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16. Abstract

This report is a consolidation of results of research conducted on Study 408 regarding delineation of concrete safety-shaped barriers (CSSBs) and urban freeway gore area crash cushions. Specific details about the research performed on each of these topics are covered in two interim reports:

TTI Report 408-1, "Delineation of Concrete Safety-Shaped Barriers"

TTI Report 408-2, "Delineation of Urban Freeway Gore Area Crash Cushions"

Based on the results of this research, recommendations regarding the delineation of both CSSBs and urban freeway gore area crash cushions are presented.

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DELINEATION OF CONCRETE SAFETY-SHAPED BARRIERS AND URBAN FREEWAY GORE AREA CRASH CUSHIONS

by

Gerald L. Ullman

Conrad L. Dudek

F. Thomas Creasey

Carlton J. Allen

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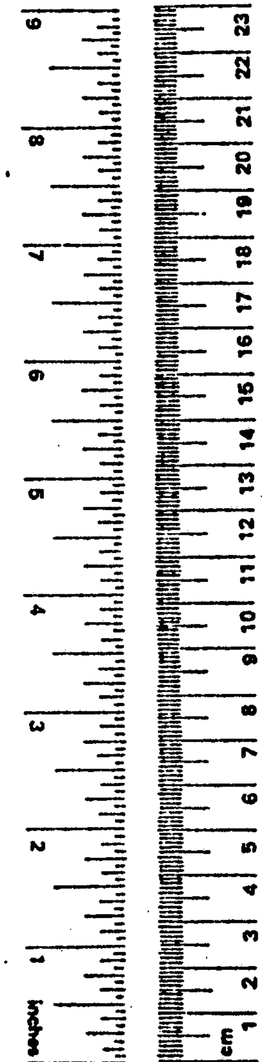
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

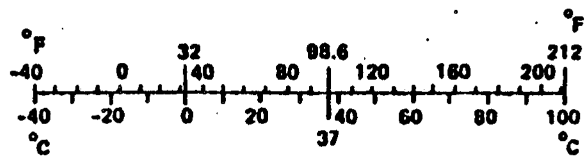
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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IMPLEMENTATION STATEMENT

The results of the research conducted for Study 408 have provided valuable insight into the delineation of 1) concrete safety-shaped barriers (CSSBs) at narrow freeway medians and highway work zone locations, and 2) urban freeway gore area crash cushions. Based on the field studies conducted at a narrow freeway median location in Houston, it is recommended that cube-corner delineators be used when the decision is made to delineate CSSBs. In situations where the barrier is located very close to the travel lanes, it is further suggested that top-mounted delineation is used rather than side-mounted delineation in order to avoid causing some drivers to be too apprehensive of the barrier. A 200-ft maximum spacing is also suggested, but consideration should be given to shorter spacings on sharp horizontal curves or other situations where it is important to insure that drivers are provided adequate control and guidance information next to the barrier.

Long-term evaluations of reflectorized chevron nose and back panels used as delineation for urban freeway gore area crash cushions show that these treatments do not appear to lose their effectiveness in reducing vehicle impacts with the cushions over a period of at least four years. Given the relatively low costs associated with installing and maintaining these treatments, its use at most urban freeway gore area crash cushion locations does seem justified. However, it should be realized that crash cushion delineation alone may not alleviate crash cushion accidents at all types of gore areas. In some case, it may be necessary to re-evaluate and modify some aspects of the motorist information upstream from the gore area in an attempt to help reduce vehicle impacts with the crash cushions.

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1. INTRODUCTION

The past twenty years have seen significant improvements in highway safety. Much of this improvement can be attributed to the development and increased use of traffic barriers to shield those hazards in the roadway environment that cannot be removed or relocated. Concrete safety-shaped barriers (CSSBs) are now being used extensively to protect longitudinal roadside hazards, to separate opposing traffic flows, and to protect workers during roadway rehabilitation and reconstruction activities. To protect spot hazards, particularly those at urban freeway gore areas, crash cushions are being used extensively. The safety value of both of these devices has been well documented (1).

It is generally recognized that while traffic barriers are useful in reducing the severity of accidents occurring at a location, they do not reduce the frequency at which these accidents occur. In fact, accident frequency may increase, as additional hardware is placed in the roadway environment. Impacts with CSSBs and crash cushions still result in property damage to vehicles and injuries to drivers and passengers. Also, repairs to the devices exposes maintenance personnel to high-speed traffic. Consequently, it is important to provide drivers with enough visual control and guidance information so that they may maintain a safe travel path and avoid impacts with the barriers.

Unfortunately, little guidance is available regarding the delineation of CSSBs or crash cushions, as very little objective driver performance data has been collected upon which to base such guidance. Also lacking is information as to the effects of traffic and road film upon the various types of delineation that can be used. The reduction in delineator visibility on CSSBs, for instance, can be significant after only a few week's time, depending on traffic and weather conditions (2).

The lack of good standard delineation procedures often results in inconsistent and inefficient applications, with an inadequate amount of delineation used in some cases while others receive excessive or redundant delineation (3).

Study Objectives

Study 408 research efforts were concentrated on two specific objectives.

1. Review current delineation practices across the state of Texas to determine similarities, differences and problem areas in CSSB and urban freeway gore area crash cushion delineation.

2. Using the results of past research and Texas State Department of Highways and Public Transportation suggestions, develop, implement and evaluate improved delineation treatments for CSSBs and urban freeway gore area crash cushions.

2. DELINEATION OF CONCRETE SAFETY-SHAPED BARRIERS (CSSBs)

Background

CSSBs are commonly used in the narrow median of freeways and high-volume expressways where it is necessary to keep errant vehicles from crossing over to the opposing lanes and into oncoming traffic. In some cases, a normal (i.e., 8 to 10 ft) median shoulder exists between the travel lanes and the barrier; in more restricted cases, the barrier may be located immediately next to the edgeline of the median (inside) travel lane.

CSSBs are also being used more and more extensively at highway work zone locations to separate traffic from the work activity. In addition to the obvious benefits of protecting workers from nearby moving traffic, the use of CSSBs also appears to result in increased traffic capacity through the work zone when compared to work zone locations where concrete barrier is not used (4). Space limitations at highway work zones usually dictate that the barrier be placed immediately next to the travel lanes.

While CSSBs can reduce the severity of run-off-the-road accidents, it is generally accepted that they do not reduce the frequency of these accidents (5). Because CSSBs are used in situations where lateral clearance between them and the travel lane is limited, impacts with CSSBs may actually occur quite often.

It is important that drivers have adequate visual control and guidance information so that they may maintain a safe travel path and avoid impacts with the barriers. Unfortunately, CSSBs are difficult to see at night and in the rain, due to poor contrast between the barrier and the roadway pavement (6,7). Consequently, the use of delineation on the CSSBs may be helpful or necessary in instances where the CSSBs are located very close to the travel lanes in order to make them more visible to drivers and to better identify the travel path next to the barrier.

This chapter summarizes the results of the research on CSSB delineation when the barrier is located very close to the travel lanes. Specific details concerning this part of the study may be found in TTI Research Report 408-1, "Delineation of Concrete Safety-Shaped Barriers" (8).

State-of-the-Art in CSSB Delineation

CSSB Delineation Practices in Texas

As the initial step in this study, a telephone survey of 23 of the 24 SDHPT Districts was conducted to determine current practices regarding CSSB delineation. The survey provided useful information as to the different types of delineation being used across the state as well as the similarities, differences, and problem areas with current delineation procedures.

It was found that most of the Districts do delineate CSSBs (or specify to that they be delineated in the construction contract) when they are used at highway work zones. However, 12 of 19 Districts that have CSSBs in the median of narrow (i.e., 0 to 12-ft clearance between the travel lanes and the barrier) urban freeways do not delineate the CSSBs. These Districts stated that they felt painted edgelines and roadway lighting were sufficient.

District personnel surveyed reported a wide variety of different types of items that had or were being used as CSSB delineation. A summary of the the types of delineators used is shown in Table 2-1. Several manufacturers and distributors sell small retro-reflective devices specifically designed to be mounted on CSSBs. These retro-reflective delineators (mounted either on top or on the side of CSSBs) were found to be the most common types of delineators used. Additional types of delineation that had been used on CSSBs included object markers (9), chevron alignment signs (W1-8) (9), battery-powered flashers, and raised reflective pavement markers and pavement tape applied to the side of the barrier. A total of five Districts reportedly had tried several types of delineation on different sections of CSSBs within their Districts.

TABLE 2-1. SUMMARY OF DISTRICT DELINEATION PRACTICES OF CONCRETE SAFETY-SHAPED BARRIERS

Type of Delineation	Number of Districts[a] Using on: Permanent Barriers	Temporary Barriers
Retro-Reflective Delineators		
mounted on top of barriers	4	7
mounted on side of barriers	4	4
Object Markers	1	3
Chevrons (on curves)	2	2
Battery-Powered Flashers	0	3
Reflective Pavement Tape	0	2
Total	11	21

a Some Districts use more than one type of delineator on CSSBs

Previous Delineation Research

The methods and results of previous and on-going CSSB delineation research conducted throughout the country were reviewed to identify the important factors to consider when evaluating CSSB delineation and some appropriate MOEs for delineation evaluation. There have been CSSB delineation studies at both narrow freeway median applications and also at highway work zones. The results from these previous studies have been synthesized and are presented in tabular format in Table 2-2.

Previous research studies have evaluated a wide variety of delineators (several small cube-corner lenses and HI sheeting delineators, vertical panels, and reflective cylinders), mounted on the top and on the side of the CSSB at spacings from 25 to 200-ft. The studies have used mainly subjective evaluations by observers and objective photometric measurements of reflectivity to determine which delineation treatments were preferable and/or more visible to drivers. The results have been mixed. For example, Mullowney (6), Khan (7), and Brackett (3) all suggested that top-mounted delineation works best. Conversely, Ugwoaba(2) recommended side-mounted delineation; the effect of delineation in the side position is not washed out by oncoming headlight glare as sometimes happens with top-mounted delineation.

With respect to delineation type, there was also some disagreement. Larger but less bright (in terms of specific intensity) delineators were recommended by Brackett and Kahn, while Ugwoaba and Mullowney recommended the use of the smaller, brighter cube-corner delineators. Even the spacings of the delineators was not without debate. Although shorter spacings were generally preferred, actual distances recommended in the studies varied from 25 to 200 ft.

Evaluation of Candidate CSSB Delineation Treatments

Study Scope

A major emphasis of Study 408 involved field studies of CSSB delineation treatments at actual highway locations. However, the scope of the study was limited to a comparative evaluation of five CSSB delineation treatments in restricted lateral clearance situations where the barrier was located less than one foot from the travel lane edgeline. Due to the limited funds and time frame over which the study was conducted, it was not possible to examine the effects of delineation on accident rates or to subsequently determine the cost-effectiveness of installing and maintaining CSSB delineation at a location.

TABLE 2-2. SUMMARY OF PREVIOUS CSSB DELINEATION RESEARCH

Researcher	Delineation Treatments Studied	Study Site Conditions	Methods of Study	Recommendations
Mullowney	Acrylic Cube-Corner and Glass Lenses, Brackets covered with HI Sheeting; Top and Side-Mounted (6 and 14-in from Top); 80-Ft Spacings on Tangents, 40-Ft on Curves	CSSB in a Narrow Freeway Median	Laboratory Photometric Measurements, Subject Evaluations (lab), Expert Evaluations (Field), Cost Considerations	Cube-Corner Delineators, Top-Mounted
Powers	Cube-Corner Delineators, Top-Mounted at Spacings from 160-Ft (Tangent) to 40-Ft (Curve)	CSSB in a Narrow Freeway Median	Subject Evaluations of Photographs taken at Study Site	160-Ft Spacing (Max) on Tangents, Closer Spacing on Curves
Brackett et. al.	Several Cube-Corner Delineators, Top and Side-Mounted (6-in from top) at 50 and 100-Ft Spacings; 6-in x 12-in Reflective Cylinders, Top-Mounted at 100-Ft Spacing; 8-in x 24-in Vertical Panel, Top-Mounted at 100 and 150-Ft Spacing	Temporary CSSBs in Work Zones	Subject Evaluations of Photographs, Limited Proving Ground Studies, Cost Considerations Studies, Cost Considerations	Vertical Panels, Reflective Cylinders, (Top-Mounted); Spacings less than 200-Ft
Khan	Cube-Corner and HI sheeting Delineators, Side-Mounted (6, 12, 18, and 24-in from top) at 100 and 25-Ft Spacings; 6-in x 12-in Reflective Cylinders, Top-Mounted at 180, 120, 90, 60, 45, and 25-Ft Spacings; 6-in x 27-in Vertical Panels, Top-Mounted at 60 and 100-Ft Spacings; Spinning Delineator, Top-Mounted at 50 and 25-Ft Spacings	Temporary CSSBs in Rural and Suburban Work Zones	Laboratory Photometric Measurements, Researcher Evaluation of Brightness in the Field, Durability, Installation Methods, Cost Considerations	Vertical Panels, Reflective Cylinders, (Top-Mounted) at 25-Ft Spacings; May use Small Delineators to Supplement Panels and Cylinders
Ugwoaba	Cube-Corner Delineators, Top and Side-Mounted at 40-Ft Spacings; Raised Reflective Pavement Markers, Side-Mounted at 40-Ft Spacings; Brackets with HI sheeting, Top Mounted at 40-Ft Spacings; Reflective Cylinders,Top-Mounted at 100-Ft Spacings; 8-in x 24-in Vertical Panels, Top-Mounted at 100-Ft Spacings	Temporary CSSBs in a Suburban Work Zone	Photometric Measurements in the Field, Subject Evaluations of Brightness, Cost Considerations	Cube-Corner Delineators, Side-Mounted (6-in from top)

HI = High-Intensity

Study Description

Original study plans called for studies of five delineation treatments to be performed on CSSBs at 1) a narrow freeway median location, and 2) a highway work zone. Unfortunately, it was not possible to locate a work zone location with characteristics suitable for this study. Consequently, a study was conducted only at a narrow freeway median location. However, because the CSSB was located very close to the inside lane as it is for many typical work zone situations, it is believed that the results obtained in this study have some application to work zone locations also.

A study of CSSB delineation was conducted on a section of IH-45 (Gulf Freeway) in Houston, TX. At this particular site, five different delineation treatments were examined:

1. Acrylic Cube-Corner Lenses (3.25-in diameter) mounted on top of the CSSB at 200-ft intervals

2. Acrylic Cube-Corner Lenses mounted on the side of the CSSB (6-in from the top) at 50-ft intervals

3. Plastic brackets (3-in high by 4.25-in wide) covered with High-Intensity (HI) Reflective Sheeting mounted on top of the CSSB at 50-ft intervals

4. Plastic brackets covered with HI sheeting mounted on the side of the CSSB (6-in from the top) at 200-ft intervals

5. Plastic cylinders (3-in diameter by 6-in high) covered with HI sheeting mounted on top of the CSSB at 50-ft intervals

The five delineation treatments selected were representative of the common delineator types, spacings, and mounting positions on the barrier. Table 2-3 summarizes the relative costs of each of the five delineation treatments. Each treatment was installed on a 0.5-mi segment of CSSB. A 0.5-mi segment between each treatment was left undelineated.

Three types of data to evaluate the treatments were collected:

1. driver performance,

2. subjective evaluations, and

3. visibility.

Driver performance data were collected at each of the delineation treatment segments using the low-light level video camera mounted on overhead sign supports spanning the freeway. Data were collected before and immediately after the treatments were installed on the CSSBs primarily during nighttime, dry pavement conditions.

TABLE 2-3. SUMMARY OF DELINEATION TREATMENTS

Treatment	Delineator	Mounting Position	Spacing (ft)	Cost/ Delineator ($)	Cost/mi of Barrier ($)
1	Cube-Corner	Top	200	2.50	66
2	Cube-Corner	Side	50	2.50	264
3	Brackets w/ HI Sheeting	Top	50	1.50	158
4	Brackets w/ HI Sheeting	Side	200	1.50	40
5	Cylinder w/ HI Sheeting	Top	50	4.50	475

HI = High-Intensity Reflective Sheeting

The second type of data collected was subjective evaluations. Each of eleven subjects drove a vehicle in the inside travel lane past each delineation treatment in succession. As they drove, subjects responded to questions concerning the brightness and effectiveness of each treatment in guiding them and helping them stay in the center of the travel lane. The delineation treatments were evaluated in both a dirty and a clean condition, again under nighttime, dry pavement conditions.

The final type of data collected was visibility, measured as the maximum distance from which the delineators in each treatment segment could be seen. This maximum visibility distance was measured periodically in order to monitor the gradual effects of dirt and road film in reducing the visibility of the treatments.

Findings

Driver Performance

Three MOEs were obtained from the driver performance data collected:

1. Lane Distribution - The proportion of traffic in the two travel lanes next to the CSSB that used the lane closest to the barrier.

2. Lateral Distance - The distance from the CSSB vehicles in the inside travel traveled. This was estimated to the nearest foot.

3. Lane Straddling - The number of vehicles observed straddling the lane stripe between the inside travel lane and lane adjacent. This number was converted to a rate per 1000 vehicles.

The delineation treatments were found to have very little practical effect upon lane distribution. This was found to be true in the late evening hours (i.e., 9 p.m. to midnight) when traffic volumes were fairly high, and also in the early morning hours (midnight to 5 a.m.) when volumes were quite low.

Similarly, little practical change was detected in the lateral distance that drivers traveled from the barrier. This was true for all of the delineation treatments examined in this study.

Table 2-4 summarizes the lane straddling rates determined from the driver performance data collected. Lane straddling was found to be a relatively rare event, and so the sample sizes are too low to be completely conclusive. However, there was some evidence that the acrylic cube-corner lenses side-mounted at 50-ft spacings (Treatment 2) resulted in a slight increase in lane straddling. A statistically significant increase was found at this treatment during the 9 p.m. to midnight time period. An increase was also evident from the midnight to 5 a.m. time period at this treatment, but this was not found to be statistically significant due to the low sample sizes.

A dramatic increase in the lane straddling rate (during the midnight to 5 a.m. time period) after delineation was also found at Treatment 4. In fact, the rate was almost 5 times greater than in the before condition. However, the after data at this segment was inadvertently collected in rainy, wet pavement conditions. The video recordings showed a significant glare problem off of the pavement from the roadway lighting and vehicle headlights, making it difficult to see the edgeline and lane stripes. Consequently, the straddling rate at this segment was not necessarily an indication of the effect the delineators had upon traffic, but instead suggested that some drivers may have difficulty staying in their lanes in nighttime adverse weather conditions.

It may be that CSSB delineation is indeed quite useful to drivers in these wet-weather conditions and may become the primary control and guidance information (since the pavement markings may not be visible). Since no data were collected during nighttime wet-weather conditions before the delineation was installed, it is not known whether this delineation treatment was effective in reducing lane straddling rates at this segment. Similarly, it was not possible to collect data during wet-weather conditions at any of the other treatment segments so that a comparison of the relative effectiveness of each under rain conditions could be made.

TABLE 2-4. COMPARISON OF LANE STRADDLING RATES: BEFORE VS. AFTER DELINEATION IH-45, HOUSTON

Lane Straddling Rate per 1000 Vehicles in Inside Lane

Treatment	High Nighttime Volume Periods: Rate Before Delin.	Rate After Delin.	Change	Low Nighttime Volume Periods: Rate Before Delin.	Rate After Delin.	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**	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[a] [2]	+ 1.1	3.5 [2]	15.4 [5][a,b]	+11.9**
5 Top-Mounted Cylinders 50-ft Spacings	0.6 [1]	0.5 [1]	- 0.1	4.9 [2]	0.0 [0]	- 4.9

[ ] Numbers in brackets represent sample sizes in number of lane straddlings observed
** Statistically Different at 0.05 Level of Significance
a This data represents only one night
b This data collected in rainy, wet pavement conditions

Subjective Evaluations

The different delineation treatments were evaluated in both a dirty (after the treatments had been in place on the CSSB for four to six months) and clean (with the delineators had been wiped clean) condition. The rankings obtained for each treatment's brightness in the dirty and clean conditions are shown in Table 2-5. Also shown is the proportion of subjects who rated the brightness of each particular delineation treatment as adequate.

In the clean condition, subjects as a group ranked the five delineation treatments about equal in terms of brightness, based on a ANOVA test for ranked data (10). However, only 5 of 10 subjects (50%) rated Treatment 5 (cylinders with HI sheeting top-mounted at 50-ft spacings) as being adequately bright, even when clean.

With the treatments in the dirty condition, the brightness rankings were found to differ significantly, based on the ANOVA test for ranked data. Subjects ranked Treatment 2 (the side-mounted cube-corner lenses at 50-ft spacings) as the brightest, and Treatment 5 as the dimmest. Meanwhile, Treatments 1 (top-mounted cube-corners 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.

Adequacy ratings of the treatments in a dirty condition generally supported the results of the relative treatment rankings. Treatment 2, ranked overall as the brightest treatment, received an adequate rating by all 11 subjects (100%). The second ranked treatment, Treatment 1, received an adequate rating by 7 subjects (64%). Treatments 4, 3, and 5 (ranked third, fourth and fifth) were given adequate ratings by 4 subjects (36%), 1 subject (9%), and 0 subjects (0%), respectively.

In addition to delineation brightness, subjects ranked each treatment in terms of its effectiveness in helping the subjects maintain a center position in the travel lane next to the CSSB and identify the correct travel path next to the barrier. The effectiveness rankings of the treatments in a dirty and clean condition are shown in Table 2-6. For the clean condition, the rankings were not statistically different. However, rankings did differ for the treatments in the dirty condition. Treatment 2 (side-mounted cube-corner lenses at 50-ft spacings) was again ranked the best, just as it had been for the brightness rankings. Treatment 1 (top-mounted cube-corner lenses at 200-ft spacings) was ranked the second most effective. Treatments 3 (top-mounted brackets with HI sheeting at 50-ft spacings) and 4 (side-mounted brackets with HI sheeting at 200-ft spacings) were ranked third and fourth most effective.

It is interesting to note that, for the dirty condition, the effectiveness rankings of Treatments 3 and 4 differed from the brightness rankings. Even though Treatment 3 was ranked as less bright than Treatment 4, it was ranked as slightly more effective. This could be due in part to the closer spacings of the delineators (50-ft vs. 200-ft spacings). As with the brightness rankings, Treatment 5 was ranked as the least effective treatment.

TABLE 2-5. SUBJECT EVALUATION OF DELINEATION TREATMENTS: BRIGHTNESS
IH-45, HOUSTON

Treatment	Clean Condition: Total Rank Score	Clean Condition: Relative Ranking	Clean Condition: Number[a] Rating Brightness Adequate	Dirty Condition: Total Rank Score	Dirty Condition: Relative Ranking	Dirty Condition: Number[b] Rating Brightness Adequate
1 Top-Mounted Cube-Corner 200-ft Spacings	30	3	10 (100%)	23	2	7 (64%)
2 Side-Mounted Cube-Corner 50-ft Spacings	23	1	9 (90%)	13	1	11 (100%)
3 Top-Mounted Brackets 50-ft Spacings	32	4	10 (100%)	40	4	1 (9%)
4 Side-Mounted Brackets 200-ft Spacings	29	2	8 (80%)	33	3	4 (36%)
5 Top-Mounted Cylinders 50-ft Spacings	36	5	5 (50%)	55	5	0 (0%)

[a] 10 subjects participated in evaluation of clean delineation

[b] 11 subjects participated in evaluation of dirty delineation

TABLE 2-6. SUBJECT EVALUATION OF DELINEATION TREATMENTS: EFFECTIVENESS
IH-45, HOUSTON

Treatment	Clean Condition: Total Rank Score	Clean Condition: Relative Ranking	Dirty Condition: Total Rank Score	Dirty Condition: Relative Ranking
1 Top-Mounted Cube-Corner 200-ft Spacings	35	4	31	2
2 Side-Mounted Cube-Corner 50-ft Spacings	19	1	13	1
3 Top-Mounted Brackets 50-ft Spacings	27	2	35	3
4 Side-Mounted Brackets 200-ft Spacings	36	5	36	4
5 Top-Mounted Cylinders 50-ft Spacings	33	3	53	5

Subjects were also asked to make comments about the treatments. For both the dirty and clean condition evaluations, the comments revealed a general dislike for delineation mounted on top of the barrier (Treatments 1, 3, and 5), and a corresponding liking for those treatments mounted on the side (Treatments 2 and 4). Subjects indicated that the treatments mounted on top of the barrier seemed to make the travel lanes appear wider than they were, and made it feel as though the delineation was drawing them closer to the barrier. However, this perceived reaction was not evident in the driver performance lateral distance data (discussed previously).

The subjects stated several reasons for liking side-mounted delineation, including a more direct line of sight, a better indication of the location of the barrier wall, and more realistic perception of lane width. Subjects also disliked the 200-ft spacings of Treatments 1 and 4, and liked the 50-ft spacings of Treatments 2 and 4. Even though Treatment 5 (top-mounted cylinders at 50-ft spacings) was also spaced at 50-ft intervals, subjects generally did not comment about the spacing of this treatment.

Delineation Visibility Over Time

The visibility distances of the delineators were determined at the time of installation and at 2, 6, 10, and 16 weeks after installation. Table 2-7 and Figures 2-1 and 2-2 summarize these results. In Figure 2-1, the graphs show the visibility of each type of delineator over the time period studied. Regardless of mounting position, the cube-corner lenses did not lose visibility as quickly or as extensively as the brackets or the cylinders with HI sheeting.

Much of the loss in visibility distance for the brackets and cylinders occurred in the first six weeks after installation. For instance, measurements made six weeks after installation showed that the top-mounted bracket with HI sheeting (Treatment 3) could be seen only from a distance of 250 ft, and the side-mounted bracket with HI sheeting (Treatment 4) and top-mounted cylinder (Treatment 5) were visible for a distance of only 150 ft. The loss experienced by cube-corner lenses was much more gradual and less severe. At six weeks time, the top-mounted cube-corner lens (Treatment 1) was visible for a distance of 900 ft, while the side-mounted lens (Treatment 2) was visible for a distance of 750 ft.

As Figure 2-1 also illustrates, the data collected 16 weeks after initial installation showed that the visibility of the delineators was better than it was at 10 weeks time. The improvement was especially noticeable in the cube-corner lenses. Extremely heavy rains the week preceding the 16 week evaluation may have washed some of the dirt from the delineators, explaining the improved visibility. It should be noted that the dramatic improvement by the cube-corner lenses was not matched by the brackets with HI sheeting or the cylinders (in fact the cylinders showed no improvement).

TABLE 2-7. VISIBILITY DISTANCE MEASUREMENTS OVER TIME

Maximum Distance at Which Delineator is Visible (ft)

Treatment	Length of Exposure (Weeks after Treatment Installation)				
	0	2	6	10	16
1 Top-Mounted Cube-Corner 200-ft Spacings	1350	1000	900	700	1000
2 Side-Mounted Cube-Corner 50-ft Spacings	1350	950	750	450	750
3 Top-Mounted Brackets 50-ft Spacings	1250	850	350	250	350
4 Side-Mounted Brackets 200-ft Spacings	1250	650	100	80	150
5 Top-Mounted Cylinders 50-ft Spacings	1050	700	200	100	100

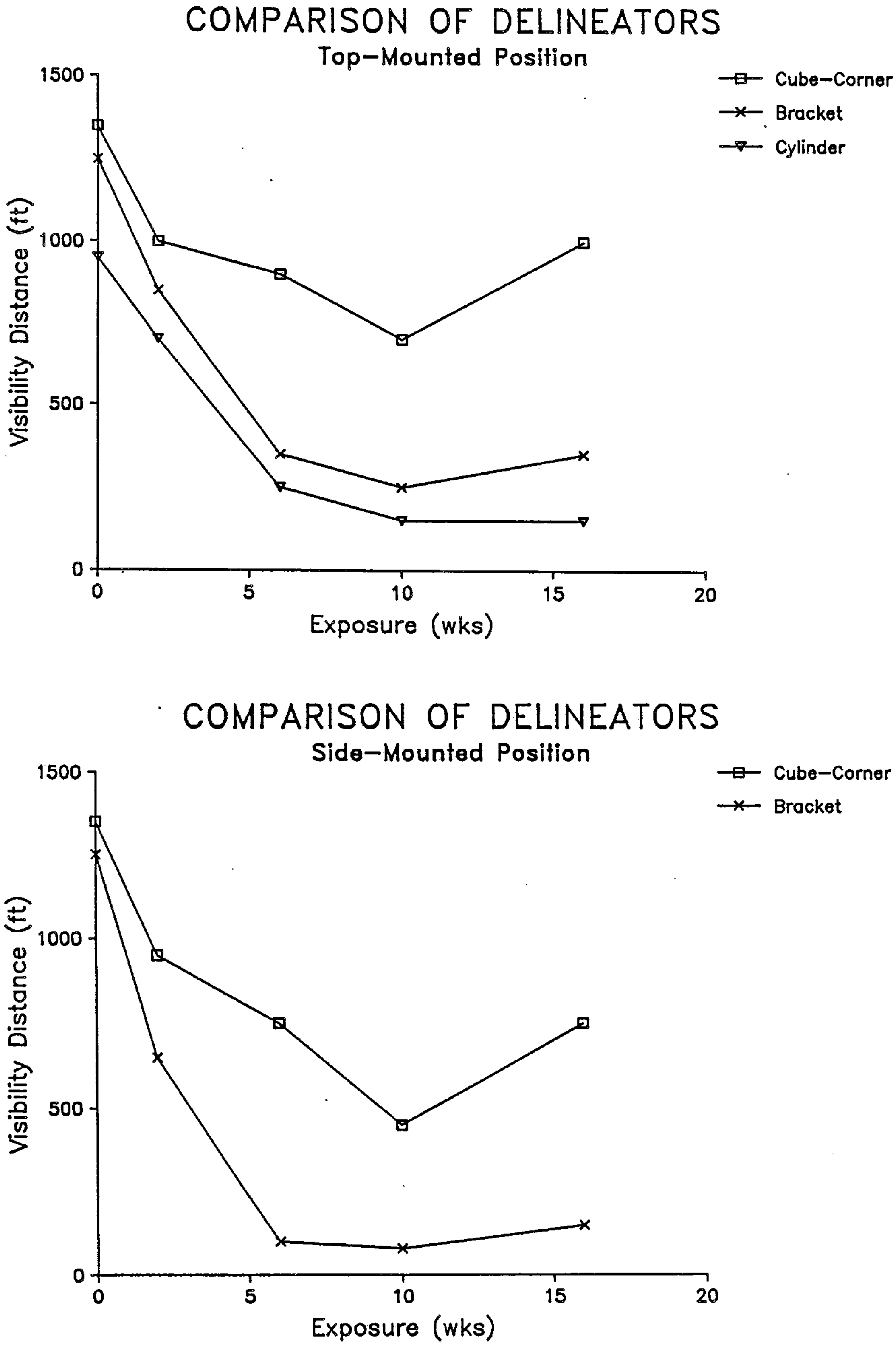
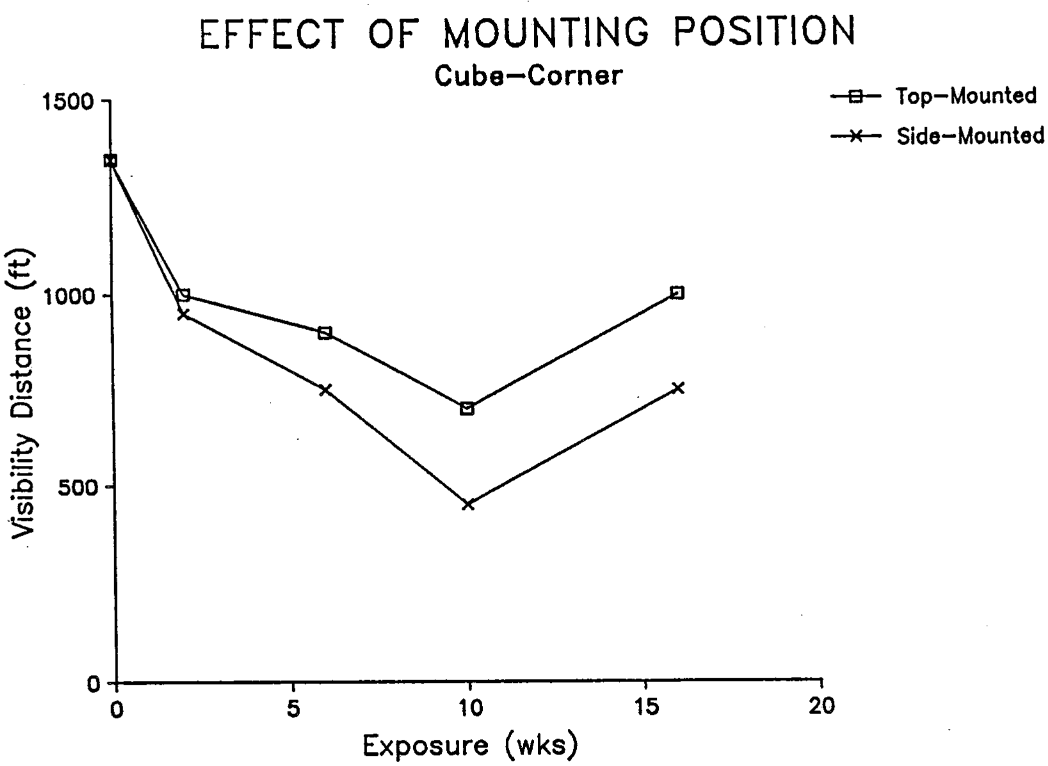


Figure 2-1. Effect of Dirt and Road Film Upon Delineators Studied, IH-45 (Houston).



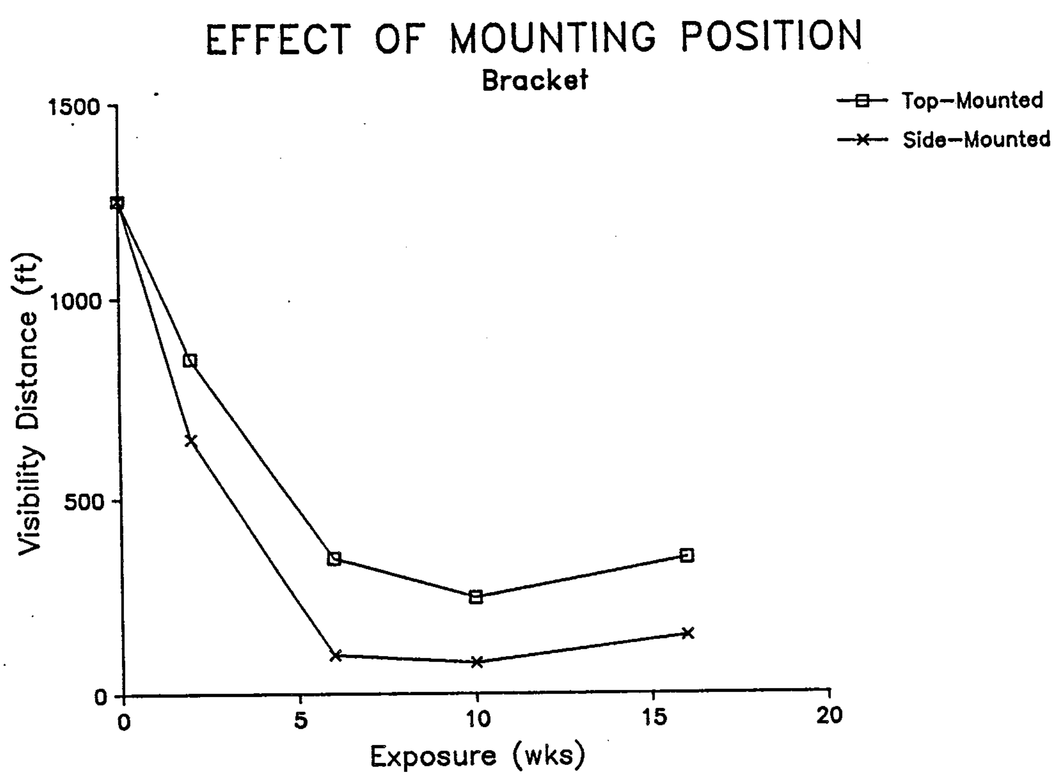


Figure 2-2. Effect of Dirt and Road Film Upon Delineators Studied at Different Mounting Positions, IH-45 (Houston).

As expected, mounting position (top or side) on the barrier effected the rate at which the visibility of both the cube-corner lenses and brackets with HI sheeting deteriorated. As shown in Figure 2-2, the visibility of delineators mounted on the side of the CSSB deteriorated at a faster rate than those mounted on top of the CSSB. This effect was more pronounced for the brackets with HI sheeting than for the cube-corner lenses. The cylinders were not mounted on the side of the barrier, and so were not included in this figure.

CSSB Delineation Cleaning

Other studies (2,7) as well as District personnel surveyed have cited the accumulation of dirt and road grime on the reflective surface of delineators as a major problem associated with the use of barrier delineation. The loss in delineator visibility as documented above also illustrate the extent of this problem. Although some delineators appear to lose their visibility less quickly than others, none are immune to the constant dirt accumulation process. The dirt that collects on these delineators is made up of a number of things including dust, oil, ground tire rubber, and vehicle exhaust emissions. During rainy, wet pavement conditions, this mixture combines with rain water on the pavement and is splashed onto the delineators by passing vehicles. This process repeats over and over until the delineators have lost all reflectivity and are not visible to drivers.

Because of the constant loss of delineator visibility over time, there has been a reluctance by some Districts to install delineators on CSSBs at some locations. There is also a reluctance to put men at risk and to spend the time to clean barrier delineators with the methods currently available. As part of Study 408, a few innovative methods of cleaning barrier delineation were identified and examined.

Self-Propelled Rotating Brush Cleaning System

The proposed self-propelled rotating brush cleaning system is a self-contained system of rotating brushes that would ride on top of a CSSB. The system would have its own water supply and motor to operate the rotating brushes and propel the machine along the top of the barrier. The system would have brushes on both the top and the side of the barrier. It would theoretically be able to be placed on top of the CSSB and perform the cleaning operation without supervision. However, several problems exist with this type of mechanism. For example, the machine would require a large powerful motor to propel the mechanism along the barrier. The mechanism would also not be usable on CSSBs where lighting or glare fence is attached or where the CSSB is discontinuous.

High Pressure Water Sprayer

A high pressure water sprayer would be used in much the same way as a wand type car wash, using the pressurized water stream to spray the delineator. The only known sprayer of this type is mounted on a trailer in District 12 (Houston), but would theoretically operate in the same manner whether mounted on a trailer or on a truck. A major drawback with this type of system is the fact that water overspray could hit oncoming traffic on the opposite side of the delineator, causing a potentially hazardous situation for an oncoming driver. The use of a spray shield or shadow vehicle may be necessary. Also, it is not known how well the water spray would clean the delineators without some type of scrubbing mechanism.

Truck Mounted Brush Head Cleaner

This cleaning system would use a brush or another type of cleaning surface mounted on the end of a rotating mast arm to clean the delineators. The system would be mounted on a truck for mobility. The truck would carry the motor, pumps, and water supply for the unit. Using adjustable arm lengths, heights and interchangeable cleaning heads, the system should work on all types of delineators, both top and side mounted. Another positive aspect of this type of system is that it could be mounted on existing vehicles, such as herbicide trucks.

Based on an analysis of the mechanisms suggested by TTI, it appeared as though the truck-mounted cleaning mechanism has considerable promise and would be capable of cleaning delineators as a slow-moving maintenance operation. Such a system could make it safer and more cost-effective to clean delineators and, in turn, make delineator usage on barriers a more attractive idea to District personnel.

3. DELINEATION OF URBAN FREEWAY GORE AREA CRASH CUSHIONS

Background

In the past, crash cushions in gore areas have proven their safety value. However, studies have shown that the introduction of crash cushions at specific gore sites does not, in general, reduce the number of accidents at those sites; rather, they reduce the severity of impact and occupant injuries (1,11). Damaged crash cushions must be repaired, resulting in significant maintenance costs and exposure of maintenance personnel to potentially hazardous situations during these repairs. Thus, the safety benefits derived from crash cushions are offset to some degree by increased maintenance, labor and operational costs.

Previous studies have addressed the idea of increasing crash cushion conspicuity in an attempt to reduce accidents with crash cushions. When sight distance to the gore area is limited, delineation treatments of crash cushions have been shown to reduce crash cushion repairs and encroachment rates through the painted portion of the gore (12,13). The short-term reductions in crash cushion repairs were so impressive in Houston that District 12 eventually installed nose and back panels at all freeway gore area crash cushions in its jurisdiction.

More recently, however, additional research (14) suggests that delineation requirements are not the same for all types of gore areas. Sites with limited sight distance to the crash cushions might benefit from increased delineation that increases the effective sight distance to the gore area. However, delineation alone may not be particularly effective at sites where the problem lies more with the visual perception of the gore area (due to the horizontal alignment or other factors). In these situations, improvements to the motorist information system, or in some cases improvements in geometrics, may be necessary to reduce crash cushion accidents.

This chapter summarizes the results of research activities on urban freeway gore area crash cushion delineation performed as part of Study 408. Specific details about these activities may be found in TTI Research Report 408-2, "Delineation of Urban Freeway Gore Area Crash Cushions" (15).

Current Gore Area Crash Cushion Delineation Practices in Texas

A telephone survey of 23 of the 24 SDHPT Districts was conducted to determine current practices regarding the delineation of gore areas protected by vehicle impact attenuators (crash cushions) The survey provided useful information as to the different types of delineation being used across the state as well as the similarities, differences, and problem areas with current delineation procedures.

Eleven of fourteen Districts surveyed with gore area crash cushions were found to use delineation. Considerable variation was evident as to the amount and type of delineation used. Some Districts used different types of delineation at different gore areas, depending on site-specific characteristics.

A summary of the different types of delineation used for gore area crash cushions, and the number of Districts using each type, is presented in Table 3-1. The most common delineation treatments used include object markers (Type 1, Type 2) (9) and striped reflective nose panels mounted on the front of the cushions. The colors that have been used for the nose panels vary District by District, with black/yellow, black/white and orange/white panels in place.

In some cases, the nose panel is supplemented with a 4-ft by 8-ft back panel to add conspicuity and increase the effective sight distance to the gore area. Flashing lights have also been installed at some gore areas in Districts 2 (Ft. Worth), 12 (Houston), and 18 (Dallas). At some high-hit locations, several types of delineation have been combined (i.e., back and nose panels, chevrons, and flashing lights) in attempts to further increase the conspicuity of the crash cushions.

TABLE 3-1. DELINEATION PRACTICES FOR URBAN FREEWAY GORE AREA CRASH CUSHIONS

Type of Delineation on or Behind Crash Cushion	Number of Districts Using[a]	
Nose Panels:		
black/yellow stripes	3	
black/white stripes	2	
		5
Object Markers on or at Nose		6
Reflective Paint on Crash Cushions		1
Guardrail Delineators		1
Supplemental Delineation:		
flashing lights		3
full gore area lighting		1
back panels		3

[a] Some Districts use more than one type of delineation on their crash cushions

Long-Term Evaluation of Crash Cushion Delineation

Background

In a 1982 TTI study of gore area delineation (12), crash cushion repair rates were used to evaluate four delineation treatments at eight gore area sites in Houston. The treatments are described in Table 3-2. These treatments consisted of varying levels of static delineation (pavement markers, chevrons, nose and back panels) and one dynamic (flashing lights) treatment. Each treatment was installed at two sites. Crash cushion repair records from each site were obtained for three years prior treatment installation. The repair records were then collected for a period of time after treatment installation (17 to 22 months), and compared to the records from before installation.

The records showed that static delineation (nose and back panels, chevrons, pavement markings) in combination with flashing lights significantly reduced crash cushion repairs at sites with initially high (6 or more repairs per year) repair rates. However, it appeared (from the data collected) that the static delineation treatments alone did not, as a group, reduce repair rates at sites with moderate (4 to 6 per year) repair rates. When evaluated on a site-by-site basis, though, some reductions in crash cushion repair rates were evident (12).

As part of Study 408, cushion records for the eight sites were again examined. These repair records were now available for four years after the initial installation of the treatments. These were obtained and examined to determine how the treatments continued to perform over time. In particular, did crash cushion repairs remain lower, or did they increase over time?

Findings

Table 3-2 is a summary of crash cushion repairs from 1979 to 1986 at the original eight gore area sites originally examined in the earlier study. Also shown in the table is the treatment level that was installed at that site. Visual examination of the numbers in the table suggests that the delineation treatments did in fact remain effective over time.

TABLE 3-2. SUMMARY OF CRASH CUSHION REPAIRS (HOUSTON SITES)

Location	Treatment Level	Year: Before Delineation 79	80	81	82	Year: After Delineation 83	84	85	86
IH-10 EB @ US 59 NB	1	4	4	2	6	3	2	1	2
IH-610 (E.L.) NB @ SH 225 EB	1	0	4	3	3	2	3	3	1
IH-610 (W.L.) SB @ US 59	2	6	6	4	6	3	3	3	2
IH-610 (W.L.) SB @ IH-10	2	5	8	4	4	0	3	4	1
US 59 SB @ IH-45	3	10	6	3	6	4	2	2	3
IH-45 NB @ US 59 SB	3	10	5	6	5	6	2	3	1
IH-610 (W.L.) NB @ US 59	4	12	10	13	12	5	7	7	5
US 59 NB @ RICHMOND AVE.	4	3	7	14	5	4	2	2	4

W.L. = West Loop
E.L. = East Loop
NB = Northbound, SB = Southbound, etc.

Figure 3-1 summarizes the average effect each delineation treatment has had on crash cushion repairs, presenting the average repair rates (by sites with identical treatments) per year before and after installation of crash cushion delineation. Over the four-year period since delineation installation, yearly repair rates were reduced (on the average) 33% at Treatment 1 sites, and 53-55% at sites where Treatments 2, 3, and 4 were installed.

Using a recent cost estimate (16) of $1,760 per repair of the steel drum crash cushions, the average annual savings in repair costs for the various treatments are shown in Figure 3-2. This cost estimate per repair includes both the labor and material costs for the actual repair of the cushion as well as an estimate of an average accident cost to motorists who collide with a steel drum crash cushion.

The values in Figure 3-2 are presented to show that all treatments did result in some yearly cost savings. These values should not be used to compare the relative effectiveness between treatments. The crash cushion repair rates before delineation was installed varied dramatically from site to site. The treatments were not evaluated across sites with similar repair rates (the sites where Treatment 4 was used had much higher repair rates initially) and so a relative comparison between treatments is not appropriate.

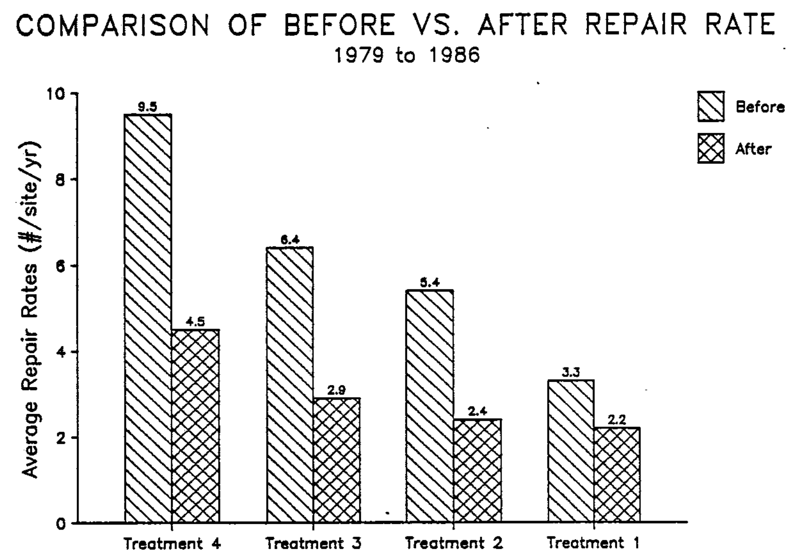


Figure 3-1. Average Annual Crash Cushion Repair Rates for Four Years Before and Four Years After Treatments were Installed at Houston Sites.

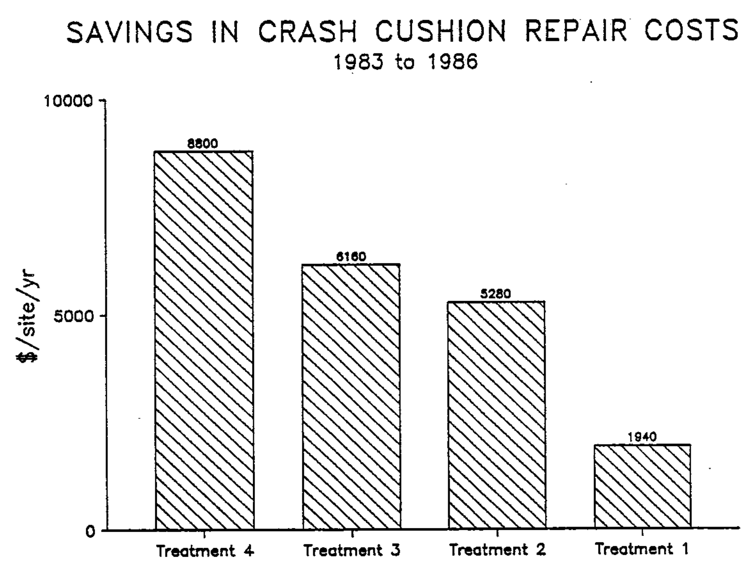


Figure 3-2. Average Annual Savings in Crash Cushion Repair Costs at Houston Study Sites.

Overall, the delineation of the crash cushions at the eight study sites was found to be very cost-effective. Total savings at the original eight Houston study sites, accumulated from the installation of the delineation treatments through 1986, was estimated at over $174,000, based on the above cost estimates.

Motorist Information System Evaluations

Background

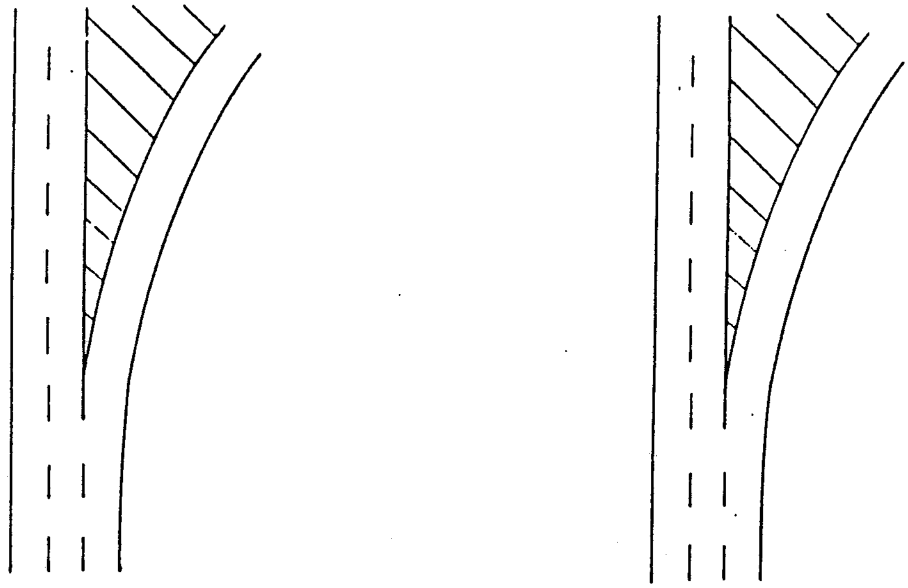
Drivers are guided in large part by the formal information (i.e., information provided by signs and markings, and by the location and positioning of signs and markings) provided on the highway. Poor information or poorly placed information can have a detrimental effect on driver behavior and could lead to erratic behavior caused by insufficient advance information.

Geometrics also play an important role in driver behavior and, alone or in combination with inadequate driver information, can lead to erratic driving behavior at gore areas. Because of geometrics and inadequate sight distances, certain types of gore areas may require extensive delineation whereas locations with adequate sight distance may require lower levels of delineation. This hypothesis prompted TTI to develop a classification system for gore areas (14). The classification is shown in Figure 3-3.

The Type I Gore Area represents a typical gore location with tangent alignment of the main roadway and a well-designed exit ramp. There are no unusual geometric features (e.g., lane drops) and sight distance to the gore area is 1500 feet or greater. Sight distances of 1500 feet have been found to provide adequate response time on high speed facilities (17,18). Sight distances less than 1500 ft could result in operational problems.

The Type II Gore Area represents similar conditions to the Type I with the exception that sight distance is restricted (e.g., by an overpass). The Type IIa represents gore areas where the sight distance is between 800 and 1500 feet. The Type IIb Gore Areas have sight distances less than 800 feet. The Type II gore Areas are more critical than the Type I because of the more restricted sight distances. It is likely that Type II Gore Areas will require more extensive delineation treatments than Type I. For example, a delineated back panel may be required to increase the effective sight distance to the gore area for the Type II, whereas sight distance is not a problem for the Type I and therefore a back panel may not be necessary.

The Type III Gore Areas introduce another geometric feature--curvature--which, in combination with lane drops,lane additions, etc., results in a visual perspective that may be confusing to the driver. The Type IIIa Gore Area contains the characteristics noted above with sight distance between 800 and 1500 feet. The sight distance to the Type IIIb Gore Area is less than 800 feet.

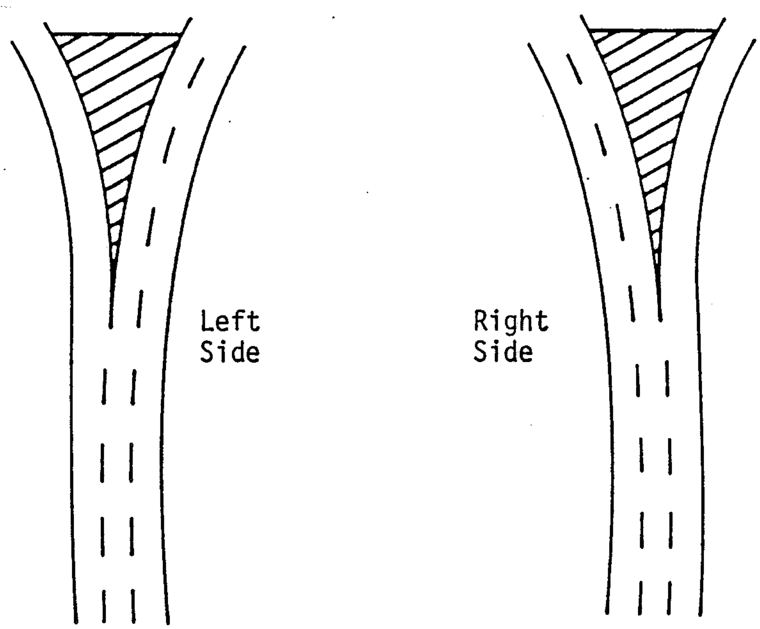


No Sight Distance Restrictions

TYPE I Sight Distance > 1500'

Sight Distance Restrictions

TYPE IIa 800' < Sight Distance < 1500'
TYPE IIb Sight Distance < 800'



Horizontal Alinement Perspective Problem

TYPE IIIa 800' < Sight Distance < 1500'
TYPE IIIb Sight Distance < 800'

Figure 3-3. Gore Area Classifications.

Whereas, the Type I and the Type II direct the driver past the gore area (either to the left or the right), the Type III directs the driver,for a period of time, into the gore area (either into the nose or the side of the crash cushions). The perspective problem in combination with inadequate (less than 1500 feet) sight distance could be responsible for a large number of gore area accidents. It is possible that the perspective and sight distance problems cannot be solved by increased gore area delineation alone. Improvements to the communication system, or in some cases improvements in geometrics may be necessary.

An evaluation of the information system, including signing, marking and delineation, was conducted at three sites (one in Ft. Worth, two in Houston) where crash cushion delineation was in place but where a higher than normal number of accidents with the cushions were occurring. At each site, the existing information system was documented, and possible informational deficiencies were identified. Improvements were then recommended that were expected to yield safety and operational benefits. A TTI Research Report, "Evaluating Urban Freeway Guide Signing - Executive Summary and Level of Service," was used as a guideline for identifying deficiencies in the informational system and for recommending improvements to the system (19).

Findings

Table 3-3 summarizes the characteristics of each of the study sites examined. Included in the table is the classification of the gore area (Type I, II, III) as well as unusual visual or geometric characteristics at each site. As is stated in the table, unique geometric characteristics at sites 2 and 3 give drivers a confusing visual perspective of the gore area, and so were classified as Type III gore areas. Site 1 was classified as a Type IIa gore area, as sight distance to the gore was obstructed by a railroad overpass.

Table 3-3 also presents the improvements to the information system that were recommended. At sites 2 and 3, additional diagrammatic signing was recommended to provide drivers with more information about the geometric features of the sites farther upstream. At site 1, recommendations were made to improve the existing information system.

These evaluations of the motorist information system upstream of Type II and Type III gore area crash cushions suggested that unusual geometric characteristics may often confuse or mislead drivers, and may be responsible for higher crash cushion accident rates. In these situations, it may be possible to adjust the information system upstream of the gore in an attempt to counteract these characteristics and give drivers critical information sooner and in a more easily understood manner.

Unfortunately, study funds did not allow the researchers to implement the above recommendations and evaluate the effectiveness of each using objective driver performance data. Consequently, it is not known whether the

TABLE 3-3. SUMMARY OF SITE CHARACTERISTICS

Site	Location	Unusual Characteristics	Gore Area Classification	Recommended Changes
1	IH-35W (NB) @ IH-30 (WB)--Ft. Worth	1. Limited Sight Distance 2. Geometric Inconsistency (Left-Handed Exit)	Type IIa Left	1. Change Signs to Interstate Designations 2. Relocate Some Signs (to Provide information Sooner) 3. Replace an Existing Word Sign with a Diagrammatic Sign
2	IH-610 (NB) @ US 59--Houston	1. Wide (5-lane) Freeway with 2-lane Exit Creates Confusing Visual Perception of the Gore Area	Type IIIa Right	1. Add an Additional Diagrammatic Sign (to Provide Information about Geometry Sooner) 2. Duplicate an Existing Diagrammatic Sign (to Make Sure All Drivers in All 5 Lanes See Sign)
3	IH-610 (SB) @ S. Post Oak--Houston	1. Geometric Inconsistency (Mainlanes Curve Left, Exit Continues Straight Ahead) Creates a Confusing Visual Perception of the Gore Area	Type IIIa Right	1. Add a Diagrammatic Sign (to Provide Information about Geometry Sooner) 2. Move Some Existing Signs (to Make Room for Diagrammatic Sign)

improvements would indeed be cost-effective to implement. As stated earlier, it may be difficult to overcome geometric inconsistencies with informational signing, since signing is used primarily for guidance and navigational purposes by drivers. Any future implementation of these recommendations should be evaluated using objective driver performance measures to determine if the changes have had the desired effect upon traffic operations and safety.

4. RECOMMENDATIONS

CSSB Delineation

Based on the results of the field studies conducted at an urban freeway location in Houston, acrylic cube-corner delineators are recommended as the best type of delineator to use on CSSBs in narrow freeway median locations. These delineators do not become dirty and less visible as fast as delineators covered with HI sheeting.

Subjects ranked the treatment with the side-mounted cube-corner lenses at 50-ft spacings as the brightest and most effective in both a clean and dirty condition. However, the driver performance data collected for this treatment under nighttime, dry pavement conditions showed a slight increase in the occurrence of lane straddling. The combination of the close (50-ft) spacing and the side-mounted position may have made some drivers too apprehensive of the barrier. Lane straddling could result in conflicts between vehicles or other operational problems. Consequently, for CSSB applications with site and lateral clearance conditions similar to those studied, it is recommended that top-mounted delineation be used. An added benefit to the use of top-mounted delineation is that it does not become dirty as fast as side-mounted delineation.

Only two levels of delineator spacing were evaluated in this study, 50-ft and 200-ft intervals. Subject comments indicated a preference for the closer spacings, but the driver performance data collected did not clearly suggest that one spacing was better than the other. Therefore, it is recommended that a 200-ft spacing be considered as a maximum for CSSB delineation. Closer spacings may be warranted, though, on CSSBs on extremely sharp curves in order to insure adequate control and guidance information is provided to drivers.

The Texas MUTCD (9) indicates the CSSBs used in work zones at night should be delineated. However, no guidance is given as to the mounting position or spacing of the delineation used. The lack of a suitable study site in a work zone application prevented an analysis of the delineation treatments under work zone conditions. However, since most CSSBs in work zone applications are located very close to the travel lanes (as they were for the field studies conducted as part of this study at a narrow freeway median installation), it is believed that the results of this study may have some applications at highway work zone locations.

One of the major issues that could not be addressed in this research is the criteria needed to decide when to delineate CSSBs in permanent installations. The above recommendations apply to situations where the decision has already been made to delineate the CSSBs and the question becomes deciding what delineation should be used. Additional research is needed to determine what effects delineation has upon traffic safety in order to be able to determine where CSSB delineation is warranted and where it will be cost effective in terms of a reduction in accident potential.

Urban Freeway Gore Area Crash Cushion Delineation

The results of this research indicate that reflectorized chevron nose and back panels on urban freeway gore area crash cushions do not lose their effectiveness in reducing vehicle impacts with the cushions over time, at least for a period of about four years. Given the relatively low costs associated with installing and maintaining this treatment, its implementation at most urban freeway gore area crash cushions appears justified. The savings in crash cushion and accident repair costs attributable to delineation can be substantial over time. For example, savings in crash cushion and accident repair costs at eight urban freeway gore area sites in Houston has amounted to over $174,000 over a four year period.

The effectiveness of crash cushion delineation does appear to depend on the specific characteristics of each site. In particular, factors such as limited sight distance to the gore and confusing visual perceptions of the gore area by drivers may influence accident rates with crash cushions at a particular location. In some cases, crash cushion delineation alone may not be sufficient, and it may be necessary to re-evaluate and modify some aspects of the motorist information system (e.g., signs, pavement markings, etc.) in advance of the gore area in an attempt to better inform and warn drivers.

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