Delineation of Concrete Safety Shaped Barriers

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In this paper, the results of a study of five delineation treatments for concrete safety shaped barriers are presented. These treatments were tested along a lighted urban freeway in Houston, Texas. A low-light video camera and time-lapse video recorder were mounted above each treatment to record nighttime traffic next to the barrier before and after the treatments were installed. Nighttime subjective evaluations were conducted when the treatments were newly installed and also after the treatments had been in place for several months and had become dirty. Study researchers also measured the visibility distances of the treatments at periodic intervals after delineation installation. The results showed that the treatments had little effect on lane distributions and vehicle lateral distances from the barrier. Subjects rated the side-mounted cube-corner lenses at 50-ft spacings as the brightest and most effective treatment of those studied. However, lane straddling rates may have increased slightly next to this treatment. Visibility data showed that the cube-corner lenses lost less of their original visibility over time than did reflective sheeting. Also, side-mounted delineation was found to become dirty and lose its visibility faster than top-mounted delineation. On the basis of the measurements taken, top-mounted cube-corner delineators at spacings no greater than 200 ft were recommended for delineating concrete safety shaped barriers.

Concrete safety shaped barriers (CSSBs) are being used more and more on highway facilities to protect drivers from roadside hazards, to separate opposing traffic flows, and to protect workers from traffic during roadway rehabilitation and reconstruction activities. At many of these installations, the barrier must be placed immediately next to the travel lane. In these instances it is important that drivers be aware of the location of the barrier and the proper travel path next to the barrier.

Unfortunately, CSSBs may be quite difficult to see at night, especially in the rain. Their concrete composition provides little contrast with the roadway pavement. This problem may occur even where fixed illumination is provided. To further complicate matters, barriers tend to accumulate dirt and trash next to them, possibly obscuring the adjacent travel lane edgeline partially or completely. It is believed that barrier-mounted delineation could be extremely useful to drivers in some cases, identifying both the location of the barrier and the correct travel path next to the barrier. Such delineation could result in improved safety, operations, and driver comfort under nighttime driving conditions.

Previous CSSB delineation research has been limited. Most studies have considered only subjective driver evaluations of various delineation treatments (*1–3*); few have collected objective driver performance data, either in a controlled field or actual field situation (*4, 5*). The majority of the studies have focused on work zone CSSB delineation (*2–5*) because geometric and visibility constraints are generally more severe at such locations. The results of these studies have been mixed. For example, one study suggests that delineation should be mounted on top of the barrier (*1*) so that it will retain its reflectivity longer and require less maintenance. On the other hand, another study recommends side-mounted CSSB delineation so that the delineators are not "hidden" by oncoming headlight glare (*3*). Larger but less bright (as measured by the specific illuminance) devices are recommended by some (*2, 4, 5*), while smaller, brighter reflectors are recommended by others (*1, 3*). Even the spacing of delineation is not without debate: distances recommended in the various studies have ranged from 25 to 200 ft.

Engineers must currently decide on the type of delineator to use, how far apart the delineators should be spaced, and where on the barrier the delineators should be placed without knowledge of the impacts that these choices have on traffic operations and safety. In addition, the effects that road film and grime have on the continued effectiveness of delineation are unknown. To address these questions, the Texas Transportation Institute conducted a study for the Texas State Department of Highways and Public Transportation to develop improved procedures for delineating concrete safety shaped barriers (*6*). The results of this research are summarized in this paper.

The specific objectives of this study were threefold:

- Determine how different delineator types, spacings, and mounting positions on the barrier affect nighttime traffic operating in the travel lane next to the barrier;
- Determine driver preference and perception of different delineator types, spacings, and mounting positions; and
- Determine how the visibility and brightness of different types of delineators deteriorate over time because of dirt and road film.

These objectives were addressed through the collection and analysis of (a) driver performance data, (b) subjective evaluations, and (c) reflectivity measurements of selected delineation treatments taken over a period of time.

STUDY DESIGN

Delineation Treatments

This research was designed to evaluate a select number of different delineator types, spacings, and mounting positions in

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a coherent, consistent manner. On the basis of the literature review, it was decided to limit the analysis to three different types of delineators:

- A round (3.25 in. diameter) acrylic cube-corner reflector,
- A small plastic bracket (about 3 in. high and 4.25 in. wide) covered with high-intensity (HI) sheeting, and
- A cylindrical tube (3 in. in diameter by 6 in. high) wrapped with HI reflective sheeting, thereby providing reflectivity at all viewing angles.

The study also considered both top-mounted and side-mounted (6 in. from the top) positions on the CSSB. As a final factor, two spacings were selected for study, at 50 ft and 200 ft.

A block experimental design to evaluate these different factors would have required 12 (3 × 2 × 2) different delineation treatment combinations. Because of limitations in study funding and scope, a quasi-Latin square design was used to select five combinations of delineator type, spacing, and mounting position on the CSSB for analysis. These treatments are given in Table 1.

These treatments were installed along a 3-mi section of urban freeway (illuminated with high-mast lighting) in Houston, Texas. A high-occupancy vehicle transitway was retrofitted in the median of the freeway, with CSSBs (located 1 ft away from the inside travel lanes) used to separate the transitway from the travel lanes. The layout of the treatments through this section is shown in Figure 1. The freeway section was primarily four lanes in each direction, with each lane approximately 12 ft wide. On the basis of 1985 data, traffic flow through the section was considered to be 180,000 vehicles per day. A number of businesses were located on the frontage roads on each side of the freeway. The signs and lights of these businesses added to the general nighttime visual complexity of the section. A gently rolling freeway alignment provided substantial sight distance throughout.

Data Collection

Driver Performance Data

Immediately before and after the delineators were installed, nighttime driver performance data were collected at each treatment

TABLE 1 SUMMARY OF DELINEATION TREATMENTS

Treatment	Delineator	Mounting Position	Spacing (ft)	Cost per Delineator ($)	Cost per Mile of Barrier ($)
1	Cube-corner	Top	200	2.50	66
2	Cube-corner	Side	50	2.50	264
3	Brackets with HI sheeting[a]	Top	50	1.50	158
4	Brackets with HI sheeting	Side	200	1.50	40
5	Reflective cylinder	Top	50	4.50	475

[a]HI = high-intensity reflective sheeting.

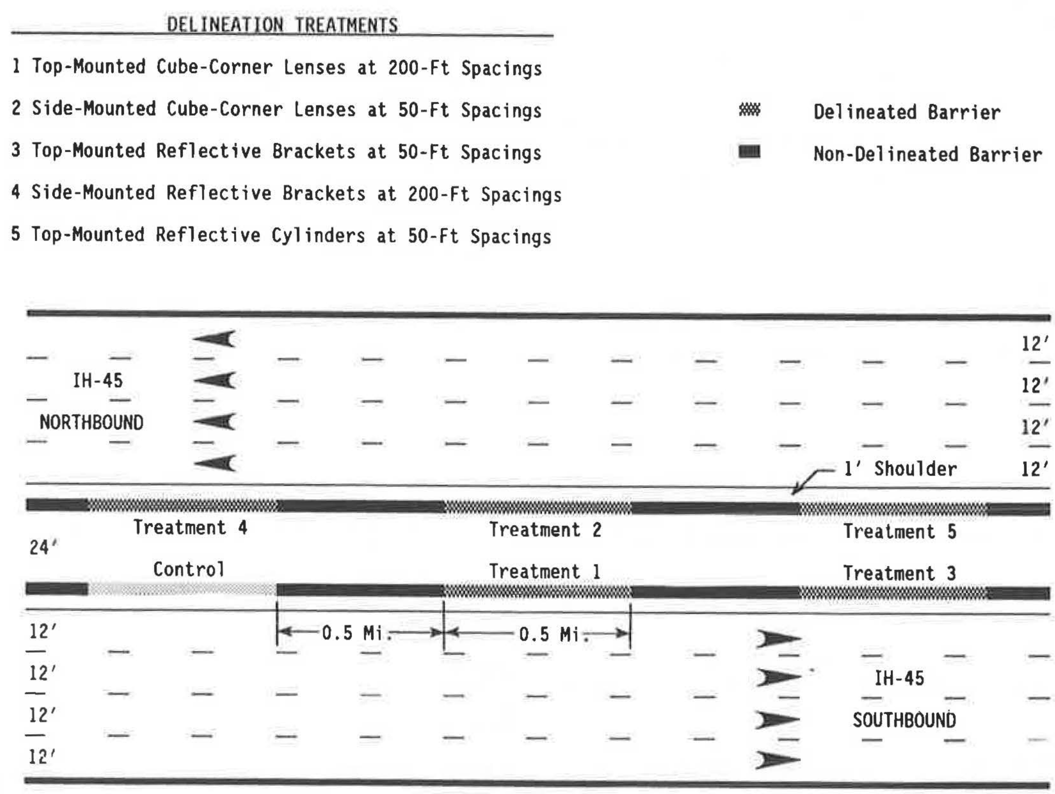

FIGURE 1 Layout of delineation treatments at the I-45 (Houston, Texas) study site.

segment by means of a low–light level video camera. The camera was mounted on overhead sign supports spanning the freeway and positioned to provide a top-down view of traffic traveling next to the barrier at each treatment segment. Videotape data were collected continuously throughout the nighttime hours on two weeknights (Monday–Thursday) at each treatment segment before and immediately after the delineators were attached to the CSSB. Although data were collected primarily under dry pavement conditions, some rain data were collected at Treatment 4 (side-mounted brackets with HI sheeting at 200-ft spacings).

To account for any time-related or other unidentified effects present during the study, data were also collected at a "control" location upstream of any delineation. Data were collected starting at the downstream treatment segment in each direction of travel (segments B and E in Figure 1). Once "before" and "after" data were obtained at a segment, the camera was moved to the next upstream segment, and the process was repeated. This was done to ensure that traffic being observed and monitored at a particular treatment segment was not influenced by a previously installed delineation treatment upstream.

The nighttime hours were divided into two time periods. The first period, from 9 p.m. to midnight, was taken to be representative of higher-volume nighttime traffic conditions. The second period, representing lower-volume nighttime conditions, began at midnight and ended at 5 a.m. Three measures of effectiveness (MOEs) were used to evaluate the effect of delineation on driver performance:

- Lane distribution Measured for the two lanes closest to CSSB. It was assumed that delineation would affect traffic primarily in these two lanes.
- Lane straddling The number of vehicles straddling the lane stripe between the two lanes closest to the CSSB.
- Lateral distance Measured as the distance between the left rear tire and the bottom of the CSSB. This measure was estimated to the nearest foot from the videotape data.

The lane distribution and lane-straddling data were measured continuously throughout the nighttime hours. However, because it was not necessary to record the lateral distance for every vehicle in the inside travel lane, measurements were sampled throughout the night in direct proportion to the actual lane volumes present.

Subjective Evaluations

In this phase of the study, a limited number of subject drivers drove a test vehicle in the leftmost inside lane next to the CSSB. Subjects then ranked the treatments in terms of the relative brightness and effectiveness in helping them maintain a safe travel path. Subjects also provided indications as to whether they felt that each treatment was adequate in terms of brightness and effectiveness (independent of the other treatments).

Ten Houston-licensed drivers evaluated the treatments in a clean, new condition, and the same ten subjects, plus an additional 20-yr-old female, also evaluated the treatments after the delineators were in place for a period of time and had become dirty. The study sample consisted of seven women (eight in the evaluation of the dirty treatments) and three men. Ages of the subjects ranged from 18 to 56 years. The subjects, as a group, were well-educated, experienced drivers. None of the participants lived near the study site, so their familiarity with the site was limited to only occasional trips through the section. Full details of the study procedure may be found in the original study report (*6*).

Delineator Visibility

The delineators were in place on the CSSB from February to June 1987. The researchers periodically examined the delineators under nighttime conditions and recorded the maximum distance at which each could be seen from within a test vehicle with its headlights set to low beam. This technique provided a quick, consistent method for monitoring the changes in delineator visibility over time. The study procedure described for the collection of the driver performance data required that the treatments be installed at different times, causing them to be exposed to slightly different weather conditions. To normalize the visibility analysis, a new delineator was installed at each of the previous treatment segments when the final (fifth) treatment was installed. Subsequent visibility assessments were then based on these specific delineators. Visibility measurements were taken at the time of the final installation and at 2-, 6-, 10-, and 16-week intervals.

STUDY RESULTS

Driver Performance Data

Lane Distribution

Table 2 presents the results of the analysis of the lane distribution data. During the higher-volume nighttime hours, the proportion of drivers using the inside travel lane decreased 3 percent at Treatment 1 (the top-mounted cube-corner lenses at 200-ft spacings) and by 1 percent at Treatment 2 (side-mounted cube-corner lenses at 50-ft spacings). Meanwhile, the proportion of drivers in the inside lane increased 2 percent at Treatment 5 (the top-mounted cylinders at 50 ft). For the low-volume conditions, the proportion of vehicles traveling in the inside travel lane decreased by 2 percent at Treatment 1 but increased 3 percent at Treatment 5. These proportional changes are very small in terms of lane volumes, so the treatments appeared to have had very little practical effect on lane distribution.

Lane Straddling

Lane-straddling rates at all of the treatment segments were quite low during the higher-volume nighttime hours, as shown in Table 3. Statistical comparisons of the rates found only one significant change, an increase at Treatment 2 (side-mounted cube-corner lenses at 50-ft spacings).

Lane-straddling rates during the lower-volume nighttime hours, although greater than those in the higher-volume hours, changed little between before and after conditions. Only Treatments 4 (side-mounted brackets at 200-ft spacings) and 5 (top-mounted cylinders at 50-ft spacings) showed statistically significant changes. Given the extremely small sample sizes obtained in this comparison, it is not appropriate to draw any

TABLE 2 COMPARISON OF LANE DISTRIBUTION DATA BEFORE AND AFTER DELINEATION, I-45, HOUSTON

Treatment	High-Volume Nighttime Periods[a]					Low-Volume Nighttime Periods[a]				
	Before Delineation		After Delineation		Difference	Before Delineation		After Delineation		Difference
	Percent	n	Percent	n	(%)	Percent	n	Percent	n	(%)
Control (no delineation)	40.4	6,963	41.4	6,304	+1.0	22.8	2,823	24.0	2,570	+1.2
(1) Top-mounted cube-corner, 200-ft spacings	41.4	6,612	38.3	5,539	−3.3[b]	23.8	2,650	21.7	2,044	−2.1[c]
(2) Side-mounted cube-corner, 50-ft spacings	38.5	6,829	36.3	5,534	−1.2[b]	25.4	2,925	26.0	2,310	+0.6
(3) Top-mounted brackets, 50-ft spacings	39.2	5,726	38.7	5,627	−0.5	24.4	1,951	26.2	2,040	+1.8
(4) Side-mounted brackets, 200-ft spacings	34.7	6,598	33.5[d]	3,040	−1.2	22.0	2,568	20.3	1,596[d,e]	−1.7
(5) Top-mounted cylinders, 50-ft spacings	35.9	4,927	37.5	5,395	+1.6[b]	22.7	1,800	25.8	2,157	+3.1[b]

[a]Percent = percentage of inside and middle lane traffic in lane next to barrier; *n* = sample size in number of vehicles.
[b]Different at 0.05 level of significance.
[c]Different at 0.10 level of significance.
[d]Data represent only 1 night.
[e]Data collected under rainy conditions, with wet pavement.

TABLE 3 COMPARISON OF LANE STRADDLING RATES, BEFORE AND AFTER DELINEATION, IH-45, HOUSTON

Treatment	High-Volume Nighttime Periods[a]					Low-Volume Nighttime Periods[a]				
	Before Delineation		After Delineation			Before Delineation		After Delineation		
	Rate	n	Rate	n	Change	Rate	n	Rate	n	Change
Control no delineation	1.5	4	0.8	2	−0.7	4.7	3	6.5	4	+1.8
(1) Top-mounted cube-corner, 200-ft spacings	0.7	2	2.4	5	+1.7	7.9	5	6.8	3	−1.1
(2) Side-mounted cube-corner, 50-ft spacings	0.0	0	1.4	3	+1.4[b]	1.3	1	5.0	3	+3.7
(3) Top-mounted brackets, 50-ft spacings	0.4	1	0.0	0	−0.4	4.2	2	3.7	2	−0.5
(4) Side-mounted brackets, 200-ft spacings	0.9	2	2.0[c]	2	+1.1	3.5	2	15.4	5[c,d]	11.9[b]
(5) Top-mounted cylinders, 50-ft spacings	0.6	1	0.5	1	−0.1	4.9	2	0.0	0	−4.9

[a]Rate = lane-straddling rate per 1,000 vehicles in inside lane; *n* = number of lane straddlings observed.
[b]Different at 0.05 level of significance.
[c]Data represent only one night.
[d]Data collected under rainy conditions with wet pavement.

solid conclusions from the data. It is interesting, however, to note that the rate was again higher for Treatment 2 and was almost statistically significant. These data may suggest that the combination of close delineator spacing and the side-mounted position may make some drivers too apprehensive of the barrier.

It should also be noted that the "after" data at Treatment 4 were collected when the pavement was wet. The video recordings showed a significant glare problem; the high-mast lighting and vehicle headlights appeared to wash out the edgeline and lane stripes. Consequently, the large increase in the lane straddling rate is not necessarily an indication of the effect that this treatment had on traffic. Instead, it indicates that some drivers have more difficulty staying in their lane at night in wet pavement conditions, even where fixed illumination is present.

Lateral Distance

As stated previously, the lateral distance data collected were measured to the nearest foot rather than on a continuous scale (portions of a foot). The Kolmogorov-Smirnoff test (7) (a nonparametric goodness-of-fit test) was applied to determine whether the probability distributions of the lateral distance data differed. During the higher-volume nighttime hours, statistically significant differences were found at Treatments 4 (side-mounted brackets at 200-ft spacings) and 5 (top-mounted cylinders at 50-ft spacings). The lateral distance distributions for these segments are shown in Figures 2 and 3. The distribution appears to have shifted slightly away from the barrier at Treatment 4, while the distribution at Treatment 5 seems to have shifted closer to the barrier.

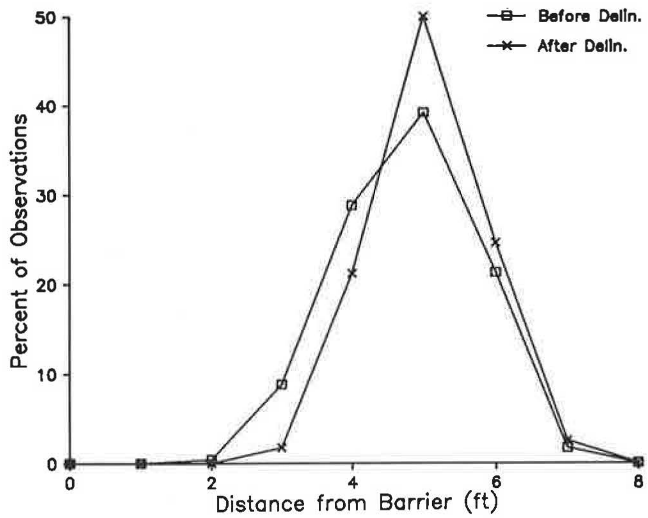

FIGURE 2 Lateral distance distribution for Treatment 4: reflective brackets, side-mounted at 200-ft spacings (9:00 p.m. to midnight).

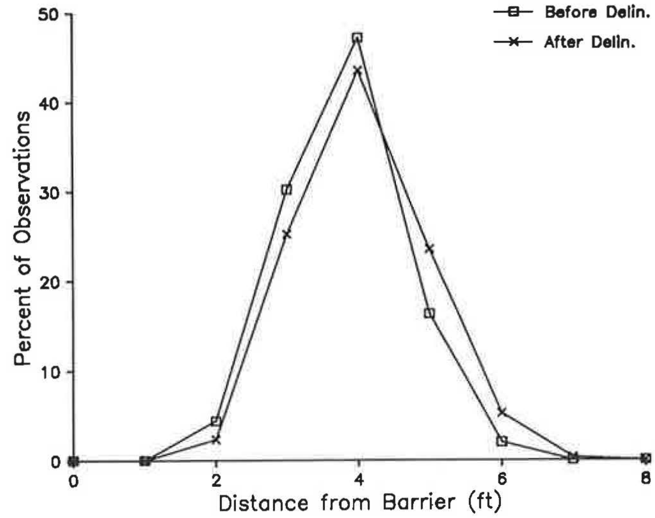

FIGURE 4 Lateral distance distribution for Treatment 1: cube-corner lenses, top-mounted at 200-ft spacings (midnight to 5:00 a.m.).

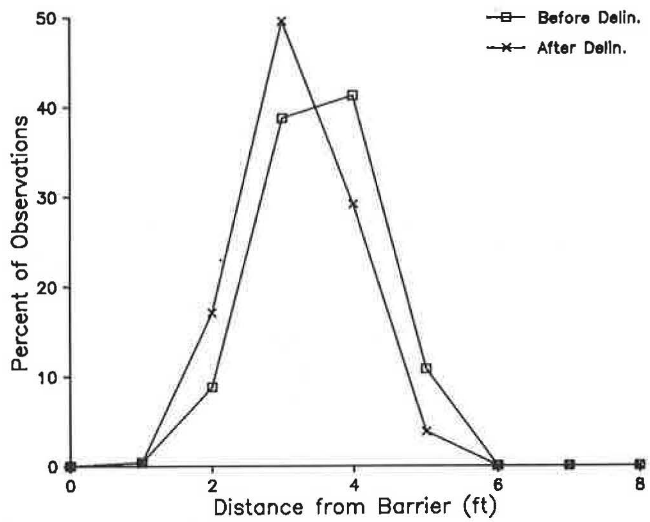

FIGURE 3 Lateral distance distribution for Treatment 5: reflective cylinders, top-mounted at 50-ft spacings (9:00 p.m. to midnight).

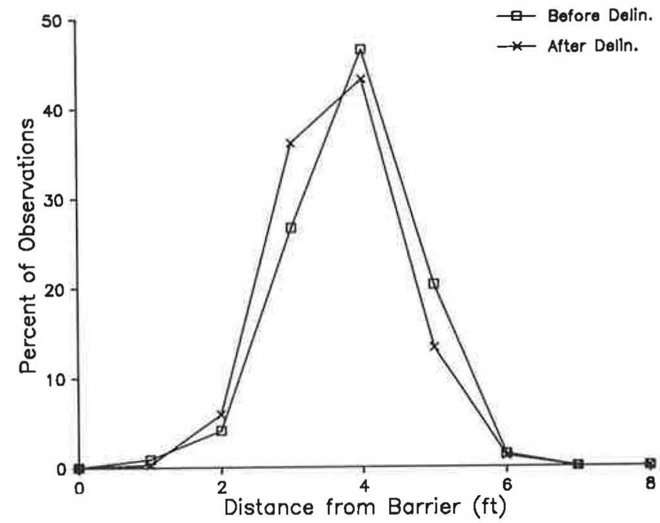

FIGURE 5 Lateral distance distribution for Treatment 2: cube-corner lenses, side-mounted at 50-ft spacings (midnight to 5:00 a.m.).

Results of the "before" and "after" comparisons at each treatment segment during lower nighttime volume hours indicate that the lateral distance distributions shifted slightly away from the CSSB at Treatment 1 (top-mounted cube-corner lenses at 200-ft spacings) but were slightly closer to the CSSB at Treatments 2 (side-mounted cube-corner lenses at 50-ft spacings) and 5 (top-mounted cylinders at 50-ft spacings). Plots of the lateral distance distributions for these treatments are presented in Figures 4–6.

Subjective Evaluations

Clean Delineators

Table 4 presents the total rank scores and adequacy ratings by the subjects of the clean delineation treatments. Overall, the brightness rankings showed very little difference between the high- and low-scoring treatments. In fact, a Friedman analysis of variance (ANOVA) test for ranked data (*8*) found no statistically significant differences, indicating that the subjects, as a group, ranked all the treatments about equal. However, the adequacy ratings obtained from the subjects indicate a different perspective. Treatments 1 through 4 received adequate ratings from at least 80 percent of the subjects. Treatment 5 (top-mounted cylinders at 50-ft spacings), on the other hand, received adequate ratings from only 50 percent of the subjects.

Table 4 also contains the total rank scores from the subjects with respect to each treatment's relative effectiveness in helping drivers maintain a safe travel path next to the CSSB. Again, a Friedman ANOVA test found that the rankings did not differ significantly. As with the brightness rankings, however, Treatment 5 received the worst total score.

During the evaluations, subjects were also asked to provide comments that they had about each treatment. Table 5 is a summary of these comments in terms of driver like or dislike of

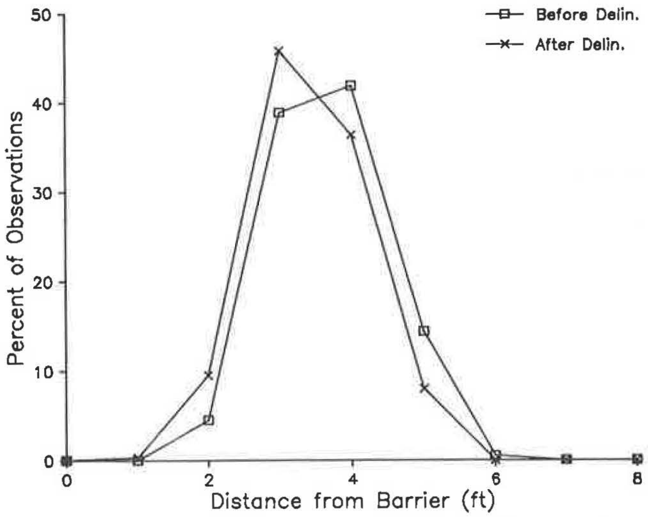

FIGURE 6 Lateral distance distribution for Treatment 5: reflective cylinders, top-mounted at 50-ft spacings (midnight to 5:00 a.m.).

the delineator type, spacing, or mounting position. No clear trend is evident with respect to delineator type: all received both positive and negative comments. The comments did show that subjects dislike the top-mounted delineation treatments, and a corresponding liking was shown for those treatments that were mounted on the side. Subjects indicated that the treatments mounted on top of the barrier seemed to make the travel lanes appear wider than they were and tended to draw them closer to the barrier. However, this perception was not demonstrated in the driver performance data, which showed vehicles closer to the barrier at Treatment 5 (top-mounted cylinders at 50-ft spacings) but farther away at Treatment 1 (top-mounted cube-corner lenses at 200-ft spacings).

Subjects offered several reasons for preferring side-mounted delineation, including a more direct line of sight for drivers, a better indication of the location of the barrier wall, and a more realistic perception of lane width. Subjects also had strong feelings about the spacings of the delineation treatments. As illustrated by the values in Table 5, the 200-ft spacing of Treatments 1 and 4 was disliked by several subjects, while a number of subjects specifically indicated that they liked the closer (50-ft) spacing.

Dirt-Covered Delineators

Subject evaluations of the treatments were also conducted after the delineators had been in place several months and had become covered with dirt and road film. Subject rankings of each treatment's brightness and effectiveness under this dirty condition are presented in Table 6. Also presented in the table is the proportion of the subjects who felt that the brightness of the particular delineation treatment was adequate.

On the basis of the Friedman ANOVA test, the rankings were found to differ significantly. Subjects ranked Treatment 2 (side-mounted cube-corner lenses at 50-ft spacings) as the brightest and Treatment 5 (top-mounted cylinders at 50-ft spacings) as the dimmest. Scores for the remaining treatments show that Treatments 1 (top-mounted cube-corner lenses at 200-ft spacings), 4 (side-mounted brackets at 200-ft spacings), and 3 (top-mounted brackets at 50-ft spacings) were ranked the second-, third-, and fourth-brightest treatments, respectively. Even in the dirt-covered condition, the brightness of Treatment 2 was rated adequate by all 11 subjects (100 percent), and 7 subjects (64 percent) rated Treatment 1 adequate. None (0 percent) of the subjects rated Treatment 5 adequate, while Treatment 3 was rated adequate by only one (9 percent) subject.

Table 6 also summarizes the subject rankings of the treatment's effectiveness in the dirty condition. The rankings were again found to be significantly different, with Treatment 2 ranked most effective and Treatment 5 ranked least effective by the subjects. The second-, third-, and fourth-place rankings corresponded to Treatments 1, 3, and 4, respectively. Even though Treatment 4 was ranked brighter than Treatment 3, it was ranked less effective by the subjects. This could be due in part to the closer spacing of the delineators for Treatment 4.

Subject comments about the dirt-covered treatments are presented in Table 7. Eight subjects (73 percent) stated that they did not like Treatment 5 (the top-mounted cylinders at 50-ft spacing), primarily because it was not bright enough. Ten subjects (91 percent) also had a strong dislike of the 200-ft spacing of Treatment 4 (the side-mounted brackets), and they mentioned that the spacing was too great to be effective. Conversely, nine subjects (82 percent) had positive comments for Treatment 2 (side-mounted cube-corner lenses at 50-ft spacings). Again, subjects stated that side-mounted delineation provided a better indication of the location of the barrier and helped guide them more effectively.

Delineator Visibility

The periodic measurements of the maximum visibility distance for each treatment are presented in Figures 7 and 8. For both mounting positions (top or side) the cube-corner lenses (Treatments 1 and 2) lost their original visibility at a slower rate than

TABLE 4 SUBJECT EVALUATION OF DELINEATION TREATMENTS, DIRTY CONDITION, IH-45, HOUSTON

	Brightness Evaluation[a]			Effectiveness Evaluation[a]	
Treatment	Total Rank Score	Relative Ranking	Number Rating Brightness Adequate	Total Rank Score	Relative Ranking
(1) Top-mounted cube-corner, 200-ft spacings	23	2	7 (64%)	31	2
(2) Side-mounted cube-corner, 50-ft spacings	13	1	11 (100%)	13	1
(3) Top-mounted brackets, 50-ft spacings	40	4	1 (9%)	35	3
(4) Side mounted brackets, 200-ft spacings	33	3	4 (36%)	36	4
(5) Top-mounted cylinders, 50-ft spacings	55	5	0 (0%)	53	5

[a]Rankings were 1 = brightest or most effective, 2 = next brightest or most effective, and so on.

TABLE 5 SUMMARY OF SUBJECT COMMENTS, DIRTY CONDITION, IH-45, HOUSTON

Treatment	Delineator Type (includes size, shape, and brightness)		Delineator Mounting Position		Delineator Spacing	
	Good	Poor	Good	Poor	Good	Poor
(1) Top-mounted cube-corner, 200-ft spacings	0	2	2	2	0	4
(2) Side-mounted cube-corner, 50-ft spacings	0	1	9[a]	1	3	0
(3) Top-mounted brackets, 50-ft spacings	2	5[b]	0	2	4	3
(4) Side-mounted brackets, 200-ft spacings	2	3	2	1	0	10[b]
(5) Top-mounted cylinders, 50-ft spacings	0	8[b]	0	1	5[a]	1

[a]Large number of positive comments.
[b]Large number of negative comments.

TABLE 6 SUBJECT EVALUATION OF DELINEATION TREATMENTS, CLEAN CONDITION, IH-45, HOUSTON

Treatment	Brightness Evaluation[a]			Effectiveness Evaluation[a]	
	Total Rank Score	Relative Ranking	Number Rating Brightness Adequate	Total Rank Score	Relative Ranking
(1) Top-mounted cube-corner, 200-ft spacings	30	3	10 (100%)	35	4
(2) Side-mounted cube-corner, 50-ft spacings	23	1	9 (90%)	19	1
(3) Top-mounted brackets, 50-ft spacings	32	4	10 (100%)	27	2
(4) Side-mounted brackets, 200-ft spacings	29	2	8 (80%)	36	5
(5) Top-mounted cylinders, 50-ft spacings	36	5	5 (50%)	33	3

[a]Rankings were 1 = brightest or most effective, 2 = next brightest or most effective, and so on.

TABLE 7 SUMMARY OF SUBJECT COMMENTS, CLEAN CONDITION, IH-45, HOUSTON

Treatment	Delineator Type (includes size, shape, and brightness)		Delineator Mounting Position		Delineator Spacing	
	Good	Poor	Good	Poor	Good	Poor
(1) Top-mounted cube-corner, 200-ft spacings	0	1	1	5[a]	0	6[a]
(2) Side-mounted cube-corner, 50-ft spacings	2	2	6[b]	1	6[b]	0
(3) Top-mounted brackets, 50-ft spacings	1	1	0	3	8[b]	1
(4) Side-mounted brackets, 200-ft spacings	1	3	3	0	0	7[a]
(5) Top-mounted cylinders, 50-ft spacings	1	2	2	2	4	0

[a]Large number of negative comments.
[b]Large number of positive comments.

did the brackets or cylinders covered with HI reflective sheeting (Treatments 3, 4, and 5). As the figures also show, the visibility distance of the delineators was greater after 16 weeks than it was after 10 weeks. The improvement is especially noticeable for the cube-corner lenses. Heavy rains that preceded the 16-week evaluation are believed to have washed some of the road film from the delineation, resulting in the improved visibility. It should be noted that the visibility distance of the brackets or cylinder with HI sheeting did not increase as noticeably as the visibility distance of the cube-corner lenses. Comparison of Figures 7 and 8 also shows, as expected, that treatments mounted on the side of the barrier lost visibility faster than the top-mounted treatments.

RECOMMENDATIONS

This paper has presented the results of a study of five CSSB delineation treatments on an illuminated high-volume urban freeway in Texas, where the CSSB was located 1 ft away from the travel lanes. Limitations in study scope and funding prevented a complete analysis of all combinations of delineator type, spacing, and mounting position examined in this study. Consequently, these results can not be taken as conclusive, and additional research on this topic will be necessary. Of the delineators examined in this study, cube-corner lenses are recommended for delineating CSSBs in narrow freeway median applications. These delineators do not lose their reflectivity due to dirt and grime as quickly as those covered with HI sheeting.

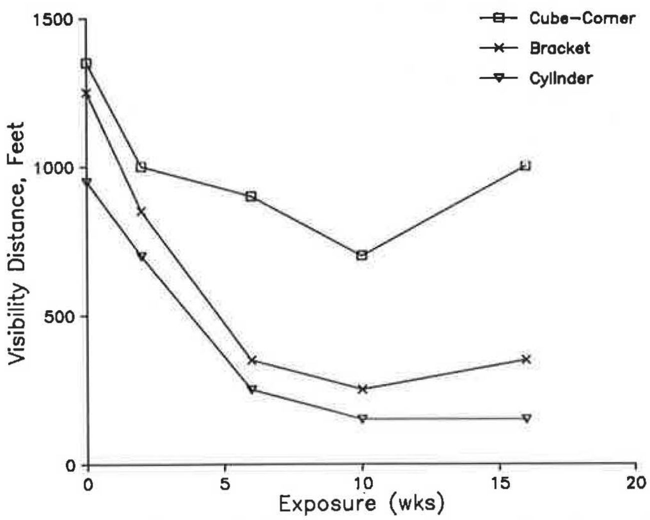

FIGURE 7 Visibility distances of top-mounted delineator treatments over time.

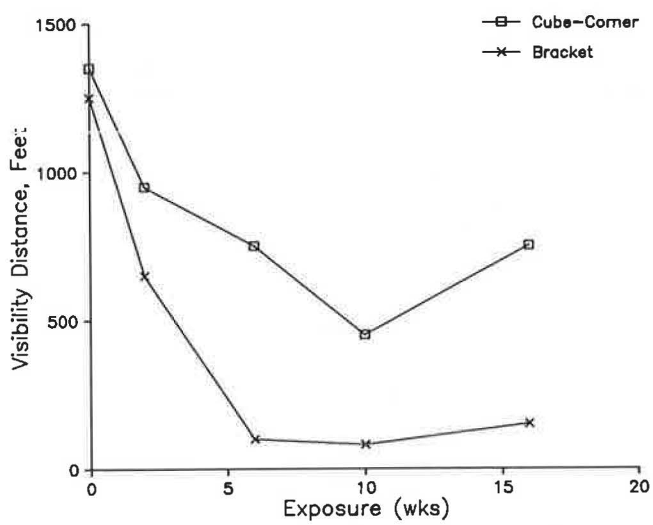

FIGURE 8 Visibility distances of side-mounted delineator treatments over time.

Lane-straddling data collected at Treatment 2 showed a slight increase, possibly indicating that the combination of the side-mounted position and the close delineator spacing may make some drivers too apprehensive of the CSSB if the barrier is located close to the travel lanes. Lane straddling could result in vehicle conflicts or other operational problems. Therefore, for situations with limited lateral clearance, top-mounted delineation is recommended.

Subjects indicated a preference for close (50-ft) spacings. However, driver performance data did not suggest that one spacing was better than the other. Therefore it is recommended that a 200-ft spacing be considered maximum. To ensure adequate control and guidance information for drivers, however, closer spacings may be necessary for CSSBs on sharp curves.

These recommendations are also suggested when CSSBs in work zones are to be delineated. Additional research is needed, however, to evaluate the effect of these and other delineation treatments in work zone applications. Research is also needed to determine what effects delineation may have on traffic safety in terms of accident potential and costs.

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