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Use of High-Speed Deflection Devices in Network-Level PMS Applications: Are We Ready?

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INTRODUCTION

Pavement Decision-Making

- Highway agencies spend billions of dollars each year on pavement assets
- At heart of decision-making process are pavement management systems (PMS)
  - Ride quality and distress are key indicators
  - Structural adequacy is another important indicator
- Falling Weight Deflectometers (FWDs) represent state-of-the-practice in structural evaluations

FWD Shortcomings

- Stop-and-go operation
- Lane closures required
  - Traffic disruptions
  - Safety hazard

- Data collection is significantly less than continuous operation

Devices that measure deflections at traffic speed can potentially overcome FWD shortcomings

Project Objectives

Objectives:

- Assess and evaluate capability of traffic speed deflection-related devices for pavement structural evaluation at network level
- Develop methodologies for enabling use of devices in pavement management

Literature Review

LITERATURE RESEARCH FORM

Project: FHWA Pavement Structural Evaluation at the Network Level
Task: 2. Identification and Assessment of Capable Devices

Completed by:

Date (dd/mm/yyyy):

Reference in FHWA Format (Authors, title, publication #, publisher, date):	
Reference Source:	Report ☐ Article ☐ Internet ☐ Interview ☐ Presentation ☐ Other ☐ Specify
Reference Abstract (if contained) or Brief Summary:	

Relevant Subject (check all that apply):	Equipment Information/Specifications ☐ Equipment Assessments/Field Studies ☐ Data Collection, Processing and QC/QA ☐ Data Analysis Methodologies ☐ Other ☐ Specify:
Does technology presented in reference merit further consideration under Task 2 "Identification and Assessment of Capable Devices"?	Yes ☐ No ☐ If yes, please give reason(s):

24 references

- Arora et al. (2006)
- Rada and Nazarian (2011)
- Flintsch et al. (2012)

Questionnaires & Interviews

Manufacturers

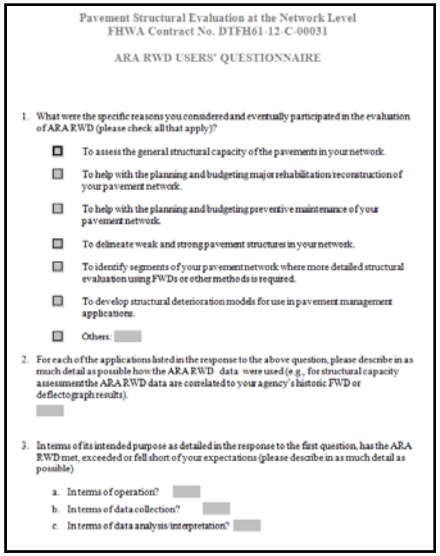
- ARA and Greenwood

TSD owners/users

- ARRB (Australia), ANAS (Italy), RBRI (Poland)

RWD users

- Connecticut, Virginia, Louisiana and Kansas DOTs



Pavement Structural Evaluation at the Network Level
FHWA Contract No. DTFH61-12-C-00031

ARA RWD USERS' QUESTIONNAIRE

1. What were the specific reasons you considered and eventually participated in the evaluation of ARA RWD (please check all that apply)?
   - ☐ To assess the general structural capacity of the pavements in your network.
   - ☐ To help with the planning and budgeting major rehabilitation/reconstruction of your pavement network.
   - ☐ To help with the planning and budgeting preventive maintenance of your pavement network.
   - ☐ To delineate weak and strong pavement structures in your network.
   - ☐ To identify segments of your pavement network where more detailed structural evaluation using FWDs or other methods is required.
   - ☐ To develop structural deterioration models for use in pavement management applications.
   - ☐ Others:
2. For each of the applications listed in the response to the above question, please describe in as much detail as possible how the ARA RWD data were used (e.g., for structural capacity assessment the ARA RWD data are correlated to your agency's historic FWD or deflectograph results).
3. In terms of its intended purpose as detailed in the response to the first question, has the ARA RWD met, exceeded or fell short of your expectations (please describe in as much detail as possible)
   a. In terms of operation?
   b. In terms of data collection?
   c. In terms of data analysis/interpretation?

Viable Devices

ARA RWD

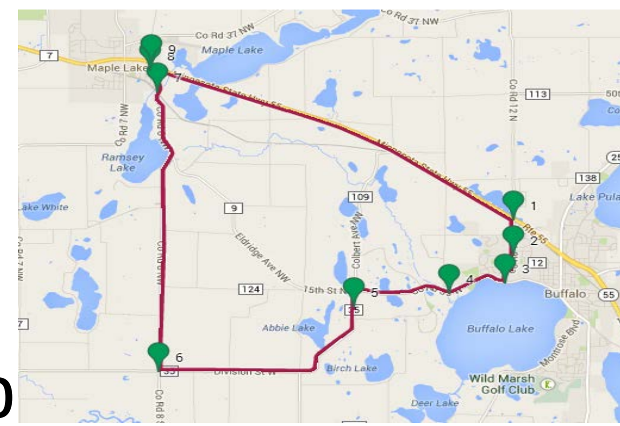
Greenwood TSD

SEPTEMBER 2013 FIELD TRIALS

Devices & Sites

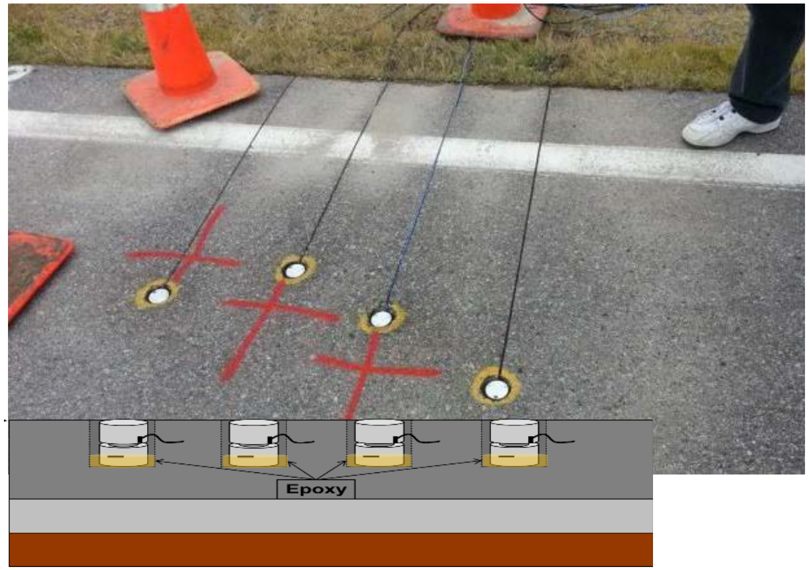
TSD, Curviameter & RWD

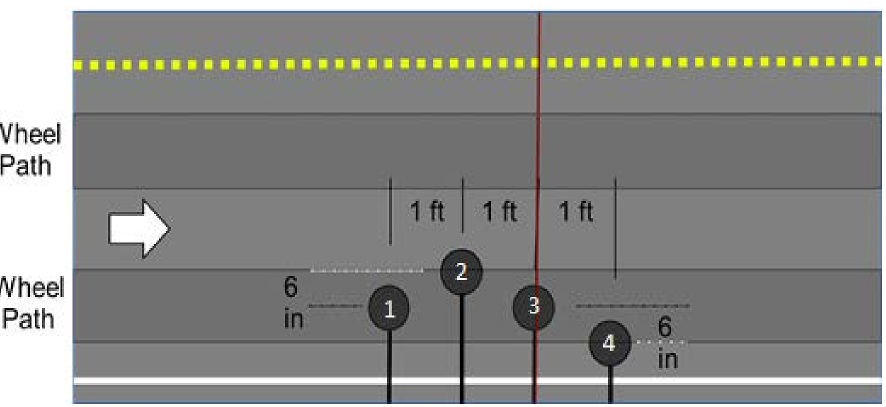
MnROAD Facility

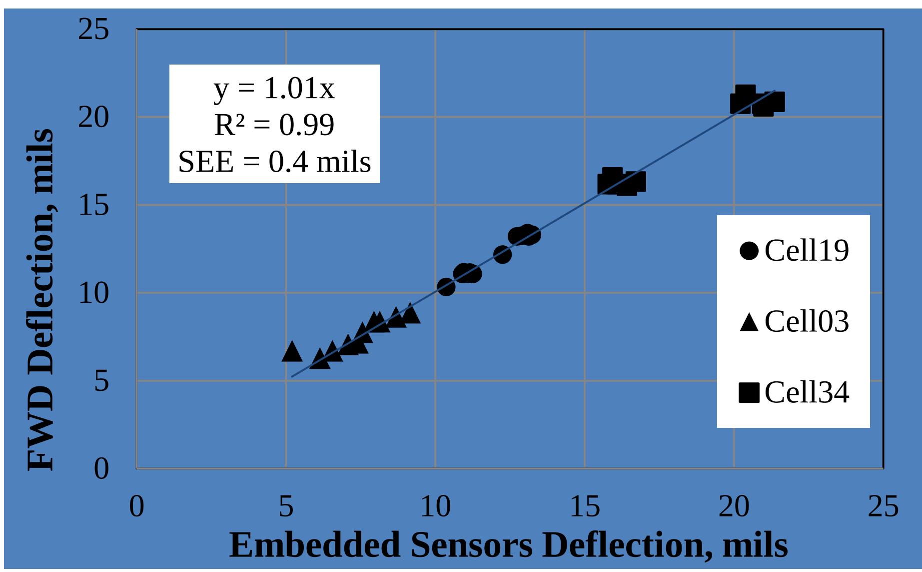


Wright County, MN 18-mile loop

Project Sensors

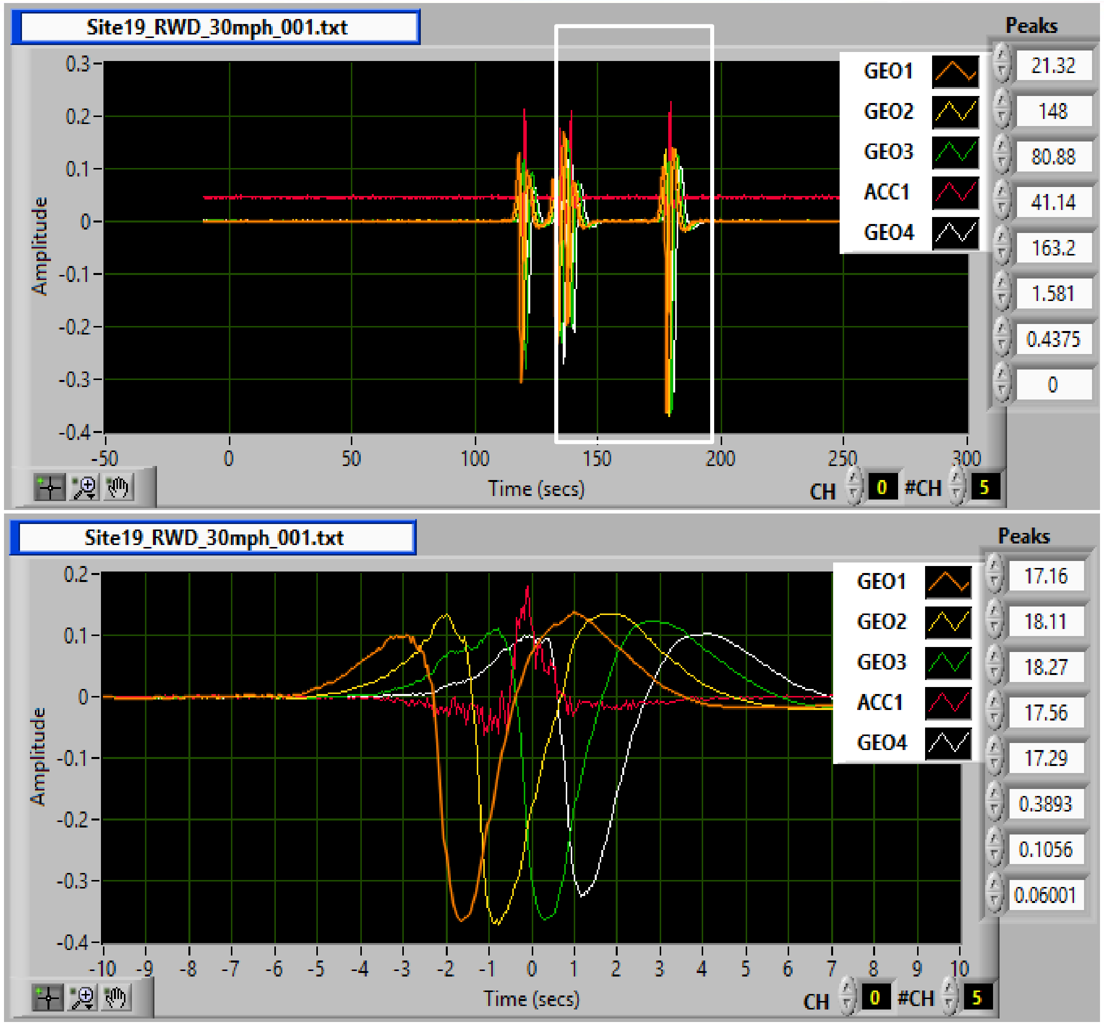






Typical Response

1. Time history data retrieved
2. True speed calculated
3. Rear tire isolated and analyzed



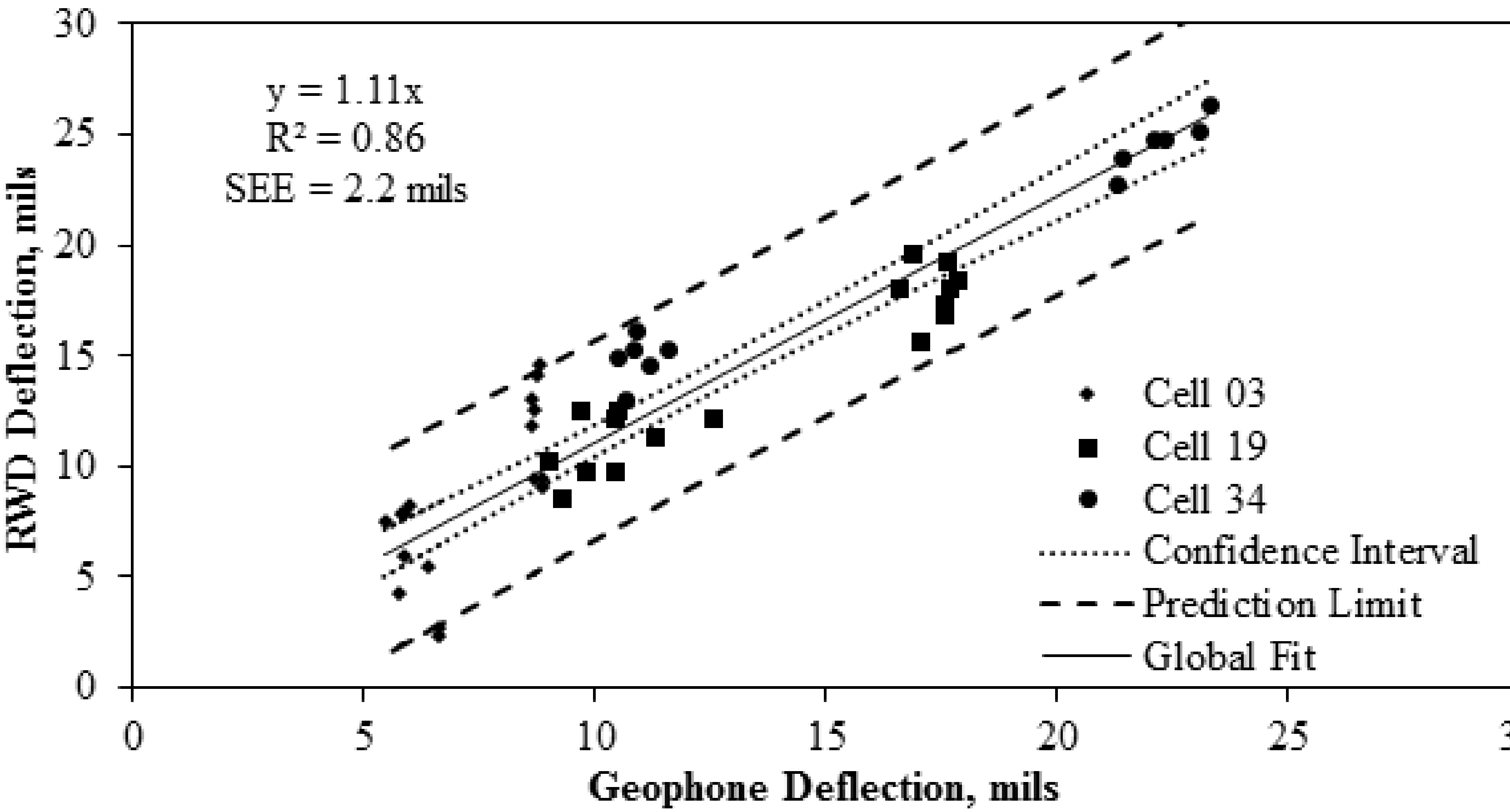
DEVICE ACCURACY & PRECISION

Accuracy

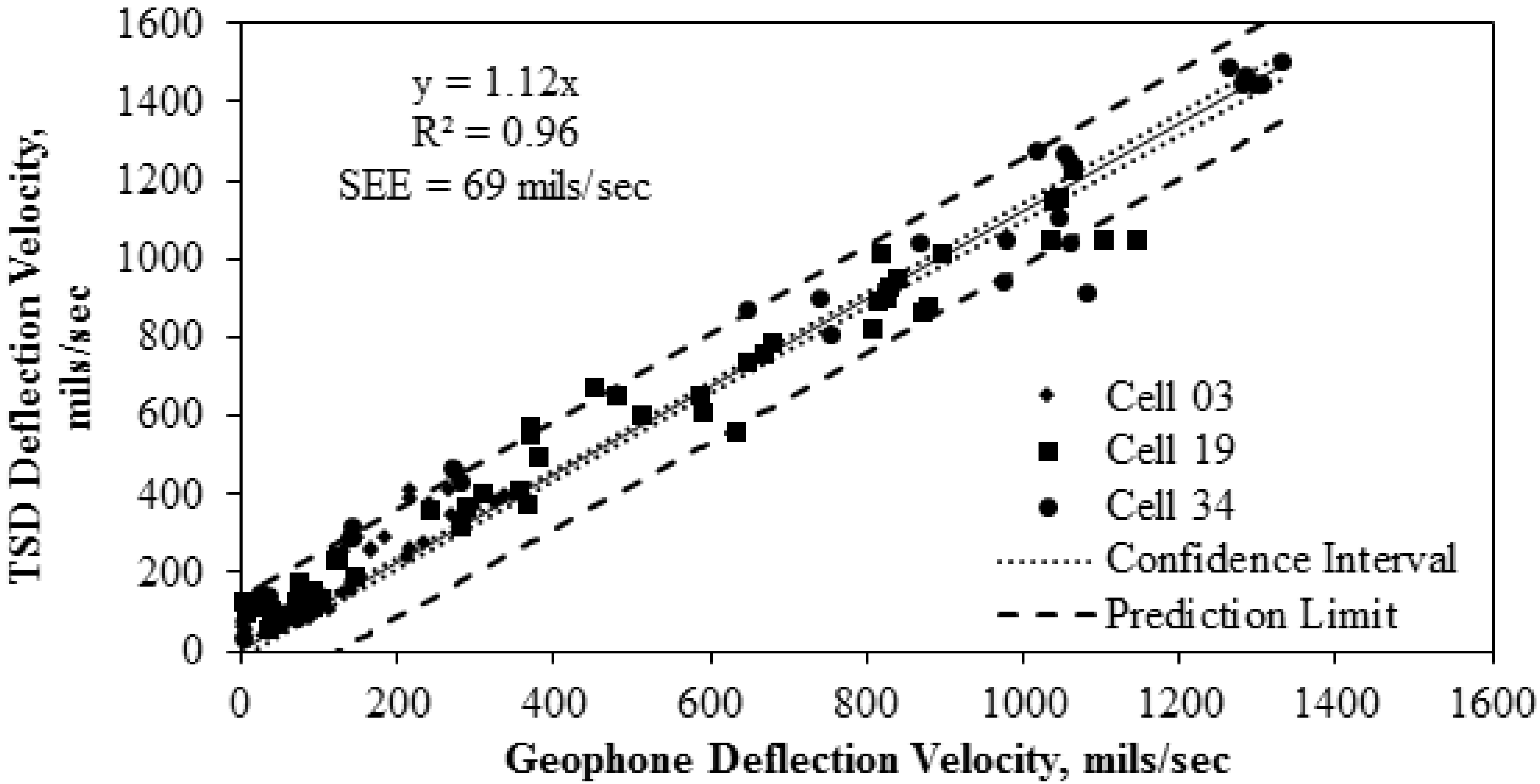
- Statistically compared device and embedded sensor deflection-related measurements
- TSD averaged data at 32.8 ft. and RWD at 50.0 ft.

TSD			RWD		
Sensor Distance (in.)	**Average Difference**	**Standard Deviation of Difference**	**Sensor Distance (in.)**	**Average Difference**	**Standard Deviation of Difference**
4	12%	5%	-7.25	11%	3%
8	4%	3%	7.75	11%	10%
12	6%	7%			
24	11%	8%			

Overall RWD Accuracy Results

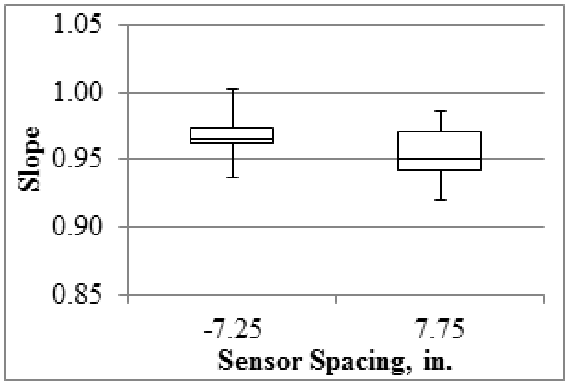


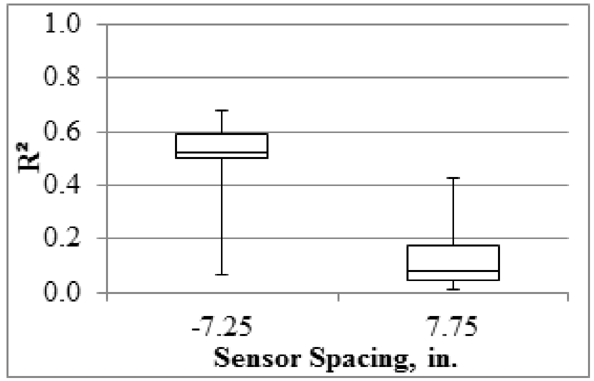
Overall TSD Accuracy Results

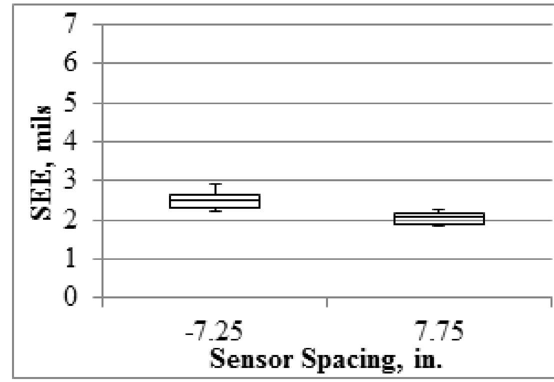


Precision Comparison

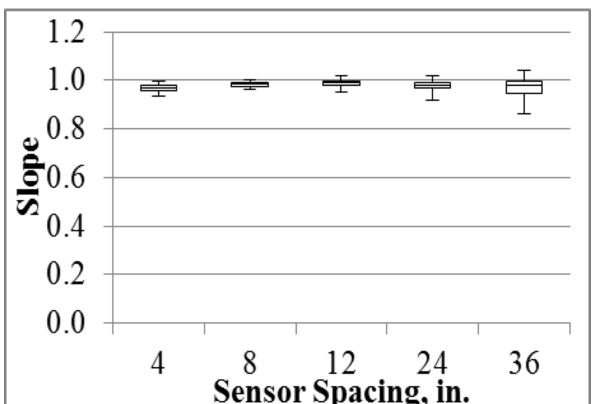
RWD

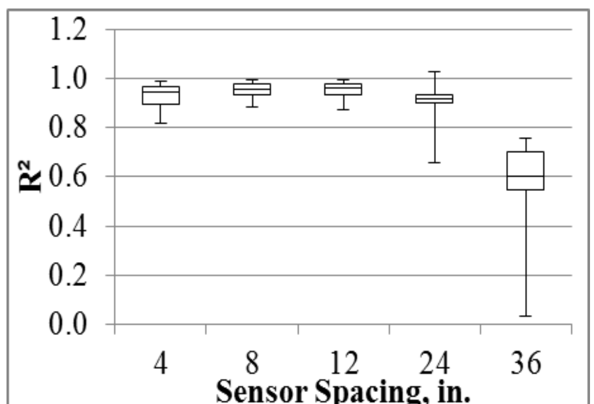


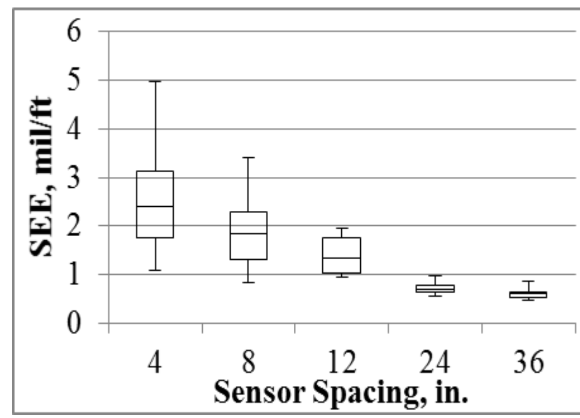




TSD



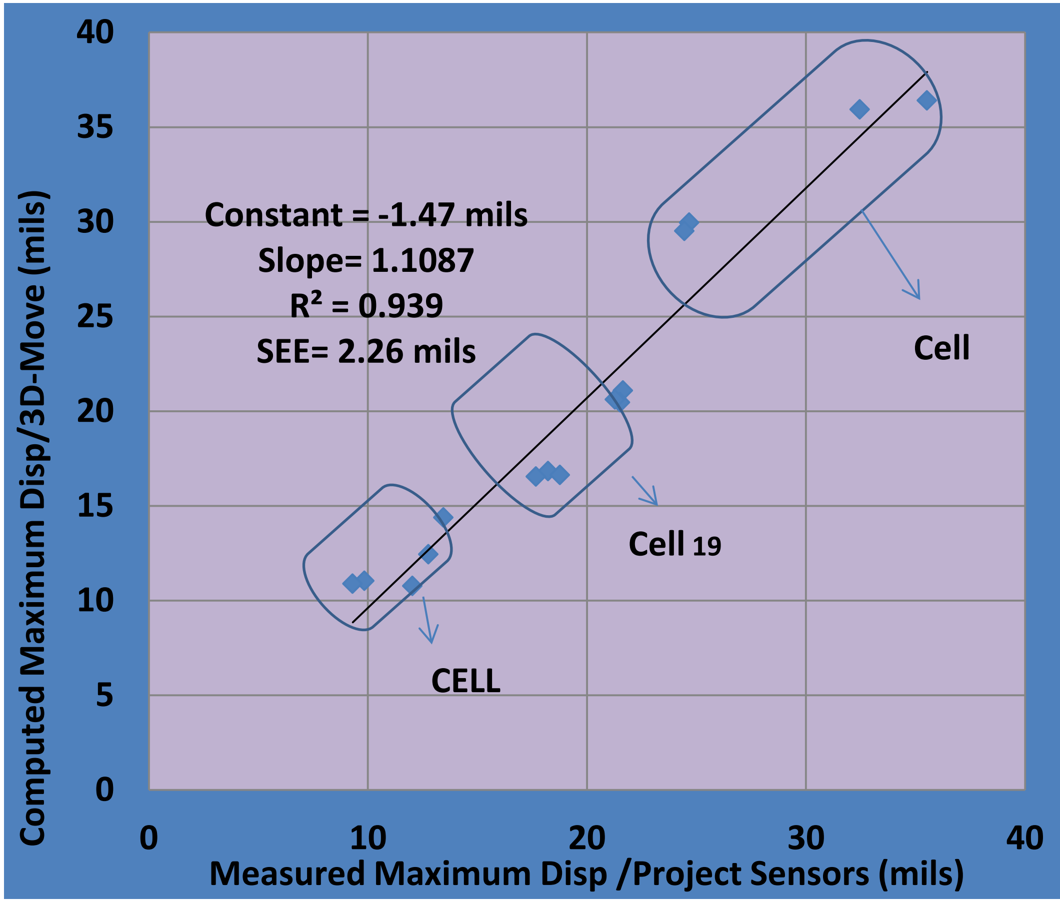




DEFLECTION INDICES & NETWORK LEVEL PMS APPLICATION

3D-Move Program

- Estimates dynamic responses within pavement structure using continuum-based finite-layer approach
- Calibrated using project sensor / TSDD measurements
- Further calibrated using strains measured with MnROAD sensors



Deflection Indices

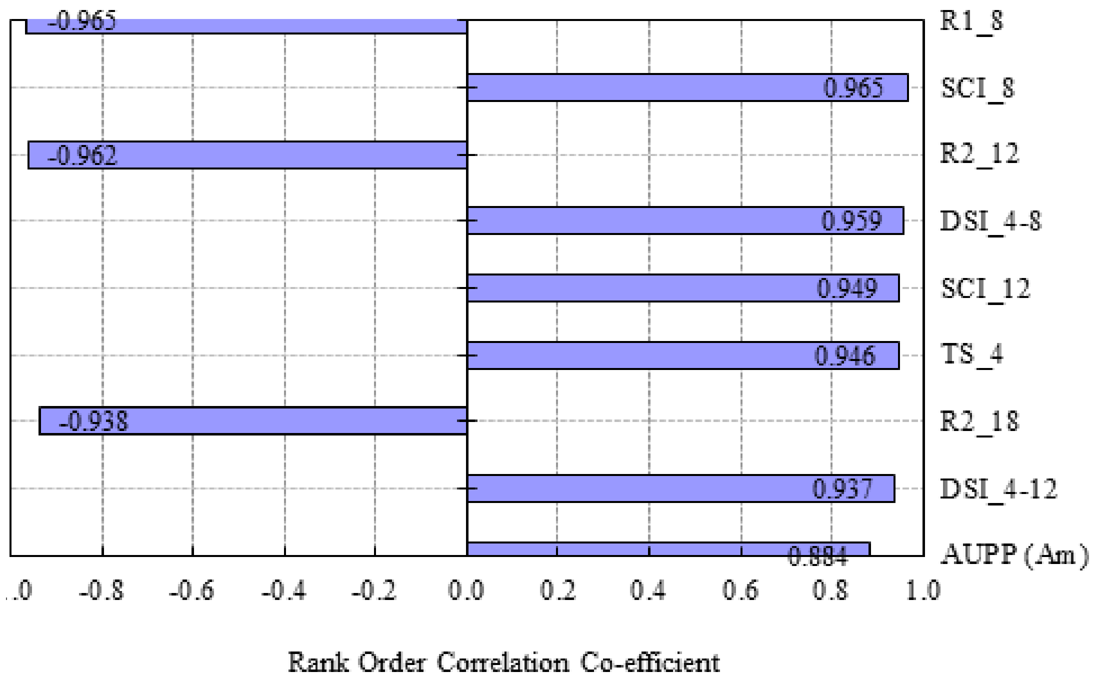
75 indices considered with respect to HMA horizontal strain

- Radius of Curvature ($R1_{12}$-Horak1 and $R2_{18}$-Horak2)
- Surface Curvature Index (SCI_{12})
- Slope of Deflection (SD_{12})

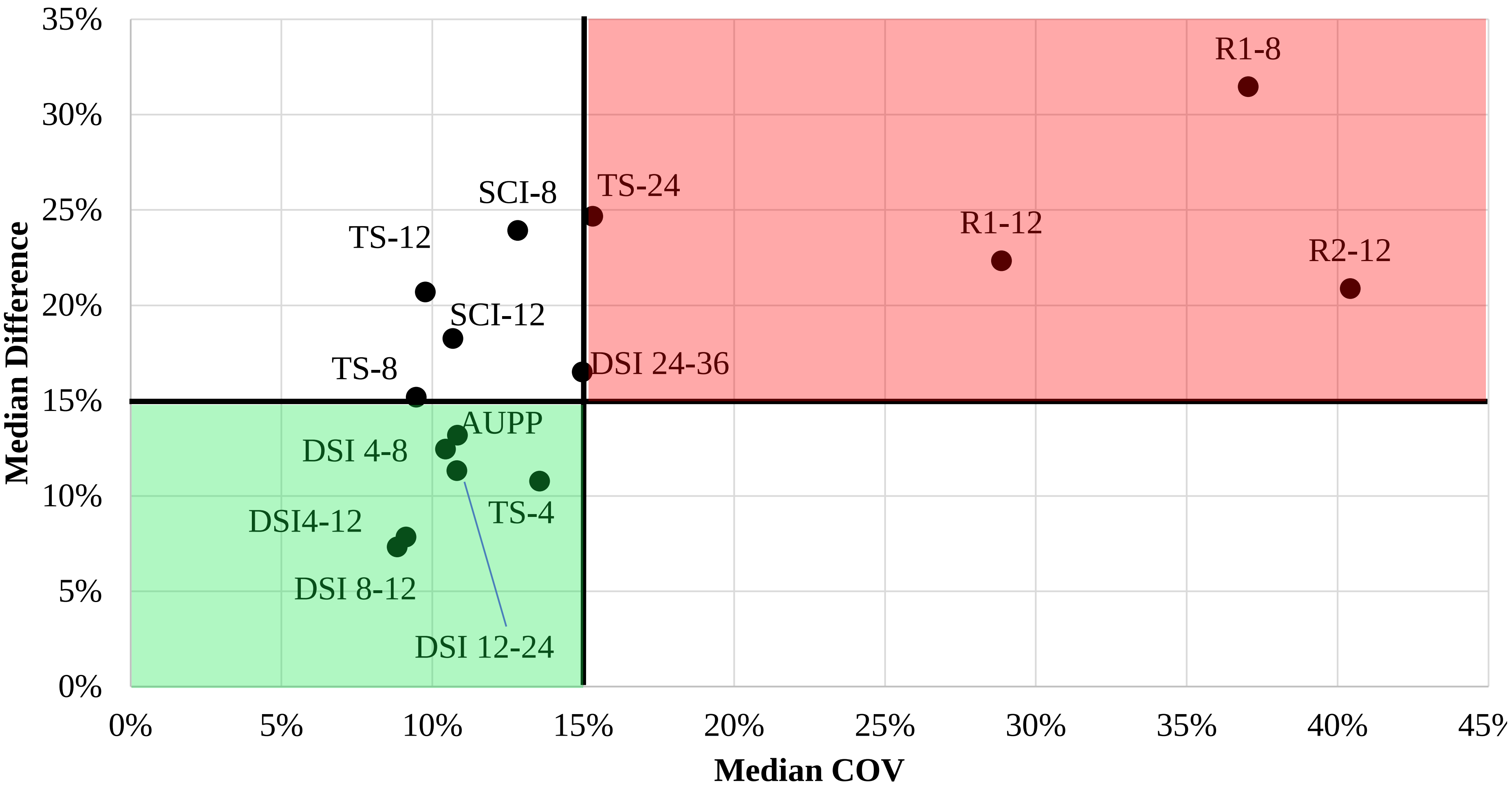
Best Indices with All Data (Relationship with Maximum Horizontal Strain)		R^2
Radius of Curvature $R=r^2(2D_0(1-D_r/D_0))$	$R1_{12}$	0.95
	$R1_{18}$	0.93
Radius of Curvature $R=r^2(2D_0(D_0/D_r-1))$	$R2_{18}$	0.95
	$R2_{24}$	0.94
Surface Curvature Index $SCI= D_0-Dr$	SCI_{12}	0.95
	SCI_{18}	0.93
Surface Curvature Index $SCIm = D_{max} - D_r$	$SCIm_8$	0.91
	$SCIm_{12}$	0.95
	$SCIm_{18}$	0.93
Deflection Slope Index $DSI_{4-r} = D_4- Dr$	DSI_{4-8}	0.93
	DSI_{4-12}	0.94
	DSI_{4-18}	0.91
Deflection Slope Index $DSI_{8-r}= D_8- Dr$	DSI_{8-12}	0.92
Slope of Deflection $SD = tan^{-1} (D_0 - D_r)/r$	SD_{12}	0.95
	SD_{18}	0.93
Tangent Slope $TS= (dD/dr)$	TS_8	0.94
Area Under Pavement Profile $(5D_0 -2D_{12"} -2D_{24"} - D_{36"})/2$	A_m	0.91

JULEA Simulations

- Monte Carlo simulations conducted to confirm adequacy, applicability and validity of best indices
- JULEA-generated database of 15,000 pavement structures



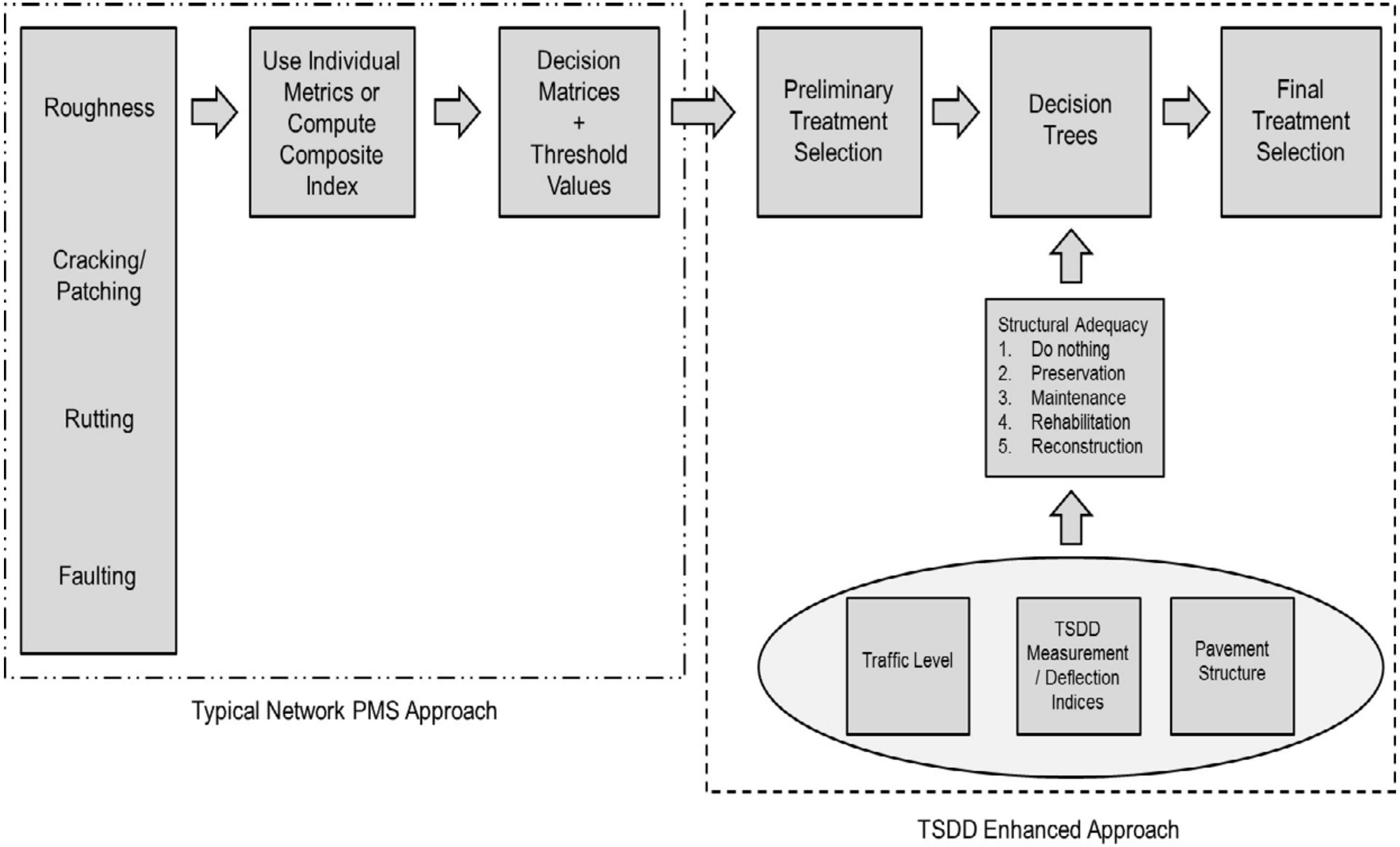
Overall Field Performance



Recommended Index

- Deflection slope index DSI_{4-12} (difference between deflections at 4 and 12 inches from applied load)
  - Most appropriate index and recommended for use in network-level PMS applications
- Surface curvature index SCI_{12} (difference between deflections at 0 and 12 inches from applied load)
  - Performed nearly as well as DSI_{4-12}, and hence could also be considered

Implementation of Findings



Network Level PMS Application

1. Select deflection index for estimating structural condition of pavement
2. Estimate horizontal strains at bottom of HMA
3. Adjust estimated strains to standard temperature
4. Establish structural adequacy using temperature corrected strain

RECOMMENDATIONS

Recommendations

- Need to take implementation steps from concept to full development
- Need validation/calibration of deflection indices and implementation procedures using field data
- Manufacturers should report statistical information (mean, std. dev., etc.)
- Desirable that averaging be done as part of analysis and not data collection

Future Research

- Confirming predictive power of deflection indices through use of measurements taken by strain gauges at bottom of HMA layer during TSDD loadings
- Expanding and validating prediction of subgrade strain to complement horizontal strains at bottom of HMA layer

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Thank you!