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State of Wyoming
Department of Transportation

U.S. Department of Transportation
Federal Highway Administration

Expert System on Guidance for the Application of Shoulder & Centerline Rumble Strips/ Stripes

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EXPERT SYSTEM

Expert systems are interactive programs designed to emulate the problem-solving skills of experts. They incorporate judgment, heuristics, intuition, and other expertise to provide knowledgeable advice about a series of tasks. [1] Expert systems have been used in transportation field for more than 30 years. Recently, researchers are using expert systems rigorously in decision making processes. The knowledge based system is one form of expert system, in which the subject knowledge is held as a set of facts and rules that may be interrogated and manipulated to provide an inferred solution or explanation for a given problem.[2]

EXPERT SYSTEM IN RUMBLE STRIPS/STRIPES

There are many requirements/factors that have to be considered before installing rumble strips/ stripes. Each agency has their own guideline and policy to install rumble strips, which varies from agency to agency. Not all factors are considered the same way in each agency's guideline. There are few agencies who consider ADT, speed limit, and residents in their policies. However, many agencies consider lane width, shoulder width, and bicycle traffic as important factors in their guidelines. The Expert System built for WYDOT is copyrighted, all rights reserved to the State of Wyoming, University of Wyoming, Department of Transportation, 2015.

This Expert System is based on responses from 29 U.S. State transportation agencies, as well as information gathered in earlier surveys, synthesis documents, and responses from 49 WYDOT engineers. This Expert System has been developed to provide guidance of rumble strips/stripes application on interstates, non-freeway divided multilane highways, undivided multilane highways, and two-lane highways in urban and rural settings. This Expert System can be used by DOTs, safety engineers, and district engineers to easily access all the information about rumble strips which will help to make decision on rumble strips installations and designs.

HOW TO USE

The Expert System is split into two main sections; shoulder rumble strips/stripes and centerline rumble strips/stripes. The first flow chart series titled "Shoulder Rumble Strips/Stripes" has six different sections based on areas and road types. By clicking any of the road types, the user will be taken to page for that type of road where all the details about installation criteria have been listed. Each of these charts is similar in forms and categories.

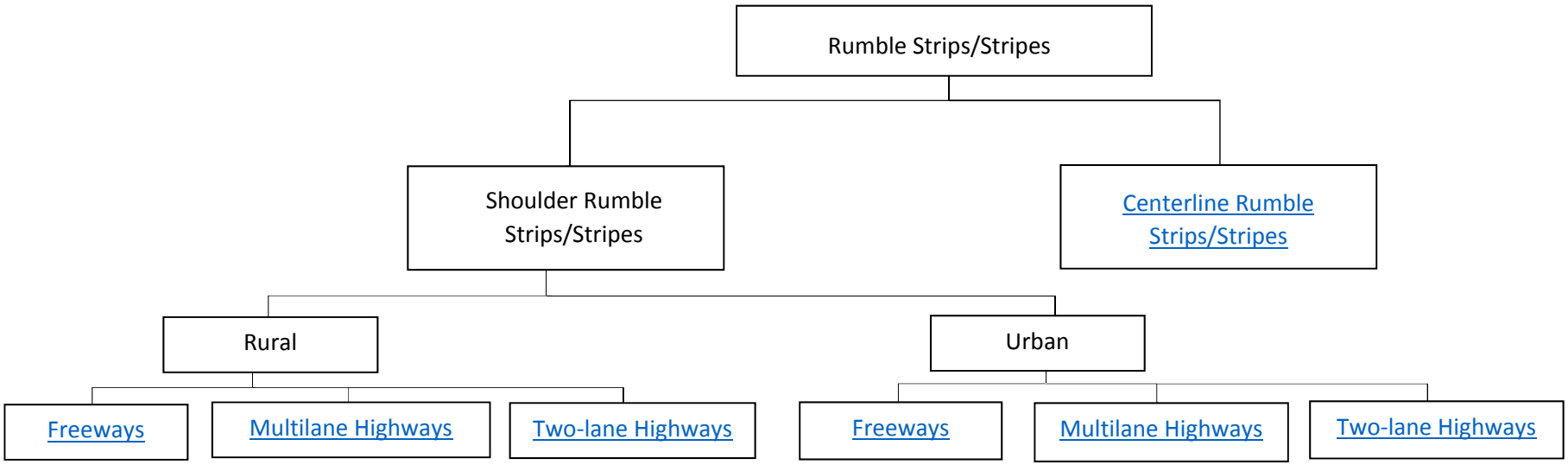
Each chart contains tabs for pavement condition, minimum shoulder width, minimum lane width, speed, heavy bicycle traffic, nearby residents, and ADT.
Before installing rumble strips in a roadway the factors in the Expert System should be checked. If all the criteria of a certain roadway type falls in the 'Green' shaded zone, it is recommended to install shoulder rumble strips in that roadway. For the 'Yellow' shaded zone, the recommendation provided in the box should be followed. The district engineers should make the final decision whether to install rumble strips or not. If there are one or more governing criteria in the 'Red' area, rumble strips should not be installed, which is a common practice followed by many states and also recommended by WYDOT engineers.

The flow chart titled "Centerline Rumble Strips/Stripes" has a single section based on roadway types. Centerline rumble strips are predominantly used in rural/urban two lane highways and multi-lane undivided highways. Lane and shoulder widths, ADT, motorcycle traffic, and noise are the important factors governing the application decision of Centerline Rumble Strips/ Stripes.

All the State DOTs and WYDOT survey responses have been referenced in the Expert System, including the information from the NCHRP Report 641. When a survey response is clicked, it will take the user to the survey results gathered for that question. When a state's name is clicked, it will take the user to the actual pages of that state's guideline/policy from which the information was extracted. For better accessibility, only important pages related to the requirements have been included in the report. Complete references can be checked via the blue URL hyperlinks provided at the end of each page.

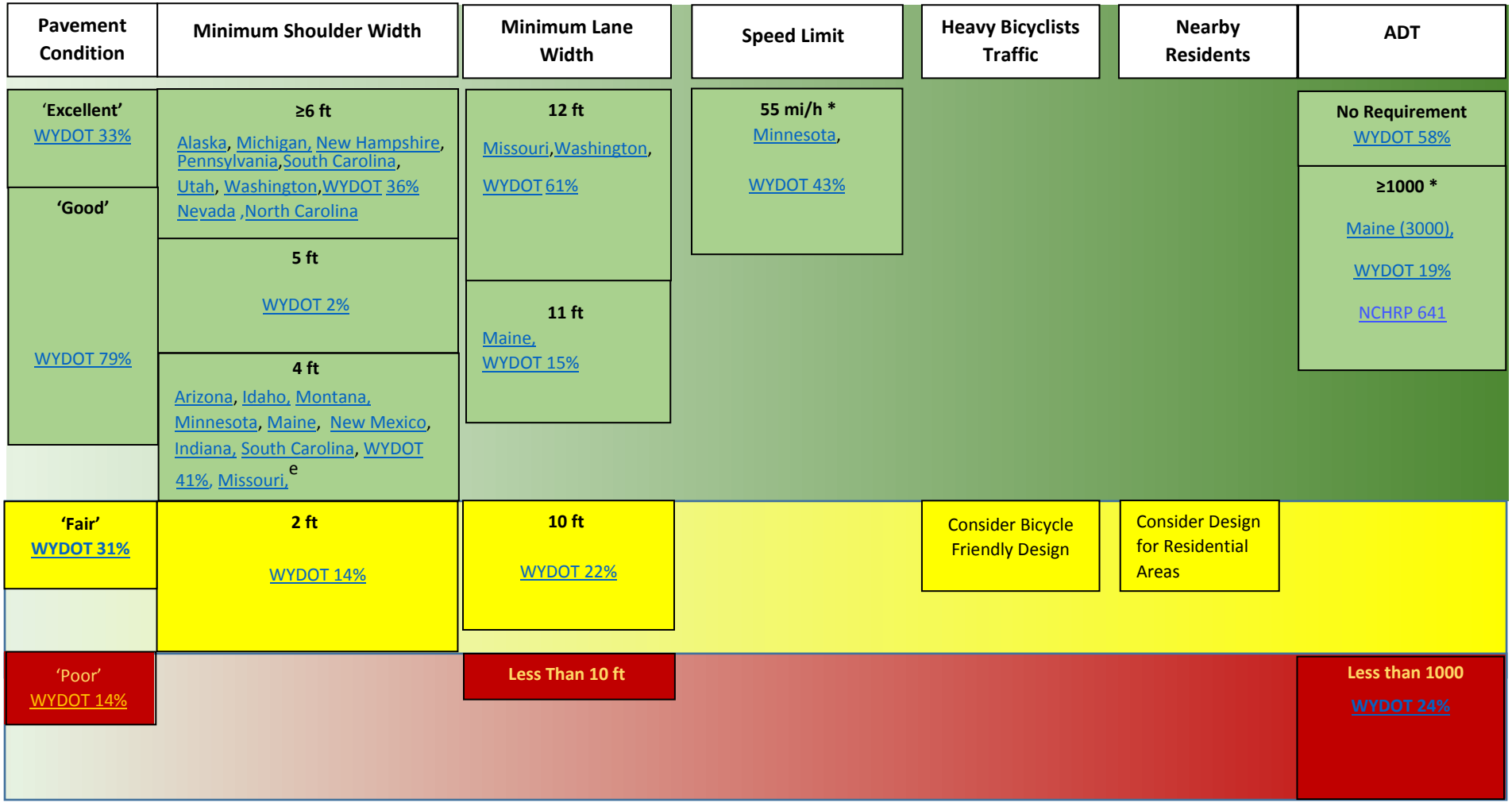
REFERENCES

1. Dym, C. L., and R. E. Levitt. Knowledge-Based Systems in Engineering. McGraw Hill, Inc., New York, 1991.
2. Michael A.P. Taylor. Knowledge-based systems for transport network analysis: A fifth generation perspective on transport network problems. Transportation Research Part A: General, Vol 24, No. 1, pp 3-14, 1990.


Rumble Strips/Stripes
Shoulder Rumble Strips/Stripes
Centerline Rumble Strips/Stripes
Rural
Urban
Freeways
Multilane Highways
Two-lane Highways
Freeways
Multilane Highways
Two-lane Highways

Shoulder Rumble Strips/Stripes

Rural Freeway



* If other requirements are met [a] Exception for Rumble Stripes [b] Centerline and shoulder/edgeline rumble strips are in combination. [c] Check the referenced link for details.

[d] Check the combined width of lane and shoulder. [e] Clear shoulder width

Common Practice in Most Agencies

Considered Based on Engineering Judgment and requirement

Avoided by Most Agencies

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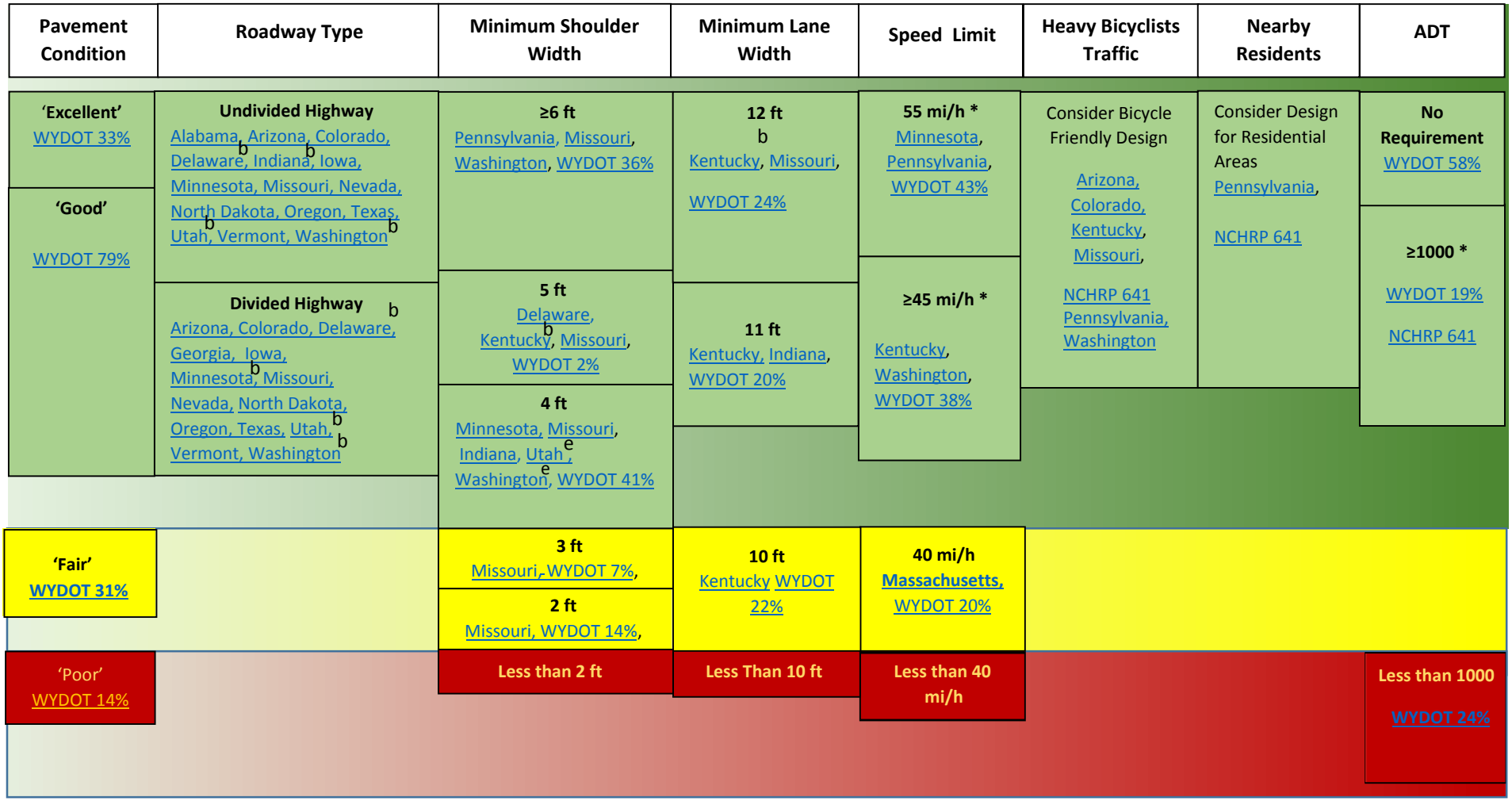
Shoulder Rumble Strips/Stripes

Rural Multi-lane Highway



* If other requirements are met

[b] Centerline and shoulder/edgeline rumble strips are in combination.

[e] Clear shoulder width

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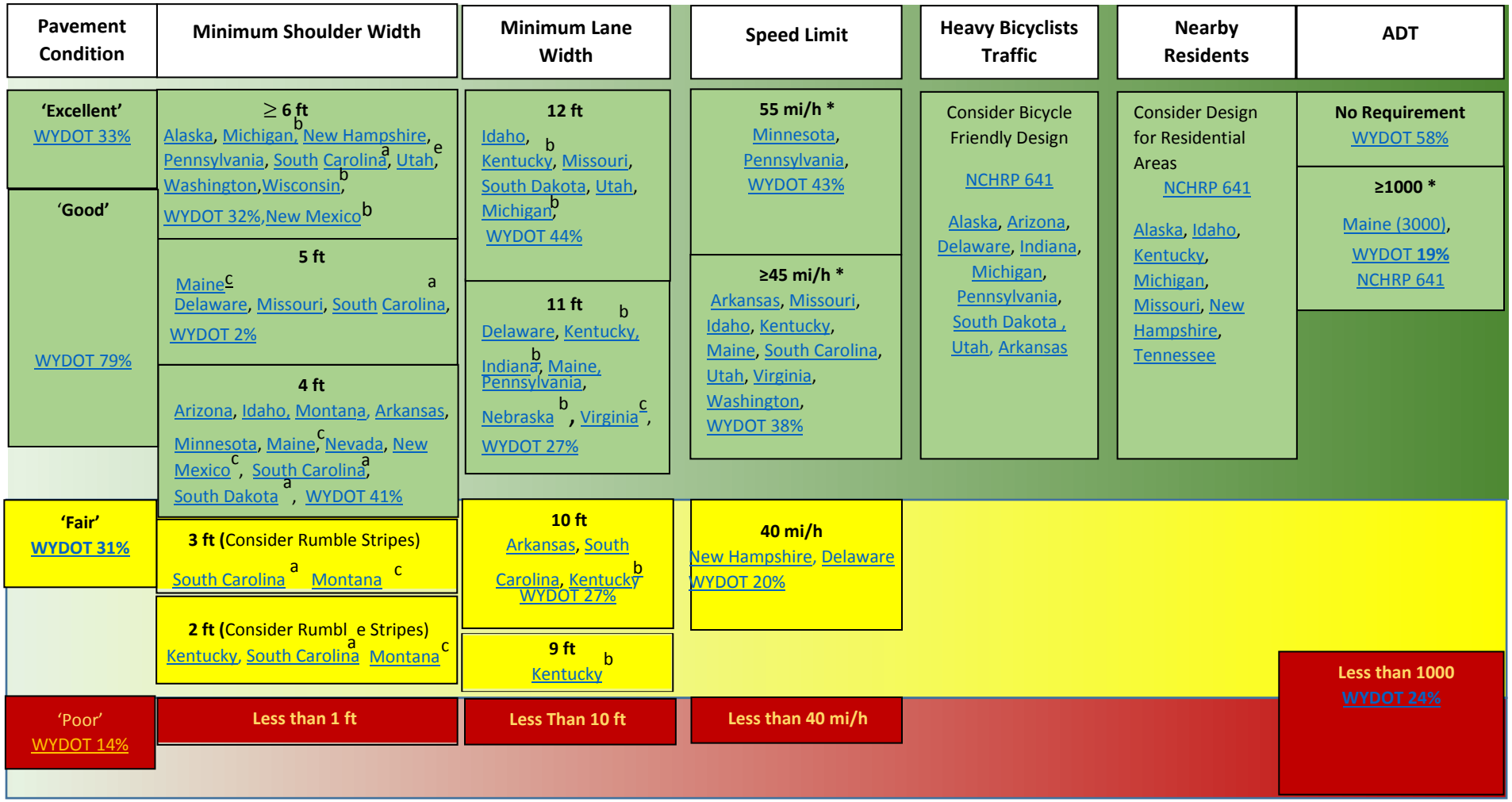
Shoulder Rumble Strips/Stripes

Rural Two-lane Highway



* If other requirements are met [a] Exception for Rumble Stripes [b] Centerline and shoulder/edgeline rumble strips are in combination. [c] Check the referenced link for details.

[e] Clear shoulder width

Common Practice in Most Agencies

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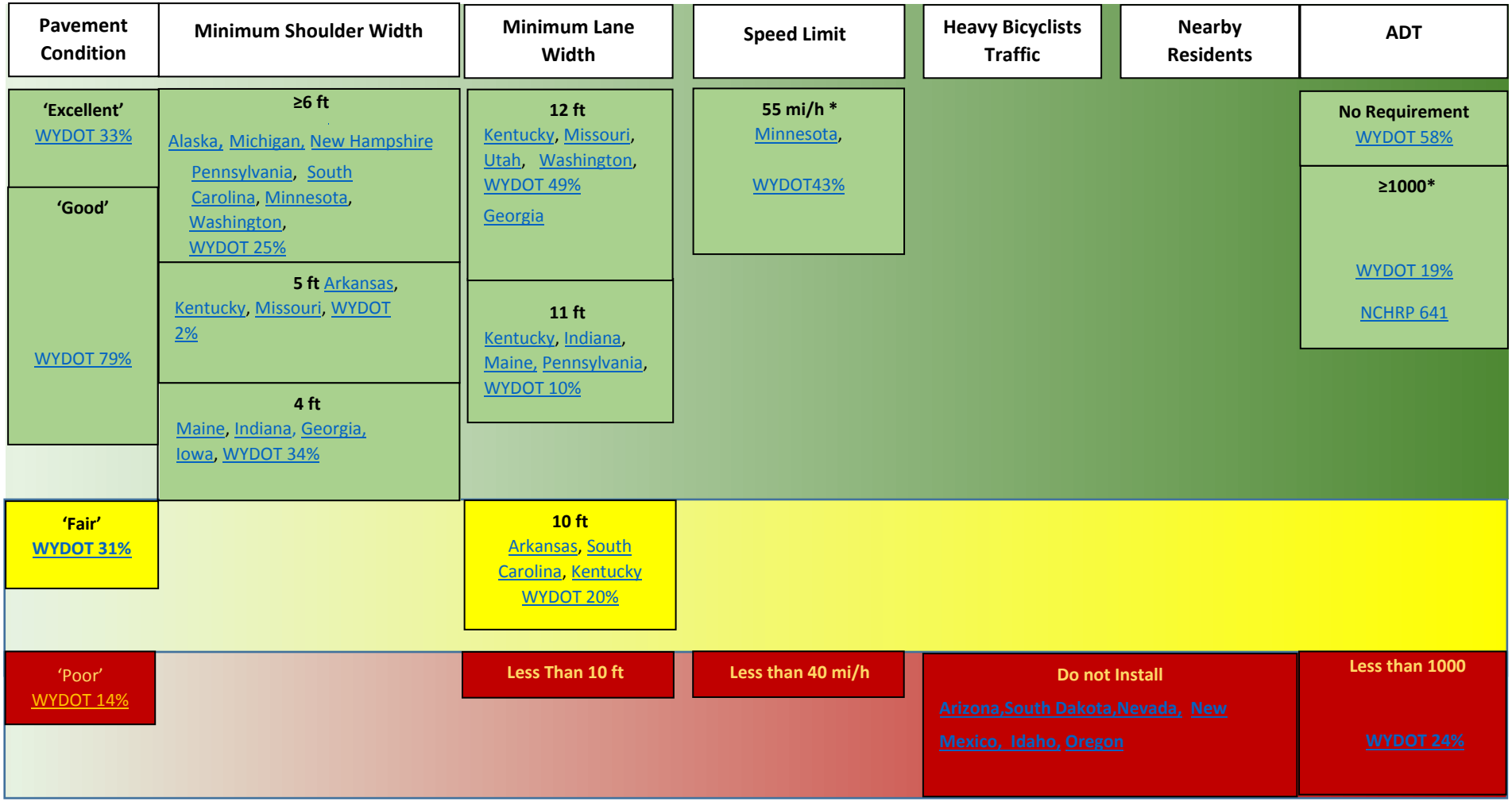
Shoulder Rumble Strips/Stripes

Urban Freeway



* If other requirements are met

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Shoulder Rumble Strips/Stripes

Urban Multi-lane Highway

Pavement Condition	Roadway Type	Minimum Shoulder Width	Minimum Lane Width	Speed Limit	Heavy Bicyclists Traffic	Nearby Residents	ADT
'Excellent' WYDOT 33%	**Undivided Highway** Delaware[b], Georgia, Iowa, Kentucky, Massachusetts, Minnesota[b], Missouri, Pennsylvania	**≥6 ft** Pennsylvania, **Minnesota** WYDOT 36%	**12 ft** Missouri, Kentucky, WYDOT 24%	**55 mi/h *** Minnesota, Pennsylvania, WYDOT 43%	Consider Bicycle Friendly Design Kentucky, Missouri, **Georgia, Iowa** NCHRP 641	Consider Design for Residential Areas Pennsylvania, NCHRP 641	**No Requirement** WYDOT 58%
'Good' WYDOT 79%	**Divided Highway** Alabama, Delaware[b], Georgia, Iowa, Kentucky, Massachusetts[b], Minnesota, Mississippi, Missouri, North Carolina, Pennsylvania	**5 ft** Delaware, Missouri, WYDOT 2%	**11 ft** Kentucky, WYDOT 20%	**≥45 mi/h *** Kentucky, WYDOT 38% **Minnesota,**			**≥1000 *** **Iowa (3000)** WYDOT 19% NCHRP 641
		4 ft **Georgia,Missouri,,** WYDOT 41%					
'Fair' **WYDOT 31%**		**3 ft** Missouri, WYDOT 7%, **2 ft** Missouri, WYDOT 14%,	**10 ft** Kentucky WYDOT 22%	**40 mi/h**			
'Poor' WYDOT 14%		**Less than 2 ft Do not Install** Missouri	**Less Than 10 ft**	**than 40 mi/h**			**Less than 1000** **WYDOT 24%**

* If other requirements are met

[b] Centerline and shoulder/edgeline rumble strips are in combination.

Common Practice in Most Agencies

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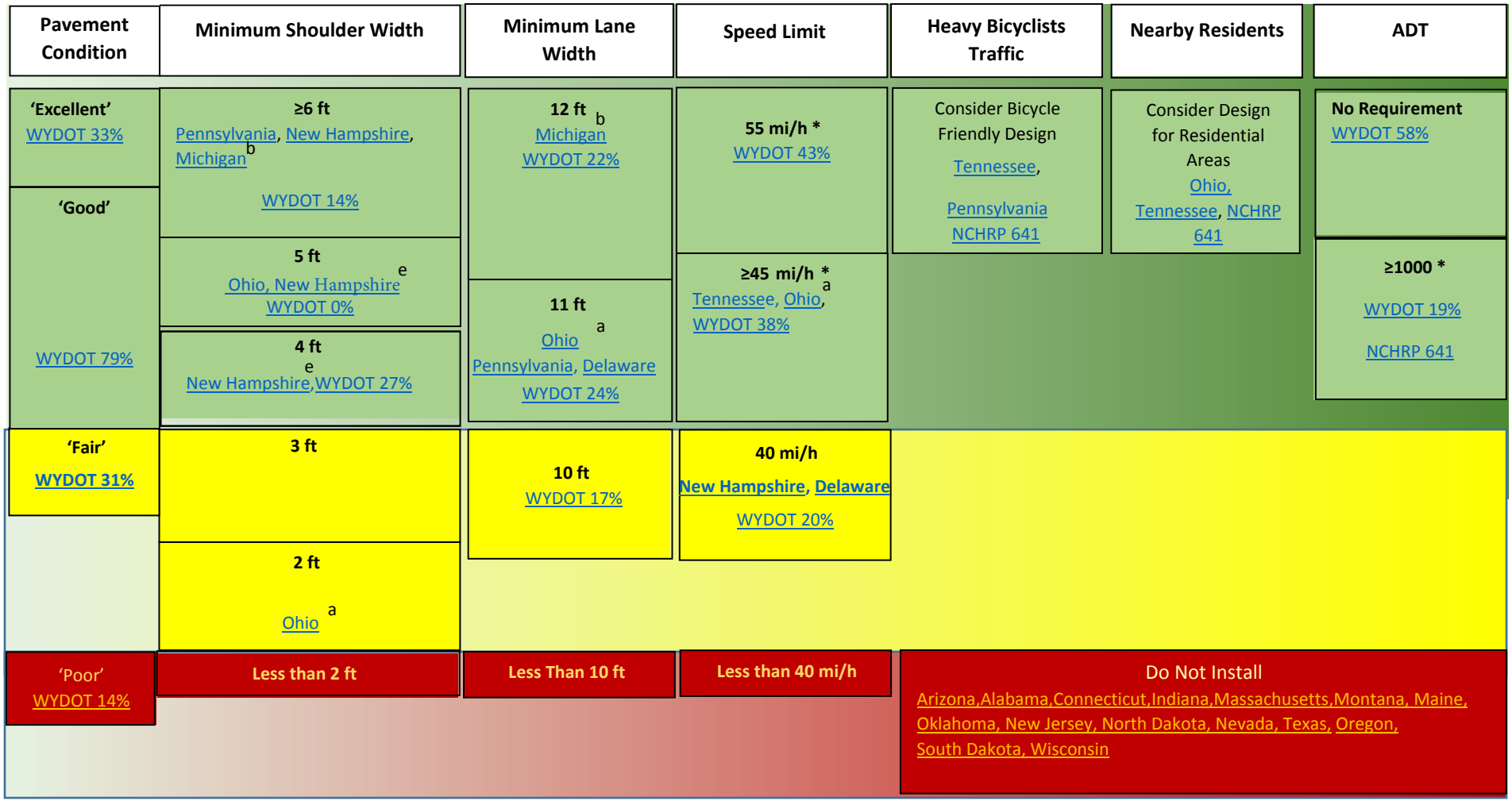
Shoulder Rumble Strips/Stripes

Urban Two-lane Highway



* If other requirements are met [a] Exception for Rumble Stripes [b] Centerline and shoulder/edgeline rumble strips are in combination. [e] Clear shoulder width

Common Practice in Most Agencies

Considered Based on Engineering Judgment and requirement

Avoided by Most Agencies

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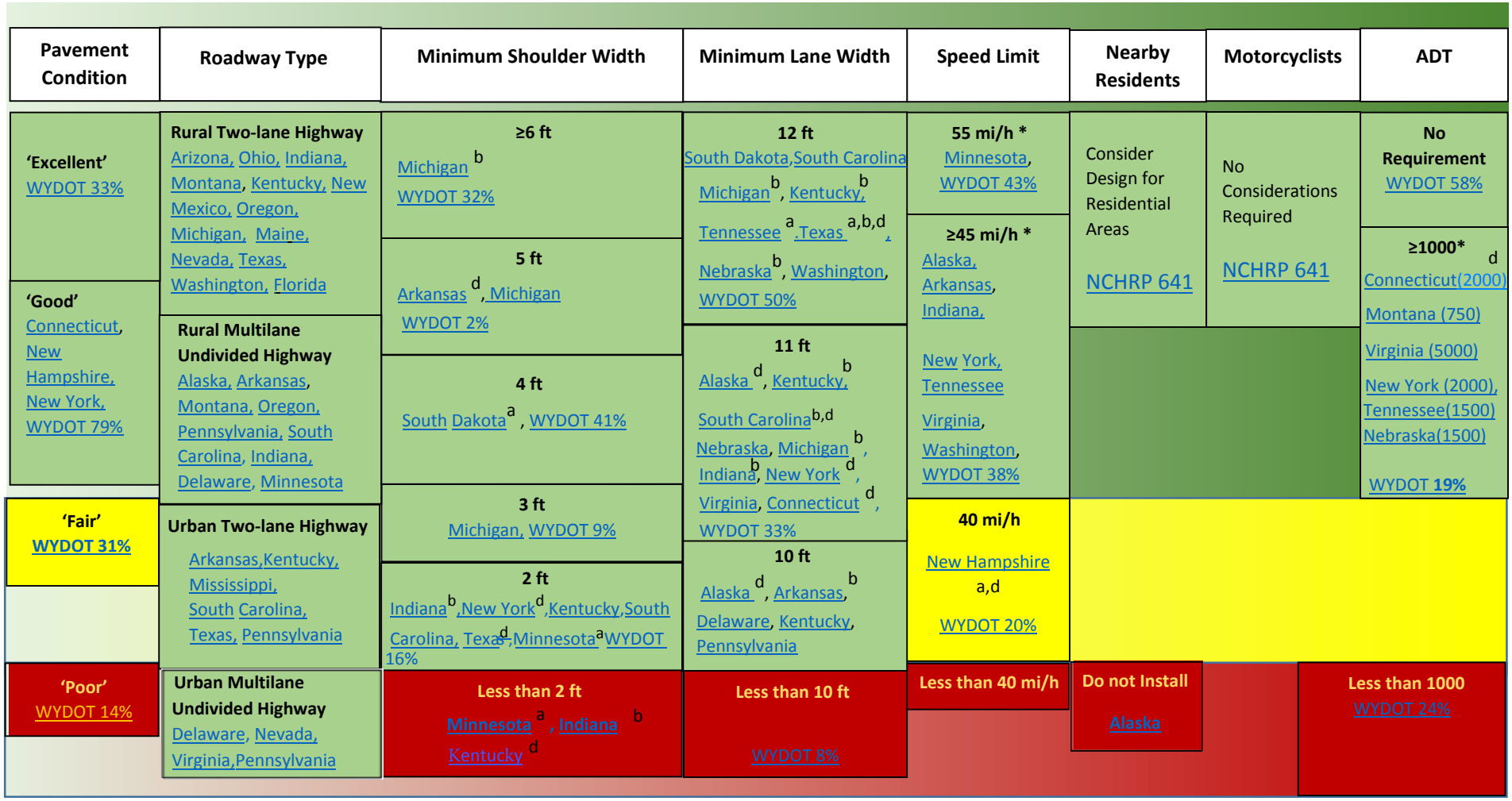
Centerline Rumble Strips/Stripes



Common Practice in Most Agencies

Considered Based on Engineering Judgment and requirement

Avoided by Most Agencies

* If other requirements are met

[a] Use stripes, check the referenced link for details.

[b] Centerline and shoulder/edgeline rumble strips are in combination.

[c] Exception, check the referenced link for details.

[d] Check the combined width of lane and shoulder.

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WYDOT SURVEY:

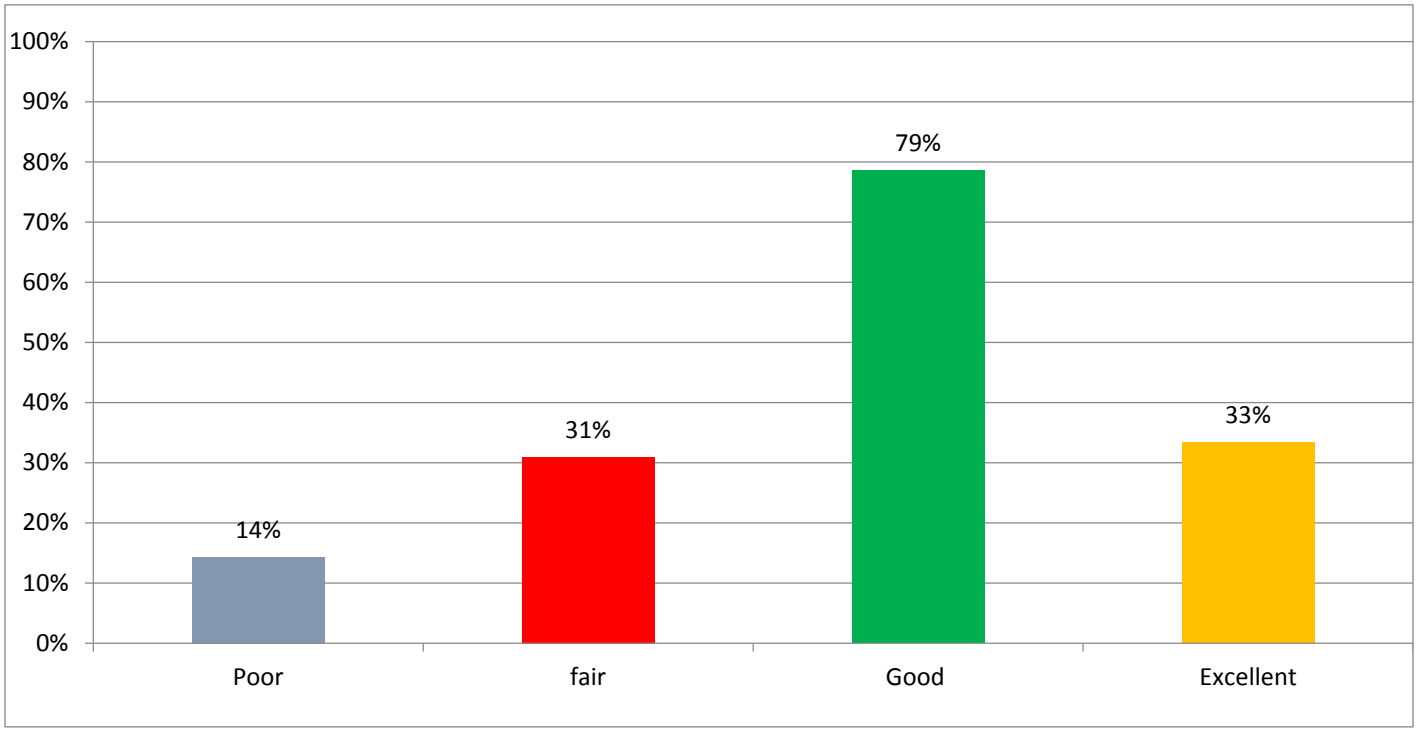

Figure 1: What should be the Recommended Condition of Asphalt Layer to Install Rumble Strips?

WYDOT engineers had been asked about the recommended condition of pavement to install rumble strips. Among the 45 respondents, 42 answered and 3 others skipped this question. This question had options for multiple answers. Among the respondents, 33 engineers (79 percent) recommended to install rumble strips on pavement with 'good' asphalt layer condition.

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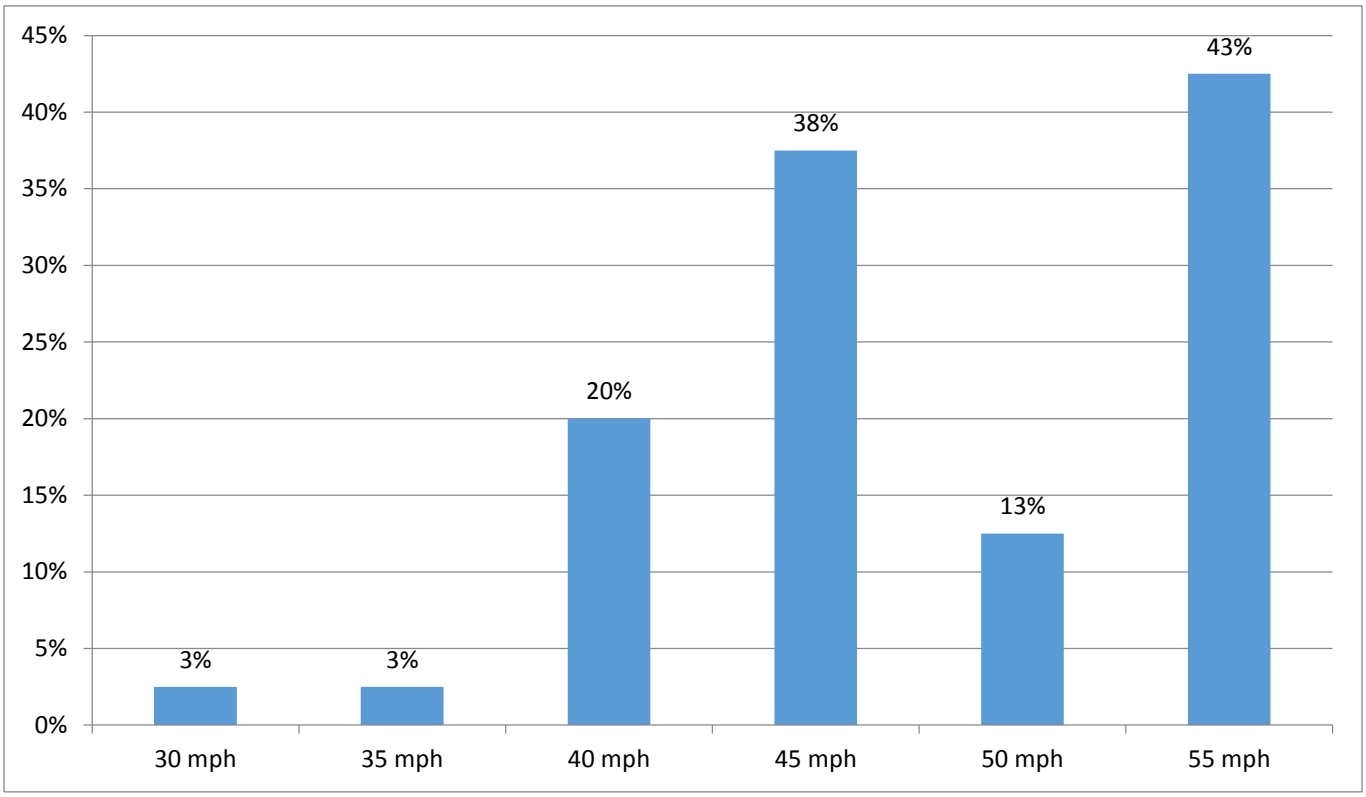

Figure 2: What should be the Minimum Speed Limit to Install Rumble Strips?

This question also had the option to choose multiple answers. Instead of asking separately for different types of roads and rumble strips, a general question asked about the speed, as it would be similar for different types of rumble strips. Though, it will vary on different types of roads which are included in the recommendation. There are many states that do not have any minimum speed limit for installation.

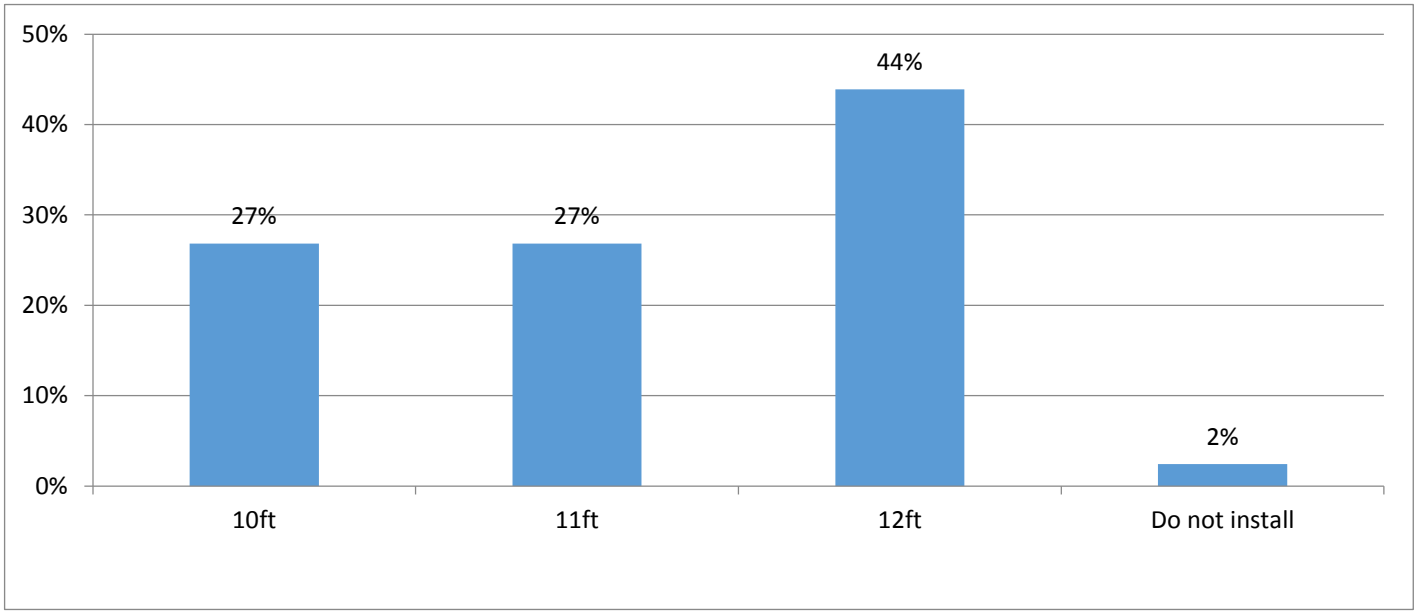

Figure 3: What should be the Minimum Lane Width to Install Shoulder Rumble Strips in Rural Two-lane Highway?

A big portion of the engineers (44 percent) recommended to use 12 feet as a minimum lane width to install rumble strips in rural two lane highways. Twenty-seven percent had recommended to install on 10 feet and 11 feet lane.

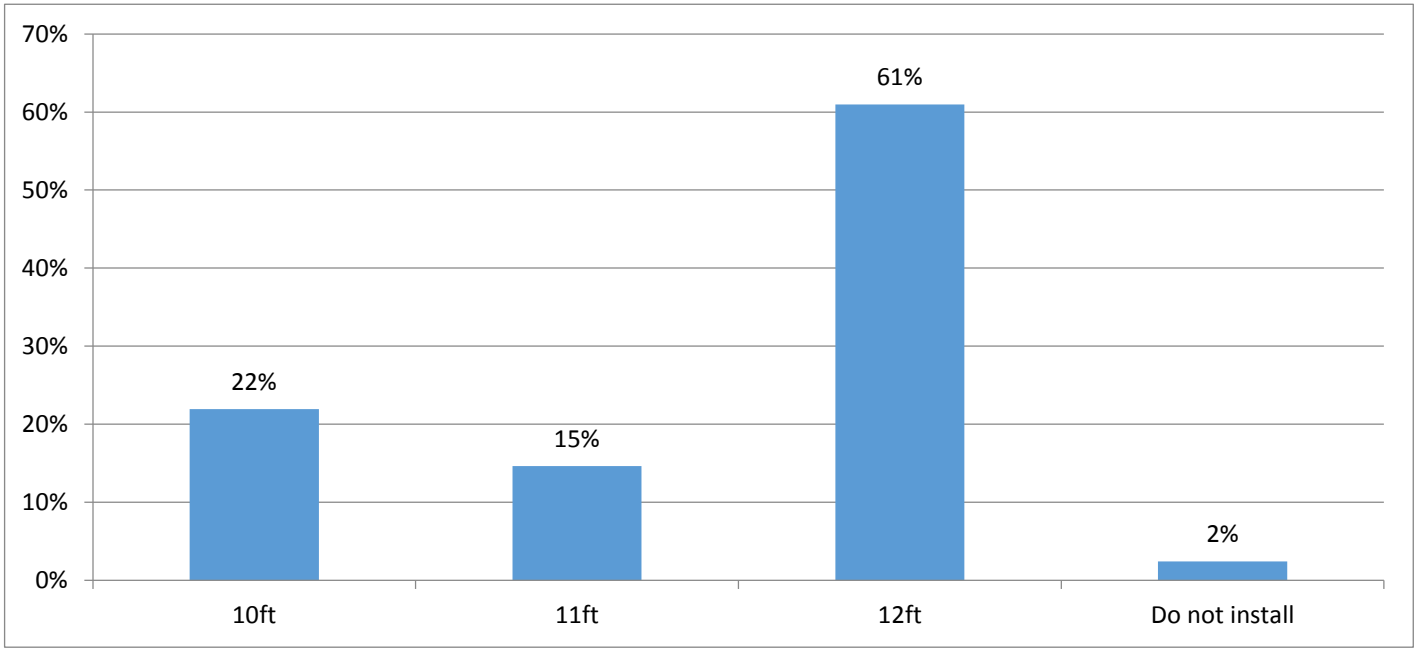

Figure 4: What should be the Minimum Lane Width to Install Shoulder Rumble Strips in Rural Freeway?

For rural freeway, 61 percent engineers recommended to install rumble strips on minimum 12 feet lane roads which is higher than what they recommended for rural two lane highway. Moreover, 11 feet lane width have been recommended by 15 percent engineers. Additionally, 2 percent recommended to install rumble strips on 11 feet roadway.

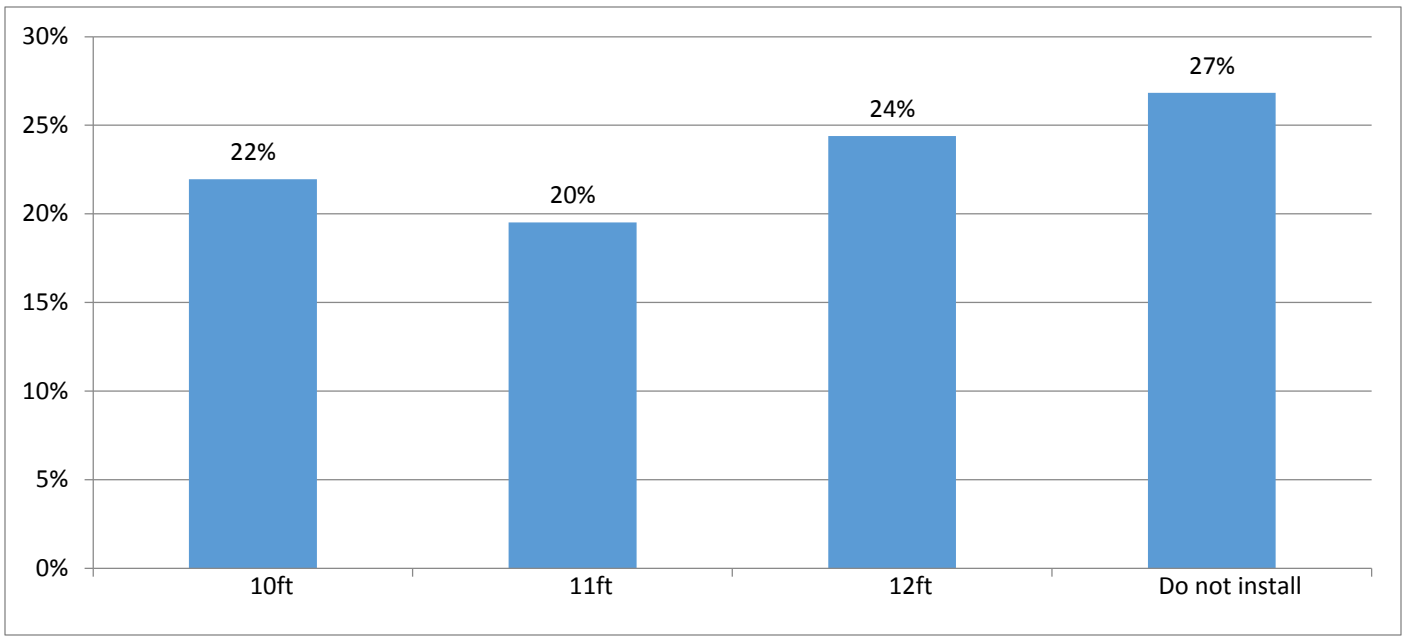

Figure 5: What should be the Minimum Lane Width to Install Shoulder Rumble Strips in Multilane Highway?

For multilane highway, 27 percent engineers suggested 'Do not install rumble strips' and 24 percent suggested for 12 feet lane width.

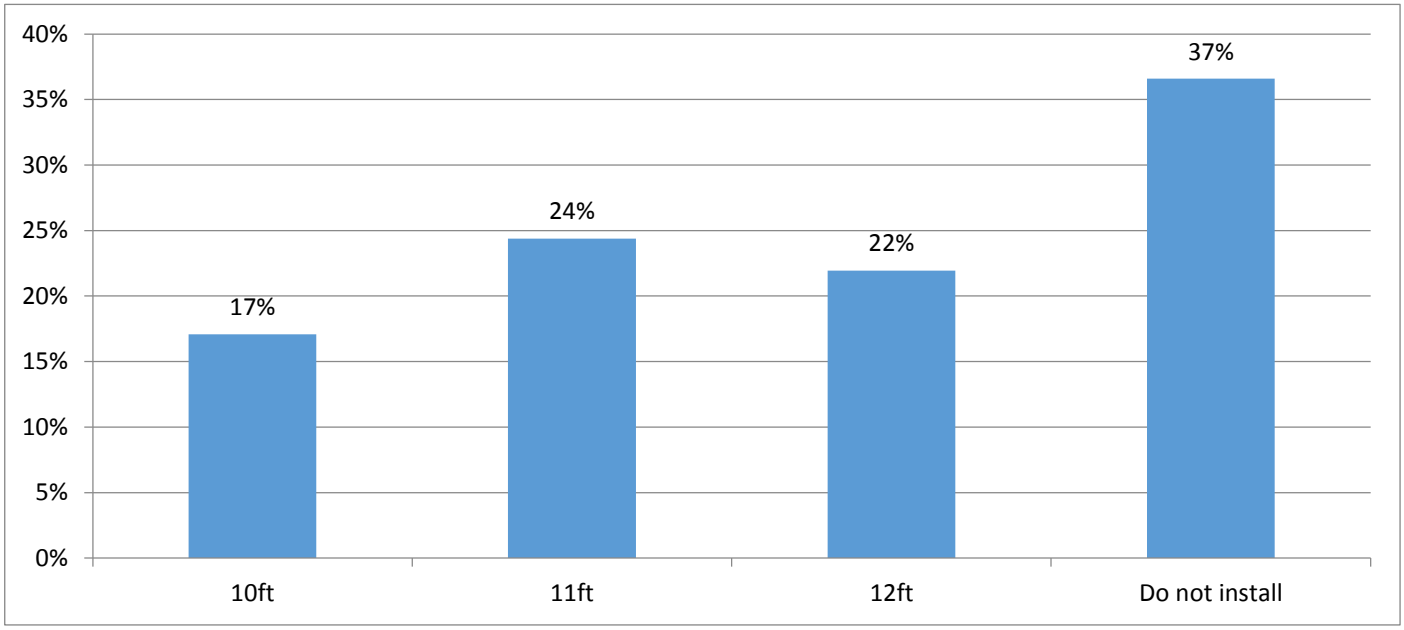

Figure 6: What should be the Minimum Lane Width to Install Shoulder Rumble Strips in Urban Two-lane Highway?

For urban two-lane highway, 37 percent engineers recommended 'Do not install rumble strips' which has received highest response in this question. The minimum lane width recommendation for 12 feet, 11 feet, and 10 feet is 22, 24, and 17 percent consecutively.

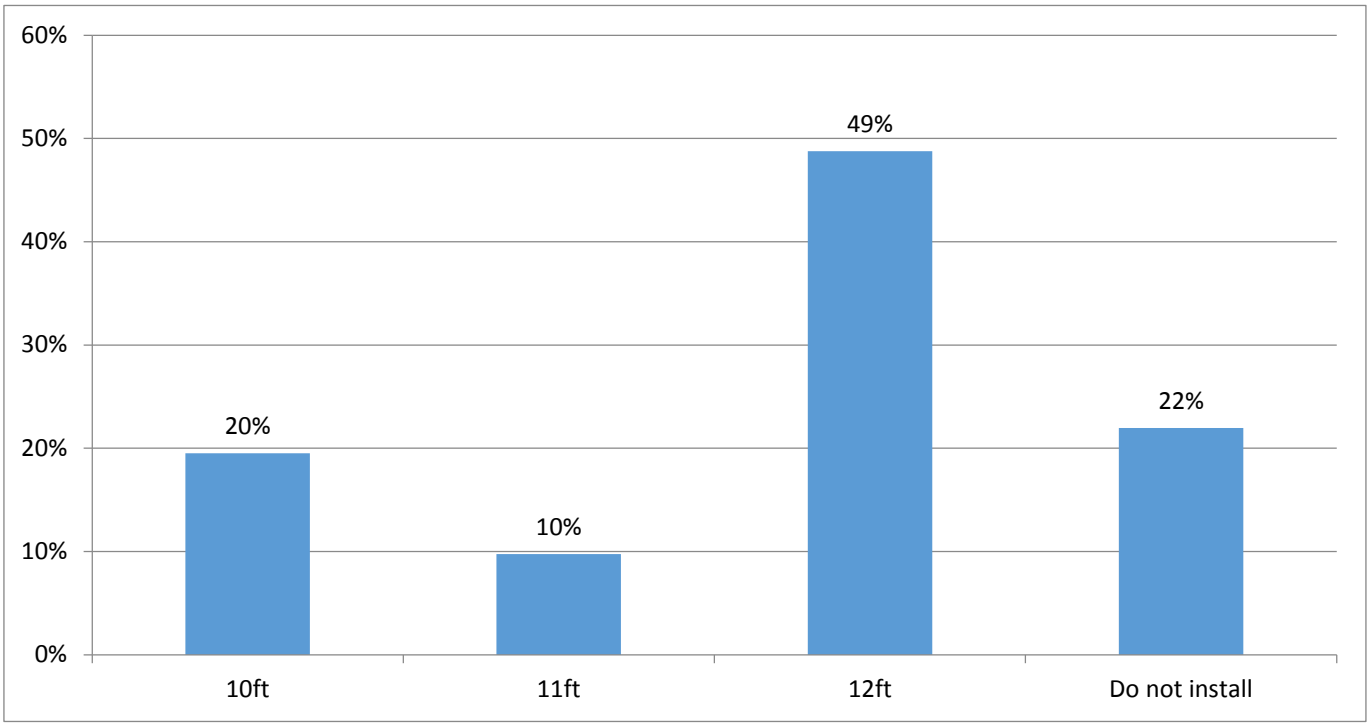

Figure 7: What should be the Minimum Lane Width to Install Shoulder Rumble Strips in Urban Freeway?

Unlike urban two-lane highway, only 22 percent recommended 'Do not install rumble strips' on urban freeway and 49 percent responded for 12 feet minimum lane width for rumble strips installation.

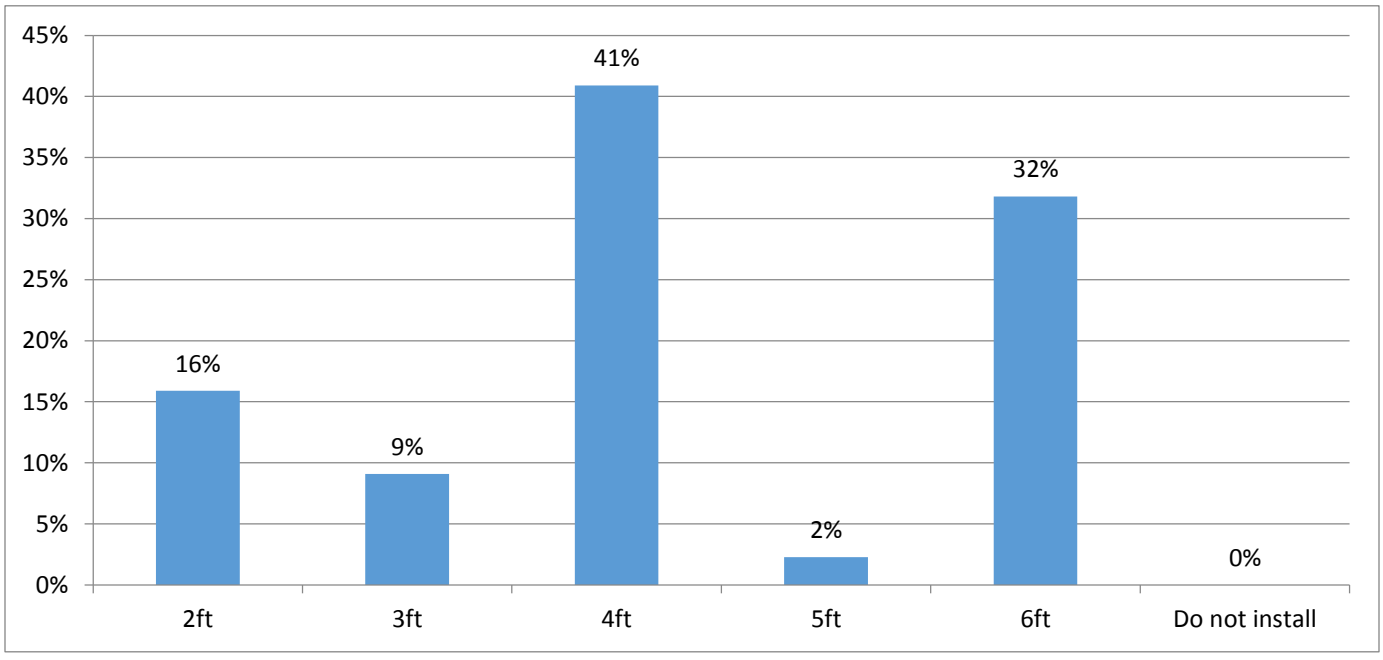

Figure 8: WYDOT Shoulder Width Recommendation for Rural Two-lane Highway

The engineers were asked about the minimum clear shoulder width too. For rural two lane highway, 41 percent recommended to provide 4 feet clear shoulder width. If 4 feet of clear shoulder width is provided, this will be clear enough for bicyclists.

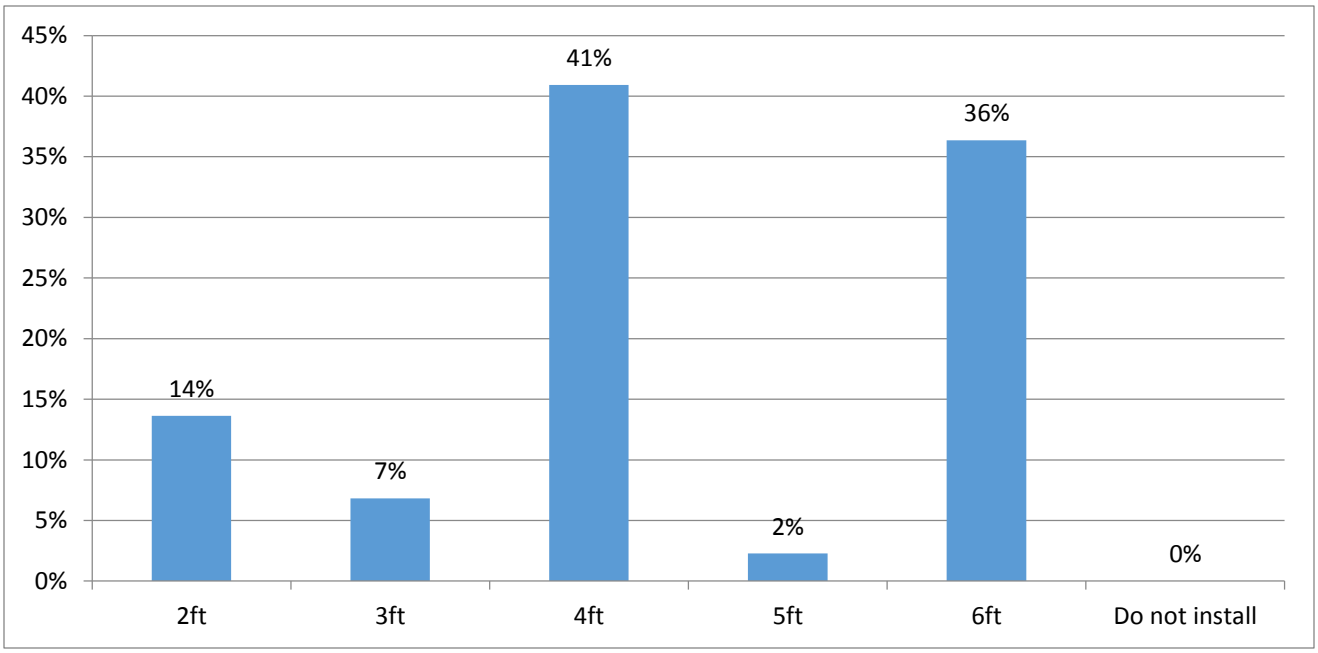

Figure 9: WYDOT Shoulder Width Recommendation for Rural Freeway

Recommendation for rural freeway and rural two lane highway are quite similar. Minimum 4 feet and 6 feet of clear shoulder width had been suggested by 41 percent and 36 percent engineers consecutively.

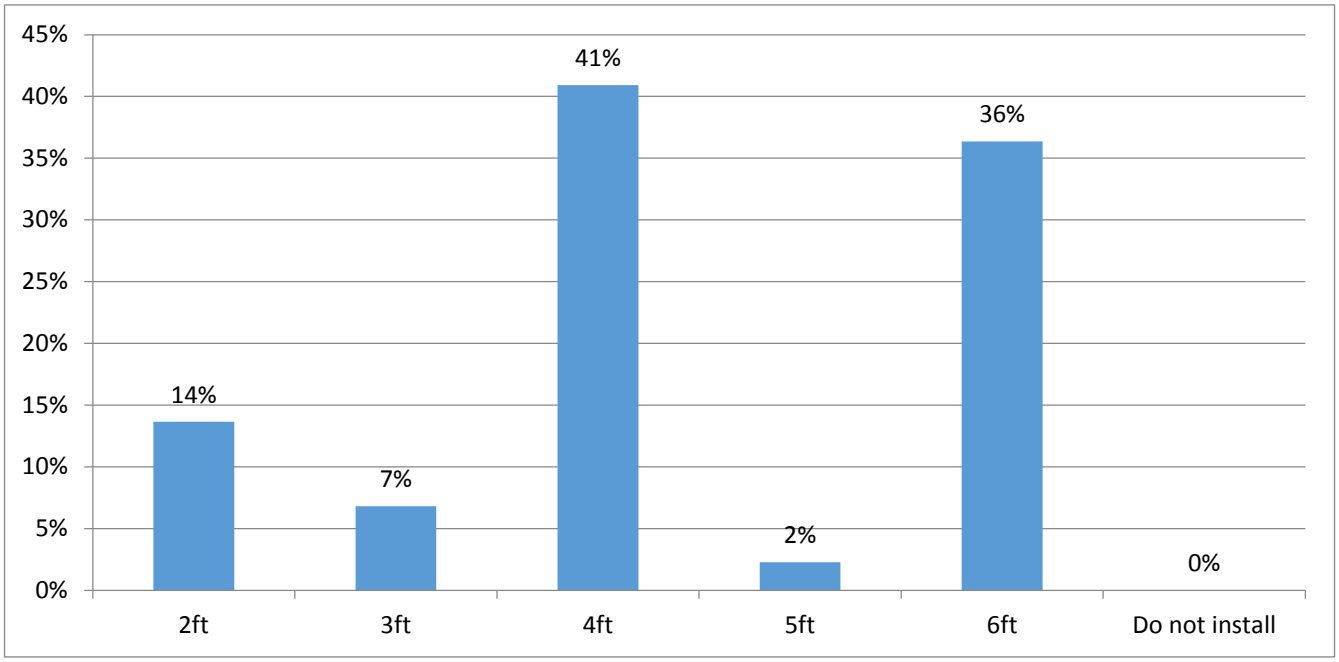

Figure 10: WYDOT Shoulder Width Recommendation for Multi-lane Highway

For multilane highway, 41 percent of engineers recommended providing 4 feet clear shoulder width as well. No one recommended to 'Do not install'.

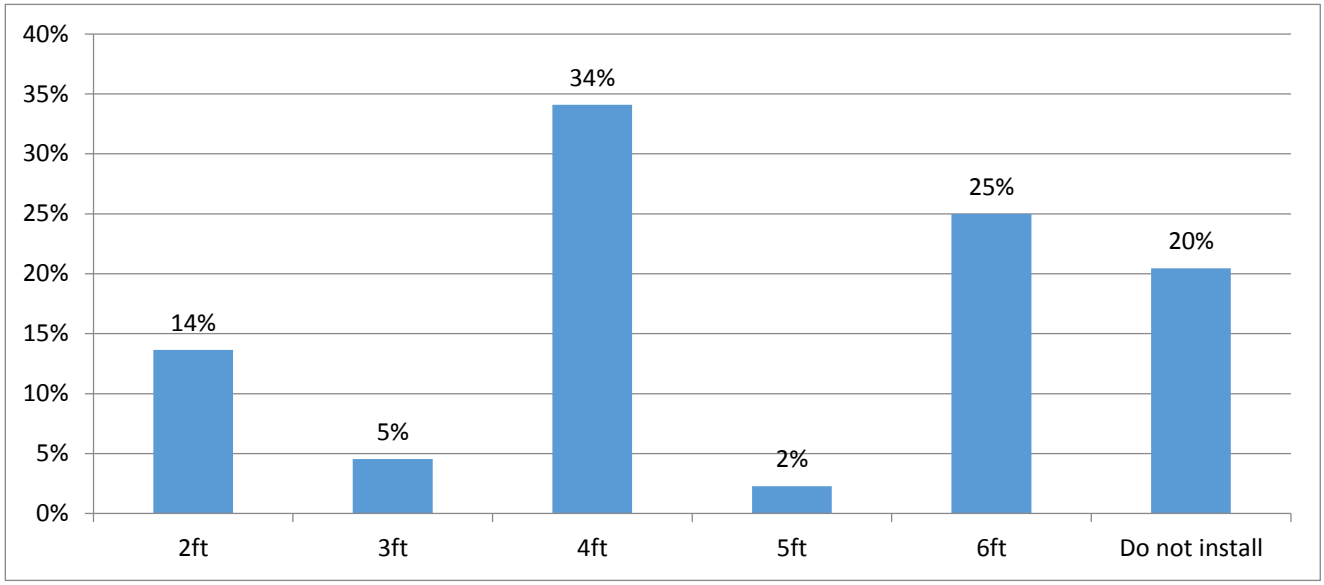

Figure 11: WYDOT Shoulder Width Recommendation for Urban Freeway

Similar to rural roadways, the majority of engineers also recommended 4 feet of clear shoulder width. But, 20 percent of the respondents also recommended 'do not install rumble strips' which had also been seen on urban freeway lane width recommendation.

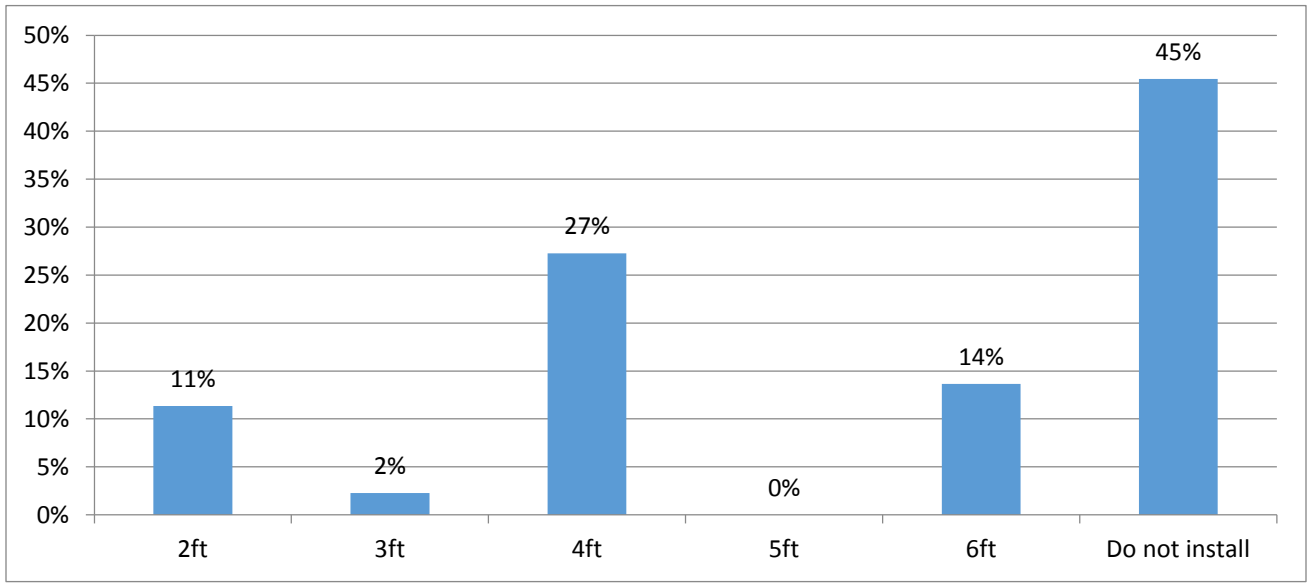

Figure 12: WYDOT Shoulder Width Recommendation for Urban Two-lane Highway

The percentage for 'Do not install rumble strips' on urban two lane highway is higher than any other road types. Only 55 percent recommended installing rumble strips where 27 percent recommended for 4 feet clear shoulder width.

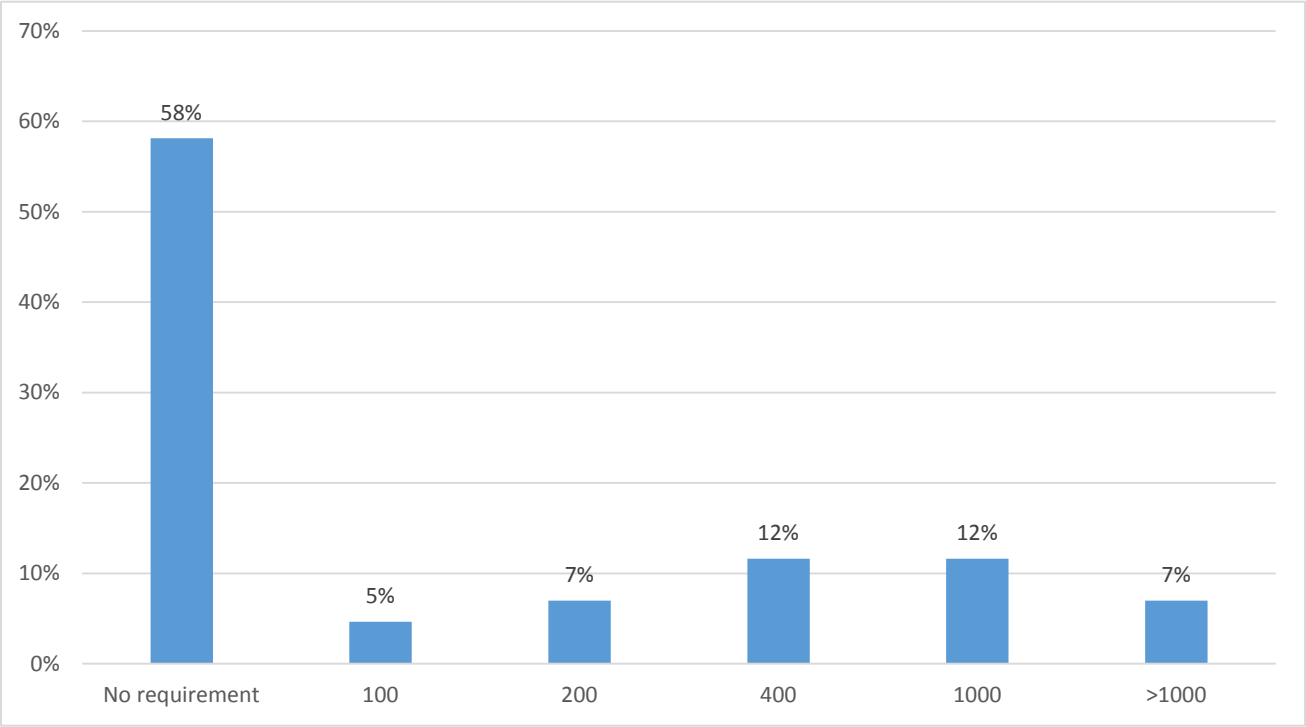

Figure 13: WYDOT ADT Recommendation

Engineers were asked for recommendation about minimum Average Daily Traffic (ADT) too. Among the respondents, 58 percent suggested installing rumble strips without considering ADT. Only 12 percent and 7 percent recommended that a minimum ADT should be 1000 vehicle/day and greater than 1000 consecutively.

Table 1: Types of Roadway Shoulder Rumble Strips are Applied (Survey Response)

Rural Freeway	Multilane Highways	Rural two-lane Highways	Urban Freeway	Urban two-lane Highways
Arizona	Arizona	Arizona		
		Florida	Florida	
South Dakota	South Dakota	South Dakota		
Alaska		Alaska		
Alabama	Alabama	Alabama	Alabama	
New Jersey			New Jersey	
North Dakota	North Dakota	North Dakota	North Dakota	
Tennessee	Tennessee	Tennessee	Tennessee	Tennessee
Mississippi	Mississippi	Mississippi	Mississippi	Mississippi
Oklahoma	Oklahoma	Oklahoma	Oklahoma	
Arkansas	Arkansas	Arkansas	Arkansas	Arkansas
		Nevada		
Texas	Texas	Texas	Texas	Texas
Michigan	Michigan	Michigan	Michigan	
Ohio	Ohio			
Indiana	Indiana		Indiana	
Kentucky	Kentucky	Kentucky	Kentucky	Kentucky
Wisconsin	Wisconsin	Wisconsin	Wisconsin	
South Carolina	South Carolina	South Carolina	South Carolina	
New Hampshire	New Hampshire	New Hampshire	New Hampshire	New Hampshire
New Mexico	New Mexico	New Mexico		
Montana	Montana	Montana		
Idaho	Idaho	Idaho		
Connecticut			Connecticut	
Pennsylvania	Pennsylvania	Pennsylvania	Pennsylvania	Pennsylvania
Maine		Maine	Maine	
Massachusetts	Massachusetts	Massachusetts	Massachusetts	
Oregon	Oregon	Oregon		
Wyoming	Wyoming	Wyoming	Wyoming	

* Blank cells mean shoulder rumble strips are not installed in that type of roadway.

Among the 29 DOTs, 27 responded they are using rumble strips in rural freeways and 25 on rural two-lane highways. Use of rumble strips in urban areas is less common than use in rural areas. Only 6 DOTs use rumble strips in urban two-lane highway, though 20 DOTs responded they are using rumble strips in their urban freeways.

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Table 2. Summary of shoulder rumble strip practices in the US.

State or province*	Pattern characteristics			Minimum requirements for installation								Dimensions				Date of policy
	Roadway type	Rumble type**	Skip Pattern	Shoulder width	Lateral clearance	ADT (vpd)	Pavement depth	Speed	Accident	Bicycle	Offset (A)	Length (B)	Width (C)	Depth (D)	Spacing (E)	
Alabama*	U frwy; U multilane divided; R freeway; R multilane divided; R multilane undivided; R two-lane	M	Continuous	N	N	N	N	N	N	N	18 in.	16 in.	7 in.	0.5 – 0.625 in.	12 in.	–
		RL	Continuous	N	N	N	N	N	N	N	0 in.	3 ft	1 in.	0.5 in.	8 in.	10/93
Alaska	U frwy; U expwy U two-lane R frwy R expwy R two-lane	M	6 ft Gap 40 ft Cycle 10 ft Gap (edgeline)	6 ft	4 ft	–	2 in.	45 mph	N	Y	2 in. for 6 in. shldr 6 in. for > 6 in. shldr	16 in.	7 in.	0.5 in.	12 in.	5/01
Arkansas*	U frwy; R frwy	M	Continuous	N	N	N	N	N	N	N	4 in.	16 in.	7 in.	0.5– 0.625 in.	12 in.	–
Arizona*	R frwy; R multilane divided; R multilane undivided; R two-lane	M	10 ft Gap 40 ft Cycle	3–6 in.	2 in.	N	N	N	N	Y	0 in.	6 in.	7 in. ± 0.25 in.	0.375 in.	12 in. ± 1 in.	5/03
											10 in.	8 in. or 12 in.	7 in. ± 0.25 in.	0.375 in.	12 in. ± 1 in.	
California	R frwy R expwy R two-lane	M	Continuous	4 ft	5 ft	N	N	N	N	Y	6–12 in.	12 in.	5 in.	0.32 in. ± 125 in.	12 in.	9/02
		RL	Continuous	4 ft	5 ft	N	N	N	N	Y	6–12 in.	12 in.	2 in.	1 in.	8 in.	
		RS	Continuous	4 ft	5 ft	N	N	N	N	Y	6–12 in.	–	–	–	–	
Colorado*	R frwy; R frwy ramps R multilane divided; R multilane undivided; R two-lane	M	12 ft Gap 60 ft Cycle	4 ft	6 ft	N	Y	N	N	N	0 in.	12 in.	5 in.	0.375 in.	12 in.	10/00
		RL,F	12 ft Gap 60 ft Cycle	4 ft	6 ft	N	Y	N	N	N	0 in.	12 in.	2.375 in.	0.5–1 in.	4 in.	
Connecticut*	U frwy; R frwy	M	Continuous	3 ft	4 ft	N	N	N	N	N	6 in. (median) 12 in (outside)	16 in. ± 0.5 in.	7 in. ± 0.5 in.	0.5– 0.625 in.	12 in. ± 0.5 in.	10/99

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Delaware*	U frwy; U multilane divided; U multilane undivided; U two-lane; R freeway; R multilane divided; R multilane undivided; R two-lane	M	Continuous	N	N	N	N	N	N	Y	12 in.	16 in.	7 in.	0.5 in.	12 in.	–
Florida	U frwy R frwy	M	11 ft Gap 28 ft Cycle	N	N	N	N	N	N	N	16 in.	16 in.	7 in. ± 0.5 in.	0.5–0.625 in.	12 in. ± 1 in.	–
		RS (asphalt)	–	N	N	N	N	N	N	N	0 in.	28 in.	2 in.	0.5 in.	12 in.	–
		RS (Thermoplastic)	–	N	N	N	N	N	N	N	0 in.	–	4 in. Min	0.5 in.	–	–
Georgia*	U frwy; U frwy ramps; U multilane divided; U multilane undivided; U two-lane; R frwy; R frwy ramps; R multilane divided; R multilane undivided; R two-lane	M	12 ft	4 ft	4 ft	400	N	N	N	N	8–12 in.	16 in.	7 in.	0.5–0.625 in.	12 in.	–
Hawaii		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Idaho*	R frwy; R multilane divided; R multilane undivided; R two-lane	M	12 ft Gap 60 ft Cycle	3 ft	N	N	N	N	N	N	0 in.	12–18 in.	7 in. ± 0.5 in.	0.5–0.625 in.	12 in.	5/05
Illinois	–	M	Continuous	–	Varies	–	–	–	–	–	12 in.	16 in.	7 in.	0.5 in.	12 in.	1/03

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State or province*	Pattern characteristics			Minimum requirements for installation								Dimensions				Date of policy
	Roadway type	Rumble type**	Skip Pattern	Shoulder width	Lateral clearance	ADT (vpd)	Pavement depth	Speed	Accident	Bicycle	Offset (A)	Length (B)	Width (C)	Depth (D)	Spacing (E)	
Indiana*	R frwy; R frwy ramps; R multilane divided; R multilane undivided	M	20 ft Gap 100 ft Cycle	4 ft	7 ft	N	5 in.	N	N	Y	0–6 in.	16 in.	7 in.	0.5 in.	12 in.	3/03
Iowa*	U frwy; U multilane divided; U multilane undivided; R freeway; R multilane divided; R multilane undivided; R two-lane	M	12 ft Gap 60 ft Cycle	4 ft	N	3,000	N	N	N	Y	0 in.	16 in.	7 in.	0.5– 0.625 in.	12 in.	1/04 4/05
Kansas	R hwy	M	Intermittent	8–10 ft	N	N	1 in.	N	N	N	16 in.	16– 17 in.	7–8 in.	0.5 in.	12 in.	3/01
Kentucky*	U frwy; U frwy ramps; U multilane divided; U multilane undivided; U two-lane; R frwy; R frwy ramps; R multilane divided; R multilane undivided; R two-lane	M	Continuous	N	N	N	Variable	N	N	N	12 in.	16 in.	7 in. ± 0.5 in.	0.5 in. ± 0.125 in.	12 in. ± 1 in.	–
		RL	Continuous	N	N	N	Variable	N	N	N	0 in.	24 in.	1.5 in. ± 0.25 in.	0.75 in. ± 0.25 in.	9 in. ± 1 in.	–
Louisiana	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Maine*	U frwy; R frwy	M	–	–	–	–	3 in.	–	–	–	0 in.	16 in.	7 in.	0.5– 0.75 in.	12 in.	–
Maryland	–	M	Continuous	N	–	–	–	–	–	–	6–12 in.	16 in. Min	7 in. ± 0.5 in.	0.5– 0.625 in.	12 in.	3/04

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Massachusetts	U frwy; U multilane divided; U multilane undivided; R freeway; R multilane divided; R multilane undivided; R two-lane	M	Continuous	2 ft	N	N	N	40 mph	N	N	4 in.	16 in.	7 in.	0.5 in.	12 in.	12/04
Michigan	–	M	Continuous	4 ft	–	–	–	–	–	–	12 in.	16 in.	7 in.	0.5–0.625 in.	12 in.	8/04
Minnesota*	U frwy; U multilane divided; U multilane undivided; R freeway; R multilane divided; R multilane undivided; R two-lane	M	12 ft Gap 60 ft Cycle	6 ft	N	N	N	50 mph	N	Y	4 in.	12–16 in.	7 in. ± 0.5 in.	0.375–0.5 in.	12 in. ± 0.5 in.	5/00
Mississippi*	U frwy; U multilane divided; R frwy; R multilane divided	M	Continuous	2 ft	4 ft	N	N	N	N	N	0 in.	15 in.	7 in.	0.5–0.625 in.	12 in.	10/04
Missouri*	U frwy; U multilane divided; U multilane undivided; U two-lane; R freeway; R multilane divided; R multilane undivided; R two-lane	–	Continuous	2 ft	N	N	3.75 in.	50 mph	N	N	0 in.	–	–	–	–	–
Montana	Interstates Primary routes	M	Continuous	4 ft	N	N	N	N	N	N	6 in.	12–16 in.	7 in.	0.5–0.75 in.	12 in.	3/96

State or province*	Pattern characteristics			Minimum requirements for installation								Dimensions				Date of policy
	Roadway type	Rumble type**	Skip Pattern	Shoulder width	Lateral clearance	ADT (vpd)	Pavement depth	Speed	Accident	Bicycle	Offset (A)	Length (B)	Width (C)	Depth (D)	Spacing (E)	
		F	Continuous	4 ft	N	N	N	N	N	N	6 in.	12–16 in.	2 in.	1 in.	4.5 in.	3/96
Nebraska	–	M	–	–	–	–	–	–	–	N	0 in.	16 in.	7 in.	0.5 in.	12 in.	–
Nevada*	R frwy; R multilane divided; R multilane undivided; R two-lane	M	Continuous	6 ft	N	N	N	N	N	Y	4 in.	16 in.	7 in.	0.5–0.625 in.	12 in.	1/01
New Hampshire	R frwy	M	Continuous	–	–	–	–	–	–	N	6–30 in.	16 in.	7 in.	0.5 in.	12 in.	–
New Jersey	U frwy R frwy	M	Continuous	3 ft (median) 8 ft (outside)	N	N	N	N	N	N	4 in.	16 in.	7 in.	0.5 in.	12 in.	–
New Mexico	R frwy R expwy R two-lane	M	Continuous	–	–	–	–	–	–	–	12 in.	16 in.	7 in. ± 0.5 in.	0.5–0.625 in.	12 in. Min	8/98
New York	R frwy U frwy	M	Continuous	N	34 in.	N	2.5 in.	N	N	Y	Varies	16 in.	7 in.	0.5–0.625 in.	–	6/97
North Carolina*	U frwy; U multilane divided; R freeway; R multilane divided; R two-lane	M	6 ft Gap 40 ft Cycle	6 ft	N	N	6 in.	N	N	Y	0 in.	16 in.	7 in.	0.5 in.	12 in.	3/05
North Dakota*	R frwy; R multilane divided; R multilane undivided; R two-lane	M	12 ft Gap 50 ft Cycle	4 ft	4 ft	2,000	N	45 mph	N	N	0 in.	Varies	6.5 in. ± 0.5 in.	0.5 in. ± 0.125 in.	12 in.	5/23/03
Ohio	R frwy U frwy	M	10 ft Gap 20 ft Cycle	4 ft	4 ft	–	–	–	0.25 acc/MVM	Y	4–6 in.	16 in.	7 in.	0.5 in.	12 in.	–
Oklahoma	Multilane Two-lane	M	Continuous	4 ft	N	N	2 in.	N	N	N	24 in. ± 3 in.	16 in. ± 1 in.	7 in. ± 1 in.	0.5–0.625 in.	12 in.	99
Oregon*	R frwy; R multilane divided; R multilane undivided; R two-lane	M	Continuous	–	4 ft	–	–	–	–	N	0 in.	–	5.5 in.	0.5 in. ± 0.125 in.	18 in.	5/05

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Pennsylvania*	U frwy; U frwy ramps; U multilane divided; U multilane undivided; R frwy; R frwy ramps; R multilane divided; R multilane undivided; R two-lane	M (Interstate)	Continuous	4 ft (median) 8 ft (outside)	N	N	N	N	N	N	12 in. ± 0.5 in. (median) 18 in. ± 0.5 in. (outside)	16–17 in.	7 in. ± 0.5 in.	0.5–0.625 in.	12 in.	4/95
		M (non-Interstate)	Continuous	6 ft	4 ft	1,500	–	≥ 55 mph	N	Y	6 in.	16 in.	5 in. ± 0.5 in.	0.375 in. ± 0.0625 in.	12 in. ± 0.5 in.	3/02
		M (non-Interstate)	Continuous	6 ft	4 ft	1,500	–	< 55 mph	N	Y	6 in.	16 in.	5 in. ± 0.5”	0.375 in. ± 0.0625 in.	11 in. ± 0.5 in.	
		M (edgeline)	Continuous	4–6 ft	4 ft	N	N	N	N	Y	0 in.	6 in.	5 in. ± 0.5 in.	0.375 in. ± 0.0625 in.	12 in. ± 0.5 in.	
Rhode Island*	U frwy; U frwy ramps; U multilane divided; U multilane undivided; R frwy; R frwy ramps; R multilane divided; R multilane undivided; R two-lane	M	Continuous	N	N	N	N	N	N	N	4 in. (median) 12 in. (outside)	16 in.	7 in.	0.5 in.	12 in.	–
South Carolina	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
South Dakota	–	RL	Continuous	–	–	2,500	–	–	–	N	8 in.	36 in.	2 in.	1 in.	8 in.	–

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State or province*	Pattern characteristics			Minimum requirements for installation								Dimensions				Date of policy
	Roadway type	Rumble type**	Skip Pattern	Shoulder width	Lateral clearance	ADT (vpd)	Pavement depth	Speed	Accident	Bicycle	Offset (A)	Length (B)	Width (C)	Depth (D)	Spacing (E)	
Tennessee	R frwy U frwy	M	Continuous	N	–	–	–	–	N	N	6 in.	16 in. Min	6 in. ± 0.5”	0.375–0.5 in.	18 in. ± 0.5 in.	–
Texas*	R frwy; R multilane divided; R multilane undivided;	M	Continuous	4 ft (median) 8 ft (outside)	6 ft	–	–	–	–	Y	0 in.	16 in.	7 in. ± 0.5 in.	0.5–0.625 in.	12 in.	5/99
		RL	Continuous	4 ft (median) 8 ft (outside)	6 ft	–	–	–	–	Y	4–8 in.	24 in.	2 in.	1 in. ± 0.125 in.	8–9 in.	
		RS	Continuous	–	–	–	–	–	–	Y	–	–	–	–	–	
Utah*	U frwy; R frwy; R frwy ramps; R multilane divided; R multilane undivided; R two-lane	M	12 ft Gap 60 ft Cycle	N	4 in.	N	N	N	N	N	Varies	12 in.	8 in. ± 0.375 in.	0.625–0.75 in.	12 in.	1/05
Vermont*	U frwy; R frwy; R multilane divided; R multilane undivided	M	Continuous	N	4 ft	N	N	N	N	Y	6–30 in.	16 in.	7 in.	0.5 in.	12 in.	–
Virginia*	R frwy	M	Continuous	N	N	N	N	N	N	N	0 in.	16 in.	7 in.	0.5 in.	12 in.	–
Washington*	U frwy; R frwy; R multilane divided; R multilane undivided; R two-lane	M	12 ft Gap 40 ft Cycle; 12 ft Gap 60 ft Cycle; 16 ft Gap 64 ft Cycle	4 ft	N	N	Variable	45 mph	.6/mi or 34/100 MVMT	Y	6 in.	16 in.	7 in. ± 0.5 in.	0.5–0.625 in.	12 in.	8/04
West Virginia	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Wisconsin	R frwy R expwy U frwy U expwy	M	–	N	–	–	–	–	N	N	30 in.	16 in.	7 in.	0.5–0.625 in.	19 in. ± 1 in.	–
Wyoming*	R frwy; R multilane undivided; R two-lane	M	12 ft Gap 60 ft Cycle	2 ft	N	N	N	45 mph	N	N	6 in.	16 in.	7 in.	0.5–0.625 in.	12 in.	9/01

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SECTION 10

Rumble Strip Application and Design Criteria

This section summarizes the implications from the key research findings for design and application of shoulder and centerline rumble strips. In formulating policies regarding the design and application of shoulder and centerline rumble strips, transportation agencies should address the following six key issues:

1. On what roadways is it appropriate to install shoulder/centerline rumble strips?
2. What type of rumble strips will be used?
3. What will the dimensions be?
4. Where will the rumble strips be installed, relative to either the edgeline or to the centerline?
5. Should the rumble strip be installed in a continuous pattern or with intermittent gaps?
6. What features or areas might necessitate an interruption in the rumble strip pattern?

After rumble strips are installed, transportation agencies should also address maintenance issues. In particular, transportation agencies should consider adopting a policy on the preparation of rumble strips prior to pavement surface overlays.

Guidance is provided below on each of these issues. First, guidance is provided on these issues as they specifically relate to shoulder rumble strip policies. Second, guidance is provided on these issues as they specifically relate to centerline rumble strip policies.

Implications on Shoulder Rumble Strip Policies

Roadway Types Where it is Appropriate to Install Shoulder Rumble Strips

Shoulder rumble strips may be considered for implementation on a wide range of roadway types, including urban freeways, urban freeway on-ramps and off-ramps, urban multilane divided highways (nonfreeways), urban multilane undivided highways (nonfreeways), urban two-lane roads, rural freeways, rural freeway on-ramps and off-ramps, rural multilane divided highways (nonfreeways), rural multilane undivided highways (nonfreeways), and rural two-lane roads. When developing a policy on which roadway type (or types) it is appropriate to install shoulder rumble strips, and for help in prioritizing actual sites for the installation of shoulder rumble strips, the following criteria have been considered by one or more transportation agencies. Guidance is provided on common values and ranges of values used by transportation agencies. The values provided here are based upon common practices by agencies rather than being substantiated by research. Also, some criteria may be considered for certain roadway types, but not others.

- **Shoulder Width:** Minimum shoulder widths for rumble strip application range from 2 to 10 ft (0.6 to 3.0 m), with 4 ft (1.2 m) being the most common value. Minimum shoulder widths may differ by roadway type.
- **Lateral Clearance:** Minimum lateral clearances range from 2 to 7 ft (0.6 to 2.1 m), with 4 ft (1.2 m) and 6 ft (1.8 m) being the most common values. Some agencies may prefer to define the lateral clearance to be the distance from the outside (i.e., right) edge of the rumble strip to the outside edge of the shoulder, while others may measure the clearance to the nearest roadside object rather than the outside edge of the shoulder.
- **ADT:** Minimum ADTs for rumble strip application range from 400 to 3,000 ADT, but in most cases fall between 1,500 and 3,000 ADT.
- **Bicycles:** Agencies address bicycle considerations in several ways, including: (a) not installing rumble strips on roads with significant bicycle traffic or if the roadway is a designated bicycle route, (b) adjusting the dimensions of the rumble strips, (c) adjusting the placement of the

rumble strips, (d) adjusting the minimum shoulder width and/or lateral clearance requirements, and/or (e) providing gaps in periodic cycles. Guidance provided in the AASHTO *Guide for the Development of Bicycle Facilities* (*98*) should also be considered.

- **Pavement Type:** Some agencies only install shoulder rumble strips on asphalt surfaces. Pavement type also influences whether rolled rumble strips can be used.
- **Pavement Depth:** Minimum pavement depths range from 1 to 6 in. (25 to 152 mm).
- **Area Type:** Some agencies only install shoulder rumble strips in rural areas, primarily due to potential noise disturbance.
- **Speed Limit:** Minimum speed limits used by agencies ranged from 45 to 50 mph (72 to 80 km/h). Some agencies also adjust the rumble strip dimensions depending upon the speed limit.
- **Crash Frequencies/Rates:** Some agencies establish a threshold value, such as the statewide average for the given roadway type.

Reliable estimates for the safety effectiveness shoulder rumble strips provide useful information for highway agencies. The most reliable and comprehensive estimates to date of the safety effectiveness of shoulder rumble strips are for freeways and rural two-lane roads. For consistency with previous sources, the results from Griffith (*1*) are indicated as applying to rolled rumble strips. The combined results of this research and the Griffith study include both milled and rolled rumble strips and are therefore indicated as applying to should rumble strips in general. There is no indication of any substantive differences in safety between milled and rolled rumble strips. The safety effectiveness estimates with their associated standard errors are as follows:

Urban/Rural Freeways

– Rolled shoulder rumble strips [based on results from Griffith (*1*)]:
  - 18 percent reduction in SVROR crashes (SE = 7) and
  - 13 percent reduction in SVROR FI crashes (SE = 12).

Rural Freeways

– Shoulder rumble strips [based on combined results from this research and Griffith (*1*)]:
  - 11 percent reduction in SVROR crashes (SE = 6) and
  - 16 percent reduction in SVROR FI crashes (SE = 8).

Rural Two-Lane Roads

– Shoulder rumble strips [based on results from this research and Patel et al., (*2*)]:
  - 15 percent reduction in SVROR crashes (SE = 7) and
  - 29 percent reduction in SVROR FI crashes (SE = 9).

Estimates on the safety effectiveness of shoulder rumble strips along rural multilane divided highway (nonfreeways) are also available, but they are not considered as reliable as the estimates for freeways and rural two-lane roads. The safety estimates for rural multilane divided highway (nonfreeways) are as follows:

Rural Multilane Divided Highways (nonfreeways)

– Shoulder rumble strips [based on results from Carrasco et al., (*3*)]:
  - 22 percent reduction in SVROR crashes and
  - 51 percent reduction in SVROR FI crashes.

The estimates above are considered appropriate only for the roadway types for which they are shown. In all likelihood, the safety benefits of shoulder rumble strips vary by roadway type because the different types of roadways have varying geometric design standards (i.e., lane widths, shoulder widths, roadside, etc.), accommodate varying traffic volumes and distributions, serve different driver populations, and accommodate a range of operating speeds. It should be clearly stated that the lack of reliable estimates of the safety effectiveness of shoulder rumble strips along the other roadway types does not indicate that shoulder rumble strips are ineffective on these other roadway types. Rather, it should be understood that the safety effects of rumble strips on these roadway types are simply unknown at this time. The safety effects have not been quantified due to limited mileage of shoulder rumble strip installations along these respective roadway types.

As a final note regarding the safety effectiveness of shoulder rumble strips, shoulder rumble strips are expected to reduce SVROR crashes involving heavy vehicles on rural freeways by approximately 40 percent, but no evidence exists to suggest that shoulder rumble strips reduce SVROR involving heavy vehicles on rural two-lane roads. Therefore, if a problem of SVROR crashes involving heavy vehicles is identified along a rural freeway, then installation of shoulder rumble strips can be expected to mitigate these types of crashes. However, if a similar problem is identified along a rural two-lane road, then it is unknown how effective shoulder rumble strips will be at mitigating such a problem. Also, evidence suggests that shoulder rumble strips reduce SVROR crashes that occur during low-lighting conditions on rural two-lane roads. This may be due to the positive guidance that rumble strips provide when the delineation of the roadway is limited. Therefore, in situations where SVROR crashes during low lighting conditions are noted, shoulder rumble strips may be considered as a potential safety improvement.

Type of Rumble Strips to Use

A variety of shoulder rumble strip types are used in North America. These include milled, rolled, raised, or formed.

Delaware(2014):

2. Multilane Conventional Roadways
    a. Bicycle-Friendly Edgeline Rumble Strips should be installed on new, reconstructed or resurfaced outside shoulders of all multilane conventional roadways. Continuous edgeline rumble strips should be installed on new, reconstructed or resurfaced inside shoulders of all multilane conventional roadways. DelDOT's Bicycle Coordinator should be notified prior to new installations of edgeline rumble strips on any multilane conventional roadway.
    b. Bicycle-Friendly Edgeline Rumble Strips should be installed as shown in Figures 2A, 2B and 2C.
    c. Rumble strips shall not be installed on bridge decks without approval from the DelDOT Bridge section.
    d. Rumble strips are to be broken for all intersections and driveway entrances where the edgeline pavement markings tie into the driveway entrance or where the edgeline pavement markings are broken. The installation of rumble strips should be stopped 25 feet prior to the Point of Curvature (PC) and restarted 25 feet after the Point of Tangency (PT).
    e. Rumble strips should not be installed on acceleration, deceleration or bypass lanes, or two-way left turn lanes. Installation should stop 150 feet prior to the diverge point of a deceleration lane and should not commence until 150 feet downstream of the merge point for an acceleration lane.
    f. To accommodate bicyclists, a minimum effective clear shoulder width of 5 feet should be provided from the outside edge of the rumble strip groove to the outside edge of the paved shoulder (see Figure 2A), or 5 feet from the outside edge of the rumble strip groove to the front face of barrier (including curb) or guardrail. Rumble strips should be discontinued 50 feet before and started 50 feet after when adjacent to guardrail where there is less than 5 feet between the outside edge of the rumble strip and the face of the guardrail.
    g. If the above clear area cannot be maintained, then consider installing Bicycle-Friendly Edgeline Rumble *Stripes* within the painted edgeline. A Rumble Stripe is a milled rumble strip that is placed on the painted edgeline and the edgeline is repainted over the top of the milled rumble strip (see Figure 3). If no shoulder exists, the installation of Rumble *Stripes* should be considered. Rumble Stripes shall meet the longitudinal design of Bicycle-Friendly rumble strips.
    h. The Bicycle-Friendly Edgeline Rumble Strip pattern shall consist of 40-foot long segments of rumble strips with 12-foot segments of no rumble strips.

3. Two-Lane Conventional Roadways
    a. Bicycle-Friendly Edgeline Rumble Strips should be installed on all rural two-lane roadways with a minimum of 11 foot lanes, 5 foot shoulders, and a posted speed limit or 85th percentile speed of 40 miles per hour or higher.
    b. Bicycle-Friendly Edgeline Rumble Strips should be considered for installation on all other two-lane roadways if an engineering study determines that road departure crash rates along the section of roadway exceed statewide or national averages for similarly

Continuous Centerline and Longitudinal Edgeline Rumble Strips, Design Gudance Memorandum, DelDOT

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classified roadways and if rumble strips are a viable crash reduction countermeasure for the particular roadway. DelDOT's Bicycle Coordinator should be notified prior to installation of edgeline rumble strips on any two-lane conventional roadway.

c. Bicycle-Friendly Edgeline Rumble Strips should be installed in accordance with the details provided in Figures 2A, 2B and 2C.

d. Rumble strips shall not be installed on bridge decks without approval from the DelDOT Bridge section.

e. Rumble strips are to be broken for all intersections and driveway entrances where the shoulder edgeline pavement markings tie into the driveway entrance or where the edgeline pavement markings are broken. The installation of rumble strips should be stopped 25 feet prior to the turn radius PC and restarted 25 feet after the turn radius PT.

f. Rumble strips should not be installed on acceleration, deceleration or bypass lanes, or two-way left turn lanes. Installation should stop 150 feet prior to the diverge point of a deceleration lane and should not commence until 150 feet downstream of the merge point for an acceleration lane.

g. Generally, continuous longitudinal rumble strips should not be applied on the shoulders of roadways within developed and urban areas. In suburban and developing areas, the designer should consult with Engineering Support to determine if noise will be a concern.

h. To accommodate bicyclists, a minimum effective clear shoulder width of 5 feet should be provided from the outside edge of the rumble strip groove to the outside edge of the paved shoulder (see Figure 2A), or 5 feet from the outside edge of the rumble strip groove to the front face of barrier (including curb) or guardrail. Rumble strips should be discontinued 50 feet before and started 50 feet after when adjacent to guardrail where there is less than 5 feet between the outside edge of the rumble strip and the face of the guardrail.

i. If the above clear area cannot be maintained, then consider installing Bicycle-Friendly Edgeline Rumble *Stripes* within the painted edgeline. A Rumble Stripe is a milled rumble strip that is placed on the painted edgeline and the edgeline is repainted over the top of the milled rumble strip (see Figure 3.) If no shoulder exists, the installation of Rumble *Stripes* should be considered. Rumble Stripes shall meet the longitudinal design of Bicycle-Friendly rumble strips.

j. The Bicycle-Friendly Edgeline Rumble Strip pattern shall consist of 40-foot long segments of rumble strips with 12-foot segments of no rumble strips.

Kentucky :

Recommended Practices

Continuous Shoulder Rumble Strips

Based upon the analysis provided above, it is recommended that continuous shoulder rumble strips and subsequently shoulders be used on all state maintained 2-lane rural highways. This practice is expected to reduce the overall crash rate and specifically reduce crashes resulting from driver inattentiveness. **Table 3** below provides specific recommendations for lane and shoulder width combinations for varying widths of pavement. This table also includes recommendations for edgelines based upon concurrent research conducted by the Kentucky Transportation Center (8). The results are presented together to provide a clear understanding of the recommended pavement section for 2-lane roads.

Table 3: Recommended Pavement Cross Section

Total Pavement Width (ft)	Lane Width (ft)	Paved Shoulder (ft)	Centerline	Edgeline
28	12	2	Yes	Yes
27	12	1.5	Yes	Yes
26	11	2	Yes	Yes
25	11	1.5	Yes	Yes
24	11	1	Yes	Yes
23	10	1.5	Yes	Yes
22	10	1	Yes	Yes
21	9	1.5	Yes	Yes
20	9	1	Yes	Yes
19	8	1.5	Yes	No
18	8	1	Yes	No
17	7.5	1	No	Yes
16	7	1	No	Yes
15	6.5	1	No	Yes
14	6	1	No	Yes

A minimum shoulder width of one foot is frequently recommended, in conjunction with edgeline and rumble strips. The typical width of a rolled in rumble strips is one foot, and edgeline width is four inches. To accommodate this combination the use of rolled in rumble strips is recommended; whereby the edgeline will be placed on the inner (nearest the travel way) four inches of the rumble strips. The literature review identified several states that use rumble stripes with beneficial results. In addition, several rumble stripe applications have been made by KYTC including KY 36 in Highway District 9. It should be noted that most examples of rumble stripes use milled-in rumble strips; therefore it is recommended that an early evaluation of rolled-in rumble stripe applications be completed to ensure proper visibility of the pavement edgeline. A proposed detail for rumble stripes using milled-in rumble strips is provided in **Appendix B**.

Maine (2013):

- Rumble strips are most effective and intended for use on road segments with speed limits of 45 mph and greater
- Surface pavement is at least 1 ¼ in. in depth (the intent of a depth guideline is that the rumble strip does not go through the new paving course)
- Travel lanes are 11ft. or greater in width
- Shoulders should be paved and 4ft. or greater in width
- Concurrence of the Safety Office in consultation with the Bicycle/Pedestrian Coordinator is required if: there is less than 4 ft. of usable shoulder between the rumble strip and the edge of pavement, or there is less than 5 ft. of useable shoulder between the rumble strip and curb or guardrail
- Corridor or corridor segment has at least 5 lane departure crashes or 2 lane departure fatalities in the past 5 years
- In rural areas where current AADT is 3,000 or greater even if there is no significant crash data
- In developed or urban areas rumble strips should not be installed unless there is a significant history of lane departure or head-on crashes
- Rumble strips shall not be installed on bridge decks or overpasses
- Rumble strips shall not be installed inside the limits of cross walks

Centerline Rumble Strips

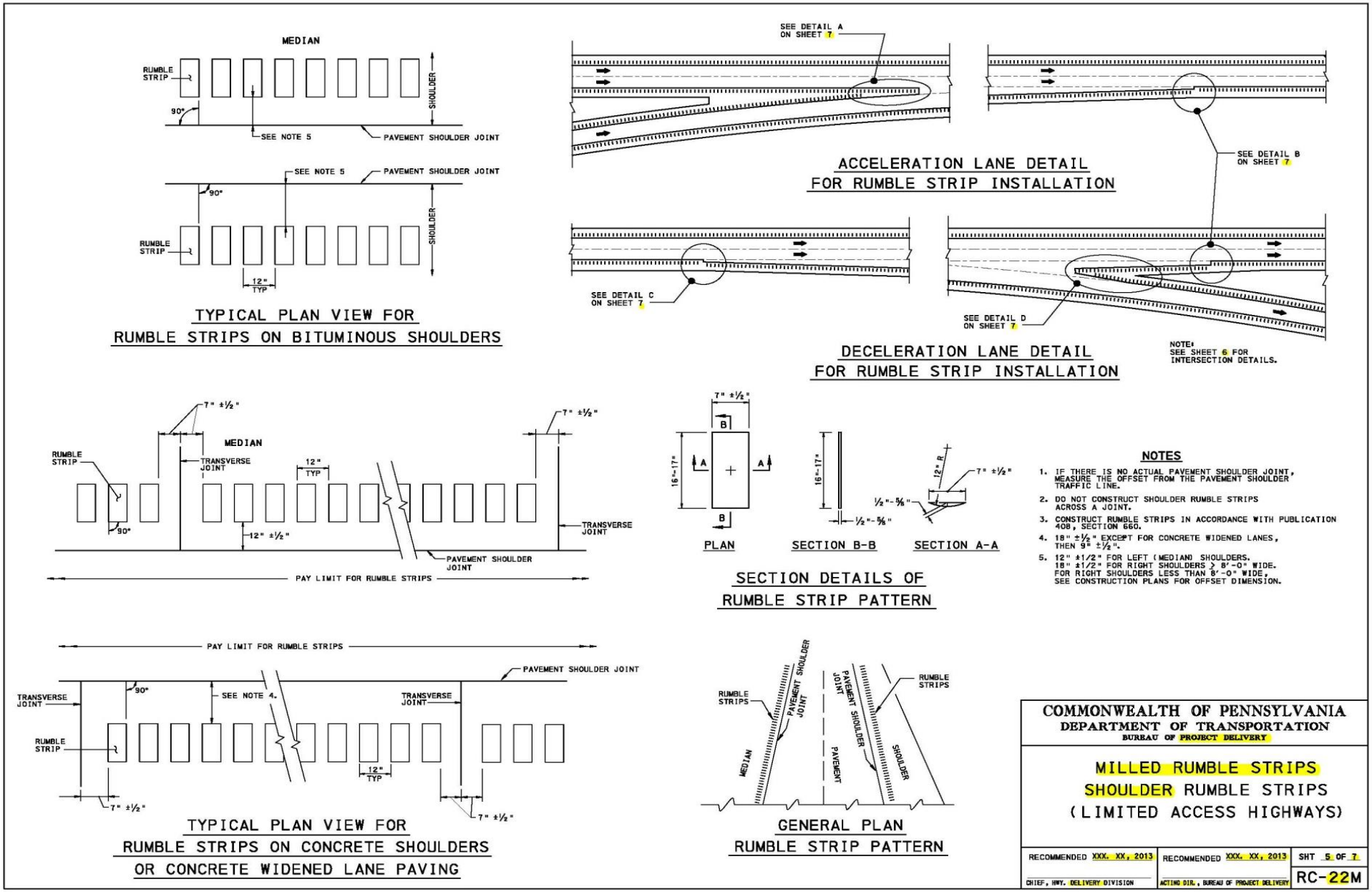
- Surface pavement is less than 3 years old and shows no signs of distress
- Corridor or corridor segment is an undivided highway
- Centerline rumble strips shall not be used where continuous two-way left-turn lanes exist
- In no-passing, double solid centerline locations, centerline rumble strips shall be continuous except for drives, entrances and intersections
- In passing zones, centerline rumble strips shall be segmented with 20 ft. of rumble strip, followed by a 20 ft. break in a repeating pattern for the length of the passing zone
- Centerline rumble strips may or may not be the physical midpoint of the road, but should coincide with the centerline striping. Painted center lines should be located as best as practicable so that they are painted on the centerline rumble strips

Edge Line Rumble Strips

- Shoulder pavement is at least 3 in. in depth
- Shoulder surface pavement is less than 5 years old and shows no signs of distress
- Barrier offset (L_B) shall provide at least a 5 ft. usable shoulder
- For the safety of bicyclists…
    - In rural areas, a 3 ft. minimum usable shoulder is required
    - In urban or village areas without curb, a 4 ft. minimum usable shoulder is required
    - In urban or village areas with curb, a 5 ft. minimum usable shoulder is required

Rumble Strip Policy for Non-Interstate Highways for Maine DOT, Maine Department of Transportation (2013) Back to Top

Pennsylvania:



Milled Shoulder Rumble Strips for Limited Access Highways, Pennsylvania Department of Transportation (2013)

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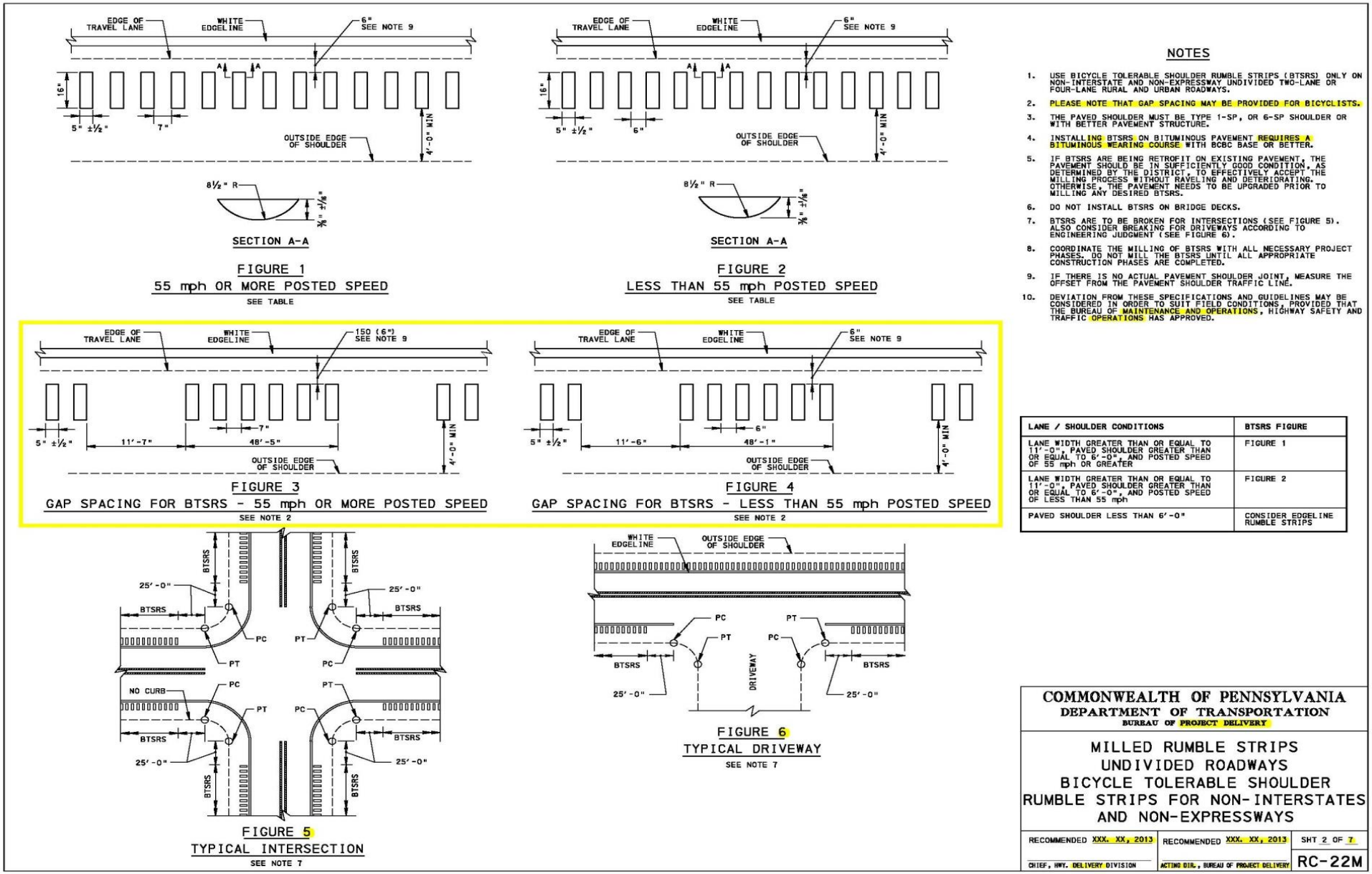
Pennsylvania: 32



Milled Rumble Strips for Non-Interstate and Non-Expressway, Pennsylvania Department of Transportation (2013)

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Viriginia (2013):

- CCLRS groove dimensions shall be 7 inches by 14 inches across by ½ inch deep, spaced in accordance with Standard RS-3 (12 inches apart, leading edge to leading edge).

- CCLRS shall be installed in Passing Zones only when directed by the Regional Traffic Engineer based on evaluation of traffic crash types and patterns.

- When CCLRS are installed in Passing Zones, the depth shall be reduced to 3/8 inch and the groove spacing may be increased to 24 inches.

  CCLRS shall not be installed:

  - within limits of bridges
  - on subdivision streets
  - on unmarked roadway pavement segments
  - within the limits of two-way turn lanes (designated as divided roadway with flush median)

SHOULDER RUMBLE STRIPE – STANDARD RS-4

- As an alternative to placing the pavement line marking on the outer edge of the travel lane, the Regional Traffic Engineer may recommend that the pavement marking be applied over the grooved area to enhance edge-line visibility. When recommended by the Regional Traffic Engineer, Shoulder (Edge-line) Rumble Stripe, Standard RS-4 shall be utilized.

- To avoid pavement raveling or deterioration, the surface course pavement joint shall be located a minimum of 6 inches **outside** of the outer edge of the milled groove or as directed by the Engineer.

- Edge-line Rumble Stripes are applicable to travel lanes ≥11 feet and are not applicable to concrete pavements.

INTERMITTENT SHOULDER RUMBLE STRIP, STANDARD RS-5

- Roadways without controlled access may include driveways, crossovers, intersections, and turn lanes, creating an environment of multiple entrances and exits. To provide accessibility to potential cyclists on these type roadways, rumble strip applications should use an “intermittent” pattern to provide gaps between the milled grooves.

- Intermittent Shoulder Rumble Strip (ISRS), Standard RS-5 is applicable to paved shoulders on appropriate Partially-Controlled and Non-Controlled Access roadways with design speed ≥ 50 mph / posted speed ≥ 45 mph and lane widths ≥ 11 feet.

Arizona (2011):

480 CONTINUOUS LONGITUDINAL RUMBLE STRIPS

480.1 INTRODUCTION

The purpose of this policy is to define when and where continuous longitudinal rumble strips may be applied on the state highway system. Also refer to ADOT ITD policy MGT 02-1 Bicycle Policy.

The purpose of continuous longitudinal rumble strips is to enhance safety by preventing run-off-road (ROR) collisions with fixed object and rollovers due to driver overcorrection type crashes. These rumble strips are intended to alert drivers by creating an audible (noise) and tactile (rumble or vibratory) warning sensation that their vehicle is leaving the traveled way (traffic lane) and that a steering correction is required. Before and after accident studies have indicated that ROR type crashes may be reduced significantly by the use of continuous longitudinal rumble strips.

480.2 POLICY

Continuous longitudinal ground-in rumble strips may be applied to the mainline roadway on projects per the recommendations and requirements of this document.

The following table should be used as a guideline in determining the groove width of the rumble strips to be installed:

Type of Roadway	Right Shoulder Width	Groove Width (both shoulders)
Undivided	less than 4'	6"
Undivided	greater than or equal to 4'	8"
Divided	less than 6'	8"
Divided	greater than or equal to 6'	12"

For divided roadways, the groove width for the left shoulder of the roadway should be the same as the width applied to the right shoulder, where possible.

On undivided two lane highways with shoulders four (4) feet and greater in width, longitudinal rumble strips should be applied. The use of longitudinal rumble strips on shoulders less than four (4) feet may be considered on a case by case basis when supported by a written traffic evaluation.

On divided highways, longitudinal rumble strips should be applied on the right (outside) shoulders with a width of four (4) feet or more and on left (median) shoulders which have a width of two (2) feet or more. The use of longitudinal rumble strips on divided highways

Section 480; ADOT Traffic Engineering Policies, Guidelines, Procedures, Arizona Department of Transportation

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with narrower shoulders than those noted may be considered on a case by case basis when supported by a written traffic evaluation.

The use of longitudinal rumble strips on all roadway shoulders less than six (6) feet wide with sections of guardrail and/or barrier shall be evaluated. The effective clear width of the shoulder in these areas if a continuous longitudinal rumble strip is installed shall be determined. The effective clear shoulder width is defined as the distance between the outside edge of the proposed rumble strip and the front face of the guardrail or barrier.

The effective clear shoulder width is important for the following reasons:

(a) Constructibility - To allow for installation equipment, i.e. grinding, a minimum effective clear shoulder width of two (2) feet is needed from the outside edge of the rumble strip groove to the front face of the barrier or guardrail. If the barrier is on a sharp curve additional width may be needed. This constructibility issue applies to all shoulders and all types of highways.

(b) Bicycle Traffic - If appreciable bicycle traffic exists or is anticipated then a minimum effective clear shoulder width of three-feet and five-inches (3'-5") should be provided from the outside edge of the rumble strip groove to the front face of the barrier or guardrail. If this clear area can not be maintained then a change of configuration and/or deletion of the rumble strip should be considered.

If these minimum clear shoulder width dimension criteria can not be maintained, then there are four possible solutions that may be considered. These possible solutions should be considered in the order that they are presented here. The first solution is to reevaluate lane widths; if the lanes are wider than 12 feet it may be permissible to reduce their width. The second solution is to move the location of the rumble strip closer to the traveled way and/or use a narrower strip width (6 inch or 8 inch). If the strip is moved closer to the traveled way it shall not infringe on the actual traffic lane. The third solution is to consider using an alternative rumble strip treatment such as profile pavement markings and/or raised pavement markers; this solution only applies to non-snow removal areas. The fourth solution is to omit the use of the longitudinal rumble strip in the area of the guardrail or barrier.

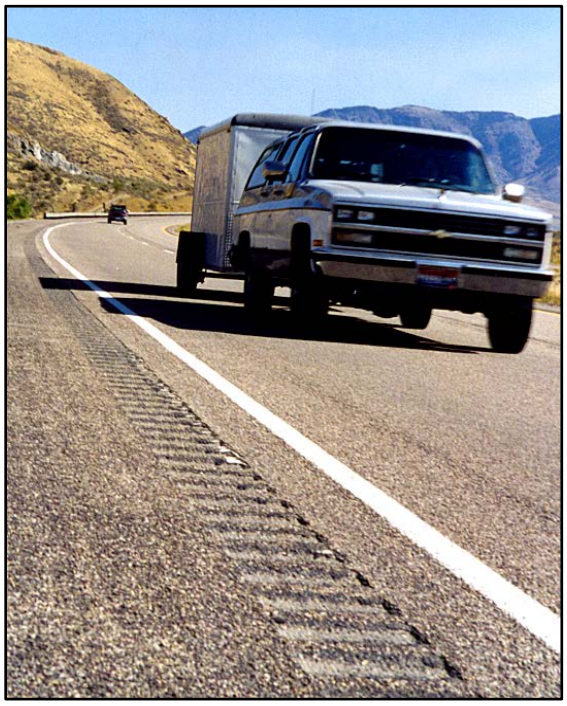
Details for rumble strip configuration and placement shall be shown on the plans. Typically the details will be included in conjunction with project striping plans. **In addition, the limits of the various type of improvements shall be indicated on the plans.**

On non-access-controlled highways, newly installed rumble strip on the right shoulder should use a pattern incorporating periodic gaps as shown on standard drawing M-22.

Continuous rumble strips shall be installed on shoulders of all controlled-access highways, and may be installed on shoulders of non-access controlled highways when supported by a written traffic evaluation

Generally, continuous longitudinal rumble strips should not be applied on the shoulders of roadways within developed and urban areas. In suburban and developing areas, the

Idaho:



A cost effective safety improvement to all roadways is the use of shoulder rumble strips. A rumble strip is a longitudinal design feature installed on a paved shoulder near the travel way. The design and installation of rumble strips is important to ensure the desired overall effectiveness is met. Research has shown that shoulder rumble strips are an effective countermeasure to reduce run off the road crashes. On rural roads, run off the road accidents account for a large number of accidents and fatalities. Studies suggest that rumble strips can largely reduce rural crashes caused due to driver fatigue, drowsiness and inattentive driving.

Primary Guidance

- Rumble strips are to be provided on roadways with paved shoulders at least

1) 4 ft. wide.

- Edge line rumble strips may be used on minor roadways as a specific safe countermeasure with a paved shoulder.
- Where several sections of edge line rumble strips are installed in close proximity, continuity should be maintained.
- Centerline rumble strips should be used on roadways with a significant head-on accident history. Where several sections of centerline rumble strips are installed in close proximity, continuity should be maintained.
- Rumble stripes (rumble under edge line markings) may be used where shoulder width will not accommodate ITD's standard rumble strip.
- Rumble strips should not be in or near urban areas.

Design Discussion

1600.06(1)(a) Roadway Rumble Strips

Roadway rumble strips are placed transversely to the traveled way to alert drivers who are approaching a change of roadway condition or object that requires substantial speed reduction or other maneuvering. Some locations where roadway rumble strips may be used are in advance of:

- Stop-controlled intersections.
- Port of entry/customs stations.
- Lane reductions where collision history shows a pattern of driver inattention.
- Horizontal alignment changes where collision history shows a pattern of driver inattention.

They may also be placed at locations where the character of the roadway changes, such as at the end of a freeway.

Contact the HQ Design Office for additional guidance on the design and placement of roadway rumble strips.

Document decisions to use roadway rumble strips in the Design Documentation Package.

1600.06(1)(b) Shoulder Rumble Strips

Shoulder rumble strips (SRS) are placed parallel to the traveled way just beyond the edge line to warn drivers they are entering a part of the roadway not intended for routine traffic use. Shoulder rumble strips are effective in reducing run-off-the-road collisions when the contributing circumstances are human factors related, such as inattention, apparently fatigued, or apparently asleep.

When shoulder rumble strips are used, discontinue them where no edge stripe is present, such as at intersections and where curb and gutter are present. Discontinue shoulder rumble strips where shoulder driving is allowed. Where bicycle travel is allowed, discontinue shoulder rumble strips at locations where shoulder width reductions can cause bicyclists to move into or across the area where rumble strips would normally be placed, such as shoulders adjacent to bridges or longitudinal barrier with reduced shoulder widths.

Shoulder rumble strip patterns vary depending on the likelihood of bicyclists being present along the highway shoulder and whether they are placed on divided or undivided highways. Rumble strip patterns for undivided highways are shallower and may be narrower than patterns used on divided highways. They also provide gaps in the pattern, providing opportunities for bicycles to move across the pattern without having to ride across the grooves. There are four shoulder rumble strip patterns. Consult the *Standard Plans* for the patterns and construction details.

1. Divided Highways

Install shoulder rumble strips on both the right and left shoulders of rural Interstate highways. Consider them on both shoulders of rural divided highways. Use the Shoulder Rumble Strip Type 1 pattern on divided highways.

Omitting shoulder rumble strips on rural Interstate highways is a design exception (DE) under any of the following conditions:

- When another project scheduled within two years of the proposed project will overlay or reconstruct the shoulders or will use the shoulders for detours.
- When a pavement analysis determines that installing shoulder rumble strips will result in inadequate shoulder strength.

- When overall shoulder width will be less than 4 feet wide on the left and 6 feet wide on the right.

2. Undivided Highways

Shoulder rumble strip usage on the shoulders of undivided highways demands strategic application because bicycle usage is more prevalent along the shoulders of the undivided highway system. Rumble strips affect the comfort and control of bicycle riders; consequently, their use is to be limited to highway corridors that experience high levels of run-off-the-road collisions. Apply the following criteria in evaluating the appropriateness of rumble strips on the shoulders of undivided highways.

- Consult the region and Headquarters Bicycle and Pedestrian Coordinators to determine bicycle usage along a route, and involve them in the decision-making process when considering rumble strips along bike touring routes or other routes where bicycle events are regularly held.
- Use on rural roads only.
- Determine that shoulder pavement is structurally adequate to support milled rumble strips.
- Posted speed is 45 mph or higher.
- Provide for at least 4 feet of usable shoulder between the rumble strip and the outside edge of shoulder. If guardrail or barrier is present, increase the dimension to 5 feet of usable shoulder. Field-verify these dimensions.
- Preliminary evaluation indicates a run-off-the-road collision experience of approximately 0.6 crashes per mile per year. (This value is intended to provide relative comparison of crash experience and is not to be used as absolute guidance on whether rumble strips are appropriate.)
- Do not place shoulder rumble strips on downhill grades exceeding 4% for more than 500 feet in length along routes where bicyclists are frequently present.
- An engineering analysis indicates a run-off-the-road collision experience considered correctable by shoulder rumble strips.

For projects that will remove and potentially replace existing shoulder rumble strips, evaluate the criteria for shoulder width and downhill grades for compliance with placement guidance. Discontinue rumble strips where the downhill grade exceeds 4% for more than 500 feet. If the usable shoulder width between the rumble strip and outer edge of shoulder is less than 4 feet (5 feet if guardrail or barrier is present) reevaluate the appropriateness of the rumble strips. Assess the existing shoulder rumble strip's impact on run-off-the-road crash experience and bicycling. Assess alternate rumble strip patterns and placement options. Consult the region and Headquarters Bicycle and Pedestrian Coordinators. Document decisions to continue or discontinue shoulder rumble strip usage where the existing usable shoulder width between the rumble strip and outer edge of shoulder is less than 4 feet (5 feet if guardrail or barrier is present).

Consult with the region or Headquarters Bicycle and Pedestrian Coordinator for determining levels of bicycle traffic for your project. The Shoulder Rumble Strip Type 2 or Type 3 pattern is used on highways with minimal bicycle traffic. When bicycle traffic on the shoulder is determined to be high, the Shoulder Rumble Strip Type 4 pattern is used.

Montana (2012):

Shoulder Rumble Strips - Installation

Interstate

Provide rumble strips on left and right shoulders of all interstate new construction, reconstruction, rehabilitation and overlay projects unless there is a specific reason not to do so. Document these reasons in the Scope of Work Report.

Where guardrail exists, evaluate the use of rumble strips on outside shoulders less than 6 feet wide and document the decision in the appropriate report.

Unless modifications discussed elsewhere in this memo are to be utilized, install rumble strips in accordance with the dimensions and locations described in the *MDT Detailed Drawings*.

National Highway, Primary and Secondary Routes

For multi-lane highways divided by a depressed median, follow the guidelines for Interstate rumble strip installation.

Where the shoulder width $\geq$ 4 feet provide rumble strips for all new construction, reconstruction, rehabilitation and overlay projects, subject to the restrictions within urban and residential areas. Where the decision is made to not use rumble strips, document the justification in the Scope of Work Report.

The installation of rumble strips is encouraged on chip seal projects where there are no existing rumble strips. The installation of rumble strips may be required on chip seal projects, when the chip seal reduces the depth of the existing rumble strip to the point where the rumble strip will not produce sufficient noise to alert the errant driver.

Where the shoulder width is between 1foot and 4 feet (1' < shoulder width $\leq$ 4') reduced lateral width rumble strips should be installed adjacent to the outside edge of the pavement. Locating the rumble strip near the edge of the pavement provides the following benefits

- To alert errant drivers despite the potentially reduced effectiveness
- Reduces impacts to bicyclists by maximizing the width of shared lane
- Reduces incidental contact
- Rumble strips that are closer to the travel lanes, especially if the lanes are narrow, could result in drivers "shying" away from the shoulder

If the decision is made to not install rumble strips where the shoulders are between 1 foot and 4 feet, document the justification for the decision in the Scope of Work Report.

Generally, rumble strips should not be provided where the shoulder width is less than 1 foot.

For two-lane, two-way highways discontinue rumble strips across the full width of all public road approaches. The decision to discontinue rumble strips at private (residential and commercial) approaches should be determined on a case-by-case basis, with the justification documented in the appropriate report.

Continue rumble strips along the full length, including tapers, of mailbox turnouts, scenic turnouts, chain-up areas, etc.

Where guardrail exists, evaluate the use of rumble strips on outside shoulders less than 6 feet

Rumble Strips Guidance, Montana Department of Transportation (2012)

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Wisconsin:

http://www.dot.wisconsin.gov/safety/motorist/roaddesign/rumblestrips/wisconsin.htm

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Utah :

Use of Rumble Strips — UDOT 06C-17

Effective: March 2, 2006 — Revised: April 26, 2007

Purpose

To define the Department's use of rumble strips on the state highway system. One of the Department's strategic goals is to improve safety. This goal can be accomplished by reducing the number and severity of single-vehicle run-off-the-road crashes while preserving safe use of the roadway by bicyclists and pedestrians. Also, using centerline rumble strips can reduce head-on crashes.

Policy

This policy applies to all highways under the jurisdiction of the Department. Placement of rumble strips will be required when the following criteria is met:

Shoulder Rumble Strips (SRS) – Divided Highways

- SRS are required on both the left and the right shoulders of all rural interstate highways.
- Consider SRS on both shoulders of other rural divided highways (non-interstate) and urban areas.

Shoulder Rumble Strips (SRS) – Undivided Highways

The use of SRS on undivided highways is based on criteria driven evaluation, of the following characteristics:

- For use on rural highways with speeds of 45 mph or higher.
- Adequate pavement structure exists on the shoulder.
- Run-off-the-road crash experience is documented.
- Shoulders are wide enough to provide a minimum of four feet of shoulder between the SRS and the edge of paved shoulder. Increase the dimension to five feet if barrier or guardrail is present at the edge of the shoulder.

Centerline Rumble Strips (CRS) – Undivided Highways

The use of CRS on undivided highways is based on criteria driven evaluation of the following characteristics:

- For use on rural highways with speeds of 45 mph or higher.
- Head-on or opposite direction sideswipe crash experience exists.

UDOT Use of Rumble Strips, Utah Department of Transportation, 2007

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South Carolina (2011):

Rumble strips shall be placed on paved shoulders or edge lines of all partial and non-controlled access roadways, subject to the following criteria: (See standard drawing 633-105-00 for details.)

- Roadway is classified as rural or displays rural characteristics
- Non Curb and Gutter cross section.
- Roadway width is 20 feet or greater.
- ADT is 500 vehicles per day or greater.
- Posted or Design speed limit is 45 MPH or greater.

Any variations from the above criteria will require a safety analysis to determine if rumble strip application is deemed appropriate. All requests for a safety analysis shall be forwarded to the Traffic Engineering Safety office for completion.

The following chart provides an overview of the type and pattern of rumble strip to be installed along different roadway types with varying paved shoulder widths.

SCDOT Rumble Strip Requirements				
Roadway Type	Paved Shoulder Width	Rumble Strip Type	Pattern	Standard Drawing Number
Fully Controlled Access or Freeways	All	16" Milled-In Rumble Strip	Continuous	401-205-01
Other Highways	0'-1'	4" Rumble StripE	Continuous	633-105-00
	>1'-<5'	8" Rumble StripE	Skip	633-105-00
	>=5'	12" Rumble StripE	Skip	633-105-00

Note: If unable to meet the above requirements, contact the Traffic Safety office

Milled-in rumble stripE (MIRS) are the preferred rumble strip application on all qualifying roadways except controlled access or expressway roadway types. Thermoplastic profile markings are an acceptable alternative only if rumble stripEs are not feasible due to structural deficiencies of a paved shoulder where MIRS may damage the surface/shoulders.

Bicycle Considerations

Rumble strip design details and location criteria were developed after receiving input from the SC cycling community, FHWA and other state DOT's. The Department has implemented the following accommodations to address the presence of cyclists:

- reducing maximum depth of milled groove,
- providing an option of various width rumble strips based on width of paved shoulder,

Alaska:

Alaska DOT/PF Policy on Rumble Strip Installation

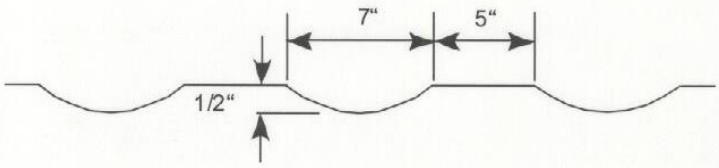
Shoulder Rumble Strips

1. Where to install: Rumble strips should be installed on rural roads with:
   a. speed limits of 50 MPH and above, and
   b. 6' or wider shoulders without guardrail or 7' or wider shoulders with guardrail.

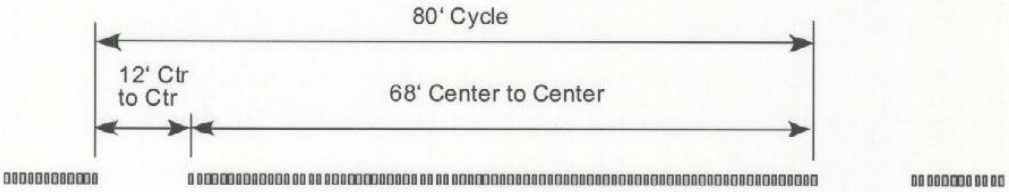
2. Installation Method: Milled rumble strips are more effective safety enhancements than rolled-in rumble strips. Use milled rumble strips unless milling is not feasible, in which case rumble strips may be rolled in.

3. Lateral Width: 16"

4. Longitudinal Milling Pattern: 7" groove, ½" deep, 5" flat



5. Gaps for bicycles: Do not install gaps on roads where bicycles are prohibited. On other roads use a 12' gap and a 68' rumble on an 80' cycle. The gap and rumble dimensions given are measured from center to center of grooves.



Exception: A 12' gap, 48' rumble, and a 60' cycle may be used on road segments with an unusually high level of bicycle usage. Regional Preconstruction Engineers must approve this change in writing, submit an informational copy of the approval to the Chief Engineer, and include the approval in the Design Study Report. Bicycle volumes must be documented. Changes in cycle length should be minimized and start/end at locations where there are significant changes in bicycle volume.

6. Offset and Alignment:
Offset the rumble strip so its inside edge is 4" from the outside edge of the shoulder stripe. If shoulder stripe location or alignment is not consistent, use offset from the centerline or lane lines. Remove existing striping and re-stripe all locations where the rumble strips overlap existing striping. In no case should rumble strips protrude inside the shoulder stripe.

Memorandum on Rumble Strips, Alaska Department of Transportation, 2009

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Minnesota(2011):

URL: http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_641.pdf. Additionally, numerous states in the region have enacted systematic policies to require rumble strips and rumble stripEs on their trunkline roadways. Michigan, Missouri, and North Dakota have policies requiring centerline rumble stripEs, plus edgeline rumble stripEs or shoulder rumble strips, on most of their rural trunkline roadways with higher speed limits. Iowa has a current statewide policy requiring the implementation of 4-foot paved shoulders and shoulder rumble strips on roads with ADTs greater than 3000. Wisconsin has no policy on rumble stripEs, but has shoulder rumble strips extensively on its trunkline roadway network.

This Technical Memorandum strengthens the provisions of both Technical Memoranda that are being combined. All of the requirements of the Technical Memorandum No. 08-04-TS-02 (Rumble Strips on Shoulders of Rural Trunk Highways) are still in place. The difference is that the requirement now extends to all high-speed rural roads where the paved shoulder is 4' or greater, instead of 6' or greater in the previous Memo.

Also, the intention of this Technical Memorandum is to emphasize the use of centerline rumble stripEs, and also provide stronger language and guidance than currently exists in Technical Memorandum No. 07-09-T-03 (Edgeline Rumble StripEs Guidance for Rural Trunk Highways).

Studies have shown that the ambient noise decibel level generated by a vehicle driving over a properly constructed rumble strip is comparable to that of a truck passing by on a standard, non-rumbled surface. The noise from rumble strips may be more noticeable as the public is more accustomed to truck traffic, the frequency of the sound is different, and rumble hits tend to be more of an impulse noise.

Purpose
To provide centerline rumble stripEs and/or shoulder rumble strips on all Rural Trunk Highways to reduce lane departure crashes, to provide increased centerline visibility during rainy conditions, and to guide motorists during snowy conditions when striping visibility is poor.

Guidelines

Definitions

Shoulder Rumble Strips
These are defined as rumble strips outside of the edgeline.

Rumble StripEs
Rumble stripEs are defined as a rumble strip that contains a pavement marking stripe. These will be referred to as either **edgeline rumble stripEs** or **centerline rumble stripEs.**

Rural Trunk Highway
This is defined as a roadway segment that has minimal residential or commercial development, with little or no further development anticipated in the future. Officially, rural segments will be defined by language in Chapter 2 of the MnDOT Access Management Manual. (Refer to the attached Reference 1, which shows the rural definition on page 10 in Chapter 2 of the MnDOT Access Management Manual.)

Requirements

Shoulder Rumble Strips
Shoulder rumble strips shall be placed on all rural highway projects where shoulders are constructed, reconstructed, or overlaid and where the posted speed limit is 55 mph or greater, and the paved shoulder width is 4 feet or greater. (This is a change from the previous standard, where shoulder rumble strips were required on highway paved shoulders of at least 6 feet in width.) Shoulder rumble strips may also be placed on rural trunk highways on shoulders less than 4 feet in width.

The location of the shoulder rumble strip will depend upon the width of the shoulder – see Figure 1 (Two-Way Bituminous Roadway with Paved Shoulder – Section View), Figure 2

recommended. However, a sufficient shoulder width should be provided (5 feet where lateral obstructions are present, 4 feet otherwise) to accommodate bicyclists.

The most recent Federal Highway Administration guidelines recommend a rumble strip with a length of 16 inches, a width of 7 inches, and a depth of 0.5 inches. However, some of the more recent literature recommends reducing the width to 5 inches and the depth to 0.375 inches on roadways that might be utilized by bicyclists. A spacing of 12 inches on center between the rumble strips is recommended. Providing a 12 foot gap with 40 to 60 foot cycles of rumble strips is recommended. The reader should examine the information presented in Appendix C, specifically that of Washington State, when considering different designs.

The recommended shoulder rumble strip dimensions of 16 inches length, 7 inches width and 0.5 inches depth for shoulder rumble strips based on those frequently employed in other states are similar to those currently used in New Mexico (12 inch length, 7.5 inch width and 0.5 to 0.625 inch depth). The recommendation of placing the rumble grooves as close to the edgeline as possible is a departure from current practice, which employs a 16 inch offset. This recommendation should be considered in conjunction with the other aspects and needs of pavement design and maintenance, such as the use of open graded friction courses.

CENTERLINE RUMBLE STRIPS

Centerline rumble strips should be applied where there is a history of opposing direction and driver inattention crashes. The most recent FHWA guidelines recommend a rumble strip with a length of 16 inches, a width of 7 inches, and a depth of 0.5 inches. These dimensions are nearly identical to those already in use in New Mexico (aside from a current width of 7.5 inches). When bicyclists are expected to use a roadway where centerline rumble strips are to be applied, 14 feet of pavement should be available beyond the centerline of the rumble strip. Centerline rumble strips are not recommended in subdivisions or on roadways with two-way left-turn lanes.

The available literature presents some contradictory conclusions when considering no-passing zones. Some literature recommends discontinuing the centerline rumble strips; others recommend a continuation. The Washington State Department of Transportation continues their centerline rumble strips through passing zones because the crashes that centerline rumble strips are intended to address still occur in these zones. In light of the potential safety benefits that centerline rumble strips offer in warning drivers in no passing zones, their continuation in such locations in New Mexico is recommended.

SHOULDER & CENTERLINE RUMBLE STRIPS

Studies addressing a combination of shoulder and centerline rumble strips are still limited. Therefore, the best guidance available at present is as follows. When both shoulder and centerline rumble strips are utilized, a 6 foot shoulder is recommended, with a 4-5 foot clear path from the edge of the rumble strip to the shoulder edge.

TRANSVERSE RUMBLE STRIPS

There are many gaps in the literature with regard to transverse rumble strips. Additionally, while some studies conclude that there are safety benefits, others indicate that the results are inconclusive. As the District Traffic Engineers throughout the state identified many locations

Arkansas (2012):

Bicyclists

A common complaint of bicyclists is that the design of a continuous SRS and a narrow shoulder sometimes require bicyclists to move into the travel lane. To address this concern, SRS with a gap pattern should be installed on highways that are not fully access controlled and the remaining shoulder width beyond the outside edge of the rumble strip is 4 feet or greater. The typical longitudinal pattern will consist of 48 feet of SRS and 12 feet without SRS. When driveways or intersections are present, the use of a gap pattern will be adjusted at the discretion of the Engineer so that the driveway or intersection may be utilized as a gap. In addition, the 3/8-inch depth of grooves of rumble strips on rural, undivided highways is considered to be less disruptive to bicyclists traveling on these routes.

Criteria for the Use of Rumble Strips

Rural, Divided Highways with Full Access Control

SRS shall be installed on both the inside and outside shoulders of rural, divided highways with full access control. Shown as Rumble Strips (Type 1) on Figure 1, these rumble strips should be 16 inches wide and 1/2 inch deep and offset 4 inches from the edge line. This offset may be increased to avoid longitudinal joints. Longitudinally, the grooves should be 12 inches on center, with a 7-inch groove and 5 inches between grooves.

Rural, Divided Highways with Partial Access Control

SRS should be installed on both the inside and outside shoulders of rural, divided, partial access control highways where the remaining paved shoulder width beyond the outside edge of a rumble strip would be 4 feet or greater. Shown as Rumble Strips (Type 2) on Figure 1, these rumble strips should be 12 inches wide, 3/8 inch deep and offset 4 inches from the edge line. This offset may be increased to avoid longitudinal joints. Longitudinally, the grooves should be 12 inches on center, with a 5-inch groove and 7 inches between grooves with a typical 48-foot rumble strip and 12-foot gap pattern.

Rural, Undivided Highways

SRS shall be installed on rural, undivided, highways where the remaining paved shoulder width beyond the outside edge of a rumble strip would be 4 feet or greater and the posted speeds are greater than 45 mph. Shown as Type 2 Rumble Strips on Figure 1, these rumble strips should be 12 inches wide, 3/8 inch deep and offset 4 inches from the edge line. This offset may be increased to avoid longitudinal joints. Longitudinally, the grooves should be 12 inches on center, with a 5-inch groove and 7 inches between grooves with a typical 48-foot rumble strip and 12-foot gap pattern.

AHTD Policy for the Use of Rumble Strip, Arkansas State Highway and Transportation Department

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4-411.02 RAISED BITUMINOUS RUMBLE STRIPS

Raised bituminous rumble strips are a traffic warning device. Raised bituminous rumble strips will require a detail to be furnished in the plans. This type of rumble strip is to be used for warning or unexpected stop conditions and shall not be used routinely as a shoulder treatment. At approaches to narrow bridges, where the shoulder width is less than the normal roadway shoulder width, the raised bituminous rumble strip may be used to warn the motoring public of this roadway condition.

4-411.03 RUMBLE STRIPS

Scored rumble strips are a traffic warning device, and when required, shall be constructed in accordance with Standard Drawings T-M-15 and T-M-15A or as shown on the plans. Raised bituminous rumble strips and scored rumble strips are the two types of rumble strips normally used in Tennessee.

Scored rumble strips and scored rumble stripes provide an audible warning to vehicles leaving the travel lane. Unlike a scored rumble stripe which is placed at the edge line location, a scored rumble strip is placed on the shoulder adjacent to the travel lane and edge line.

Refer to Section 4-716.15 for guidelines for placement of rumble strips on shoulders. Scored shoulders will be constructed on asphalt or concrete shoulders. Asphalt shoulders must have a minimum depth of pavement of one and one-half inches. Scored shoulders should also be omitted adjacent to ramps, acceleration and deceleration lanes including tapers and along the radius of side road approaches, entrances and median crossovers.

Rumble strips shall be specified on all new construction and resurfacing projects on the Interstate System and access controlled state routes. Both the inside and the outside shoulders shall be scored. The scored rumble strip shall be constructed in accordance with Standard Drawing T-M-15. Rumble strips are to be paid for under Item No. 411-12.01, Scoring Shoulders (Continuous) (16 inch Width), L.M. For estimating purposes, the item will be measured longitudinally along the edge of each shoulder and will usually be four (4) times the project length less deductions for entrance and exit ramps, public roads, and bridges. When concrete shoulders are present rumble strips are to be constructed in accordance with Standard Drawing RP-CS-1 or RP-CS-2. Rumble strips on concrete shoulders shall be paid for under Item No. 501-03.10, Concrete Shoulder Rumble Strips, L.F. The item will be measured as the actual length of pavement scored along each shoulder.

Refer to Section 4-716.15 for guidelines for placement of rumble strips on non-access controlled state routes. When rumble strips are placed on non-access controlled routes, paved shoulders should be 8ft. or wider. A 30 foot rumble will be followed by a 10 foot gap in the rumble to allow for bicycles to cross without having to traverse the rumble strip. Rumble strips should normally only be placed on rural routes with posted speeds of 45 mph or greater. Rumble strips may be used on urban routes where accident history or other factors warrant the placement. When placed on urban routes, designers should give consideration to expected bicycle traffic and noise generated. The scored rumble strip shall be constructed in accordance with Standard Drawing T-M-15A. Rumble strips are to be paid for under Item No. 411-12.02, Scoring Shoulders (Non-continuous) (16 inch Width), L.M. The item will be measured and paid as the actual length of pavement scored along each shoulder. Rumble strips should be omitted on shoulders adjacent

to designated bike lanes and may also be omitted from locations recommended by the TDOT bicycle coordinator.

4-411.04 RUMBLE STRIPES

Rumble stripes are a traffic warning device, and when required, shall be constructed in accordance with Standard Drawing T-M-16. A scored rumble stripe is a scored rumble placed along the outside edge line of the travel lane with the edge line placed along the scored rumble.

Refer to Section 4-716.15 for guidelines for the placement of rumble stripes. Rumble strips should normally only be placed on rural routes with posted speeds of 40 mph or greater. The rumble stripe shall consist of a 30 foot scored rumble followed by a 10 gap to allow for bicycles to cross without having to traverse the rumble. Rumble stripes may be used on urban routes where accident history or other factors warrant the placement. When placed on urban routes, designers should give consideration to expected bicycle traffic and noise generated.

Scored rumble stripes are to be paid for under Item No. 411-12.03, Scoring for Rumble Stripe (Non-Continuous) (8 inch Width), L.M. or Item No. 411-12.04, Scoring for Rumble Stripe (Non-Continuous (4 inch Width), L.M. The item will be measured and paid as the actual length of pavement scored along each shoulder.

When rumble stripes are specified, pavement markings shall be Spray Thermoplastic (60 mil). Enhanced Flatline Thermoplastic Markings shall not be used. Striping is to be paid for under the appropriate pavement marking item number. Rumble stripes should be omitted on shoulders adjacent to designated bike lanes and may also be omitted from locations recommended by the TDOT bicycle coordinator.

4-411.05 RIDEABILITY SPECIFICATIONS

For all projects having asphaltic concrete surface Grading "D", a determination shall be made as to whether or not the rideability specification shall be included in the contract. This determination will be made by the State Construction Office after the plans have been submitted.

4-414.05 COMPUTATIONS FOR MICRO-SURFACING

Item No. 414-03.01 Emulsified Asphalt for Micro-Surfacing

0.12 x Below aggregate quantity = Tons

NOTE: Application rate based on 12 percent of the dry weight of the aggregate.

Item No. 414-03.02 Aggregate for Micro-Surfacing

$$\frac{\text{Surface area (Sq. Yd.)} \times \mathbf{XX} \text{ Lb./ Sq. Yd.}}{\text{2,000 Lb./ Ton}} = \text{Tons}$$

NOTE: Application rate of 30 pounds (approximate depth 0.375”) per square yard shall be used if plans require a leveling mixture (14 pounds per square yard) and a surface

CONCLUSIONS AND RECOMMENDATIONS

INTRODUCTION

In December, 2001, FHWA issued a technical advisory for use in the design and installation of shoulder rumble strips [(2)]. The advisory is intended to provide guidelines for use of shoulder rumble strips on appropriate rural segments of the National Highway System (NHS). The following provides a description of the recommendations for the design and placement of shoulder rumble strips, and the warrants that should be considered in installing the strips.

DESIGN AND PLACEMENT RECOMMENDATIONS

The advisory recommends the use of continuous, milled shoulder rumble strip on rural freeways and expressways on the National Highway System. When used on roadways with a 3 m (10 ft) shoulder, the strip should be installed as close to the edge line as possible, leaving at least 2.4 m (8 ft) of clear shoulder width remaining available after installation.

If an engineering study or crash analysis indicates that the number of crashes would be reduced by installing shoulder rumble strips, then shoulder rumble strips can also be used on non-freeway facilities, such as rural multilane and two-lane roadways. Additional countermeasures may be implemented instead of or in addition to shoulder rumble strips. These countermeasures may include improved roadway geometry, additional signing and markings, or increased pavement skid resistance.

FHWA also recommends that shoulder rumble strips be coupled with continuing driver behavior safety programs to educate the driving public on the dangers of drowsy and inattentive driving and to alert bicyclists on the increased use of shoulder rumble strips. Cooperation should be sought between agencies and bicycle group in the development of policies, standards and implementation techniques.

FHWA INSTALLATION WARRANTS

FHWA provides guidelines that should be considered when installing shoulder rumble strips. The guidelines are based on the review of policies and practices of shoulder rumble strips for 41 jurisdictions in the United States.

Shoulder Rumble Strips and Bicyclists, Report No. FHWA–NJ–2002–020, New Jersey Department of Transportation, 2007

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Missouri:

EXECUTIVE SUMMARY

The Missouri Department of Transportation (MODOT) began using shoulder rumble strips (SRS) on bituminous shoulders of interstate and freeway projects in 1991. Designs for concrete shoulders have since been added. Though successful in reducing run-off-the-road (ROR) accidents, shoulder rumble strips often encroach on the portion of shoulder used by bicyclists. In Missouri, many bicyclists ride in the two foot strip between the edge line and the rumble strip instead of on the right side of the rumble strip. They are reluctant to ride on the right side of the strip due to debris that is not swept clear by traffic wind currents. MODOT, consequently, posed two specific design questions to be addressed by this project. The first is whether strips could be narrowed from the current 36" width and be moved closer to the edge line to encourage bicyclists to ride on the right side of the strip further from traffic. The second question relates to problems associated with concrete pavements and follows from the first question. Currently concrete pavements are striped at 12' and their construction joint with shoulder is at 14'. Can SRS be designed narrow enough and be placed close enough to the striping so as to avoid the joint?

The objective of this multi-phase project was to develop a set of guidelines for the use and design of rumble strips in Missouri which addresses the needs of both motorists and bicyclists and to specifically answer the two design questions posed. With regard to these questions, it was found that SRS narrower than the current width and that would fit within the construction joint area could indeed be designed and used safely.

This Report provides a set of guidelines for the use and design of SRS in the State of Missouri. Key recommendations pertaining to SRS use are as follows:

1. Install on all rural freeways and expressways.
2. Do not install in urban areas unless an engineering study has been conducted and has found that run off road crash history exceeds acceptable values and it is determined that SRS would be effective in reducing those numbers.
3. Speed limit must exceed 45 mph
4. On non-freeway/expressway sections, free shoulder width must exceed four feet (five feet in guard rail sections). Shoulders not meeting these criteria are not wide enough to accommodate both SRS and cyclists. In this latter event, decision must be made whether, for shoulders wider than two feet, whether crash history or cyclist usage should be given priority on the facility. When SRS are installed in this case, cyclists must be denied access to the facility. For shoulders less than two feet wide, SRS should not be installed.
5. The uninterrupted length of highway must exceed 1/30 of the design speed.

The following SRS design recommendations are proposed:

1. Milled-in SRS with 5 inch grooves, 7/16 inches deep, on 12 inch spacing.
2. For all freeways use continuous strips that are 16 inches wide and 6 inches offset from the shy line
3. For non-freeways with shoulder widths exceeding 6 feet, use intermittent strips (12 foot gaps with 60 foot cycles) that are 16 inches wide and 6 inches offset from the shy line
4. For non-freeways with shoulder widths from 5 feet to 6 feet, use intermittent strips (same pattern as above) that are 12 inches wide, on the shy line
5. For non-freeways with shoulder widths from 2 feet to 5 feet, conduct needs studies based upon crash histories and bicycle use
6. For non-freeways with shoulder widths less than 2 feet, do not install SRS.

A process for evaluating the on-site performance of rumble strips to be used to refine the guidelines to best suit Missouri's conditions is also provided.

Shoulder Rumble Strips in Missouri, Report No: RDT 03-007, Missouri Department of Transportation, 2003

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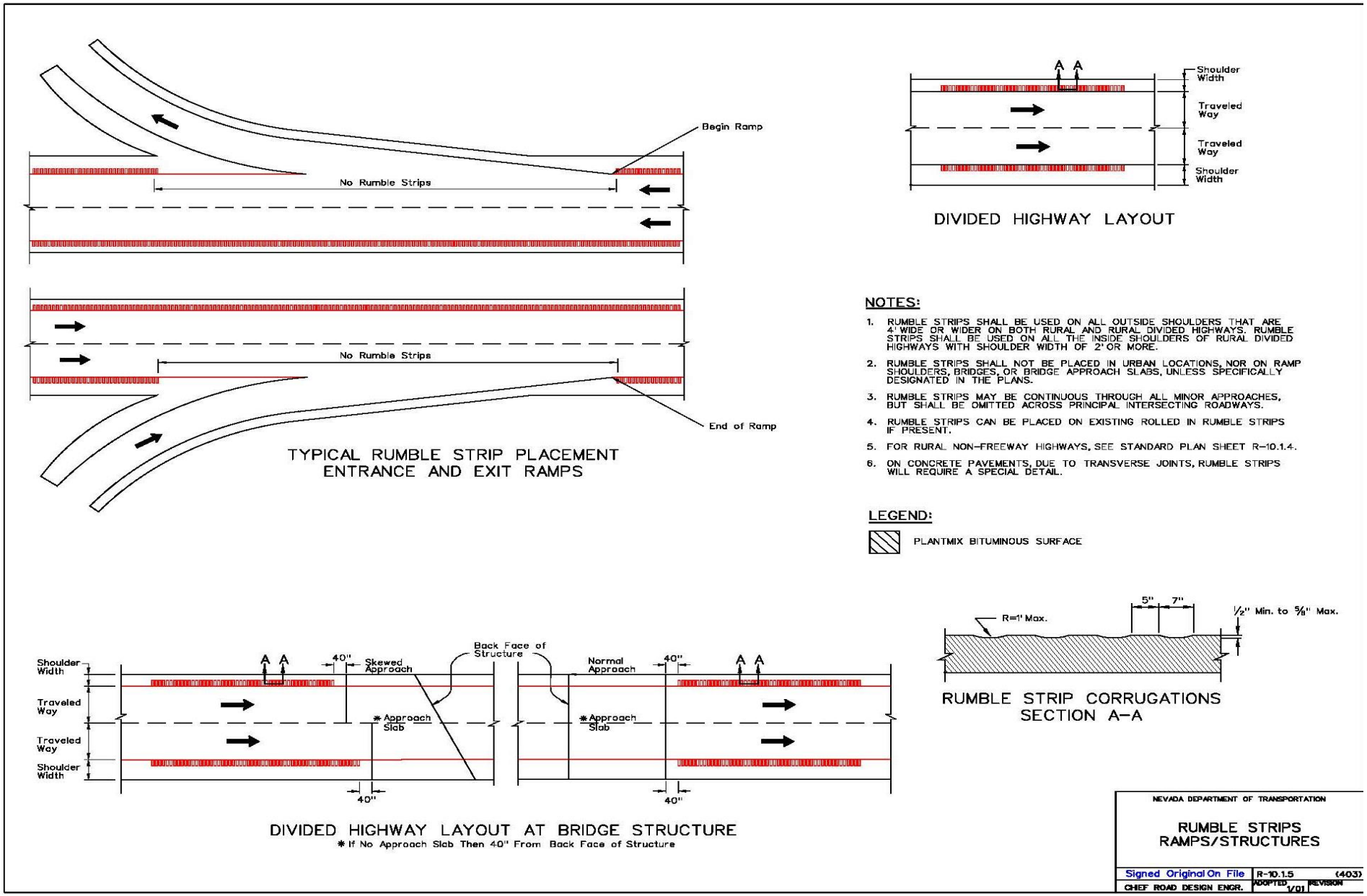
Nevada (2010):



Rumble Strips Ramps/Structures, Nevada Department of Transportation, 2010

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Ohio (2010):

Edgeline Rumble Stripes

Draft Update of ODOT Traffic Engineering Manual

Ohio Department of Transportation

UPDATED: Wednesday, September 08, 2010

The Ohio Department of Transportation is investing approximately $4 million during State Fiscal Year 2011 to install roughly 1,335 miles of edgeline rumble stripes along many sections of Ohio's state highway system (non-interstate). As part of a statewide systematic safety improvement effort, the goal is to reduce fatal and serious-injury accidents caused by drivers running off the road. Edgeline rumble stripes are recommended by the Federal Highway Administration as a relatively low-cost investment that can yield high returns on safety.

A recent ODOT safety analysis showed that fixed-object crashes are one of the leading causes of serious injuries and deaths on Ohio roadways. Approximately 3,000 serious injuries and 450 fatalities every year in Ohio are a result of drivers running off the road and colliding with trees, ditches, utility poles or other fixed objects. These crashes represent about 35% of all fatalities and 30% of all serious injuries each year. **National studies have shown that rumble strips and stripes can decrease crashes by between 20% and 35%.**

There is a difference between the rumble STRIPS on the interstates and the rumble STRIPES being placed on several state routes. The smaller stripes are half as deep and only a third of the width of interstate strips. The smaller stripes run under the painted edgeline (which actually makes the edgeline easier to see at night and wet pavement conditions). The narrower width and more shallow depth of the rumble stripe also create less noise when driven over by vehicles - enough to wake the driver but not so much to be disruptive to people living along the state route.

Below is the draft edgeline rumble stripe guidance that is expected to be included in the next update to ODOT's Office of Traffic's Traffic Engineering Manual (TEM) in October.

EDGELINE RUMBLE STRIPES

General

Edgeline rumble stripes consist of a series of rumble strips which are ground into the pavement and then overlaid with an edge line pavement marking. The benefits include increased wet / night visibility of the edge line pavement markings and the corresponding audio and vibratory impacts which result when a motorist's tires pass over the rumble strips.

Guidelines and Placement Standards

Edgeline rumble stripes are to be installed on ODOT-maintained roadways meeting all of the following criteria:

- 2' or greater shoulder
- 80 PCR or greater, and shoulder condition suitable for rumble stripe treatment
- 11' minimum lane width
- 2 lane routes outside urban areas
- Speed limit greater than 45 mph

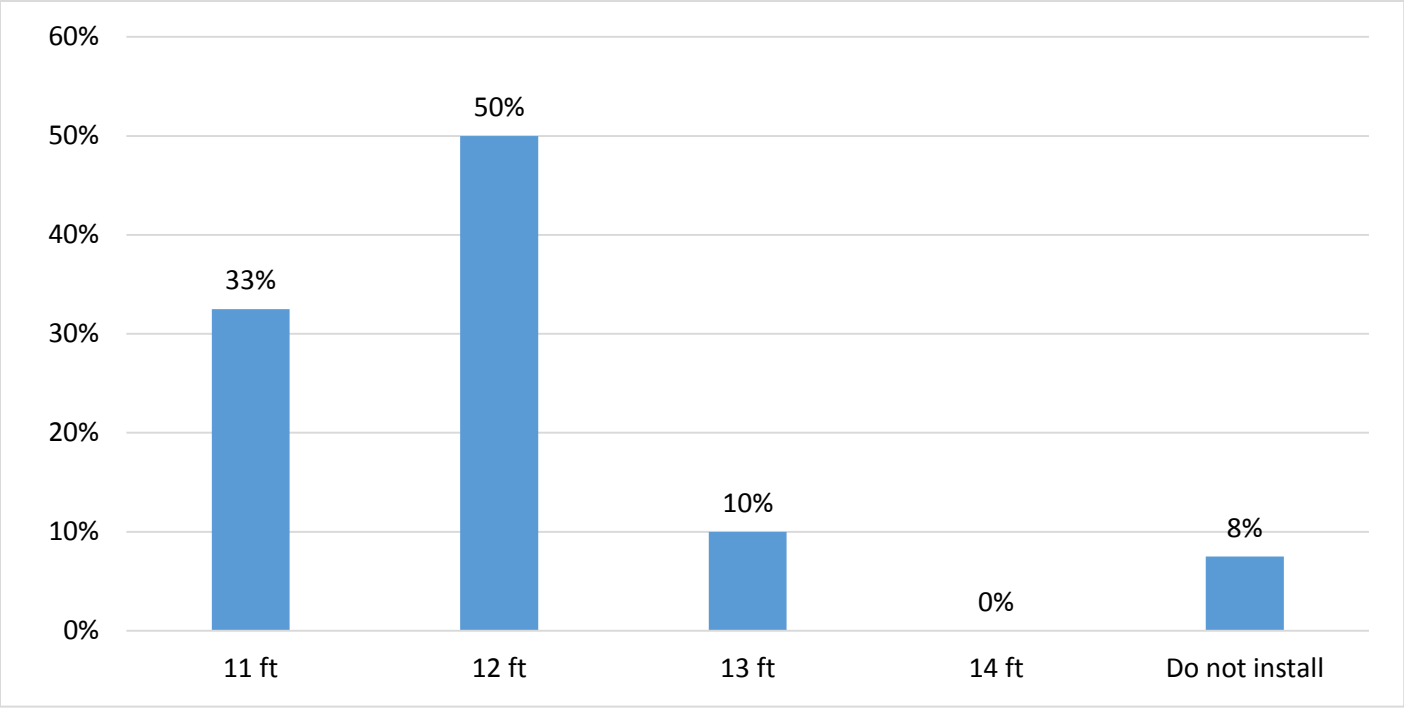


Figure 14: What should be the Minimum Lane Width to Install Centerline Rumble Strips in Rural Two-lane Highway?

Half of the engineers (50 percent) recommended to use 12 feet as a minimum lane width to install centerline rumble strips in rural two lane highways. Thirty-three percent had recommended to install on 11 feet lane.

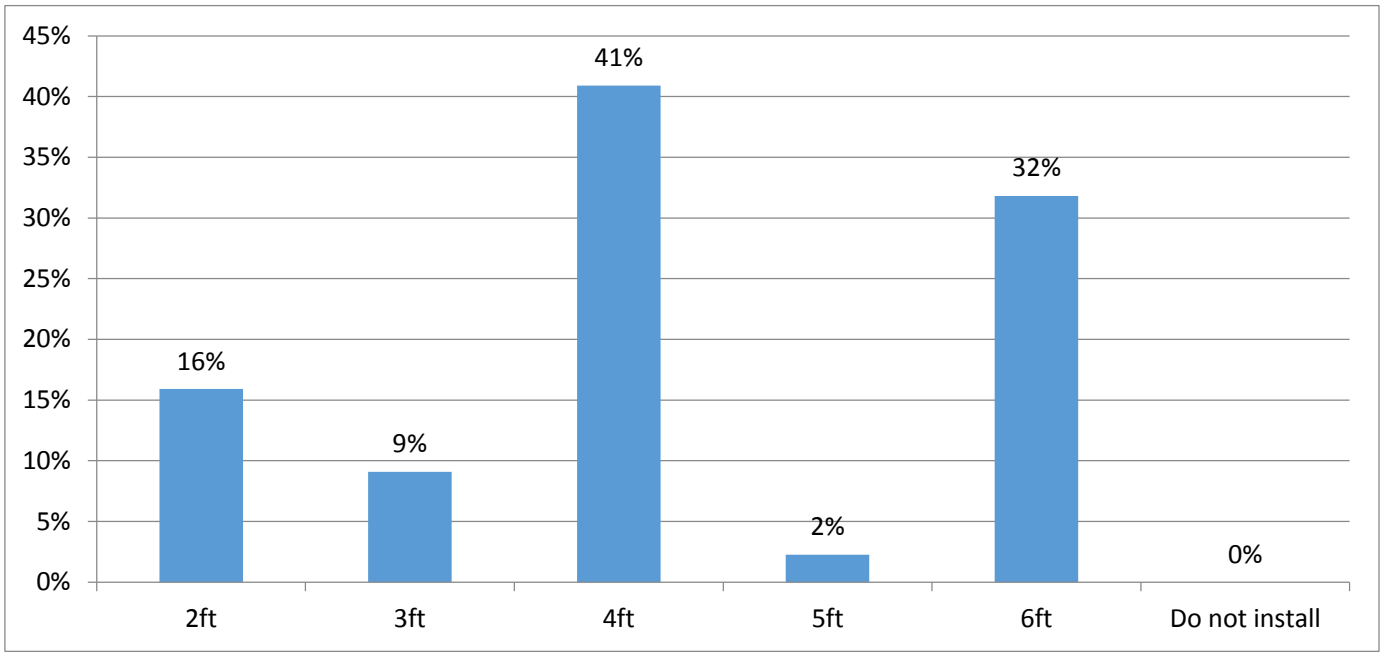


Figure 15: WYDOT Shoulder Width Recommendation for Rural Two-lane Highway

The engineers were asked about the minimum clear shoulder width too. For rural two lane highway, 41 percent recommended to provide 4 feet clear shoulder width. If 4 feet of clear shoulder width is provided, this will be clear enough for bicyclists.

Table 3: Types of Roadway Centerline Rumble Strips are Applied (Survey Response)

Rural Multilane Undivided Highways	Rural Two-lane Highways	Urban Two-lane Highways
	Arizona	
	Florida	
South Dakota	South Dakota	
	Alaska	
	New Jersey	
	North Dakota	
	Mississippi	Mississippi
Arkansas	Arkansas	Arkansas
	Nevada	
Texas	Texas	Texas
	Michigan	
	Ohio	
	Indiana	
	Kentucky	Kentucky
South Carolina		South Carolina
	New Hampshire	
	New Mexico	
Montana	Montana	
	Idaho	
	Connecticut	
Pennsylvania	Pennsylvania	Pennsylvania
	Maine	
Oregon	Oregon	
Wyoming	Wyoming	

* Blank cells mean shoulder rumble strips are not installed in that type of roadway.

Among the 29 DOTs, 27 responded they are using rumble strips in rural freeways and 25 on rural two-lane highways. Use of rumble strips in urban areas is less common than use in rural areas. Only 6 DOTs use rumble strips in urban two-lane highway, though 20 DOTs responded they are using rumble strips in their urban freeways.

Table 4: Summary of centerline rumble strip practices in the US.

State or province*	Pattern characteristics			Minimum requirements for installation						Dimensions				Date of policy
	Roadway type	Rumble type**	Placement	Lane width	ADT (vpd)	Speed	Accident	Pavement depth	Bicycle	Length (B)	Width (C)	Depth (D)	Spacing (E)	
Alabama*	R two-lane		Into lane	N	N	N	N	N	N	–	–	–	–	–
Alaska	–	M								12 in.	5–7 in.	0.5 in.	10–12 in.	–
Arkansas*	R two-lane		Within pm	N	N	N	N	N	N	–	–	–	–	–
Arizona*	R multilane undivided, R two-lane	M	Within pm Into lane	N	N	N	N	N	N	–	–	–	–	–
California	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Colorado*	R multilane undivided, R two-lane	M	Within pm	N	N	N	N	Varies	N	12 in.	5 in.	0.375 in.	12 in.	6/02
Delaware*	U multilane undivided; R multilane undivided, R two-lane	M	Into lane	N	N	N	N	N	N	16 in.	7 in.	0.5 in.	12 in.	–
Hawaii	–	M	–	–	–	–	–	–	–	18–24 in.	4 in.	–	24 in.	–
Idaho*	R multilane undivided, R two-lane	–	Within pm Into lane	N	N	N	Y	N	N	–	–	–	–	–
Iowa*	R two-lane	–	Into lane	N	N	N	N	N	N	–	–	–	–	–
Kansas		M	–	–	–	–	–	–	–	12 in.	6.5 in.	0.5 in.	12 in. 12 in. and 24 in.	–
Kentucky*	R two-lane	M	Into lane	N	N	N	Y	Varies	N	24 in.	7 in.	0.5–0.625 in.	24 in.	–
Maine*	B multilane undivided	–	Into lane	N	N	N	N	3 in.	N	–	–	–	–	–
Maryland	–	M	–	–	–	–	–	–	–	18–24 in.	4 in.	0.5 in.	varies	–
Massachusetts	–	M	–	–	–	–	–	–	–	16 in.	6 in.	0.5 in.	12 in.	–
Michigan	–	M	–	–	–	–	–	–	–	16 in.	7 in.	0.375 in.	19 in.	–
Minnesota*	R two-lane	M	Beside pm	N	N	50 mph	N	N	N	12–16 in.	7 in.	0.5 in.	19 in.	–
Missouri*	R two-lane	M	Within pm	N	N	N	N	3.75 in.	N	12 in.	6.5 in.	0.5 in.	12.5 in.	–
Nebraska	–	M	–	–	–	–	–	–	–	16 in.	7 in.	0.5–0.625 in.	12 in.	–
Nevada*	U multilane undivided; R multilane undivided, R two-lane	–	Into lane	N	N	N	Y	N	N	–	–	–	–	–
North Carolina*	R two-lane	–	Into lane Beside pm	N	N	N	N	6 in.	N	–	–	–	–	–
Oregon*	R multilane undivided, R two-lane	M	Within pm Into lane	N	N	N	N	N	N	16 in.	7 in.	0.5 in.	12 in.	–

State or province*	Pattern characteristics			Minimum requirements for installation						Dimensions				Date of policy
	Roadway type	Rumble type**	Placement	Lane width	ADT (vpd)	Speed	Accident	Pavement depth	Bicycle	Length (B)	Width (C)	Depth (D)	Spacing (E)	
Pennsylvania*	U multilane undivided; R multilane undivided, U two-lane R two-lane	M	Within pm Into lane	10 ft	Y	N	Y	N	N	16 in.	7 in. ± 0.5 in.	0.5 in. ± 0.0625 in.	24 in. and 48 in.	3/02
		M	Within pm Into lane	10 ft	Y	N	Y	N	N	14–18 in.	7 in. ± 0.5 in.	0.5 in. ± 0.0625 in.	24 in.	
Texas*	R multilane undivided, R two-lane	M	Into lane	N	N	N	N	N	N	16 in.	7 in.	0.5 in.	17 in.	–
Utah*	R multilane undivided, R two-lane	M	Into lane	N	N	N	N	N	N	12 in.	8 in.	0.625–0.75 in.	12 in.	–
Virginia*	U multilane undivided; R multilane undivided, R two-lane	M, RS	Within pm	N	N	N	N	N	N	16 in.	7 in.	0.5 in.	12 in.	–
Washington*	R multilane undivided, R two-lane	M	Within pm	12 ft	N	N	N	Varies	N	16 in.	5 in.	0.375 in.	12 in.	–
Wisconsin	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Wyoming*	R two-lane	M	Into lane	–	N	N	N	–	N	12 in.	7.5 in.	0.5 in.	14.5 in.	–
Canadian Provinces														
														–
Alberta	–	M	–	–	–	–	–	–	–	12 in.	6–8 in.	0.2–0.35 in.	13–15 in.	–
British Columbia*	R multilane undivided, R two-lane	M	Within pm	> 11 ft Eng. review	N	N	N	N	N	12 in. ± 0.375 in.	5.5 in. ± 0.75 in.	0.32 in. ± 0.125 in.	12 in.	5/04
Ontario*	R two-lane	M	Within pm	N	N	N	N	3 in.	N	12 in.	6 in. ± 0.75 in.	0.375 in. ± 0.125 in.	12 in.	–
Saskatchewan*	R multilane undivided, R two-lane	M	Within pm Into lane	N	N	N	N	N	N	12 in.	4–7 in.	0.315 in. ± 0.079 in.	10–13 in.	–

* Indicates state/province responded to survey and information from the survey is reflected in this table.
** Rumble Strip Type Abbreviations: M = Milled RS = Raised

other roadway types, the low cost of installation, and relatively few concerns, centerline rumble strips are considered appropriate for installation along a range of roadway types including multilane undivided highways and two-lane roads in both rural and urban areas.

- For roadways where bicyclists are not expected (e.g., freeways), shoulder rumble strip patterns should be designed to produce sound level differences in the range of 10 to 15 dBA in the passenger compartment; and on roadways where bicyclists can be expected or near residential or urban areas, shoulder rumble strip patterns should be designed to produce sound level differences in the range of 6 to 12 dBA in the passenger compartment.
- Centerline rumble strip patterns should be designed to produce sound level differences in the range of 10 to 15 dBA in the passenger compartment, except near residential or urban areas where consideration should be given to designing centerline rumble strips to produce sound level differences in the range of 6 to 12 dBA in the passenger compartment.
- Statistical models developed in this research to predict the sound level difference in the passenger compartment when traversing rumble strips can be used to design rumble strip patterns that produce the desired alerting properties. Predictive models are available that include, as independent variables, the four primary rumble strip dimensions (i.e., length, width, depth, and spacing), vehicle speed, angle of departure, pavement type (asphalt or concrete), pavement condition (wet or dry), rumble strip type (milled or rolled), and location (shoulder or centerline).
- In situations where it is desirable to provide more lateral clearance for bicyclists or for installing shoulder rumble strips on roads with very narrow shoulders, shoulder rumble strips can be designed with relatively narrow lengths (e.g., 6 in. [152 mm]) and still generate the desired sound level differences in the passenger compartment.

Recommendations for Future Research

The key unresolved issues associated with shoulder rumble strips that should be addressed in future research are as follows:

- **Better quantify the safety effectiveness of rumble strip applications on different types of roads:** The most reliable and comprehensive estimates on the safety effectiveness of shoulder rumble strips are available for freeways and rural two-lane roads. Estimates on the safety effectiveness of shoulder rumble strips along rural multilane divided highway (nonfreeways) are also available but are not considered as reliable as the estimates for freeways and rural two-lane roads. The safety effectiveness estimates for freeways, rural two-lane roads, and rural multilane divided highways are considered appropriate only for the respective roadway types.

  The safety benefits of shoulder rumble strips along urban freeways (by themselves), urban freeway on-ramps and off-ramps, urban multilane divided highways (nonfreeways), urban multilane undivided highways (nonfreeways), urban two-lane roads, rural freeway on-ramps and off-ramps, and rural multilane undivided highways (nonfreeways) have not been quantified at this time due to limited mileage of shoulder rumble strip treatments along these respective roadway types. In the future it is desirable to calculate reliable safety estimates for these roadway types. Given the current state of applications, this issue should likely not be addressed for at least another 3 to 5 years to allow for more installations along the respective roadway types.
- **Determine the optimal placement of shoulder rumble strips on rural two-lane roads:** Conclusive evidence shows that on rural freeways rumble strips placed closer to the edgeline are more effective in reducing SVROR FI crashes compared to rumble strips placed farther from the edgeline. However, for other roadway types (e.g., rural two-lane roads), there is no conclusive evidence based upon crash statistics to indicate that offset distance influences the safety effectiveness of shoulder rumble strips. Further investigations, potentially through kinematic modeling, should be made to assess the optimal placement of shoulder rumble strips along roadway types, focusing primarily on rural two-lane roads.
- **Determine the optimal longitudinal gaps in rumble strips to provide accessibility for bicyclists while maintaining the effectiveness in reducing lane departures:** It may be possible to provide accessibility for bicyclists, while still preserving the effectiveness of rumble strips for motor vehicles, by providing longitudinal gaps in rumble strips. Moeur (*99*) addressed this issue from a bicyclist's perspective. However, this research did not account for vehicle speed and trajectory. In addition, the Moeur study did not vary the length of the rumble strip patterns, and the trajectories of bicyclists as they navigate from the outside of the rumble strip along the shoulder to the inside of the rumble strip near the travel lane are a function of bicycle speed, gap length, and rumble strip groove length. Further investigation into these issues is desirable.
- **Better quantify the safety effectiveness of shoulder rumble strips in varying conditions:**
  - **Along varying roadway geometry.** Studies concerning the safety effectiveness of shoulder rumble strips have utilized crash data collected over long segments of highway, such that the study segments included both tangents and horizontal curves. No distinction has been made in these studies or in the present research between

Delaware (2014):

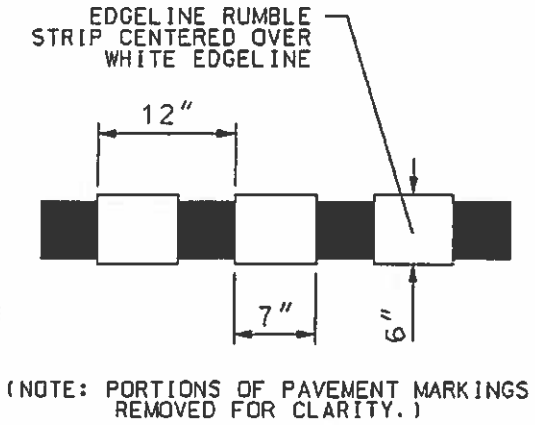
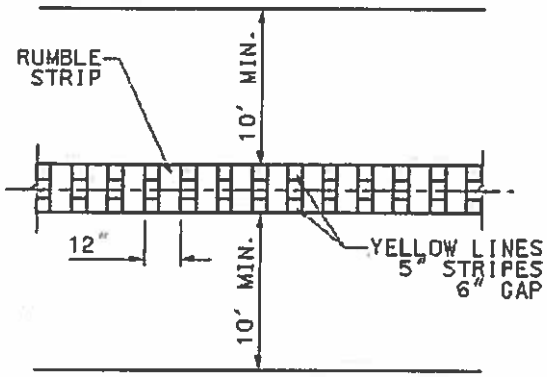


FIGURE 3
EDGELINE RUMBLE STRIPE DETAILS
NOT TO SCALE

B. Center Line Rumble Strips

1. Center line rumble strips should be considered on all conventional two-lane and undivided multilane roadways where an engineering study determines that crossover or head-on crash rates along the section of roadway exceed statewide or national averages for similarly classified roadways and if rumble strips are a viable crash reduction countermeasure. The study should be reviewed and approved by the Chief Traffic Engineer.
2. The installation of center line rumble strips shall be in accordance with Figures 4A and 4B. Center line rumble strips should start and end following the center line striping.
3. Center line rumble strips shall not be installed on bridge decks without approval from the DelDOT Bridge section.
4. In areas where the center line leads into a raised concrete island, the rumble strips should be discontinued 25' in advance of these islands.
5. In areas where the center line splits to create, for example a turn lane, the rumble strips should be placed only along the double yellow center line that is *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 Figure 4A.
6. 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 Figure 5.



(NOTE: PORTIONS OF PAVEMENT MARKINGS REMOVED FOR CLARITY.)

FIGURE 4A
CENTER LINE RUMBLE STRIP DETAILS
NOT TO SCALE

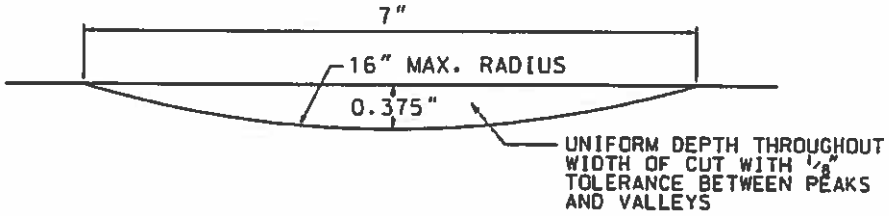


FIGURE 4B
CENTER LINE RUMBLE STRIP DETAILS
NOT TO SCALE

Kentucky 2008:

Recommended Pavement Cross Section

Total Pavement Width (ft)	Lane Width (ft)	Paved Shoulder (ft)	Centerline	Edgeline
28	12	2	Yes	Yes
27	12	1.5	Yes	Yes
26	11	2	Yes	Yes
25	11	1.5	Yes	Yes
24	11	1	Yes	Yes
23	10	1.5	Yes	Yes
22	10	1	Yes	Yes
21	9	1.5	Yes	Yes
20	9	1	Yes	Yes
19	8	1.5	Yes	No
18	8	1	Yes	No
17	7.5	1	No	Yes
16	7	1	No	Yes
15	6.5	1	No	Yes
14	6	1	No	Yes

The Insurance Institute for Highway Safety (IIHS) conducted a comprehensive before and after study evaluating CLRS applications in seven states. The study concluded that total crashes were reduced by 15 percent and head on and opposite direction sideswipe crashes were reduced by 21 percent. The study further noted that "consideration should be given to wider application of center line rumble strips on rural two-lane roads to reduce injury crashes." The report is considered the most comprehensive and definitive analysis of the use of centerline rumble strips, due to the large number of sites and level of statistical analysis.

As a result of the recommendations of the IIHS study, NCHRP Syntehsis 339 and NCHRP 500 Centerline Rumble Strips are recommended as a countermeasure to mitigate the occurrence of opposite direction head on and sideswipe crashes on undivided highways. Based upon other states practice, permitting the use of narrower roadways with lanes 11 foot or 10 foot with appropriate shoulder is recommended.

Virginia (2013):

- Left paved shoulder widths between 2 feet and 4 feet outside of the travel lane may be considered for continuous rumble strips if adequate "total shoulder" recovery area is provided. This decision will be made at the joint discretion of the Regional Traffic Engineer, District Materials Engineer and the Project Manager.

- Minimum of 4 feet outside of the milled rumble strip groove when providing for bicycles. If large bicycle volumes are present or expected, a minimum of 5 foot paved shoulder outside of the groove is desirable, particularly if there are obstructions such as guardrail. Additional shoulder width may be necessary if horse and buggy traffic is present or expected.

CONTINUOUS SHOULDER RUMBLE STRIP, STANDARD RS-1

- For Rural Roadways with Fully-Controlled Access, Continuous Shoulder Rumble Strip (CSRS) Standard RS-1 is to be specified for Right and Left Paved Shoulders.

- For Divided Roadways with Partially-Controlled / Non-Controlled Access, Continuous Shoulder Rumble Strip (CSRS) Standard RS-1 may be specified for left (median) shoulders with Design Speeds ≥ 50 mph / Posted Speeds ≥ 45 mph.

- Continuous Shoulder Rumble Strip grooves shall be milled as follows:

  - 7 inches by 16 inches across by ½ inch deep.

  - 6 inch positive offset from the outside edge of pavement edge-line.

CONTINUOUS CENTERLINE RUMBLE STRIP, STANDARD RS-3

- For No-Passing Zones on New and Existing Undivided Non-Access Controlled roadways, Continuous Centerline Rumble Strip (CCLRS), Standard RS-3, is to be provided as recommended by the Regional Traffic Engineer based on the following:

  - Design Speeds ≥ 50 mph / Posted Speeds ≥ 45 mph
  - Through Travel Lane Widths ≥ 11 feet
  - Minimum 4" asphalt pavement and sufficient condition determined by the District Materials Engineer to effectively accept the milling process without raveling or deteriorating. Otherwise, the pavement should be upgraded prior to milling.

- For existing roadways, first consideration for CCLRS should be given to those with multiple lanes, posted speeds ≥ 45 mph and with traffic volumes > 5000 AADT.

Instructional and Informational Memorandum Report No. IIM-LD 212.5, Virginia Department of Transportation (2013)

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South Dakota :

Centerline Rumble Strips/Stripes

The purpose of centerline rumble strips/stripes is to reduce the number of head on collisions. Centerline rumble strips/ stripes can be considered on undivided rural sections of highways where crash history indicates a potential for increased head on collisions. Recommendations to install centerline rumble strips/stripes should be coordinated with Department's Traffic and Safety Engineer.

Bicycle Use

The engineer should take into consideration the amount of bicycle use on a facility and its relation to shoulder width and lateral clearance. A minimum of 4 foot shoulder is required to accommodate bicycle use. If rumble strips/stripes are recommended on sections with less than 4 foot shoulders, a thorough analysis of bicycle use should be completed. Information pertaining to bicycle use can be obtained by contacting local bicycle shops and user groups.

Rumble Strip/Stripe Guidelines for Asphalt Mainline Surface

Table 7- 4 provides rumble strip/strip guidelines for asphalt mainline surface.

Functional Classification	Shoulder Width[1,2,3]	Mainline Width	Strip Width	Rumble Type	Continuous or Intermittent
Interstate	4' inside 10' outside	28'	12"	Rumble Strip	Continuous
Non-Interstate	4'	24'+shld	8"	Rumble Stripe	Intermittent
	> 4'	28'	12"	Rumble Strip	Intermittent

Table 7- 4. Rumble Strip/Stripe Guidelines for Asphalt Mainline Surface

[1] The use of rumble strips/stripes on sections with shoulders less than 4 foot should be reviewed with the Region Traffic Engineer and the Department's Traffic and Safety Engineer after an analysis of historical crash data, inslope, fixed objects, horizontal/vertical alignment, current and future bicycle use, and other design elements.

[2] For sections of roadway with 4 foot shoulders, the engineer should use 8 inch rumble stripes in lieu of rumble strips in order to provide adequate lateral clearance for bicycle use. The engineer should also consider the inslope rate, location of fixed objects as compared to the edge of traveled way, horizontal/vertical alignment and other design elements.

[3] For sections of roadway with greater than 4 foot shoulders the shoulder type may be asphalt, concrete, or gravel (except interstate). A 28 foot mainline top for asphalt paving should be constructed to accommodate the use of rumble strips on the mainline pavement. The use of 12 inch rumble stripes can be considered as an effort to increase visibility of pavement markings upon recommendation from the respective Region Traffic Engineer.

Shoulder rumble strip installation considered at any other locations must involve the region and Headquarters Bicycle and Pedestrian Coordinators as a partner in the decision-making process.

Consult the following website for guidance on conducting an engineering analysis:
www.wsdot.wa.gov/design/policy/roadsidesafety.htm

1600.06(1)(c) Centerline Rumble Strips

Centerline rumble strips are placed on the centerline of undivided highways to alert drivers that they are entering the opposing lane. They are applied as a countermeasure for crossover collisions. Centerline rumble strips are installed with no differentiation between passing permitted and no passing areas. Refresh pavement markings when removed by centerline rumble strips.

A March 2011 WSDOT study found that centerline rumble strips were highly effective across the state highway network, and most effective on roadways where: the AADT is less than 8,000, the combined paved lane and shoulder width is 12 to 17 feet, and the posted speed is 45 to 55 mph.

Centerline rumble strips are evaluated using a programmatic approach, starting with a preliminary review of each rural undivided highway as a potential installation site. The HQ Design Office conducts the preliminary review, evaluating cross-centerline crash history and pavement width. A list of sites is generated from this review and periodically updated and distributed to the regions for a more detailed analysis of each site. The presence of a particular site on the preliminary list does not imply that rumble strips must be installed.

The preliminary review conducted in the Design Office does not assess pavement structure; traffic volume and composition; type and volume of nonmotorized users; or proximity to roadside residents. Region project development staff are expected to evaluate these items, and to field-verify roadway widths and appropriate project limits. The final determination about the appropriateness of centerline rumble strips is the responsibility of region project development staff. Although these decisions are made in the region, it is important that they be evaluated in a consistent manner from region to region. Evaluate the following criteria in determining the appropriateness of centerline rumble strips.

1. Crash Experience

WSDOT has evaluated the effectiveness of centerline rumble strips on roadways with various lane and shoulder widths. For roadways with a combined lane and shoulder width of 15 feet or more, the benefits are substantial. These highways exhibited a 50% reduction in fatal and serious injury crashes, when looking at both cross-centerline and run-off-the-road-right (ROTRR) crashes. For roadways with 12 to 14 feet of combined lane and shoulder width, the benefits are more closely aligned with reductions in cross-centerline crashes. There are mixed results with ROTRR crashes on 12- to 14-foot-wide roadways, although when combined with the cross-centerline crashes, the net result indicates an overall 25% reduction in fatal and serious injury crashes. Further evaluation of apparent run-off-the-road vehicles that cross the centerline and end on the opposing roadside may be of value.

Review the collision history to determine the frequency of collisions with human factors contributing circumstances such as inattention, apparently fatigued, apparently asleep, over the centerline, or on the wrong side of the road. These types of cross-centerline crashes are considered to be correctable with centerline rumble strips.

Montana (2012):

- Where centerline rumble strips will be used on narrow roads, it should be noted that drivers tend to shy away from centerline rumble strips which could adversely affect vehicle/bicycle interaction. The use of a modified lateral width rumble strip should be evaluated

In all cases the benefits to bicyclists must be weighed against the potential for roadway departure incidents, since greater offsets reduce the effectiveness of rumble strips

Centerline Rumble Strips (CLRS)

Centerline rumble strips function the same as shoulder rumble strips, but target head-on and opposite direction sideswipe crashes rather than run-off-the-road crashes. Since centerline rumble strips are not faced with the same width limitations as shoulder rumble strips, they could conceivably be installed on every undivided two-way roadway. However, as centerline rumble strips can potentially adversely affect some driver behavior and involve greater maintenance concerns, the following guidance is provided to aid in the prioritization of their installation.

Centerline rumble strips will not be installed on roadways with ADT < 750 unless there is a history of crossover-related crashes. For all other routes the following elements should be evaluated in determining where centerline rumble strips will be installed. The basis for the determination should be documented in the Scope of Work Report

- Lane width – Since drivers will tend to shy away from the rumble strip, consider using reduced lateral width rumble strips on roadways with finished top widths less than 28 feet.

- Corridor vs. spot treatment – Since the location of lane departure crashes are typically random, it is recommended that centerline rumble strips be installed in corridors or long segments of highway.

- Design speed/ Speed limit – Research has shown that centerline rumble strips provide little benefit where speeds are less than 45 mph.

- Horizontal alignment – Although research indicates that centerline rumble strips provide the same benefit on tangents as they do on horizontal curves, the centerline rumble strips can have a traffic calming effect on roads with a substantial amount of horizontal curvature.

- Motorcycles – Although research indicates that centerline rumble strips present no measurable risk to motorcyclists, the studies have been rather limited and motorcyclists tend to consider them a nuisance.

Rumble Strips Guidance, Montana Department of Transportation (2012)

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roadway characteristics and prevailing land use, not necessarily a location inside an urban area boundary.

1. Selection by roadway type.

   a. Rural two-lane and multi-lane undivided roads.

      1) Segment with posted speed limits ≥ 50 mph. Centerline and edge line rumble stripes should be specified.

      2) Segment with posted speed limits < 50 mph. Centerline or edge line rumble stripes generally should not be specified, although special circumstances may justify their use, e.g., the presence of significant history of run-off-road, opposite direction side swipe, and head-on crashes.

   b. Rural multi-lane divided non-freeway.

      1) Segment with posted speed limits ≥ 50 mph. Centerline rumble stripes are not applicable. Edge line rumble stripes may be specified on the inside or outside shoulders, or on both sides. Among other factors in this design decision is past traffic safety performance.

      2) Segment with posted speed limits < 50 mph. Centerline rumble stripes are not applicable. Edge line rumble stripes generally should not be used, although special circumstances may justify their use.

   c. Rural freeway (interstate or non-interstate). Edge line rumble stripes generally should not be specified. Centerline rumble stripes are not applicable.

2. Design elements that preclude rumble stripes. Should the combination of center and edge line rumble stripes not be viable the designer should specify the use of only centerline rumble stripes. When centerline rumble stripes alone are not viable then edge line rumble stripes alone should be specified.

   a. Centerline and edge line rumble stripes in combination. Centerline and edge line rumble stripes should not be used in combination when one or more of the following design elements are present:

      1) the posted speed limit is less than 50 mph;

2) the design lane width is less than 11 ft;

3) the design paved shoulder width is less than 2 ft;

4) urban segment or a segment with a two-way left-turn lane;

5) chip seal (seal coat) surface within 1 year of surface application;

6) pavement surface treatment with an active warranty, e.g., Microsurface or ultrathin bonded wearing course (UBWC) within 3 years of construction;

7) rural segment with significant bicycle traffic and paved shoulder width is less than 4 ft; or

8) rural segment where horse-drawn vehicles are known to regularly use the shoulder and shoulder width is less than 10 ft.

b. Centerline rumble stripes only. Centerline rumble stripes alone are not normally used when one or more of the following design elements are present:

1) the posted speed limit is less than 50 mph;

2) the design lane width is less than 10 ft;

3) urban segment or a segment with a two-way left-turn lane;

4) chip seal (seal coat) surface within 1 year of surface application; or

5) pavement surface treatment with an active warranty, e.g. Microsurface or UBWC within 3 years of construction.

c. Edge line rumble stripes only. Edge line rumble stripes alone are not normally used when one or more of the following design elements are present:

1) the posted speed limit is less than 50 mph;

2) the design paved shoulder width is less than 2 ft;

3) urban segment;

Alaska (2009):

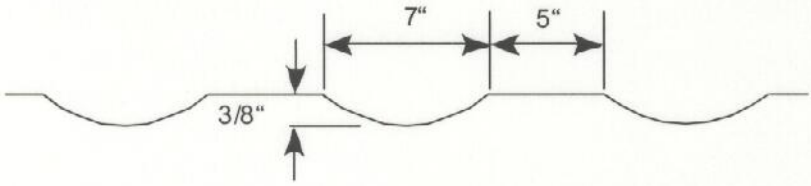
Centerline Rumble Strips

Centerline rumbles may be installed on the centerline of undivided rural highways where there is a history of severe head-on/crossover crashes.

1. Installation Method: Install centerline rumble strips by milling.

2. Lateral Width: 12"

3. Longitudinal Milling Pattern: 7" groove, 3/8" deep, 5" flat.



4. Continuity: Where installed, centerline rumble strips should continue through both passing and no-passing zones.

5. Medians: Centerline rumbles may be installed in painted medians where a double yellow stripe separates opposing traffic.

6. Breaks: Centerline rumbles should be broken for all public streets and commercial approaches with 500 or more vehicles per day. Centerline rumbles should not be broken for private driveways, public streets, or commercial approaches with 500 or fewer vehicles per day

7. Exclusions: Do not install centerline rumble strips:
   a. bordering two-way left turn lanes,
   b. in urban areas,
   c. on roads with speed limits of 45 MPH or less,
   d. where combined lane and shoulder width in each direction is less than 14 feet,
   e. on pavements or surface treatments less than 2" thick,
   f. on bridge decks, bridge approach slabs, or concrete weigh-in-motion slabs,
   g. on roads that are programmed for overlay, rehabilitation, or reconstruction in less than three years.

8. Striping Replacement: Replace existing pavement markings where removed by centerline rumble installation.

Memorandum on Rumble Strips, Alaska Department of Transportation, 2009

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February 5, 2008
Revised September 9, 2013

NEW HAMPSHIRE
DEPARTMENT OF TRANSPORTATION

RUMBLE STRIP INSTALLATION GUIDELINES

The following are guidelines established for the use of milled rumble strips/stripes along New Hampshire roadways. Run off the road (ROR) crashes and head-on collisions due to fatigued, inattentive, or otherwise impaired drivers are a major contributor to New Hampshire's fatal and injury crashes. Rumble strips are placed as a countermeasure for driver error, rather than roadway deficiencies. Milled shoulder rumble strips/stripes and milled centerline rumble stripes (CRS) provide low-cost highly effective safety solutions that alert drivers when they drift from their travel lane, providing an opportunity for the driver to maneuver their vehicle back into the proper travel way. Another benefit of shoulder rumble strips/stripes is that they alert pedestrians and bicyclists of possible danger from errant vehicles that leave the travel way and enter the shoulder area. Because of their proven significant safety benefits at a relatively low cost (NCHRP Synthesis Report 641), a project specific cost to benefit analysis will not be required for these countermeasures to be Highway Safety Improvement Program funded.

General Design Guidelines for the Installation of Milled Rumble Strips/Stripes on New Hampshire Highways

Milled Shoulder Rumble Strips (SRS) will be installed on all Interstate Highways, and similarly Limited Access divided highways to reduce the number of run off the road crashes. Milled SRS should also be considered on roadway segments and corridors with the following characteristics:

1. Posted speed limit of 40 MPH or greater.
2. Minimum of 6' wide shoulders.

Rumble "Stripes" will generally not be installed on Interstate or similar Limited Access highways, but may be used on median side shoulders or other facility types where determined advantageous by the Department.

- Milled Centerline Rumble Strips/Stripes (CRS/S) will be considered on an individual project-by-project basis to reduce the number of crossing the centerline road crashes. Milled CRS/S should be considered on roadway segments and corridors with the following characteristics:

  1. Posted speed limit of 40 MPH or greater.
  2. Pavement width of 28'or greater
  3. Existing pavement in good condition and minimum wearing course depth of 1 ¼ inches (so that the installation of CRS will not accelerate pavement delamination and deterioration of the centerline pavement joint).

A public informational meeting will be held within the affected communities.

Minnesota: (2014):

Centerline Rumble Stripes
Centerline rumble stripes shall be placed on all rural highway construction and maintenance projects where pavement is constructed, reconstructed, or overlaid and where the posted speed limit is 55 mph or greater. This applies to both multi-lane undivided and two-lane undivided highways.

Exceptions
Based on engineering judgment, the District Traffic Engineer may gap centerline rumble stripes near residential homes, particularly in passing zone areas and curvilinear alignments. Appropriate gaps for driveway entrances can be found on Figure 10. If the gapping causes centerline rumble installation to be less than 1/8 mile (660 feet), the centerline rumble may be omitted for this segment.

Based on engineering judgment, the District Traffic Engineer may gap shoulder rumbles on the inside of a horizontal curve with nearby residences if a Safety Edge or wider shoulder is installed.

On rural highways where the lane width is 11 feet or less, or the paved shoulder width is 2 feet or less, shoulder rumble strips or edgeline rumble stripes may be placed on both sides of the road in lieu of a centerline rumble stripe.

In all cases, edgeline rumble stripes may be substituted for shoulder rumble strips and still meet the standards within this Technical Memorandum.

Shoulder rumble strips are not required in areas where there is a bus shoulder. However, it is assumed that bus shoulders will usually be installed in areas that are NOT defined as rural trunk highways in the Access Management Guide.

Shoulder rumble strips are not required in locations with guardrail or cable barrier implemented.

Even in cases where shoulder rumble strips are not required due to a narrow paved shoulder width, their installation, or the installation of an edgeline rumble stripe, is encouraged for proactive safety reasons.

Districts shall consider placing centerline rumble stripes and shoulder rumble strips on in-place shoulders at locations on which no construction, reconstruction, or overlay projects are scheduled in the near future as a systematic proactive safety measure. The District Materials Engineer should make recommendations regarding the structural adequacy of the in-place roadway and/or shoulder to receive rumble strips.

Width of rumble strips
Rumble strips are usually 12” in width. The width of the rumble strip can be reduced to within the range of 8”-12” when paved roadway width is limited. A 16” rumble is required on freeway segments. Any design of rumble strips that are smaller than 8” in width, or that deviate from the rumble cycle of 12” called for in Figures 4-8 shall require approval by the State Traffic Engineer.

The standard width of centerline rumble stripes is 16” of total rumble. The 16” may be continuous or split into two 8” rumbles which straddle the centerline pavement joint (each rumble typically 2” away from the joint, creating a 4” gap between rumbles). Any design of centerline rumble stripes that are smaller than 16” of total rumble width or that deviate from the corrugation cycle detailed in Figures 6 through 8 shall require approval by the State Traffic Engineer.

All rumble strips shall meet any and all specifications for Milled Rumble Strips in the MnDOT Standard Specifications for Construction or Special Provisions. This includes a requirement that rumble strips be milled in bituminous pavement, and not rolled.

Special Consideration for Narrow Shoulders

On roadways with narrow shoulders (less than 5 feet, 4 inches) where a crash analysis shows a high incidence of roadway departure crashes, a type of shoulder rumble strip called shoulder rumble stripes should be considered.

If installed, shoulder rumble stripes should be installed on rural highways where the shoulder width is less than 5 feet, 4 inches and the posted speeds are greater than 45 mph. Shown as Rumble Stripes on Figure 1, these rumble stripes should be placed at the edge of the travel lane and should be 6 inches wide and 3/8 inch deep. Longitudinally, the grooves should be 12 inches on center, with a 5-inch groove and 7 inches between grooves, and the 4-inch wide edge line installed on top of the grooves. A typical 48-foot rumble strip and 12-foot gap pattern should be used when considering the use of shoulder rumble stripes. The minimum lane width shall be 10 feet.

Consideration for trucks should be given when installing shoulder rumble stripes. The out-to-out track width of a WB-67 (semi with a 53-foot trailer) design vehicle is 10 feet at curves with a radius of 800 feet and 11 feet at curves with a radius of 500 feet.

Centerline Rumble Strips

Centerline rumble strips (CLRS) should be considered on selected rural highways where a crash analysis and engineering study reveals a high incidence of roadway departure crashes. As shown on Figure 1, CLRS should be 16 inches wide and 3/8 inch deep. Longitudinally, the grooves should be 12 inches on center, with a 5-inch groove and 7 inches between grooves, and the "double yellow" centerline installed on top of the grooves.

CLRS should be installed on bidirectional rural highways with a posted speed greater than 45 mph where the lane plus shoulder width beyond the rumble strip will be at least 14 feet. The minimum lane width shall be 10 feet. CLRS shall not be installed in passing zones. When determining locations for CLRS, consideration should be given to all road users, access points along the highway and residential areas.

Implementation

Rumble Strips should be included as individual construction projects are let to contract on highways meeting the criteria listed previously. In addition, statewide or regionwide rumble strip or rumble stripe projects on highways meeting the criteria listed previously may be developed and let to contract as funds become available.

AHTD reserves the right to modify the design and application of rumble strips or rumble stripes to the extent AHTD considers appropriate for the safety and benefit of all users.

**Permanent Pavement Markings, Raised Pavement Markers,
Rumble Strip and Rumble Stripe Guidelines Notes**

1. The contractor may elect to use either thermoplastic or preformed plastic for specialty striping items. These items include stop lines, cross walks, arrows, words, channelization, and other specialty striping items except lines.

2. The following footnote shall be added to all Specialty Striping Items: **"The contractor may elect to substitute Preformed Plastic for Thermoplastic. Preformed Plastic shall be paid for at the same unit price as bid for Thermoplastic."**

3. Specialty striping items may be either paint or thermoplastic.

4. Snowplowable Raised Pavement Markers (SRPMs) shall conform to this guidance:

    a. SPRMs located along centerlines of 2 direction roadways (Yellow Stripe) shall be paid for under Item No. 716-01.21 "Bi-directional snowplowable raised pavement markers (reflector on both sides), per each. Lenses shall be yellow
    b. SRPMs on lane lines between lanes of the same travel (Broken White Stripes) direction on undivided roadways shall be paid under Item No. 716-01.22, Snwplwble Pvmt Mrkrs (Mono-Dir) (1 Color), per each. Lenses shall be clear or white
    c. SRPMs on lane lines between lanes of the same travel (Broken White Stripes) direction on divided roadways shall be paid for under Item No. 716-01.23, Snwplwble Pvmt Mrkrs (Bi-Dir) (2 Color), Each. Lenses shall be clear of white on the upstream side (facing traffic), lenses shall be red facing downstream side (facing wrong-way traffic).
    d. Refer to T-M-series standard drawings for details. Three lane and multilane roads with 2-way traffic will normally require both mono-directional and bi-directional snowplowable raised pavement markers. Two lane roads will normally require bi-directional snowplowable raised pavement markers.

5. Rumble strips are not required on ramps.

6. Centerline Rumble Stripes may only be used if justified by crash history and if the road meets the following conditions:

    a. Design Speed of 45 mph or greater
    b. ADT of 1500 or greater
    c. Lane width of 12 feet or greater
    d. Undivided Section
    e. No passing or one way passing zone

7. For concrete shoulders, the rumble strip is to be placed in accordance with standard drawings RP-CS-1 or RP-CS-2. Item No. 501-03.10, Concrete Shoulder Rumble Strips, L.F. The length of scoring shall be measured as the actual length of pavement scored.

8. Rumble Strip for Interstate or Freeway, See STD DWG T-M-15
   Rumble Strip for Non-access controlled route, See STD DWG T-M-15A
   Edgeline Rumble Stripe, See STD DWG T-M-16
   Centerline Ruble Stripe, See STD DWG T-M-16A

9. See 4-411.03 and 4-411.04 for additional guidance regarding rumble strip and rumble stripe placement.

Table 4-3 (Sheet 2 of 2)

Instructional Bulletin No. 14-04, Tennesse Department of Transportation,2014

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Michigan(2012)

Table 1. Roadway Site Characteristics

RUMBLE STRIPS INSTALLED	HIGHWAY	LANE WIDTH (FT)	PAVED SHOULDER WIDTH (FT)	AVERAGE DAILY TRAFFIC (2009)	NUMBER OF DATA COLLECTION LOCATIONS	
CENTERLINE AND SHOULDER	M-19 - Site 1	12	6	5,500	Passing Zones	3
					Curves	2
	M-25	12	8	3,300	Passing Zones	2
	M-136 - Site 2	11	8	6,000	Passing Zones	1
	US-41 - Site 1	12	8	4,100	Passing Zones	1
					Curves	1
	US-41 - Site 2	12	8	4,500	Passing Zones	1
					Curves	1
CENTERLINE	M-19 - Site 2	11	3	5,300	Passing Zones	1
					Curves	3
	M-46	11	3	4,900	Passing Zones	2
	M-136 - Site 1	11	3	1,500	Passing Zones	3
					Curves	2
	M-93	12	5	2,900	Passing Zones	1
					Curves	2
	M-81	12	3	4,800	Passing Zones	3
					Curves	1

Note: Rumble strips were not present in the "Before" period at any of the locations.

Data Collection

Video data were collected at the study sites both before and after installation of the rumble strips. "Before" period data were collected between June 2010 and August 2010. Data were again collected at the same locations in November 2010 and/or May - June 2011 after, the rumble strips had been installed for a minimum of 30 days during normal weekdays. All data were collected during daylight hours under dry pavement conditions. Geometric data, including lane width, shoulder width, lateral offset of the rumble strips from the centerline and/or shoulder, and the rumble strip dimensions were measured at each field sites.

Elevated high definition video cameras were installed on existing roadside poles at each study site to stealthily record the behavior of vehicles traveling through the study roadway segments. Each camera was mounted on top of a lightweight aluminum pole that telescoped from 7 to 20 feet and securely strapped to a rigid roadside sign post or a utility post. Between four and ten hours of video were typically recorded at each location during the "Before" and "After" data collection periods.

California (2011):

Do not install milled shoulder rumble strips:

a) Between through or turning lanes at intersections.
b) On bridge decks, approach slabs, or concrete weigh in motion slabs; alternative proprietary raised profile rumble strips materials are available to apply for use in these areas.

Centerline Rumble Strips

Where:

Centerline rumble strips should be considered for installation on undivided highways as a measure to reduce cross centerline collisions.

Installation method:

Centerline rumble strips are ground into the pavement surface; engineering judgment should be used to evaluate the condition of the pavement prior to centerline rumble strip installation.

Alignment:

Where installed, centerline rumble strips should be installed continuously through passing and no passing zones as a pavement treatment below various pavement markings.

Centerline rumble strips may be installed in or below painted medians between lanes. Decisions regarding the width of the median should be made based upon the judgment of the traffic engineer recommending their installation. For medians 24 inches or greater in width, roadways are noted as divided per CVC section 21651; evaluation of the speed zone when considering a median installation is recommended.

Dimensions:

Lateral width is 6" - 12". Larger widths may be used to accommodate special circumstances at the direction and approval of the district traffic engineer (for example, to highlight areas within medians or buffers zones between lanes where traffic is not desired).

The recommended longitudinal milling pattern is 5" groove + or – 1", 5/16" depth + or – 1/16", and 1 foot center to center spacing + or – 2".

Layout Considerations:

Centerline rumble strips should be broken for all public street intersections and commercial driveways with approximately 500 or more vehicles per day.

Operational Considerations:

Bicyclists may have the need to cross over the centerline therefore the rumble strip depths mentioned above are recommended. Centerline rumble strip depths greater than recommended may be installed based upon engineering judgment and with the approval of the district traffic engineer.

Special Considerations:

Engineering judgment should be used when considering installation as follows:

a. Within suburban or urban areas or on roads with speed limits of 35 mph or less where noise may be a concern.
b. When pavement condition is deteriorated or exhibits cracking; pavement improvement may be needed to complete the treatment, consult the District Maintenance engineer if there are questions regarding pavement quality.

ADA Notice For individuals with sensory disabilities, this document is available in alternate formats. For information call (916) 653-3657 or TDD (916) 654-3880 or write Records and Forms Management, 1120 N Street, MS89, Sacramento, CA 95814.

New York (2011):

Selection Criteria

CARDs should be installed on any 1R or more complex projects meeting all of the following criteria:

- Median: There is no raised median, two-way left-turn lane (TWLTL) or median barrier. CARDs are appropriate for flush medians.
- Length: Total project quantity is 500 m (1,500') or more. Because of the cost of mobilizing the equipment to mill in the CARDs, projects that would result in the placement of less than 500 m (1,500') of CARDs may be exempted. Several locations can be combined into a single project to improve the efficiency and cost of the milling operation.
- Speed: The posted speed is 45 mph or greater. The likelihood of a severe injury or fatality increases dramatically in collisions of 80 km/h (50 mph) or greater.
- Volume: A current AADT of 2,000 vpd or more. The primary benefit of CARDs is to reduce the incidence of head-on and sideswipe collisions. As traffic volumes decrease, the likelihood of such collisions decreases, with or without the use of CARDs.
- Roadway Width: FHWA recommends that the combined with of the lane(s) and shoulder width in each direction should be at least 3.9 m (13'). Since State Highways have a minimum 2' paved shoulder in uncurbed sections and the maximum legal width of a vehicle is 8.5', a minimum lane width of 11' is recommended to avoid having vehicles riding on the shoulder, over the CARDs, or in adjacent lanes.
- Pavement: The pavement should be in good condition to avoid problems milling deteriorated pavement.

Installation of CARDs is encouraged as area-wide stand-alone projects on existing pavements meeting the criteria above.

Design

Tires running over rumble strips produce sound and vibration. To minimize noise and avoid incidental contact from vehicles operating within the travel lane or vehicles adjusting their position within the travel lane, CARDs should be placed under the centerline marking. This requires the width to be reduced from 450 mm (16") for MIRADs to 300 mm (12") for CARDs. Additionally, the spacing should be increased from 300 mm (12") to 600 mm (24") since CARDs will be placed much closer to the travel lane compared to MIRADs. It is theorized that the closer the rumble strip to the travel lane, the more acute the angle of impact would be during unintentional lane departures (i.e., drifting), allowing for the rumble strips to be spaced further apart and still have enough noise and

Centerline Rumlbe Strips on Secondary Highway: A Systematic Crash Analysis, New York State Department of Transportation,2011

Connecticut:

At the time of publishing of the NCHRP's Report 641, 29 States have installed centerline rumble strips, and since them numerous more States have installed centerline rumble strips, including New York and all of the New England States.

Connecticut Criteria for CLRS installation

Centerline rumble strips will be considered for installation at locations that meet the following criteria:

- ***Speed***
  The speed limit is 45 mph or greater.
- ***Traffic Volume***
  The average daily traffic on the road is at least 2,000 vehicles per day.
- ***Pavement***
  The pavement should be in good condition and has been overlaid in the last three years.
- ***Roadway Width***
  The location is to have a minimum of 13 feet of width from the centerline to the edge of pavement.
- ***Length***
  The length of the proposed centerline rumble strips segment should be at least one mile.

Additionally, centerline rumble strips will be discontinued at breaks in the centerline due to intersections with other roads or major driveways, passing zones, crosswalks or two-way left-turn lanes.

See the attached files for links to details on CLRS in Connecticut.

Connecticut Department of Transportation Webstite/ Accessed December 2014

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Kansas (2011):

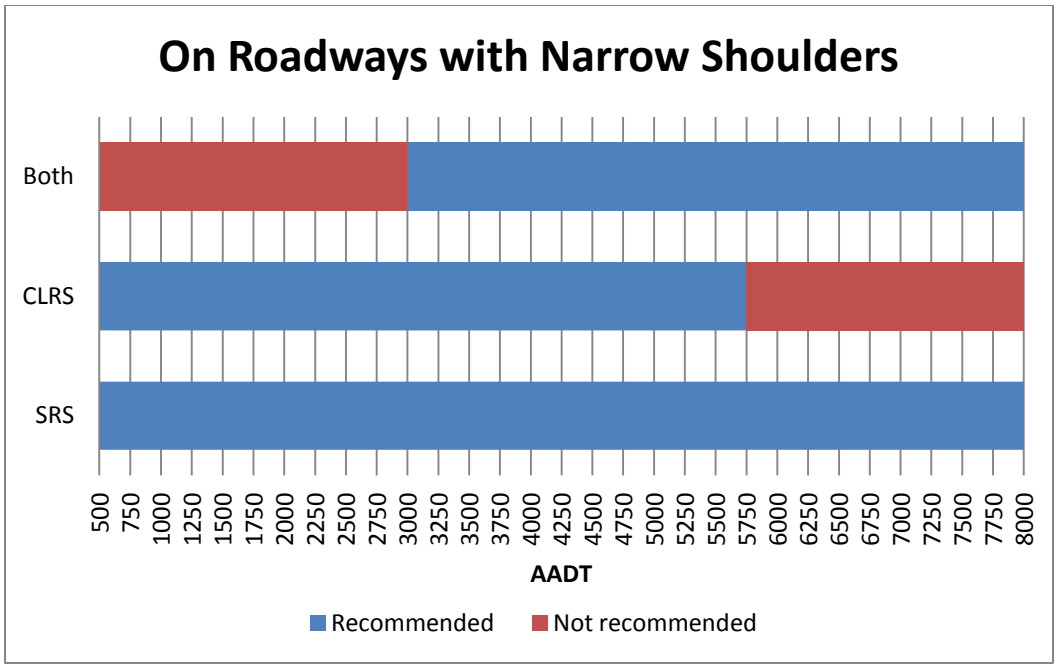

FIGURE 7.6
Recommendations for Highways with Narrow Shoulders

The economical recommendation based on total correctable crashes showed that for narrow shoulders, the highest B/C configuration was *SRS only*. For medium and large shoulders, the results were mixed. In these cases, for AADTs lower than 4,000 vehicles per day, the predominant highest B/C configuration was *CLRS only*. For AADTs greater than 4,000 vehicles per day, the *both* configuration resulted in the highest B/C.

Overall, this study recommends the installation of CLRS in rural, two-lane, undivided rural roads in Kansas, depending on AADT and shoulder width levels. Both patterns currently installed in Kansas (football-shaped and rectangular-shaped CLRS) have provided crash reductions, which have reflected in economic benefits for society. Shoulder width and traffic volume should be considered as crash predictors for enhancement of the benefits. General guidelines are summarized below for future better applications of CLRS.

rumble strip. Keeping the shoulders reasonably free from debris through periodic brooming and by the prompt removal of disabled vehicles (within the limits of Maryland law) will encourage bicyclists to ride to the right of the rumble strip.

B. CENTERLINE RUMBLE STRIPS

Centerline rumble strips should be installed along an undivided highway with a 40 mph or greater posted speed limit and 10 foot or greater lane widths in a generally rural area unless, based on engineering judgment, it has been determined that their installation would not improve safety.

Centerline rumble strips should NOT be installed:

- In the area of intersections with public roads. Centerline rumble strips should be stopped 25 to 50 feet (25 feet for lower speed roadways and up to 50 feet for higher speed roadways) in advance of the point of curvature of intersections or at the beginning of the taper for the left-turn lane.
- In areas with a high density of access points or in areas with short distances between access points.

Additional Guidance and Consideration

- Centerline rumble strips may be installed in passing zones; however, the noise impacts to residential areas nearby should be considered.
- Consideration must be given to bicycle travel and the potential impact of reducing the clear lane width where bicycles ride in the roadway.

C. Transverse rumble strips

Transverse rumble strips may be used to attract the driver's attention to unexpected conditions or to bring the driver's attention to other warning devices. Transverse rumble strips may be considered for the following conditions:

1. Approaches to Intersections (Signalized, Stop Controlled, Roundabouts)

Transverse rumble strips should be considered on the approaches to intersections where there is a demonstrated safety problem (e.g. high crash rate), adequate trial of other warning devices has failed to reduce the crash frequency, and any of the following conditions exist:

- Inadequate stopping sight distance or signal/sign visibility.
- Intersection is at an unexpected location.
- Intersection is located on a roadway on which motorists have not been required to stop for a long period of time or distance.

2. Approaches to Horizontal Curves

Transverse rumble strips should be considered on the approaches to horizontal curves where there is a demonstrated safety problem (e.g. high crash rate), adequate trial of other warning devices has failed to reduce the crash frequency, and any of the following conditions exist:

- A significant speed reduction from the posted speed limit is required to safely traverse the curve.
- Curve is located at an unexpected location.

3. Approaches to Reduced Speed Zones

Transverse rumble strips should be considered on the approaches to reduced speed zones where an engineering study finds that excessive speeding is a problem in a reduced speed zone and adequate trial of other regulatory devices has failed to reduce the occurrence of speeding. Factors that may indicate a need include:

- Posted speed reduction of 20 mph or greater.

Texas:

- CRSs should be installed along the delineated CL on undivided roadways without TWLTL.
- CRSs may be installed along the edgeline delineating pavement stripes for TWLTL. The TWLTL should have at least a 14-foot (4.3-meter) width from the outside edges of the solid edgelines, and the CRSs will be reduced to 12 ± 0.5 inches (305 ± 13 mm) in width for each edgeline. Alternatively, CRSs may be installed down the middle of a TWLTL.
- In areas where delineated left-turning bays are installed, the CRSs should follow the outside CL pavement marking to the direction of travel with the left-turn bay.
- All CRSs should be continuous and will be installed in both passing and no-passing zones (CRSs).
- Breaks in the CRSs will start at least 50 feet (15.2 m) and no more than 150 feet (45.7 m) prior to each approach for the following instances:
  - Bridges
  - Roadways with guardrails that do not provide at least 2 feet (0.6 m) of shoulder width.
  - Intersections
  - Driveways with high usage or large trucks
- CRSs should not be cut into joints; they should be placed to one side of the joint, or the particular individual rumble strip should be skipped.
- RPM and lane striping should be placed according to current TxDOT standards as addressed in the Texas Manual of Traffic Control Devices (TMUTCD) and TxDOT Standard Sheets.
  - When specifying RPM placement, the project engineer should use the standard specifications as depicted in TxDOT standard drawing PM(2)–00A, "Position Guidance Using Raised Pavement Markers" and should not use the supplemental standard PM(3)-00A.
  - The individual CRS closest to the placement of an individual RPM should be skipped, and the RPM should be placed equidistant from the two remaining adjacent CRSs.
  - Profile markings should not be used in conjunction with CRSs.
- CRSs should not be installed in areas with the following conditions unless approved by the Traffic Operations Division:
  - Roadways with less than 12-foot (3.7-meter) wide lanes.
  - Roadways with less than 2-foot (0.6-meter) wide paved shoulders.
  - Roadways with less than 2.5 inches (64 mm) in slab thickness for asphalt concrete.
  - Roadways with less than 2.5 inches (64 mm) in slab thickness between the top of the roadway surface to the top of the rebar or structural reinforcement in Portland cement concrete.
  - Roadways with significant deterioration and/or raveling ("significant" will be defined by the project engineer with regards to current TxDOT engineering practices).
  - Current construction projects are not complete and may conflict (i.e., an overlay or widening are scheduled or under construction).

"Effectiveness of Rumble Strips on Texas Highways: First Year Report" Report No. FHWA/TX-05/0-4472-1, Texas Department of Transportation, 2003

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Nebraska (2014):

Installation should follow the Special Plans Section of the Nebraska Department of Roads Standard/Special Plans Book. The appropriate pay item is "Rumble Strip, Asphalt" and/or "Rumble Strip, Concrete". Rumble stripes will be paid for as rumble strips.

Average Daily Traffic (ADT): The total volume of traffic in a time period greater than one day and less than one year (measured in whole days), divided by the number of days in the chosen time period. The result is given in Vehicles per Day (VPD).

Future

When rumble strips, edge line rumble stripes or centerline rumble strips are placed they will be perpetuated on subsequent projects and not be obliterated without their function being replaced with a similarly effective mitigation measure for ROR departures (ex. lighting). Since the installation will substantially modify the ROR crash history, use of the warrants to justify continued use of the rumble stripes would be inaccurate. In the event that department maintenance operations or activities obliterate the rumble strips/stripes, they are not required to be reinstalled until the next resurfacing project. Rumble strips/stripes may be restored earlier if directed by the District Engineer.

Shoulder Rumble Strips

After reviewing the crash data and research literature, the NDOR has determined the following to be guiding principles for the installation of shoulder rumble strips on the state highway system.

- Shoulder rumble strips will be constructed on the shoulders, including the median shoulders, for all Interstate and expressway projects (new construction, reconstruction, and 3R).
- Shoulder rumble strips should be constructed on 6 foot wide or wider surfaced shoulders for all new construction and reconstruction projects on rural high-speed two-way two-lane highways.
- Shoulder rumble strips should be constructed on 3R projects over one-half mile in length on rural high-speed highways with continuous surfaced shoulder widths of 6 feet or greater.
- Existing rumble strips will be perpetuated on 3R projects over one-half mile in length. When project lengths are less than one-half mile, the rumble strips may be added to another project in the area to reduce mobilization fees.
- Projects with surfaced shoulders with curb and flume will be reviewed for inclusion of milled in rumble strips by Roadway Design.

Shoulder rumble strips may be placed at the direction of the Traffic Engineer or designee to address other traffic operations issues beyond those presented here.

Sent to: NDOR Roadway Design, NDOR "Distribution B", and selected consultants.

Policy for the Installation of Rumble Strips and Stripes, Nebraska Department of Roads, 2014

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Edge Line Rumble Stripes

After reviewing the crash data and research literature, the NDOR has determined the following to be guiding principles for the installation of rumble stripes on the state highway system.

- Roadway type – Rural two-lane undivided with two way traffic.
- Lane width –12 feet with 2 feet integral shoulders for a 28 feet minimum total top width; Edge Line Rumble Stripes may be installed on shoulders up to 6 feet in width when recommended by Traffic.
- Pavement section with a recommended minimum overlay thickness of 2.5 inches of pavement and the surface in good condition.
- ADT in excess of 500 VPD.
- On curves with a ROR crash history.
- Crash history evaluation period of at least three years.
- Posted speed limit of 50 mph or greater.

Edge line rumble stripes may be placed at the direction of the Traffic Engineer or designee to address other traffic operations issues beyond those presented here.

Centerline Rumble Strips

After reviewing the crash data and research literature, the NDOR has determined the following to be guiding principles for the installation of centerline rumble strips on the state highway system.

- Roadway type – Rural two-lane undivided with two way traffic.
- Lane width – no less than 11 ft.; the lane width will be 12 ft. minimum where edgeline rumble stripes are present.
- Pavement section with a recommended minimum overlay thickness of 2.5 in. of pavement and the surface in good condition.
- ADT in excess of 1,500 VPD.
- Posted speed limit of 50 mph or greater.
- Evaluation period of at least three years and minimum length of segment of three miles.
- Cross lane departure and opposite direction sideswipe crashes greater than 0.4 crashes per mile per year evaluated for a minimum three mile segment for a minimum of three years where the combination of cross lane departure and opposite direction sideswipe crashes exceeds 1.0 crash per year per hundred million vehicle miles traveled.
- Segments may be added for continuity when the gap between highway segments with centerline rumble strips is less than 5 miles in length.
- Highway segments in excess of 10 miles in length that warrant the installation of centerline rumble strips under the preceding warrants will be reviewed to determine if the entire segment warrants the installation of centerline rumble strips. Gaps in excess of 5 miles in a segment that exhibit no cross lane departure and opposite direction sideswipe crashes may be omitted from the roadway to receive centerline rumble strips.

Sent to: NDOR Roadway Design, NDOR "Distribution B", and selected consultants.

tive on these other roadway types. Rather, it should be understood that the safety effects are simply unknown at this time. The safety effects have not be quantified at this time due to limited mileage of centerline rumble strip installations along these respective roadway types. Also, limited mileage of dual applications of rumble strips (i.e., centerline and shoulder rumble strips installed on the same road section) along rural two-lane roads prohibited formal evaluation of the safety effectiveness of this treatment along this respective roadway type; however, because the safety effect of this treatment is unknown and not quantified does not imply that the treatment is ineffective.

Finally, concerns have been expressed about the poten-tial of motorcyclists losing control of their motorcycles when they encounter centerline rumble strips. Based upon a recent study, conclusive evidence exists to show that centerline rumble strips add no measurable risk to motor-cyclists. Therefore, there is no need to consider potential adverse effects for motorcyclists when developing a cen-terline rumble strip policy. Similarly, there is no need to prohibit the use of centerline rumble strips on roadways with significant motorcycle traffic.

Type of Rumble Strips to Use

Nearly all transportation agencies in North America that install centerline rumble strips use milled rumble strips. As indicated above for shoulder rumble strips, the primary advantages of milled rumble strips over other types is that they can be installed at any time on new or existing pavements.

Dimensions of Centerline Rumble Strips

The general principles of the related discussion above for shoulder rumble strips hold true for determining the dimensions of centerline rumble strips. Regarding the recommended design threshold values for centerline rumble strips, it is recommended that centerline rumble strip patterns be designed to generate approximately 10 to 15 dBA above the ambient in-vehicle sound level. Due to the placement of the rumble strips in the center of the roadway, bicyclists should very rarely encounter the rumble strips themselves, so bicyclists rarely need to be considered in design dimensions of centerline rumble strips. On the other extreme, crash data presented in Section 2, Crashes and Heavy Vehicles, suggest that heavy vehicles should potentially be considered in the design of centerline rumble strips. Designing centerline rumble strips to generate approximately 10 to 15 dBA above the ambient in-vehicle sound level should be more than sufficient to alert drivers of heavy vehicles, based upon the results of the safety evaluation of shoulder rumble strips.

The noise prediction models in Tables 82 and 83 are applicable for designing centerline rumble strips. The following are the most common dimensions of milled centerline rumble strips used throughout North America:

- Length: 12 or 16 in. (305 to 406 mm);
- Width: 7 in. (178 mm);
- Depth: 0.5 in. (13 mm); and
- Spacing: 12 in. (305 mm).

Based upon the noise prediction models, this pattern generates a sufficient amount of noise in the upper range of the recommended design thresholds.

Near residential or urban areas, consideration should be given to designing centerline rumble strip patterns that generate between 6 to 12 dBA above the ambient in-vehicle sound level to minimize the impacts on nearby residents.

Placement of Centerline Rumble Strips Relative to the Centerline Pavement Markings

The placement of centerline rumble strips can be within the pavement markings, extend into the travel lane, or on either side of the centerline pavement markings. The most common type of application is to install centerline rumble strips that protrude into the travel lane, followed by centerline rumble strips that are within the limits of the painted centerline pavement marking. Only a few transportation agencies currently install centerline rumble strips on either side of the centerline pavement marking. It should be noted that the safety estimates provided above for centerline rumble strips do not directly consider the placement of the rumble strips relative to the centerline pavement markings.

The discussion above for shoulder rumble strips related to concerns over the visibility and retroreflectivity of pavement markings when rumble strips are installed on the edgeline (i.e., edgeline rumble strips) also applies to centerline rumble strips. In summary, concerns over the visibility and retroreflectivity of pavement markings should not prohibit the use of centerline rumble strips.

Features or Areas That Might Necessitate an Interruption in the Centerline Rumble Strip Pattern

Within a centerline rumble strip policy, consideration should be given to specific features or areas where the rumble strip pattern should be discontinued or interrupted to

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REFERENCES

HIGHWAY SAFETY ENGINEER

SOUTH CAROLINA PROFESSIONAL ENGINEER
NO. 19854
JOEY D. RIDDLE

SIGNATURE

12/16/14
DATE

#	DATE	CHK	DESCRIPTION
6			
5			
4			
3			
2			
1	16-DEC-14	JDR	REVISED DIMENSIONS AND NOTES
0	23-AUG-12	GEM	REVISED "X" AND "Y" DIMENSIONS

SCDOT

SOUTH CAROLINA DEPARTMENT OF TRANSPORTATION
DESIGN STANDARDS OFFICE
955 PARK STREET
ROOM 405
COLUMBIA, SC 29201

STANDARD DRAWING

STANDARD PAVEMENT MARKINGS
RUMBLE STRIPES

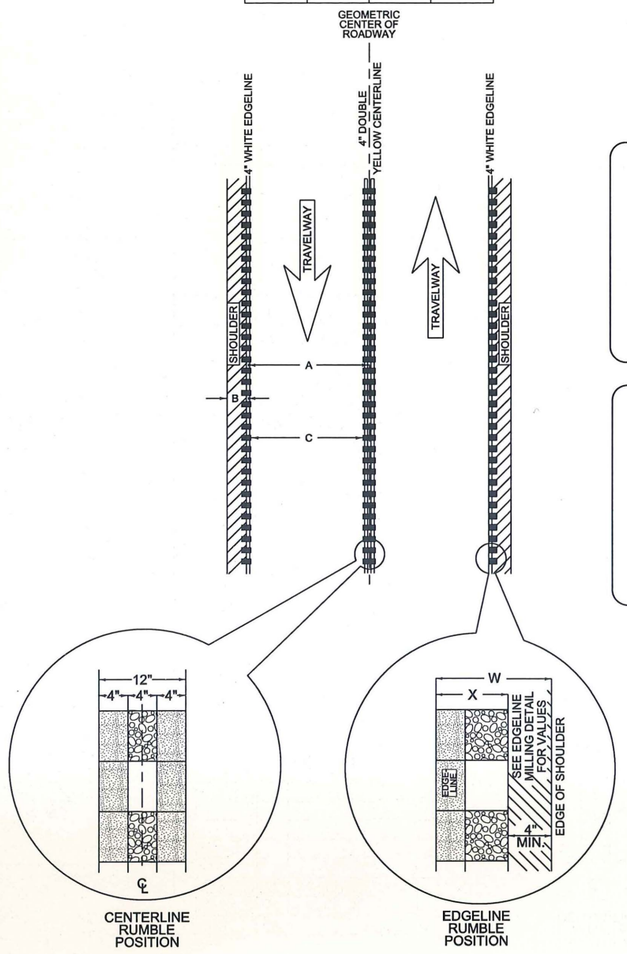
633-105-00

EFFECTIVE LETTING DATE | FEBRUARY 2015

THIS DRAWING IS NOT TO SCALE

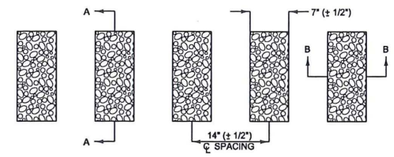
RUMBLE STRIP INSTALLATION LANE DIMENSIONS

ROADWAY WIDTH	A	B	C
28'	12'	2'	11'
26'	11'	2'	10'

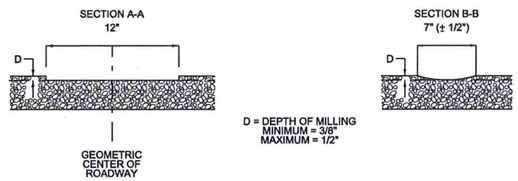


STANDARD PAVEMENT MARKINGS
RUMBLE STRIPES

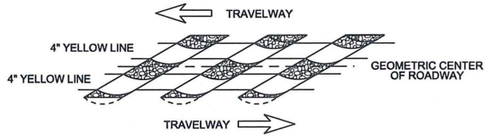
MILLED IN RUMBLE STRIP DETAIL



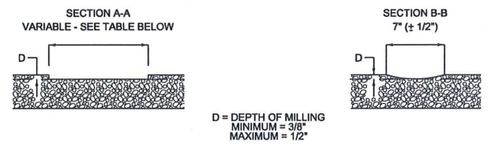
CENTERLINE MILLING DETAIL



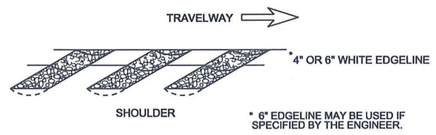
ISOMETRIC VIEW - CENTERLINE



EDGELINE MILLING DETAIL



ISOMETRIC VIEW - EDGELINE



NOTES:

1.) RUMBLE STRIPE SHOULD NOT BE MILLED INTO CONCRETE BRIDGE DECKS, APPROACH SLABS OR CURB AND GUTTER SECTIONS.

2.) RUMBLE STRIPE MAY BE MILLED INTO NEW OR EXISTING SURFACES. FOR EXISTING PAVEMENT, THE SURFACE SHOULD BE IN SUFFICIENTLY GOOD CONDITION TO PREVENT RAVELING OR DETERIORATION.

3.) A 4" UNDISTURBED PAVEMENT AREA SHOULD BE MAINTAINED FROM THE RUMBLE STRIPE TO THE OUTSIDE EDGE OF PAVEMENT.

4.) ON NON FULLY CONTROLLED HIGHWAYS, FREEWAYS OR INTERSTATE HIGHWAYS, A SKIP PATTERN SHOULD BE INSTALLED ON A 60' CYCLE (48' OF RUMBLE STRIPE, 12' GAP) WHERE THE PAVED SHOULDER WIDTH IS 1' OR GREATER.
-SEE ILLUSTRATION BELOW-

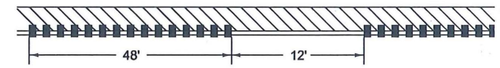
RUMBLE STRIPE DIMENSIONS

W(feet)	X(inches)
0' - 1'	4"
> 1' - < 5'	8"
≥ 5'	12"

W = PAVED SHOULDER FROM EDGELINE TO EDGE OF PAVEMENT (FEET)

X = WIDTH OF MILLED IN RUMBLE STRIP (INCHES)

SKIP PATTERN



CONTINUOUS PATTERN

INSTALLATION LIMITS FOR RUMBLE STRIPS AT INTERSECTIONS