Research Report
KTC-10-01/SPR 330-07-4I

KENTUCKY TRANSPORTATION CENTER

EVALUATION OF RUMBLE STRIPES

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EVAUATION OF RUMBLE STRIPES

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EXECUTIVE SUMMARY

Lane departure has been shown to be a major cause of serious traffic crashes. Installing a rumble strip on the shoulders of two lane roads provide drivers with an audible warning that they are leaving their lane of travel. Painting the edge line on the rumble strip has the possible benefit of providing more wet, nighttime delineation through the portion of the edge line painted on the sloped portion of the groove. The objectives of this study were to: a) monitor the initial installations of rumble stripes and b) evaluate the results of rumble stripe installations.

Ten rural, two-lane road locations were selected by the Kentucky Transportation Cabinet across the state for the initial installations. A total of 67.7 miles were included with the installations completed in the summer of 2009. The locations were selected after a review of crash records.

The rumble strip had a width of 12 inches and a length of 7 to 7.5 inches. The depth was between ½ and 5/8 inch. The rumble strips were placed on 12 inch centers. The four-inch wide white edge line was placed in the leftmost edge of the rumble strip adjacent to the travel lane.

The total pavement width (including the width of the paved shoulder) varied at the locations from a minimum of 22 feet to a maximum of 27 feet. In some instances the rumble strip was placed at the edge of the pavement while there was pavement outside the rumble strip at other locations. There was a problem encountered at only one of the ten locations. The issue related to a narrow lane width which resulted from placing the rumble strip with 18 inches of pavement outside the rumble strip. There were positive comments at all the other locations.

The crash data show that the most common type of crash before the installations was a single vehicle type of crash. This is the type of crash that shoulder rumble stripes are designed to reduce. There was a very small percentage of opposite direction type of crash.

The results of the current evaluation support additional installations of rumble stripes. The crash history at the original installations will be monitored. Recommendations relating to the installation procedure were made to consider for future rumble stripe installations.

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- Tracy Lovell
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The cooperation of the various resident engineers and inspectors were very helpful in organizing inspections of the installations. Also, their input into the evaluation of the installation process was valuable.

1.0 BACKGROUND

Lane departure has been shown to be a major cause of serious traffic crashes. This type of crash is a major problem on rural, two-lane roads. Efforts to reduce this type of crash on the existing roadway system have included pavement markings, traffic signs, and rumble strips. Typical pavement markings include centerline, edge lines, and raised pavement markers. Traffic signs include advance curve warning signs, advisory speed signs, and chevrons. Rumble strips have been placed on the shoulder (outside the edge line) and less frequently on the centerline.

A relatively new method of providing delineation of the edge line is a rumble stripe. This involves placement of the edge line on a rumble strip. The 2009 Manual on Traffic Control Devices (MUTCD) provides examples of longitudinal rumble strip markings which include rumble stripes. The examples include: edge line not on rumble strip, edge line on rumble strip, and center line on rumble strip. The MUTCD states that the edge line may be located alongside or on the rumble strip.

Installing a rumble strip on the shoulders of two lane roads provide drivers with an audible warning that their vehicle is leaving their lane of travel. Painting the edge line on the rumble strip has the possible benefit of providing increased wet, nighttime delineation on the portion of the edge line painted on the sloped portion of the groove.

The two objectives of this study were to:

1) monitor the initial installations of rumble stripes in Kentucky and
2) evaluate the results of the rumble stripe installations.

1.0 PROCEDURE

2.1 Selection of Locations

Locations were selected by the Kentucky Transportation Cabinet (KTC) so that they would be installed across the state. The original projects were let in March and April of 2009. A total of 67.7 miles were included in 10 projects. Projects were included in 10 of the 12 KTC highway districts.

The locations were selected after a review of crash records. All the locations were on rural, two-lane roads.

The installations were made in the summer months of 2009. All of the projects involved resurfacing the road, placement of the rumble strips, and striping the centerline and edge lines.

Following is a list of the locations of these projects.

County	Route	Milepoint Range	Length
Ballard	US 51	0.137-3.233; 4.88-7.33	5.546
Allen	KY 100	0-12.642	12.642
Nelson	US 62	17.38-24.969	7.589
Henry	US 421	15.087-21.475	6.388
Gallatin	US 42	9.6-15.173	5.573
Garrard	KY 39	0-5.325	5.325
Lewis	KY 59	0-10.959	10.959
Magoffin	KY 7	0-3.651	3.651
Leslie	KY 699	3.153-8.173; 13.573-15.993	9.44
Letcher	KY 7	0-2.6	2.6

2.2 Design of Rumble Stripe

A special note for rumble stripes was included in the project plans. It was noted that they were experimental. It was also noted that the pavement width (driving surface) should remain constant throughout the project in the two-lane sections. Any additional pavement width should be placed in the shoulder. Exceptions could be made due to curve widening or instances deemed necessary by the engineer.

The following chart was provided to provide guidance to the resident engineers. In all instances, the paved shoulder width was listed as variable. The pavement width was defined as the driving surface and did not include shoulders. The rumble stripes decreased this width by two feet. For example, if there was a total pavement width of 20 feet this would consist of two nine-foot lanes with two one-foot rumble stripes.

Pavement width (feet)	Lane Width (feet)
26	12
25	11.5
24	11
23	10.5
22	10
21	9.5
20	9
19	8.5
18	8
17	15*
16	14*
15	13*
14	12*

* For these widths there would be an edge line and no centerline.

The width at all of the locations was sufficient to allow the placement of a centerline and edge lines. The pavement widths varied.

The rumble strips were omitted through major intersections, at railroad crossings, through marked crosswalks, and on bridge decks or approach slabs. The rumble strips were installed through minor intersections and entrances and through mailbox turnouts. The rumble strips were to be placed in areas with a posted speed limit greater than 45 mph.

The rumble strips were milled into the asphalt. Each strip had a width of 12 inches and a length of 7 to 7.5 inches. The depth was between ½ and 5/8 inch. The rumble strips were placed on 12 inch centers. The four-inch wide edge line was to be placed in the leftmost edge of the rumble strip adjacent to the travel lane.

3.0 RESULTS

3.1 Installations

Contact was made with the resident engineers at all of the installation locations. Observations during the installation of the rumble strips were made at several locations. Discussions were held with the resident engineers, inspectors, and contractors to obtain their opinions and suggestions. Some of the locations were inspected before and/or during installation with all of the locations inspected after the rumble stripes were installed.

The total pavement width (including the width of the travel lanes and paved shoulder) varied at the locations from a minimum of 22 feet to a maximum of 27 feet. In some instances the rumble stripe was placed at the edge of the pavement while there was pavement outside the rumble stripe at other locations. The difference in the placement of the rumble strip relative to the edge of the pavement resulted in a pavement wedge outside the rumble strip at some locations with no wedge at others.

The decision about where to place the rumble strip relative to the edge of the pavement was generally related to the total pavement width. The rumble strip was placed at the edge of the pavement at locations with less total pavement width in order to provide the maximum width for the travel lanes. Another consideration was the amount of truck traffic with an effort made to provide the maximum lane width at locations with a large percentage of truck traffic.

The edge line was placed at the edge of the rumble strip nearest the travel lane at all but two locations. In Nelson County the stripe was placed in the middle of the rumble strip while the stripe was placed at the edge of the rumble strip furtherest from the travel lane in Allen County.

Following is a summary of the total width of the pavement, the width between the edge lines, and the width between the rumble strips at the ten installation sites. There was a range in pavement width at most of the locations.

	Width (feet)		
County/Route	Total	Between Edge Lines	Between Rumble Strip
Ballard; US 51	25-27	22-23	22-23
Allen; KY 100	22-23	19-20	17-18
Nelson; US 62	23	20	19
Henry; US 421	25	21-21.5	21
Gallatin; US 42	24	21	21
Garrard; KY 39	23-24	19	19
Lewis; KY 59	22-23	18-19	18-19
Magoffin; KY 7	24	22	22
Leslie; KY 699	22-24	19-21	19-21
Letcher; KY 7	23-24	20-21	20-21

The closest distance between the rumble strips was 17 feet in Allen County. This resulted from the decision to have a pavement wedge of 18 inches outside the rumble strip. This was the reason that the stripe was placed at the edge of the rumble strip next to the shoulder (rather then adjacent to the travel lane). Driving through this section of road during both day and night conditions showed that there was adequate pavement for vehicles to drive and meet other vehicles safely. However, due to some complaints, the rumble strip was removed at the Allen County location.

There were no complaints at the other locations. While there was discussion by some of the resident engineers in areas with a large amount of truck traffic that the rumble stripe may force truck drivers to position their truck closer to the center of the road, their opinion after the installation was positive. Observations showed that the rumble stripe did not force drivers closer to the centerline. Comments from drivers were that the rumble strip allowed them to know when they were close to the edge of the pavement.

Several issues were noted during the installations which should be addressed in the future. The objective was to maintain a constant lane width with any variance in pavement width to be placed on the shoulder. For this to occur, the center of the pavement must be located to use in placing the centerline. This requires marking the center of the pavement rather than using the pavement joint (which may not be located at the exact center of the pavement). If the center of the pavement is identified, the desired lane width can then be marked and used to place the rumble strip at a location which will enable a constant lane width. Any variance in the total pavement width will then result in varying widths of pavement outside the one-foot rumble strip (rather than lane width).

At locations where the rumble strip extends to the edge of the pavement, with no pavement wedge, there is a possibly of having some areas with a small shoulder dropoff (especially at the outside of curves). To address this possibility, the contract could

include dense graded aggregate (DGA) material or milling material, if available as part of the resurfacing project, to use if a shoulder dropoff is created.

The rumble strip must be free of debris when the edge line is painted. The rumble strip is sweep immediately after the rumble strip is cut. However, debris can collect in the bottom of the groove is the stripe is not placed for a few days. The stripe will not be durable in the bottom of the groove if it is placed on debris. The striping contractor should ensure that the groove is free of debris before the edge line is placed.

Care must be taken by the striping contractor to keep the edge line within the rumble strip. The specifications showed that the four-inch edge line was to be placed at the edge of the rumble strip adjacent to the travel lane. It is difficult for the striper to maintain the edge line at exactly this location (especially in curves). Inspections found that, at some locations, a portion of the edge line was sprayed outside the groove (into the travel lane). An option would be to place the edge line in the center of the 12-inch rumble strip. This would allow for a variation in the location of the edge line with the line remaining in the groove. This location would also add one foot to the distance between the edge lines.

Observations were made during both dry and wet nighttime conditions. The rumble stripes were found to provide good delineation, even under wet conditions.

Photographs of the installations at various locations, during and after installation, are given in the Appendix.

3.2 Crash Analysis

Crash data were analyzed for the five-years of 2004 through 2008 to show the crash history at the sites before the installations were conducted in the summer of 2009. Following is a table showing the traffic volume (average daily traffic (ADT)) and crash rate at each location. The crash rate is given in terms of crashes per 100 million vehicle miles (C/100MVM).

County	Route	ADT	Length	Crash Rate
Ballard	US 51	3,500	5.5	155
Allen	KY 100	2,500	12.6	223
Nelson	US 62	3,700	7.6	231
Henry	US 421	4,100	6.4	74
Gallatin	US 42	4,200	5.6	124
Garrard	KY 39	1,500	5.3	378
Lewis	KY 59	600	11.0	216
Magoffin	KY 7	600	3.7	341
Leslie	KY 699	1,500	7.4	149
Letcher	KY 7	1,300	2.6	310

The types of crashes at these locations were analyzed. Following is a summary of the numbers of single vehicle (SV) and opposite direction sideswipe or head-on collisions (SS/HO). The number of injury crashes is also given.

		SV		SS/HO		Injury		
County/Route	Total	No.	Percent	No.	Percent	No.	SV	Percent SV
Ballard; US 51	55	35	64	1	2	16	10	63
Allen; KY 100	127	74	58	18	14	34	20	59
Nelson; US 62	117	53	45	7	6	32	19	59
Henry; US 421	35	19	54	2	6	8	3	38
Gallatin; US 42	53	30	57	3	6	21	12	57
Garrard; KY 39	54	39	72	4	7	15	12	80
Lewis; KY 59	27	20	74	2	7	15	12	80
Magoffin; KY 7	14	9	64	2	14	8	6	75
Leslie; KY 699	30	15	50	6	20	17	9	53
Letcher; KY 7	19	11	58	2	11	9	6	67
All	531	305	57	47	9	175	109	62

The crash data show that the most common type of crash was the single vehicle type of crash. This is the type of crash that shoulder rumble stripes are designed to reduce. There is a very small percentage of an opposite direction type of crash.

4.0 RECOMMENDATIONS

The current evaluation support additional installations of rumble stripes. The crash history for the original installations will be monitored in order to compare crashes before and after the rumble stripes were installed. The following recommendations should be considered in the installation process.

1. After paving, the centerline should be marked to assist in placing the centerline at the proper location. This will assist in obtaining a consistent lane width. The location of the edge of the rumble strip should then be marked using the centerline marking as a guide.

2. DGA material should be provided in the contract for use at locations where a shoulder dropoff issue must be addressed. An alternative is the use of milling material (if available).

3. The groove must be swept properly. The striping should be completed as soon as possible after the rumble strips are placed to minimize the accumulation of any debris in the groove (which will create a problem with striping durability). It may be necessary to clean the groove as part of the striping process.

4. Care must be taken when striping the edge line to keep the line within the rumble strip. An alternative to placing the edge line at the edge of the rumble strip adjacent to the travel lane would be placing the edge line in the center of the rumble strip. This would allow a small variance of the four-inch stripe within the 12-inch rumble strip with the stripe remaining in the groove. This position would add one foot to the distance between the edge lines and six inches to each lane width (between the center and edge lines) and would eliminate the problem of a portion of the edge line being placed outside the rumble strip.

5. When sufficient pavement width is available (a minimum width of 22 feet), the outside minimum one foot of paved shoulder should be "wedged" to reduce the potential of shoulder dropoffs.

6. For a total pavement width of 22 feet or more, the distance taken for the shoulder wedge and rumble strip would take four feet of pavement. This would result in a minimum lane width of nine feet. The lane width would increase for pavement widths over 22 feet.

6. For a total pavement width less than 22 feet, either do not provide a shoulder wedge or place the rumble strip on the wedge. The rumble strip could be moved closer to the edge of pavement by placing the stripe in the rumble strip. There is no problem with the striping contractor moving the striping head so that any portion of the rumble strip can be striped.

7. Following is a summary of lane and shoulder widths for various total pavement widths. In all cases, the width of the rumble strip is one foot. The minimum width between edge lines is 18 feet. This assumes placing the stripe at the edge of the rumble strip adjacent to the lane. Placing the edge line in the middle of the one-foot rumble strip would add one foot to the distance between the edge lines and would add ½ foot to the lane width.

Lanes and shoulder	Pavement Width (feet) Between Edge lines	Lane	Shoulder
26	22	11	2*
25	21	10.5	2*
24	20	10	2*
23	19	9.5	2*
22	18	9	2*
21	18	9	1.5
20	18	9	1

* The outside one foot of pavement is a shoulder "wedge" to reduce any shoulder dropoff (the one-foot rumble strip is not placed on this portion of the shoulder).

8. An alternative to use for the most narrow lane widths is to reduce the width of the rumble strip from 12 inches. Other states use edge line rumble strip widths of six and eight inches. This would increase lane widths.

APPENDIX

Photographs of Rumble Stripe Installations

Figure A-1. Installation of Rumble Strip (Magoffin County).

Figure A-2. Installation of Rumble Strip (Magoffin County).

Figure A-3. Using Drip Line as Guide to Place Rumble Strip (Lewis County).

Figure A-4. Use of Edge Line as Guide (note pre-marked centerline) (Garrard County).

Figure A-5. Reflectivity Measurement on Complete Rumble Stripe (Garrard County).

Figure A-6. Painting Rumble Strip (Garrard County).

Figure A-7. Use Edge Line as Guide (placing stripe in center of rumble strip) (Nelson County).

Figure A-8. Completed Rumble Stripes (Henry County).

Figure A-9. Rumble Stripe Installation (Leslie County).

Figure A-10. Rumble Stripe Location (Note stripe outside rumble strip) (Letcher County).

Figure A-11. Rumble Stripe in Allen County (placed on outside of rumble strip).

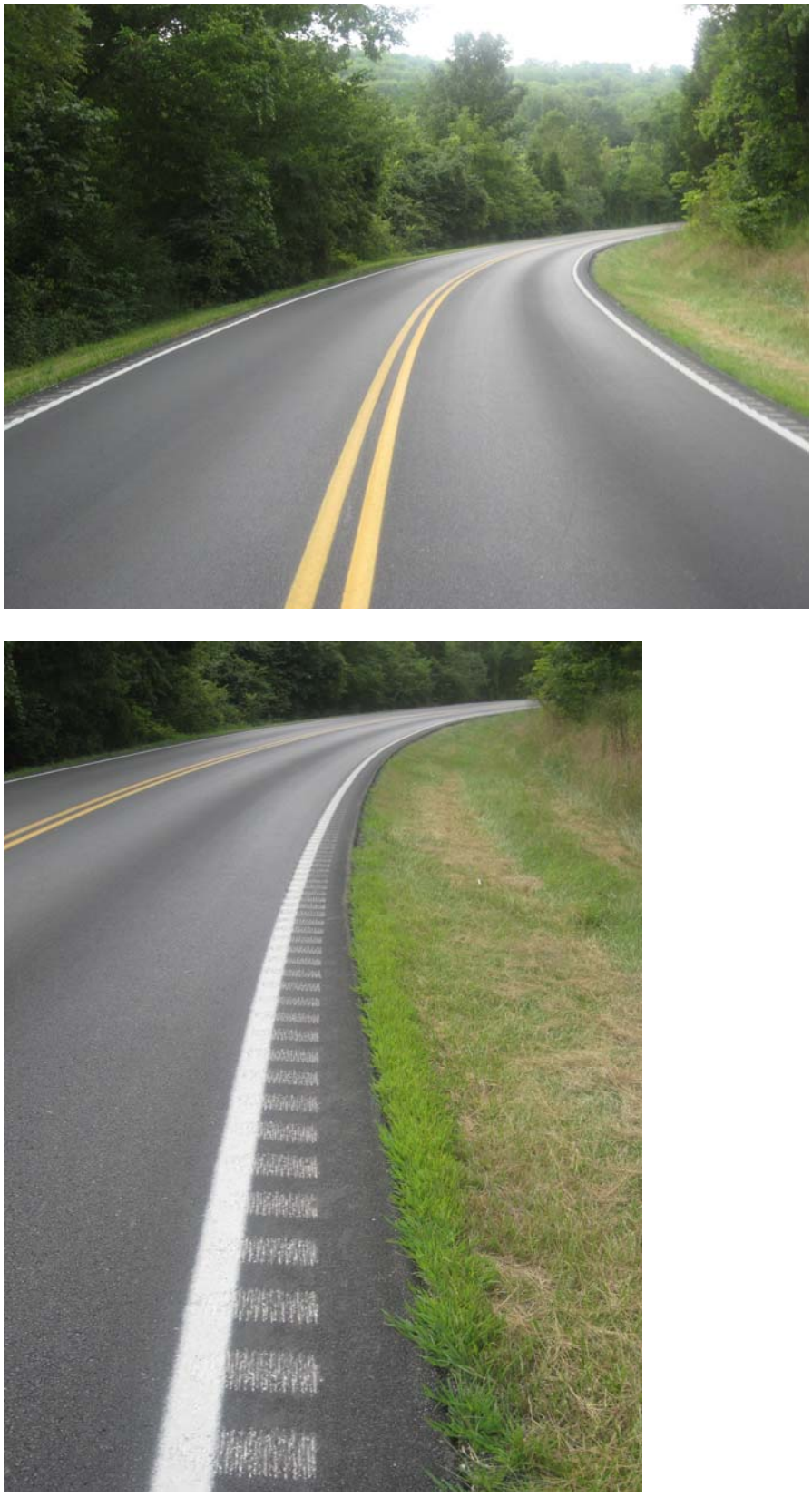

Figure A-12. Rumble Stripe Installation (Gallatin County).

Figure A-13. Rumble Stripe (Dry, Nighttime Condition) (Garrard County).

Figure A-14. Rumble Stripe (Wet, Nighttime Condition) (Garrard County).

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