Synthesis of Practices for the Implementation of Centreline Rumble Strips

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Abstract

In North America, agencies are applying rumble strips along the centrelines of undivided two-way roads to reduce crossover collisions. This practice appears to be limited due to a lack of published knowledge regarding design practices, site selection for installation, expected benefits, and possible difficulties. In addition, there are no national guidelines in North America for the installation of centreline rumble strips (CLRS).

In Canada, three provinces (Alberta, Saskatchewan, and British Columbia) have implemented centreline rumble strips. In the United States, according to a survey conducted in 2003, 20 states have installed CLRS, and 18 states are considering installations.

The Transportation Association of Canada (TAC) Synthesis of Best Practices for the Implementation of Shoulder and Centreline Rumble Strips (2001) includes discussion of the initial benefits of CLRS and early knowledge of their implementation; additional information has become available since.

iTRANS was commissioned by TAC to perform a technical review of recent CLRS research and current practices for CLRS implementation. The objective of the project is to prepare a synthesis of current practices, and recommend implementation guidelines. This project is in the process of national approval by the TAC Chief Engineers' Council which represents the jurisdictional membership.

This paper summarizes the characteristics of current centreline rumble strip applications in Canada and internationally. A discussion of the safety effectiveness and potential concerns, such as maintenance and driver behaviour, as identified in current literature. Recommendations for the installation of CLRS are provided.

Introduction

Rumble strips are raised or grooved patterns installed on the road surface to provide both an audible warning (rumbling sound) and a physical vibration to alert drivers; longitudinal (shoulder and centreline) rumble strips are intended to alert drivers that they are leaving the travel lane. In addition to providing a warning to drivers, rumble strips may help drivers maintain the travel lane during inclement weather when visibility is poor (1).

Shoulder rumble strips have proven to be very effective in warning motorists that they are about to drive off the road. Many studies have also shown a very high benefit-to-cost (B/C) ratio for shoulder rumble strips (SRS), making them among the most cost-effective safety treatments available (1).

Centreline rumble strips are similar to shoulder rumble strips in design and intent. Centreline rumble strips (CLRS) are applied along the centre of undivided roadways. The target collision types for CLRS are head-on and opposite-direction sideswipe collisions due to inattentive

drivers. Run-off-road-left collisions may be considered as a secondary target collision type, particularly if shoulder rumble strips are not present.

The following sections summarize current applications of CLRS in Canada and internationally. This is followed by a discussion of common issues related to rumble strips, such as maintenance and driver behaviour.

Current Applications

In North America, agencies are applying rumble strips along the centrelines of undivided two-way roads to reduce crossover collisions. However, this practice appears to be constrained due to a lack of published knowledge regarding design practices, site selection for installation, expected benefits, and possible detriments.

As defined in the Transportation Association of Canada (TAC) Best Practices for the Implementation of Shoulder and Centreline Rumble Strips (2), the terminology used in this paper for centreline rumble strip dimensions and design parameters is illustrated in Figure 1.

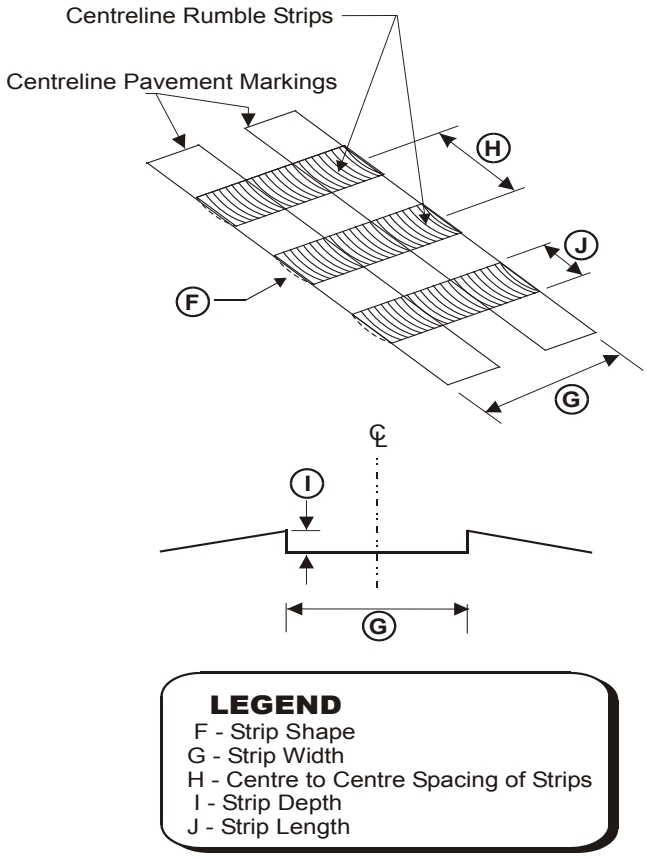

Figure 1: Centreline Rumble Strip Terminology

In Canada, three provinces (Alberta, Saskatchewan, and British Columbia) and Parks Canada have implemented CLRS. Their practices are summarized below.

Current Applications: Alberta

In Alberta, CLRS are installed only in no passing zones on rural two-lane highways with a posted speed of 100 km/h (design speed of 110 km/h) (Figure 2). Locations are usually selected based on a pattern of collisions related to horizontal curvature and/or passing in a no passing zone (e.g., three or more related collisions in the last five years).

Figure 2: Milled centreline rumble strips in Alberta (Photo: Dr. John Morrall)

In 1999, the province developed installation criteria for centreline rumble strips to be installed on highway segments with the following characteristics (3):

- Selected horizontal curves on undivided highways that have a history of collisions that could be reduced through the use of additional guidance to assist drivers in keeping within the designated lanes
- All horizontal curves of undivided highways where there are double-barrier lines (no passing in both directions)
- All double-barrier lines at no passing zones of climbing lanes or passing lanes
- All double-barrier lines at no passing zones at tangent sections where the length is greater than 300 m

Centreline rumble strips are not installed within 200 m (650 ft) of residences. In addition, short sections of double-barrier centrelines in advance of intersections do not require rumble strips if they are on tangent (straight alignment). Temporary warning signs are installed for six to twelve months after construction to advise motorists of the installation of a new traffic control device (i.e., CLRS) (4) (Figure 3).

In Alberta, milled rumble strips are installed at the centreline, with a width of 300 mm (12 inch), a length of 150 to 200 mm (6 to 8 inch), in a round shape with a depth of 7 ± 2 mm (0.28 to 0.35 inch). Rumble strips are spaced 300 mm (12 inch) apart in a continuous pattern, measured from centre to centre (4, 5, 6). The presence of SRS does not influence site selection process for the installation of CLRS in Alberta (4).

Figure 3: Temporary warning sign installed in Alberta

Current Applications: Saskatchewan

In Saskatchewan, CLRS are a relatively new practice. Guidelines, policies, or warrants regarding the installation of CLRS in general situations have not been developed to date in Saskatchewan. In 2001, CLRS were installed as a pilot project at a location that experienced a high frequency of head-on collisions in response to concerns of local residents (7).

Centreline rumbles strips have also been installed in Saskatchewan on undivided two-lane to divided four-lane transitions, specifically on the two-lane section approaching the transition. The CLRS start approximately where a "No Passing" sign is located and end at the gore point where the rumble strips become like shoulder rumble strips (SRS) (7).

In Saskatchewan, milled centreline rumble strips are installed directly on top of the pavement markings, with a width of 100 mm (4 inch), a length of 150 mm (6 inch), in a round shape with a depth of 8 to 12 mm (0.3 to 0.5 inch). Rumble strips are spaced 150 to 175 mm (6 to 7 inch) measured from edge to edge, or 250 to 275 mm (9.8 to 10.8 inch) measured from centre to centre. At 2- to 4-lane transitions, centreline rumble strips have similar dimensions, except they are wider (300 mm, 12 inch), and are spaced 150 to 175 mm edge to edge, or 300 to 325 mm (11.8 to 12.8 inch) centre to centre (7).

Current Applications: British Columbia

In British Columbia, a recent Technical Bulletin (DS04002) (8) states that centreline rumble strips should be considered on undivided rural two-lane, three-lane, or four-lane highways in no passing zones (i.e., a double solid painted centreline) in the following three scenarios:

1. New highway sections
2. When re-paving, rehabilitating, or reconstructing existing undivided rural two-, three- or four-lane highway sections
3. Other undivided rural two-, three-, or four-lane highway sections that are not part of a project but would benefit from the installation of CLRS (to decrease the frequency of crossover centreline collisions)

The B.C. Technical Bulletin continues by stating that CLRS should not be used in urban areas, such as highway sections with any of the following (8):

- Speed zone of 70 km/h or less in the vicinity of a residential or urban area
- Curb and gutter or a sidewalk
- Average driveway spacing less than 150 m or average intersection spacing less than 500 m

In addition to the above points, British Columbia has the following guidelines (8):

- CLRS shall begin at the start of the double solid painted centreline
- With a painted flush median < 2.0 m wide, apply CLRS in the centre of the painted median
- With a painted flush median ≥ 2.0 m, follow application guidelines for SRS
- Interrupt CLRS prior to driveways and intersections; do not need to interrupt for field entrances
- Do not install on bridge decks, overpasses, or other concrete surface structures
- Discontinue CLRS within 200 m of a residential or urban area
- Applying CLRS on lane widths less than 3.4 m requires an engineering review
- Recommended minimum depth of pavement is 50 mm

In British Columbia, milled rumble strips are installed directly on the centreline, or in the centre of a flush painted median less than 2.0 m wide. CLRS have a width of 300 ± 10 mm (12 ± 0.4 inch), a length of 140 ± 20 mm (5.5 ± 0.8 inch), a depth of 8 ± 2 mm (0.3 ± 0.08 inch), are round in shape with a radius of 300 mm (12 inch) radius. Rumble strips are spaced 300 mm (12 inch) apart in a continuous pattern, measured from centre to centre. A lateral tolerance for placement is specified at ± 10 mm (0.4 inch) left or right of the outside edge of the centreline pavement marking (8).

Current Applications: Parks Canada

Parks Canada has installed centreline rumble strips on sections of the TransCanada Highway within national parks. Guidelines, policies, or warrants regarding the installation of CLRS in general situations have not been developed to date.

Current applications include the Icefields Parkway from TransCanada Highway to KM-52, as well as in the following no passing zone sections of the TransCanada Highway (9), totalling close to 200 km of installed CLRS:

- Banff National Park from Castle Junction to the British Columbia border
- Yoho National Park (east to west boundary)
- Glacier National Park (east to west boundary)
- Mount Revelstoke National Park (east to west boundary)

In addition, CLRS were installed in Fall 2004 on the TransCanada Highway, regardless of passing zone, between Castle Junction and the Alberta/British Columbia border (9) (Figure 4). Signs are typically posted on the roadside of the TransCanada Highway to inform drivers of the presence of rumble strips.

Parks Canada uses the same design dimensions as Alberta, outlined above (9).

Figure 4: CLRS installed on the TransCanada Highway (Photo: Dr. John Morrall)

Current Applications: United States and International

In the United States, according to a survey conducted in 2003, twenty states have installed CLRS (Alaska, Arizona, California, Colorado, Connecticut, Delaware, Hawaii, Kentucky, Maryland, Massachusetts, Minnesota, Nevada, New Hampshire, New Mexico, Ohio, Oregon, Pennsylvania, Virginia, Washington, Wyoming), twelve states are "considering" CLRS, four states will "probably" install CLRS, one state (Kansas) has "definite plans" to install in the near future (10). More recently, one state (New York) plans to install test applications of CLRS in each region (11).

In total, 38 states have installed or might install CLRS in the near future. However, only three states reported five or more installations and nine states indicated greater than 15 miles of CLRS installed in their state (10); indicating that CLRS are not used extensively in any state.

In the United States, the majority of CLRS are installed on rural two-lane highways, however, some states (e.g., Kentucky, Maryland, Oregon, Pennsylvania, and Virginia) indicate CLRS could be or have been installed on four-lane undivided roadway sections.

Four states install CLRS only in no passing zones (California, Washington, Massachusetts, Connecticut); and seven states indicate installations in all zones (i.e., passing and no passing) (Arizona, Colorado, Delaware, Maryland, Minnesota, Oregon, Pennsylvania). Figure 5 illustrates one CLRS installation in a passing zone in Delaware. At this time, it is not clear if the remaining states that install CLRS do so in no passing zones or all zones. Those agencies that install CLRS in passing zones reason that drivers are more likely to go to sleep on long, straight stretches (where passing is permitted) thus CLRS may be effective at these locations (2).

Figure 5: Centreline rumble strips in Delaware (www.deldot.net/static/projects/rumblestrip/index.html)

The cross-sections of roads with CLRS vary from state to state. Recently, a survey was conducted focused on finding warrants for the installation of CLRS (5). The survey provides the following insight, based on eighteen responses: fourteen from U.S. states, and three Canadian provinces:

- The majority (58%) of respondents did not think warrants for CLRS are appropriate. Two respondents (11%) answered that a warrant would be appropriate, and one provided a draft warrant document (Missouri).
- The majority of respondents would prefer guidelines based on "engineering judgment".

Traffic volumes and traffic mix appears to vary from state to state. Based on reviewed literature, ADT information was found for eight states (California, Colorado, Delaware, Maryland, Michigan, Minnesota, Oregon, Washington), and ranged 5,000 to 22,000 veh/day (11).

Applied CLRS dimensions also range greatly from state to state. Based on the literature reviewed and surveys performed:

- Width (across road) 100 to 450 mm
- Length (along road) 150 to 200 mm
- Depth 9.5 to 19 mm
- Spacing (centre to centre) 300 to 1200 mm

Sixteen states use a continuous CLRS pattern (Alaska, Arizona, California, Colorado, Connecticut, Delaware, Hawaii, Kentucky, Massachusetts, Minnesota, Nevada, New Hampshire, Ohio, Pennsylvania, Virginia, Washington) and New Mexico uses an intermittent pattern of approximately 2 metres of rumble strips spaced 2 metres apart (5). The CLRS pattern in Maryland varies by installation. Oregon uses two patterns, installed in either passing or no passing zones, and apply continuous CLRS in flush medians 1.2 m (4 ft) in width or greater.

Internationally, few references to centreline rumbles strips were found. One study was conducted in the Netherlands combining raised shoulder and centreline rumble strips (rumble strips are also referred to as chipping strips) (12). The raised centreline rumble strip is 300 mm (12 in) wide. Other design dimensions were not published. The Netherlands uses a continuous pattern on the centerline (12).

Safety Effectiveness

Recent work completed by Persaud et al. (11) used an empirical Bayes approach to analyse a cross-section of locations in seven states. All locations were two-lane rural roads, with both horizontal and tangent alignments, and ADT ranging from 5,000 to 22,000 veh/day (average of 9,000 veh/day). The average segment length was 2 km. Persaud et al. (11) found the following collision reductions:

- 15% reduction in all injury collisions combined (with a 95% confidence interval of 5 to 25%)
- 25% reduction in head-on and opposing-direction sideswipe injury collisions (with a 95% confidence interval of 5 to 45%)
- 21% reduction in head-on and opposing-direction sideswipe collisions of all severities (with a 95% confidence interval of 5 to 37%)

Documented Issues

Some agencies cite the noise generated by rumble strips as a disadvantage. Noise concerns are valid, and most agencies are aware of the need to evaluate potential noise impacts on residential areas prior to implementing CLRS. As noted previously, Canadian jurisdictions do not apply CLRS within 200 m of a residential or urban area; this is primarily to address the noise generated by CLRS.

The survey of agencies performed by Russell and Rys (5) found that some jurisdictions are concerned that implementing CLRS will reduce the effective lane width of the travel lane, particularly on narrower roads. Based on the literature reviewed, nineteen states reported that lane width was not adjusted when CLRS were applied. This is likely because CLRS are generally installed on the longitudinal pavement joint, and the centreline marking painted over top.

Some discussion was found in the literature regarding the most effective type of rumble strip construction (i.e., milled, rolled, or formed). Based on current applications, milling is the most popular method, and appears to provide accurate yet rapid installation of rumble strips. Milled rumble strips have been found to be equally effective on new, existing, or reconstructed surfaces, both asphalt and concrete pavement surfaces. Milled rumble strips are more appropriate than raised rumble strips for Canadian application due to snowplough activity.

Maintenance of rumble strips is also a concern, particularly in Canada's climate, with ice and snow or other debris that may build up in the grooves. There is concern that this build-up may reduce the effectiveness of CLRS, and perhaps lead to pavement deterioration. Overall, agencies that have noted debris or water standing in the milled grooves have found no reduction in the effectiveness of the CLRS. Most jurisdictions note that little or no maintenance of milled-in

CLRS is required to maintain their effectiveness (based on subjective measures). Jurisdictions have not documented an increase in the rate of pavement deterioration.

The impact of rumble strips on pavement markings has also been voiced by some agencies. There is some debate related to the placement of pavement markings (i.e., should they be applied on top of or beside CLRS). There is also debate that if the centreline marking is painted on top of the rumble strip, the pavement markings may deteriorate faster or their visibility and retroreflectivity may be reduced. Most jurisdictions have experienced no difficulties or adverse wear of pavement markings after the installation of CLRS; subjective evaluations indicate that the pavement marking in the groove may actually experience less wear and tear. There is, however, no certain evidence if painting on top of CLRS increases or decreases pavement marking visibility or retroreflectivity.

There is no clear evidence that drivers respond to CLRS in undesired ways. Driver and bicycle reaction to contact with CLRS has been studied using simulators and controlled field testing. There is some concern that if CLRS are implemented on routes with high bicycle volumes, drivers may move away from the centreline and closer to cyclists, but there is no factual evidence to support this concern.

Although there is intuitive concern for motorcyclists who encounter CLRS, there have been no quantified or recorded incidents of negative effects. No adverse experiences of truck drivers and CLRS were found in the literature.

Conclusions

Much like shoulder rumble strips, centreline rumbles strips have been found to produce favourable safety improvements by assisting motorists to maintain the travel lane.

In Canada, three provinces (Alberta, Saskatchewan, and British Columbia) and Parks Canada have implemented CLRS. In the United States, at least twenty states have installed CLRS, twelve states are "considering" CLRS, four states will "probably" install CLRS, and two states have "definite plans" to install in the near future.

Although valid concerns such as the noise generated by vehicle contact with the rumble strip must be considered prior to installation, based on the current experience of North American jurisdictions, there appears to be substantial benefits from the installation of CLRS.

In summary, the most common design dimensions for CLRS in North America are:

- Width (across road) 300 or 400 mm
- Length (along road) 180 mm
- Depth 12.5 mm
- Shape Round
- Spacing (centre to centre) 300 mm

Recommended Guidelines

Similar to the recommended design approach for shoulder rumble strips, recommended dimensions for CLRS are:

- Width (across road) 300 mm (or 500 mm for heavy trucks)
- Length (along road) 175 ± 25 mm
- Depth 8 ± 2 mm
- Shape Round
- Spacing (centre to centre) 300 mm

These dimensions are within the range of dimensions currently applied across North America, and are consistent with the dimensions published in TAC's "Best Practices for the Implementation of Shoulder and Centreline Rumble Strips" (2001).

The intent of CLRS is to alert the motorist that they are crossing the centreline. The target collision types of head-on, opposite-direction sideswipe, and run-off-road-left can occur in both "no passing" zones and where passing is permitted. Therefore, CLRS may be considered on undivided, rural, two-lane, three-lane, or four-lane highways in all zones (passing or no passing) in the following cases:

- New highway sections
- When repaving, rehabilitating or reconstructing existing highway sections
- Other highway sections that are not part of a project but would benefit from the installation of CLRS in terms of safety (i.e., decreasing the number of crossover centreline crashes).

It is recommended that CLRS applications be discontinued:

- 200 m in advance of residential or urban areas
- 60 m in advance of intersections and/or bridge decks.

CLRS are not recommended for consideration on highway sections where:

- Posted speed limit is 70 km/h or less in the vicinity of a residential or urban area
- There are curbs and gutter or a sidewalk
- Average spacing of driveways is less than 150 m and/or average spacing of intersections is less than 500 m.

These recommendations are in the process of national approval by the TAC Chief Engineers' Council which represents the jurisdictional membership.

Future Research

Based on the review of current literature, there are some gaps in knowledge, and opportunities for research on other rumble strip applications, such as:

- Additional analysis of the safety benefits of CLRS in Canada
- Additional research of the impact on motorcyclists, bicyclists, and emergency vehicle operators
- Optimum spacing between rumble strips

- The impact of snow, ice, and debris build-up on pavement marking visibility and rumble strip effectiveness
- Scientific evaluation in a controlled setting of retroreflectivity of pavement markings applied on top of rumble strips, to date most jurisdictions report only subjective evaluations
- Research on the use of "lane line" or "edgeline" rumble strips, which are applied between lanes of the same direction
- Research on the use of "mid lane" rumble strips, which are applied along the centre of a travel lane, parallel to the direction of travel.

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