TECHBRIEF

LTPP

Quantification of Smoothness Index Differences Related to LTPP Equipment Type

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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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Background

Researchers in the Long-Term Pavement Performance (LTPP) program are conducting a major data collection effort. They are using an inertial profiler to collect longitudinal profile data at regular intervals on two wheelpaths located along the LTPP program test sections. In the LTPP program, the United States and Canadian Provinces are divided into four regions for the purposes of data collection, and a regional support contractor (RSC) operates an inertial profiler in each region.

After collecting the profile data, the researchers process the data to compute roughness indices, such as the international roughness index (IRI), root mean square vertical acceleration (RMSVA), slope variance, and the Mays index. They then store the computed roughness parameters and profile data in the LTPP database and make these data available to other members of the research community.

From the start of the LTPP program through the end of 1996, researchers collected profile data at the test sections using an incandescent profiler (model number DNC 690) manufactured by K.J. Law Engineers. In late 1996, each RSC replaced their model DNC 690 profiler with a T-6600 infrared profiler manufactured by K.J. Law Engineers. In September 2002, each RSC replaced their T-6600 profiler with an International Cybernetics Corporation (ICC) model MDR 4086L3 laser profiler.

The height sensors on each of the three profilers have a different footprint size. The DNC 690 profilers had a footprint of 150 millimeters (mm) by 6 mm with the 150-mm side being perpendicular to the direction of travel. The T-6600 profilers had an elliptical footprint that was 38 mm by 6 mm, with the 38-mm side perpendicular to the direction of travel. The ICC profilers that are currently in use are equipped with laser height sensors that have a circular footprint of approximately 1.5 mm in diameter.

The LTPP program conducted a research project recently to (1) compare IRI values obtained by the different inertial profilers, (2) investigate data collection characteristics and compare profile data collected by the different inertial profilers, and (3) investigate the factors that contribute to differences in IRI values for data obtained from the LTPP profilers and Dipstick®. That analysis indicated good agreement in the IRI values among the different inertial profilers used in the LTPP program. This indicates that the IRI values in the LTPP database can be used to analyze roughness progression at test sections without any adjustments to the IRI values obtained by the different profilers.

Findings: Comparison of Profile Data Obtained by the Profilers

The data from the DNC 690 and T-6600 profilers showed good agreement, despite some differences in the profiles of the test sections with significant long-wavelength content. These differences may be attributed to the different long-wavelength cutoff filter values used with the two profilers

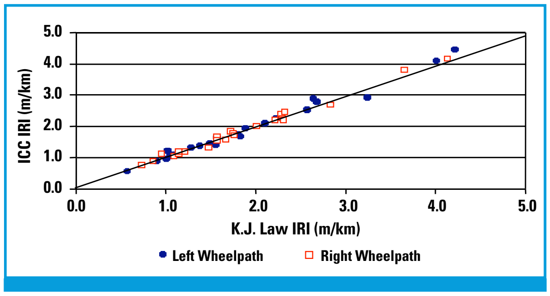

Figure 1. This chart shows the relationship between the IRI values for the K.J. Law Engineers T-6600 and ICC profilers.

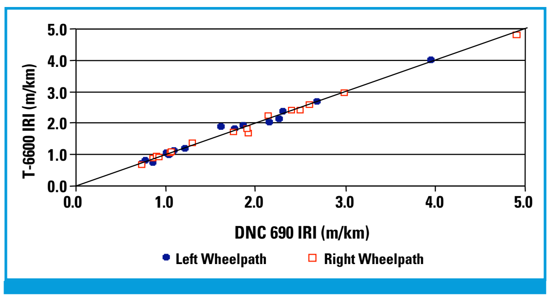

Figure 2. This chart shows the relationship between the IRI values for the K.J. Law Engineers DNC 690 and T-6600 profilers.

(91 and 100 meters (m) for the DNC 690 and T-6600, respectively). It appears both of these profilers use the same long-wavelength cutoff filtering technique. Comparison of 25-mm interval profile data for the T-6600 and ICC profilers also indicated good agreement between the two profilers for wavelengths between 1 and 40 m, which is within the wavelength range that predominantly influences the IRI. For wavelengths less than 1 m, the ICC profiler typically showed a higher wavelength content than the T-6600 profiler. This was attributed to the smaller footprint of the ICC profiler, which most likely caused texture effects and a higher magnitude of narrow features to be recorded. For wavelengths greater than 40 m, the T-6600 profiler recorded more wavelength content than the ICC profiler. This was attributed to the differences in the long-wavelength filtering techniques used by the two profilers, although both profilers applied an upper-wavelength cutoff filter of 100 m.

Findings: Comparison Between Dipstick and Profiler IRI

The Dipstick, a hand-operated device manufactured by The Face Companies®, has a digital inclinometer that measures the elevation difference between the device's two footpads. Researchers use Dipstick during LTPP profiler comparisons to obtain reference elevations along the two wheelpaths at the test sections. When properly calibrated and operated, Dipstick provides profiles as good as those from rod-and-level surveys, but at a fraction of the time and cost.

The study indicated that a variety of factors could cause the IRI values obtained from the Dipstick data to differ from the

IRI values obtained from the profiler data. The factors that contributed to these differences were (1) sampling qualities of the Dipstick, (2) variations between the path followed by the profiler and the path where the Dipstick measurements were performed, (3) features recorded by the profiler that the Dipstick missed because of differences in sampling intervals, (4) discrepancies caused when the footpads of the Dipstick bridge over narrow, downward features that are measured by the profiler, (5) features that are recorded by the profiler but are underestimated by the Dipstick because the footpad of the device may not rest in the deepest part of a feature, and (6) errors in Dipstick measurements.

Recommendations for Improving Current LTPP Data Collection and Data Processing Procedures:

- The current field procedures for collecting profile data using inertial profilers are considered to be adequate, and no changes to current procedures are required.

- Errors during the collection of Dipstick data can occur because of data recording errors and equipment problems. A closure error check is performed at the end of Dipstick data collection as a quality control procedure. However, it is still possible to pass the closure error criterion even with erroneous data, as compensation effects can cancel out errors. During data collection in the field, particular attention should be paid before recording high data values to ensure that such readings are indeed correct.

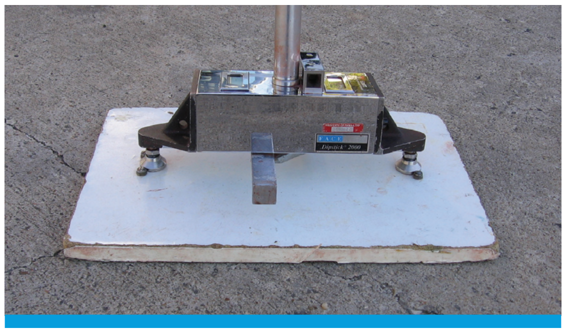

Figure 3. A view of the Dipstick.

- Currently, the LTPP program has in place several procedures to ensure the quality of profile data. These procedures include (1) overlay of the profile data obtained from repeat runs to evaluate the repeatability of the data, (2) overlay of data collected during the current data collection with data collected during the previous site visit to determine whether or not they agree, (3) verification that spikes noted in the profile were caused by pavement features and not by any other factor, (4) evaluation of the repeatability of the IRI values, and (5) comparison of IRI values obtained for each wheelpath during the current data collection with IRI values obtained during the previous site visit. However, all these quality control checks are performed on the averaged data and will not detect problems that may occur in wavelengths less than 1 m. Short-wavelength data can be evaluated only by analyzing 25-mm data. It is recommended that a quality control procedure be adopted to check the 25-mm data collected by the profilers. The recommended procedure is to obtain a set of data collected by each of LTPP's profilers at regular intervals and compare the data with the data collected at the same sites during the previous visit to the site by using power spectral density (PSD) plots. A consistent difference in the short wavelengths for the two data sets or any sharp spikes in the PSD plots for wave numbers greater than 1 cycle/m will indicate potential problems in the short-wavelength data collected by a profiler.

Recommendations for LTPP Profiler Comparisons:

- To compare the outputs obtained from the four LTPP profilers, it is recommended that comparisons be conducted at regular intervals. The data obtained from such comparisons will verify whether all four of the profilers are collecting similar data.

- The current profiler comparison procedures emphasize the comparison of IRI values. Although there can be differences in short-wavelength data collected by the profilers, such as for wavelengths less than 1 m, the IRI values can nevertheless show very good agreement because these short wavelengths do not influence the IRI. It is, therefore, recommended that, in addition to the current data analysis procedures, the 25-mm data collected by the profilers be evaluated using PSD plots during future comparisons so that researchers also can compare the short-wavelength data collection capabilities of the profilers.

- Although the Dipstick can be used to check IRI values obtained from the profilers, it cannot be used to check the accuracy of the profilers on pavements that have rough features or distress. The current LTPP comparisons use an IRI difference of ±0.16 m/km between the profiler and Dipstick IRI values to judge the accuracy of the LTPP profilers. If differences outside of this limit are obtained on pavements with distress or on rough pavements, it does not necessarily mean there is a problem with the profiler. An investigation, however, should be performed to identify the cause of the difference in IRI values.

- Research performed for this project showed that agreement in IRI values at a section between the profilers can occur because the errors compensate for each other. Roughness profiles or cross-correlations are techniques that can be used to compare spatial distribution of IRI within a section between the profilers. It is recommended that such procedures be used with current procedures when analyzing data from LTPP comparison studies.

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Distribution—This TechBrief is being distributed according to a standard distribution. Direct distribution is being made to the Divisions and Resource Center.

Availability— The publication from which this TechBrief was developed, *Quantification of Smoothness Index Differences Related to Long-Term Pavement Performance Equipment Type* (FHWA-HRT-05-054), 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 Research and Technology Product Distribution Center, HRTS-03, FHWA, 9701 Philadelphia Court, Unit Q, Lanham, MD 20706, telephone: 301–577–0818, fax: 301–577–1421.

Key Words—LTPP, international roughness index, IRI, profile index, inertial profilers, Dipstick, pavement data collection, pavement profile, profile measurement, profiler.