US Experience with Centerline Rumble Strips on Two-Lane Roads: Pattern Research and North American Usage

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ABSTRACT

Shoulder rumble strips are widely used throughout the United States (US), including Kansas. However, Kansas has several miles of two-lane highway with no shoulder. These highways have a number of single vehicle run-of-the-road crashes and crashes from cars going across the centerline and colliding with on-coming vehicles. Some US states have been experimenting with centerline rumble strips. The Kansas Department of Transportation (KDOT) wishes to install and evaluate several miles of centerline rumble strips (CLRS) and contracted with Kansas State University (KSU) to survey other states and summarize their experience, select the best rumble strip pattern and to develop a research design to evaluate KDOT field test installations. The paper will summarize the findings from a nationwide survey. It will describe the study to select the best rumble strip pattern. The field installation and research design to evaluate driver reaction and motorist acceptance will also be presented.

Key words: centerline rumble strips—mitigating cross over crashes—rumble strips
INTRODUCTION

Modeled after shoulder rumble strips, centerline rumble strips are placed between opposing lanes of traffic to alert drivers that they have crossed over into the path of oncoming traffic. The purpose of this research is to determine which rumble strip pattern will be most effective at accomplishing this task, determine driver reaction and motorist acceptance and, long term, determine whether these centerline rumble strips will indeed reduce the number of crossover accidents in the locations where they are installed.

The purpose of rumble strips is to provide motorists with an audible and tactile warning that their vehicle is approaching a decision point of critical importance to safety or that their vehicle has partially or completely left the road or their lane. Rumble strips can be installed either on the traveled surface of the roadway or the roadway shoulder. Rumble strips placed on the traveled surface are warning devices intended to alert drivers to the possible need to take some action (1).

CURRENT STATUS

The use of rumble strips on shoulder highways to warn drivers that they are leaving (or have left) the traveled surface is becoming increasingly popular. Today shoulder rumble strips are being used on rural and urban highways throughout the United States (US) as a method to reduce drift-off-the-roadway accidents, and their effectiveness has produced as high as a 60 percent reduction for these types of accidents in some installations (2).

The study covered in this paper is still in progress and the authors are currently updating a survey of North American states and provinces but have not synthesized the results as the data collection phase is still in progress. Also, the Kansas test sections, originally scheduled to be completed in 2001, have only recently been completed (July 2003). Thus, this paper can cover only the testing and analysis of the Kansas test patterns, a brief summary of a published report of a Colorado DOT study, controversy over CLRS in Colorado, their status in Canada and methodology to be used to evaluate the recently completed Kansas test sections.

INITIAL NORTH AMERICAN SURVEY

Initially, a phone survey was conducted in the Fall of 1999 of the DOT of various states with centerline rumble strips (CLRS) in place. The states involved in this survey were Colorado, Arizona, California, Pennsylvania, Oregon, and Washington. Its purpose was to accumulate and analyze data regarding the types and dimensions of centerline rumble strips being installed in these locations and any problems or concerns they raised. This was followed by a more formal survey that was sent to all 50 states and all Canadian provinces. This survey was written to address the following questions:

- Are centerline rumble strips in use?
- How were they constructed (milled or rolled)?
- What are their dimensions? (width, length, depth)
- What pattern type was chosen?
- Are they located in all zones or only in double yellow ‘no passing’ zones?
• How long have they been in use?
• Has any data been gathered?
• What type of research was conducted on that data?
• What were the results?

This survey produced 23 responses. Florida, Michigan, South Dakota, New Hampshire, Virginia, North Carolina, Missouri, Illinois, New York, Indiana, Texas, Wisconsin, Utah, and Nova Scotia, Canada, all were either considering installations or asked for additional information and results. California, Oregon, Massachusetts, Washington, Arizona, Colorado, Connecticut, Pennsylvania, and Alberta, Canada, responded that they had centerline rumbles strips installed at various locations. This information can be seen in Table 1.

**TABLE 1. Various Other States’ Milled Centerline Rumble Strips**

<table>
<thead>
<tr>
<th>State</th>
<th>Width</th>
<th>Length</th>
<th>Depth</th>
<th>Spacing Between Strips</th>
<th>All Zones or No Pass Only</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>California</td>
<td>6.5”</td>
<td>16”</td>
<td>0.5”</td>
<td>Continuous 24”</td>
<td>No Pass Only</td>
<td>Used with raised thermoplastic striping and reflectors</td>
</tr>
<tr>
<td></td>
<td>6.5”</td>
<td>16”</td>
<td>0.5”</td>
<td>Continuous 12”</td>
<td>No Pass Only</td>
<td>Markings installed over strips</td>
</tr>
<tr>
<td></td>
<td>6.5”</td>
<td>16”</td>
<td>0.5”</td>
<td>Continuous 24”</td>
<td>No Pass Only</td>
<td>Markings installed over strips</td>
</tr>
<tr>
<td>Washington</td>
<td>7”</td>
<td>16”</td>
<td>0.63”</td>
<td>Continuous 12”</td>
<td>No Pass Only</td>
<td>Used with 4’ median</td>
</tr>
<tr>
<td>Oregon</td>
<td>6.5”</td>
<td>12”</td>
<td>0.5”</td>
<td>Continuous 12”</td>
<td>All Zones</td>
<td>Markings installed over strips</td>
</tr>
<tr>
<td>Arizona</td>
<td>6.5”</td>
<td>8”</td>
<td>0.5”</td>
<td>Continuous 12”</td>
<td>All Zones</td>
<td>Narrower to reduce residential noise</td>
</tr>
<tr>
<td></td>
<td>6.5”</td>
<td>5”</td>
<td>0.5”</td>
<td>Continuous 12”</td>
<td>All Zones</td>
<td>Narrower to reduce residential noise</td>
</tr>
<tr>
<td>Massachusetts</td>
<td>6.5”</td>
<td>18”</td>
<td>0.5”</td>
<td>Continuous 12”</td>
<td>No Pass Only</td>
<td>Markings installed over strips</td>
</tr>
<tr>
<td>Pennsylvania</td>
<td>6.5”</td>
<td>30”</td>
<td>0.5”</td>
<td>Alternating 24 &amp; 48”</td>
<td>No Pass Only</td>
<td>Across centerlines - 12’ lanes</td>
</tr>
<tr>
<td></td>
<td>6.5”</td>
<td>16”</td>
<td>0.5”</td>
<td>Alternating 24 &amp; 48”</td>
<td>No Pass Only</td>
<td>Outside centerlines - 12’ lanes</td>
</tr>
<tr>
<td></td>
<td>6.5”</td>
<td>16”</td>
<td>0.5”</td>
<td>Alternating 24 &amp; 48”</td>
<td>No Pass Only</td>
<td>Between centerlines - 12’ lanes</td>
</tr>
<tr>
<td></td>
<td>6.5”</td>
<td>18”</td>
<td>0.5”</td>
<td>Alternating 24 &amp; 48”</td>
<td>No Pass Only</td>
<td>Across centerlines - 11’ lanes</td>
</tr>
<tr>
<td></td>
<td>6.5”</td>
<td>10”</td>
<td>0.5”</td>
<td>Alternating 24 &amp; 48”</td>
<td>No Pass Only</td>
<td>Outside centerlines - 11’ lanes</td>
</tr>
<tr>
<td></td>
<td>6.5”</td>
<td>12”</td>
<td>0.5”</td>
<td>Alternating 24 &amp; 48”</td>
<td>No Pass Only</td>
<td>Between centerlines - 11’ lanes</td>
</tr>
<tr>
<td>Colorado</td>
<td>6.5”</td>
<td>12”</td>
<td>0.5”</td>
<td>Continuous 12”</td>
<td>All Zones</td>
<td>Markings installed over strips</td>
</tr>
<tr>
<td>Connecticut</td>
<td>6.5”</td>
<td>16”</td>
<td>0.5”</td>
<td>Continuous 12”</td>
<td>No Pass Only</td>
<td>Markings installed over strips</td>
</tr>
<tr>
<td>Alberta, Canada</td>
<td>6.5”</td>
<td>12”</td>
<td>0.5”</td>
<td>Continuous 12”</td>
<td>All Zones</td>
<td>Markings installed over strips</td>
</tr>
</tbody>
</table>

Note:
Width - represents dimension parallel to travel surface
Length - represents dimension perpendicular to travel surface

Since the above survey, the Colorado DOT published a report on 17 miles of CLRS that were installed in 1996 on a winding, two-lane mountain highway for evaluation. (3) The report stated:

“Comparison of traffic records for similar 44-month periods before and after the installation showed the following:

• Head-on accidents decreased from 18 to 14.
• Sideswipe from opposite directions decreased from 24 to 18.
• Average daily traffic (ADT) increased from 4007 in 1992 to 5661 in 1999.

• Average ADT for the 44-month period before construction was 4628, for the same time span and the same months after construction it was 5463.”

Also, positive comments were received from the public, and during the four-year evaluation, no adverse pavement deterioration was noted.

The report went on to “highly recommend” using CLRS in areas where that “have a history” of head-on and sideswipe accidents.

This Colorado report is not without controversy. A study of the same data by a University graduate student came to a different conclusion. (Davis, V., unpublished data). Mr. Davis concluded, “Because the data fails to show a statistically significant reduction in crossover accidents for the two time periods future installation of centerline rumble strips based on this data would not be justified.”

Also, various bicycle advocates in Colorado are opposed to CLRS on two-lane, mountain roads with no shoulders. According to Bicycle Colorado (2002) (info@bicyclecolo.org, unpublished data) they cite the Davis study and claim 400 letters opposed the planned milling of CLRS on two Canyon roads.

Other states are going forward with studies of CLRS. New York, for example, plans “Centerline Audible Roadway Delineator” test installations in each of the state’s regions. (Bray J., unpublished data) It should be pointed out that New York, as in most states, will use them only in no passing zones, i.e., “where opposing traffic is separated by a double yellow line.”

In Canada, the only province using any CLRS is Alberta. In a recent Transportation Association of Canada (TAC), Synthesis of Practice Report (2001). (4) The report summarized the testing in Alberta as follows:

“Testing in Alberta has found that many motorists encroach on the centreline of the road and this has resulted in complaints from nearby residents of the excessive noise. Testing of various depths of milled-in rumble strips, retaining the same length and spacing of strips, using three different vehicle types (tractor trailer, pick-up truck, and motorcycle) was completed. For centerline rumble strips, the testing led to the recommendation that rumble strips be at least 8 mm (0.2 inches) deep and 300 mm (7.5 inches) wide. Motorcycles encountered no adverse handling conditions when riding on or over the rumble strips except for braking, which was not an issue since it was unlikely that deceleration would occur entirely within the rumble strip zone. Where significant heavy vehicle use was encountered, a 500 mm (12.05 inches) wide rumble strip created more significant noise and vibration in the cab of a tractor-trailer.”

The report recommended the following design dimensions. (4)

- The following design dimensions for continuous milled-in centerline rumble strips are appropriate:
  - Strip Shape: Rounded
  - Strip Width: 300 mm (7.5 inches), within painted lines
  - Spacing Between Strips: 300 mm (7.5 inches)
  - Strip Depth: 8 ±2 mm (0.2 ± .05 inches)
  - Strip Length: 175 ±25 mm (4.4 ± .6 inches)
KANSAS PATTERN TESTS

After compiling and analyzing the results of these surveys, it became apparent that there was no standard in the types and dimensions of rumble strips being used and tested. Members of the KSU research team then drafted a proposal for centerline rumble strip testing in the state of Kansas. This proposal called for the evaluation of three different patterns (continuous 12 inches on center, continuous 24 inches on center, and alternating 12 & 24 inches on center) consisting of four different widths each (5, 8, 12, and 16 inches), for a total of 12 test patterns (see Figures 1, 2 and 3). Decibel (dB) and steering wheel vibration (g) levels would then be recorded at the driver’s position during a series of tests at various speeds utilizing multiple vehicle types. This testing would attempt to validate an optimum pattern for centerline rumble strip installations in the state of Kansas.

**FIGURE 1. Kansas Blueprint of Continuous 12 Inches on Center Pattern**

**FIGURE 2. Kansas Blueprint of Continuous 24 Inches on Center Pattern**
The Kansas centerline rumble strip test patterns were installed in May 2000 on the southbound lane of Interstate 135 approximately 8 miles south of Salina, Kansas (see Figure 4). The rumble strips were installed in such a way that the general driving public would not contact them under normal driving circumstances.

The vehicle tests were conducted using seven vehicles. The seven vehicles consisted of: two large trucks (a 1996 International Harvester 4900 DT 466 dump truck and a 1995 Ford L8000 dump truck), a full-size pickup truck (1991 Chevrolet 2500), a full-size passenger car (1993 Pontiac Bonneville), a compact passenger car (1994 Ford Escort Wagon), a minivan (1995 Ford Aerostar), and a sport utility vehicle (1997 Jeep Cherokee). The vehicles negotiated the rumble strips in such a manner that the driver’s side wheels made contact with the rumble strips.

**Interior Noise Level And Steering Wheel Vibration Testing**
Testing at this site would consist of both interior noise level testing and steering wheel vibration testing. These are tested because sound and touch are the two senses that the rumble strips alert when the driver’s visual senses become impaired (falling asleep, becoming distracted, etc.).

Interior noise level testing was conducted by measuring the noise levels generated by the rumble strips as the vehicles passed over each test section. The data was recorded using a Quest Technologies Model Q-300 dosimeter, with a remote microphone clipped to the driver’s collar just below the right ear (see Figure 5). This meter operates at 32 samples per second, and displays the highest decibel reading taken during any one-second period. While the tests were conducted, the climate control system, radio, and any other noise-producing sources were turned off, and the windows were rolled up, to eliminate as much background noise as possible. A video camera was used to record the noise levels on the dosimeter as the vehicle passed over the test strips. This data was then transcribed from the videotape, analyzed to locate the proper test strip intervals, and then entered into Microsoft Excel for evaluation. Each vehicle negotiated the rumble strips at 60 mph. This speed was chosen because it is the current speed limit on many of the rural two-lane highways in Kansas.

![Figure 5. Quest Technologies Q-300 Noise Dosimeter and External Microphone](image)

**Results Of Noise Tests**

The decibel level average and standard deviation for each vehicle over each test section at 60 mph and 30 mph were calculated. The data was then analyzed for trends. Looked at were trends by pattern type and by rumble strip length. The results showed a trend in pattern type at both 60 mph and 30 mph. Among all of the vehicles tested, the continuous 12 inches on center pattern produced the highest average decibel levels, followed by the alternating 12 & 24 inches on center pattern and finally the continuous 24 inches on center pattern produced the lowest average decibel levels. Further analysis shows that over a given distance, the continuous 12 inches on center pattern has the greatest number of rumble strip indentations, followed by the alternating 12 & 24 inches on center pattern, and finally the continuous 24 inches on center pattern, which has the fewest indentations. Thus, it can be theorized that patterns with higher densities of rumble strip indentations produce higher average decibel levels. As for trends in decibel levels due to rumble strip length, it does appear that the longer rumble strips do generally produce higher average decibel levels, but there is no consistency among the longer lengths. This could be explained as a result of the vehicle tires not remaining in full contact with the shorter rumble strip patterns.
Steering Wheel Vibration Tests

Steering wheel vibration testing was conducted by measuring the vibration levels in the steering wheel of each vehicle that was generated by the rumble strips as the vehicles passed over each test section at 60 mph. The data was recorded using a MicroDAQ Model SA-600 accelerometer, which was firmly attached to the steering wheel of the vehicle by duct tape (see Figure 6). This accelerometer simultaneously samples and internally records the peak acceleration levels on all three axes (X, Y, and Z) at a rate of 4 readings per second. The accelerometer was controlled by MicroDAQ proprietary software by a laptop computer via the serial port. This data stored after each vehicle trial was then downloaded directly to Microsoft Excel for analysis. During testing, the drivers were instructed to maintain as minimal contact with the steering wheel as safely possible, so that the dampening effects caused by touching the steering wheel would be minimized.

![MicroDAQ SA-600 3-Axis Accelerometer](image)

FIGURE 6. MicroDAQ SA-600 3-Axis Accelerometer

The alternating 12 & 24 inches on center pattern produced the highest average vibration levels in four of the six remaining vehicles (the 1996 IH 4900 DT 466 Dump Truck removed from analysis) and the second highest average levels in the other two. Conversely, the continuous 24 inches on center pattern had none of the highest vibration levels, and only produced the second highest in two of the six. Thus, the highest overall vibration was produced by the alternating 12 & 24 inches on center pattern, followed by the continuous 12 inches on center pattern, and lowest were produced by the continuous 24 inches on center pattern.

Patterns Selected

Based on the results of the tests conducted, two patterns were chosen for further testing in an actual highway setting, pattern 4 (continuous 12 inches on center, 12 inches long) and pattern 6 (alternating 12 & 24 inches on center, 12 inches long) (see Figures 1 and 2). A section of each pattern was recently installed on a two-lane Kansas highway. Further testing will be conducted throughout the summer and fall of 2003.
FIELD ANALYSIS PLAN

The Kansas Department of Transportation (KDOT) recently installed approximately 50 miles of these two patterns of centerline rumble strips on a two-lane rural highway in June 2003. The Kansas State University (KSU) research team will evaluate motorist reaction, public opinion, study such things as vehicle positioning before and after, and observe drivers actions.

The KSU research team will observe and videotape vehicle positioning as the vehicles travel over tangent and curved sections of the highway where the CLRS have been constructed and compare them with similar sections without CLRS. The KSU research team will set up an interview station and hand out a stamped, self-address questionnaire to approximately 500 drivers. The questionnaire is shown on the next page (see Figure 7).

1. How often do you travel this section of highway? _ daily _ 2-3 times per week _ weekly _ monthly _ seldom
2. Type of vehicle: _ passenger car _ van _ SUV _ large truck _ pickup _ motorcycle _ RV _ other (specify) _____________________
3. Did your tires make contact with the centerline rumble strips? _ continuous pattern _ alternating pattern _ both patterns _ neither
   **** IF YOU SELECTED “neither” ON #3, PLEASE SKIP QUESTIONS 4 - 6 ****
4. Which patterns do you feel were adequately loud to gain your attention? _ continuous pattern _ alternating pattern _ both patterns _ neither
5. Which patterns do you feel adequately vibrated the steering wheel? _ continuous pattern _ alternating pattern _ both patterns _ neither
6. Overall which patterns of rumble strips would you recommend be installed? _ continuous pattern _ alternating pattern _ both patterns _ neither
7. Have you ever fallen asleep or dozed off while driving a vehicle? _ no _ yes, once or twice _ yes, infrequently _ yes, frequently
   If “yes”, what woke you up? ________________________________
8. Do you think centerline rumble strips will reduce accidents? _ yes _ no
   COMMENTS__________________________________________________
   NAME/ADDRESS________________________________________________________________________

FIGURE 7. Questions for Drivers During Field Analysis

CONCLUSIONS

CLRS appear to have the potential of reducing risk of certain types of accidents on two-lane, rural roads. However, their actual benefit has yet to be proven and they are not without controversy. Several states are considering their use but are being cautious and waiting for the results of additional studies.
ACKNOWLEDGEMENTS

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