Technical Advisory

U.S. DEPARTMENT OF TRANSPORTATION

Federal Highway Administration

Subject

ROADWAY SHOULDER RUMBLE STRIPS

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Paragraph

1. What is the purpose of this Technical Advisory? This Technical Advisory contains information on state-of-the-practice for the design and installation of shoulder rumble strips and provides guidelines for their use on appropriate rural segments of the National Highway System (NHS).

2. Does this Technical Advisory supersede another FHWA Technical Advisory? This Technical Advisory supersedes the information on shoulder rumble strips contained in Attachment 1, Typical Shoulder Treatments, of Technical Advisory T 5040.29, Paved Shoulders, dated February 2, 1990.

3. What is the definition of a shoulder rumble strip? A shoulder rumble strip is a longitudinal design feature installed on a paved roadway shoulder near the travel lane. It is made of a series of indented or raised elements intended to alert inattentive drivers through vibration and sound that their vehicles have left the travel lane. On divided highways, they are typically installed on the median side of the roadway as well as on the outside (right) shoulder.

4. What is the background on rumble strip development and use?

a. One of the Federal Highway Administration's (FHWA's) primary goals is to reduce the number and severity of single vehicle, run-off-the-road

crashes while preserving safe use of the roadway by bicyclists and pedestrians. Roadway improvements intended to decrease run-off-the-road crashes include better geometric design, increased skid resistant roadway surfaces, more durable pavement markings, and more visible roadside signs. In recent years, several State transportation agencies and toll road authorities have also installed and evaluated the effects of shoulder rumble strips on run-off-the-road crashes, particularly on rural Interstate highways and toll facilities. The results of these evaluations have consistently shown significant decreases in single-vehicle run-off-the-road crashes.

b. Pavement surface texture or audible/vibrational treatments have been in use for nearly fifty years as a means to alert errant drivers leaving the travel lane. Such treatments have been improved over the years in an effort to develop strip elements that are more effective and can be more easily and accurately installed.

c. 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. In the mid to late 1980s the Pennsylvania Turnpike Commission, after considering and testing several shapes, developed a rumble strip made of indented curved shapes which were 13 mm (1/2 in) deep, 180 mm (7 in) wide parallel to the travel lane and 400 mm (16 in) long perpendicular to the travel lane. The Commission determined this shape provided the best design for alerting drivers of both cars and trucks that their vehicles had crossed onto the roadway shoulder. The Commission found that the installation of the milled-in strip was preferred over the rolled-in design, not only because it was more effective, but also because it could be placed on existing pavement and could be more easily controlled during placement. Subsequently, many other states began to use this milled-in design because of its effectiveness and ease of installation.

5. When is the use of rumble strips warranted?

a. Run-off-road (ROR) crashes account for almost one-third of the deaths and serious injuries each year on the Nation's highways. For several years, inattentive driving has been identified as a significant causal factor in many of these crashes. While distracted, drowsy, or fatigued driving is not always identifiable during crash investigations, such behavior is considered by many to be prevalent among a large number of drivers involved in crashes of all types. Inattentive driving is considered by some to be as serious a problem as drunk or drugged driving.

b. A number of studies have demonstrated the benefits of shoulder rumble strips in reducing death and serious injury caused by inattentive drivers in ROR crashes. The methodologies used in these effectiveness studies and

their results vary from state to state, but all show some measure of crash reduction attributed to the presence of shoulder rumble strips. Many studies show very high benefit to cost (B/C) ratios for shoulder rumble strips making them among the most cost effective safety features available. To date, these studies have generally focused on rural freeways and toll facilities. Additional studies are needed to determine the effectiveness of shoulder rumble strips on two-lane rural roads.

c. Rumble strips will not eliminate ROR crashes caused by excessive speed, sudden turns to avoid on-road collisions, or high-angle encroachments. Because they are intended to alert drivers "drifting" off the road, rumble strips are most effective when installed near the edge line adjacent to relatively wide shoulders. This placement provides motorists leaving the traveled way at a shallow angle with both time and space to steer back onto the roadway safely. Rumble strips installed at the outside edge of a shoulder with no useable recovery area beyond the shoulder are of questionable value. Long sections of relatively straight roadways that make few demands on motorists are the most likely candidates for the installation of shoulder rumble strips.

d. A shoulder rumble strip has the additional benefit of providing a warning which may prevent an inattentive driver from traveling very far onto the shoulder and possibly striking a parked vehicle, a bicyclist, a pedestrian, or highway workers. A rumble strip may also serve as an effective means of locating the edge of the travel lane during inclement weather. Heavy rain or light snow often obscures the pavement marking edge line. Under conditions of poor or limited visibility, a rumble strip can help drivers maintain their proper lane position.

6. What types of rumble strip designs are most often used?

a. Types: There are four basic rumble strip designs or types: milled-in, rolled-in, formed, and raised.

(1) Milled-in: This design is made by cutting (or grinding) the pavement surface with carbide teeth affixed to a 600 mm (24 in) diameter rotating drum. The indentations formed are approximately 13 mm (1/2 in) deep, 180 mm (7 in) wide parallel to the travel lane and 400 mm (16 in) long perpendicular to the travel lane. The indentations are approximately 300 mm (12 in) on center and offset from the edge of the travel lane a distance of 100 mm (4 in) to 300 mm (12 in). Some research has been completed recently on the effectiveness of narrower and shallower cuts. Such variations from the original dimensions are discussed in detail in paragraph 8.

(2) Rolled-in: The rolled-in design is generally installed by using a steel wheel roller to which half sections of metal pipe or solid steel bars are welded. The compaction operation presses the shape of the pipe or bar into the hot asphalt shoulder surface. The resultant shape is generally 25 mm (1 in) deep, 50 mm (2 in) to 64 mm (2.5 in) wide parallel to the travel lane and 450 mm (18 in) to 900 mm (35 in) long perpendicular to the travel lane. The indentations are usually set 200 mm (8 in) on center and offset from the travel lane edge from 150 mm (6 in) to 300 mm (12 in).

(3) Formed: The formed rumble strip is added to a fresh concrete shoulder with a corrugated form which is pressed onto the surface just after the concrete placement and finishing operations. The resultant indentations are approximately 25 mm (1 in) deep, 50 mm (2 in) to 64 mm (2.5 in) wide parallel to the travel lane and 400 mm (16 in) to 900 mm (35 in) long perpendicular to the travel lane. The indentations may be in continuous pattern, but are generally in groups of five to seven depressions spaced approximately 15 m (50 ft) apart and offset from the travel lane at about 300 mm (12 in).

(4) Raised: Raised rumble strip designs can be made from a wide variety of products and installed using several methods. The elements may consist of raised pavement markers, a marking tape affixed to the pavement surface, an extruded pavement marking material with raised portions throughout its length or an asphalt material placed as raised bars on the shoulder surface. The height of the raised element may vary from 6 mm (1/4 in) to 13 mm (1/2 in). Spacing and width across the shoulder vary widely.

b. Location:

(1) Most states offset shoulder rumble strips just outside the edge line of the travel lane by a distance of 100 mm (4 in) to 300 mm (12 in). This keeps the strip elements some distance from the construction joint between the travel lane and shoulder; it helps reduce the number of inadvertent hits from passing traffic, especially larger trucks; and it allows for a substantial width of the paved shoulder to remain available for other users of the shoulder. A few states prefer to offset the rumble strip by as much as 770 mm (30 in) on wide shoulders to allow for maintenance vehicles and work zone traffic to straddle the rumble strip when driving on the shoulder. Such placement, however, moves the strip further away from the travel lane and narrows the recovery area outside the strip, thereby reducing the time available for an errant motorist to take corrective action after crossing the rumble strip. It also reduces the travel path available to bicyclists using the shoulder.

(2) Some states have installed milled-in shoulder rumble strip elements 300 mm (12 in) in width perpendicular to the travel lane instead of the original 400 mm (16 in). This is done to leave more of the paved shoulder clear for bicyclists. If the width is made much less than 300 mm (12 in), there is concern that a vehicle's tires, especially those of a large truck, may bridge the indentations, making them less effective in providing a vibration alert. However, at least one study found that large vehicle ROR crashes were a very small percentage of the overall problem. Some states have used rumble strips even narrower than 300 mm (12 inches) on facilities with particularly narrow shoulders and significant run-off-road crash experience. At least two states have installed 200 mm (8 in) strips coincident with the roadway edge lines.

(3) A few states place shoulder rumble strips along the freeway acceleration and deceleration lanes. However, most install the strip only along the shoulder near the edge of the through travel lanes and stop it at the beginning and end of auxiliary lanes. Shoulder rumble strips are generally not placed on freeway ramps, although they have been used to alert drivers of an especially tight turn entering the exit ramp.

c. Spacing:

(1) Most shoulder rumble strips are installed without any breaks or gaps except at exit and entrance ramps and at street intersections and major driveways on non-freeway facilities. The strips are not placed near the intersection or driveway approaches to allow vehicles to maneuver into and out of the intersections and driveways.

(2) At least one state uses an intermittent gap in their freeway rumble strip installation of 1.5 m (5 ft) in length between sets of milled-in elements 2.1 m (7 ft) in length. This state determined that this length of gap in the strip provides more of an alert sensation to the driver than does the continuous strip.

(3) In some of the first installations of formed-in rumble strip elements on concrete shoulders, the spacing between groups of corrugated elements was often between 12 m (40 ft) and 15 m (50 ft). While an errant driver might hit some of these elements on the shoulder, they were not as effective in alerting drivers as continuous shoulder rumble strips. Most strips on concrete are now placed continuously with the elements spaced 300 mm (12 in) on center and offset from transverse shoulder joints by at least 200 mm (8 in).

7. How are rumble strips typically installed?

a. An advantage of the milled-in strip is that it may be installed at any time, not only during shoulder construction, as long as the shoulder pavement is of sound material. As with all shoulder rumble strips, it is important to insure a constant and uniform alignment with the edge of the travel lane and that the proper depth and center to center spacing is maintained throughout the length of the installation. To protect milled-in strips from oxidation and moisture, some states place an asphalt fog seal over the milled-in strips.

b. Some difficulties have been reported with the installation of rolled-in rumble strips on asphalt shoulders. These indentations are installed with a steel drum roller at the time of final asphalt compaction. If the installation is done when the asphalt temperature is too low, the indentation may not reach the proper depth and if the temperature is too high, the asphalt may not stabilize, and the proper depth and shape of the indentations are not attained. Also, with the steel drum roller riding on steel pipes or bars spaced every 200 mm (8 in), there may be insufficient asphalt compaction between the indentations and proper density may not be attained. This may lead to premature deterioration of the shoulder surface.

c. In placing indented shoulder rumble strips on concrete shoulders, at least one state allowed a contractor to select either the milling method or the forming method for installing the standard milled shape. While the appearance and uniformity of the forming method was not as good as the milling method, the vibration and sound results were reported to be similar.

d. Raised pavement markers, thermoplastic edge lines with raised portions, and raised preformed tapes are generally not used in climates where snow-plowing is likely to destroy them.

8. How can the adverse effects of rumble strips on bicyclists be reduced?

a. The FHWA fully supports the following statement from the 1999 American Association of State Highway and Transportation Officials (AASHTO) Guide for the Development of Bicycle Facilities:

"Rumble strips or raised pavement markers….are not recommended where shoulders are used by bicyclists unless there is a minimum clear path of 0.3 m (1 ft) from the rumble strip to the traveled way, 1.2 m (4 ft) from the rumble strip to the outside edge of paved shoulder, or 1.5 m (5 ft) to adjacent guardrail, curb or other obstacle."

b. Rumble strips should only be installed when an adequate unobstructed width of paved surface remains available for bicycle use. To aid a

bicyclist's movement to the left of a shoulder rumble strip when needed to avoid debris, make turns or avoid other shoulder users, some states provide periodic gaps of 3.0 m (10 ft) to 3.6 m (12 ft) between groups of the milled-in elements throughout the length of the shoulder rumble strip. A study by one state recommends a gap of 3.6 m (12 ft) between milled-in elements of 8.5 m (28 feet) to 14.6 m (48 feet). Other states have specified 3.0 m (10 ft) gaps between 3.0 m (10 ft) milled-in elements.

c. Small stones, sand and other debris often collect on roadway shoulders. Usually the air turbulence caused by passing traffic will keep the portion of the shoulder closest to traffic relatively clear of such debris. For this reason, most bicyclists prefer to ride on that portion of the shoulder nearest to traffic to avoid debris. To provide a clear area beyond the rumble strip for bicycle travel, highway maintenance agencies should periodically sweep shoulders along identified bicycle routes and other routes of high bicycle usage.

d. Recent studies by two states attempted to develop modified rumble strip designs that would be more acceptable to bicyclists. The principle adjustments to the milled-in strip elements considered were reduced depth, reduced width and changes to the center-to-center spacing. Also, several types of raised elements have been tested and evaluated. These studies are identified in references m. and n. in paragraph 10. Both studies concluded that a reasonable compromise between maximum warning to errant motorists and tolerable discomfort to bicyclists were reduced-depth, milled rumble strips.

9. What are the FHWA's recommendations for the installation of shoulder rumble strips?

a. Continuous, milled shoulder rumble strips should be installed on rural freeways and expressways on the NHS as an effective means of reducing single vehicle, run-off-road crashes caused primarily by any form of motorist inattention. While they may be installed on a project-by-project basis, economies of scale and timely implementation of shoulder rumble strips make system-wide installation projects highly desirable.

b. There are a significant number of run-off-road crashes on non-freeway facilities such as rural multi-lane and two-lane roadways. Therefore, the FHWA recommends that shoulder rumble strips be used on those roadways for which an engineering study or crash analysis suggests that the number of these crashes would likely be reduced by the presence of rumble strips. In some cases, other countermeasures such as improved roadway geometry, additional signing and markings, or increased pavement skid resistance may be more appropriate than rumble strips or used in conjunction with

them. When rumble strips are recommended, the following guidelines should be followed to the maximum extent practical:

(1) Standard milled rumble strips, installed as close to the edge line as practical, should be used when a 2.4 m (8-foot) clear shoulder width remains available after installation of the rumble strip. This is the recommended treatment for roadways with 3.0 m (10 foot) shoulders.

(2) A modified design should be used along shoulders 1.8 or 2.4 m (6 or 8 feet) wide when the remaining available clear shoulder width is less than 1.8 m (6-feet) and the road can be used by bicyclists. The most recent studies indicate a milled depth of approximately 10 mm (3/8 inch) provides reasonable warning to most motorists while not being unduly dangerous to cross on a bicycle when necessary. Several states have used narrower strips (e.g., 300 mm (12 inches) or less) perpendicular to the direction of traffic with apparent success. Others, as noted above, have adopted a gap spacing to allow a bicyclist to cross into the travel lane and back without having to ride directly over the rumble strips. Since rumble strips are not intended to be ridden on by bicyclists and should be crossed with care, gaps in the strip pattern may be more effective in allowing safe crossings and are much easier to achieve than modest reductions in the depth of each milled strip. A 3.6 m (12 ft) long gap between 14.6 (48 ft) long sections of rumble strip is recommended. Consideration should be given to increasing the gap spacing, narrowing the width of the rumble strips, widening the shoulders for bicycle use, or all of the above on long downhill grades where bicycle speeds are likely to increase significantly.

(3) Rumble strips should not normally be used when their installation would leave a clear shoulder pathway less than 1.2 m (4-feet) wide (or less than 1.5 m (5-feet) wide if there is an obstruction such as a curb or guardrail) to the right of the rumble strip for bicycle use. At locations where such space does not exist to the right of the rumble strip, a rumble strip may be installed if it is at least 0.3 m (1 foot) to the right of the edge line. In this case, a bicyclist would be expected to ride to the left of the rumble strip, essentially along the outside edge of the traffic lane.

c. Regardless of the type of rumble strip element installed, shoulder rumble strip usage should be coupled with continuing driver behavior safety programs aimed at educating the general driving public on the dangers of drowsy and inattentive driving. These programs need to encourage drivers to practice responsible behavior in preventing impaired and unsafe driving habits. Likewise, bicyclists should be made aware of the increased use of

shoulder rumble strips and remain alert for their presence while riding along high-speed roadways.

d. Rumble strips should not normally be used in urban or suburban areas or along roadways where prevailing speeds are less than 80 km/h (50 mph). When used on non-access controlled facilities, they should be discontinued in advance of driveways and intersections and other locations where they would be crossed on a regular basis. Where rumble strips are being installed for the first time or where their use might be unexpected, appropriate signs and pavement markings alerting both motorists and cyclists to their presence are advisable. Since standard signing and markings do not presently exist, one state has initiated an experimental study under Section 1A-10 of the Millennium Edition of the Manual on Uniform Traffic Control Devices to develop and evaluate proposed signing and marking for rumble strips.

e. All responsible agencies should work in cooperation with bicycle groups, enforcement agencies, emergency groups and other roadway users, to develop policies, design standards and implementation techniques that address the safety and operational needs of all roadway users.

f. Some states have installed milled centerline rumble strips on two-lane roads having a history of head-on and opposite-direction sideswipe crashes. Most of these installations have consisted of transverse grooves extending across the double yellow centerline and the space between them. Initial evaluation efforts have shown reductions in the types of crashes that centerline rumble strips address. The Insurance Institute for Highway Safety (IIHS) has recently proposed a long-term evaluation of the overall effectiveness of this treatment and is seeking candidate sites nationwide. Transportation agencies interested in participating in this study are encouraged to contact Mr. Richard Retting at IIHS at rretting@iihs.org or at 703-247-1582 for details.

10. Are there any reference materials on rumble strip use and effectiveness?

Yes, the following references apply to the use of rumble strips.

a. *Use of Rumble Strips to Enhance Safety - A Synthesis of Highway Practice;* National Cooperative Highway Research Program Synthesis 191, Douglas W. Harwood, 1993.

b. *Shoulder Rumble Strips: A Method To Alert Drifting Drivers;* Pennsylvania Turnpike Commission, Neal E. Wood, P.E., January 1994.

c. *Application and Evaluation of Rumble Strips on Highways;* Utah Department of Transportation, Salt Lake City, Utah, Institute of

Transportation Engineers 64th Annual Meeting, October 16-19, 1994, Dallas, Texas, Eric Yuan-Chin Cheng, Ezequiel Gonzalez, and Mack O. Christensen, 1994.

d. *A Study of Effectiveness of Various Shoulder Rumble Strips on Highway Safety;* Virginia Department of Transportation, Chung S. Chen, November 1994.

e. *Continued Research on Continuous Rumble Strips;* University of Maine for the Maine Department of Transportation, Final Report, Technical Paper 94-4, Per Garder and John A. Alexander, December 1995.

f. *Shoulder Rumble Strip Effectiveness: Drift-Off-Road Accident Reductions on the Pennsylvania Turnpike;* Pennsylvania Turnpike Commission; Transportation Research Record 1573, John J. Hickey, January 1997.

g. *Effectiveness of Shoulder Rumble Strips: A Survey of Current Practice;* Report No. FHWA/NY/SR-97/127, Engineering Research and Development Bureau, New York State Department of Transportation, Rick L. Morgan, Dan E. McAuliffe, September 1997.

h. *The Effectiveness and Use of Continuous Shoulder Rumble Strips;* Federal Highway Administration, Kerry Perrillo, August 1998.

i. *Guide for the Development of Bicycle Facilities;* 1999, American Association of State Highway and Transportation Officials Task Force on Geometric Design.

j. *Analysis of Gap Patterns in Longitudinal Rumble Strips to Accommodate Bicycle Travel;* Moeur, R.; Transportation Research Record, No. 1705, Pedestrian and Bicycle Transportation Research 2000, pp 93-98.

k. *Safety Evaluation of Rolled-In Continuous Shoulder Rumble Strips Installed on Freeways;* Michael S. Griffith; Statistical Methods in Transportation and Safety Data Analysis for Highway Geometry, Design, and Operations. Transportation Research Record, No.1665, October 1999, pp. 28-34.

l. *Bicycle-Tolerable Shoulder Rumble Strips;* Pennsylvania Department of Transportation, Elefteriadoiu, L. et al., March 2000.

m. *Evaluation of Milled-In Rumble Strips, Rolled-In Rumble Strips and Proprietary Applications;* California Department of transportation, Troy R. Bucko and Ahmad Khorashadi, May 2001.

n. *Bicycle-Friendly Rumble Strips;* Colorado Department of Transportation, William Outcalt, May 2001.

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