Research & Technology Transfer

Alaska Department of Transportation & Public Facilities

This in an excerpt from the study named below - it only contains references pertinent to rumble strips.

Review of Crash Reduction Factors (CRF) for Use in the Highway Safety Improvement Program Handbook

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13. ABSTRACT (Maximum 200 words)

This report reviews the crash cost reduction factors for countermeasures currently listed in the Alaska Department of Transportation and Public Facility's Highway Safety Improvement Program (HSIP) Handbook (HSIPHB) and provides revised values based a literature survey of research and references. In addition, crash cost reduction factors are proposed for the five treatments that are not currently listed in the HSIPHB, including cable barrier median barriers, pavement traction enhancement, flashing yellow arrow left turn indications, "HAWK" pedestrian signals, and concrete median barriers. There is a section on practices by other state DOT organizations, many of which are similar to the final recommendations this report. Alaska HSIP data is evaluated for safety effectiveness. The report provides an analysis and recommendations for the HSIP post evaluation process. This project and report also included research of the effectiveness of Active Advance Warning Flashers (AAWF) and shoulder rumble strips based upon Alaskan crash experience.

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Alaska HSIP Crash Reduction Experience

There were three HSIP projects that implement this treatment. Overall reduction in target crashes was 93% and cost was reduced 95%. This improvement was evaluated for effectives with results presented in Table 8 on page 40 in Chapter 4. Effectiveness of Alaskan HSIP Projects. Even with the low number of sites, the decrease in total crashes is significant.

Summary of Literature Review

Because of the wide range of applications for this treatment, no conclusive research was found in the literature review.

Analysis and Recommendations

Based on the Alaskan HSIP experience, the 2008 HSIPHB values of 90% CCRF is recommended to be retained. This value was published in the February 2009 revision of the HSIPHB.

Crash Reduction Improvement 306: Shoulder Rumble Strips

The target crashes for this treatment include single vehicle lane departure or run-off-road crashes where the contributing factor is driver fatigue, inattention, or distraction.

The 2008 HSIPHB has used a CCRF of 50% for shoulder rumble strips. This improvement was not included in the February 2009 revision.

Alaska HSIP Crash Reduction Experience

Chapter 8. Before and After Study of Shoulder Rumble Strips In Alaska includes a study of Alaska Northern Region and Central Region highways. This study found crash costs (injuries and fatality) were reduced by 22% after the rumble strip treatment on rural two-lane highways. The standard error of the mean, with 19 observations was 9.2%. The 95% confidence interval does not include “0” within its range of values.

No reduction was apparent on multi-lane facilities.

Summary of Literature Review

Elvik and Vaa include rumble strip results from meta-analysis of three USA studies. NCHRP 617 uses a before-after study of urban and rural freeway that included 55 treatment sites and 55 matched comparison sites from rural and urban freeways in Illinois. The treatment sites included 196 miles of rural freeway and 67 miles of urban freeway. The NCHRP 617 results indicate that the predictive certainty of the values is medium high, but cautioned not to use these for non-freeway applications.

Patel et al.[54] studied rumble strips on 182 miles of rural, two-lane highways in Minnesota using an empirical Bayes analysis. At the time that this was published, there had been no other studies performed on two-lane highways.

The following table summarizes selective findings of the review.

Table 25. Summary of Selected Findings, Shoulder Rumble Strips

Type of Improvement	Crash Type	Crash Severity	Effectiveness						References
			AMF	Crash Reduction Factor	Std Error	Interval		Interval type	
						Low	High		
All Accidents	All	Injury		-2%		-26%	17%	95% Conf. Int.	Elvik and Vaa
Run off the road Accidents	ROR	All		31%		15%	45%	95% Conf. Int.	
Freeways, Rural and Urban	Single Vehicle ROR	All	0.820	18%	7%				NCHRP 617
Freeways, Rural and Urban	Single Vehicle ROR	Injury	0.870	13%	12%				
Freeways, Rural	Single Vehicle ROR	All	0.790	21%	10%				
Freeways, Rural	Single Vehicle ROR	Injury	0.930	7%	16%				
Two-Lane Rural Highways	Single Vehicle ROR	All		13%	8%				Patel et al.
Two-Lane Rural Highways	Single Vehicle ROR	Injury		18%	12%				

Analysis and Recommendations

All of the crash reduction factors in the above table have point estimators that agree in proximity to the CCRF of 22% that was determined in the Alaskan study. However, all CRF in the table have a standard error that results in a 95% confidence interval that contains “0” indicating a possibility of no real reduction with rumble strips.

Based on the Alaskan study, it is recommended that the next version of the HSIPHB use a treatment CCRF of 20% for shoulder rumble strips in reduction of the target crashes on two-lane highways.

During the draft report review, the State of Alaska Traffic Engineer requested that a multi-lane shoulder rumble strip CCRF be included in this report. The studies summary presented Table 25 on page 93 indicates severity reductions on freeways from 7% to 18%, but it is emphasized that all have a standard error that results in a 95% confidence interval that contains “0” indicating a possibility of no real reduction with rumble strips. It is recommended that a CCRF of 10% be used until other information becomes available.

The following table presents revisions to CCRF table that should be implemented in the next publication of the HSIPHB.

Table 26. HSIPHB CCRF Table Revisions for Improvement 306 Rumble Strips on Shoulders

Improvement Type Number	Type of Improvement / Accident Types Susceptible to Reduction	Crash Cost Reduction Factor	Comments
306	Rumble strips on shoulders		
306.1	Two-lane rural highways, 45 MPH and above, non ice/snow run off the road accidents	-20%	
306.2	Four-lane rural highways, 45 MPH and above, non ice/snow run off the road accidents	-10%	

Crash Reduction Improvement 307: Flattening of Horizontal Curves

The target crashes for this treatment include all non-intersection crashes within a realigned horizontal curve. Crashes on horizontal curves may be the result of drivers being unaware that the curve is ahead, or unaware of the safe speed to negotiate the curve. Speeds that are greater than the design speed of the curve can result in lane departures, which then may culminate in a

Summary of Literature Review

NCHRP 617 uses Elvik and Vaa's meta-analysis of 38 international studies as the base of their recommendation of an AMF of 0.80 (20% CRF) for total nighttime crashes after installation of roadway illumination, and a nighttime injury AMF of 0.71 (29% CRF) after illumination is installed. No dispersion information is presented in NCHRP 617, but Elvik and Vaa's data show 95% confidence intervals that confirm the CRF is good, and that there is a true change in crashes after the treatment. Furthermore, NCHRP 617 states the AMF are medium high predictive quality.

Analysis and Recommendations

Even though the results of the Alaska Study are not statistically significant, the point estimate of the CRF and CCRF are considerably higher than the 2008 HSIPHB value of 20% CCRF. Also, the CRF for injuries in NCHRP 617 is 29%, which may be use as an approximate value for the CCRF, and again is higher than the 2008 value.

As such, it is recommended that the 2008 HSIPHB value of 20% CCRF be increased to a value 25% CCRF. This value was entered into the February 2009 revision of the HSIPHB.

Crash Reduction Improvement 317: Install Centerline Rumble Strips (45 MPH and above)

Target crashes for this treatment are non-ice/snow head-on and head-on sideswipe accidents on rural two-lane roads.

The 2008 HSIPHB value for this reduction factor is 25%.

Alaska HSIP Crash Reduction Experience

DOT&PF has not conducted any before-after studies of this treatment.

Summary of Research

Persaud et al[55] performed an empirical Bayes before-after analysis of center line rumble strips that is the basis of the NCHRP. Crash and traffic volume data were collected for 210 miles on 98 treatment sites with centerline rumble strips on rural two-lane roads in California, Colorado, Delaware, Maryland, Minnesota, Oregon, and Washington. The average length of the treatment sites was two miles, and AADT ranged from 5,000 to 22,000.

The study results are in the following table.

Table 28. Summary of Selected Findings, Installation of Centerline Rumble Strips

Crash Type	Crash Severity	Effectiveness						References
		AMF	Crash Reduction Factor / Function	Interval		Interval Type	Study Type	
				Low	High			
All	All	0.860	14%	8%	20%	95% Confidence	EB Before-After	Persaud, et al.
All	Injury	0.850	15%	5%	25%	95% Confidence	EB Before-After	
Frontal/ opposing direction sideswipe	All	0.790	21%	5%	37%	95% Confidence	EB Before-After	
Frontal/ opposing direction sideswipe	Injury	0.750	25%	5%	45%	95% Confidence	EB Before-After	

Analysis and Recommendations

If we accept injury CRF as an approximate CCRF, then Persaud's results for head-on/opposing sideswipe agrees well with the 2008 HSIPHB. The 95% confidence interval is fairly wide so that the point estimate value may not represent the actual CCRF mean, but the interval does not include "0" thus, indicating a true change had occurred after rumbles trips were installed. It is recommended that the 2008 HSIPHB CCRF of 25% be continued. This value was included in the February 2009 revision of the HSIPHB.

CHAPTER 8. BEFORE AND AFTER STUDY OF SHOULDER RUMBLE STRIPS IN ALASKA

This chapter summarizes the results of a before-after analysis as to the effectiveness of rumble strips in correcting single vehicle roadway departure crashes (run-off-road with various collision endings). The before period began in 1994 and terminated on the year prior to construction of the rumble strips, 1999 for Central Region and 2001 for Northern Region. The after period began in 2001 for the Central Region and 2003 for Northern Region, and both periods terminated in 2006. The studies were performed only for rumble strips that survived the entire after duration.

LOCATIONS

Central Region

The Central Region awarded a construction contract in the winter/spring of 2000 for construction of 713 miles of grooved-in shoulder rumble strips. The project began construction in May of 2000 and finished construction in September 2000. The project locations are generally depicted in the following table.

Table 34. Central Region Rumble Strip Locations

Highway	Plan Rumble Strip Location (Segments include Short Gaps)
Gamble/Ingra Street	15th to Fireweed
Glenn Highway	Airport Heights to Sutton, MP 97 to MP 100, MP 109 to MP 118
Kenai Spur Highway	Soldotna to Kenai
Minnesota Drive	Tudor Road to Old Seward Highway
Ocean Dock Road	Whitney Road to Port
Parks Highway	MP 39 to MP 45, MP 100 to MP 163
Seward Highway	36th Avenue to Sterling Wye, MP 8 to MP 18, MP 37 to MP 45
Sterling Highway	Soldotna to Sterling, MP 117 to MP 157

Northern Region

The Northern Region awarded a construction contract for 1,092 miles of grooved-in shoulder rumble strips in 2002. The project began construction in May of 2002 and finished construction in August 2000. The project locations are generally depicted in the following table.

Table 35. Northern Region Rumble Strip Locations

Highway	Plan Rumble Strip Location (Segments include Short Gaps)
Alaska Highway	MP 1255.0 to MP 1419.3
George Parks Highway	MP 163.2 to MP 262.0, MP 288.0 to MP 355
Glennallen Highway	MP 118.6 to MP 186.0
Richardson Highway	MP 0.0 to 114.9, MP 185.5 to 190.1, MP 268.7 to MP 359.9
Steese Highway	MP 2.0 to MP 11.0
Tok Cutoff Highway	MP 0.0 to MP 30.0, MP 38.1 to MP 123.8

RUMBLE STRIP INVENTORY AND DATA REDUCTION

There was uncertainty as to whether rumble strips that were in the original construction plans were in place over the study period. There may be several reasons for any discrepancies. The first is that the actual construction locations and quantities may have not matched plan locations because of adjustments to accommodate field conditions. The second reason is that Alaskan roads require frequent, substantial maintenance efforts; often resulting in new pavement or chip seals. If so, it is unlikely that rumble strips in the maintained area would survive. Finally, other projects may have constructed after rumble strip installation which obliterated existing rumble strips without replacement.

As such, inventories were necessary prior to and after the study to determine which rumble strips had survived the entire study period.

Central Region Inventory

The Central Region Traffic and Safety staff performed a windshield inventory of the rumble strips in the summer of 2007. This information was reduced to a survey spreadsheet, which was transmitted to Kinney Engineering, LLC for data analysis. Their data excluded the Gamble/Ingra Street, Minnesota Drive, and Ocean Dock Road segments that are in Table 34.

Northern Region Inventory

As part of this study, Kinney Engineering, LLC inventoried the Department's Northern Region Rumble Strip projects to establish locations of strips that have survived and are functioning; and therefore to be included in a before and after study.

Preparation and mobilization work began during mid-July 2008. As part of this effort, Kinney Engineering, LLC outfitted a vehicle with a distance measuring instrument, flashing warning beacons and warning signs. We also met with Central Region staff on their data collection effort, obtained their forms and advice on collecting data, and obtained as-built plans of the rumble strip project from the Northern Region.

On August 6, 2008, two technicians deployed to the field to begin six days of data collection. The highways inventoried included:

- Parks Highway, Coal Creek (Northern Region boundary) to Fairbanks
- Steese Highway, Fairbanks to Fox
- Richardson Highway, Fairbanks to Valdez
- Alaska Highway, Delta Junction to Canadian Border
- Tok-Cutoff, Tok to Gakona
- Glenn Highway, Glenallen to the Northern Region Boundary

Two technicians were required to perform the work accurately and, most importantly, safely. The observer was responsible for observing key features such as fixtures with known coordinate data sets (CDS) milepost (MP) and beginning and ending of rumble strips, then recording the distance measure. The distances on the measuring devices were reset every three to five miles at known fixture CDS MP to minimize cumulative errors (this was recommended by Central Region Staff). The driver's sole responsibility was to operate the vehicle and avoid conflicts with approaching vehicles. Our vehicle was typically slower than the prevailing traffic, so when other vehicles approached we would pull over to allow them to pass safely. We traveled under a flashing yellow beacon and with a slow vehicle sign on the back.

Rumble strip beginning and endings were noted. Breaks for driveways and intersections were not recorded to be consistent with the Central Region. Shoulder widths were noted.

Data Reduction

Data from the Central Region was entered into spreadsheets for both travel directions on each highway. The data used the CDS milepoints as a basis of location, which was reconciled with actual measurement lengths. It should be noted that frequently the CDS log, highway milepoints, and actual measurements were not matched closely, and Kinney Engineering reconciled these differences prior to completing the analysis.

The spreadsheet was set up to assign a rumble strip annotation, segment number, and length of segment. Early in the analysis process it was decided by State and Region staff (Kurt Smith and Ron Martindale) and Kinney Engineering that effective rumble strips may include intermittent breaks, and that the law enforcement or self-reporting coding of the crashes were not precise enough to accurately locate the actual location of an event. As such, it was decided to create a reduction spreadsheet that had dynamic rumble strip beginnings and endings based upon the allowable gap between the actual locations. In doing so, we were able to capture many of the crashes that were just outside of the inventoried intervals. We checked several highways and found that between ½ to two-mile gaps would not change the total crashes in the analysis by much (for those highways evaluated), and one-mile gaps or less between two rumble strip segments was treated as one continuous rumble strip segment.

The analysis was performed for each direction of a highway, designated northbound or southbound. All highways that were evaluated have northbound and southbound vectors, and the eastbound westbound coded crashes would be assigned the logical northbound or southbound direction. For example, a westbound crash on the Glenn Highway between Palmer and Glennallen was coded as a southbound crash for purposes of this analysis.

RESULTS

Crash and Rate Performance

The following tables present before and after results for shoulder rumble strip installation on two-lane rural highways in Central and Northern Regions. The first table includes all crash counts and the second table focuses on injury and fatal crash counts.

Table 36. Summary for State Northern Region and Central Region: Crash Reduction by Shoulder Rumble Strips Two-Lane Highways, All Crashes

	Before Crashes	Before Vehicle Miles Travel	After Crashes	Before Vehicle Miles Travel	% Rate Reduction ("-"crash rate increased)	95% Confidence Level (Method shown in Figure 18)
Total	546	3.31E+09	428	2.71E+09	-4.43%	Not Significant
Those Roadways with Reduction	379	2.084E+09	260	1.921E+09	-25.57%	Significant @ 95% Confidence Level
Central Region	233	1.411E+09	246	1.686E+09	-11.62%	Result is not certain
Northern Region	313	1.896E+09	182	1.027E+09	7.37%	Crashes Increased, N/A

Table 37. Summary for State Northern Region and Central Region: Crash Reduction by Shoulder Rumble Strips Two-Lane Highways, Injuries and Fatalities

	Before Crashes	Before Vehicle Miles Travel	After Crashes	Before Vehicle Miles Travel	% Rate Reduction ("-"crash rate increased)	95% Confidence Level (Method shown in Figure 18)
Total	336	3.31E+09	215	2.71E+09	-21.99%	Significant @ 95% Confidence Level
Those Roadways with Reduction	247	2.25E+09	129	1.90E+09	-38.38%	Significant @ 95% Confidence Level
Central Region	141	1.41E+09	119	1.69E+09	-29.35%	Significant @ 95% Confidence Level
Northern Region	195	1.90E+09	96	1.03E+09	-9.09%	Not Significant

The following two tables present before and after results for shoulder rumble strip installation on four-lane divided highways in the Central and Northern Regions. Four lane highways had rumble strips on the outside and inside shoulders.

Table 38. Summary for State Northern Region and Central Region: Crash Reduction by Shoulder Rumble Strips Four-Lane Highways, All Crashes

	Before Crashes	Before Vehicle Miles Travel	After Crashes	Before Vehicle Miles Travel	% Rate Reduction ("-"crash rate increased)	95% Confidence Level (Method shown in Figure 18)
Total	220	1.49E+09	247	1.61E+09	4.28%	Crashes Increased, N/A
Those Roadways with Reduction	103	6.04E+08	113.00	7.21E+08	-8.20%	Not Significant
Central Region	204	1.22E+09	234	1.46E+09	-4.02%	Not Significant
Northern Region	16	2.74E+08	13	1.51E+08	47.54%	Crashes Increased, N/A

Table 39. Summary for State Northern Region and Central Region: Crash Reduction by Shoulder Rumble Strips Four-Lane Highways, Injuries and Fatalities

	Before Crashes	Before Vehicle Miles Travel	After Crashes	Before Vehicle Miles Travel	% Rate Reduction ("-"crash rate increased)	95% Confidence Level (Method shown in Figure 18)
Total	128	1.60E+09	131	1.61E+09	1.72%	Crashes Increased, N/A
Those Roadways with Reduction	68	8.69E+08	61	8.18E+08	-4.67%	Not Significant
Central Region	118	1.32E+09	123	1.44E+09	-4.27%	Not Significant
Northern Region	10	2.74E+08	8	1.66E+08	31.93%	Crashes Increased, N/A

This data supports a conclusion of marginal to modest crash reductions for all crashes (5% for all locations, but 25% where there was improvement). However, injury and fatality reduction, the primary surrogate for crash cost reduction, was about 21% to 22%.

This study found no safety improvement after installation of shoulder rumble strips on four-lane divided highways.

Analysis

The following scatter plot shows the before-after performance of injury/fatality rates.

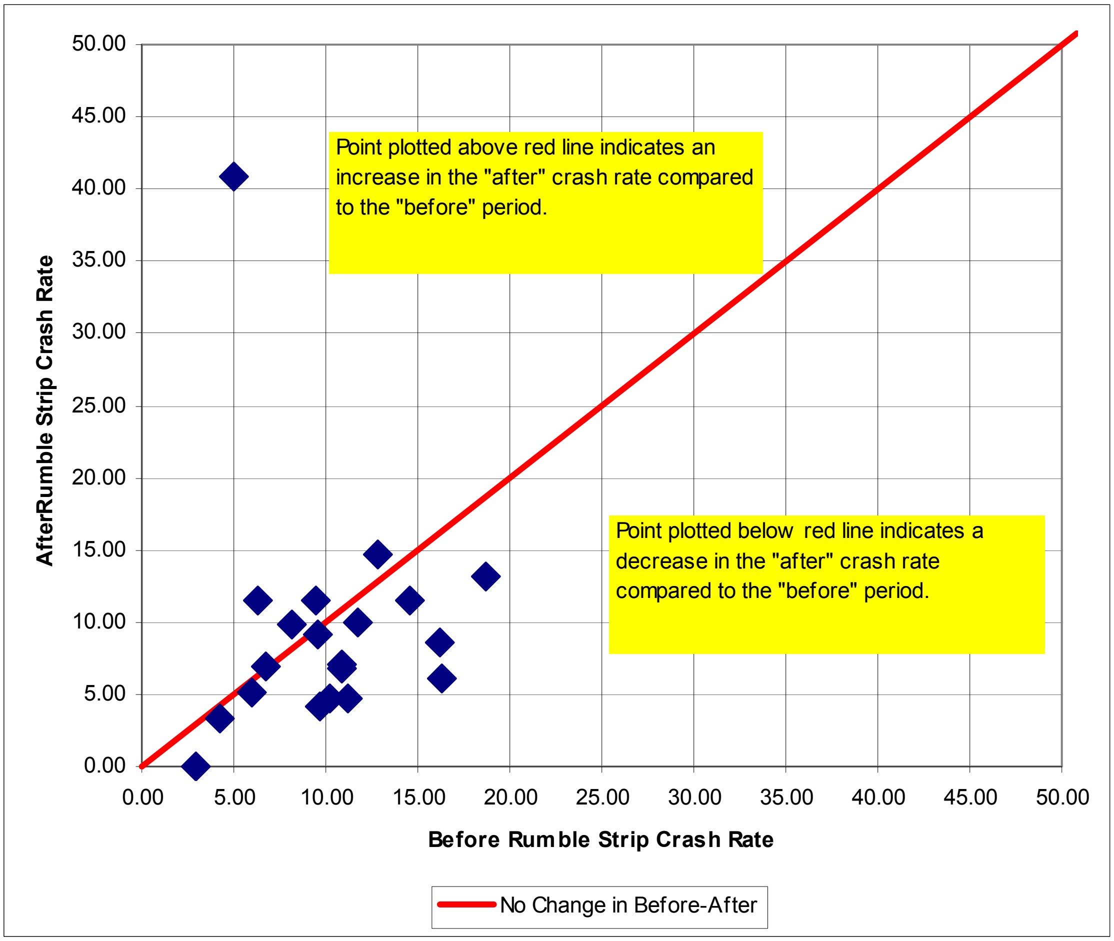

Figure 20. Chart. Graph of Before-After Injury and Fatality Crash Rates

The point at before = 5, after = 41 appears to be an outlier (Tok Cutoff, where low number of crashes doubled), and therefore, was removed from further analysis. Otherwise, most locations experienced a drop in rate.

A paired t-test of means shows the before rate average to be 10.3 injury and fatality crashes per hundred million vehicle miles (HMVM), with an after rate average at about 7.8 crashes per HMVM. This is significant at a p=0.01.

The mean CRF for injuries and fatalities is 21.9% (with outlier removed). The standard error is 9.2% and the 95% confidence interval is between 3% and 41%. Since the 95% confidence interval does not contain “0”, there was a reduction in severity crashes, but the mean may be substantially lower than the best estimate of 21% to 22 %.

RECOMMENDATIONS

It is recommended that a crash cost reduction factor of 20% be adopted for two-lane shoulder rumble strip installations. This is consistent with other studies discussed in Chapter 6. Revised List Of Crash Cost Reduction Factors For Inclusion In The HSIP Handbook, in the section titled Crash Reduction Improvement 306: Shoulder Rumble Strips on page 92.

During the draft report review, the Alaska State Traffic Engineer requested that a CCRF for multi-lane highways be included in the HSIPHB. There is inconsistency between the Alaskan results (showing an increase) and other research on multi-lane highways that show a decrease in crashes. As such, a CCRF of 10% was adopted by this study for 4-lane highways. This is discussed in detail under Crash Reduction Improvement 306: Shoulder Rumble Strips on page 92,