Benefits of Using On-Board Sound Intensity Measurements in Conjunction with Traditional Highway Noise Measurement and Analysis Procedures

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Outline

• Background
• Discussion of Sites and Results
  – Site 1: SR 85
  – Site 2: US 101
• Conclusions & Final Thoughts
• “Guidance on Pavement as a Noise Abatement Measure”, February 2016
  – Continues to restrict use of quieter pavement as a noise abatement measure under 23 CFR 772.
  – Encourages DOTs to research and construct quieter pavements when appropriate.
  – Allows for the use of pavement types other than TNM average pavement for the modeling of existing noise levels with FHWA approval.
Background – Caltrans Quiet Pavement Policy

• Chap. 1100 of Hwy Design Manual, May 2012
  – Encourages consideration of “emerging technologies intended to mitigate traffic noise at the source in order to minimize noise emanating from the highway.” Quieter pavement is listed as the only example

• TeNS, September 2013
  – Pavement Type is listed as a pertinent site condition that can be accounted for in the (existing) model.
  – Allows for optional calibration adjustments for various pavement types to account for otherwise unexplained differences between measured and predicted noise results.
Example Projects Described

• Site 1: SR 85 Express Lanes Project,
  – 33.7 miles, including portions of US 101
  – Lane addition, both directions

• Site 2: US 101 Express Lanes Project
  – 36.55 miles of Interstate
  – Lane conversion and conversion, both directions
SR 85 Express Lanes - Overview

• Existing: 2 mainline lanes + 1 HOV lane in each direction (NB & SB)

• Future: 2 mainline lanes + 1 HOT lanes in each direction (NB & SB)

• 33.7 miles, including portions of US 101

• 1-3% trucks, depending on segment
SR 85 Express Lanes – Project Limits

SILICON VALLEY EXPRESS LANES

LEGEND
- Phase 1: In Operation
- Phase 2
- Phase 3
- Phase 4
- Future Phases: TBD
- HOV Lane to HOV Lane Connector
SR 85 Express Lanes - Measurements

• Wayside Measurements (23 CFR 772 Methods)
  – Noise sensitive receptors included residences, parks, trails, schools, and churches
  – 10 long-term measurements (24-hr+)
  – 128 short-term measurements (20-min)
  – Additional modeled locations

• OBSI Tire/Pavement Noise Source Measurements
  – Survey method used
  – Outside lane of each direction of travel
  – Total of 70 NB sections and 70 SB sections
Bridge Decks and Structures
Generally Aged LT (107 to 108 dBA)

SR 85 Express Lanes – Pavement Examples

North of I-280
Aged LT PCC (~107 dBA)

SR 87 to I-280
Ground PCC
(103 to 104 dBA)

Monterey Rd to SR 87
NB: Newer Asphalt (~98 dBA)
SB: Older Asphalt (102 to 103 dBA)
SR 85 Express Lanes – Example NB Pavements

Sound Intensity Level, dBA vs. 1/3 Octave Band Center Frequency, Hz

- Northern Section Northbound
- Mid Section Northbound
- Southern Section Northbound
SR 85 Express Lanes – Example SB Pavements

![Sound Intensity Level Graph]

- **Northern Section Southbound**
- **Mid Section Southbound**
- **Southern Section Southbound**

**Y-axis:** Sound Intensity Level, dBA

**X-axis:** 1/3 Octave Band Center Frequency, Hz

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[Graph showing sound intensity levels across different frequencies for different sections of the SR 85 express lanes.]
SR 85 Express Lanes – OBSI Results

[Graph showing the measurement of overall sound intensity level (in dBA) along a road with various locations marked, such as I-280 NB, Bridge Deck, SR 17, Overpass, Bridge Decks, Aged LT PCC, Ground PCC, Older AC, Newer AC, TNM Average, and Southbound vs. Northbound.]
SR 85 Express Lanes - Conclusions

- OBSI survey method can help DOTs prioritize areas where quieter pavement might provide the greatest noise reductions
US 101 Express Lanes - Overview

• Existing: 3 mainline lanes + 1 HOV lane in each direction (NB & SB)

• Future: 3 mainline lanes + 2 HOT lanes in each direction (NB & SB)

• 36.55 miles of Interstate

• 4-10% trucks, depending on segment
US 101 Express Lanes – Project Limits

[Diagram of US 101 Express Lanes – Project Limits]
US 101 Express Lanes - Measurements

• Wayside Measurements (23 CFR 772 Methods)
  - Noise sensitive receptors included residences, golf courses, trails, hotels, schools, churches
  - 14 long-term measurements (24-hr +)
  - 153 short-term measurements (20-min)
  - Additional modeled locations

• OBSI Tire/Pavement Noise Source Measurements
  - Survey method used
  - Outside lane of each direction of travel
  - Total of 88 NB sections and 96 SB sections
US 101 Express Lanes – Pavement Examples

Segment 1
NB Various AC (Ave: 101 dBA)
SB Older PCC (Ave: 104 dBA)

Segment 2
NB & SB Various AC (Ave: 101 dBA)
Pavement changes from AC to PCC at over & under passes

Segment 3
AC Outer Lanes (Ave: 104 dBA), PCC Inner Lanes

*OBSI start points labeled in Red
US 101 Express Lanes – Example SB Pavements

The image shows a graph comparing sound intensity levels at different frequencies for three different pavement types: SB Segment 1 PCC Avg, SB Segment 2 Porous AC, and SB Segment 2 Non-porous AC. The graph plots sound intensity level against 1/3 octave band center frequency. The data indicates that the sound intensity levels vary significantly across different frequency bands, with SB Segment 1 PCC Avg showing the highest levels at lower frequencies, while SB Segment 2 Non-porous AC has lower levels overall.
US 101 Express Lanes – Example NB Pavements
US 101 Express Lanes – OBSI Results

Southern End

Rengstorff Ave
Moffett Blvd
I-880
Alum Rock Rd
SR 85

Inner PCC Lane (4 Points)

Tenant Ave

104.5 dBA

104.0 dBA

TNM Average

Northern End

SR 85
SR 87

100.3 dBA
100.7 dBA

Segment 1
Segment 2
Segment 3

Distance, miles

Sound Intensity Level, dBA

-4 -2 0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38

Northbound
Southbound
Background – OBSI Normalization

- OBSI Normalization based on NCHRP 10-76
  - Used experimental version of TNM by Volpe to account for pavements within TNM
  - TNM Average OBSI Level = 102.5 dBA
  - 1 dB OBSI change = \sim 0.8 dB Wayside level change

Normalization = (OBSI_{Meas.} - 102.5) \times 0.8
# US 101 Express Lanes – Simple Statistics

<table>
<thead>
<tr>
<th>Criteria</th>
<th>No. Improved</th>
<th>Total Number</th>
<th>% Improved</th>
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<tbody>
<tr>
<td>Total</td>
<td>90</td>
<td>157</td>
<td>57%</td>
</tr>
<tr>
<td>Model Higher</td>
<td>71</td>
<td>107</td>
<td>66%</td>
</tr>
<tr>
<td>Model Lower</td>
<td>19</td>
<td>50</td>
<td>38%</td>
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<tr>
<td>Prediction within 2dB of Measured</td>
<td>34</td>
<td>87</td>
<td>39%</td>
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<tr>
<td>Prediction NOT within 2dB of Meas.</td>
<td>56</td>
<td>70</td>
<td>80%</td>
</tr>
<tr>
<td>No Shielding</td>
<td>5</td>
<td>8</td>
<td>63%</td>
</tr>
<tr>
<td>Setback</td>
<td>16</td>
<td>38</td>
<td>42%</td>
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<tr>
<td>Adjacent to US 101</td>
<td>48</td>
<td>77</td>
<td>62%</td>
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<tr>
<td>Homogeneous Pavement, Near Lane</td>
<td>77</td>
<td>112</td>
<td>69%</td>
</tr>
<tr>
<td>Homogeneous Pave. Both Directions</td>
<td>69</td>
<td>101</td>
<td>69%</td>
</tr>
<tr>
<td>Homogeneous Pavement and Predictions NOT within 2dB of Meas.</td>
<td>52</td>
<td>55</td>
<td>95%</td>
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</table>
US 101 Express Lanes – Porous Pavement Results

Both Directions: Porous OGAC

Modeled - Measured Level, dB

- Non-normalized
- Normalized for Near Lane OBSI
• OBSI measurements helped explain differences between measured and modeled noise levels
• For areas with porous pavements, additional noise reduction is seen at wayside, not accounted for in TNM or with OBSI
• Lane-by-lane survey should be used, especially where pavement type or lanes usage vary.
• OBSI can help DOTs prioritize areas where quieter pavement might provide the greatest noise reductions
• OBSI can help explain differences between measured and modeled noise levels for purposes of model calibration when pavement levels vary from TNM Average
• Careful consideration should be made when using pavement type to calibrate existing levels, so that future predictions are representative of future conditions
• OBSI should be made for each lane of travel
• Use of a ‘moving average’ OBSI level would allow the correlation of a localized OBSI level for each wayside location
• Use of Volpe’s modified version of TNM (or the pavement options included in the regular TNM version) allow for pavement to be included in the model directly
• Thank you for your attention!

– Questions?