MIDWEST SMART WORK ZONE DEPLOYMENT INITIATIVE

MwSWZDI

FHWA POOLED FUND STUDY

Report Title	Report Date: 2002

Reflectorized Sleeves for Barrel Delineators

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Supplemental Funding Agency Name and Address (if applicable)

Supplemental Notes

Abstract
The reflectorized sleeves are designed to wrap around a standard reflectorized drum, providing an alternate color scheme (orange, white, and green stripes). The use in this evaluation was to apply the sleeves to drums on an exit within an Interstate work zone where the exit is delineated by drums. The intent of the application was to provide more positive guidance for the driver by more clearly defining which two drums on the mainline mark the mouth of the exit ramp. Three configurations of sleeves were compared to baseline data collected without the sleeves. The measure of effectiveness was the speed reductions occurring within the exiting stream before the vehicles leave the mainline. Speeds were monitored just upstream of the exit and immediately downstream of the exit on both the ramp and on the mainline. Custom software was developed to identify exiting vehicles in the downstream data and extract their speeds from the upstream data. The idea is that drivers often slow while still on the mainline, partly because the ramp is more difficult to identify when delineated by drums than under normal conditions. If the drum sleeves improve the delineation of the ramp, drivers will be less apt to slow down before exiting, thus providing for smoother flow on the mainline. The sleeves were easily installed, did not come off the drums even under severe duress (i.e., being blown over by a store and being run over by a truck), and they proved to be quite durable. Several drums were hit by vehicles during the test and only one sleeve suffered major damage. The speed data showed no statistically significant difference between the baseline and any of the three tested configurations. In retrospect, the site was less than ideal for this test because the location was nearly ideal for safety. The road was flat and straight, and only a short portion of the mainline was delineated by drums. Consequently, the ramp was very well delineated without the sleeves. While the may have some benefit, they were not needed at this site. Additionally, their effect would likely be most pronounced at night when delineation is most critical, but the traffic volumes on the exit at night were too low to support statistical analysis.

Reflectorized Drum Sleeves

Technology

The drum sleeves slip over and wrap around a traditional drum. The retro-reflective material has a color scheme comprised of 6" bands of green, orange, white, and green, in that order from bottom to top. The intention of the sleeves is to allow traffic engineers to provide additional positive guidance to the driver by using drums that are easily distinguishable from the standard orange and white drums in order to more clearly delineate the drive path. The application in which the sleeves were evaluated in this study was a highway construction zone where the edge line is delineated by drums and an exit ramp was temporarily extended to accommodate two-way traffic on the westbound lanes while the eastbound lanes were under construction. The exit ramp was also delineated by drums. The drums with non-standard colors (i.e., the drum sleeves) were intended to help the driver more easily identify the entrance to the ramp. The sleeves cost $50 each and are manufactured by

Reflexite Americas
315 South Street
New Britain, CT 06051

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Fax: (860) 832-9267
www.reflexite.com

Because the green stripes in the drum sleeves does not conform to the current Manual on Uniform Traffic Control Devices (MUTCD), a request to experiment was submitted to the Federal Highway Administration (FHWA) and approval obtained prior to testing. The request and approval are provided in Appendix A.

Study site

Eastbound Vera Road exit of I-70, 20 miles west of Topeka, Kansas.

ADT = 18,000 vpd Is this ADT directional? NO
T = 20.5%
D = 60%
$V_{current}$ = 70 mph
$V_{construction}$ = 60 mph
$V_{advisory}$ = NA

Figure 1 shows a portion of the construction plans depicting the traffic control for the evaluation site.

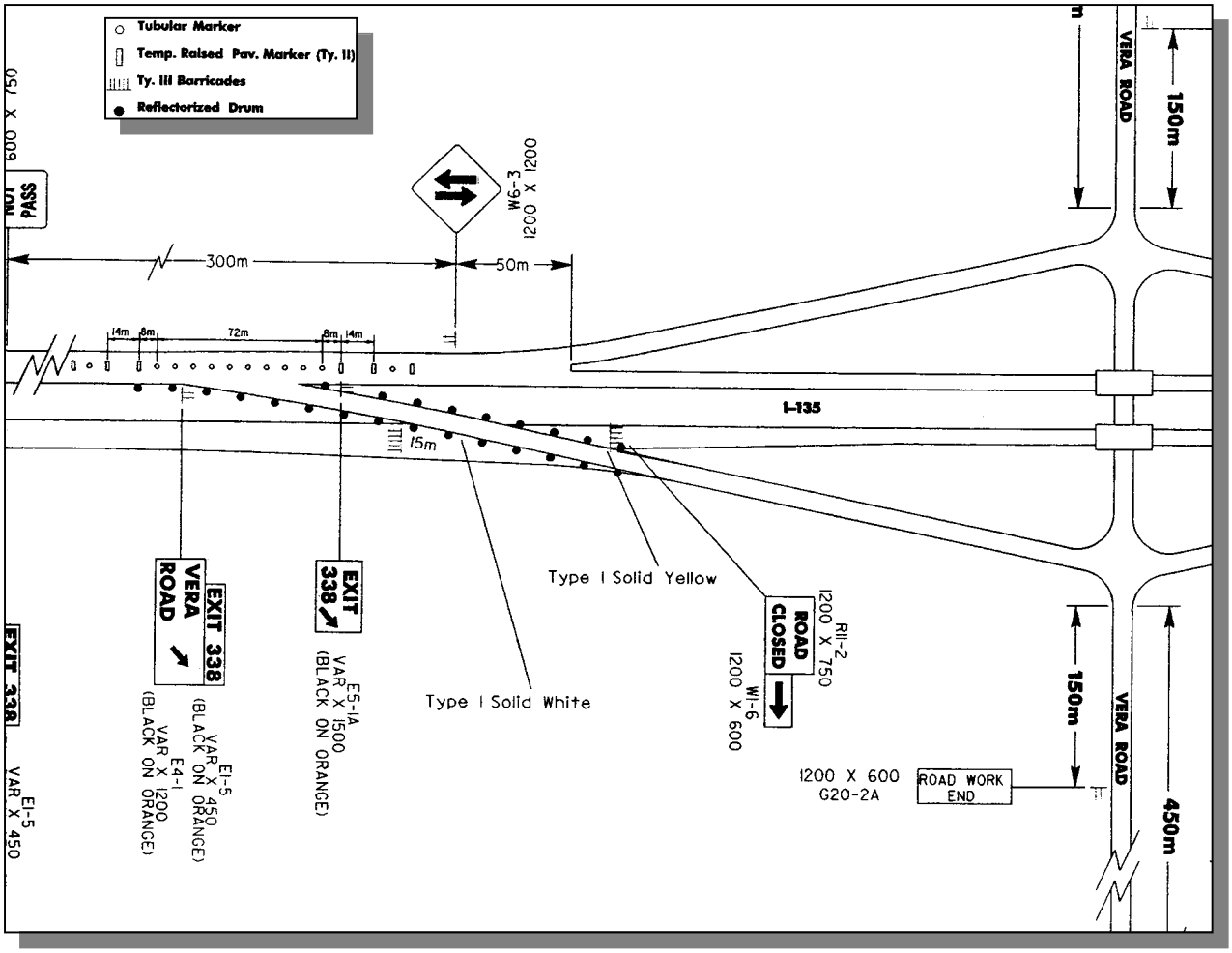

Figure 1. Excerpt of traffic control diagram from construction plans.

Data Collection

In the application evaluated, the drum sleeves were intended to make the exit clearer. When an exit is not clear (i.e., drivers have difficulty distinguishing which two drums mark the mouth of the exit ramp), turning traffic will slow as they approach the exit (before leaving the mainline), interrupting the flow on the mainline and contributing to congestion within the work zone. To test whether or not the drum sleeves helped alleviate this problem, pneumatic hoses and automatic traffic recorders were used to measure speeds on the mainline and to identify which vehicles were turning and which were through traffic. Figure 2 shows the locations of the hoses relative to one another. Individual vehicles were matched between the upstream data point (DP101) and the downstream data point (DP102) using a computer utility. Vehicles that were observed on the exit ramp at DP102 were noted and their speeds at DP101 extracted.

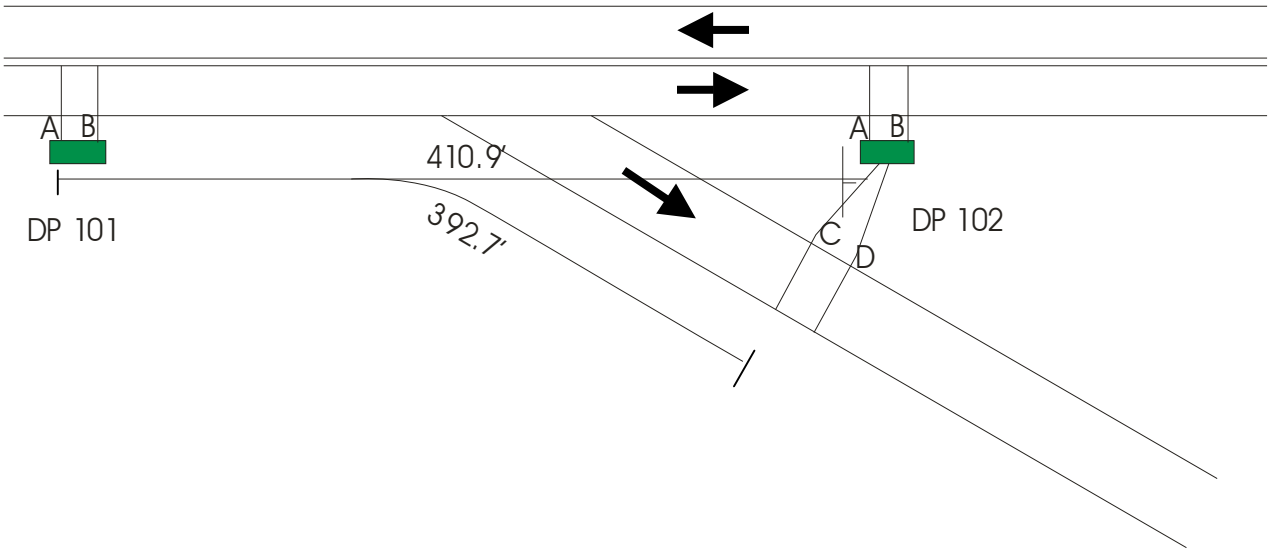

Figure 2. Diagram of data collection points. (not to scale)

Collection Technique

Previous experience has shown that hoses on relatively new PCC pavement fail very quickly. The rough texture of the pavement acts as a coarse abrasive, eroding the underside of the hoses. Depending on traffic volumes, failure can occur in as little as one day. To alleviate this problem, mastic tape (nylon web backing with butyl adhesive) was applied to the pavement underneath the hoses, as well as being used to secure them. The mastic below served as a protective bed, separating the hoses from the abrasive pavement surface.

The hoses lasted approximately one week before failure occurred. The failure, however, was not due to the pavement, but was caused by the stress on the hoses as they were struck by vehicle tires. The resulting failure mode was a complete severing of the hose in the traveled lane. The hoses were replaced, and additional mastic tape was applied overtop of the hoses across the wheel paths. This technique proved successful, preserving the hoses throughout the remaining two weeks of the evaluation, at which time all hoses were still functioning with little or no apparent damage. The mastic over the hoses had nearly worn through, although the adhesive was holding the hoses firmly in place.

Small diameter hoses proved to work better than standard diameter hoses for this application. The forces on the small diameter hoses are more directly downward. The larger diameter results in greater lateral forces, which tend to push the hoses from their protective mastic bed and onto the bare pavement where erosive damage begins to occur. Additionally, the sound inside a passenger car as it passes over the larger hoses is quite noticeable, while that occurring with the smaller diameter hoses is nearly imperceptible.

Speed Data

Speeds were monitored for three weeks. The first week was used as the baseline condition in which no drum sleeves were used. At the beginning of the second week, drum

sleeves were installed in Configuration 1, and at the beginning of the third week, the sleeves were adjusted to conform to Configuration 2. All three configurations are depicted in Figure 3. Equipment failures and severe storms required that some data be omitted from the analysis. The resulting times for which data was analyzed are given in Table 1.

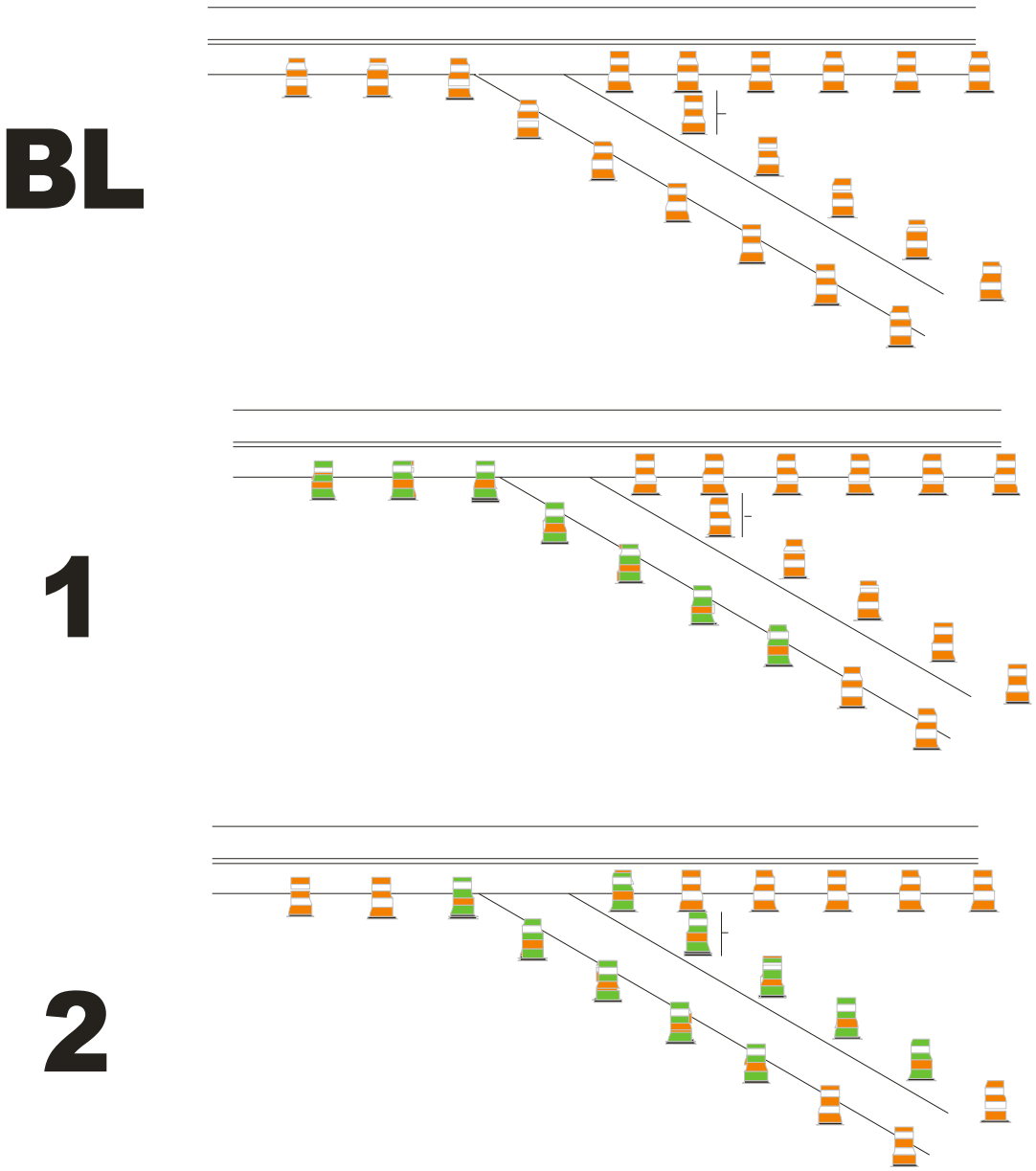

Figure 3. Sleeve configurations: Baseline, 1, and 2.

Table 1. Data Collection Times

	Start Time		End Time	
Baseline Day	Fri 3/30/2001	4:22 PM	Sat 3/31/2001	5:08 PM
Config 1 Day	Mon 4/9/2001	3:20 PM	Thu 4/12/2001	6:35 PM
Config 2 Day	Fri 4/13/2001	2:40 PM	Sun 4/15/2001	2:30 PM
Baseline Night	Fri 3/30/2001	8:31 PM	Tue 4/3/2001	12:00 AM
Config 1 Night	Mon 4/9/2001	8:30 PM	Fri 4/13/2001	12:00 AM
Config 2 Night	Fri 4/13/2001	8:30 PM	Fri 4/20/2001	9:05 PM

Daylight was taken to be from 9:00 AM to 7:30 PM. Nighttime was taken to be from 8:30 PM to 5:30 AM the following morning. Early morning hours were omitted from the daytime data, because the eastbound direction on this segment is due east, and the early morning sun dominates all visibility or conspicuity issues until an our or two after sunrise. 9:00 AM was deemed sufficient to alleviate the problem of veiling glare from the sun.

Cost-Related Factors

The time required to affix the sleeves was measured and the wear of the vests over the two-week period was observed.

Data Analysis

The objective of the study is to show whether or not the drums have a significant effect on the speeds of vehicles immediately prior to exiting. Consequently, to remove the effects of platooning, vehicles with headways less than 5 sec were filtered out to guarantee that only free flow speeds were considered. The remaining vehicles were classified as car (i.e., passenger car) and truck (i.e., heavy vehicle) based on axle counts and spacings.

Analysis of variance (ANOVA) was applied separately to each Configuration/Time of Day/Vehicle Type combination to determine if there existed a difference in the mean speeds that could be attributed to the drum sleeves. The 10-mph Pace was also examined.

Results

Table 2 provides a summary of the speed data. The first row of the table is the total vehicles recorded. The remainder of the table only includes vehicles operating at free flow speed (as indicated by a headway of 5 sec or more). Exiting volumes were small, averaging a little less than 1% during the day and a little less than 0.5% at night. The speeds of exiting vehicles were lower, as might be expected. Typically the difference was 10-15 mph, with one exception. For trucks during the day when Configuration 2 was present, the speeds of exiting traffic averaged 20 mph lower than the speeds for through traffic. The lower speeds observed for exiting vehicles was probably caused by construction activities. Construction vehicles were observed driving half-way down the ramp and then turning into the construction area. These observations in addition to the fact that the effect was not observed in passenger cars suggest that there may have been more construction vehicles during the week of Configuration 2, and their tendency to travel slowly as they prepare to enter the construction area resulted in the lower mean speed.

The sleeves required less than 2 minutes each to install. Removal time was similar. The drums are affixed with nylon straps and a threaded buckle, as shown in Figure 4. The sleeves hold firmly to the drums. Although several drums were knocked over by severe storms and at least two were hit by vehicles, none of the sleeves came off their drums. When the sleeves were removed, all sleeves seem as tightly affixed to the drum as when they were installed.

The two sleeves that were on drums that were struck by vehicles suffered only minor damage, although the damage to one was near the upper buckle, probably requiring under most circumstances that it be removed from service. Figure 5 shows the drum most severely damaged, and Figure 6 shows the resulting damage to the drum sleeve that had been attached. The other sleeve that was damaged during the test is shown in Figure 7.

Figure 4. Drum sleeve installation.

Table 2. Summary of speed data characteristics.

	Baseline Day Cars	Config 1 Day Cars	Config 2 Day Cars		Baseline Day Trucks	Confi 1 Day Trucks	Config 2 Day Trucks
All Vehicles							
Count	6798 veh	12005 veh	13911 veh		1052 veh	3344 veh	1639 veh
Through Traffic							
Count	969 veh	2605 veh	2097 veh		493 veh	1521 veh	681 veh
Standard Dev	3.4 mph	4.1 mph	4.8 mph		2.7 mph	4.3 mph	4.4 mph
Average	61.9 mph	61.8 mph	61.7 mph		61.3 mph	60.4 mph	60.6 mph
Confidence Int	± 0.2 mph	± 0.2 mph	± 0.2 mph		± 0.2 mph	± 0.2 mph	± 0.3 mph
85th Pctile	64.9 mph	65.6 mph	65.6 mph		64.3 mph	64.0 mph	64.1 mph
10 mph Pace	61 mph	61 mph	61 mph		60 mph	61 mph	61 mph
Exiting Traffic							
Count	51 veh	94 veh	76 veh		8 veh	36 veh	2 veh
Standard Dev	4.9 mph	5.9 mph	6.7 mph		7.3 mph	6.1 mph	2.5 mph
Average	48.1 mph	47.8 mph	49.1 mph		45.5 mph	46.9 mph	40.4 mph
Confidence Int	± 1.4 mph	± 1.2 mph	± 1.5 mph		± 6.1 mph	± 2.1 mph	± 22.2 mph
85th Pctile	52.8 mph	53.5 mph	56.5 mph		50.2 mph	52.7 mph	41.6 mph
10 mph Pace	49 mph	49 mph	47 mph		34 mph	46 mph	39 mph
Pct Exiting	0.8%	0.8%	0.5%		0.8%	1.1%	0.1%

	Baseline Night Cars	Config 1 Night Cars	Config 2 Night Cars		Baseline Night Trucks	Config 1 Night Trucks	Config 2 Night Trucks
All Vehicles							
Count	3423 veh	2579 veh	5933 veh		1164 veh	1606 veh	2522 veh
Through Traffic							
Count	1418 veh	1243 veh	2522 veh		847 veh	1185 veh	1836 veh
Standard Dev	5.0 mph	5.0 mph	4.9 mph		3.9 mph	3.8 mph	3.7 mph
Average	63.5 mph	63.5 mph	63.4 mph		61.0 mph	61.8 mph	61.6 mph
Confidence Int	± 0.3 mph	± 0.3 mph	± 0.2 mph		± 0.3 mph	± 0.2 mph	± 0.2 mph
85th Pctile	68.5 mph	68.2 mph	68.2 mph		64.7 mph	65.4 mph	65.2 mph
10 mph Pace	63 mph	63 mph	63 mph		61 mph	62 mph	61 mph
Exiting Traffic							
Count	12 veh	21 veh	20 veh		2 veh	2 veh	0 veh
Standard Dev	7.2 mph	6.3 mph	4.6 mph		0.2 mph	10.7 mph	-
Average	49.2 mph	51.4 mph	50.1 mph		50.7 mph	41.2 mph	-
Confidence Int	± 4.5 mph	± 2.9 mph	± 2.2 mph		± 1.8 mph	± 95.7 mph	-
85th Pctile	56.2 mph	55.0 mph	53.9 mph		50.8 mph	46.4 mph	-
10 mph Pace	37 mph	53 mph	49 mph		51 mph	34 mph	-
Pct Exiting	0.4%	0.8%	0.3%		0.2%	0.1%	-

Figure 5. Drum that was destroyed during the test.

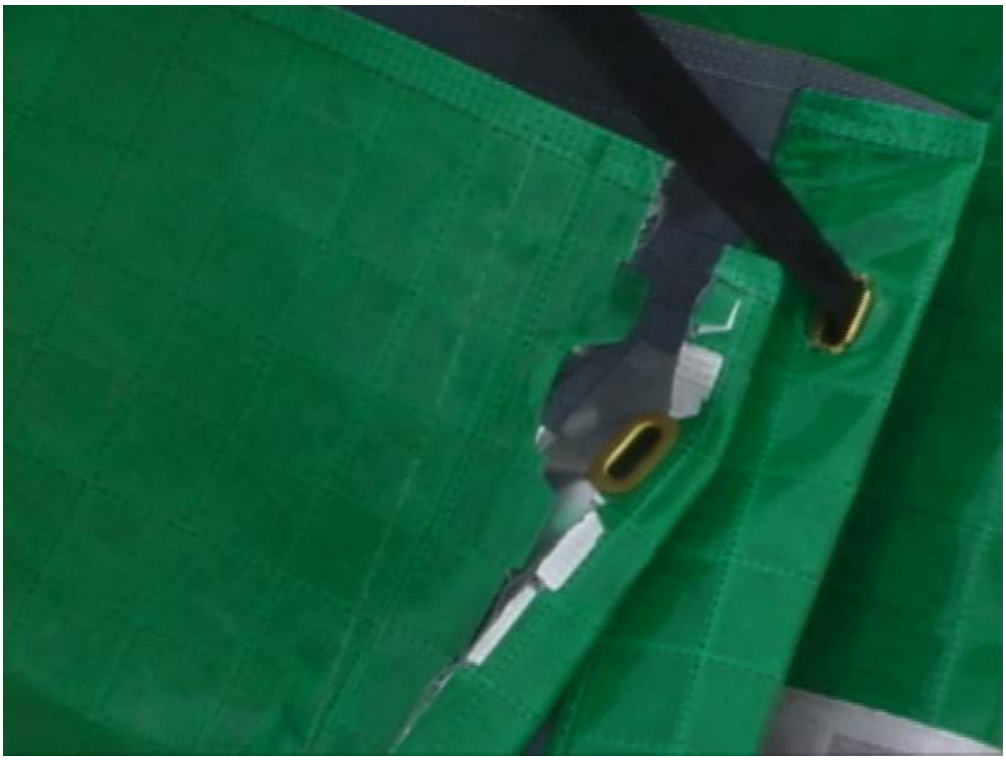

Figure 6. Resulting damage to sleeve on drum that was destroyed.

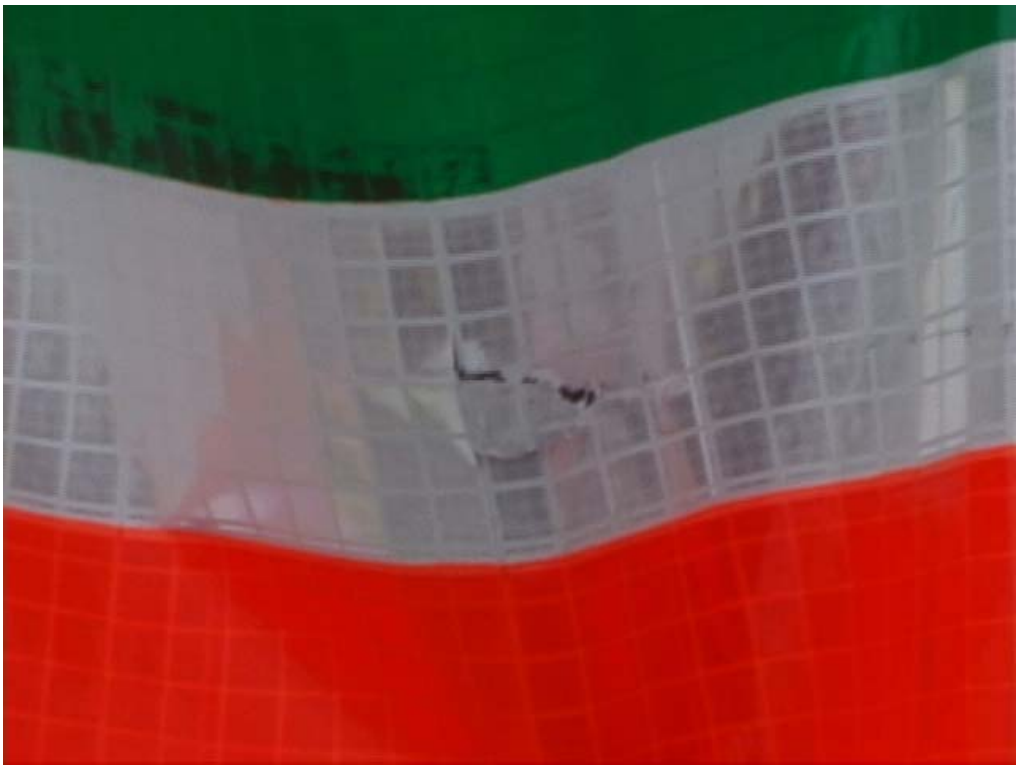

Figure 7. Minor damage to drum sleeve.

In all conditions except those where fewer than 8 vehicles were observed (at free flow speed), the difference between the mean speed for either configuration and that for the baseline data was smaller than either confidence interval. ANOVA bore out that no statistically significant effect was observed with respect to the application of the drum sleeves. Table 3 shows the results for passenger cars during the day. The P-value of 0.387 indicates that there is not sufficient evidence to claim the means aren't the same. The results for other conditions were very similar.

Table 3. ANOVA results for passenger cars during daytime.

Groups	*Count*	*Sum*	*Average*	*Variance*
Baseline Day Cars	51	2455.5	48.1	23.5
Config 1 Day Cars	94	4492.3	47.8	35.0
Config 2 Day Cars	76	3727.8	49.1	45.3

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	68.5	2	34.23	0.953	0.387	3.037
Within Groups	7833.5	218	35.93			
Total	7901.9	220				

Conclusions

No significant effect on speeds was observed when the drum sleeves were deployed. Either the drum sleeves have no effect in general, or they do have an effect, but the test did not capture that effect. The latter is suspected, but cannot be demonstrated without further testing.

The speeds of exiting vehicles were significantly lower than those of through vehicles, as might be expected. The slower exiting speeds confirms the original assumption that exiting traffic could slow mainline flow, increasing work zone congestion. Further, they suggest that the demands on the driver relative to the driving task are relevant, and that a device that can reduce those demands has the potential to reduce work zone congestion by delay caused by exiting vehicles.

Figure 8 shows the exit from the mainline at night both with and without drum sleeves in use. As can be seen from the figure, the sleeves are easily distinguishable from the non-sleeved drums. Additionally, the image reveals the primary reason the data were inconclusive. The exit is so clearly marked without the drum sleeves that no improvement was needed.

The installation and removal of the devices was quick and simple, and the durability appears to be very good. If they can be shown to have a positive effect on work zone congestion under some circumstances, the sleeves may prove to be a valuable tool for work zone traffic control.

Figure 8. Study site with and without drum sleeves (Configuration 2).

Recommendations

The results of the test were encouraging with respect to the ability of the methodology to capture effects of the drum sleeves. No change in driver behavior was observed when the sleeves were installed, but it is suspected that exit site used for the evaluation was already clearly delineated, nullifying any potential benefit of the sleeves that might exist. Nonetheless, the potential safety benefits are significant, and the life cycle cost is minimal, given that the sleeves can be reused. It is recommended that the test be repeated at a more complex site where the need for additional traffic control is more acute. (Note: a subsequent test has been approved for 2002).

Appendix A: Approval of Request to Experiment

U.S. Department
of Transportation
Federal Highway Administration

400 Seventh St., S.W.
Washington, D.C. 20590

December 8, 2000

Refer to: HOTO-1

Mr. Kurt Miyamoto
Traffic Control Engineer
Kansas Department of Transportation
Bureau of Traffic Engineering
217 Southeast Fourth Street, Fourth Floor
Topeka, KS 66603-3504

Dear Mr. Miyamoto:

Thank you for your November 14 letter to the Office of Transportation Operations, Federal Highway Administration. In your letter, you requested approval to experiment with drum sleeves (skirts) on a project along an Interstate or freeway route. Your request, submitted in accordance with the requirements of Section 1A-6 of the Manual on Uniform Traffic Control Devices (MUTCD), is approved, pending receipt of the following information you referred to in your Request to Experiment:

1. Location of the project;
2. Specification of the start and finish dates; and
3. Quantifying the performance Measures of Effectiveness (MOEs) you identified in your request.

You may fax the information to Mr. Harold Lunenfeld at 202-366-3225.

For reference purposes, we have assigned the following official experimentation number and title to your request: VI-112(E)–"Channelization Drum Sleeves." Please refer to this number in future correspondence.

If you require assistance in preparing your response, please contact Mr. Charles Sears at 202-366-1555.

Sincerely yours,

for Shelley J. Row, P.E.
Director, Office of Transportation
Operations

STATE OF KANSAS

KANSAS DEPARTMENT OF TRANSPORTATION
BUREAU OF TRAFFIC ENGINEERING
Thacher Building
217 SE Fourth Street, Fourth Floor
Topeka, Kansas 66603-3504
Ph. (785) 296-3618 FAX (785) 296-3619
TTY (785) 296-3585

Bill Graves
Governor

E. Dean Carlson
Secretary of Transportation

Mike Crow, P.E.
Chief

November 14, 2000

Experimentation Request

Ms. Shelley Row
Office of Transportation Operations
FHWA HOTO-1
400 7th Street, SW
Washington, DC 20590

Dear Ms. Row

The Kansas Department of Transportation, in accordance with Section 1A-6 of the Manual of Uniform Traffic Control Devices (MUTCD), is requesting approval to field test drum sleeves (skirts) on a project along an interstate or freeway route. The drum sleeves slip over and wrap around a traditional drum. The color scheme is retroreflective material with six-inch bands of green, orange, white and green working from the bottom to the top.

The location of the skirts will be within the construction zone at the gore areas of various exit ramps. The purpose of our test is to determine if the use of drum sleeves makes exit ramp locations more distinguishable to the driver and reduces potential rear end accidents. We plan to compare the effectiveness of drums with sleeves and without sleeves during the daytime and nighttime. The performance of the drum sleeves will be measured by the following methods: vehicle exit ramp speed, driver behavior characteristics (visual study), maintenance requirements, and subjective conspicuity. We plan on implementing the drum sleeves on a project that begins early next Spring.

After the project is selected and prior to starting the experiment for each location, we shall inform you (by fax and e-mail) the starting and ending experiment dates for each location of drum sleeves.

At least five exit ramp locations will be selected along a project to test and evaluate the performance of the drum sleeves. The number of drums with sleeves and the configuration will be varied at each location to see which configuration works best and is most effective.

The Kansas Department of Transportation agrees, upon completion of the experiment, to remove all experimental drum sleeves and restore the project site to the standards that were in place prior to the study. We also agree to terminate the experiment at anytime it is determined that significant safety hazards either directly or indirectly are attributable to the experimentation. We also recognize that the Office of Transportation Operations (HOTO) of the Federal Highway Administration may terminate the approval of this experiment at any time if there is an indication of hazards.

The estimated time of completion is the fall of 2001. We will be gathering information and reporting the outcome every six months through the completion of the project. We agree to provide the FHWA a copy of the final report within three months following the completion of the experiment.

Our outcome performance measures will be based on accumulated data. A range of success will be given for each drum sleeve configuration and the overall success will be determined by comparing the results from when using and not using drum sleeves. A study on driver behavior will be evaluated at the ramp gore areas. The visibility of the drum sleeves will be analyzed by comparing the distances at which the sleeves first become visible. The drum sleeves will be on video while doing the visibility analysis. The durability of the drum sleeves shall be analyzed by reviewing maintenance records and existing drum sleeves at the end of the project. The percentage of replacement and retroreflective condition of each drum sleeve will be evaluated. The maintenance required for drum sleeves will be evaluated daily by the project crew and traffic control personnel. All field records pertaining to the drum sleeves shall be reviewed. The inspector and contractor personnel shall be interviewed. Also, driver behavior and vehicle exit ramp speeds will be evaluated. The overall opinion and recommendation of the evaluation team will be included with the test results.

Sincerely,

Kurt Miyamoto
Traffic Control Engineer

KM:pc
c: Ernest Huckaby