ACPA GUIDE SPECIFICATION

Pavement Smoothness Requirements

This document provides guideline specifications useful for developing project specifications for pavement smoothness for newly constructed roadways. It is not applicable for pavement preservation or rehabilitation roadway activies. It also is not applicable to industrial or parking facilities. This guideline should not be used as a specification referenced in contract documents. An owner, engineer or contractor should apply these guidelines to create specifications for specific local projects. To do so, the owner, engineer or contractor can choose from amongst the standards and test methods provided in these guidelines.

This document references appropriate standards, test methods, and specifications of the American Association of State Highway and Transportation Officials (AASHTO), gorvernmental agencies, and the American Society of Testing Materials (ASTM). These references assume that the contractor and the engineer will use the applicable standards or methods that are in effect when bids are solicited for the project. It also assumes that the specification writer will choose the standards or tests most suitable for their agency/project.

APPLICABILITY

This guide specification is directly applicable to major roadways with posted speed limits both above and below 45 mph. The guides were developed for each of these speed based situations and are applicable to the following types of facilities:

- Speeds At or Above 45 mph
  - Interstate Highways
  - Primary Highways
  - Secondary Roads
  - County Roads
  - Arterial Collectors
- Speeds Below 45 mph
  - County Roads
  - Secondary Roads
  - Primary Highways
  - Arterial Collectors

BACKGROUND ON PAVEMENT SMOOTHNESS

To achieve a succussful project, it is important that the specification writer possesses a basic understanding of inertial profiling systems and their application and limitations. Inertial Profiling Systems (IPS) are used to establish the profile of the roadway surface. To accomplsih this, the equipment uses three instruments: an accelerometer to measure the movement of the vehicle body, a laser height sensor to measure the distance from the pavement surface to the vehicle body, and a distance measurement device for determining the position along the roadway.

Although IPS have used various sensor types throughout the years to measure the distance from the roadway to the vehicle, in recent times this measurement has been accomplished primarily through the use of lasers.

With the advent of the laser for height measurement, a new problem emerged regarding the texture of the pavement. Since most lasers at the time had very small footprints, similar to the laser pointers of today, the laser could drop into and out of the pavement texture whether it was a tined or grooved surface. This resulted in diamond ground and grooved surfaces, as well as longitudinally tined surfaces, receiving artificially high measurement readings due to the small laser footprint size. This issue came to light in about 2002 when the ACPA conducted a study to quantify the extent of the problem (ref 1). Based on the findings, the ACPA approached the laser industry to attempt to solve the problem. The laser industry responded with the introduction of the RoLine™ laser that eliminates the measurement issues associated with footprint size. A line laser typically employs a footprint size of approximately four inches.

Subsequently, the RoLine™ laser has evolved to an even wider footprint, faster sampling laser named the "Gocator™". Having achieved the same performance capabilities as the Roline™ laser, the "Gocator™" laser is replacing the Roline™ as the commercially available wide-footprint laser.

Today it is possible to conduct real time smoothness measurement and this provides an even greater opportunity to attain smoother concrete pavements. Better process control and real time quality control is now possible.

The International Roughness Index (IRI) was originally developed on a World Bank Project in the mid 1980s to enable correlation of different road roughness devices (ref 2). The IRI has since become the world standard as the roughness measurement statistic of choice.

Reliable pavement smoothness measurements can best be obtained through the use of the IRI roughness statistic and effective specifications. Of particular concern to the successful measurement of concrete pavements is the use of the RoLine™ or Gocator™ laser for the height measurement in the IPS system.

Today, there are two aspects of the IRI roughness statistic used by agencies. The first is the long-interval roughness of a section of a roadway. By convenience (and not of necessity) a 528 ft. long section of roadway is often analyzed for roughness. The IRI of the entire section is computed and assigned a single value to represent that section or "lot". This approach uses a fixed base length of 528 ft. and the analysis applies only to the profile data obtained within the beginning and ending limits of that specific 528 ft. long section of pavement.

Another use of the IRI is for short-interval roughness (i.e. localized roughness). In this approach, a 25 ft. base length is used for the analysis instead of a 528 ft. length. It should be noted that the shorter the base length, the higher the resulting IRI values computed due to averaging over a shorter and shorter distance. The originator of the IRI statistic stated: "that the variation of IRI found over the length of a road is more extreme when the base length is short should be taken into account when reporting instrument accuracy or writing roughness specifications. Specifically, the accuracy of high-speed profiling systems should be specified according to base length." (ref 3)

In addition, instead of the base length being evaluated over a "fixed" section of profile data as with long-interval analysis, the base length is continuously moved across all the profile data one point at a time producing thousands of results. This approach provides a large distribution of data and is more sensitive to finding pavement locations that may have excessive roughness; and hence the term localized roughness. Since each and every point along the profile is averaged over a 25 ft base length, any roughness zone will be identified.

The question that persists regarding short-interval roughness is its relevance to consumer ride comfort. That is, how do the values relate to consumer ride quality? Examination of the various state specifications will provide additional reflection on this issue as there is considerable discrepancy among criteria. No reported panel ratings have been conducted at this time to establish specification limits for short-interval roughness.

IRI based short-interval roughness also presents implementation and budgetary considerations for contractors and agencies. Under some current DOT specification thresholds, the areas of short-continuous IRI roughness can range from only several feet to a hundred or more feet in length. As a result, compared to rolling straightedge or profilograph based bump detection, IRI roughness can be more challenging to locate and correct on the roadway. In addition, the overall bump count using short continuous IRI tends to be significantly higher than with previous methods. So in addition to the question of appropriate thresholds for IRI based short-interval roughness, further analysis techniques such as bump merger and minimum bump length need to be evaluated.

Technically, IRI has a specific definition and it pertains to the profile obtained along the line of measurement which, for practical purposes, is a single wheelpath (ref 3). If the IRI is obtained in both wheelpaths and then averaged, it is referred to as the Mean Ride Index (MRI). Most agency specifications are referring to MRI even though it may be designated as IRI. Another roughness statistic that is encountered is the Half-Car Roughness Index or HRI. The HRI is a roughness statistic that is calculated by applying the IRI algorithm to the simultaneous average of the left and right wheelpath profiles. The computed value of the HRI will typically range from 80% to 100% of the value computed for the IRI.

Historically, many states used a profilograph specification for measurement of pavement ride quality for construction purposes. Although this was an effective tool, the technology is over a half century old and IPS technologies are more accurate and more efficient and it should be the goal of all agencies to convert to IPS measurement systems. To transition from a profilograph based to a profiler based specification, several issues need to be addressed. At minimum, they are as follows:

- Type of Roughness Statistic (i.e. IRI, MRI, HRI)
- Determination of Smoothness Requirements for Acceptance
- Incentive and Disincentive Amounts, if Applicable
- Continuous or Step Function Pay Schedule, if Applicable
- Consideration of the Effect of Time of Day of Testing on Measured Profile
- Effect of Long-Duration Time Delay on Measured Profile
- Long-Interval Roughness versus Short-Interval Roughness
- Category of Roadway (speed & type such as urban, rural, etc)

Roadway Category

Although some states only have one category of smoothness specification, most states designate requirements based upon at least roadway speed with different specifications typically used for roadways above and below 45 mph. Some states have several categories of specifications based on the roadway type as well. Perhaps the most current trend is the recognition of the need for a separate urban-interstate specification due to the traffic limitations. It should be emphasized that the IRI was developed for a vehicle speed of 50 mph and much slower or higher speeds may require different specifications.

SCOPE OF THIS GUIDELINE

This guideline includes all of the provisions necessary to create a project smoothness specification. Specification language and helpful commentary cover appropriate provisions and descriptions for equipment requirements, equipment calibration and verification procedures, operation of the equipment and accurate determination of the pavement smoothness and attendant pay factors and corrective measures. The specification writer should incorporate appropriate project details and assumptions into the project specification developed using this guideline. It is recommended to consult with your local or national ACPA representative for any advice on developing a project specification.

APPLICABLE TESTING STANDARDS

AASHTO:

M 328-10 Standard Specification for Inertial Profiler

R 40-10 Measuring Pavement Profile Using a Rod and Level

R 54-10 Standard Practice for Accepting Pavement Ride Quality when Measured Using Inertial Profiling Systems

R 56-10 Certification of Inertial Profiling Systems

R 57-10 Operating Inertial Profiling Systems

ASTM:

E 867 Standard Terminology Relating to Vehicle-Pavement Systems

E950 Standard Test Method for Measuring the Longitudinal Profile of Traveled Surfaces with an Accelerometer Established Inertial Profiling Reference

E 1926 Standard Practice for Computing International Roughness Index of Roads from Longitudinal Profile Measurements

E 2560 Standard Specification for Data Format for Pavement Profile

TERMINOLOGY

Accelerometer: An instrument that measures acceleration. Inertial profilers use the on-board accelerometer(s) to establish the inertial reference value (i.e., relative height) that can be combined with the height sensor and DMI data to produce a complete profile.

Area of Localized Roughness (ALR): Any point with a continuous 25 ft length of IRI exceeding that required by the specifications.

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

Corrective Action: Additional work necessary to meet the required specification limits. This generally consists of diamond grinding of the pavement.

Disincentive: A contract provision that provides a monetary penalty for smoothness levels not achieving the requirements specified by the owner or agency.

Distance Measurement Instrument (DMI): An instrument used to determine the longitudinal distance traveled by the inertial profiler during testing.

Equipment Certification: A process required by agencies to validate that a given inertial profiler is capable of meeting the minimum specified accuracy and repeatability standards during construction testing.

Height Sensor: A sensor used in an inertial profiler to measure the vertical distance between the sensor and the pavement surface. This distance is combined with the accelerometer output and the DMI data to produce the surface profile.

Half-car Roughness Index (HRI): A roughness statistic that is calculated by applying the IRI algorithm to the simultaneous average of the left and right wheelpath profiles.

High-Speed Profiler: An inertial profiler that uses a passenger type vehicle, such as a truck or car, to collect profile data at highway speeds. These devices are suitable for collecting data over long stretches of roadway and when testing must be done under traffic conditions.

Incentives: A contract provision that provides a monetary reward for smoothness levels exceeding the requirements specified by the owner or agency.

Inertial Profiler: A commercial device produced to measure pavement profile. The device uses an accelerometer to form an inertial reference, a laser-height sensor to measure the pavement surface location relative to that reference, and a DMI to measure the longitudinal distance traveled during the testing. These sensor outputs are used by the equipment to produce the pavement profile.

International Roughness Index (IRI): A roughness statistic that summarizes the impact of pavement profile on vehicle response for a passenger car, of specified properties, traveling at 50 mph. The IRI is computed from a single longitudinal profile using a quarter-car simulation as described in ASTM E1926.

Localized Roughness: Same as Short-Interval Roughness.

Light-Weight Profiler: An inertial profiler that is relatively light-weight, such as a golf cart or ATV, that is used to test new pavements that have not attained sufficient strength to allow loads imposed by passenger-car type vehicles. Lightweight profilers travel at lower speeds and may not require as much "lead-in" distance as high speed profilers, making them ideal for testing shorter segments that are closed to traffic. Light-weight profilers are also ideally suited for diamond grinding operations where the roadway can be tested prior to removal of the traffic control at the end of the day.

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

Long-Interval Roughness: The IRI computed using a baseline interval of 528 ft. This is commonly used as the acceptance criteria for pavement smoothness and for incentives and disincentives.

Lot: A lot is typically 528 ft. of a single pavement lane over which profile testing has been conducted and will be compared to the contract smoothness specifications.

Mean Roughness Index (MRI): A roughness statistic calculated by averaging the IRI values computed for the left and right wheelpath profiles, respectively.

Operator Certification: A process required by agencies to determine that a given profile operator can pass a specific set of written and field operational tests. Successful operators are then certified by the agency for a specific time frame.

Profiler: An instrument used to measure pavement profiles.

Profiler 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.

Profiler Lead-Out: The distance necessary for an inertial profiler to safely stop or until the data collection system is turned off.

ProVAL: (Profile Viewing and AnaLysis) is an engineering software application that allows users to view and analyze pavement profiles in many different ways. The software is typically used for analyzing profile features and for computing the IRI, MRI, and HRI values for construction acceptance. The program also computes the localized roughness values and can be used to identify needed areas for diamond grinding to improve smoothness. This software is provided by the FHWA and is a free download at www.roadprofile.com.

Quality Assurance (QA): An independent construction management process implemented to ensure the final product conforms to all requirements. Typically, QA programs ensure that the various QC procedures are providing the intended product and that test results conform to owner's expectations.

Quality Control (QC): A construction management process implemented by the contractor to fulfill contract requirements specified by an owner. The quality of each of the construction processes are monitored during production to ensure compliance. QC monitors production quality such that changes or corrections can be made in real time ensuring consistent specification compliance.

Quarter Car Filter: A computer algorithm that calculates the suspension deflection of a simulated mechanical system with a response similar to one corner (i.e. one quarter) of a passenger car travelling at 50 mph.

Reference Device: A device used to obtain the true or accepted profile of a pavement. Typical references devices used for this purpose are rod and level, inclinometer-based and walking profilers**.**

Road Roughness: The deviations of a pavement surface from a true plane which results in characteristic dimensions affecting vehicle dynamics and ride quality.

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

Sample Interval: The longitudinal distance between captured data points obtained during profile testing.

Segment Length: The length of pavement over which the profile is obtained and the smoothness index is recorded.

Short-Interval Roughness: Short sections of pavement that contribute disproportionately to the overall roughness index value; also referred to as localized roughness. The values are determined using the quality assurance module in ProVAL based on the IRI Ride Quality Index and Short Continuous Analysis with 25 ft. base length.

Smoothness Assurance Model (SAM): SAM is an analysis component in the Profile Viewing and Analysis (ProVAL) software. Users can use SAM to produce pavement roughness reports in various forms (including short continuous, long continuous, and fixed interval reports) and to perform grinding simulation as an option.

Testing Laboratory: An organization that measures, examines, performs tests, or otherwise determines the characteristics or performance of materials or products. This may include organizations that offer commercial testing services, an in-house quality control function, or other organization providing the required testing services.

Testing Technician: A person(s) that is an engineer, engineering technician, or experienced craftsman, with qualifications in the appropriate field.

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

Wheelpath: The location where pavement profile measurement is conducted. The wheelpath is defined by the specification, and is intended to represent the path where vehicle wheels travel when properly positioned within the travel lane.

REFERENCES

This guide specification incorporates language or concepts from various project or state specifications and includes best practice provisions. The following documents were used in preparation of this specification:

1. ACPA, Constructing Smooth Concrete Pavements, Concrete Paving Technology, ACPA, 2002
2. Sayers, M., Gillespie, T., Quiroz, C., "The International Road Roughness Experiment; Establishing Correlation and a Calibration Standard for Measurements," Work Bank Technical Paper 45, 1986
3. Sayers, M., Profiles of Roughness, Transportation Research Record 1260, Transportation Research Board, National Research Council, Washington, D.C. 1990
4. Karamihas, S. and Gillespie, T., Assessment of Profiler Performance for Construction Quality Control, University of Michigan Transportation Institute, December 2002
5. Karamihas, S., ACPA 2005 Repeatability Study, University of Michigan Transportation Institute, November 2005
6. SmoothPavements.com website

7. Gillespie, T., Sayers, M., and Segel, L., “Calibration of Response-Type Road Roughness Measuring Systems.” NCHRP Rept. No. 228, December 1980
8. AASHTO M 328-10 Standard Specification for Inertial Profiler
9. AASHTO R 56-10 Standard Practice for Certification of Inertial Profiling Systems
10. AASHTO R 57-10 Standard Practice for Operating Inertial Profiling System
11. AASHTO R 54-10 Standard Practice for Accepting Pavement Ride Quality when Measured Using Inertial Profiling Systems
12. Ministry of Transportation, Ontario, Test Method LS-296, Method of Test for Calibrating, Correlating, and Conducting Surface Smoothness Measurements Using an Inertial Profiler.
13. North Dakota DOT Special Provision for Rigid Pavement Surface Tolerance
14. Caltrans SSP for Profile Data
15. Scofield, L., Development of PCCP Ride Measurement Equipment and Specifications, White Paper prepared for ACPA Smoothness Task Force, September, 2013.

1.0 General

PS-1.01 **Description of Work:** The work consists of providing all pavement profile-measurement equipment and personnel necessary to conduct profile testing to establish the Mean Ride Index (MRI) values and areas of short-interval roughness specified for construction acceptance purposes for newly constructed pavements.

2.0 Equipment

PS-2.01 **Equipment:** The equipment shall consist of an inertial profiling system (IPS) that conforms to and is operated in accordance with the AASHTO specifications indicated below. A minimum 4 inch line-laser sensor will be required and a 1 inch recording interval used. The data will be collected without using the 250mm filter as this filter will be applied during the analysis of the data. The equipment will be certified annually by the agency in accordance with the AASHTO standards and the agency will affix a decal on the equipment indicating successful certification and the expiration date. The same requirements for equipment and operators will be used for quality control testing (QC), quality assurance testing (QA), and acceptance testing.

- **M 328-10** Standard Specification for Inertial Profiler
- **R 54-10** Standard Practice for Accepting Pavement Ride Quality when Measured Using Inertial Profiling Systems
- **R 56-10** Standard Practice for Certification of Inertial Profiling Systems
- **R 57-10** Standard Practice for Operating Inertial Profiling Systems

Re-certification of equipment will be required anytime failure of a major component occurs as identified in AASHTO R 57-10; specifically failure of an accelerometer, noncontact height sensor, circuitry for the collection of raw data, change of or major modification to the host vehicle. Minor adjustments to the equipment are permissible as indicated in AASHTO R57-10.

Equipment may consist of a light-weight profiler or high speed profiler meeting all requirements and specifications found in AASHTO M 328. For areas that cannot be effectively tested using an IPS, a 12 ft straightedge will be used. Requirements for this testing are provided in Section 4.0.

PS-2.02 **Operator:** The operator will be certified by the agency prior to conducting testing. Certification should require the demonstration of proper knowledge and skills in conducting profiling operations in accordance with the previously cited AASHTO specifications and the agency's specification requirements. The skills and knowledge should be directly applicable to proper operation of an IPS and collection and analysis of IPS data. The certification should be valid for a period of two years and the agency should maintain a listing of certified operators.

3.0 Surface Profile Testing

PS-3.01 **Verification of Equipment Prior to Profile Testing:** At least five days prior to conducting inertial profile testing, or initiating a change in operator or ISP equipment, the contractor will provide the agency with both equipment and operator certification documents. The contractor will also submit a list of manufacturer's recommended test procedures for IPS calibration and verification.

In addition to the annual certification requirements, a project associated control section(s) will be established for conducting project specific IPS calibration verification. This testing will consist of verifying the longitudinal distance and vertical height measurements in accordance with AASHTO R 57-10 and the manufacturer's recommendations. The contractor shall notify the engineer at least two days prior to conducting the verification testing such that the engineer can observe the testing. This testing will be conducted prior to commencement of any IPS testing and at least annually if the project duration is lengthy. It may also prove beneficial to concurrently verify the QC, QA, and acceptance equipment at the same time.

At minimum, testing will consist of distance measurement verification, block test, bounce test, cross-correlation testing, and manufacturer's recommended tests. It is desired that the control section be a straight, level section, at least 850 ft in length (to allow for IPS stabilization) and similar in texture and roughness to the project specifications. In no case should the selected pavement section exceed a MRI of 120 inches per mile. The section should be free of surface distresses and reasonably consistent profile between the left and right wheel paths.

To establish the MRI of the of the control section, five repeat runs will be conducted over a designated 528 ft subset of the control section. The average of the five runs will be considered the MRI of the control section; provided that the cross correlation of the measurements, as determined using the latest version of ProVAL, is at least 90 percent. Within 2 days of the testing, the contractor will submit the ProVAL profiler certification analysis report for cross-correlation test results for approval to the agency. The contractor may elect to submit the results at the time of testing for approval by the agency at that time. Once approved, ISP testing may proceed. The contractor will maintain a log of the cross-correlation testing and all subsequent control section measurements in accordance with AASHTO R56-10. It is recommended to develop control plots to evaluate any drift in the control section roughness over time.

PS-3.02 **IPS Test Location, Number of Runs, and Exclusions:** Profile testing will be conducted in the left and right wheelpaths. For IPS testing, wheelpaths are designated as 3 feet from and parallel to the edge of a lane. Left and right are relative to the direction of travel. One test in each wheelpath will be conducted. The MRI for the lot will be determined by averaging the two wheelpath IRI results.

The IPS will be used at all pavement test locations where it is practical and can effectively be accomplished. The exclusions to this are:

1. Bridge decks and approach slabs
2. Intersections and roundabouts
3. At grade railroad crossings
4. Traffic lanes less than 1,000 feet in length including ramps, turn lanes, and acceleration and deceleration lanes
5. Side roads, approaches, and short superelevation transitions
6. Areas within 15 feet of manholes and drains
7. Shoulders
8. Weigh-in-motion areas
9. Miscellaneous areas such as medians, gore areas, turnouts, and maintenance pullouts
10. Beginning and end of project
11. Finished surfaces within 25 feet before and after the excluded areas shown in 1, 2, 3, and 9 or before any change from PCCP to AC
12. Short isolated pavement areas requiring handwork.

13. Safety Reasons
14. Any specific project conditions that warrant exclusion and is agreed to by the agency and contractor.

PS-3.03 **Quality Control Testing (QC):** Quality control (QC) testing in the context of these guidelines refers to IPS testing conducted on the hardened concrete surface. It is recognized that real-time smoothness control is a valuable tool for producing smooth pavements and effectively controlling the quality of the contractor's operation. At this time, the results of that testing have not been universally accepted by agencies as a QC procedure. For the remainder of this document, QC, Quality Assurance (QA), and acceptance testing all refer to measurements obtained on the hardened surface. For QC testing, it is recommended that testing be conducted within three days of production to better relate to the actual placement profile.

Prior to conducting QC testing each day, the contractor will conduct equipment verification testing consisting of: (1) Block Test (AASHTO R 57-10), (2) Bounce Test (AASHTO R 57-10 and or the manufacturer's recommendations), (3) DMI test, and (4) Additional manufacturer recommended procedures. If possible, saw laitance and any debris should be removed from the surface to prevent interference with profile measurement.

QC testing will be evaluated on a lot basis for long-interval roughness acceptance (see Table A). A lot is defined as a single paved lane, 528 feet (0.1 mile) long. Any partial lot less than or equal to 250 feet long will be included in the previous lot. However, any partial lot greater than 250 feet long will be treated as an independent lot. The MRI for each lot will be determined and reported to the agency within 24 hrs of testing.

QC testing will evaluate short-interval roughness acceptance (see Table B) using the individual wheelpath IRI results developed using a 25 ft continuous base length. Particular care is necessary to ensure that the actual location of deficient areas can be determined for any subsequent corrective action. This requires the use of accurate GPS positioning or surveyed locations. The short-interval roughness IRI will be reported concurrently with the long-interval MRI.

During initial paving it may be beneficial to conduct profile measurements during different times of the day to determine if diurnal changes are occurring in the pavement profile. This is not common, but can occur under certain conditions. If this situation is occurring, it may be more difficult to relate the real-time smoothness levels to the QC testing.

PS-3.04 **Quality Assurance Testing (QA)**: By definition, this testing needs to be independent of the QC testing. Therefore, it can be accomplished by the agency or an independent tester. QA testing should adhere to all the requirements specified herein for the contractor QC and project acceptance testing. Testing must be done by certified equipment and operators that have also demonstrated the efficacy of such equipment and procedures on the project associated control section by achieving the cross-correlation requirements. The agency will determine the percentage, if any, of project tested for the QA effort.

Acceptable QA results occur when the contractor QC and independent QA results are within 10% for all lots for the long-interval roughness. If this does not occur, the Department and Contractor will attempt to determine the probable causes for the difference. If an acceptable reason cannot be determined, the Engineer may require recalibration of the contractor IPS equipment and to re-profile the pavement. If the results are deemed inaccurate due to operator error, the Engineer may disqualify the contractor IPS operator.

For those sections that exceeded the 10% difference criteria, the contractor will retest the areas. If excessive differences still exist between the contractor and agency results, the contractor can accept the agency results or request referee testing by an independent party at the contractor's expense. The independent party will be required to conform to all the requirements specified herein.

It is recommended that QA testing be accomplished within one week of production of the sections tested.

PS-3.05 **Acceptance Testing:** It is recommended that an effective QC and QA process be employed such that the accepted QC data can be used for project acceptance testing for determination of the price adjustment indicated in Table A. This eliminates the need to retest the pavement upon completion of paving.

For agencies which conduct their own acceptance testing, it is recommended that the testing be accomplished no more than one week after lot(s) production and before opening to traffic. Acceptance testing should conform to all the requirements stated herein for QC and QA testing. It is also desirable that acceptance testing occur under similar conditions and similar times of the day as the QC testing to provide a better correlation to production test results. This is particularly important if significant changes are occurring in the results due to daily temperature shifts.

Prior to conducting acceptance testing, the agency will notify the contractor at least two days in advance of the time of testing such that the contractor can observe the testing.

A dispute resolution process should be established to evaluate acceptance test results which differ significantly from the QC and/or QA testing. This should include third party testing if needed.

4.0 Straight Edge Testing

PS-4.01 **Acceptance Requirements:** For the exclusions where IPS testing is not practical, the pavement surface will be tested using a straightedge or a device such as a walking or inclinometer based profiling system that can simulate a straightedge. In those locations the surface will not vary from the lower edge of a 12-ft straightedge by more than:

- 1/8 inch when the straightedge is laid parallel with the centerline
- ¼ inch when the straightedge is laid perpendicular to the centerline and extends from edge to edge of a traffic lane.

5.0 Data Analysis

PS-6.01 **Long-Interval Roughness Determination:** The MRI for every lot will be determined using the current version of ProVAL with a 250mm filter applied and a base length of 528 ft.

PS-6.02 **Short-Interval Roughness Determination:** The IRI for each wheelpath will be determined using the current version of ProVAL with the 250 mm filter applied and a continuous 25 ft base length selected. This result is also commonly referred to as localized roughness. Table B indicates the required values.

6.0 Correction of Deficient Areas

PS-6.01 General: Areas which do not meet the required ride quality for either the long or short interval roughness, or those areas which the contractor desires to further improve the long-interval ride quality for incentive purposes, shall be diamond ground. This shall apply to both the long-interval roughness and short-interval roughness requirements indicated in Tables A and B.

Prior to diamond grinding, the contractor will provide the engineer with a proposal outlining the details of the corrective plan. Once the engineer has approved the plan, the contractor can commence diamond grinding when the pavement has cured for at least 10 days and/or the pavement has attained a modulus of rupture of 550 psi.

The contractor will correct the entire lane width and begin and end grinding at lines perpendicular to the roadway centerline. The corrected area must have a uniform texture and appearance. Any damage to joint sealing will be repaired at the contractor's expense.

Once grinding has been completed, the corrected area(s) will be retested using the IPS unless it is an excluded area, in which case a 12 ft straightedge is used to retest the area(s). The final retested values will then be used for measurement and payment determination.

7.0 Measurement and Payment

PS-7.01 Measurement for Pavement Ride Quality: All areas tested with the IPS and the straightedge will be measured by the square yard.

PS-7.02 Long-Interval Ride Quality: Payment for acceptable long-interval ride quality will be based on individual lots in accordance with Table A for all areas tested with the IPS. The incentive and disincentive amounts are applied on a square yard basis and are in addition to the standard bid item prices.

It should be noted again that these requirements are guidelines and that Table A cannot apply equally to all projects and circumstances. The applicability of Table A requirements to each specific project should be confirmed based upon local experience and anticipated conditions at the time of construction. Many factors such as construction phasing, topography, alignment, intersections, intersecting roadways, etc. all influence the ability to achieve these requirements. As such, Table A requirements should be modified, as necessary, to accommodate the specific project conditions.

For roadways with speed limits below 45 mph, the applicability of Table A is complicated further by the development of the IRI which, as previously described, was at a speed of 50 mph. As speeds become less than this, the shorter wavelengths begin to have greater impact and the relevance of the IRI to the local streets and urban settings becomes more questionable. NCHRP currently has a project underway investigating this issue and changes in the future years may result from that work. In the mean time, specifiers, should be aware of this issue and modify Table A guidelines as necessary based on current experience and expected conditions.

PS-7.03 **Short-Interval Ride Quality:** Acceptance for short-interval ride quality will be based on achieving the minimum requirements indicated in Table B. No incentive or disincentive will be applied.

As with Table A, the Table B requirements cannot apply to all project conditions and should be modified as necessary to best represent actual construction practices. Short-interval ride quality is unique in that there is currently a large variability among state agency requirements; ranging from 80 to 200 inches per mile (see Reference 15). This suggests that the relevance of this particular requirement needs additional research to be properly defined.

Today, the industry has the ability to make very precise measurements and use very sophisticated software for analysis. However, the fact that it can be easily measured and analyzed does not infer that lower is better. There is a cost associated with achieving low levels of short-interval roughness and the selected levels should be based upon meeting consumer expectations in ride quality. Unlike, the old profilograph specification where a bump of a certain length and magnitude was required before corrective action occurred; the area of short-interval roughness is less specific. That is, it could be interpreted as a single point (by definition) or it could be defined by a minimum area such that it must be at least 15 ft in length, etc. Further research is necessary on the impact of short-interval roughness on consumer satisfaction.

PS-7.04 **Payment for Ride Quality in Excluded Areas:**

Areas tested with the straightedge will receive full payment for the square yards of excluded areas. Incentives and disincentives are not applied to these areas and all areas must meet the requirements.

TABLE A PRICE ADJUSTMENT SCHEDULE**			
Speed Less Than 45 MPH		Speed Equal to or Greater than 45 MPH	
MRI	Adjustment	MRI	Adjustment
<55	+$2.25/sq yd	<40	$2.25/sq yd
55 to 74	(75-MRI)*0.1125	40 to 59	(60-MRI)*0.1125
75 to 90	0	60 to 75	0
91 to 110	(90-MRI)*0.1125	76 to 90	(75-MRI)*0.1125
>110	Corrective Action	>90	Corrective Action

******It is important to note that incentive/disincentives can vary based upon the particular roadway conditions, construction practices, and agency requirements. Each project should be specified based on its own merits and requirements.

TABLE B SHORT-INTERVAL ROUGHNESS REQUIREMENTS	
Speed Less Than 45 MPH	Speed Equal to or Greater than 45 MPH
IRI ≤ 190	IRI ≤ 175