TECHBRIEF

Help with Converting Pavement Smoothness Specifications

Report No. FHWA-RD-02-112
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Introduction

Pavement smoothness is a key factor in determining highway user satisfaction. To adequately represent drivers' opinions of roadway conditions, many highway agencies are transitioning to the International Roughness Index (IRI) or to the Profile Index (PI) using a 0.0-millimeter (mm) blanking band ($PI_{0.0}$) from the PI using a 5-mm or 2.5-mm blanking band ($PI_{5\text{-mm}}$ or $PI_{2.5\text{-mm}}$). This has led to the need for correlation equations to relate the current $PI_{5\text{-mm}}$ or $PI_{2.5\text{-mm}}$ smoothness specification levels with those to be used in the new specifications.

To address this issue, research was initiated to develop a practical tool to assist in the transition from $PI_{5\text{-mm}}$ or $PI_{2.5\text{-mm}}$ to IRI or $PI_{0.0}$. Information developed in this research can be used by highway agencies to estimate the level of IRI and $PI_{0.0}$ smoothness associated with their current pavement smoothness specifications.

Key Findings

Key findings of this research include:

- Linear equations for converting from $PI_{5\text{-mm}}$ and $PI_{2.5\text{-mm}}$ to $PI_{0.0}$ and IRI indices.
- Modified equations to account for effects of climate and pavement type, where statistically appropriate.
- Quantified variability information for each correlation.
- IRI and $PI_{0.0}$ specification levels converted from currently reported agency full-pay levels.

LTPP

The Long Term Pavement Performance (LTPP) program is a 20-year study of in-service pavements across North America. Its goal is to extend the life of highway pavements through various designs of new and rehabilitated pavement structures, using different materials and under different loads, environments, subgrade soil, and maintenance practices. LTPP was established under the Strategic Highway Research Program and is now managed by the Federal Highway Administration.

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Data

The FHWA Long-Term Pavement Performance (LTPP) Program provided profile data used in this research. Since 1996, LTPP has collected pavement surface profile data from more than 1,700 test sections (typically 152.5 meters (m) long) across the United States and Canada. LTPP uses a high-speed inertial profiler, rated as class I according to ASTM E-950-98, to record profile data at 25-mm intervals. IRI values for each profile are computed using LTPP software according to the ASTM E-1926-98 protocols. Researchers obtained climatic and pavement type information from the LTPP database.

Analysis

To determine the PI values from the profiles, researchers employed a commonly used simulation method. Lightweight profilers simulating PI values have been in use for more than 5 years, and several manufacturers have proven that they can correlate well with PIs obtained from profilographs. For this study, researchers used the algorithm employed by the lightweight profiler that the LTPP profiler manufacturer developed. Because the same sensors, filtering, and sampling interval are used for the manufacturer's high-speed profiler and lightweight profiler, this simulation held the best promise of matching profilograph PI output.

Results

Based on the data shown in figures 1 and 2, a linear relationship is evident between IRI and $PI_{0.0}$ for both asphalt concrete (AC) and portland cement concrete (PCC) pavements. Rather good correlation coefficients result from these direct comparisons, with an R^2 of 0.87 and 0.83 for AC and PCC pavements, respectively.

Statistical analysis reveals that, in certain instances, a small portion of the variability in the relationships between IRI and PI can be related to climate and

Figure 1. IRI vs. $PI_{0.0}$ for AC pavements.

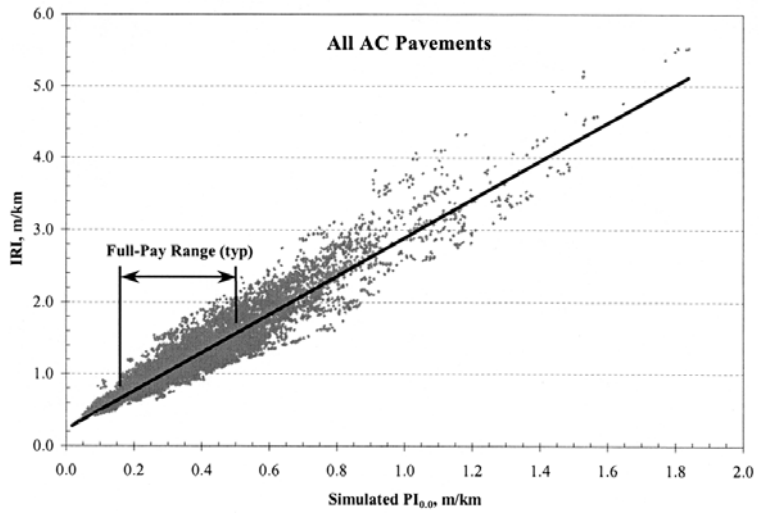
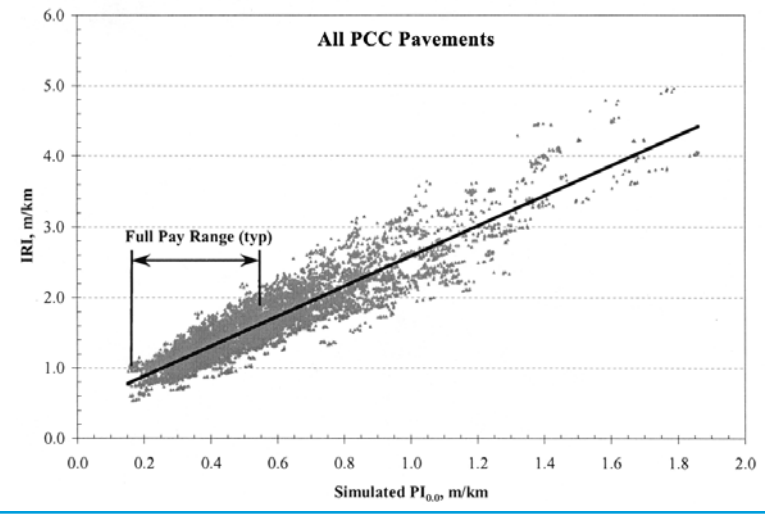


Figure 2. IRI vs. $PI_{0.0}$ for PCC pavements.



pavement type. To provide agencies with the most accurate equations, these variables were included in the PI to IRI models shown in table 1.

Climatic regions used in these tables are defined as dry freeze (DF), dry non-freeze (DNF), wet freeze (WF), and wet non-freeze (WNF). Climates with average annual rainfall of more than 508 mm per year were considered designated as having a freezing index of more than 66°C-days per year.

As expected, the relationship between $PI_{5\text{-mm}}$ and $PI_{0.0}$ is also linear, as figures 3 and 4 illustrate. The variability in these relationships is an indication of the pavement roughness data that is lost when a wider blanking band is used. The R^2 value for all AC pavements increased to 0.90 for all PCC pavements.

No statistical differences in the correlations were noted for jointed-plain, jointed-reinforced, and continuously reinforced concrete (JPC, JRC, and CRC) pavements. However, statistical differences were noted between original AC pavements, AC overlays of AC, and AC overlays of PCC. Also, climatic effects accounted for some of the variability in the equations. Therefore, the correlations in table 2 include several pavement types and climatic regions.

PI-to-IRI index conversion equations and varibility indices.

Table 1. Pavement Type Climate[a] Blanking Band (mm) Correlation Equation.

Pavement Type	Climate[a]	Blanking Band (mm)	Correlation Equation (IRI = mm/km, PI = mm/km)	N	SEE	R^2
AC	1,2,3,4	0.0	IRI = 2.66543*$PI_{0.0}$ + 213.01	14,170	200.17	0.89
AC	1,2,3,4	5.0	IRI = 3.78601*$PI_{5\text{-mm}}$ + 887.51	13,775	292.26	0.77
AC/AC	1	0.0	IRI = 2.74599*$PI_{0.0}$ + 265.42	1,854	191.97	0.91
AC/AC	2	0.0	IRI = 2.68169*$PI_{0.0}$ + 274.67	1,494	184.64	0.81
AC/AC	3,4	0.0	IRI = 2.42295*$PI_{0.0}$ + 301.90	5,126	178.81	0.84
AC/AC	1	5.0	IRI = 4.25316*$PI_{5\text{-mm}}$ + 957.80	1,824	288.17	0.79
AC/AC	2	5.0	IRI = 4.39478*$PI_{5\text{-mm}}$ + 883.20	1,345	308.23	0.45
AC/AC	3,4	5.0	IRI = 3.42671*$PI_{5\text{-mm}}$ + 876.80	4,906	265.85	0.63
AC/PCC	1,2,3,4	0.0	IRI = 2.40300*$PI_{0.0}$ + 292.93	4,156	205.58	0.79
PCC	1,3	0.0	IRI = 2.12173*$PI_{0.0}$ + 439.76	12,039	259.63	0.84
PCC	2	0.0	IRI = 2.58454*$PI_{0.0}$ + 423.09	1,448	176.54	0.88
PCC	4	0.0	IRI = 2.3582*$PI_{0.0}$ + 317.19	2,888	236.51	0.84
PCC	1,3	5.0	IRI = 2.62558*$PI_{5\text{-mm}}$ + 1,205.73	11,946	305.96	0.77
PCC	2	5.0	IRI = 3.51673*$PI_{5\text{-mm}}$ + 1,226.35	1,364	268.70	0.72
PCC	4	5.0	IRI = 2.87407*$PI_{5\text{-mm}}$ + 1,229.63	2,885	297.37	0.74

[a] Climatic zones: 1=DF, 2=DNF, 3=WF, 4=WNF.

Table 2. PI-to-$PI_{0.0}$ index conversion equations and variability.

Pavement Type	Climate[a]	Correlation Equation (PI = mm/km)	N	SEE	R^2
AC	1,3	$PI_{0.0}$ = 1.35776*$PI_{5\text{-mm}}$ + 275.48	5,684	83.58	0.88
AC	2,4	$PI_{0.0}$ = 1.46417*$PI_{5\text{-mm}}$ + 240.09	8,093	71.73	0.86
AC/AC	1	$PI_{0.0}$ = 1.56038*$PI_{5\text{-mm}}$ + 250.89	1,826	73.74	0.88
AC/AC	2	$PI_{0.0}$ = 1.75837*$PI_{5\text{-mm}}$ + 222.84	1,347	79.32	0.66
AC/AC	3,4	$PI_{0.0}$ = 1.45876*$PI_{5\text{-mm}}$ + 233.59	4,908	71.53	0.81
PCC	1	$PI_{0.0}$ = 1.39512*$PI_{5\text{-mm}}$ + 343.08	2,182	71.19	0.87
PCC	2	$PI_{0.0}$ = 1.36715*$PI_{5\text{-mm}}$ + 313.25	1,366	66.42	0.86
PCC	3	$PI_{0.0}$ = 1.20723*$PI_{5\text{-mm}}$ + 367.91	9,764	86.73	0.91
PCC	4	$PI_{0.0}$ = 1.19909*$PI_{5\text{-mm}}$ + 390.49	2,885	85.19	0.85

[a] Climatic zones: 1=DF, 2=DNF, 3=WF, 4=WNF.

Applications

These correlation equations can be used to assist agencies transition from the $PI_{5\text{-mm}}$ smoothness index to IRI or to $PI_{0.0}$. For example, a wet-freeze State has specified a full-pay range for new PCC pavements of $PI_{5\text{-mm}}$ between 79 and 110 mm/kilometer (km). State officials can use equations 14 and 25 to determine that a comparable IRI range would be 1,413 to 1,495 mm/km and a comparable $PI_{0.0}$ range would be 463 to 501 mm/km.

Similarly, for AC pavement smoothness specifications (full-pay is 64 to 110 mm/km), the State could use equations 2 and 17 to estimate a comparable IRI range of 1,130 to 1,304 mm/km and a comparable $PI_{0.0}$ range of 362 to 425 mm/km.

Figure 3. $PI_{0.0}$ vs. $PI_{5.0}$ for AC pavements.

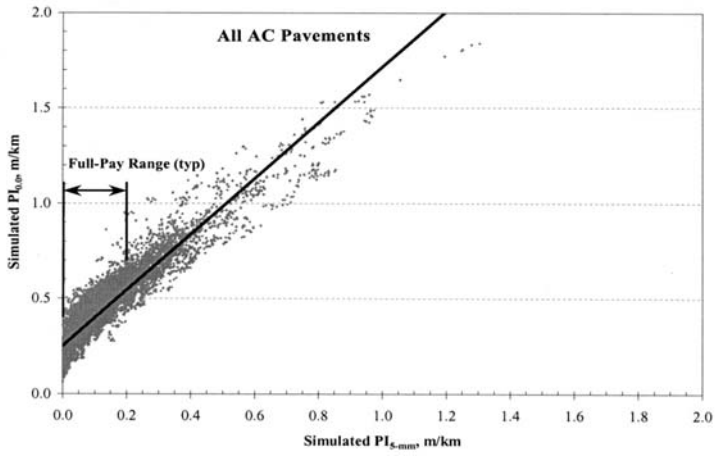
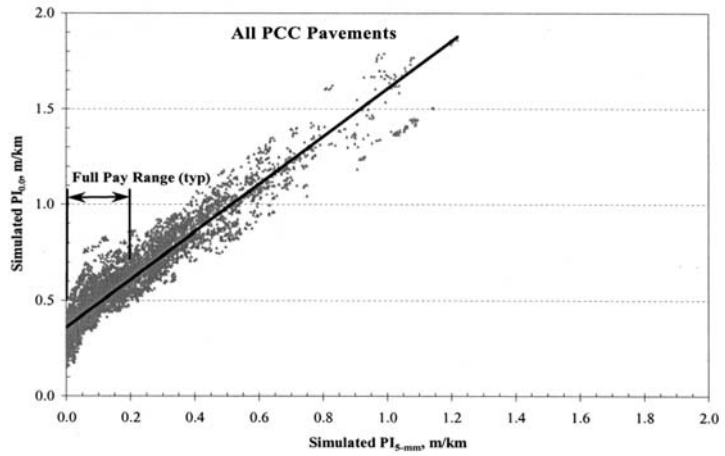


Figure 4. $PI_{0.0}$ vs. $PI_{5.0}$ for PCC pavements.



Recommendations

To make this research useful, it is recommended that agencies:

1. Evaluate the validity of the research results based on agency conditions and experience.

2. Use the correlation equations and variability information to estimate the required level of smoothness for a specification that transitions to IRI or $PI_{0.0}$. It is recommended that the derived specification limits be adjusted to reflect agency implementation practices such as segment length, segment averaging, scope of application, and index computation method.

3. Track the results of the new smoothness specification and adjust agency smoothness requirements to meet the abilities of contractors and the benefit-cost of smoother roadway surfaces.

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Distribution–This TechBrief is being disseminated according to a standard distribution. Direct distribution is being made to the Resource Centers and Divisions.

Availability–The publication linked to this TechBrief is *Pavement Smoothness Index Relationships*, Final Report (Report No. FHWA-RD-02-057). It is available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161. A limited number of copies will be available from the R&T Report Center, FHWA, 9701 Philadelphia Court, Unit Q, Lanham, MD 20706, telephone: (301) 577-0818, fax: (301) 577-1421.

Key Words–International Roughness Index, Profile Index, correlation, specification, smoothness.