Variability and Visualization of Tire-Pavement Noise Measurements

Concrete Pavement Surface Characteristics Program

Authors

Robert Otto Rasmussen
Vice President, The Transtec Group, Inc.
robotto@thetranstecgroup.com
512-451-6233

Richard Sohaney
Project Manager, The Transtec Group, Inc.

Paul Wiegand
Transportation Research Engineer,
Institute for Transportation at Iowa State University

National Concrete Pavement Technology Center
2711 South Loop Drive, Suite 4700
Ames, IA 50010-8664
www.cptechcenter.org

Director
Tom Cackler
515-294-5798
tcackler@iastate.edu

Managing Editor
Sabrina Shields-Cook
515-294-7124
shieldsc@iastate.edu

National Concrete Pavement Technology Center

Tech Center

IOWA STATE UNIVERSITY
Institute for Transportation

Introduction

In 2004, the Concrete Pavement Surface Characteristics Program (CPSCP) was initiated to help optimize concrete pavement surface characteristics without compromising safety, pavement durability, or cost effectiveness (see page 6). For the last six years under the CPSCP, tire-pavement noise data from more than 1,500 unique, concrete pavement test sections have been collected and evaluated. The pavement test sections vary in length but are typically 500 to 600 ft long. The majority of the test sections are textured using the common techniques of diamond grinding, drag, longitudinal tining, and transverse tining. Compilation of all of the data has resulted in an extensive database of tire-pavement noise measurements.

Early in the program, one of the key findings was the amount of variability in tire-pavement noise. Variability was evident from section to section and within sections. This finding led to a challenge for the concrete pavement industry: to understand, and then control, this variability. To do this, it was important to develop techniques to visualize the test results.

This document discusses two types of tire-pavement noise variability—between pavement sections and within pavement sections—and provides references for constructing concrete pavements with more consistent tire-pavement noise. This document also introduces a tool for visualizing tire-pavement noise in a manner that appeals to, and can be understood by, a broad audience.

How is Tire-Pavement Noise Measured?

Tire-pavement noise is commonly measured either in close proximity to the source (near the tire-pavement contact area) or from the roadside (or wayside). Of the two methods, source measurements have numerous advantages for the pavement engineering community, because they allow for the efficient evaluation of many test sections for comparison and ranking purposes. The CPSCP tests utilized source methods, particularly the on-board sound intensity (OBSI) method.

The OBSI test method [1, 2, 3] measures tire-pavement noise at the source using microphones in a sound intensity probe configuration mounted on the outside of a vehicle, near the tire-pavement interface, as illustrated in Figure 1. Measurements are performed while the test vehicle drives across the pavement of interest, using an ASTM F 2493 Standard Reference Test Tire (SRTT),

Figure 1. On-board sound intensity (OBSI) test method with view of microphones mounted in close proximity to the tire contact patch

and at a constant vehicle speed, typically 60 mph, as illustrated in Figure 2.

The most commonly-reported test result is an average A-weighted sound intensity level, sometimes referred to as an OBSI level. This quantifies tire-pavement noise associated with the test section and, for concrete pavements, typically ranges from 98 to 108 dBA.

Variability between Sections

Using OBSI, variability can be observed by comparing average levels between test sections, particularly pavement sections with the same nominal texture type. For this, an average tire-pavement noise level is evaluated over the complete length of each test section. A 528-ft test section at a vehicle test speed of 60 mph (88 ft/sec) corresponds to an averaging time of six seconds (528 ft / 88 ft/sec = 6 sec).

It was found that, when comparing pavement surfaces constructed to the same nominal standard, subtle differences in the as-constructed texture could result in corresponding differences in average OBSI levels. Differences of 5 to 6 dBA between the quietest and loudest of these surfaces are typical. Figure 3 shows an example of longitudinally tined surfaces exhibiting this variability. Note that, while the texture on the left might appear to be more aggressive, it is actually quieter than the surface on the right. This underscores the complex relationship between texture and noise.

Also note that differences between the quietest and loudest surfaces increase even more when comparing surfaces that have been in service and have experienced wear due to traffic and maintenance activities, which affect the noise levels.

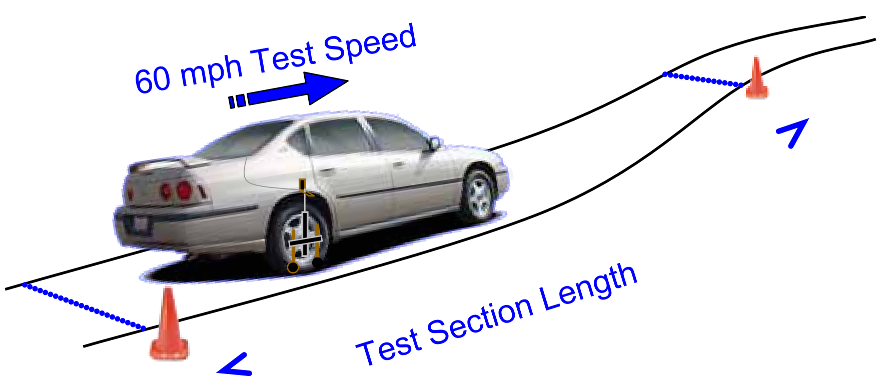

Figure 2. Vehicle with microphones traversing a test section

Figure 3. Two longitudinally-tined concrete pavements with average OBSI tire-pavement noise levels of 99 dBA (left) and 105 dBA (right)

Figure 4 shows this variability in a graphic format using cumulative distribution curves. In the graph, the horizontal axis is tire-pavement noise level (OBSI level), and the vertical axis is cumulative distribution. For example, the trend corresponding to drag textures indicates that 10 percent of the test sections have OBSI levels of 100.5 dBA or less, and about 10 percent have a level that exceeds 105 dBA. That is a difference of 4.5 dBA.

Figure 4 also allows comparison and ranking of tire-pavement noise between concrete pavements of different texture. However, such comparisons should be interpreted carefully. For example, although diamond grinding results in pavements that are generally quieter than transversely-tined pavements, this is not always the case; it is possible to construct a transversely-tined surface that is quieter than some diamond ground surfaces, particularly aged diamond ground surfaces.

Observations such as this have been made previously, and numerous forms of guidance have been developed as a result [4, 5]. The key to constructing a quieter concrete pavement with any texture method is to employ materials and construction methods that provide better consistency and control of the finished surface texture.

Variability within Sections

A second category of variability identified by the CPSCP is tire-pavement noise within pavement test sections; that is, some areas of pavement within one test section are louder than others. To characterize the within-section variability, the test section can be divided into a series of shorter lengths, and OBSI levels calculated by averaging over the shorter lengths and comparing those averages.

Dividing the test section into 44-ft lengths at a test speed of 60 mph

(88 ft/sec) corresponds to an averaging time of 0.5 seconds. An even shorter length, 7 ft, corresponds to a very short averaging time of about 0.08 seconds. The compromise when using shorter averaging times is an accompanying increase in uncertainty (or loss of accuracy). The selection of the most appropriate averaging time therefore depends on what characteristic about the tire-pavement noise is sought and how much uncertainty can be tolerated.

To illustrate this, the graph in Figure 5 shows the OBSI level as a function of distance for a test section using two different averaging times. When a very short average is used (7 ft or 0.08 sec), the red line on the graph clearly indicates impulse events that occur at 20-ft intervals along this pavement section. These impulses are an audible "slap" that corresponds to the tire interacting with very wide joints constructed between concrete slabs, as shown in the Figure 5 photo. When a longer average is used (44 ft or 0.5 sec), the impulse levels are significantly reduced and, in fact, lead to lower levels at joints as an artifact of the averaging time (length) and the joint spacing [6].

Figure 5 illustrates the benefit of using a very short averaging time to identify isolated features in a pavement. However, a shorter interval inherently contains larger uncertainty. In other words, there is more error in the calculated level at any given point.

For most pavements, where the tire-pavement noise does not contain large transients, the selection of a 44-ft (0.5-sec) average length is found to be a good compromise. Figures 6 and 7 illustrate the within-section variability using 44-ft (0.5-sec) averaging for sections among both the lowest and highest within-section variability, respectively.

Using a 0.5-sec averaging time, Figure 8 illustrates the cumulative distribution

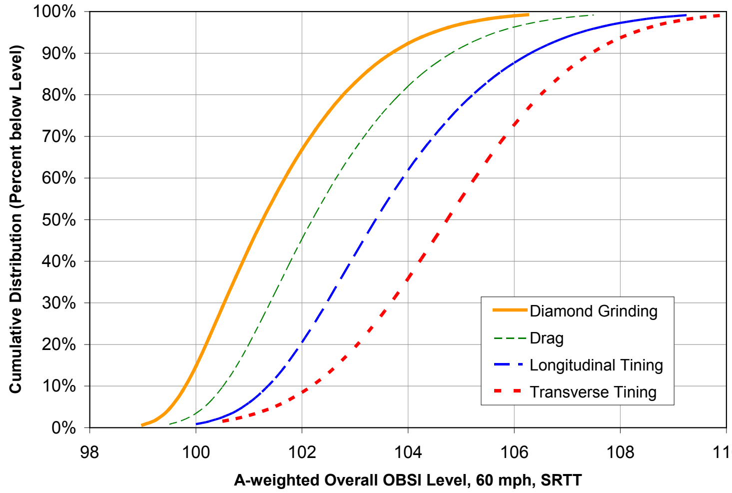

Figure 4. Cumulative distribution plot showing tire-pavement noise variability for the four common concrete pavement textures

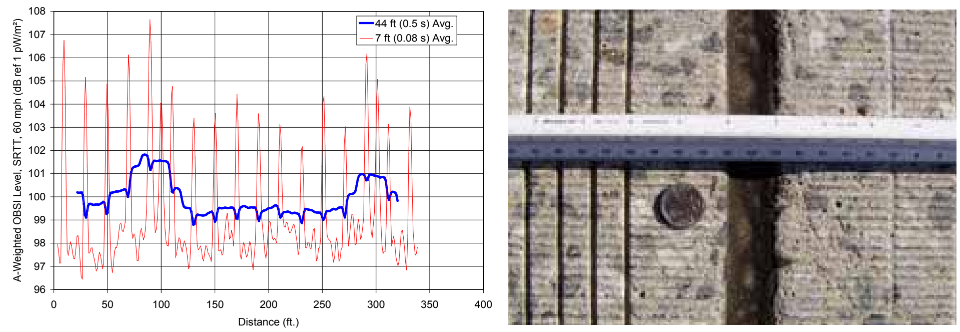

Figure 5. CPSCP Section 209-D having large within-section variability with measured OBSI level versus distance using long and short averaging lengths (left) and photo of pavement joint corresponding to significant tire-pavement noise generation (right)

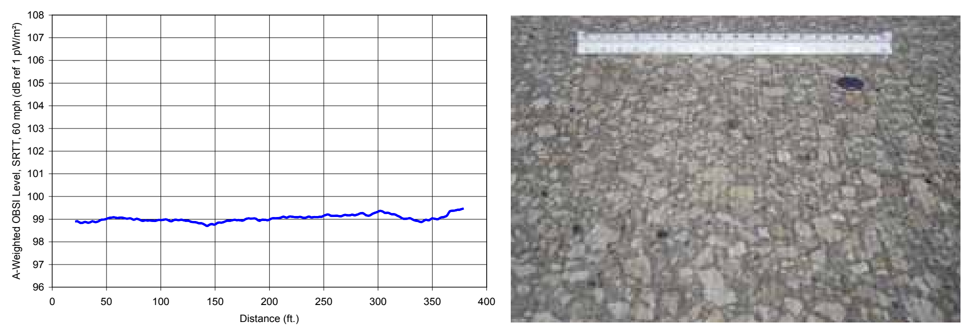

Figure 6. CPSCP Section 205-E having small within-section variability with OBSI level versus distance (left) and photo of the pavement surface texture (diamond ground) (right)

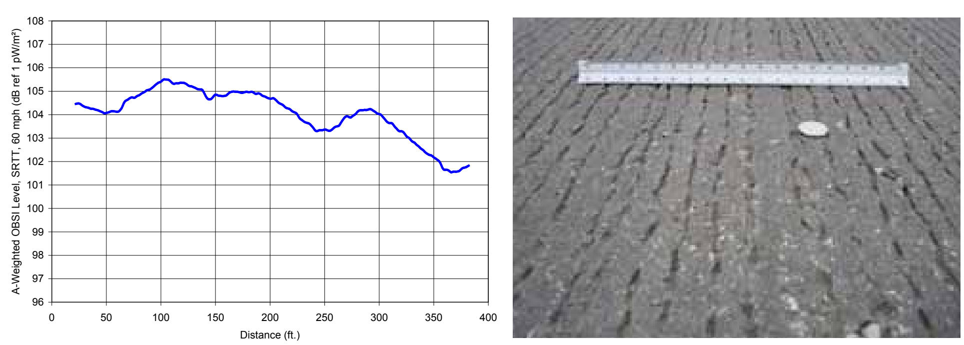

Figure 7. CPSCP Section 205-K having large within-section variability with OBSI level versus distance (left) and photo of the pavement surface texture (longitudinally-tined) (right)

of within-section variability for the four most common concrete pavement textures. The metric used for within-section variability is the 90-percent range, meaning the lowest and highest 5 percent of the levels within a test section are discarded and the difference (range) between the remaining minimum and maximum levels is the 90-percent range.

As shown, the diamond grinding technique typically results in sections that have low within-section variability. Tined sections can also have low within-section variability, but the distributions also indicate they have a greater probability of having higher within-section variability.

Based on these data, the question may be how to construct a concrete pavement that is consistently quiet along the entire length. As with the control of variability from section to section, the key is to use materials and construction methods that provide better consistency and control of the finished surface texture [4, 5].

Visualization of Tire-Pavement Noise

The results of this study can potentially have a significant impact in reducing tire-pavement noise without compromising other important factors such as safety and durability. However, tire-pavement noise data in the form of plots of level-versus-distance can be difficult to understand, particularly by pavement engineers who could make use of such data but have little to no experience in acoustics or noise control engineering. One objective of the CPSCP is to provide important concepts, such as the degree of tire-pavement noise variability, efficiently and accurately and in useful ways that facilitate meaningful decision-making.

To that end, the CPSCP has employed the Google Earth™ mapping service with powerful, interactive, visualization capabilities. A tool has been developed that allows the OBSI test results to be viewed in Google Earth™, superimposed on the associated roadways. As illustrated in Figure 9, the height and color of any given point along the road indicate the OBSI level (using the 0.5-sec average).

Additional features of the tool include the presentation of photographs and audio samples of tire-pavement noise (OBSI), as illustrated in Figure 10. The zoom, pan, and rotate features provide the ability to interact with the data and understand their relationships to surrounding geographic features.

Using the Google Earth™ mapping service, pavement engineers can easily identify louder and quieter highway sections and their proximity to residences and other sensitive receivers. The results of OBSI measurements and how they can be used to improve the quality of life can be readily distributed to facilitate both technical and policy discussions on quieter concrete pavements.

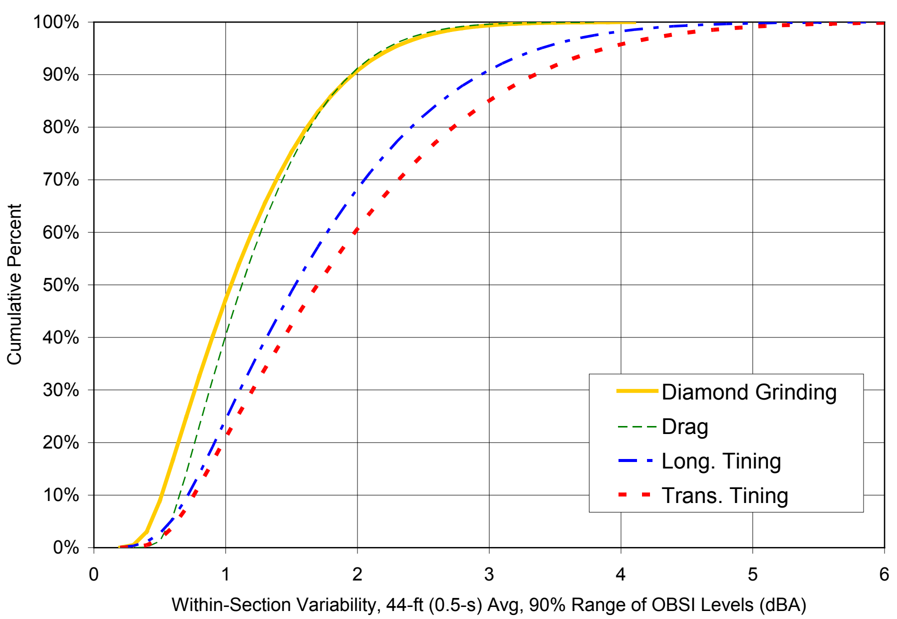

Figure 8. Distribution of within-section variability of OBSI level test results by texture using 44-ft (0.5-sec) averaging and the 90-percent range

Summary

In this document, various means of characterizing the variability of tire-pavement noise have been summarized, with particular emphasis on within-section variability.

In addition, an innovative visualization tool has been introduced that is based on the Google Earth™ mapping service and allows OBSI results to be more readily demonstrated to a broad audience.

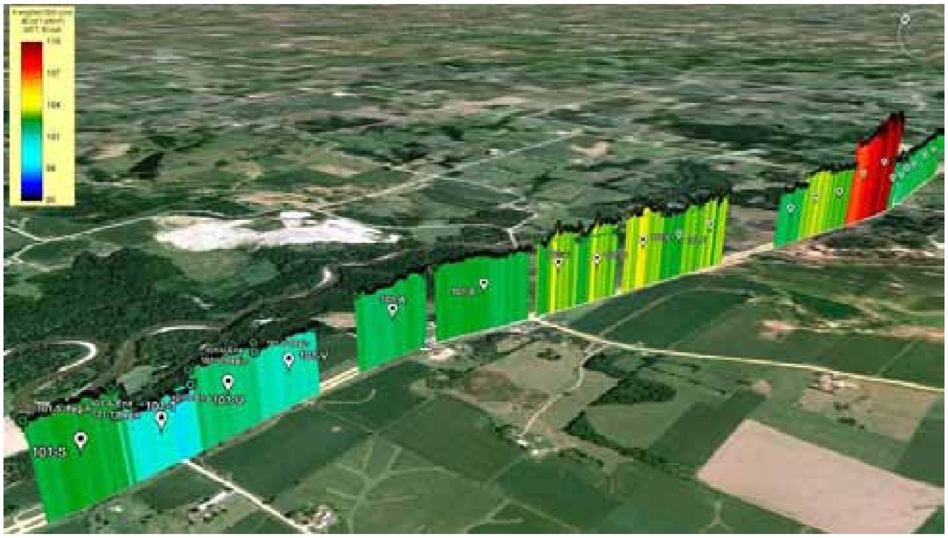

Figure 9. Google Earth™ visualization of various pavement test sections on CPSCP Site 101

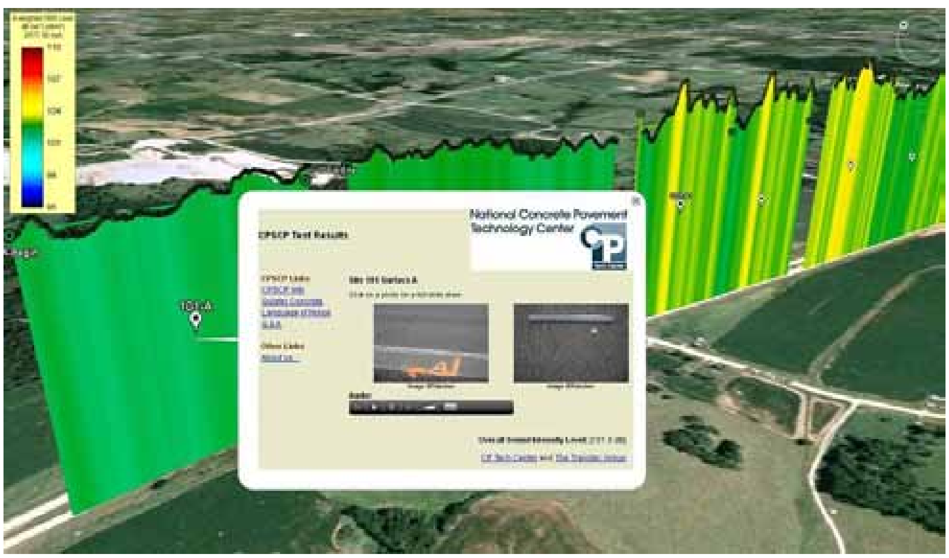

Figure 10. Google Earth™ zoomed-in view of CPSCP Site 101, test Section E, showing inset including photographs and audio player

References

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2. American Association of State Highway and Transportation Officials. "Standard Method of Test for Measurement of Tire/Pavement Noise using the On-Board Sound Intensity (OBSI) Method." AASHTO Specification TP 76-10 (2010).

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5. Robert Rasmussen, et al. *What Makes a Quieter Concrete Pavement?* National Concrete Pavement Technology Center, Ames, Iowa. Tech Brief (2010).

6. Robert O. Rasmussen, et al. "Quiet concrete pavement surfaces." Proceedings NOISE-CON 10 (2010).

For More Information

- American Association of State Highway and Transportation Officials, "Standard Method of Test for Measurement of Tire/Pavement Noise using the On-Board Sound Intensity (OBSI) Method." AASHTO Specification TP 76-10 (2010).
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About the Concrete Pavement Surface Characteristics Program

In December 2004, a coalition was formed between the National Concrete Pavement Technology Center (National CP Tech Center), the Federal Highway Administration (FHWA), the American Concrete Pavement Association (ACPA), and the International Grooving and Grinding Association (IGGA).

The mission of the program was to help optimize concrete pavement surface characteristics—more specifically, it was to find innovative solutions to make concrete pavements quieter without compromising safety, durability, or cost effectiveness.

The current program is now operating under Pooled Fund TPF-5(139) with the additional support of state departments of transportation (DOTs), including California, Iowa, Minnesota, New York, Texas, Washington, and Wisconsin.

Recent focus is on developing specific guidance to properly design and construct quieter concrete pavements. Innovative concrete pavement surfaces are also being evaluated to assess their potential as viable solutions.

For more information about the CPSCP, contact

Paul Wiegand
National CP Tech Center
515-294-7082
pwiegand@iastate.edu

About the National Concrete Pavement Technology Center

The mission of the National Concrete Pavement Technology Center is to unite key transportation stakeholders around the central goal of advancing concrete pavement technology through research, tech transfer, and technology implementation.