# 2399
# Pavement Surface Smoothness

## 2399.1 DESCRIPTION

The final mainline and all other pavement surfaces where the posted vehicle speed is 30 mph [48 km/hr] or greater shall be measured using an Inertial Profiler (IP) and the International Roughness Index (IRI), except those specifically excluded by Table 2399.5-2. Pavement smoothness for each lane will be computed by obtaining the IRI for the left and right wheel paths in an individual lane and then averaging the results. The averaged results will be used to determine pay adjustments. Each lane shall be tested and evaluated separately.

Unless otherwise authorized by the Engineer, all smoothness testing shall be performed in the presence of the Engineer. The Engineer and the Contractor shall mutually agree upon scheduling of smoothness testing so that testing can be observed. Any testing performed without the Engineer's presence, unless otherwise authorized, may be ordered rerun at the Contractor's expense.

The term "smoothness" will mean the composite IRI value per 0.1 mile [0.1609 km] segment on which pay adjustments are made. The term "areas of localized roughness" will mean those areas exceeding the limiting criteria for a continuous IRI calculation with a 25-ft [7.62-m] interval, as computed using the most recent version of the FHWA's Profile Viewing and Analysis (ProVAL) software.

All costs relative to the Contractor providing the IP, appropriate test results, and associated traffic control shall be incidental to the unit bid price for Wearing Course Mixture for bituminous pavements, for Concrete Pavement for concrete pavements, or for Concrete Grinding.

## 2399.2 EQUIPMENT

The Contractor shall furnish a properly calibrated, documented, and Mn/DOT-certified IP. The IP shall export raw profile data in an unfiltered ERD file format, and shall produce a profilogram (profile trace of the surface tested). The IP shall conform to the Class 1 requirements of the most recent revision of ASTM E950 and must be certified according to the most recent procedure on file in the Pavement Engineering Section. Mn/DOT certification documentation shall be submitted to the Engineer prior to the IP being used on the project. Settings for individual certified profilers are on file in the Mn/DOT Pavement Engineering Section, and are accessible at www.dot.state.mn.us/materials/smoothness.html.

Profile analysis for determination of IRI and areas of localized roughness will be conducted using the most recent version of the ProVAL Software. IRI values shall be reported in units of in/mi [m/km]. Units of m/km shall be reported to two digits right of the decimal, and units of in/mi shall be reported to one digit right of the decimal, following the rounding procedures found in AASHTO R11.

## 2399.3 OPERATOR CERTIFICATION

The Contractor shall furnish an operator, trained in the operation of the particular IP furnished under section 2399.2, and knowledgeable in the use of the most recent version of the ProVAL software. All profiler operators shall pass a proficiency test and possess a current certification issued by the Department. Documentation of operator certification shall be presented to the Engineer upon request.

## 2399.4 PAVEMENT SURFACE TESTING

The Contractor shall remove all objects and foreign material on the pavement surface prior to surface evaluation. The Contractor will be responsible for all traffic control associated with testing and any corrective work (when applicable) that is required of the final pavement surface.

The IP shall be run in the direction the traffic will be moving. Profiles shall be measured in the left and right wheel paths of each lane.

Each lane will be separated into segments 0.1 mi [0.1609 km] in length. Final segments in a lane that are less than 0.1 mi [0.1609 km] shall be evaluated as an independent segment, and pay adjustments will be prorated for length. Segments 10 ft [3.05 m] long or less, and the first and last 10 ft [3.05 m] of projects that do not connect to an existing segment for which the Contractor is responsible, shall be evaluated by the Engineer using a 10-ft [3.05-m] straightedge. Surface deviations using the straightedge that deviate from a straight line by more than 1/4 inch in 10 ft [6 mm in 3.05 m] shall be subject to corrective work. Transverse joints shall be evaluated by centering the straightedge longitudinally across the transverse joint.

Each pass shall be made continuously, regardless of length, but shall terminate prior to items in the list of exclusions in Table 2399.5-2. The subsequent pass shall begin approximately 50 ft [15.24 m] prior to, and shall include, construction headers and end-of-day work joints. In concrete pavements, terminal headers that tie into existing Portland cement concrete pavement shall be evaluated, and smoothness measurements shall begin approximately 50 ft [15.24 m] before and end approximately 50 ft [15.24 m] after terminal headers. Bridge approach panels and bridge surfaces are exempt from these requirements; however, paving start-up areas are not exempt.

For percent improvement projects, the smoothness shall be measured prior to the start of construction (initial IRI) and after the completion of construction (final IRI). Stationing used for the final smoothness measurement shall be the same as that used for the initial smoothness measurement, to allow for a direct comparison when calculating the percent improvement. Both the initial IRI and the final IRI will be measured with the same IP.

### A Smoothness

The IRI for the left and right wheel paths in an individual lane will be computed and then averaged when determining pay adjustments. Each lane shall be tested and evaluated separately. The Engineer shall determine the length in miles [kilometers] for each mainline traffic lane. The IP shall be operated at the optimum speed as defined by the manufacturer. For percent improvement projects, the initial IRI and final IRI will be used to calculate the percent ride improvement.

### B Areas of Localized Roughness

Areas of localized roughness will be identified using the ProVAL "Smoothness Assurance" analysis, calculating IRI with a continuous short interval of 25 ft [7.62 m] and the 250-mm filter applied. Only the right wheel path will be used to determine areas of localized roughness. The longitudinal limits of the corrective work shall be taken from the ProVAL "Grinding" section within the "Smoothness Assurance" analysis, using the "Default Grinding Strategy" option.

## 2399.5 EXCLUSIONS

Table 2399.5-1 indicates areas that are excluded from smoothness evaluation, but must still be measured with the IP, and are still subject to evaluation for Areas of Localized Roughness and the 10-ft [3.05-m] straightedge. Table 2399.5-2 indicates areas that are excluded from surface testing with the IP, but are subject to evaluation with the 10-ft [3.05-m] straightedge.

**Table 2399.5-1. Areas Excluded from Smoothness Evaluation**

| **For All Pavements** |
|---|
| Paving where the posted vehicle speed is less than 45 mph [73 km/hr] |
| Ramps, loops, acceleration and deceleration lanes less than 500 ft [152.5 m] in length |
| Projects less than 1000 ft [305 m] in length |
| **For Bituminous Pavements** |
| Single lift overlays over concrete |

**Table 2399.5-2. Areas Excluded from Smoothness and Areas of Localized Roughness Evaluation**

| **For All Pavements** |
|---|
| Turn lanes, crossovers |
| 10 ft [3.05 m] on either side of obstructions such as manholes, water supply castings, etc., in lane in which obstruction is located |
| Intersections constructed under traffic – begin and end exclusion 100 ft [30.5 m] from the intersection radius |
| Paved shoulders, side streets, side connections |
| **For Concrete Pavements** |
| Bridge decks and approach panels (The occurrence of bridges shall not interrupt the continuity determination) |
| Undoweled shoulders less than 10 ft [3.05 m] wide |
| Headers adjacent to colored concrete |

Areas that are excluded from surface testing with the IP but subject to evaluation with the 10-ft [3.05-m] straightedge as shown in Table 2399.5-2 above, and that show no variation greater than 1/4 inch in 10 ft [6 mm in 3.05 m] over the span of the straightedge in the longitudinal or transverse direction, may remain in place without correction or penalty if, in the judgment of the Engineer, the smoothness is satisfactory.

Corrected variations will be considered satisfactory when the 10-ft [3.05-m] straightedge shows the deviations are less than or equal to 1/4 inch in a 10 ft [6 mm in a 3.05 m] span in any direction.

## 2399.6 SUBMITTALS

This section describes the submittals required throughout the project with respect to pavement surface testing.

### A Prior to Profiling

The IP operator shall present to the Engineer current, valid documentation, issued by the Department, indicating the inertial profiling equipment certification and the operator's certification, as described in sections 2399.2 and 2399.3, respectively.

### B Day of Profiling

The Contractor shall submit the printed profilogram (graphical trace), indicating each segment's IRI value, and the signature of the Operator to the Engineer on the same day the profiling is conducted.

The Contractor shall also submit electronic files in ERD format that represent the raw data from each pass. The electronic ERD filenames shall follow the standardized format shown below. Electronic ERD files that do not follow this standardized naming convention will not be accepted.

YYMMDD-T-N-D-L-W-S.ERD

Where:

- 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

For example: "080721-I-35W-I-2-L-5+21.ERD" would indicate a beginning station of 5+21, in the left wheel path of the second lane (one lane left of the driving lane), in the increasing (northbound) direction of I-35W, tested on 21 July 2008.

**If the actual data is not submitted by the Contractor to the Engineer on the same day as the profiling was conducted, the Department will not pay incentives for those segments but any disincentives will still apply.**

**C Upon Completion of Pavement Placement**

Within five calendar days after all pavement placement, and prior to the commencement of any corrective work, the Contractor shall submit a paper ProVAL summary report for each lane, indicating the results of the "Ride Statistics at Intervals" and the "Smoothness Assurance" analyses. The Contractor shall follow the naming convention specified in section 2399.6.B when creating ProVAL summary reports. If no corrective work is required, the Contractor shall submit the final spreadsheet summary as described in section 2399.6.E.

**D Prior to Corrective Work**

If corrective work is required, the Contractor shall submit a written corrective work plan to the Engineer according to the requirements in section 2399.8. The Engineer shall approve of the Contractor's plan prior to the Contract starting corrective work. In addition, the corrective work plan shall include the locations (begin and end points) that will be corrected.

**E After Corrective Work**

Within five calendar days after all required corrective work is completed, the corrected areas shall be reprofiled with a certified IP according to section 2399.4. Updated ProVAL reports as described in section 2399.6.C and a spreadsheet summary shall be submitted to the Engineer. The spreadsheet summary shall be in tabular form, with each 0.1-mi [0.1609-km] segment occupying a row. An acceptable spreadsheet summary template in electronic form is available on the Mn/DOT Smoothness web page, which can be accessed at www.dot.state.mn.us/materials/smoothness.html.

## 2399.7 PAY ADJUSTMENT

Smoothness requirements will be evaluated by the IRI equations for bituminous pavements, concrete pavements, or percent improvement projects, as applicable. Equations HMA-A, HMA-B, and HMA-C are for use with bituminous pavements. Equations PCC-A and PCC-B are for use with concrete pavements. Equation PI-A is for use with percent improvement projects.

Pay adjustments will be based on the IRI determined for each segment, and will be based on the equations and criteria in Table 2399.7-1 (bituminous), Table 2399.7-2 (concrete) or Table 2399.7-3 (percent improvement) as applicable.

Pay adjustments will only be based on the segment IRI value (or percent improvement value, for percent improvement projects) measured prior to any corrective work, except that segments where corrective work is required shall be reprofiled after corrective work has been performed and included in the pay adjustment calculations. The segment IRI value is the average of the IRI values computed with the left and the right wheel path passes, individually.

For bituminous and bituminous percent improvement projects, the Contractor will not receive a net incentive payment for smoothness if more than 25.0% of all density lots for the project fail to meet minimum density requirements.

**A Bituminous Pavements**

The total smoothness incentive shall not exceed 10.0% of the total mix price for pavement smoothness evaluated under IRI Equation HMA-A, or 5.0% of the total mix price for pavement smoothness evaluated under Equation HMA-B, or HMA-C. Total mix shall be defined as all mixture placed on the project.

Typically, equation HMA-A will be used for 3-lift minimum construction, equation HMA-B will be used for 2-lift construction, and equation HMA-C will be used for single lift construction.

**Table 2399.7-1. Pay Adjustments for Bituminous Pavements**

| Equation | English | | Metric | |
|---|---|---|---|---|
| | IRI in/mi | Pay Adjustment $/0.1-mi | IRI m/km | Pay Adjustment $/0.1609 km |
| HMA-A | < 30.0 | 400.00 | < 0.47 | 400.00 |
| | 30.0 to 65.0 | 850.00 – 15.000 x IRI | 0.47 to 1.03 | 850.00 – 957.450 x IRI |
| | > 65.0 | Corrective Work to 56.7 in/mi or lower | > 1.03 | Corrective Work to 0.89 m/km or lower |
| HMA-B | < 33.0 | 270.00 | < 0.52 | 270.00 |
| | 33.0 to 75.0 | 600.00 – 10.000 x IRI | 0.52 to 1.18 | 600.00 – 638.950 x IRI |
| | > 75.0 | Corrective Work to 60.0 in/mi or lower | > 1.18 | Corrective Work to 0.94 m/km or lower |
| HMA-C | < 36.0 | 180.00 | < 0.57 | 180.00 |
| | 36.0 to 85.0 | 414.00 – 6.500 x IRI | 0.57 to 1.34 | 414.00 – 410.500 x IRI |
| | > 85.0 | Corrective Work to 63.7 in/mi or lower | > 1.34 | Corrective Work to 1.01 m/km or lower |

**B Concrete Pavements**

For concrete pavements, equation PCC-A will be used for projects where the posted speed will be 45 mph [73 km/hr] or greater. For concrete pavement rehabilitation projects, equation PCC-B will be used when the Contract specifies pay adjustments for concrete grinding.

**Table 2399.7-2. Pay Adjustments for Concrete Pavements**

| Equation | English | | Metric | |
|---|---|---|---|---|
| | IRI in/mi | Pay Adjustment $/0.1-mi | IRI m/km | Pay Adjustment $/0.1609 km |
| PCC-A | < 50.0 | 890.00 | < 0.79 | 890.00 |
| | 50.0 to 90.0 | 2940.00 – 41.000 x IRI | 0.79 to 1.42 | 2940.00 – 2597.800 x IRI |
| | > 90.0 | Corrective Work to 71.7 in/mi or lower | > 1.42 | Corrective Work to 1.13 m/km or lower |
| PCC-B | < 50.0 | 450.00 | < 0.79 | 450.00 |
| | 50.0 to 71.2 | 1511.30 – 21.226 x IRI | 0.79 to 1.12 | 1511.30 – 1344.900 x IRI |
| | 71.3 to 90.0 | 0.00 | 1.13 to 1.42 | 0.00 |
| | > 90.0 | Corrective Work to 90.0 in/mi or lower | > 1.42 | Corrective Work to 1.42 m/km or lower |

**C Percent Improvement Projects**

Pay adjustments will be based on the number of segments and the percent improvement values. The total pay adjustment for smoothness shall not exceed 5.0% of the total mix price. Total mix shall be defined as all mixture placed on the project. No corrective work will be required and no negative pay adjustment will be assessed if the initial segment IRI value is less than 60.0 in/mi [0.95 m/km] and the percent improvement is greater than zero. Percent improvement (%I) will be calculated as follows:

$$(\%I) = \frac{\text{(Initial Segment IRI – Final Segment IRI)}}{\text{Initial Segment IRI}} \times 100$$

where Initial Segment IRI is the IRI determined by the Contractor prior to any patching or other repair, and Final Segment IRI is the IRI determined by the Contractor after paving is completed.

For pay adjustments to be computed, the Initial Segment IRI must be measured prior to construction according to Section 4.A of this specification.

**Table 2399.7-3. Pay Adjustments for Percent Improvement Projects**

| Equation | Percent Improvement (%I) | Pay Adjustment, per $/0.1-mi [$/0.1609-km] segment |
|---|---|---|
| PI-A | > 64.0 | 180.00 |
| | 15.0 to 64.0 | -236.00 + 6.500 x (%I) |
| | < 15.0 | Corrective Work to 36.3%I or higher |

## 2399.8 CORRECTIVE WORK

The Contractor shall notify the Engineer at least 24 hours prior to commencement of the corrective work. The Contractor shall not commence corrective work until the methods and procedures have been approved in writing by the Engineer.

All smoothness corrective work for areas of localized roughness shall be for the entire lane width. Pavement cross slope shall be maintained through corrective areas.

Localized areas for which the IRI value is less than 125.0 in/mi [1.97 m/km] shall be considered acceptable. Localized area for which the IRI value is 125.0 in/mi [1.97 m/km] or greater, or less than 250.0 in/mi [3.94 m/km] may be accepted if the ride is satisfactory in the judgment of the engineer. The engineer may require that such sections either be corrected by the contractor or assessed deductions as indicated in Table 2399.8-1. Any localized area for which the IRI value is 250.0 in/mi [3.94 m/km] or greater must be corrected.

Prior to commencing corrective work by grinding, the ProVAL Grinding Simulation, with an 18-foot [5.5-m] wheelbase grinder and a maximum grinder depth of 0.3 in [7.62 mm], must indicate a predicted improvement to the 25-ft IRI value for sections proposed to be ground. If the grinding simulation does not predict improvement for a section, that section must be corrected by a method other than grinding or the appropriate deduction in Table 2399.8-1 will apply.

**Table 2399.8-1. Deductions and Corrective Work Requirements.**

| ALR (25-ft IRI) | Deduction, per linear 1.0 ft [0.3048 m] |
|---|---|
| < 125.0 in/mi [1.97 m/km] | Acceptable |
| ≥ 125.0 [1.97 m/km] and < 150.0 [2.36 m/km] | $5 |
| ≥ 150.0 [2.36 m/km] and < 250.0 [3.94 m/km] | $10 |
| ≥ 250.0 [3.94 m/km] | Must grind or repair |

Areas of localized roughness will be considered acceptable when the retested segment indicates no areas of localized roughness. If, after retesting, any areas of localized roughness remain, these will be assessed as indicated in Table 2399.8-1.

For concrete pavement rehabilitation projects, the Contractor shall correct all areas of localized roughness for which the IRI value is greater than 90.0 in/mi [1.42 m/km], based on the locations recommended by the ProVAL “Smoothness Assurance” analysis.

Corrective work by diamond grinding may result in thin pavements. The Engineer shall determine if this condition needs to be verified by coring. Additional coring for thickness verification shall be at no cost to the Department. Thin pavement sections after diamond grinding may result in thickness price deductions.

Surface corrections shall be made prior to placing permanent pavement markings. In the event that permanent pavement marking are damaged or destroyed during corrective work, they will be replaced at no cost to the Department.

Residue and excess water resulting from this grinding shall be handled in accordance with Mn/DOT Specification 1717.

**A Bituminous Pavements**

Unless otherwise approved by the Engineer, corrective work shall be by an approved surface diamond grinding device consisting of multiple diamond blades. Other methods may include overlaying the area, or replacing the area by milling and inlaying. Any corrective work by milling and inlay or by overlay shall meet the specifications for smoothness over the entire length of the correction. If the surface is corrected by milling and inlay or by overlay, the surface correction shall begin and end with a transverse saw cut. The Engineer may require diamond ground bituminous surfaces to be fog-sealed by the Contractor at the Contractor's expense.

**B Concrete Pavements**

Unless otherwise approved by the Engineer, corrective work shall be by an approved surface diamond grinding device consisting of multiple diamond blades. Joint sealant that has been damaged by diamond grinding on concrete pavement as determined by the Engineer shall be repaired and replaced at no expense to the Department.

**C Percent Improvement Projects**

The Engineer may require that the Contractor, at no expense to the Department, correct segments with a percentage improvement of less than 15.0%.

**2399.9 RETESTING**

The Engineer may require any portion or the total project to be retested if the results are questioned. The Engineer will decide whether Mn/DOT, an independent testing firm, or the Contractor will retest the roadway surface.

If the retested IRI values differ by more than 10.0% from the original IRI values, the retested values will be used as the basis for acceptance and any pay adjustments. If the retested data is within 10.0% of the original IRI values, the original data will be used. The Contractor will be responsible for any costs associated with retesting if the retested values differ by more than 10.0% from the original values.

If the Engineer directs the Contractor or an independent testing firm to perform retesting (besides that required after corrective work) and the original results are found to be accurate, the Department will pay the Contractor or the independent testing firm $100.00 per lane mile [$62.14 per lane km] that is retested, with a minimum charge of $500.00.