Rehabilitated PCC Surface Characteristics

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Rehabilitated PCC Surface Characteristics

- Project Background
- Surface Characteristics Field Testing
- Data Analysis
- Other Noise Testing
- Next Steps
Project Background

• Diamond Grinding
  – Historically a rehabilitation activity to correct defective surface textures
  – Some states use diamond grinding as an initial surface texture
  – Pavement/Tire noise reductions are often an added benefit
• Diamond Grinding
  – Further research has identified grinding characteristics that can enhance quietness, safety, and ride comfort
Project Background

• Timeline
  – Initial laboratory investigation at Purdue University
  – June 2007: Proof-of-Concept grinding at MnROAD Cell 37 (Low Volume Road)
  – Oct. 2007: Innovative Grind and conventional Grind on Cells 7 and 8
Project Background

• Timeline
  – 2009: Statistical Pass-by Noise Measurements
  – Sept. 2011: Rolling Resistance Testing
  – 2007 – present: field testing and data analysis
Types of Grinding at MnROAD

- Cell 7: Innovative Grind
- Cell 8: Conventional Grind
- Cell 9: Ultimate Grind
- Cell 12: Control Section – No Grind
Cell 8: Conventional Grind

Stacked Grinding Head

Resulting Texture
Cell 8: Conventional Grind

Close up of Resulting Texture
Cell 7: Innovative Grind

Stacked Grinding Head

Resulting Texture
Cell 9: Ultimate Grind

Innovative Grind

Ultimate Grind
Field Testing Program

- Periodic Testing
  - Noise (On-Board Sound Intensity)
  - Friction (ASTM E-274)
  - Texture (Mean Texture Depth)
  - Smoothness (International Roughness Index)

- One-Time Testing
  - Rolling Resistance
Ride Quality

IRI of Cells 7, 8 and 12 Driving Lanes

- Cell 7 (IDG)
- Cell 8 (CDG)
- Cell 12 (TT)

Date:
- 1-Jun-08
- 18-Dec-08
- 6-Jul-09
- 22-Jan-10
- 10-Aug-10
- 26-Feb-11

IRI (in/Mile)
- 120
- 110
- 100
- 90
- 80
- 70
- 60
- 50
- 40
RoboTex testing by Transtec to be conducted soon
Rolling Resistance

- Rolling Resistance testing conducted September 2011.
- Results not yet available.
Rolling Resistance

Sample Rolling Resistance Results

![Graph showing fuel consumption vs. rolling resistance coefficient](image)
Rolling Resistance

Effects of Rolling Resistance

- Transmission friction
- Aerodynamic drag
- Rolling resistance (circled)
- Rotating parts inertia
- Vehicle inertia
- Engine friction

Percent of total energy consumed
Roadside Measurements

- **Vehicle Noise Sources:**
  - Tire/pavement noise
  - Power train noise
    - Vehicle engine casing, fans and air intake
    - Combustion exhaust system
    - Transmission, differential and axles
  - Air turbulence
- OBSI measurements isolate the tire/pavement noise
- Roadside measurements include all vehicle noise
- Statistical Pass-By (SPB) measurement is the roadside noise level of an “average” vehicle traveling over a particular pavement
Measurement Standards

Measurement of Highway-Related Noise

Cynthia S.Y. Lee
Gregg G. Fleming

U.S. Department of Transportation
Research and Special Programs Administration
John A. Volpe National Transportation Systems Center
Acoustics Facility, DTS-75
Kendall Square
Cambridge, MA 02142-1093

Final Report
May 1996

INTERNATIONAL STANDARD
ISO 11819-1

Acoustics — Measurement of the Influence of road surfaces on traffic noise —
Part 1:
Statistical Pass-By method

Acoustique — Mesurage de l’influence des revêtements de chaussées sur le bruit émis par la circulation —
Partie 1: Méthode statistique au passage
Measurement Setup

- adjacent lane
- test lane (road surface under test)
- median marking
- test lane centre
- lane edge marking
- shoulder or other road-side area
- Area with arbitrary covering: grass or plants shall not be tall; depressions shall be covered.
- Microphone position
- No requirements in this area. Min. area covered with material having sound absorption similar to that of tested surface.
Microphone Positions

• 25’ and 50’ microphone positions
Vehicle Categories

- **Automobiles/Cars:**
  - Passenger vehicles or light trucks with two axles and four wheels
  - designated primarily for nine or fewer passengers or for transportation of cargo
  - gross vehicle weight generally less than 4500 kg (9900 lb)
- **Medium Trucks:**
  - cargo vehicles with two axles and more than four wheels
  - gross vehicle weight generally between 4500 kg (9900 lb) and 12,000 kg (26,400 lb)
- **Heavy Trucks:**
  - cargo vehicles with three or more axles
  - gross vehicle weight generally greater than 12,000 kg (26,400 lb)
- **Buses:**
  - busses and coaches with two or three axles
  - designated for transportation of nine or more passengers
  - supplementary data not included in the analysis data set.
- **Motorcycles:**
  - vehicles with two or three tires with an open-air driver and/or passenger compartment
  - supplementary data not included in the analysis data set.
Passby Event Quality

• Ensure that measurement is of a single vehicle only
• Intent is noise of the target vehicle 10 dB greater than any other noise present at the microphone position.
• Maximum measured noise level of the vehicle pass-by must meet two criteria:
  – Sufficient signal-to-noise ratio
  – Clearly distinguishable from other traffic noise on the road
• Discard Individual vehicles under the following conditions:
  – Vehicles present in the other lane
  – Clearly exhibit unusual or atypical noise characteristics
  – Not moving at constant speed, such as accelerating or braking vehicles
  – Significant deviation in lateral position
  – Other noise interferences are observed
• If the candidate event is not otherwise discarded, the event is assessed for acoustical quality.
Passby Event Quality
High-Volume Traffic Challenges

Average Monday-Wednesday Traffic for June, 2007
(both lanes)

Vehicle volume

Hour of day

Average of A/1
Average of MT/2a
Average of HT/2b
Adapted Measurement Procedure

• Capture high-quality digital audio recordings
  – Used acoustic instrumentation microphones
  – Calibration tone recorded hourly
  – Evaluate acoustic quality criteria
  – Measure maximum vehicle emission level
• Capture simultaneous video recording
  – Vehicle classification
  – Ensure disturbing vehicles not present
• Capture vehicle speeds with logging radar sensor (Mn/DOT)
• In-office analysis of synchronized audio and video
  – Replay events to ensure quality
  – Find events which couldn’t have been captured in field
Field recording equipment

• At control pavement specimen
Field recording equipment

- At subject pavement specimen
Results Summary

A-weighted Sound Level (dBA re. 20 µPa)

- Innovative grind (subject)
- Burlap-drag (control)
- Innovative grind (cell 7)
- Conventional grind (cell 8)
- Transverse-tined (cell 97)

25 ft mic
- Cars
- Heavy vehicles

60 65 70 75 80 85 90 95 100
Comparison of Mn/ROAD test cells

Sound Level Difference (dB) vs. \( \frac{1}{3} \text{Octave Band Center Frequency (Hz)} \)

Cell 7 v 8 Cars (N=49)  
Cell 7 v 97 Cars (N=49)  
Cell 7 v 97 Trucks (N=9)  
Cell 8 v 97 Cars (N=49)  
Cell 8 v 97 Trucks (N=9)
Significance of Paired Measurements

- Paired t-test for cars (N=49)
- Paired t-test for trucks (N=9)
## Control Pavement Regression

<table>
<thead>
<tr>
<th></th>
<th>Veh. cat 1 (cars)</th>
<th>Veh. cat 2a (dual-axle)</th>
<th>Veh. cat 2b (multi-axle)</th>
<th>Total for Veh. cat 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference speed (km/h)</td>
<td>115</td>
<td>107</td>
<td>107</td>
<td>107</td>
</tr>
<tr>
<td>Number of vehicles</td>
<td>104</td>
<td>25</td>
<td>52</td>
<td>77</td>
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<tr>
<td>Average speed* (km/h)</td>
<td>115.2</td>
<td>105.7</td>
<td>107.6</td>
<td>107.0</td>
</tr>
<tr>
<td>St. dev. of speed* (km/h)</td>
<td>1.1</td>
<td>1.1</td>
<td>1.1</td>
<td>1.1</td>
</tr>
<tr>
<td>Regr. line intercept</td>
<td>50.1</td>
<td>-1.0</td>
<td>10.6</td>
<td>4.8</td>
</tr>
<tr>
<td>Regr. line slope</td>
<td>17.2</td>
<td>44.9</td>
<td>41.1</td>
<td>43.4</td>
</tr>
<tr>
<td>Correlation coefficient</td>
<td>0.24</td>
<td>0.58</td>
<td>0.44</td>
<td>0.51</td>
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<tr>
<td>Average sound level (dBA)</td>
<td>85.6</td>
<td>89.9</td>
<td>94.2</td>
<td>92.8</td>
</tr>
<tr>
<td>Std. dev. of sound level (dBA)</td>
<td>1.9</td>
<td>3.0</td>
<td>2.1</td>
<td>2.4</td>
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<tr>
<td>Std. dev. of sound level residuals (dBA)</td>
<td>1.9</td>
<td>2.5</td>
<td>1.9</td>
<td>2.1</td>
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<tr>
<td>$L_{veh}$ (at ref. speed)</td>
<td>85.6</td>
<td>90.1</td>
<td>94.1</td>
<td>92.8</td>
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</tbody>
</table>

* Value converted from the logarithm of speed.
Subject Pavement Regression

<table>
<thead>
<tr>
<th></th>
<th>Veh. cat 1 (cars)</th>
<th>Veh. cat 2a (dual-axle)</th>
<th>Veh. cat 2b (multi-axle)</th>
<th>Total for Veh. cat 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference speed (km/h)</td>
<td>115</td>
<td>107</td>
<td>107</td>
<td>107</td>
</tr>
<tr>
<td>Number of vehicles</td>
<td>101</td>
<td>27</td>
<td>52</td>
<td>79</td>
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<tr>
<td>Average speed* (km/h)</td>
<td>115.1</td>
<td>107.7</td>
<td>106.3</td>
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<tr>
<td>St. dev. of speed* (km/h)</td>
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<td>1.1</td>
<td>1.1</td>
<td>1.1</td>
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<td>Regr. line intercept</td>
<td>74.6</td>
<td>45.7</td>
<td>-15.5</td>
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<tr>
<td>Regr. line slope</td>
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<td>21.1</td>
<td>53.5</td>
<td>43.7</td>
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<tr>
<td>Correlation coefficient</td>
<td>0.05</td>
<td>0.17</td>
<td>0.49</td>
<td>0.38</td>
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<td>Average sound level (dBA)</td>
<td>83.1</td>
<td>88.7</td>
<td>92.8</td>
<td>91.4</td>
</tr>
<tr>
<td>Std. dev. of sound level (dBA)</td>
<td>2.6</td>
<td>3.1</td>
<td>2.9</td>
<td>2.9</td>
</tr>
<tr>
<td>Std. dev. of sound level residuals (dBA)</td>
<td>2.6</td>
<td>3.1</td>
<td>2.5</td>
<td>2.7</td>
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Next Steps

• Continue MnROAD data collection and analysis
• Identify trends in the data
• Develop project reports
• Develop Technical Brief for FHWA on the benefits of innovative grinding techniques
• Project scheduled for completion in Nov. 2012