“Pavement/tire noise has been studied for well over 30 years and several large databases have been compiled in the last decade. NCHRP Synthesis 268 is a summary of the research findings of this extensively studied topic.”
• Vehicle-generated noise comes from:
  – engine,
  – exhaust system,
  – aerodynamic noise
  – tire noise.

\[
\{\text{Power train noise}\} \quad\quad \{\text{Coast-by noise}\}
\]

• For $\geq 50$ mph, pavement/tire noise dominates.
FHWA - Noise Abatement Criteria

67 dB(A)

“this is not an absolute value or design standard, only a level where noise mitigation must be considered”
The Decibel Scale

Sound Pressure, N/sq. m.

Decibel Level

- Hearing Threshold
- Conversation
- Discomfort
- Pain Threshold

0 20 40 60 80 100 120 140

0.000001 0.00001 0.0001 0.001 0.01 0.1 1 10 100 1000
Increasing the decibel level by 10 doubles the noise intensity!

[Bar graph showing noise levels for Conversation (60 dB), Highway Traffic (70 dB), and Train (80 dB), Chain Saw (90 dB, 100 dB)]
What Can Be Done?

Erect Noise Walls or Plant Trees/Shrubs

Control Surface Texture
Noise Walls

Effective only for those in line-of-sight.

Do not reduce noise at source.
Noise Walls

- Effectiveness must justify expense.
- Cases:
  - I-40, Knoxville: >$25,000/home
  - I-285, Atlanta: Requirements of > 69 dB(A) and < $50,000/home
  - U.S. 441, West Boca, FL: > 67dB(A), <$30,000/home, reduction of > 5dB(A)
  - Nationwide (FHWA, 1998): >$1M/mile
Surface Texture

Conclusions, “In general, when dense-graded asphalt and PCC pavements are compared, the dense-graded is quieter by 2 to 3 dB(A)”
The Decibel Scale

67 dB(A)

50 ft
A reduction of 3 dB(A) is like doubling the distance from the noise.

$$67 \text{ dB(A)} - 3 \text{ dB(A)} = 64 \text{ dB(A)}$$
Conclusions: “In general, when dense-graded asphalt and PCC pavements are compared, the dense-graded is quieter by 2 to 3 dB(A)”

A 3dB(A) reduction corresponds to:
- doubling the distance
- reducing traffic volume by 50%
- reducing traffic speed by 25%
Conclusions: “Open-graded asphalt shows the greatest potential for noise reduction for pass-by noise. Reduction when compared to dense-graded asphalt ranged from 1 to 9 dB(A).”

A 9dB(A) reduction corresponds to:
- a reduction in traffic noise by almost 50%!
AR - OGFCs
Reduce Noise and Improve Visibility
Noise Reduction
Open vs Dense Graded Mixes

Source: NCHRP 284
What Can Be Done?

• DOTs indicate a strong need for pavement noise control strategies.

• Proper selection of pavement surface is the best method to reduce noise from pavement/tire interactions.
Effect of Pavement Surface

• OGFC is the quietest surface type. *(Wayson, NCHRP Synthesis 268)*

• SMA has also proven to be a quiet surface. *(Wisconsin DOT, 1993)*

• Dense graded HMA surfaces are quieter than PCC pavements. *(Hibbs and Larson, Report FHWA-SA-96-068, May 1996)*
Noise Makes News!

Families Near I-275 are lobbying the Michigan DOT for sound abatement. In 1999, MDOT rebuilt I-275 with concrete. Residents contend the project has increased noise levels. Levels have been registered upwards of 90 decibels.

Steve Phillips of Berkshire, England-based TRL Limited spoke about England’s 10-year plan to install quieter surfaces on 60% of main trunk roads. The surfaces will be SMA or OGFC.
Noise Reduction 101

Quiet, Please!
<table>
<thead>
<tr>
<th>Noise Source</th>
<th>Decibel Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thunder Clap, Live Rock Music, Chain Saw</td>
<td>120</td>
</tr>
<tr>
<td>Steel Mill, Riveting, Auto Horn (1M)</td>
<td>110</td>
</tr>
<tr>
<td>Jet Take Off, Lawn Mower, Jack Hammer</td>
<td>100</td>
</tr>
<tr>
<td>Busy Urban Street, Diesel Truck, Food Blender</td>
<td>90</td>
</tr>
<tr>
<td>Garbage Disposal, Dishwasher, Freight Train (15 M)</td>
<td>80</td>
</tr>
<tr>
<td>Freeway Traffic (15), Vacuum Cleaner</td>
<td>70</td>
</tr>
<tr>
<td>Conversation in Restaurant, Office, Background Music</td>
<td>60</td>
</tr>
<tr>
<td>Quiet Suburb, Conversation at Home</td>
<td>50</td>
</tr>
<tr>
<td>Library</td>
<td>40</td>
</tr>
<tr>
<td>Quiet Rural Area</td>
<td>30</td>
</tr>
</tbody>
</table>
Noise Facts

- Doubling the distance from the noise source = 3 dB decrease.
- 10 dB increase = Doubling the Loudness (80 dB is 2x as loud as 70 dB)
## Noise Reduction By Tire Design

### Asimmetrico

![Tire Image]

### Features
- Open inner shoulder takes up and expels surface water
- Continuous tread pattern in the outer shoulder
- Siping in the outer shoulder
- Asymmetrical tread geometry
- Optimum tread blocks
- "Y," "W," and "Z" speed rated

### Benefits
- Improved wet traction
- High cornering speeds
- Less rolling noise
- Good steering precision
- Reduces driving noise
- Rated for speeds up to 150-169 mph

---

Reduce Total comfort Sophisticated design
Hot Mix with Asphalt Rubber Binder Reduces Tire/Pavement Noise

• Open Graded Mix Design
  – Aggregate Structure
  – Porous Surface

• Binder Strength
  – Can Hold The Mix Together
  – Resists Oxidation Longer
Thin AR OGFCs used by ADOT on I-17 since 1990 with low maintenance costs ($250/lane-mile/yr).
## Recent Sound Studies

<table>
<thead>
<tr>
<th>State</th>
<th>County or City</th>
<th>Year</th>
<th>Noise Level Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arizona</td>
<td>Phoenix</td>
<td>1990</td>
<td>10 dB - (hot mix vs chip seal)</td>
</tr>
<tr>
<td></td>
<td>Tucson</td>
<td>1989</td>
<td>6.7 dB - (hot mix vs PCCP)</td>
</tr>
<tr>
<td>California</td>
<td>Sacramento County</td>
<td>1999</td>
<td>7.7-5.1 dB (Before and After, DGAC vs A-R OGFC)</td>
</tr>
<tr>
<td></td>
<td>Orange County</td>
<td>1992</td>
<td>3-5 dB (A-R OGFC vs DGAC)</td>
</tr>
<tr>
<td></td>
<td>Los Angeles County</td>
<td>1991</td>
<td>2-5 dB (A-R OGFC vs DGAC)</td>
</tr>
</tbody>
</table>
Noise Reduction After Repaving with DGAC
Sacramento Co. PW

- Before 1995
- 1 Mo After 1995
- 4 Years After 1999

Decibels dB
Noise Reduction After Repaving with A-R
Sacramento Co. PW

<table>
<thead>
<tr>
<th>Time</th>
<th>Decibels dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before 1993</td>
<td>69</td>
</tr>
<tr>
<td>1 Mo After 1993</td>
<td>66</td>
</tr>
<tr>
<td>16 Mos later 1995</td>
<td>64</td>
</tr>
<tr>
<td>6 Yrs later 1999</td>
<td>61</td>
</tr>
</tbody>
</table>
Analysis of Traffic Noise Emanating From U.S. 60 Before and After Paving With Asphalt-Rubber

Han Zhu, Ph.D.
Arizona State University Civil Engineering

Douglas D. Carlson
Rubber Pavements Association

Can Xiao
Arizona State University Civil Engineering

www.rubberpavements.org
“ADOT has also included rubber asphalt surfacing in this project as a pavement preservation strategy. Independent studies indicate a noise reduction up to 4.5 dBA using rubber asphalt surfacing providing additional noise reduction benefits.”
US 60 Noise Analysis Locations 180 meters West of Kyrene
US 60 Before
Residential Area
US 60 After
## US 60 After

<table>
<thead>
<tr>
<th>Location</th>
<th>Before</th>
<th>After</th>
<th>Decrease</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shoulder (15m)</td>
<td>79.8</td>
<td>72.6</td>
<td>7.2</td>
</tr>
<tr>
<td>Soundwall (30m)</td>
<td>76.6</td>
<td>67.1</td>
<td>9.5</td>
</tr>
<tr>
<td>Residential (120m)</td>
<td>51.7</td>
<td>45.6</td>
<td>6.1</td>
</tr>
</tbody>
</table>
Summary

• Highway noise is important to the public.
• Small changes in dB level are noticeable.
  – Decrease of 9 dB(A) reduces noise by 50%
  – Decrease of 3 dB(A) is like doubling distance
Summary

Noise walls can work, but:
  They are expensive.
  They don’t work in all types of terrain.
  Source of noise is still there.
Asphalt pavements can reduce noise at the source by up to 9 dB(A).
Summary

Asphalt pavements for noise reduction in order of effectiveness:

- OGFC
- SMA
- Dense-Graded HMA
Asphalt Rubber Pavements are Quiet