Sound Advice for Mitigating Roadside Rumble Strip Noise Levels

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Rumble Strips

- Rumble strips are a safety device created by milled or raised roadway patterns
- Primary function is to elevate noise and vibration levels inside a vehicle cabin to warn drivers when their vehicle has departed from the normal wheel path within a lane
- Typically placed along the centerline, edge line, or shoulder of two lane roadways but can also be applied to multi-lane facilities

Rumble Strips

- Wayside noise generated by rumble strips has increasingly become a concern for the public
- Noise concerns are primarily an issue on rural highways where traffic volumes are relatively low
- Proposals to add rumble strips to rural highways are being met with opposition by neighbors because of noise
- Caltrans is under pressure to respond to public criticism of rumble strip safety projects and we need to think critically about how rumble strip noise levels can be mitigated

Rumble Strips

- In addition most traffic safety engineers have little or no understanding of highway acoustics
- Caltrans is developing a technical advisory:
  - provide acoustic-related guidance for design engineers to reference
  - to provide them with a menu of options to consider for mitigating rumble strip noise
- This presentation discusses these potential noise mitigation strategies
- Builds upon the presentation rumble strip research that Bruce Rymer and Paul Donavan gave at the 2016 ADC40 meeting in Montana

Mechanics of Warning Device Tire/Pavement Interaction

- Raised pavement makers (RPMs or Botts Dots) create a very positive texture (above grade) that punches the tire and elevates noise levels.

Mechanics of Warning Device Tire/Pavement Interaction

- The standard Caltrans grind rumble strip pattern also has a transverse texture element to it that we know from quiet pavement studies is an inherently louder pattern.
- Transverse textures are oriented perpendicular to tire movement and typically also punch the tire and elevate noise levels.

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Mechanics of Warning Device Tire/Pavement Interaction

- Sinusoidal pattern or “mumble strip”
- The sinusoidal pattern is below grade and has a rounded shape that follows the radius of a typical passenger car tire and punches it less and this helps to reduce exterior noise levels.

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Key Design Parameters for Mumble Strips

- Lower roadside noise levels
- Maintain or increase interior sound and vibration levels
- Minimal disturbance to vehicle dynamics
- Bicycle friendly
- Fit within roadway cross-section
- Limit depth of material removal
- Cost effective
- Easy to construct

Key Design Parameters for Mumble Strips

- The idea for this sinusoidal rumble strip “mumble strip” combines concepts initiated in European studies, General Motors sound and vibration work, and Caltrans’ quieter pavement studies
- Dr. Paul Donavan of Illingworth and Rodkin developed an optimal shape for the sinusoidal rumble strip profile based upon tire geometry, tire dynamics, and typical light vehicle response functions
- The goal achieved by the sinusoidal rumble strip was to maintain or elevate interior noise and vibration levels and reduce exterior pass-by noise levels

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Rumble Strip Noise Mitigation Strategies

- Strategy 1 – Mumble Strips
- Strategy 2 - Rumble Strip Setback
- Strategy 3 – Combine 1 and 2
- Strategy 4 - Lower Potential for Rumble Strip Strikes
- Strategy 5 – Horizontal Curves
- Strategy 6 – Short walls or berms

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Strategy 1 – Mumble Strips

1. Lower roadside noise levels at the rumble strip source by installing a quieter sinusoidal “mumble” strip

Strategy 1 – Mumble Strips

- In 2012, mumble strips following the recommended design were installed by Caltrans District 1 in Humboldt County along US Highway 101
- These mumble strips were evaluated for exterior noise and interior disturbance
- Conventional warning devices, specifically, ground rumble strips and pavement markers, also were evaluated

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Strategy 1 – Mumble Strips

Ground rumble strip

Raised marker

Mumble strip

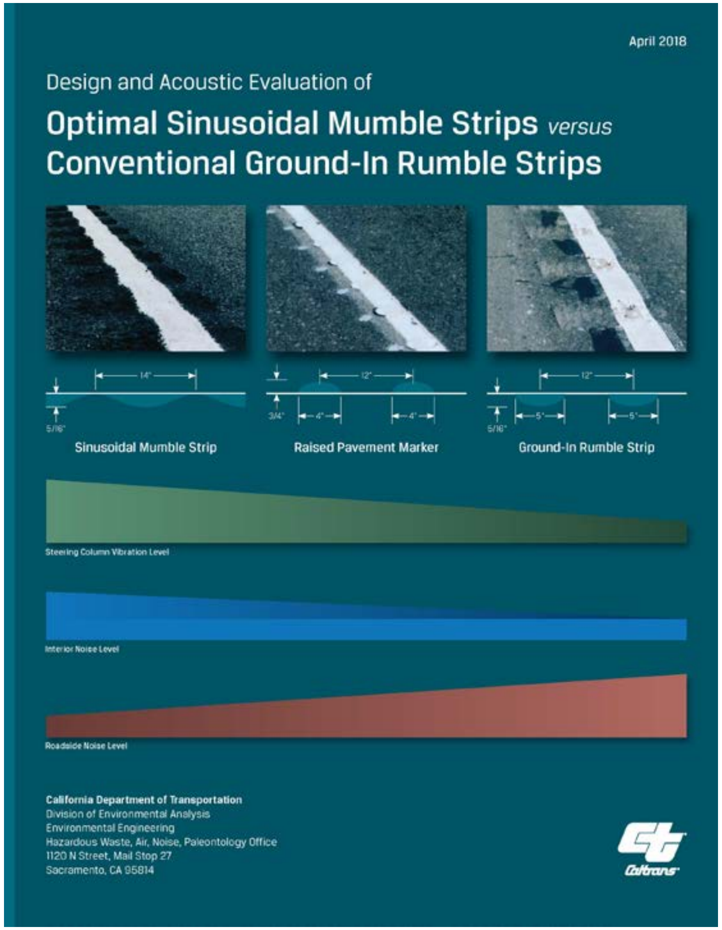
Strategy 1 – Mumble Strips

- Measured with vehicle traveling at 60 mph:
  - Exterior pass-by noise at 25 feet
  - interior noise
  - vibration levels on the seat track and on the steering column
- Later, a fifth vehicle was tested in the same manner with the addition of on-board sound intensity and body panel vibration measurements

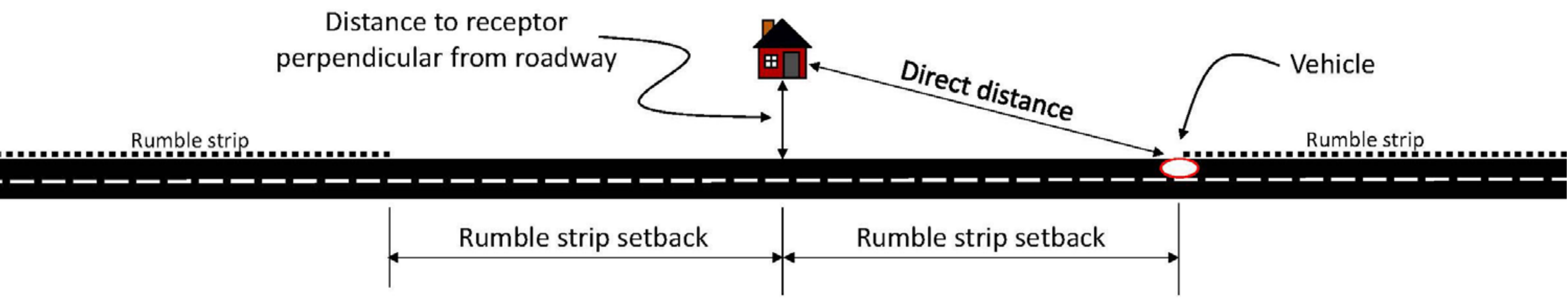
Strategy 1 – Mumble Strips

- Relative to conventional warning devices, mumble strips reduced the overall A-weighted exterior noise levels by about 6 decibels for four different types of passenger vehicles
- Interior disturbance levels created by the mumble strips were generally comparable or better than those generated by the ground rumble strips

Strategy 1 – Mumble Strips



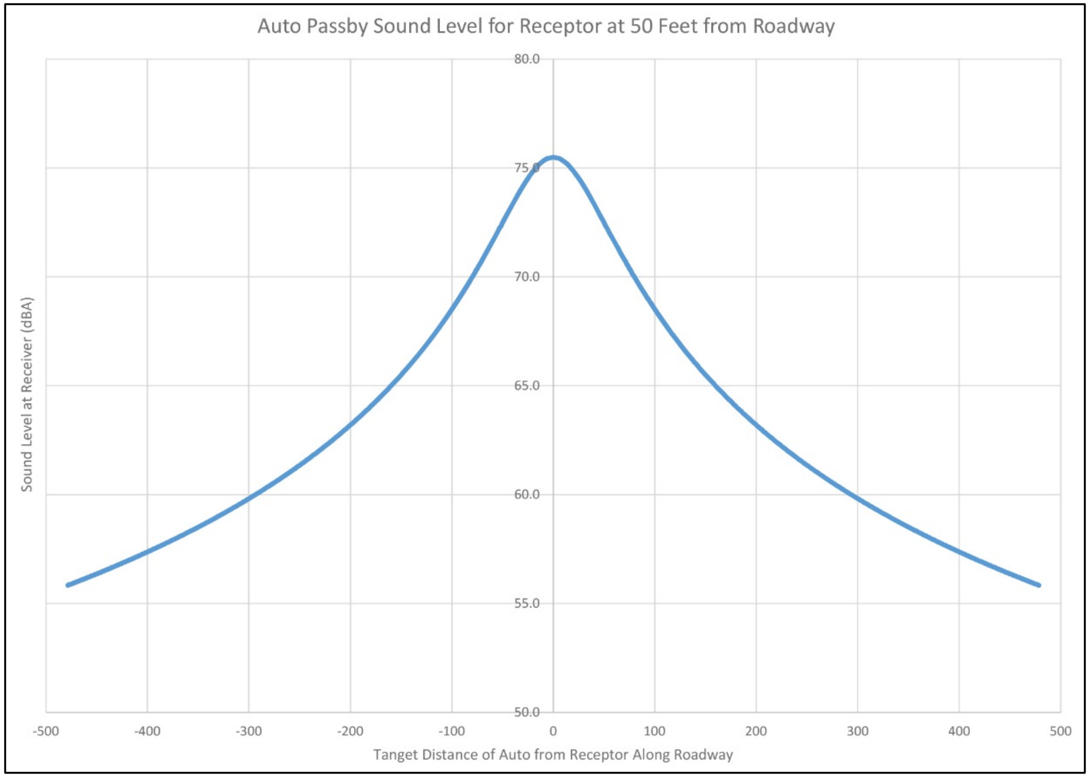
Strategy 2 - Rumble Strip Setback



Strategy 2 - Rumble Strip Setback

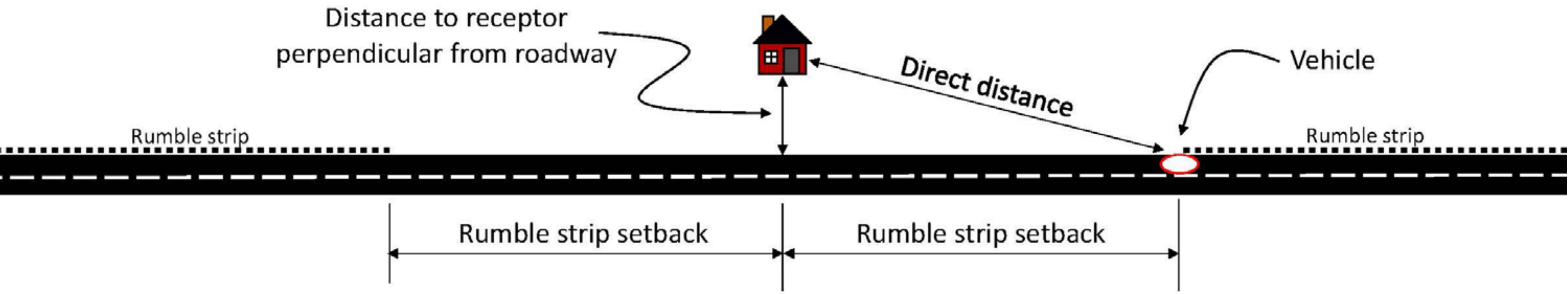
- In April 2015 FHWA has published a guidance document entitled “Rumble Strip Implementation Guide: Addressing Noise Issues on Two-Lane Roadways
- This guide states that studies conducted in Minnesota have shown that:
  - when rumble strips end approximately 650 feet prior to residential or urban areas, the noise impacts are tolerable
  - at a distance of 1,640 feet, the noise generated from rumble strips is negligible

Strategy 2 - Rumble Strip Setback



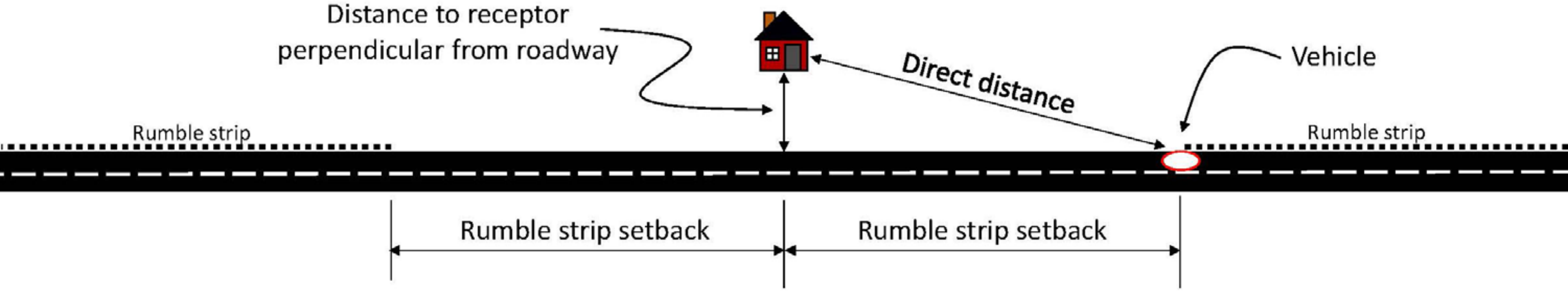
75.5 dB Lmax at 50 feet and 60 mph for auto on “average pavement”

Strategy 2 - Rumble Strip Setback



- Average rumble strip passby Lmax is about 12.6 higher than auto passby Lmax on average pavement
- Rumble strike is a point source so calculate the distance at which the rumble strip strike sound level is equal to the auto passby
- Simple hard site point source calculation
  - Direct distance/Distance to receptor = $10^{(12.6/12)}$ = 4.3

Strategy 2 - Rumble Strip Setback



Rumble Strip Type	Direct Distance Factor*
Standard – hard site	4.3
Standard – soft site	3.1
Mumble – hard site	2.0
Mumble – soft site	1.7

*Direct Distance/Distance to Receptor

Strategy 2 - Rumble Strip Setback

Distance to Receptor	Setback from Receptor (4.3 hard site factor)
50	215
100	430
150	645
200	860
250	1075
300	1290
350	1505
400	1720
450	1935

~ “tolerable”

Strategy 3 – Combine 1 and 2

Apply mumble strips and setbacks

Distance to Receptor	Setback from Receptor (2.0 hard site factor)
50	100
100	200
150	300
200	400
250	500
300	600
350	700
400	800
450	900

Strategy 4 - Lower Potential for Rumble Strip Strikes

- Limit or eliminate installations where maneuvering traffic and driver decision points are made:
  - through commercial/town centers,
  - bordering two-way left turn lanes,
  - high volume turning areas,
  - driveways

Strategy 5 – Horizontal Curves

- Place rumble strips beyond off-tracking vehicle wheels around horizontal curves if space and traffic safety considerations allow

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Strategy 6 – Short walls or berms

If space allows and cross sectional geometry facilitates it, install a low height noise barrier, either a solid barrier, or a landscaped berm, between the rumble strips and the receptor

Questions