Directional Rumble Strips for Reducing Wrong-Way Driving Freeway Entries

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Objectives

- To Conduct Feasibility Study of Directional Rumble Strips for Preventing Wrong-Way Entries on Freeway Exit Ramps

- About 360 Fatalities Per Year Caused by Wrong-Way Driving.

- Most of WWD Found to Enter From Exit Ramps
Tasks

- Literature Review (Completed)
- Conceptual Designs (Completed)
- Field Testing In-vehicle Sound and Vibration Analysis (50% Completed)
- National Survey (40% Completed)
- Effectiveness Evaluation
- Design Guidelines
Initial Field Tests in Illinois

- Shoulder Rumble Strips on I-270, I-55
- Passenger car: Volkswagen Jetta
- Speed: 10 mph to 60 mph at an 10 mph increment
- iTestMic and 3-axle accelerometer
Initial Field Tests in Alabama

- 8 Locations, 3 types of Transverse Rumble Strips
- Passenger car: Ford
- Speed: 10 mph to 60 mph at an 10 mph increment
- Sound Level Meter & 3-axle Accelerometer

Extech HD600
Measurement Specialists 35201A
## Configurations of tested TRS

<table>
<thead>
<tr>
<th>Sites</th>
<th>Location</th>
<th>Speed limit (mph)</th>
<th>Raised or Grooved</th>
<th>Number of sets</th>
<th>Strips in each set</th>
<th>Total Length (ft)</th>
<th>Length (ft)</th>
<th>Width (in)</th>
<th>Spacing (in)</th>
<th>Thickness (in)</th>
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<tbody>
<tr>
<td>1</td>
<td>AL147</td>
<td>40</td>
<td>Raised</td>
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<td>Raised</td>
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<td>6.2</td>
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<td>Raised</td>
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<td>9</td>
<td>6.0</td>
<td>8.0</td>
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<td>4</td>
<td>US280</td>
<td>65</td>
<td>Raised</td>
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<td>5</td>
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<td>23.5</td>
<td>5.5</td>
<td>10.60</td>
<td>0.08</td>
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<td>5</td>
<td>US280</td>
<td>65</td>
<td>Raised</td>
<td>5</td>
<td>5</td>
<td>6.60</td>
<td>24</td>
<td>6.20 on 8.80</td>
<td>9.65</td>
<td>0.06 +0.06</td>
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<td>5</td>
<td>5.60</td>
<td>23.5</td>
<td>6.3</td>
<td>9.05</td>
<td>0.06</td>
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<td>7</td>
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<td>Raised</td>
<td>5</td>
<td>5</td>
<td>5.60</td>
<td>23.0</td>
<td>6.3</td>
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<td>Raised</td>
<td>5</td>
<td>5</td>
<td>5.60</td>
<td>23.0</td>
<td>6.3</td>
<td>9.05</td>
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<td>DOT Documents</td>
<td>-</td>
<td>6–25</td>
<td>-</td>
<td>6.6–12</td>
<td>4–6.1</td>
<td>4.5–18</td>
<td>0.3–0.625</td>
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</table>
Mechanical Model

Newton-Second Law: \[ m \ddot{x} + b \dot{x} + k x = b \ddot{y} + k y \]

Displacement of the tire \( y \)

\[
\begin{align*}
y = \frac{h}{l_1} (v(t - t_0^{(2i)}) + l_1) \\
y = -\frac{h}{l_2} (v(t - t_0^{(2i+1)}) + l_2)
\end{align*}
\]

\[ i = 0, 1, 2, ..., k, .... \]

and

\[
\begin{align*}
\dot{y} = \frac{h}{l_1} v \\
\ddot{y} = -\frac{h}{l_2} v
\end{align*}
\]

\[ i = 0, 1, 2, ..., k, .... \]

A simple-degree-of-freedom spring-mass-damper system

Draft graph for potential DRS
Conceptual Designs

• Pattern 1

• Pattern 2

Image: Advanced Traffic Markings (ATM)
Conceptual Designs

• Pattern 3

• Pattern 4

Image: EVONIC INDUSTRIES

Image: Platelocks Inc.
Vendor Survey

Directional Rumble Strips Feasibility and Design Survey

This survey is in support of the research project “Directional Rumble Strips for Reducing Wrong-Way Driving Freeway Entries,” a study conducted by Auburn University and Southern Illinois University-Edwardsville and funded by the University Transportation Center (UTC) Region 5 through the University of Minnesota. The purpose is to conduct feasibility studies of different conceptual designs for the directional rumble strips (DRS) and develop a new safety countermeasure for wrong-way driving on exit ramps.

Birmingham, Alabama

Mobile, Alabama

The DRS is a variation of transverse rumble strips (TRS, also named in-lane rumble strips). When vehicles roll over the rumble strips from either direction, the conventional TRS provides motorists with the same levels of sound and vibration. The DRS is designed to generate elevated noises and vibrations to warn wrong-way drivers and normal noises and vibrations to slow down the traffic for the right-way direction when they are approaching exit ramp terminals.
Vendor Survey

Type A

This design consists of five strips with 6.16 feet of spacing along the driving direction. The width of each strip is 20 inches. Two different components are installed on the angled panel. A raised wedge is about 8 inches in length, which provides a smooth transition for vehicles traveling in the right direction. This is followed by the application of four semicircular raised bands with a maximum height of 0.6 inches (or more) above pavement. For the wrong-way drivers, the height and the suddenness of the bands could generate haptic warning signals.

- Absolutely Inappropriate
- Inappropriate
- Somewhat Inappropriate
- Neutral
- Somewhat Appropriate

Type B

A 0.25-inch pavement marking strip is placed first and is followed by a 0.5-inch pavement marking strip. The height of the strips gradually increases to 1 inch by combining different thicknesses of tapes. A more aggressive pattern may be made to increase the haptic signals, such as stacking a 0.25-inch pavement marking strip on top of the 1-inch pavement marking strip. The strips in each set are 6 feet apart to generate the best variation in signals.

- Absolutely Inappropriate
- Inappropriate
- Somewhat Inappropriate
- Neutral
- Somewhat Appropriate
- Appropriate
- Absolutely Appropriate
Vendor Survey

Question 3: Please rate the properties of the DRS by 1-5 scale based on your expectation of their potential to reduce wrong-way driving.

Note:
1=Low Priority;
2=Low-Medium Priority;
3=Medium Priority;
4=Medium-High Priority;
5=High Priority

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<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimum dimensions (e.g., length, width, depth, spacing)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Visual attentiveness (e.g., retro-reflecting properties and coloring)</td>
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<tr>
<td>Minimum level of stimuli (i.e., sound or vibration) necessary to alert inattentive drivers</td>
<td></td>
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</tr>
<tr>
<td>Impact of noise produced by rumble strips on adjacent residents</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Effect on pavement performance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Effect on maintenance</td>
<td></td>
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</tbody>
</table>

Question 4: Does your agency have any product or applications that could work as the DRS for exit ramps?

- Yes (please describe)
- No

Question 5: Do you have any ideas or suggestions about the DRS? If available, please also provide materials you are going to use and the estimated cost.

May we have the name, e-mail, and phone number of the contact person involved in rumble strips design, manufacture, and application in your agency? Or could you recommend us to a person to contact for conceptual design so that we may obtain additional information?
Effectiveness Evaluation

Field Test for Pattern 1
- Acceptable sound and vibration with comparison to current TRS
- z-axis largely affected by the DRS with a max acceleration of around 1.5(g)
- Not enough difference in both directions

![Field Test Image]

Sound Level in Frequency Domain
Vibration of travelling in right direction
Vibration for wrong direction
Effectiveness Evaluation

Field Test for Pattern 2

- The stripes all 7 feet long with 0.25, 0.5, 0.75, and 1 inches different thickness
- 3 different interval distance
- Different speeds of 30 mph, 35 mph, 40 mph, 50 mph
- Tested on both directions 3 times
Next Steps

- National Survey Analysis
- Effectiveness Evaluation of Conceptual Designs
- Further Field TRS Tests
- Optimized DRS Design and Guidelines
Thank you!