Quieter Pavements

Caltrans Division of Environmental Analysis
Traffic Noise

• Not the loudest, but the most pervasive environmental noise
• $$ to mitigate with sound walls
• Quality of life issue for people near major roadways
• Thoughtful design lowers noise impacts
• Pavement #1 Product of Caltrans
Quieter Pavement Studies

- Awareness
- Develop Measurement Methods
- Inventory various pavement acoustics
- Demonstration & Research Projects
- Longevity studies
- Noise abatement implementation
Exhaust

Tire/Pavement

Engine

Truck Vehicle Noise Sources
Light Vehicle Noise Sources

Tire/Pavement

Engine
What does Caltrans have control over?

Can changing just pavement influence T/P subsource?

Can T/P subsource change overall wayside noise levels?
Light Vehicle Pass-by Level

Sound Pressure Level, dBA vs. Vehicle Speed, km/h

- Non-Accelerating
- Accelerating
- Tire Noise Dominated

Procedure Works on This Part

Source: FHWA REMELs Data Base
Isolate Affect of Pavement on Each Vehicle Type in Traffic
Isolate the Effect of Pavement on Tire Noise

Isolate the effect of pavement on tire noise alone
I-80 Davis Wayside Noise Reduction

Benefits lasted beyond 0.5-2yrs

![Graph showing sound pressure level over frequency for different time periods]
I-80 Davis Wayside Noise for 16 Years

Sound Pressure Level, dBA

One-Third Octave Band Frequency, Hz

Baseline
1-Year
7-Year
8-Year
9-Year
10-Year
11-Year
12-Year
16-Year

Single OGAC Pavement
LA-138 QP Study

5 Typical Flexible Pavements
End-to-End

Low ADT
Clean Single Vehicle Pass-Bys
Vs I-80 Davis Continuous Traffic Stream

2000

Problem: Blowing Wind
Roadside (Wayside) Pass By Method

Statistical Pass By (SPB)   ISO 11819-1

Mic Array

Met data
Vehicle Classification
Speed
Examples of Percentage Split Between Upper and Lower Source Heights (Cruise)

<table>
<thead>
<tr>
<th>Source Heights</th>
<th>Low Frequencies (500 Hz and below)</th>
<th>High Frequencies (2000 Hz and above)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AUTO</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 ft</td>
<td>27%</td>
<td>2%</td>
</tr>
<tr>
<td>0 ft</td>
<td>73%</td>
<td>98%</td>
</tr>
<tr>
<td>12 ft</td>
<td>57%</td>
<td>46%</td>
</tr>
<tr>
<td>HEAVY TRUCK</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 ft</td>
<td>43%</td>
<td>54%</td>
</tr>
</tbody>
</table>

Source: Bowlby and Assoc., TNM 2.5 Caltrans Training Course Oct 2016
Measurement

“Roll-Down”

Traffic Noise
CTIM TP 99

Vehicle Noise
SIP TP 98
SPB ISO 1189-1

Tire Noise
OBSI AASHTO T360
CPX ISO 11819-2
Measurement “Roll-Down”

Traffic Noise
CTIM TP 99

Vehicle Noise
SIP AASHTO TP 98
SPB ISO 1189-1

Tire Noise
OBSI AASHTO T 360
CPX ISO 11819-2

Roll-up for wayside prediction
Tire-Pavement Source Measurements

CPX

OBSI

Sound Pressure

Sound Intensity
Close Proximity Method (CPX) or Trailer Method at NCAT Test Track
Tire-Pavement Noise Surveys

LA-138 5 Flexible pavements end-to-end
Mojave 58 By Pass
Rigid Pavement w Various Textures
Applied Textures to Baseline Surfaces

#1 – Grind
#2 – Grind
#3 – Groove
#4 – Groove
#5 – Grind
#6 – Groove & Grind
#7 – Groove
#8 – Grind
GM invented Sound Intensity Measurements
OBSI Quantifies Pavement Acoustics

Overlap btw Pavement Types
Many pavement acronyms

Collect Database of Pavement Acoustics
OBSI vs. PB Levels

Data Points - OBSI vs. 7.5m
1 to 1 Fit (0.6 dB Avg Dev)

Data Points - OBSI vs. 15m
1 to 1 Fit (0.7 dB Avg Dev)

• 12 pavements (PCC & AC)
• 3 tire types
• 2 speeds (97 & 72 km/h)

SRTT 28.3 dB at 50 Ft
(light vehicle)
Tire/Pavement Source
Level to “Passby” Comparison

Test Tires matter
Aqua-Tread & SRTT

105 dB
83 dB @ 25 ft
77 dB @ 50 ft
California & Arizona Data Base

A-weighted sound intensity level, dB

- OG/RAC Pavements
- PCC Pavements
- DGA Pavements

Mostly 1 : 1
Pavement OBSI : Roadside
Exception: Super Absorptive Flexible Pavement

Sound Propagation Tests:
- Subtract sound pressure level from average sound intensity level to calculate difference.
- Measure sound pressure at 25 & 50 ft.
- Measure average sound intensity over face of the loudspeaker.

NCAT Test Track

Marin Co. 101
Flexible Pavements – Texture & Porosity

Dual Layer Porous Asphalt - $$$

Small Aggregate Size

Coarse Aggregate Size

95 dBA
Examples & Case Studies
Quieter Rigid Pavements – Direction of Texture

Uniform Transverse Tining
107 dBA

Random Transverse Tining
109 dBA

Longitudinal Tining
102 dBA

Direction of Travel

Caltrans history: Only SDOT to do LT for 30 years – off Structures
Quieter Rigid Pavements

Direction of Travel

#5 – Ground

101 dBA

99 dBA
Portland Cement Concrete Data Base

Source: Transtec
Long-term Sound Measurement

OBSI Levels decreased 10 dB(A)

At 500 ft. peak hour Leq dropped 7-8 dB(A)
48,000 AADT in 2002 w/ 14 % Trucks
Quieter Rigid Pavements – Grinding

- ~10 dB Difference

TT Texture done to elevate friction; construction process
SE’s don’t like to grind; removes protective ‘skin’, and reduces rebar cover
Safety not an issue - LT off Structures since 1970’s
San Francisco Oakland Bay Bridge

Two Tales of the ‘Bridge Whisperer’
OBSI Tire/Pavement Measurements on the SFOBB
Minimize Noise Impacts to USCG Dorm
Completed Temporary Viaduct Structure
Eastbound Lower Deck
Average Overall Levels
106.1 dBA
Westbound Upper Deck
Average Overall Levels
106.2 dBA
Comparison of Bay Bridge Average Level to other Structures and Ground PCC Surfaces
Use LT Texture PCC – Avoid Additional Load of OGAC on Temp Viaduct Deck
Story 2 - Millions $$ Walkway with Million $ View
Public Access Walkway to Treasure Island – Cantilevered off EB Structure
OBSI Post Construction Measurements

Changed Deck Spec from TT to LT Texture

Quieter LT Texture – Lowered Noise Level exposure Adjacent Walkway

LT Deck Texture Reduced Walkway Noise Levels 8-10 dB
Cautionary Tales of Pavement Promoters (Rigid & Flexible)
ADOT Quiet Pavement Pilot Program (QP3)

AZ – Home to RPA
ADOT would have seen noticeable reduction just by changing rigid pavement specification from TT to LT.
Quiet flexible RAC product marketed to WsDOT; could overcome temperature construction issues & solve noise problem. .....SO much quieter than rigid pavement.....

WSJ Story - “Quiet Pavement Doesn’t Work!”
(Doesn’t mention heavily rutted WsDOT lanes due to snow tires and chains)
European Exposed Aggregate – “is SO Quiet”

-- Mostly not; need ½ inch or less aggregate to be quiet
Acoustical Longevity – Long Term Research

- Arizona DOT, QP3
  - 12-Year Study
  - AADT Varies over 330 miles of study area

- Caltrans, Davis I-80
  - 16-Year Study
  - 146,000 AADT, 7.6 % trucks

- Caltrans, LA 138: Flexible Pavement (4,400 AADT, 14% trucks)

- Caltrans, Mohave SR 58: Concrete Texturing (17,000 AADT, 37% trucks)
Quieter Pavement and Heavy Vehicles

- Trucks ~10 dB louder than cars (wayside)
- Tire-noise major contributor
  - More aggressive tires and more of them
- Range in OBSI level for truck tires on a single pavement is 14 dB (similar to pavement range)

- Acoustical characteristics and pavements ranking consistent for car and truck tires
  - Aggressive treaded tires result in smaller ranges
Figure D.12. Overall A-Weighted OBSI levels for each test pavement from October 2002 through October 2011 versus years since construction for Goodyear Aquatred test tire.
Figure D8. Overall A-Weighted OBSI levels for each test pavement from 2003 to 2012 with rate of increase per year shown for the Goodyear Aquatred test tire.
# Pavement Acoustic Longevity Summary

<table>
<thead>
<tr>
<th>Project</th>
<th>Pavement Details</th>
<th>Rate of Increase, dB/Year</th>
<th>Mid-Project Year Traffic Loading</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADOT QP3</td>
<td>ARFC³</td>
<td>0.50</td>
<td>Varies</td>
</tr>
<tr>
<td>Davis I-80 (6-lanes)</td>
<td>OGAC²</td>
<td>0.3 to 0.4</td>
<td>146,000 AADT, 7.6% Trucks (2006)</td>
</tr>
<tr>
<td>LA 138 (2-lanes)</td>
<td>DGAC</td>
<td>0.09</td>
<td>4,400 AADT, 14% Trucks (2007)</td>
</tr>
<tr>
<td></td>
<td>OGAC 75 mm²</td>
<td>0.47</td>
<td></td>
</tr>
<tr>
<td></td>
<td>OGAC 30 mm²</td>
<td>0.41</td>
<td></td>
</tr>
<tr>
<td></td>
<td>RAC(O)²,³</td>
<td>0.38</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BWC</td>
<td>0.33</td>
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<tr>
<td>Mohave Bypass SR 58 (4-lanes)</td>
<td>LT PCC</td>
<td>0.09</td>
<td>17,000 AADT, 37% Trucks (2007)</td>
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<tr>
<td></td>
<td>Ground PCC, S1</td>
<td>0.12</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ground PCC, S5</td>
<td>0.12</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Burlap Drag PCC</td>
<td>0.09</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Grooved PCC, S3</td>
<td>0.16</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Grooved PCC, S4</td>
<td>0.15</td>
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<tr>
<td>SR 85, Saratoga, CA (6-lanes)</td>
<td>Ground and Grooved Long. Tined PCC</td>
<td>0.38</td>
<td>122,000 AADT, 0.57% Trucks (2007)</td>
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<tr>
<td>I-280, San Mateo County (6-lanes)</td>
<td>Diamond Ground PCC</td>
<td>0.28</td>
<td>105,000 AADT, 2.3% Trucks (2006)</td>
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<tr>
<td></td>
<td>Texture Ground PCC</td>
<td>0.35</td>
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<td></td>
<td>RAC(O)³</td>
<td>0.58</td>
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<tr>
<td></td>
<td>OGAC²</td>
<td>0.81</td>
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<tr>
<td>I-10, Casa Grande, AZ (6-lanes)</td>
<td>AR-ACFC³</td>
<td>0.33</td>
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<tr>
<td></td>
<td>ACFC</td>
<td>0.43</td>
<td>51,000 AADT (2007)</td>
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<tr>
<td></td>
<td>SMA</td>
<td>0.30</td>
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<tr>
<td></td>
<td>Porous-ACFC²</td>
<td>0.68</td>
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<tr>
<td></td>
<td>Porous Euro Mix²</td>
<td>negligible</td>
<td></td>
</tr>
</tbody>
</table>

**Averages**
- Asphalt – 0.46 dB/Yr
- Concrete – 0.19 dB/Yr
Acoustic Beam Forming System

- Type WL9x6D2509 Foldable wheel Array
- Equal length arms
- 8.2ft in diameter
- 54 microphones
- Acquisition by B&K PULSE system
- Data processed by delay & sum method
- 315 to 4,000 Hz
At freeway speed for Autos and Heavy Trucks, majority of acoustic energy is at T/P interface and below 3.3 feet.
Quieter Pavement Bulletin Design Guidance Oct 2009 (omitted Structures)
Quieter Pavement

- Lower initial cost than barriers
- Larger area of reduction
- Can be used anywhere
- Noise levels increase over time
- Maintaining performance requires periodic rehabilitation
Developing a Quiet Pavement Strategy is an important process for addressing traffic noise impacts – OBSI is an important tool.
Federal Highway Administration

2009 Environmental Excellence Award

For Excellence in Environmental Research:

Quieter Pavement Research: Development of Technology for Measurement of Tire/Pavement Noise Using the On-Board Sound Intensity Method

California Department of Transportation
Arizona Department of Transportation
Illingworth and Rodkin, Inc.
General Motors

The California Department of Transportation (Caltrans) Division of Environmental Analysis adapted a little-known General Motors measurement methodology to precisely quantify tire/pavement acoustics. The new methodology, On Board Sound Intensity (OBSI), is based on acoustic work done on test tracks in the 1970’s by General Motors. The dominant noise source on light vehicles operating at freeway speed is tire/pavement noise. The noise levels between different pavements can vary widely depending on material type and surface texture. It was this tire/pavement noise phenomenon that led Caltrans to develop a precise measurement methodology for quantifying pavement acoustics. The Caltrans modified approach uses one standard tire to evaluate many different pavements in real time with traffic on active freeways. The unique aspect of this procedure is that it allows pavement noise to be separated from other noise generators on a moving vehicle. This work has demonstrated that lowering pavement noise levels also lowers community noise adjacent to highways. Development of quieter pavement is a tool transportation departments may use to lower overall traffic noise levels in the community. A better understanding of tire/pavement acoustics will improve noise modeling calculations and noise-mitigating design features. This Caltrans/GM developed process is now being adopted as a measurement standard by AASHTO, ASTM, and SAE.

September 14, 2009

Federal Highway Administrator

Questions?