Longitudinal Rumble Strips Require a Safety Compromise for Bicycles and Motor Vehicles

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1 INTRODUCTION

Longitudinal rumble strips are placed along roadway edges in order to alert inattentive drivers of laterally drifting motor vehicles with noise and vibration. Figure 1 illustrates one side of a two-lane road having a double center line. A single edge line separates the travel lane from an adjacent paved shoulder. As shown, a 4-wheel motor vehicle has drifted laterally and the right front wheel has contacted the rumble strip, a series of vertically profiled indentations (shown as short vertical dashed lines). The intended result is for the vehicle driver to be alerted by noise and steering wheel vibration, then make a steering correction to return to the travel lane.

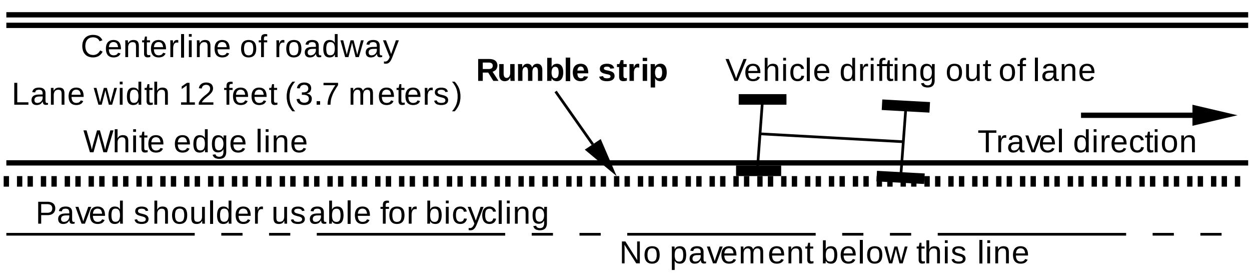

Figure 1: Travel lane of a two-lane roadway, with paved shoulder, rumble strip, and drifting vehicle.

Rumble strips along or near the edge line ("shoulder rumble strips" or "edge line rumble strips") result in very rough pavement in or near the lateral position that would otherwise be selected by many bicyclists as their preferred path of travel. As a result, bicyclists must choose to ride on either side of the rumble strip. The shoulder to the right of the rumble strip is often appropriate for bicycles, but hazards include substandard pavement, collected debris, and parked vehicles. Alternatively to riding on the shoulder for safety as well as courtesy to passing vehicle drivers, bicyclists have the right to use the roadway, defined in California as the travel lane to the left of the edge line. Bicycle safety is enhanced by freedom to move from the shoulder to the roadway in order to avoid the above hazards, and conversely moving from the roadway to the shoulder while vehicles pass. However, riding across the rough rumble strip detracts from safety. Therefore, a key challenge is to improve bicycle safety while also providing a means to alert the occasional inattentive vehicle driver. The presentation will describe how bicycle safety can be improved by using raised markers instead of grooves.

2 BICYCLE GAPS AND GROUND-IN RUMBLE STRIPS IN CALIFORNIA

Bicycle gaps, or simply "gaps," have been implemented in some rumble strips in an effort to improve bicycle safety. Gaps are relatively short, frequent smooth spots for bicycles to cross without riding directly on the rough strip. Figure 2 illustrates one gap pattern recommended by the United States Federal Highway Administration (FHWA) [1]. Every 60 feet, there is a 12-foot smooth spot between 48-foot segments of rumble strip grooves.

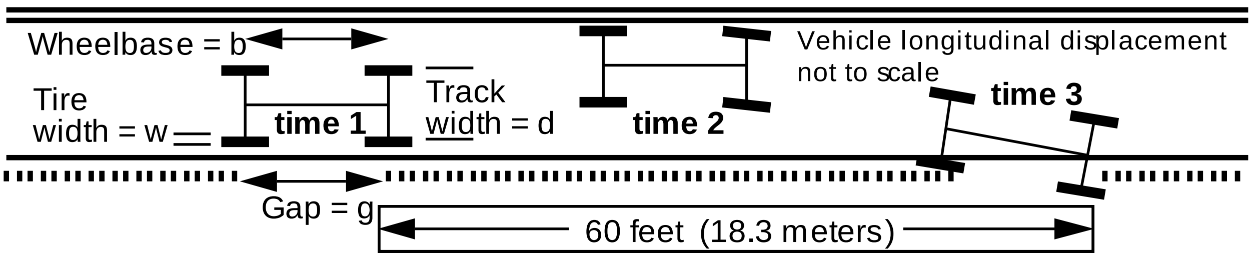

Figure 2: Travel lane of a two-lane roadway, with gaps in a shoulder rumble strip, and a drifting vehicle.

Figure 2 additionally illustrates the potential concern that gaps might permit a motor vehicle to drift off the roadway without the driver experiencing the desired noise and vibration. Such lateral drifting maneuvers are analyzed in a subsequent section of this paper, with respect to variables for time, lateral acceleration, vehicle yaw rotation, and lateral position. The bicycle versus vehicle safety tradeoff with gap length is analyzed.

As implemented by the California Department of Transportation (DOT), the term "rumble strip" specifically refers to a series of depressions in the pavement, most frequently made by grinding. Figure 3 (top) shows a side view to scale of the standard profile adopted by the California DOT. Figure 3 (bottom) shows an actual rumble strip profile implemented in July 2016 on California State Route 84, as measured by the authors. Regardless of gaps, the excess depth is a significant concern for bicycle safety, particularly if wheels are smaller.

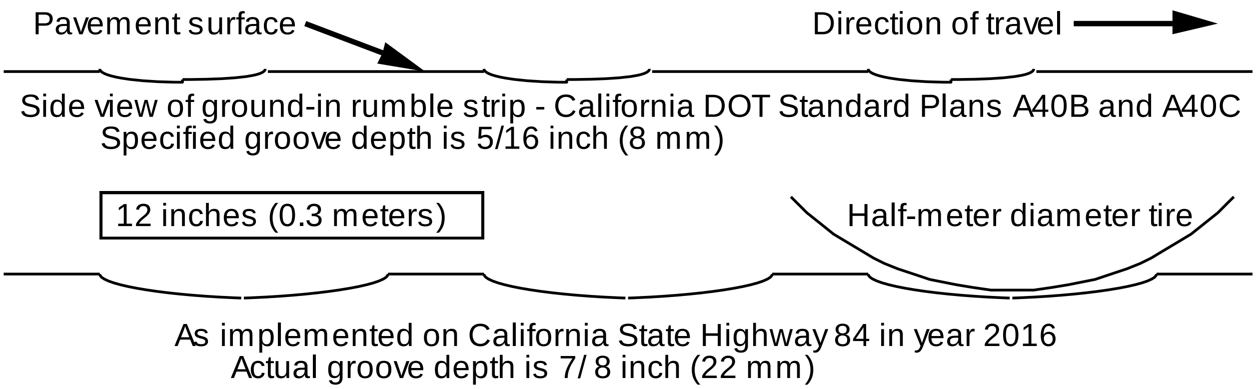

Figure 3: Profiles for California rumble strips, showing the standard (top) and a case of extreme depth (bottom).

3 BICYCLE TESTING ON RUMBLE STRIPS WITH AND WITHOUT GAPS

Considering Figure 2, gap length is clearly a trade between bicycle safety and vehicle safety. While standard gap patterns have been documented as beneficial to bicyclists [2], the authors have observed under real conditions on two California state highways that the necessary continuous attentiveness to the gap pattern is a significant mental workload that tends to compete with attentiveness to other hazards including passing vehicles, debris and natural pavement defects. Furthermore, rumble strip grooves and gaps are difficult to see and distinguish at night. The final paper and conference presentation will include documented severe injury incidents on rumble strips at night, even with the use of high-quality bicycle headlights.

In 2001, the California DOT invited volunteer bicyclists to test ground-in rumble strips of four different depths, in comparison with seven other options for alerting drifting vehicle drivers. In the final report, subjective ratings for controllability, on a scale from 1 (uncontrollable) to 5 (entirely safe), were plotted as in Figure 4 [3]. Notably absent data includes a rating for bicycle safety as a function of speed, e.g. for fast downhill riding.

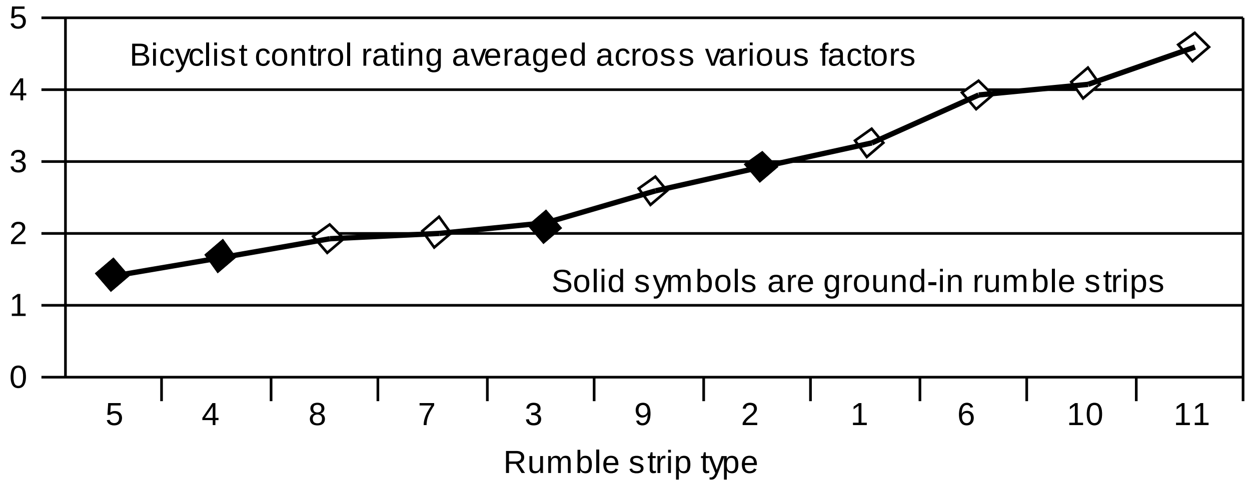

Figure 4: Bicycle test data graph as presented by the California DOT in its 2001 report.

In the graph, including zero on the vertical axis scale resulted in a miscalculation and a misinterpretation of the danger to bicyclists. It was necessary to review several different sections of the report for explanations of the numerals on the horizontal axis, an arbitrary scale. The data for the four ground-in rumble strips is re-plotted here in Figure 5, using a linear scale for groove depth. The curve is extrapolated to show that the recently measured excessive depth on State Route 84 would most likely make bicycles uncontrollable. One tentative conclusion is that the cost of fixing poorly-implemented rumble strips exceeds that of safer alternatives.

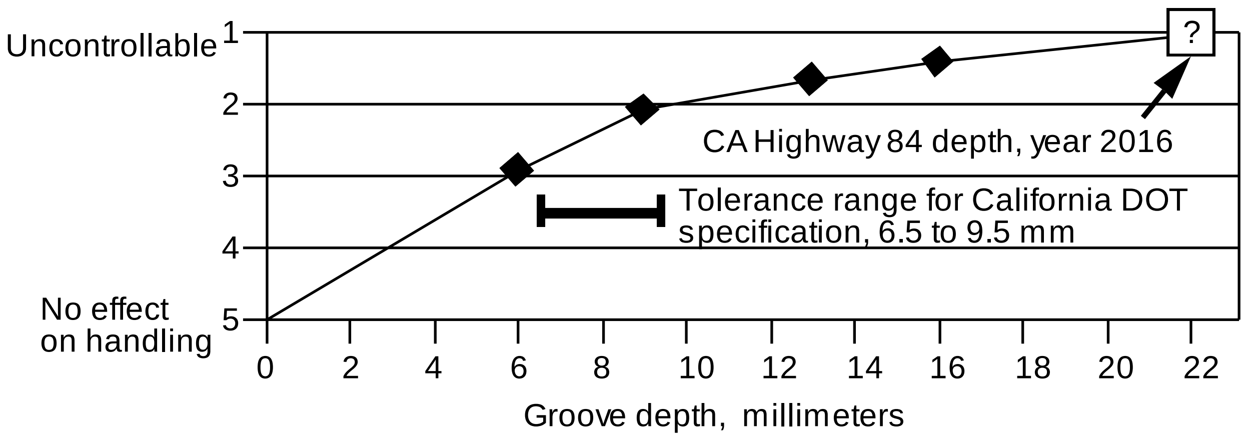

Figure 5: Bicycle test data from 2001 report, plotted with improved labeling and a linear scale for groove depth.

REFERENCES

[1] Federal Highway Administration, *Shoulder and Edge Line Rumble Strips*, Technical Advisory T5040.39, Revision 1, November 2011.

[2] R. C. Moeur, "Analysis of Gap Patterns in Longitudinal Rumble Strips to Accommodate Bicycle Travel", *Transportation Research Record* 1705 (2000), pp. 93-98, Paper No. 00-0248.

[3] J. Bhullar, C. Copelan, T. Bucko, A. Khorashadi, "*Evaluation of Milled-In Rumble Strips, Rolled-In Rumble Strips and Audible Edge Stripe*" Traffic Operations Program, California Department of Transportation, Sacramento, May 2001.