Research Report
KTC-08-04/SPR319-06-1F

KENTUCKY TRANSPORTATION CENTER

EVALUATION OF THE EFFECTIVENESS OF PAVEMENT RUMBLE STRIPS

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EVALUATION OF THE EFFECTIVENESS OF PAVEMENT RUMBLE STRIPS

(Final Report)

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16. Abstract

This report analyzes the effectiveness of continuous shoulder rumble strips (CSRS) and centerline rumble strips (CLRS) on rural two lane roads in Kentucky. This study evaluates the safety benefits, and design details associated with the application of the CSRS and CLRS. The recommended practices proposed as a result of the crash analysis have the potential to reduce both run off the road and opposite direction crashes on rural two lane roads in Kentucky. These recommendations provide benefits for narrow roadways with little to no shoulder as well as larger roadways with wider paved shoulders.

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Executive Summary

The lack of national research on the application of continuous shoulder rumble strips on two lane roads with little to no shoulder combined with the prevalence of these applications on Kentucky roadways allowed for detailed crash analysis. Two sets of crash analyses were performed to analyze the fundamental questions of the study.

1. Do continuous shoulder rumble strips reduce crash frequency on rural two lane roads with little or no shoulder?

2. When limited pavement width is available, should shoulder width be increased to provide continuous shoulder rumble strips or should lane width be maximized?

A crash analysis for 162 roadway segments with and without shoulder rumble strips was conducted using a three –year crash history. Additional analysis was conducted using all state maintained two-lane roadway sections to determine crash attributes consistent with lane and shoulder width combinations. Based on this analysis the following conclusions were made.

- Two-lane rural roads with continuous shoulder rumble strips have a statistically significant (at 90% confidence interval) lower total crash rate than roadways without CSRS.

- Two-lane rural roads with continuous shoulder rumble strips have a statistically significant (at 90% confidence interval) lower crash rate resulting from inattention/drowsiness than roadways without CSRS.

- Two-lane rural roads exhibit a statistically significant (at 90% confidence interval) decrease in run off the road crash rates as lane width increases.

- Crash rates on 2-lane rural roads are generally lower when shoulder width is maximized and lane width in minimized.

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 as shown in the table below.

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.

Introduction

Significant research has been conducted addressing the effectiveness of rumble strips. This research has shown that continuous shoulder rumble strips (CSRS) are an effective countermeasure against run-off the road crashes on high-speed multi-lane facilities with shoulder greater than three feet in width. Centerline Rumble Strips (CLRS) have been shown to an effective countermeasure against head-on crashes on rural two-lane roads. However, research has not been conducted evaluating the use of CSRS on roadways with narrow shoulders.

Complaints about rumble strip applications are limited and are primarily related to and rideability concerns from the cycling community and road noise concerns from adjacent residences. These potential disadvantages therefore call for the evaluation of rumble strips efficacy to avoid placing unneeded or ineffective countermeasures when potential impacts may occur.

Placement and construction techniques of rumble strips vary widely across Kentucky and the country. Guidelines and policies are needed to provide a uniform application of rumble strips throughout the state.

Literature Review

The 2006 Kentucky Traffic Collision Facts cites driver inattention as the most frequently cited contributing factor in crashes, being cited in over 41 percent of all crashes. Distraction, falling asleep and fatigue account for another 5 percent of all crashes (1). It is noted that distracted and fatigued driving is not always identifiable during crash investigations and such behavior is considered by many to be prevalent among a large number of drivers involved in crashes of all types. (2)

Continuous Shoulder Rumble Strips

One such measure that has been used extensively to address these types of crashes is the continuous shoulder rumble strip. The Federal Highway Administration (FHWA) defines the shoulder rumble strip as “a longitudinal design feature installed on a paved roadway shoulder near the travel lane. It is made of a series of indented or raised elements intended to alert inattentive drivers through vibration and sound that their vehicles have left the travel lane.” The FHWA states that shoulder rumble strips have demonstrated their benefits in reducing death and serious injury caused by inattentive drivers and show very high benefit to cost (B/C) ratios making them among the most cost effective safety features available. Rumble strips have additional benefits and may serve as an effective means of locating the edge of the travel lane when the pavement marking edge line is obscured helping drivers maintain their proper lane position. (2)

The FHWA Technical Advisory recommends a system-wide installation of continuous shoulder rumble strips on rural freeways and expressways. This recommendation is made due to the proven cost effectiveness of the rumble strip and the random occurrence of crashes resulting from inattentiveness. On non-freeway facilities “such as rural multi-lane and two-lane roadways, the FHWA recommends that shoulder

rumble strips be used on those roadways for which an engineering study or crash analysis suggests that the number of these crashes would likely be reduced by the presence of rumble strips. When rumble strips are recommended, the following guidelines should be followed to the maximum extent practical:" (2)

> (1) Standard milled rumble strips, installed as close to the edge line as practical, should be used when a 2.4 m (8-foot) clear shoulder width remains available after installation of the rumble strip. This is the recommended treatment for roadways with 3.0 m (10 foot) shoulders.
>
> (2) A modified design should be used along shoulders 1.8 or 2.4 m (6 or 8 feet) wide when the remaining available clear shoulder width is less than 1.8 m (6-feet) and the road can be used by bicyclists…
>
> (3) Rumble strips should not normally be used when their installation would leave a clear shoulder pathway less than 1.2 m (4-feet) wide (or less than 1.5 m (5-feet) wide if there is an obstruction such as a curb or guardrail) to the right of the rumble strip for bicycle use. At locations where such space does not exist to the right of the rumble strip, a rumble strip may be installed if it is at least 0.3 m (1 foot) to the right of the edge line. In this case, a bicyclist would be expected to ride to the left of the rumble strip, essentially along the outside edge of the traffic lane.

It is interesting to note the differences between recommended practices for expressway and non-expressway facilities. System wide installation is recommended due to economies of scale on expressways; however, engineering studies are required on non-expressway installations. Furthermore, the placement of rumble strips on rural roadways is primarily dictated by accommodation of cyclists on the shoulder. The Technical Advisory does not address the potential different needs and interactions of cyclists and vehicles on rural roadways with little to no shoulder, where cyclists are required to travel in the travel lane with or without rumble strips. In fact the advisory states that "Rumble strips installed at the outside edge of a shoulder with no useable recovery area beyond the shoulder are of questionable value." The Technical Advisory also concentrates on the use of milled in rumble strips and does not consider the cost saving benefits of rolled in rumble strips which are placed during paving operations at little to no additional cost. (2).

The Kentucky Transportation Cabinet (KYTC) has formalized a policy on the use of shoulder rumble strips with a Special Note from the Division of Design in 1995 indicating that they are required on new and reconstructed roadways. Specifications regarding rumble strips on resurfaced roadways can be found in the 2004 Standard Specifications for Road and Bridge Construction, Section 403 – Production and Placement of Asphalt Mixtures, Subsection 403.03.08 – Rumble Strips. This section reads as follows.

> **(B) Other Roads.** Construct rolled rumble strips on shoulders of facilities with posted speed limits greater than 45 MPH. Do not install rumble

strips on facilities with posted speed limits 45 MPH or less unless specified in the plans or directed by the Engineer.

Construct rolled rumble strips on mainline shoulders to the dimensions shown below. On shoulders less than 3 feet, shorten the length and distance of the strips as the Engineer directs. Time the rolling operation so indentations are at the specified size and depth without causing unacceptable displacement of the asphalt mat. Correct unacceptable rolled rumble strips by sawing.

The Department will require sawed rumble strips in place of rolled rumble strips if indicated on the plans or directed by the Engineer.

(C) Pavement Wedge Texturing. Construct pavement wedge texturing on all pavement wedges that are paved monolithically or constructed using a surface mixture. Construct pavement wedge texturing to the dimensions identified as "rolled" below. When using Asphalt Mixture for Pavement Wedge, binder, or a base mixture, the Department will not require pavement wedge texturing. (3)

It should be noted that Pavement Wedge Texturing, as referenced above in 'C' is used to define the rolled in indentations used on rural roads. The wide spread use of the rolled in rumble strip in Kentucky was originally designed to provide a visual differentiation of the travel way and shoulder on monolithic pavements. Additionally, the standards and specifications do not provide guidance for the engineer to "shorten the length and distance of the strips" which leads to inconsistent practices across the state, especially on narrow roadways. There is also confusion regarding the item 'C' which in practice leads to many rumble strips being placed on the pavement wedge, a position which is ineffective for crash reduction.

The most comprehensive research on state use of rumble strips is NCHRP Synthesis 191 conducted in 1993. The synthesis included both in-lane and continuous shoulder rumble strips (CSRS). The synthesis conducted a nationwide survey of state and local highway agencies and identified 35 state highway agencies and nine toll authorities using continuous shoulder rumble strips along extended sections of major highways and/or freeways to alert motorists that they are leaving or have left the traveled way (4).

The earliest experiments with CSRS were conducted on New Jersey parkways in the 1950's followed by Illinois in 1960 and Arizona and Florida in the 1970's. This early research showed that the use of CSRS can reduce run off the road accident rates by as much as 20 to 50 percent. A 1985 study conducted by the FHWA found that run off the road accidents at 24 sites in 11 states decreased by 20 percent, which proved to be statistically significant at the 95 percent confidence level.

Casual field observation and anecdotal evidence has been strong throughout the history of rumble strips beginning with endorsement of CSRS by the Wisconsin State

highway patrol, after officers observed vehicles leaving the road and being alerted to the successfully recover (4).

Despite the documented crash reduction potential all identified studies evaluated dealt primarily with parkways and expressways or roadways with significant shoulder width.

Centerline Rumble Strips

Another application of continuous rumble strips that has recently come into practice is that of centerline rumble strips (CLRS) on two-lane undivided roadways to mitigate centerline cross over crashes. The first evaluated application of centerline rumble strips was conducted in 2000 on a 23-mile section of California highway. A record six fatal crashes resulting in 14 deaths was observed in 1995. CalTrans implemented a delineation project in conjunction with milled-in centerline rumbles trips. Fitzpatrick et al, compared 25 months of before data to 34 months of after crash data on the section. Prior to the project 10 fatal crashes were observed compared to one in the after period. NCHRP 440 also evaluated two unnamed routes, for two years before and after the installation of CLRS, however, no significant crash reduction was recorded (5). NCHRP Report 500 presents CLRS as a strategy to keep vehicles from encroaching into the opposite lane; however, the report concludes that CLRS have not been sufficiently evaluated to be considered a proven strategy. The treatments have been tried and no negative effects were identified in the report (6). Proper evaluation was noted to be difficult as CLRS are often implemented in conjunction with numerous other improvements.

In order to address the inconclusiveness of the various studies on CLRS the Insurance Institute for Highway Safety (IIHS) conducted a comprehensive before and after study evaluating CLRS applications in seven states, California, Colorado, Delaware, Maryland, Minnesota, Oregon and Washington including 98 sites and 210 miles of roadway (7). 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.

NCHRP Synthesis 339 conducted a survey of state highway agencies to determine the need for policy guidelines and warrants for the use of the CLRS (5). The conclusion of the survey was that there should not be warrants for the use of CLRS, rather there should be guidelines based on engineering judgment and available data which considers geometric factors and crash history.

Review of policies on the use of centerline rumble strips was shown to vary between states. All states surveyed required documented instances of head on or sideswipe meeting crashes. In addition, some states require the occurrence of fatal crashes (California) to justify the use of centerline rumble strips. The responsibility for review and approval varies among the states from the district safety engineer (Pennsylvania)

to required approval by the state highway engineer (Oregon). Of those states providing minimum roadway width requirements for centerline rumble strips, (Pennsylvania, Minnesota, Missouri) all permit the use of centerline rumble strips on roadways greater than or equal to 20 feet (10 feet lanes) with shoulder; Missouri does require a design exception for roadways less than 24 feet.

It is interesting to note the difference between centerline rumble strip policies and continuous shoulder rumble strips in that CSRS are applied as a systemic proactive approach, while CLRS are reserved as a more reactive approach to existing problem areas.

Due to the relative novelty of the CLRS, several concerns have frequently been raised about there use, safety and maintenance. These include:

- Danger to bicyclists
- Effect on motorcycles
- Roadside noise complaints
- Drivers reacting to the left
- Pavement deterioration
- Effect on different types of pavement material
- Striping visibility
- Increased snowplow wear
- Limited after data
- Effects on emergency vehicles
- Lack of widely accepted guidelines
- Water snow and ice accumulation

Despite the many expressed concerns no adverse effects were documented by Synthesis 339.

Synthesis 339 did not identify any issues regarding motorcyclists and CLRS through the literature review. A subjective evaluation of rideability over CLRS was conducted in Colorado and Kansas roads by the Chief of the Bureau of Traffic Engineering of Kansas DOT and his opinion was that they do not present a safety problem.

Another concern over the use of centerline rumble strips is the effect of causing drivers to shy away from the centerline, which may increase the likelihood of run off the road crashes. To address this concern Pennsylvania DOT investigated whether CLRS affected the lateral placement of vehicles on the roadway. Tests applications of milled in CLRS were conducted on two-lane roadways with both 11 and 12 foot wide lanes. The study indicated that on 12 foot lane sections, vehicles shifted away from the centerline an average of 5.5 inches and three inches on the 11 foot sections. In addition, it should be noted that continuous shoulder rumble strips are often placed on the left side of the lane on divided highways without documented negative impacts.

Of special concern to KYTC was the effect of pavement deterioration and the accumulation of snow and ice in the rumble strip depression. To address these concerns, a special meeting was held with maintenance personnel from Districts 6, 9

and 11 where limited applications of centerline rumble strips exist on the Daniel Boone Parkway, Mountain Parkway and AA Highway. The purpose of this meeting was to specifically address these maintenance issues. Pavement deterioration along the centerline joint was noted on the Mountain Parkway and Daniel Boone Parkway; however, it was noted that this was a retrofit application and pavement performance was poor before the rumble strip placement. The other applications did not note any significant problems of pavement deterioration when placed on new pavement. Additionally, issues of water and ice accumulation in the centerline rumble strip was determined to be a non-issue.

Crash Analysis

Due to the comprehensive analysis of the use of centerline rumble strips conducted by the IIHS (7), and the limited availability of Kentucky data with regard to CLRS applications, further analysis of these treatments was not deemed to be necessary. However, the lack of national research on the application of continuous shoulder rumble strips on two lane roads with little to no shoulder combined with the prevalence of these applications on Kentucky roadways allowed for detailed crash analysis. Two sets of crash analyses were performed to analyze the fundamental questions of the study.

3. Do continuous shoulder rumble strips reduce crash frequency on rural two lane roads with little or no shoulder?

4. When limited pavement width is available, should shoulder width be increased to provide continuous shoulder rumble strips or should lane width be maximized?

In order to answer the first questions above it was necessary to conduct crash analysis to determine the safety benefit of rumble strip installations.

Study sections were identified through a statewide survey of highway district personnel to identify roadway sections having both edgeline and centerline and rumble strips and sections with edgeline, centerline and NO rumble strips. This effectively limited the sample to roadways with a width greater than 20 feet. Current KYTC practice of installing rumble strips on nearly all roadways limited the sample size of sections without rumble strips. Sections with rumble strips were then identified with similar characteristics of those not containing rumble strips. These sections were then reviewed to verify the presence/absence of rumble strips and to evaluate the overall quality of the roadway section and of the rumble strip application. A total of 162 unique sections were identified for the crash analysis; 109 sections with rumble strips and 53 without. A list of all sections evaluated in the study is contained in **Appendix A**.

A three-year crash history for these sections was identified and preliminary crash analysis was conducted. Crash data was obtained from the Collision Report Analysis for Safer Highways (CRASH) database. Crash data analyzed included the manner of collision and human, vehicular and environmental contributing factors so that the effect of rumble strips on various types of crashes could be analyzed. Roadway section information was gathered from the Highway Performance Monitoring System (HPMS) database and verified from field reviews.

Figure 1 shows the distribution of overall crash rates and ADT's for the two samples. **Table 1** summarizes the average crash rate for each sample for total crashes, run off the road crashes, and crashes resulting from driver inattention.

Figure 1: ADT and Crash Rate Distribution

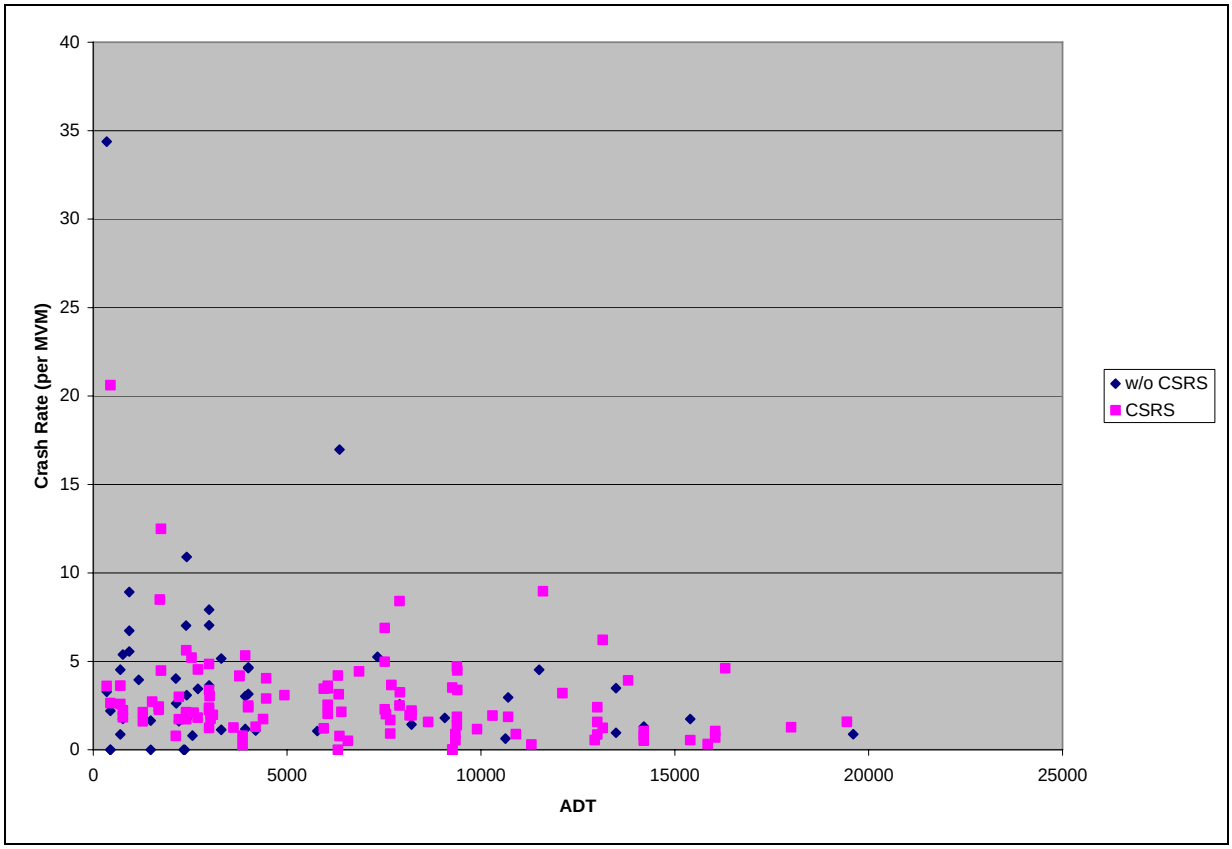


Table 1: Crash Rate Summary (Crashes per MVM)

Crash Type	Rumble Strips	NO Rumble Strips
All Crashes	2.67	3.91
Run Off Road	0.97	1.84
Driver Inattention	1.04	1.69

As can be seen from the table preliminary results indicate that those sections with rumble strips have a lower crash rate than those without (2.67 Crashers per MVM –vs- 3.91 Crashes per MVM).

While the analysis above shows promising results for the use of rumble strips, the variability of crash rates shown in Figure 1 and the relatively small sample size of roadways without rumble strips caused some initial concern. In addition, unaccounted factors could be influencing the results of crash rates. For instance, due to the previous policy of placing rumble strips on every roadway, those without rumble strips could provide a biased sample. That is, these roadways may have narrower lane widths, lower ADTs or be less functionally important, and therefore receive less

maintenance attention. While the sample and field reviews were designed to limit the influence of these factors, they could not be fully eliminated. To address these issues, statistical analysis in the form of multi-variate regression was performed to 1) identify the statistical significance of the difference in average crash rates, and 2) identify and account for the effect of additional factors that may influence crash rates beyond the presence of continuous shoulder rumble strips.

The regression analysis originally evaluated a wide range of variables from the available roadway data including field notes and the HPMS database. Two factors proved to influence the crash rate. These are the presence of rumble strips and lane width. Regression analysis was then performed evaluating the significance of these variables on three different crash rates. These are 1) the total crash rate, 2) lane departure crash rate and 3) crash rate involving human factors inattention and/or being asleep. The lane departure crash rate was examined because it focuses on the crash type that is addressed by rumble strips; lane departure crashes examined included fixed object, non-fixed object crashes etc., based on directional analysis codes. Crashes resulting from inattention focused on the primary contributing factor that is addressed by the presence of rumble strips; the analysis included the following human factors:

- Cell Phone
- Distraction
- Fatigue
- Fell Asleep
- Inattention
- Lost Consciousness/Fainting
- Overcorrecting/Oversteering

Table 2 summarizes the standardized coefficient for each variable evaluated and the corresponding significance value for each variable.

Table 2: Regression Analysis Results

Dependent Variable	Independent Variables	Standardized Coefficient	Significance
Total Crash Rate	Rumble Strip Present (Binary)	-1.870	0.063
	Lane Width	1.093	0.276
ROR Crash Rate	Rumble Strip Present (Binary)	-0.047	0.545
	Lane Width	-0.283	0.000
Inattention Crash Rate	Rumble Strip Present (Binary)	-0.155	0.053
	Lane Width	0.042	0.594

Based upon this analysis the following conclusions are drawn.

- Two-lane rural roads with continuous shoulder rumble strips have a statistically significant (at 90% confidence interval) lower total crash rate than roadways without CSRS.

- Two-lane rural roads with continuous shoulder rumble strips have a statistically significant (at 90% confidence interval) lower crash rate resulting from inattention/drowsiness than roadways without CSRS.

- On two-lane rural roads the presence of continuous shoulder rumble strips was not shown to have a statistically significant impact on run off the road crash rates when lane width was accounted for.

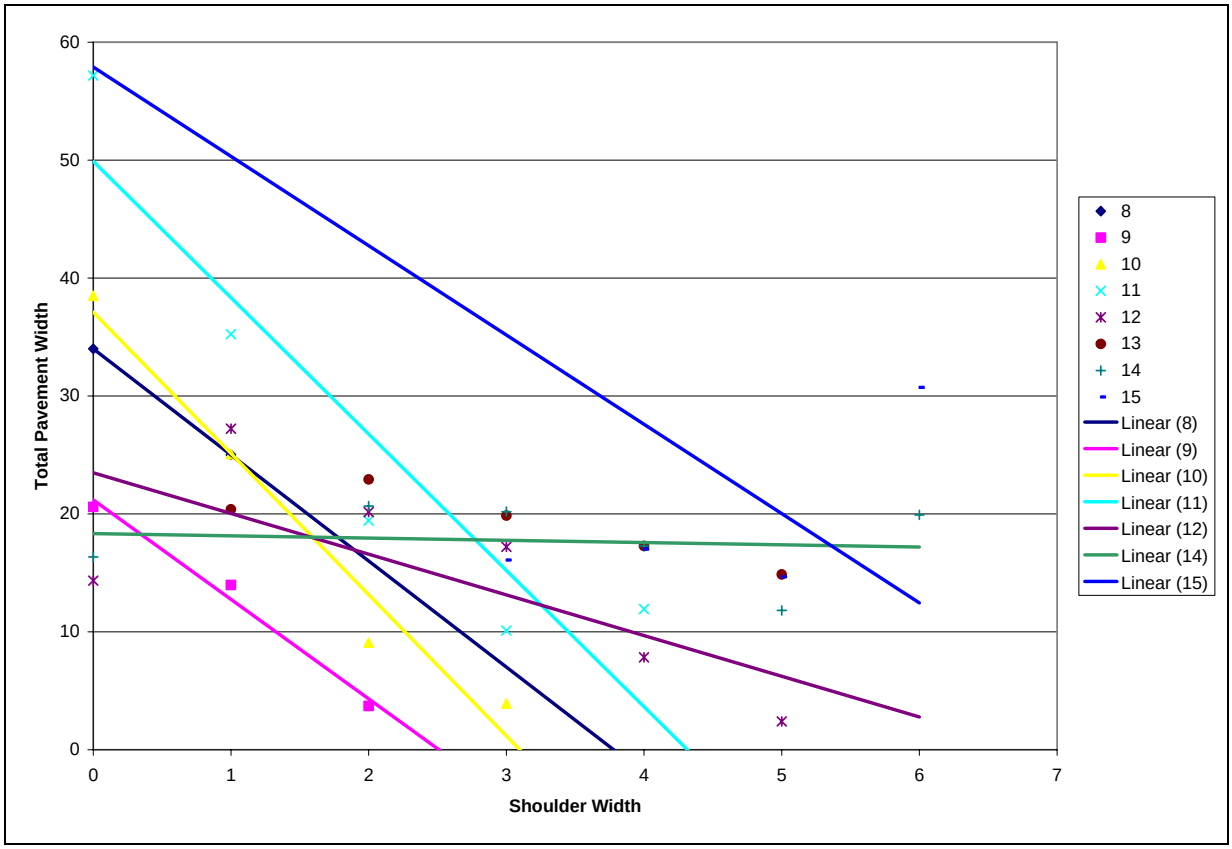
- Two-lane rural roads exhibit a statistically significant (at 90% confidence interval) decrease in run off the road crash rates as lane width increases.

Two effective countermeasures are identified from the analysis 1) installation of continuous shoulder rumble strips and 2) increased lane widths. However, in implementing these results a conflict occurs, in that in order to place rumble strips on a roadway, lane width will often have to be decreased, unless pavement widening is possible. On many two-lane rural roads, it is impractical to widen the roadway to accommodate both of these needs. Additionally the analysis presented above only evaluated lane width and did not take into account the total available pavement width including shoulders, where rumble strips would be located. Therefore, further analysis was required to evaluate the optimum lane/shoulder configuration for a set pavement width. A review of the literature did not identify previous studies which had evaluated this scenario, rather most evaluate increasing lane and/or shoulder width while holding the other constant. The problem with this analysis is that it is impractical in practice as often it is only possible to achieve a given width of pavement, lane width plus shoulder width.

As the goal of this analysis was to investigate the safety impacts of shoulder and lane width configurations, and not specifically address the presence of rumble strips, a larger database could be used. This analysis evaluated all of the 2-lane rural roadway sections contained in the Highway Performance Monitoring System (HPMS). The database included 8086 sections totaling over 50,000 miles of roadway. Roadways were categorized by total pavement width which was defined as the lane width plus the shoulder width. Reported total pavement widths ranged from 16 feet to 30 feet. The median pavement width was 24 feet including a two foot shoulder.

Common pavement widths were grouped together and crash rates were determined for each subset determined by the shoulder width. For instance, sections having a 24 foot pavement width included roadways with 12 foot lanes/ no shoulder, 11 foot lanes/1 foot shoulder and 10 foot lanes/ two foot shoulders. For each pavement width group, trends in the crash rate were identified based upon the variation of the shoulder, i.e, for a 24 foot pavement do crash rates increase, decrease or remain the same as shoulder width increases (and lane width decreases). This will allow for the determination of the optimum lane width/shoulder width configuration for a given available pavement width. In addition, the trends across each group can be compared to determine the limit where wider lanes should be favored over wider shoulders or vice versa. The results of this analysis are presented in **Figure 2**, which shows the trend line for each pavement width as shoulder width increases.

Figure 2: Crash Rate as a function of Total Pavement Width and Shoulder Width



As can be seen from the analysis, all pavement widths show a decreasing crash rate as shoulder width increases. In addition, this analysis agrees with previous research that shows a decrease in crash rates as lane widths are increased and shoulders widths held constant and as shoulder widths are increased and lane widths held constant. Similarly decreased crash rates are associated with increased pavement widths which is consistent with the regression analysis presented above.

Based upon this analysis the following conclusion is drawn.

- Crash rates on 2-lane rural roads are generally lower when shoulder width is maximized and lane width in minimized.

This may be explained by the fact that drivers typically drive slower on roadways with narrower lane widths, while at the same time a wider recovery area (shoulder) is provided.

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**.

Centerline Rumble Strips

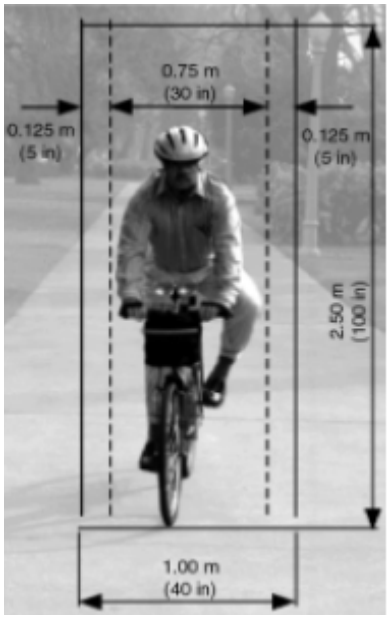
Based upon the conclusions of the IIHS study of centerline rumble strips and the recommendations of NCHRP 500, the use of Centerline Rumble Strips is recommended as a countermeasure to mitigate the occurrence of opposite direction head on and sideswipe crashes on undivided highways. Current KYTC policy permits the use of CLRS on roadways with minimum 12 foot lanes, however, based upon other states practice, permitting the use of narrower roadways with lanes 11 foot or 10 foot with appropriate shoulder is recommended. Before and after studies should be conducted after these applications to determine the need for expansion of the CLRS applications, to the extent of CSRS. CLRS are only recommended in the form of milled-in rumble strips on new pavement in order to preclude any potential maintenance issues concerning the centerline joint.

Accommodation of Cyclists

Concerns over the use of shoulder rumble strips have often been expressed by the bicycling community. These concerns primarily state that rumble strips 1) are not safe to be ridden on by cyclists, 2) present a barrier between the traffic lane and shoulder restricting movements to/from the shoulder and 3) are typically placed in the optimum spot for riding, i.e., next to traffic but outside of the debris collecting on the shoulder. As a result of these concerns the use of rumble strips on any roads has been questioned as to their effectiveness and appropriateness. As can be seen in the above analysis rumble strips are an effective countermeasure to run off the road crashes. In addition, by examining the concerns summarized above and how cyclists and autos interact on narrow 2-lane roads, it can be seen that rumble strip applications on these roads do not present a substantial problem to the cyclist.

On narrow two lane rural roads with little to no shoulder cyclists are forced to ride within the travel lane, as no other option exists. When examining the space occupied by the cyclists and automobile it is clear that the presence of rumble strips does not further impact the cyclists on these types of roads. According to the AASHTO Guide for the Development of Bicycle Facilities, the operating width of a cyclists is 30 inches, or 2.5 feet (9). (See **Figure 3**). The AASHTO Green Book cites the width of the passenger car design vehicle as seven feet (10). The Kentucky Driver License Manual mandates a clearance of three feet when passing a cyclist (11). Examining the width of the cyclist, clearance width and vehicle width, a minimum lane width of 12.5 feet is needed for a vehicle to safely pass a cyclist without encroaching upon the oncoming lane. Therefore, it is necessary for a passing vehicle to encroach upon the oncoming lane with or without the presence of shoulder rumble strips. Upon examination, the concerns noted above are only applicable on roadways with substantial shoulder width where it would be possible to separate bicycle and automobile traffic on two separate facilities (travel lane and shoulder). On two lane roads with minimal shoulder, an automobile should pass cyclists as they would any other vehicle on the roadway.

Figure 3: Bicyclist Operating Space (9)



Construction Practices

Based upon the field review and other observations on the state roadways, one of the most challenging elements of the use of continuous shoulder rumble strips is the proper construction and placement. The crash analysis cited above only analyzed "good" rumble strip placements where the rumble strip 1) was placed on top of the pavement surface and not the pavement wedge and 2) was constructed properly so as to maximize the rumble strip depth. **Figures 4 and 5** show examples of proper and improper rumble strip placement.

Figure 4: Good Rumble Strip Construction

Figure 5: Poor Rumble Strip Construction

The most consistent construction practices have been evidenced with milled-in rumble strip placements. However, constructability of milled-in rumble strips becomes an issue on narrow two lane roads, due to maintenance of traffic operations as well as increased costs. Therefore, rolled-in rumble strips are the preferred method of placement for two lane roads with minimal shoulder.

Several methods have been used to place rolled-in rumble strips. Most include the use of a steel drum with rebar welded onto the drum at the specified spacing and rolled over the fresh asphalt. This method works well if the drum is controlled, placing the rumble strips in the proper position. Several methods have been used to control the drum, ranging from rigid attachments to the paver and/or roller

to being pulled by a chain behind the paver. Some of these methods are shown in **Figures 6 and 7**.

Figure 6: Rigid Attachment to Roller

Figure 7: Pulled Behind Paver

It is imperative that control be established over the method of placement to provide 1) consistent placement on the shoulder and 2) consistent pressure to provide adequate depth of the rumble strip. For this reason rigid applications are recommended or the use of a separate roller with the rumble strip protrusions. Non-rigid systems of control have been observed to roll over and lose control, leading to poor placement of rumble strips.

One other issue that needs to be addressed is the construction of the shoulder itself. As identified above, the use of a minimum one foot shoulder is recommended on most roadways regardless of available pavement width. The shoulder should contain the rumble strip and pavement edgeline. The use of this shoulder may be beneficial in addressing pavement edge drops offs as shown in **Figure 8**. An increased slope on the shoulder may be used to minimize the edge drop off. It is the recommended that the shoulder slope does not exceed a 4H:1V slope so that a recoverable slope may be provided. It is the opinion of the researchers that a rumble strip on a non-recoverable slope is not able to provide safety benefits. KYTC has shown that the use of the modified screed, or separate placement of the shoulder can provide excellent shoulder placement and minimize pavement edge drop offs, (**Figures 9 and 10**).

Figure 8: Pavement Edge Drop Off (12)

Figure 9: Proper Shoulder Placement; Modified Screed (12)

Figure 10: Variable Shoulder Slope; Separate Shoulder Placement (12)

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Appendix A

Crash Analysis Sample Data

County	RT	BMP	EMP	EDGE	CSRS	Comments
Bullitt	KY 1020	0	1.112	YES	YES	2 lane rural area; strips are wide, deep, and very effective; ample shoulder
Bullitt	KY 1020	1.112	2.615	YES	YES	2 lane, narrow shoulder; strips are far from edgeline and narrow
Bullitt	KY 1020	2.615	2.876	YES	YES	2 lane business area; strips are new and deep but narrow
Bullitt	KY 1020	2.876	3.292	YES	YES	2 lane, industrial area; strips are worn and crumbly, ineffective
Bullitt	KY 1020	3.292	4.305	YES	YES	2 lane, ample shoulder; strips are wide enough but not deep, somewhat effective
Bullitt	KY 1020	4.305	5.082	YES	YES	2 lane rural area; strips are narrow, deep, and effective; narrow shoulder
Bullitt	KY 1450	0	0.736	NO	NO	2 lane road in fair condition, no shoulder
Bullitt	KY 1450	0.736	0.997	NO	NO	road through neighborhood, no shoulder
Bullitt	KY 1450	0.997	1.425	NO	NO	2 lane rural road, older pavement
Bullitt	KY 1450	1.425	1.912	YES	NO	new asphalt, no shoulder
Bullitt	KY 1450	1.912	2.187	YES	YES	new asphalt with middle turn lane in places; strips are wide but shallow
Bullitt	KY 1450	2.187	2.861	YES	NO	older asphalt, 2 lane, occasional turn lane, heavy traffic
Bullitt	KY 1450	2.861	3.554	YES	YES	2 lane congested area; strips are wide and deep, very effective
Bullitt	KY 1526	0	2.87	NO	NO	narrow, curvy, country road, no shoulder
Bullitt	KY 1526	2.87	4.917	NO	NO	road still narrow but fewer curves, more houses
Bullitt	KY 1526	4.917	9.52	NO	NO	2 lane rural, curvy road
Bullitt	KY 1526	9.52	10.01	NO	NO	very curvy, hilly road with new asphalt, low shoulder
Bullitt	KY 1526	10.01	10.922	YES	NO	2 lane road, narrow shoulder, congested area
Bullitt	KY 1526	10.922	11.217	YES	NO	3 wide lanes, congested area, wider shoulder
Bullitt	KY 1526	11.217	11.7	YES	YES	4 lane with median, business district, I-65 overpass; strips are wide and deep
Bullitt	KY 1526	11.7	12.967	YES	YES	2 lane limited access, wide shoulder; deep, wide strips are in good condition
Bullitt	KY 1526	12.967	13.01	YES	NO	2 lane urban road, congested
Bullitt	KY 1526	13.01	14.12	YES	YES	2 lane urban road, heavy traffic; strips are worn and not very effective
Bullitt	KY 1526	14.12	16.939	YES	YES	2 lane, newer asphalt; strips are wide but not deep, out on edgeline
Bullitt	KY 2673	0	1.573	NO	YES	strips are in fair condition but narrow

County	RT	BMP	EMP	EDGE	CSRS	Comments
Bullitt	KY 2673	1.573	1.772	NO	NO	no shoulder, pavement is decent
Bullitt	KY 2673	1.772	3.233	NO	NO	no shoulder, road condition is poor
Bullitt	KY 2706	0	2.46	NO	YES	2 lane country road, no shoulder; strips are new and deep, very effective
Bullitt	KY 2706	2.46	3.637	NO	NO	2 lane newly paved road, residential
Floyd	KY 7	0	7.934	YES	YES	Newly paved, very smooth; strips are wide and fairly deep, very effective
Floyd	KY 7	7.934	12.787	YES	YES	Newly paved, guardrail on one side; strips are wide and deep, very effective
Floyd	KY 404	0	1.87	YES	NO	newer pavement drops off a few inches at edge
Floyd	KY 404	1.87	2.577	YES	NO	35 mph congested area, shoulder is wide and mostly gravel
Floyd	KY 404	2.577	3.123	YES	YES	wide shoulder; strips are wide and well built, very effective
Floyd	KY 404	3.123	8.124	YES	NO	wide 2 lane road, drops off at roadside
Floyd	KY 979	0	1.764	YES	NO	2 lane newly paved, no shoulder, road drops off sharply
Floyd	KY 979	1.764	5.958	YES	YES	new asphalt; new strips, narrow in places but deep and effective
Floyd	KY 979	5.958	8.265	YES	YES	older 2 lane road; strips are very worn, not even noticeable driving on them
Floyd	KY 979	8.265	9.298	YES	NO	pavement is older but still smooth, small shoulder
Floyd	KY 979	9.298	11.359	YES	YES	2 lane older asphalt; strips are wide but very crumbly, slightly effective
Floyd	KY 979	11.359	11.75	YES	NO	relatively congested area, 2 foot shoulder
Floyd	KY 979	11.75	13.472	YES	YES	2 lane,somewhat populated area; strips are narrow and very worn, ineffective
Floyd	KY 979	13.472	15.21	YES	NO	2 lane treacherous country road, hilly, curvy
Floyd	KY 979	15.21	17.67	YES	YES	residential area; strips are wide but worn and not very effective
Floyd	KY 979	17.67	19.231	YES	NO	2 lane rural highway, wide gravel shoulder
Floyd	KY 1428	0	1.781	YES	NO	2 lane urban area, wide shoulder on one side for parking
Floyd	KY 1428	1.781	2.215	YES	NO	good pavement, smooth raod, no shoulder
Floyd	KY 1428	2.215	4.5	YES	YES	2 lane rural road; strips are old but wide and deep, still effective
Floyd	KY 1428	4.5	4.892	YES	NO	smooth country raod, no shoulder
Floyd	KY 1428	4.892	5.65	YES	YES	2 lane road in good condition; strips are worn and crumbly but still very effective

County	RT	BMP	EMP	EDGE	CSRS	Comments
Floyd	KY 1428	5.65	6.216	YES	NO	35 mph zone, curb on both sides
Floyd	KY 1428	6.216	8.717	YES	YES	rural 2 lane; strips are wide, deep enough to be mostly effective
Floyd	KY 1428	8.717	12.473	YES	YES	2 lane country road; strips are wide but very worn, hardly effective at all
Floyd	KY 1428	12.473	13.289	YES	YES	road is still country, a little wider; strips are worn and very ineffective
Floyd	KY 1428	13.289	16.688	YES	NO	urban area, lots of cross traffic, parking on sides
Floyd	KY 1428	16.688	17.257	YES	NO	gravel shoulder on one side, concrete barrier on other
Franklin	US 60	0	3.721	YES	YES	2 lane highway; strips are wide and pretty deep, effective
Franklin	US 60	3.721	6.33	YES	NO	5 lane, somewhat residential, curb
Franklin	US 60	6.33	6.945	YES	NO	5 lane heavy traffic urban area, curb
Franklin	US 60	6.945	8.097	YES	NO	2 lane downtown, curb
Franklin	US 60	8.097	8.275	YES	NO	2 lane, 1 way, parking on both sides of street
Franklin	US 60	8.275	10.46	NO	NO	4 lane congested urban area, mostly curb
Franklin	US 60	10.46	11.375	YES	NO	4 lane divided, busy, curb
Franklin	US 60	11.375	11.91	YES	YES	5 lane business district; deep, wide strips, very effective
Franklin	US 60	11.91	12.07	YES	NO	5 lane, heavy traffic area
Franklin	US 60	12.07	14.038	YES	YES	4 lane divided highway; strips are deep, wide very effective
Henry	KY 193	0	3.257	YES	YES	2 lane road, narrow shoulder; strips are wide enough but very worn and ineffective
Henry	KY 193	3.257	7.545	YES	YES	2 lane rural road with 2 ft shoulder; strips are wide but worn, not effective
Henry	KY 193	7.545	8.212	YES	NO	2 lane entering urban area, no strips no shoulder
Henry	KY 193	8.212	9.578	YES	NO	new pavement, ample shoulder
Henry	KY 573	0	0.577	NO	NO	urban area, some curb
Henry	KY 573	0.577	3.1	NO	YES	2 lane rural road; strips are medium width, deep and somewhat effective
Henry	KY 573	3.1	4.9	NO	YES	country road; strips are narrow but pretty deep, almost effective
Henry	KY 573	4.9	6.398	NO	NO	older pavement, no shoulder very country
Henry	KY 573	6.398	6.475	YES	NO	2 lane urban-ish area, 2 ft shoulder

County	RT	BMP	EMP	EDGE	CSRS	Comments
Henry	KY 573	6.475	8.895	NO	NO	2 lane country raod, no shoulder
Henry	KY 573	8.895	13.296	NO	YES	rural road; strips are narrow but deep, somewhat effective
Jefferson	KY 22	0	3.561	YES	YES	mostly 3 lane high traffic; strips are extra wide and deep, extremely effective
Jefferson	KY 22	3.561	4.392	YES	NO	retail area 4 lane, curb
Jefferson	KY 22	4.392	4.615	YES	NO	6 lane divided, congested area with curb
Jefferson	KY 22	4.615	4.974	YES	NO	2 lane country road, small shoulder
Jefferson	KY 22	4.974	5.822	YES	YES	2 lane somewhat residential; strips are wide but old and crumbly, not effective
Jefferson	KY 22	5.822	6.198	YES	YES	new asphalt; extra wide, extra effective strips
Jefferson	KY 22	6.198	6.517	YES	YES	2 lane country road, 2 ft shoulder; strips are wide but very shallow, hardly effective
Jefferson	US 42	0	0.965	NO	NO	3 lane congested area, one way
Jefferson	US 42	0.965	3.89	NO	NO	4 lane retail area, curb
Jefferson	US 42	3.89	4.21	YES	NO	4 lane new asphalt, nice neighborhood
Jefferson	US 42	4.21	5.65	YES	YES	new asphalt, residential area; strips are deep wide and very effective
Jefferson	US 42	5.65	6.428	YES	NO	5 lane business district with curb
Jefferson	US 42	6.428	8.8	YES	YES	4 lane new asphalt; strips are deep, pretty wide, very effective
Jefferson	US 42	8.8	11.835	YES	YES	4 lane older asphalt; strips are deep, wide enough to be effective
Jefferson	US 60	0	2.042	NO	NO	2 lane, parking on both sides
Jefferson	US 60	2.042	4.12	NO	NO	4 lane, congested area, curb
Jefferson	US 60	4.12	6.3	NO	NO	6 lane business district, curb
Jefferson	US 60	6.3	8.06	YES	YES	5 lane high traffic; strips are wide, shallow, barely rumble
Jefferson	US 60	8.06	9.675	YES	YES	5 lane busy retail center; strips are old but wide and effective
Jefferson	US 60	9.675	9.91	YES	NO	5 lane, multiple entrances, wide shoulder
Jefferson	US 60	9.91	10.733	YES	YES	busy retail center; strips are deep, wide and rumbly
Jefferson	US 60	10.733	11.2	YES	NO	5 lane divided, high traffic, full lane for shoulder
Jefferson	US 60	11.2	12.895	YES	YES	busy retail center; strips start well outside edgeline, very effective

County	RT	BMP	EMP	EDGE	CSRS	Comments
Jefferson	US 60	12.895	15.702	YES	YES	4 lane, congested area; strips are weathered but wide and somewhat effective
Jefferson	US 60	15.702	16.473	YES	YES	2 lane plus occasional turn lane; strips are very short but very deep and rumbly
Jefferson	US 60	16.473	17.375	YES	YES	2 lane residential area; strips are spaced and shallow but quite effective
Jefferson	KY 146	0	1.061	YES	NO	4 lane high traffic business center, curb
Jefferson	KY 146	1.061	2.36	YES	YES	2 lane road is somewhat rural; strips are very worn, wide but flat and ineffective
Jefferson	KY 146	2.36	2.738	YES	NO	all curb, retail center
Jefferson	KY 146	2.738	3.56	YES	YES	newer 3 lane, all apartments; strips are in excellent condition
Jefferson	KY 146	3.56	4.27	YES	YES	2 lane road next to RR track; strips are very shallow and far from road, ineffective
Jefferson	KY 146	4.27	5.44	YES	NO	2 lane road, some residential, no shoulder
Jefferson	KY 146	5.44	7.028	YES	YES	2 lane country road; strips are old and but still wide and deep enough to be effective
Jefferson	KY 146	7.028	7.691	YES	YES	4 lane at I 265 interchange; strips are wide but shallow and not very effective
Jefferson	KY 146	7.691	8.335	YES	YES	mostly 3 lane; strips are wide and pretty effective
Jefferson	KY 146	8.335	8.825	YES	YES	busy 2 lane road; strips are deep, wide and effective
Jefferson	KY 155	0	4.257	YES	YES	2 lane road, full lane shoulder; strips are wide and rumbly
Jefferson	KY 155	4.257	6.06	YES	YES	2 lane rural highway, 2 ft shoulder, strips are wide and deep, effective
Jefferson	KY 155	6.06	6.279	YES	YES	4 lane raised median, full lane shoulder; strips are deep, wide very rumbly
Jefferson	KY 155	6.279	6.889	YES	YES	4 lane new asphalt; strips are new and extemely effective
Jefferson	KY 155	6.889	7.619	YES	YES	2 lane older road; strips are wide but very worn, ineffective
Jefferson	KY 155	7.619	8.185	YES	NO	new road surface 2-3 ft shoulder
Jefferson	KY 155	8.185	8.268	YES	YES	2 lane narrow shoulder; strips are old but wide and effective
Jefferson	KY 155	8.268	9.35	YES	NO	2 lane sparsely populated area, curb
Jefferson	KY 155	9.35	10.255	YES	NO	4 lane, multiple entrances, curb
Jefferson	KY 155	10.255	13.16	YES	YES	5 lane full lane shoulder; strips are wide but shallow, still slightly effective
Jefferson	KY 155	13.16	16.541	YES	NO	4 lane with raised median, retail center
Jefferson	KY 913	0	0.347	YES	NO	3 lane road, no shoulder

County	RT	BMP	EMP	EDGE	CSRS	Comments
Jefferson	KY 913	0.347	1.812	YES	NO	4 lane with raised median, curb
Jefferson	KY 913	1.812	2.263	YES	NO	6 lane with raised median, curb
Jefferson	KY 913	2.263	2.945	YES	YES	4 lanes, raised median; strips limited to patches just before large interchange
Jefferson	KY 913	2.945	3.261	YES	NO	4 lane, raised median, curb
Jefferson	KY 1447	0	2.002	YES	NO	2 lane business district with curb
Jefferson	KY 1447	2.002	2.574	YES	NO	5 lane residential area with curb
Jefferson	KY 1447	2.574	5.094	YES	YES	2 lane rural road with 2 ft shoulder; strips are crumbly but wide and effective
Jefferson	KY 1447	5.094	6.08	YES	NO	5 lane high traffic area with curb
Jefferson	KY 1447	6.08	7.461	YES	YES	4 lane road with raised median; strips are worn but wide and rumbly
Jefferson	KY 1447	7.461	9.242	YES	YES	2 lane country road, 1-2 ft shoulder; strips are wide and mostly effective
Jefferson	KY 1531	0		NO	NO	character of road is consistant from beginning to end
Jefferson	KY 1531		12.656	NO	NO	narrow, country road, no edgeline, no strips
Jefferson	KY 1819	0	5.21	YES	NO	2 lane rural road, no shoulder
Jefferson	KY 1819	5.21	6.01	YES	YES	road widens, more driveways; strips are narrow, outside edgeline, but effective
Jefferson	KY 1819	6.01	9.12	YES	YES	2 lane residential area; strips are in excellent condition, very effective
Jefferson	KY 1819	9.12	9.737	YES	NO	wide 3 lane road, retail center, curb
Jefferson	KY 1819	9.737	10.13	YES	YES	still 3 lanes, less congested; short strips are worn, only slightly effective
Jefferson	KY 1819	10.13	10.95	YES	YES	3 lane road 35 mph zone; strips are extremely effective
Jefferson	KY 1819	10.95	12.572	YES	YES	2 lane residential area; strips are old but still effective
Jefferson	KY 1819	12.572	12.96	YES	NO	4 lane with raised median, curb
Jefferson	KY 1819	12.96	13.833	YES	YES	2 lane residential area; strips are very short, but deep and rumbly when driven on
Jefferson	KY 1819	13.833	14.13	YES	YES	2 lane road leaving busy retail; strips are mostly broken off with edge of road
Jefferson	KY 1932	0	2.864	YES	NO	5 lane, mostly residential area with curb
Jefferson	KY 1932	2.864	3.398	YES	NO	5 lane retail area with curb
Jefferson	KY 1932	3.398	4.743	YES	NO	4 lane mostly residential, I 264 interchange, curb

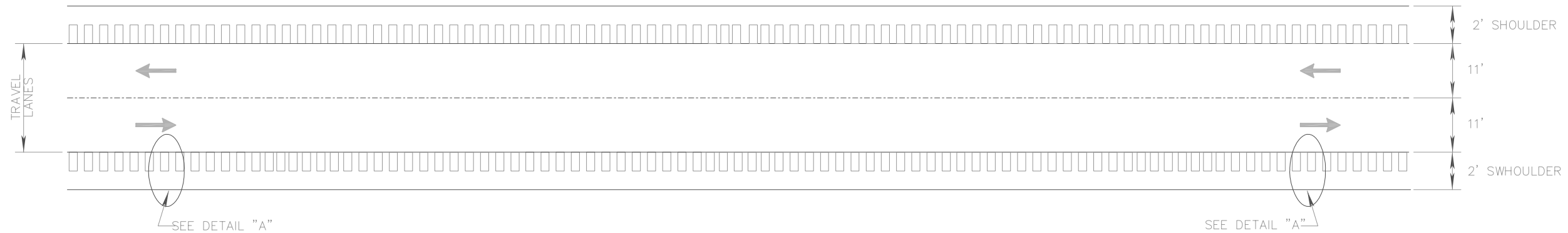
County	RT	BMP	EMP	EDGE	CSRS	Comments
Jefferson	KY 1932	4.743	5.234	YES	NO	2 lane neighborhood street, no shoulder
Jefferson	KY 1932	5.234	5.573	YES	NO	crowded retail area, mostly with curb, very high traffic
Jefferson	KY 1932	5.573	6.59	YES	NO	newly paved 2 lane neighborhood road, narrow shoulder
Oldham	KY 22	0	2.33	YES	YES	2 lane rural road, added shoulder; strips are barely visible, very ineffective
Oldham	KY 22	2.33	3.241	YES	YES	2 lane rural road; strips are outside edgeline, narrow but effective
Oldham	KY 22	3.241	3.377	YES	NO	2 lane urban center, multiple entrances
Oldham	KY 22	3.377	4.011	YES	YES	2 lane freshly paved; strips are wide but shallow, still mostly effective
Oldham	KY 22	4.011	4.91	YES	YES	rural residential area; strips are overgrown in places but deep and effective
Oldham	KY 22	4.91	7.61	YES	YES	2 lane rural highway; strips are wide but shallow, only somewhat effective
Oldham	KY 22	7.61	11.058	YES	YES	2 lane rural highway, older pavement; strips are excellent
Oldham	KY 22	11.058	11.569	YES	NO	somewhat congested residential area, new asphalt
Oldham	KY 22	11.569	12.12	YES	YES	2 lane country road; strips are wide enough, deep enough, effective
Oldham	KY 22	12.12	14.509	YES	YES	2 lane country road; strips are wide enough, very deep, very effective
Oldham	US 42	0	1.848	YES	NO	2 lane rural road, older asphalt, 2 ft shoulder
Oldham	US 42	1.848	5.865	YES	NO	wide 2 lane rural highway, 2-3 ft shoulder
Oldham	US 42	5.865	6.162	YES	NO	scenic byway, asphalt old but good condition, narrow shoulder
Oldham	US 42	6.162	8.735	YES	YES	narrow 2 lane road; strips are overgrown in places, very worn, barely effective
Oldham	US 42	8.735	13.096	YES	YES	2 lane country road; strips are old but wide and deep, effective
Oldham	US 42	13.096	16.115	YES	YES	2 lane relatively congested area; strips are wide and very deep, very effective
Oldham	US 42	16.115	19.221	YES	YES	rural 2 lane road; strips are old and worn but still somewhat effective
Oldham	KY 53	0	2.335	YES	YES	2 lane rural highway; strips are worn, narrow not very effective
Oldham	KY 53	2.335	3.005	YES	YES	2 lane rural road with occasional residence; strips are wide but worn, sllightly effective
Oldham	KY 53	3.005	3.081	YES	NO	2 lane country road, fresh asphalt, no strips
Oldham	KY 53	3.081	5.706	YES	YES	2 lane rural highway newly paved; strips are narrow but deep and very effective
Oldham	KY 53	5.706	6.094	YES	NO	5 lane busy retail/industrial area, curb

County	RT	BMP	EMP	EDGE	CSRS	Comments
Oldham	KY 53	6.094	7.03	NO	NO	4 lane downtown area with curb
Oldham	KY 53	7.03	7.41	YES	NO	2 lane residential, full lane shoulder for parking on both sides
Oldham	KY 53	7.41	10.62	YES	YES	2 lane rural highway; strips are old but wide and deep enough to be mostly effective
Oldham	KY 146	0	2.361	YES	YES	2 lane alongside RR track; strips look new, deep and wide enough to be very effective
Oldham	KY 146	2.361	2.642	YES	YES	2 lane busy urban area; strips are very wide, deep enough to rumble
Oldham	KY 146	2.642	2.847	YES	NO	3 lane retail area, busy traffic, curb
Oldham	KY 146	2.847	4.363	YES	YES	2 lane more rural; strips are new and very effective
Oldham	KY 146	4.363	7.015	YES	YES	2 lane rural highway; strips are narrow but deep and effective
Oldham	KY 146	7.015	7.419	YES	NO	2 lane, some businesses, wide shoulder
Oldham	KY 146	7.419	9.472	YES	YES	2 lane country road; strips are new and very effective
Oldham	KY 146	9.472	9.784	YES	NO	mostly 2 lane, occasional turn lane, rural residential
Oldham	KY 146	9.784	10.487	YES	YES	2 lane rural residential area; strips are old and worn but still deep and mostly effective
Oldham	KY 146	10.487	11.254	YES	NO	urban center, full lane shoulder for parking on both sides
Oldham	KY 146	11.254	11.45	YES	NO	2 lane industrial area, multiple entrances
Oldham	KY 146	11.45	14.813	YES	YES	2 lane rural highway; strips are narrow but deep and effective
Oldham	KY 329	0	0.5	YES	YES	2 lane rural road, narrow shoulder; strips are worn but wide and somewhat effective
Oldham	KY 329	0.5	5.2	YES	YES	2 lane rural road, narrow shoulder; strips are narrow and very worn, ineffective
Oldham	KY 329	5.2	6.4	YES	YES	2 lane freshly paved; new strips are wide and deep, very effective
Oldham	KY 329	6.4	7.226	YES	YES	residential area, new asphalt, I 71 ramp; strips are in excellent condition
Oldham	KY 329	7.226	7.426	YES	NO	busy 2 lane rural highway, 2 ft shoulder
Oldham	KY 329	7.426	8.935	YES	YES	wide 2 lane road, high traffic; strips are wide but very worn, ineffective
Oldham	KY 362	0	0.975	NO	NO	2 lane rural area, high traffic
Oldham	KY 362	0.975	1.416	YES	YES	2 lane rural road, new asphalt; strips are wide enough, shallow, but effective
Oldham	KY 362	1.416	3.039	NO	YES	narrow 2 lane, no shoulder; wide strips are shallow, only somewhat effective
Oldham	KY 393	0	2.562	NO	NO	2 lane narrow country road

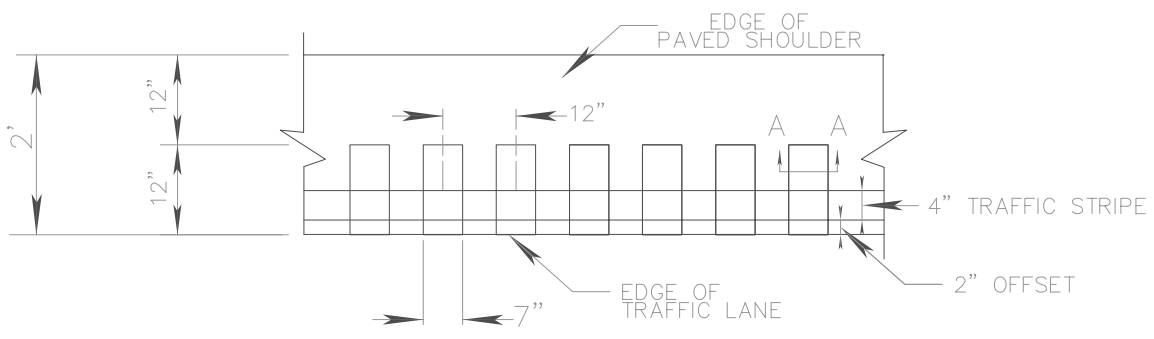
County	RT	BMP	EMP	EDGE	CSRS	Comments
Oldham	KY 393	2.562	3.961	YES	YES	newly paved 2 lane country road
Oldham	KY 393	3.961	4.762	YES	YES	2 lane rural road with older asphalt; strips are on edge of road, somewhat effective
Oldham	KY 393	4.762	5.45	YES	YES	wide 2 lane road, interstate ramp; strips are wide and deep, very effective
Oldham	KY 393	5.45	5.69	YES	YES	2 lane country road in good condition; strips are crumbly and mostly ineffective
Oldham	KY 393	5.69	6.993	YES	NO	2 lane urban area, wide lanes wide shoulder
Oldham	KY 393	6.993	10.572	YES	YES	2 lane rural area; strips are narrow and very worn and crumbly, very ineffective
Oldham	KY 524	0	0.356	YES	NO	2 lane curvy country road
Oldham	KY 524	0.356	0.956	YES	YES	freshly paved 2 lane curvy country road
Oldham	KY 524	0.956	3.419	YES	NO	2 lane rural residential area
Oldham	KY 524	3.419	3.849	YES	NO	2 lane neighborhood road, multiple entrances
Oldham	KY 524	3.849	5.413	NO	YES	narrow 2 lane road; strips are very narrow, some over edge, very ineffective
Oldham	KY 524	9.341	12.148	NO	NO	narrow country 2 lane road

Appendix B

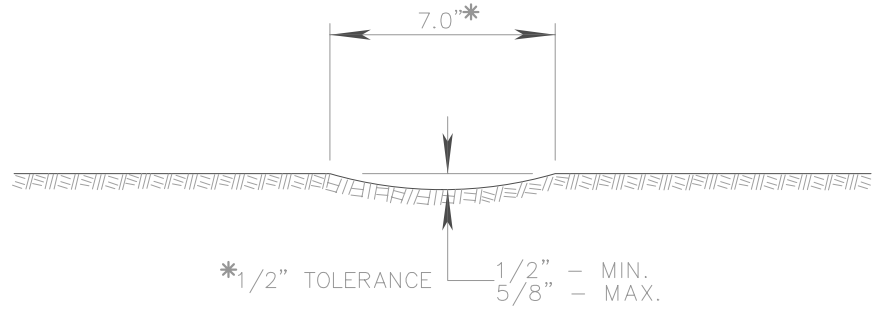
Rumble Stripe Detail



PLAN VIEW



DETAIL "A"



SECTION "A–A"

GENERAL NOTES

1. SAWED RUMBLE STRIPES SHALL BE APPLIED ON LEFT AND RIGHT SHOULDERS OF ALL PAVED SHOULDERS ON THIS PROJECT
2. SAWED RUMBLE STRIPES SHALL BE OMITTED ACROSS PRINCIPAL INTERSECTING ROADWAYS OR OTHER INTERRUPTIONS IN NORMAL SHOULDER WIDTH AS DIRECTED BY THE ENGINEER
3. COST TO BE PAID FOR USING APPROPRIATE PAY ITEMS
4. SAWED RUMBLE STRIPES SHALL BE APPLIED TO MAINLINE ONLY.

SAWED RUMBLE STRIPE

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