2024 EDITION

International Roughness Index

Missouri Department of Transportation

IRI

2024 updates

- Updated The first Three chapters.
    - Profiling basics has been split into 3 sections
        1. Introduction to IRI
        2. AASHTO M328, R56, and R57
        3. Profiler Sensitivity
    - Section 1 = Profiling basics is now rewritten and titled; “Introduction to IRI”
    - Section 2 = This is NEW: Added AASHTO Methods 328, R56, and R57.
    - Section 3 = Profiler Sensitivity
- Updated the location and the list for the IRI Proficiency test.

IRI

Table of Contents

Introduction to IRI

INTRODUCTION TO IRI

MoDOT IRI Certification

07/19/2023

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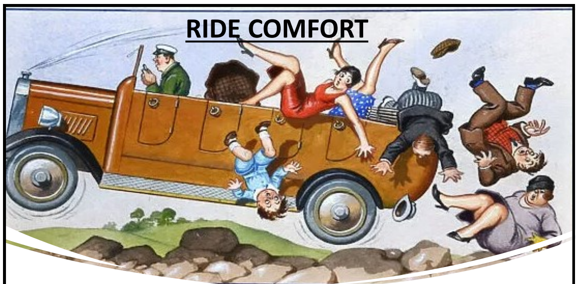
RIDE COMFORT



Pavement surface roughness is generally defined as an expression of irregularities in the pavement surface that adversely affects the ride quality of a vehicle (and thus, the user).

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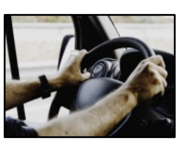
Ride Comfort Depends on…

- Road Roughness
- Vehicle Response to the road
- Human Response to vibration





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SMOOTH ROADS

- **Roughness** is the result of surface deviations from a true planer surface with characteristic dimensions that *affect ride* quality.
- Conversely, **Smoothness** is the lack of roughness.
- As an important indicator of pavement performance, smoothness is used interchangeably with roughness.

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Smooth Road - Benefits

- Improved pavement performance
- Longer Service life
- Improved safety
- Reduced fuel consumption
- Reduced vehicle maintenance cost

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Smooth Roads – Index System

- The first component of any smoothness specification is the smoothness index system that will be used.

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REFERENCES

- **ASTM E950** : Defines classifications of surface profiling devices
- **AASHTO M328** : Standard Specification for Inertial Profiler
- **AASHTO R54** : Pavement Ride Quality when measured using inertial profiling systems
- **AASHTO R56** : Certification of Inertial Profiling Systems
- **AASHTO R57** : Operating Inertial Profiling Systems

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TERMINOLOGY

- **Reference Device**: a device used to obtain the true profile of a pavement. Devices such as rod and level, Dipstick ™ and walking profiler are considered reference devices.
- **True Profile**: The undistorted shape of a pavement surface.
- **International Roughness Index (IRI)**: A static that summarizes the roughness qualities impacting vehicle response based on the Golden-Car vehicle model at a standard simulation speed of 49.7 mph.

More terms are in the glossary.

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TRUE PROFILE

- '**True**' profile is the actual cross-section of a pavement surface.
- The sum of a unique set of surface waves along the cross-section creates a profile.

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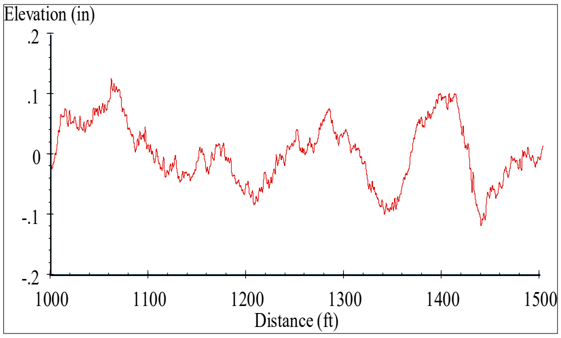
True Profile - Cross section



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Smooth Roads – Measurement

- Measure of pavement roughness produced by filtering a '**true profile**' through a mathematical model called a '**quarter car**'.
- Calculates the suspension deflection of a simulated mechanical system with a response like a passenger vehicle.

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QUARTER CAR MODEL

- **Quarter-car** modeled as:
  - One tire
  - Mass of axle supported by tire
  - Suspension spring and damper
  - Mass of the body supported by tire
- Simulation speed is 50 mi/hr.
- Suspension motion is accumulated by vertical displacement and divided by distance traveled to give IRI in inches/mile.

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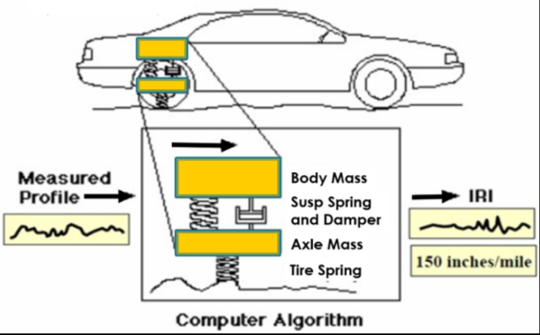
Quarter Car (Golden Car) Filter



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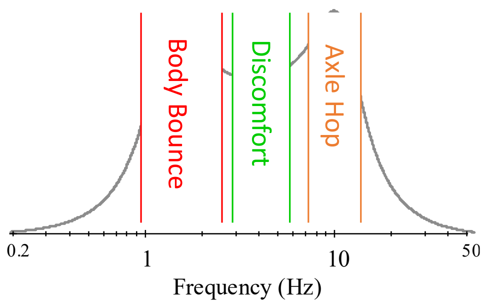
Smooth Roads - IRI Sensitivity



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Smooth Roads – Index System

- IRI is reported in units of inches/mile or meters/kilometer.
- Profile traces are collected in either one or both wheelpaths within a pavement lane.
- The most common smoothness index is the **International Roughness Index (IRI)**. IRI can be determined using measurements from any valid profiler (Inertial profiler) which generates a profile trace showing the "true" shape of the pavement surface. This pavement profile is fed into an algorithm that determines the IRI value for the pavement.

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Smooth Roads - IRI

- **International Roughness Index (IRI)** In using the IRI Index for smoothness, the lower the calculated IRI, the smoother the pavement will ride. The higher the IRI, the rougher the pavement will ride.

IRI scale (in/mi)	Description
<=60	Very Smooth
61 – 120	Smooth
121 – 170	Fair
171 – 220	Rough
>=220	Very Rough

- **IRI** is used to define a characteristic of the **longitudinal profile** of a traveled wheel track and constitutes a standardized roughness measurement.

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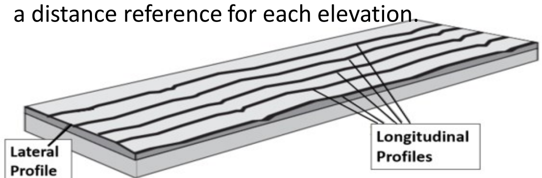
Smooth Roads – Longitudinal Profiles

- **Longitudinal Profile** Is a longitudinal two-dimensional slice of a road surface taken along an imaginary line that consists of elevation value and a distance reference for each elevation.



IRI is calculated from a measured longitudinal road profile by accumulating the output from a quarter-car model and dividing by the profile length to yield a summary roughness index with units of slope. **17**

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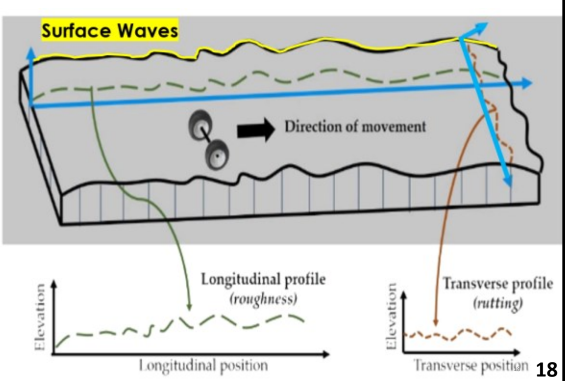
Smooth Roads - Longitudinal Profile and Waves



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FIVE PROFILING DEVICES IN MISSOURI

1. Distant Past Straightedge

2. Recent Past California Profilograph

3. Present Light Weight Inertial Profiler

4. Present High Speed Inertial Profiler

5. Present Reference Profiler

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1. Straightedge

- 15’ Rolling Straightedge
- Useful to study localized roughness issues.
- Does not record true profiles.

Smoothness = Straightedge Deviation

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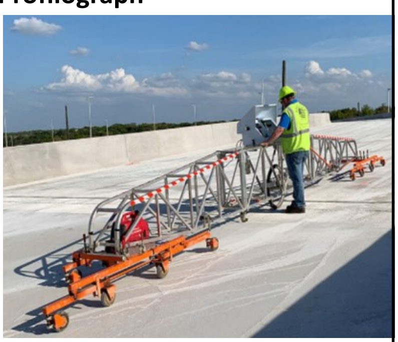
2. California Profilograph

- Truss-type California profilograph.
- Ability to collect continuous profile data.
- Does not record true profiles of the road.



Smoothness = Profile Index (PI)

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3. & 4. Inertial Profilers

- Generate **TRUE PROFILES**.
- Record wheel path elevation profiles.
- Inertial profiling systems include:
  - Laser Height Sensor
  - Accelerometer
  - Distance Measurement Instrument
  - Data Collection system to a software or ProVal to calculate IRI values.

Light-weight profiler

High Speed Profiler

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Inertial Profilers

- Profilers are typically mounted to the front or back of a pickup truck, van, or on light weight profilers.
- Contains equipment software that can convert true profile data to multiple smoothness indices.

Light-weight profiler

High Speed Profiler

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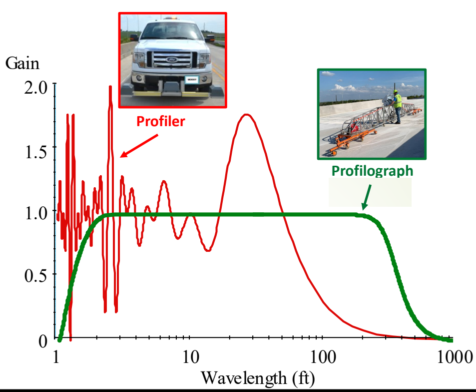
Profilograph VS Profiler profiles



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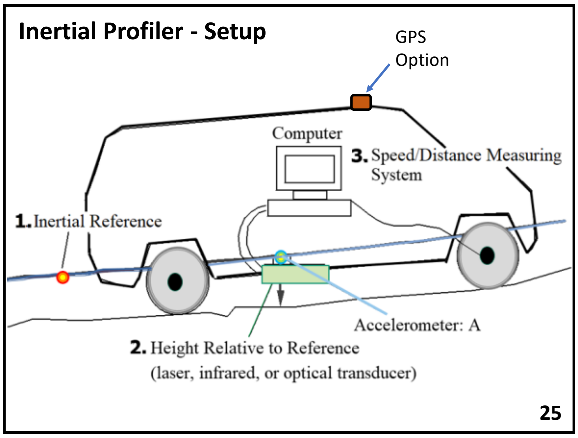
Inertial Profiler - Setup
GPS Option
Computer
3. Speed/Distance Measuring System
1. Inertial Reference
Accelerometer: A
2. Height Relative to Reference
(laser, infrared, or optical transducer)
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Collection and storage

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Data collection window
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twin mtn job
EOP

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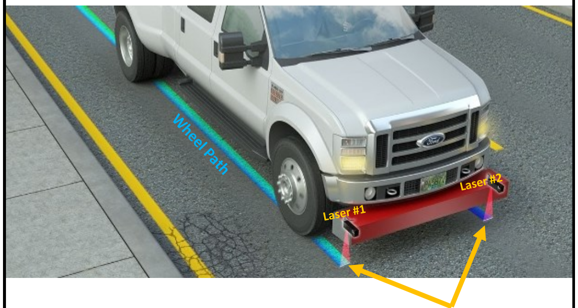
MEAN ROUGHNESS INDEX (MRI)



Lasers measuring Left and right wheel paths for the same lane measuring a true profile.

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Mean Roughness Index (MRI)

- The average of the IRIs from the left and right wheel paths for the same lane is the Mean Roughness Index (MRI).
- Pavement smoothness is quantified as averaging the results of the IRI for the left and the right wheel paths in an individual lane.
- Every 0.1-mile (528 ft) section of the lane is analyzed.

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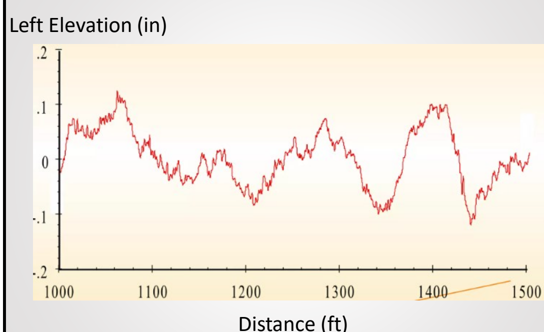
True Profile - Graph



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5. Reference Profiler (SurPRO)

- MoDOT's primary reference profiler
- Reference profilers obtain <u>true</u> profiles of pavement.
- Used for verification of profilers.
- Dispute resolution
- Repeatability cross correlation above 98%.

Profile Accuracy:
0.01 in/25 ft
Plus, level error for non-closed loop surveys.

Computed Roughness Indices:
IRI, RN (PRI, RI)

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Dispute Resolution

- Any dispute between the engineer and contractor regarding IRI QC/QA comparisons that cannot be settled at the project level is arbitrated with the MoDOT reference profiler.
- The results of the reference profiler are binding for the engineer and the contractor.

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AASHTO

AASHTO M328 Inertial Profiler
ASHTO R56 Certification of Inertial Profiling Systems
AASHTO R57 Operating Inertial Profiling Systems

State Technical College of Missouri Airport – Official Testing Site

Certification of Inertial Profiling Systems

AASHTO M328, R56 and R57

MoDOT IRI Certification

Rev 12/06/2023

1

INTRODUCTION

Ask Jason Blomberg
For updates and dates
to certify profilers. 573-526-4338

- All inertial profilers used for construction acceptance must be VERIFIED annually, call Jason Blomberg for the location.
- Operators of inertial profilers shall hold current certification issued by the Technician Certification Program (TCP).

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INTRODUCTION

The certification test section is measured with a reference profiler.

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INTRODUCTION

- MoDOT will not calibrate or 'fix' inertial profilers at the certification site.
- Inertial profilers will not be able to adjust filters to match desired results.
- No filters are allowed.
  - Except for built-in 10-inch low pass filter that can't be turned off.
- Un-calibrated equipment can generate erroneous data!!

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SCOPE

- Inertial Profilers are used to measure longitudinal surface elevation based on an inertial reference system that is mounted on a host vehicle.
- This presentation is to provide standards and procedure for obtaining certification for longitudinal surface elevation profile measurements and network-level data collection.

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SCOPE

- System and operator certification include the following:
  1. Verification of calibration
  2. Field Certification of equipment
  3. Certification of operators

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MODOT NOTE: SCOPE

Calibration of the inertial profiler re-establishes target values in which it operates by correcting the scale of a transducer. This calibration is usually conducted by the manufacturer.

Verification/Certification of the inertial profiler checks the calibration values annually to determine if it is still valid/accurate.

Certification of the driver/operator will be renewed every 5 years. (Completed at STC College classroom)

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TERMINOLOGY

- **Distance Measuring Instrument (DMI)**: A transducer used to determine the longitudinal distance that the measurement vehicle has traveled.
- **Inertial Profiler (IP):** A profile measurement device that measures the pavement profile using an accelerometer to form an inertial reference and a height sensor to measure the pavement surface height relative to that reference.
- **ProVAL**: Computer application used for pavement ride quality analysis.

NOTE: More definitions can be found in the glossary

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REFERENCES

- **AASHTO R 56**
  Certification of Inertial profiling system
- **AASHTO R 57**
  Operating Inertial Profiling Systems
- **AASHTO M 328**
  Inertial Profiler

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THREE STANDARDS

1. Longitudinal (528 ft = 0.1 mile)

- Longitudinal verification standard will be a straight and level roadway test section of at least 528 ft in length with sufficient lead-in distance for the vehicle to attain a constant speed before the start of the test section and a safe stopping distance.
- Measure this length accurately to within 0.05% using a measurement tape.

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THREE STANDARDS

2. Vertical (Block Test)

- The vertical measurement standard will be flat plates or gauge blocks 0.25, 0.50, 1.0 and 2.0 inch in thickness.
- Using a calibrated digital caliper, verify the block thickness of the smooth base plate, the 0.25, 0.50, 1.0 and 2.0 inch gauge blocks, accurate to within 0.001 inch. Mark each block with its known thickness and record it in the log.

NOTE: Each inertial profiler must have their own blocks.

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THREE STANDARDS

3. Vertical (Bounce Test)

- The vertical displacement will be measured from flat plates centered on the ground beneath the height sensors.
- Performed over a simulated distance of 528 ft. A vertical displacement (bounce) of the vehicle of 1 – 2 inches will be performed.

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EQUIPMENT

Minimum Requirements:

The inertial profiling system must meet all requirements and specification found in AASHTO M328 and must be currently certified in accordance with AASHTO R 56.

- **Host Vehicle** – Capable of traveling at a constant speed while traveling at least 20mph for high-speed profilers and at least 15mph for low-speed profilers while collecting pavement profile data.

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EQUIPMENT

Three Transducers OR Sub-Systems
for measuring longitudinal pavement profiles:

1. Height sensor – (Vertical measure)
2. Accelerometer – (Vertical measure)
3. Distance Sensor – (Horizontal measure)

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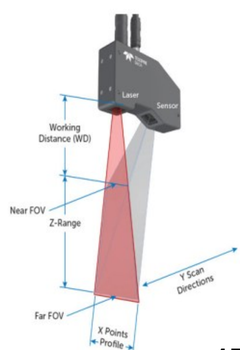
EQUIPMENT
Transducer

1. Height Sensor:
(Lasers)

- Measures the <u>vertical</u> distance (height) between the vehicle and the pavement surface.
- Vertical measurements are usually acquired by one or multiple non-contact laser sensors.
- Lasers are a 4” beam, or a single point laser.



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Height Sensors

EQUIPMENT
Transducer

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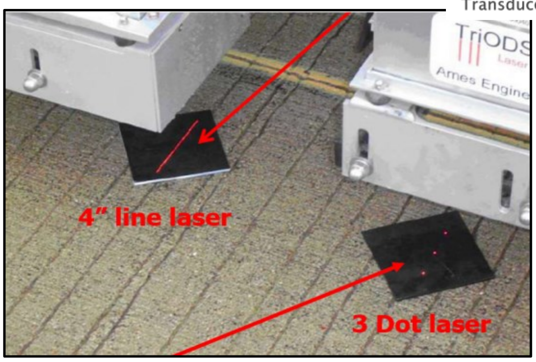
More Height Sensors

EQUIPMENT
Transducer



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2. Accelerometers:

EQUIPMENT
Transducer

- Measures vertical acceleration.
- Vehicle must be traveling a minimum speed of 7 miles/hr. to measure acceleration.
- An inertial profiler uses the signal from the on-board accelerometer(s) to compute the inertial reference value such as relative height that can be combined with the height sensor data to produce a complete profile.
- An accelerometer is paired with each wheel path height sensor to cancel out the vertical motion of the host vehicle.

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EQUIPMENT
Transducer

Distance Measuring Instrument (DMI):

- A horizontal measure, the DMI is a transducer, that measures the longitudinal distance traveled by the profiler.
- Rotation of a wheel measured by detection of pulses as the wheel rotates and notches pass.
- Affected by rolling radius of tire.
- GPS beginning to replace tire-mounted DMIs.
- The DMI, must be accurate to within 0.15% per mile when traveling at the vehicles maximum specified test speed.

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EQUIPMENT
Transducer

DMI

GPS - DMI

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Optical Trigger Device: EQUIPMENT

- Automatically initiates data collection at a specified location.
- Triggered when it detects a change in reflectivity.
- Mounted either vertically or horizontally in the profiler.
- Vertical is triggered by a reflective tape on pavement.
- Horizontal is triggered by a cone with a reflective mark placed on the shoulder.
- Essential for defining section profile limits and for repeated testing.

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EQUIPMENT
Optical Trigger Device

Starting the Measurement – MODOT

- The optical trigger should be used to automatically start the profiler when the machine crosses the testing start point.
  - If conditions preclude using the optical trigger, then the start and end point may be manually triggered, but the profile data must be adjusted to precisely superimpose over the profile length.

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EQUIPMENT
Optical Trigger Device

Advantages of Automated Triggering – MoDOT

- Data collection can be initiated at exact start of the section.
- Roughness features can be identified at correct location in the field based on profile data.
- Repeatability of profile data and roughness indices can be evaluated.

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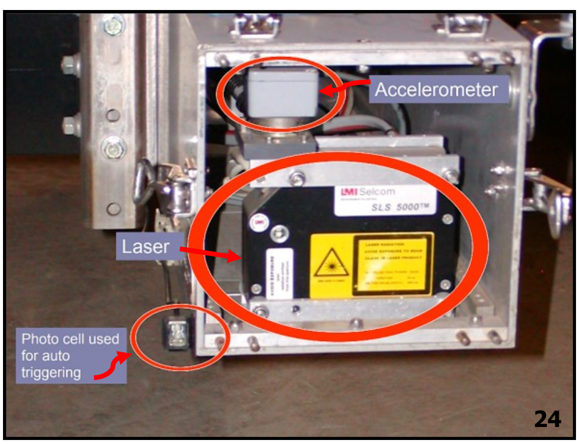

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EQUIPMENT

Integrated System

- Must include hardware and software capable of storing inertial profiles by combining the data from the inertial referencing system, the distance measuring instrument, and the height sensor.
- Must be capable of measuring and storing profile elevations at 3 in. intervals or less.

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EQUIPMENT
Integrated System

Must have the capability of computing the profile elevation data into a summary roughness statistics (IRI) over a section length equal to 0.1 mile (528 ft.) for each longitudinal path profiled.

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EQUIPMENT
Integrated System

- Must have a design to allow field calibration and verification of calibration for the distance measurement (horizontal) subsystem and the height measurement (vertical)subsystem described in "Procedures".
- Must be approved by MODOT verification and certification process.
- Maintain a Calibration Verification Log in accordance with AASHTO R56 to maintain records of calibration history.

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PROCEDURE

1. **Daily calibration verification** is required for QA testing on all MODOT contracts.
2. **Verifying Calibration – Completed Annually** – the following daily verification procedure is required for QA testing and is recommended when an inertial profiler is to be used as a QC instrument.
   - Check the tire air pressure on the wheels of the host vehicle daily and maintain according to the vehicle manufacturer's recommendations.

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Vertical Verification of calibration consists of two tests:

1. **Block Test**
2. **Bounce Test**

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PROCEDURE
Verifying Calibration

1. BLOCK TEST:
   The block test verifies the sensors for accurate elevation readings. This check is performed after the operating system has reached operation stability per manufacturer. During the test, do not lean on the profiler or cause it to move in any way.

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BLOCK TEST:

PROCEDURE
Verifying Calibration

1. Place a smooth base plate under the height sensors. Allow the system to measure this height. Zero out the sensors.
2. Center a 0.25-inch block under the height sensors on top of the bas plate and record height measurement.
3. Replace the 0.25-inch block with the 0.50-inch block. Record the height measurement.
4. Replace the 0.50-inch block with the 1.00-inch block. Record the height measurement.

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BLOCK TEST:

PROCEDURE
Verifying Calibration

5. Replace the 1.00-inch block with the 2.00-inch block. Record the height measurement.
6. For each gauge block, the absolute difference between the height measurement and the actual gauge block thickness should be less than or equal to 0.01 inch.

Side Note: As a minimum perform the 1 and 2 inch measurement blocks, if fails the minimum test, then perform the full range of block measurements.

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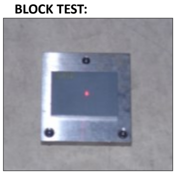
Height Sensor Verification

PROCEDURE
Verifying Calibration

BLOCK TEST:



Reading on base plate + calibration plate (H1)

Reading on base plate + 1 inch block + calibration plate (H2)

H2 – H1 = Block Height

1-inch block must be within ± 001 inch to pass

NOTE: Calibrated blocks should be marked with accurate measure as well as recorded in the log from earlier work.

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2. BOUNCE TEST

PROCEDURE
Verifying Calibration

State Technical College Airport

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BOUNCE TEST:

PROCEDURE
Verifying Calibration

This test is performed while the host vehicle is on a flat level surface. It is performed after the operating system has reached operational stability according to the manufacturer. Follow the manufacturer's recommendation for performance procedure of the bounce test. The static portion of the test should result in an IRI of less than 3 inch per mile and the bounce portion shall result in an IRI of less than 8 inch per mile. This test is performed over a simulated 528-foot section.

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BOUNCE TEST

PROCEDURE
Verifying Calibration

1. The typical method for a high-speed host vehicle, is to push the mounting system (bumper) down an inch or so and allow to rebound.
2. For a lightweight slow-speed host vehicle, stand toward the center of the vehicle platform and hop up and down such that all four corners of the vehicle create a bounce.
3. Save the test results on the latest version of ProVAL software.

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Driving the Test-Track

- Drive at a constant speed;
  - Manufacturer provides operating speed range.
  - Usually ranges from 15 to 65 mi/hr. for high-speed profilers.
  - Max speed for lightweight profilers is usually 20 mi/hr.
- Accelerometer cannot measure accurately at low speeds.
- Do a 'dry run' through testing length for familiarization.

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PROCEDURE
Verifying Calibration

LONGITUDINAL VERIFICATION: (accelerometer)

1. Clean the roadway path to be measured of all debris. Collect data on dry pavement. (Damp pavement is OK, if approved by MODOT).
2. Warm up host vehicle tires and operating system in accordance with manufacturer's recommendations.
3. Turn off filters, except the built in 10-inch low pass filter.

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LONGITUDINAL VERIFICATION

PROCEDURE
Verifying Calibration

4. Perform the longitudinal verification by navigating the inertial profiler over a measured test section of 528 ft. ± 0.1 ft.

5. If the profiler's distance measuring subsystem measures the length of the test section to within 0.2% of its actual length, the system has passed the test. If the system fails to measure the length with in 0.2% the calibration, it shall be adjusted according to the manufacture's guidelines and longitudinal verification repeated.

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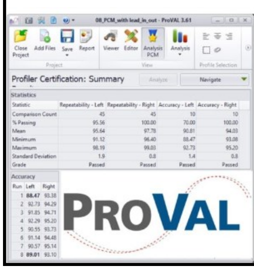
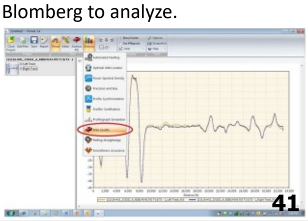
LONGITUDINAL VERIFICATION

PROCEDURE
Verifying Calibration

6. Measured profiles shall be saved and analyzed in ProVAL.

Note: After the test run at the airport, results shall be saved on a thumb drive and given to Jason Blomberg to analyze.





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CERTIFICATION

1. Success in achieving an **average of 92% repeatability** when correlating with other contractor certification files will result in a PASS for that category.

2. Success in achieving an **average of 90% accuracy** in each wheel path when compared to the MoDOT accepted calibration test run will result in a PASS for that category.

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OPERATOR CERTIFICATION

- Operators of inertial profilers must pass a written exam (computerized), a proficiency test, and be certified to operate an inertial profiler.
- Must have undergone training on the use of the specific inertial profiler they will be operating in the field.
- Must know how to perform profiler checks, collect profile data.

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OPERATOR CERTIFICATION

- Must bring their profiler with them to the test site for annual certification. The profiler certification may be on a different day from the exam and proficiency tests.

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OPERATOR CERTIFICATION

- MoDOT Certification card:

Aggregate Technician (AT) ☐	5/31/2027	Plasticity Index (PI)	5/31/2027
Bituminous Technician (BT) ☐	5/31/2027	Concrete Field (CF)	5/31/2027
Soil Density (SD) ☐	5/31/2027	Concrete Strength (CS)	5/31/2027
Superpave QC/QA (SP) ☐	5/31/2027	Field Density (FD)	
Agg. Specific Gravity (ASG)		Low Slump (LS)	5/31/2027
Tension Strength Ratio (TSR)	5/31/2027	HMA Aggregate Test (HMA) ☑	5/31/2027
Registered Intern (RI)		Binder Ignition (BI)	5/31/2027
International Roughness Index (IRI)	5/31/2027	Compressive Strength (CM)	

Note: Check mark indicates a restriction.

MoDOT Technician Certification (573) 522-2742

This is to verify that: John Doe

is certifed to perform inspection or testing on MoDOT Projects. TCP-MQE

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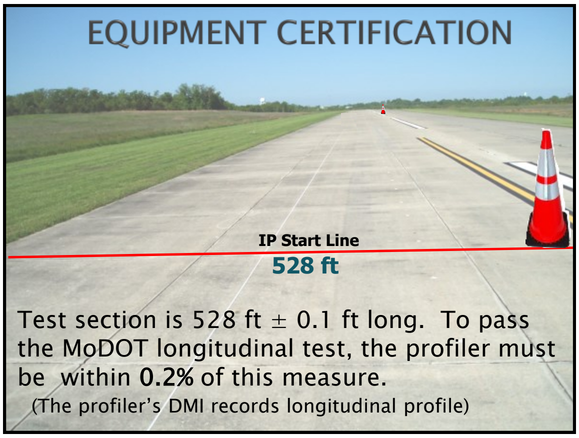

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EQUIPMENT CERTIFICATION

12 DYNAMIC CERTIFICATION TESTS

1. Test Sections –
Must be ≥528 ft. in length. With a proper lead in distance and safe stopping distance.

MODOT Note: The profiler should stay a constant transverse distance from the centerline or shoulder. Both wheel paths should be **3 feet** from and parallel to the edge of lane (assuming 12-foot lane width).

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EQUIPMENT CERTIFICATION

Speed Changes – MoDOT

- Operate at a **constant speed** while collecting data.
  - Manufacturer provides operating speed range.
  - Usually ranges from 15 to 65 mi/hr. for highspeed profilers.
  - Max speed for lightweight profilers is usually 20 mi/hr.
- Accelerating or decelerating while collecting profile data will contaminate the data.
- Newer 'zero-speed' Inertial Profilers are exception to this requirement.

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Lead-in Distance

- Profiler needs a lead-in distance to bring it up to speed and to initialize filters used for profile computation
- Manufacturers' recommendations should be followed regarding lead-in distance

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Lead-out Distance

- At the project end point the profiler continues for a lead-out distance.
- The profiler should not start to slow until passing the end point, so the accelerometers and the resulting data points are not affected.

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EQUIPMENT CERTIFICATION

2. Reference Profiles –
Shall be made on the designated profile trace of each test section.

- Five repeat runs of the candidate inertial profiler shall be made at each test speed on the designated profile trace of each test section in the prescribed direction of measurement.
- Make five runs at the maximum desired certification speed and five runs at the minimum desired certification speed.

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EQUIPMENT CERTIFICATION

Reference Profiles

- Data collection shall be automatically triggered at the starting location of the section, and reported so that a longitudinal position of zero occurs at the starting location.
- An automatically detected mark at the end of the section may be used to verify the DMI repeatability and accuracy.

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EQUIPMENT CERTIFICATION

3. Test Data –

Report data shall be reported in a format specified by MODOT (ProVAL).

- **Use the naming convention as indicated in up coming slide.**
- The performance of the profiler is evaluated by analyzing the test data using cross-correlation to establish the repeatability and accuracy for the application of the device. *ProVAL* software can be used for this.

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(Table 1) Electronic ppf file Naming Convention*

Abbreviation	Definition
YYMMDD-###_	Contract ID (Letting date-Call Number)
YYMMDD_	Test Date
Q _	Type of quality test (C for control, a for assurance)
D	Direction of Lane (N,E,W or S)
L	Lane number (1for inside lane, increasing by one for each lane to the right)
W	Wheel path (L, R, or B)
S	Beginning Log Mile or Station (Rounded to nearest thousandth log mile or foot)

- Example: 100528-501_111103_C_N2R105045.ppf

YYMMDD-###_YYMMDD_Q_DLWS.ppf

100528-501_111103_C_N2R105045.ppf

Letting Date, Call #, Test Date, QC, North, Lane 2, Right Wheel Path, Station #(1050+45)

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Naming Convention

Example #2:

Station:	945 + 15
Purpose:	Quality Control
Letting Date:	06/09/2023
Test Date:	07/16/2023
Lane Direction:	West
Lane:	Inside Lane
Wheel Path:	Left
Call Number:	390

Answer: 230609 390 230616 C W1L 94515

YYMMDD-###_YYMMDD_Q_DLWS.ppf

Letting Date, Call #, Test Date, QC, West, Inside, Left Wheel Path, Station #(945+15)

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EQUIPMENT CERTIFICATION

4. Equipment Repeatability –

Evaluate repeatability using the cross-correlation of the filtered output.

- Calculate the repeatability score of each trace.
  - For single-sensor profilers, one score for each path will be determined:
  - For dual-path profilers, twice as many scores with be determined, two for each test section.
  - When the IRI is applied to the profile, the IRI filter should be used.

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EQUIPMENT CERTIFICATION

Equipment Repeatability

- **Equipment Precision (Repeatability)**
  - Compare ten Inertial Profiler runs over same test section against each other.
  - Calculate repeatability agreement score.
  - Score of **0.92%** or greater is required.

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EQUIPMENT CERTIFICATION

5. Equipment Accuracy –
Evaluate accuracy using the cross-correlation of the appropriate filtered output. On each trace, cross-correlate each of the ten profiles to the reference profile.

Equipment Accuracy (reproducibility)

- 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.

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EQUIPMENT CERTIFICATION

6. Cross-Correlation –
When cross-correlating two profiles, the following steps are required:

- Apply the filter associated to both traces before cross-correlating them. (for IRI, use the IRI filter).
- When comparing a profile from a candidate device to a reference profile, interpolate the candidate profile to the recording interval of the reference profile.

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EQUIPMENT CERTIFICATION

7. Verification of Computed Ride Statistics (IRI)– The test equipment software must be capable of computing and reporting the IRI of each profile trace tested.

- The performance of the calculation of known accuracy.
- Each IRI value should be comparable to the value from the reference program such as *ProVAL*, with an error not greater than **2%**.

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EQUIPMENT CERTIFICATION

8. Distance Measurement Instrument Test–

MODOT can elect to test the accuracy of the DMI on one section.

- It is recommended this test be performed before the profiler obtains data at the test sections because an error in the DMI can cause the profiler to fail the Equipment Accuracy criteria.

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EQUIPMENT CERTIFICATION

9. Distance Measurement Instrument Test Section – Provide a section for the DMI testing.

- The test section at least 1000 ft in length, with proper lead in distance for constant speed before the start of the section and a safe stopping distance at the end.
- Can use the section that was used for accuracy and repeatability testing.
- Clearly mark the starting and ending points of the test section.

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EQUIPMENT CERTIFICATION

Distance Measurement Instrument Accuracy

- Measure the distance between the starting and ending points with a measurement tape.
- At least 3 auto-triggered runs at the lowest and highest test speeds of the candidate inertial profiler shall be made on the designated length of pavement in the prescribed direction of measurement.

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EQUIPMENT CERTIFICATION
Distance Measurement Instrument Accuracy

- At the end of each run, record the reading from the profiler's DMI.
- For high-speed profilers, this results in at least six values.
- Collection speed-governed devices should **make at least 5 runs**.

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EQUIPMENT CERTIFICATION

10. DMI Accuracy –
Compute the absolute difference between the DMI readings and the known distance of the path tested for each run.

- The average of the absolute difference for both the high-speed and low-speed runs. If applicable, must be less than **0.2%** to pass the test.

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EQUIPMENT CERTIFICATION

11. Test Results – Reporting
MODOT documents the certification results. Results may include the following:

- Identification of the profiler tested, make, model serial number, software version, owner, etc.
- Date of last certification
- Operator of the profiler
- Name of individual conducting the test.
- Date of the test
- Number of paths the profiler can measure in the same run.

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EQUIPMENT CERTIFICATION
Reporting

- Filter type, name of the filter program, and application program version number used to evaluate the profiler accuracy.
- Overall determination from the test: Pass or Fail.
- Known longitudinal distance of the DMI test section.
- Average absolute difference between the DMI readings and the known distance, expressed in distance unit and as a percentage of the known longitudinal distance.
- Information on each trace: overall repeatability score, overall accuracy score, and average % difference of the IRIs computed from the profiles and those from the reference software.

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EQUIPMENT CERTIFICATION
Reporting

- The report shall also label each test result with a Pass or Fail depending on whether the given test value meets or fails to meet the prescribed criterion.
- The profiler must pass all tests to be certified.
- A MODOT certification label, decal or marking shall be placed on the profiler as evidence of certification. This decal shall show the expiration date (month and year) of the certification.

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EQUIPMENT CERTIFICATION

Post-Operational Checks – MoDOT

- Perform cursory check on raw profile data to see if it is reasonable.
- Look at IRI values and see if they are reasonable.
- Overlay repeat runs and see if they match.

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EQUIPMENT CERTIFICATION

Post-Profiling- MoDOT

- Save ppf file data to flash drive or other electronic media. Raw data must be submitted to the Engineer within 24hr of testing.
- Raw profiles shall be analyzed by MoDOT in ProVAL.

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International Roughness Index

(IRI)

2024

Proficiency Pack

Name: ____

Employer: ____

AASHTO TM59: IRI Profiler Operator Qualification

PROFICIENCY CHECKLIST

Applicant____

Employer____

	Trial 1	Trial 2
1. Explain: Is the machine certified by MoDOT? Setup with values on calibration certificate? Is the driver IRI certified?		

2. Explain: Items that should be checked prior to profiling.
• Vehicle fluid levels .... _____
• Headlights, signals, **safety strobes/beacons, signage**........ _____
• Profile path project readiness – dry run .... _____
• Warm up
  ○ Engine........ _____
  ○ Transmission........ _____
  ○ **Tires**........ _____
• **Tire pressure** .... _____
• Visually check sensors .... _____
• Static sensor check........ _____		

3. Explain: Distance Measurement Instrument (DMI) verification procedure (Actual DMI testing will be completed at the Airport in Linn) ❑ Clean, dry, (damp ok) testing track. ❑ Warm up host vehicle tires and operating system ❑ Turn off filters ❑ Set-up the computer for profiling the testing track ❑ Line up with the cone, ready the trigger device ❑ Navigate the inertial profiler over a measured test section of 528 ft. ± 0.1 ft. ❑ Maintain the vehicle at a constant speed through out the test. ❑ Save the profile in a file, transfer to a thumb drive, hand over to the Engineer to analyze ❑ Is the result within 0.15% of the measured length? ❑ If profiler does not meet the 0.15%, make adjustments and repeat the run. NOTE: GPS-DMI must pass within 0.15% of the measured length.	Pass Fail	Pass Fail

4. Demonstrate: Laser Height verification procedure Block Test: ❑ Placed a smooth base plate under the height sensors. Allow the system to measure this height. Zero out the sensors. ❑ Centered a 0.25-inch block under the height sensors on top of the base plate and recorded height measurement. ❑ Replaced the 0.25-inch block with the 0.50-inch block. Record height measurement. ❑ Replaced 0.50-inch block with the 1.00-inch block. Recorded height measurement. ❑ Replaced 1.00-inch block with the 2.00-inch block. Recorded height measurement. ❑ Gauge block height measurement recorded in the calibration log. ❑ For each gauge block, the absolute difference between the height measurement and the actual gauge block thickness is less than or equal to 0.01 inch.		
5. Demonstrate: Bounce Test ❑ Vehicle parked on a level surface? ❑ Performed after operating system has reached operational stability according to manufacture? ❑ With the base plates in position simultaneously under both wheel path sensors, place the vehicle in an operating mode that simulates longitudinal movement and initiate profile data collection. (vehicle is in park) ❑ Subjected the vehicle to a vertical displacement of approximately 1 to 2 in. for the time required to travel 528 ft. ❑ Measured profiles saved and analyzed in ProVAL. ❑ System showed a passing result?		
	Pass Fail	Pass Fail

Examiner:_______________________________Date:________________________

Profiler Sensitivity

MoDOT

Profiler Sensitivity

MoDOT IRI Certification

Rev: 07/20/2023

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Physical & Environmental Effects on Profiles

- There are numerous physical and environmental effects that can effect profile data.
- Debris on pavement can artificially and adversely impact smoothness.

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Hills and Grades

- Can affect accelerometer signals as axis is tilted from vertical
- Theoretical study indicated no problems expected when grade is less than 6 percent

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Curves

- Tilt can affect accelerometer signals.
- Lateral acceleration on curves can contaminate accelerometer signals.
- Theoretical study indicated errors in roughness indices are not significant until lateral acceleration exceeds 0.15 g.

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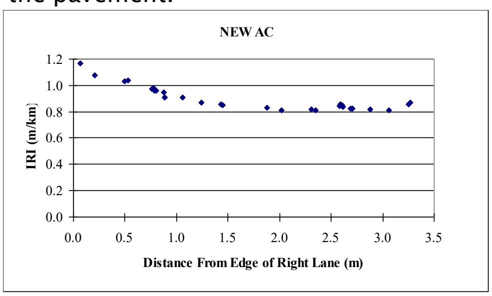
Transverse Variations in IRI

- Different IRI values can be obtained depending on your transverse location on the pavement.



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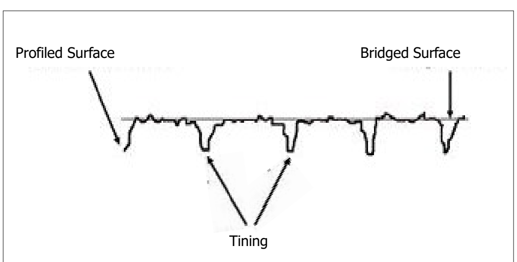
Profiling and Surface Texture

- Longitudinal tining can affect measurements. Transverse tining to a lesser degree.



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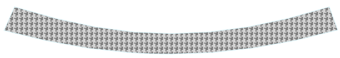
Profiling and slab curling

- Soon after construction curling effects are unlikely to be present.
- Curling is more pronounced during early morning.
- Pronounced curling can be seen on profile data.



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Profiling and Wind

- Wind can make it difficult to track a consistent path.
- If consistent path is not tracked, variations may occur between repeat runs if transverse variations are present.
- High winds can affect data collected by ultrasonic sensors.

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Profiling and Moisture

- Profiling wet pavements cause erroneous data to be collected; however,…
- ….profiling may be performed on damp pavement, but….
- …..do not profile pavements with standing water or if passing vehicles cause water spray

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Tire Pressure

- DMI usually attached to a wheel of the vehicle
- Distance based on revolutions of the wheel
- Tire pressure affects the number of revolutions made in a given distance
- Check cold tire pressure and adjust to pressure used during calibration

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Profiling Sensitivity

A few things that can affect the quality of a profile.

- Changes in speed
- Braking
- Debris in the lane
- Not familiar with the road
- Backed up traffic
- Pulling over for emergency vehicles

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Smoothness Specification

Smoothness Specification
Section 610

MoDOT IRI Certification

07/19/2023

1

610.1

» Description

2

2

- This work shall consist of measuring the smoothness of the final pavement surface using the International Roughness Index (IRI).

- Note: <u>Pre-operational checks include</u>:
  - Check tire pressure
  - Vehicle fluids
  - Headlights, signals, safety strobes/beacons, signage
  - Profile path project readiness - do a dry run
  - Warm up: Engine transmission, and tires
  - Visually check sensors
  - Static sensor check

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Applicable Pavement Types

a) Multi-lift asphalt construction
   Sections 401 and 403
b) Concrete pavement construction
   Sections 502 and 506
c) Combination of surface planning (diamond grinding, milling) and single lift asphalt construction
d) Single lift asphalt construction
   Sections 401 and 403

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610.2

Material Requirements

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610.2.1 Inertial Profiler

- Inertial Profiler (IP)
  - Certified annually
  - Meeting AASHTO M 328 requirements

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610.2.2
ProVAL Software

- (used to)
  - Compute IRI smoothness
  - Locate **A**reas of **L**ocalized **R**oughness (ALR)

  Note: See MoDOT TM-59

  ALR: Is any segment of roadway where the roughness contributes disproportionately to the overall roughness index value.

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610.2.3 Straightedge

- A rolling 10-foot straightedge shall be used for checking longitudinal elevation changes.
- A 4-foot straightedge shall be used for checking transverse elevation changes.

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610.3

» Certification

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Equipment Certification

- All inertial profilers shall be annually certified at the MoDOT certification site in accordance with TM-59.
  - State Technical College of Missouri (STC) at Linn is the current site.

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Equipment Certification

Per MoDOT TM-59, an inertial profiler shall have ≥ 90% average cross-correlation accuracy for five test runs.

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Operator Certification

- Operator of the Inertial Profiler shall hold current certification issued by the Technician Certification Program (TCP).

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610.4

» Construction Requirements

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610.4.1 Smoothness Increments

a) Section – A section is a day's paving and shall begin and terminate at the construction joints. Interruptions designated by the engineer which cause placement to cease and begin at a new location will be considered as a separate section for that day's operation if the separate section is greater than 250 feet.

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610.4.1 Smoothness Increments

b) Segment – Sections shall be divided into segments of **0.1 mile (528 ft.)** lengths except for the last segment.

- If the last segment is greater than 250 feet and less than 0.1 mile, the segment shall be measured as an independent segment.
- If the last segment is 250 feet or less, the profile for that segment shall be included in the evaluation for the previous segment.
- The combined segment IRI shall be weighted for the length.

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610.4.2
Profiling Areas

- 610.4.2.1 Profiling will be applicable to the surface of all the following:
  a) Mainline paving
  b) Auxiliary lanes, turning lanes and ramps for projects consisting of more than 0.5 mile of total profilable pavement.

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610.4.2
Profiling Areas

- 601.4.2.2 Profiling will not be required for the following exceptions:
- **(a)** Bridge decks, bridge approach slabs and concrete approach pavements.
- **(b)** Pavement on horizontal curves with a centerline radius of curve less than 1000 feet and pavement within the super elevation transition of such curves.

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610.4.2
Profiling Areas

- **(c)** Pavement on vertical curves having a “K” value less than 90 and a length less than 500 feet.
- **(d)** Pavement width transitions.
- **(e)** Fifty (50) feet in the direction of travel on each side of utility appurtenances such as manholes or valve boxes.

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610.4.2 Profiling Areas

- **(f)** Fifty (50) feet in the direction of travel on each side of intersecting routes with special grade transition.
- **(g)** Shoulders
- **(h)** Interruptions designated by the engineer which provide independently placed sections shorter than 50 feet.

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610.4.2 Profiling Areas

- **(i)** The last 15 feet of any section where the prime contractor is not responsible for the adjoining surface.
- **(j)** Any lane which abuts an existing lane not constructed under the same contract.

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610.4.2 Profiling Areas

- 610.4.2.3 – In addition to the exceptions in Section 610.4.2.2, profiling may be waived by the engineer if staging of the overall project; such as multiple entrance lane gaps, lane staging, etc.; affects the normal paving operation, or if multiple profile exceptions continuously exist on a large portion of the same roadway. Upon waiver, exempted areas shall be checked with a 10-foot straightedge.

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610.4.3 Longitudinal Straightedging

- Any pavement surface not measured with an inertial profiler shall be measured with a 10-foot straightedge.
- The straightedge path in the longitudinal direction for driving lanes will be located 3 feet from the outside edge and for shoulders will be located in the center.

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610.4.3 Longitudinal Straightedging

- Shoulders that are paved integrally with an adjacent driving lane will not require straightedging.
- Any variations in the longitudinal direction exceeding 1/8 inch (1/4 inch for shoulders) in 10 feet shall be marked for correction in a manner approved by the engineer.

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610.4.3 Longitudinal Straightedging cont.

- Regardless of the smoothness measurement method used, the engineer may check any location of the paved surface with a straightedge for unacceptable bumps or low spots.

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610.4.4
Transverse Straightedging

- The engineer shall randomly check driving lanes for variations in the transverse direction with a 4-foot straightedge.
- Any variations in the transverse direction more than 1/4 inch shall be marked for correction in a manner approved by the engineer.

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610.4.5

- Full Depth Pavement and Multi lift Overlays

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610.4.5
Full Depth Pavement and Multi-lift Overlays

- These construction procedures apply to pavement treatment described in Section 610.1 (a) and (b).

a) Multi-lift asphalt construction
(Sections 401 and 403)

b) Concrete pavement construction
(Sections 502 and 506)

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610.4.5.1
Quality Control Testing

- The contractor shall perform quality control (**QC**) testing in accordance with MoDOT TM-59 procedures on all eligible profiling areas and provide electronic files for smoothness in .PPF format. **QC** testing may be performed daily, or the contractor may elect to profile at the end of paving.

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610.4.5.1
Quality Control Testing

- Reported IRI for each segment is the average of both wheel paths.
- Furnishing inaccurate test results may result in decertification of the operator.

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610.4.5.2
Quality Assurance Testing

- The engineer will perform quality assurance (QA) testing with a MoDOT inertial profiler to verify the QC test results.
- The engineer shall select a continuous portion of roadway that constitutes at least 10 percent of the project lane-miles.

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610.4.5.2 QA Testing

- Both the contractor and engineer shall profile the same QA test length.
- The QC and QA profile data collection shall be automatically started and stopped with electronic triggers.

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610.4.5.2 QA Testing

- The contractor shall provide the electronic file for the QA test length run in .PPF format to the engineer within 24 hours of testing.

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610.4.5.2 QA Testing

- The IRI value for each segment within the QA test length shall be computed as the average of both wheel paths.
- The absolute value of the difference between the contractor and engineer IRIs shall be computed for each segment within the QA test length.

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610.4.5.2
QA Testing

- The average of the absolute values of the IRI difference shall be 8 inches/mile or less.
- The absolute value of the IRI difference for any single segment shall be 12 inches /mile or less.

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610.4.5.3
Areas of Localized Roughness

- All **A**reas of **L**ocalized **R**oughness (ALR) shall be corrected
- ALRs are defined as
  - any length of pavement, having a final posted speed greater than 45 mph, with a continuous section 25-foot average IRI of 125.0 inches or greater
  - any length of pavement, having a final posted speed of 45 mph or less (or AADT ≤ 3500 for ≤ 3" overlays), with a continuous section 25-foot average IRI of 175.0 inches or greater.

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610.4.5.3
Areas of Localized Roughness (ALR)

- After correcting ALRs, additional correction may be necessary to reduce any profile segment in a pavement with a final posted speed greater than 45 mph, to an average IRI of 80.0 inches or less; or reduce any profile segment in a pavement with a final posted speed of 45 mph or less to average IRI of 125.0 inches/mile or less.

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610.4.5.4 Method of Correction

- Corrective action to eliminate ALRs and improve the average IRI shall be accomplished by a method approved by the engineer. Diamond grinding may be used, but the use of an impact device will not be permitted.
- Total grinding depth shall be limited to ¼ **inch.**

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610.4.5.4 Method of Correction

- Satisfactory longitudinal grinding is acceptable as the final surface of the corrected pavements.
- All corrective work shall be completed prior to determination of pavement thickness.

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610.4.5.4 Method of Correction

- The contractor shall reprofile the corrected lengths to verify smoothness compliance and submit an electronic data file in .PPF format to the engineer within **48 hours** after testing.

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610.4.6

» Multi-treatment Overlays

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610.4.6 Multi-treatment Overlays

- These construction procedures apply to pavement treatments described in Section 610.1 (c).

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610.4.6.1(Multi-treatment) Quality Control Testing

- The QC requirements are the same as Section 610.4.5.1, except pavements with ≤ 3500 **AADT** shall meet requirements for multi-lift ≤ 3”.

AADT = Average Annual Daily Traffic

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610.4.6.2 (Multi-treatment) Quality Assurance Testing

- The QA requirements are the same as Section 610.4.5.2.

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610.4.6.3 Areas of Localized Roughness

- All ALRs, as defined in Sec 610.4.5.3, exceeding 175.0 inches/mile shall be corrected.

ALR = Areas of Localized Roughness

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610.4.6.4 Method of Correction

- The requirements are the same as Section 610.4.5.4.

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610.4.7

» Single Lift Overlays

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610.4.7 Single Lift Overlays

- These construction procedures apply to pavement treatments described in Section 610.1 (d)
  - Single lift asphalt construction (Sections 401 and 403)

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610.4.7.1 (Single Lift Overlays) Pre-Construction QC Testing

- Prior to performing any resurfacing work, the contractor shall profile the outside wheel path in accordance with TM-59.
- This control profile will serve as the baseline for calculating percent improvement for the project.

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610.4.7.2 (Single Lift Overlays) Post-Construction QC Testing

- As soon as practical after resurfacing, the contractor shall profile the outside wheel path again.
- The same stationing shall be used to ensure a direct comparison with the pre-construction profile.

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610.4.7.3(Single Lift Overlays) Post-Construction QA Testing

- Same as Sec 610.4.5.2, except that testing shall only be performed in RWP.

RWP = Right Wheel Path

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610.4.7.4 (Single Lift Overlays) Post-Construction QA Testing

- As soon as practical after resurfacing, the contractor shall profile the outside wheel path again.
- The same stationing shall be used to ensure a direct comparison with the pre-construction profile.

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610.4.8

» Marred Surface Area

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610.4.8
Marred Surface Area

- Any area of a segment that has corrective grinding performed without covering the entire segment shall be defined as a marred surface area.

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610.5

» Basis of Payment

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610.5.1
Fixed Value Improvement

- The following basis of payment procedures shall apply to all pavement treatments described in Section 610.1 (a), (b) and (c).
  a) Multi-lift asphalt construction contained in Sections 401 and 403.
  b) Concrete pavement construction contained in Sections 502 and 506.
  c) Combination of surface planning, such as diamond grinding or milling, and single lift asphalt construction contained in Sections 401 and 403

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610.5.1.1
Smoothness Adjustment

- Smoothness adjustments will be paid per segment based on the profile index before any corrections
  - Except for the allowances in Section 610.5.1.5 (Section Correction)
- Any segment with an IRI above the maximum limit in Tables 2 and 3 must be corrected through a method approved by the engineer to achieve the desired smoothness.

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610.5.1.1
Smoothness Adjustment

- When paving widths are greater than the travel lane widths, incentive payment will apply to the driving lane design driving width only.

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610.5.1.2 Incentives

- Incentive payment for smoothness shall be based on either Table 2 or Table 3.
  - Table 2 shall be used for pavements having a final posted speed greater than 45 mph, except multi-lift overlays ≤ 3" and multi-treatment overlays on routes with ≤ 3500 AADT.
  - Table 3 shall be used for pavements having a final posted speed of 45 mph or less, and multi-lift overlays ≤ 3" and multi-treatment overlays on routes with ≤ 3500 AADT.
- Constant-width acceleration and deceleration lanes shall be considered as mainline pavements.

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610.5.1.2 Incentives

Table 2

International Roughness Index, Inches Per Mile	Percent of Contract Price
40.0 or less	105
40.1 - 54.0	103
54.1 - 80.0	100
80.1 or greater	100a

Table 3

International Roughness Index, Inches Per Mile	Percent of Contract Price
70.0 or less	103
70.1- 125.0	100
125.1 or greater	100b

[a] After correction to 80.0 inches per mile or less.
[b] After correction to 125.0 inches per mile or less.

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610.5.1.3 Segment Correction

- If the contractor elects to diamond grind an entire segment and the corrected surface drops below the maximum IRI limits in Table 1 or 2, then the contractor cannot receive any incentives, but the marred surface area deductions for that segment will be waived.

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610.5.1.4
Section Correction

- If the contractor elects to diamond grind an entire section then all segments within the section will be eligible for their respective incentives and the marred surface area deductions for that section will be waived.

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610.5.2
Percent Improvement

- The following basis of payment procedures shall apply to all pavement treatments described in Section 610.1 (d).
  - [Single lift asphalt construction Sections 401 and 403]

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610.5.2.1
Percent Improvement

- The contract price for resurfacing will be adjusted based on the improvement in the profile index for each segment with an initial IRI greater than 60 inches/mile according to Table 3.

Table 4

Percent Improvement (Change in IRI / Initial IRI) X 100	Percent of Contract Unit Price For Pavement
35.0 or greater	103
20.0 to 34.9	100
0.0 to 19.9	97[c]

[c] After correction to 0.0 or greater.

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610.5.2.1 Percent Improvement

- Any segment with an initial IRI less than or equal to 60 inches per mile shall receive no percent improvement price adjustment if the segment IRI after placement of the overlay is also less than or equal to 60 inches per mile.

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610.5.2.1 Percent Improvement

- Any segment with an initial IRI less than or equal to 60 inches per mile that has an IRI greater than 60 inches per mile after placement of the overlay shall be paid at 97 percent of the contract unit price for pavement, but no correction shall be required.

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610.5.3 Deductions

- A minimum deduction of 20 percent of the contract unit price of the paving quantities will be made for marred surface areas as defined in Section 610.4.7.
- The deduction will be applied to an area of pavement extending from edge of the pavement to a longitudinal joint or between longitudinal joints in that section of pavement affected.
- If the length of the section affected is less than 10 feet, the deduction will be computed for 10 feet.

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610.5.4
Testing Cost

- The contract unit price for pavement will be considered as full compensation for all items entering into the construction of the pavement including the cost of smoothness testing.

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610.5.5
Dispute Resolution

- Any dispute between the engineer and contractor regarding IRI QC/QA. comparisons that cannot be settled at the project level shall be arbitrated with the MoDOT reference profiler per the test procedure in TM-59.
- The results of the reference profiler shall be binding for the engineer and the contractor.

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622.30

» Diamond Grinding Existing Concrete Pavement

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622.30.4 Smoothness Requirements

- After completion of any pavement repairs, the contractor shall run the control IRI profile in the outside wheel path in accordance with TM-59.
- Areas where excessive subsidence or faulting prevent diamond grinding coverage may be excluded from IRI testing by the engineer.

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622.30.4 Smoothness Requirements

- After diamond grinding each segment shall be reprofiled and after analysis with the ProVAL software have a final IRI per segment of 65 percent of the control IRI or 80 inches per mile, whichever is greater.

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622.30.4 Smoothness Requirements

- After achieving minimum required smoothness the contractor **cannot** grind into bonus.

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622.30.4 Smoothness Requirements

- The contract unit price for diamond grinding will be adjusted based on the final IRI for any segment before corrections, according to the following schedule

IRI, inches per mile	Increase in Contract Unit Price
40.0 or less	$0.25
40.1 to 54.0	$0.15
54.1 to 80.0	None
80.1 or greater	None*

* After correction to either equal to or less than 65 percent of the control IRI or 80.0 inches per mile.

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Questions?

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(573)526-4338

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ProVAL PSD Analysis Examples

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JCP Joint Faulting

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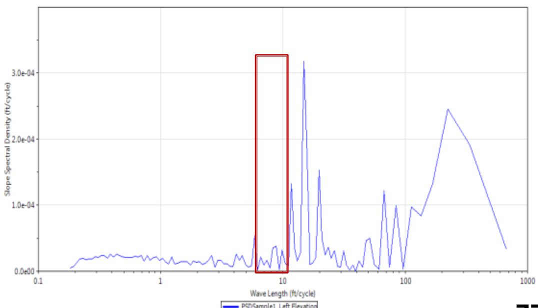
PSD Analysis

JPCP Joint Faulting



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HMA – Inadequate Compaction Freq/Amp

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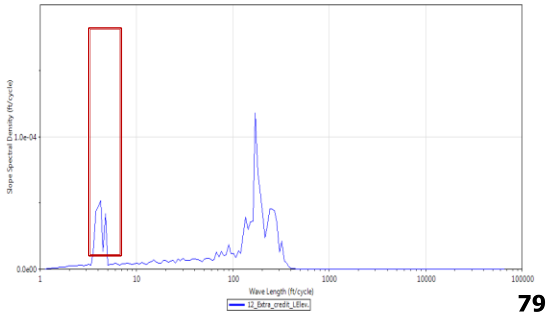
PSD Analysis

Inadequate Roller Freq/Amp Settings on HMA



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Concrete Paving Stringline

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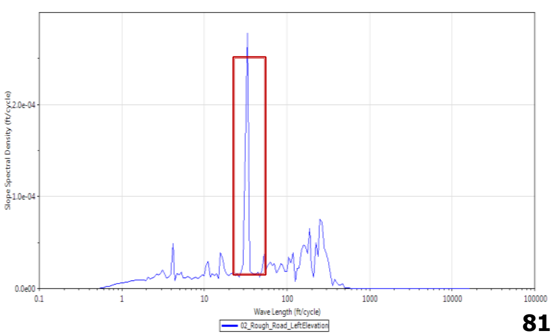
PSD Analysis

Stringline Sags



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MoDOT - TM59

Test Method

106.3.2.59 TM-59, Determination of the International Roughness Index

From Engineering Policy Guide

This method describes the procedure for determining the International roughness index (IRI) of pavement surfaces in English units.

Contents

106.3.2.59.1 Equipment

Inertial Profiler. The International roughness index (IRI) shall be measured with an inertial profiler (IP). The IP shall meet the equipment requirements of AASHTO M 328, which include the following three primary transducers: (1) a height sensor that measures the distance between the pavement and a vehicle reference point, (2) an accelerometer that measures the vehicle vertical acceleration in response to the pavement profile and (3) a distance sensor that provides a location reference as the vehicle moves longitudinally (see Fig. 106.3.2.59.1). The IP shall also be equipped with an automated triggering system that can automatically start and stop data collection using a reference mark. The IP shall store the profile elevation data at an interval of 2 in. or less and have a vertical measurement resolution of 0.001 in. or less. The IP equipment may be either the low speed or high speed type. The IP shall be capable of exporting unfiltered raw profile data to an electronic file (conforming to ASTM E 2560) that can be imported into the ProVAL software program.

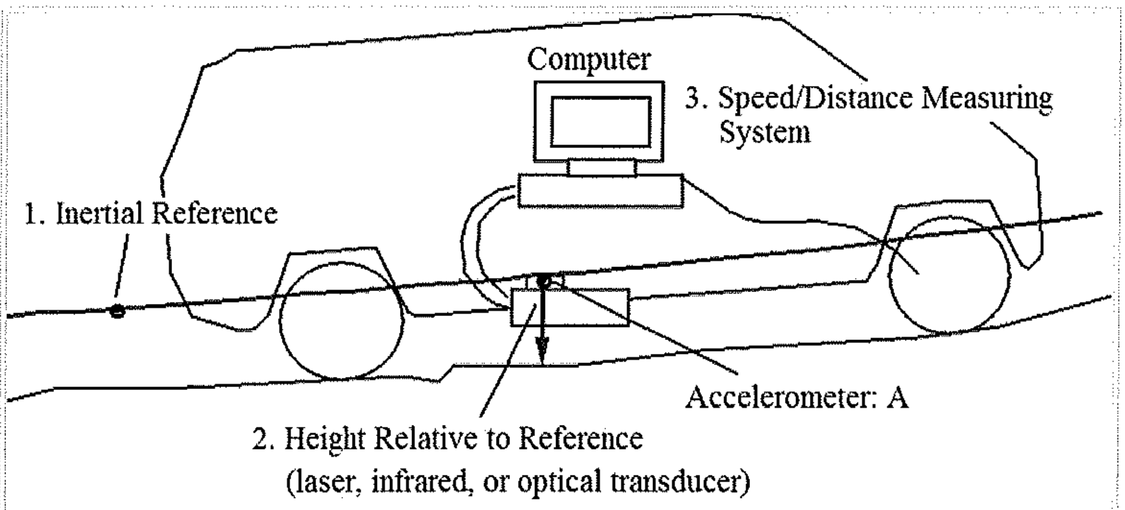


Fig. 106.3.2.59.1

ProVAL. The profile file shall be evaluated using the ProVAL software program. ProVAL is a free program developed by The Transtec Group under contract with the FHWA. The current program version is ProVAL 3.4 (http://www.roadprofile.com/) and can be downloaded.

106.3.2.59.2 Inertial Profiler Certification Procedures

Each IP used for construction acceptance testing on a MoDOT project shall be annually certified (verified) at the Linn State Technical Colleg test site. The test site will have a known IRI in two wheel paths, measured with a reference profiler.

The inertial profiler (IP) shall have its low- and high-pass filters set to zero prior to the certification test. The IP shall have any other controls set according to manufacturer's specifications. The two sensors in the profiler shall be spaced 6 ft. apart.

The IP operator may perform trial profile runs prior to the certification testing. The IP shall start far enough in advance of the test section to reach data collection speed. The IP operator shall perform five profile runs on the test section collecting data in both wheel paths. The IP shall move at a constant speed over the test section. An IP with two sensors shall measure both wheel path profiles in a single pass. An IP with one sensor shall measure each wheel path profile individually. Upon completion of testing, the IP operator shall provide the certification engineer the unfiltered profiles in .ppf file format on a readable electronic storage device such as a flash drive. Each file shall be labeled in the following format:

Contractor_IP Manufacturer_IP Type_Unique Equipment ID #_Wheel Path Tested_Test Run #.ppf
For "IP Type" enter "HS" for high speed and "LS"' for low speed.
For "Wheel Path Tested" enter "L" for left, "R" for right and "B" for both.
For "Test Run #"' enter 1,2,3,4 or 5.
Ex. CBI_Ames_HS_600406_B_2.ppf.

MoDOT will analyze the submitted data using ProVAL. Based on AASHTO R 56-10, the test results of the inertial profiler (IP) shall meet the following requirements:

- Minimum average cross-correlation repeatability shall be 92%.
- Minimum average cross-correlation accuracy shall be 90%.

A ProVAL certification report shall be generated for each inertial profiler (IP) that receives acceptable test results at the certification. The report shall be digitally signed with the State Construction and Materials Engineer signature and shall be electronically stored on the MoDOT V:-drive and sent to the contractor or testing consultant. Inertial profilers that do not pass the certification test shall be corrected offsite by their respective owners and recertified at a later date.

106.3.2.59.3 Construction Acceptance Procedures

Testing Conditions. All objects and foreign material shall be removed from the pavement surface. There shall be no standing water in the wheel paths during testing. Inertial profiler high- and low-pass filters shall be set at zero.

Testing Limits. The inertial profiler shall measure the surface of a pavement section in both wheel paths, that are located 3 ft. from and parallel to the edges of the lane, running in the direction of travel.

- The starting point shall be 50 ft. before the start of the day's paving.
- The starting point shall be a known station or logmile measured to the nearest foot.
- The IP shall use an automated triggering mechanism to initiate data collection at the starting point and end data collection at the ending point.
- The starting point shall be visibly marked for the duration of the project so that subsequent profile measurements may be closely matched.

Data Submittal. The contractor shall submit an electronic file in .ppf format containing the unfiltered raw data collected at the section. Data shall be submitted within 24 hours of the testing on each section. A day's report may consist of more than one section. Inertail profiler files with QC data results shall be submitted to MoDOT using the naming convention in Table 106.3.2.59.3.

Table 106.3.2.59.3, Categories of Warning Signs and Plaques

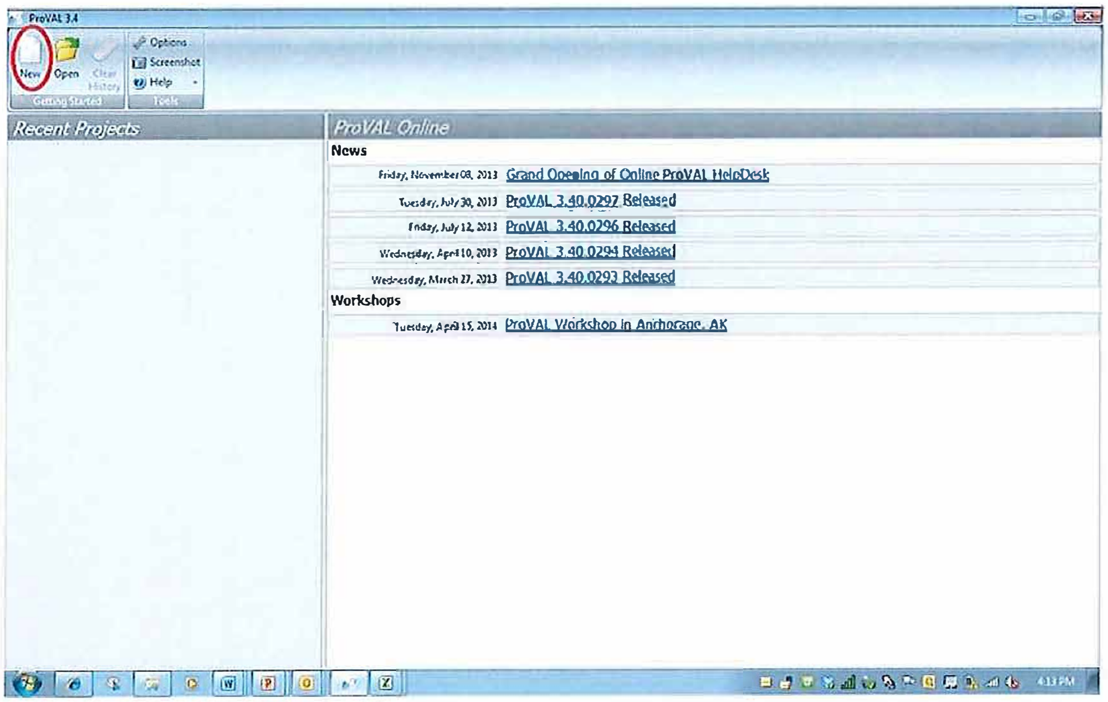
Electronic Profilograph File Naming Convention*	
Abbreviation	Definition
YYMMDD-###_	Contract ID (Letting Date-Call Number)
YYMMDD_	Test Date
Q_	Type of quality test (C for control, A for assurance)
D	Direction of Lane (N,E,W or S)
L	Lane number (1 for inside lane, increasing by one for each lane to the right)
W	Wheel path (L, R, or B)
S	Beginning Station (rounded to nearest foot)
* Example: 100528-501_111103_C_N2R105045.PPF	

Data Analysis. The engineer shall use the ProVAL program to analyze the QC file. ProVAL shall also be used for quality assurance (QA) test data. The analysis will consist of two primary components: 1) *segment smoothness* evaluated with the "Ride Quality" module and 2) *areas of localized roughness* (ALR) evaluated with the "Smoothness Assurance" module.

106.3.2.59.3.1 Segment Smoothness

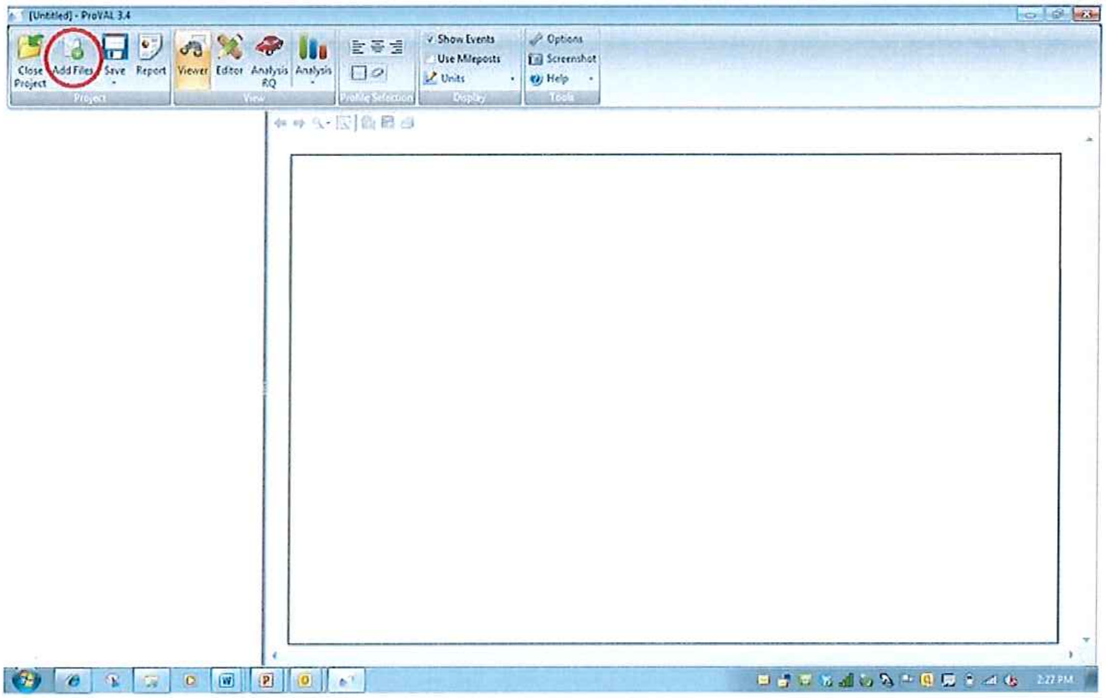
The data will first be analyzed for ride quality, which will determine the average IRI for each wheel track on a per segment basis. The steps are as follow:

- **Open ProVAL program.**
- **Select "New".**



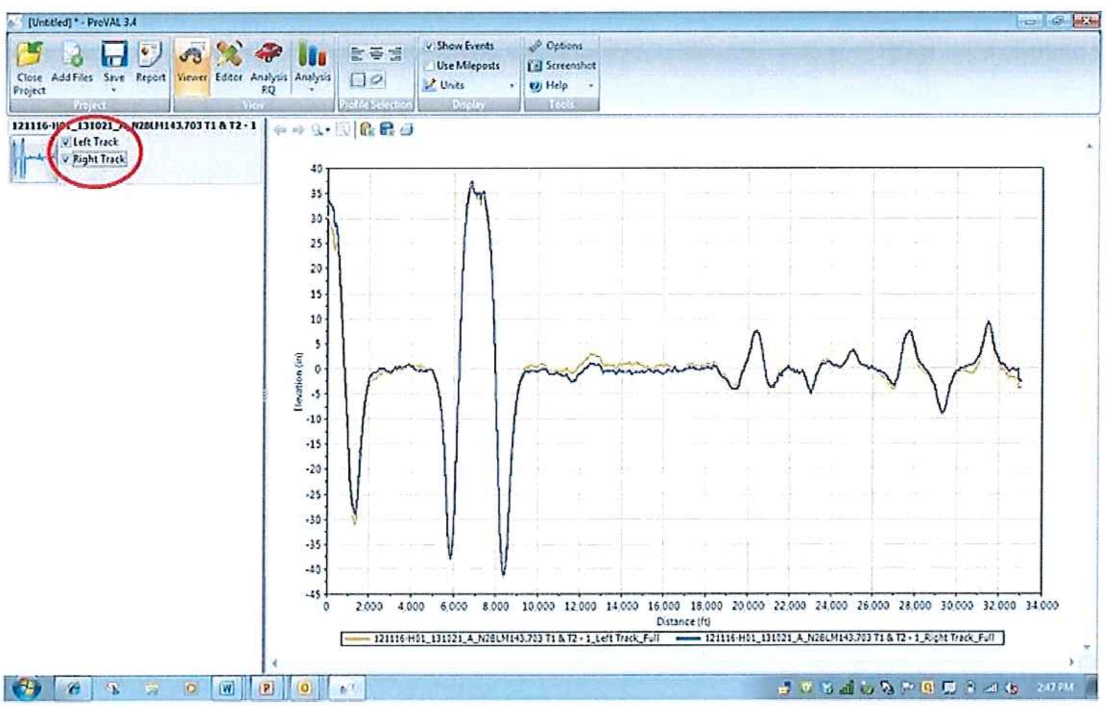
- **Select "Add Files" to import PPF file with QC/QA profile data.**

File(s) will contain either right and left track profiles or single wheel track profiles.

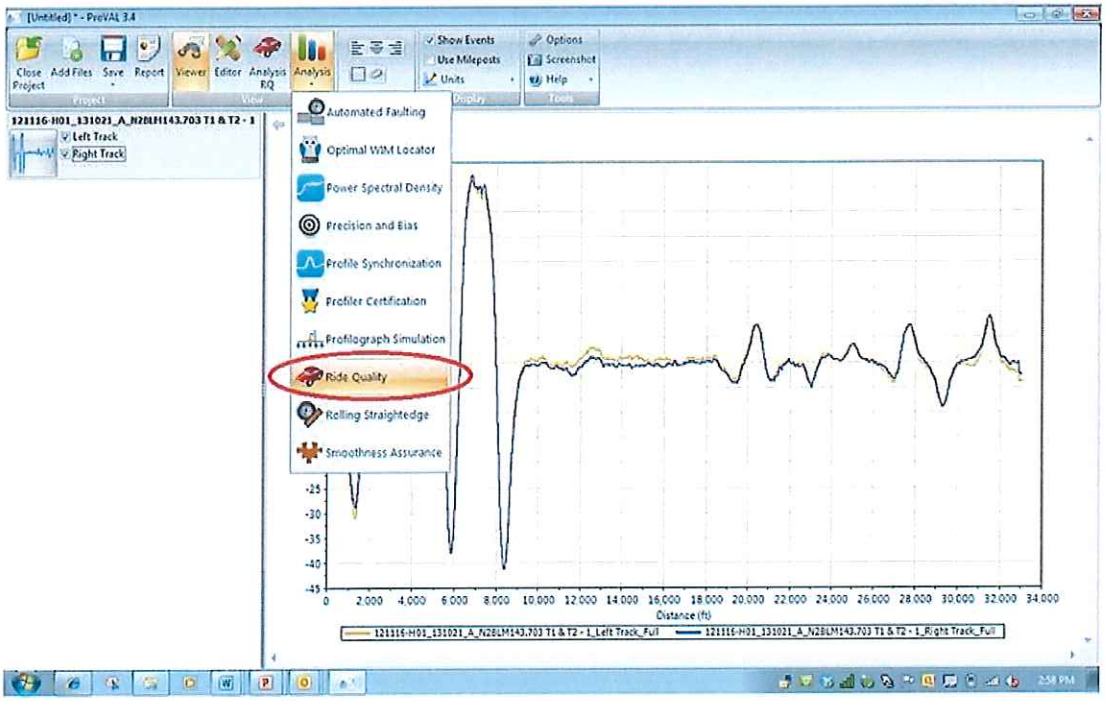


- **Select left elevation and right elevation.**

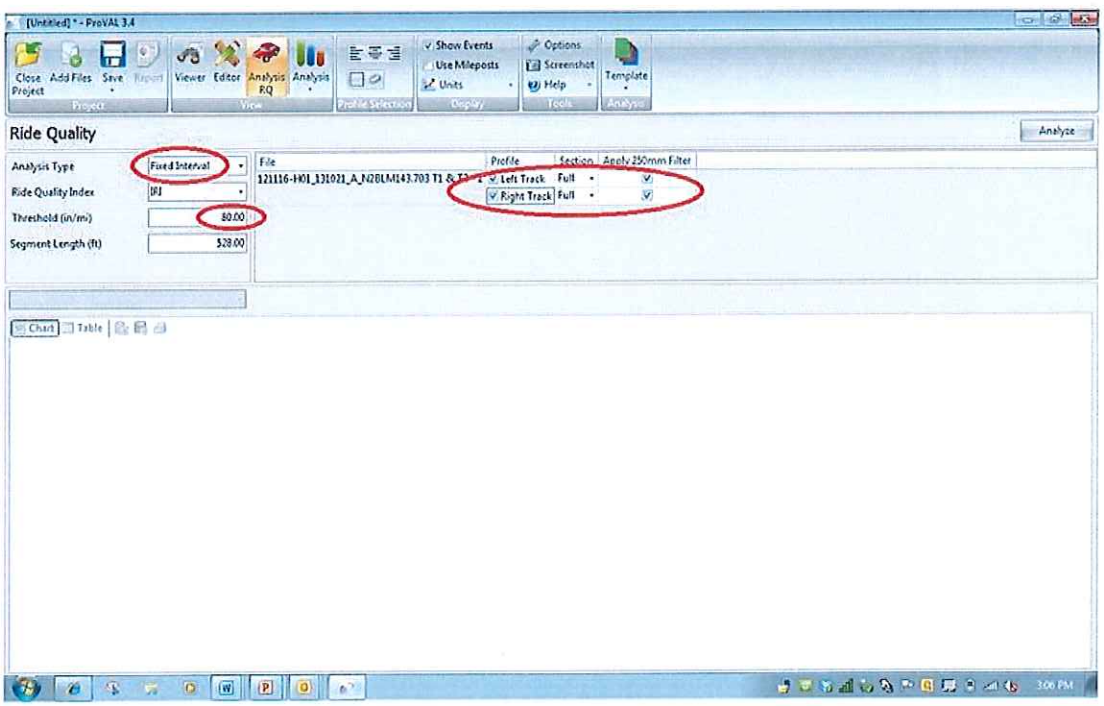
The following example uses a file containing both wheel paths. The program will correctly align files with individual wheel paths, provided the data collection was initiated at the same starting station for both files. The next screen shot shows the actual change in elevation along the profile length.



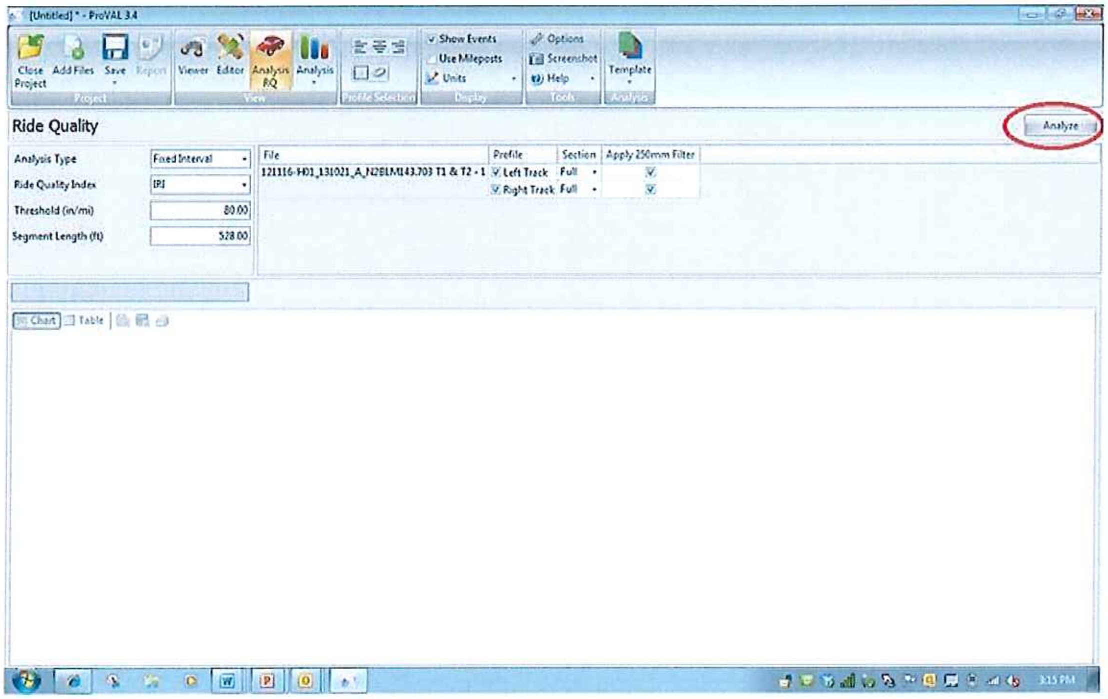
- **Select "Ride Quality" in the "Analysis" module.**



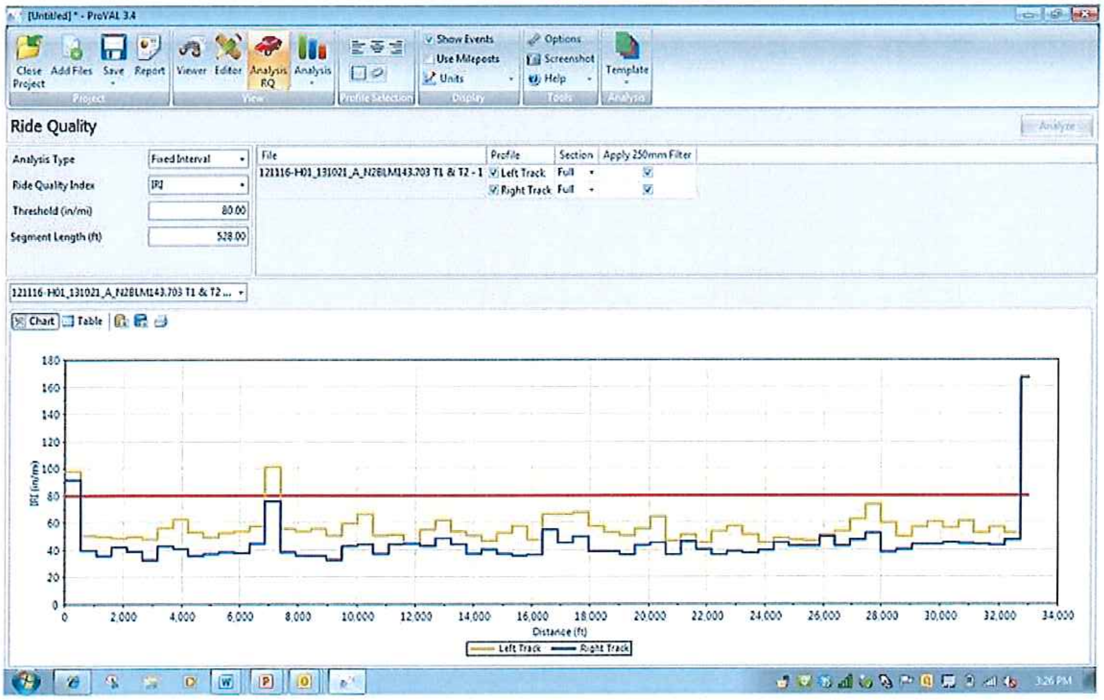
- **Select "Fixed Interval" in the "Analysis Type" dropdown box.**
- **Change "Threshold" limit to 80 (in/mi). (*Note:* this threshold applies to pavement with posted speeds over 45 mph. The threshold is 125 (in/mi) for lower speed routes.) The "Segment Length" should show the default value of 528 ft. and the "Ride Quality Index" should show the default name of "IRI".**
- **Check box for "LElev." and "RElev." and make sure the "Apply 250mm Filter" box is checked for both.**



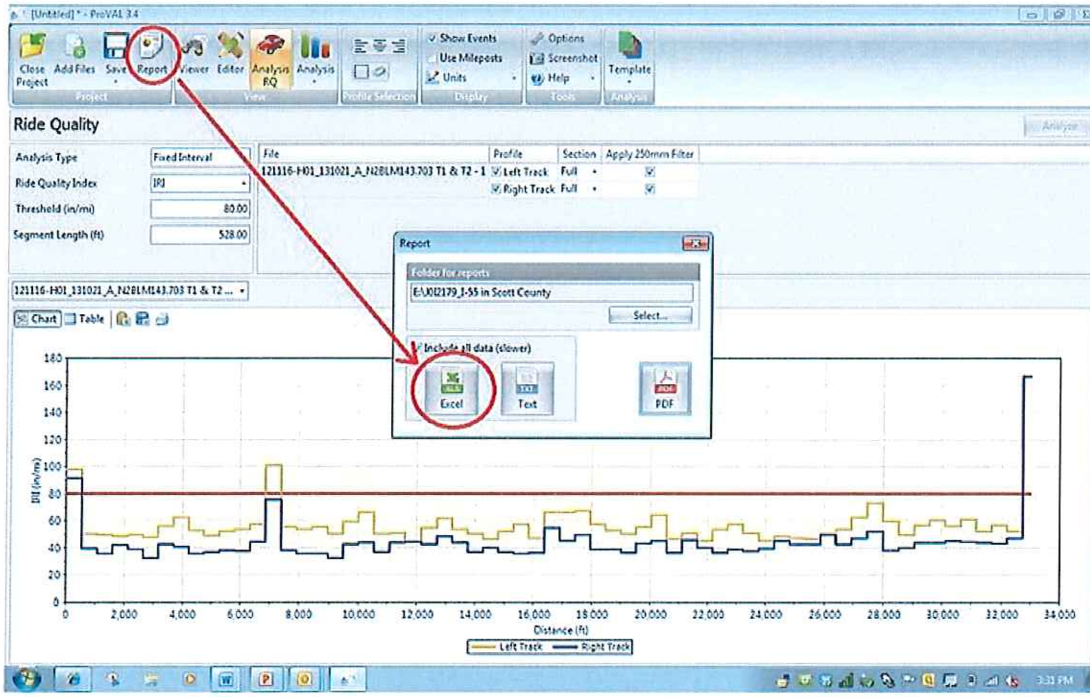
- **Select "Analyze".**



The average IRI of a wheel path for each 528 ft. long segment will be shown on the screen. The drop down menu above table at left can be used to view either left or right wheel path IRI values

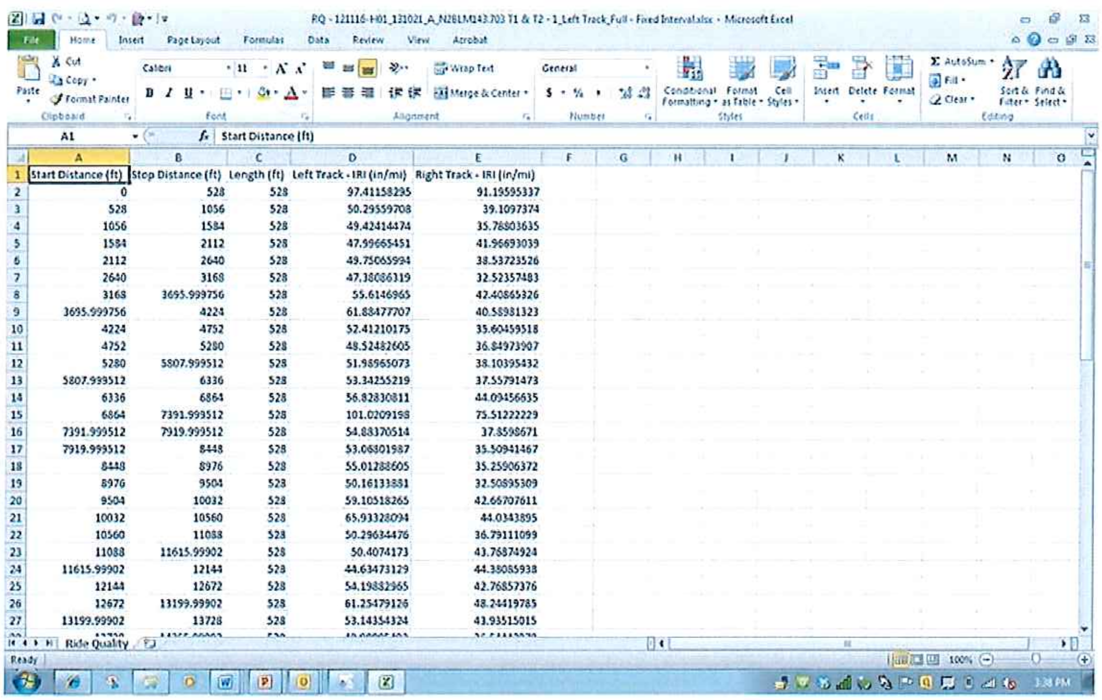


- **Select "Excel" in the "Report" dropdown box.**



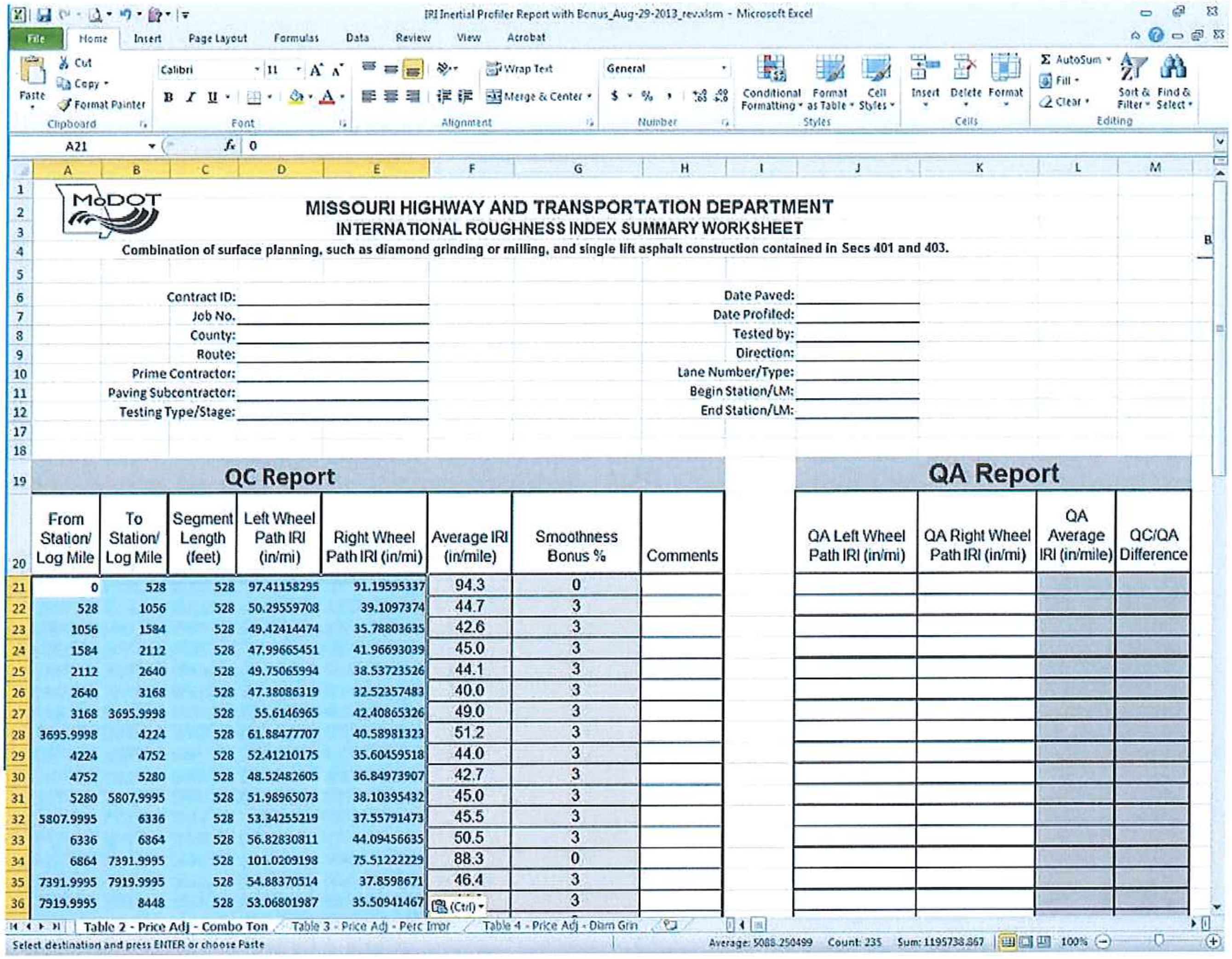
- Open the Excel file.

Average IRI for each segment for both wheel paths is listed in the Excel spreadsheet.



	Start Distance (ft)	Stop Distance (ft)	Length (ft)	Left Track - IRI (in/mi)	Right Track - IRI (in/mi)
2	0	528	528	97.41158295	91.19595337
3	528	1056	528	50.29559708	39.1097374
4	1056	1584	528	49.42414474	35.78803635
5	1584	2112	528	47.99665451	41.96693039
6	2112	2640	528	49.75065994	38.53723526
7	2640	3168	528	47.38086319	32.52357483
8	3168	3695.999756	528	55.6146965	42.40865326
9	3695.999756	4224	528	61.88477707	40.58981323
10	4224	4752	528	52.41210175	35.60459518
11	4752	5280	528	48.52482605	36.84973907
12	5280	5807.999512	528	51.98965073	38.10395432
13	5807.999512	6336	528	53.34255219	37.55791473
14	6336	6864	528	56.82830811	44.09456635
15	6864	7391.999512	528	101.0209198	75.51222229
16	7391.999512	7919.999512	528	54.88370514	37.8598671
17	7919.999512	8448	528	53.06801987	35.50941467
18	8448	8976	528	55.01288605	35.25906372
19	8976	9504	528	50.16133881	32.50895309
20	9504	10032	528	59.10518265	42.66707611
21	10032	10560	528	65.93328094	44.0343895
22	10560	11088	528	50.29634476	36.79111099
23	11088	11615.99902	528	50.4074173	43.76874924
24	11615.99902	12144	528	44.63473129	44.38085938
25	12144	12672	528	54.19882965	42.76857376
26	12672	13199.99902	528	61.25479126	48.24419785
27	13199.99902	13728	528	53.14354324	43.93515015

- Copy and paste this data into the "IRI Inertial Profiler Report with Bonus" Excel spreadsheet in the V:\Smoothness folder. Select the appropriate individual worksheet in the "Start" worksheet (first tab); based on posted route speed, pavement type and pay unit type. The worksheet will automatically generate pay factors for each segment.



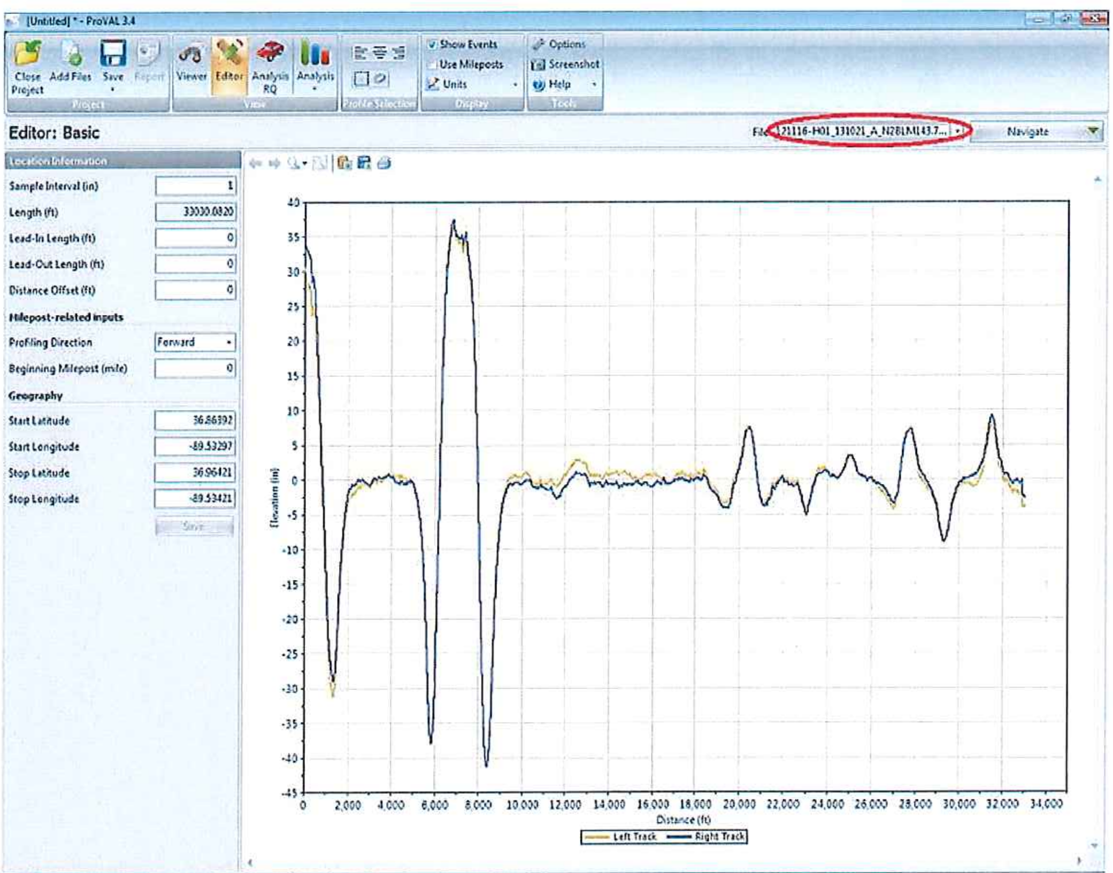
From Station/ Log Mile	To Station/ Log Mile	Segment Length (feet)	Left Wheel Path IRI (in/mi)	Right Wheel Path IRI (in/mi)	Average IRI (in/mile)	Smoothness Bonus %	Comments	QA Left Wheel Path IRI (in/mi)	QA Right Wheel Path IRI (in/mi)	QA Average IRI (in/mile)	QC/QA Difference
0	528	528	97.41158295	91.19595337	94.3	0					
528	1056	528	50.29559708	39.1097374	44.7	3					
1056	1584	528	49.42414474	35.78803635	42.6	3					
1584	2112	528	47.99665451	41.96693039	45.0	3					
2112	2640	528	49.75065994	38.53723526	44.1	3					
2640	3168	528	47.38086319	32.52357483	40.0	3					
3168	3695.9998	528	55.6146965	42.40865326	49.0	3					
3695.9998	4224	528	61.88477707	40.58981323	51.2	3					
4224	4752	528	52.41210175	35.60459518	44.0	3					
4752	5280	528	48.52482605	36.84973907	42.7	3					
5280	5807.9995	528	51.98965073	38.10395432	45.0	3					
5807.9995	6336	528	53.34255219	37.55791473	45.5	3					
6336	6864	528	56.82830811	44.09456635	50.5	3					
6864	7391.9995	528	101.0209198	75.51222229	88.3	0					
7391.9995	7919.9995	528	54.88370514	37.8598671	46.4	3					
7919.9995	8448	528	53.06801987	35.50941467	[illegible]	3					

There may be exempted areas per Sec 601.4.2.2 (http://www.modot.org/business/standards_and_specs/SpecbookEPG.pdf#page=9) within the section profile limits. The engineer should verify that the limits do not go beyond the eligible exemption area. The contractor may elect to:

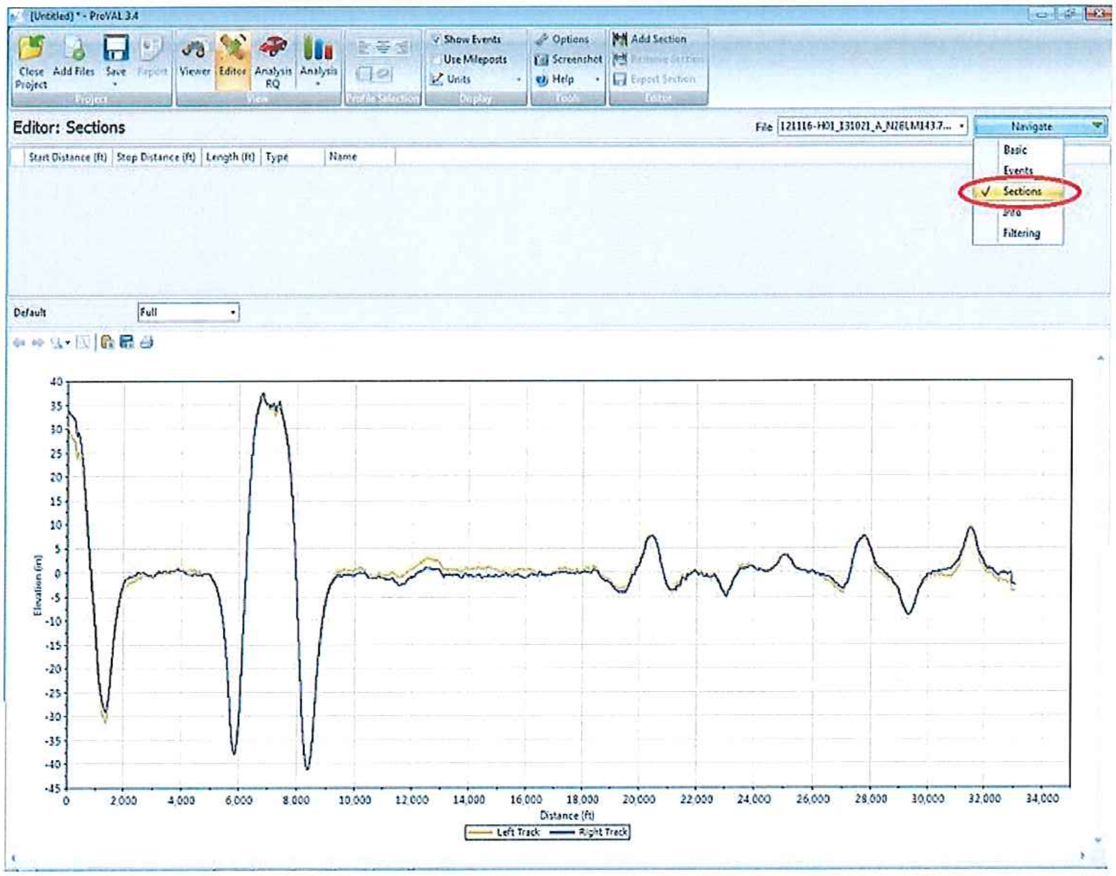
1) Stop the profile run at the beginning of the exemption and begin a new section profile at the end of the exemption.
2) Manually enter exemption boundaries in the data acquisition software during the profile run (typically performed with high speed IPs).
3) Enter a "leave-out" area in ProVAL during the ride quality analysis. The instructions for performing this are as follows:

- **Select "Editor". Select the file from the File dropdown menu.**

- Select the IP file from the "File" dropdown box.

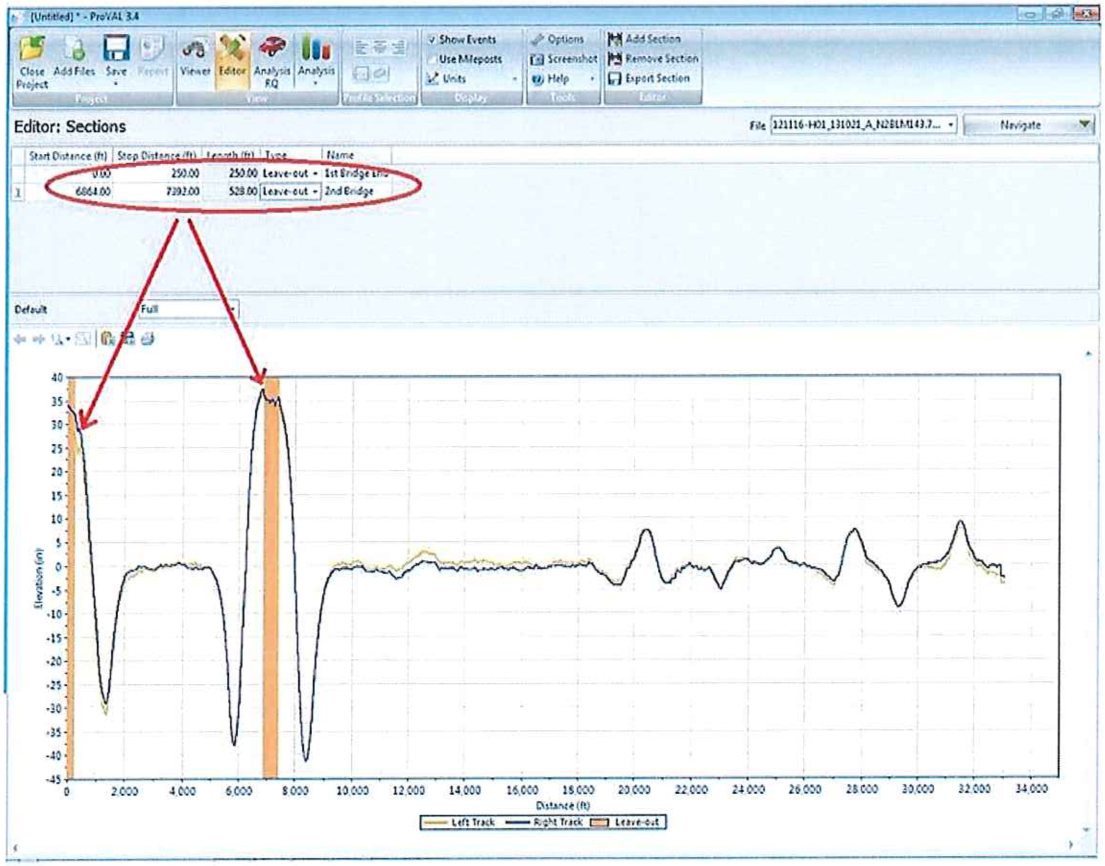


- Select "Sections in the "Navigate" dropdown box.

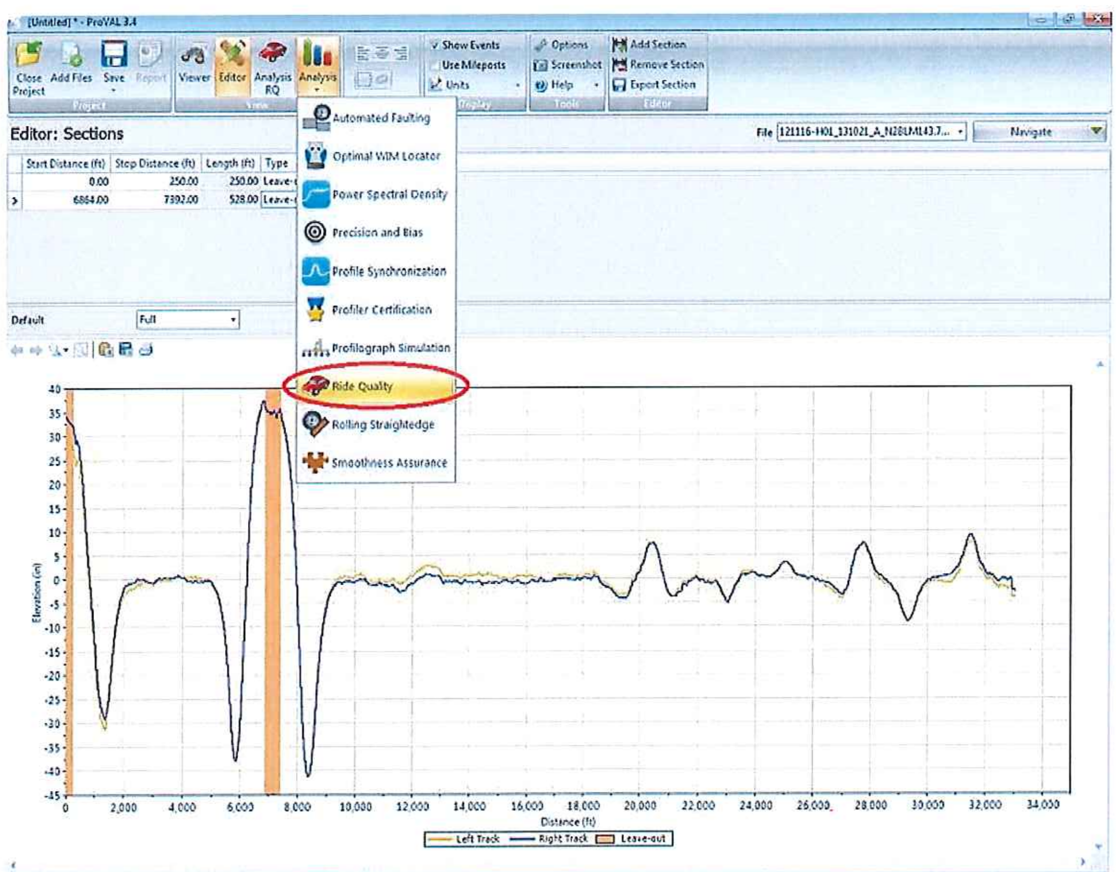


- **Select "Add Section".**
- **Enter section(s) Start Distance, Stop Distance, Type (Leave-out) and Name.**

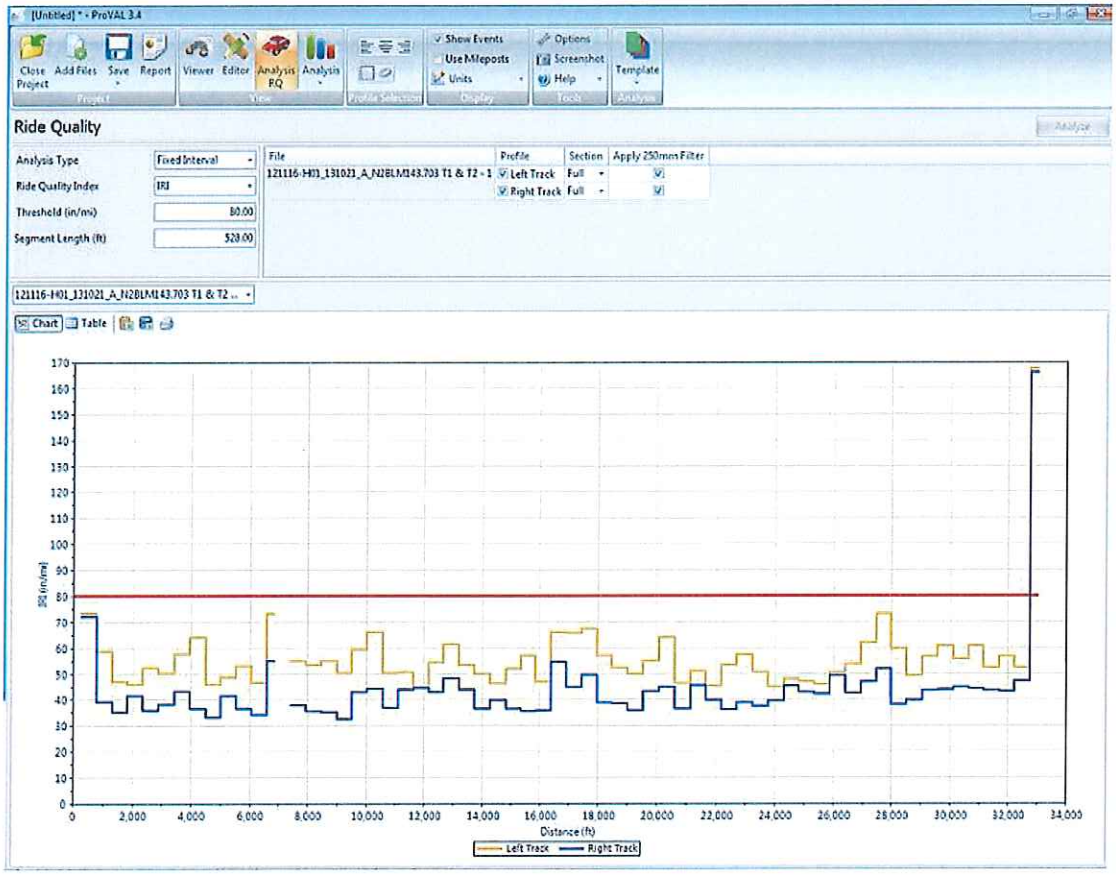
For this example, assume there are two leave-out areas: one at the beginning where a bridge approach on the upstream side is within limits and another over a mile farther where there is another bridge.



- **Select "Analysis" and select "Ride Quality".**

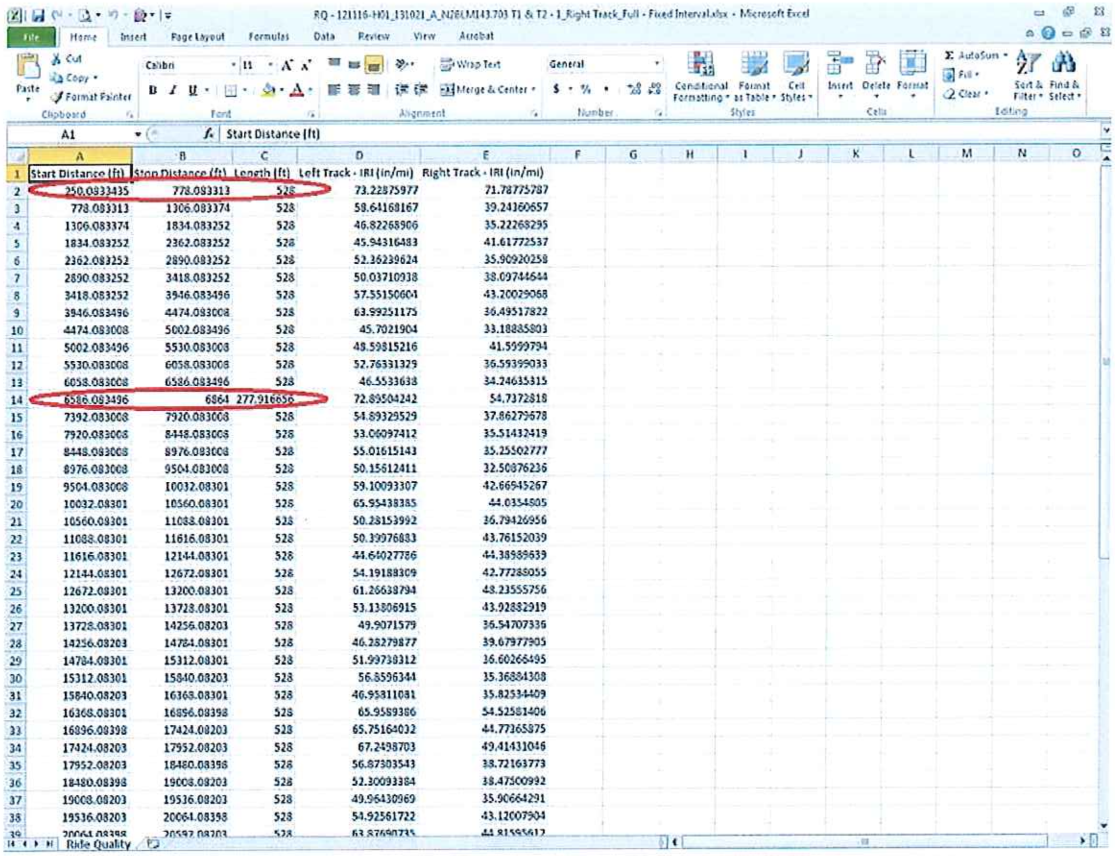


The ride quality summary shown below now excludes the exempted areas of the profile and abbreviates the associated segments accordingly.



- Select "Excel" in "Report" dropdown box.
- Open the Excel report.

Since the first leave-out was at the beginning of the project, ProVAL has shifted the boundaries of the original segments to maintain 528-ft. lengths. However, it truncates the segment preceding the second bridge, so that it can again begin with 528-ft. lengths on the other side of the bridge. This means leave-outs should be established and analyzed in ProVAL prior to exporting the results to the "IRI Inertial Profiler Report with Bonus" Excel spreadsheet in the V:\Smoothness folder.



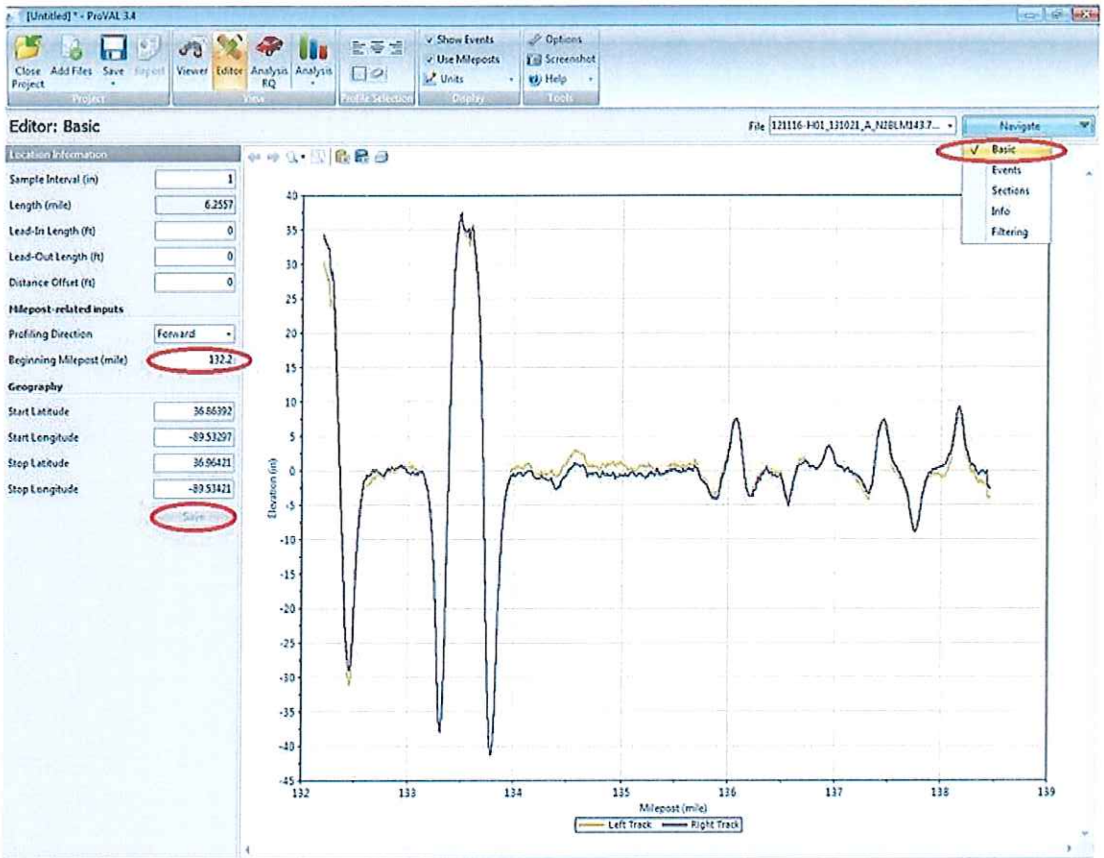
	Start Distance (ft)	Stop Distance (ft)	Length (ft)	Left Track - IRI (in/mi)	Right Track - IRI (in/mi)
2	250.0833435	778.083313	528	73.22875977	71.78775787
3	778.083313	1306.083374	528	58.64168167	39.24360657
4	1306.083374	1834.083252	528	46.82268906	35.22268295
5	1834.083252	2362.083252	528	45.94316483	41.61772537
6	2362.083252	2890.083252	528	52.36239624	35.90920258
7	2890.083252	3418.083252	528	50.03710938	38.09744644
8	3418.083252	3946.083496	528	57.55150604	43.20029068
9	3946.083496	4474.083008	528	63.99251175	36.49517822
10	4474.083008	5002.083496	528	45.7021904	33.18885803
11	5002.083496	5530.083008	528	48.59815216	41.5999794
12	5530.083008	6058.083008	528	52.76331329	36.59399033
13	6058.083008	6586.083496	528	46.5533638	34.24635315
14	6586.083496	6864	277.916656	72.89504242	54.7372818
15	7392.083008	7920.083008	528	54.89329529	37.86279678
16	7920.083008	8448.083008	528	53.06097412	35.51432419
17	8448.083008	8976.083008	528	55.01615143	35.25502777
18	8976.083008	9504.083008	528	50.15612411	32.50876236
19	9504.083008	10032.08301	528	59.10093307	42.66945267
20	10032.08301	10560.08301	528	65.95438385	44.0354805
21	10560.08301	11088.08301	528	50.28153992	36.79426956
22	11088.08301	11616.08301	528	50.39976883	43.76152039
23	11616.08301	12144.08301	528	44.64027786	44.38989639
24	12144.08301	12672.08301	528	54.19188309	42.77285055
25	12672.08301	13200.08301	528	61.26638794	48.23555756
26	13200.08301	13728.08301	528	53.13806915	43.92882919
27	13728.08301	14256.08203	528	49.9071579	36.54707336
28	14256.08203	14784.08301	528	46.28279877	39.67977905
29	14784.08301	15312.08301	528	51.99738312	36.60266495
30	15312.08301	15840.08203	528	56.8596344	35.36884308
31	15840.08203	16368.08301	528	46.95811081	35.82534409
32	16368.08301	16896.08398	528	65.9589386	54.52581406
33	16896.08398	17424.08203	528	65.75164032	44.77365875
34	17424.08203	17952.08203	528	67.2498703	49.41431046
35	17952.08203	18480.08398	528	56.87303543	38.72163773
36	18480.08398	19008.08203	528	52.30093384	38.47500992
37	19008.08203	19536.08203	528	49.96430969	35.90664291
38	19536.08203	20064.08398	528	54.92561722	43.12007904
39	20064.08398	20592.08203	528	63.87690735	44.81595612

106.3.2.59.3.1.1 Inserting Leave-Outs

Prior to analyzing ride quality some reformatting of the stationing will probably be necessary. In this example, assume the beginning of the inertial profiler run is at log mile 132.2.

- Select "Navigate" dropdown box
- Select "Basic"
- Enter 132.2 in "Beginning Milepost (mile)" box
- Select "Save"

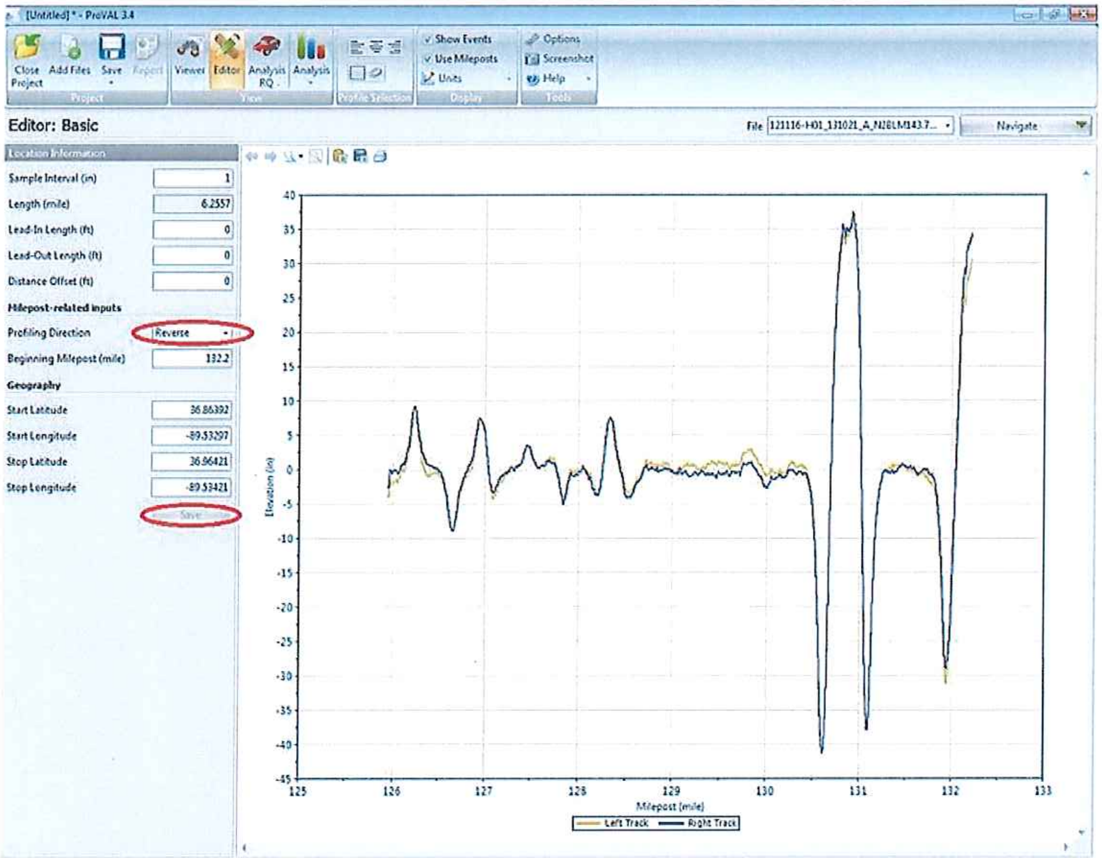
ProVAL has now reformatted the stations to represent actual project limits for the profile section.



106.3.2.59.3.1.2 Reversing Stations

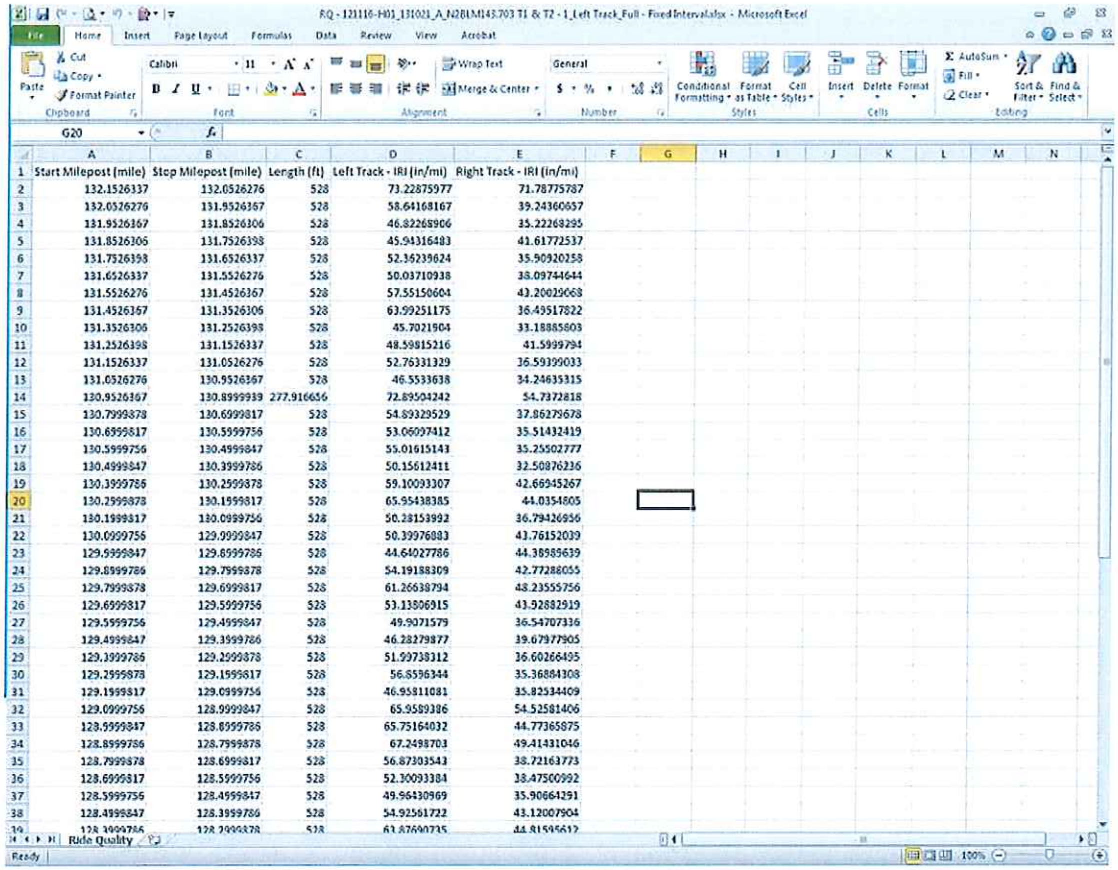
Another situation that may arise is when the direction of travel is in a station descending direction. ProVAL can also easily make this adjustment in the "Editor" mode. For this example, the starting log mile 132.2 will be retained.

- Select "Profiling Direction" dropdown box
- Select "Reverse"
- Select "Save"



Rerunning the ride analysis and creating the Excel report file will provide segment data in the reverse direction.

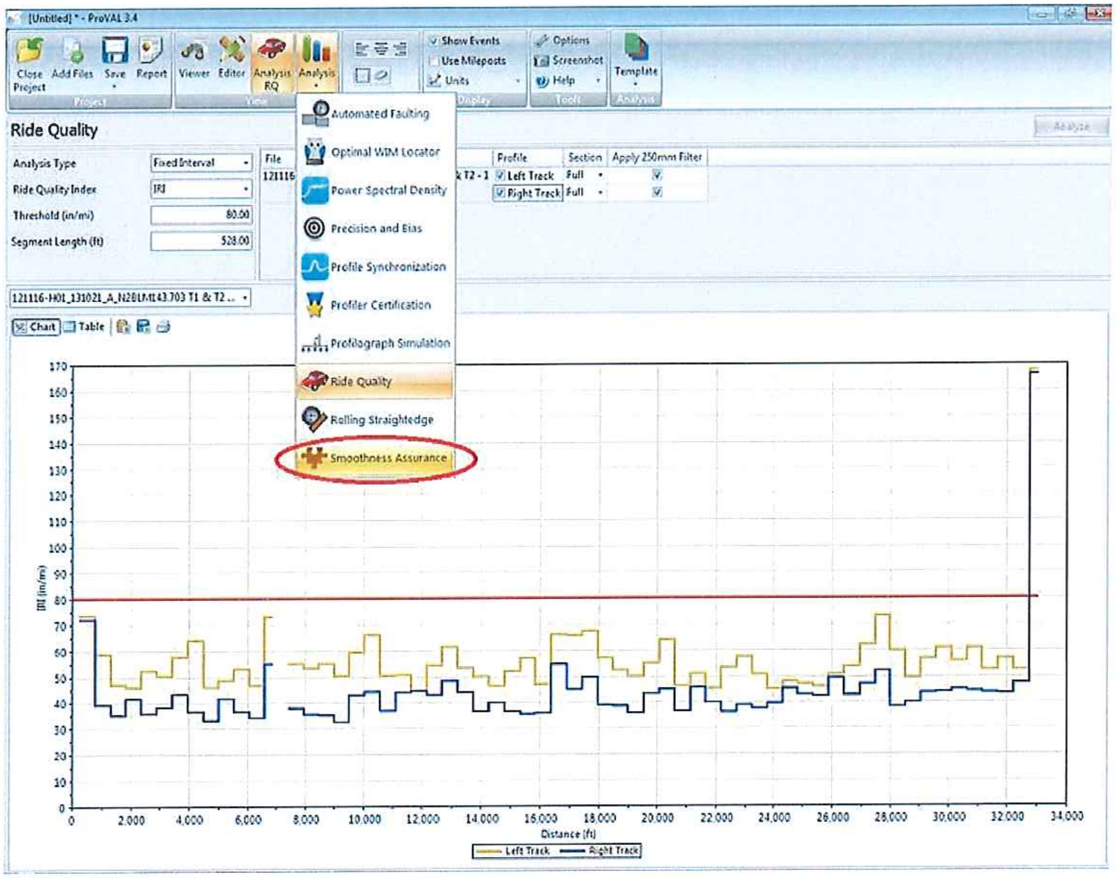
- Select "Analysis" and select "Ride Quality".
- Select "Excel" in "Report" dropdown box.
- Open the Excel report.



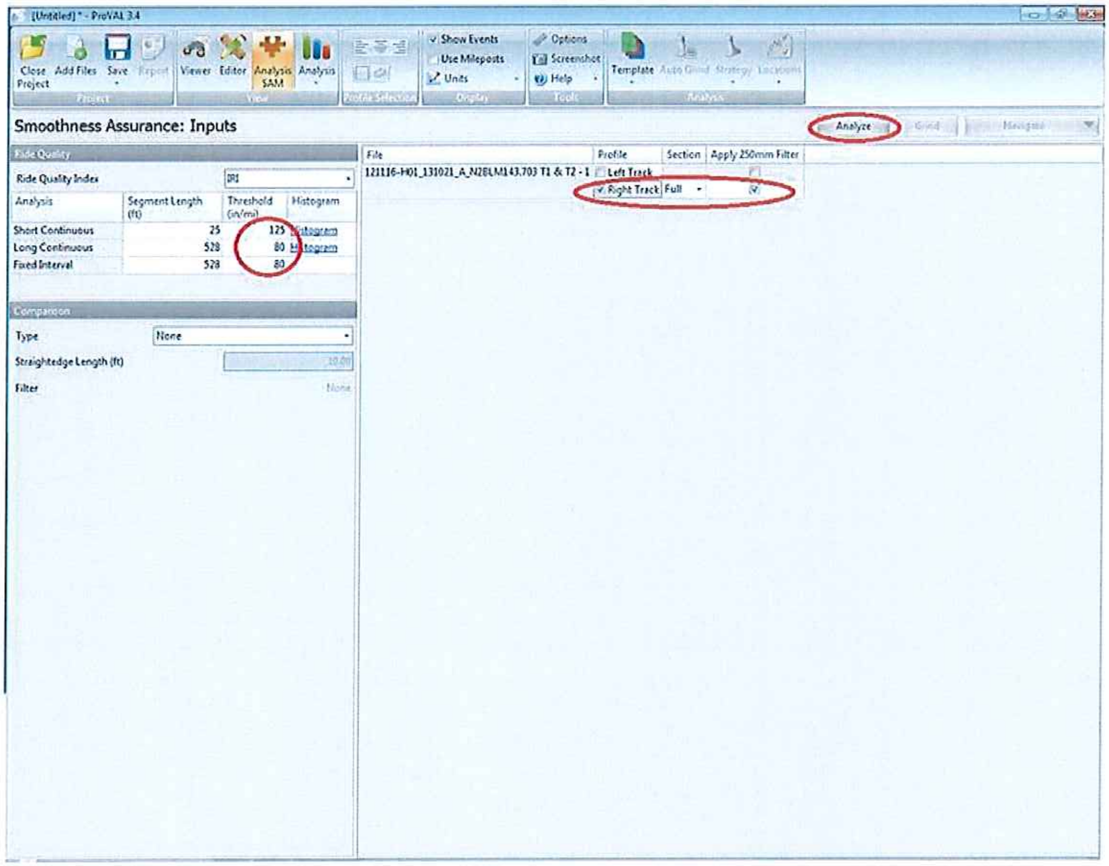
	Start Milepost (mile)	Stop Milepost (mile)	Length (ft)	Left Track - IRI (in/mi)	Right Track - IRI (in/mi)
2	132.1526337	132.0526276	528	73.22875977	71.78775787
3	132.0526276	131.9526367	528	58.64168167	39.24360657
4	131.9526367	131.8526306	528	46.82268906	35.22268295
5	131.8526306	131.7526398	528	45.94316483	41.61772537
6	131.7526398	131.6526337	528	52.36239624	35.90920258
7	131.6526337	131.5526276	528	50.03710938	38.09744644
8	131.5526276	131.4526367	528	57.55150604	43.20029068
9	131.4526367	131.3526306	528	63.99251175	36.49517822
10	131.3526306	131.2526398	528	45.7021904	33.18885803
11	131.2526398	131.1526337	528	48.59815216	41.5999794
12	131.1526337	131.0526276	528	52.76331329	36.59399033
13	131.0526276	130.9526367	528	46.5533638	34.24635315
14	130.9526367	130.8999939	277.916656	72.89504242	54.7372818
15	130.7999878	130.6999817	528	54.89329529	37.86279678
16	130.6999817	130.5999756	528	53.06097412	35.51432419
17	130.5999756	130.4999847	528	55.01615143	35.25502777
18	130.4999847	130.3999786	528	50.15612411	32.50876236
19	130.3999786	130.2999878	528	59.10093307	42.66945267
20	130.2999878	130.1999817	528	65.95438385	44.0354805
21	130.1999817	130.0999756	528	50.28153992	36.79426956
22	130.0999756	129.9999847	528	50.39976883	43.76152039
23	129.9999847	129.8999786	528	44.64027786	44.38985639
24	129.8999786	129.7999878	528	54.19188309	42.77288055
25	129.7999878	129.6999817	528	61.26638794	48.23555756
26	129.6999817	129.5999756	528	53.13806915	43.92882919
27	129.5999756	129.4999847	528	49.9071579	36.54707336
28	129.4999847	129.3999786	528	46.28279877	39.67977905
29	129.3999786	129.2999878	528	51.99738312	36.60266495
30	129.2999878	129.1999817	528	56.8596344	35.36884308
31	129.1999817	129.0999756	528	46.95811081	35.82534409
32	129.0999756	128.9999847	528	65.9589386	54.52581406
33	128.9999847	128.8999786	528	65.75164032	44.77365875
34	128.8999786	128.7999878	528	67.2498703	49.41431046
35	128.7999878	128.6999817	528	56.87303543	38.72163773
36	128.6999817	128.5999756	528	52.30093384	38.47500992
37	128.5999756	128.4999847	528	49.96430969	35.90664291
38	128.4999847	128.3999786	528	54.92561722	43.12007904
39	128.3999786	128.2999878	528	63.87690735	44.81595612

106.3.2.59.3.2 Areas of Localized Roughness

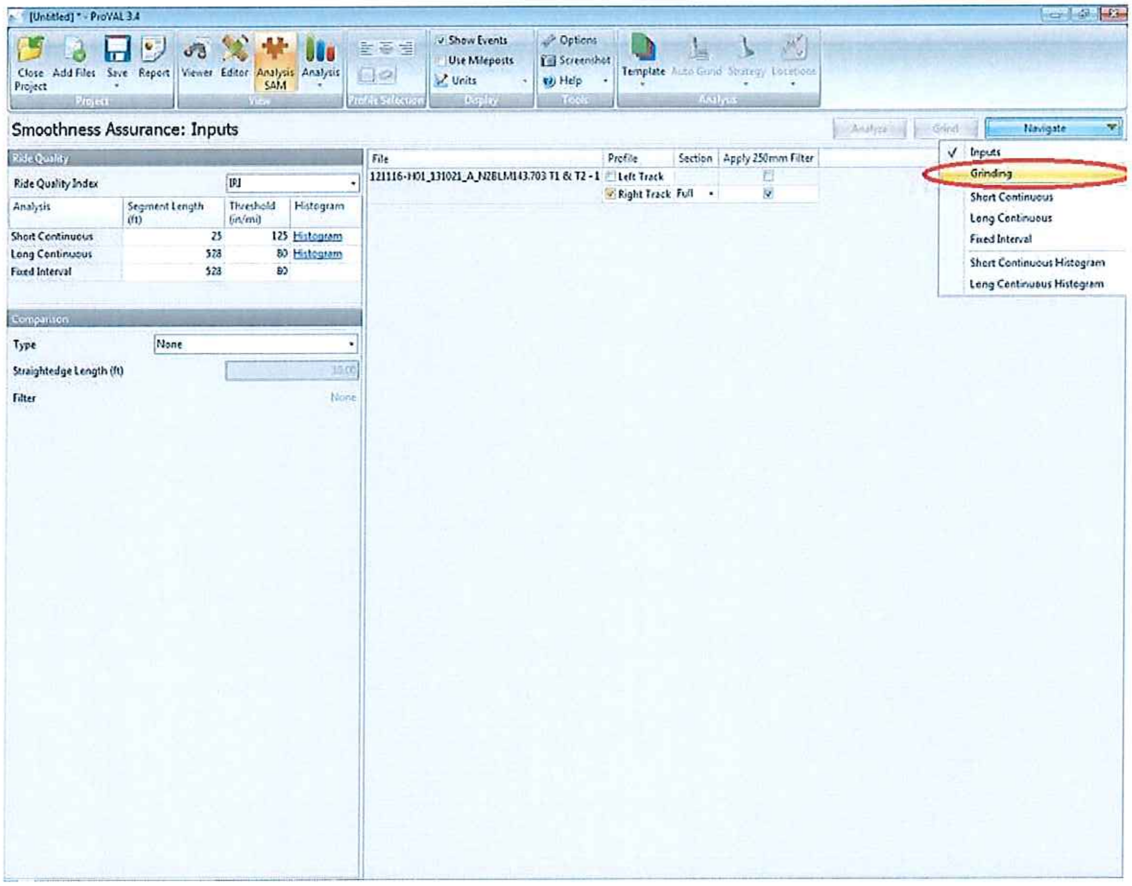
- **Select "Smoothness Assurance" in "Analysis" dropdown box.**



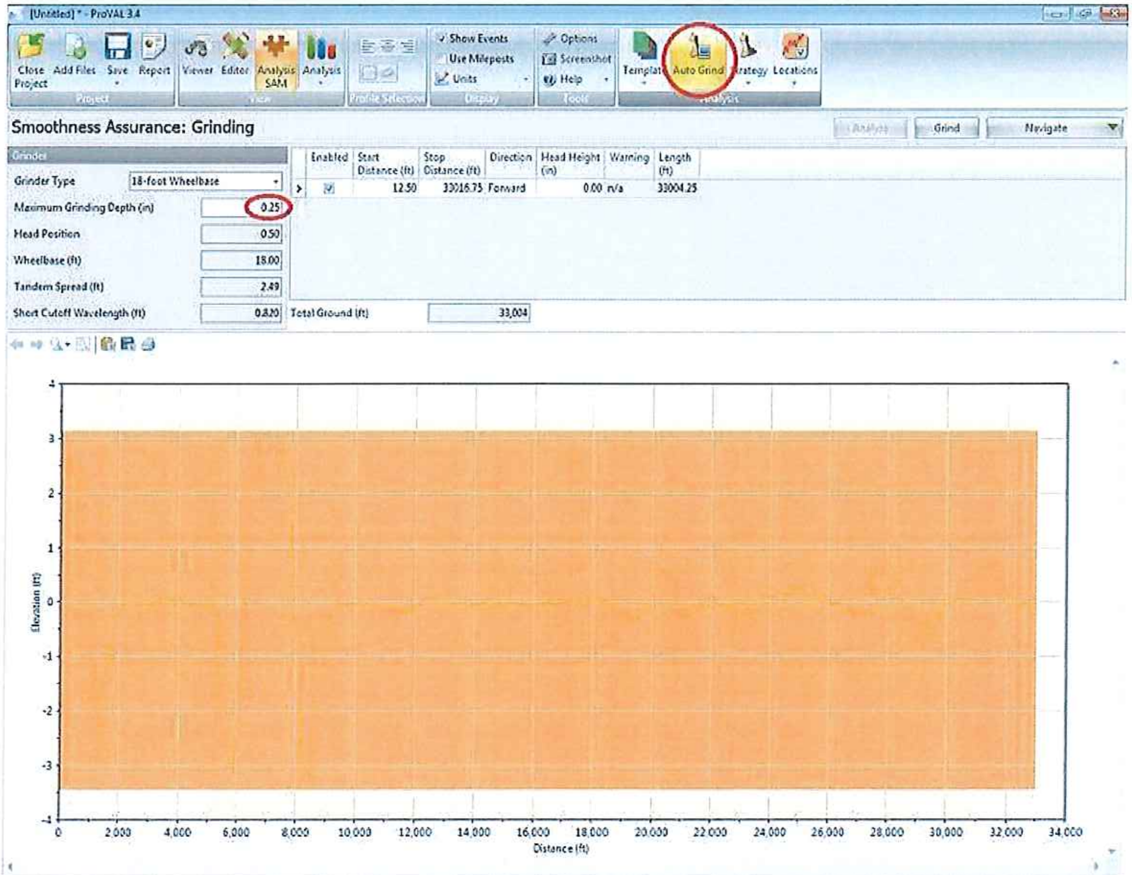
- Change "Threshold" value for "Short Continuous" analysis to 125 (in/mi) in the "Ride Quality" section. (The segment length for "Short Continuous" should be set at the default value of 25 ft.). Change "Threshold" for "Long Continuous" and "Fixed Interval" in the "Profile" section to 80 (in/mi). (The "Segment Length" for both "Long Continuous" and "Fixed Interval" should be set at the default value of 528 feet.)
- Check "Right Elevation" only in the "Profile" section (ensure "Apply 250mm Filter" is also checked).
- Select "Analyze".



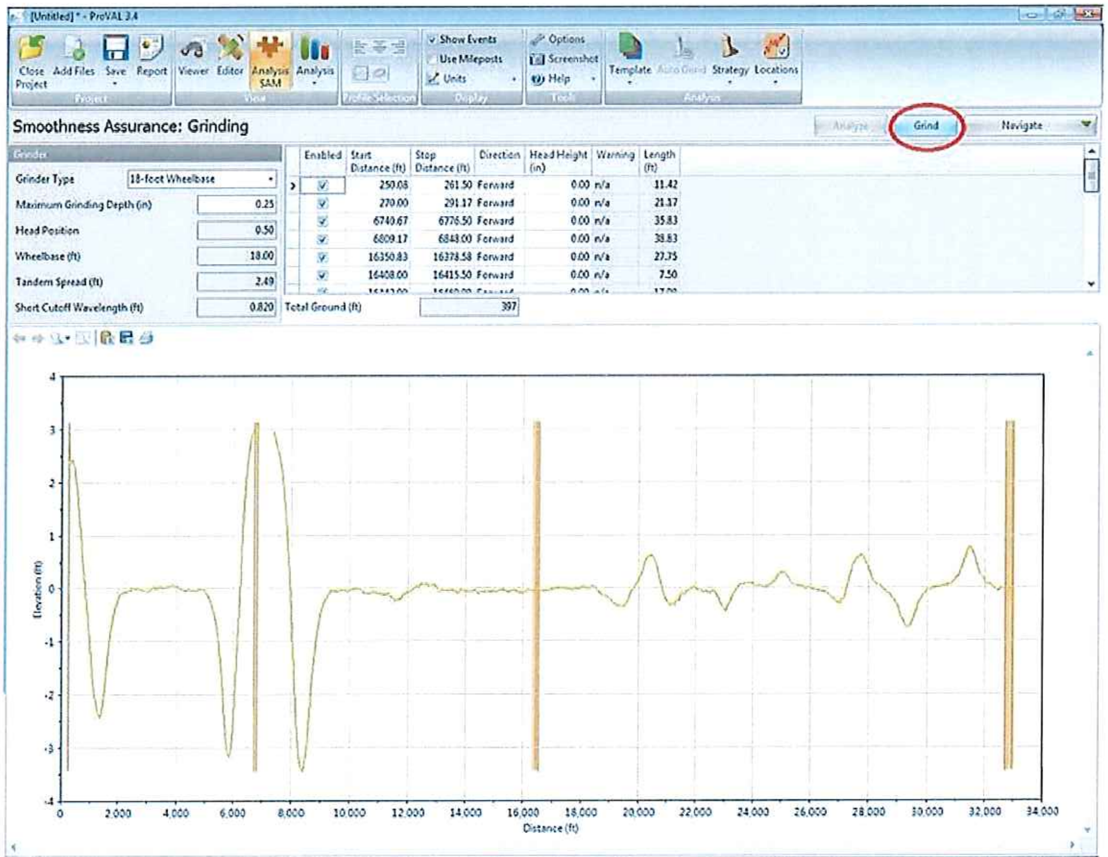
- **Select "Grinding" in the "Navigate" dropdown box.**



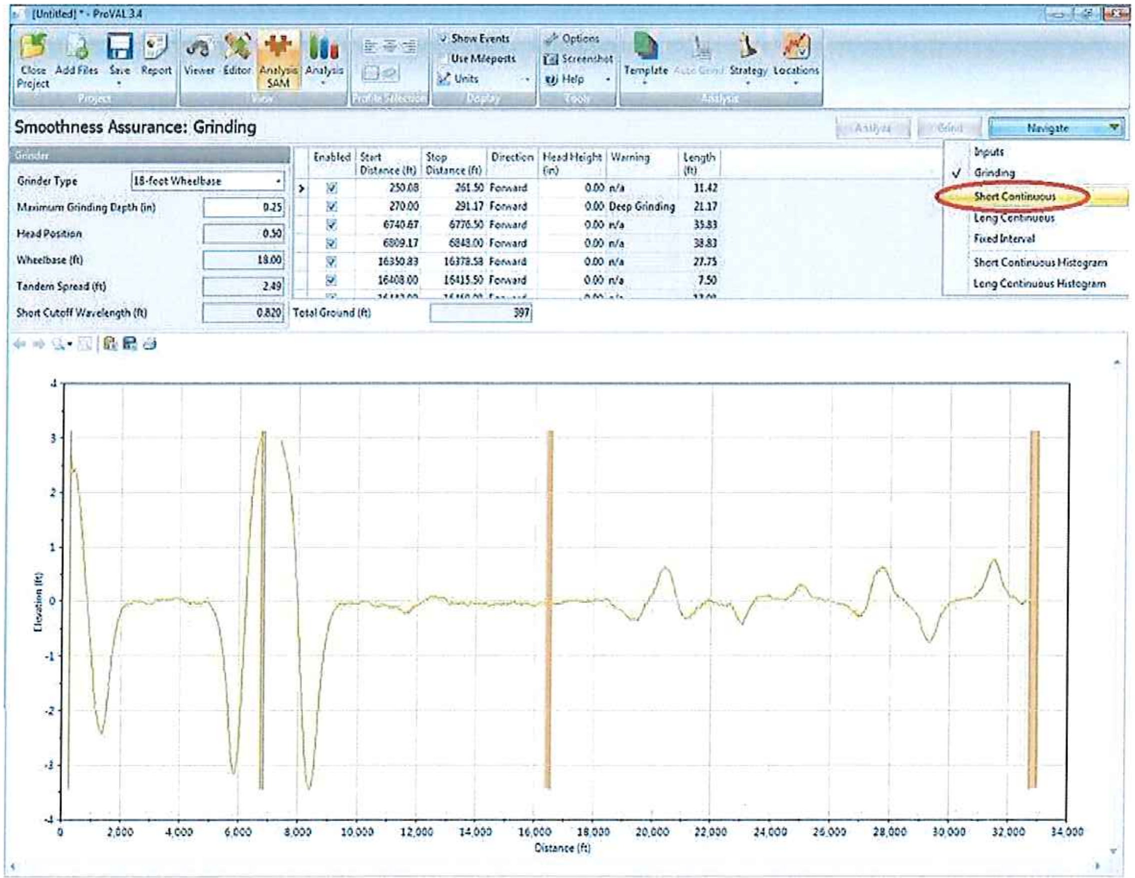
- Enter 0.25 inches for "Maximum Grinding Depth" in "Grinder" section. (The following parameters should show the default values, which are Head Position = 0.50, Wheelbase (ft) = 18.00, Tandem Spread (ft) = 2.49 and Short Cut-Off Wavelength (ft) = 0.820 ft.)
- Select "Auto Grind".



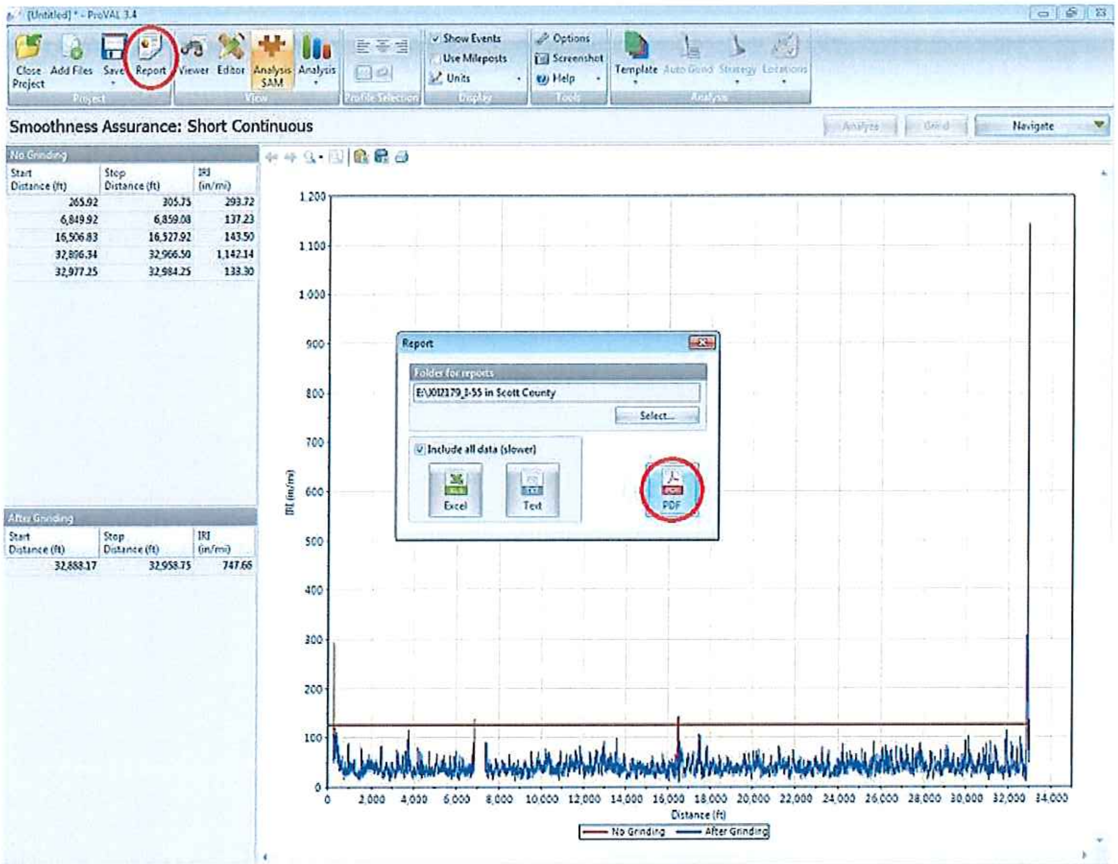
- **Select "Grind".**



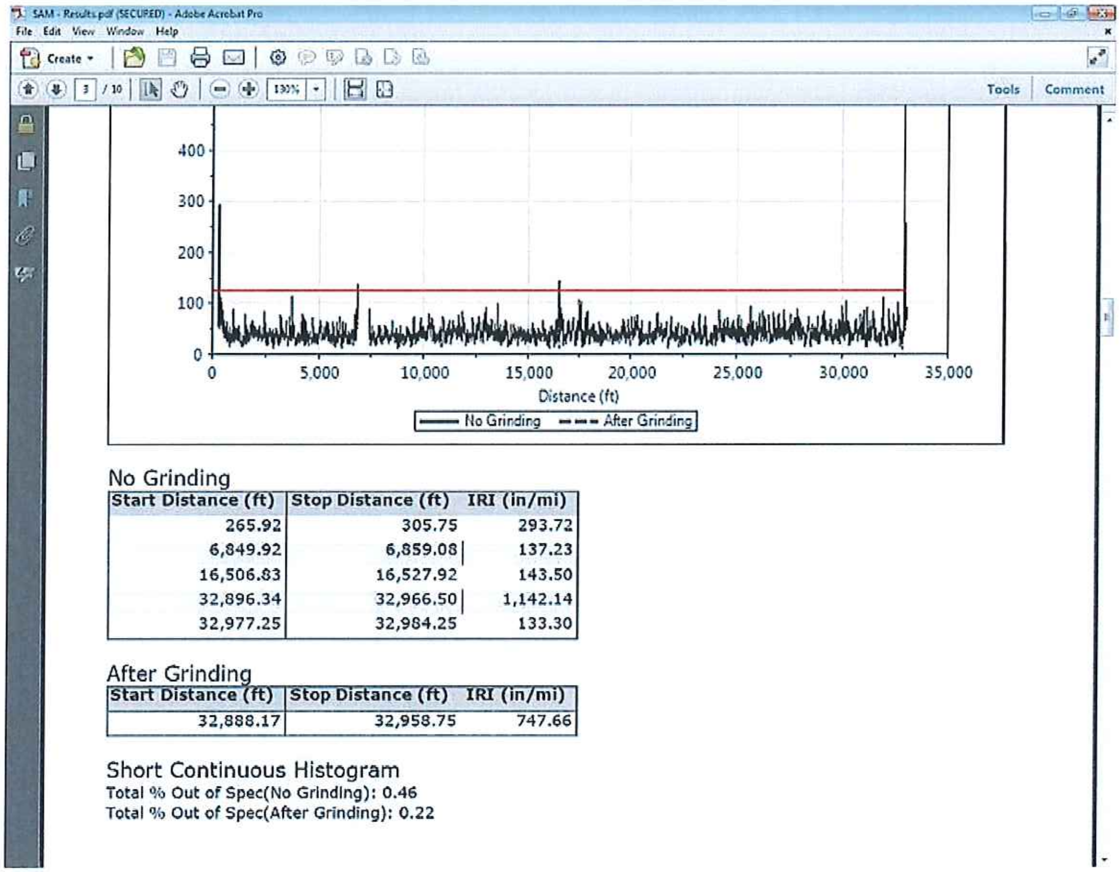
- **Select "Short Continuous" in "Navigate" dropdown box.**



- **Select "PDF" in "Report" dropdown box.**



The grinding report is generated showing locations of areas of localized roughness (ALR). The grinding simulation numerically indicates what the expected improvement in smoothness should be when the ALRs are diamond ground. This information serves as a guide for both the contractor and the engineer for determining which ALRs can be corrected with conventional grinding and which may require other corrective measures.



No Grinding

Start Distance (ft)	Stop Distance (ft)	IRI (in/mi)
265.92	305.75	293.72
6,849.92	6,859.08	137.23
16,506.83	16,527.92	143.50
32,896.34	32,966.50	1,142.14
32,977.25	32,984.25	133.30

After Grinding

Start Distance (ft)	Stop Distance (ft)	IRI (in/mi)
32,888.17	32,958.75	747.66

Short Continuous Histogram
Total % Out of Spec(No Grinding): 0.46
Total % Out of Spec(After Grinding): 0.22

Comparisons for IRI before and after grinding are shown in tabular and bar graph form.

106.3.2.59.4 Dispute Resolution

In the event that the QC/QA results are not within tolerance (after the absolute value of the difference between the contractor and engineer IRIs are computed for each segment within the QA test length, the average of the absolute values of the IRI difference shall be 8 in./mile or less and the absolute value of the IRI difference for any single segment shall be 12 in./mile or less), the MoDOT SurPro reference profiler shall arbitrate the dispute. The engineer shall randomly select a 528 ft. area within the disputed pavement length and run the MoDOT reference profiler in the left and right wheel paths. The arbitration profile shall be correlated with its corresponding QC and QA profiles in ProVAL. Whichever of the average QC/QA IRI profiles is closer to the arbitration IRI profile shall be the binding profile for the purpose of construction acceptance.


MoDOT Reference Profiler

Retrieved from "http://epg.modot.org/index.php?title=106.3.2.59_TM-59,_Determination_of_the_International_Roughness_Index&oldid=37513"

Category: 106.3.2 Material Inspection Test Methods

- This page was last modified on 8 June 2016, at 12:39.

Glossary

Glossary

Accelerometer – a sensor that measure acceleration. An inertial profiler uses the signal from the on-board accelerometer(s) to compute the inertial reference value (i.e., relative height) that can be combined with the height sensor data to produce a complete profile. See also Height Sensor.

Aliasing – The error that can result when a signal is sampled at a rate less than twice the frequency of the various sinusoidal components that compose the signal. To avoid aliasing, the signal is band limited so that the sampling frequency used will be greater than twice as high as the highest frequency component in the signal. It is also described as the error that results from sampling a long wavelength signal that is mixed with a short wavelength noise signal.

Anti-aliasing filter – A low-pass analog filter that suppresses short-wavelength contamination of longer-wavelength measurements to improve the accuracy of the sampling process.

Accuracy – Lack of error. The root-mean-square value of the error when comparing measured values with “deemed correct” or reference values. See also Repeatability.

Amplitude – the maximum value of a periodic curve measure along its vertical axis with reference to the horizontal axis.

Bias Error – Error stemming from systematic problems, including inaccurate calibration, physical damage, or a defect in the profiler’s design.

Blanking Band – A band that is placed over a profilograph trace to “mask” the portion of the trace that is not counted as roughness.

Bode Plot – A frequency response plot made on log-log axes.

Bounce Test – A test performed on an inertial profiler when stationary in order to check the measurement system.

Calibration – The process of correcting the scale of a transducer.

Continuous IRI – A series of IRI values calculated over a running interval, one for each profile data point throughout the test section. Each IRI value is provided at the midpoint of the running interval.

Correlation Analysis – Analysis that describes how one variable relates to another.

Digital Filter – A calculation procedure that transforms one signal into another to eliminate irrelevant data.

Dipstick – A static, inclinometer-based proprietary device used to measure elevations at individual points (originally used for measuring floor flatness).

Distance Measurement Instrument (DMI) – A transducer used to determine the longitudinal distance that the measurement vehicle has traveled.

Filtering – Procedure to extract desired information from a signal that also contains unwanted information (commonly called noise). Digital filtering is a calculation procedure that takes one set of numbers and transforms them into another set in which the noise is reduced. Moving average is one type of such transformation or filter.

Frequency Response – The ratio of output amplitude to input amplitude for a sinusoid.

Gain – The ratio that a filter amplifies or attenuates an input signal component at a given wavelength or frequency.

Golden Car – The quarter-car model used in IRI computation. See also IRI.

Half-car Roughness Index (HRI) – A number calculated by applying the IRI algorithm to the average of two profiles.

Height Sensor – A sensor used in an inertial profiler to measure the vertical distance between the sensor and the pavement surface.

High-Pass Filter – A digital filter that produces an anti-smoothing effect that reduces the effect of long wavelengths. See also Low-Pass Filter.

Index – Measure of standard. Within the context of this test method, a suitably chosen index quantifies the ride quality of a pavement.

Inertial Profiler – A profile measurement device that measures the pavement profile using an accelerometer to form an inertial reference and a height sensor to measure the pavement surface height relative to that reference.

International Roughness Index (IRI) – A statistic that summarizes the roughness qualities impacting vehicle response based on the Golden-Car vehicle model at a standard simulation speed of 49.7 mph (80 km/h).

Lead-In – The distance required for an inertial profiler to reach an acceptable speed and for the data collection filters used in the profile computation to stabilize. See also Lead-Out.

Lead-Out – A safe distance for an inertial profiler to operate to a stop position or until the data collection system is turned off. See also Lead-In.

Light-Weight Profiler – An inertial profiler that is relatively light-weight (golf cart, ATV, etc.) compared with high-speed profilers (vans, trucks, cars, etc.). It is often operated much slower than prevailing traffic speed. See also High-Speed Profiler.

Line Laser – A line laser obtains a series of data points along a line, which is typically perpendicular to the travel direction, with the line typically being 4 in. long. A single, bridged elevation value is computed from the data.

Linear System – A system in which the output is directly proportional to the input.

Localized Roughness – Short sections of roadway that contribute disproportionately to the overall roughness index value. Also referenced as “hot spots”

Longitudinal Profile – A longitudinal two-dimensional slice of a road surface taken along an imaginary line that consists of elevation values and a distance reference for each elevation.

Low-Pass Filter – A smoothing filter, such as moving-average, that reduces the effect of short wavelengths. See also High-Pass Filter.

Mean Panel Ratings – A subjective rating system whereby automobile passengers rate the smoothness of a given road after driving on it.

Mean Roughness Index (MRI) – A number calculated by averaging the IRI values from the two-wheel path profiles.

Measurement Range – The detectable range of heights, accurately measurable by the sensor.

Moving Average – Filtering process whereby each data point is replaced with the average value of several adjacent points or elevations. It is a smoothing process because the changes from one elevation point to the next will not be as significant due to the fact that the difference in elevation has been divided by the total number of data pints in the averaging scheme. It is a type of low-pass filter.

Moving Average Filter – A digital filter that replaces each profile elevation point with the average of several adjacent points.

Portability – The ability to obtain consistent results when using different types of measurement devices.

Power Spectral Density (PSD) – A method that describes how the power of a signal (i.e. a time average of signal energy) or time series is distributed with frequency.

Precision – The measure of variation between multiple measurements, expressed in standard deviation.

Profile Index – A generic summary number calculated from a profile. This term should be avoided since it may be confused with PrI or RN. See also PrI and RN.

Profiler – An instrument used to measure road profiles.

Profiler Certification – A procedure used to determine whether a profiler satisfies a specific set of performance criteria.

Profiler Operator Certification – A procedure used to determine whether a profiler operator passes a specific set of written and field operational tests in order to be certified for operating profilers.

Profilograph – A device used to measure smoothness by measuring the deviations of a pavement surface using a mid-point measuring wheel from the reference established by a set of wheels (6 for a California-type) at either end of the device.

Profilograph Index (PrI) – A smoothness index that is computed from a profilograph trace. This is sometimes called Profile Index (PI), but is more specifically called PrI.

Reference Device – A device used to obtain the true profile of a pavement. Devices such as rod and level, Dipstick (TM) and walking profiler are considered reference devices.

Repeatability – The expected standard deviation of measurements obtained in repeated tests using the same device on a single, randomly-selected pavement surface.

Reproducibility – The standard deviation of the error included in a single measurement, relative to a reference measurement. The reproducibility of a device included errors that are systematic with respect to that device, but random with respect to a particular test.

Report interval – The longitudinal distance between the outputs of a profile index value.

Ride Number (RN) - A calculated roughness index, between 0 and 5, that approximates the Mean Panel Rating for a pavement surface. See also Mean Panel Ratings, IRI, and PrI.

Ride – Also spelled out as “Ride Quality”. Measured as accelerations in the vehicle body.

Road Roughness – The deviations of a pavement surface from a true plane surface with characteristic dimensions that affect vehicle dynamics and ride quality.

Rod and Level – Static equipment used to measure elevations at individual points, commonly used for land surveying.

Rolling Straightedge – Profiling equipment generally consisting of a rigid beam (or frame) with support wheels on either end and a measuring wheel at the middle, which is rolled over the surface to be profiled.

Roughness Profile – A plot that shows the variation of roughness over a section of pavement. This is also referred to as a "continuous roughness report."

Response-type Road Roughness Measuring System (RSRRMS) – A system that measures suspension deflection of either one or two wheels of either a passenger car or a towed trailer and records these deflections as "counts" or as actual measured deflection.

Running interval – A set longitudinal distance that is stepped through a test segment by an increment shorter than its length.

Sample Interval – The longitudinal distance between captured data points.

Sampling Rate – The rate at which the height sensor measures vertical displacement. A typical sampling rate provides many height measurements from which a single value is derived for reporting at the sample interval.

Segment Length – The length of section of pavement where a smoothness index is recorded.

Signal Processing – The mathematical transformation and analysis of signals.

Signal – A series of numbers.

Sensors – devices that measure physical quantities. They are responsive to a change in a physical measurement such as distance, temperature, and acceleraton.

Sinusoid – A periodic curve defined by wavelength, amplitude and phase.

Smoothness – Lack of roughness or lack of significant bumps and dips from the pavement surface that cause discomfort to motorists.

Standard Error – The portion of the total error due to random effects.

Transducer – Device that converts variables of one type (i.e., distance) into those of another type (I.e., voltage). These conversions must conform to a known transformation (i.e., proportional) to be useful.

True Profile – The undistorted shape of a pavement surface.

Valid Profiler – A profiler that provides the same statistical values that would be obtained from the true profile.

Verification Site – A pavement section used to periodically check if an inertial profiler is functioning properly.

Wave Band – A range of frequencies. In profile analysis, wave band often refers to spatial frequencies. See also Wave Number.

Wave Number – The number of wave cycles per unit length.

Wavelength – The distance between peaks or crests of a wave or sinusoid.