DELINEATION SYSTEMS FOR TEMPORARY TRAFFIC BARRIERS IN WORK ZONES

by

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Research Scientist

(The opinions, findings, and conclusions expressed in this report are those of the author and not necessarily those of the sponsoring agencies.)

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ABSTRACT

Providing for the safety of traffic traversing construction and maintenance work zones is becoming increasingly complex, and over the past several years, temporary concrete barriers have come into use as a means of protecting work crews as well as motorists. This report discusses five delineation systems for such barriers, including the system presently being used in Virginia. Presented is information on the fabrication, installation, durability, and cost of the systems.

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INTRODUCTION

Providing for the safe passage of traffic through construction and maintenance zones is becoming increasingly complex. Temporary barriers are being used to keep traffic from entering a work area or from impacting objects or excavations within an area. Although most such barriers are delineated, some are not adequately distinguishable from their surroundings, especially at night. In this respect, temporary barriers may fail to satisfy the MUTCD requirement that motorists "be guided in a clear and positive manner while approaching and traversing construction and maintenance work areas." In response to this situation, the Federal Highway Administration (FHWA) let a contract for a project titled "Use and Delineation of Traffic Barriers in Work Zones," which included an evaluation of delineation systems under test track conditions. When the results of this evaluation become available, it was determined that there was a need to install some of the delineation systems at construction sites to observe their effectiveness under road conditions.

PURPOSE AND SCOPE

The purpose of this study was to examine, under highway conditions, three temporary barrier delineation concepts recommended by the FHWA. In addition, the study included the system presently used in Virginia. Since available funds were limited, the examination was restricted to the methods of installation and removal, maintenance, replacement, cost, and durability. The effectiveness of each system in delineating the barriers was not investigated. Only portable concrete barriers placed parallel to the flow of traffic were considered for use with each delineation system.

SYSTEMS EXAMINED

The four systems examined are described below and shown schematically in Figure 1.

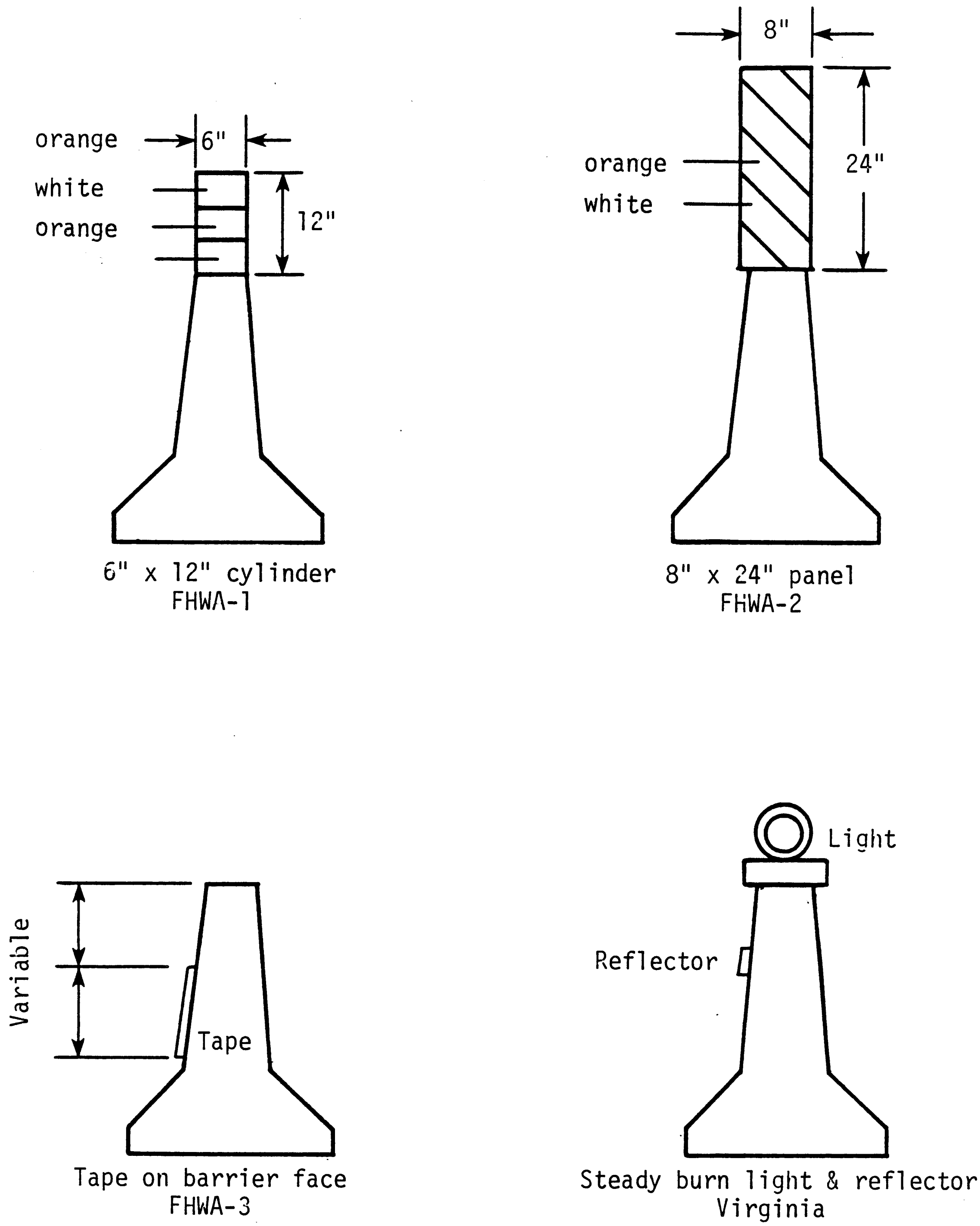

Figure 1. Schematic of delineation systems.

Systems Recommended by the FHWA

1. 6 in by 12 in reflective cylinders placed on top of the barrier and spaced at 100-ft intervals
2. 8 in by 24 in hazard panels placed on top of the barrier and spaced at 100-ft and 150-ft intervals
4. Continuous stripe (4 in minimum width) of reflective tape on face

It is noted that the spacing of the delineators placed on top of the barriers varied depending on the curvature of the roadway. Also, the tape was placed in different widths at different locations on the barrier face. These variables are discussed later for each site at which the systems were observed.

Systems Used in Virginia

Steady burn warning lights placed on top of the barrier and spaced at 96-ft intervals. Reflective barrier delineations (1.8 in by 4.2 in by 0.75 in) with reflective surface area of 3.25 in^2 installed on traffic side midway between warning lights and approximately 25 in from bottom of barrier.

PROCEDURE

The objectives of this study were accomplished by performing the following tasks, which are discussed below.

-- Fabricate delineators
-- Selection work sites
-- Install delineators
-- Compute overall costs
-- Determint durability
-- Document appearance of installations with film

Fabrication of Delineators

The 8-in by 24-in panels and the 6-in by 12-in cylinders for the delineation systems were fabricated in the district shops. The panels were made from 0.080-in aluminum and covered with high intensity sheeting of alternating 4 in silver/orange diagonal stripes. The cylinders were made from p.v.c. pipe which was cut into 12-in sections and covered with high intensity sheeting.

The tape applied to the barrier face was 3M yellow bissymetric (1.75 index bead) pavement tape.

Work Sites

The test sites selected were on construction projects where temporary concrete barriers were being used.

The sites and treatments were installed in the sequence in which they are described below. It is noted that the delineators are spaced in multiples of 12 ft since the length of the barrier is 12 ft. Each barrier has a threaded insert at mid-length on the top.

Site 1

Site 1 was in the southbound lanes of the Richmond-Petersburg Turnpike (Interstate 95) south of the Colonial Heights toll plaza. This section of highway has a -0.5% grade and a 2° curve to the right. The southbound AADT is 21,000 vehicles. The roadway has no lights; however, lights on adjacent signs, streets, etc., provides some illumination in the area. The delineation systems used follow.

- -- System 1: 4" tape - 192' (12" from barrier top)
  6" tape - 192' (12" from barrier top)
  12" tape - 192' (12" from barrier top)
- -- System 2: Virginia standard steady burn lights already in place. 11 lights @ 48' o.c. = 528'
- -- System 3: 6" x 12" cylinder on barrier top, 8 @ 72' o.c. = 576'
- -- System 4: 8" x 24" panel on barrier top, 8 @ 72' o.c. = 576'

The 72-ft spacing for the cylinders and panels was used as a compromise between the existing 48-ft spacing of the steady burn lights and the FHWA recommended distance of 100 ft.

In addition to the recommended 12-in stripe on the barrier face, 4-in and 6-in widths were placed for observation. Because of the degree of curvature and the 48-ft spacing of the steady burn lights, the FHWA spacing of 150 ft for the 8-in by 24-in panels was not used.

Site 2

Site 2 was also south of the Colonial Heights toll plaza on the Richmond-Petersburg Turnpike, but in the northbound lanes. The highway curves to the left 2° and has a +0.5% grade. It has an AADT of 21,000 vehicles. The light conditions were similar to those at site 1.

- -- System 1: Virginia steady burn lights in-place on each side of experimental sections. Spacing @ 48' o.c.
- -- System 2: 8" x 24" panel on barrier top, 8 @ 72' o.c. = 576'
- -- System 3: 6" x 12" cylinder on barrier top, 8 @ 72' o.c. = 576'
- -- System 4: 4" tape - 192' (3" above pavement)
  6" tape - 192' (3" above pavement)
  12" tape - 192' (3" above pavement)

The 72-ft spacing of the cylinders and panels was used for the reason stated above for site 1. Also, 4-in and 6-in wide stripes were used in addition to the 12-in stripe. Each stripe was positioned 3-in above the pavement, which is the point at which the barrier taper starts.

Site 3

Site 3 was in the northbound lanes of Interstate 95 north of the Fredericksburg Route 17 interchange. This site curves to the left at .3° and has a +2.4% grade. The AADT is 21,500.

There were no lights on or adjacent to this section of highway.

- -- System 1: Virginia steady burn lights in place on both sides of experimental section. Spacing @ 96' o.c.
- -- System 2: 6" x 12" cylinder on barrier top, 6 @ 96' o.c. = 576'
- -- System 3: 8" x 24" panel on barrier top, 6 @ 96' o.c. = 576'
- -- System 4: 8" x 24" panel on barrier top, 5 @ 144' o.c. = 720'
- -- System 5: 4" tape - 192' (12" from barrier top)
  6" tape - 192' (12" from barrier top)
  12" tape - 192' (12" from barrier top)

Because of the 12-ft length of the barrier, spacings of 96 ft and 144 ft were used, respectively, for the FHWA recommended 100-ft and 150-ft spacings.

Site 4

The last site chosen was on Route 44, eastbound to Virginia Beach and east of the Newtown Road interchange. This section of road has no lights, but there is noticeable light from adjacent streets. The highway has a 1° curve to the right and no grade. The AADT for this section of highway is 55,000.

-- System 1: Virginia steady burn lights in place on both sides of the experimental section. Spacing @ 96' o.c.
-- System 2: 8" x 24" panels on barrier top, 6 @ 96' o.c. = 576'
-- System 3: 8" x 24" panels on barrier top, 5 @ 144' o.c. = 720'
-- System 4: 4" tape - 240' (3" above pavement)
6" tape - 240' (3" above pavement)
-- System 5: 6" x 12" cylinder on barrier top, 6 @ 96' o.c. = 576'

Only 4-in and 6-in stripes were used on the barrier face since observations at the previous sites had indicated that the 12-in stripe was too wide.

Installation of Delineators

The experimental delineator systems were installed by Department personnel as described below.

Cylinders

The cylinder was attached to the top of the barricade by using a threaded insert set in the barrier during fabrication. A bracket, as shown in Figure 2, was used to attach the cylinder to the barrier with a 3/8-in bolt screwed into the insert. The aluminum bracket is 2 in wide, 14 in high, and 0.125 in thick, and the cylinder is attached to it with two 1/4-in bolts. Figure 3 shows the cylinder in place on the top of a barrier.

Panels

The panels were attached to the barricade by the same arrangement as used for the cylinders; however, the bracket was larger and was fabricated of steel. The 0.125 in thick bracket was 14 in high and 2 in wide. A 3/8-in bolt was used to secure the panel to the barrier.

The photographs in Figure 4 show front and back views of a panel in place. It is noted that the brackets originally were fabricated from 0.125-in aluminum; however, after some of these failed, the switch was made to steel. The aluminum brackets appeared to have broken under repeated stress caused by the air turbulence acting on the panel.

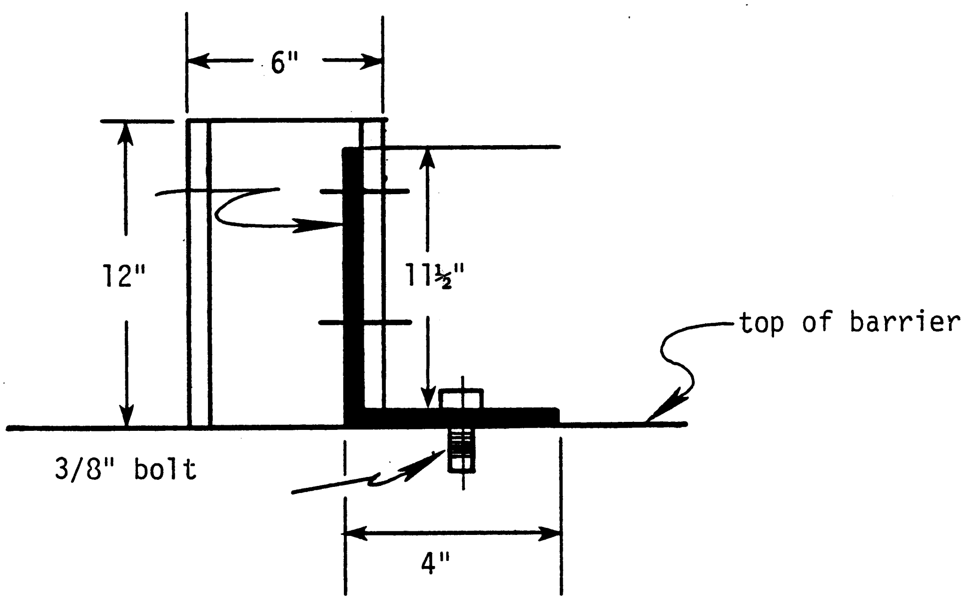

Figure 2. Bracket for attaching cylinder to barrier.

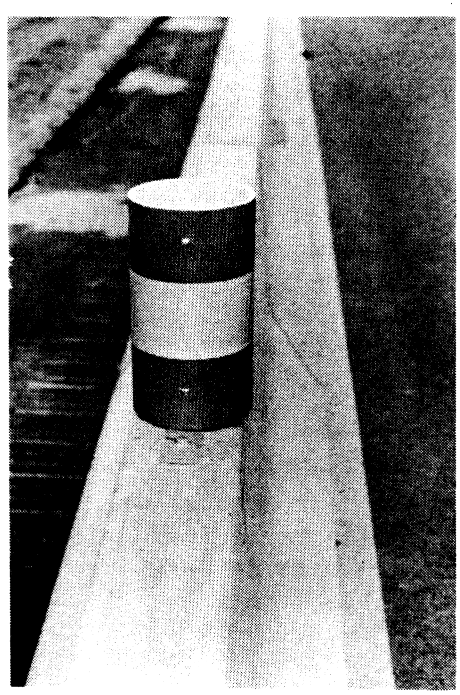

Figure 3. Cylinder on barrier.

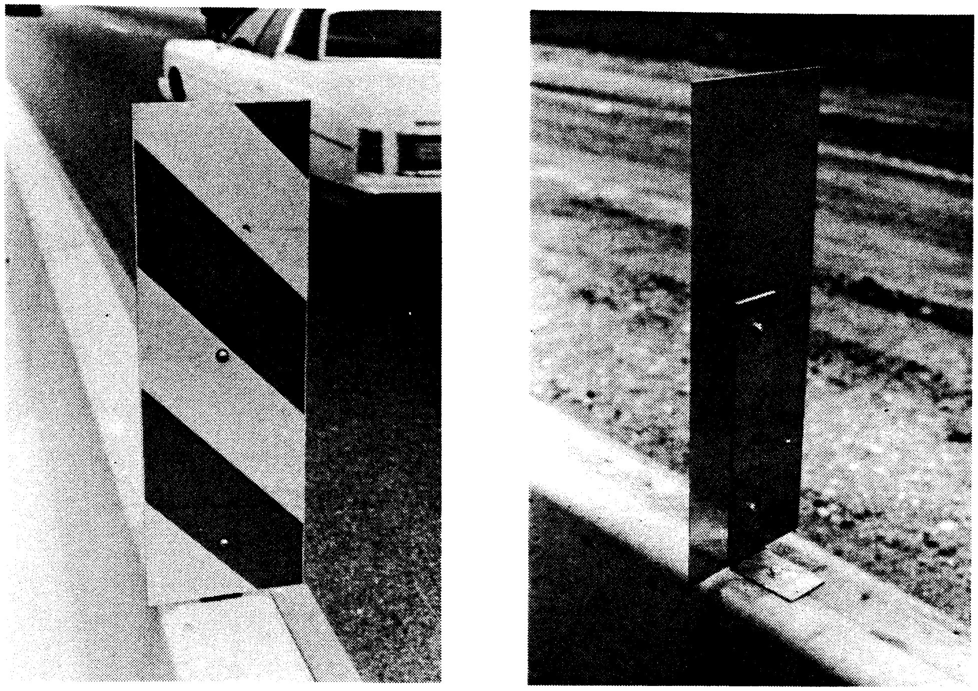

Figure 4. Front (left) and back views of panel on barrier.

Since the cylinder and panel were attached to the barrier by workmen working from the highway median or the side opposite the traffic flow, no special traffic control was required.

Tape on Barrier Face

Preformed reflective tape was attached to the face of the barrier at different heights as noted above. The tape was attached by priming the barrier face as shown in Figure 5. After the barrier face was marked for proper alignment, the tape was pressed against the barrier using rollers as shown in Figure 6. It was necessary to close a lane for this operation.

Steady Burn Lights

The steady burn lights were attached to the barrier top using a bracket and 3/8-in bolts. The reflectors used with the lights are attached to the barrier face with an adhesive. No traffic control is necessary for placement of the lights and reflectors.

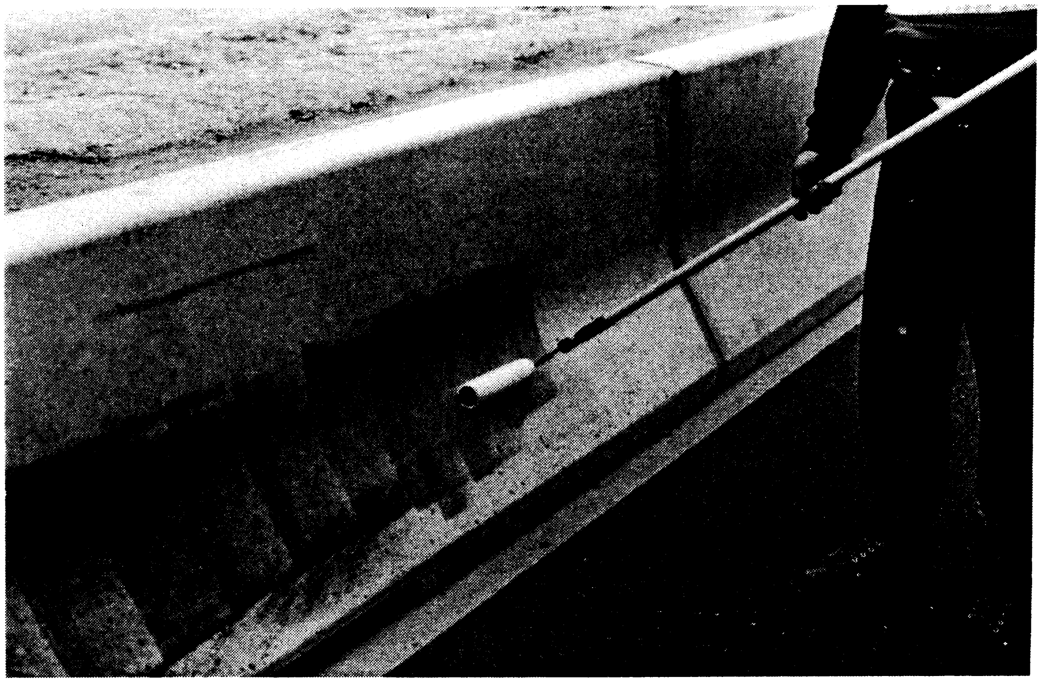

Figure 5. Priming barrier face for tape.

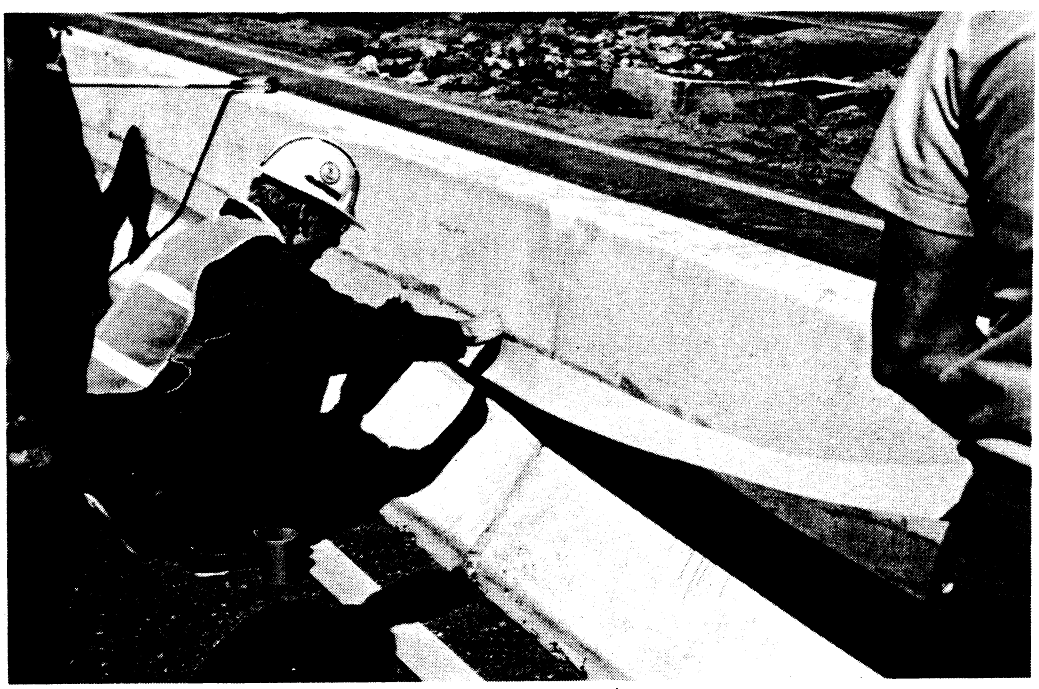

Figure 6. Attaching tape to barrier face.

Cost of Delineators

Materials and Fabrication

The costs of fabricating the delineators are given in Table 1. The costs of the reflectorized cylinders and panels include the costs of materials and labor. The materials included p.v.c. pipe and aluminum blanks, respectively, for the cylinders and panels, plus the sheeting, attachment brackets, and nuts and bolts. Labor involved the cutting and sizing of the delineators and brackets and attaching the sheeting. It is noted that the attachment brackets for the panels were more expensive than those for the cylinders because of the need to use steel.

Table 1

Cost of Fabrication

Delineator	Cost per Unit
6" x 12" cylinder	$17.89
8" x 24" panel	$20.05
Tape:	
- 4" wide	$0.51/ft
- 6" wide	$0.76/ft
- 12" wide	$1.52/ft
Steady burn light & reflector	rental rate: $0.68 - $1.40/unit/day

The cost of the preformed tape was that paid to the manufacturer for 50-yd rolls.

The daily rental rate paid to contractors for steady burn lights ranged from $0.68 to $1.40 per unit, depending upon the project type and location.

Installation

Installation of the cylinders and panels generally took about the same amount of time since both were bolted to the top of the barrier utilizing the threaded inserts. However, in many cases the threads in the inserts were stripped, and this made it difficult to secure the delineators. This problem would have to be corrected if the cylinders or panels were used, especially the panels as any rotation lessens their delineation capabilities. For normal operations, it took 5 minutes or less for one person to install a delineator and about 2 minutes to remove one.

For the sites on which the preformed tape was used, the cost of labor for installation was approximately $0.06/ft for the 4-in and 6-in material, and approximately $0.07/ft for 12-in material. Also, the cost of a lane closure has to be added, unless the tape is placed on the barricades prior to their installation on the highway.

Repair and Replacement

For this study, the cylinders and panels were not cleaned: therefore, there was no cost for routine maintenance. The devices were, however, maintained by replacing those lost and realigning and straightening those bent. Based on the rate of loss on the experimental installations, approximately 15% of the panels and 5% of the cylinders would be lost per year. Also, approximately 50% of the panels would be bent and 43% would need to be realigned in a year. No cylinders had to be aligned or repaired.

The barrier tape was not cleaned during the study and none was lost.

Total Project Cost

Using the data from the shop fabrication and test sites, an estimate of the project cost for each delineation system was made. For the purpose of comparison, data were projected for a section 1 mi long. Table 2 gives the total project costs which include fabrication, installation, and repairs for each system. The total costs given are for an assumed life of 1 year for the delineators.

It is noted that the total project cost for the steady burn lights is based on the range of rental fees charged by the contractors for various projects in Virginia.

The total yearly project cost was the lowest for the panels spaced at 144 ft centers primarily because fewer markers had to be used per mile. The barrier stripes were significantly more expensive than the cylinders and panels, with the cost increasing with the increase in the width of the tape. The high cost of the barrier striping was the result of the high purchase price of the tape and the cost of the lane closure required for installation.

A comparsion of the panels and cylinders spaced at 96-ft intervals revealed that the cylinders were the least expensive.

Table 2

Total Project Cost per Mile

Delineation Treatment	Material & Fabrica.	Initial Install. & Removal	Yearly Repair	Yearly Replace.	Total 1-yr Cost
6" x 12" cylinder @ 96' spacing	$ 984	$ 68	$ --	$ 49	$1,101
8" x 24" panel @ 96' spacing	1,103	68	34	174	1,379
8" x 24" panel @ 144' spacing	742	47	22	118	929
Barrier striping					
4" wide	2,693	480	--	--	3,173
6" wide	4,013	480	--	--	4,493
12" wide	8,026	563	--	--	8,589
Va. steady burn lights & reflectors					
$0.68/day @ 96' spacing					13,651
$1.40/day @ 96' spacing					28,105

Based on the rental rate for steady burn lights, the Virginia system was much costlier than the others. It is noted that if the other systems (cylinders, panels, or striping) were rented to the Department as were the lights, the costs may be different than those shown.

The cost of delineation may be influenced by the project duration since the more frequently the delineators are installed and removed, the higher the cost. Because of the relatively short period of observation, it was not possible to obtain information for a statement on this variable.

Durability

Periodic observations were made during the 4-to-6-month (spring-summer 1985) observation period.

Cylinders

Overall, no cylinders were lost or were observed to have sustained significant damage. There was slight scarring of the sheeting on various delineators; however, it was not detrimental to the reflective qualities. Stability against transitional and rotational forces presented no problem, primarily due to the design, which allowed the cylinder to rest on the barrier top in addition to being attached to it. Also, the cylindrical design allowed rotation without detriment since the reflective surface available for delineation remained the same regardless of rotation.

Although some road film was evident on the cylinders, it did not seem to significantly decrease the reflectivity, and with a regular maintenance routine, any detrimental effects of dirt, road film, etc., should be kept to a minimum.

Panels

With the panel, durability was more of a problem than with the cylinders, primarily because the larger area and thin metal of the former made it more vulnerable to contact by vehicles, workmen, etc. Also, there was some bending due to wind turbulence; however, in all cases the panel was simply straightened to its original position with minimal effort.

There was a tendency for some panels to rotate; however, none were observed to be ineffective for delineation. The cause of rotation was the inability to secure the panel brackets to the barrier because of stripped threads in the inserts used for attachment. The inserts were plastic and many were damaged. Also, the single attachment point allowed the panel to rotate if the bolt was loose.

Road dirt accumulation was similar to that on the cylinders, and was no obvious detriment to the reflective qualities of the sheeting.

Barrier Striping

All tape placed on the barrier wall performed quite well, with none needing replacement. The striping was able to withstand several "hits," as evidenced by tire marks, etc., indicating that vehicles had come in contact with the tape.

Although road dirt accumulated on the tape, it did not get worse with time, and the striping continued to provide delineation.

Steady burn Lights

Few problems were observed for the steady burn lights, since these are routinely maintained under the rental arrangement. Occasionally, a light would not be burning and others would be rotated or slightly bent.

Movie Documentation

Pictures were taken of all systems at each site under the following conditions:

Daylight -- dry pavement
Night -- dry pavement
Night -- wet pavement

The movies were edited, placed on a single reel, and are available upon request.

CONCLUSIONS

Based on the methods of shop fabrication and field installation used, and on periodic field observations, the following conclusions are presented.

Installation and Replacement

The panels, cylinders, and lights were simply and quickly installed utilizing the threaded inserts in the top of the concrete barriers. Problems were encountered with deterioration of the existing threaded inserts allowing the delineators to loosen and rotate or fall off. Application of the tape to the barrier face was more difficult, requiring a lane to be closed as well as additional personnel to make the application as compared with the number needed to install the cylinders, panels, and lights.

Removal and replacement of the cylinders, panels, and steady burn lights was simple, requiring a minimum of time and effort; however, the problems noted with the damaged threaded inserts were evident when replacing delineators. Although no tape was replaced during the evaluation, replacement would require a lane closure.

Durability

All systems displayed good durability. The panels presented problems because of their tendency to bend and rotate; however, they could be very easily realigned. Dirt and road film did not seem to be a problem, as accumulations reached a point at which they did not worsen and the retroreflection of the delineators was still deemed acceptable. The delineators placed on top of the barriers can be easily and safely cleaned if necessary.

It is noted that the systems were in place during the spring and summer months and thus were not exposed to a winter environment.

Cost

The cylinders were the cheapest of the delineators to fabricate, with the panels being next. The tape was significantly more expensive, with the purchase price per linear foot increasing as the tape width increased.

The costs of installation and removal were the same for the panels and cylinders, since the attachment procedure was the same for both. The cost of applying and removing the tape was significantly greater because of the additional manpower and traffic control required for application.

The total replacement cost was more for the panels since they had a higher loss rate. Also, the panels required more time for repair and realigning than did the cylinders. It is noted that routine maintenance was not included as a cost item.

A comparison of the total project cost for 1 year revealed that for equal spacing the cylinders were more economical than the panels.

The system including steady burn lights was significantly more expensive than the others.

Increasing the spacing of the cylinders, panels, or lights would decrease the cost, since fewer devices would be used; however, without knowledge of the effective of spacing on traffic flow and safety, no increase in spacing should be supported. The acquisition of such knowledge was not within the scope of this study.

RECOMMENDATIONS

Based on the cost of fabrication, replacement, and removal, along with the degree of simplicity in attaching the delineators to the barriers, the cylinders and panels have advantages over the other systems. Problems with the threaded inserts used to attach the cylinders and panels should be remedied if these delineators are used.

Striping on the barrier face, which requires a lane closure for application, proved to be durable; however, more input concerning its service life, loss of retroreflectivity with age, and its performance under different weather conditions should be required before it is used.

Because of the significantly higher cost of Virginia's system utilizing steady burn lights and reflectors, a more detailed analysis should be made of its costs and effectiveness relative to those of the alternative systems.

It is not recommended that the systems using cylinders, panels, or tape be used for barrier delineation without additional information on their performance. Also, it is important to consider the influence of each system in terms of legibility, target value, and effectiveness of delineation on traffic flow characteristics and traffic safety.

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Standard Title Page -- Report on State Project

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Title and Subtitle

"Evaluation of a Bridge Deck Expansion Joint"
(Experimental Feature -- Royston Unidam Type LK-120)

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Supplementary Notes

Abstract

Two Royston Unidam LK-120 bridge deck expansion joints were installed as experimental features on the Rte. 50 EBL bridge over the Shenandoah River in Clark County, Virginia. The joints were evaluated with respect to their ease of installation and performance after five years of service. It was found that the joint is difficult to install to the prescribed opening distance between the hold-down angles. The performance of the elastomeric material has not been totally satisfactory. On one of the two joints the elastomer has failed over a 3-ft length in the right-hand lane, and considerable sagging of this material in both joints suggests that the failure may become more widespread with time. As a result, the riding quality over the joints has been impaired and traffic impact noise has increased. In general, the performance of the joint has been unimpressive and its use on other bridges is not recommended.