

## S-1 (2399) PAVEMENT SURFACE SMOOTHNESS

(2011 version)

Always use with SP2005-109 (CONCRETE PAVEMENT) and SP2005-140 (PLANT MIXED ASPHALT PAVEMENT).

NEW WRITEUP 1/11/11

SP2005-142.3

The following is hereby added to the Mn/DOT Standard Specifications:

### 2399.1 DESCRIPTION

This work consists of measuring the smoothness of the final concrete or bituminous surface.

#### A Definitions

The Department defines “smoothness” as the composite International Roughness Index (IRI) value per 0.1 mi [0.1609 km] segment. The Department defines “areas of localized roughness” (ALR) as areas greater than the limiting criteria for a continuous IRI calculation with a 25 ft [7.62 m] interval, as calculated using the FHWA’s Profile Viewing and Analysis (ProVAL) software.

### 2399.2 MATERIAL REQUIREMENTS

#### A Inertial Profiler (IP)

Provide a Department certified, calibrated, and documented IP meeting the requirements of ASTM E 950, Class 1 and procedures maintained by the Mn/DOT Pavement Engineering Section. Refer to the procedures maintained by the Mn/DOT Pavement Engineering Section or to the Mn/DOT Smoothness website for the required settings for individual certified profilers.

Provide an IP capable of producing a profilogram and exporting raw profile data in an unfiltered electronic Engineering Research Division (ERD) file format. Produce ERD filenames in the YYMMDD-T-N-D-L-W-S.ERD standardized format in accordance with Table 2399-1:

<b>Abbreviation</b>	<b>Definition</b>
YY	Two-digit year
MM	Month (include leading zeros)
DD	Day of month (include leading zeros)
T	Route type (I, MN, US, CSAH, etc.)
N	Route number (no leading zeros) and auxiliary ID (if applicable, for example E, W, etc.)
D	Primary route direction (I or D)
L	Lane number (1 for driving lane, increasing by one for each lane to the left)
W	Wheel path (L, R, or B, indicating Left, Right, or Both)
S	Beginning station

#### B Profile Analysis Software

Use ProVAL software to conduct a profile analysis to determine smoothness and ALR. Report IRI values in units of in per mi to one digit right of the decimal [m per km to two digits right of the decimal] in accordance with conventional rounding procedures.

#### C Operator Certification

Provide an operator, trained in the operation of the particular IP in accordance with 2399.2.A, “Inertial Profiler”, and knowledgeable in the use of the required profile analysis software in accordance

with 2399.2.B, “Profile Analysis Software.” Ensure profiler operators pass a proficiency test and possess a current certification issued by the Department. The Contractor may access a list of certified operators on the Mn/DOT Smoothness website. Provide documentation of operator certification to the Engineer.

## **D Submittals**

### **D.1 Before Profiling**

Provide the Engineer with current, valid documentation, issued by the Department, indicating the inertial profiling equipment certification and the operator’s certification.

### **D.2 Day of Profiling**

Submit a printout containing the inertial profiler’s settings, each segment’s IRI values, and the signature of the operator to the Engineer on the same day of the profiling.

Submit electronic files in ERD format representing the raw data from each pass on the same day of the profiling.

**If the Contractor fails to submit actual data to the Engineer on the day of profiling, the Department will require the Contractor to reprofile the measured segments.**

### **D.3 Upon Completion of Pavement Placement**

Within 5 calendar days after all pavement placement and before beginning corrective work, submit a paper ProVAL summary report for each lane, indicating the results of the “Ride Quality” and the “Smoothness Assurance: Grinding” analyses. Use the “Default Grinding Strategy” option to determine the longitudinal limits of the corrective work taken from the ProVAL “Grinding” section within the “Smoothness Assurance” analysis. Use the ERD filenames in accordance with 2399.2.A, “Inertial Profiler” to create ProVAL summary reports.

If the summary reports indicate no required corrective work, submit a paper ProVAL summary report indicating the results of the “Smoothness Assurance: Short Continuous Histogram” and “Smoothness Assurance: Long Continuous Histogram” analyses, and the final spreadsheet summary in accordance with 2399.2.D.5, “After Corrective Work.”

### **D.4 Before Corrective Work**

If the summary reports indicate required corrective work, submit a written corrective work plan to the Engineer in accordance with 2399.3.E, “Corrective Work.” Include the beginning and ending points of locations planned for correction in the corrective work plan. Do not begin corrective work before the Engineer approves the plan.

If the Engineer elects to assess a monetary deduction for ALR in accordance with Table 2399-7 instead of requiring corrective work, submit a paper ProVAL summary report indicating the results of the “Smoothness Assurance: Short Histogram” and “Smoothness Assurance: Long Histogram” analyses, and the final spreadsheet summary in accordance with 2399.2.D.5, “After Corrective Work.”

### **D.5 After Corrective Work**

After reprofiling, submit a paper summary ProVAL report for each lane, indicating the results of updated “Ride Quality” analyses and the results of the “Smoothness Assurance: Short Continuous Histogram” and “Smoothness Assurance: Long Continuous Histogram” to the Engineer. Submit a spreadsheet summary in tabular form, with each 0.1 mi [0.1609 km] segment occupying a row to the Engineer. The Contractor may access an acceptable spreadsheet summary template in electronic form on the Mn/DOT Smoothness website.

**2399.3**

**CONSTRUCTION REQUIREMENTS**

Using an IP, measure the final mainline and other pavement surfaces for IRI in areas with a posted vehicle speed of at least 30 mph [48 km/h] unless otherwise excluded in Table 2399-2.

Unless otherwise approved by the Engineer, perform all smoothness testing in the presence of the Engineer. Mutually agree on a schedule for smoothness testing with the Engineer. Rerun tests performed in the absence of the Engineer as directed by the Engineer at no additional cost the Department.

The Engineer will use a 10 ft [3.05 m] straightedge to evaluate areas excluded from surface testing with the IP in accordance with Table 2399-3.

**A Pavement Surface Testing**

Remove objects and foreign material from the pavement surface before performing the pavement surface evaluation. Provide traffic control required for testing and performing corrective work on the final pavement surface.

Run the IP in the direction of traffic. Measure profiles in the left and right wheel paths of each lane.

Test and evaluate each lane separately. The Engineer will determine the length in miles [kilometers] of each mainline traffic lane. Operate the IP at the optimum speed as recommended by the manufacturer.

Separate each lane into segments 0.1 mi [0.1609 km] in length. Evaluate the remainder segment less than 0.1 mi [0.1609 km] in each lane as an independent segment. The Engineer will prorate pay adjustments for length.

Make each pass continuously, regardless of length, and end passes before exclusions in accordance with Table 2399-3, "Areas Excluded from Smoothness and ALR Evaluation." Begin each subsequent pass 50 ft [15.24 m] before and including, construction headers and end-of-day work joints. In concrete pavements, evaluate terminal headers tying into existing portland cement concrete pavement.

For percent improvement projects, measure the smoothness before the beginning of construction and after the completion of construction. Use the same stationing for the final smoothness measurement as the stationing used for the initial smoothness measurement, to allow for a direct comparison when calculating the percent improvement. Measure the initial IRI and the final IRI with the same IP.

The Engineer will use a 10 ft [3.05 m] straightedge to measure for surface deviations greater than ¼ in [6 mm] in 10 ft [3.05 m]. The Engineer will evaluate transverse joints by centering the straightedge longitudinally across the transverse joint. The Engineer will require corrective work on surface deviations.

**B Exclusions**

Use the IP to measure the areas excluded from smoothness evaluation in accordance with Table 2399-2. The Engineer will use a 10 ft [3.05 m] straightedge to evaluate ALR and areas excluded from surface testing in accordance with Table 2399-2:

<b>Table 2399-2</b>	
<b>Areas Excluded from Smoothness Evaluation</b>	
<b>For All Pavements</b>	
Paving in areas with a posted vehicle speed no greater than 45 mph [73 km/hr]	
Ramps, loops, acceleration and deceleration lanes no greater than 500 ft [152.4 m] long	
Projects less than 1,000 ft [304.8 m] in length	

<b>For Bituminous Pavements</b>
Single lift overlays over concrete

The Engineer will use a 10 ft [3.05 m] straightedge to evaluate areas excluded from surface testing with the IP in accordance with Table 2399-3:

<b>Table 2399-3</b>
<b>Areas Excluded from Smoothness and ALR Evaluation</b>
<b>For All Pavements</b>
Turn lanes, crossovers
10 ft [3.05 m] on either side of obstructions in lane that obstruction is located
Intersections where mainline profiles are merged or blended into the cross street profile – begin and end exclusion 100 ft [30.5 m] from the intersection radius
Side streets, side connections
Junctions between pavement and bridge approach panels, junctions between pavement and bridges
<b>For Bituminous Pavements</b>
Paved shoulders
<b>For Concrete Pavements</b>
Undoweled shoulders less than 10 ft [3.05 m] wide
Headers adjacent to colored concrete

## **C Calculations**

### **C.1 Smoothness**

Obtain the IRI for the left and right wheel paths in an individual lane using the ProVAL “Ride Quality” analysis with the 250 mm filter. Calculate pavement smoothness for each lane by averaging the IRI for the left and right wheel paths in the lane. The Engineer will use the averaged results to determine pay adjustments.

For percent improvement projects, use the initial IRI and final IRI to calculate the percent ride improvement.

### **C.2 Areas of Localized Roughness**

Identify ALR using the ProVAL “Smoothness Assurance” analysis, calculating IRI with a continuous short interval of 25 ft [7.62 m] with the 250 mm filter. Only use the right wheel path to determine ALR.

## **D Pay Adjustments**

### **D.1 Smoothness**

Evaluate smoothness requirements using the equations and criteria in accordance with the following tables:

- (1) Table 2399-4 for bituminous pavements,
- (2) Table 2399-5 for concrete pavements, and
- (3) Table 2399-6 for percent improvement projects.

The Engineer will base pay adjustments on the segment IRI value (or percent improvement value, for percent improvement projects) measured at the completion of surface pavement, unless corrective work is required by the summary report results. If a segment is less than 100 ft [30.5 m] in length, and corrective work is required by Table 2399-4, Table 2399-5, or Table 2399-6, the Engineer will waive the corrective

work requirement for the segment and instead assess a prorated maximum disincentive. The segment is still subject to ALR analysis in accordance with Table 2399-7

For segments requiring corrective work, reprofile the segment after performing corrective work as directed by the Engineer and enter the reprofiled left and right wheel path IRI values into the final spreadsheet summary. Calculate the segment IRI value by averaging the IRI values calculated from the left and the right wheel path passes.

**D.1.a Bituminous Pavements**

The Department will provide a total smoothness incentive no greater than 10 percent of the total price of mix used for the pavement evaluated by IRI Equation HMA-A, or no greater than 5.0 percent of the total price of mix used for pavement evaluated by IRI Equation HMA-B or IRI Equation HMA-C. The Department defines the total mix as all pavement mixture placed on the Project.

Equation	IRI in/mi [m/km]	Pay Adjustment \$/0.1 – mi [0.1609 km]
HMA-A	< 30.0 [0.47]	400.00 [400.00]
	30.0 – 75.0 [0.47 – 1.18]	850.00 – 15.000 × IRI [850.00 – 957.450 × IRI]
	> 75.0 [1.18]	Corrective Work to ≤ 56.7 in/mi [0.89 m/km]
HMA-B	< 33.0 [0.52]	270.00 [270.00]
	33.0 – 85.0 [0.52 – 1.34]	600.00 – 10.000 × IRI [600.00 – 638.950 × IRI]
	> 85.0 [1.34]	Corrective Work to ≤ 60.0 in/mi [0.94 m/km]
HMA-C	< 36.0 [0.57]	180.00
	36.0 – 95.0 [0.57 – 1.50]	414.00 – 6.500 × IRI [414.00 – 410.500 × IRI]
	> 95.0 [1.50]	Corrective Work to ≤ 63.7 in/mi [1.01 m/km]

For bituminous projects, the Engineer will not pay a net incentive payment for smoothness if greater than 25 percent of all mainline density lots for the Project fail to meet the minimum density requirements in accordance with 2360, “Plant-Mixed Asphalt Pavement.”

**D.1.b Concrete Pavements**

For concrete pavements, the Engineer will use equation PCC-A. For concrete pavement rehabilitation projects or concrete grinding, the Engineer will use equation PCC-B if the Contract requires pay adjustments for concrete grinding.

Equation	IRI in/mi [m/km]	Pay Adjustment \$/0.1 – mi [0.1609 km]
PCC-A	< 50.0 [0.79]	890.00 [890.00]
	50.0 – 90.0 [0.79 – 1.42]	2940.00 – 41.000 × IRI [2940.00 – 2597.800 × IRI]
	> 90.0 [1.42]	Corrective Work to ≤ 71.7 in/mi [1.13 m/km]
PCC-B	< 50.0 [0.79]	450.00 [450.00]
	50.0 – 71.2 [0.79 – 1.12]	1511.30 – 21.226 × IRI [1511.30 – 1344.900 × IRI]
	71.3 – 90.0 [1.13 – 1.42]	0.00
	> 90.0 [1.42]	Corrective Work to ≤ 71.3 in/mi [1.13 m/km]

**D.1.c Percent Improvement Projects**

The Engineer will base pay adjustments on the number of segments and the percent improvement values. The Engineer will not make total pay adjustments for smoothness greater than 5 percent of the total

mix price. The Department defines the total mix as all mixture placed on the Project. The Engineer will not require corrective work and will not assess a negative pay adjustment if the initial segment IRI value is less than 60.0 in per mi [0.95 m per km] and the percent improvement is greater than zero. The Engineer will calculate the percent improvement in accordance with the following equation:

$$\%I = \left( \frac{\text{InitialSegmentIRI} - \text{FinalSegmentIRI}}{\text{InitialSegmentIRI}} \right) \times 100$$

Determine the Initial Segment IRI before patching or other repair. Determine the Final Segment IRI after the completion of paving.

<b>Table 2399-6 Pay Adjustments for Percent Improvement Projects</b>		
<b>Equation</b>	<b>Percent Improvement (%I)</b>	<b>Pay Adjustment, per \$/0.1 mi [\$/0.1609 km] segment</b>
PI-A	> 64.0	180.00
	15.0 to 64.0	-236.00 + 6.500 × (%I)
	< 15.0	Corrective work to %I of at least 36.3

For bituminous percent improvement projects, the Engineer will not pay a net incentive payment for smoothness if greater than 25.0 percent of all mainline density lots for the Project fail to meet minimum density requirements in accordance with 2360, “Plant-Mixed Asphalt Pavement.”

Correct segments with a percentage improvement of less than 15 percent at no additional cost to the Department as required by the Engineer.

## **D.2 Areas of Localized Roughness**

The Engineer will evaluate ALR in accordance with Table 2399-7.

Do not begin corrective work by grinding until the ProVAL Grinding Simulation with an 18 ft [5.5 m] wheelbase grinder and a grinder depth no greater than 0.3 in [7.62 mm] indicates a predicted improvement to the 25 ft [7.62 m] IRI value for software proposed grind sections. If the grinding simulation does not predict improvement for a section, correct that section by a method other than grinding. If the Contractor performs grinding on sections contrary to the grinding simulation prediction, the Department will reduce payment for the work as determined by the Engineer and in accordance with Table 2399-7:

<b>Table 2399-7 ALR Monetary Deductions and Corrective Work Requirements</b>		
<b>Equation</b>	<b>25ft [7.62 m] Continuous IRI, in/mi [m/km]</b>	<b>Corrective Work or Monetary Deduction, per linear 1.0 ft [0.3048 m]</b>
HMA-A or HMA-B, and a posted vehicle speed > 45 mph [73 km/hr]	< 125.0 [1.97]	Acceptable
	≥ 125.0 [1.97] and < 175.0 [2.76]	Corrective work or \$10.00, as directed by the Engineer
	≥ 175.0 [2.76] and < 250.0 [3.94]	Corrective work or \$25.00, as directed by the Engineer
	≥ 250.0 [3.94]	Corrective work or \$50.00, as directed by the Engineer
PCC-A or PCC-B, and a posted vehicle speed > 45 mph [73 km/hr]	< 125.0 [1.97]	Acceptable
	≥ 125.0 [1.97] and < 175.0 [2.76]	Corrective work or \$10.00, as directed by the Engineer
	≥ 175.0 [2.76] and < 250.0 [3.94]	Corrective work or \$25.00, as directed by the Engineer
	≥ 250.0 [3.94]	Corrective work as directed by Engineer
HMA-C, PI-A, or any paving with a posted vehicle speed ≤ 45 mph [73 km/hr]	< 175.0 [2.76]	Acceptable
	≥ 175.0 [2.76] and < 250.0 [3.94]	\$10.00
	≥ 250.0 [3.94]	\$25.00

The Engineer will consider ALR acceptable if the retested segment indicates no ALR. The Department will reduce payment for ALR remaining after retesting as determined by the Engineer and in accordance with Table 2399-7, “ALR Monetary Deductions and Corrective Work Requirements.”

### **D.3 Straightedge Evaluation**

For areas subject to evaluation with a 10 ft [3.05 m] straightedge, the Engineer may allow variations no greater than ¼ in [6 mm] within the span of the straightedge in the longitudinal or transverse direction to remain in place without correction or penalty.

For corrected variations, the Engineer will accept deviations no greater than ¼ in [6 mm] within the span of a 10 ft [3.05 m] straightedge in any direction.

### **E Corrective Work**

Notify the Engineer at least 24 h before beginning corrective work. Do not begin corrective work before the Engineer approves the methods and procedures in writing.

Perform corrective work using a surface diamond grinding device consisting of multiple diamond blades, unless otherwise approved by the Engineer. Fog-seal diamond ground bituminous surfaces as required by the Engineer and at no additional cost to the Department. Repair and replace joint sealant damaged by diamond grinding on concrete pavement as directed by the Engineer and at no additional cost to the Department.

The Contractor may correct bituminous pavements by overlaying the area or replacing the area by milling and inlaying as approved by the Engineer. If milling and inlaying or overlaying, perform work in accordance with 2399, “Pavement Surface Smoothness,” over the entire length of the correction. If milling and inlaying or overlaying, use a transverse saw cut to begin and end the surface correction.

Perform smoothness corrective work for ALR across the entire lane width. Maintain the pavement cross slope through corrective areas.

Perform coring to determine if diamond grinding corrective work results in thin pavements, as directed by the Engineer. Provide additional coring for thickness verification at no additional cost to the Department. The Department may reduce the payment for thin pavement sections after diamond grinding. Handle residue and excess water resulting from diamond grinding in accordance with 1717, "Air, Land, and Water Pollution."

Perform surface corrections before placing permanent pavement markings. Replace permanent pavement marking damaged or destroyed by corrective work at no additional cost to the Department.

Reprofile the corrected areas with the same certified IP in accordance with 2399.2.A, "Inertial Profile" within 5 calendar days after the completion of corrective work required by the Engineer.

**F Retesting**

Perform retesting as directed by the Engineer and within 30 days of the original profiling.

If the retested IRI values differ from the original IRI values by greater than 10 percent, the Engineer will use the retested values as the basis for acceptance and pay adjustments. If the retested values differ from the original values by greater than 10 percent, the Department will not pay for the cost of retesting.

If the retested IRI values differ by no greater than 10 percent of the original IRI values, the Engineer will use the original values. If the Engineer verifies the accuracy of the original results, the Department will pay for retesting as directed by the Engineer, except for retesting required after corrective work, at \$100 per lane mi [\$62.14 per lane km] retested or \$500, whichever provides the greater amount.

**2399.4 METHOD OF MEASUREMENT — VACANT**

**2399.5 BASIS OF PAYMENT**

The Department will include the cost of the IP, testing, and traffic control in the relevant Contract unit price for wearing course mixture for bituminous pavements, concrete pavement for concrete pavements, or for concrete grinding.