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FHWA POOLED FUND STUDY

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Removable Orange Rumble Strips

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Supplemental Notes

Abstract
The strips were deployed in advance of a bridge repair project in central Kansas on a two-lane rural road. The construction traffic control utilized a temporary signal to control flow through the single open lane across the bridge, and standard KDOT traffic control was used in advance of the signal, including two sets of asphalt rumble strips, one starting at about 1000-ft in advance of the signal and the other at about 1500-ft. The removable strips were installed 2500-ft in advance of the signal. The thickness of the strips (roughly 1/8-in) was not sufficient to be reliably detected by drivers. However, there was a statistically significant reduction in vehicle speeds after the installation of the strips, suggesting that the orange color of the strips acted as a warning device.

REMOVABLE ORANGE RUMBLE STRIPS

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Description

Advance Traffic Markings will provide enough "orange rumble strip" (ORS) to install rumble strips in advance of a signal operation for a one lane bridge project. ORS is a 1/8-inch thick self-adhesive plastic strip, which is orange in color. The product is marketed to be placed across the roadway in order to cause noise and minor vibration of the vehicle when the vehicle traverses the strips. The noise and vibration therefore heightens the drivers' attention to the roadway conditions.

Study site

The study site was the approach to a bridge repair project on US 36 in Smith County, Kansas. The segment carried an ADT of 2700 vpd (T=11.5, D=60%). The posted speed was 110 km/hr. Figure 1 shows a diagram of the test segment excerpted from the construction plans.

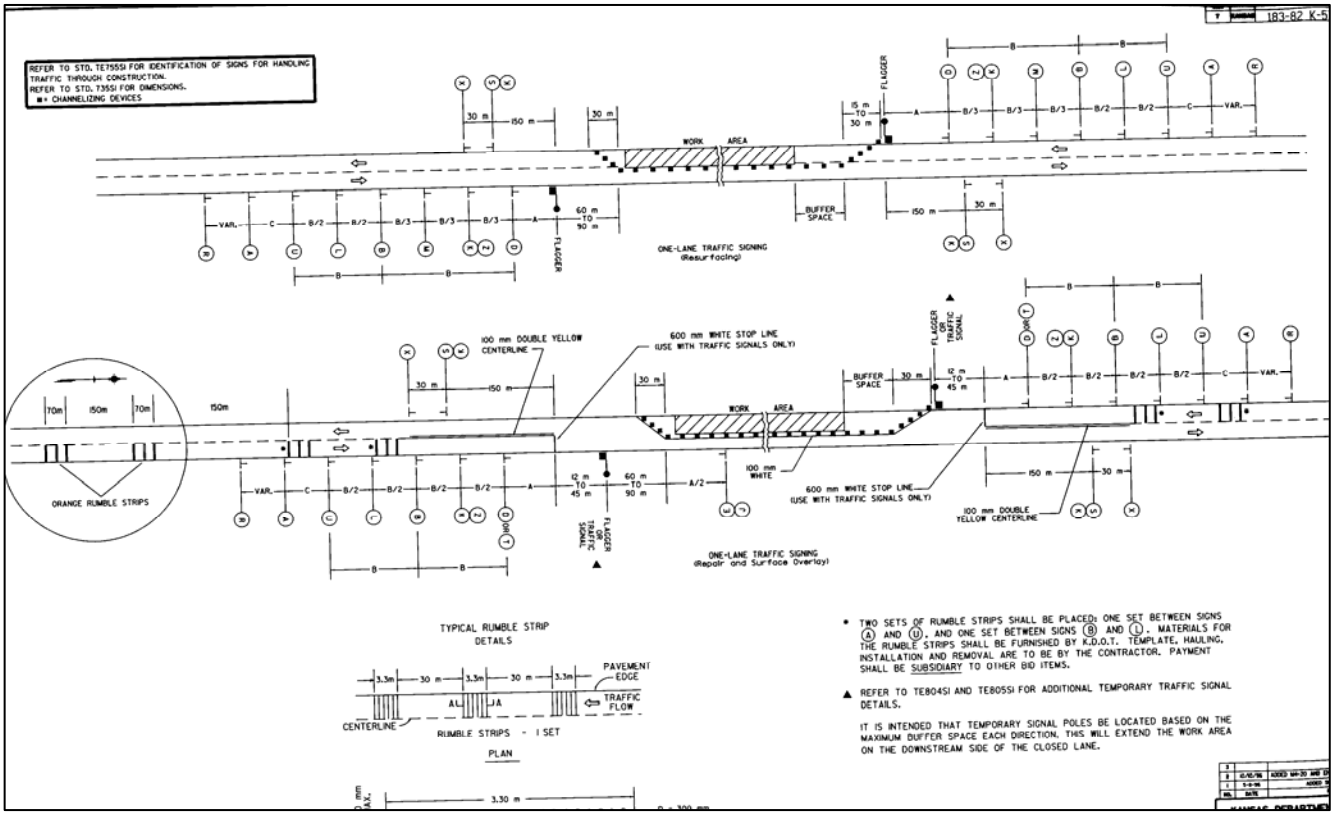

Figure 1. Plan view of study site.

In advance of the standard rumble strips for the signal operations for bridge resurfacing approximately 5 mi east of Smith Center.

A traffic control diagram of the test segment is given in Figure 2. It should be noted that the rumble strips being evaluated were installed upstream of a full complement of asphalt rumble strips laid out as per KDOT standard procedures. This aspect of the test configuration was deemed necessary to minimize liability.

Performance Measures

The objectives of this application and the associated performance measures are shown in Table 1.

Table 1. Orange Removable Rumble Strips: Objectives and Performance Measures.

Provide advance warning to drivers	1. Speed 2. Visibility
Minimize risk to highway workers	3. Ease of installation and removal
Perform for life of project	4. Durability of material and adhesive

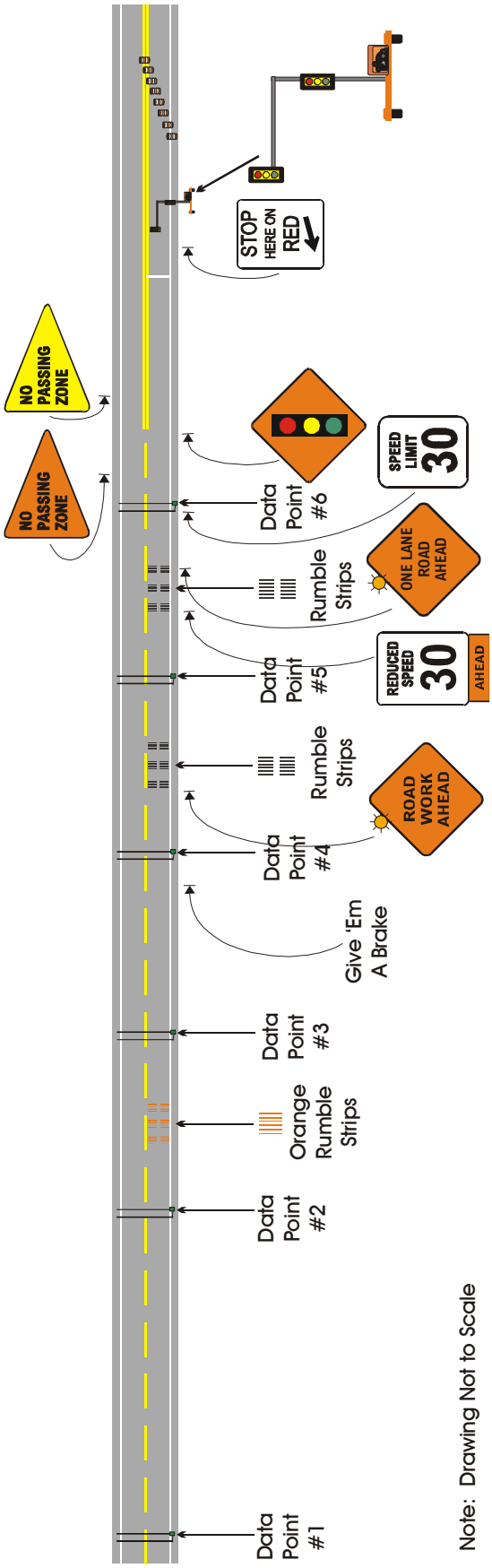

Figure 2. Test Site Traffic Control Diagram

Speed data was collected using pneumatic pneumatic tubes and automatic traffic recorders at six simultaneous locations as shown in Figure 2. When the rumble strips were installed, the counter at data point 6 was moved to a seventh location to help determine if drivers were crossing the center line to avoid driving over the removable strips. However, the counter failed to operate properly after being moved. Consequently, the data could not be used. No data was collected at data point 6 after the installation of the removable rumble strips, so data point 6 was dropped from the analysis. Speed and classification data was collected for approximately one day prior to installation of the removable rumble strips and approximately one day afterward. Both days were weekdays.

Other parameters investigated were the effort necessary to install and to remove the strips, and the subjective effectiveness with respect to the noise and vibration from the strips as perceived by drivers of various types of vehicles.

Experimental Design

Study type: before and after.

Data Collected

Speeds

Collection method: pneumatic tubes and automatic traffic recorders

Sample size: 24 hr before and 24 hr after installation at locations as described above.

Analysis technique: comparison of 85^{th} percentile, mean, and standard deviation.

Visibility

Collection method: visual observation

Sample size: N/A

Analysis technique: subjective comparison

Durability

Collection method: testimonials of construction inspector

Sample size: N/A

Analysis technique: summary.

Evaluation Results

The data collected showed a significant change in mean speeds and 85th percentile speeds downstream of the removable rumble strips for both passenger cars and trucks. Data compared was for identical times of day. Weather conditions were nearly identical. Because of the low volumes at night, analysis of data collected during dark conditions only did not yield usable results.

Speeds

In order to remove the effects of platooning, only records associated with a headway of 5 seconds or more were considered, based on the Highway Capacity Manual's recommendations for estimating percent time delay. The sample sizes, means, 85th percentiles, and standard

deviations for all five data points are shown in Table 2 for passenger cars, and in Table 3 for trucks.

Recalling that the removable rumble strips were located between data points 2 and 3, data points 3 and 4 are of the greatest interest, using data point 1 as a baseline. The mean speed at point 1 for passenger cars decreased by 0.4 mph after the installation of the removable rumble strips, a statistically insignificant change. For trucks, however, the mean speed at point 1 decreased by 2.9 mph. This change is statistically significant at the 99% confidence level. The change may be due in part to construction activity approximately 1 mile upstream of data point 1. This construction activity occurred just off US 36, at the bottom of the upgrade preceding data point 1. A change in the construction activity that required vehicles to slow at the bottom of the upgrade might explain why the mean speed of trucks was affected while that of passenger cars was not.

To filter out the effects of the change in means speeds at data point 1, data at other locations was compared relative to data point 1 during the same time period. The changes in mean speeds and 85^{th} percentile speeds relative to data point 1 are shown for passenger cars and for trucks in Table 4. The data is in miles per hour.

Table 2. Evaluation Results for Passenger Cars

	1	2	3	4	5
Before					
Count	535	526	530	530	522
Mean	63.8	64.7	62.6	56.7	53.3
Std Dev	6.1	5.7	6.3	7.9	8.9
85th %-ile	69.0	70.0	68.0	65.0	63.0
After					
Count	487	487	482	493	490
Mean	63.4	64.4	60.5	54.1	52.3
Std Dev	6.7	6.2	7.1	8.4	8.5
85th %-ile	68.0	70.0	67.0	62.0	62.0

Table 3. Evaluation Results for Trucks

	1	2	3	4	5
Before					
Count	118	117	117	112	116
Mean	63.3	65.9	63.5	56.7	53.3
Std Dev	6.6	5.2	5.4	7.5	9.1
85th %-ile	69.5	71.0	69.0	63.0	62.0
After					
Count	127	128	134	127	133
Mean	60.4	63.2	59.8	51.5	48.8
Std Dev	8.1	7.1	7.6	8.8	9.1
85th %-ile	67.0	70.0	67.0	61.1	58.2

Table 4. Speed Comparison With Data Point 1

Passenger Cars

		1 to 2	1 to 3	1 to 4	1 to 5
mean	before	0.9	-1.2	-7.1	-10.5
	after	1.0	-2.9	-9.3	-11.1
85th %-ile	before	1.0	-1.0	-4.0	-6.0
	after	2.0	-1.0	-6.0	-6.0

Trucks

		1 to 2	1 to 3	1 to 4	1 to 5
mean	before	2.6	0.3	-6.6	-10.0
	after	2.8	-0.6	-8.9	-11.6
85th %-ile	before	1.6	-0.5	-6.5	-7.5
	after	3.0	0.0	-5.9	-8.8

The 1000 feet between data points 1 and 2 is a downgrade following a half-mile long upgrade, thus the speed increases are to be expected. The reductions in mean speeds observed at data point 3 compared to data point 1 were 1.7 mph greater after the installation of the removable rumble strips for passenger cars, and 0.9 mph for trucks. At data point 4, the reductions were 2.2 mph for passenger cars and 2.3 mph for trucks. All of these differences were statistically significant. More importantly, the reductions may be an indication that the rumble strips are alerting drivers to the work zone conditions ahead. It is noteworthy that at the location of the removable rumble strips, the work zone is not visible. Only the first sign ("Give 'Em A Brake") can be seen, as shown in Figure 3.

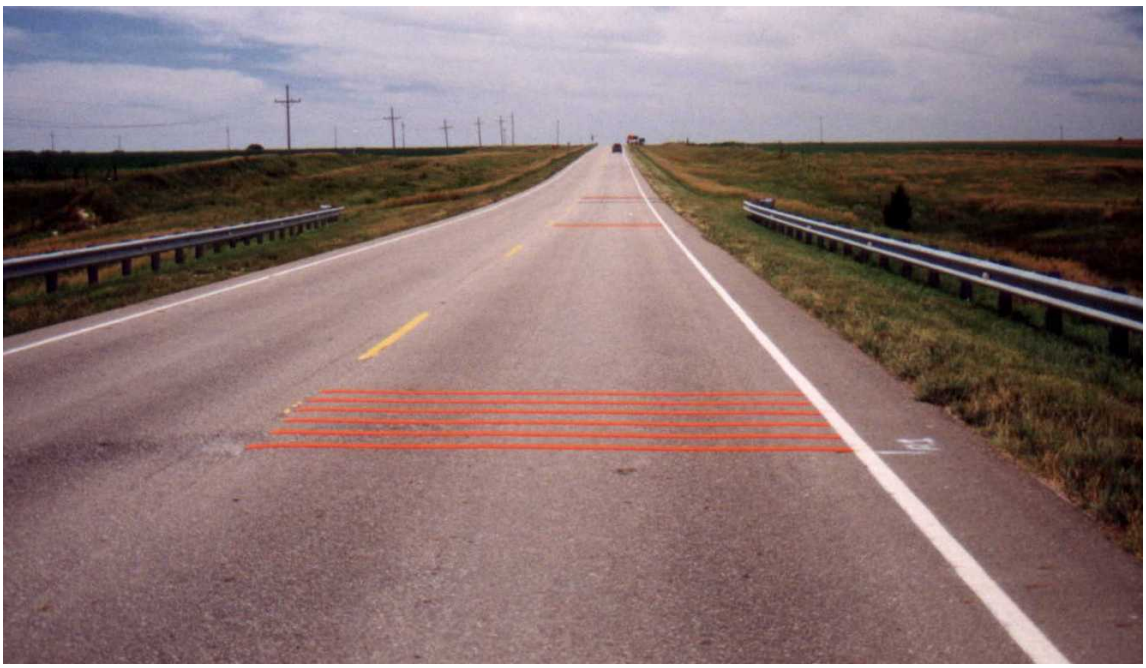

Figure 3. Removable Rumble Strip Evaluation Installation

Installation

The installation of the removable rumble strips was very simple. The locations were set out with a measuring wheel and a tape measure. A 12" spacing was chosen to coincide with the spacing of the standard pattern of asphalt rumble strips. Strips were cut in 12 ft segments, as depicted in Figure 4, to run from centerline to edgeline. One by one, each strip was held on each end while a third crew member peeled the protective backing to expose the tar based adhesive. Then the strip was positioned on the pavement and pressed into place. Finally, a tampering cart with a 200 lb loading, shown in Figure 5, was rolled across each strip six times to assure good adhesion between the strip and the pavement. No additional adhesive was used, and the strips were placed on the pavement in its existing condition.

Because the amount of product available was insufficient for a complete pattern of rumble strips, the pattern was adjusted to include only one set of three groups of strips, each comprised of 6 strips. A crew of 5 men worked for approximately 30 minutes to install the pattern of 18 strips. It should be noted than only one member of the crew had ever worked with this product before. It is likely that an experienced crew of 3 could have performed the installation just as quickly.

Figure 4. Cutting Rumble Strips to Appropriate Length

Figure 5. Tampering Card Used During Installation

Removal

To remove the strips, a corner is pulled up using a utility knife, screwdriver, or similar tool, then the strip is simply peeled off the pavement. After approximately one day, one of the strips was deliberately removed. It came up easily, taking only a few seconds, and coming up in one piece. Though the strip was intact, the strips are not reusable because the initial use degrades the adhesive backing. A strip was removed after two weeks, and considerably more effort was required, indicating that a good seal had been created, though only one worker (with appropriate traffic control) and a matter of seconds were required to perform the removal.

Durability

During the first week after the installation, three of the strips detached from the pavement. An examination of the bottom of the strips revealed a significant amount of dirt and gravel, indicating that the use of a blower would have improved the durability of the installation.

Driver's Perspective

Several different types of vehicles were used to obtain a qualitative evaluation of the strips from the driver's perspective. The orange color is very visible, and is consistent with the MUTCD recommendations for work zones. The contrast between the new asphalt of the standard rumble strips and the worn pavement is minimal, and almost imperceptible under nighttime driving conditions. The removable rumble strips created a slight audible effect with little or no tactile effect for the driver of a passenger car. For both motorcycles and trucks (a KDOT dump truck was used for evaluation purposes), no audible or tactile effect was perceived by the driver.

Conclusions

The removable rumble strips were easily installed and removed. While the adhesive was insufficient under the test conditions, the use of a blower to clear the installation area of loose particles would likely yield a satisfactory seal between the strips and the pavement. After two weeks the strips showed no noticeable wear.

The thickness of the strips seemed insufficient to create noticeable audible and tactile warning to the driver, especially in trucks. However, the reductions observed in both the mean

and the 85th percentile speeds indicate that the color of the strips alone is sufficient to have a positive effect. Additionally, drivers have been observed crossing the centerline to circumvent standard asphalt rumble strips. Rumble strips that are less dramatic in their effect might serve the purpose of alerting the unattentive driver while providing less impetus for drivers to leave their lane in an unsafe avoidance maneuver.

The qualitative analysis of the strips' effectiveness from the driver's perspective suggested that 6 strips per group was insufficient. More strips would have improved the effectiveness. The total length of a group was 7 feet, compared to 11 feet for asphalt rumble strips, due to the difference in the width of the individual strips.

It is also possible that the 1-ft spacings are not optimal. Because the strips are only 1/4 to 1/6 the thickness of asphalt rumble strips, the optimal spacing may be significantly different.

The advantage afforded by the visible warning provided by the orange color of the strips was considered to be very significant by the KDOT Bureau of Traffic Engineering. A subsequent evaluation is being discussed in which strips with a 20% greater thickness will be used. Another suggested technique which may be investigated is to use a double thickness, placing one strip directly on top of another.

The removable rumble strips, placed conspicuously in the traveled way, offer the driver an important visual cue that they are approaching a work zone—one which may be observed by the many drivers who routinely do not read roadside signs. The audible effect is also an important warning mechanism for drivers of passenger cars, though a thicker strip is desired to increase the audible effect and provide some tactile feedback. The ease of installation and removal combined with the positive effect afforded mostly by the orange color make this a very

appealing traffic control device for certain circumstances, such as short term maintenance operations on two lane roads.

Recommendations

Based on the results of this evaluation, it is recommended that the configuration and techniques used in this evaluation be modified to improve the performance of the strips, especially for trucks. Specifically, the application of the strips should be modified as follows.

1. A double thickness should be used, one strip laid directly on top of another. This is recommended to increase the tactile and audible feedback to the driver.
2. The spacing between strips should be increased. A nominal increase from 1 ft to 1.5 ft is suggested, although this value is somewhat arbitrary and needs to be investigated further.
3. The number of strips in the configuration should be increased. A nominal increase from 6 strips per group to 10 strips per group is suggested, although this value is somewhat arbitrary and needs to be investigated further.
4. The pavement should be swept or blown clean to remove loose debris prior to the installation of the strips.