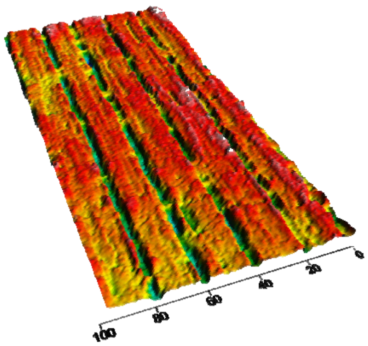
Concrete Pavement Surface Characteristics Program



Site Evaluation Report

Site 349-1
Two-Lift Concrete Paving
Trial/Demonstration Project
East 1100 Road
Pleasanton, Kansas

Tested 26-27 June 2008
Reported 1 July 2008

National Concrete Pavement Technology Center

Tech Center

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Ames, Iowa, 50010
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Overall Site Information

Report Date:

1 July 2008

Report Revision:

1.00

CPSCP Site/Visit Number:

349-1

Owner/Agency:

Kansas Department of Transportation

Owner/Agency Representative:

Mr. Andy Gisi, AGisi@ksdot.org, (785) 296-3008

Test Location (approx.):

East 1100 Road, Pleasanton, Kansas
Two-Lift Concrete Paving Field Trial/Demonstration
Surface A, Longitudinal Tining
Surface B, Exposed Aggregate Concrete

Site Description:

The testing was conducted in cooperation with KDOT, including Andy Gisi of the Bureau of Materials and Research, among others both at KDOT and Koss Construction. The construction of this project is part of an innovative technology demonstration of two-lift concrete paving, which is a commonly used technique in Europe. Both a "conventional" longitudinally tined texture and an exposed aggregate concrete texture were used and evaluated during this field trial.

Number of Test Surfaces:

Two (2)

Test Surface Summary:

ID	Description	Direction	Lane	Length (ft.)	Nominal Surface
A	Longitudinal Tining – ¾” spacing	EB	Right	500	PCC
B	Exposed Aggregate Concrete	EB	Right	500	PCC

Testing Conducted:

- On-Board Sound Intensity
- RoboTex Texture
- CTM Texture
- DFT Friction

Site Maps:

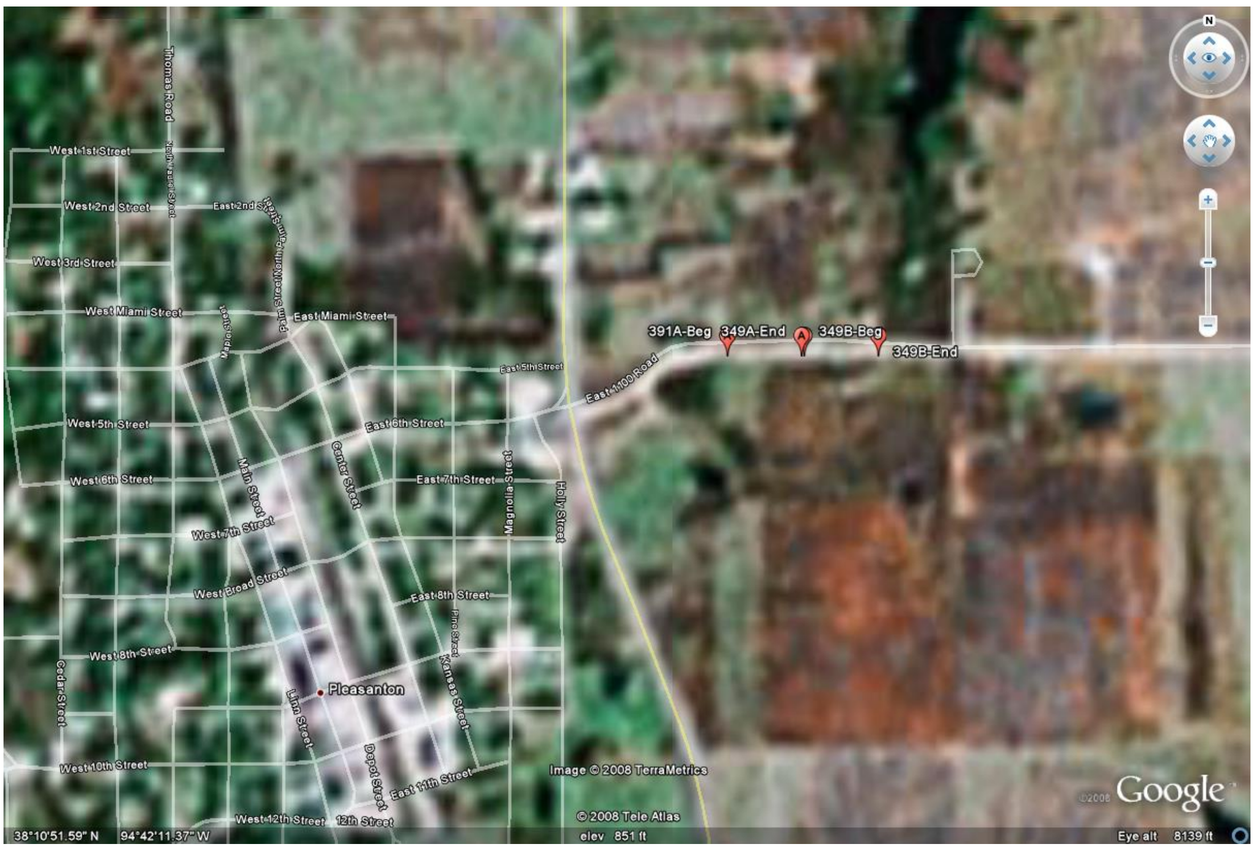


Figure 1: Overall Site Map of both Surfaces.

On-Board Sound Intensity (OBSI)

Approximate Test Date/Time:

27 June 2008, 1:00pm

Weather Data:

Date / Time	Air Temperature (˚F)	Relative Humidity (%)	Wind Speed (mph)	Barometric Pressure (MSL) (inHg)
27 June 2008 1:00 pm	81	56	8	29.82

Elevation: 850 ft.

Air density correction: + 0.52 dBA (normalized to ρ = 1.21 kg/m^3)

Equipment Identification and Calibration:

- All microphone calibrations were within 0.5 dBA
- All acoustical equipment is certified and up-to-date on calibrations per ANSI.
- Additional information on equipment and certifications available upon request.

Site Condition:

- No free moisture present on surface.
- Pavement reasonably free of loose debris.
- No large objects within 2 ft. of pavement edge.
- No horizontal curvature.
- No significant grade changes.
- Crossfall appears typical for this type of roadway.
- **Due to recent construction, surface was covered in curing compound.**

Pavement Temperatures:

Monitored by CP Tech Center and available upon request

Test Vehicle:

2003 Buick Century

Test Tire:

- ASTM F 2493 Standard Reference Test Tire (SRTT)
- Cold Inflation Pressure: 30 psi

Nominal Test Speed:

60 mph

Representative Photographs:

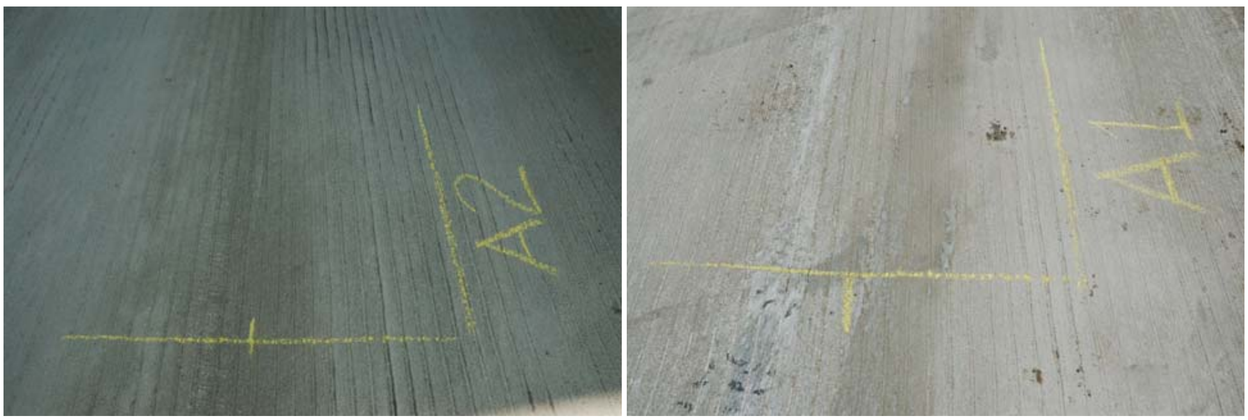


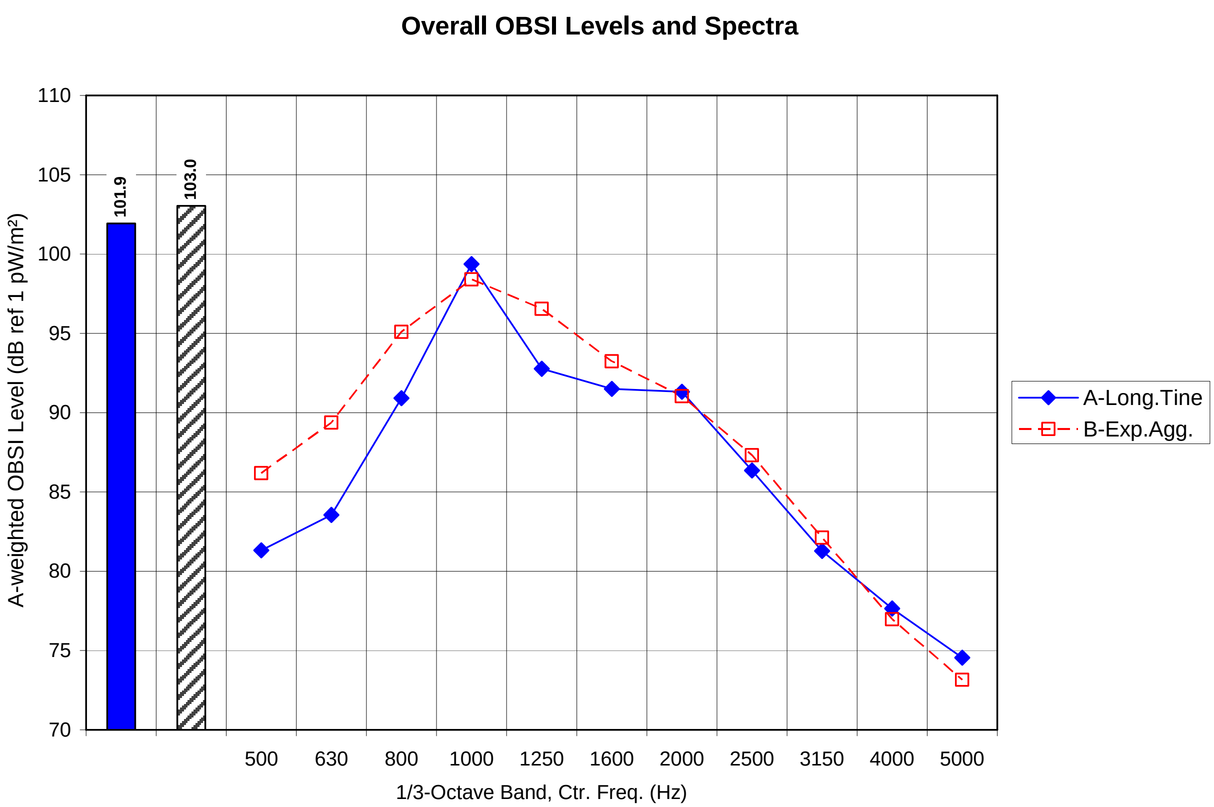
Figure 2: Surface A – Longitudinal Tining.

Figure 3: Surface B – Exposed Aggregate.

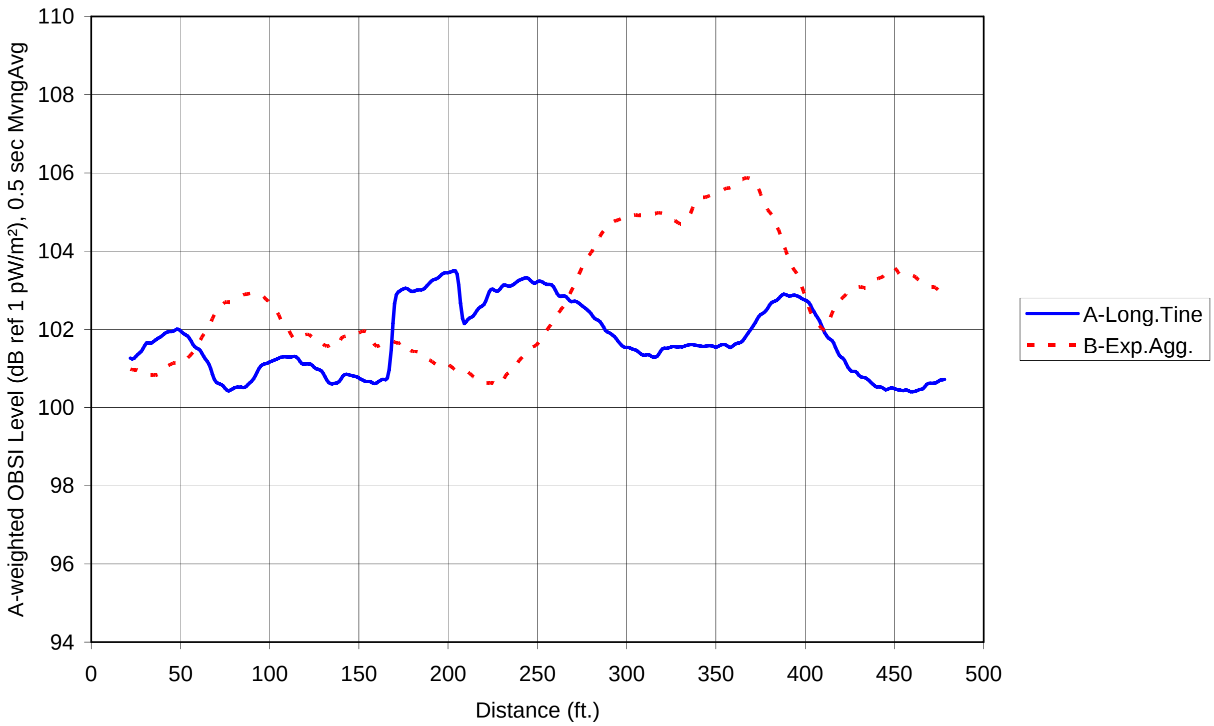
Overall Sound Intensity Levels:

All levels in A-weighted dB ref 1pW/m²
Table headings contain center frequencies of third-octave bands in Hz
Total levels include levels within third-octave bands from 500 to 5000 Hz

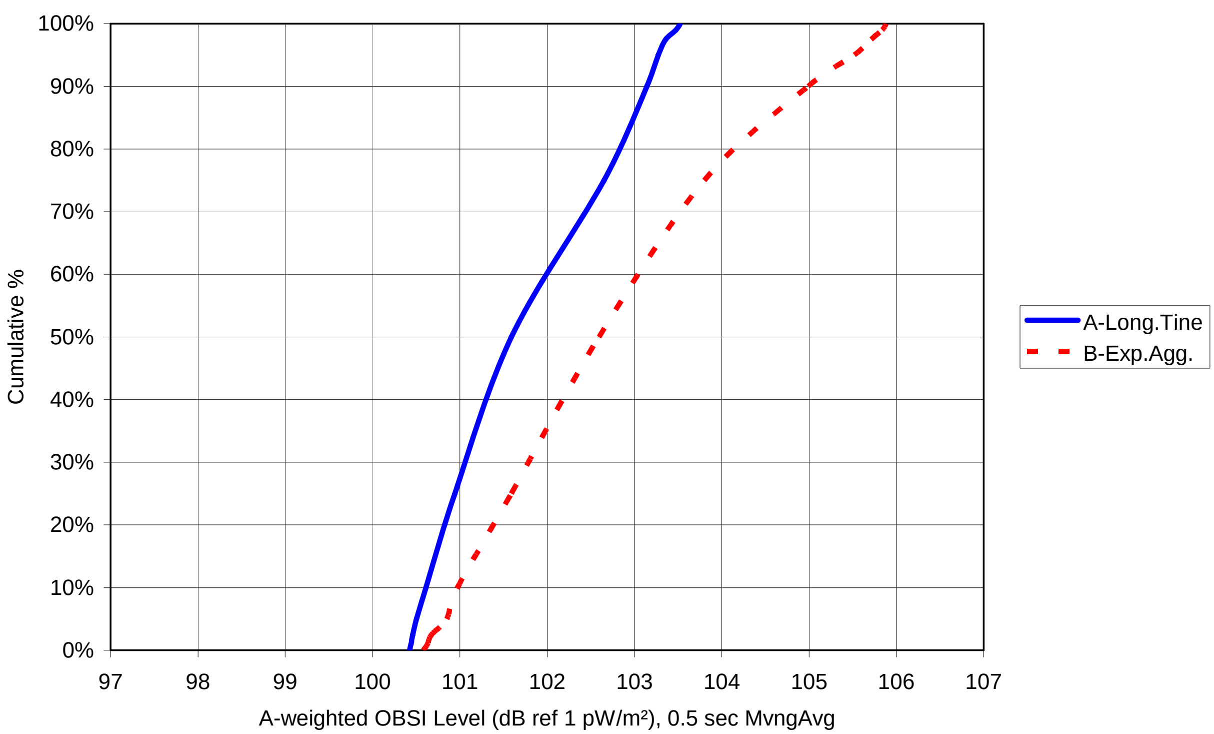
Surface	Nominal Texture	Overall	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000
A	Long. Tining	101.9	81.3	83.6	90.9	99.4	92.8	91.5	91.3	86.4	81.3	77.6	74.6
B	Exposed Agg.	103.0	86.2	89.4	95.1	98.4	96.5	93.2	91.0	87.3	82.1	77.0	73.2



Spatial Variability of OBSI Levels



Cumulative Distribution of OBSI Levels



Appendix A: Overview of the CPSCP

Introduction

Texturing concrete pavements is often done while the concrete is still in a fresh (plastic) state. One technique uses burlap, inverted artificial turf, or other materials to *drag* the fresh concrete surface. The more common technique for highway applications is termed *tining*, where grooves are created by dragging a rake along the newly placed concrete surface [1]. For hardened concrete, texturing (or retexturing) can be done by *grinding* or *grooving* the concrete surface using diamond saw blades. In the former case, the blades are very close together (typically 2-3 mm); blades used for grooving are typically spaced at 19 to 25 mm (0.75 to 1 in.) [1]. Figure A-1 illustrates some of the more common concrete pavement textures.

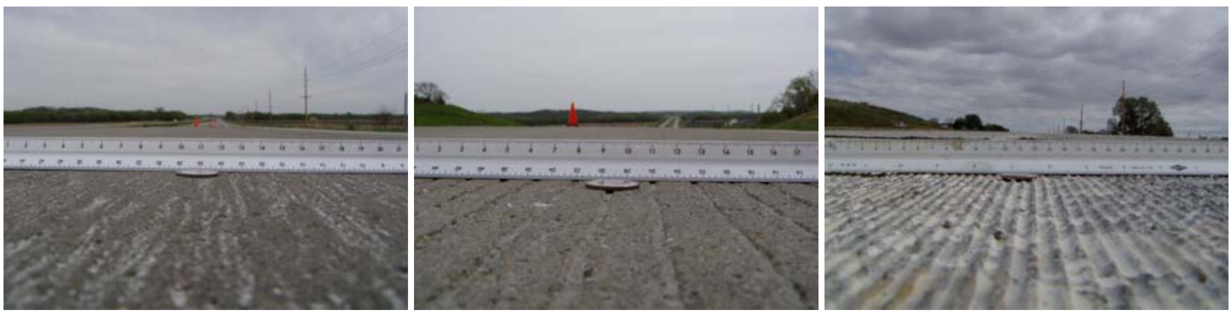


Figure A-1. Photographs of typical drag, tining, and diamond grinding textures.

No matter how texturing is accomplished, however, it is known that it will affect noise, not to mention friction, smoothness, splash & spray, and nearly all other functional demands of that pavement. The problem lies in the fact that little is known about the relationship between texture and noise. To date, extensive research has been conducted to explore this, albeit with an emphasis on asphalt pavements [2,3]. The exact relationships, however, remain illusive. It is commonly recognized that a lot remains to be understood about the fundamental mechanisms that generate and amplify tire-pavement noise, not to mention how these mechanisms are affected by texture.

Background

Beginning in 2003, Iowa State University, through what is now the National Concrete Pavement Technology Center, facilitated the formation of a broad industry coalition formally designated as the Concrete Pavement Surface Characteristics (CPSC) Program. This partnership includes the Federal Highway Administration (FHWA), the American Concrete Pavement Association (ACPA), various State Departments of Transportation (DOTs), and numerous other private and public sector partners. To date, the major work element of this program has been a comprehensive field experiment [4]. As part of this experiment, over 1000 unique test sections representing approximately 400 nominal textures and totaling 70 km (45 mi.) in length have been evaluated for noise, texture, friction, and other relevant measures.

Measurements

Noise measurements under the CPSCP include controlled pass-by, in-vehicle noise, and tire-pavement noise via the on-board sound intensity (OBSI) method. The OBSI technique is based on procedures described by Dr. Paul Donavan of Illingworth & Rodkin (USA) [5], originally developed and refined at General Motors as specification GMN7079TP [6], and related to the ISO (Draft) Close Proximity (CPX) test specification 11819-2 [7].

Texture measurements were also done by several methods. One technique used is a circular track meter (CTM), which based on ASTM E 2157. The CTM uses a spot laser for height measurement, which is mounted on a rotating arm of known length [8]. While a good test, it has a number of drawbacks. To overcome these, in 2005, a new measurement technique was developed that can measure pavement texture in three dimensions, thus allowing the characterization of the anisotropy inherent with most concrete pavement textures.

The resulting system is termed *RoboTex* – Robotic Texture Measurement System. RoboTex is largely built around the capabilities of the RoLine machine vision sensor manufactured by LMI-Selcom. This sensor has the capabilities to report distance measurements across a line of laser light that is constantly emitted and periodically sampled. Capturing and reporting elevations is done at a constant 1000 Hz, with between 100 and 118 discrete points captured across the 100 mm line. The result is a sample interval of 1 mm or less, and a vertical height resolution of 0.01 mm.

As illustrated in Figure A-2, RoboTex consists of the laser mounted onto a robotic chassis including a remote-control drive train and steering assembly. The gears are designed so that an operational speed of slightly less than 0.5 m/s is realized. At this speed, the individual lines are spaced at less than 0.5 mm. With these capabilities, RoboTex possesses the ability to assess relevant wavelengths of mega- and macrotexture in three dimensions. The dataset can be viewed as a 100-mm wide continuous "swath" traveling down the road.

Figure A-2. Photographs of RoboTex measurement system.

The technology inherent with both the OBSI measurements for noise and the RoboTex measurements for texture allowed for synchronization of the two. During the field experiments, reference points were interlaced into both data, allowing texture and noise "traces" to be compared during post-processing.

Data Analysis and Presentation

The following include statements that resulted from the analysis of the data collected to date under the CPSCP.

Ranking Texture by dBA

As described in Appendix A, early tire-pavement noise data ranked drag and grinding among the quieter textures and transverse tining among the loudest, based on averages for these nominal texture types. However, there are many texture subsets within each class. This general ranking does not always hold true, especially given the variability that is present.

Rank ordering to date has been based in large part on sound levels measured near the tire-pavement source, using OBSI. Rank ordering by sound level as received wayside will likely be similar, however, as work by Dr. Paul Donavan and Caltrans has demonstrated [5]

OBSI Ranges

Measured tire-pavement noise levels for concrete pavements range from 97 dBA on the low end to over 110 dBA on the high end. It should be noted that a 10 dBA level change can be illustrated as a "doubling" of perceived sound (albeit this is generally true for the same type of sound).

Based on the data collected to date, this range of noise values is likely representative of the total population of concrete pavements in the country. While there may outliers on the high end, the 97 dBA level is likely be close to the lowest possible for concrete pavements using conventional technology (i.e., dense concrete, as opposed to porous/pervious).

Texture Geometry

In the early stages of analysis, there at first appeared to be a relationship between texture depth and tire-pavement noise. However, this is an oversimplification and was quickly dismissed, as it falls short of truly characterizing the relationship between texture and noise. The correlation that does sometimes appear is likely to have more to do with the fact that a deeper (more aggressive) texture causes more disturbances of the concrete surface, and thus leads to random deposits of concrete on the surface that, in turn, increase noise.

Characterizing the exact relationship between texture and noise is an ongoing task under the CPSCP. While trends are evident, there are sometimes exceptions, which underscore the need for a more fundamental model. One issue is the need to establish better indices for describing texture. Spectral analysis of the texture, for example, coupled with the texture skew (bias), has revealed a lot more clarity in these relationships.

Wear Rate

Analysis of the data to date have shown that early wear on textures (when opened to traffic) will often lead to a 1 to 2 dBA decrease in tire-pavement noise. With traffic volume as only one variable, snow plowing and other environmental effects appear to also be impacting the wear as well. Once this initial change has occurred, however, there is typically an increase in noise level over time, as the texture will change under traffic and due to the climate and maintenance activities. The rate of change is a function of both the texture configuration and the quality of the concrete, among numerous other factors.

Better Practices for Design and Construction

The current emphasis of the CPSCP is the development of guidelines for the design and construction of quieter concrete pavements that do not compromise on safety, durability, or cost. Better practices are currently under review by the highway community. In the process of developing these guidelines, the following steps were considered as a guide:

1. Recognize what properties of a pavement surface make it quiet (and what make it loud);
2. Design the pavement surface in such a way to avoid those adverse properties;
3. Construct the pavement surface to also avoid those adverse properties, but also in a manner that is both consistent and cost effective.

The first item has been addressed in large part under the CPSCP, and through the results of numerous other studies [1,3,5]. Figure A-3 summarizes some of the key relationships, and can serve as a reference for those seeking to better understand the link from the design and construction to the most relevant as-constructed properties affecting tire-pavement noise.

Concrete Pavement Surface Properties that affect Tire-Pavement Noise

- **Surface texture (bumps and dips)**
    - Avoid (flatten) texture that repeats itself at intervals of 1 inch or larger.
    - Avoid extremely smooth (e.g., floated or polished) surfaces; instead, some fine texture (that is on the scale of 1/8 to 1/4 inch) should be provided.
    - Texture should be "negatively" oriented, meaning that any "deep" texture should point down (e.g., grooves) rather than up (e.g., fins).
    - Striations or "grooves" should, if possible, be oriented in the longitudinal direction, as opposed to the transverse direction.
    - If grooves are oriented in the transverse direction, they should be closely spaced and randomized whenever possible.
- **Concrete properties**
    - The mortar (at least, near the surface) should be strong, durable, and wear resistant. Mix design is a key factor, but so are proper placement techniques including finishing and especially curing.
    - Siliceous sands should be used whenever possible in order to improve durability and friction.
    - For diamond ground pavements, the coarse aggregate in the mixture will constitute the majority of the wearing surface. Ideally, the aggregate should therefore be hard, durable, and polish resistant in order to maintain the intended texture and thus intended noise level over time.
    - For tined textures, there should be an adequate depth of mortar near the surface to hold the intended geometry.
    - Given that there may be conflicting objectives between what is required of the concrete near the surface, and what is needed both structurally and for economy, two-lift construction may be a consideration.
- **Joints**
    - If joints are present, they can contribute to not only overall noise level, but also annoyance.
    - Narrow, single cut joints are preferred over widened (reservoir) cuts.
    - Faulted joints should be avoided by providing adequate load transfer.
    - Excess joint sealant should be avoided, especially if it protrudes above pavement surface.
    - Spalled joints should be prevented through proper design, materials selection, and construction.

Figure A-3. Concrete pavement surface properties that affect tire-pavement noise.

Better practices to improve surface properties and thus tire-pavement noise are really about establishing a higher order of control over the texture and other surface properties. It is not about designing or building "innovative" surfaces, but rather the control of conventional texturing techniques. There should be a renewed awareness of the impact that some of the subtle operational characteristics can have on the texture as constructed.

Predictable tire-pavement noise levels are not about how the texture is imparted as much as it is the recognition and management of the sources of variability. Regarding the concrete, it has to do with the fact that the contractors are imparting texture into a material with inherent variability in both stiffness and plasticity. Concrete changes from batch-to-batch… it changes within a batch. The wind and the sun play a major role, as does the timing of the concrete mixing, transport, placement, and (eventually) the texturing and curing (the latter being important for acoustical durability).

For today, we can promote better practices that focus our attention on what we should be doing better on today's concrete spreads. For tomorrow, the solution will likely be automation of the texturing operation. Over the years, slipform concrete paving operations have become more and more automated. Automatic grade control, for example, is now a virtually standard feature for most slipform pavers. Monitoring of vibrator functionality and frequency is also common. Maybe the texturing operation is next.

To meet the demands for predictable low-noise surfaces, automation will allow the paver, texture cart, and grinding operators to monitor the texture being produced, and make adjustments on the fly. Ultimately, this approach may be the best way to achieve a specified "target texture" on concrete pavements. For now, we can make significant improvements by simply adopting "better practices".

References

1. U. Sandberg and J. Ejsmont, *Tyre/Road Noise Reference Book*. Informex, Handelsbolag, Sweden, 2002.
2. R. Rasmussen, Y. Resendez, G. Chang, and T. Ferragut, *Synthesis of Practice for the Control of Tire-Pavement Noise using Concrete Pavements*, Iowa State Univ., 2006.
3. *Guidance manual for the implementation of low-noise road surfaces*, FEHRL Report 2006/02, Ed. by Phil Morgan, TRL, 2006.
4. T. Ferragut, R. Rasmussen, P. Wiegand, E. Mun, and E.T. Cackler, *ISU-FHWA-ACPA Concrete Pavement Surface Characteristics Program Part 2: Preliminary Field Data Collection*, National Concrete Pavement Technology Center Report DTFH61-01-X-00042 (Project 15, Part 2), 2007.
5. P. Donavan and B. Rymer, "Quantification of Tire/Pavement Noise: Application of the Sound Intensity Method", *Proceedings of Inter-Noise 2004*, Prague, the Czech Republic, 2004.
6. General Motors, "Road Tire Noise Evaluation Procedure," Test Procedure GMN7079TP, 2004.
7. ISO, "Acoustics – Measurement of the influence of road surfaces on traffic noise – Part 2: The close proximity method," ISO TC 43 / SC 1 N, ISO/CD 11819-2, 2000.
8. ASTM, "Standard Test Method for Measuring Pavement Macrotexture Properties using the Circular Track Meter," Standard E 2157, 2001.