

**Western Federal Lands Highway Division
FP Specification Change
Pavement Smoothness/Roughness**

The Western Federal Lands Highway Division (WFLHD) is making a significant change in its method of measuring and paying for smoothness on its paving projects. In the past, pavement smoothness has been measured using a California type profilograph with acceptance and payment based on the Profile Ride Index (PrI).

In 2004, the WFLHD will begin using a portable inertial profiler to measure the profile of the road surface. The profile data will be run through an algorithm to determine the International Roughness Index (IRI) and a pay factor will be determined based on the IRI or in the case of overlays the percent improvement in IRI.

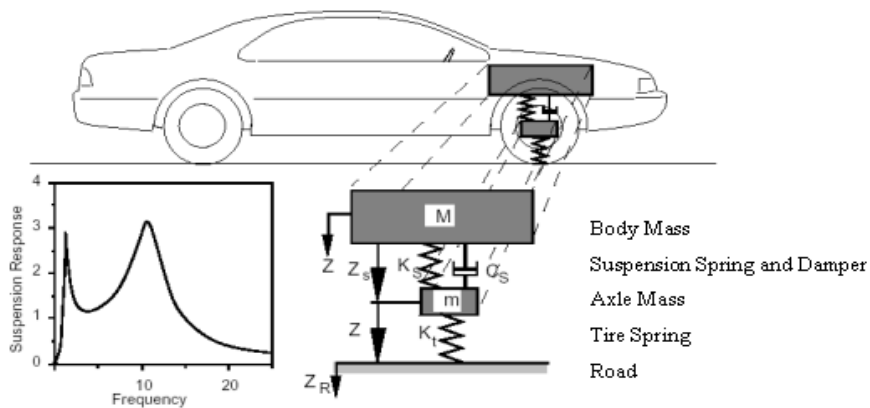
The PrI and IRI are significantly different. What may have been considered an acceptable or even a good ride with the PrI may not be acceptable when measured by the IRI. What follows, is a brief explanation of IRI vs. PrI, an excerpt from WFLHD’s new smoothness specification, and a list of additional resources on IRI and paving smooth roads.

IRI vs. PrI

The IRI simulates the response of a vehicle traveling over a road having a given profile. The IRI is more closely correlated to what a driver behind the wheel actually feels, than is the PrI.

In the IRI model the total vertical movement of the “body mass” is accumulated as a “golden” or “standardized” vehicle is simulated traveling over a measured profile. The accumulated vertical movement of the vehicle or “body mass” is then divided by the total distance traveled. The IRI is typically reported in inches/mile or meters/kilometer for each 0.1 miles or 0.1 kilometers respectively. Figure 1 demonstrates the basic principle behind the IRI model.

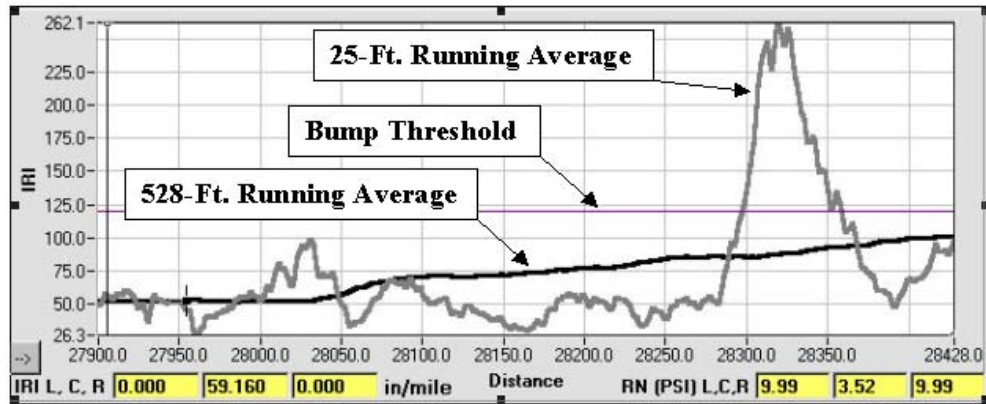
Figure 1 – Vehicle Response Model



The upper limit of average roughness over a 0.1-mile or 0.1 kilometer for new construction that is considered barely acceptable without correction is 95 inches/mi or 149.9 meters/kilometer. Individual bumps can be detected by looking at the average IRI value calculated over a shorter distance, say 25 feet or 7.62 meters. An average IRI value over 25 feet (7.62 meters) greater than 120 inches/mile or 1.894 meters/kilometer indicates a bump and requires correction. Bumps are readily identified by examining a continuous plot of IRI values over the span of interest. Figure 2 shows two plots of continuous IRI values

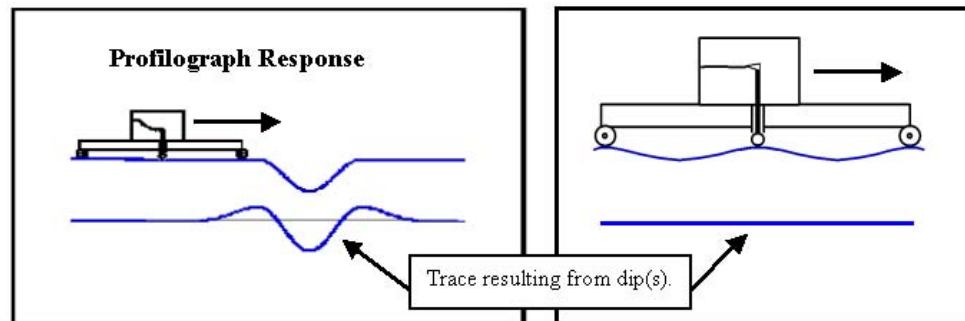
on a recently completed pavement. The first plot is that of the 528-ft running average IRI while the second is that of a 25-ft running average IRI. The sharp increase in the 25-foot IRI identifies the location of a poorly constructed joint tying into an existing pavement. Under the new specification, this joint requires correction.

Figure 2 – Plots of Continuous IRI



Unlike a profilograph, an inertial profiler can provide an accurate profile of the road surface. The profile obtained from a profilograph is actually a distorted profile of the road. This can result in some types of roughness being totally missed and others types being exaggerated (see Figure 3).

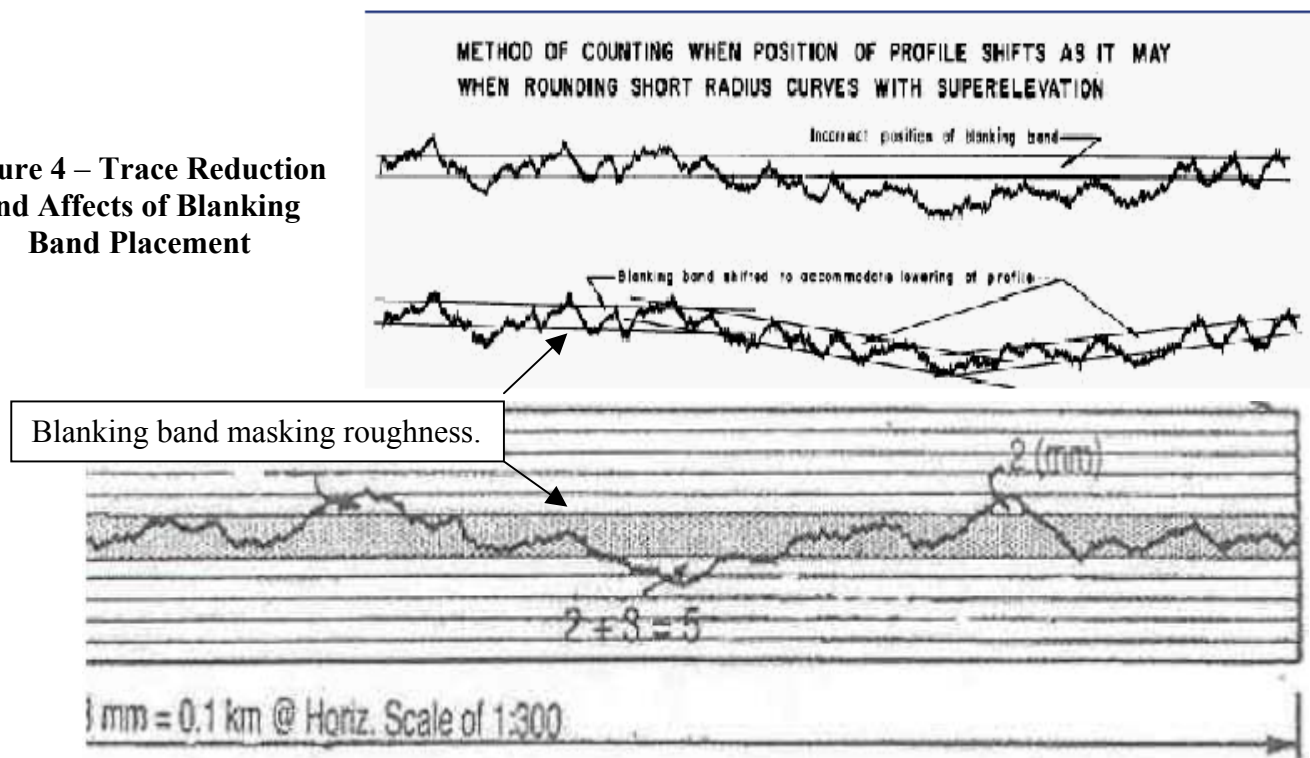
Figure 3 – Distorted Profilograph Traces



In reading a profilograph trace, a 0.2 blanking band is typically employed. This blanking band masks out some of the roughness of the road. With the advent of optical scanners and digitized systems, zero blanking bands can be employed, but this does not completely eliminate the problems associated with the trace. The roughness obtained from the trace is also related to how the blanking band is placed on the trace. The positioning can have a significant affect on the PrI that is obtained. Figure 4 shows a typical trace showing the blanking band and positioning affects.

These are a few of the reasons why the WFLHD is changing to measuring pavements using an inertial profiling system and adopting the use of IRI. It also explains in part why a road that was considered acceptable using a profilograph may not be acceptable using the IRI.

Figure 4 – Trace Reduction and Affects of Blanking Band Placement



The IRI has been an accepted method of indexing pavement roughness since the 1970s. Its use however has been primarily for research and as part of pavement management systems used by highway agencies. Over the past few years, interest in tying the IRI data of aged pavements to initially constructed IRI data has increased. Thus, several states have developed construction acceptance specifications based on IRI.

In 2003, AASHTO adopted four Provisional Standards:

- MP 11-03, Standard Equipment Specification for Inertial Profiler,
- PP 49-03, Standard Practice for Certification of Inertial Profiling Systems,
- PP 50-03, Standard Practice for Operating Inertial Profilers and Evaluating Pavement Profiles, and
- PP 51-03, Standard Practice for Pavement Ride Quality when Measured Using Inertial Profile Systems.

These four standards have greatly enhanced the utility of the IRI. The four standards address the minimum equipment requirements and capabilities; provide guidance on certifying and verifying proper functioning of the equipment/operator system; standardize the method of collecting, analyzing and reporting data; and provide a guide specification for acceptance of pavement roughness using IRI.

The WFLHD has assisted the expert task group and participated in research efforts leading to development of the four standards. We have procured inertial profiling equipment for measuring the IRI, and have developed a construction specification and acceptance plan for both new construction and overlays. Those portions of the new specification that are of interest follow:

SPECIFICATION

401.16 Pavement Roughness. The CO will measure roughness of the final paved surface course within 21 days after final rolling of the completed roadway paving, and before placement of any surface treatment. In addition to the pavement roughness type requirements, construct all pavement surfaces to meet the requirements of (b) below.

(a) International roughness index (IRI). The CO will furnish and operate an inertial profiler conforming to AASHTO PP 50 and validated according to AASHTO PP 49. Furnish personnel to provide flagging operations as may be required. The CO will measure the roughness in the middle portion of each lane.

Areas of localized roughness will be identified using a continuous report of IRI. The continuous report will be calculated with a 25-foot base length. This will yield the IRI of every possible 25-foot segment. Any area for which the continuous report exceeds an IRI of 120 in/mi will be considered an area of localized roughness.

A continuous report of road roughness is defined as the roughness profile from “Profiles from Roughness,” TRR 1260, by Mike Sayers. Its use for detection of localized roughness, as required here, is demonstrated in “Using a Ride Quality Index for Construction Smoothness Specifications,” TRR 1861, by Swan and Karamihas.

An IRI value will be determined for each 0.1-lane mile of traveled way. Cattle guards and bridges not being overlaid will be excluded from the calculation of IRI and determination of localized roughness. Measure excluded areas according to (b) below.

(1) Type III pavement roughness (IRI measurements for reconstructed and new roads). The CO will measure the roughness of the final paved surface course. Defective areas are 0.1-mile segments with IRI values greater than 95 inches per mile or areas of localized roughness.

The pay adjustment factor (computed to two decimal points) for each 0.1-mile segment will be determined from Table 401-3.

IRI (inches per mile)	Pay Adjustment Factor (PAF)
Less than 30.0	PAF = 12.50
30.0 to 59.9	PAF = 25 – 0.4167 (IRI)
60.0 to 65.0	PAF = 0.00
65.1 to 95.0	PAF = 81.25 – 1.25 (IRI)
Greater than 95.0	Rejected ⁽¹⁾

(1) Pay adjustment factor when corrections are not allowed equals minus 37.50.

(2) Type IV pavement roughness (IRI measurements for overlay, recycle with overlay, or milling with overlay projects). The CO will measure the roughness of the existing surface prior to construction traffic. The existing surface is the original surface before overlaying, recycling, or milling. The existing IRI will be used to determine the percent improvement for each 0.1-mile segment.

The CO will measure the roughness of the final paved surface course. Defective areas are areas of localized roughness or 0.1-mile segments having a percent improvement less than 0.9 or 25.4 as determined from Table 401-4.

The percent improvement in IRI will be determined to one decimal place for each 0.1-mile segment according to the following formula:

$$\% \text{ Improvement} = [(\text{Original IRI} - \text{Final IRI}) / \text{Original IRI}] * 100$$

The pay adjustment factor (computed to two decimal points) for each 0.1-mile segment will be determined from Table 401-4.

Single Lift ⁽¹⁾ Percent Improvement (%)	Pay Adjustment Factor ⁽¹⁾	Multi-Lift ⁽²⁾ Percent Improvement (%)	Pay Adjustment Factor ⁽²⁾
Greater than 48.4	PAF = 12.50	Greater than 61.1	PAF = 12.50
24.8 to 48.4	PAF = 0.5274(%) – 13.027	43.3 to 61.1	PAF = 0.6983(%) – 30.168
12.4 to 24.7	PAF = 0.00	34.0 to 43.2	PAF = 0.00
0.9 to 12.3	PAF = 3.2609(%) – 40.435	25.4 to 33.9	PAF = 4.3605(%) – 148.260
Less than 0.9	Reject ⁽³⁾	Less than 25.4	Reject ⁽³⁾

- (1) For single lift overlays with no other corrective work such as milling, grinding or preleveling in excess of 25 percent of the surface area the of existing pavement.
- (2) For multiple lift operations such as milling, grinding or preleveling followed by one or more lifts of pavement or two or more lifts of pavement without milling, grinding or preleveling.
- (3) Pay adjustment factor when corrections are not allowed equals minus 37.50.

(b) Type V pavement roughness (straightedge measurement). Use a 10-foot metal straight edge to measure at right angles and parallel to the centerline. Defective areas are surface deviations in excess of 1/4 inch in 10 feet between any two contacts of the straightedge with the surface.

(c) Defective area correction. Correct defective areas from (a) and (b) above. Obtain approval for the proposed method of correction. Grinding is an acceptable method of correction provided the area ground does not exceed 700 square feet per location, and is limited to an average of one location per lane mile with no more than two locations per lane mile. Grinding in excess of these limits is not an acceptable method of correction unless it is accompanied by an overlay or a single-course surface treatment over the entire length of the project.

If grinding is allowed, grind the pavement surface with a diamond blade machine and apply a fog seal according to subsection 409.10. The endpoints of the areas where a grinder is to be applied shall be optimized via grinding simulation. Grinding simulation shall be done with the purpose of grinding the minimum area needed to decrease the roughness to acceptable limits.

If no corrections are allowed, no adjustment will be made to the pay adjustment factors.

The CO will re-measure corrected areas once at no expense to the Contractor. Subsequent re-measures will cost \$2,000 each. The roughness values obtained will replace the original values and the smoothness pay adjustment will be computed.

401.19 Payment. For pavement type III or IV pavement roughness, a separate adjustment will be made. The dollar amount of the adjustment will be determined by summing the pay adjustment factors determined in Subsection 401.16 for each 0.1-mile and multiplying that sum by the contract unit bid price.

The specification will be phased in starting in 2004 with full implementation planned for 2006. In 2004, a contractor will be able to obtain the full bonus allowed by the specification, but deducts will be reduced to 70% of the calculated value from Table 401-3 or Table 401-4 as applicable. In 2005, deducts will be reduced to 85% of the calculated value. In 2006 there will be no adjustment of the deduct value.

The metric version of the specification is the same, however the acceptance equations are different since the measurement units are different (meters/km vs. inches/mi). Regardless of whether a project is measured in metric or US Customary units, the amount of bonus or deduct earned on a project basis is similar.

ADDITIONAL RESOURCES

To learn more about IRI you can download the book “The Little Book of Profiling” by Michael W. Sayers and Steven M Karamihas, by visiting:

www.umtri.umich.edu/erd/roughness/litbook.html

To learn how to pave smooth roads read: HMA Pavement Smoothness – Characteristics and Best Practices for Construction, Publication No. FHWA-IF-02-024, March 2002.

If you have any questions concerning the specification, please contact our Materials QA Engineer, Bruce E. Wasill, at 360-619-7703.