

SECTION 401—PAVEMENT SMOOTHNESS MEASUREMENT USING INTERNATIONAL SMOOTHNESS INDEX (IRI)

401.1 DESCRIPTION.

401.11 This work shall consist of furnishing profile testing equipment to perform pavement smoothness measurements in accordance with requirements described herein.

401.2 CONSTRUCTION REQUIREMENTS.

401.21 Straightedge Measurements. The final surface of all Plant-Mix Bituminous Pavement (PMBP), Stone Matrix Asphalt (SMA), Open-Graded Friction Course (OGFC), and Portland Cement Concrete Pavement (PCCP) not subject to profile measurement shall be tested using an approved 3.0-m (10-ft) straightedge at both right angles and parallel to the centerline. All surface deviations in excess of 3 mm in 3.0 m (1/8 in. in 10 ft) shall be corrected as directed by the Project Manager. The following are specifically excluded from profile measurement and shall be evaluated using a straightedge.

A. Shoulders, turnouts, median lanes and other areas less than 0.1 mile, as designated by the Project Manager during a pre-paving conference.

B. Concrete pavement slab removal and replacement, and intersections not paved integrally with the main line.

401.22 Profile Measurements. The longitudinal smoothness of the final surface of PMBP, SMA, or PCCP shall be tested using an approved profile measuring device. OGFC shall be tested in accordance with Section 401.26C.

401.23 Profile Testing Equipment. The Contractor shall provide, operate, and maintain on the project a Department certified profile measurement device. The profile measurement device shall be provided and operated in conformance to current ASTM E 950 Class I requirements using a quarter car simulation and a 91-meter (300 feet) filter length.

A computer filtering cutoff frequency as established by profile measuring device certification shall be used. The filter setting shall be automatically displayed on the profile trace.

401.24 Technician Certification. The Department's Technician Training and Certification Program (TTCP) shall certify all individuals performing profile testing for acceptance and pay adjustment. The certification will be based on demonstration of ability and a written test. Term and expiration date of certification and requirements for renewal of certification shall be as established by the TTCP.

If a concern arises as to the competence of a certified individual, this concern must be documented in writing to the Department's State Materials Engineer and the Assistant District Engineer. The Department's State Materials Bureau through the TTCP will investigate the concern. If this investigation substantiates the concern, corrective action or de-certification will be implemented in accordance with procedures established by the TTCP Board of Directors.

401.25 Profile Measuring Device Calibration and Certification. The profile measuring device shall be certified in accordance with the Department's standard practice for certification of profile measuring devices. The profile measuring device shall have a current TTCP calibration sticker or shall have a manufacturer's calibration and certification certificate which shall only be

valid until the date of the next TTCP sponsored annual profile measuring device certification validation test is held.

The Contractor shall calibrate the profile measuring device. Both horizontal and vertical calibration shall be performed prior to each use. Additional calibrations or verifications may be required as directed by the Project Manager. Calibration shall be performed in accordance with the manufacturer's approved procedures and the Contractor shall maintain copies of the calibration documentation and manufacturer's procedures with the machine.

If the profile measuring device does not meet manufacturer's calibration requirements, the contractor shall remove the machine from the project until adjustments can be made to bring the device back to calibration requirements. The TTCP profile measuring device Certification Number shall be reported to the TTCP Administrator in order to provide notification that the non-calibrated machine shall not be used on other projects until calibration can be achieved. Once the machine is re-certified by the manufacture, a copy of the certificate shall be provided to the Department's TTCP Administrator.

401.26 Profile Measurement. The Contractor shall thoroughly sweep the roadway surface to be profiled and notify the Project Manager for approval prior to beginning any profile operation.

The profile measuring device shall be operated at a reduction length of 100 m (528.0 ft). The profile measuring device shall be operated in conformance with manufacturer's recommendations. The profile measuring vehicle shall be capable of maintaining the correct speed in accordance with the manufacturer's recommendations without interfering with traffic or the operation of the profile measuring device and shall be operated on the driving surface of the roadway.

The Contractor shall determine the International Roughness Index (IRI) for each lane, reported to the nearest mm per km (0.1-in./ mi), in accordance with the following:

A. PMBP or SMA Reconstruction/New Construction.

1. The IRI shall be determined for each 0.1-km (0.1-mi) section or fraction thereof.
2. Two profile traces shall be made for each lane. The traces shall be located 1.0 m (3 ft) from and parallel to the approximate location of pavement lane lines unless otherwise directed by the Project Manager.
3. At transverse joints, the profile traces shall commence 5.0 m (15 ft) into the previous placement.
4. The IRI used for evaluating each 0.1-km (0.1-mi) section shall be the average of these two profile traces. This information shall be submitted in a summarized format approved by the Project Manager. The profile traces shall be maintained by the Contractor.

B. PMBP or SMA Rehabilitation/Overlay Construction.

1. An initial IRI shall be determined for the existing pavement surface. The initial IRI shall be determined before the Contractor performs any activity that may significantly alter the IRI of the existing surface.

When cold milling, planing, hot in-place recycling, cold in-place recycling, pulverizing or other intermediate treatment of the existing surface is specified before overlaying, the initial IRI shall be determined before the intermediate treatment commences.

2. A final IRI shall be determined for the top lift of the PMBP or SMA overlay.
3. The IRI shall be determined for each 0.1-km (0.1-mi) section or fraction thereof.

4. For both the initial IRI and the final IRI, two profile traces shall be made for each lane. The traces shall be located 1.0 m (3 ft) from and parallel to the approximate location of pavement lane lines unless otherwise directed by the Project Manager. The initial IRI and final IRI traces shall begin and end at the same stations.
5. At transverse joints, the profile traces shall commence 5.0 m (15 ft) into the previous placement.
6. The IRI used for evaluating each 0.1-km (0.1-mile) section shall be the average of these two profile traces. This information shall be submitted in a summarized format approved by the Project Manager. The Contractor shall maintain the profile traces.

C. Open-Graded Friction Course.

1. The IRI shall be determined for purposes of comparison with that of the top lift of PMBP or SMA in order to determine eligibility for a price adjustment incentive.
2. The IRI shall be determined for each 0.1-km (0.1-mile) section or fraction thereof.
3. Two profile traces shall be made for each lane. The traces shall be located 1.0 m (3 ft) from and parallel to the approximate location of pavement lane lines unless otherwise directed by the Project Manager.
4. At transverse joints, the profile traces shall commence 5.0 m (15 ft) into the previous placement.
5. The IRI used for evaluating each 0.1-km (0.1-mi) section shall be the average of these two profile traces. This information shall be submitted in a summarized format approved by the Project Manager. The Contractor shall maintain the profile traces.

D. Portland Cement Concrete Pavement.

1. The IRI shall be determined for each 0.1-km (0.1-mi) section, or fraction thereof.
2. Two profile traces shall be made for each lane. The traces shall be located 1.0 m (3 ft) from and parallel to the approximate location of pavement lane lines unless otherwise directed by the Project Manager.
3. At transverse construction joints, the profile traces shall commence 5.0 m (15 ft) into the previous placement.
4. The IRI used for evaluating each 0.1-km (0.1-mi) section shall be the average of these two profile traces. This information shall be submitted in a summarized format approved by the Project Manager. The Contractor shall maintain the profile traces.

Additional profiles shall be taken to retest paved surfaces that have received corrective work, and as directed by the Project Manager, to check previously submitted data or to identify the limits of surface irregularities.

Each profile trace shall include the following information:

Project number
Date
Analysis method (Quarter Car Only)
Filter length (91 meter (300 feet) Only)
Lane profiled
IRI in mm/km (in. per mi)
Beginning and ending stations

Intermittent reference stations at least every 10 m (50 ft)
Horizontal equation stations
Location of bridge abutments
Net total linear meters (feet) of each lane
Operator's signature

Profile testing is considered part of the paving operation. The proposed frequency for profile testing shall be included in the paving plan submitted by the Contractor at the pre-paving conference.

The Project Manager before any subsequent paving operation shall approve the final IRI summary.

401.27 IRI Evaluation for Corrective Work. For determining corrective work needed and pay adjustments, the pavement shall be evaluated in 0.1-km (0.1-mi) sections. When the IRI exceeds 1011 mm/0.1-km (64.1 in./0.1-mi.), the pavement shall be evaluated by the Contractor in order to develop an appropriate corrective action plan. The corrective action plan, which may include diamond grinding, overlaying, removing and replacing or no action at all, shall be submitted to the Project Manager for review and approval. After the corrective action, if any, has been taken, the area shall be re-profiled or otherwise evaluated to verify compliance with specification requirements. All corrective action, including all necessary traffic control, shall be completed at the Contractor's expense.

A. PMBP Reconstruction/New Construction, SMA Reconstruction/New Construction, or PCCP. If the average IRI of any 0.1-km (0.1-mi) section is 725 mm (46.0 in./0.1-mi.) or less after corrective work, additional corrective work for the purpose of reducing the IRI shall not be allowed.

If the average IRI of any 0.1-km (0.1-mi) section is greater than 725 mm (46.0 in./mi.), but less than 1010 mm (64.0 in./0.1-mi.) after corrective work, the Contractor may accept a price reduction, or take additional corrective action to reduce the IRI.

If the average IRI of any 0.1-km (0.1-mi) section is 1011 mm (64.1 in./0.1-mi.) or greater after corrective work, additional corrective work shall be performed to reduce it to 1010 mm (64.1 in./0.1-mi.) or less.

B. PMBP Overlay or SMA Overlay Construction. If, after corrective action, the percentage of improvement in any 0.1-km (0.1-mi) section is greater than that specified to require corrective action, additional corrective work for the purpose of reducing the IRI will not be allowed.

If, after corrective action, the percentage of improvement in any 0.1-km (0.1-mi) section is less than that specified to require corrective action and the actual IRI is 1011 mm/0.1-km (64.1 in./0.1-mi.) or greater, additional corrective work shall be performed to bring it to an acceptable level.

Regardless of the percentage of improvement, additional corrective work will not be allowed when the actual IRI is 1010 mm/0.1-km (64.0 in./0.1-mi.) or less.

401.28 Corrective Work. Corrective work shall be limited to diamond grinding, overlaying or removing and replacing. The Contractor shall submit a written corrective work proposal to the Project Manager that includes the methods and procedures that will be used. The Contractor shall not commence corrective work until the methods and procedures have been approved in writing by the Project Manager.

Approval by the Project Manager shall not relieve the Contractor of the responsibility of producing work in conformity with the specifications.

All corrective work including all necessary traffic control shall be completed at the Contractor's expense.

Corrective work shall conform to the following:

- A. **Diamond Grinding.** Diamond grinding shall be performed by a roadway planing device to the extent necessary to bring the IRI or percentage of improvement to an acceptable level for PMBP or SMA. The diamond grinding shall not reduce planned pavement thickness by more than 7.5 mm (0.3 in.) and shall be "daylighted" to produce a smooth finish. When an OGFC is not required as part of the contract, fog seal approved by the Project Manager shall be used.

For PCCP, additional diamond grinding shall be performed as necessary in the transverse direction such that the lateral limits are at a constant offset from and parallel to the nearest lane line or pavement edge, and in the longitudinal direction such that the grinding begins and ends at lines normal to the pavement centerline. All diamond ground locations shall be neat rectangular areas of uniform appearance. The surface texture shall be such that the skid resistance is comparable to adjacent sections that do not require grinding. All damage to the curing membrane resulting from diamond grinding shall be repaired immediately. All diamond grinding work including necessary traffic control and curing membrane repair shall be completed at the Contractor's expense.

- B. **Overlaying.** When an additional lift of PMBP or SMA is used to correct a rough pavement, it shall meet all the requirements of the appropriate specification as specified in the contract. The overlay lift shall extend the full width of the underlying pavement surface and have a finished compacted thickness sufficient to correct the roughness and produce a final surface meeting all specification requirements.

If the overlay does not meet the longitudinal smoothness requirement, a second overlay will not be allowed. Repairs to an overlay not meeting smoothness requirement shall be corrected by diamond grinding or removing and replacing as approved by the Project Manager.

- C. **Removing and Replacing.** When repair of rough pavement is made by removing and replacing, the pavement shall be removed the full width of the lane and the full thickness of the course in areas requiring corrective work. The removal area shall begin and end with a transverse saw cut perpendicular to centerline. Replacement material shall be PMBP, SMA, or PCCP meeting all requirements of the contract.

All sections on which corrective work was performed shall be re-profiled.

For PMBP Rehabilitation/New Construction, SMA Reconstruction/New Construction, or PCCP, the average IRI of the corrected area shall be 1010 mm/0.1-km (64.0 in./0.1-mi.) or less, or further corrective work will be required.

For PMBP, SMA rehabilitation/overlay construction, or PCCP, either or both of the following conditions shall exist or further corrective work will be required:

1. The percentage of improvement for the corrected area is within the acceptable range
2. The actual IRI of the corrected area is 1010 mm/0.1-km (64.0 in./0.1-mi.) or less.

401.3 BASIS OF PAYMENT.

401.31 All surface smoothness testing and corrective work to bring the final surface within specification smoothness shall be included in the unit contract price for Plant-Mix Bituminous Pavement (PMBP), Stone Matrix Asphalt (SMA), Open-Graded Friction Course (OGFC), and Portland Cement Concrete Pavement (PCCP). No separate payment will be paid for surface smoothness testing and corrective work.

401.32 Price Adjustment. A price adjustment will be calculated for each 0.1-km (0.1-mi) section of travel lane. The price adjustment shall apply to the total accepted quantity of the mainline PMBP or SMA as referenced by Section 420, or to the total square meters (square yards) of PCCP constructed under this contract for the roadway length represented by the IRI. The price adjustment shall be determined by applying the appropriate percentage to the unit bid price for the pay item Plant Mix Bituminous Pavement (PMBP), Stone Matrix Asphalt (SMA), or Portland Cement Concrete Pavement (PCCP).

401.321 Price Adjustment for PMBP or SMA Reconstruction/New Construction. Price adjustments will be based on the final average IRI after removing high points and performing any corrective work.

If the IRI obtained on the OGFC in any 0.1-km (0.1-mi) section is greater than the IRI determined for the underlying PMBP or SMA, the price adjustment will be based on the IRI of the OGFC.

Unit price adjustments for multiple lift overlays will be made in accordance with Table 401-A.

**Table 401-A
PROFILE PAY ADJUSTMENT SCHEDULE
PMBP OR SMA RECONSTRUCTION / NEW CONSTRUCTION OR PORTLAND CEMENT
CONCRETE PAVEMENT**

IRI Mm per 0.1-km Section (mm/0.1-km)	IRI In. per 0.1-mi Section (in./0.1-mi.)	Pay Factor
390 or Less	25.0 or Less	105.0
391 to 475	25.1 to 30.0	103.0
476 to 570	30.1 to 36.0	102.0
571 to 665	36.1 to 42.0	101.0
666 to 725	42.1 to 46.0	100.0
726 to 790	46.1 to 50.0	98.0
791 to 865	50.1 to 55.0	96.0
866 to 900	55.1 to 57.0	94.0
901 to 945	57.1 to 60.0	92.0
946 to 1010	60.1 to 64.0	90.0
1011 or Greater	64.1 or Greater	Corrective Work Required

401.322 Price Adjustment for PMBP or SMA Rehabilitation/Overlay Construction. Price adjustments will be based on the percentage of improvement after removing high points and performing any corrective work.

The percentage of improvement (% I) shall be calculated as follows:

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

or

$$\% I = \frac{(\text{Initial IRI} - \text{OGFC IRI})}{\text{Initial IRI}} \times 100$$

If the percentage of improvement calculated using the IRI of the OGFC is less than the percentage of improvement calculated using the final IRI of the PMBP or SMA, the price adjustment will be based on the percentage of improvement calculated using the IRI of the OGFC.

Unit price adjustments will be made in accordance with Table 401-B for single lift overlays.

For each 0.1-km (0.1-mi) section, if the Initial IRI is less than or equal to 725 mm (46.0 in) the "New Construction," Table 401-A, shall be used.

**Table 401-B
PROFILE PAY ADJUSTMENT SCHEDULE
SINGLE LIFT OVERLAY**

Percentage of Improvement (%) 0.1-km(0.1-mi.) Section	Pay Factor
65.1 or Greater	105.0
60.1 to 65.0	103.0
55.1 to 60.0	102.0
50.1 to 55.0	101.0
30.1 to 50.0	100.0
30.0 or Less	Corrective Work Required

Regardless of the percentage of improvement, additional corrective work will not be allowed when the actual IRI is 1010 mm/0.1-km (64.0 in./0.1-mi.) or less.

401.323 Price Adjustment for Miscellaneous Pavement. Unit price adjustments will be made in accordance with Table 401-C for miscellaneous pavement to include ramps, tapers, and holding lanes.

**Table 401- C
PROFILE PAY ADJUSTMENT SCHEDULE
FOR RAMPS, TAPERS, AND HOLDING LANES**

IRI Mm per 0.1-km Section (mm/0.1- km)	IRI In. per 0.1-mi Section (in./0.1-mi.)	Pay Factor
570 or Less	36.0 or Less	105.0
571 to 665	36.1 to 42.0	103.0
666 to 725	42.1 to 46.0	102.0
726 to 865	46.1 to 55.0	100.0
866 to 900	55.1 to 57.0	98.0
901 to 945	57.1 to 60.0	95.0
946 to 1010	60.1 to 64.0	93.0
1011 to 1075	64.1 to 68.0	90.0
1076 or Greater	68.1 or Greater	Corrective Work Re- quired.