Delaware Department of Transportation
Division of Transportation Solutions
Design Guidance Memorandum

Memorandum Number 1-18 Revised

1. Road Design Manual
2. Bridge Design Manual
3. Utilities Design Manual
4. Real Estate Manual
5. Standard Specifications
6. Standard Construction Details
7. Traffic Design Manual

Title: Longitudinal Center Line and Shoulder Rumble Strips Effective date: _____

Sections to Implement:

X Project Development	X Planning	___ DTC
X Bridge	X Engineering Support	X Traffic
X Right-of-Way	X Maintenance & Operations	X Construction
X Utilities		

I. Purpose

To define when and where longitudinal center line or shoulder rumble strips should be applied within the state highway system.

II. Background

The purpose of longitudinal center line or rumble strips is to enhance safety by mitigating the potential of crossover or road departure crashes. Rumble strips are intended to alert drivers by creating an audible (noise) and tactile (rumble or vibratory) warning sensation to indicate to the driver that the vehicle is leaving the traveled way (traffic lane) and that a steering correction may be required. Before and after crash studies have indicated that both crossover and roadway departure crashes may be reduced by the installation of rumble strips. A study conducted in Minnesota in 2004 found that the placement of shoulder rumble strips on a divided highway yielded a crash modification factor (CMF) of 0.83 for all crash types. The Crash Modification Factor clearinghouse website includes CMFs for centerline rumble strips ranging from 0.86 to 0.91 for all crash types. Additionally, centerline and shoulder rumble strips are recognized by the Federal Highway Administration as a proven safety countermeasure.

The intent of the rumble strip is to gain the attention of a driver. Naturally, the byproduct of this measure is noise, both inside and outside of the vehicle. In isolated areas, with little to no residential land use, the exterior noise generated by the rumble strip is usually not a problem. However, when installed in areas where housing is in close proximity to a roadway, even on roadways in rural areas, the exterior noise from rumble strips may impact nearby residents. To address concerns such as noise and cyclist rideability, DelDOT's rumble strip designs were modified in 2014.

Recently, DelDOT has experimented with the use of sinusoidal rumble strips, also known as "mumble strips." Sinusoidal rumble strips are similar to conventional longitudinal rumble strips but utilize a wave pattern ground into the pavement which reduces the external noise produced from a vehicle traveling across them. Conventional longitudinal rumble strips consist of a repeating rectangular pattern, which has been found to generate more external noise than the sinusoidal rumble strips. A study completed by the Minnesota Department of Transportation in 2016 compared various types of sinusoidal rumble strip patterns to determine the optimal pattern that provides for the most reduction in exterior noise, while maintaining an adequate level of interior noise. That study also included the

standard rectangular pattern rumble strip to compare against. The study results indicate that the increase in exterior noise from no rumbles strip to a sinusoidal rumble strip was between 2.3dBA and 6.4 dBA whereas the increase in exterior noise from no rumble strip to a conventional rumble strip was 18.3 dBA. This indicates that the sinusoidal rumble strips produce 65% - 87% less additional exterior noise than a traditional milled rumble strip. There have not been studies to date documenting the difference in crash reduction between traditional and sinusoidal rumble strips.

III. Case Studies

To assess the noise impacts of rumble strips, DelDOT has conducted several noise studies. In 2006, a noise study was conducted to evaluate the noise impacts of shoulder rumble strips along a test area on I-495 at the 12th Street interchange. This study found that noise level increases due to a vehicle striking the rumble strip were clearly perceptible at 100 feet from the source, barely perceptible at 250 from the source and not readily perceptible at 400 feet from the source. The study concluded that rumble strips should not be considered along I-495 where residences are located within 500 feet of the proposed rumble strip. It should be noted that shoulder rumble strips were installed along all of I-495 in 2015, however, the shallower 3/8" depth rumble strip was used to reduce noise impacts.

In 2012, a noise study was performed to investigate the external noise impacts of shoulder rumble strips on two-lane rural roadways. The study measured noise levels produced by a passenger and a heavy (dump truck) vehicle traveling over an shoulder rumble strip for a length of 400 feet. The noise level was measured at four distances perpendicular to the roadway; 50 feet, 250 feet, 500 feet and from 1,000 feet. The study concluded that the noise generated by vehicles driving across rumble strips are not typically perceptible from distances 275 feet or greater from adjacent residences and that noise impacts should be given special consideration when installing rumble strips adjacent to residences within these distances from the outside of the proposed rumble strip.

Finally, a study comparing the noise impacts of conventional rumble strips to the new sinusoidal (mumble) strip design was conducted in 2019. That study found that the average noise level increases in the study areas due to the test vehicles (minivan or DelDOT dump truck) striking the shoulder sinusoidal rumble strip were less than 2 dBA at all offset distances where noise measurement data was collected (50 feet, 150 feet, 250 feet and 400 feet) and overall the sinusoidal rumble strips generated less noise level increases than the conventional rumble strips to which they were compared. Additionally, the study found that the noise generated by vehicles driving across sinusoidal rumble strips will not typically be perceptible from distances 50 feet or greater from adjacent residences, indicating that the sinusoidal rumble strip design may have more versatility in many areas of the state, creating less impacts on the quality of life of residences while improving safety.

IV. Design Guidance and Warrants

Longitudinal center line and shoulder rumble strips should be considered and installed per the following guidelines and details.

A. Shoulder Rumble Strips

1. Warrants for Use
    a. Interstates, Freeways and Expressways (Limited Access Facilities)

i. Longitudinal shoulder rumble strips should be installed on new, reconstructed and resurfaced shoulders (inside and outside shoulders) of all Interstates, freeways and expressways, regardless of crash history.

ii. Longitudinal shoulder rumble strips should be installed on both the inside and outside shoulders of new, reconstructed and resurfaced interchange ramps regardless of crash history.

b. Multilane Conventional Roadways

i. Bicycle-friendly shoulder rumble strips should be installed on new, reconstructed or resurfaced outside shoulders of all multilane conventional roadways.

ii. Continuous shoulder rumble strips should be installed on new, reconstructed or resurfaced inside shoulders of all multilane conventional roadways with a minimum shoulder width of 4 feet.

c. Two-Lane Conventional Roadways

i. Bicycle-friendly shoulder rumble strips should be installed on all rural two-lane roadways with a minimum travel lane width of 11 feet, minimum shoulder width of 5 feet, and a posted speed limit or 85th percentile speed of 45 miles per hour or higher.

ii. Bicycle-friendly shoulder rumble strips should be considered for installation on all other two-lane roadways if an engineering study determines that roadway departure crash rates exceed statewide or national averages for similarly classified roadways and if rumble strips may be an appropriate crash reduction countermeasure.

2. Design and Layout Guidelines

a. Interstates, Freeways and Expressways:

i. The design of the longitudinal shoulder rumble strips should be in accordance with Appendix A.

b. Multilane Conventional Roadways:

i. Rumble strips on multilane conventional roadways shall be of the sinusoidal design as shown in Appendix B.

ii. Rumble strips within the right shoulder of a multilane conventional roadway shall be of the bicycle-friendly sinusoidal design as shown in Appendix B.

iii. Rumble strips within the left shoulder of a multilane conventional roadway shall be of the continuous sinusoidal design as shown in Appendix B.

c. Two-Lane, Two-Way Roadways:

i. Rumble strips on two-lane, two-way roadways shall be of the sinusoidal design as shown in Appendix C.

d. General Design and Layout Guidelines:

i. Rumble strips may be installed on bridge decks, unless the bridge deck has an overlay less than 2-inches thick. The designer should contact the Bridge Section

to confirm the composition of the bridge deck prior to installation of rumble strips. Additionally, rumble strips shall not be cut into bridge deck patches or re-installed after a bridge deck has been patched within the rumble strip line.

ii. The bicycle-friendly shoulder rumble strip pattern shall consist of 40-foot long segments of rumble strips with 12-foot segments of no rumble strips (see Appendix B and C).

iii. Rumble strips are to be broken for all intersections and driveway entrances where the shoulder pavement markings tie into the driveway entrance or where the edge line pavement markings are broken. The installation of rumble strips should be stopped prior to the Point of Curvature (PC) and restarted after the Point of Tangency (PT) as shown in the details in Appendix B and C.

iv. Rumble strips should not be installed on acceleration, deceleration or bypass lanes on conventional roadways. Installation should stop prior to the diverge point of a deceleration lane and should not commence until downstream of the merge point for an acceleration lane as shown in the details in Appendix B and C.

v. To accommodate bicyclists, a minimum effective clear shoulder width of 5 feet (preferred), 4 feet (minimum) should be provided from the outside edge of the rumble strip groove to the outside edge of the paved shoulder (see Appendix B and C), or 5 feet (preferred), 4 feet (minimum) from the outside edge of the rumble strip groove to the front face of curb, guardrail or barrier. Rumble strips should be discontinued 50 feet before and started 50 feet after when adjacent to curb, guardrail or barrier where there is less than 5 feet (preferred), 4 feet (minimum) between the outside edge of the rumble strip and the face of the curb, guardrail or barrier.

vi. If the above clear area cannot be maintained, then consider installing bicycle-friendly edge line rumble *stripes* within the painted edge line. A rumble stripe is a milled rumble strip that is placed directly on the painted edge line. The edge line is then repainted over top of the milled rumble strip (see Appendix B and C). Rumble stripes shall meet the longitudinal design of bicycle-friendly rumble strips.

vii. Sinusoidal shoulder rumble strips or rumble stripes should be installed in areas where the perpendicular distance to the nearest residential property is more than 50 feet. Engineering judgment should be used to determine if sinusoidal rumble strips should be installed in areas where the distance to the nearest residential home is 50 feet or less.

viii. If rumble strips are installed in a residential area where the distance is 50 feet or less, outreach to the area legislators and property owners should be conducted, informing them of the need for rumble strips.

ix. Rumble strips should not be milled into pavements composed of slurry seals, microsurfacing, thin overlays or chip sealed surfaces.

B. Center Line Rumble Strips

A. Warrants for Use

a. Center line rumble strips should be considered on all conventional two-lane and undivided multilane roadways where an engineering study determines that crossover, head-on, and/or opposite direction sideswipe crash rates exceed statewide or national averages for similarly classified roadways and if rumble strips may be an appropriate crash reduction countermeasure. The study should be reviewed and approved by the Chief of Traffic Engineering.

B. Design and Layout Guidelines

a. Center line rumble strips shall be of the sinusoidal design shown in Appendix D.

b. Center line rumble strips should end prior to the centerline striping ending and start after the start of the centerline striping approaching an intersection (see details in Appendix D).

c. Center line rumble strips shall not be discontinued where striping indicates passing is permitted.

d. Rumble strips may be installed on bridge decks, unless the bridge deck has an overlay less than 2-inches thick. The designer should contact the Bridge Section to confirm the composition of the bridge deck prior to installation of rumble strips. Additionally, rumble strips shall not be cut into bridge deck patches or re-installed after a bridge deck has been patched within the rumble strip line.

e. In areas where the center line leads into a raised concrete island, the rumble strips should be discontinued where the raised concrete island starts.

f. In areas where the center line splits to create an additional lane, such as a left turn lane, the rumble strips should be placed <u>only</u> along the double yellow center line *not* forming the left turn lane. Should a back-to-back left turn lane scenario exist, center line rumble strips should follow the double yellow center line in accordance with Appendix D.

g. On roads with recessed pavement markers (RPMs), center line rumble strips should begin one foot downstream of the RPM housing and terminate one foot upstream of the RPM housing, as shown in Appendix D.

h. Center line rumble strips shall not be installed on either side of two-way left turn lanes.

C. Other Considerations

The composition of the new pavement section or the thickness, condition, and type of existing pavement needs to be determined prior to the application of longitudinal rumble strips. The installation of longitudinal rumble strips on pavement that is of questionable thickness, condition, or type (e.g. hot-mix over P.C.C. pavement) needs to be evaluated to ensure that the installation of the rumble strip will be possible without adverse impact to the pavement or the performance of the strip. The designer should contact the Materials and Research Section for existing pavement cores. If no core data is available, pavement cores should be obtained, and the information reviewed with the Materials and Research Section.

For long-term construction projects on roadways with existing rumble strips, the rumble strips should be removed or completely filled in if the temporary traffic control plans require traffic to be shifted onto the shoulder or crosses a center line. To remove the rumble strips, complete a mill and overlay within the rumble strip area or use a Department-approved asphaltic sealer material to fill in the rumble

strips, flush with the existing pavement. If used, the sealer material shall be removed at the end of the project to restore the rumble strips. If rumble strips are removed by milling and overlaying the pavement, the rumble strips shall be re-installed at the end of the project.

The guidance and the figures herein do not account for all possible applications (e.g. rural gore areas). Therefore, it may be necessary for the designer to develop special application plans or details for the application of milled or alternative longitudinal rumble strip treatments. All such plans and details should be submitted to the HSIP Manager in the Traffic Engineering Section for review prior to their use on a project. This includes the use of center line rumble strips on two-way highways where additional factors such as lane width, total roadway width, etc. should be considered.

Requirements for placement of rumble strips including beginning and ending stationing, rumble strip type, etc. should be depicted on the signing, striping and conduit plans within the project's construction plan package. Appropriate notes and details should be provided on these plan sheets as well.

V. Justification

To improve safety by alerting inattentive drivers through vibration and sound with continuous longitudinal center line and/or shoulder rumble strips that their vehicles have left the travel lane. This safety countermeasure has shown proven results, is a proven safety countermeasure within the Federal Highway Administration's Everyday Counts Program (EDC-5) and is a recommended strategy for reducing roadway departure crashes as part of the State of Delaware Strategic Highway Safety Plan.

Prepared by: Traffic Section
Revised: December 16, 2020

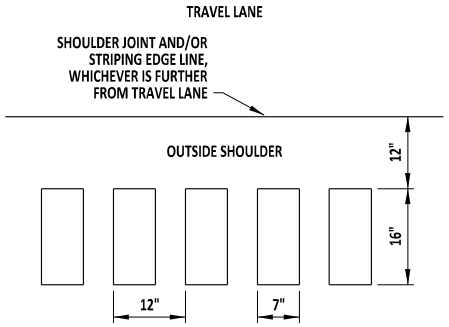
Peter Haag DelDOT — 12/30/2020
Recommended by: Chief of Traffic Engineering — Date

12/31/2020
Recommended by: Deputy Director - Design — Date

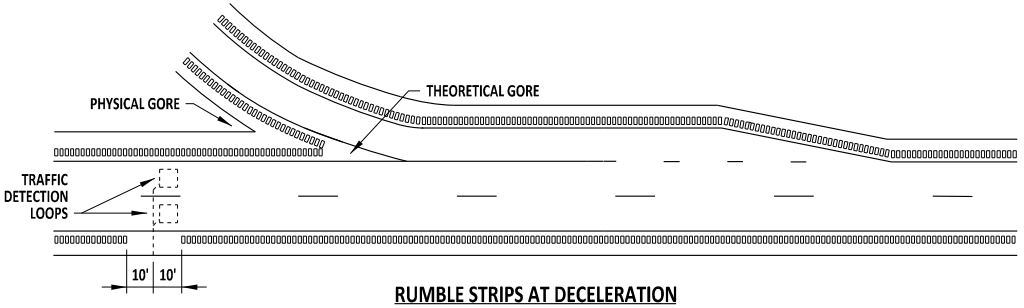
01/11/2021
Approved: Chief Engineer — Date

Distribution:
Transportation Solutions Assistant Directors
Maintenance & Operations District Engineers
Transportation Solutions
Planning
Construction
Consultants
DelDOT Internet Site

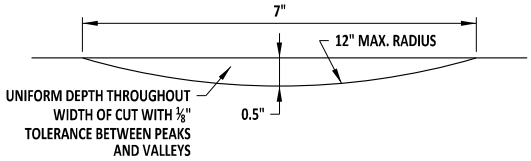
SCALE : NTS



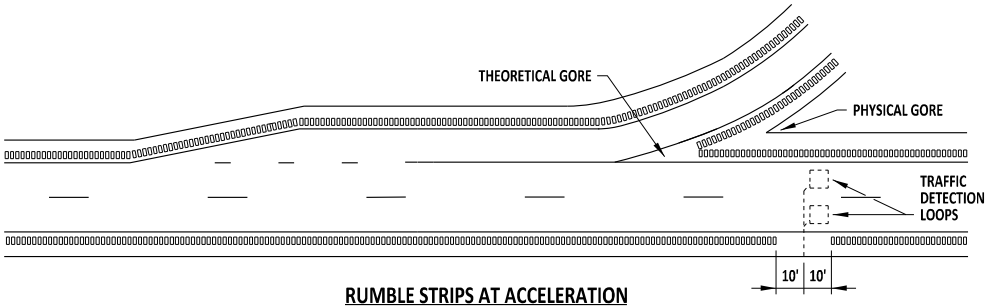
CONTINUOUS EDGELINE RUMBLE STRIP DETAILS



RUMBLE STRIPS AT DECELERATION LANES AND FREEWAY OFFRAMPS



RUMBLE STRIP SECTION - INTERSTATES, FREEWAYS AND EXPRESSWAYS



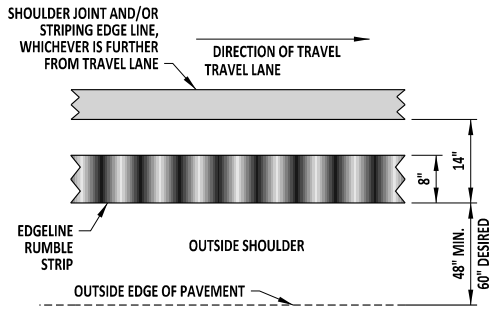
RUMBLE STRIPS AT ACCELERATION LANES AND FREEWAY ONRAMPS

NOTES:
1.) DIMENSIONS MAY BE FIELD ADJUSTED AS DIRECTED BY THE ENGINEER.

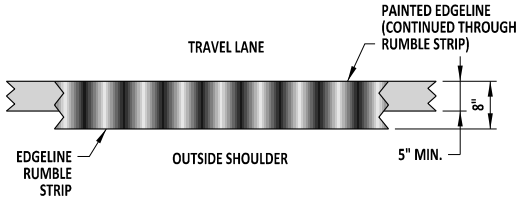
DelDOT	ENGINEERING SUPPORT / DATE RECOMMENDED	CONVENTIONAL SHOULDER RUMBLE STRIPS ON INTERSTATES / FREEWAYS / EXPRESSWAYS	REVIEWED DEPUTY DIRECTOR - DESIGN / DATE
		DGM 1-18 / APPENDIX A	APPROVED CHIEF ENGINEER / DATE

12/15/2020

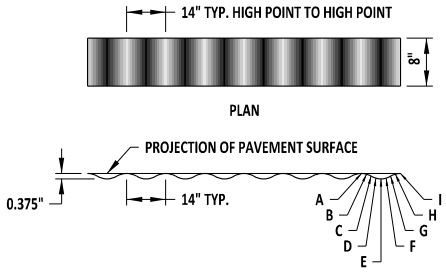
SCALE : NTS



SINUSOIDAL SHOULDER RUMBLE STRIP

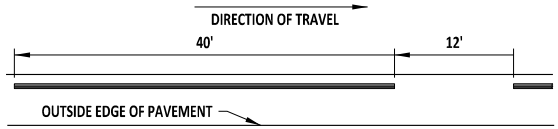


SINUSOIDAL EDGE LINE RUMBLE STRIPE

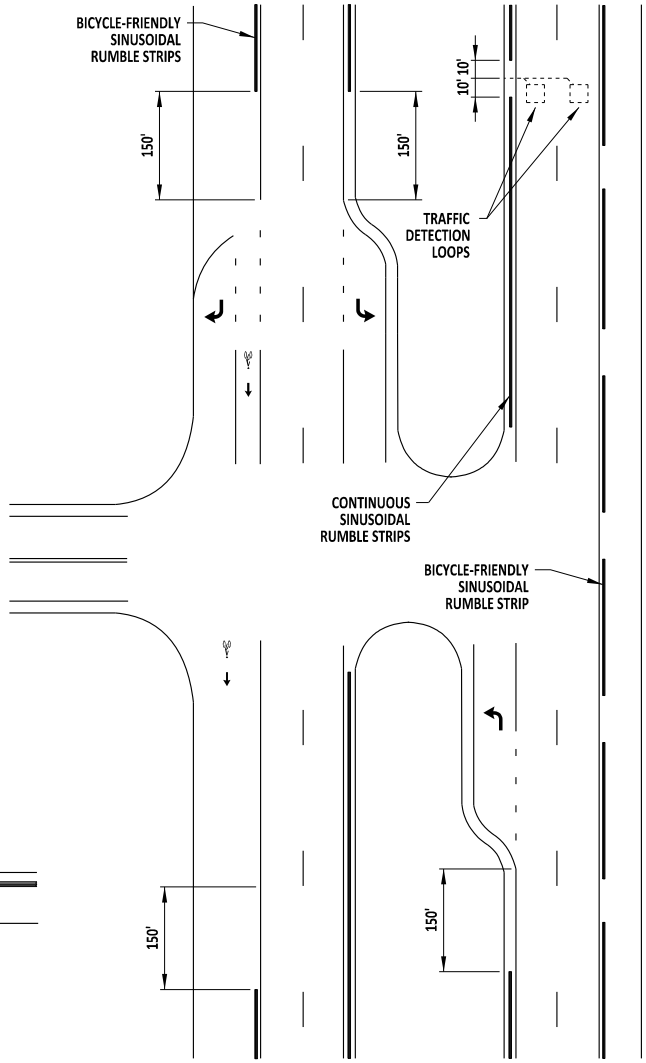


DESIGN OF CURVE PROFILE FOR SINUSOIDAL RUMBLE STRIP		
POINT	DEPTH FROM PAVEMENT SURFACE (IN.) (+/- 1/32")	DISTANCE FROM HIGH POINT "A" (IN.)
A	1/16	0
B	1/8	1 3/4
C	7/32	3 1/2
D	11/32	5 1/4
E	3/8	7
F	11/32	8 3/4
G	7/32	10 1/2
H	1/8	12 1/4
I	1/16	14

RUMBLE STRIP SECTION - SINUSOIDAL SHOULDER RUMBLE STRIPS



BICYCLE-FRIENDLY SINUSOIDAL SHOULDER RUMBLE STRIP SEGMENT DETAILS



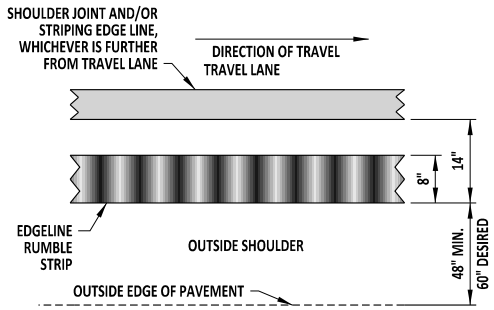
SINUSOIDAL SHOULDER RUMBLE STRIPS AT INTERSECTIONS

NOTES:
1.) DIMENSIONS MAY BE FIELD ADJUSTED AS DIRECTED BY THE ENGINEER.

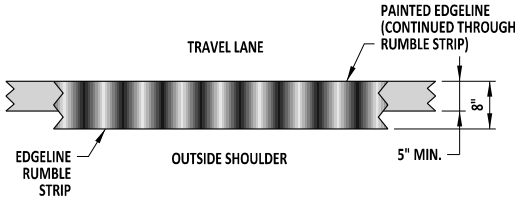
DelDOT	ENGINEERING SUPPORT / DATE — RECOMMENDED	SINUSOIDAL SHOULDER RUMBLE STRIPS ON MULTI-LANE CONVENTIONAL ROADWAYS	REVIEWED — DEPUTY DIRECTOR - DESIGN / DATE
		DGM 1-18 / APPENDIX B	APPROVED — CHIEF ENGINEER / DATE

12/15/2020

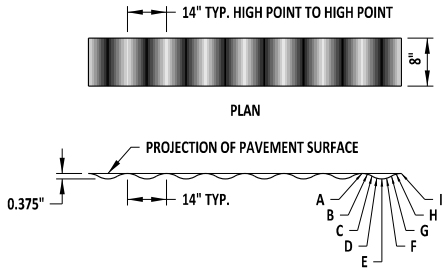
SCALE : NTS



SINUSOIDAL SHOULDER RUMBLE STRIP

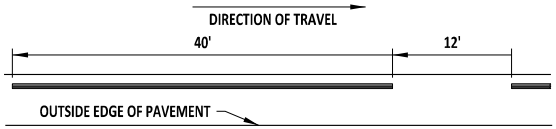


SINUSOIDAL EDGE LINE RUMBLE STRIPE

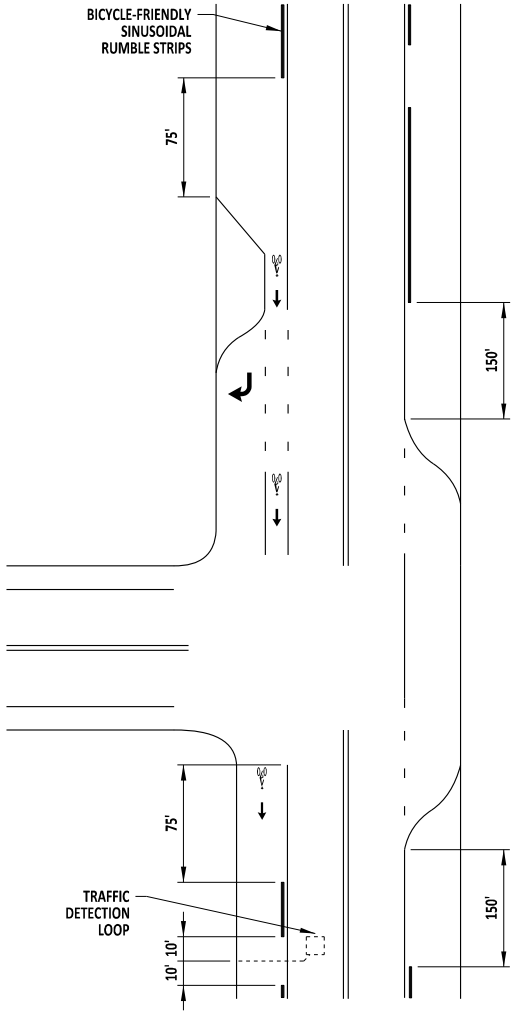


DESIGN OF CURVE PROFILE FOR SINUSOIDAL RUMBLE STRIP		
POINT	DEPTH FROM PAVEMENT SURFACE (IN.) (+/- 1/32")	DISTANCE FROM HIGH POINT "A" (IN.)
A	1/16	0
B	1/8	1 3/4
C	7/32	3 1/2
D	11/32	5 3/4
E	3/8	7
F	11/32	8 3/4
G	7/32	10 1/2
H	1/8	12 1/4
I	1/16	14

RUMBLE STRIP SECTION - SINUSOIDAL SHOULDER RUMBLE STRIPS



BICYCLE-FRIENDLY SINUSOIDAL SHOULDER RUMBLE STRIP SEGMENT DETAILS



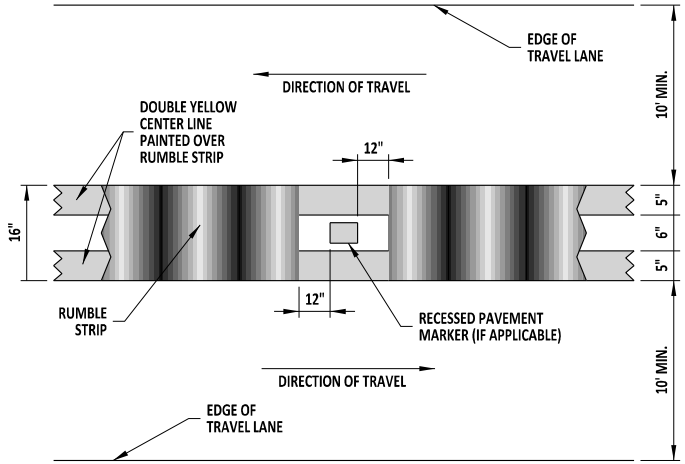
BICYCLE-FRIENDLY SINUSOIDAL SHOULDER RUMBLE STRIPS AT INTERSECTIONS

NOTES:
1.) DIMENSIONS MAY BE FIELD ADJUSTED AS DIRECTED BY THE ENGINEER.

DelDOT	ENGINEERING SUPPORT / DATE RECOMMENDED	SINUSOIDAL SHOULDER RUMBLE STRIPS ON TWO-LANE ROADWAYS	REVIEWED DEPUTY DIRECTOR - DESIGN / DATE
		DGM 1-18 / APPENDIX C	APPROVED CHIEF ENGINEER / DATE

12/15/2020

SCALE : NTS



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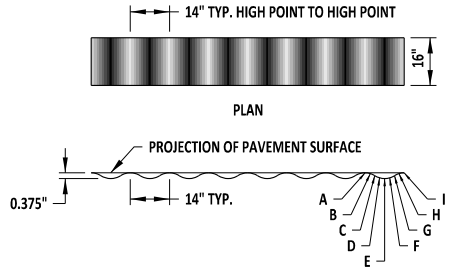

RUMBLE STRIP SECTION - SINUSOIDAL SHOULDER RUMBLE STRIPS

DESIGN OF CURVE PROFILE FOR SINUSOIDAL RUMBLE STRIP		
POINT	DEPTH FROM PAVEMENT SURFACE (IN.) (+/- 1/32")	DISTANCE FROM HIGH POINT "A" (IN.)
A	1/16	0
B	1/8	1 3/4
C	7/32	3 1/2
D	11/32	5 1/4
E	3/8	7
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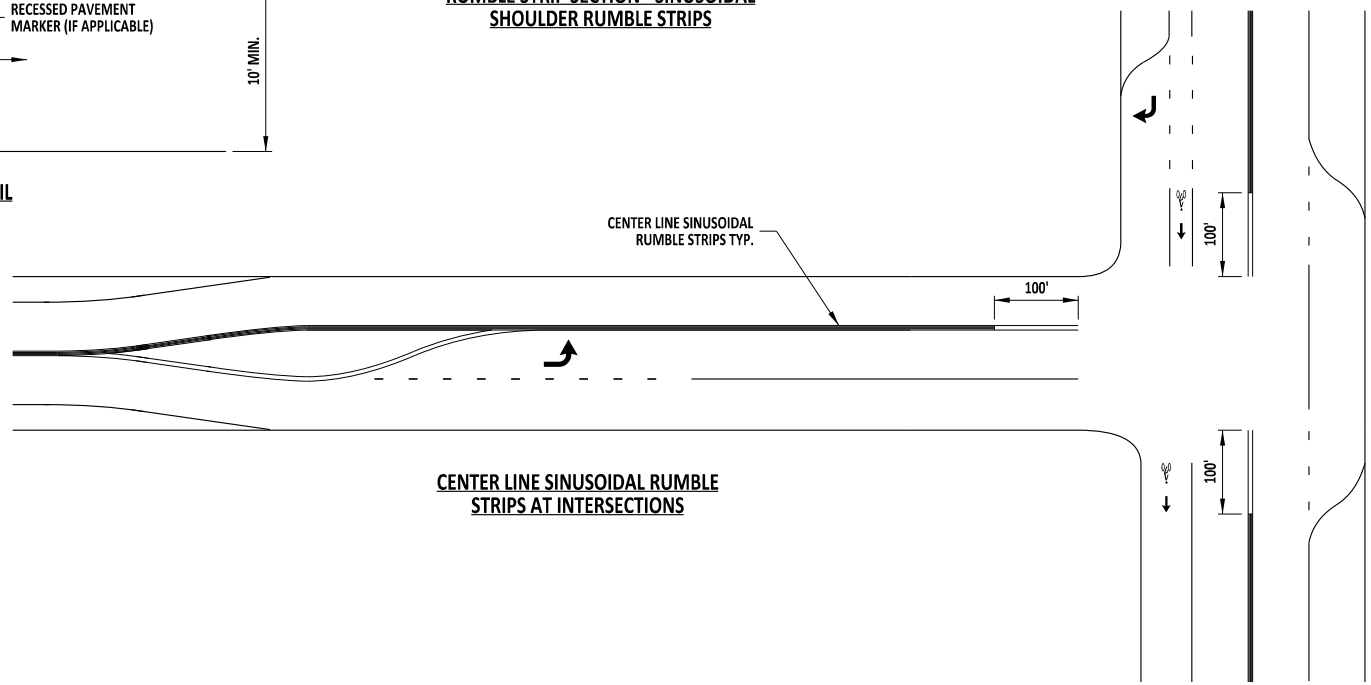
G	7/32	10 1/2
H	1/8	12 1/4
I	1/16	14



CENTER LINE SINUSOIDAL RUMBLE STRIPS AT INTERSECTIONS

NOTES:
1). CENTER LINE RUMBLE STRIPS SHALL NOT BE INSTALLED ON TWO-WAY LEFT TURN LANES, UNLESS DIRECTED BY THE ENGINEER.

2). DIMENSIONS MAY BE FIELD ADJUSTED AS DIRECTED BY THE ENGINEER.

DelDOT

ENGINEERING SUPPORT DATE
RECOMMENDED

CENTER LINE SINUSOIDAL RUMBLE STRIPS

DGM 1-18 | APPENDIX D

REVIEWED DEPUTY DIRECTOR - DESIGN DATE
APPROVED CHIEF ENGINEER DATE

12/15/2020