Federal Highway Administration
TECHNICAL ADVISORY

SHOULDER AND EDGE LINE RUMBLE STRIPS

T 5040.39, Revision 1
November 7, 2011

1. **PURPOSE:** To transmit updated information and guidelines for the design and installation of shoulder and edge line rumble strips on appropriate segments of paved roads in the United States. This information applies to a wide range of projects including new construction, reconstruction, resurfacing, and safety improvements. Highway professionals should consider the needs of all road users, existing roadway conditions, the scope of the project, and the surrounding environment when applying this information and guidance.

2. **CANCELLATION:** This Technical Advisory supersedes the information contained in T 5040.35, Roadway Shoulder Rumble Strips, dated December 20, 2001 and T5040.39, Shoulder and Edge Line Rumble Strips dated April 22, 2011.

3. **DEFINITIONS:** A ***shoulder rumble strip*** is a longitudinal safety feature installed on a paved roadway shoulder near the outside edge of the travel lane. It is made of a series of milled or raised elements intended to alert inattentive drivers (through vibration and sound) that their vehicles have left the travel lane. An ***edge line rumble strip*** is a special type of shoulder rumble strip placed directly at the edge of the travel lane with the edge line pavement marking placed through the line of rumble strips. It is sometimes referred to as an ***edge line rumble stripe.*** (See Figure 1)

4. **BACKGROUND:** One of the Federal Highway Administration's primary safety goals is to reduce the number and severity of roadway departure crashes. These consist of run-off-road (including cross median) crashes and cross center line crashes on undivided roads. Safety improvements proposed to address this goal include initiatives to keep vehicles on the roadway, to improve the likelihood of a safe recovery after a roadway departure, and to reduce the severity of those crashes that do occur. Shoulder or edge line rumble strips are one of the proven countermeasures that reduce the risks of run-off-road crashes.

    a. ***The target driver:*** Rumble strips are placed as a countermeasure for driver error, rather than roadway deficiencies. They are designed primarily to assist distracted, drowsy, or otherwise inattentive drivers who may unintentionally drift over the edge line. For this set of drivers, the audible and vibratory warning produced by rumble strips greatly improves the opportunity for a safe recovery. In a study of 1,800 run-off-road freeway crashes, one state found that drift-off-road crashes (due to inattentive driving) resulted in death or serious injury at a rate three to five times higher than other categories of run-off-road crashes. Where drivers don't safely recover, the warning created by rumble strips often improves driver reaction, thereby reducing crash severity.

    b. ***Early rumble strip development:*** Pavement surface textures and treatments to provide audible and vibratory warning to drivers have been in use for over 50 years as a means to alert drivers leaving the travel lane. Rolled-in strips on asphalt shoulders and formed-in strips on concrete shoulders were two of the earlier designs used in installing shoulder rumble strips by a number of states. A major limitation was that they had to be installed with new pavement. There were also difficulties in consistently obtaining the desired shape. In the 1980s, the Pennsylvania Turnpike Commission developed a milled-in rumble strip design that could be installed on existing pavement. A series of trials led to a preferred design of ½ inch deep and 7 inches by 16 inches, producing tire vibration and noise with much greater alerting capacity than the rolled-in installation. Specified dimensions could also be produced more consistently. Subsequently, many other states began to use this milled-in design because of its effectiveness and ease of installation.

c. ***Recent history:*** In the 1990s, several state transportation agencies and toll road authorities installed the milled-in shoulder rumble design pioneered in Pennsylvania, mostly on rural freeways and expressways. In recent years, many agencies have extended the use of rumble strips to two-lane roads because a significant portion of run-off-road crashes occur on these roads. Some agencies have also designed and installed narrower rumble strips where roadway widths limited the use of standard designs. The wider use of rumble strips has also led to a great number of design modification choices to accommodate bicyclists, who are also legal road users.

d. ***Striping the rumble:*** The practice of placing the edge line pavement markings over the rumble strip improves nighttime marking visibility, particularly in wet conditions, by better positioning the marking optics on the back side of each rumble, compared to limiting their normal position within the flat marking. This practice can also increase the longevity of the markings, particularly within the rumble, due to reduced wear from tires and added protection from plowing activity.

5. EFFECTIVENESS: Run-off-road crashes account for approximately one-third of the deaths and serious injuries each year on the Nation's highways. Drift-off crashes, caused by drowsy, distracted, or otherwise inattentive driving, are a subset of run-off-road crashes. This subset contains the specific crash types that are most likely to be reduced by shoulder or edge line rumble strips. Many researchers have studied the effect of rumble strips on the larger set of run-off-road data because these crashes can be easily identified in crash databases. Some studies have addressed the more specific drift-off subset by analyzing narratives in the crash reports. In both cases, milled rumble strips are among the most cost-effective countermeasures available for this type of crash, since they directly address driver risk factors.

a. ***Run-off-road injury crashes:*** NCHRP Report 641 documents milled shoulder and edge rumble strips to provide statistically significant reductions in single-vehicle run-off-road injury crashes: 10 to 24 percent on rural freeways, and 26 to 46 percent on two-lane rural roads. Reductions were also shown on other types of roadways, but the estimates are not as statistically reliable.

b. ***Drift-off-road crashes:*** Studies of milled freeway shoulder rumble strips in Michigan and New York documented drift-off-road crash reductions of 38 and 79 percent.

c. ***Navigational aid in bad weather:*** Shoulder and edge line rumble strips may also serve as an effective means of locating the travel lane during inclement weather. Fog, snow, or blinding rain often obscure pavement markings. The vibration provided by rumble strips can assist drivers from unintentionally leaving the roadway in these conditions. In addition to vibration, there are potential visibility benefits. Even a light rain can seriously reduce the retroreflective capacity of pavement markings. When the edge line marking is placed within the rumble strip, the vertical component will often still be visible under these adverse conditions.

d. ***Noise and vibration:*** The common milled rumble designs have been shown to be more effective at producing both noise and vibration, as compared to earlier designs, and are credited with higher crash reduction factors. Design, application, and construction factors also contribute to the effectiveness of a rumble strip installation. Further information on these factors is discussed below.

6. APPLICATION CONSIDERATIONS: Edge line and shoulder rumble strips have the potential to reduce run-off-road crashes on any paved road. A summary of rumble strip practices and policies as of 2005 is included in NCHRP Report 641.

a. ***Corridor vs. spot treatment:*** Due to the difficulty in determining where a driver will become distracted or drowsy, it is recommended that rumble strips be installed system-

wide or in corridors, prioritized by the frequency of the specific crash types targeted by the treatment. Agencies may use crash predictors such as traffic volume or trip types (e.g. shift workers, younger drivers). Crash history will often reveal high-priority corridors, but spot installations of rumble strips based solely on crash history are not expected to be as effective. Within a corridor application, however, there may be spots where discontinuing the rumble strip installation may be prudent. Some of these issues are covered under Sections 9 and 10.

b. ***Urban vs. rural:*** While rumble strips have been extensively used in rural areas where run-off-road crash problems exist, use on urban freeways or other roadways functionally classified as urban is also effective. Whether the roadway is classified as rural or urban, the use of rumbles should be determined on the merit of the cross-section and appropriate to the context. Characteristics and concerns that often limit the usefulness or application include low speeds, noise for adjacent residences, pavement width, presence of curb and gutter, and significant turning movements or other conflicts of both motorists and other road users.

c. ***Left vs. right:*** On divided highways, shoulder rumble strips should be placed on the left shoulder as well as on the right. A comprehensive Michigan study of 1,887 drift-off freeway crashes showed that approximately an equal percentage of vehicles involved in crashes initially drifted to the left as to the right.

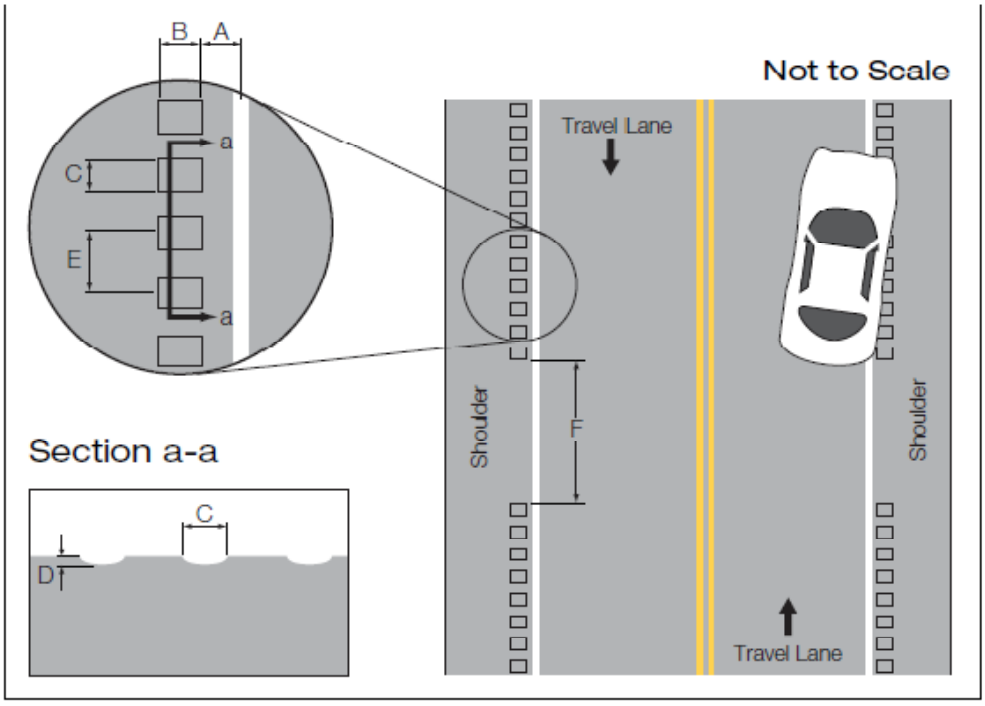
d. ***Combination of shoulder and center line rumble strips:*** The practice of installing both center line and shoulder rumble strips along the same segments of road is becoming more common. A Missouri study of the installation of rumble strips with wider markings during resurfacing showed the greatest reduction in serious injury crashes were found when both center line and edge line rumble strips were installed with the wider markings. Some studies have shown center line rumbles cause motorists to shift vehicle position slightly toward the shoulder. Therefore, when applying shoulder and center line rumble strips in combination, consideration should be given to total pavement width to determine how to best accommodate and serve all road users, particularly in no passing zones, where drivers may be reluctant to cross the center line to pass a bicyclist (see Section 9).

7. DESIGN: The design of rumble strips factor into their effectiveness. The terminology used in this technical advisory is shown in Figure 1.

a. ***Types:*** There are four basic rumble strip designs or types: milled-in, raised, rolled-in, and formed. Research indicates milled rumble strips produce significantly more vibration and noise inside the vehicle than rolled rumbles. The key design parameter related to effectiveness of the rumble strips is the dimensions, which tend to be easier to control with milled-in rather than rolled-in or formed rumbles. Profiled markings and other forms of raised rumble strips are sometimes used in climates where plowing is not a common occurrence. The effectiveness of raised rumble strips has not been widely studied. They are typically very narrow and prone to wear or displacement.

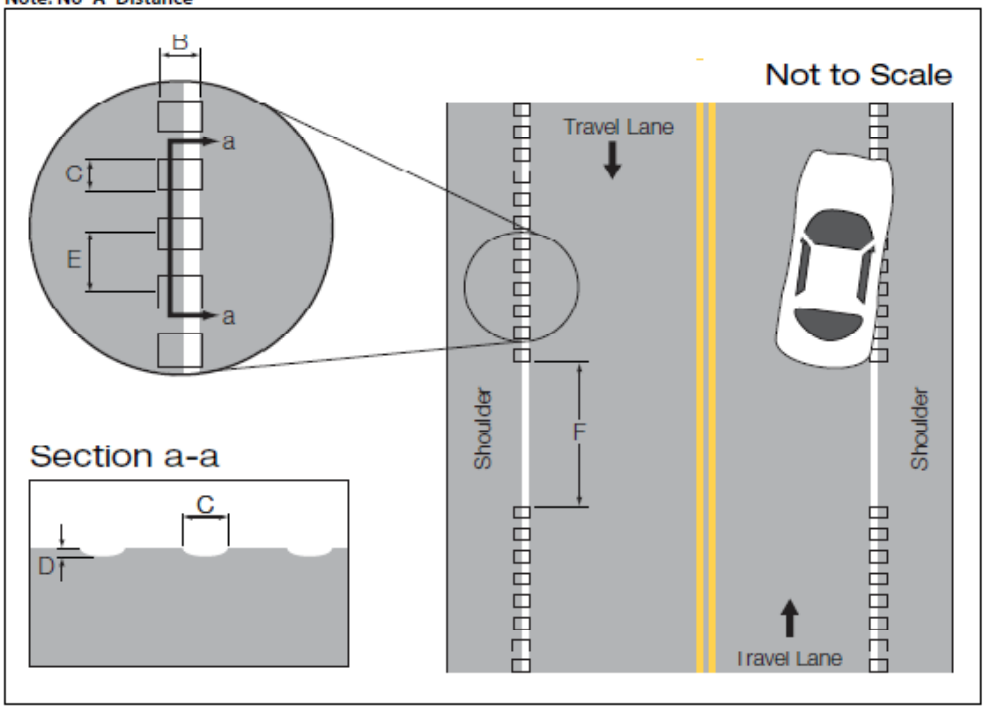
b. ***Dimensions:*** Optimum dimensions for milled rumble strips depend on operating conditions, cross-sectional characteristics, and potential road users. Two key dimensions that have the most effect on the alerting sound and vibration of rumble strips are depth (D) and width longitudinal to the road (C) as shown in Figure 1. Most crash studies referenced here evaluated shoulder or edge line rumble strips of 7 inches wide (C) by 16 inches long (B) with a depth (D) of one-half inch.

Shoulder Rumble Strips



Edgeline Rumble Stripes

Note: No "A" Distance



Legend

→ = Direction of Travel		B = Length		E = Spacing	
▯▯▯ = Rumble Strip		C = Width		F = Bicycle Gap	
A = Offset		D = Depth			

Figure 1

One study showed the variation in length transverse to the road (B) had the least effect on noise produced in the vehicle compared to the other dimensions. The same study indicated that a rumble acting on the driver side tires, such as a shoulder rumble strip located on the inside (left) of a divided highway, produced more noise in the vehicle at the critical driver position than rumbles on the right.

c. ***Location:*** Edge line rumble stripes or shoulder rumble strips with a narrow offset (A) from the edge line have been shown to be most effective, because the driver is alerted sooner and it provides a slightly larger recovery area after being alerted. This is supported by research showing a statistically significant higher reduction in crashes on rural freeways for rumble strips with narrow or no offset, as opposed to those with 9 inches or more offset. For rural two-lane roads, research on the impacts of narrowing the offset distance is inconclusive. Most agencies also take the location of the pavement joint into account to avoid cutting the strip across or immediately adjacent to the joint. In superelevated sections where the shoulder slopes in the opposite direction from the roadway, consideration should be given to placing the rumble strips on the superelevated side so that the driver is warned prior to crossing the slope break.

d. ***Continuous vs. intermittent application:*** In the early days of rumble strip design, rumbles were formed intermittently onto freshly poured concrete shoulders. Since that time, the benefits of continuous rumble presence have been acknowledged and most rumble applications today provide for continuous application of the rumble line, which includes breaks only for pre-determined situations such as intersections, major driveways and recurring bicycle gaps.

8. INSTALLATION: Offset should be measured from the edge of the travel lane, not from the edge of the shoulder, the width of which may vary. Monitoring is necessary to ensure that proper depth and center-to-center spacing is maintained throughout the length of the installation.

a. ***Milled rumble strips:*** Most North American transportation agencies mill rumble strips into their asphalt or concrete pavement. The milling operation can be performed at any time, either in small quantity as part of a construction project, or in large quantity, taking advantage of the economy of scale by installing rumble strips for long sections or a number of corridors.

b. ***Raised rumble strips:*** Raised rumble strips using raised pavement markers or other available products are sometimes used in climates where snow-plowing is not a common occurrence. This can be useful where milling would create a concern with the pavement integrity or where the paved shoulder is planned to be converted to a lane in the future.

c. ***Rolled-in rumble strips:*** Rolled-in rumble strips are installed during the compaction phase. While the asphalt pavement is still hot, a steel drum roller fitted with protruding steel bars rolls the pavement and provides indentations in the asphalt. This method cannot attain common dimensions for milled rumbles and therefore produces less vibration to alert drowsy drivers. Several construction difficulties have been reported with the installation of rolled-in rumble strips, including insufficient compaction, inconsistent dimensions, and difficulties installing patterns such as bicycle gaps.

d. ***Formed rumble strips***: Rumble strips of similar shape and depth to milled designs have been successfully formed into fresh portland cement concrete pavement. However, while the formed rumbles can achieve the desired rumble shape, consistency concerns and the limitation on installation during the paving operation remain.

e. ***Edge line rumble stripes:*** This application may be installed by milling over existing pavement markings, which initially reduces the area of the marking visible to the motorist.

Alternatively, some agencies install the rumble strip and new edge line at a small offset from the existing edge line, to prevent nuisance contacts with the rumbles. In either case, proper installation of an edge line rumble stripe includes the step of restoring the pavement marking over the top of the rumble strips.

9. **ACCOMMODATION OF ALL ROAD USERS:** Safe accommodation of all road users should be considered when designing and applying rumble strips. This includes passenger and commercial vehicle drivers, bicyclists, pedestrians, and others. Flexibility is provided within this advisory to address the needs of these users based on the existing and projected use in the specific corridor. Bicyclists, in particular, are affected by rumble strips. Where shoulders are available and clear, bicyclists will often choose to use them to avoid conflicts with faster moving vehicles in the travel lane. However, as legal road users, they may also be in the travel lane. There are a number of measures that should be considered to accommodate bicyclists.

    a. ***Wide shoulders:*** Shoulders improve safety for all road users. Where existing cross-section exists or paved shoulders can be added within the scope of the project, it is preferred to allow at least four feet beyond the rumble strips to the edge of the paved shoulder. Designers should be familiar with the FHWA design guidance found at http://www.fhwa.dot.gov/environment/bikeped/design.htm, which recommends states not install rumbles on *new construction* and *reconstruction* projects where shoulders are used by bicyclists unless this condition is met. Where guardrail, curb, or other continuous obstructions exist, additional width may be needed to provide adequate clearance for bicyclists (refer to current AASHTO bicycle guidance for additional information).

    b. ***Bicycle gaps:*** Where any width paved shoulder exists beyond the rumble strip and bicycles are allowed to ride, recurring short gaps should be designed in the continuous rumble strip pattern to allow for ease of movement of bicyclists from one side of the rumble to the other. A typical pattern is gaps of 10 to 12 feet between groups of the milled-in elements at 40 to 60 feet.

    c. ***Edge line rumble strips:*** Use edge line rumble strips or a smaller offset (A) where it will allow additional shoulder area beyond the rumble strip that is usable to a bicyclist, pedestrian or other road user. In determining the appropriate offset, designers should consider truck traffic in the corridor and the proximity of residences, which may call for a *larger* offset.

    d. ***Adjusted rumble dimensions:*** (See Figure1) Decreased length transverse to the roadway (B) of either edge line or shoulder rumble strips may provide additional space usable to a bicyclist. Other minor adjustments in design dimensions, such as increased center-to-center spacing (E), reduced depth (D), and reduced width longitudinal to the roadway (C), have been shown to reduce impacts to bicyclists when they must be traversed. Crash modification factors have not been developed for these adjustments, but it is anticipated they will have a somewhat reduced effectiveness in alerting drivers, which is considered a reasonable tradeoff for an agency attempting to balance the needs of all road users.

10. **MITIGATING ADVERSE EFFECTS:** A balance between the safety of motorists, the potential adverse effects on the life of the pavement, and effects on nearby residents should be considered when installing rumble strips.

    a. ***Maintenance:*** Early concerns of accelerated pavement deterioration due to installation of milled rumble strips have proven to be unfounded. However, common practice is to locate the rumble strips at least a few inches from joints to reduce any potential acceleration of pavement deterioration. While rumble strips placed on pavement in good condition will be more cost-effective by virtue of being in place longer, shoulder deterioration is a safety issue with or without the presence of rumble strips. Experience

has shown that traffic flow near the rumble keeps water from accumulating in the strip. Where there are deterioration concerns, an asphalt fog seal can be placed over milled-in strips to reduce oxidation and moisture penetration.

Recent experience in Michigan has shown that shoulder preventative maintenance treatments such as chip seal, ultra-thin hot mix asphalt, and micro-surface, can be compatible with rumble strips. Chip seal on top of an existing rumble strip has been shown to retain the basic shape of the rumble, although losing some cross-section. However, stones from the chip seal enhance the noise and vibratory properties of the rumble. Micro-surface and ultra-thin hot mix asphalt overlays fill in existing lines of rumble strips, but a fresh line of rumble strips can be cut into the overlay at the same location without significant delaminating caused by the underlying filled-in rumbles.

b. ***Noise to nearby residents:*** Citizen acceptance of a state or local agency safety countermeasure should be taken into consideration as it can affect the long-term viability of that strategy. Although rumble strips are not intended to be traversed except when a driver leaves the roadway, rumble strip installations may produce noise complaints where there are nearby residences. Particularly when issues such as numbers of large vehicles, narrow lane widths, curves, or significant passing or turning maneuvers combine. Mitigation may include:

    i. Increasing the offset (A), particularly through curves where off-tracking is prevalent or in corridors with high volumes of truck traffic.

    ii. Removal of the rumbles in the vicinity of turn lanes or in spot locations such as a single house along a segment of roadway. The need to discontinue the use of rumbles in spot locations should not necessarily prevent their use along a segment or corridor.

    iii. Modifying other dimensions of the rumble strip. Note that noise measurements outside the vehicle should be used when mitigating this issue, not passenger compartment noise measurements that are used in studies of the effectiveness in alerting the driver.

Some surveys have shown that informed citizens often consider the improved safety worth the nuisance noise and that residents become accustomed to the noise fairly quickly.

11. PUBLIC INVOLVEMENT AND OUTREACH: Transportation agencies should follow established procedures to involve all road users and stakeholders (including motorist associations, bicycle organizations, enforcement agencies and emergency responders) in developing rumble strip implementation standards and practices. This can help establish expectations for projects with varying scopes of work and expedite project development.

When an agency is introducing edge line or shoulder rumble strips into an area for the first time or on a large scale, they should consider public outreach to inform the general public of the safety goals, explain how the treatment works, present historical success, and explain mitigation measures. Proactive newspaper articles, explanatory brochures, web-based videos, agency websites, and a variety of other outreach efforts have been used by many state DOTs and local agencies for this purpose. The expense of removing rumble strips can be significantly higher than the installation cost, so careful consideration of design and application along with public involvement and outreach often provides the most efficient use of limited funds.

12. RECOMMENDATIONS:

a. ***Installation:*** On new and reconstruction projects, four feet of paved shoulder should extend beyond the rumble strip. Continuous, milled edge line or shoulder rumble strips should be considered:

i. System-wide on all rural freeways and other rural highways with posted or statutory speeds of 50 mph or greater (i.e. systemic safety projects).

ii. Along rural or urban corridors where significant numbers of run-off-road crashes that involve any form of motorist inattention have been identified (i.e. location-specific safety improvement projects).

iii. During any highway project with a history of run-off-road crashes or where shoulder or edge line rumble strips were overlaid during the paving process (e.g. reconstruction or resurfacing projects).

b. ***Accommodation and Mitigation:*** To position a rumble strip program for the best chance of public acceptance, agencies should:

i. Consider accommodation of all road users and the potential adverse side effects mentioned in this advisory,

ii. Collaborate with stakeholders, and

iii. Modify the design and application of rumbles to the extent the agency considers appropriate to meet the safety goal.

c. ***Public Involvement and Outreach:*** Established public involvement procedures should be followed to ensure road user and community needs are properly addressed. When rumble strips are being introduced on a large scale or in a new area, public outreach should also be considered.

13. REFERENCES: The following resources are available on shoulder and edge line rumble strips.

a. Torbic, D.J. et al., *Guidance for the Design and Application of Shoulder and Centerline Rumble Strips*, National Cooperative Highway Research Program Report 641, 2009.
b. Morena, David A., *The Nature and Severity of Drift-Off Road Crashes on Michigan Freeways, and the Effectiveness of Various Shoulder Rumble Strip Designs*, Presented at the 82nd Annual Meeting of the Transportation Research Board, 2003.
c. Perrillo, Kerry, *The Effectiveness and Use of Continuous Shoulder Rumble Strips*, Federal Highway Administration, New York, 1998.
d. Hickey, John J. Jr., *Shoulder Rumble Strip Effectiveness, Drift-Off-Road Accident Reductions on the Pennsylvania Turnpike*, Transportation Research Record 1573, 1997.
e. Sayed, T., *Impact of Rumble Strips on Collision Reduction on British Columbia Highways: A Comprehensive Before and After Safety Study,* Transportation Research Record 2148, 2010.
f. Carlson, Paul J. et al., *Evaluation of Wet-Weather and Contrast Pavement Marking Applications: Final Report*, Texas Transportation Institute, 2007.
g. Potts, Ingrid B.et al., *Benefit-Cost Evaluation of MoDOT's Total Striping and Delineation Program,* Midwest Research Institute, 2008.
h. Moeur, Richard C., *Rumble Strip Gap Study, Final Report*, Arizona DOT, 1999.
i. USDOT, Policy Statement on Bicycle and Pedestrian Accommodation Regulations and Recommendations, 2010.
j. Elefteriadou, L., et al., *Bicycle-Friendly Shoulder Rumble Strips*, Pennsylvania Transportation Institute, 2000.

k. American Association of State Highway and Transportation Officials (AASHTO), *Guide for the Development of Bicycle Facilities*, Washington, DC, 1999.