



Inertial Profiler Implementation

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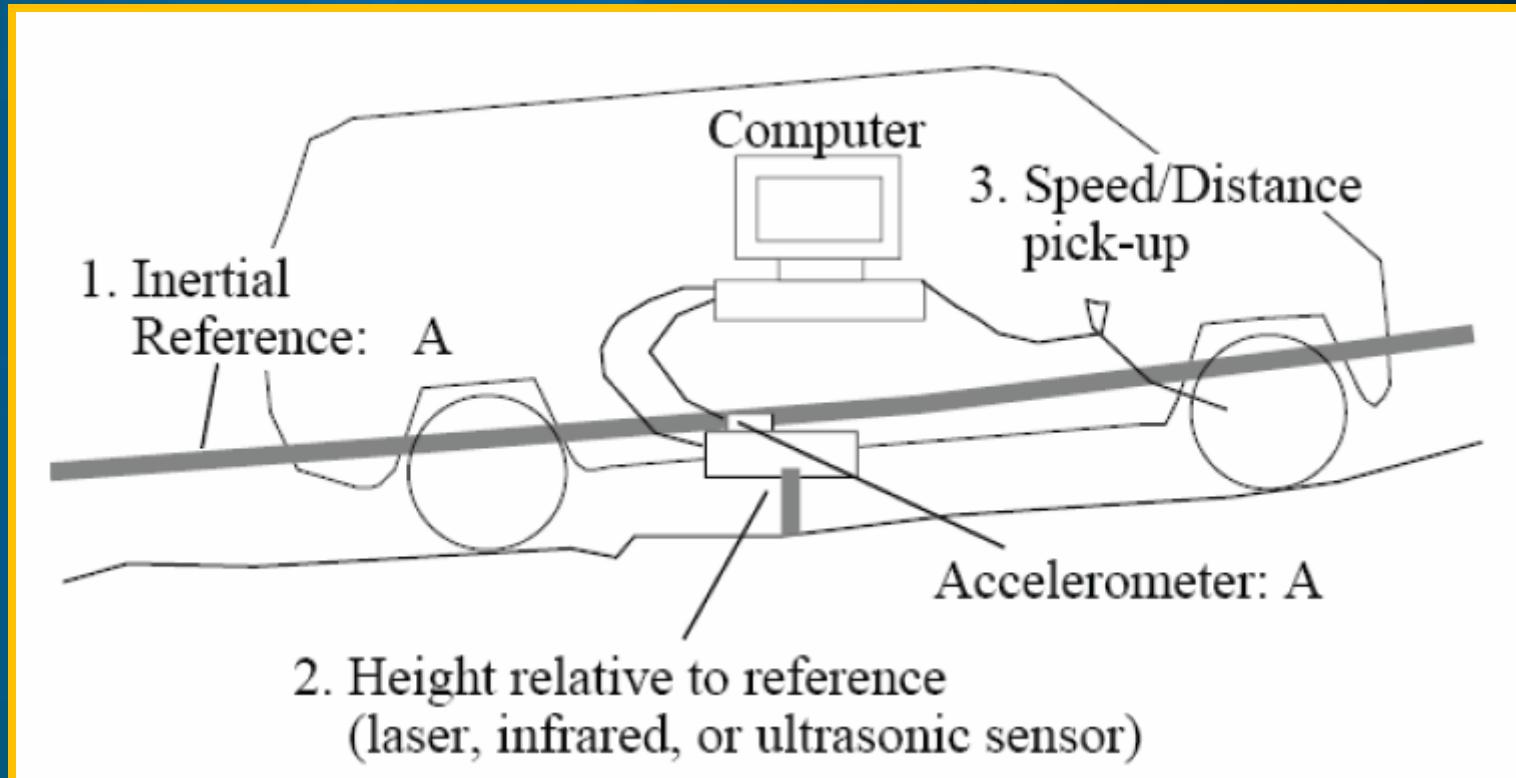
Topics

- Inertial Profiler 101
- California's new certification site
- Certification testing schedule/requirements
- Testing results
- Review Caltrans' smoothness specification

Inertial Profiler Components

- Accelerometer
 - Reference elevation
- Laser Height Sensor
 - Height relative to reference
- Distance Measuring Instrument
 - Longitudinal distance

Inertial Profiler



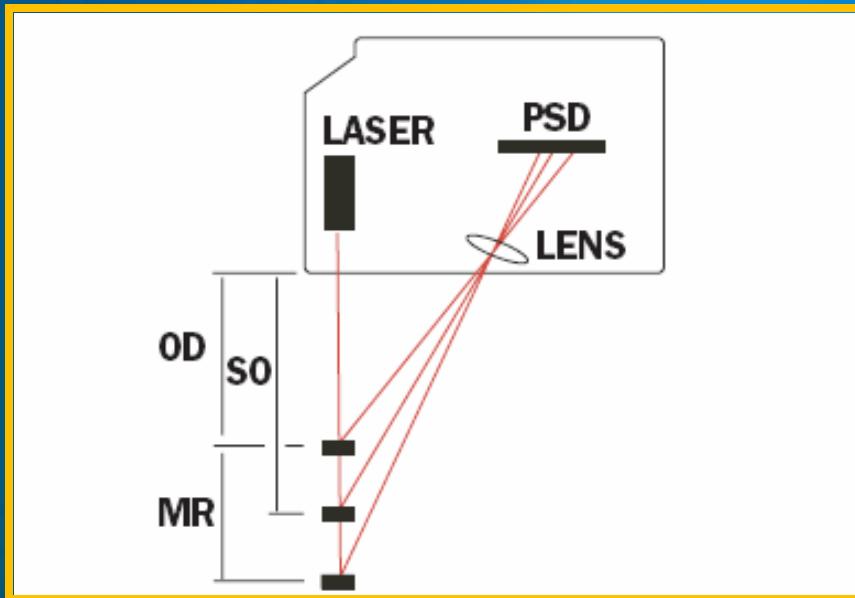
Accelerometers

- Accelerometers are used in a wide variety of machines
 - Seismology equipment
 - Car alarm systems
 - Crash detection/air bag deployment sensors
- Measures the vertical movement of the vehicle body relative to the inertial reference

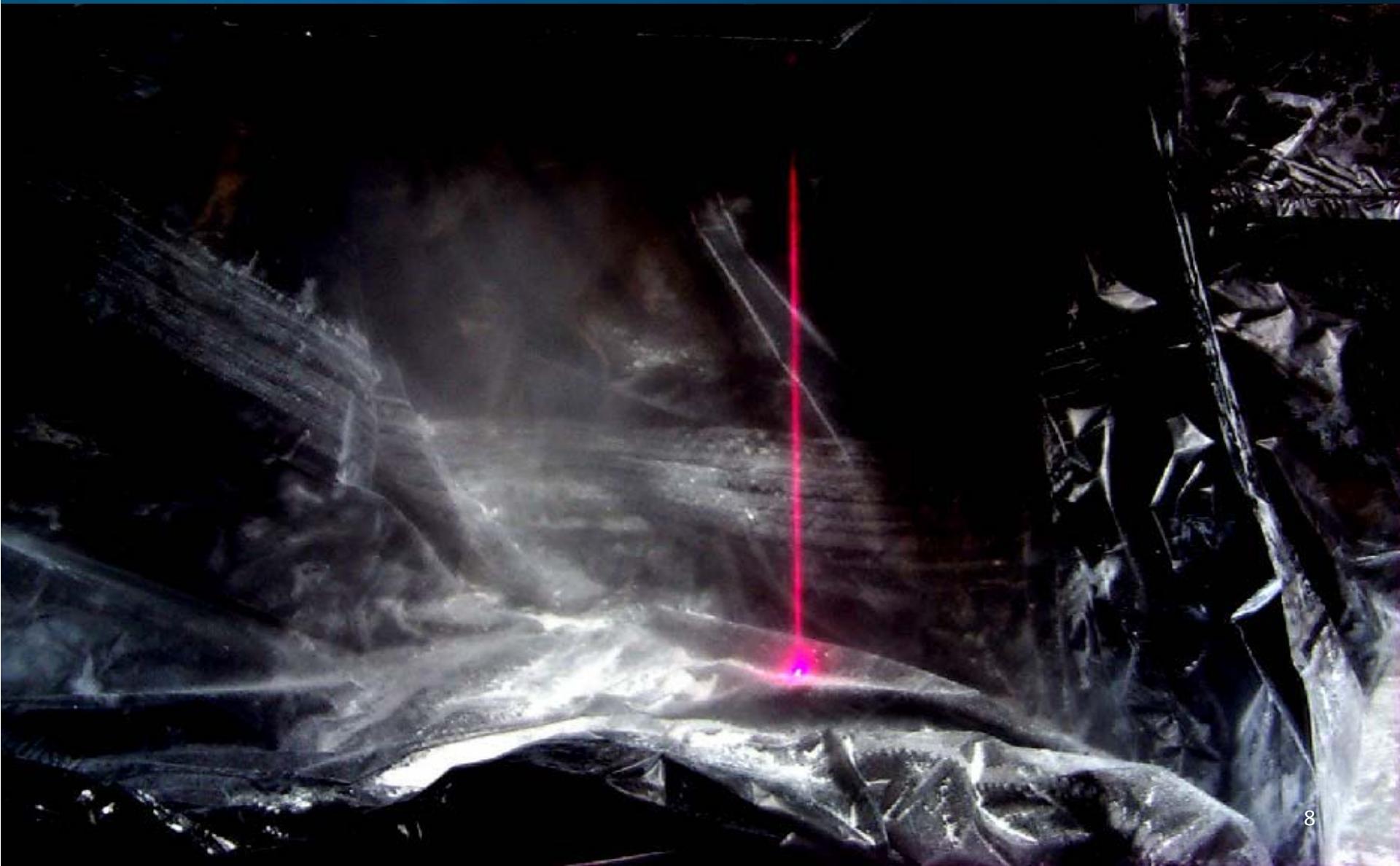


Laser Height Sensors

- The laser height sensors measure the distance from the reference plane to the pavement surface. They operate around 16KHz. At 60 mph they can take about 15 readings per inch of vehicle travel.



Dot Laser

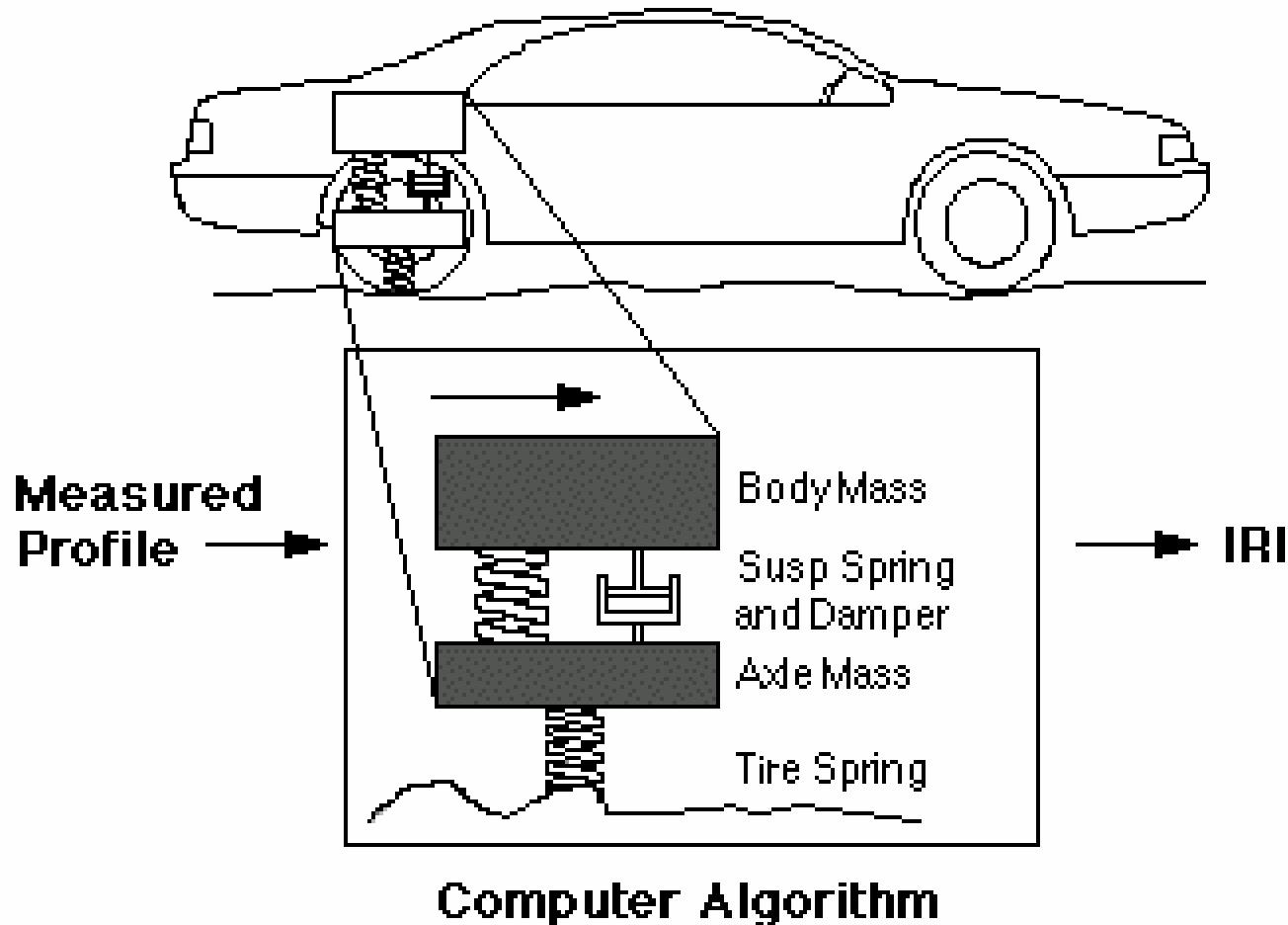


Line Laser

RoLine Laser



International Roughness Index

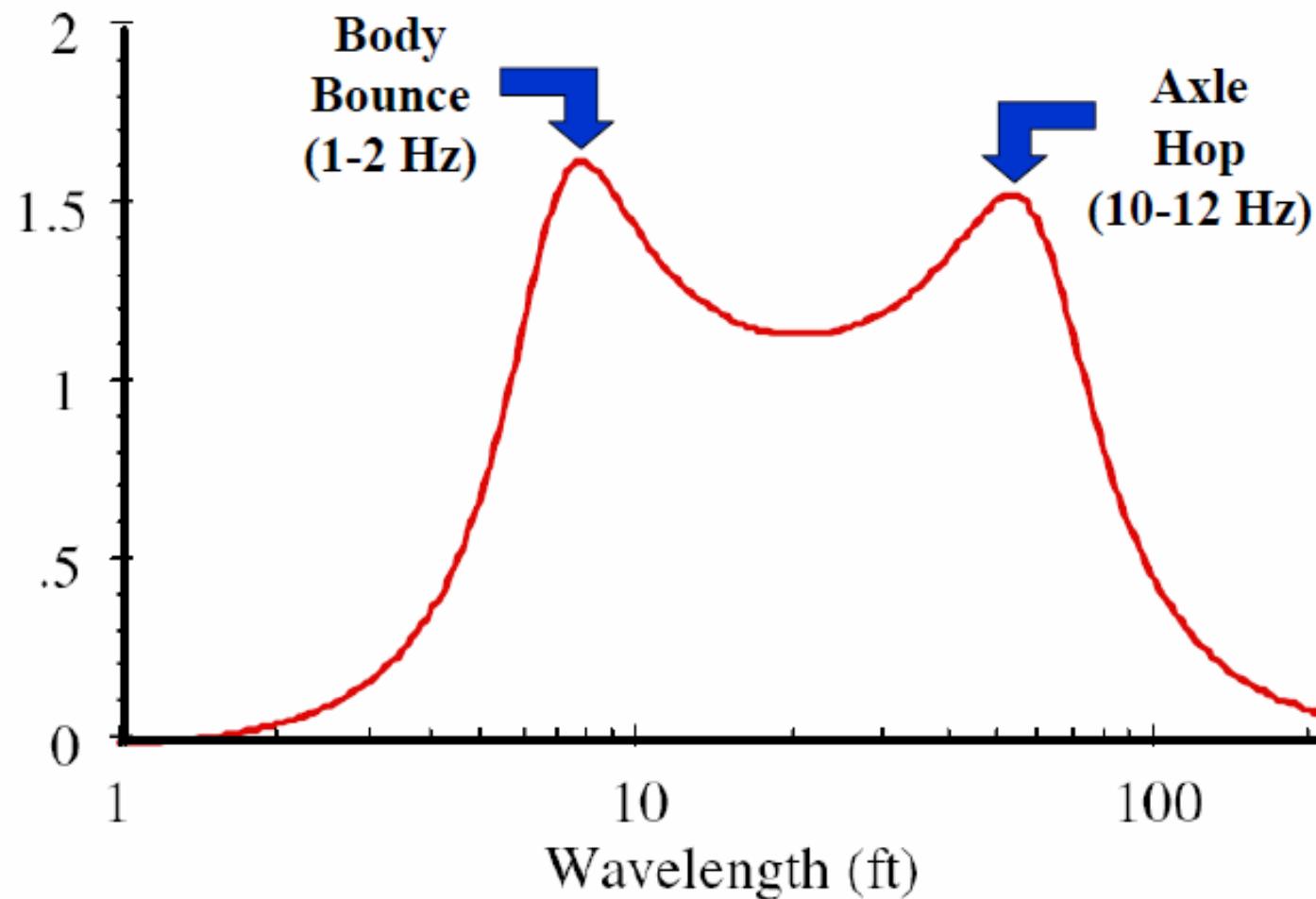


International Roughness Index

- Calculated at 80 km/hr (49.7 mph) to cover the same wavelengths that affect road using vehicles.
 - Fast speeds are effected most by long wavelengths
 - Slow speeds are effected most by short wavelengths
- Sensitive to the range of wavelengths detectable by most road users (4 to 100 feet).
- Maximum sensitivity to the most objectionable wavelengths, body bounce (~7 ft) and axle hop (~50 ft)

IRI Sensitivity

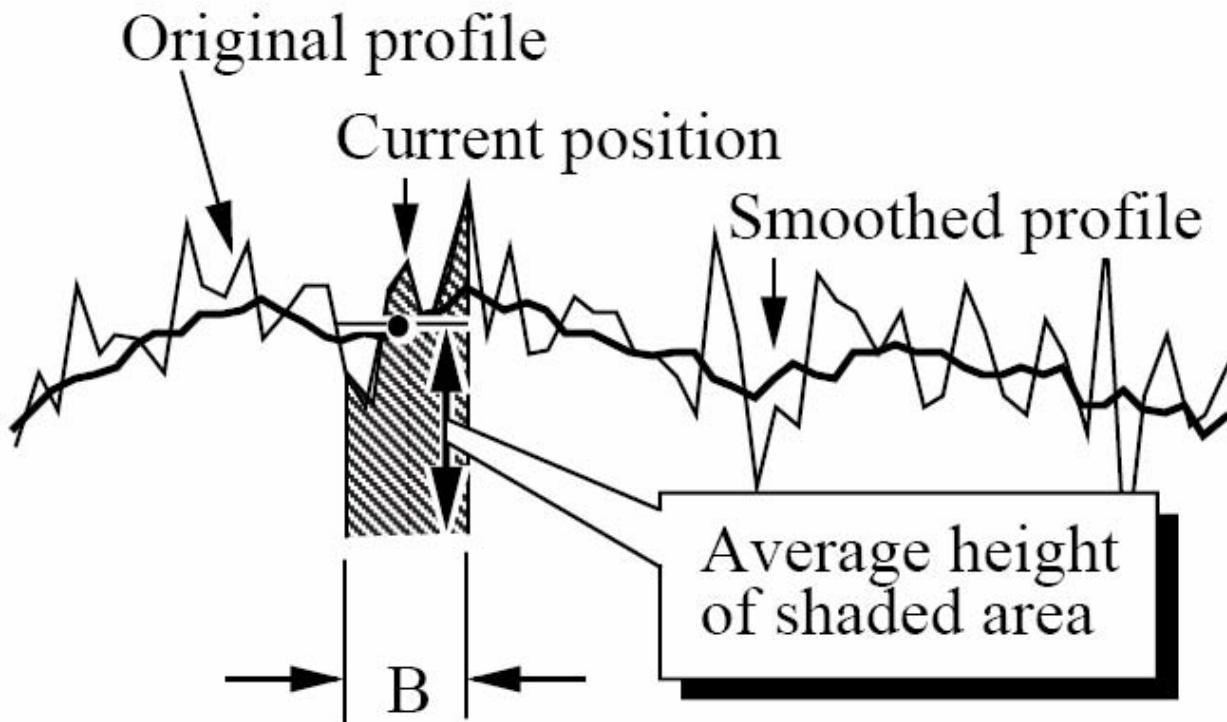
IRI Response



International Roughness Index

- The raw profile is filtered twice
 - First the 250mm (9.8") moving average filter is applied
 - Second the IRI (Quarter Car) filter is applied

Moving Average Filter (Low Pass)



Where $B = 250$ mm (9.8 in) for IRI
(represents tire contact with ground)

Inertial Profiler



Front Mount



Rear Mount



Side Mount

Reference Profiler



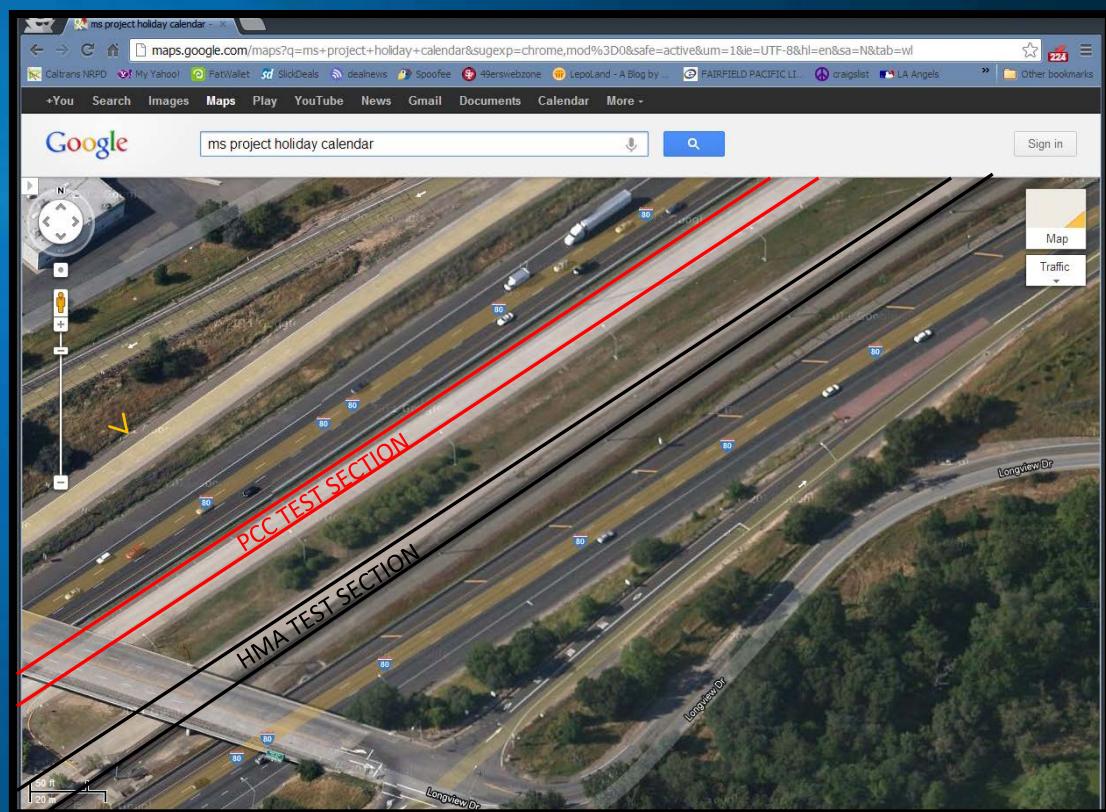
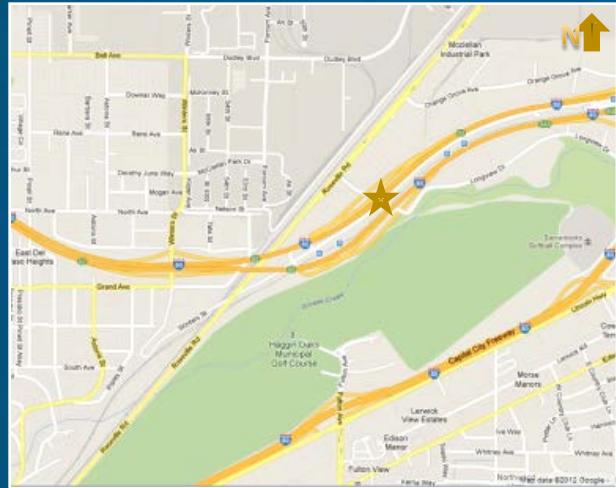
Inertial Profiler Benefits

- Collects data at a high rate of speed (approx. 30 mph to 60 mph)
- Collects data for both wheel paths simultaneously
- No traffic control
- Safer
- Cost Savings

Calibration Site Information

- The site is located in the median of Interstate 80 at the Sacramento Regional Transit Light Rail station (Watt/I-80) parking lot.
- Two test sections (asphalt and concrete)
- University of California Pavement Research Center and METS will administer calibration program
- Calibration tests will be conducted on call initially, 2 to 4 times per year thereafter
- Calibration tests will commence in July 2013

Calibration Site



Testing Schedule/Requirements

- Day 1 – Translab (5900 Folsom Blvd, Sacramento, CA 95819)
 - The following tests will be performed:
 - Classroom session (2 to 4 hrs)
 - Operator written test
 - Block (laser test)
 - Bounce (accelerometer test)
- Day 2 – Calibration Site
 - The following tests will be performed:
 - Block (laser test)
 - Bounce (accelerometer test)
 - DMI (distance measuring test)
 - Repeatability (precision)
 - Reproducibility (comparison to reference profile/device)
- All tests will be done in accordance to AASHTO standards
 - R 56-10 “Certification of Inertial Profiling Systems”
 - R 57-10 “Operating Inertial Profiling Systems”

Testing Schedule/Requirements

- Cost to be determined and could be up to \$1,000
- Up to 6 units per day will be certified
- Will certify the first year on demand with 2 to 4 weeks notification

Vehicle Tests

- Block Test
 - AASHTO R57-10, Section 5.3.2.3.1
 - This test will be conducted on a relatively flat and level area
 - Its purpose is to check the height measurements from the height sensor(s) of the test vehicle using blocks of known heights (i.e. 0.5 inch, 1.0 inch, 2.0 inch).
- Bounce Test
 - AASHTO R57-10, Section 5.3.2.3.2
 - Its purpose is to ensure that the data from the height sensor and accelerometer are legitimate and being properly combined to compute the longitudinal elevation profile
- Distance Measurement Index Test
 - AASHTO R56-10, Section 8.4
 - Tests accuracy of profilers distance measurement instrument (DMI)

Vehicle Tests

- Equipment Precision (Repeatability)
 - AASHTO R56-10, Section 8.3.1.2
 - Compare ten Inertial Profiler runs over same test section against each other
 - Calculate repeatability agreement score
 - Score of 0.92 or greater is required
- Equipment Accuracy (Reproducibility)
 - AASHTO R56-10, Section 8.3.1.4
 - Compare several inertial profiler runs over same test section against a reference profiler
 - Calculate accuracy agreement score
 - Score of 0.90 or greater is required

Operator Tests

- Classroom session
- 20 questions, minimum 70% for passing
- Observe calibration procedures
 - Block
 - Bounce
 - DMI
- Observe data collection & evaluate submittals

Testing Results

- Equipment passing the calibration tests
 - Will be issued a decal/certification document valid for 12 months
 - Decal will be affixed to each laser/accelerometer unit tested
- Operators passing the written and practical tests
 - Will be issued a certification document valid for 12 months
 - The certification document will identify the system (software and hardware) of inertial profiler that the operator is certified to operate
- Results will also be posted on Caltran's smoothness website at the following address:
http://www.dot.ca.gov/hq/maint/Pavement/Offices/Pavement_Engineering/Smoother_Pavements.html

Testing Results

- Failed tests (Equipment or Operator)
 - May re-test the following day (if site available)
 - Only one re-test per operator/equipment allowed

Standard Special Provision (SSP)

Smoothness

- SSP 39-1.12 (HMA) and SSP 40-1 (PCC) were posted on 2/22/2013
- ALL pavement projects are now required to use this SSP
- SSP requires the use of inertial profilers, in lieu of California Profilograph, to measure smoothness
- Contractors required to report data in IRI/MRI format

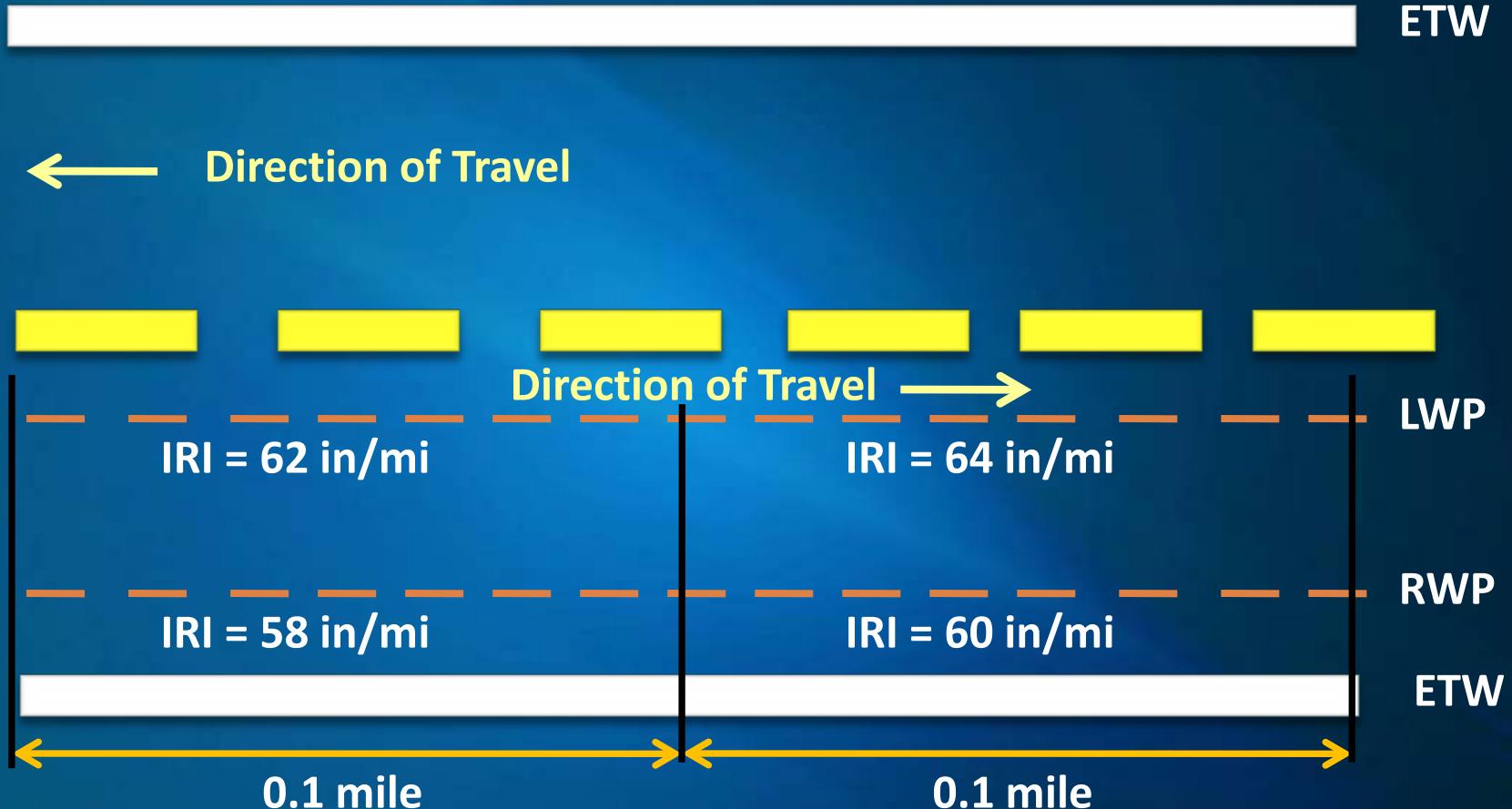
Standard Special Provision

Definitions

- Pavement smoothness is quantified as averaging the results of the IRI for the left and right wheel paths in an individual lane
- The average of the IRIs from the left and right wheel paths for the same lane is the mean roughness index (MRI)
- A lane is analyzed every 0.1 mile (528 ft) section

Standard Special Provision

Definition - IRI



RWP = Right Wheel Path
LWP = Left Wheel Path

Standard Special Provision Definition - MRI



RWP = Right Wheel Path
LWP = Left Wheel Path³⁰

Standard Special Provision

Verification and Calibration Tests

- The following tests must be run in the Engineer's presence each day before performing inertial profiling:
 - Block Test (ref. AASHTO R57-10)
 - Bounce Test (ref. AASHTO R57-10)
 - Distance Measurement Instrument Test (ref. AASHTO R56-10)
 - Manufacturer's Recommended tests
- The following test must be run in the Engineer's presence before performing inertial profiling at least annually at a project level:
 - Cross Correlation Test (Repeatability)
 - Agreed upon test section

Standard Special Provision

HMA Acceptance Values

HMA^a Pavement Smoothness Acceptance Criteria

HMA thickness	MRI requirement
> 0.20 foot	60 in/mi or less
≤0.20 foot	75 in/mi or less

^a Except OGFC

OGFC Pavement Smoothness Acceptance Criteria

OGFC placement on	MRI requirement
New construction, or HMA overlay	60 in/mi or less
Existing pavement	75 in/mi or less
Milled surface	75 in/mi or less

MRI for each 0.1 mile section of a lane

Standard Special Provision

PCC Acceptance Values

- MRI of 60 in/mile or less for the following:
 - All concrete pavement
 - After grinding existing concrete pavement

MRI for each 0.1 mile section of a lane

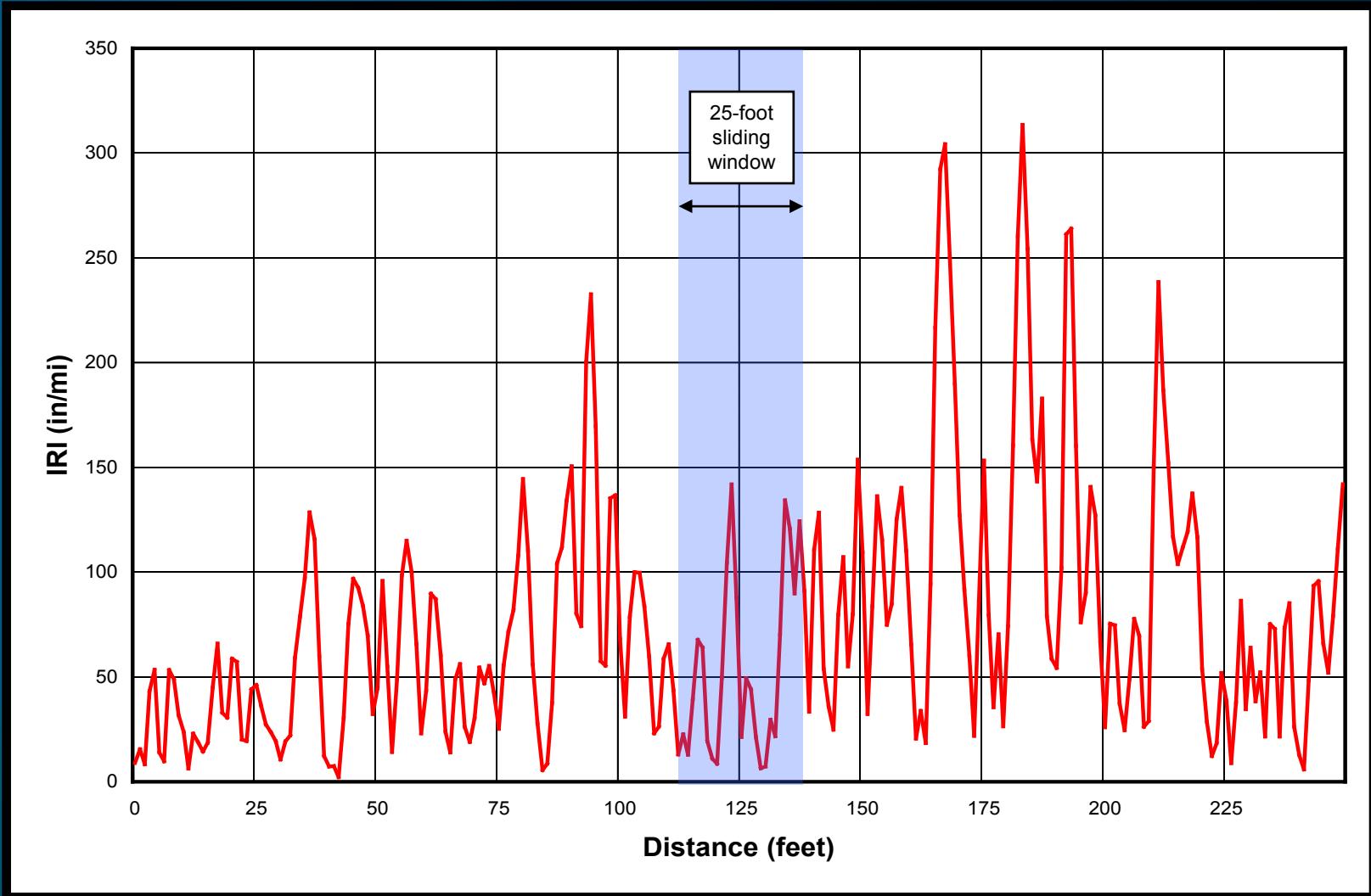
Standard Special Provision

Areas of Localized Roughness

- “Must Grinds” are now defined as “Areas of Localized Roughness”
- Areas of localized roughness uses a continuous IRI for each wheel path with a 25 ft interval
- Areas of localized roughness that exceed 120 in/mile must be corrected regardless of the IRI values of a 0.1 mile section

Standard Special Provision

Areas of Localized Roughness



Standard Special Provision

Smoothness Measurement

- Contractor to notify Engineer of start location by station and start time at least 2 business days before profiling
- Begin and end station will be marked on pavement shoulder before profiling
- Following “leave out” areas will be recorded
 - Begin and end of all bridge approach slabs
 - Begin and end of all bridges
 - Begin and end of all culverts visible on the roadway surface

Standard Special Provision

Smoothness Correction

- For HMA, if the final surface does not comply with the smoothness acceptance values the contractor can do the following:
 - Grind the pavement to within specified tolerances
 - Remove and replace it
 - Place an overlay of HMA
- For PCC, if the final surface does not comply with the smoothness acceptance values the contractor can do the following:
 - Grind the pavement to within specified tolerances
 - Remove and replace it

Standard Special Provision

Quality Assurance

- Caltrans will independently collect profile data
- For each 0.1 mile section, the contractor's IRI values must be within 10 percent of Caltrans' IRI values

Standard Special Provision Submittals

- Within 5 business days before start of profiling or changing profile or operator
 - Inertial Profiler certification
 - Operator certification
 - Manufacturer's recommended calibration and verification tests
- Within 2 business days after profiling engineer approved test section
 - Cross correlation test results

Standard Special Provision Submittals

- Provide data within 2 business days after each day of profiling
- Profile data must include:
 - Raw profile data for each lane (ppf extension)
 - ProVAL ride quality analysis report in IRI for both wheel paths
 - ProVAL ride quality analysis report in MRI for each lane
 - ProVAL smoothness assurance analysis report in IRI for both wheel paths
 - GPS data
 - Manufacturer's recommended calibration and verification results
 - AASHTO calibration and verification test results

Standard Special Provision

Prepaving Inertial Profiler

- Applies to existing asphalt concrete areas receiving an HMA overlay (including OGFC)
- Prepaving inertial profiler data will allow for:
 - Future analysis
 - Identify existing roadway condition (especially for proposed overlays less than or equal to 0.20 ft)

Standard Special Provision ProVAL Reports

Ride Quality Analysis Report

Ride Quality Analysis

ProVAL Reports

Analysis: Ride Quality

Inputs

Threshold (in/mi): 80.00
Segment Length (ft): 528.00
Exclude Leave-outs: Yes

Selections

File	Profile	Section	Apply 250mm Filter
I-10 East Lane 1 T1 & T2 - 1	Left Track	Full	Yes
I-10 East Lane 1 T1 & T2 - 1	Right Track	Full	Yes
I-10 East Lane 2 T1 & T2 - 1	Left Track	Full	Yes
I-10 East Lane 2 T1 & T2 - 1	Right Track	Full	Yes
I-10 West Lane 1 T1 & T2 - 1	Left Track	Full	Yes
I-10 West Lane 1 T1 & T2 - 1	Right Track	Full	Yes
I-10 West Lane 2 T1 & T2 - 1	Left Track	Full	Yes
I-10 West Lane 2 T1 & T2 - 1	Right Track	Full	Yes

Leave-outs

Results

Start Distance (ft)	Stop Distance (ft)	Length (ft)	I-10 East Lane 1 T1 & T2 - 1: Left Track (in/mi)	Note
0.00	528.00	528.00	125.60	
528.00	1,056.00	528.00	126.20	
1,056.00	1,584.00	528.00	69.67	
1,584.00	2,112.00	528.00	76.83	
2,112.00	2,640.00	528.00	76.70	
2,640.00	3,168.00	528.00	74.20	
3,168.00	3,696.00	528.00	65.02	
3,696.00	4,224.00	528.00	71.48	
4,224.00	4,752.00	528.00	174.98	
4,752.00	5,280.00	528.00	73.83	

Standard Special Provision ProVAL Reports

Smoothness Assurance Analysis Report

Smoothness Assurance Analysis

ProVAL Reports

Analysis: Smoothness Assurance

Selections

File	Profile	Section	Apply 250mm Filter
10-0M8004_Hwy99_NB Turlock_Lane 3_09172012_01 - T1 & T2 - 1	RElev.	Full	Yes

Leave-outs

10-0M8004_Hwy99_NB Turlock_Lane 3_09172012_01 - T1 & T2 - 1

Start Distance (ft)	Stop Distance (ft)	Length Distance (ft)	Name
8,528.001	8,843.001	315.000	Lander
16,160.002	16,944.002	784.000	Walnut OH
18,108.002	18,395.002	287.000	West Main
23,862.003	24,117.003	255.000	Fulkerth
29,661.004	29,923.004	262.000	Monte Vista
33,631.004	34,088.004	457.000	Turlock OH

Grinding

Grinder

Grinder Type: 18-foot Wheelbase
Maximum Grinding Depth (in): 0.30
Head Position: 0.50
Wheelbase (ft): 18.00
Tandem Spread (ft): 2.49
Short Cutoff Wavelength (ft): 0.820

Strategy: Default Strategy

Total Ground (ft): 2,503.75

Enabled	Start Distance (ft)	Stop Distance (ft)	Direction	Head Height (in)	Warning	Length (ft)
True	19.67	50.75	Forward	0	n/a	31.08
True	62.17	80.83	Forward	0	n/a	18.67
True	99.00	122.58	Forward	0	n/a	23.58
True	158.75	172.25	Forward	0	n/a	13.50
True	184.00	205.83	Forward	0	n/a	21.83

Standard Special Provision ProVAL Reports

Profiler Certification Analysis Report
(Cross correlation test)

Profiler Certification Analysis

Cross Correlation Test

Analysis: Profiler Certification

Inputs

Maximum Offset (ft): 5.00
Minimum Repeatability (%): 92
Minimum Accuracy (%): 90
Basis Filter: IRI (with 250mm Filter)
Comparison Filter: IRI (with 250mm Filter)

Selections

File	Profiles	Basis	Run	Sample Interval
06-OL6404_Hwy 99 Repeatability Test_130122_01 T1 & T2 - 1	Left + Right	No	1	1.000000
06-OL6404_Hwy 99 Repeatability Test_130122_02 T1 & T2 - 1	Left + Right	No	2	1.000000
06-OL6404_Hwy 99 Repeatability Test_130122_03 T1 & T2 - 1	Left + Right	No	3	1.000000
06-OL6404_Hwy 99 Repeatability Test_130122_04 T1 & T2 - 1	Left + Right	No	4	1.000000
06-OL6404_Hwy 99 Repeatability Test_130122_05 T1 & T2 - 1	Left + Right	No	5	1.000000
06-OL6404_Hwy 99 Repeatability Test_130122_06 T1 & T2 - 1	Left + Right	No	6	1.000000
06-OL6404_Hwy 99 Repeatability Test_130122_07 T1 & T2 - 1	Left + Right	No	7	1.000000

Results

Statistics

Statistic	Repeatability - Left	Repeatability - Right
Comparison Count	21	21
% Passing	100.00	100.00
Mean	95.67	95.29
Minimum	93.00	92.00
Maximum	97.00	97.00
Standard Deviation	1.3	1.6
Grade	Passed	Passed

ProVAL



Websites of Interest

Smoothpavements.com
Roadprofile.com



Thank You