The ADOT Quiet Pavement Pilot Program

Paul R Donavan, Sc.D.
ADOT Situation Pre-2002

• 150 miles of new freeways to be added in the Phoenix area, 1985 to 2007
• Existing and new freeways are Portland Cement Concrete (PCC) with transverse tining
• Community complaints in areas where freeways added – sound walls not preferred
• Knowledge of quieter pavement application in its infancy
US Federal Policy

• Pavement can not be considered as traffic noise abatement in FHWA funded projects

• FHWA Traffic Noise Model (TNM) only allows of an “average” pavement type

• FHWA noise abatement requirements:
  – Feasible reduction – 5 dB
  – Reasonable cost

• New possibility of “pilot projects” which account for pavement based on previous state research
Arizona Quiet Pavement Pilot Program

• 115 miles of freeway to be overlaid with ARFC ($34 million)

• 4 dB “credit” allowed for pavement by FHWA relative to TNM predicted noise level

• Long term research project to measure performance over 10 years ($3.8 million)

• Multiple Measurements Types (or “Sites”)
Pre & Post Overlay

ARFC Overlay (25mm Thick)

Random Transverse Tined PCC
QPPP ARFC Specifications

• 18 to 22% crumb rubber particles
• Asphalt rubber binder of 9.1 to 9.6% by weight
• Aggregate gradations:
  – 95% 9.5mm chips
  – 5% fine aggregate
• Void content typically 20 to 21%
• However, no indication of being a porous pavement
Light Vehicle Pass-by Level

Sound Pressure Level, dBA vs. Vehicle Speed, mph

- Non-Accelerating
- Accelerating
- Tire Noise Dominated

Source: FHWA REMELs Data Base
Caltrans Quieter Pavement Research on I-80 near Davis

Old DGAC Surface
79 dBA

New Quieter OGAC Overlay
73 dBA
Arizona Quiet Pavement Program: Preliminary Work

• Development of measurement methods
• Construction and evaluation of pavement test sections
• Pavement selection – ARFC with almost 30 years of history
• Evaluation of pavement age and noise performance
• Investigations of alternative PCC surface textures
Isolating the Pavement Performance

No big deal, just go out and measure it before and after

**BUT**

It depends on
- Traffic speed
- Traffic Volume
- Traffic mix
Measurement Methods

Traffic Noise
- CTIM TP 99

Individual Vehicle Noise Pass-by Noise
- SIP TP 98
- SPB ISO 1189-1

Isolate Vehicle Noise then Tire Noise

Tire Noise
- OBSI AASHTO T360
- CPX ISO 11819-2
CPX Trailer – ISO Procedure

CPX Mics

Acoustical Enclosure
ADOT Two Sound Intensity Probe Concept

Sound Propagating from the tire
ARFC Applications
Difference in Noise with Pavement Age

Range of Existing PCC Surfaces (OBSI)

Overall Noise Level, dBA (CPX & SI)

Number of Year of Since Construction

- Sound Intensity Level - 0.27 dB/Yr
- CPX Sound Pressure Level - 0.33 dB/Yr
Arizona I-10 Casa Grande AC Research Test Sections

- Constructed in 2000
- First tested in 2002
- Pavements – 6 of each:
  - Asphalt rubber AR-ACFC
  - Conventional ACFC
  - Stone mastic SMA
  - Porous ACFC
  - Porous European PEM
Casa Grande Research Test Sections

On-Board Sound Intensity Level, dBA

<table>
<thead>
<tr>
<th>ARFC</th>
<th>SMA</th>
<th>P-ACFC</th>
<th>PEM</th>
<th>ACFC</th>
</tr>
</thead>
<tbody>
<tr>
<td>97.6</td>
<td>100.6</td>
<td>100.9</td>
<td>101.7</td>
<td>100.2</td>
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</table>
SR 202 Test Surfaces

Uniform Transverse Tining

Random Transverse Tining

Longitudinal Tining

Direction of Travel
SR 202 Test Surface Results

![Graph showing test results for different conditions.]

- **Random Transverse Timing**
- **Uniform Transverse Timing**

**Axes:**
- **Y-axis:** Increase in level over longitudinal timing, dBA
- **X-axis:**
  - All Light Vehicle Passbys
  - Test Car Passbys
  - Sound Intensity
SR 202 Test Surface Results

Sound Intensity

Sound Pressure

One-Third Octave Band Center Frequency, Hz

Random Transverse
Longitudinal
Uniform Transverse
Definition of the QPPP

• Originated as a cooperative research project between ADOT & FHWA in April 2003

• 10-year project with 3 components
  – Type 1 measurements of tire/pavement noise
  – Type 2 noise measurements in residential settings
  – Type 3 noise measurements in “research grade” sites

• Additional pavement characteristic measurements
Measurement Types & Locations
Tire/Pavement Source Levels
Type 1 Measurements

- Consistent with AASHTO T360
- Goodyear Aquatred 3 tire
- 60 mph, 5 second average
- Outside lane both directions at 115 mileposts

- Developed correlation for CPX to OBSI
- Initially 2 times per year, later once
Type 2 “Backyard” Measurements

- One-hour Leq’s from three 20 minute samples
- Traffic data collected
- Modeled in TNM (not available)
- Data for 78 sites acquired initially
Typical Type 3 Measurements

- 50 ft common to all 5 Sites
- 100 ft (or 95 ft) common
- 4 Sites with varying further distances
Type 3 Measurements at Site 3A on SR 101

Prima Freeway
Type 3 Measurements at Site 3B on SR 101
Type 3 Measurements at Site 3C on I-10
Type 3 Measurements at Site 3D on SR 202

Red Mountain Freeway
Type 3 Measurements at Site 3E on SR 101

Price Freeway

100 ft Mic Location

50 ft Mic Location
## Initial Type 3 Measurement Results

<table>
<thead>
<tr>
<th>Site 3A</th>
<th>Site 3B</th>
<th>Site 3C</th>
<th>Site 3D</th>
<th>Site 3E</th>
</tr>
</thead>
<tbody>
<tr>
<td>OBSI 50ft/12ft</td>
<td>OBSI 50ft/5ft</td>
<td>OBSI 50ft/5ft</td>
<td>OBSI 95ft/5ft</td>
<td>OBSI 246ft/5ft</td>
</tr>
<tr>
<td>OBSI 50ft/5ft</td>
<td>OBSI 50ft/5ft</td>
<td>OBSI 50ft/5ft</td>
<td>OBSI 50ft/5ft</td>
<td>OBSI 50ft/12ft</td>
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<tr>
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<td>OBSI 50ft/5ft</td>
<td>OBSI 141ft/5ft</td>
<td>OBSI 50ft/5ft</td>
<td>OBSI 50ft/5ft</td>
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<tr>
<td>OBSI 50ft/5ft</td>
<td>OBSI 100ft/5ft</td>
<td>OBSI 275ft/5ft</td>
<td>OBSI 50ft/5ft</td>
<td>OBSI 50ft/1.3ft</td>
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### Noise Reduction with ARFC Overlay, dB

- **Type 1**
- **Type 3**
Comparison of Noise Reductions for Measurement Types

• Type 1 & 3 noise reductions within ½ dB at 50 ft distance & ¾ dB averaged over distance

• Type 2 noise reductions 3 to 4 lower than Type 1 & 3

• Why didn’t they “correlate”? 
Common Type 2 Measurement Site

Microphone Location
Freeway Opposite of Measurement Site
Analysis of Type 2 Sites

- Categorized site geometries
- Modeled in TNM
- Applied additional reduction due to ARFC
  - Research version of TNM
  - Use OBSI levels to adjust for actual pavement
Freeway Recessed 12ft with 12ft Barrier Located 70ft from Near Lane

- Barrier Reduction
- Recess Reduction
- Pavement Reduction

Predicted Traffic Noise Level, dBA vs. Distance to the Center of the Near Lane of Vehicle Travel, ft
Initial Type 1 Results

![Graph showing sound intensity level vs. 1/3 Octave Band Center Frequency](image)

- 3A Post Overlay
- 3D Post Overlay
- 3E Post Overlay
- UT Pre Overlay
- RT Pre Overlay
Type 1 Results at Type 3 Sites

Averages:
- Pre-Overlay – 107.6 dBA
- Post-Overlay – 97.1 dBA
- Year 12½ – 103.7 dBA
Type 1 Results – All Freeways

AZ PCC Average = 105.5 dBA

- $y = 0.64x + 96.52$  
  $R^2 = 0.97$
- $y = 0.48x + 98.07$  
  $R^2 = 0.90$
- $y = 0.52x + 97.39$  
  $R^2 = 0.92$
- $y = 0.34x + 99.27$  
  $R^2 = 0.84$
- $y = 0.35x + 97.21$  
  $R^2 = 0.79$
- $y = 0.39x + 97.40$  
  $R^2 = 0.85$
- $y = 0.50x + 97.27$  
  $R^2 = 0.93$

ARFC Pavement Age

Overall OBSI Levels, dBA

Legend:
- SR 101, Agua Fria Freeway
- SR 101, Pima Freeway
- SR 101, Price Freeway
- I-17
- SR 51
- I-10
- SR 202
- Site 1 Averages
Traffic Noise & Pavement

79 dBA

70 dBA
Type 3 Site Noise Levels with Age

Average Rate of Increase – 0.40 dB/yr
# Type 3 Site Noise Reductions

<table>
<thead>
<tr>
<th></th>
<th>Site 3A</th>
<th>Site 3B</th>
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<th>Site 3D</th>
<th>Site 3E</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Initial Noise Reduction</strong></td>
<td>9.3 dB</td>
<td>9.2 dB</td>
<td>8.8 dB</td>
<td>11.4 dB</td>
<td>9.1 dB</td>
</tr>
<tr>
<td><strong>Final Noise Reduction</strong></td>
<td>3.2 dB after 12 years</td>
<td>6.8 dB after 10 years</td>
<td>6.3 dB after 10 years</td>
<td>4.8 dB after 10.5 years</td>
<td>4.2 dB after 9.5 years</td>
</tr>
<tr>
<td><strong>Final Noise Comparison to TNM average at 10 years</strong></td>
<td>1.1 dB</td>
<td>4.1 dB</td>
<td>3.2 dB</td>
<td>-1.6 dB</td>
<td>0.2 dB</td>
</tr>
</tbody>
</table>
Acoustic Longevity – Why Do Pavements Get Noisier?

2002
100 dBA

2008
102 dBA
Different?

The Old
9.5 mm Max
Aggregate

The New
9.5 mm Max
Aggregate

98.2 dBA

103.2 dBA
Worn Pavements

Accelerated Wear

Natural Wear
Worn Pavements

Accelerated Wear

Natural Wear

Signs of Wear
QPPP Site 3D After 8 Years

2004

2012
Other Topics Covered in Final Report

• Pavement sound absorption
  – Effective flow resistance (EFR)
  – Acoustic impedance measurement

• Mean profile depth

• Acoustic longevity of Casa Grande Asphalt Test Sections

• Measurement Performance of PCC textures
  – Random Transverse Tine
  – Uniform Transverse Tine
  – Longitudinal Tine
  – Diamond “Whisper” ground
Sound Absorption

ARFC is non-porous
Mean Profile Depth vs Age

![Graph showing Mean Profile Depth vs Age](image)

- **Years since AFRC Overlay**: 2009 to 2016
- **Mean Profile Depth, mm**: 0.60 to 1.60
- **Sites**: Site 3A, Site 3C, Site 3D, Site 3E
- **R² = 0.62**
Summary

• The QP3 produce significant reduction in wayside traffic noise – 9.6 dB on average
• At the end of monitoring, the reduction was still averaging 5.1 dB
• Wayside noise increase at an average rate of 0.4 dB/year & tire/pavement source levels at 0.5 dB/year
• At the end, levels averaged 1.4 dB lower than TNM predictions

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
How Do You Trade These Off?

- Pavement noise data
  - Initial expected performance
  - Longevity performance

- Barrier performance
  - How high (& square meters)
  - Extent of reduction

- Cost data
  - Initial
  - On-going
Goals & Analysis

• Determine the noise reduction goal
• Model the acoustic performances of all approaches
  – Barrier or pavement
  – Combined
• Apply Life Cycle Cost Analysis
• Select the lowest overall cost with the most reduction & impact
Example Implementation Approach

https://inceusa.org/publications/technology-for-a-quieter-america/#cost-benefit
Thank You
For Your Attention
Site 3B Results

![Graph showing 15-min Average Leq Level, dBA vs One-Third Octave Band Frequency Center, Hz for different months and years.](image)