Application and Evaluation of Rumble Strips on Highways

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INTRODUCTION

In Utah, single vehicle accidents account for about 30 percent of total accidents each year. These single vehicle accidents are normally caused by vehicles first leaving the travel lane, and then either hitting various roadside objects or becoming overturned. As the vehicle's speed increases, its momentum also increases proportionately. Thus, the severity of an accident is generally greater with increased vehicle speed. This is why fatal accidents tend to involve more high speed vehicles. The relationship between rumble strips, which serve as a safety device on highways, and travel speed is twofold: (1) In travel lanes, rumble strips caution or force drivers to reduce travel speed when they approach a particular area, such as an intersection, a crosswalk, a curve or a school zone; and (2) on highway shoulders, its roughness and noise draws drivers' attention (perhaps even waking the driver) when the vehicle is leaving the travel lane.

The purposes of this paper are 1) to discuss the application of rumble strips on highway shoulders in Utah, and 2) to evaluate its effectiveness from a safety perspective.

APPLICATION OF RUMBLE STRIPS

Need for Rumble Strips

A common contributing factor of many accidents is driver error. Some of the errors are caused by fatigue or inattention. Although it is a traffic engineer's responsibility to provide a safe driving environment, it is generally not possible for a design or operational procedure to reduce driver errors.

When a driver is fatigued or falls asleep, the inattentiveness to vehicle operation may cause the vehicle to leave its travel lane. During the time when the vehicle is leaving the travel lane and shoulder pavement, the driver's reaction plays a critical role in determining whether or not an accident occurs. At this moment, the shoulder width provides the driver with a reaction area for either returning to the travel lane or safely directing the vehicle to the roadside. Thus, wider shoulder width provides more time for drivers to react. Since many accidents happen within a blink of an eye, lengthening drivers' reaction time by even a hundredth of a second will save many lives.

Current Practice in Utah

Safety engineers in Utah recognize the safety benefit of rumble strips. For State 3R projects (resurfacing, restoration and rehabilitation), installation of shoulder rumble strips has been one of the countermeasures for single vehicle run-off- the-road accidents. Engineers view the 3R projects as an opportunity to make long needed safety improvements to older highways at the same time as pavement repairs are made. The Utah Department of Transportation (UDOT) has developed a standard for the use of shoulder rumble strips for highway projects. The conditions for use are as follows:

1. Only on plant mix seal coat surface or new concrete pavement (Not where bituminous surface overlay or chip seal might be used in the near future).

2. Minimum of 32 feet surface (two 12-foot lanes with 4-foot shoulders).

3. Highways with 50 MPH or greater design speed.

4. Where accident experience shows need.

Current UDOT design standards of rumble strips are illustrated in Figures 1 and 2.

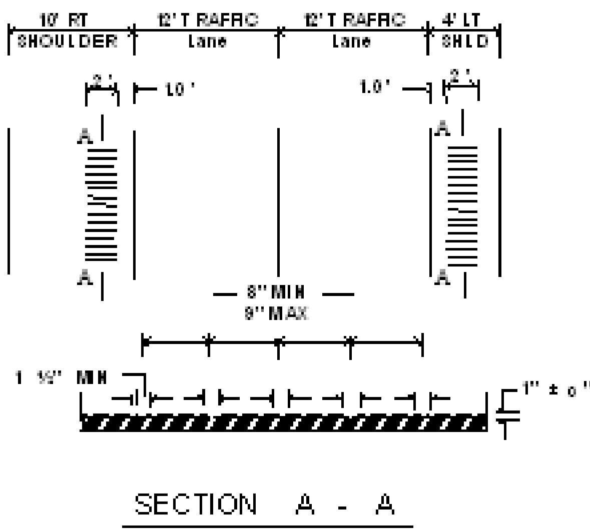

Figure 1. Design Standards for Asphalt Rumble Strips

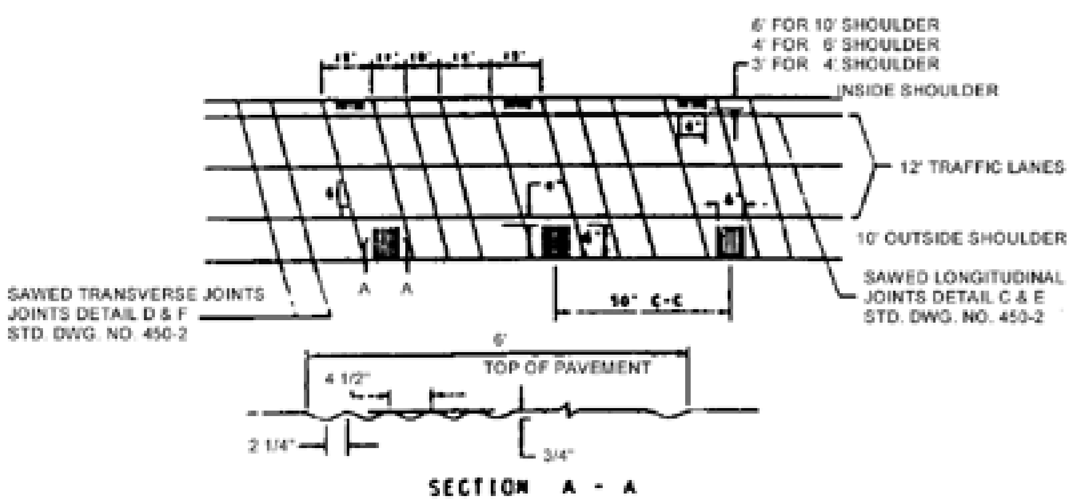

Figure 2. Design Standards for Concrete Rumble Strips

There are two methods for installing rumble strips. The rolled-in type is installed by a special roller, which has welded steel pipes on its wheel. While the asphalt concrete is still hot, the roller passes over the surface and installs the rumble strip. The milled-in type is a newer design. It is installed by a diamond bit grinder designed to cut the pavement, (either asphalt or concrete) as needed. Milled-in rumble strips can be installed anytime after the new surface construction and on old pavement as well.

Design Consideration

Milled-in versus Rolled-in Traffic control is critical during road construction. Since the milled-in rumble strips can be installed anytime, the shoulder can be used as a temporary travel lane without detours during construction. However, the use of rolled-in rumble strips can only be installed when the pavement is first laid. Additionally, when rumble strips are identified as a countermeasure for road segments with high run-off-the-road accident rates, the milled-in approach is the only way to install rumble strips on the existing pavement.

Offset from Edge of Travel Lane Presently, there is no consistent standard among highway agencies for the location of rumble strips . For instance, in Utah the one foot offset from the edge of the travel lane on asphalt pavement (with a continuous design) is used, but in New York State, the offset is four inches. Theoretically, rumble strips are expected to be installed as close to the travel lane as possible to provide the earliest warning possible by noise or vehicle vibration. Assuming a passenger car traveling 50 MPH at the center of a 12-foot travel lane, it will take 0.082 second to reach the edge of the travel lane (using a 30 degree travel path when the driver falls asleep). Location of rumble strip installation is critical to its effectiveness. For every foot the rumble strip is offset from the edge of the travel lane, there is an additional 0.03 second delay in warning. Similarly, an additional foot in the width of rumble strips generates an additional 0.03 second of warning duration.

Literature has indicated that the reaction time for unexpected information (no information content in this case) for an average driver is less than one second. (**1**) The fraction of a second in delay or extension of warning can make the difference as to whether a driver can take appropriate action to avoid an accident.

However, cyclists' opinions vary concerning the installation of rumble strips. In the summer of 1993, an informal survey was conducted in Utah. Through a press release and newspaper articles, cyclists were asked to comment on the placement of rumble strips. Among the 126 responses, twenty two (17%) said rumble strips should not be used. Fifty nine (46%) preferred the placement of the rumble strips against the travel lane line, allowing the strip to be used as a buffer zone against traffic. Many commented that this would only be effective if the shoulders were wide enough to allow an adequate width (4-5 feet) for the cyclists to ride safely to the right of the rumble strips. Forty five (35%) preferred the rumble strip be placed as far to the right as possible, allowing cyclists to utilize the shoulder area with the least amount of gravel and debris.

EVALUATION OF SHOULDER RUMBLE STRIPS

Accident data Collection

Because installation of shoulder rumble strips has just recently been widely accepted, it has received very limited safety evaluations. The intent of this study is to evaluate the difference in accident rate experience between highway segments with and without rumble strips. Three interstate segments were selected for the study, Along I-15 the segments 1) started at St. George, Utah and ended just south of Provo, Utah; and 2) started north of Salt Lake City, Utah and ended at Tremonton, Utah. The single segment along I-80, started west of Salt Lake City, Utah, and ended at Wendover, Utah on the Utah, Nevada border. All segments studied were checked to ensure there were no changes in the status of the rumble strips during the studied time period, thus maintaining the consistency of data. Presently, accidents that occur on the ramps at interchange areas are considered as freeway accidents. Therefore, in order to maintain uniform characteristics, segments that contain interchanges were excluded in this study. As a result, 41 segments (30 asphalt and 11 concrete pavement) with rumble strips with a total of 185.91 miles and 35 segments without rumble strips with a total of 110.36 miles were evaluated. Among the group with rumble strips, there were 74.76 miles of concrete pavement and 111.15 miles of asphalt pavement. Table 1 presents the summary of the segments evaluated.

Table 1. Summary of Segments Studied

Rumble Strips	No. of Segments	Total Length
Yes	11-concrete	74.76 miles

	30-asphalt	111.15 miles
Total	41	185.91 miles
No	35	110.36 miles

The type of pavement and design of shoulder rumble strips were collected from the field. Accident data for the years 1990-1992 for each segment (excluding interchange areas) were generated using the Utah Department of Transportation's Computerized Accident Records System (CARS). This system is one of five systems selected by the Federal Highway Administration (FHWA) for its Highway Safety Information System (HSIS) based on the quality and quantity of data collected, and the demonstrated ability to merge data from different files. (**2**)

Data Analysis

Accident Rates Comparison Statistical analysis was conducted to compare the accident history of the two groups, namely those segments with and without rumble strips. The accident data analyzed was for the years 1990-1992. The accident rates (number of accidents per million vehicle miles) of each group were used in comparison. This took into account the traffic exposure and length of each segment. Both overall accident rates and run-off-the-road type accident rates of each group were compared.

The results show that accident rates for both overall and run-off-the-road accidents were lower on those sections with rumble strips. For those sections with rumble strips, the accident rates were found to be 0.713 and 0.394 for overall and run-off-the-road accidents, respectively. Highway sections without rumble strips were found to have accident rates of 0.951 (33.4% higher) and 0.500 (26.9% higher) for overall and run-off-the-road accidents, respectively.

Table 2 presents these results.

Table 2. Accident Rate Comparison

	With Rumble Strips	Without Rumble Strips
Acc. Rate (Overall)	0.713	0.951 (33.4% higher)
Acc. Rate (Run-off-Road)	0.394	0.500 (26.9% higher)

Statistical t tests were conducted to verify the significance level of difference on accident rates for both groups. One of the assumptions to validate the use of a t test is that the two populations in comparison had the same variances. (**3**) Therefore, F statistical tests were performed to verify this assumption. The results of the F tests indicate that the hypothesis "the two populations have the same variances" were rejected, using a (level of significance) = 0.05. This rejection disabled the use of t tests to verify the significant level of difference in accident rates.

Presently in Utah, rumble strips are discontinuous and offset on concrete pavement and continuous and not offset on asphalt pavement. Further study and analysis was done to compare accident rates of rumble strips segments on asphalt and rumble strip segments on concrete. The results show the overall accident rate of 0.797 for concrete pavement to be 16.9% higher than that of 0.682 for asphalt pavement. The run-off-the-road accident rate of 0.458 for concrete pavement is 23.8% higher than that of 0.370 for asphalt pavement. Table 3 presents the results of the comparison.

Table 3. Accident Rate Comparison By Pavement Type

	Asphalt	Concrete
Acc. Rate (Overall)	0.682	0.797 (16.7% higher)
Acc. Rate (Run-off-Road)	0.370	0.458 (23.8% higher)

The results of F tests for these comparisons also disabled the use of t test to verify the significant level of differences in accident rates.

Severity Comparison The severity of accidents that occurred on the studied areas were also reviewed. The measurement in severity comparison was the number of serious accidents (incapacitating injury and fatal) per mile. The results show the presence of rumble strips is also effective in lowering the number of fatal and incapacitating accidents. When rumble strips were present, a rate of 1.58 and 1.26 serious accidents per mile were found for overall and run-off-the-road accidents, respectively. The absence of rumble strips attributed to rates of 2.01 (27.2% higher) and 1.37 (8.7% higher) for overall and run-off-the-road accidents, respectively. Rumble strips, therefore, not only prevent accidents, but lower the severity of those accidents which do occur. Furthermore, consideration was given to which design was most effective in reducing serious accident rates. The continuous design (found on asphalt surfaces in Utah) proved more effective over the discontinuous design (found on concrete surfaces in Utah). In overall accidents, concrete was found to be 40.4% higher than asphalt (1.91 compared to 1.36 serious accidents per mile). In run-off-the-road accidents only, concrete was 50.4% higher than asphalt (1.58 compared to 1.05 serious accidents per mile). These data are illustrated in tables 4 and 5.

Table 4. Comparison of Serious Accidents*

	With Rumble Strips	**Without Rumble Strips**
No. Acc./mile (Overall)	1.58	2.01 (27.2 % higher)
No. Acc./mile (Run-off-Road)	1.26	1.37 (8.7 % higher)

*Includes incapacitating and fatal accidents only.

Table 5. Asphalt vs Concrete Accident Severity Comparisons

	Asphalt	**Concrete**
No. Acc./mile (Overall)	1.36	1.91 (40.4 % higher)
No. Acc./mile (Run-off-Road)	1.05	1.58 (50.4 % higher)

CONCLUSIONS

The results of this study indicate that freeways without shoulder rumble strips experience a higher rate of accidents over those highways with shoulder rumble strips. In this study, the results were 33.4% and 26.9% higher for overall and run-off-the-road accidents, respectively. As shown, highway segments with rumble strips on asphalt (continuous and near travel lane design), had lower accident rates than highway segments with rumble strips on concrete (discontinuous and offset from travel lane design). The continuous rumble strips on asphalt road surfaces guarantee the noise and vibration warning whenever the vehicle is leaving the travel lane. The discontinuous rumble strips on concrete surfaces in Utah are mostly located on outside shoulders, and each block is 50 feet apart, center to center. This discontinuous design proved to be less effective in alerting drivers to potentially dangerous driving patterns. Different variances between the two groups compared disabled the use of the t test to verify the significant level of the difference. The different variances may be attributable to the characteristics of each segment, such as roadway geometry, weather, surface conditions, and traffic patterns. Further studies can be conducted by sorting by these factors.

The comparison of serious accidents (incapacitating and fatal) between the two study groups (with and without rumble strips) shows the effectiveness of rumble strips in lowering accident severity. Furthermore, the continuous design proved to be even more effective over the discontinuous design, lowering even further the number of serious accidents.

Based on the results of this safety analysis, the following are recommended when considering installation of rumble strips along highway shoulders:

1. Shoulder rumble strips should be installed on highway and freeway shoulders.
2. Rumble strips should be as wide as possible.
3. Highway segments with high run-off-the- road accident rates, such as rural areas should receive highest priorities.
4. Detours during road construction should be considered when determining the method of installation. Generally, the milled-in type will be an effective method during any phase of construction.
5. As suggested by the data, continuous design is preferred over discontinuous design.
6. Rumble strips should be placed as close to the travel lanes as possible. Such placement not only provides advance warning to drivers, but provides a buffer zone between traffic and cyclists on the shoulder.

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