Performance of Roadside Sound Barriers with Sound Absorbing Edges

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Joint Transportation Research Program
Safe Quiet and Durable Highways

Sound Barriers

Diffracted path

Diffraction at the edge of the barrier

Straight path

Shadow zone

Traffic noise

Barrier

Receiver

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Example: Cantilevered barrier at Dordrecht, the Netherlands


Barrier Effectiveness

Each additional 1 m height = 1.5 dB(A) additional attenuation

Line of sight blockage = 5 dB(A)

from www.fhwa.dot.gov
Barrier Problem

Numerical Simulation
Rigid Barrier with Reflecting Ground
Metrics of Barrier Performance

- Noise Reduction (NR)
- Insertion Loss (IL)
- Transmission Loss (TL)

Insertion Loss

- Difference between the SPL's at the receiver without and with barrier

\[ IL = L_{p, \text{without}} - L_{p, \text{with}} \]
Motivation

- Highway sound barriers often used to solve community noise problems
- Barriers expensive (approx $20/ft^2 of barrier installed)
- Barrier performance and cost directly proportional to height
- Are there ways to enhance performance, reduce costs?
**Objectives**

- **Investigate relatively novel barrier concepts:**
  - non-uniform edge geometries
  - absorbing materials
- **Develop and validate boundary element method for sound barrier performance predictions**
  - Design optimization
- **Investigate new metrics to compare performance of different barrier concepts**

**Rationale**

- **Most existing models approximate: based on geometrical acoustics (“ray theory”)**
  - or semi-empirical
- **Model often not amenable to complex barrier shapes**
- **Comparing barrier at one single location introduces a bias**
- **Novel concepts and FEM models not new**
  - work still needed for assessment
Methods

- **Laboratory Experiments**
  - small barrier models in anechoic room
  - random and impulsive input signals
  - time windowing eliminate effects of spurious reflection
  - Fourier methods to calculate TF’s
- **Boundary Element Predictions**
  - LMS Sysnoise (MSC Patran pre-processor)
  - Indirect variational method
- **Field Measurements**
  - Full scale tests on actual barrier

Novel Concept:
Sound Absorbing Barrier Top
Laboratory Experiments

- Scaled Model (1:10)
- Initial Assessment of Novel Concept Performance

Barrier configurations

- i) Rigid linear extension
- ii) Rigid T-shape
- iii) Sound absorptive treatment (soft top)
Microphone Locations

Dimensions in cm

Experimental setup
Local insertion loss comparisons

• Insertion Loss with Sound Absorbing Top Better
• Varies with Receiver Location

Insertion loss distribution at 6300 Hz (1/3 octave band)
Spatially-averaged insertion loss

Shape Optimization
Space-averaged insertion loss

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QUASH

• closed-cell foam made of polyolefin
• good sound absorption at low and medium frequencies
• does not absorb water as much as conventional materials like fibers, polyurethane foams, and melamine foams
• UV tolerant
• Performance comparable to that of Fiberglas, depending on frequency
### Space-averaged insertion loss

![Space-averaged insertion loss graph](image)

**Conclusion from Scaled Model Studies**

- The Addition of Sound Absorbing Materials on Barrier Top Improves Performance
- Advantage over other design concepts
- Shape of the “soft top” has an effect on the barrier performance
- Circular shape optimal
- Use of QUASH promising for outdoor implementation
On-site measurements

- Preliminary measurements at three locations
- Measurement site: east of York Rd. and on the south side of bypass in South Bend, IN
- Chosen for relatively level, grassy terrain, distant from residential and commercial buildings
- Measurements were done before and after the absorptive material installation to evaluate the effectiveness of add-on device

Map of the measurement site

- Community park
  - Fairly large open space
  - Grass covered
  - Nearby Residents
  - Existing barrier gaps
### Instrumentation

- Four Bruel & Kjaer 12.6 cm (½ in.) microphones (Type 4089 and 4090)
- Bruel & Kjaer Pulse analyzer (1 hour one-third octave band measurements)
- Davis Weather Wizard III weather station (direction and speed of the wind and temperature)
- Traffic classifier (numbers and average speeds of cars, mid-size and heavy trucks over one hour)

### TNM simulations

- TNM: “Traffic Noise Model”, available from the Volpe Center, commissioned by FHWA
- Goal to approximate SPL from existing barrier to assess benefits from barrier attachments
- Geometry of simulation input from road plan giving grade and curvature, as well as dimensions of wall
- Traffic density data obtained using a traffic classifier
Measurement locations (top view)

- Roadside
- 1st barrier: 5.5 m, 6.1 m
- Reference microphone
- 2nd barrier
  - Microphone 1: 7.5 m
  - Microphone 2: 15 m
- Microphones

TNM Model

- Westbound
- Eastbound
- Reference microphone
- Microphone 1
- Microphone 2
- Microphone 3
- Grass-covered ground

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### Measured traffic data (8/31/02)

<table>
<thead>
<tr>
<th>Type of vehicles</th>
<th>1 PM – 2 PM</th>
<th>2 PM – 3 PM</th>
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<tr>
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<tr>
<td>Cars</td>
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<td>780</td>
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<td>95.6 kmph</td>
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<tr>
<td>Mid-sized trucks</td>
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<td>17</td>
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<tr>
<td></td>
<td>88.8 kmph</td>
<td>90.0 kmph</td>
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<tr>
<td>Heavy trucks</td>
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<td></td>
<td>95.0 kmph</td>
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<tr>
<td>Mid-sized trucks</td>
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<tr>
<td></td>
<td>95.3 kmph</td>
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<tr>
<td>Heavy trucks</td>
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<td>47</td>
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<tr>
<td></td>
<td>90.0 kmph</td>
<td>96.6 kmph</td>
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</table>

### A-weighted overall sound pressure level

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</thead>
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<td>Measured</td>
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<td>Reference Microphone</td>
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<td>75.3 dBA</td>
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<td>Microphone 2 (15 m)</td>
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<tr>
<td>Microphone 3 (30 m)</td>
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<tr>
<td></td>
<td>57.8 dBA</td>
<td>54.8 dBA</td>
</tr>
</tbody>
</table>

- TNM under-predicts SPL by 1 dB to 3 dB
- complex terrain, atmospheric factors possible reasons
Treatment of barrier gap

- **Horizontal edge treatment (initial plan)**

  ![Diagram of horizontal edge treatment]
  Requiring at least 100 m long treatment for the receiver at 25 m

- **Vertical edge treatment (final plan)**

  ![Diagram of vertical edge treatment]

Receiver location selection

- **Two diffraction paths: over the top and around the edge**

  ![Diagram showing two diffraction paths]

- **Receiver locations chosen where diffraction around vertical edge dominates**

  ![Diagram showing receiver locations]

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Measurement locations

roadside

1st barrier

5.5 m

6.1 m

reference microphones

absorptive treatment

microphones 1 2 3

5 m

2nd barrier

7.5 m

Picture of the Site
Design of add-on treatment

- Polyolefin plastic foam or QUASH

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Picture of Modified Barrier

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Absorptive treatment is more effective deeper in shadow zone.

Measurement results
Summary of Road Tests

- On-site preliminary measurements were performed
- The sound absorbing edge concept was effective at high frequencies
- A larger installation is required for more rigorous investigation

BEM Model Validation:
Straight rectangular barrier
**Experimental validation**

- *BEM models accurate*
  - more accurate than diffraction based models

- *Detailed experiments challenging even in controlled laboratory conditions, with*
  - known input signals
  - minimal environmental effects
  - high precision instrumentation
  - lots of post-processing

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**Effects of Complex Geometries**

uni-radial | bi-radial | tri-radial

Surface in shadow region

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Effects of Complex Shapes: Sound power over the shadow region

Conclusions

- **BEM models accurate**
  - allow design optimization for complex designs
- **Irregular top shapes don’t affect sound power in shadow region**
- **T-shaped barriers moderately better than straight barriers (for equivalent quantities of material)**
- **Benefits of absorbing material on barrier top verified in laboratory and on-site!**
  - no models yet
  - further work needed for concept to be implementation-ready