Surface Texture Issues Related to Concrete Pavements

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Introduction

- Concrete pavements have proven to be the best performing and least expensive pavements in the long-term.
- Despite this fact, many myths regarding concrete pavements continue to be voiced.
- The “current” myth is that concrete pavements are inherently noisy.
Myth vs. Fact

- Incorrectly textured concrete pavements can be noisy, just as poorly textured asphalt pavements are noisy.
- Concrete textures can be engineered to be both quiet and provide a high degree of safety.
- Noise is NOT about materials, it is about surface texture.
Historical Perspective

- Concrete roadway construction began at the turn of the century
  - Mainly developed to “get out of the mud”
  - By 1914, there were 2,348 miles paved out of Portland Cement Concrete
- Until the mid 1970’s, the most common texture was burlap drag
Historical Perspective (cont.)

- In the late 1970’s, the FHWA “mandated” that all PCC pavements be transversely tined through a Technical Advisory on Surface Textures

- Why?
  - An accident on Washington Beltway killed several congressional aides
  - FHWA was sued by the Insurance Institute and the Center for Automobile Safety to make roadways safer
Historical Perspective (cont.)

- At the time, FHWA was experimenting with Skid Numbers and surface texture
  - SN > 35 are safe
  - SN of transversely tined PCC Pavements ~ 50 – 60
    - Higher numbers = Higher safety
- In an effort to address the suit, FHWA stated that all PCC pavements w/ speeds greater than 45 mph had to be transversely tined unless FHWA could be shown that some other texture was as safe.
The “Exception” - California

- Developed and adopted longitudinal tining instead of transverse tining
  - Heavier burlap drag [early 1970’s]
  - Heavy longitudinal brooming
  - Deep longitudinal tining [late 1970’s]
    - 1/2, 3/4, and 1 inch spacings at 1/8 and 3/16 inch depths
Why Longitudinal Texturing?

- Improved resistance to lateral skidding
- Improved durability
  - Better wear characteristics
- Reduced noise
  - Interior vehicle & exterior tire
- Reduced wet weather accidents
  - Earlier grooving studies showed decrease
“Reduction in Wet Pavement Accidents on Los Angeles Metropolitan Freeways” (1971)
“Reduction in Wet Pavement Accidents on Los Angeles Metropolitan Freeways” (1971)

Diagram showing the relationship between years of operation and wet pavement accident rate per million vehicle passages per lane. The note indicates that 1 ACC/MVK is equivalent to 1.6 ACC/MVM.
Benefits of Texturing

- **IMPROVED SAFETY**
  - Minimizes hydroplaning
  - Channels water off of pavement surface
  - Improves surface friction (SN)

- **Reduced noise**
Tire/Pavement Sound

- All tire/pavement interactions result in discrete sound signatures (i.e. different intensities at different frequencies)
- Not all sound is objectionable and much of it is due to factors other than tire/pavement interaction
- The key is to identify and mitigate noise wherever possible
Typical Sound Levels

Common Indoor and Outdoor Noise Levels

- **Jet Flyover** at 1000 feet
- **Gas Lawn Mower** at 3 feet
- **Diesel Truck** at 50 feet
- **Urban Daytime**
- **Gas Lawn Mower** at 100 feet
- **Heavy Traffic** at 300 feet
- **Typical Urban Daytime**
- **Urban Nighttime**

**Rural Nighttime**

**Sound Level (dBA)**

- **140** Threshold of pain
- **130**
- **120**
- **110**
- **100**
- **90**
- **80**
- **70**
- **60**
- **50**
- **40**
- **30**
- **20**
- **10**
- **0**

**Common Indoor Noises**

- **Rock Band** at 15 feet
- **Food Blender** at 1 feet
- **Garbage Disposal** at 3 feet
- **Vacuum Cleaner** at 10 feet
- **Normal speech** at 3 feet
- **Dishwasher next room**
- **Library**
- **Bedroom at night**

**Note:** Sound is perceived differently by every individual
Sources of Highway Noise

- Tire/Pavement Noise: 41%
- Induction System: 21%
- Unallocated Sources: 17%
- Engine: 2%
- Cooling Fan: 7%
- Exhaust: 12%
Sources of Highway Noise (cont.)

- Exhaust: 90%
- Engine: 2%
- Cooling Fan: 2%
- Induction System: 2%
- Tire/Pavement Noise: 2%
- Unallocated Sources: 2%
Surface Texture: Friction vs. Noise

Key elements

- Maintain adequate friction for safety (wet and dry pavement conditions)
  - Cost effective
  - Durable
- Minimize objectionable noise
  - Identify objectionable noise levels (frequency and intensity)
  - Adopt a meaningful evaluation criteria
  - Engineer and implement an appropriate solution
Identify Objectionable Noise Levels

Comparison of Noise Rankings
Identify Objectionable Noise Levels (cont.)

- Noise peaks from uniform tining
- Tining, 38 mm
- Non-tined surface

Sound Pressure Level, dB vs Frequency, Hz
Evaluation Criteria

- Many devices and test criteria are currently in use
  - Pass-by
  - Statistical pass-by
  - Close proximity
  - Sound intensity
  - Others
- The over-riding question is....what do you want to measure?
How Is Noise Controlled?

- At the source
  - Pavement texture, vehicle & tire configuration
- Distance from source
  - 3 dBA reduction for each doubling of distance
  - 25ft = 70dBA, 50ft = 67dBA, 100 ft = 64
- Barriers
  - Berms, walls or combination of both
Engineering the Optimal Texture

- The optimal surface texture should consider noise but **MUST** consider safety
- Many options are available
  - Transverse tining
  - Longitudinal tining
  - Skewed tining
  - Astroturf drag
  - Diamond grinding
  - Exposed aggregate surface
  - Others
# Texture Categories

<table>
<thead>
<tr>
<th>$10^{-6}$</th>
<th>$10^{-5}$</th>
<th>0.0001</th>
<th>0.001</th>
<th>0.01</th>
<th>0.1</th>
<th>1.0</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microtexture</td>
<td>Macrotecture</td>
<td>Megatexture</td>
<td>Roughness</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

- **Wet Pavement Friction**
- **Exterior Noise**
- **Interior Noise**
- **Splash and Spray**
- **Rolling Resistance**
- **Tire Wear**
- **Tire Damage**
Micro- vs. Macro-Texture

<table>
<thead>
<tr>
<th>SURFACE</th>
<th>Scale of Texture</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Macro (Large)</td>
</tr>
<tr>
<td>A</td>
<td>Rough</td>
</tr>
<tr>
<td>B</td>
<td>Rough</td>
</tr>
<tr>
<td>C</td>
<td>Smooth</td>
</tr>
<tr>
<td>D</td>
<td>Smooth</td>
</tr>
</tbody>
</table>
Options for Noise Control: New Concrete Pavements

- Newly constructed concrete pavements have a number of options for texturing
  - Tining
  - Astroturf drag
  - Diamond grinding
  - Others
Options for Noise Control: Existing Concrete Pavements

- Existing concrete pavements have the option of either diamond grinding or grooving.
The “Other” Option: Arizona ARFC Overlays

- .75” to 1” nominal overlay
- Contains approximately 15% rubber
- Open graded mix designs
  - Require routine maintenance
  - Traps snow and ice
  - Not durable in northern climates
  - Noise increases due to consolidation
Surface Texture Research

- Numerous State, Federal, and Industry funded research programs have looked at the surface characteristics of both concrete and asphalt pavements.
- The following slides highlight several of these efforts.
Noise and Skid Measurements
US 285

Colorado DOT
## Results

<table>
<thead>
<tr>
<th>Description</th>
<th>(dBA)</th>
<th>(SN 40R)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long. Tined Concrete</td>
<td>75</td>
<td>43.3</td>
</tr>
<tr>
<td>Asphalt Surface (SMA)</td>
<td>74</td>
<td>51.5</td>
</tr>
<tr>
<td>Transverse Tined Conc.</td>
<td>82</td>
<td>43.5</td>
</tr>
<tr>
<td>¼ inch Ground Test Sect.</td>
<td>76</td>
<td>47.6</td>
</tr>
<tr>
<td>Reduction in Noise level</td>
<td></td>
<td></td>
</tr>
<tr>
<td>From Original Tining</td>
<td>6</td>
<td>NA</td>
</tr>
</tbody>
</table>
Noise Measurements beside Roadway
(25 feet from center of Lane)
Noise and Texture on PCC Pavements: a Multi-State Study

Federal Highway Administration
Wisconsin Department of Transportation
Marquette University
HNTB
Test Locations, 57 Sites
Marquette University Study

- 10 New Wisconsin Test Sites on Highway 29
- 57 other test sites in Colorado, Iowa, Michigan, Minnesota, North Dakota, and Wisconsin
  - 2 Uniform Skew
  - 4 Random Skew
  - 7 Uniform Longitudinal
  - 2 Random Longitudinal
  - 4 13-mm Uniform Transverse
  - 4 19-mm Uniform Transverse
  - 7 25-mm Uniform Transverse
  - 15 Random Transverse (several different spacings)
  - 1 Diamond Ground
  - European Exposed Aggregate
  - 5 Asphalt (1 SHRP, 2 Dense-graded, 2 SMA)
Noise Analysis – Exterior

Sound Pressure Level (dB)

Frequency (Hz)

- Wisc. #15 - 25mm Trans., (ETD = .274 mm)
- Wisc. #10 - 19mm Trans., (ETD = .401 mm)
- Wisc. #9a - 13mm Trans., (ETD = .417 mm)
Noise Analysis – Exterior (cont.)

- New Wis. #1 - 25mm Random Trans., (ETD = .656 mm)
- New Wisc. #2 - 19mm Random Trans. (ETD = 1.284 mm)
- Wisc. R2 - Truly Random (Zignego), (ETD = .713 mm)
- Minn. #4 - 38mm Random Trans. LTD, (ETD = .388 mm)

Lmax values:
- New Wis. #1: 86.6 dBA
- New Wisc. #2: 86.3 dBA
- Wisc. R2: 83.4 dBA
- Minn. #4: 82.6 dBA
Noise Analysis – Exterior (cont.)

New Wisc. #7 - 19mm Random Skew 1:4, (ETD = .718 mm)

New Wisc. #5 - 19mm Random Skew 1:6, (ETD = .708 mm)

L_{max} = 83.1 dBA

L_{max} = 82.4 dBA
Noise Analysis – Exterior (cont.)

- Wisc. #16 - Skidabrader, (ETD = .830 mm)  
  \[ L_{\text{max}} = 84.6 \text{ dBA} \]

- Iowa #8 - Milled Surface (Carbide Grnd.), (ETD = .835 mm)  
  \[ L_{\text{max}} = 83.8 \text{ dBA} \]

- Minn. #1 - 19mm Random Long., LTD, (ETD = .928 mm)  
  \[ L_{\text{max}} = 81.7 \text{ dBA} \]

- Wisc. #5 - Ground PCCP, (ETD = .918 mm)  
  \[ L_{\text{max}} = 81.2 \text{ dBA} \]
## Comparative Noise Levels

Noise reduction relative to uniform tining with 0.7 ETD

<table>
<thead>
<tr>
<th>Texture (0.7ETD)</th>
<th>Exterior (Lmax)</th>
<th>Interior (Leq)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Random Trans:</td>
<td>1-3 dBA</td>
<td>&lt;1 dBA</td>
</tr>
<tr>
<td>- Random Skewed:</td>
<td>4 dBA</td>
<td>1.5-2 dBA</td>
</tr>
<tr>
<td>- Longitudinal:</td>
<td>4-7 dBA</td>
<td>2 dBA</td>
</tr>
<tr>
<td>- AC (open text.)</td>
<td>5 dBA</td>
<td>2-3 dBA</td>
</tr>
</tbody>
</table>
Quiet Pavement Pilot Program

Federal Highway Administration

Arizona Department of Transportation

Caltrans
ADOT Findings
Whisper Grinding Test Section

- 58 Percent decrease in IRI (Roughness)
- 27 Percent increase in friction
- 95.5 dBA noise on whisper ground sections
Concrete vs. Asphalt OGFC

- The following slides illustrate some of the advantages of constructing or maintaining concrete surfaces.
Typical ARFC Noise Research Results - ADOT

- “The results shown represent the average of twenty projects. The projects were located on I-8, and I-10, and ranged in age from three years to twelve years. The regression indicates approximately a 5 dBA increase in noise generation in a ten year period. The current data further indicates that AR-ACFCs typically range from 94 to 99 dBA throughout their life.”
“Note that the long-term structural integrity of rubberized asphalt, particularly in interstate applications, is not well known.”

“Also, the long-term noise reduction is not known. Research has shown that the noise benefits of asphalt pavements in general will likely lessen as the pavement wears.”
Selection Criteria

- Properly designed and textured concrete pavements are safe, durable and quiet.
- The acoustic durability of concrete pavements far exceeds that of open-graded asphalt pavements (and possibly porous concrete pavements).
- Consider the real cost of routinely replacing the AC surface...traffic delays, construction zone safety concerns...user costs.
Conclusions

- Lowest exterior noise levels (acceptable texture)
  - ACP (OG)
  - Longitudinal tined PCCP

- Lowest interior noise levels (acceptable texture)
  - ACP (OG)
  - Longitudinal tined PCCP
  - Random skewed PCCP

- Uniform transverse tining causes whine
  - For a given spacing and pattern, apparently, noise increases with depth/width
Conclusions

- Longitudinal (and random skewed) PCCPs are among the quietest textures
  - Exterior and interior noise levels
  - Comparable to ACP
  - Easily constructed
  - Subjectively acceptable
  - No discrete tones
  - Can have good friction
Conclusions

- Random transverse tined PCCP
  - Sensitive to spacing
  - Too uniform spacing creates discrete tones
  - Tine spacing needs to be designed
  - May still result in unacceptable noise levels
Conclusions

- Diamond ground sections have no discrete frequency (or whine)
- Diamond grinding can be an acceptable noise reducing strategy for uniform spaced transverse tining
- Noise reductions of approximately 3dBA can be expected
THANKS !!!

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