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A SYNTHESIS OF CURRENT PRACTICES AND POLICIES FOR SHOULDER RUMBLE STRIPS

Prepared by

Rod E. Turochy, Ph.D., P.E.

Prepared for

Highway Research Center
Auburn University

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Rod E. Turochy, Ph.D., P.E.

Highway Research Center
Department of Civil Engineering
Auburn University

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ABSTRACT

Rumble strips are placed on paved highway shoulders to alert drowsy or inattentive drivers that they are leaving the travel lanes; accordingly, the primary safety benefit of shoulder rumble strips is a reduction in run-off-road crashes. Several studies have shown that milled, or ground-in rumble strips provide significantly greater auditory and vibratory stimuli than other types. Several states have studied the primary safety benefits and the cost effectiveness of milled shoulder rumble strips, reporting reductions in run-off-road crashes of up to 70%. Extensive studies have also been conducted to assess the impact of milled rumble strips on bicycles. In 2001 the Federal Highway Administration published a technical advisory on this topic, recommending the use of milled rumble strips and suggesting values for dimensions of length, width, and depth. A subsequent survey of 36 state highway agencies revealed that over 90% of these states now use milled shoulder rumble strips. Most states have selected rumble strip dimensions consistent with the technical advisory; however, a wide range of practices exists regarding offset distance from the travel lane and provision of gaps to facilitate bicycle crossings. Over 30% of states have applied rumble strips on the centerlines of two-lane rural roads. Negative aspects of the now-widespread use of milled shoulder rumble strips include sporadic noise complaints from nearby residents, difficulties faced by bicyclists, and occasional water-related pavement damage. While the benefits of milled shoulder rumble strips have been well-documented, research and guidance are needed regarding on offset distance, accommodation of bicyclists, and several secondary effects.

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1. INTRODUCTION

Rumble strips consist of changes in the pavement profile intended to alert drivers, through resultant auditory and vibratory stimuli, to a change in roadway conditions or vehicle trajectory. When placed on the paved shoulders of high-speed highways, rumble strips are intended to alert a driver to the fact his or her vehicle has left the designated travel lanes and may be in danger of running off the roadway altogether. The Alabama DOT (ALDOT) requested the assistance of the Highway Research Center at Auburn University to provide research and technical assistance on the topic of shoulder rumble strips (SRS), specifically rumble strips that are milled or ground into the pavement. As the safety benefits of SRS have been well-documented (e.g., reductions in run-off road crashes), the purpose of this research effort was to ascertain the current state of practice and to synthesize relevant literature on issues other than the primary purpose (safety benefits) of shoulder rumble strips. Although several types of rumble strips exist, in recent years many states have adopted milled rumble strips as the preferred type; milled SRS became an ALDOT standard in 2000. Milled rumble strips are simply grooves of specified dimensions cut into the pavement; the grooves themselves are placed transverse to the direction of travel, while a continuous series of these grooves runs longitudinally with the roadway, allowing for vibratory and auditory effects when the rumble strips are struck by a vehicle tire. FHWA published a technical advisory on SRS in 2001 recommending milled SRS as the preferred type due to its superior performance in providing a loud, jarring warning over rolled-in rumble strips.

1.1 Purpose and Scope

The purpose of this effort was to document current practices with milled SRS and present the findings in a report to ALDOT. Through the knowledge gained from a review of published literature and research reports, and a survey of state transportation departments, conclusions on the state of the practice and recommendations for ALDOT to consider are presented.

The scope of the research was confined to the following issues that were either specifically included in the research proposal or added after a series of telephone conversations with several ALDOT officials:

- the use of shoulders as travel lanes during construction activities
- bicycle comfort and safety on non-freeway roads
- ambient noise levels in residential areas
- shoulder width where the milled rumble strips are used with permitted bicycle use and guardrail is needed
- safety of milled rumble strips in front of driveways and intersections
- configuration and design standards
- cost differences between milled rumble strips and other rumble strip types

1.2 Methods

This study was carried out through the following tasks:

- A series of telephone conversations with ALDOT engineers with expertise in highway design, construction, maintenance, and traffic operations. These conversations served to ensure that the objectives and scope of the project were consistent with ALDOT interests, and to elicit any additional issues of interest to ALDOT.
- A review of the literature pertaining to shoulder rumble strips was undertaken to capture the findings of past investigations into issues associated with SRS. While safety-related benefits, such as reductions in run-off-road crashes, were noted, this effort primarily focused on summarizing findings related to the seven points noted in the project scope.
- A survey was developed to ascertain current state DOT practices and experiences regarding issues identified in the scope of this project. The survey was reviewed by ALDOT engineers and then distributed to state DOTs in July 2002.
- The findings of the survey and literature review, along with derived conclusions and recommendations, are included in this final report, which documents the entire research effort.

2. LITERATURE REVIEW

A review of published literature uncovered a broad body of research findings dating to the 1980s pertaining to rumble strips placed on highway shoulders. The literature focuses primarily on issues of design standards and safety benefits. This review of the literature first presents some highlights of the safety benefits of shoulder rumble strips, followed by the evolution of shoulder rumble strips, with emphasis on the design and configuration of the milled-in type, and then addressing other issues associated with shoulder rumble strips, such as noise, impact on bicyclists, and cost.

Since the focus of this study is specifically on milled rumble strips, a brief explanation of the differences between this type and other types is warranted.

2.1 Safety Benefits of Shoulder Rumble Strips

The safety benefits of shoulder rumble strips have been studied by several state DOTs and other agencies and are therefore well-established. As the primary focus of this report is on SRS practices rather than a quantification of impacts on safety, a brief overview of documented safety benefits is provided here. California DOT began rolling in rumble strips on freeway shoulders in 1976. Rumble strips were installed on the median and right shoulder side of over 160 miles of freeway over a 5-year period. An analysis of crash data one year before and one year after installation found a 49% reduction in run-off-road (ROR) crashes (63% reduction of right shoulder ROR crashes and 18% reduction of left shoulder ROR crashes), which contributed to a 19% reduction of crashes of all types (Chaudoin and Nelson 1985). A study conducted for the Federal Highway Administration examined safety effects of SRS in 11 states and found a 20% reduction in ROR crashes across all sites studied. However, a 9% reduction was observed at designated control sites over the same time period (Ligon et al. 1985). The safety effects of rolled SRS installations on rural Illinois freeways in the early 1990s were evaluated using the installations as a treatment group. A "best estimate of the average safety effectiveness" of continuous rolled SRS was a 21% reduction in single-vehicle ROR crashes on rural freeways, and an 18% reduction in single-vehicle ROR crashes on all freeways (Griffith 1999).

More recently, as milled-in SRS have become the predominant type, several states have reported noteworthy safety benefits. On the Pennsylvania Turnpike, milled-in SRS were installed on five additional safety-critical sections totaling 31 miles in the early 1990s. These sites exhibited a 70% reduction in ROR crashes in a time period of 12 to 42 months after installation when compared with 30 to 36 months of crash data before installation (Wood 1994). Tennessee DOT (TDOT) reports "a 31% reduction in run-off the road crashes on the areas of the Interstate" where the milled-in SRS have been installed; TDOT began installing milled SRS in 1996 (Tennessee DOT 2002). Virginia DOT, which had begun installing milled SRS in 1994 and has completed installation on its entire rural Interstate highway system, found a reduction of 51% in ROR crashes and a 48% reduction in ROR crash fatalities (Virginia DOT 2003).

2.2 Design and Configuration of Milled SRS

In the first reported experimentation with milled-in SRS, the Pennsylvania Turnpike Commission found promising safety benefits, ultimately adopting the milled type as the preferred standard. The Turnpike Commission experimented with five different design configurations of varying depths and longitudinal lengths for the grooves on their test facility. An SRS pattern with grooves of 4 inches in length, 12 inches center-to-center spacing and 0.5 inch depth was selected for use based on testing of noise levels and test driver preferences. In 1989, a section of rolled-in SRS designated as the Sonic Nap Alert Pattern (SNAP) was installed on a six-mile downgrade that had exhibited a poor safety record with respect to ROR crashes. For wider implementation on the Turnpike, milled-in SRS were considered. Initial testing showed a noise level of 3 dB (decibels) greater than that of the rolled-in SRS. The length dimension was modified to 7 inches to accommodate the cutting drum available for SRS installation, and the SNAP standard was modified to include milled-in SRS of this dimension. The milled-in SRS were installed on five additional safety-critical sections totaling 31 miles. These sites exhibited a 70% reduction in ROR crashes in a time period of 12 to 42 months after SNAP installation when compared with 30 to 36 months of crash data before installation (Wood 1994).

In 1994, the Virginia Department of Transportation (VDOT) conducted a study of the roughness and noise levels associated with three types of rumble strips: rolled-in (flexible pavement), milled-in (flexible pavement), and corrugated (formed in rigid pavement). The pertinent dimensions of the milled SRS grooves, length (7 inches), spacing (12 inches), and depth (0.5 inch), were the same as those adopted in Pennsylvania. The vibratory effect of the SRS was quantified using the international roughness index (IRI), a measure of pavement roughness. The additional roughness of the SRS, beyond that measured in the traveled lane in the test sections, was 36.7% for rolled, 501% for milled, and 40.5% for corrugated, respectively. The VDOT study concluded that milled SRS provide over 12 times the additional roughness provided by rolled SRS. Noise levels were measured at speeds of 65 mi/h in the test sections. On flexible pavements, the average noise level of the test sections was 75 dB. Rolled and milled SRS produced noise levels of 77.5 and 85.8 dB, respectively. Therefore, the increase in noise level provided by milled SRS was about 3 times greater than that of rolled SRS (Chen 1994).

A shift toward the predominance of the milled-in type of SRS has occurred only in the past ten years or so. A synthesis of practice conducted for the National Cooperative Highway Research Program, based on a survey conducted in 1992, does not make note of milled SRS -- all agencies surveyed used either raised or rolled rumble strips (Harwood 1993). A subsequent survey conducted by the New York State Department of Transportation in 1997 found 19 agencies regularly used SRS; 14 of these used rolled SRS and 12 used milled SRS (seven agencies reported use of both types) (Morgan and McAuliffe 1997).

In 1999, the California Department of Transportation (Caltrans) studied several different types of devices intended to warn errant drivers, with the study objective of quantifying noise, vibration, and impacts on bicyclists. The rolled SRS predominant in California at the time was used as a baseline; milled SRS (of four different depths) were also tested, as were several pavement markers and markings. Both the noise and vibration produced by six different motor vehicles traversing milled SRS of depths of $^3/_8$-inch, $^1/_2$-inch, and $^5/_8$-inch were greater than those produced by traversing the rolled SRS. However, a group of 55 bicyclists subjectively rated the milled SRS of $^5/_8$-inch and $^1/_2$-

inch depth most poorly on comfort and control criteria among the eleven devices tested. The $^{3}/_{8}$-inch deep grooves were rated better from a statistical perspective. The recommendations to Caltrans from the study were to adopt milled SRS with grooves of $^{5}/_{16}$-inch depth (with a tolerance of $^{1}/_{16}$-inch) (Bucko and Khorashadi 2001). Interestingly, the groove depth recommended was substantially less than that used in the Pennsylvania study and that recommended in a subsequent Federal Highway Administration Technical Advisory (FHWA 2001).

In December 2001, the Federal Highway Administration finalized a technical advisory providing guidance on rumble strip placement. The technical advisory recommends that "continuous, milled shoulder rumble strips should be installed on rural freeways and expressways…," and the technical advisory also recommends that rumble strips be placed on other roadways "for which an engineering study or crash analysis suggests that the number of crashes would likely be reduced by the presence of rumble strips." Guidance on dimensions of milled SRS include the following: groove depth of 0.5-inch, longitudinal length (in the direction of travel) of 7 inches, width (transverse to the direction of travel) of 16 inches, center-to-spacing of 12 inches, and an offset from the edge line of 4 to 12 inches. However, the technical advisory also notes that recent research (e.g., Bucko and Khorashadi 2001) indicates that shallower grooves and widths of less than 16 inches may be used. Also, the technical advisory states that a longitudinal gap in the groove pattern may be used to facilitate bicycle crossings of the milled SRS; specifically, a gap of 12 ft between 48 ft grooved sections is recommended, based on recent research (e.g., Moeur 2000) as noted below. In summary, FHWA recommends milled SRS as the preferred type with dimensions as noted above.

2.3 Bicycle Concerns with Milled SRS

In addition to providing noise and vibratory alerts to errant motorists, the travel path of bicyclists across milled SRS is often considered in the design and configuration of milled SRS. One survey of practices found that 13 of 19 agencies reported "including consideration of bicyclists into their specifications or policies concerning their use" (Morgan and McAuliffe 1997). More recently, the Pennsylvania Transportation Institute conducted a study of milled SRS alternative dimensions with the purpose of identifying a configuration that is relatively accommodating to bicyclists traversing the SRS while still providing substantial safety benefits (through noise and vibratory alert to motorists). The study involved both simulation modeling of bicyclists and live participants. Six configurations were studied, including the current Pennsylvania standard and other combinations of longitudinal length between 5 and 7 inches, spacing between 11 and 12 inches, and depth between $^1/_4$ and $^1/_2$ inch. Regarding bicycle-friendliness, the six patterns were evaluated based on objective measures, such as angular acceleration and pitch, as well as subjective measures based on test participants' opinions about comfort and safety issues. Noise levels were also measured. Interestingly, the pattern that bicyclists most favored also produced the lowest noise level (78 dB at 55 mi/h) among the six patterns. The SNAP pattern developed on the Pennsylvania Turnpike produced the highest noise level (89 dB at 55 mi/h) but was least favored by bicyclists. Two other patterns were recommended for use on low- and high-speed, non-limited-access facilities (producing noise levels of 81 and 79 dB, respectively) that involve shallower grooves and shorter spacing than the SNAP pattern (Elefteriadou et al. 2000). However, as of August 2002, the Pennsylvania Department of Transportation had not yet adopted the recommendations.

A study conducted in Arizona investigated the issue of providing gaps, or breaks, in the milled SRS pattern to facilitate bicycle crossings. An experiment to determine an appropriate length of such a gap, recognizing the trade-off between gaps so long that errant vehicles may cross the SRS in the gap (thereby not striking the grooves) and gaps so short that bicyclists have substantial difficulty utilizing the gaps, was conducted using twenty-eight bicyclists of a wide range of skill levels. After testing several gap lengths, a length of 12-ft was recommended for use with the 12-inch wide rumble strips in use in Arizona. The remaining issue to be determined was the frequency of these gaps in the longitudinal direction; cycles of 40-ft (28-ft between gaps) and 60-ft (48-ft between gaps) were recommended for implementation. These cycles respectively provide 70% and 80% coverage of the shoulder with grooves in the SRS pattern (Moeur 2000).

2.4 Other Secondary Issues With Milled SRS

Much of the attention given to research on rumble strips, beyond the direct safety benefits, has been associated with design issues and bicyclist accommodations. However, several other issues have been identified and addressed in the literature including costs, noise complaints, and adequacy of shoulder widths. In the survey conducted in the early 1990s for the NCHRP Synthesis, 22% of the responding agencies had received noise complaints about rumble strips (a combination of raised and rolled-in strips both in shoulder and travel lane applications); the subsequent New York State DOT survey noted that 21% of responding agencies had received noise complaints associated with milled SRS (Harwood 1993).

Two issues associated with bicycle travel are the traversability of the grooves, as noted above, and the provision of sufficient width outside of the SRS for bicycle travel. The NCHRP survey found that 7% of agencies had received complaints from bicyclists (Harwood 1993). Regarding shoulder width, FHWA recommends ensuring compliance with the recommendation of the American Association of State Highway and Transportation Officials (AASHTO). Specifically, AASHTO states that there should be a minimum of 4 ft from the outside edge of the rumble strip to the edge of the paved shoulder, and a minimum of 5 ft from the outside edge of the rumble strip to an adjacent guardrail, curb, or other obstacle (FHWA 2001). Recommendations based on recent research by Caltrans are slightly more accommodating to bicyclists, recommending installation of milled SRS on highways where bicycles are permitted only if a minimum of 5 ft is provided between the rumble strip and the paved shoulder (Bucko and Khorashadi 2001).

3. STATE OF THE PRACTICE

A key aspect of this research effort was to document the state of rumble strips practice, and associated policies, pertaining to the issues identified in the purpose and scope of the study. First, the current practices of the Alabama Department of Transportation are presented, followed by the findings of a survey of state DOTs, as described below.

3.1 Practices of the Alabama Department of Transportation

The Alabama Department of Transportation (ALDOT) began using rumble strips to improve highway safety in the 1980s. In 1999, ALDOT began using milled SRS on rural freeways and other locations as specified in new construction plans. The dimensions of the milled SRS are shown in Figure 1. A typical installation is shown in Figure 2. The dimensions for length, width, depth, and spacing used by ALDOT are consistent width the guidance given in the FHWA Technical Advisory. The offset dimension used in Alabama is 18 inches, and no provisions are made to provide gaps in the pattern to accommodate bicycle crossings.

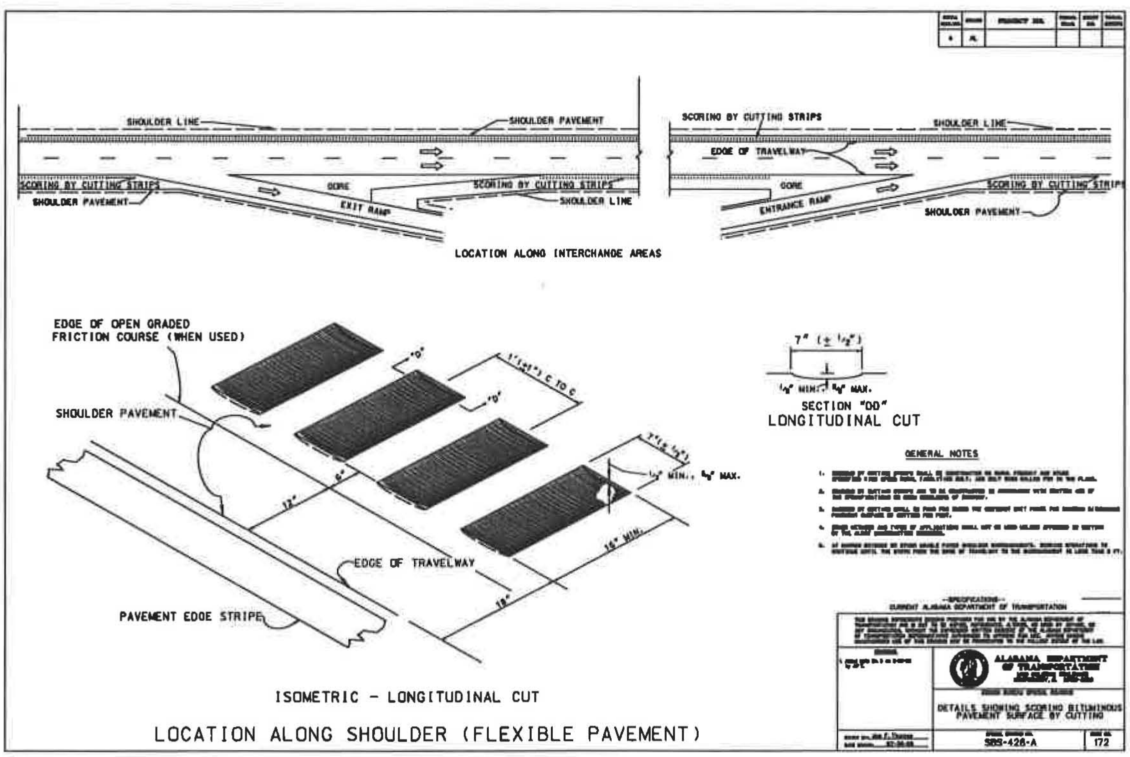

Figure 1. Alabama Department of Transportation Milled SRS Drawing

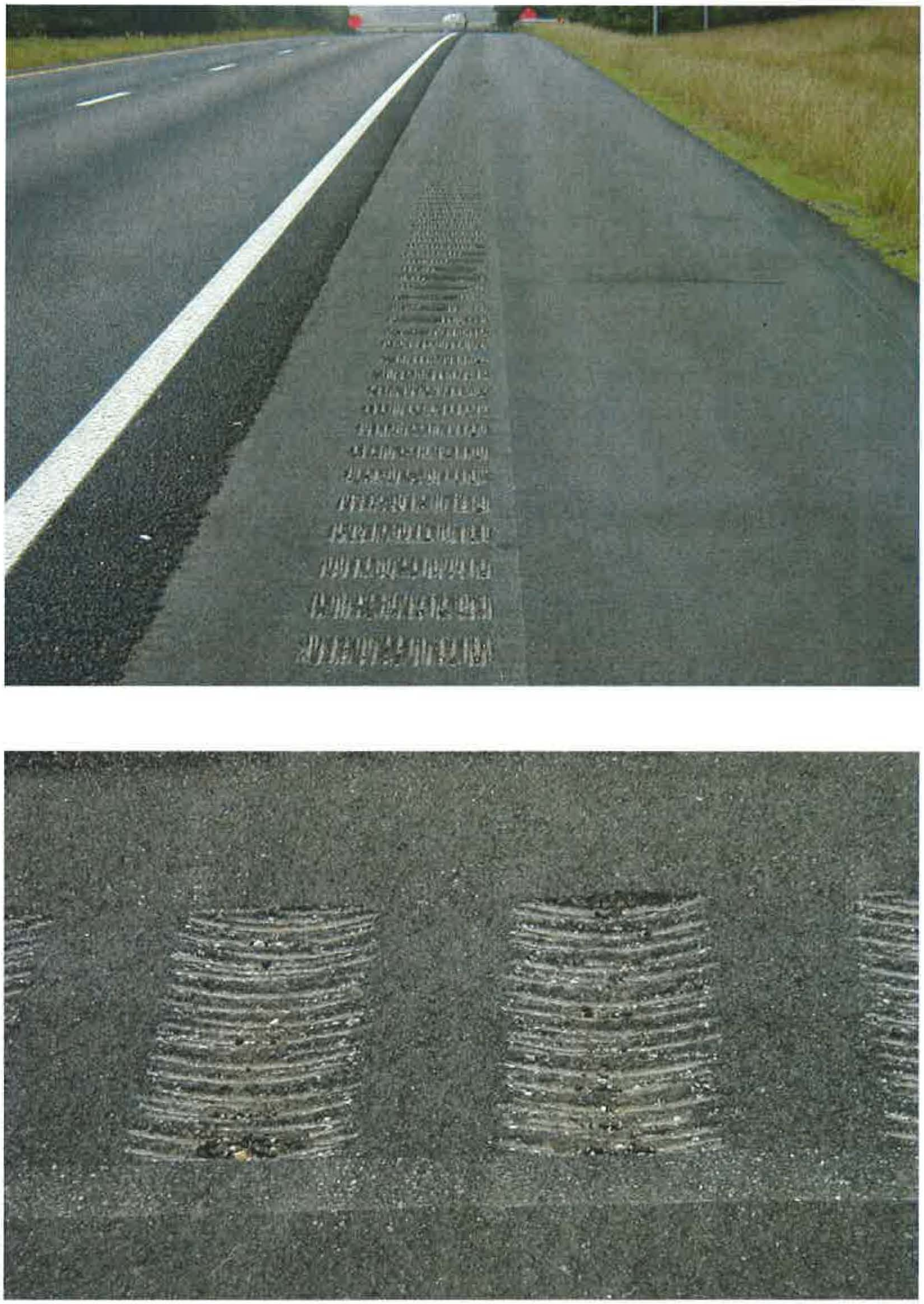

Figure 2. Typical Milled SRS Installation on an Alabama Freeway

3.2 Survey of Practices in Other States

To ascertain the current state of practice regarding rumble strip policies, a survey of state DOTs was conducted. While surveys of rumble strip practices have been conducted in the recent past by DOTs in New York (Morgan and McAuliffe 1997) and Minnesota (FHWA 2001), those surveys had smaller sets of questions and more limited scopes than this survey. The "Survey of Transportation Agencies Regarding Rumble Strip Practices", included in this report as Appendix A, consisted of 13 questions that attempt to address the issues identified in the purpose and scope of this study and to obtain some additional background.

The survey was distributed to 49 state DOTs (excluding Alabama) in July 2002; 38 responses were received, yielding a response rate of 78%. 35 (92%) of the responding agencies were using milled SRS at the time of the survey. One of the other three states indicated that milled SRS would be used starting in 2003. Underscoring the relative newness of the milled-in type of SRS, 23 of the 35 states (66%) using milled SRS had only been doing so since 1995. The remainder of this section of the report summarizes the responses given by the 35 states using milled SRS to each of the remaining questions in the survey; unless otherwise specified, the percentages reported refer to these 35 states.

Design Dimensions

Information on six dimensions (longitudinal length, depth, transverse width, spacing, offset, and gap) related to milled SRS was obtained. The FHWA Technical Advisory makes specific recommendations on four of these dimensions: 7 inches in longitudinal length (the length of the groove as measured in the direction of traffic), 0.5 inch in depth, 16 inches in width (as measured perpendicular to traffic flow), and 12 inches in center-to-center spacing. The survey showed that most states adhere to the FHWA guidance. 86% of states use 7 inches as the nominal groove length; about half (47%) of these states add a tolerance value ranging between $^1/_4$ and 1 inch. Other states used values of five, six, or eight inches for length. 86% of states also use $^1/_2$ inch as the nominal groove depth; most of these states (63%) use tolerance values of $^1/_8$ inch, one state uses 0.1 inch, two states use $^1/_4$ inch, and the remaining states do not specify a tolerance value. The remaining

14% of states use depth values of $^3/_8$-inch or $^5/_8$-inch. Regarding width, 83% of states use 16 inches as recommended by FHWA; tolerances are typically not specified for width. The remaining states use either 8 or 12 inches for the width. All states (using milled SRS) use a 12-inch center-to-center spacing between grooves, with a small number of states specifying a tolerance of 1 inch.

The FHWA Technical Advisory does not recommend values for offset from the edge line (pavement marking) or edge of the traveled lane. A wide variety of values is used by the states, ranging from two to 36 inches. 37% of states specify offset values as a function of shoulder width or type of highway. For example, two states use an offset of 6 inches when the shoulder width is less than six feet, and 30 inches if the shoulder width is greater than or equal to six feet. Reasons for using different offsets for different shoulder widths may include avoiding placing the grooves so close to the outside edge of the paved shoulder such that pavement breakup is facilitated and ensuring that a paved shoulder usable for bicycles exists outside of the rumble strip on roads without full lane width paved shoulders. Among the states that use a single value for the offset, 6 inches is most common (23% of states); however, the average value is approximately 12 inches; there is no general trend among the states for the offset dimension.

Provision of a break, or gap, in the grooves to facilitate bicycle crossings has been adopted by 26% of states; however, as with the offset value, no consensus exists in the dimensions used. Among the nine states that reported using such gaps, 44% use a pattern of 12-ft gaps and 48-ft of grooves, resulting in a "coverage" of 80% of the SRS. The patterns used in the other five states give coverage of 50% to 85%. One state reported that gaps are used only on right shoulder applications, another state indicated use of gaps only on roads other than freeways, and one state indicated that gaps are used "as needed", implying that gaps are only used at locations where a strong argument can be made for their use.

Cost

Several states reported cost data as part of their survey responses; these values varied widely as well. Milled SRS are typically applied either to existing highways via a contract whose specific focus is application of milled SRS in long runs, or in a construction or maintenance contract via a unique pay item. Costs vary widely; generally, the unit cost (most often in linear feet) decreases as the length of the run increases. Contracts to retrofit highways with milled SRS (typically including several miles in one contract) tend to produce lower unit costs than construction or maintenance contracts that typically have runs of less than five miles. Costs reported in the survey range from a low of $0.05 per linear foot to a high of $1.50 per linear foot. 26% of states reported values less than or equal to $0.10 per linear foot. One state indicated that for approximately 1600 linear miles (8,448,000 linear feet), the cost was $280 per linear mile (about $0.053 per linear foot).

Noise Complaints

17% of states reported receiving noise complaints from nearby residents. One state removed the milled SRS due to such complaints; another indicated that the offset dimension was increased to reduce the occurrences, another state indicated noise complaints have arisen in urbanized areas where the shoulder is used to maintain traffic in certain circumstances.

Impacts on Construction and Maintenance Activities

A possible detrimental impact of milled SRS can occur when a portion of the shoulder is used to carry traffic during a construction or maintenance activity that occupies some or all of the travel lanes. 40% of states reported that provisions are made to modify or remove milled SRS to minimize impacts to traffic that may use the shoulder during highway work activities. Among these states, the treatments used vary, but most states either fill the grooves with a slurry, chip seal, or asphalt concrete, or completely overlay the affected area with new asphalt concrete.

Other Identified Problems

In addition to noise complaints, a small number of states reported a wide variety of unexpected problems arising from the implementation of milled SRS. One state reported that the rumble strips may hold stormwater and make pavement more susceptible to water-related damage; while another reported applying an asphalt emulsion seal to the strips to reduce possible moisture damage. Another state reported a concern with "maintaining effectiveness after applying seal coats." Yet another state reported that spalling of asphalt concrete observed after a milled SRS installation was due to the grooves being placed on the longitudinal joint between the travel lane and the shoulder. However, with only 9% of states reporting such problems, it appears that problems with pavement structure deterioration due to the use of milled SRS are rare and isolated incidents.

Two states (6%) each reported that the milled SRS had played a role in the occurrence of a crash. One state noted that a motorcyclist had hit the rumble strips and lost control of the motorcycle; another state reported that a "driver woke up due to the rumble strips and oversteered, causing a rollover." As only two cases were reported in which the milled SRS were associated with crashes (rather than the prevention of crashes), such incidents are likely to be extremely rare anomalies.

Other Uses and Benefits

Many states have adopted policies or are experimenting with the use of milled rumble strips on the centerlines of two-lane highways, with the intention of reducing head-on and other lane-crossover incidents. 26% of states using milled rumble strips on shoulders are using milled centerline rumble strips to some extent, while another 11% of states are considering or studying such applications prior to their use. Some of these states have reported substantial safety improvements; for example, one state reports a 30% reduction in head-on crashes across several sites where milled centerline rumble strips were installed, while another state reported a 90% reduction at one site. Other benefits noted in the survey responses were associated with helping drivers keep their vehicles in the travel lanes during weather conditions with poor visibility (specifically snow and fog).

4. CONCLUSIONS

The purpose of this study was to summarize the state of the practice on state DOT policies on shoulder rumble strips (SRS), with particular focus on SRS milled into the pavement. Issues identified for investigation included design standards and dimensions of milled SRS, impacts on bicycle safety and comfort, necessary shoulder width, costs, noise impacts, impacts on construction and maintenance activities, and safety issues with milled SRS in front of driveways and intersections. Information was gathered through a literature review focused on these topics and a survey of state DOTs, to which 38 of 49 (78%) targeted agencies responded; 92% of these state DOTs are using milled SRS. These two efforts yielded sufficient information to characterize the state of the practice on all issues identified in the project scope with the exception of safety issues at driveways and intersections.

There is a high degree of consistency among the states on four of the six dimensions for milled SRS: longitudinal length, depth, width, and spacing. The vast majority of states follow the guidance provided in the FHWA Technical Advisory: length of 7 inches, depth of ½ inch, width of 16 inches, and a center-to-center spacing between adjacent grooves of 12 inches. The offset (distance from the edge line or edge of travel lane to the SRS) varies widely among states, ranging from two to 36 inches. Although six inches is most common, only 23% of states use this value. 37% states use a range of offset values depending upon highway type (e.g., freeway) and/or shoulder width. A gap in the groove pattern to facilitate bicycle crossings is provided by 26% of states; 44% of these states use a gap of 12 ft between 48 ft of grooves. Most states that use milled SRS on highways where bicycles are permitted only apply them where at least 4 ft of paved shoulder remains outside the SRS.

While milled SRS typically constitute a separate pay item in highway contracts, the range of values varies widely, primarily as a function of the amount of SRS (typically measured in linear feet, meters, kilometers, or miles) and whether the primary purpose of the contract is to install milled SRS (e.g., to retrofit existing highways) or to improve a section of roadway in which milled SRS could be viewed as an incidental item. Values below $0.10 per linear foot were reported by several states for SRS contracts or as the low end of a range of values. The high value reported was $1.50 per linear foot.

Work activities sometimes require agencies to move traffic onto the shoulder; 40% of states reported that milled SRS were addressed, either by filling the grooves or applying a new surface layer of asphalt concrete. Noise complaints from nearby residents were reported by 17% of states using milled SRS; in a small number of cases the SRS were removed or placed further from the travel lane (increasing the offset dimension).

Unexpected problems, as well as additional benefits, were reported by several states. 9% of states reported pavement deterioration after installation of the milled SRS. Perceived benefits, in addition to the primary purpose of reducing run-off-road crashes, included providing guidance to drivers in poor visibility conditions (specifically snow and fog). Additionally, several states (37%) reported using milled rumble strips on the centerlines of two-lane highways or studying this possibility, with noteworthy reductions in crash rates involving vehicles traveling in opposing directions. The National Cooperative Highway Research Program is currently conducting a synthesis of current practice on centerline rumble strips.

5. RECOMMENDATIONS

The policies and practices of the Alabama Department of Transportation are generally consistent with practices of other states and the guidance given by the Federal Highway Administration. Issues that would possibly improve the current ALDOT policy, as identified through this study, include:

- Provision of a gap in the SRS on highways where bicycles are permitted (highways other than freeways). Several states have adopted such a policy without noting any compromise of the primary safety benefit of milled SRS.
- Consideration of retrofitting existing freeways with milled SRS. Several states have undertaken programs to install milled SRS on all freeways rather than waiting for substantial maintenance activities to be performed.

Further research that would yield more information for rumble strip policies includes:

- A study to determine an optimal offset distance. Such a research project would examine issues that may affect offset distances, including recovery area beyond the SRS, impact on wide loads and other vehicle whose drivers may stray only slightly from the travel lane while still properly attending to the driving task.
- A study to determine appropriate gap cycles. While such a study has been conducted in Arizona, there are several factors that are different in Alabama, including the width (16 inches rather than 12 inches), types of highways on which milled SRS are placed, and types of highways on which bicyclists are permitted.
- An experiment and study of safety benefits associated with using milled SRS on the centerline of rural two-lane highways. Such an effort would involve the selection of a small number of locations, based on a traffic engineering and safety review, where such an installation would be expected to provide substantial benefits. The results of such a study could guide development of a statewide policy on centerline rumble strips.

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Appendix A:

SURVEY OF TRANSPORTATION AGENCIES REGARDING SHOULDER RUMBLE STRIP PRACTICES

AUBURN UNIVERSITY HIGHWAY RESEARCH CENTER

SURVEY OF TRANSPORTATION AGENCIES REGARDING SHOULDER RUMBLE STRIP PRACTICES

1. Does your state use rumble strips on highway shoulders?

2. What type(s) of shoulder rumble strip (SRS) is currently used?*

   *If your state does not use milled-in, or ground-in rumble strips, please discontinue the survey and return it in the enclosed envelope. Thank you.

3. When did your agency begin using milled SRS, and why was this type selected?

4. Please provide the dimensions currently used in the milled SRS (longitudinal length, width, depth, and center-to-center spacing *or* gap between strips), *OR*, please enclose a copy of the standard/specification used with your survey response.

5. What is the offset distance between the edgeline / edge of traveled way and the milled rumble strip? (if different offset distances are used for different types of highway, please provide this information for all types.)

6. Are milled SRS spaced intermittently (as opposed as continuously without breaks) to provide gaps in the longitudinal direction (e.g. to facilitate bicycle crossings)? If these gaps are provided in some cases, what are the criteria/facility types for using gaps, and what are the dimensions used to provide these gaps?

7. Is the cost of installation of milled SRS included in other contract bid items, or are they paid for as a separate bid item? If a separate bid item, what is the typical range of costs, or average cost?

8. Has your agency evaluated the performance and/or effectiveness of milled SRS using either motor vehicle safety criteria (e.g. reduction in run-off-road crashes) or using other measures of highway user satisfaction? If so, please provide information on how to obtain a copy of the report.

9. Have any unexpected problems or difficulties been encountered with the adoption of milled SRS? If so, please elaborate.

10. Have any other problems or difficulties been encountered related to noise from milled SRS?

11. Has traffic been detoured onto highway shoulders with milled SRS during construction/maintenance activities? If so, are any provisions made to modify or remove the SRS to minimize traffic impacts?

12. Are there any other comments or experiences your agency has had with milled rumble strips (for example, placing pavement markings/striping on the SRS, use of rumble strips on the centerlines of two-lane highways, etc.)?

13. Who may the investigator contact if follow-up information is needed?

Thank you for your time!

Please return the questionnaire in the enclosed postage-paid envelope, or send it to:

Rod E. Turochy
Department of Civil Engineering
Harbert Engineering Center
Auburn University AL 36849-5337