IMPLEMENTATION GUIDELINE FOR NON-FREEWAY CENTERLINE RUMBLE STRIPS

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This document presents a guideline for the implementation of non-freeway centerline rumble strips on high speed rural highways. It includes recommended practices, according to MDOT standards, and describes effective strategies and techniques that can be used in the implementation and maintenance phases to help alleviate road user and community concerns. The use of centerline rumble strips should be considered as an effective safety measure to reduce lane departure crashes.

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INTRODUCTION AND BACKGROUND

Introduction

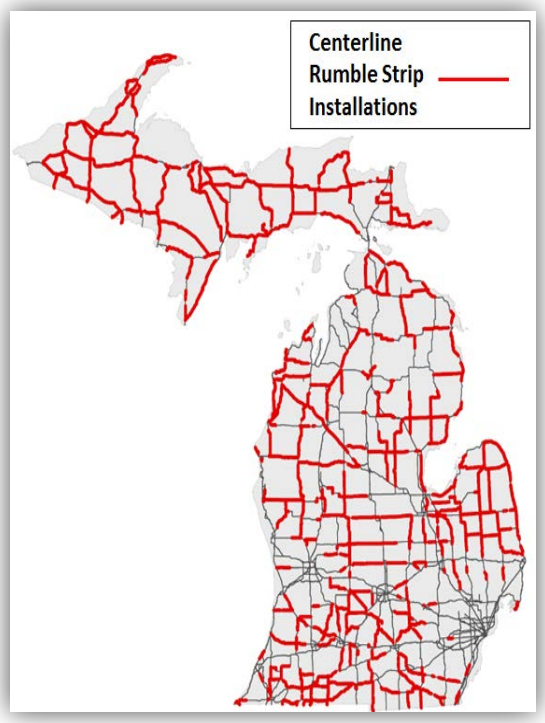
High-speed, undivided highways often experience an over-representation of crashes involving cross-centerline lane departure related crashes. Often the head-on, opposite sideswipe, or run-off-the-road to the left crashes on two-lane highways are the most severe.

Centerline rumble strips (CLRS) are used to alleviate left side lane departure-related crashes and injuries. The potential benefit of such treatments, when considered with associated installation maintenance costs, presents an attractive scenario.

Centerline rumble strips are a set of transverse grooves applied on the centerline of a roadway to alert inattentive (distracted, drowsy, unfocused, etc.) drivers who may unintentionally drift over the centerline. Rumble strips provide a tactile and audible warning to alert drivers. The warning provided by the centerline rumble strips gives the driver an opportunity to appropriately correct their action, or reduce speed, which may result in crash avoidance or severity reduction.

Michigan Department of Transportation (MDOT) Rumble Strip Program

The Michigan Department of Transportation maintains approximately 5,400 miles of high speed two-lane rural highways. While traffic volumes on these rural highways are relatively low, a study in 2007 revealed that an average of 23,750 crashes, including 122 fatal crashes, occurred on these roadways annually. A substantial portion of these crashes involved centerline encroachment-related crashes. Head-on, sideswipe opposite direction and run-off-the road left crashes are also associated with centerline encroachment. While shoulder rumble strips (SRS) have been in use to alleviate run-off-the road crashes for quite some time in many states, including Michigan, the use of centerline rumble strips have been sporadic at best. Various national and state sponsored research has indicated sufficient value for installing CLRS.



MDOT embarked on a system-wide CLRS implementation program for all of their high speed two-lane rural highways in 2008. This system-wide program included the installation of CLRS on 5,400 miles of two-lane MDOT highways within a three-year period. A system-wide CLRS implementation program is uncommon. It was realized that to have such a program provided a rare opportunity for a robust evaluation of the effectiveness of CLRS on rural two lane highways.

The MDOT study [Phase I *(1)*] included driver and road user behavioral characteristics with and without CLRS, in addition to a comprehensive crash evaluation study [Phase II *(2)*] that determined the safety performance of the installation of CLRS.

The Phase II study involved identifying the crashes that involve at least one vehicle crossing or encroaching on the centerline that could be impacted by the presence of CLRS. In the MDOT effectiveness evaluation study of CLRS on high speed two-lane highways, target crashes were identified using the noted criteria. Snowy/icy pavement can also influence the centerline crossing/encroachment incidences, and therefore an increase or decrease in target crashes in any specific year could be influenced by annual snow fall. In order to eliminate this potential source of bias, the target crashes in the MDOT study eliminated the crashes that included snowy or icy pavement as a contributing factor.

The MDOT systemwide CLRS implementation program demonstrated a 47% reduction in total target crashes and 44% reduction in fatal and incapacitating injury target crashes following the installation of CLRS.

Purpose of the Guideline

The purpose of this guideline document is to provide information to local road agency (county, city, and township) officials who may want to consider the use of CLRS either systemwide or at site-specific locations. Considerations for use of CLRS include:

- Assessment of historical crashes that can be alleviated by the installation of CLRS
- Adequacy of roadway geometry, such as, pavement width, lane width, shoulder characteristics and roadside characteristics to accommodate the installation of CLRS
- Travel speed and traffic volumes
- Residential property in the vicinity
- Public support.

This guideline provides information regarding these issues, as well as cost and benefit data for road agencies to prepare a CLRS implementation plan.

History and Earlier Studies

Pavement surface textures and treatments to provide both a tactile and audible warning to the driver have been in use for over several decades. The use of SRS on freeways has been in existence for many years, providing objective data regarding safety benefits. This strategy has been applied as a means to alert drivers drifting out of the travel lane. Although the use of centerline rumble strips on two-lane high-speed highways has been increasing, still it has not experienced the level of implementation as shoulder rumble strips.

Delaware was the first state to document the crash reductions as a result of installing centerline rumble strips. In 1994, Delaware's Department of Transportation (DOT) installed centerline rumble strips along a 2.9 mile section of roadway to determine their effectiveness. This study performed a three-year "Before" and six-year "After" impact study and found average annual head-on collisions decreased by 90%, other crashes caused by motorists crossing the centerline decreased by 60%, and there were no fatal crashes (at the study segments) during the "After" study period *(3)*.

A review of the standards and practices of various states indicates that in excess of 30 states have established CLRS installation guidelines and/or standard plans, and of these states approximately 20 have documented CLRS safety performance results. The effectiveness evaluation results vary widely and may be due to the differences in the definition of target crashes and sample sizes of the roadway segments used in the evaluation study. Eliminating the outliers (both very high and very low), the range of total crash reduction is between 19% and 46%, with the reduction in fatal crashes between 25% and 48%.

Research Results

The effectiveness of centerline rumble strips, based on past research in other states and also the MDOT rumble strip study (Phases I and II), can be summarized as follows:

- Impact on Driver Behavior
  - Vehicles tend to be more centrally positioned within the lane
  - Major encroachments across the centerline decreases for both tangent segments and horizontal curves
  - Lateral placement is shifted away from the roadway centerline where CLRS is present

- Impact on Crashes
  - Documented crash reductions for lane-departure-related crashes. The Michigan research found a 47% reduction in total target crashes.
  - Documented crash reductions for fatal and injury crashes. The Michigan research found a 44% reduction in fatal and severe injury target crashes.

- Impacts on Bicyclists
  - No evidence of an increase in bicycle-involved crashes
  - Vehicles tend to move away from the centerline with CLRS
  - Vehicular traffic moves closer to bicyclists who may be traveling on the outer edge of the travel lane

- Impact on Pavement Deterioration
  - Visual field assessments concluded rumble strips did not have any significant detrimental effect on the pavement life
  - Any sand or water accumulated in the grooves is cleared by air movement caused by passing traffic
  - Imagery reviews concluded that there was no adverse impact on the short-term pavement performance

- Impact on Noise
    - Pass-by method showed increases in the level of ambient noise
    - Noise is affected by both the speed and type of vehicle
    - Rumble strip depth is the biggest factor affecting the amount of noise produced due to CLRS, however spacing also impacts the generated noise

INSTALLATION STANDARDS

The NCHRP-641 *(4)*, 2009, provided a summary of CLRS practices. The centerline rumble strips installed by various states range from 12 to 24 inches in width, 5 to 8 inches in length, 3/8 to 3/4 of an inch in depth, and 10 to 48 inches in spacing.

The use of CLRS on two-lane high speed highways should consider the functionality of the treatment and the environment within which it is being installed. The standards and guidelines presented here are those of MDOT. It is not required that local agencies follow the same standards and guidelines that MDOT applies.

Geometric Requirements

Centerline rumble strips can be ground or cut into both concrete and hot-mix asphalt pavements, but cannot be formed in. MDOT applies centerline rumble strips on all rural two-lane and four-lane roadways in both passing and non-passing zones where the posted speed limit is 55 miles per hour and the lane plus paved shoulder width beyond the centerline rumble strip is greater than 13 feet in width (see Figure 1). If safety concerns outweigh other issues, such as noise and bicycle use, non-freeway centerline rumble strips can be considered for use on roadways that do not meet the criteria. In developed rural areas where driveway density exceeds 30 access points within a half a mile, MDOT chooses to omit non-freeway centerline rumble strips, unless a crash history exists *(5)*.

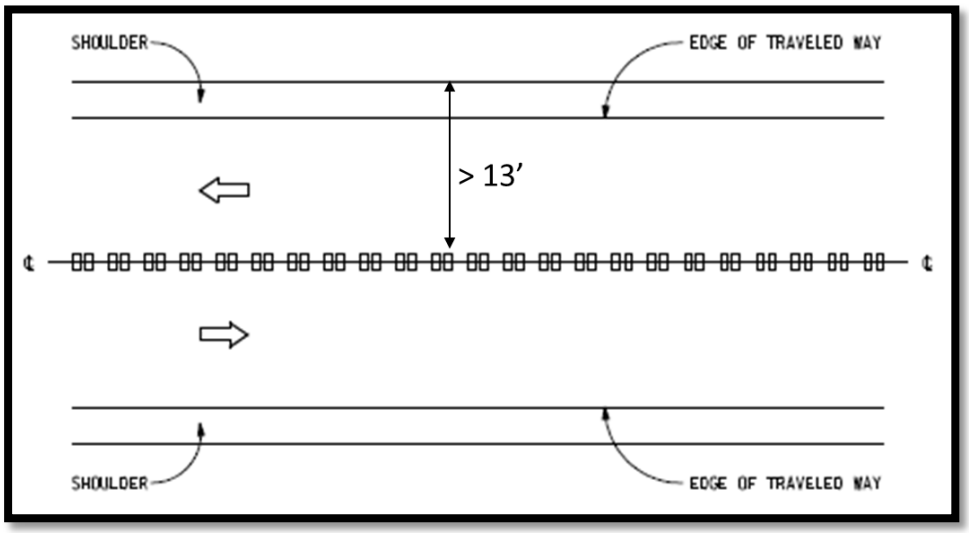


Figure 1. Centerline Rumble Strip on Two-Way Roadway (MDOT Standard)

Rumble Strip Standards

Figure 2 shows size, shape, spacing and groove information MDOT uses for CLRS. Figure 3 shows the dimensions used for interrupting CLRS at intersections. The standards for CLRS interruptions at driveways, bridges, culverts, and at railroad grade crossings are shown in the MDOT Design Standards. For further details, see MDOT's Standard Plan Series R-112 *(6)*.

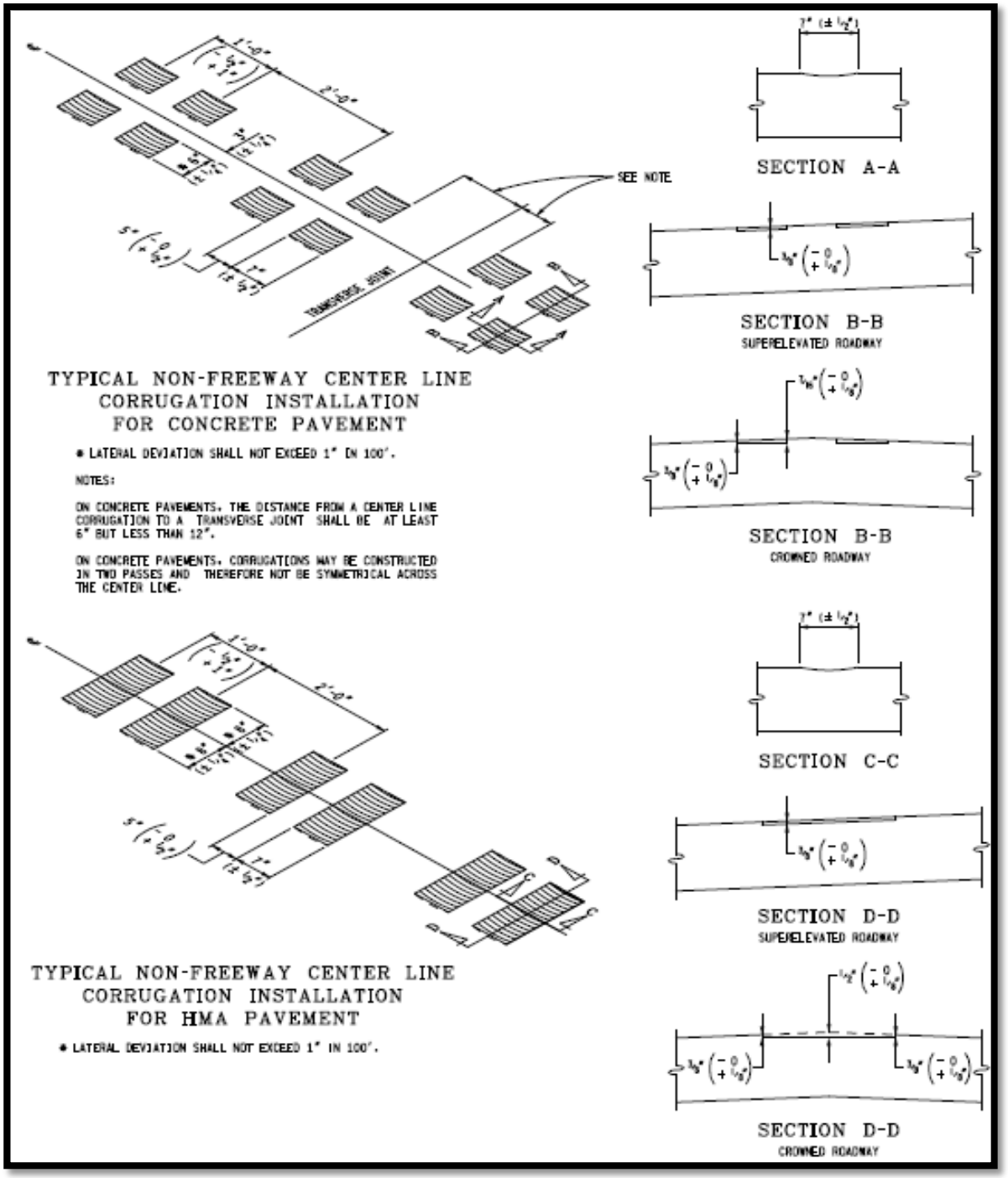


Figure 2. MDOT Non-Freeway Centerline Rumble Strip Dimensions *(6)*

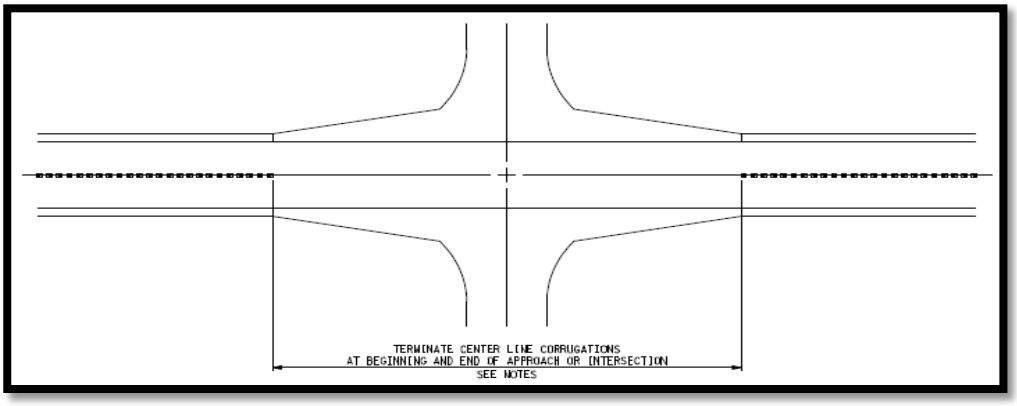


Figure 3. Centerline Rumble Strips at Intersections *(6)*

GUIDELINE

Lane Departure Crashes

A lane departure crash is when a vehicle leaves the travel lane resulting in a collision. Centerline lane departure traffic crashes are often the most severe, including head-on, opposite sideswipe, and run-off-the-road to the left type crashes.

- Corrective Measures: Centerline rumble strips are used to reduce centerline lane departure crashes by providing inattentive drivers who encroach upon the centerline with both a tactile and audible warning. This warning may result in crash avoidance or severity reduction.

Mix of Traffic

The safe accommodation of all road users' needs to be considered when designing and applying centerline rumble strips. Although there is no evidence associated with centerline rumble strips increasing bicycle-involved crashes or affecting motorcycle passing events, the following concerns need to be considered:

- **Bicyclists:** Presence of CLRS may cause vehicles to move away from the centerline to avoid contact with the rumble strip and effectively move closer to bicyclists who may be traveling on the outer edge of the lane *(7)*.

- **Motorcyclists:** The MUTCD permits the use of warning signs (W8-15 and W8-15P) to notify motorcyclists of the presence of CLRS so they are aware when wanting to pass *(8)*, although MDOT chooses not to install these signs.

Horizontal Curvature and Grades

Centerline rumble strips can be installed at horizontal curves with appropriate radius to alert drivers when they are compensating too much to the left in order to complete the turn *(9)*. In super-elevated segments, centerline rumble strips also give the driver guidance on speed by alerting the driver to increase their speed if they encroach the centerline rumble strip.

Land Use

Centerline rumble strips may be used on all rural two-lane and four-lane roadways in both passing and non-passing zones. In developed rural areas where driveway density exceeds 30 access points within a half a mile, MDOT chooses to omit centerline rumble strips *(5)*. Centerline rumble strips are typically not used in urban or suburban areas.

Noise

While the installation of CLRS provides safety benefits, the noise produced by vehicles may generate community concerns. Road agencies can help minimize the noise generated by centerline rumble strips through design modifications *(10)* such as shallower depth and larger spacing. Road agencies may provide information regarding the safety benefits of CLRS to the interested public to gain support in the community. To prevent nuisance noise, CLRS should not be milled to depths exceeding 0.5 inches.

Cost of Rumble Strip Installation

The cost of installation of rumble strips depends on the quantity of lineal feet and continuity of segments. The MODT rumble strip installation program's average cost was $0.12 per feet for HMA pavements and $0.27 per feet for concrete pavements. For small projects, the cost of equipment mobilization tends to increase the average per-foot cost.

Maintenance Issues

Although there is no substantial evidence of an increase in short-term pavement distresses caused by centerline rumble strips *(1,11)*, rumble strips still need to be incorporated as part of a preventative maintenance program. Rumble strip maintenance can be addressed in the following surface treatments *(12)*:

- **Non-Structural Hot Mix Asphalt Overlay:** Rumble strips will effectively be filled in after an HMA overlay and will likely need to be re-established.
- **Surface Milling with Non-Structural HMA Overlay:** Rumble strips must be re-established after milling and HMA overlay.
- **Chip Seal:** Chip seal can be placed over existing rumble strips. Multiple chip seal applications may reduce the effectiveness of the rumble strips and re-establishment may be necessary. MDOT has a Frequently Used Special Provision (FUSP) available to address the maintenance of existing centerline rumble strip during double chip seals *(13)*.
- **Micro-Surfacing:** Existing centerline rumble strips should be filled in and re-ground after micro-surfacing *(14)*.
- **Fog Seal:** The most widely used method of applying preventative maintenance treatments over the rumble strips to reduce oxidation and moisture penetration *(15)*.

The MDOT Road Maintenance Manual *(12)* should be followed for future maintenance of CLRS.

ESTIMATING FUTURE SAFETY BENEFITS

MDOT's Rumble Strip Program included a three year before-and-after crash study to evaluate the impacts associated with centerline rumble strips. Since MDOT's Rumble Strip Program was a policy change that took place not only on high crash volume highways, but on all rural non-freeway highways as well, the before-and-after analysis mitigated the regression to the mean effect generally addressed by using the Empirical Bayes method of analysis.

Crash Reduction

Future crash reduction is expected for lane departure crashes (i.e. head-on, opposite sideswipe, run-off-the-road to the left) after implementing centerline rumble strips *(2)*:

The MDOT rumble strip study *(2)* indicated the following lane-departure crash reductions:

- Total crashes = 47%
- Fatal (K) and Disabling Injury (A) crashes = 44%

Determining Future Crashes during Post Rumble Strip Installation

Using the noted crash reduction factors and other factors developed as part of the MDOT Phase II study *(2)*, a road agency can calculate the potential benefits associated with crash and injury reduction.

Crash and Injury Costs

In 2012, the average economic cost per death, injury, or crash by calculating the costs of wage and productivity losses, medical expenses, administrative expenses, motor vehicle damage, and employers' uninsured costs can be estimated as *(16)*:

- Fatal Crash: $1,410,000
- Incapacitating Injury (A): $72,700
- Non-Incapacitating Evident Injury (B): $23,400
- Minor Injury (C) and Property Damage Only (PDO): $8,900

BUILDING PUBLIC SUPPORT

Building public support for the introduction of a roadway treatment is important; however, the safety effectiveness consideration should ultimately decide site-specific or systemwide implementation of rumble strips. Many safety treatments (including rumble strips) may sometimes impact the comfort and convenience of potential users, but there is also a duty to provide roadways that promote the safety of the motoring public.

Preparing and Disseminating Public Information

Proactive public outreach can be through newspaper articles, explanatory brochures, web-based videos, flyers, documents, and agency websites. These documents should contain quick facts and safety benefits that can be disseminated to the public to help spread the word on why centerline rumble strips are being installed in their area (see Figures 4 and 5).

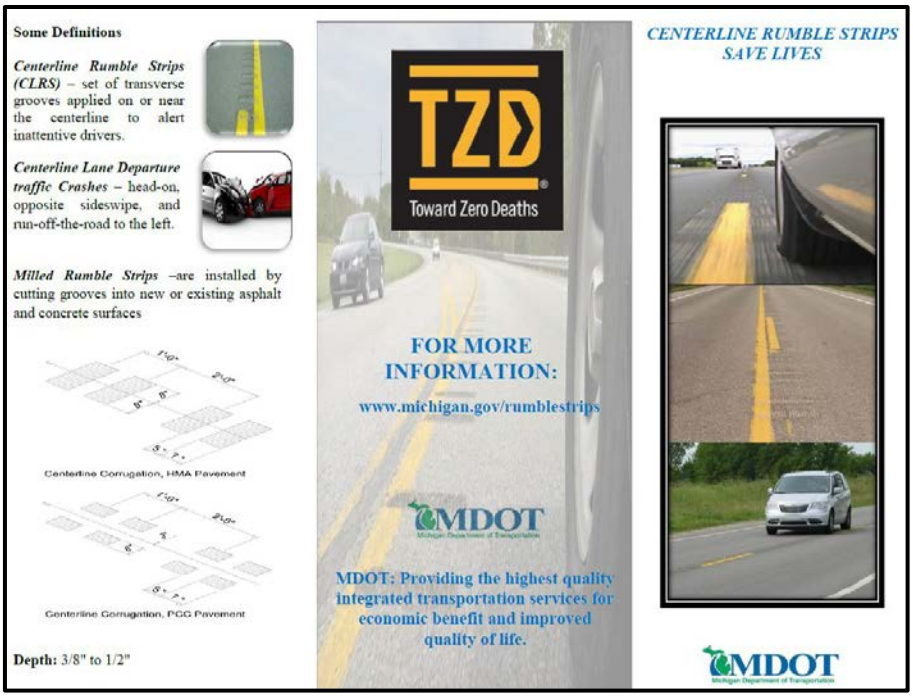


Figure 4. Michigan Rumble Strips Brochure *(17)*

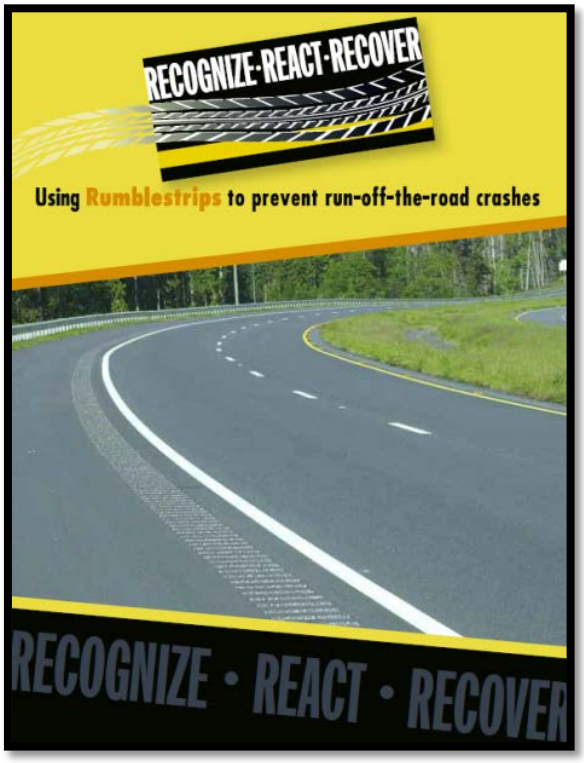


Figure 5. Recognize, React, Recover Brochure [Source: Roadway Safety Foundation *(18)*]

Hosting Public Information Meetings and Open Houses

Prior to implementing centerline rumble strips, transportation agencies should try to notify all road users, including passenger and commercial motorists, bicycle organizations, enforcement agencies, and emergency responders to help educate the public on the safety goals. Public outreach can also help establish expectations for projects with varying scopes of work and help expedite the project *(8)*. The main focus is to convince the public that the safety benefits of centerline rumble strips outweighs any additional maintenance or noise concerns.

Holding Public Hearings

A public hearing may be used for receiving rumble strip feedback from the public at large and to discuss the pros and cons. Testimony from both the transportation agency discussing the safety benefits (i.e. crash reduction) and the public discussing their concerns (i.e. noise, bicyclists) may be recorded as a part of the public record.

REFERENCES

1. Datta, T.K., T.J. Gates, and P.T. Savolainen. Impact of Non-Freeway Rumble Strips Phase 1. ORBP Reference Number: OR09084A. June 26, 2012.

2. Datta, T.K., et al. Evaluation of Non-Freeway Rumble Strips - Phase II. ORBP Reference Number: OR13-007. March 31, 2015.

3. Delaware Department of Transportation, Delaware Strategic Highway Safety Plan. http://deldot.gov/information/community_programs_and_services/DSHSP/safety_improvement_projects.shtml.

4. Torbic, D, et al. *Guidance for the Design and Application of Shoulder and Centerline Rumble Strips.* NCHRP Report 641. NCHRP, TRB, Washington, D.C., 2009.

5. Road Design Manual. Michigan Department of Transportation. http://mdotcf.state.mi.us/public/design/englishroadmanual/

6. Michigan Department of Transportation Standard Plan, Shoulder and Centerline Corrugations, R-112-H (Sheets 5 and 6), June 2010. http://mdotcf.state.mi.us/public/design/files/englishstandardplans/largespdetfiles/R112H.pdf

7. Center Line Rumble Strips, Technical Advisory, Federal Highway Administration, November 2011. http://safety.fhwa.dot.gov/roadway_dept/pavement/rumble_strips/t504040/t504040.pdf

8. McGee, H.W. and F.R. Hanscom. *Low Cost Treatments for Horizontal Curve Safety*. U.S. Department of Transportation, Federal Highway Administration. http://safety.fhwa.dot.gov/roadway_dept/horicurves/fhwasa07002/ch5.cfm

9. Carlson, P.J. and J.D. Miles. *Effectiveness of Rumble Strips on Texas Highways: First Year Report*. Report 0-4472-1. Texas Transportation Institute, College Station, Texas, September 2003.

10. Rumble Strip Noise Study, Delaware Department of Transportation, September 2012. http://deldot.gov/information/community_programs_and_services/DSHSP/pdf/RumbleStrip_compressed.pdf

11. William (Skip) Outcalt. Centerline Rumble Strips Report No. CDOT-DTD-R-2001-8 Interim Report. Colorado Department of Transportation Research Branch, August 2001. https://www.codot.gov/programs/research/pdfs/2001/centerline.pdf

12. Capital Preventative Maintenance, 2003 Edition, Michigan Department of Transportation, April 2010.

13. Special Provision for Pavement Performance Warranty for Double Chip Seals, 2012 Spec Book, Michigan Department of Transportation. http://mdotcf.state.mi.us/public/dessssp/spss_source/03SP508C.pdf

14. Special Provision for Micro-Surfacing Corrugations (Rumble Strips), 2012 Spec Book, Michigan Department of Transportation. http://mdotcf.state.mi.us/public/dessssp/spss_source/03SP508C.pdf

15. Watson, M, et al. Long Term Maintenance Effects on HMA Pavements Caused by Rumble Strips and Available Preventive Treatment Methods. MnDOT, St Paul, MN, 2008.

16. Estimating the Costs of Unintentional Injuries, 2012. National Safety Council.

17. Rumble Strips Brochure, Michigan Department of Transportation (MDOT). https://docs.wayne.edu/551b0e5698c21.pdf

18. Recognize, React, Recover Brochure, Using Rumblestrips to Prevent Run-Off-The-Road Crashes, Roadway Safety Foundation. http://www.roadwaysafety.org/wp-content/uploads/ror-brochure-final.pdf