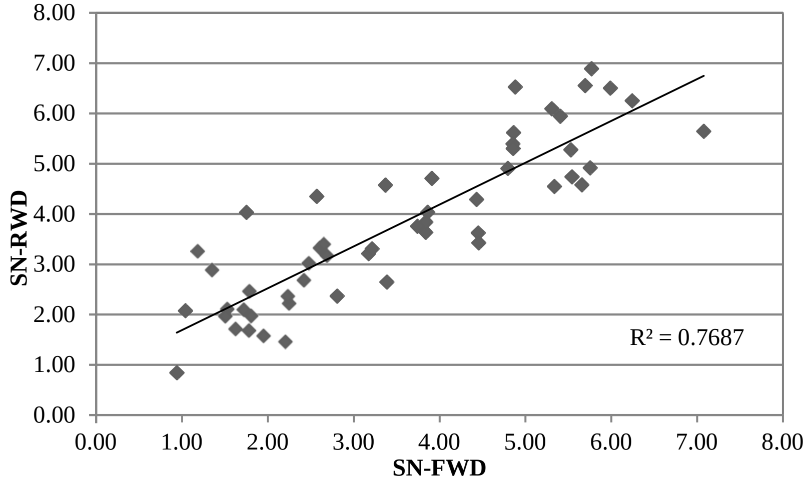
- 2009 Study led by Mostafa Elseifi (LSU)
- Developed model to predict SN from RWD data
  - Based on RWD & FWD data from LA DOT test sites- 16 sites, 2.5 km each

$$SN_{RWD} = -6.37 - \frac{150.69 * RI^{-0.81}}{RI + 19.04} + 23.52 * RWD^{-0.24} - 1.39 * \ln(SD)$$

RI = RWD Index (mils^2) = Avg. RWD deflection * SD of RWD deflection;
SD = standard deviation of RWD deflection on a road segment (mils);
RWD = Avg. RWD deflection measured on a road segment (mils); and

LSU Model Accuracy

- Model based on FWD & RWD data from 52 segments
- Accuracy deemed acceptable
  - Coeff of Determination, $R^2 = 0.77$

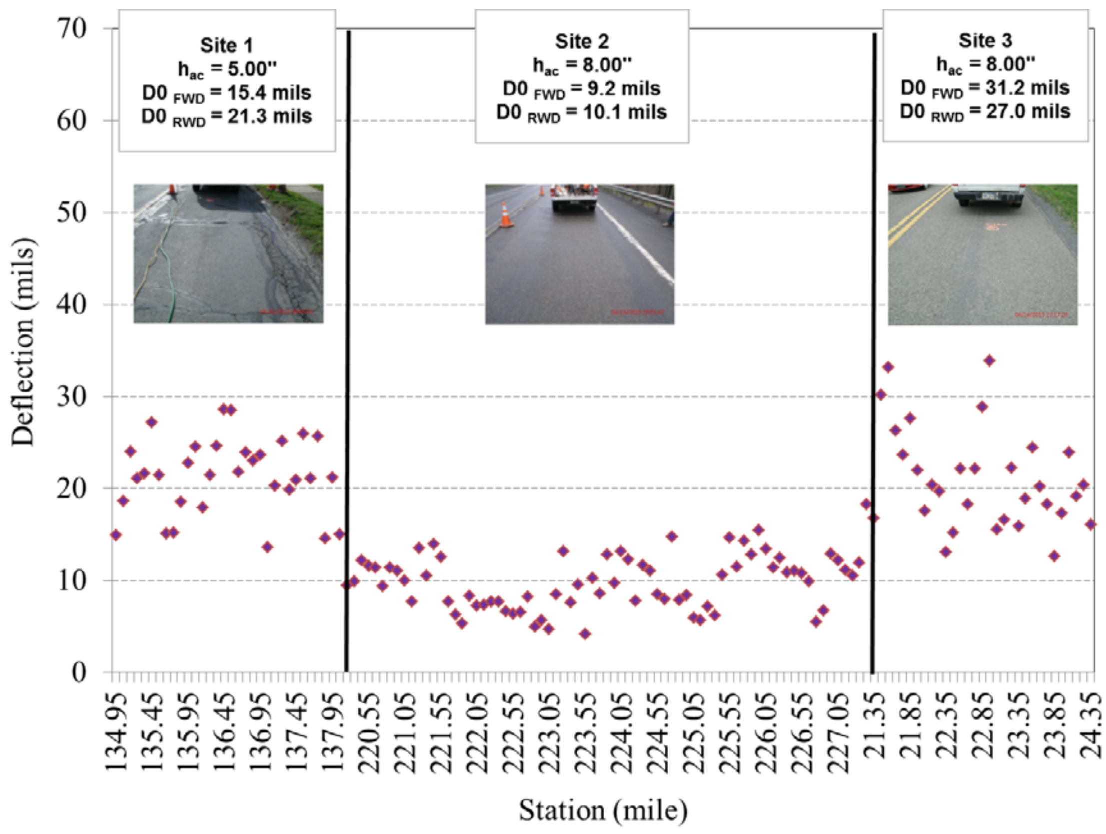


Relationships between SN based on FWD and SN based on RWD for the Independent Network Sites

LSU Model Tested with PennDOT RWD Data

- LSU used PennDOT data to test model outside of LA conditions
- Compared SN from model to SN from FWD
- LA model & LA data- SN prediction error = 27%
- LA model & PA data- SN prediction error = 19%

RWD Deflection Variability & Pavement Strength



- From Elseifi et al 2014

Louisiana Study Conclusions

- Scattering & uniformity of RWD data follows road conditions
- LSU model developed with LA data appears applicable beyond LA pavements
- RWD serves as reasonable indicator of structural integrity (network level)
- Further validation & evaluation of model is recommended

Overall Summary

- Innovative Rolling Wheel Deflectometer (RWD) provides tool for rapid evaluation of large road networks
- Lower cost & less traffic disruption than conventional methods
- RWD less accurate than FWD
- RWD useful in categorizing groups of pavement for network evaluations
- PennDOT's RMS algorithm provides reasonable estimate of SN (other agencies could adopt)

Questions???

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