LTPP Automated Faulting Method (AFM)

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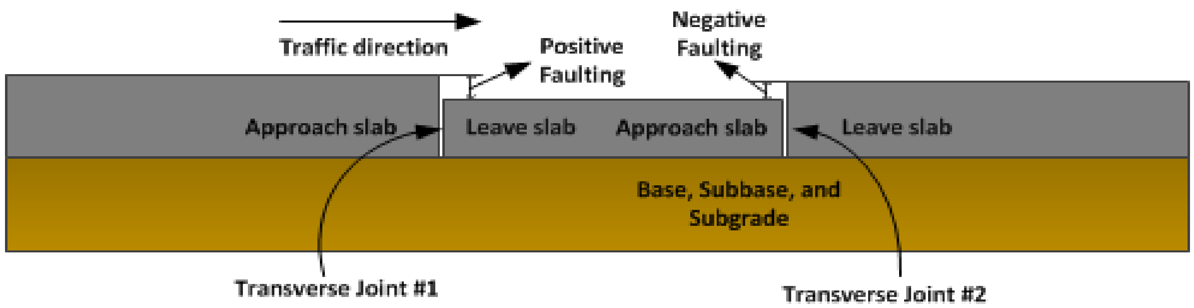
LONG TERM Pavement PERFORMANCE

Presentation Overview

- Introduction
- Research objectives
- Profile data processing
- Analysis results
- Conclusions

Faulting



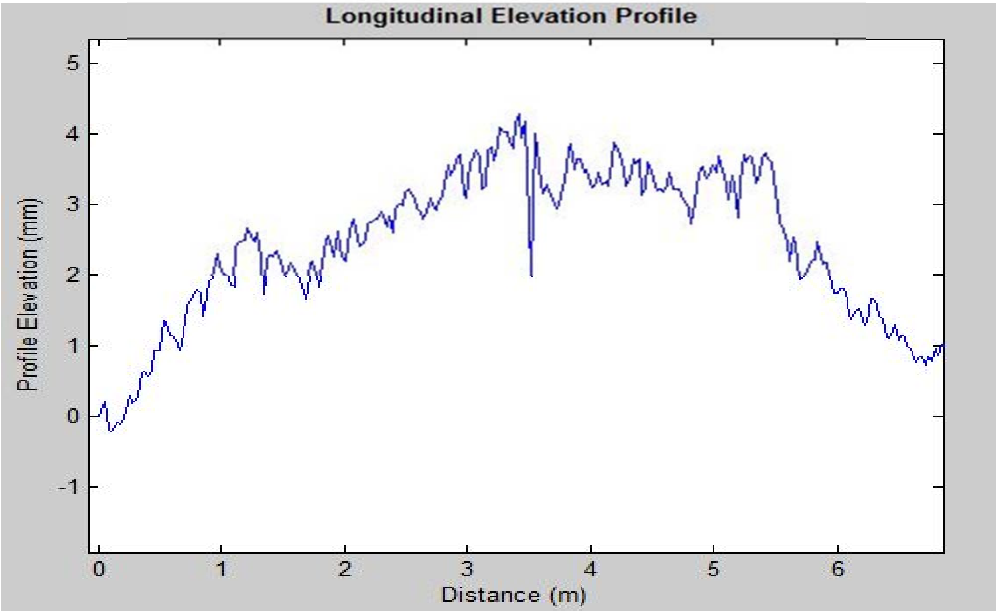
- Factors that contribute to faulting
  - Slab pumping, inefficient load transfer, slab settlements, curling, warping etc.
- Key pavement performance indicator
- Plays prominent role in pavement surface roughness
- Major impact on pavement life-cycle cost

Joint Faulting Measurements

- Manual method using Georgia Faultmeter (GFM)
  - Time-consuming
  - Traffic control
  - Lane closure
  - Safety measures
  - Personnel cost etc.

- Automated method using inertial profiler
  - Faster and Safer
  - No lane closure
  - No traffic control
  - Cost-effective etc.

Longitudinal Elevation Profile from Inertial Profiler



Research Objectives

- Develop an automated faulting method (AFM)
  - Identify Joint Plain Concrete Pavement (JPCP) transverse joints and
  - Compute faulting at the detected joint locations
- Evaluate two existing AASHTO R-36 methods
  - ProVAL AFM (method-A)
  - FDOT PaveSuite (method-B)

Profile Data Processing

- Joint detection challenges
  - Joint spacing
  - Cracks
  - Spalled joints
  - Filled and closed joints
  - Skewed joints
  - Sampling interval
  - Profiler precision

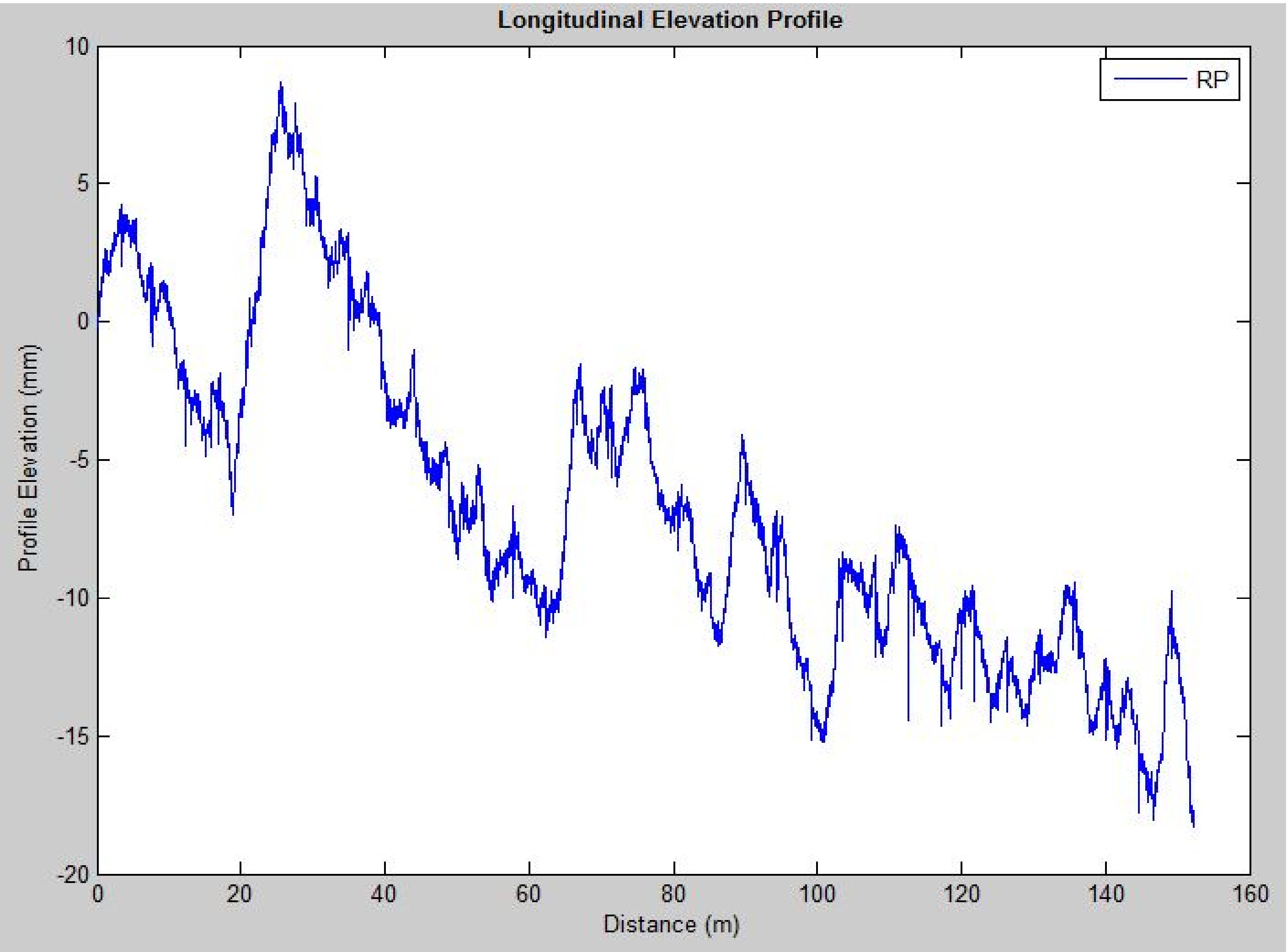
Profile Data Processing Cont.

- About LTPP profiler data
  - 25 mm sampling interval
  - ERD file format (text file)
- Processing steps using Matlab
  - Import profile ERD file
  - Filter and normalize profile elevation points
  - JPCP joint detection
    - Peakdet algorithm (Elli Billauer)
    - Moving window using Peakdet
  - Compute joint faulting
    - ASSHTO R-36
    - Slope method

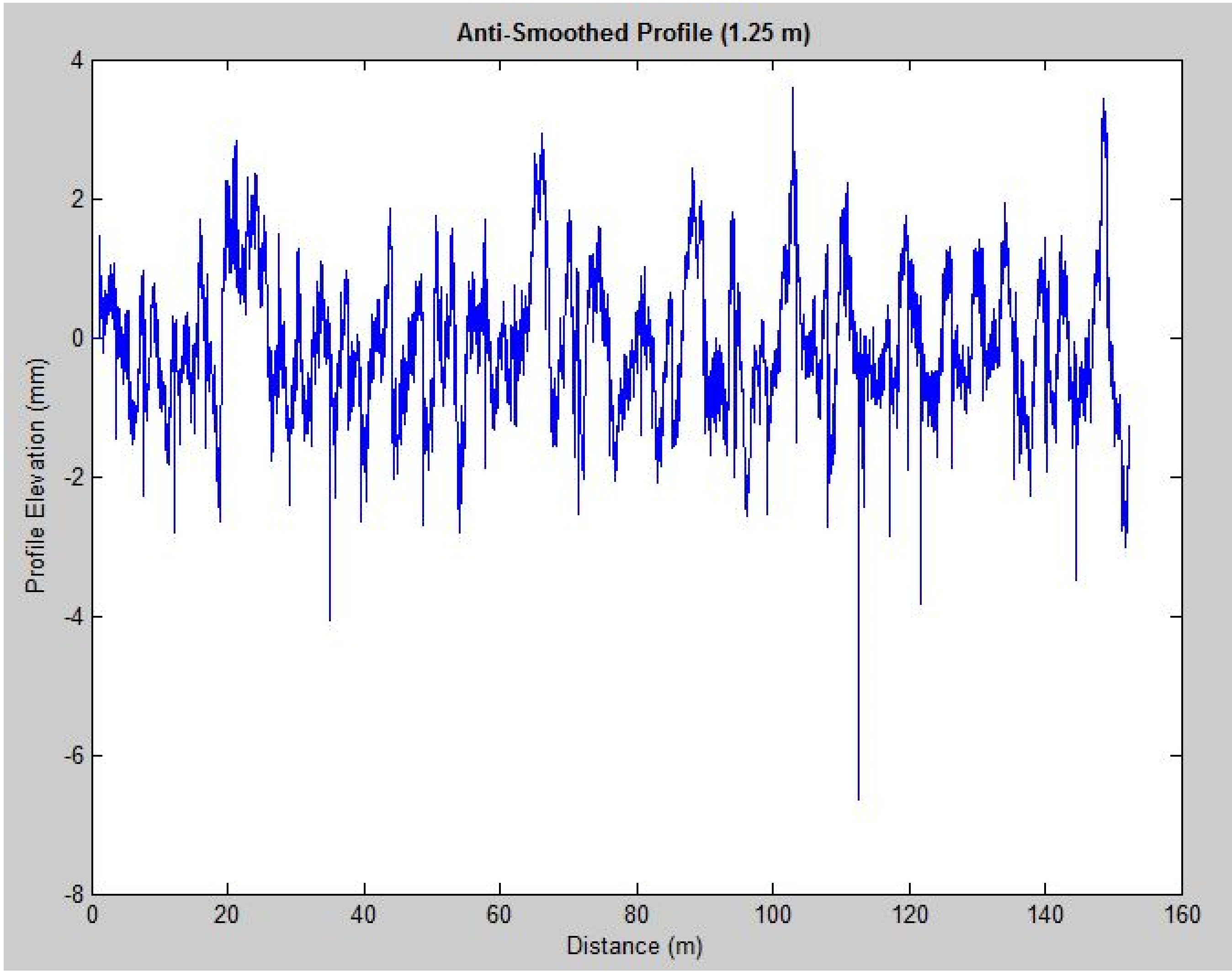
Profile Data Processing Cont.

- Filter and normalize profile elevation points
  - Moving average
  - Anti-smoothing
  - Root mean square (RMS)

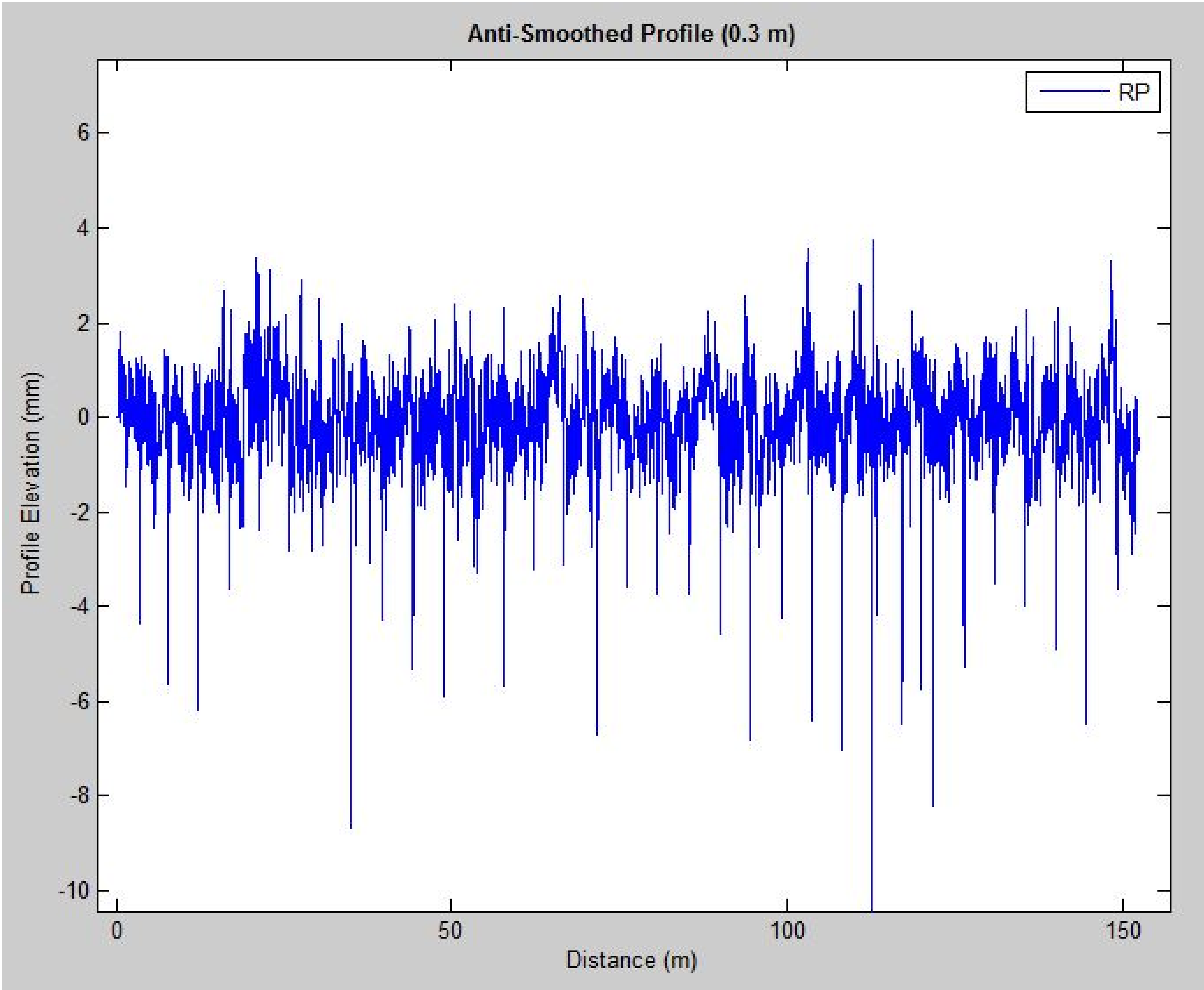
Original Elevation Profile



Anti-Smoothed Profile (1.25 m)



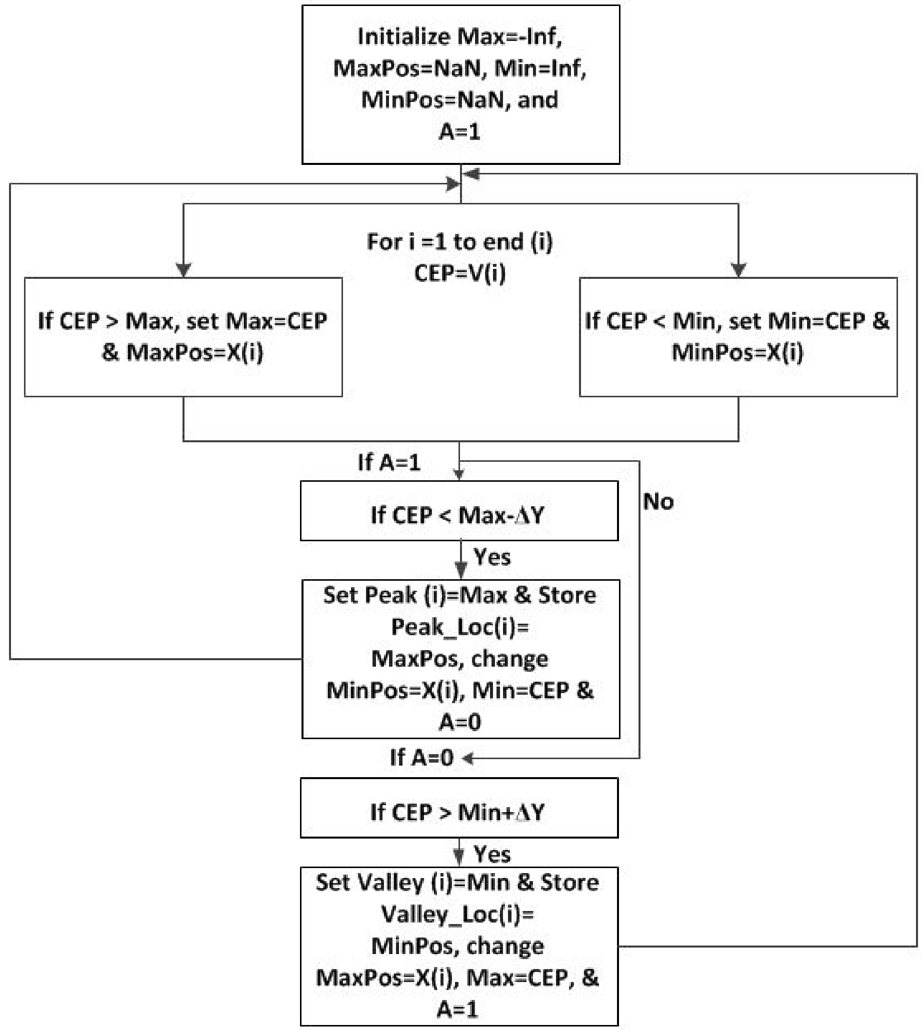
Anti-Smoothed Profile (0.3 m)



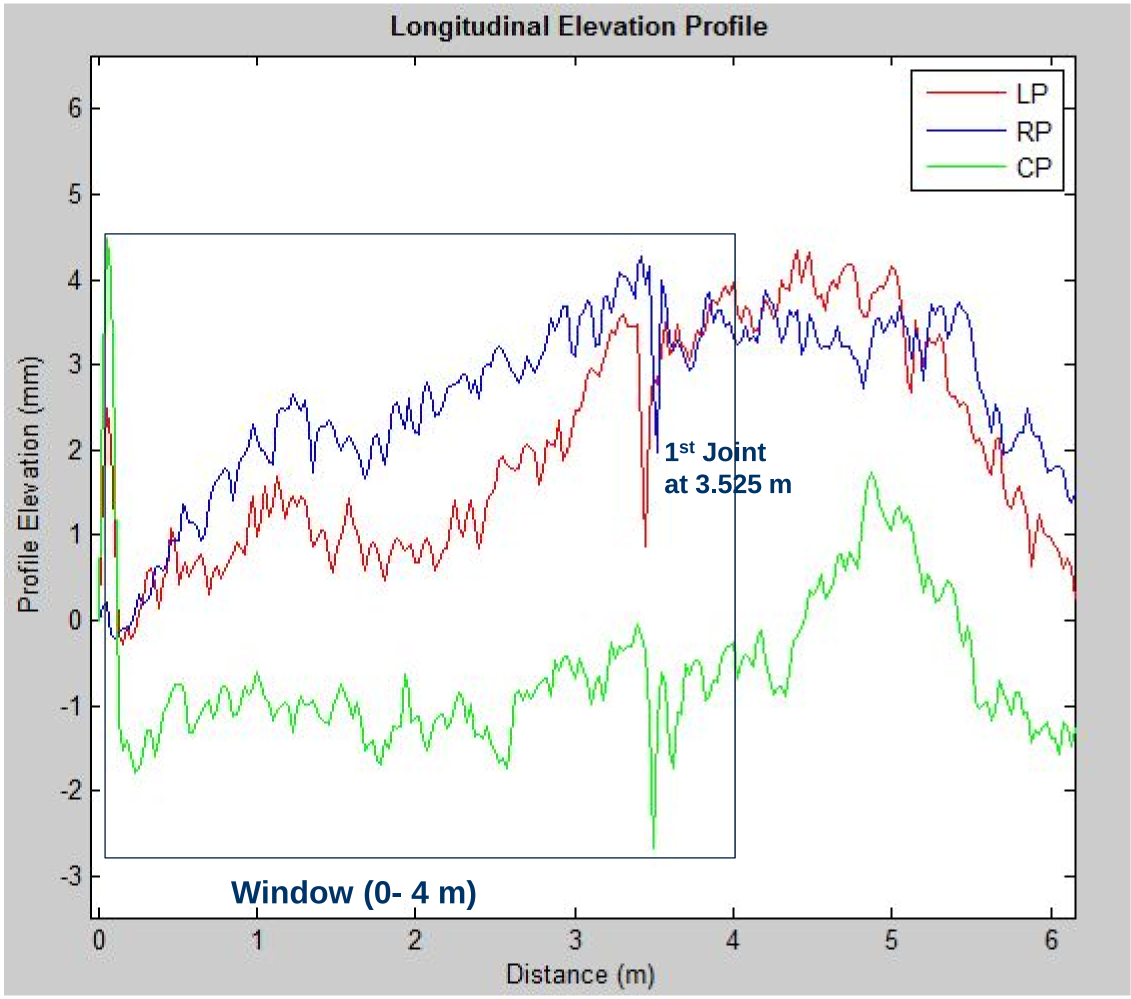
Peakdet Algorithm

- Variables and values used in Peakdet algorithm
  - V is the profile elevation array
  - X is the profile elevation location/position array
  - CEP is the current elevation point
  - DY is the criterion used to detect the joint
  - Max is the maximum elevation
  - MaxPos is the maximum elevation position
  - Min is the minimum elevation
  - MinPos is the minimum elevation position
  - Inf stands for infinity
  - NaN stands for not a number

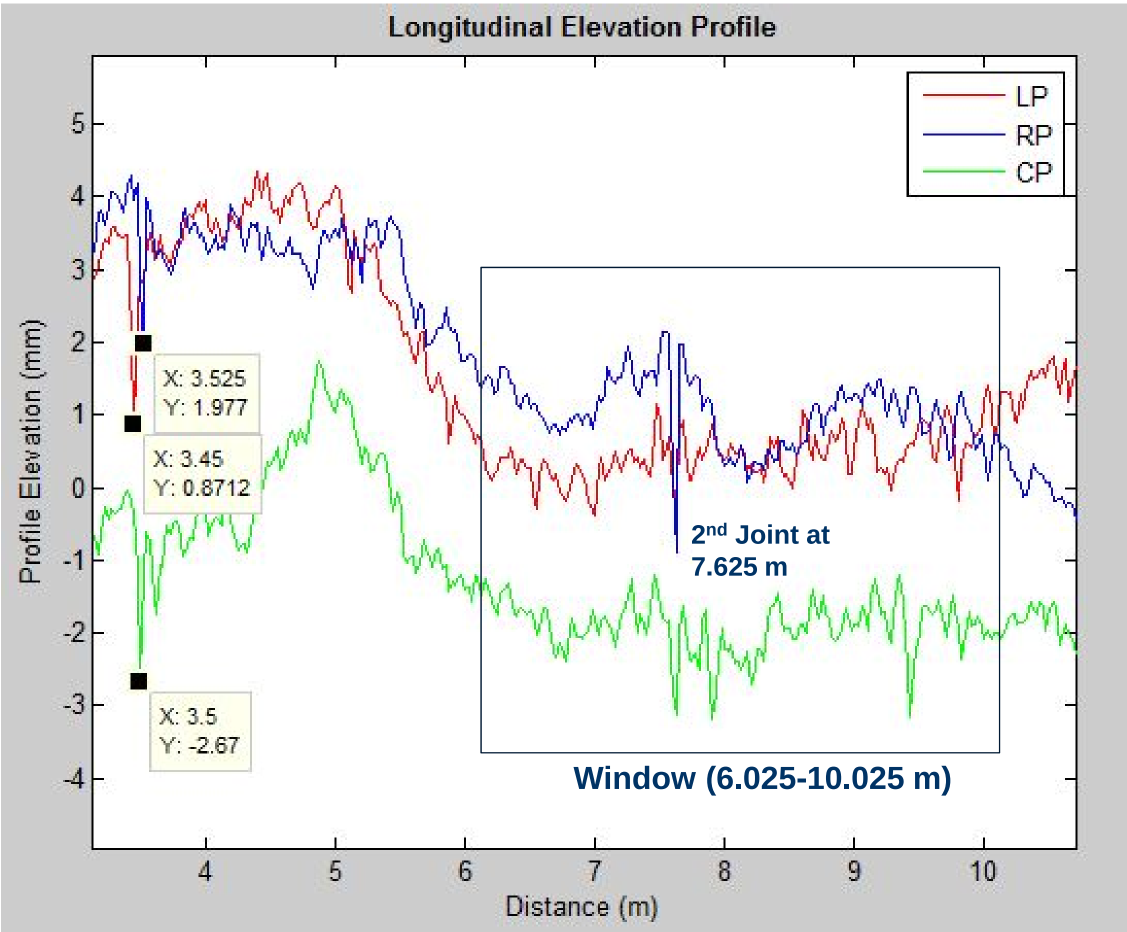
Peakdet Algorithm Cont.



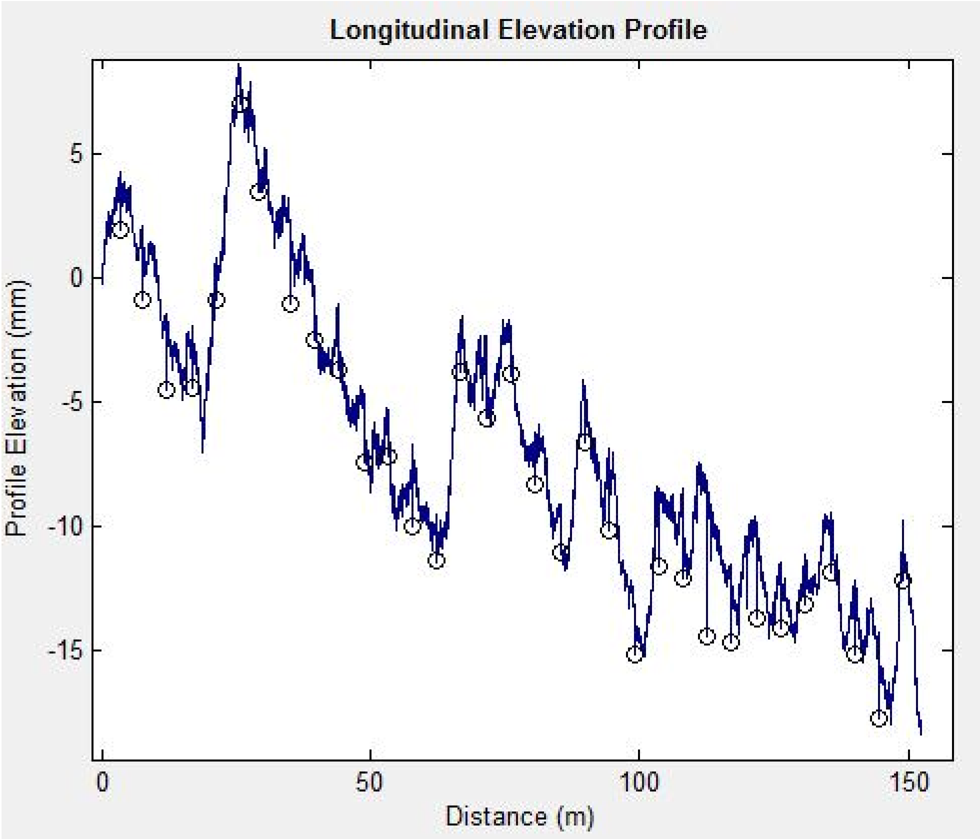
Moving Window using Peakdet



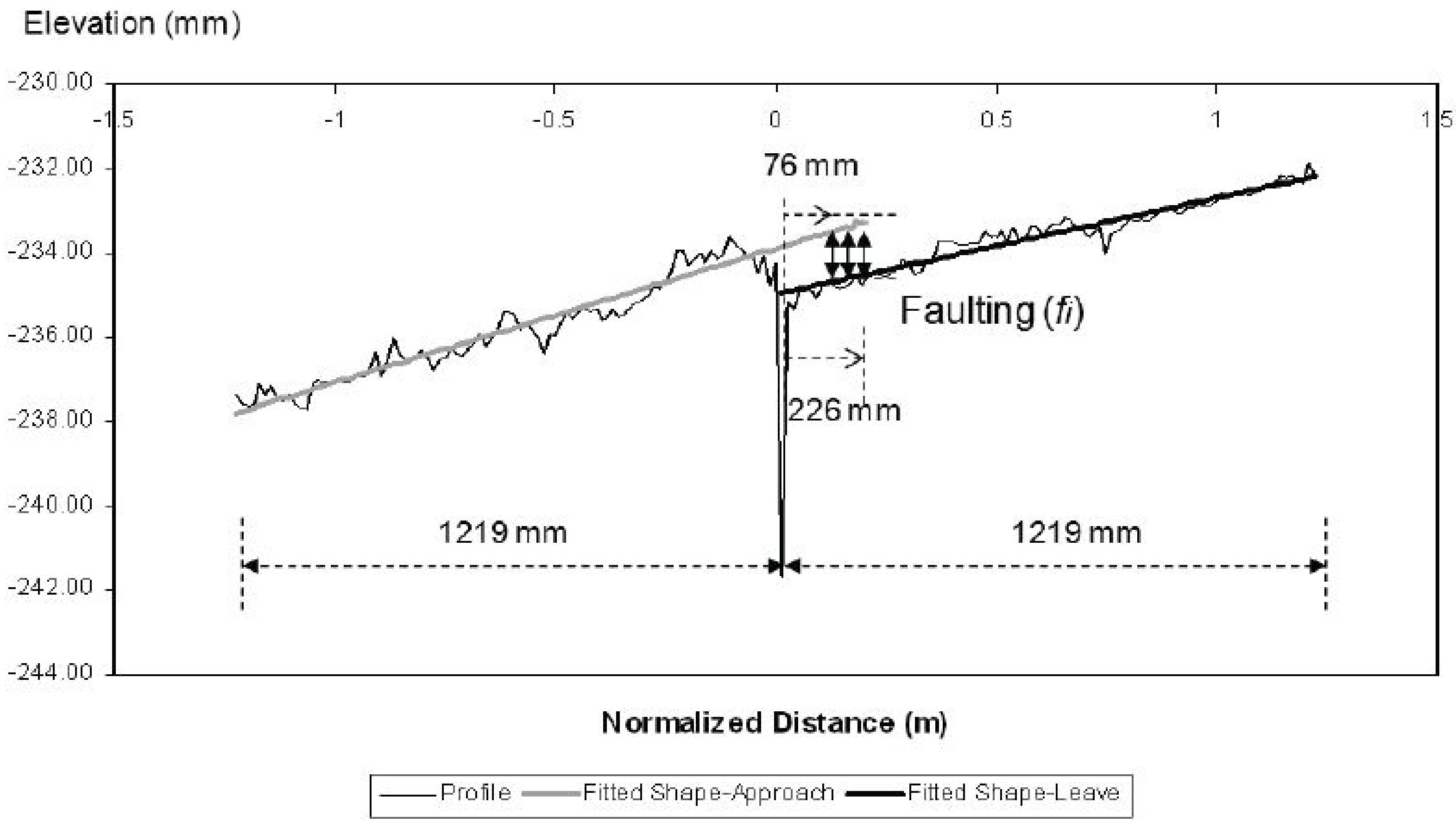
Moving Window using Peakdet Cont.



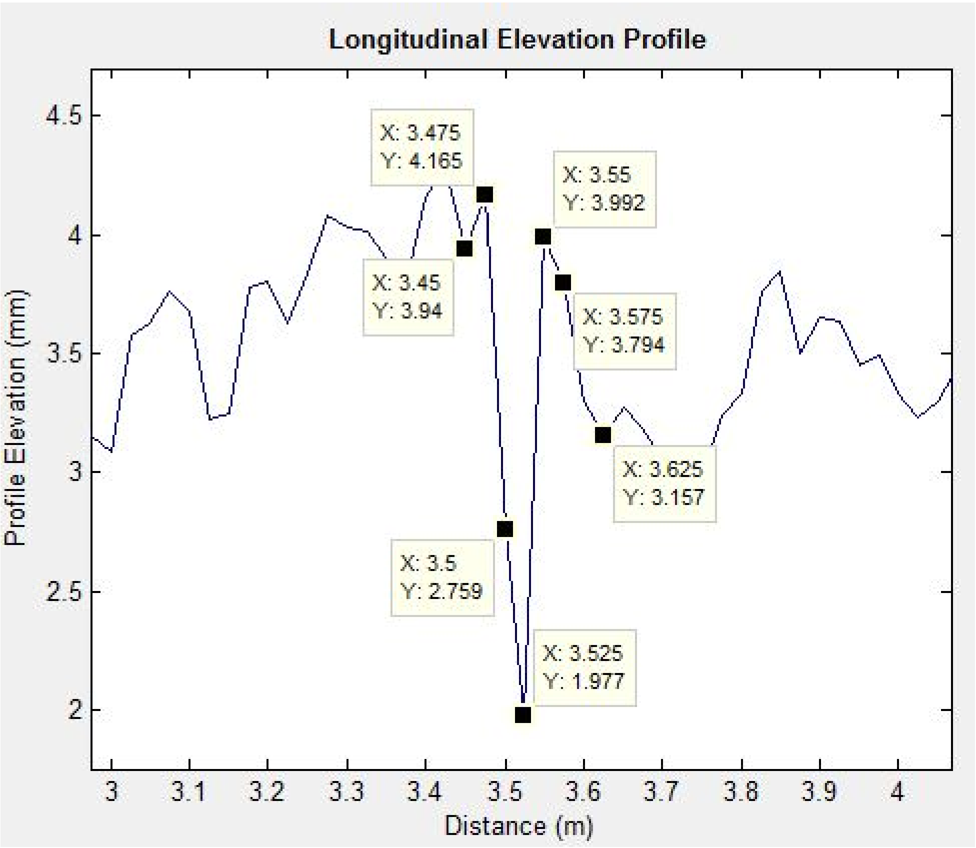
Moving Window using Peakdet Cont.



Joint Faulting
(ASSHTO Method-A)



Joint Faulting (Slope Method)

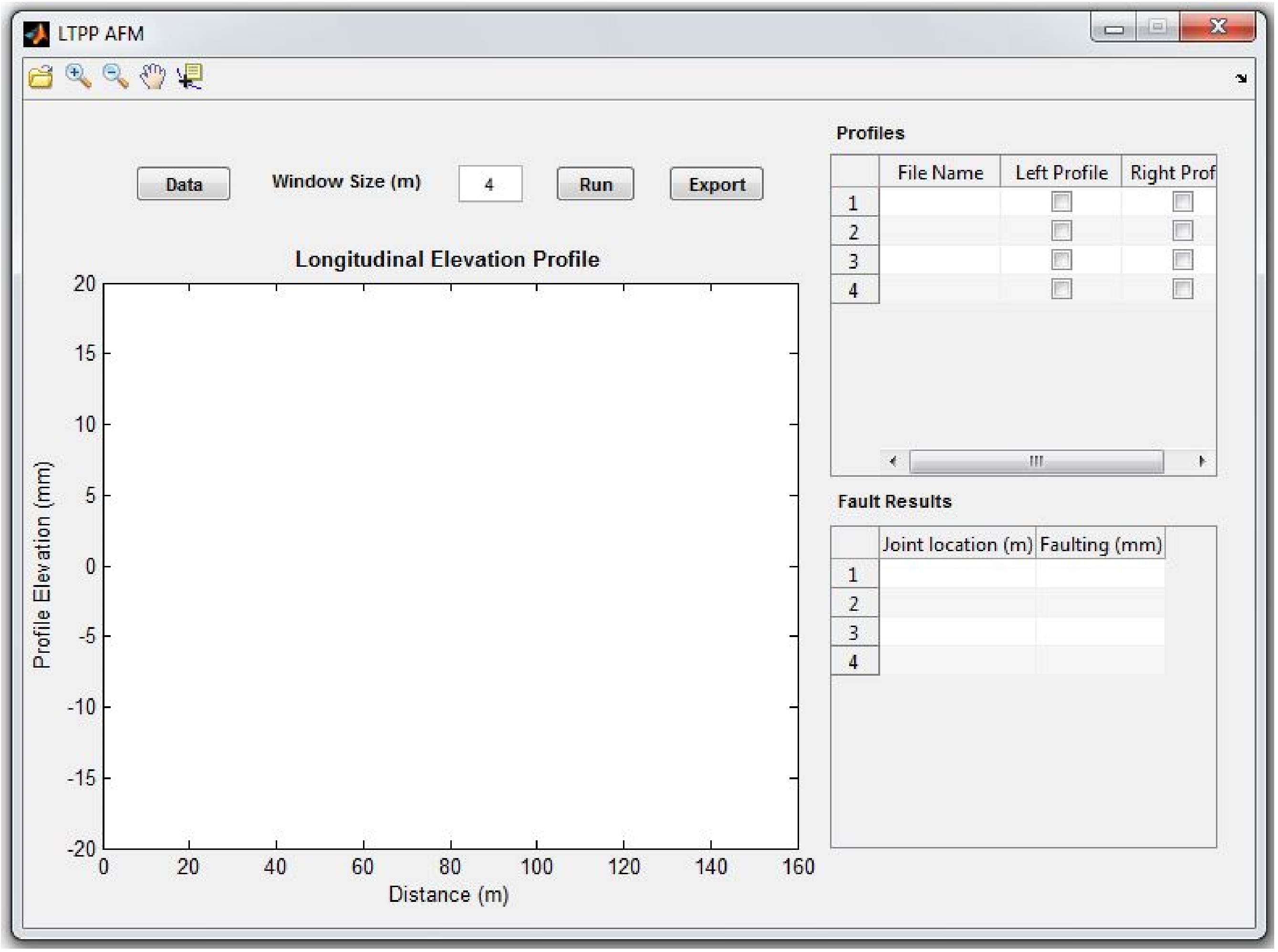


Approach Slab			
y2	1.977	2.759	3.94
y1	2.759	3.94	4.165
X2	3.525	3.5	3.45
x1	3.5	3.45	3.475
Slope	31.28	23.62	**9**

Leave Slab		
y2	3.992	3.794
y1	1.977	3.992
X2	3.55	3.575
x1	3.525	3.55
Slope	80.6	**7.92**

P1=4.165 mm
P2=3.794 mm
Faulting = P1- P2
= 0.371 mm

LTPP AFM Graphical User Interface (GUI)



Analysis Results

- Background
  - Six LTPP test sections (500 ft)
  - Eight repeat runs by LTPP profilers (25 mm)
  - One Florida DOT test section (1000 ft)
  - Five repeat runs by five HSIP (20.7 mm)
  - Three replicate Georgia Faultmeter Measurements (GFM) per joint
- Study comparison
  - ProVAL AFM (ASSHTO Method A) Vs. LTPP AFM
  - FDOT PaveSuite (ASSHTO Method B) Vs. LTPP AFM

LTPP AFM Joint Detection Results using LTPP Profiler Data

STATE CODE	SHRP ID	Survey Date	Total # Trans. Joints	ERD File 1		ERD File 2		ERD File 3		ERD File 4		ERD File 5		Avg. True Positives Detected	Joint Detection rate (%)
				TP	FP	TP	FP	TP	FP	TP	FP	TP	FP		
13	3019	11/27/2007	25	25	0	25	0	25	0	25	0	25	0	25	100.0%
31	3018	12/18/2003	32	32	0	32	0	32	0	32	0	32	0	32	100.0%
36	4018	4/13/2010	8	8	0	8	1	7	1	7	1	8	1	7.6	95.0%
37	201	9/19/2002	33	32	0	33	0	33	0	33	0	33	0	32.8	99.4%
42	1606	10/15/2003	10	9	2	10	0	10	0	10	1	9	1	9.6	96.0%
49	3011	10/9/2007	34	34	0	34	0	34	0	34	0	34	0	34	100.0%

TP = True positive, FP = False positive

- Joint detection rate ranged from 95% to 100%

ProVAL AFM Joint Detection Results using LTPP Profiler Data

STATE CODE	SHRP ID	Survey Date	Total # Trans. Joints	ERD File 1		ERD File 2		ERD File 3		ERD File 4		ERD File 5		Avg. True Positives Detected	Joint Detection rate (%)
				TP	FP	TP	FP	TP	FP	TP	FP	TP	FP		
13	3019	11/27/2007	25	22	1	21	1	23	0	22	1	23	0	22.2	88.8%
31	3018	12/18/2003	32	28	0	29	0	29	0	29	0	30	0	29	90.6%
36	4018	4/13/2010	8	7	5	4	7	3	10	7	6	6	5	5.4	67.5%
37	201	9/19/2002	33	31	0	31	0	30	0	31	0	30	0	30.6	92.7%
42	1606	10/15/2003	10	6	5	6	4	6	7	5	9	6	8	5.8	58.0%
49	3011	10/9/2007	34	34	0	33	1	34	0	34	0	34	0	33.8	99.4%

TP = True positive, FP = False positive

- Joint detection rate ranged from 58% to 99.4%

FDOT and LTPP AFM Joint Detection Results using FDOT HSIP

AFM Method	Total # Trans. Joints	FDOT HSIP Profiler		Joint detection rate (%)
		TP	FP	
FDOT AFM	50	48	8	96%
LTPP AFM		48	0	96%

TP = True positive, FP = False positive

- Joint detection rate of 96% was found for both FDOT PaveSuite and LTPP AFM

LTPP AFM Joint Faulting Results (Slope Method) using LTPP Profiler Data

STATE CODE	SHRP ID	Survey Date	GFM Avg. Section Faulting (mm)	Avg. Section Faulting for all five Runs (mm)	Avg. Section |Bias| for all five Runs (mm)
13	3019	11/27/2007	0.84	0.56	0.80
31	3018	12/18/2003	4.41	3.28	3.72
36	4018	4/13/2010	1.75	-3.05	5.07
37	201	9/19/2002	0.15	0.37	0.44
42	1606	10/15/2003	3.30	0.39	2.98
49	3011	10/9/2007	3.32	3.48	0.95

ProVAL AFM Joint Faulting Results using LTPP Profiler Data

STATE CODE	SHRP ID	Survey Date	GFM Avg. Section Faulting (mm)	Avg. Section Faulting for all five Runs (mm)	Avg. Section |Bias| for all five Runs (mm)
13	3019	11/27/2007	0.84	1.13	0.99
31	3018	12/18/2003	4.41	5.04	0.88
36	4018	4/13/2010	1.75	-6.58	8.75
37	201	9/19/2002	0.15	1.08	1.02
42	1606	10/15/2003	3.30	1.35	2.46
49	3011	10/9/2007	3.32	4.71	1.46

LTPP AFM Joint Faulting Results (ASSHTO Method) using LTPP Profiler Data

STATE CODE	SHRP ID	Survey Date	GFM Avg. Section Faulting (mm)	Avg. Section Faulting for all five Runs (mm)	Avg. Section |Bias| for all five Runs (mm)
13	3019	11/27/2007	0.84	-0.56	1.86
36	4018	4/13/2010	1.75	-12.06	13.81
37	201	9/19/2002	0.15	1.66	1.59
42	1606	10/15/2003	3.30	-0.38	3.68

ProVAL AFM Joint Faulting Results using LTPP Profiler Data

STATE CODE	SHRP ID	Survey Date	GFM Avg. Section Faulting (mm)	Avg. Section Faulting for all five Runs (mm)	Avg. Section |Bias| for all five Runs (mm)
13	3019	11/27/2007	0.84	1.13	0.99
36	4018	4/13/2010	1.75	-6.58	8.75
37	201	9/19/2002	0.15	1.08	1.02
42	1606	10/15/2003	3.30	1.35	2.46

Joint Faulting Results using FDOT HSIP Data

Method	GFM Avg. Section Faulting (mm)	Avg. Section Faulting (mm)	Avg. Section |Bias| (mm)
FDOT AFM	1.81	1.69	1.05
LTPP AFM (Slope Method)		1.62	1.14

Conclusions

- The developed LTPP automated faulting method is reliable in detecting JPCP transverse joints
  - The LTPP AFM joint detection rate ranged from 95% to 100% for LTPP profiler data
  - The ProVAL AFM joint detection rate ranged from 58% to 99.4% for LTPP profiler data
  - For HSIP data both the FDOT PaveSuite and the LTPP AFM has joint detection rate of 96%

Conclusions Cont.

- Fault measurements using LTPP Profiler data
  - The average difference between faulting estimated by the ProVAL AFM and that measured by GFM ranged from 0.88 to 8.75 mm
  - LTPPL AFM (slope method) and that measured by GFM ranged from 0.44 to 5.07 mm
  - LTPPL AFM (ASSHTO method) and that measured by GFM ranged from 1.59 to 13.81 mm

Conclusions Cont.

- Fault measurements using FDOT HSIP data
  - The average difference between faulting estimated by the FDOT PaveSuite and that measured by GFM was 1.05 mm
  - LTPPL AFM (slope method) and that measured by GFM was 1.14 mm
- More robust joint fault computation methods are required to accurately measure joint faulting using profiler data

Questions