

VIRGINIA DEPARTMENT OF TRANSPORTATION

LOCATION AND DESIGN DIVISION & TRAFFIC OPERATIONS DIVISION

INSTRUCTIONAL AND INFORMATIONAL MEMORANDUM

GENERAL SUBJECT: Rumble Strips and Rumble Stripes	NUMBER: IIM-LD-212.7 IIM-TE-368.1
SPECIFIC SUBJECT: Continuous Pattern: Shoulder Rumble Strip Centerline Rumble Stripe Intermittent Pattern: Shoulder Rumble Strip Shoulder Rumble Stripe	DATE: September 2, 2022
	SUPERSEDES: IIM-LD-212.6 IIM-TE-368.0
LOCATION AND DESIGN DIVISION APPROVAL: Emmett Heltzel, P.E. State Location and Design Engineer Approved September 1, 2022	TRAFFIC OPERATIONS DIVISION APPROVAL: Raymond J. Khoury, P.E. State Traffic Engineer Approved September 2, 2022

Changes are shaded.

CURRENT REVISION

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- This memorandum has been rewritten to provide additional options and guidance for the applicability of Rumble Strips and Rumble Stripes, including direction on how to address common design and locational issues and the addition of sinusoidal rumble strips and stripes.
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EFFECTIVE DATE

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- This memorandum is effective upon receipt.
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BACKGROUND

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- A Roadway Departure crash occurs after a vehicle leaves its travel lane and crosses an edge line, edge of pavement, or center line and collides with another vehicle or a fixed object or the vehicle overturns.

- Roadway Departure crashes are frequently severe and account for the majority of highway fatalities in the United States (51% of traffic fatalities – annual average of 19,168 – in the US between 2016 and 2018, according to FHWA).
- Over half of traffic fatalities and nearly 40 percent of serious traffic injuries in Virginia involve Roadway Departure crashes (about 420 deaths and 2870 serious injuries per year according to the Virginia 2022-2026 Strategic Highway Safety Plan).
- Rumble Strips and Stripes are cylindrical or sinusoidal grooved patterns milled into roadway or shoulder pavement that alert drivers through detectable noise and vibration when a vehicle's wheels leave the travel lane. Rumble Stripes are similar to Strips with the exception that for Stripes the pavement marking (Centerline or Edge Line) is installed *within* the groove.
- Rumble Strips and Stripes are one of the most effective engineering countermeasures available that reduce roadway departure crashes.
- Rumble Strips and Stripes have a demonstrated roadway departure crash reduction of typically 35-50 percent, with some situations having higher crash reductions. For FHWA reference documents on Roadway Departure treatments including grooved rumbles and their effectiveness, see http://safety.fhwa.dot.gov/roadway_dept/ and <http://www.cmfclearinghouse.org/>.
- NCHRP Report 641 (http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_641.pdf) provides information on various state design practices and published evaluation studies at the time.
- Sinusoidal rumble strips produce comparable vehicle interior noise levels and vibrations to cylindrical strips but reduce vehicle exterior noise levels by as much as 6dBA. Such noise reduction is equivalent to doubling the distance between the noise source and the receptor. California, Oregon, Minnesota, and Indiana have researched sinusoidal rumble strips, and several states are implementing them, including Virginia, which has approved special designs for several installations in recent years.

POLICY FOR USE OF RUMBLE STRIPS AND RUMBLE STRIPES

- Rumble Strip(e)s are to be provided on new and existing roadways in accordance with this memorandum, the current edition of the [Road and Bridge Standards Section 300](#), and as recommended by the Project Design Engineer and approved by the District Traffic Engineer in consultation with the Resident Administrator and District Bicyclist and Pedestrian Coordinator. Rumble Strip(e)s are highly recommended safety countermeasure for mitigating roadway departure crashes on roadways that do not have adequate shoulder or clear zone width.
- Rumble Strip(e)s may be either “Continuous” or “Intermittent” and are applicable as shown in Table 1.

- Rumble Strip(e) installation on the outside (right) shoulder of Non-Controlled Access roadways shall use an “Intermittent” groove pattern to provide gaps between the milled grooves for cyclist comfort and maneuverability when transitioning from one side of the grooves to the other. The Project Design Engineer, in consultation with District Traffic Engineer and District Bicyclist and Pedestrian Coordinator, may insert a Special Provision and contract language to install continuously milled rumble strip(e)s on a case by case basis if the location warrants.
- Sinusoidal rumble strip(e)s have design standards, designated as RS-7 to 10 in Table 1, that may be installed in noise sensitive areas.

TABLE 1 – RUMBLE STRIP AND STRIPE PATTERNS AND APPLICATIONS				
STANDARD (Note 1)	FUNCTIONAL CLASSIFICATION	ROADWAY (Notes 2 and 3)	LOCATION	PATTERN
RS-1 / RS-7	Interstate Freeway Expressway	Fully-Controlled Access – Divided (with median)	Median and/or Outside Shoulder	Continuous
RS-4 / RS-9 RS-5 / RS-10	Arterial Collector Local	Partially- and Non-Controlled Access - Divided (with median)	Median Shoulder	
RS-3 / RS-8		Partially- and Non-Controlled Access – Undivided (or with flush medians)	Centerline	
RS-4 / RS-9 RS-5 / RS-10 RS-6		Partially- and Non-Controlled Access – Divided or Undivided (with or without median)	Outside Edge Line or Shoulder	Intermittent

Note 1	RS-1 through RS-6 are cylindrical rumble grooves, while RS-7 through RS-10 are sinusoidal rumble grooves. RS-2 designation has been removed and is no longer used.
Note 2	VDOT classifies a roadway segment with two-way center left lanes as a “divided roadway with flush median”.
Note 3	For information on “Fully-Controlled Access”, “Partially-Controlled Access” and “Non-Controlled Access”, see the AASHTO Green Book, Chapter 2.

- Rumble Strip(e)s are **not** appropriate for bridge decks, surface drainage structures, railroad crossings, marked crosswalks, intersection areas, or other areas identified by the District Traffic Engineer in consultation with the Resident Administrator.
- Standalone Rumble Strip(e) installation projects shall follow all environmental legislation and regulation and may require a Programmatic Categorical Exclusion (PCE). The District Environmental Section shall participate in project scoping and identify documented resources and environmental issues. However, Rumble Strip(e) within a paving or shoulder project would be covered by the overall project SWPPP and ESC Plans and regulations as specified in in the Contract Documents. Hence, there are no separate or specific permits for the Rumble Strip(e) operation.
- Standalone Rumble Strip(e) installation projects shall conform to Location and Design storm water and erosion sediment control requirements in consultation with District Environmental and Hydraulics following the most recently issued subject [I&IMs](#).

- The sequence of rumble groove installation (milling), with respect to pavement markings and markers installation, shall be determined by the contractor and approved by the Engineer. All marking and marker specification and standards shall be followed and quality controlled by the Engineer.
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CRITERIA FOR DETERMINING USE OF RUMBLE STRIPS AND RUMBLE STRIPES

- Rumble Strip(e)s are appropriate for new rural freeway, expressway, arterial, collector, and local roadway segments that are being constructed or for existing roadways, particularly those being resurfaced or reconstructed, with adequate pavement condition for mill in place installation.
- Sinusoidal Rumble Strip(e)s are appropriate for both rural and for urban roadway classifications. For example, Rumble Strips (RS-1) and Sinusoidal Rumble Strips (RS-7) are appropriate for rural interstates and Sinusoidal Rumble Strips (RS-7) are appropriate for urban interstates or rural designated areas with adjacent noise sensitive land uses.
- The responsible District Traffic Engineer will verify that Rumble Strip(e)s are an appropriate measure through an engineering study documented in the project files and will select the standard to be used through consultation with the Resident Administrator, District Maintenance Manager, and District Materials Engineer, and District Bicyclist and Pedestrian Coordinator. The following factors should be considered when determining and prioritizing both the appropriateness and feasibility of roadways for Rumble Strip(e) installation and the utilized standard:
 - 3 to 5-year history of Roadway Departure crashes, physical evidence of crashes, or potential for future crashes.
 - Roadway geometry (horizontal alignment, lane and shoulder widths, roadway access, roadside design) and continuity along a route corridor or segment.
 - Traffic volumes (AADT) and percent heavy vehicles; existing or expected bicycle travel.
 - Design Speed / Posted Speed.
 - Pavement conditions (depth and existing quality).
 - Roadway Functional Classification / type of facility.
 - Adjacent land use.
 - Traffic Control Devices, e.g., lane markings, present or planned.
- In general, first priority should be given to higher-speed routes with higher traffic volumes and a history of, or potential for, Roadway Departure crashes.

POLICY FOR RUMBLE STRIPS AND STRIPES FOR TRAVEL LANE & PAVED SHOULDER WIDTHS

- When evaluating travel lanes and paved shoulders for the application of centerline and/or shoulder Rumble Strip(e)s, the following items shall be considered:
 - Minimum of 4-inch travel lane pavement thickness and sufficient condition determined by the District Materials Engineer to effectively accept the groove milling process without raveling or deteriorating. Otherwise, the travel lane pavement should be upgraded prior to milling the rumbles. See the most recent Road and Bridge Specifications Section 315 for other pavement coating with emulsion considerations.
 - Minimum of 2-inch shoulder pavement thickness and sufficient condition determined by the District Materials Engineer to effectively accept the milling process without raveling or deteriorating. Otherwise, the shoulder pavement should be upgraded prior to milling the grooves.
 - For Fully-Controlled Access roadways the location of the Shoulder Rumble Strip is set by Standard RS-1 or RS-7.
 - For Partially-Controlled and Non-Controlled Access roadways, the location and width of Shoulder Rumble Strip(e)s, in relation to the edge line, will depend on the width of the paved shoulder. The Project Design Engineer, in consultation with the responsible District Traffic Engineer, Bicyclist and Pedestrian Coordinator and the Resident Administrator, has discretion for the installation of Centerline Rumble Stripes and the lateral placement of Shoulder Rumble Strip(e)s to reduce crashes and to provide appropriate accommodations for non-motorized users as shown in Figure 1 and as follows:
 - On divided highways, travel lanes shall be 11.0 feet or wider, measured from center of markings where median (left) or outside (right) Rumble Strip(e)s are installed. Median (left) paved shoulder widths 5 inches or wider (with a 4" edge line) or 3 inches or wider (with a 6" edge line) left of the travel lane edge line will accommodate a RS-4 Rumble Stripe or RS-9 Sinusoidal Rumble Stripe. Median paved shoulder widths 17 inches or wider will accommodate a RS-5 Rumble Strip or RS-10 Sinusoidal Rumble Strip.
 - For two-lane undivided highways, the through travel lane widths shall be greater than 10.0 feet when centerline Rumble Stripes (RS-3) or Sinusoidal Rumble Stripes (RS-8) are installed without shoulder Rumble Strip(e)s. Through travel lane widths shall be greater than 11.5 feet where centerline Rumble Stripes are installed with shoulder Rumble Strip(e)s, as shown in Table 2. On two-lane undivided roadways with less than 11.5 feet of through lane width, Rumble Stripes (RS-4) or Sinusoidal Rumble Stripes (RS-9) may be placed on both sides of the road with five-inch shoulders in lieu of placing centerline Rumble Stripes (RS-3) or Sinusoidal Rumble Stripes (RS-8). The decision on which rumble groove – centerline or shoulder – to install on such roadways may be guided by the history of Roadway Departure crash characteristics.

TABLE 2 – RUMBLE INSTALLATION FOR TWO-LANE UNDIVIDED ROADWAYS					
PAVED SHOULDER WIDTH	RS-3 / RS-8 <i>Note 1</i>	RS-4 / RS-9 <i>Note 2</i>	RS-5 / RS-10	RS-6	PAVEMENT WEDGE <i>Note 3</i>
0 - < 5"	✓				✓
5" - < 1.5'	✓	Bike sharing lane			✓
1.5' - < 3.5'	✓	Bike partially sharing lane over/around edgeline		✓	✓
3.5' - < 5.5'	✓	bike on shoulder separated by rumble/ edgeline			<i>Note 3</i>
≥ 5.5'	✓	bike on shoulder separated by rumble and edgeline	✓		Optional

Note 1	RS-3 / RS-8 require 10-foot minimum travel lane width. Travel lane widths are measured from center of centerline to outside edge of the edge line.
Note 2	When less than 11.5 feet of through travel lane width is available, centerline rumble stripes (RS-3 / RS-8) or shoulder rumble stripes (RS-4 / RS-9) may be installed at the direction of the District Traffic Engineer based on the crash experience of the subject roadway segment.
Note 3	See Pavement Shoulder Wedge I&IM TE-391 . Pavement wedge is required for shoulder widths less than 4 feet and recommended on wider shoulders where edge drop off issues may prevail.

- On Non-Access Controlled highways where bicyclist full accommodations are provided, a minimum of 4 feet of pavement should be provided outside (to the right) of the milled Rumble Strip(e)s if no other obstacles are present adjacent the travel lane, such as a barrier. A minimum of 5 feet of paved shoulder outside of the groove is preferred where obstacles exist adjacent the travel lane. RS-4 and RS-9 are applicable for paved shoulders ≥ 3.5 feet but provide bicyclist full accommodations for paved shoulders ≥ 4.5 feet. RS-5 and RS-10 provide full accommodations for paved shoulders ≥ 5.5 feet. The wider shoulders with Rumble Strip(e)s provide early audible warning of errant vehicles and offer cyclists the option of cycling on 3 feet or more of paved surface to the outside of the grooved rumbles. Additional graded shoulder width may also be necessary if horse and buggy traffic is present or expected.
- On Non-Access Controlled highways, where the outside (right) paved shoulder is between 0.5 feet and 1.5 feet, a RS-4 or a RS-9 may be installed. Where these minimal shoulder widths exist, cyclists are expected to occupy the travel lane.
- On Non-Access Controlled highways, where the paved outside (right) shoulders are between 1.5 feet and 3.5 feet wide, RS-6 places the Rumble Strip on the outside edge of the pavement to maximize the available area for cyclists between the grooves and the travel lane.
- On Non-Access Controlled highways with variable outside paved shoulder widths less than 3.5 feet, the Project Design Engineer should consult with the jurisdiction

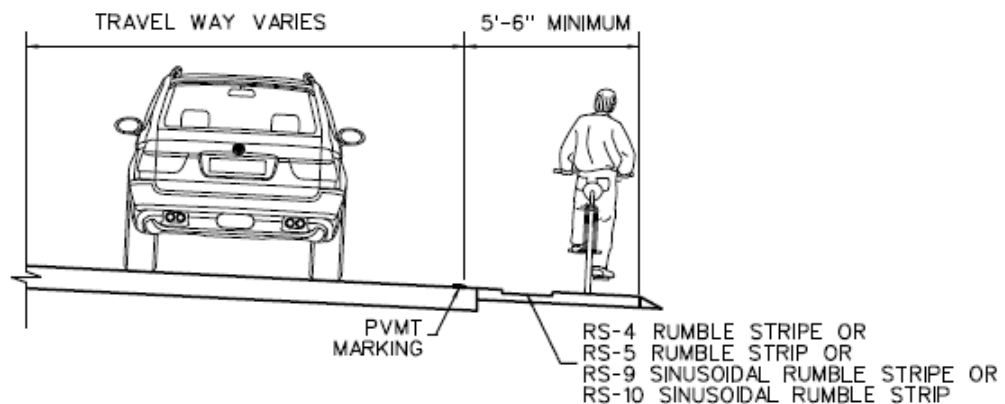
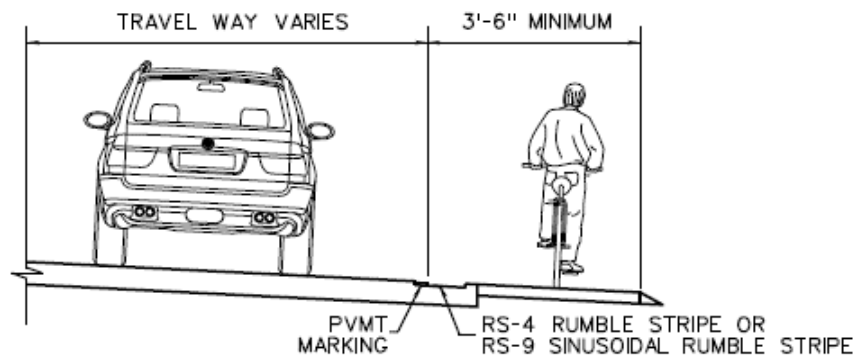
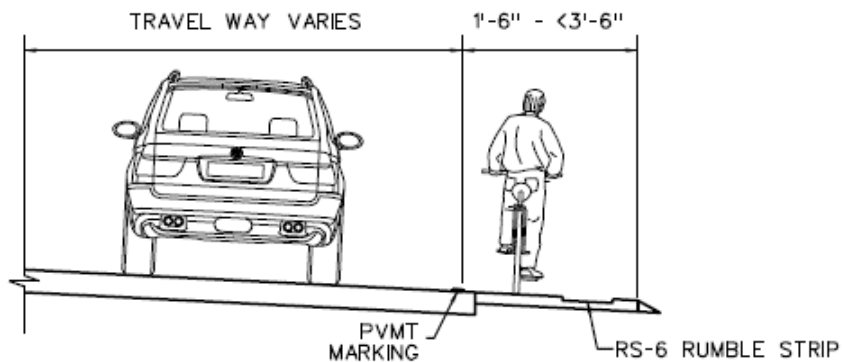
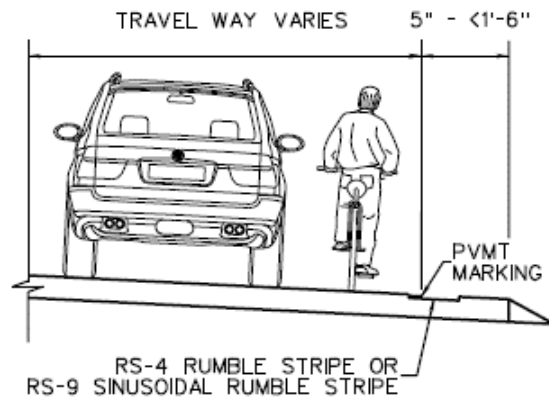
and the District Bicycle and Pedestrian Coordinator to determine expected non-motorized use and to define the preferred standard, RS-4/RS-9 or RS-6.

- The selected standard and design should consider continuity of the shoulder rumble groove offset between major intersections/interchanges, physical and maintenance jurisdiction boundaries, and the anticipated users. Using consistent rumble groove dimensions and offsets on projects will also improve contractor efficiencies and costs. Installation of Rumble Strip(e)s on short segments of roadway, such as paving project limits less than one to two miles, are acceptable but should be designed in anticipation of a consistent cross-section and Rumble Strip(e)s standard with future projects along a corridor. A corridor Rumble Strip(e)s plan should be developed to establish short, medium, and long-term designs for various segments of each route.
- Additional graded shoulder width to provide at least 4 feet of vehicle recovery area outside of the edge line is preferred. This decision will be made at the joint discretion of the responsible District Traffic Engineer, Resident Administrator, District Materials Engineer, and the Project Design Engineer.
- Rumble Strip(e)s shall **not** be installed:
 - within limits of bridges or median cross-overs;
 - within limits of intersections with public roadways, commercial entrances, marked crosswalks, and railroad crossings as directed by the Project Design Engineer per the standard;
 - within the limits of bridge drainage aprons, or special design shoulder slot inlets;
 - on two-way left turn lanes (designated as divided roadway with flush median), subdivision streets; or,
 - on unmarked roadway pavement segments.

Figure 1: Shoulder Rumble Strip(e)s Options on Partially- and Non-Controlled Access Roadways

PAVED SHOULDER WIDTH*	RUMBLE STRIP(E)
0' - <5"	NONE
5" - <1.5'	RS-4 RUMBLE STRIPE OR RS-9 SINUSOIDAL RUMBLE STRIPE
1.5' - <3.5'	RS-6 RUMBLE STRIP
3.5' - <5.5'	RS-4 RUMBLE STRIPE OR RS-9 SINUSOIDAL RUMBLE STRIPE
>- 5.5'	RS-4 RUMBLE STRIPE OR RS-5 RUMBLE STRIP OR RS-9 SINUSOIDAL RUMBLE STRIPE OR RS-10 SINUSOIDAL RUMBLE STRIP

*Measured from pavement outside edge to edge of pavement as shown.



CONTINUOUS GROOVE SHOULDER RUMBLE STRIP, STANDARD RS-1, AND CONTINUOUS GROOVE SINUSOIDAL SHOULDER RUMBLE STRIP, STANDARD RS-7

- For *Roadways with Fully-Controlled Access*, Continuous Groove Shoulder Rumble Strip Standard RS-1 and Continuous Groove Sinusoidal Shoulder Rumble Strip Standard RS-7 are to be specified for *Outside (Right) and Median (Left) Paved Mainline Shoulders*.
- Based on crash history and engineering judgement, RS-1 or RS-7 may be installed along ramp auxiliary lanes, acceleration/deceleration lane tapers, and along one or both sides of ramp lanes beyond the physical gore at the discretion of the District Traffic Engineer in consultation with the Resident Administrator.
- Sinusoidal RS-7 Rumble Strips shall be considered for noise sensitive adjacent land uses. See discussion below under noise concerns.
- Continuous Groove Shoulder Rumble Strips shall be milled into asphalt concrete pavements as shown on the section views in Standard RS-1 and RS-7, and as follows:
 - RS-1: 7 inches wide by 16 inches across (length) by ½ inch deep with 12-inch leading edge spacing.
 - RS-7: 14-inch wide wavelength by 16 inches across (length) by ½ inch deep with 14 inches from leading edge of wavelength to leading edge of wavelength.
 - 6-inch positive offset from the outside edge line or 5-inch positive offset from the median edge line.
 - The groove shall be a minimum of 4 inches from surface course pavement joints with the joint between the edge line and groove. The joint may be placed outside of the groove as directed by the Project Design Engineer.
- RS-1 and RS-7 cut into existing pavements shall be coated with liquid asphalt emulsion following VDOT Specifications, Special Provisions, and Copy Notes. Emulsion coating of new/resurfaced asphalt pavements is not required but may be specified at the discretion of the District Materials Engineer.

CENTERLINE RUMBLE STRIPE, STANDARD RS-3, AND CENTERLINE SINUSOIDAL RUMBLE STRIPE, STANDARD RS-8

- For *New and Existing Undivided Roadways*, the installation of Centerline Rumble Stripe (CLRS) RS-3 or RS-8 is specified by the Project Design Engineer and/or District Traffic Engineer (in consultation with the Resident Administrator) based on the following:
 - Speed limit \geq 45 mph.
 - Lane widths for undivided two-lane highways shall be as shown in Table 2 notes. For multi-lane undivided roadways, the lane adjacent to the rumble shall be \geq 11.0 feet center to center of markings.
 - Pavement depths and condition.
 - Adjacent land-uses. Sinusoidal RS-8 Rumble Stripes shall be considered for noise sensitive areas. See discussion below under noise concerns.

- For existing roadways, first priority when considering installation of CLRS should be given to routes with a speed limit \geq 55 mph, higher traffic volumes, and a history of Roadway Departure crashes that involved crossing the centerline.

- CLRS grooves shall be milled into pavements as shown on the section and plan views in Standards RS-3 and RS-8 and as follows:
 - RS-3: 7 inches wide by 16 inches across (length) by 3/8 inch deep, and spaced 12 inches apart from leading edge to leading edge.
 - RS-8: 14-inch wide wavelength by 16 inches across (length) by 1/2 inch deep with 14 inches apart from leading edge of wavelength to leading edge of wavelength.
 - The 16-inch length accommodates installation of plastic inlaid markers following the preferred PM-8 Type C configuration.
 - CLRS shall only be installed in Passing Zones with continuous patterns having either 12 or 24 inch spacing when specified in the contract documents or as directed by the Engineer.

- CLRS grooves milled into existing pavements shall be coated with liquid asphalt emulsion following VDOT Specifications, Special Provisions and Copy Notes. However, following Specifications in Sections 315, 512 and 704, additional maintenance of traffic and cure time will be necessary prior to installing pavement markings. Emulsion coating of new/resurfaced asphalt pavements is not required but may be specified and applied at the discretion of the Project Design Engineer.

EDGE LINE RUMBLE STRIPE, STANDARD RS-4, AND EDGE LINE SINUSOIDAL RUMBLE STRIPE, STANDARD RS-9

- On *non-interstate/freeway/expressway roadways*, Standard RS-4 Edge Line Rumble Stripes or Edge Line Sinusoidal RS-9 Rumble Stripes are an installation option, especially when a minimum paved shoulder is available to allow for early detection and recovery. In addition to providing immediate warning to the driver, Rumble Stripes also extend the life and visibility of edge line pavement markings.
- For *New and Existing Divided and Undivided Non-Access Controlled roadways*, Standard RS-4 and Standard RS-9 are to be specified by the Project Design Engineer and/or responsible District Traffic Engineer (in consultation with the Resident Administrator and District Bicyclist and Pedestrian Coordinator) based on the following:
 - Speed limit \geq 45 mph.
 - Lane Widths \geq 11.0 feet when installed with CLRS on multi-lane roadways and \geq 11.5 feet when installed with CLRS on two-lane roadways.
 - Milled with continuous grooves on divided roadway median (left) side paved shoulders \geq 5 inches.
 - Paved outside (right) shoulder widths \geq 5 inches and $<$ 1.5 feet or \geq 3.5 feet (see Figure 1 and Table 2).
 - Additional graded shoulder width may also be necessary if horse and buggy traffic is present or expected.
 - Pavement depths and condition.
 - Adjacent land-uses. Sinusoidal RS-9 Rumble Stripes shall be considered for noise sensitive areas. See discussion below under noise concerns.
- Edge line Rumble Stripe grooves shall be milled into asphalt concrete pavements as shown on the section and plan views in Standards RS-4 and RS-9 and as follows:
 - RS-4: 7 inches by “L” inches across (length) by 3/8-inch deep, spaced 12 inches apart, leading edge to leading edge.
 - RS-9: 14-inch wide wavelength by “L” inches across (length) by 1/2 inch deep with 14 inches from leading edge of wavelength to leading edge of wavelength.
 - For Standard length variants A, B, and C, “L” equals 6, 9, and 12 inches, respectively. Variant length shall be selected based on available shoulder width and specified in the contract documents and plan assembly.
 - The groove should be a minimum of 4 inches from surface course pavement joints with the joint outside of the groove as directed by the Project Design Engineer.
 - Intermittent 15-foot gap provided between each 45-foot section of Rumble Stripe grooves on the outside (right) shoulder. Gaps for private driveways are at the discretion of the Engineer. However, the layout should attempt to align gaps to with driveways, so the length of the grooved sections may vary according to the Engineer’s design.
- RS-4 and RS-9 grooves milled into existing pavements shall be coated with liquid asphalt emulsion following VDOT Specifications Sections 315, 512 and 704, Special Provisions and Copy Notes. Additional maintenance of traffic and cure time will be necessary prior to installing pavement markings. Emulsion coating of new/resurfaced asphalt pavements

is not required but may be specified and applied at the discretion of the Project Design Engineer.

EDGE LINE SHOULDER RUMBLE STRIP, STANDARD RS-5, AND EDGE LINE SHOULDER SINUSOIDAL RUMBLE STRIP, STANDARD RS-10

- Edge Line Shoulder Rumble Strip, Standard RS-5, and Edge Line Shoulder Sinusoidal Rumble Strip, Standard RS-10, should be specified for paved shoulders on appropriate higher classification (such as principal arterials), *Partial-Controlled and Non-Controlled Access* roadways based on the following:
 - Speed limit \geq 45 mph.
 - Lane widths \geq 11 feet on multi-lane roadways and \geq 11.5 feet when installed with CLRS on two-lane roadways.
 - Milled with continuous grooves on divided roadway median (left) side paved shoulders \geq 17 inches.
 - If there is a potential for cyclists on the roadway, RS-5 is only recommended where at least 5.5 feet of right shoulder pavement width is available (see Figure 1 and Table 2). A 5-foot paved shoulder outside of the groove is desirable, particularly if adjacent obstructions are present such as guardrail. If less than 5.5 feet of paved shoulder width is available, RS-4 (shoulder width \geq 3.5 feet) or RS-6 (1.5 feet \leq shoulder width $<$ 3.5 feet) are recommended to minimize potential impacts to cyclists.
 - Additional graded shoulder width may also be necessary if horse and buggy traffic is present or expected.
 - Pavement depths and condition.
 - Adjacent land-uses. Sinusoidal RS-10 Rumble Strips shall be considered for noise sensitive areas. See discussion below under noise concerns.

- Edge Line Shoulder Rumble Strip, RS-5, and Edge Line Shoulder Sinusoidal Rumble Strip, RS-10, shall be milled into asphalt concrete pavements as follows:
 - RS-5: 7 inches by “L” inches across (length) by 3/8-inch deep, spaced 12 inches apart from leading edge to leading edge.
 - RS-10: 14-inch wide wavelength by “L” inches across (length) by 1/2 inch deep with 14 inches apart from leading edge of wavelength to leading edge of wavelength.
 - For Standard length variants A and B, “L” equals 9 and 12 inches, respectively. Variant length shall be selected based on available shoulder width and specified in the contract documents and plan assembly.
 - The groove shall be a minimum of 4 inches from surface course pavement joints with the joint between the edge line and groove. The joint may be placed outside of the groove as directed by the Project Design Engineer.
 - Intermittent 15-foot gap provided between each 45-foot section of Rumble Strip grooves on the outside (right) shoulder. Gaps for private driveways are at the discretion of the Engineer. However, the layout should attempt to align gaps in groove sections with driveways, so the length of the grooved section may vary based on the Engineer’s design.

- RS-5 and RS-10 milled into existing pavements shall be coated with liquid asphalt emulsion following VDOT Specifications Sections 315, 512 and 704, Special Provisions and Copy Notes. Emulsion coating of new/resurfaced asphalt pavements is not required but may be specified and applied at the discretion of the District Materials Engineer.
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SHOULDER EDGE RUMBLE STRIPS, STANDARD RS-6

- Shoulder Edge Rumble Strip, Standard RS-6, is appropriate for *Partial-Controlled and Non-Controlled Access* roadways based on the following:
 - Speed limit \geq 45 mph.
 - Lane widths \geq 11 feet on multilane roadways and \geq 11.5 feet when installed with CLRS on two-lane roadways.
 - Milled with continuous grooves on divided roadway median (left) side paved shoulders \geq 17 inches.
 - Paved outside (right) shoulder widths \geq 1.5 feet and $<$ 3.5 feet (see Figure 1 and Table 2) and bicycle traffic is present or expected.
 - A minimum of 3 inches shall be provided to the edge of pavement for new construction or paving projects. Adding a Pavement Shoulder Wedge ([IIM-MD-002](#) and [IIM-TED-391](#)) is required when RS-6 is installed to ensure the integrity of the pavement edge. The layout should provide a single offset dimension from the edge line for variable shoulder widths between 1.5 and 3.5 feet such that the Rumble Strips do not encroach on the 3-inch minimum offset for the length of the project. On a given route the same rumble groove offset should be maintained for visual and functional continuity.
 - Pavement depths and condition.
 - Adjacent land-uses. Fewer encroachments are expected for this standard than the other Rumble Strip/Stripe designs. See discussion below under noise concerns.
- Shoulder Edge Rumble Strips, RS-6 shall be milled as follows:
 - RS-6: 7 inches by “L” inches across (length) by 3/8-inch deep, spaced 12 inches apart from leading edge to leading edge.
 - For Standard length variants A and B, “L” equals 9 and 12 inches, respectively. Variant length shall be selected based on available shoulder width and specified in the contract documents and plan assembly.
 - Intermittent 15-foot gap provided between each 45-foot section of Rumble Strip grooves on the outside (right) shoulder. Gaps for private driveways are at discretion of the Engineer. However, the layout should attempt to align gaps in groove sections with driveways, so the length of the grooved rumble strip sections may vary according to the Project Design Engineer’s design.
- RS-6 milled into existing pavements shall be coated with liquid asphalt emulsion following VDOT Specifications Sections 315, 512 and 704 and Special Provisions, and Copy Notes. Emulsion coating of new/resurfaced asphalt pavements is not required but may be specified and applied at the discretion of the District Materials Engineer.

DESIGN CONSIDERATIONS FOR BICYCLISTS

- A number of provisions have been incorporated in this guidance to better accommodate cyclists, including:
 - Designs rumbles from the premise that bicycles may be present on any Non-Controlled Access roadway and therefore builds in bicycle considerations into all shoulder Rumble Strip(e) options (except the RS-1 and RS-7). Although bicycle considerations are built in, the Project Design Engineer should seek and document consultation with the VDOT District Bicyclist and Pedestrian Coordinator before a Rumble Strip(e)s project is installed.
 - Specifies that all Non-Access Controlled outside (right) shoulder / edge line Rumble Strip/Stripe options are Intermittent, to accommodate cyclist maneuverability between the travel lane and paved or unpaved shoulder. Variation from the standard shall have documented consultation from the VDOT District Bicyclist and Pedestrian Coordinator and the Resident Administrator.
 - Includes the RS-6 to place Rumble Strips on the outside edge of pavement when the available shoulder width is ≥ 1.5 and < 3.5 feet, to maximize the shoulder width provided for cyclists. This improves upon the previous practice of placing rumble grooves in the middle of available narrow shoulder space, thereby creating an uneven surface where many cyclists prefer to ride when limited shoulder space is available.
 - Identifies the RS-4 and RS-9 standards as the preferred treatment on Non-Access Control highways with paved shoulders ≥ 5 inches and < 1.5 feet wide or ≥ 3.5 feet in width. This maximizes the number of roadways with a minimum 4-foot-wide paved shoulder for cyclists and will provide audible warning for cyclists when a motorist first encroaches into the shoulder.
 - Reduces the depth of the Rumble Strip from $\frac{1}{2}$ -inch to $\frac{3}{8}$ -inch deep grooves for all non-Sinusoidal Rumble Strip(e) standards except the RS-1.
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NOISE CONCERNS

- The District Environmental Section shall be involved when concerns about noise pollution arise when a Rumble Strip(e) project is designed and installed at a location that did not previously have rumble grooves, especially in areas with residences, parks, or certain businesses. Three characteristics of noise are important to assessing the subjective community responses: intensity, frequency, and varying characteristics over time. Intensity is the measure of energy magnitude and is directly related to pressure. Pressure levels, sensed over wide ranges, are expressed in logarithmic scale units called decibels (dB). Frequency measures the tonal qualities of sound. People are more sensitive to sounds in middle to high frequencies. Studies have shown that the ambient noise decibel level generated by vehicles driving over $\frac{1}{2}$ -inch rumble grooves is comparable to that of a truck passing by on the travel lane, particularly at distances less than 250 feet away. However, the noise from rumble grooves may be more noticeable as the public is more accustomed to truck noise, the frequency of the sound is different and rumble grooves tend to produce short term impulse noise. Studies also indicate that the depth of the groove changes the noise level. So, the depth for all cylindrical Rumble Strip(e) standards,

except the RS-1, are reduced to 3/8 inch deep grooves, which will result in a lower sound level compared to older 1/2 inch deep groove installations.

- Noise concerns are most commonly associated with RS-3 (Centerline Rumble Stripe), RS-4 (Intermittent Shoulder Rumble Stripe), and to a lesser extent RS-5 (Intermittent Shoulder Rumble Strip). To minimize the noise concerns associated with RS encroachments, Sinusoidal versions of the RS standards have been developed for application throughout the state. RS-7, RS-8, RS-9, and RS-10 are all Sinusoidal groove patterns, which studies have proven produce less ambient noise than traditional cylindrical rumble grooves. Research by [Oregon DOT](#) provides a good comparison of noise measurements for designs consistent with VDOT including consideration of the groove length and truck traffic. Appendix D of the Oregon report provides a good description of background traffic (line) source versus rumble strike (point) source sound propagation.
- Along the portions of a roadway corridor that have adjacent sensitive land uses situated within 250 feet of the travel way, the Project Design Engineer, in consultation with the District Traffic Engineer and Resident Administrator, may adjust the installation based on engineering judgement as follows:
 - Omit the centerline Rumble Stripes (RS-3 or RS-8) in areas with sensitive noise receptors, particularly in passing zones.
 - Increase the centerline Rumble Stripe (RS-3) spacing from 12 inches to 24 inches within two and/or one-way passing zones.
- A consistent Rumble Strip(e) standard should be selected for a route/corridor. If a Sinusoidal Strip(e) standard is selected for a specific segment of a project due to noise concerns, strong consideration should be given to applying the same Sinusoidal Strip(e) standard along the entire length of the route/corridor.

METHOD OF SHOWING RUMBLE STRIPS/STRIPES IN THE PLAN ASSEMBLY

- Projects requiring the use of Rumble Strip(e)s shall indicate the begin and end stations on the plan view for median, centerline, and outside shoulder locations. The limits shall include the Rumble Strip(e) standard(s) to be used including the variant length "L" selected for the available paved shoulder width.
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SUMMARIZATION AND PAYMENT

- Quantities for Rumble Strips and Rumble Stripes are to be shown in the Pavement Summary.
- Quantities will be shown as linear feet of "Rumble Strip" or "Rumble Stripe" regardless of type of application (continuous/intermittent/centerline) or method of pavement marking. Measurement is to include the length of application, measured longitudinally along the

edge of pavement in the field and paid for in linear feet of shoulder where actually placed and accepted (excluding test site, per Spec 315).

- Deductions are to be taken for bridge decks, acceleration/deceleration lanes, gore areas, intersections, driveways, crossovers, surface drainage structures, and other sections where the Rumble Strip(e)s are not installed on the project.
- For Intermittent outside (right) Shoulder Rumble Strip(e)s (RS – 4, 5, 6, 8, 9, and 10), there is to be no deduction in measurement for the 15-foot gap between the 45-foot grooved sections, except as noted above.
- When Rumble Strip(e)s are installed in **existing** and **new** asphalt concrete pavement, the entire Rumble Strip/Stripe area shall be coated with Liquid Asphalt Coating according to the VDOT Specifications, Special Provisions and Copy Notes and District guidelines regarding application to new asphalt pavements. This coating shall be measured and paid for in square yards, estimated as follows:
 - For 16-inch groove – Pay area shall be *20 inches* (0.556 yd.) times the length of Rumble Strip(e) application, measured longitudinally along the edge of pavement.
 - For 12-inch groove – Pay area shall be *15 inches* (0.417 yd.) times the length of Rumble Strip(e) application, measured longitudinally along the edge of pavement.
 - For 9-inch groove – Pay area shall be *11 inches* (0.306 yd.) times the length of Rumble Strip(e) application, measured longitudinally along the edge of pavement.
 - For 6-inch groove – Pay area shall be *8 inches* (0.222 yd.) times the length of Rumble Strip(e) application, measured longitudinally along the edge of pavement.
- For shoulder rumble strips only, overspray shall not extend more than 2 inches beyond the width of cut and/or shall not come in contact with pavement markings.
- The following pay items have been established (applicable to Continuous Shoulder, Intermittent Shoulder, and Centerline applications):

Pay Item	Pay Unit	Item Code
Rumble Strip(e) Cylindrical (Asphalt)	Lin. Ft.	10700
Liquid Asphalt Rumble Coating (Strip/Stripe)	S.Y.	10701
Rumble Strip(e) (Concrete)	Lin. Ft.	10702
Rumble Strip(e) Sinusoidal (Asphalt)	Lin. Ft.	10703
Rumble Strip(e) Sinusoidal (Concrete)	Lin. Ft.	10704

SPECIFICATIONS

- The most recent, as revised with Special Provisions, Road and Bridge Specifications shall be used for Rumble Strip(e) installation and is available at:
<http://www.virginiadot.org/business/const/spec-default.asp>