2019 EDITION

Technician Certification

International Roughness Index

Missouri Department of Transportation

IRI

Table of Contents

Profiling Basics

MoDOT

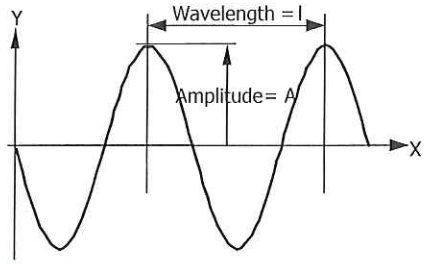
Profiling Basics

MoDOT IRI Training

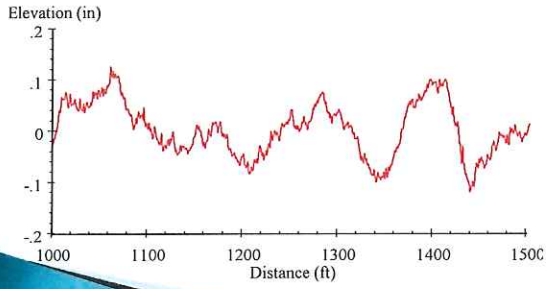
True (Road) Profile

- '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.

Wavelength and Amplitude



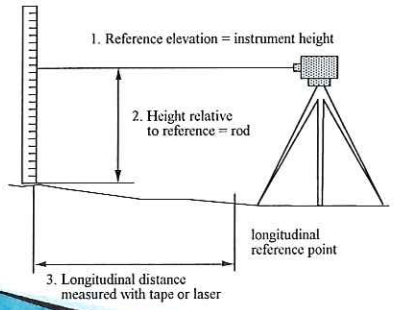
Surface Profile Cross-Section



Measuring True Profile

- Inertial profilers (lightweight, high speed) can collect true profiles.
- A true profile never changes with properly calibrated equipment.
- A profile trace obtained with a profilograph is *not* a true profile.

Basic True Profile Measurement



Roughness and Smoothness

- 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.

Smoothness Benefits

- Satisfied road users
- Decrease in fuel consumption and vehicle maintenance costs
- Pavements that are built smoother remain smoother over time and provide a longer service life

Profiling Devices in Missouri

- Distant Past – Straightedge
- Recent Past – California Profilograph
- Present – Inertial Profiler

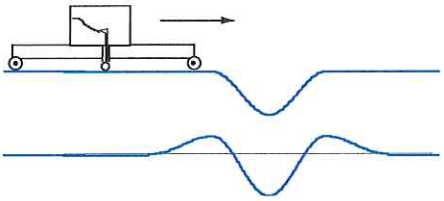
Smoothness Indices in Missouri

- Distant Past – Straightedge deviation
- Recent Past – Profile Index (PI)
- Present – International Roughness Index (IRI)

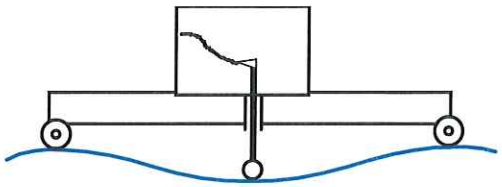
Profilograph Limitations

- Does not record true profile of road.
- Some wavelengths are measured correctly, some amplified, and some attenuated.
- The turning radius of the equipment is large.
- Slow operation.

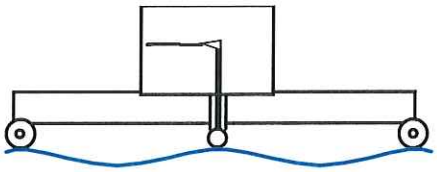
Profilograph Response



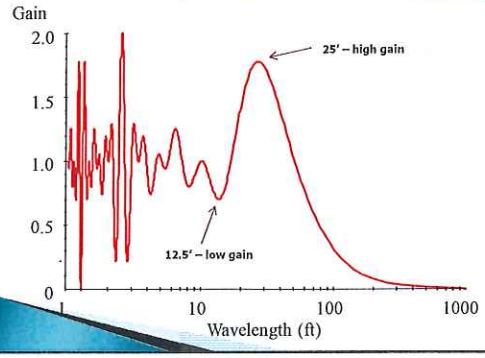
Profilograph Response



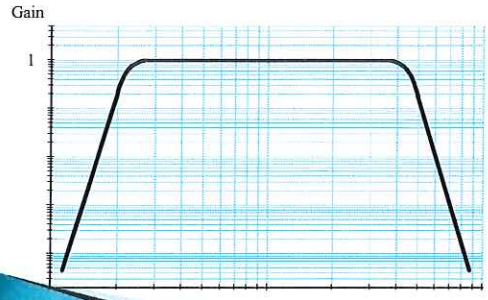
Profilograph Response



California Profilograph Response



Ideal Profile Wavelength Sensitivity



Profilograph Limits PI Usefulness

- The fact that a profilograph cannot measure true profile degrades the effectiveness of the profile index (PI) itself.
- PI is an aggregate of surface irregularities with variable wavelength gains.

Who Said This?

"No claim is made that the roughness or <u>riding quality</u> of a pavement is directly or completely reflected by the profile index."

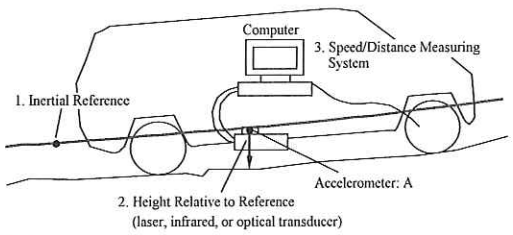
"It should again be emphasized that strictly speaking, the devices reported herein do not furnish a direct index to <u>"riding qualities."</u>

Francis Hveem – inventor of the California profilograph (circa 1960)

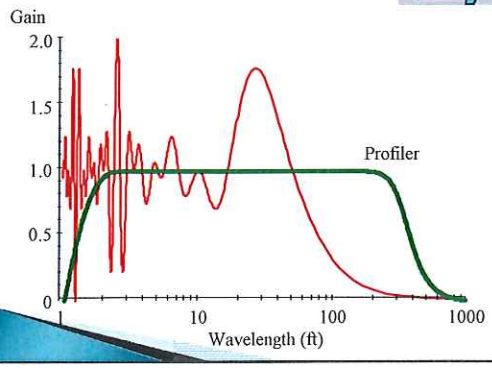
Inertial Profiler

- Can measure true profile.
- Comes in form of low speed and high speed devices.
- Equipment software can convert true profile data to multiple smoothness indices.

Inertial Profiler



Profiler Response



International Roughness Index

- 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 similar to a passenger vehicle.

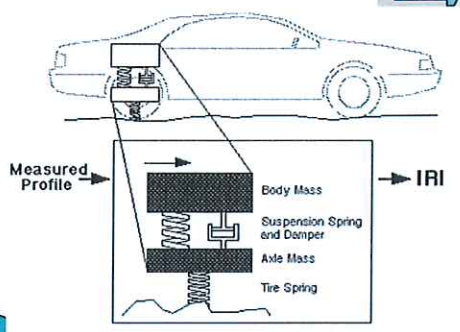
International Roughness Index

- Doesn't exactly represent 'roughness' of every vehicle, but closely approximates the vast majority.
- Mean roughness index (MRI) = average of right and left wheel path IRIs.

IRI Car Model

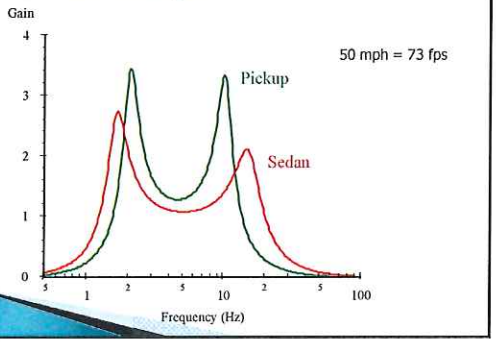
- Quarter-car modeled as: one tire, mass of axle supported by tire, suspension spring and damper, mass of the body supported by tire.
- Simulation speed is 50 mi/hr.
- Suspension motion is accumulated by vertical displacement and divided by distance traveled to give IRI in inches/mile.

Quarter Car Model

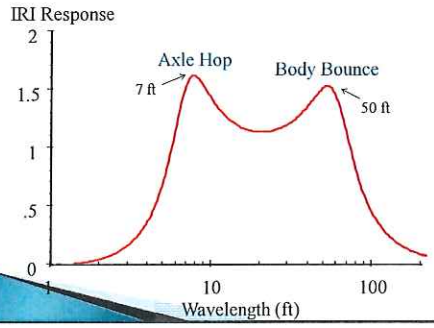


Computer Algorithm

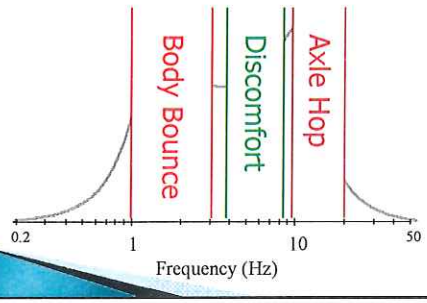
Vehicle Response to Wavelengths



International Roughness Index



IRI Sensitivity



Profiling Equipment

MoDOT IRI Training

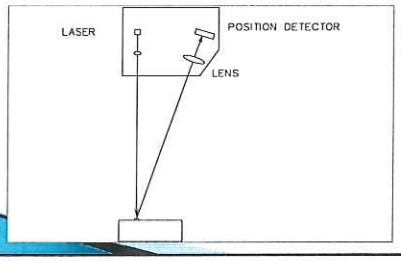
Inertial Profilers

Components of an Inertial Profiler

1. Height sensor
2. Accelerometer
3. Distance measuring instrument (DMI)
4. Software for computing profile

Height Sensor

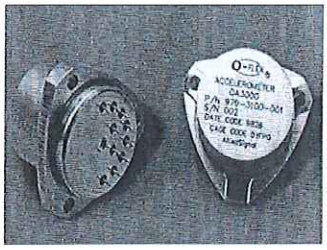
- Measures vertical distance from vehicle to road by means of triangulation



Accelerometers

- Measure vertical acceleration
- Vehicle must be above a minimum speed to measure acceleration
- Need sufficient range of measurement

Accelerometers



Distance Measuring Instrument

- DMI measures distance traveled by profiler
- Rotation of wheel measured by detection of pulses as wheel rotates and notches pass
- Affected by rolling radius of tire
- GPS beginning to replace tire-mounted DMIs

Optical Trigger Device

- Automatically initiates data collection at a specified location
- Triggered when it detects a change in reflectivity
- Mounted either vertically or horizontally in profiler

Optical Trigger Device

- 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

Reference Profilers

- Reference profilers obtain true profile of pavement
- Used for verification of profilers
- Types of Devices
  - Rod and Level (Survey)
  - Walking Profilers
  - Dipstick

Reference Profilers (SurPRO)

MoDOT's primary reference profiler

Reference Profilers (Dipstick)

MoDOT's backup reference profiler

Profiler Setup

MoDOT IRI Training

Verification

Verification checks calibration values to determine if they are still valid/accurate. If not, calibration must be performed to reestablish values.

Calibration

Calibration re-establishes target values in which the profiler operates by correcting the scale of a transducer.

Calibration usually requires highly precise equipment, that isn't available in the field, and is typically conducted in a controlled environment (usually at the manufacturer).

Daily Equipment Checks

- Laser Height Verification
- Accelerometer Calibration
- Bounce Test
- DMI Calibration

IMPORTANT: Follow manufacturer-provided operator's manual!

Daily Vehicle Checks

- Oil
- Gas
- Headlights
- Safety lights

Height Sensor Calibration

- Laser height sensors cannot be calibrated by user, however, user can perform a verification check.
- Re-calibrate laser height sensors (check with manufacturer) when:
  - Repairs are made on suspension
  - Repairs are made on bumper housing them
  - Tires are replaced or rotated

Height Sensor Verification

- Performed while the profiler is stationary.
- Procedure for checking
  - Place leveling plate, then obtain reading
  - Place block on leveling plate, then obtain reading
  - Difference in reading = height of block
  - Should be within 1% of actual height of block

Height Sensor Verification

Reading on Base plate + calibration plate (H1)

Reading on Base Plate + 25 mm Block + Calibration Plate (H2)

H2 – H1 = Block Height

For 25 mm block within ± 0.25 mm

Accelerometer Calibration

- Accelerometers have built-in calibration system that allows them to be calibrated electronically
- Performed using the computer system
- Calibration factor saved in computer

Bounce Test

- Checks if accelerometers and height sensors are functioning satisfactorily
- Profiler is bounced while stationary. Profile displayed is checked to see if profiler is functioning properly

Bounce Test

- As profiler is obtaining measurements at same point, amplitude of bouncing motion should not appear on profile
- Generally, amplitude of recorded profile < 1% of induced motion on sensor

DMI Calibration

- Section of known length laid out
- Tire pressure checked and adjusted if necessary
- Profiler driven to warm up tires
- Profiler driven over section
- Actual distance of section entered to computer
- Calibration factor computed by computer

Un-calibrated equipment can generate erroneous data!!

Profiler Sensitivity

MoDOT IRI Training

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.

Hills and Grades

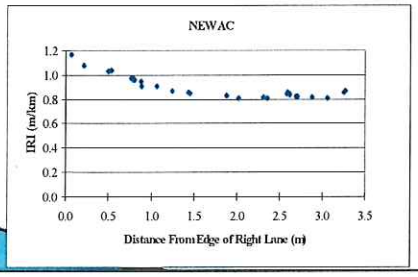
- Can affect accelerometer signals as axis is tilted from vertical
- Theoretical study indicated no problems expected when grade is less than 6 percent

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

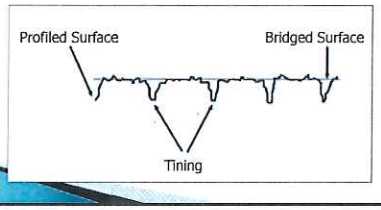
Transverse Variations in IRI

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



Surface Texture

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



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

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

Surface 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

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

Profiler Operation

MoDOT IRI Training

Operator Safety

- Stay alert!
- Wear appropriate safety apparel
- Follow safety plan
- Do 'dry run' through testing length for familiarization

File Naming Convention

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 (1 for driving lane, increasing by one for each lane to the ~~left~~ ← right)
W	Wheel path (L, R, or B)
S	Beginning Station (rounded to nearest 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)

Pass Filters

ALL filters must be off prior to testing!
(exception for built-in 10-inch low pass filter that can't be turned off).

Operating 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

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

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 effected

Starting the Measurement

- 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.

Advantages of Automated Triggering

- 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

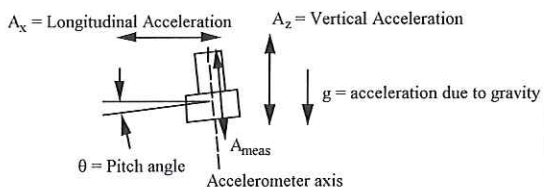
Profiler Position

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).

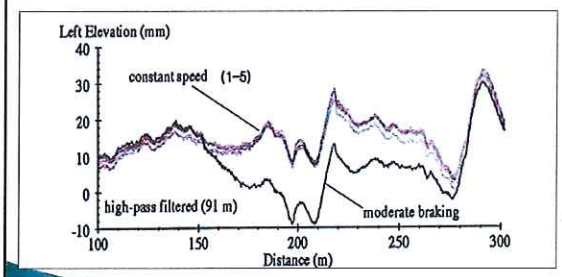
Speed Changes

- Operate at a constant speed while collecting data
- Accelerating or decelerating while collecting profile data will contaminate data

Speed Changes

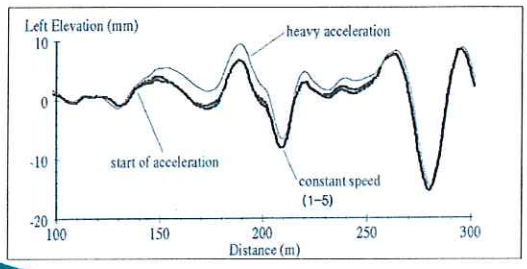


Effect of Braking on Profile Data



1 mm = 0.04 in 1 m = 3.3 ft

Effect of Acceleration on Profile



1 mm = 0.04 in 1 m = 3.3 ft

Post-Operational Checks

- 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.

Post Profiling

- 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.

Thank You!

Questions?

john.donahue@modot.mo.gov
(573)526-4334

Smoothness Specification

MoDOT

Smoothness Specification
Section 610

MoDOT IRI Training

610.1

» Description

2

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

3

Applicable Pavement Types

a) Multi-lift asphalt construction
   Sections 401 and 403

b) Concrete pavement construction
   Sections 502 and 506

c) Combination of surface planing (diamond grinding, milling) and single lift asphalt construction

d) Single lift asphalt construction
   Sections 401 and 403

610.2

» Material Requirements

5

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 areas of localized roughness (ALR)

Note: See MoDOT TM-59

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.

610.3

» Certification

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.

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

12

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 with the exception of 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.

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 superelevation transition of such curves.

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

- QA test length is independent of previous QC section boundaries. The contractor may use it for a QC section if previously untested.
- 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 areas of localized roughness (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

- 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.

37

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.

38

610.4.6

» Multi-treatment Overlays

39

610.4.6
Multi-treatment Overlays

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

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".

610.4.6.2 (Multi-treatment) Quality Assurance Testing

- The QA requirements are the same as Section 610.4.5.2.

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.

610.4.6.4
Method of Correction

- The requirements are the same as Section 610.4.5.4.

610.4.7

» Single Lift Overlays

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)

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.

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.

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.

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.

610.4.8

» Marred Surface Area

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.

32

610.5

» Basis of Payment

33

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

31

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.

55

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.

56

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.

57

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.

58

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.

59

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.

60

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]

61

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.

62

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.

63

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.

64

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.

65

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.

66

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.

67

622.30

» Diamond Grinding Existing Concrete Pavement

68

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.

69

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.

70

622.30.4
Smoothness Requirements

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

71

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.

72

Questions?

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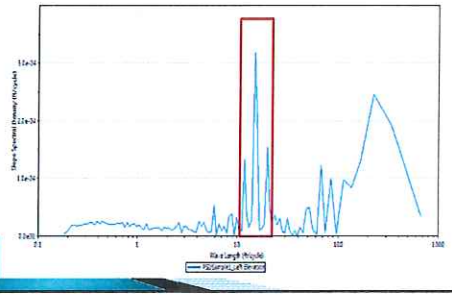
ProVAL PSD Analysis Examples

JCP Joint Faulting

PSD Analysis

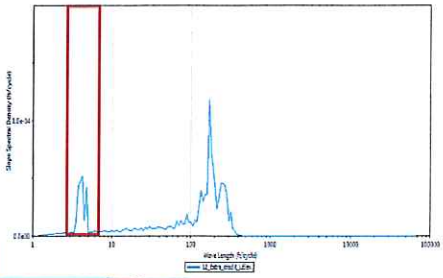
JPCP Joint Faulting



HMA – Inadequate Compaction Freq/Amp

PSD Analysis

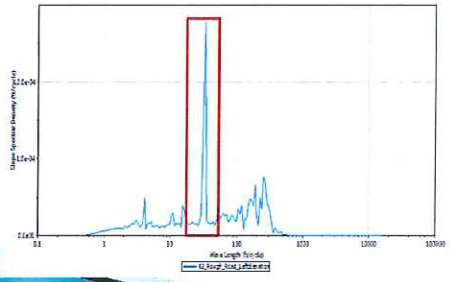
Inadequate Roller Freq/Amp Settings on HMA



Concrete Paving Stringline

PSD Analysis

Stringline Sags



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.

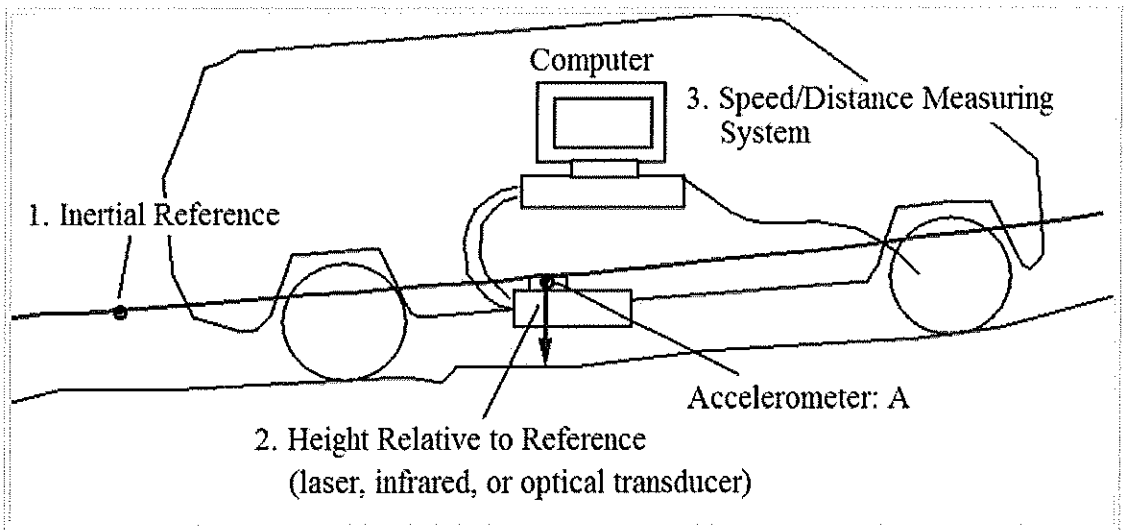


Fig. 106.3.2.59.1

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

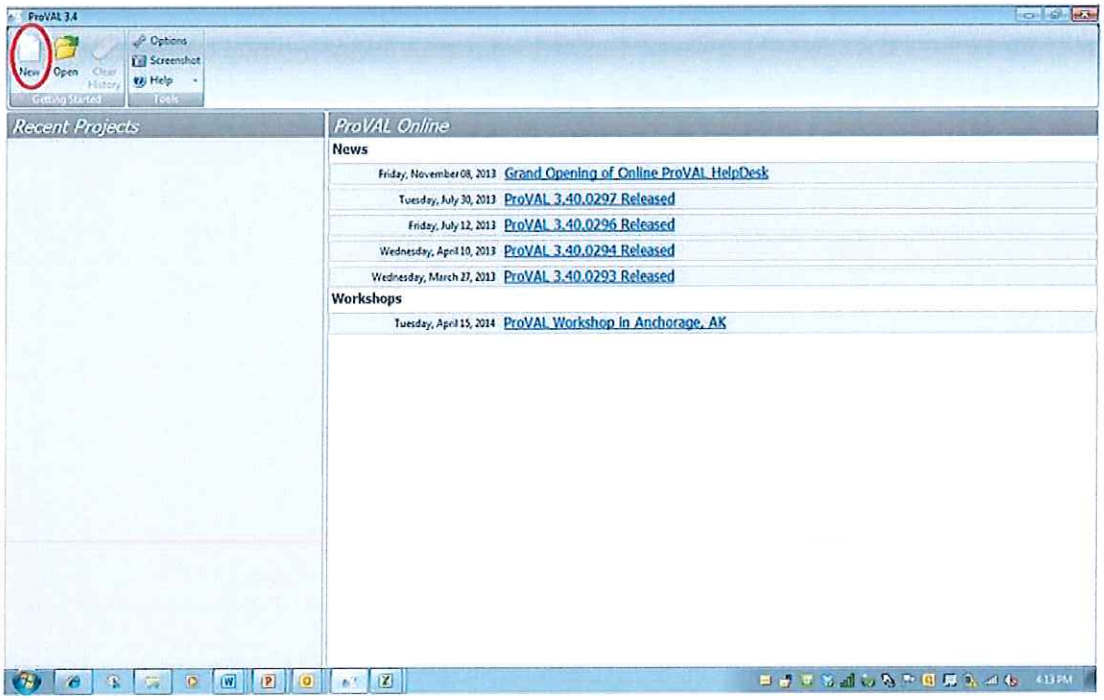
Electronic Profilograph File Naming Convention*	
Abbreviation	Definition
YYMMDD-###_	Contract ID (Letting Date-Call Number)
YYMMDD_	Test Date
Q_	Type of quality test (C for control, A for assurance)
D	Direction of Lane (N,E,W or S)
L	Lane number (1 for inside lane, increasing by one for each lane to 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

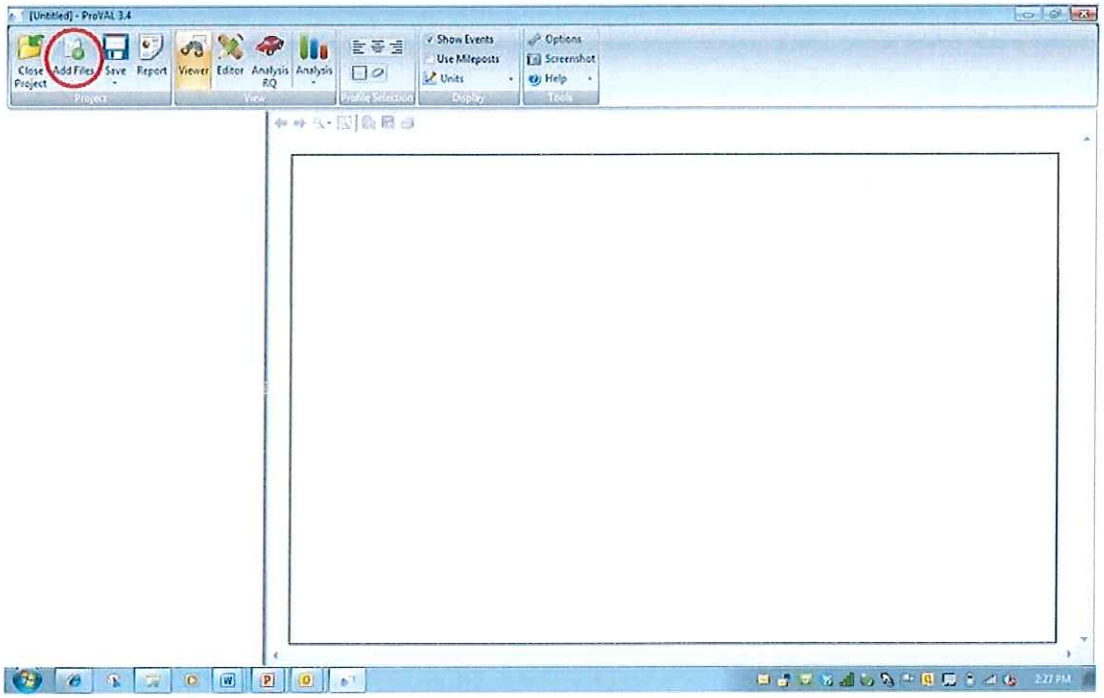
The data will first be analyzed for ride quality, which will determine the average IRI for each wheel track on a per segment basis. The steps are as follow:

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



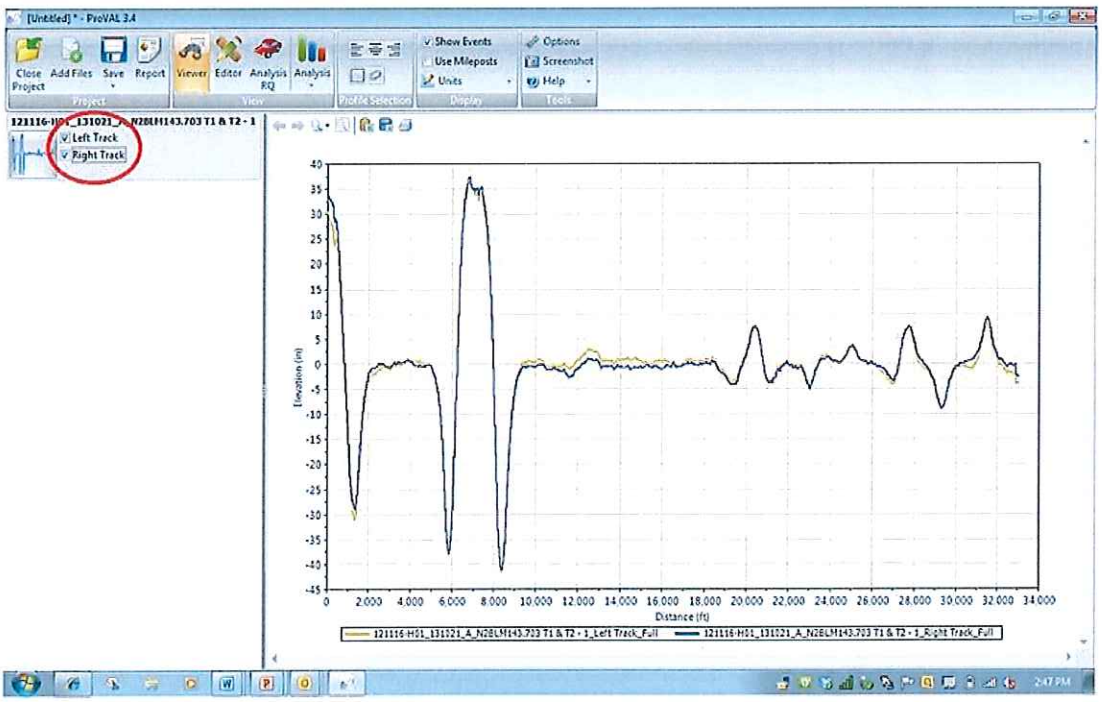
- **Select "Add Files" to import PPF file with QC/QA profile data.**

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

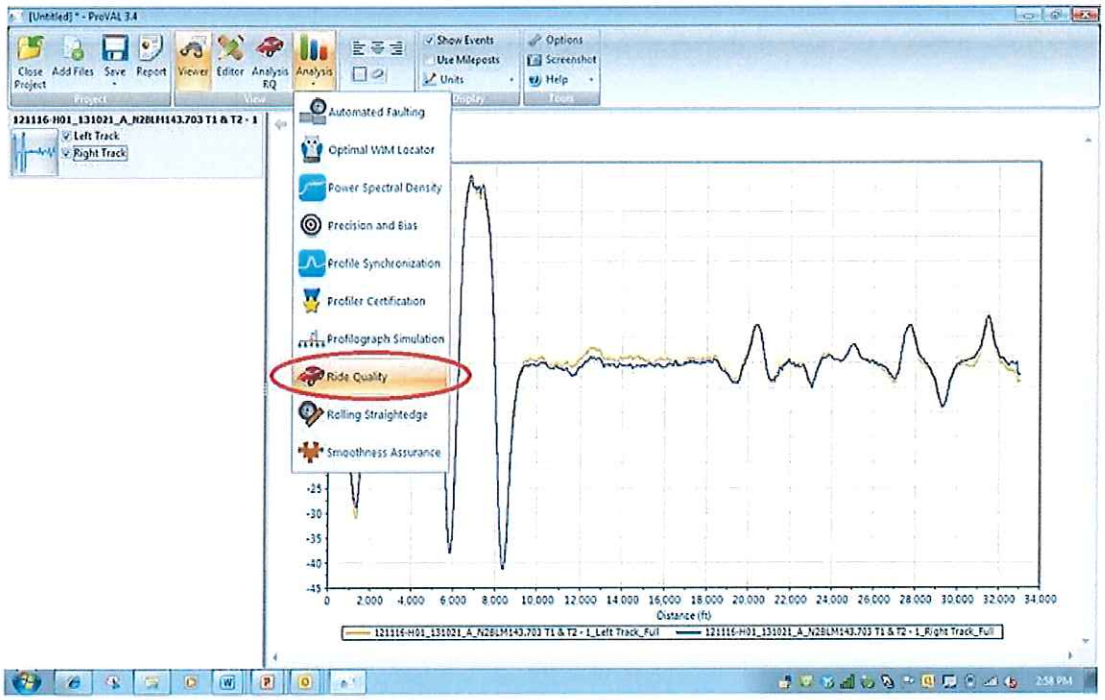


- **Select left elevation and right elevation.**

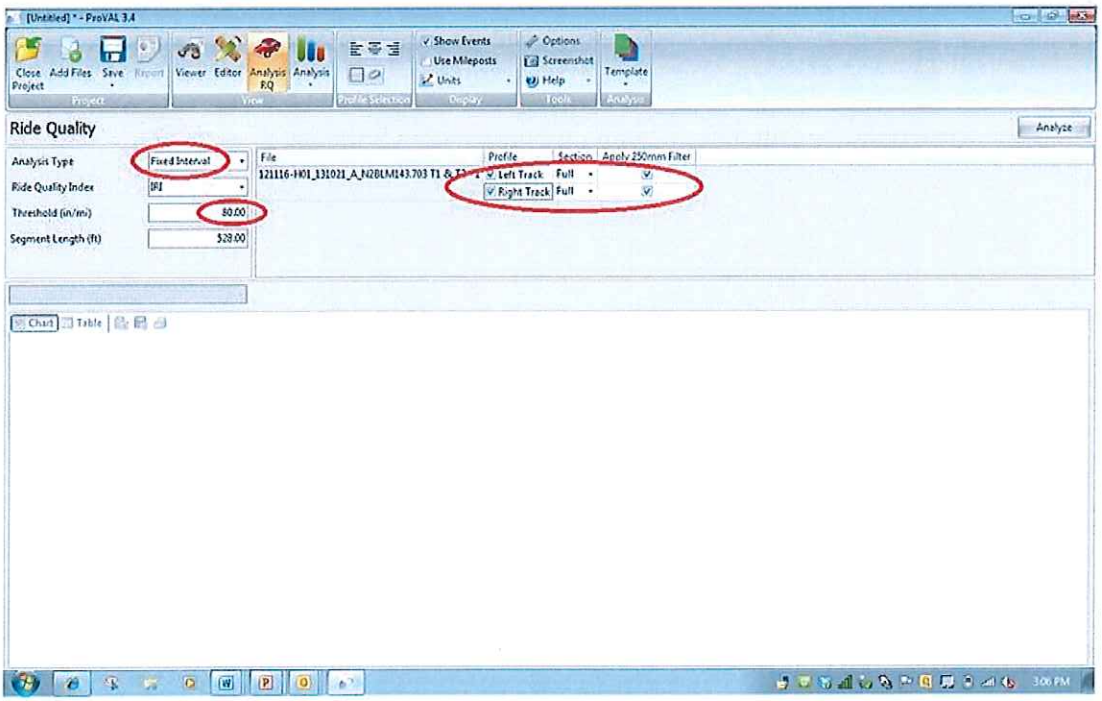
The following example uses a file containing both wheel paths. The program will correctly align files with individual wheel paths, provided the data collection was initiated at the same starting station for both files. The next screen shot shows the actual change in elevation along the profile length.



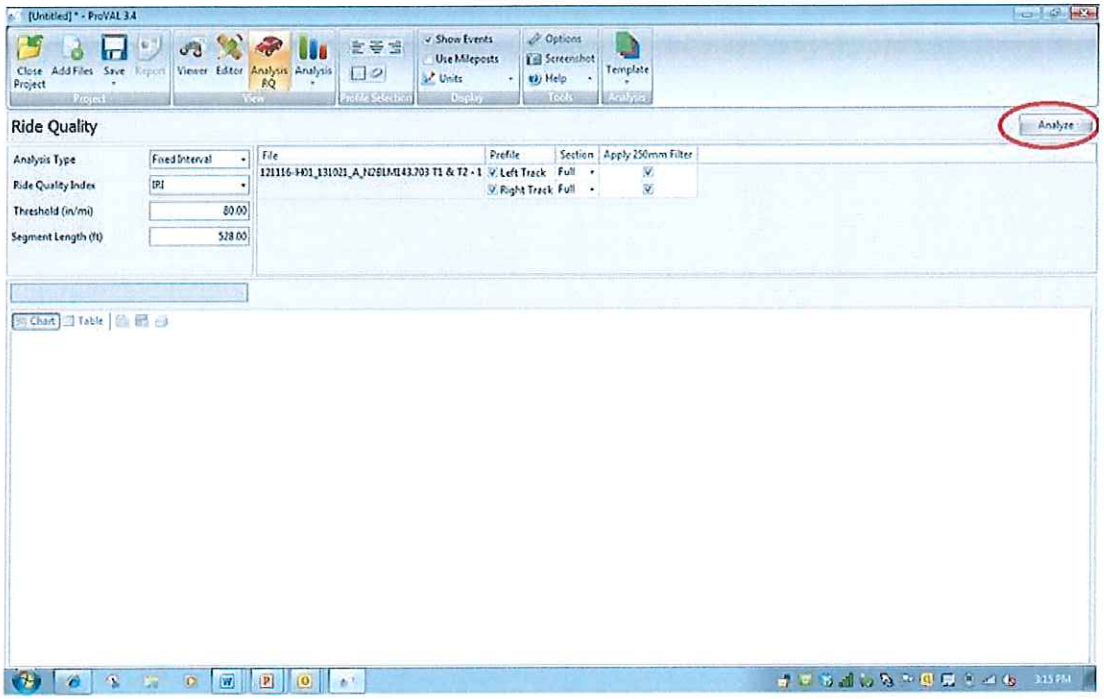
- **Select "Ride Quality" in the "Analysis" module.**



- **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.**

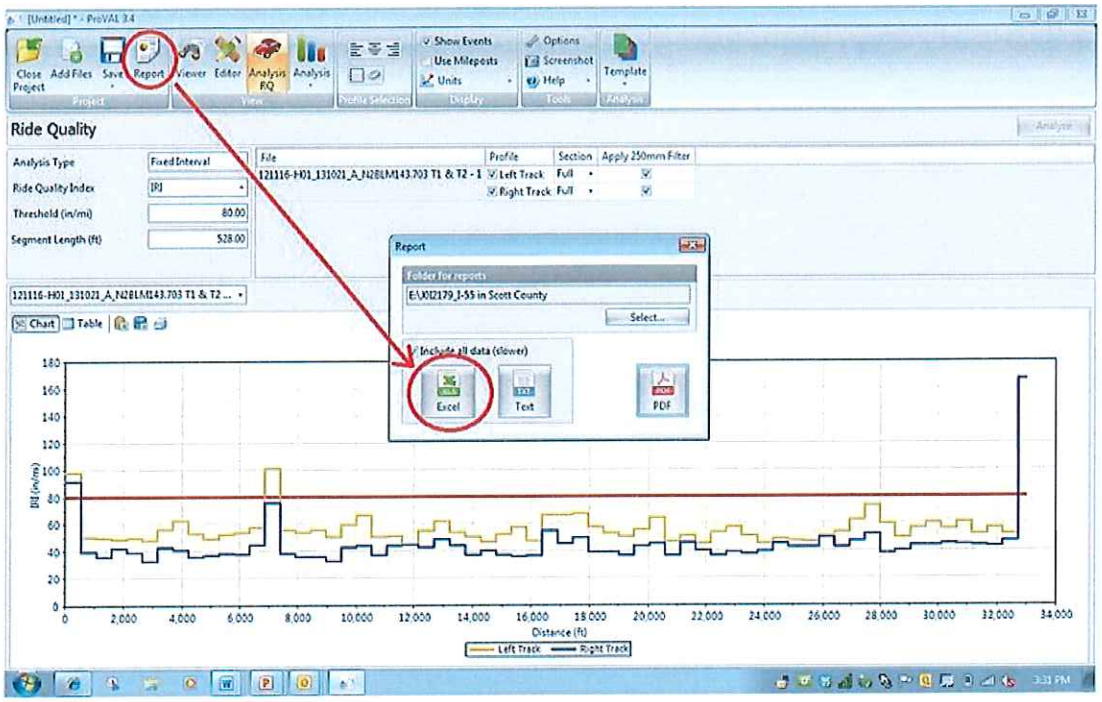


- **Select "Analyze".**



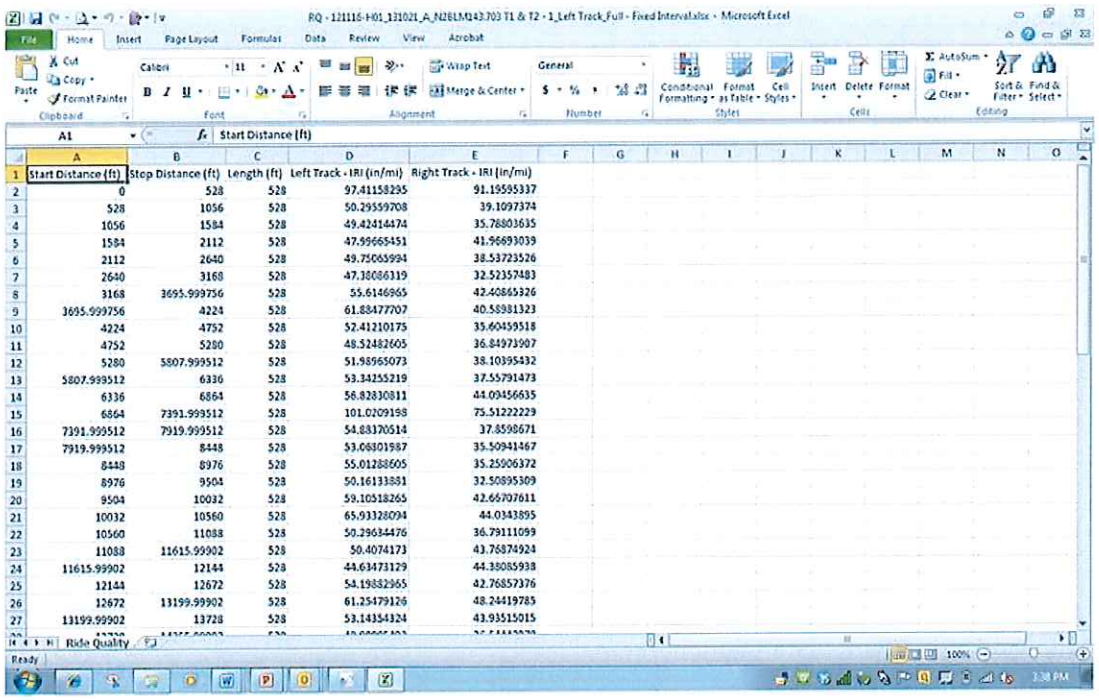
The average IRI of a wheel path for each 528 ft. long segment will be shown on the screen. The drop down menu above table at left can be used to view either left or right wheel path IRI values

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



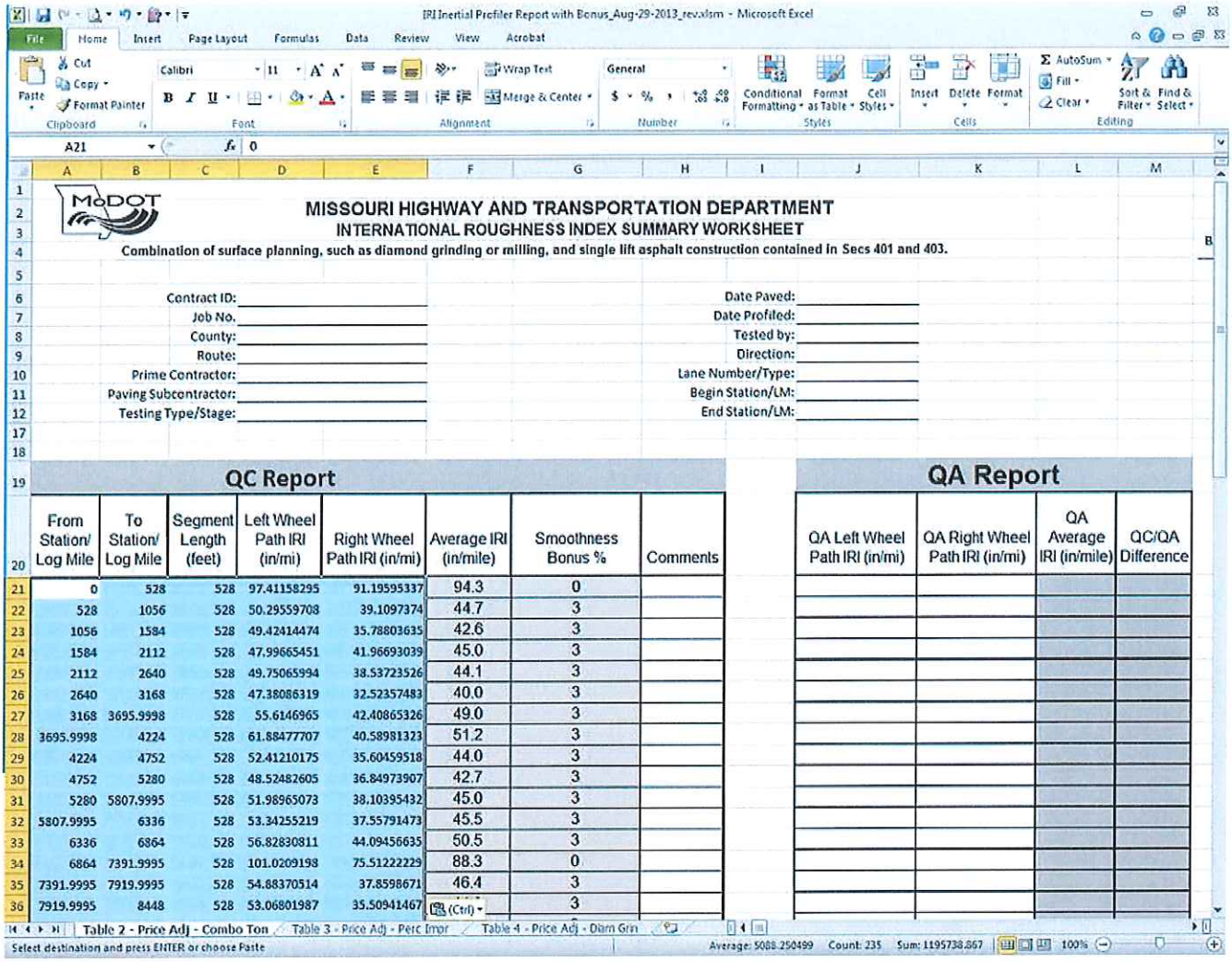
- Open the Excel file.

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)
0	528	528	97.41158295	91.19595337
528	1056	528	50.29559708	39.1097374
1056	1584	528	49.42414474	35.78803635
1584	2112	528	47.99665451	41.96693039
2112	2640	528	49.75065994	38.53723526
2640	3168	528	47.38086319	32.52357483
3168	3695.999756	528	55.6146965	42.40865326
3695.999756	4224	528	61.88477707	40.58981323
4224	4752	528	52.41210175	35.60459518
4752	5280	528	48.52482605	36.84973907
5280	5807.999512	528	51.98965073	38.10395432
5807.999512	6336	528	53.34255219	37.55791473
6336	6864	528	58.82830811	44.09456635
6864	7391.999512	528	101.0209198	75.51222229
7391.999512	7919.999512	528	54.88170514	37.8598671
7919.999512	8448	528	53.06801987	35.50941467
8448	8976	528	55.01288605	35.25906372
8976	9504	528	50.16133881	32.50895309
9504	10032	528	59.10518265	42.66707611
10032	10560	528	65.93328094	44.0343895
10560	11088	528	50.29634476	36.79111099
11088	11615.99902	528	50.4074173	43.76874924
11615.99902	12144	528	44.63473129	44.38085938
12144	12672	528	54.19882965	42.76857376
12672	13199.99902	528	61.25479126	48.24419785
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.



MISSOURI HIGHWAY AND TRANSPORTATION DEPARTMENT
INTERNATIONAL ROUGHNESS INDEX SUMMARY WORKSHEET
Combination of surface planning, such as diamond grinding or milling, and single lift asphalt construction contained in Secs 401 and 403.

Contract ID: ____ Date Paved: ____
Job No. ____ Date Profiled: ____
County: ____ Tested by: ____
Route: ____ Direction: ____
Prime Contractor: ____ Lane Number/Type: ____
Paving Subcontractor: ____ Begin Station/LM: ____
Testing Type/Stage: ____ End Station/LM: ____

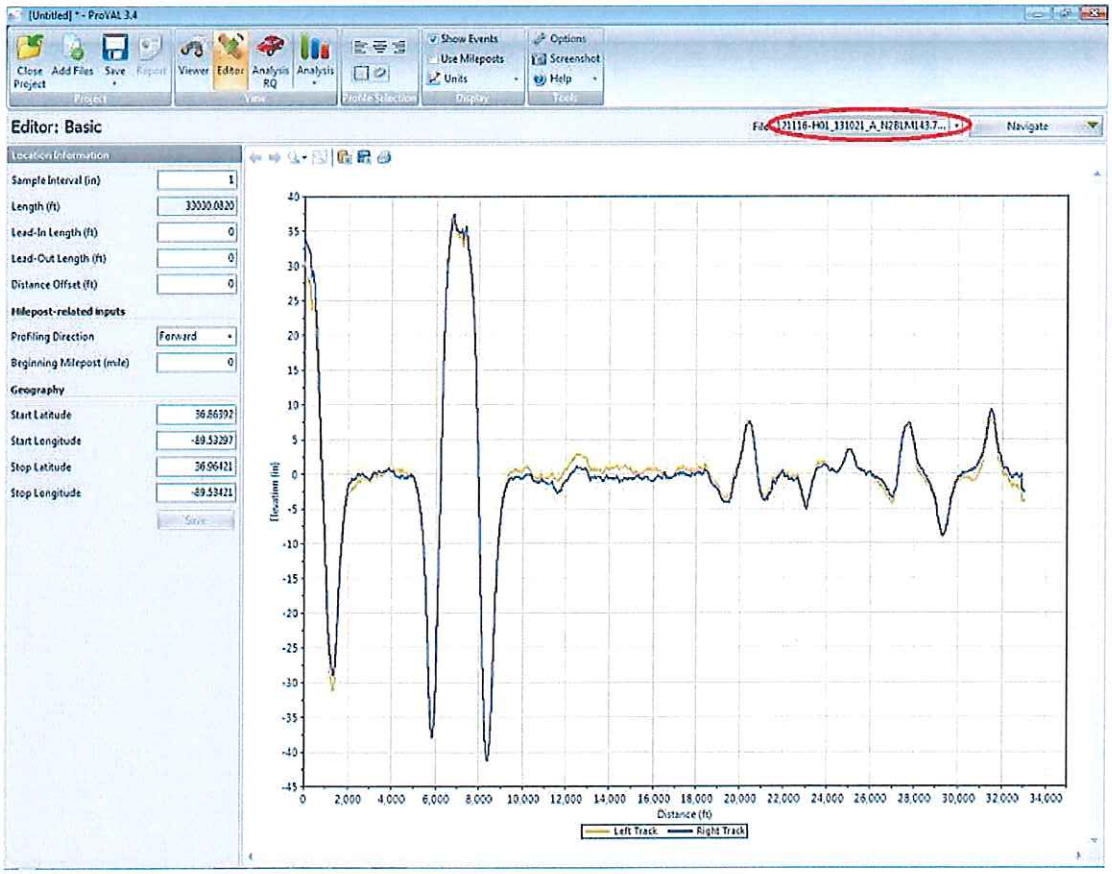
QC Report								QA Report			
From Station/ Log Mile	To Station/ Log Mile	Segment Length (feet)	Left Wheel Path IRI (in/mi)	Right Wheel Path IRI (in/mi)	Average IRI (in/mile)	Smoothness Bonus %	Comments	QA Left Wheel Path IRI (in/mi)	QA Right Wheel Path IRI (in/mi)	QA Average IRI (in/mile)	QC/QA Difference
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:

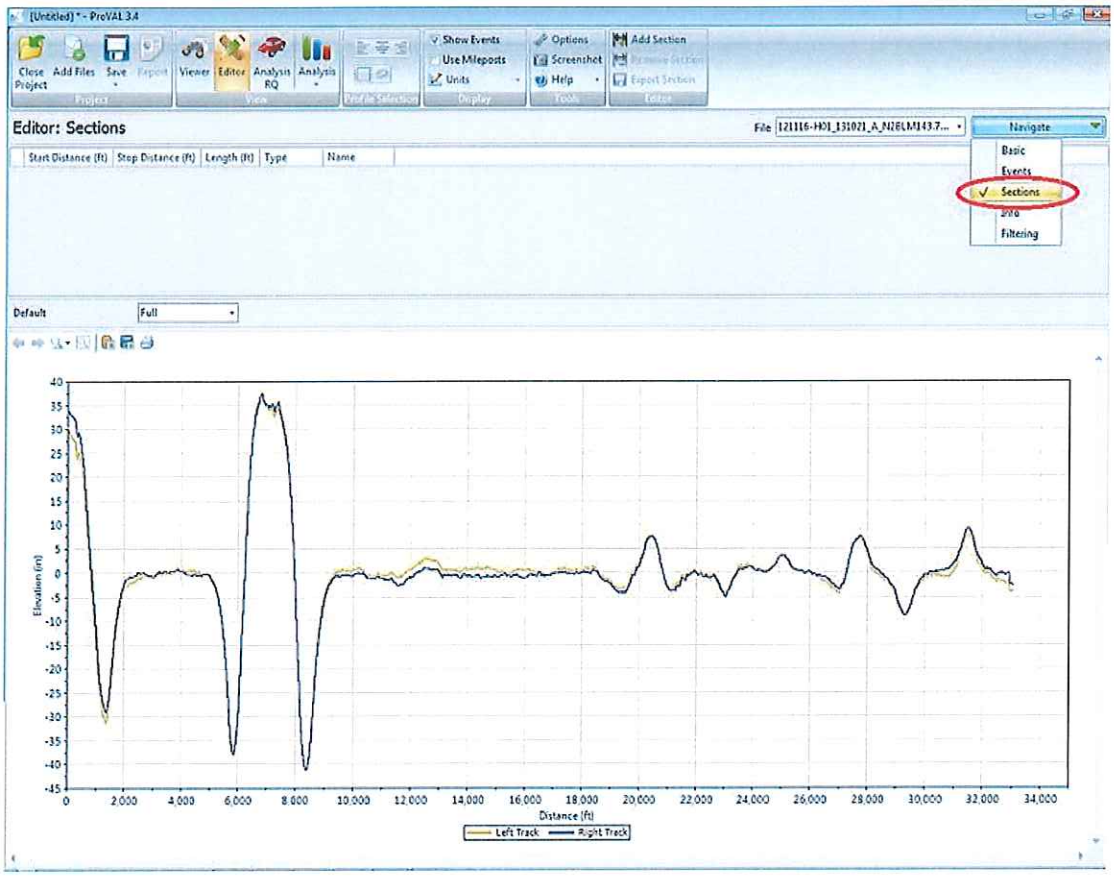
1) Stop the profile run at the beginning of the exemption and begin a new section profile at the end of the exemption.
2) Manually enter exemption boundaries in the data acquisition software during the profile run (typically performed with high speed IPs).
3) Enter a "leave-out" area in ProVAL during 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.

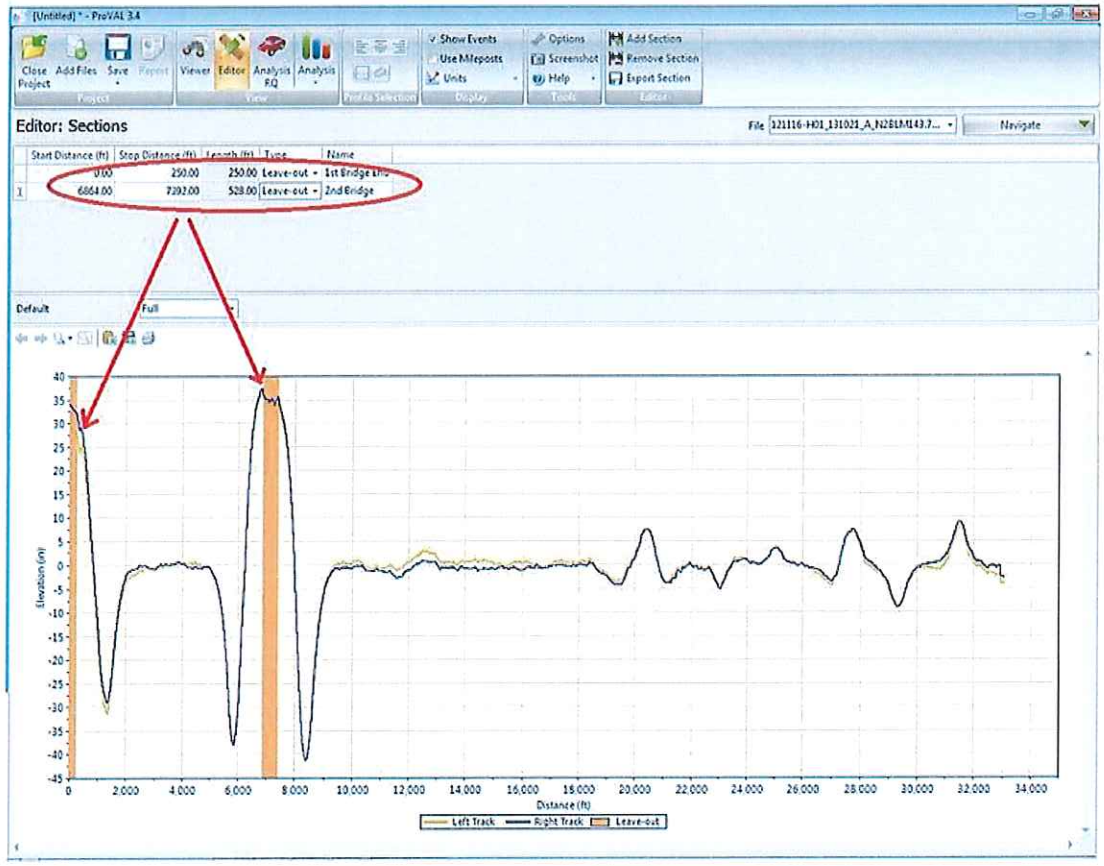


- Select "Sections in the "Navigate" dropdown box.

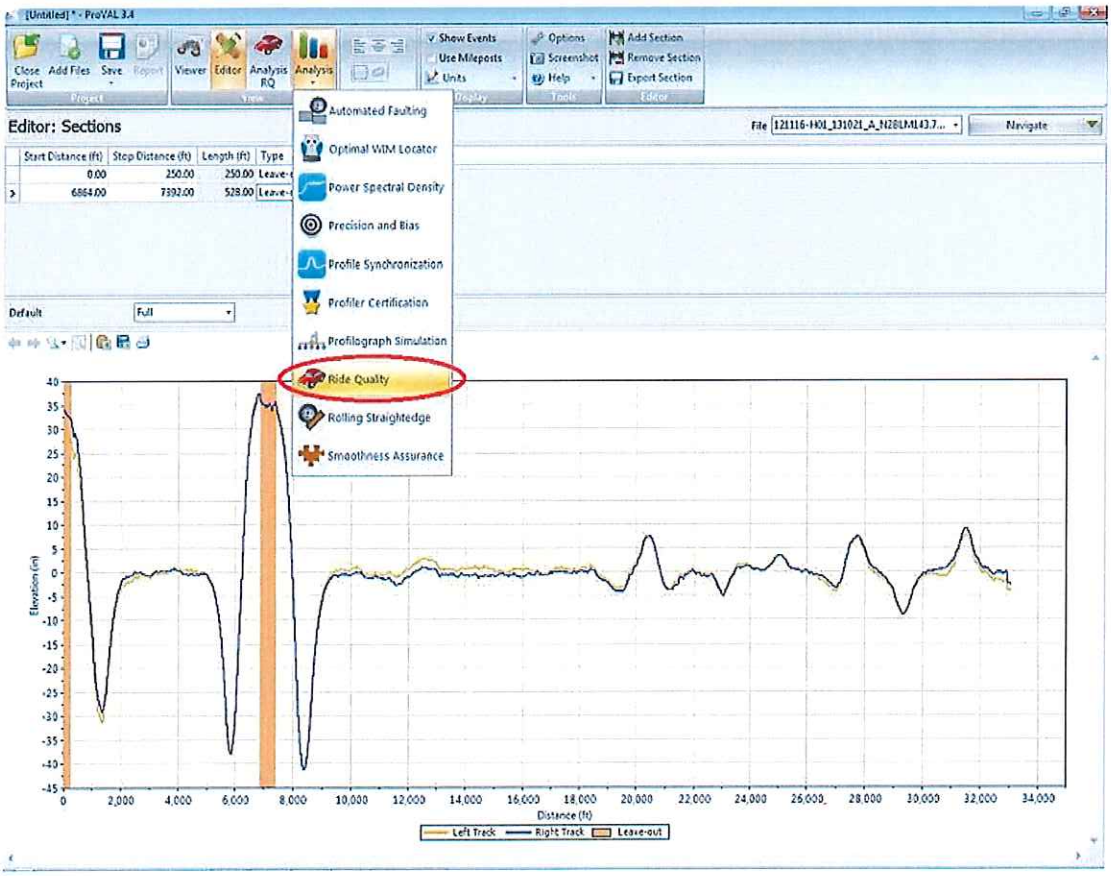


- **Select "Add Section".**
- **Enter section(s) Start Distance, Stop Distance, Type (Leave-out) and Name.**

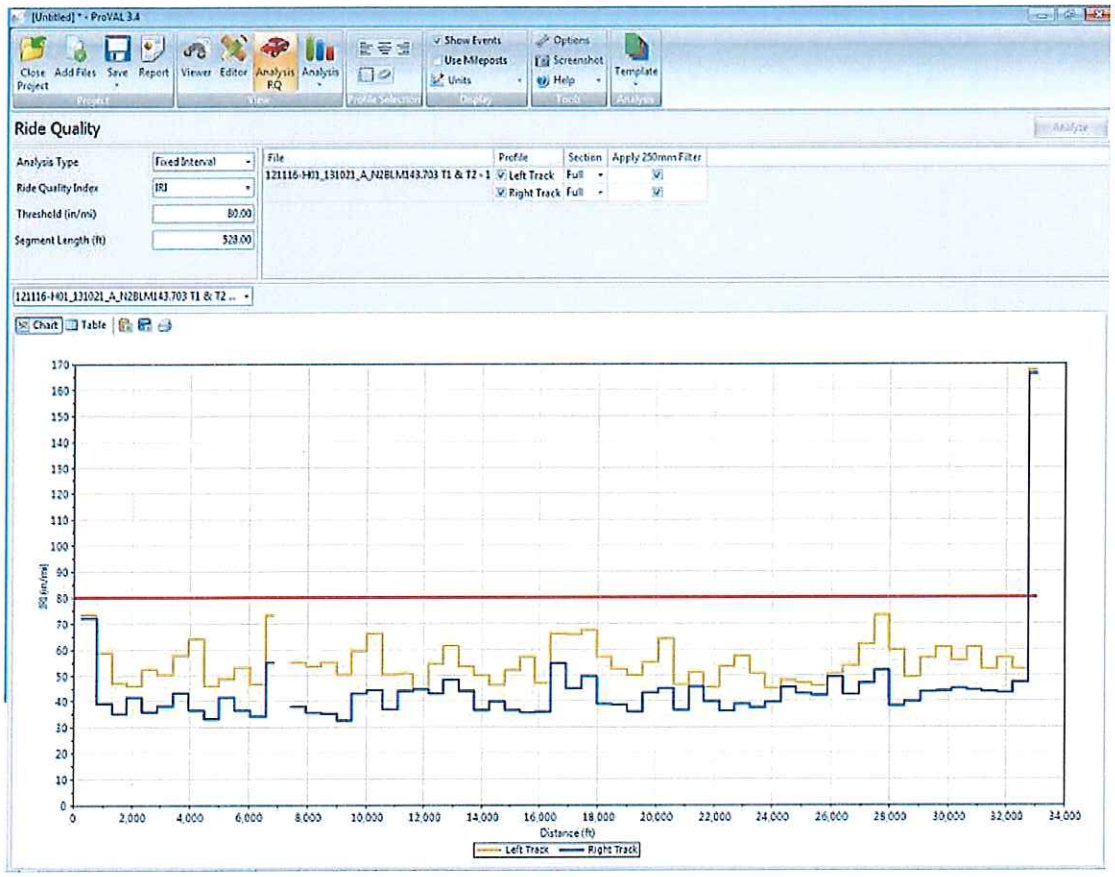
For this example, assume there are two leave-out areas: one at the beginning where a bridge approach on the upstream side is within limits and another over a mile farther where there is another bridge.



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

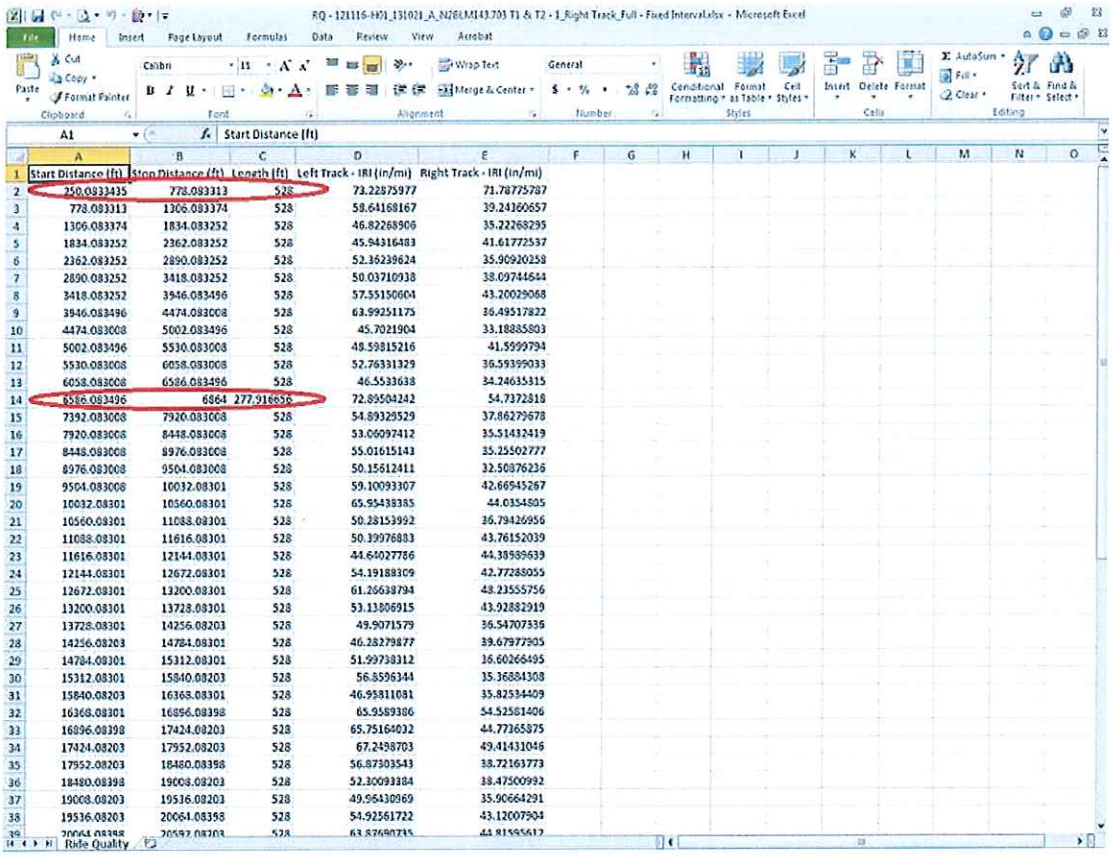


The ride quality summary shown below now excludes the exempted areas of the profile and abbreviates the associated segments accordingly.



- 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.



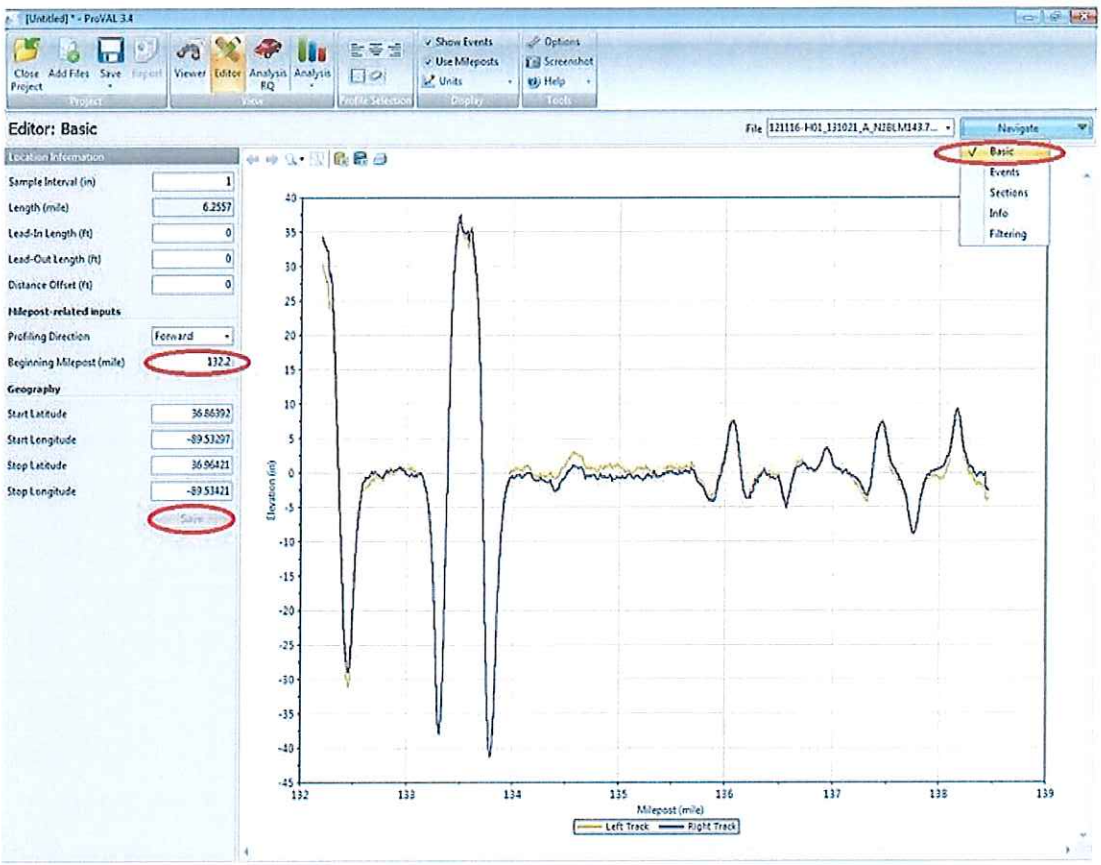
Start Distance (ft)	Stop Distance (ft)	Length (ft)	Left Track - IRI (in/mi)	Right Track - IRI (in/mi)
250.0833435	778.083313	528	73.22875977	71.78775787
778.083313	1306.083374	528	58.64168167	39.24360657
1306.083374	1834.083252	528	46.82268906	35.22268295
1834.083252	2362.083252	528	45.94316483	41.61772537
2362.083252	2890.083252	528	52.36239624	35.90920258
2890.083252	3418.083252	528	50.03710938	38.09744644
3418.083252	3946.083496	528	57.55150604	43.20029068
3946.083496	4474.083008	528	63.99251175	36.49517822
4474.083008	5002.083496	528	45.7021904	33.18885803
5002.083496	5530.083008	528	49.59815216	41.5999794
5530.083008	6058.083008	528	52.76331329	36.59399033
6058.083008	6586.083496	528	46.5533638	34.24635315
6586.083496	6864	277.916656	72.89504242	54.7372818
7392.083008	7920.083008	528	54.89329529	37.86279678
7920.083008	8448.083008	528	53.06097412	35.51432419
8448.083008	8976.083008	528	55.01615143	35.25502777
8976.083008	9504.083008	528	50.15612411	32.50876236
9504.083008	10032.08301	528	59.10093307	42.66945267
10032.08301	10560.08301	528	65.95438385	44.0354805
10560.08301	11088.08301	528	50.28153992	36.79426956
11088.08301	11616.08301	528	50.39976883	43.76152039
11616.08301	12144.08301	528	44.64027786	44.38989639
12144.08301	12672.08301	528	54.19188309	42.77288055
12672.08301	13200.08301	528	61.26638794	48.23555756
13200.08301	13728.08301	528	53.13806915	43.92882919
13728.08301	14256.08203	528	49.9071579	36.54707336
14256.08203	14784.08301	528	46.28279877	39.67977905
14784.08301	15312.08301	528	51.99738312	36.60266495
15312.08301	15840.08203	528	56.8596344	35.36884308
15840.08203	16368.08301	528	46.95811081	35.82534409
16368.08301	16896.08398	528	65.9589386	54.52581406
16896.08398	17424.08203	528	65.75164032	44.77365875
17424.08203	17952.08203	528	67.2498703	49.41431046
17952.08203	18480.08398	528	56.87303543	38.72163773
18480.08398	19008.08203	528	52.30093384	38.47500992
19008.08203	19536.08203	528	49.96430969	35.90664291
19536.08203	20064.08398	528	54.92561722	43.12007904
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"

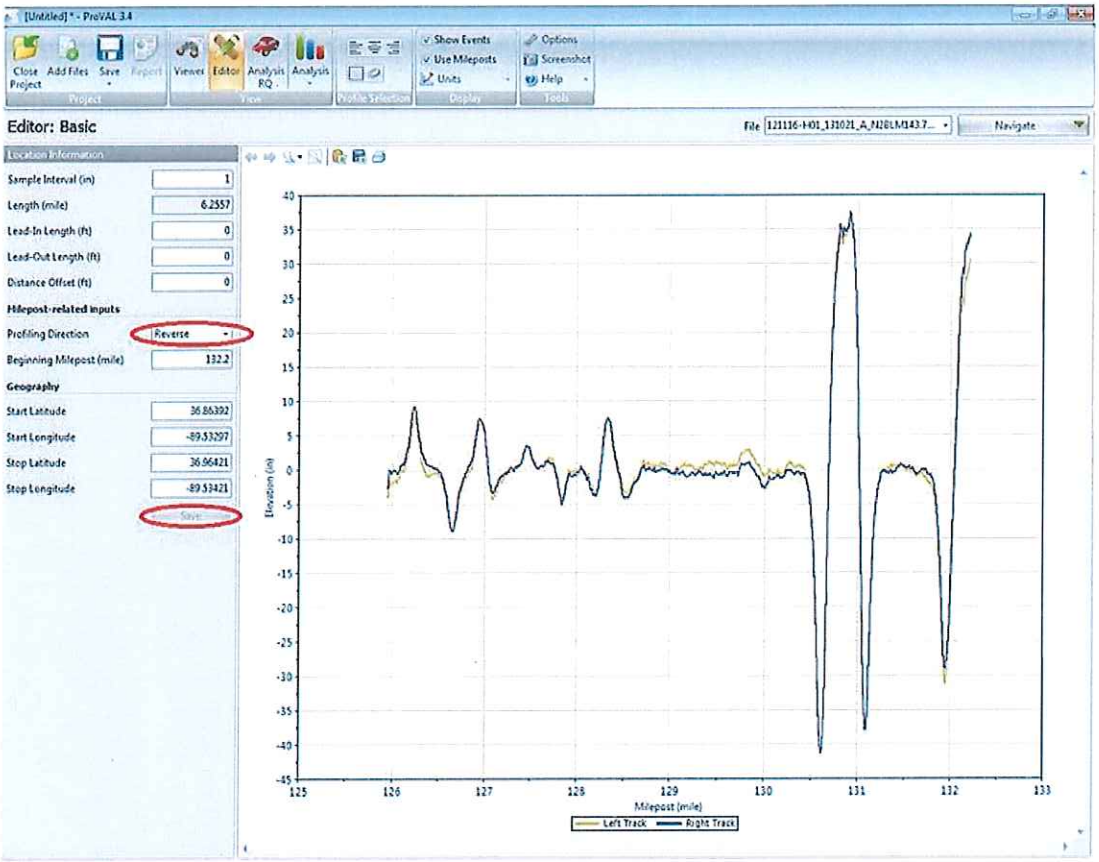
ProVAL has now reformatted the stations to represent actual project limits for the profile section.



106.3.2.59.3.1.2 Reversing Stations

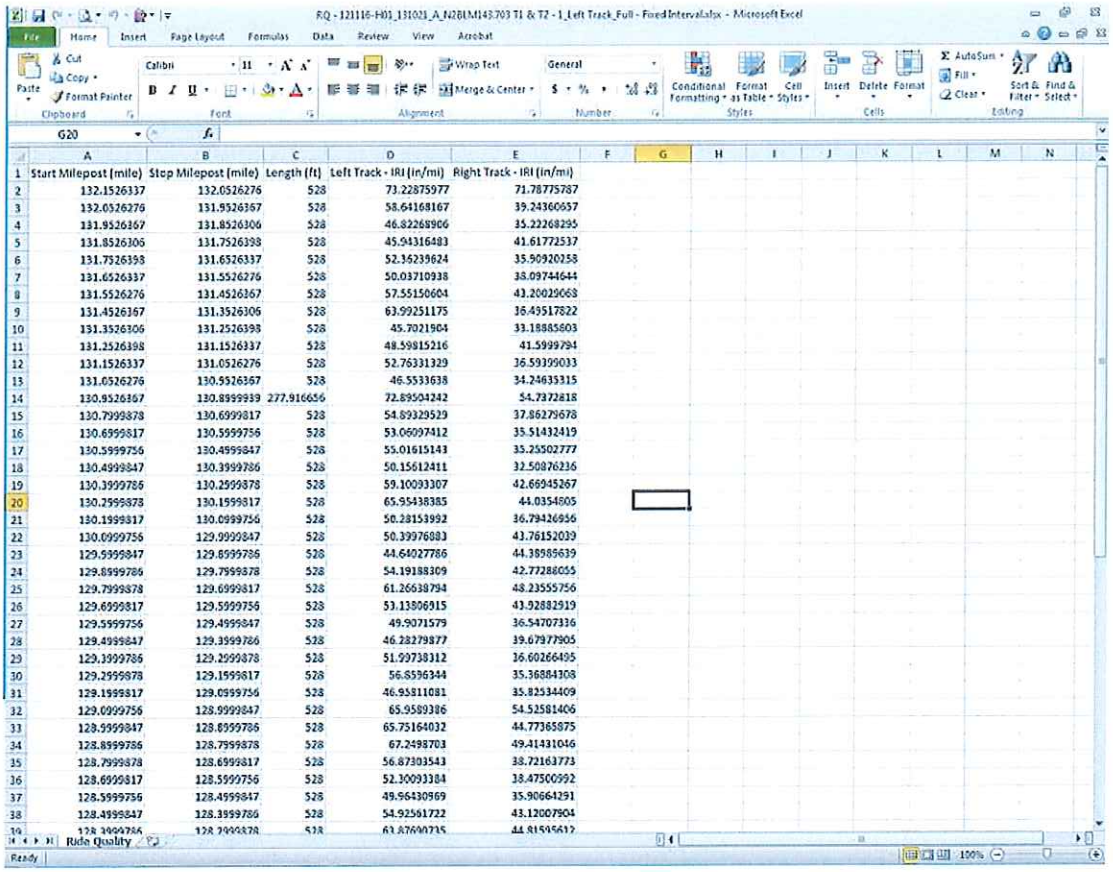
Another situation that may arise is when the direction of travel is in a station descending direction. ProVAL can also easily make this adjustment in the "Editor" mode. For this example, the starting log mile 132.2 will be retained.

- 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.

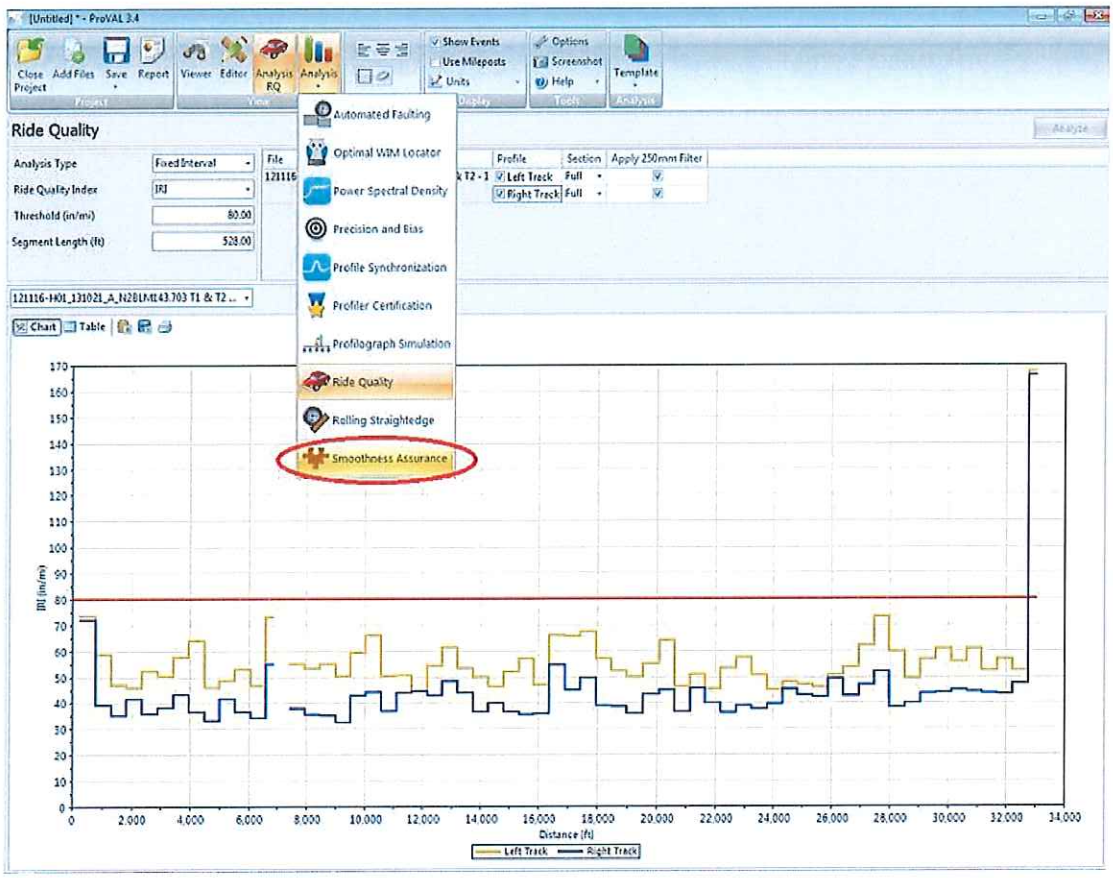
- Select "Analysis" and select "Ride Quality".
- Select "Excel" in "Report" dropdown box.
- Open the Excel report.



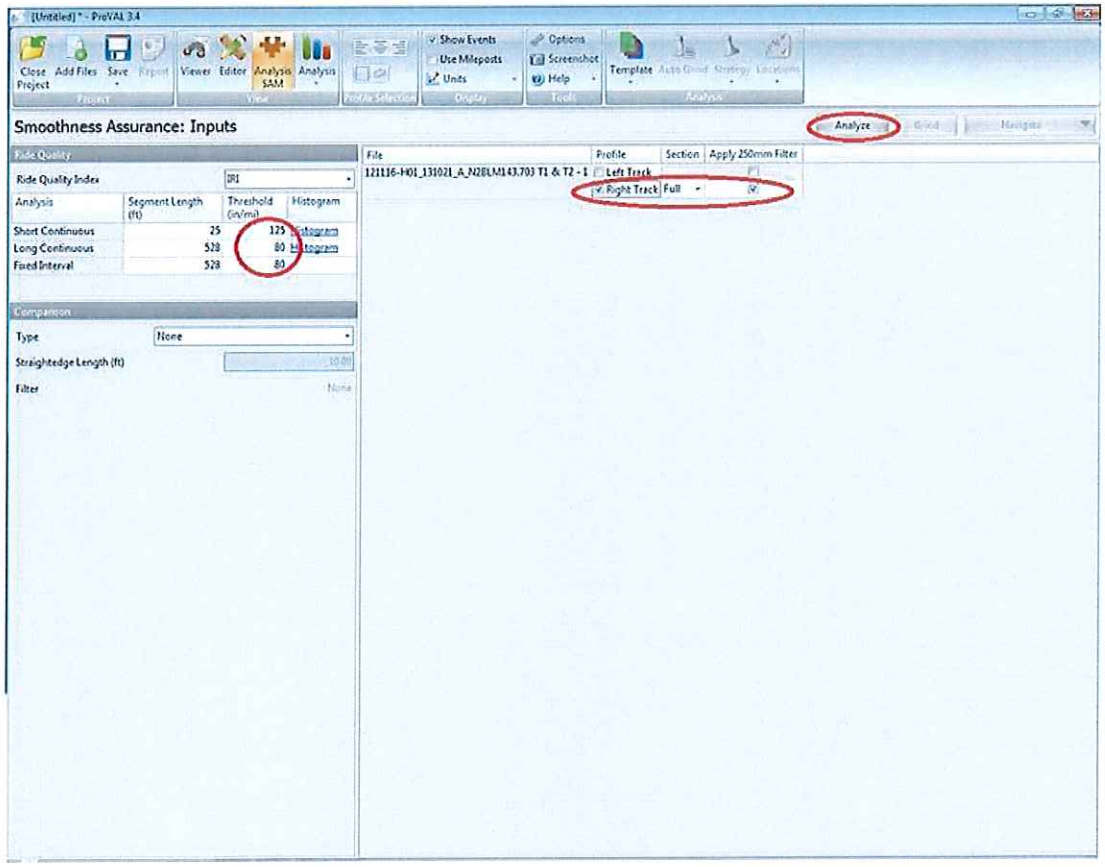
Start Milepost (mile)	Stop Milepost (mile)	Length (ft)	Left Track - IRI (in/mi)	Right Track - IRI (in/mi)
132.1526337	132.0526276	528	73.22875977	71.78775787
132.0526276	131.9526367	528	58.64168167	39.24360657
131.9526367	131.8526306	528	46.82268906	35.22268295
131.8526306	131.7526398	528	45.94316483	41.61772537
131.7526398	131.6526337	528	52.36239624	35.90920258
131.6526337	131.5526276	528	50.03710938	38.09744644
131.5526276	131.4526367	528	57.55150604	41.20029668
131.4526367	131.3526306	528	63.99251175	36.49517822
131.3526306	131.2526398	528	45.7021904	33.18885603
131.2526398	131.1526337	528	48.59815216	41.5999794
131.1526337	131.0526276	528	52.76331329	36.59399033
131.0526276	130.9526367	528	46.5533638	34.24635315
130.9526367	130.8999939	277.916656	72.89504242	54.7372818
130.7999878	130.6999817	528	54.89329529	37.86279678
130.6999817	130.5999756	528	53.06097412	35.51432419
130.5999756	130.4999847	528	55.01615143	35.25502777
130.4999847	130.3999786	528	50.15612411	32.50876236
130.3999786	130.2999878	528	59.10093307	42.66945267
130.2999878	130.1999817	528	65.95438385	44.0354605
130.1999817	130.0999756	528	50.28153992	36.79426956
130.0999756	129.9999847	528	50.39976883	43.76152039
129.9999847	129.8999786	528	44.64027786	44.38985639
129.8999786	129.7999878	528	54.19188309	42.77288055
129.7999878	129.6999817	528	61.26638794	48.23555756
129.6999817	129.5999756	528	53.13806915	43.92882919
129.5999756	129.4999847	528	49.9071579	36.54707316
129.4999847	129.3999786	528	46.28279877	39.67977905
129.3999786	129.2999878	528	51.99738312	36.60266495
129.2999878	129.1999817	528	56.8596344	35.36884308
129.1999817	129.0999756	528	46.93811081	35.82534409
129.0999756	128.9999847	528	65.9589386	54.52581406
128.9999847	128.8999786	528	65.75164032	44.77365875
128.8999786	128.7999878	528	67.2498703	49.41431046
128.7999878	128.6999817	528	56.87303543	38.72163773
128.6999817	128.5999756	528	52.30093384	38.47500992
128.5999756	128.4999847	528	49.96430969	35.90664291
128.4999847	128.3999786	528	54.92561722	43.12007904
128.3999786	128.2999878	528	63.87600735	44.81595612

106.3.2.59.3.2 Areas of Localized Roughness

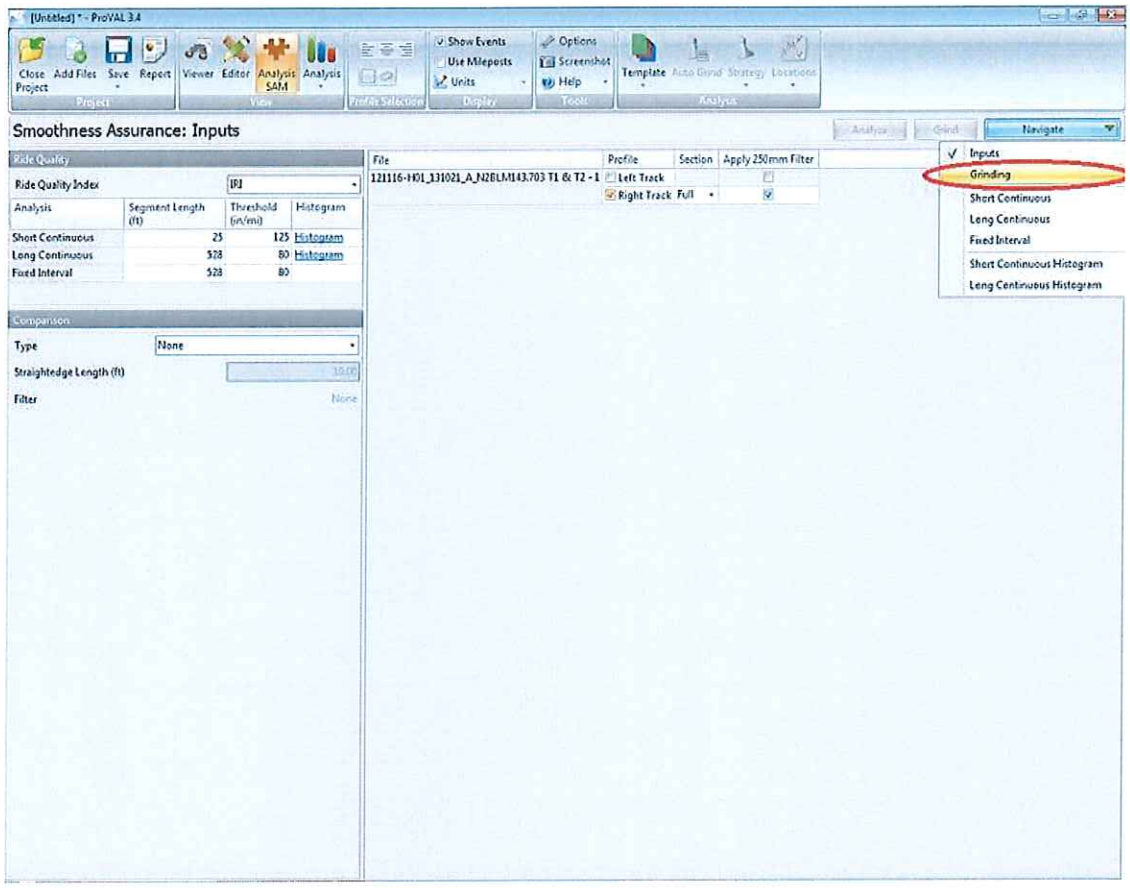
- **Select "Smoothness Assurance" in "Analysis" dropdown box.**



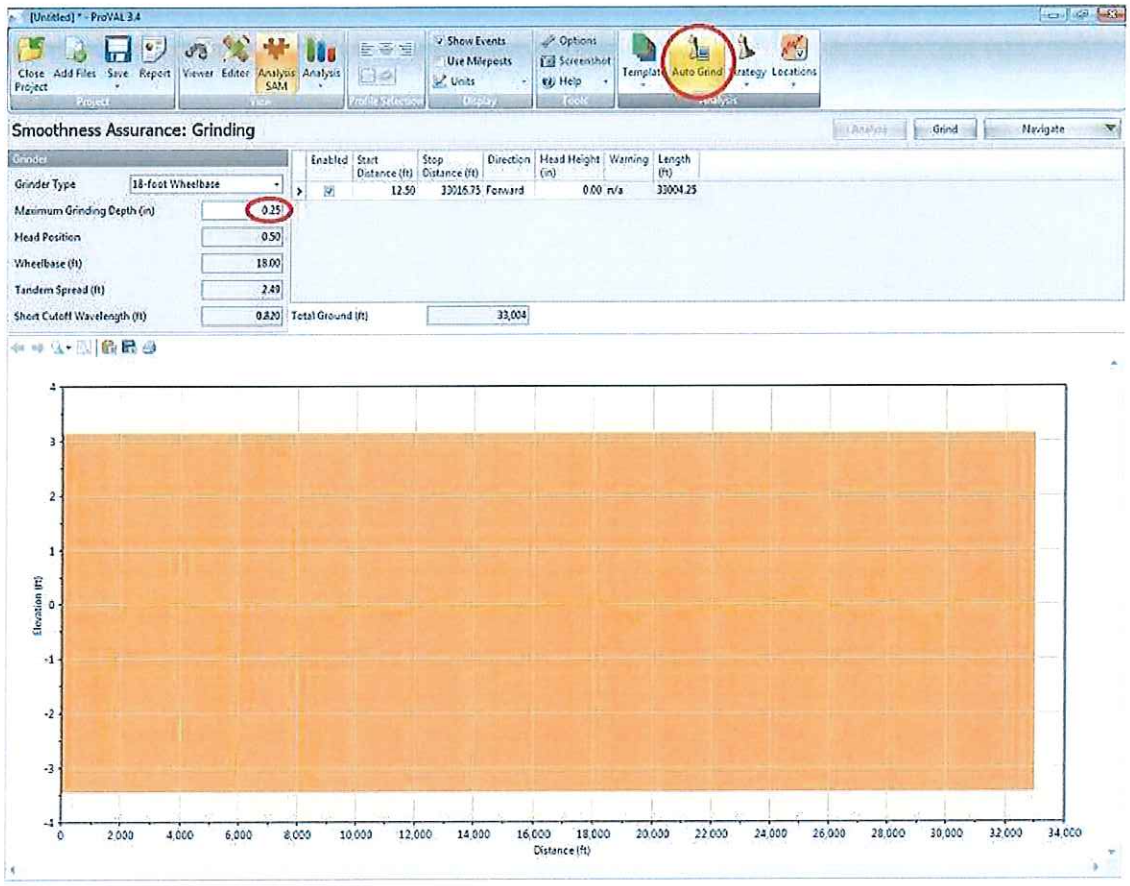
- **Change "Threshold" value for "Short Continuous" analysis to 125 (in/mi) in the "Ride Quality" section. (The segment length for "Short Continuous" should be set at the default value of 25 ft.). Change "Threshold" for "Long Continuous" and "Fixed Interval" in the "Profile" section to 80 (in/mi). (The "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".**



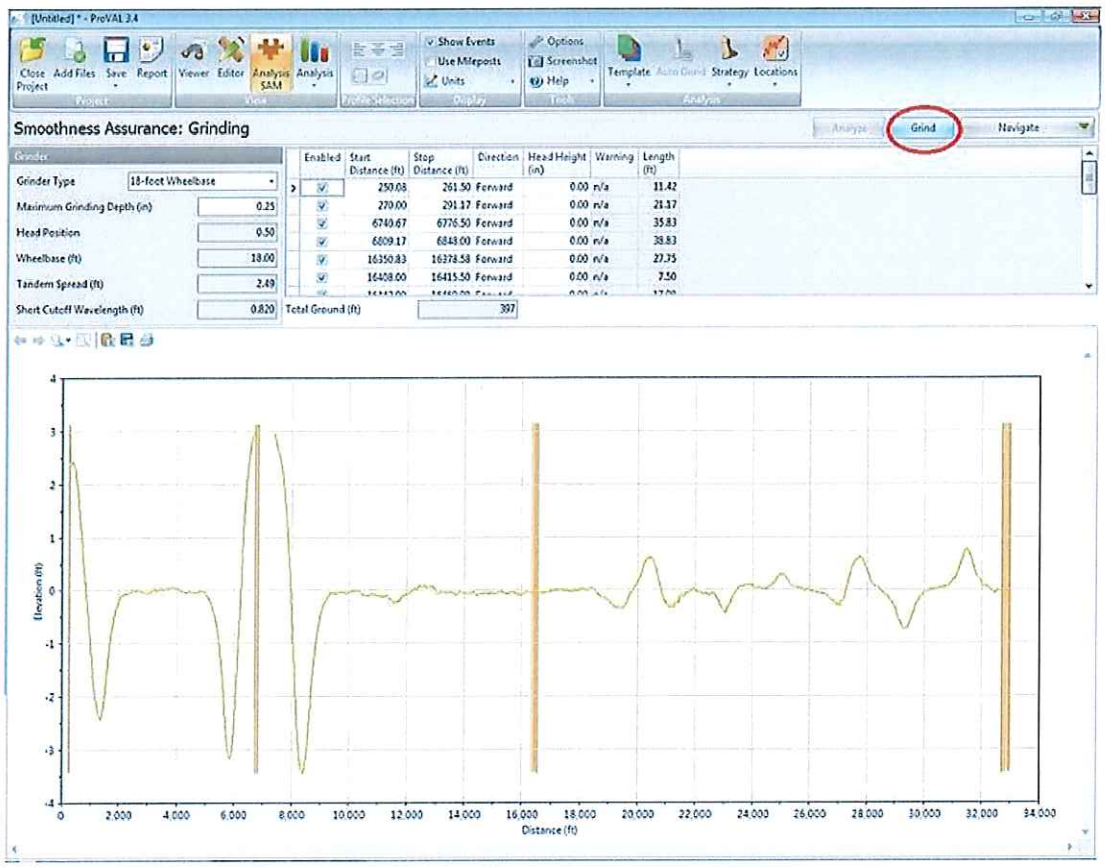
- **Select "Grinding" in the "Navigate" dropdown box.**



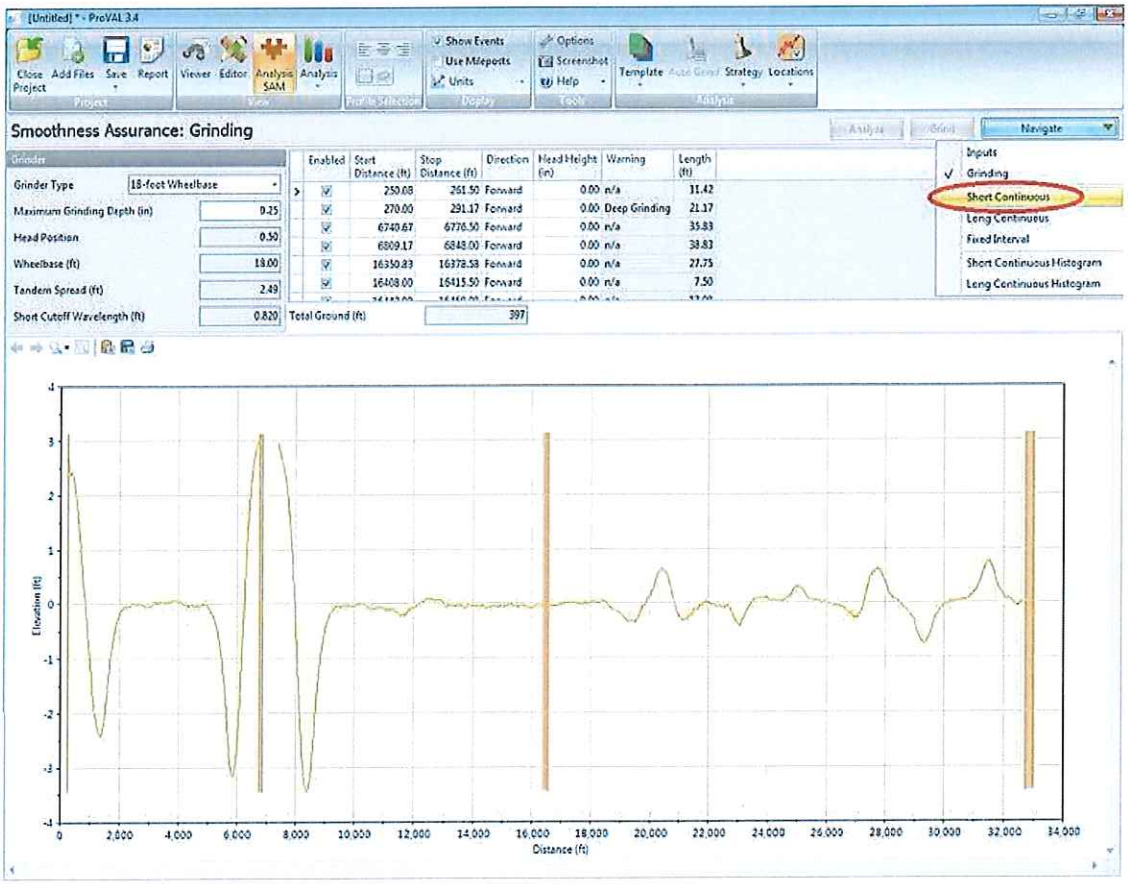
- **Enter 0.25 inches for "Maximum Grinding Depth" in "Grinder" section. (The following parameters should show the default values, which are Head Position = 0.50, Wheelbase (ft) = 18.00, Tandem Spread (ft) = 2.49 and Short Cut-Off Wavelength (ft) = 0.820 ft.)**
- **Select "Auto Grind".**



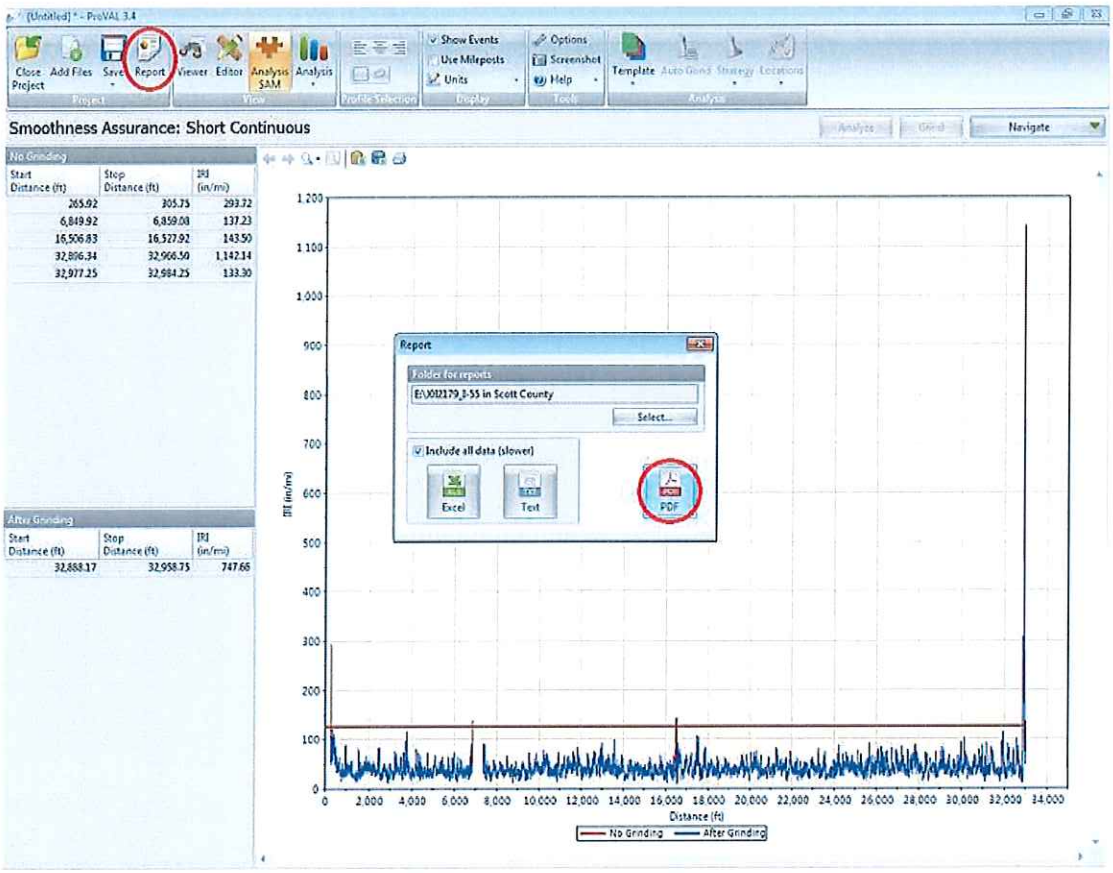
- **Select "Grind".**



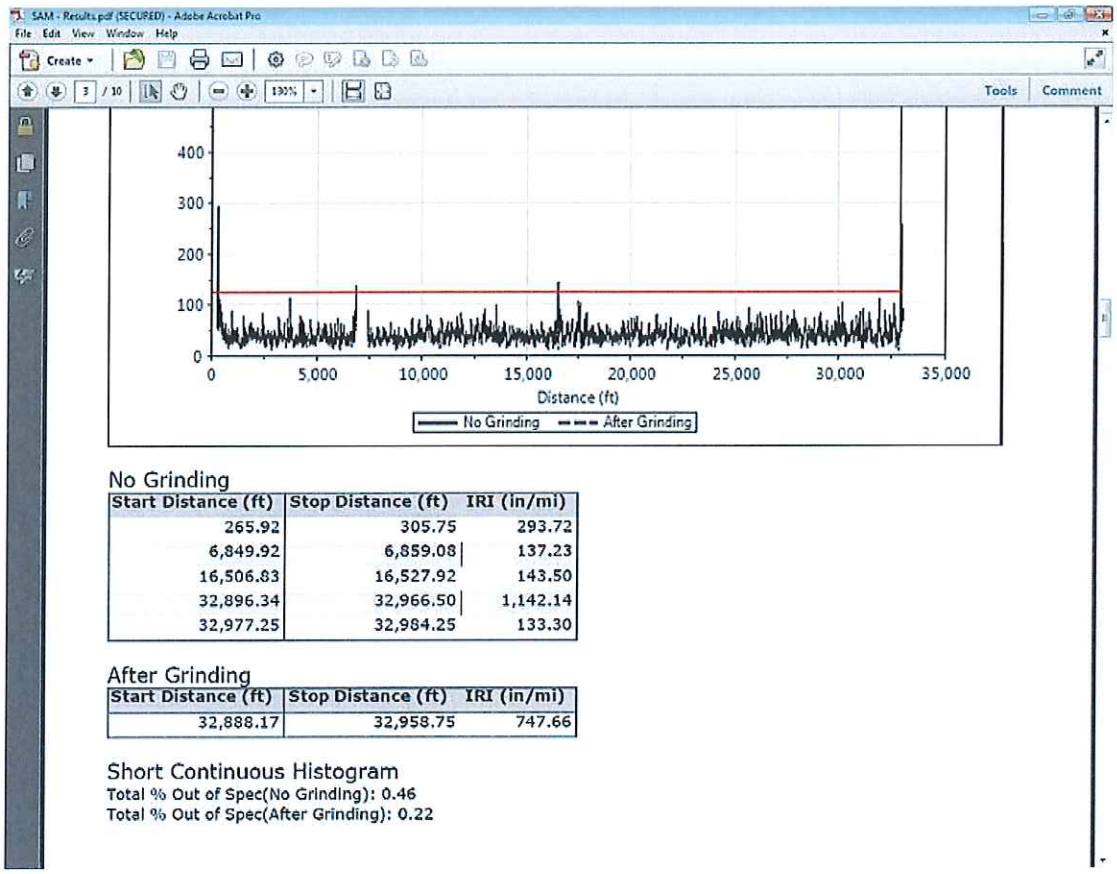
- **Select "Short Continuous" in "Navigate" dropdown box.**



- **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

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.

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.

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.

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.

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.

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 wheelpath profiles.

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.

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.

Sample Interval – The longitudinal distance between captured data points.

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.

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.

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.

Performance Checklist

MoDOT

MODOT TM 59: IRI Profiler Operator Qualification
PROFICIENCY CHECKLIST

Applicant:_____

Employer:_____

Part 1

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

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
  o Engine..... ____
  o Transmission ..... ____
  o **Tires** ..... ____
• **Tire pressure** ..... ____
• Visually check sensors..... ____
• Static sensor check ..... ____		

3. Explain: Distance Measurement Instrument (DMI) verification procedure		
4. Demonstrate: Laser Height verification procedure		
5. Demonstrate: Bounce Test		
	Pass Fail	Pass Fail

Supplemental Examiner:_____

MODOT TM 59: IRI Profiler Operator Qualification
PROFICIENCY CHECKLIST

Part 2 **Report #** ____ ____

4. Generate a profile Trial #		
• Set up file entering project specifics ➢ Project Name ➢ Contract Number ➢ Project Location ➢ Segment Length ➢ Profile Start station ➢ Profile End station ➢ Pavement Type ➢ Direction of Profile ➢ Number of Lane ➢ Operator's Name ➢ Special Provisions & Comments • Generate trace • **Save File (Use naming convention with the information provided)** • Provide raw data in ppf Format (Some older machines may use ERD)		

Pass Fail

Pass Fail

Final Examiner:_____ Date:_____