Reflections from Highway Noise Barriers and the Use of Absorptive Materials in the U.S.

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Presentation Overview

- A little history
- The Caltrans experience
- Other DOTs’ perspectives
- What’s going on?
- Some consequences and considerations
- How can TNM help?
A Little History

  - Community Reaction: Highway noise level $L(\text{Hwy})$ vs. Ambient level $L(\text{Amb})$
  
  Modified from 1969 Boeing Field study by Sawley and Gordon:

<table>
<thead>
<tr>
<th>$L(\text{Hwy})$ relative to $L(\text{Amb})$</th>
<th>Community Reaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>$L(\text{Hwy})$ less than $L(\text{Amb})$</td>
<td>No reaction</td>
</tr>
<tr>
<td>$L(\text{Hwy})$ 0 to 9 dB higher</td>
<td>No reaction to sporadic complaints</td>
</tr>
<tr>
<td>$L(\text{Hwy})$ 9 to 16 dB higher</td>
<td>Sporadic complaints to widespread complaints</td>
</tr>
</tbody>
</table>
A Little History

- Guidance from 1973 BBN-developed FHWA “Fundamentals and Abatement” training course:
  - Human response to sound level differences:
    - 0.5 dB – just barely detectable in laboratory environment
    - 2-3 dB – just detectable for “real-life sounds or noises”
    - 5 dB – readily noticeable
  - Receivers opposite the barrier (direct noise not blocked):
    - “Reflected noise increase usually not significant”
    - “Little benefit would be derived from making the barrier absorptive”
  - Similar language is repeated in 1980 FHWA Training Course
A Little History

- **1970s** – Multiple reflections recognized as potential problem, where barrier IL degradations may be large
- **Single reflections assumed okay** – increase <3 dB
- **Studies of multiple reflections from parallel barriers**
  - 1975 FHWA-sponsored BBN study – multiple reflections
  - 1980 Menge scale model study of sloped (tilted) barriers
  - 1982 Hayek parallel barrier study – analytical & empirical
  - 1987 Slutsky & Bertoni prediction procedure
  - Late 1980s – Anderson RAYverb model (later into TNM)
  - Early 1990s – Volpe Center parallel barrier studies, including the Dulles test barriers
- Volpe report resulted in FHWA guidance on width-to-height ratio – greater than 10:1 means <3 dB increase, so “acceptable”
1978 – Mas Hatano “Evaluation of Noise Barrier Reflection”

- Thanks to Bruce Rymer for much historical material!
The Caltrans Experience
1978 – Mas Hatano “Evaluation of Noise Barrier Reflection”

- Measured along same roadway opposite wall & no wall
- Covered walls with absorptive blankets
- Could not reliably measure any noise-level increases
- Increases must be <3 dBA, so “can’t be normally perceived from one day to the next”
1989 – Rudy Hendriks & Joe Hecker – Parallel Barrier Absorptive Demonstration Project

- Noise complaints after parallel reflective barriers built
The Caltrans Experience
1989 Parallel Barrier Absorptive Demonstration Project

- Sound-absorptive material added to opposite-side barrier in carefully-conducted demonstration project of parallel barriers
- Sound-level decreases measured 0 to 3 dB
- Conclusion: differences inaudible, so ineffective treatment
The Caltrans Experience

- 1998 – Rudy Hendriks – Technical advisory: Guidelines for studying the effects of noise barriers on distant receivers
  - Before and after noise barrier studies – detailed measurement methodology and documentation requirements
  - “A change of 3 dBA or less will be considered no change”
The Caltrans Experience
1999 URS/I&R/Caltrans – I-680 Before and After Barrier Study

LEGEND
- Noise Monitoring Station
- Meteorological Monitoring Station
- Existing Soundwall
- Planned Soundwall

Project No. 51-951039NC.00
I-680 Stone-Kemline Soundwall Study

METEOROLOGICAL AND NOISE MONITORING LOCATIONS

URS Greiner Woodward Clyde

Figure 2-1
- Detailed noise and meteorological measurements:
  - Several sites at different distances: 300 to 3000 ft
  - Behind and opposite the barrier
  - Under morning and nighttime conditions

- Measured 1 to 2 dB increases opposite the barrier, higher increase was farther away

- Increases not considered significant
The Caltrans Experience
1999 Woodward-Clyde/I&R/Caltrans – I-580 Abatement Study

Source: Woodward-Clyde, 1999
Progressive noise abatement treatments, including walls and absorbing panels

Detailed noise and meteorological measurements:
- Several sites behind the barrier
- Closest residence opposite the barrier
- Under morning and nighttime conditions

Measured 2 dB increase opposite the barrier

Absorption on retaining wall increased barrier IL from 3-4 dB to 5 dB
The Caltrans Experience

- **2001 – JSA/HMMH**
  U.S. 101, San Rafael
  - New noise barrier generated complaints on opposite side of highway, on a rising hillside.
  - Long-term noise monitoring at 8 community sites
  - Simultaneous monitoring of atmospherics
  - Investigation of candidate absorptive materials for retrofit
  - Investigation of potential quiet asphalt overlays
The Caltrans Experience
2001 JSA/HMMH – U.S. 101 Noise Study
- Installed absorptive panels
- Added open-graded asphalt overlay

Photo: Marin Independent Journal
News report in Marin Independent Journal, Jan 2010

“Patrick Murphy of San Rafael likes what he doesn't hear. Crews are finishing the installation of thousands of sound-absorbing panels as part of a $3 million retrofit of the existing Highway 101 soundwall to give area neighbors relief from freeway noise.”

"It's a significant change," said Murphy, who lives on Lincoln Hill in San Rafael and has lobbied Caltrans for more than a dozen years to improve the soundwalls. "The white noise that you hear is gone. What's missing is the 'shhhhh.'"
Other DOTs’ Perspectives

- Some DOTs started to specify sound-absorbing barriers opposite residential areas in the 1980s and 1990s.
  - Complaints from opposite-side residents
  - Caltrans’ experience
  - Recommendations from consultants
  - Post and panel construction made it affordable

- DOTs with current policy of specifying absorption opposite noise-sensitive areas:
  - Virginia DOT
  - New York State DOT
  - Massachusetts DOT

- Caltrans’ history with concrete block as primary barrier material – difficult to specify affordable absorption
What’s Going On?

- Human sensitivity to changes in noise levels and sound
  - 1947 JASA article by George Miller shows sensitivity to changes at less than 0.5 dB for broadband noise

Source: Harris, Handbook of Acoustical Measurements and Noise Control, 1991
What’s Going On?

- Whatever changes people hear are attributed to reflections from the new barrier built for the neighbors
  - Long-term familiarity with a noise environment may enable residents to perceive small changes in level of 1 dB or less
  - Audio listening tests: people can hear frequency shifts of as little as 0.1 dB – heard as a change in sound character
  - New propagation paths may change temporal character of vehicle pass-bys – truck pass-bys sound different
Some Consequences and Considerations

- People are hearing changes with new reflective barriers
  - Fairness in state policies – who “deserves” a barrier
  - “Barrier envy” may influence attitudes

- Accurate TNM has little safety factor in IL computation

- Loss of “insignificant” 1 or 2 dB in IL due to reflections can make barriers not attain minimum required 5 dB IL

- Which costs more: absorptive material or PR headaches, additional noise studies and lawsuits?

- Absorption can be cost effective depending on geometry
How Can TNM Help?

- TNM allows barriers to be specified as absorptive
  - Absorptive barriers in TNM provide up to 1 dB more IL than reflective barriers (at locations in shadow zone of treated barrier), but . . .
  - Single reflections currently not implemented in TNM
  - Must use “image roads” or other methods to correctly account for single reflections

- Parallel barrier module
  - Estimates degradation from multiple reflections
  - Helps predict benefits of absorptive barriers or different geometries
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