Approach-End Treatment of Channelization—Signing And Delineation

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The general objectives of the research project were to evaluate the effects of design, signing, delineation, and illumination of channelization on the factors of safety, efficiency of operation, and capacity. The specific phases of research covered in this report dealt with the signing and delineation of channelization, and with the effect of channelization and approach-end treatment on certain characteristics of driver behavior.

• IN 1960, the research project, "Channelization" was initiated by the Texas Transportation Institute in cooperation with the Texas Highway Department. Its general objectives involved investigating the effects of design, signing, delineation, and illumination of channelization on the factors of safety, efficiency of operation, and capacity. The specific phases of the research covered in this report dealt with the signing and delineation of channelization, and the effect of channelization and approach-end treatment on certain characteristics of driver behavior. Because of the discrete nature of the studies, each of the subjects is presented separately in the report.

To avoid hazardous situations, careful consideration must be given to the approach-end treatment of channelization in regard to design, signing, and delineation. Signing used to denote the beginning of the island, and to locate it with respect to the roadway cross-section should have excellent visibility characteristics to provide adequate advance warning to the driver. In addition to signing of the approach-end, the island curb should be delineated from the remainder of the roadway to establish a proper perspective of the change in geometric conditions. The delineation should provide continuity over a considerable distance so that the driver will be aware of the overall configuration of the introduced channelization. Finally, the channelizing island and approach-end treatment must be designed geometrically to provide a natural maneuver for traffic to flow around the island.

In the first phase of this research, several materials were tested under controlled conditions to determine their relative effectiveness in delineating island curbs. The superior material, as indicated by the controlled tests, was then installed under actual traffic conditions to provide an evaluation of its practical performance characteristics.

In the second phase, several KEEP RIGHT signs used on channelization were tested to determine their relative visibility and legibility characteristics. In the third phase, studies were made at three stages in the development of channelization and approach-end treatment to determine the effect on driver behavior. In these studies a GSR recorder was used to measure driver tension responses, and traffic speeds were measured through several sections of the channelized area.

DELINEATION

Several currently used delineation materials were tested to determine their comparative effectiveness. Then the most effective of the materials was used in studies of performance under actual traffic conditions.

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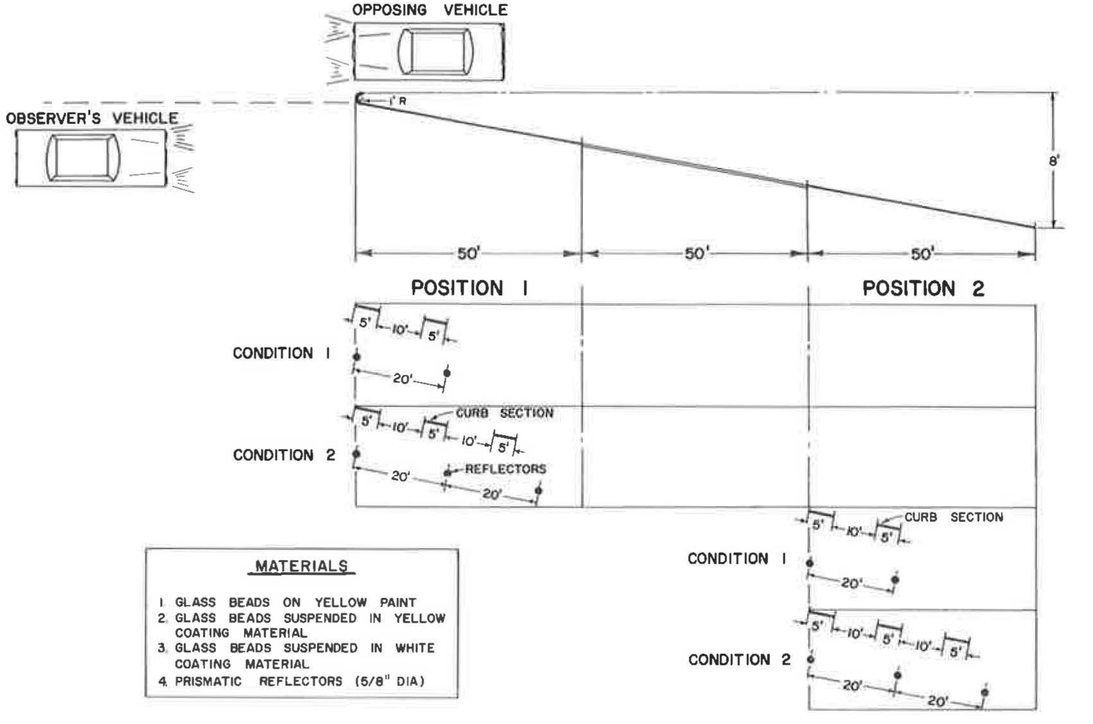

Figure 1. Delineation test site.

Comparison of Delineation Materials

In this phase of the research, studies were conducted to evaluate comparatively the effectiveness of several materials currently used in delineating island curbs. The materials tested were (1) yellow paint reflectorized with glass beads, (2 and 3) highly reflective coating material with glass beads in suspension (yellow and white), and (4) prismatic-type reflectors (⅝ in. in diameter) mounted on top of the island curb.

Description of Study

To facilitate a comparison of the materials, simulated conditions of channelization were devised and tested on runways at the Texas A & M College Research and Development Annex, which was at one time the Bryan Air Force Base. Through such controlled conditions it was possible to eliminate a number of variables such as grade, alignment, outside light sources, and variable opposing headlights that would normally be encountered in tests of the materials at actual installations of channelization.

To simulate a channelizing island, 5-ft long curb sections were constructed of wood and shaped to resemble a barrier-type island curb. The curb sections were coated with the various test materials. The prismatic reflectors were mounted in wooden blocks that could easily be aligned with the path of the test vehicle. To form the approach-end of the island, an island nose was shaped from sheet metal and reflectorized, and either the curb sections or the reflectors were placed along a line from the island nose tapered for a lateral transition of 8 ft in 150 ft of length. The details of the island layout and the test conditions are shown in Figure 1.

The materials were tested at two positions along the taper to determine any effects of the relative position of the materials with respect to a vehicle with opposing head-

TABLE 1

RESULTS OF CURB DELINEATION STUDY

Position	Driver No.	Replication No.	Visibility Distance (ft)							
			Material 1, Condition		Material 2, Condition		Material 3, Condition		Material 4, Condition	
			1	2	1	2	1	2	1	2
Position 1	1	1	200	160	120	140	180	180	760	760
		2	200	220	140	180	180	160	840	920
	2	1	220	200	160	180	160	220	680	680
		2	200	220	140	240	140	180	580	740
	3	1	140	200	120	120	180	160	620	580
		2	160	200	180	140	180	180	660	820
	4	1	200	200	140	180	200	240	640	680
		2	160	240	160	140	200	200	600	700
Avg.			185	205	145	165	178	190	672	735
			195		155		184		704	
Position 2	1	1	200	140	140	120	140	160	1,040	1,080
		2	140	160	160	140	140	140	820	880
	2	1	120	180	120	140	140	140	800	840
		2	140	160	100	120	100	100	600	660
	3	1	160	120	100	80	140	140	560	460
		2	180	160	100	100	160	140	720	660
	4	1	220	220	120	180	140	220	980	1,060
		2	180	200	180	140	160	160	1,000	1,020
Avg.			167	167	128	128	140	150	816	834
			167		128		145		825	

lights at the island nose. Position 1 consisted of placing the curb sections and the reflectors in the 50-ft section of the taper immediately following the island nose. For position 2, the curb sections and reflectors were placed in the third 50-ft section of the taper.

To test the effect of length or continuity of the delineation provided by the materials, two test conditions were established. Condition 1 consisted of two curb sections placed 10 ft apart, or two reflectors placed 20 ft apart. For condition 2, three curb sections or three reflectors were used at the same spacing (Fig. 1).

The visibility tests were conducted with an opposing vehicle and the observers' vehicle operating on low-beam headlights. The opposing vehicle was parked at the nose of the island to simulate the most critical condition of two vehicles meeting under actual conditions. The exact critical position of the opposing vehicle was verified by preliminary testing.

In the tests, four observers drove a predetermined loop on runways that included the simulated channelization. Prior to beginning the test, each observer was instructed to indicate the number of curb sections or reflectors he could see as he came into the range of visibility. The distance from the nose of the island at which the observer could distinguish the correct number of curb sections or reflectors was determined (to the nearest 20 ft) as the visibility distance. To avoid any anticipation on the part of the observer, the materials, positions, and conditions were completely randomized.

The experiment was designed to test the four materials under two conditions in each of two positions, making possible a total of 16 combinations. Also, two replications of the experiment were required of each observer to increase the reliability of the results.

Findings

The results of the study (Fig. 2) indicate that the prismatic reflectors were visible at distances three to four times those of the other materials. These results show further that there was no appreciable difference in the visibility distances of any of the coating-type materials. Material 1, beads-on-paint, was visible at a greater distance than the other two coating materials. However, the visibility distances of all three materials were below what could be considered acceptable for good delineation. Table 1 lists the results in detail to provide a more exacting comparison.

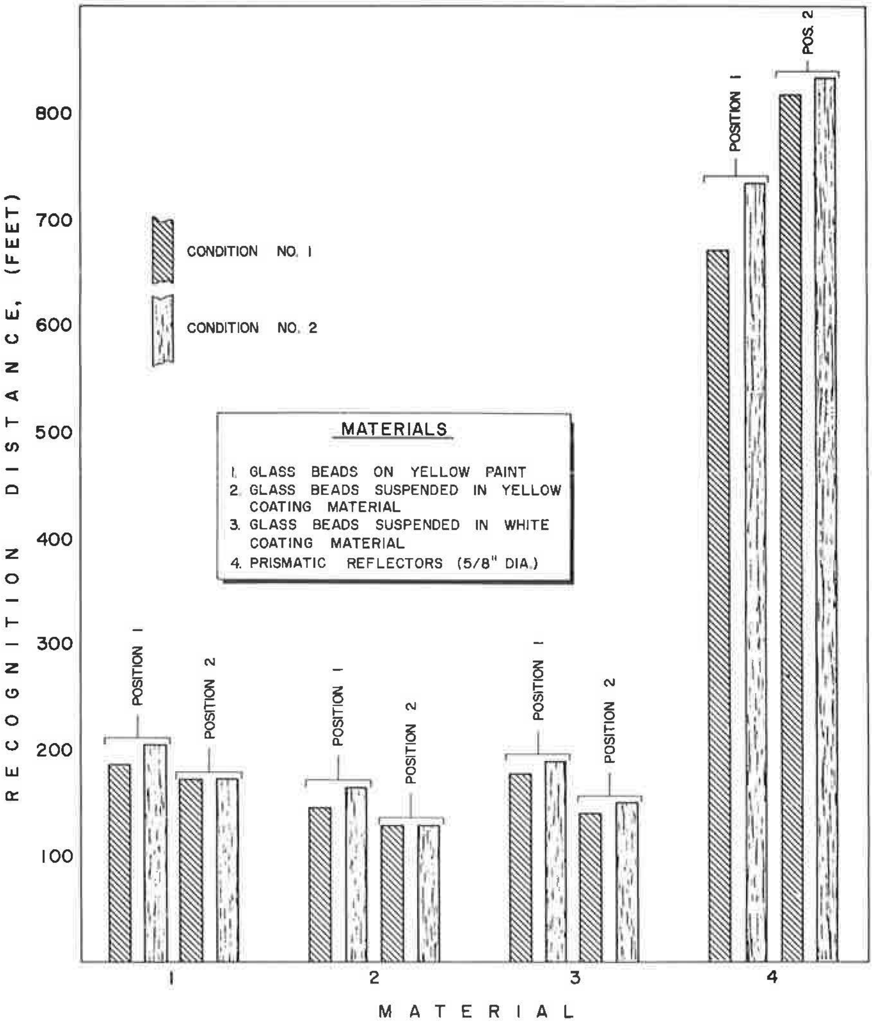

Figure 2. Visibility distance of curb delineation material.

The superiority of the reflectors was primarily attributable to two characteristics:

1. The prismatic reflective surfaces in the reflector provide greater reflection efficiency, and
2. The reflectors were mounted perpendicular to the stream of traffic, whereas, the coating-type materials were placed virtually parallel to the traffic stream.

Preliminary observations indicated that the coating-type materials provided good visibility when the test curb sections were placed perpendicular to the traffic stream. However, the visibility of the curb sections in the perpendicular position was not as great as for the prismatic reflectors. This is substantiated by the results of visibility tests on signs constructed of the same or similar materials discussed later.

Visibility vs Position.— A comparison of the visibility distances of the materials according to their position relative to the island nose and hence relative to the opposing vehicle (positions 1 and 2, Fig. 1) showed that the coating-type materials were less effective in position 2 than in position 1 (see Fig. 2). On the other hand, the visibility distance of the reflectors was increased approximately 100 ft by moving them to posi-

TABLE 2

COMPARISON OF VISIBILITY DISTANCES OF MATERIALS FOR NORMAL WEATHER CONDITIONS VS INCLEMENT WEATHER CONDITIONS

Material	Visibility Distance			
	Position 1		Position 2	
	Visibility Range, (ft)	Avg. Visibility Distance, (ft)	Visibility Range, (ft)	Avg. Visibility Distance, (ft)
Material 1, beads-on-paint	100-160[1]	130[1]	0-120[1]	60[1]
	140-240	195	120-220	167
Material 2, yellow reflective coating	60-80[1]	70[1]	40-80[1]	60[1]
	120-240	155	80-180	128
Material 3, white reflective coating	60-80[1]	70[1]	60-80[1]	70[1]
	140-240	184	100-220	145
Material 4, ⅝-in. prismatic reflectors	440-500[1]	470[1]	420-760[1]	590[1]
	580-920	704	460-1080	825

[1]Slow steady drizzle with wipers on.

tion 2, 100 ft behind the island nose. This increase in performance was attributed to the fact that moving the reflectors 100 ft along the taper also moved them 5 ft laterally and reduced the effect of the "halations" of the opposing vehicle's lights. The other three materials showed a slight decrease because their reflective power was not great enough to compensate for the increased distance from the light source. The visibility distances were measured from the island nose rather than from the actual position of the material.

Visibility vs Condition.—Increasing the number of curb units or reflectors from two to three such as in conditions 1 and 2, increased the visibility only slightly in position 1 and practically none in position 2. This increased visibility indicated a dissipation of the halation's effect of the opposing headlights when the materials were laterally removed. This also is an indication that continuous delineation offers greater advantages than a concentration of materials at the island nose.

These differences in visibility distances according to position and condition were not statistically significant. However, the differences were considered worthy of mention because of the consistency of the results.

It is logical that the delineation, when tested under controlled conditions, bore greater significance when all outside light sources were eliminated except for the opposing vehicle. This probably resulted in greater recognition distances than could be expected under actual conditions. However, the study was aimed at evaluating comparative visibility more than actual distances at which the materials were visible.

Visibility vs Inclement Weather.—On one particular occasion, a slow drizzle interrupted the normal testing of materials. Rather than cancel the night's work, limited tests were conducted to evaluate the visibility of the materials during inclement weather. The test data were obtained using two drivers in one replication of the study. The results given in Table 2 in comparison with normal weather tests indicate a general reduction in visibility of about 50 percent due to inclement weather conditions. The reflectors were not affected as much as the coating-type materials. It is significant to note that the reflectors provided good visibility even in inclement weather.

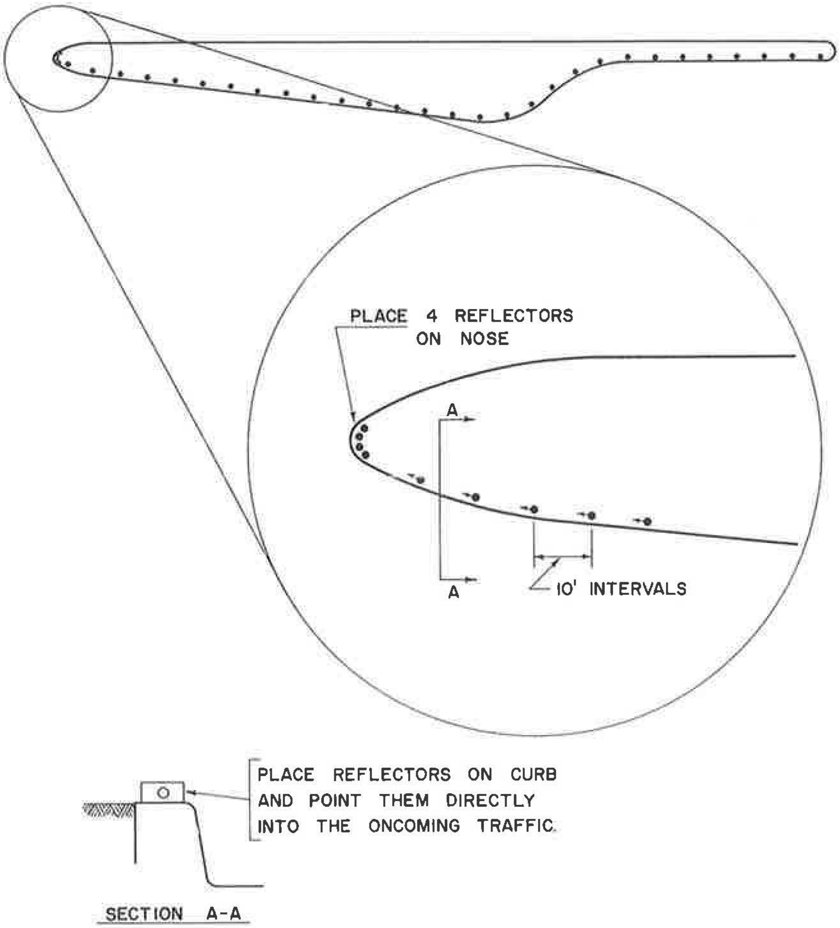

Figure 3. Installation layout for performance studies.

Performance Studies

The results of the tests of delineation materials definitely showed that the prismatic reflectors offered the greatest effectiveness under controlled conditions of testing. To evaluate the efficiency of the reflectors under actual traffic conditions, they were installed on several divisional islands in the Houston, Bryan, and Waco districts of the Texas Highway Department. In Houston and Bryan, the reflectors were installed on divisional islands on arterials carrying high traffic volumes through highly developed areas. The locations were illuminated with mercury vapor-type luminaires.

In the Waco district and at another location in the Bryan district, the reflectors were installed on islands in rural areas where traffic volumes were low and outside light sources were negligible. The reflectors were installed in wooden blocks with the face of the reflector mounted flush with the face of the block. The wooden blocks were then mounted on top of the curb at 10-ft intervals (Fig. 3). The wooden blocks were not considered permanent mounting facilities, but merely an economical means of holding the reflectors in place for observation under actual traffic conditions.

No tests were conducted to evaluate the actual visibility distances of the reflectors under normal service because the variables that could influence their visibility were too great in number for the results of such a study to be of any great significance. However, observations indicated that the reflectors performed satisfactorily when first installed, even in the lighted areas.

 

Figure 4. Delineators at night, Bryan urban installation.

The Bryan urban installation is shown in Figure 4 and the real advantage of the prismatic reflectors is illustrated. Due to their great range of visibility, the entire divisional island including the added left-turn lane is clearly outlined before the driver. As an indication of the range of visibility, the island was approximately 500 ft in length with an opening at 310 ft. This view is comparable to the driver's view of the island when approaching with high-beam headlights. For low-beam conditions, approximately the same view is seen with slightly less intensity.

The reflectors installed in the rural locations have given satisfactory service with little or no maintenance required. The installation in the Waco district has drawn numerous favorable comments from highway patrolmen and officials of a nearby military base. Apparently, the delineators have improved the visibility of introduced divisional island channelization at a high-speed rural intersection.

The performance studies in the urban areas have pointed up maintenance problems that must be resolved through further experimentation. During inclement weather, the visibility of the reflectors was reduced by road film coating the face of the reflectors. The Houston test installation was most seriously affected by weather conditions. However, it was anticipated that Houston would be the most critical test area because of a great amount of rainfall combined with the existing soil type and poor drainage due to flat topography.

The reflectors installed in the Bryan area provided acceptable service for a period of three months (Sept. to Dec.) when there was not a great amount of rainfall. During that time, it was estimated that their reflectivity was reduced approximately 30 percent by road film coating the face of the reflector. Shortly afterward, they were subjected to an extended period of slow drizzle and rain in which their reflectivity was reduced about 75 percent. However, it was observed that heavy rains removed some of the road film and thus restored an appreciable amount of their reflectivity. The fact remains that the reflectors, mounted as previously described, are in some cases subject to road film and are not effective during inclement weather when most needed. This pointed out a definite need for the development of a mounting device for the reflectors which will serve as a shield from the splash or road film.

The amount of road film and the rate of its deposition on the face of the reflectors are considered to result from the amount of dirt and foreign matter on the roadway, the proximity of the traffic stream and the volume of traffic in the lane adjacent to the reflectors. From the performance studies, it appears that the proximity of the traffic stream may have the greatest effect. However, all of these factors will be considered in further research.

SIGN VISIBILITY

It is common practice to utilize the KEEP RIGHT sign in directing traffic around channelizing islands. Most frequently the sign is used in conjunction with painted and reflectorized curbs to delineate and define the island. However, signs are quite fre-

SIGN NUMBER 1

SIGN NUMBER 2

SIGN NUMBER 3

SIGN NUMBER 4

SIGN NUMBER 5

SIGN NUMBER 6 & 7

SIGN NUMBER 8

Figure 5. Test signs.

quently used without additional delineation, especially in rural areas where channelizing islands normally are not curbed. Therefore, there is considerable dependency on the proper function of the KEEP RIGHT sign, particularly where it is used alone.

First, due consideration should be given to the true function of the sign. Because it is of generally standard form and so widely used, it probably can be considered more as a symbol than a printed message. For this reason, its recognition or knowledgeable visibility is more important than its actual legibility.

TABLE 3

SIGNS USED IN VISIBILITY AND LEGIBILITY TESTS

Sign No.	Type of Sign	Sign Size (in.)	Letter size (in.)
1	Beads-on-paint; black letters on white background (Texas Highway Department Standard)	24 by 30	5
2	Reflective sheeting; black letters on white background	24 by 30	5
3	White letters and arrow inset with prismatic reflectors on black background	24 by 30	4
4	Internally illuminated; black letters on white opaque background (no arrow)	24 by 36	7
5	Same as No. 1 except black and white hash mark panel mounted below sign	24 by 30	5
	Panel	24 by 36	-
6	Same as No. 1 except externally illuminated	24 by 30	5
7	Same as No. 2 except externally illuminated	24 by 30	5
8	White reflective sheeting letters and arrow on black background	24 by 30	5

The KEEP RIGHT sign is of generally standard form (Fig. 5). However, there are several different innovations, depending primarily on the different types of materials and construction techniques.

Description of Study

Studies were conducted to compare the visibility and legibility characteristics of several types of signs and sign arrangements currently being used. The signs selected for study are shown in Figure 5 and described in Table 3. Most of these signs were selected because of their particular appeal in certain areas. The standard Texas Highway Department sign (No. 1) is used extensively throughout the State; however, some districts have recently gone to other types of signs or modifications of the standard type. In some districts, a hash mark panel has been placed immediately below the KEEP RIGHT sign. Also, some districts have installed external illumination on the standard type signs.

Sign No. 3, on which the message is composed of letters and the arrow formed of prismatic reflectors, has been used favorably on high-type facilities. Also it has seen some application as a KEEP RIGHT sign. Sign No. 8 was selected to provide a materials comparison with No. 3.

Mounting Height.—There are some differences in policy regarding the most effective mounting height for KEEP RIGHT signs. The "Texas Manual on Uniform Traffic Control Devices for Streets and Highways" specifies that such signs on channelizing islands should be mounted with the bottom edge not more than 7 ft nor less than 3.5 ft from the pavement surface. The "Manual on Uniform Traffic Control Devices for Streets and Highways," published by the Bureau of Public Roads, specifies that mounting height should be at least 7 ft in business and residence districts or in any case when there may be obstructions to view. It is logical that the greater mounting height will provide better visibility over the tops of vehicles ahead. Also, it is possible that mounting the sign at the maximum height will increase its visibility by removing it from the influence of opposing headlights. On the other hand, the higher mounting height may reduce the reflectivity of the sign. Since there is apparently no record of such a comparison, all signs were tested at mounted heights of 3.5 and 7 ft.

Test Site.—Tests were conducted to compare the relative visibility and legibility characteristics of the signs. These tests were conducted on the runways at the A & M College Research and Development Annex to provide greater control over the variables influencing sign visibility, and thus provide a more accurate evaluation. Testing in this remote location served to eliminate a number of variables, particularly the effects of external light sources and variable geometrics and grades.

In designing the study, it was recognized that these idealized conditions would not yield actual visibility and legibility distances that would apply directly to field applications. However, the selected testing procedure and conditions were expected to yield a relative comparison of the visibility and legibility characteristics.

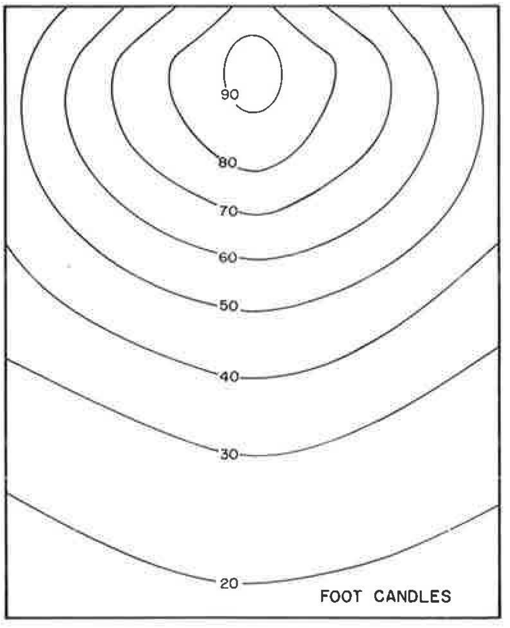

Figure 6. Light intensity pattern for externally illuminated sign No. 6.

Selection of Criteria.—In the selection of criteria for measurement of comparative performance, careful consideration was given to what is believed to be the two primary functional characteristics of the KEEP RIGHT sign. The sign is universally used to mark the approach-end of channelization islands. Such widespread and repetitive application causes the sign to perform as a symbol rather than as a literal message. In other words, the sign has accomplished its purpose when its general shape and the shape of the arrow are visible to the driver. These characteristics are generally visible before it is possible for the driver to read the message. For this reason, the distance at which the driver could recognize the sign in its general form was selected as the primary criterion for comparison. The distance at which all letters of the signs were legible was selected as a secondary measure.

Study Procedure.—To facilitate the study, four observers were selected to drive a vehicle at uniform speed (15 mph) through the test area and indicate the point at which they could recognize the general form of the sign. The distance was also recorded when the driver was able to read the message.

Before beginning the study, the observers were briefed on their duties in the test. Also, trial runs were conducted to familiarize the observers with the signs being used. This was considered necessary to reduce the learning effect inherent in repeated tests involving the human mind. Also, the test runs were considered justifiable because drivers on the roadway frequently encounter the sign, and thus have gained familiarity in its use and purpose.

The test was designed to obtain two observations of each sign by each observer at both mounting heights, comprising a total of 32 observations for each driver. Because of the time consuming nature of the study, the two replications were conducted on separate nights to avoid undue fatigue.

In the test, the signs were drawn randomly within each mounting height to reduce any influences on the data resulting from anticipation by the observer. In other words, the signs were all randomly tested at the 3.5-ft mounting height. The sign mounting brackets were then raised to the 7-ft height and randomly tested again. Testing heights were not randomized because of the difficulty involved in changing the mounting height, particularly in the case of the internally illuminated sign which was permanently attached to the sign support.

An effort was made to simulate the most critical visibility conditions that could normally be expected at any sign installation with exception to weather conditions. To simulate a realistic situation, the observer's vehicle was operated on low-beam lights and an opposing vehicle, also with low-beam lights, was located adjacent to the sign. Preliminary observations ascertained the most critical position of the opposing vehicle to be immediately adjacent to the sign. Apparently the greatest influence of the opposing vehicle is derived from the halation of the glare that surrounds the light. In these same observations, there was no indication that small changes in the angle of the opposing vehicle (0 to 15 degrees) had any appreciable effect on the visibility of the sign.

The external lighting used on signs Nos. 6 and 7 consisted of two 15-w fluorescent tubes mounted in a white reflector. The reflector was mounted 18 in. from the sign

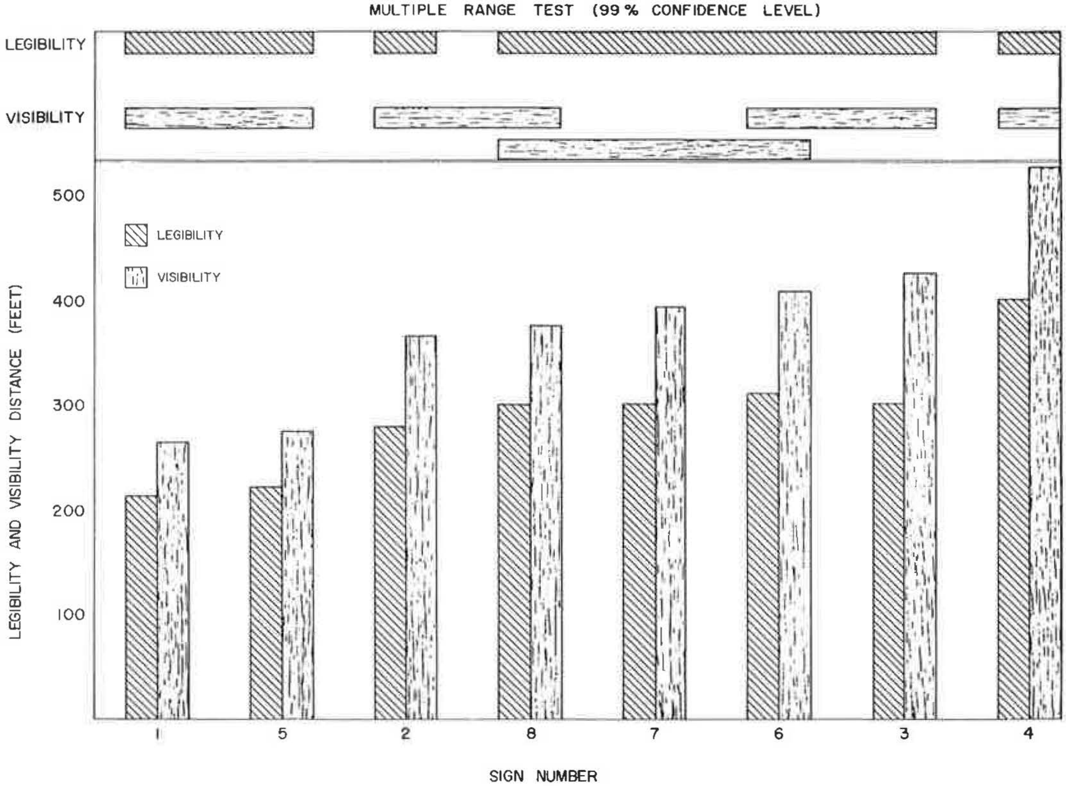

Figure 7. Legibility and visibility distance of signs.

and parallel with the top of the sign. The intensity and distribution of light on the surface of the sign are shown in Figure 6.

Analysis of Data

The data collected in the study of visibility and legibility distances were treated by fixed-effects model of analysis of variance to evaluate any significant differences in the various signs. A multiple range test was applied to the average visibility and legibility distances to rank them according to their order of superiority and establish statistical reliability of any differences in the average values.

Discussion of Results

Visibility Comparisons.—Figure 7 shows the average visibility distance for each sign and the results of the multiple range test in arranging the various signs in groups of significantly different visibility distances. According to this comparison, the internally illuminated sign (No. 4) was superior to all others tested. In the order of relative performance, the second group included the prismatic reflector sign (No. 3) and the Texas Highway Department standard beads-on-paint sign with external illumination (No. 6).

The third group included both externally illuminated signs (Nos. 6 and 7) and the special white reflective sheeting legend on black background (No. 8). The fourth group consisted of the standard reflective sheeting sign (No. 2) and the special sign with reflective sheeting legend. The lowest group in order of performance consisted of the Texas Highway Department standard beads-on-paint type (No. 1) and the same sign with the hash-mark panel mounted below (No. 5).

TABLE 4

ANALYSIS OF VARIANCE SIGN VISIBILITY TEST

Variation Source	Degrees of Freedom	Sum of Squares	Mean Square	F Ratio
Drivers	3	4,033.8	1,344.6	151.0[1]
Replications	1	81.3	81.3	9.1[1]
Signs	7	7,729.8	1,104.2	128.0[1]
Drivers/replications	3	161.7	53.9	6.0[1]
Drivers/signs	21	646.4	30.8	3.5[1]
Replications/signs	7	111.4	15.9	1.8
Drivers/replications/signs	21	278.6	13.3	1.5
Residual	64	569.9	8.9	—

[1] 1 percent level.

TABLE 5

ANALYSIS OF VARIANCE SIGN LEGIBILITY TEST

Variation Source	Degrees of Freedom	Sum of Squares	Mean Square	F Ratio
Drivers	3	538.2	179.4	138.0[1]
Replications	1	8.5	8.5	6.5[2]
Signs	7	954.1	136.7	105.0[1]
Drivers/replications	3	92.3	30.8	23.7[1]
Drivers/signs	21	160.1	7.6	5.8[1]
Replications/signs	7	16.5	2.4	1.8
Drivers/replications/signs	21	27.0	1.3	1.0
Residual	64	82.5	1.3	-

[1] 1 percent level.
[2] 5 percent level.

The results of this test are not completely clear-cut because there were overlaps in the ranges at signs Nos. 6 and 8. Actually, these signs can be considered in both groups but the groups cannot be combined.

Legibility Comparison.—Average values of the relative legibility distances of the signs are also shown in Figure 7. The results of the range test on the legibility distances were not greatly different from the results of the visibility tests, except that the groups were a little more clearly defined. The internally illuminated sign maintained its superiority. In this comparison the two externally illuminated signs (Nos. 6 and 7), the prismatic reflector sign (No. 3) and the special sign with reflective sheeting legend (No. 8) formed the second group. The standard reflective sheeting sign was alone in the third group. The Texas Highway Department standard (No. 1) and the hash-mark panel variation (No. 5) again comprised the lowest group.

Mounting Heights.—The analysis showed no differences in either the visibility or legibility of the signs at the 3.5- and 7-ft mounting heights under the conditions established in the study. Apparently, any advantages of either height cannot be measured in terms of night visibility or legibility.

Reliability of Results.—As anticipated, the analysis of data for visibility and legibility revealed a great amount of variation in drivers and replications as well as the previously described differences in signs. As indicated by Tables 4 and 5, the great-

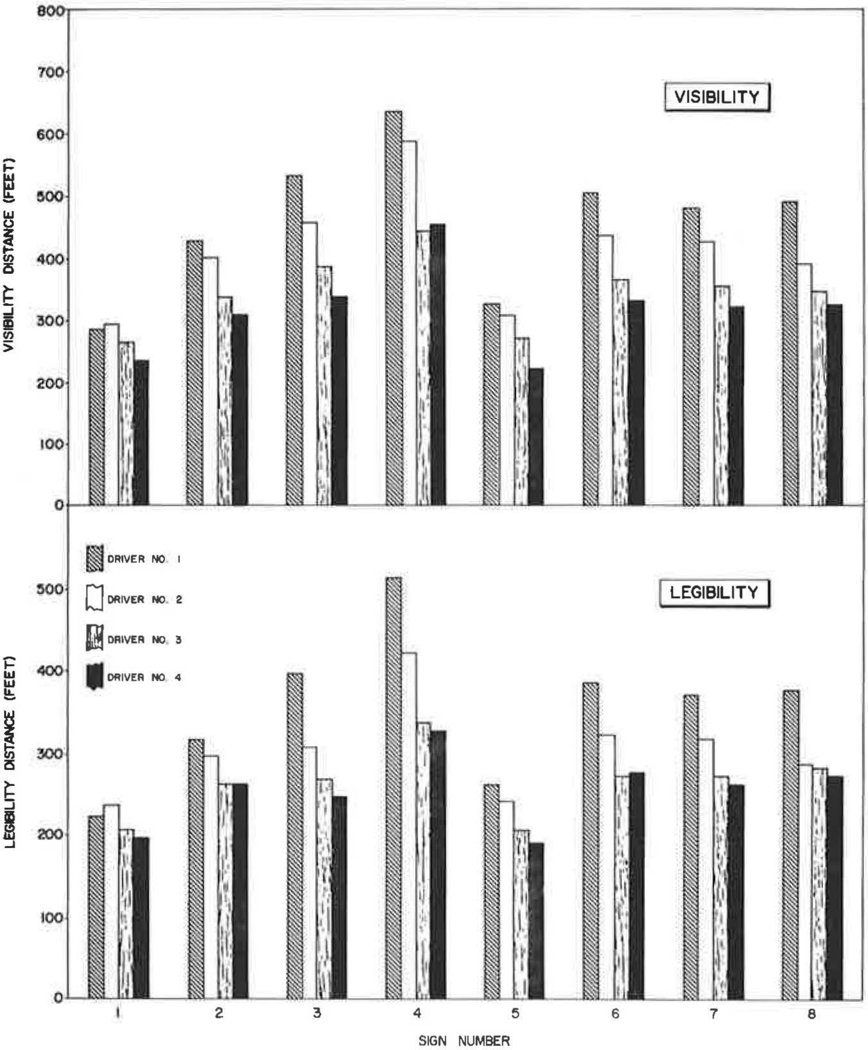

Figure 8. Comparison of legibility and visibility distance of each driver for each sign.

est variation was observed among the drivers. This variation can be explained by the normal differences in visual ability of individuals and should not detract from the results because there was consistency among the relative visibility distances of each of the drivers for each of the signs (Fig. 8). In only two instances (driver No. 1 on sign No. 1 and driver No. 3 on sign No. 6) did the general pattern change.

The analysis of variance indicated significant differences in legibility and visibility distances for each of the two replications. A comparison of the mean distances for each of the replications indicated a decrease between replications 1 and 2 (Table 6). The real causes of these differences are not readily evident. Aside from possible variations due to changes in climatic conditions and in the physical and mental conditions of the drivers, it is theorized that the drivers were more accustomed to the test conditions during the second replication, and therefore, exerted a lesser amount of effort in making the observations. At any rate, the differences in replications are quite small when viewed in light of differences in drivers and signs (Tables 4 and 5).

Because the analysis of variance is based on the assumption that the data are normally distributed, tests were conducted to verify normality. These test results were satisfactory.

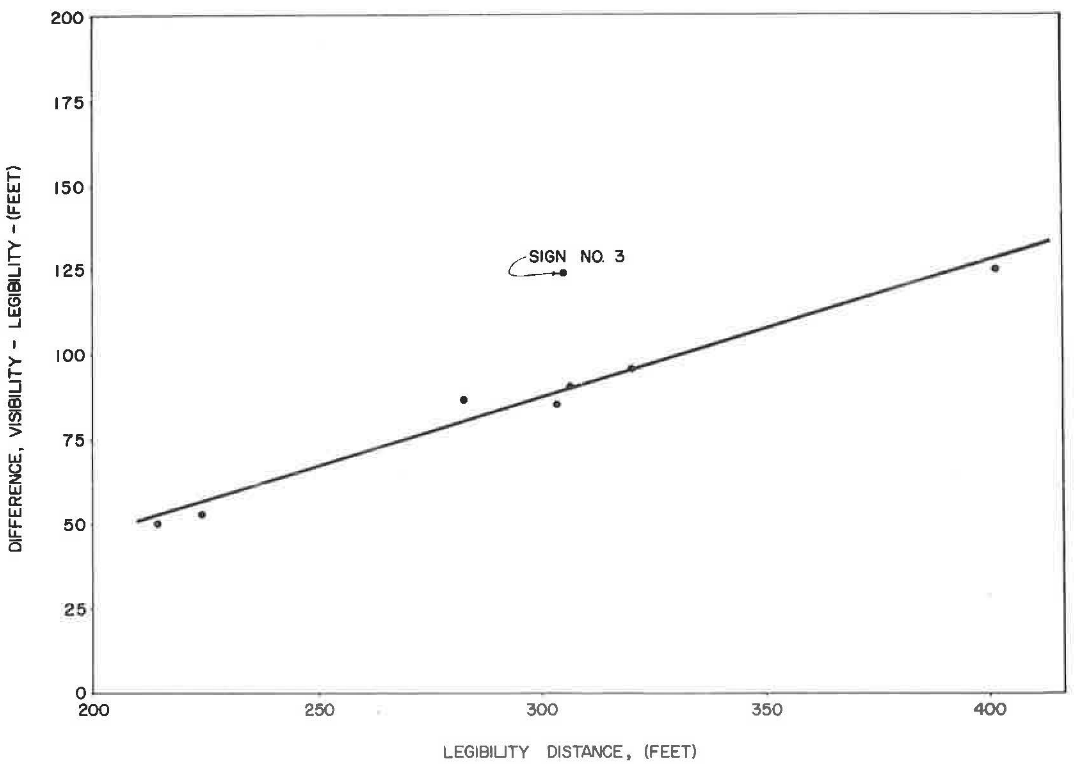

Figure 9. Relationship between visibility and legibility distances of signs.

Evaluation of Results.—The internally illuminated sign provided greater visibility and legibility distances than any other sign tested. However, this indication of superiority must be considered in light of certain circumstances or conditions. The only internally illuminated sign available for testing purposes was a 24- by 36-in. sign with a legend composed of 7-in. letters, which naturally afforded a greater legibility distance than the signs with 5-in. letters.

The second group, which included the prismatic reflector sign, the special reflective sheeting sign, and the externally illuminated word-signs provided good legibility and visibility characteristics. Of this group, the prismatic reflector sign is considered worthy of individual consideration on a practical level because of its relatively high performance characteristics and comparatively low cost of installation. High performance takes on even greater importance when it is recalled that the sign legend is composed of 4-in. letters. The outstanding visibility characteristic of the sign is further demonstrated in Figure 9 which shows a linear visibility-legibility relationship for all other signs tested. However, the visibility of the prismatic reflector sign is proportionately greater than its legibility. This characteristic is attributable to the good visibility of the large arrow displayed on the sign.

The visibility and legibility distances are apparently of great value in evaluating performance characteristics of signs. However, there are a number of other factors to be considered in making a practical selection of a type of sign for marking channelization. The first and primary consideration should be continuity of service. All of the illuminated signs, especially the internally illuminated sign, depend on electrical power and consequently are subject to power failures and bulb or tube malfunctions. As an illustration of this effect, preliminary observations of the signs showed that the visibility distance of the internally illuminated sign was less than 100 ft when power was discontinued. This would indicate no serviceability in the event of power failure.

TABLE 6

SIGN VISIBILITY TESTS: MEAN VISIBILITY DISTANCES

Driver	Sign Number								Avg.
	1	2	3	4	5	6	7	8	
1	280	425	530	635	325	505	480	490	459
2	290	400	455	585	305	435	425	390	411
3	260	345	385	440	270	365	355	345	346
4	230	305	335	450	220	330	320	325	314
Avg.	265	369	426	528	280	409	395	388	382
1[1]	265	380	430	558	288	408	398	398	
2[1]	265	358	422	498	272	410	392	378	

[1]Replication.

A second consideration in the selection of a sign is its contrast with the physical characteristics of the area. In urban or developed areas, there are numerous illuminated advertisements and street lights which reduce the target value of any sign. The internally illuminated sign could be greatly affected because it is quite similar to these foreign light sources. Consideration should be given to the conditions surrounding the site, and to the resulting requirements for visibility and legibility. A final consideration, but by no means least, is the comparative cost of installation, replacement, operation and maintenance of signs.

EFFECT OF CHANNELIZATION ON DRIVER BEHAVIOR

Description of Study

The primary reason for introducing channelization into a roadway is to segregate traffic into more orderly movement. If this is accomplished, the capacity and safety of the facility are increased. On the other hand, the introduction of channelization almost invariably places a physical barrier in the path of the traffic stream. Therefore, considerable dependence is placed on signing and delineation to alert the driver to the physical barrier and guide him comfortably and safely around the island.

Studies were conducted to determine the effect of introducing channelization with normal signing and delineation on driver behavior—more specifically, his tension or emotional level and speed of operation. Additional studies were conducted to evaluate the effect of special techniques of approach-end treatment on driver behavior.

A highway intersection scheduled for channelization was selected, and studies of traffic operation and driver behavior were conducted after each of three stages of installation. The stages of development were:

1. No Channelization.—The section of roadway to be channelized was 28 ft wide; 8-ft paved shoulders were provided.

2. Divisional Island Channelization.—A divisional island was installed to provide a protected left-turn lane (Fig. 10). The approach-end was tapered 8 ft in 150 ft; the island was 12 ft at the widest point. The approach-end treatment was a standard KEEP RIGHT sign mounted near the nose of the island and barrier-type curbs coated with yellow paint and reflectorized with glass beads.

3. Divisional Island Channelization with Special Approach-End Treatment.—The geometrics of the island remained unchanged. The special approach-end treatment was based on the results of previous research on delineation, and other channelizing techniques.

(a) A delineation line conforming to a 1^0 curve was installed beginning approximately 400 ft before the island nose and continuing to the widest point of the

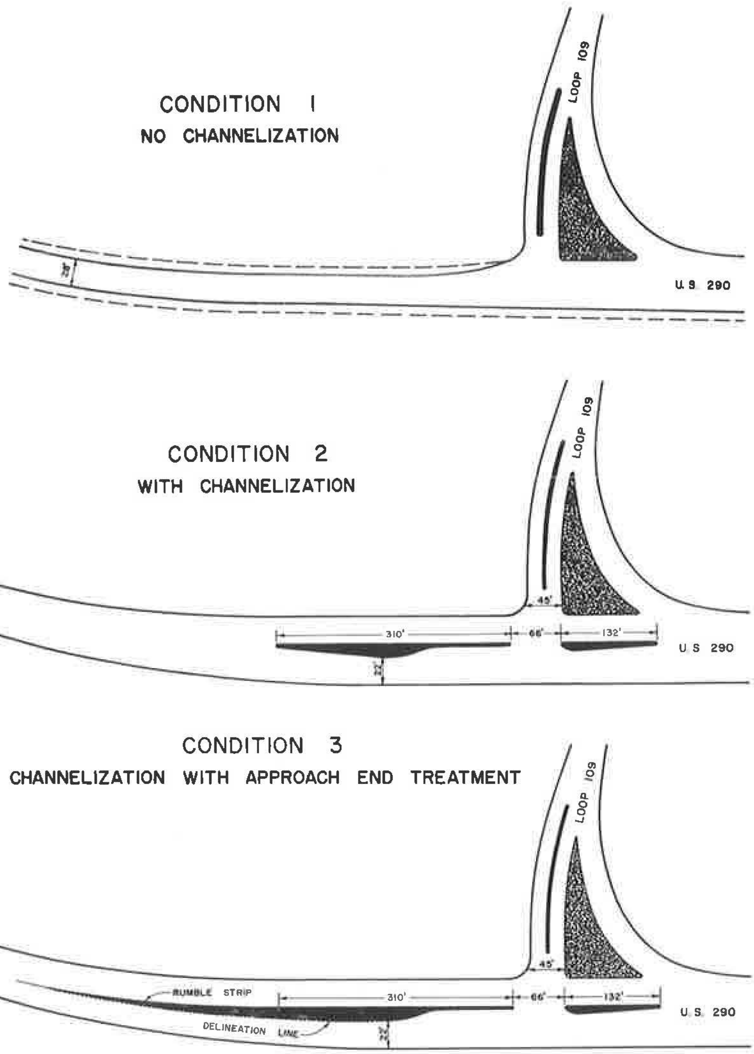

Figure 10. Three stages of channelization.

channelizing island (Fig. 10). This line consisted of 4-in. diameter, button-type lane markers spaced at 3-ft intervals. Two types of markers were used alternately: white reflectorized markers for nighttime visibility and yellow non-reflectorized markers for daytime visibility. The line's purpose was to provide advance warning of the channelization island and outline a smooth transition path around the island.

(b) As a supplement, a rumble strip was installed to provide an audible warning to the driver encroaching on the area between the delineation line and the actual channelizing island. The rumble strip consisted of a surface treatment using $\frac{5}{8}$-in. light-colored aggregate.

(c) Prismatic reflectors, $\frac{7}{8}$ in. in diameter, were installed on the island curb to delineate the physical barrier. Reflectors were spaced at 25-ft intervals and aimed in the direction of oncoming traffic.

Study Methods.—Two study techniques were used to obtain data on driver behavior and traffic operation. The test car method measured driver tension responses and

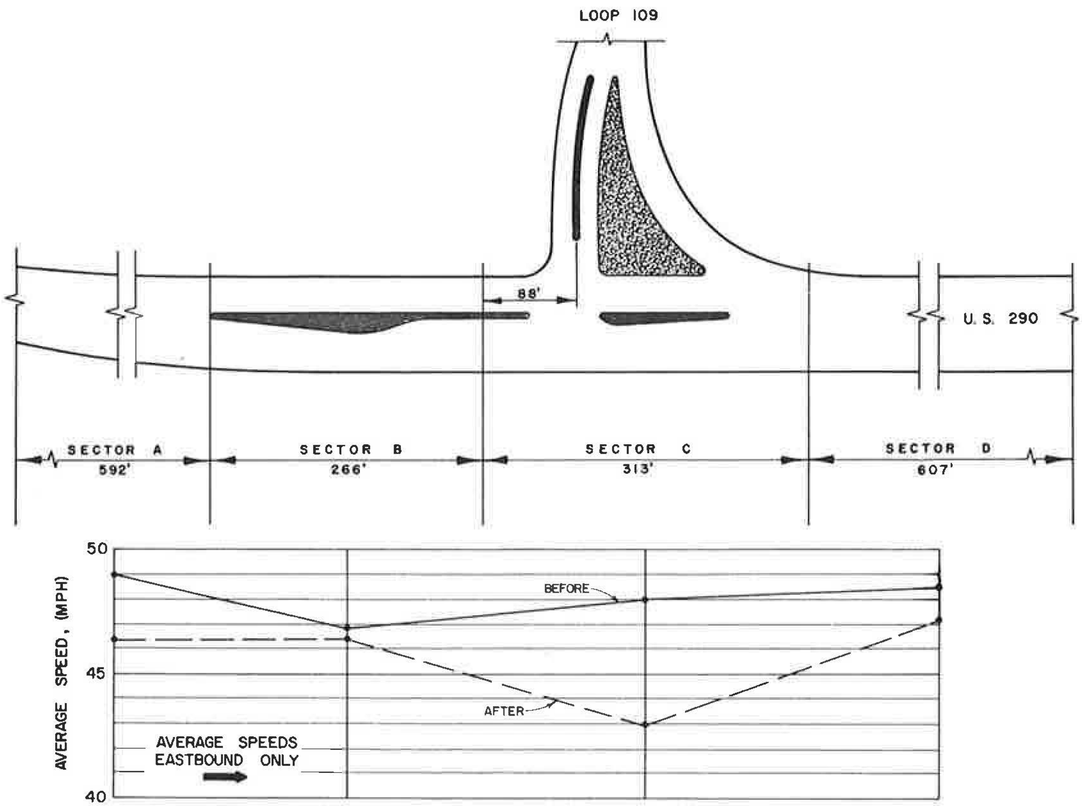

Figure 11. Individual vehicle speed study.

speeds of selected drivers operating a test car in a series of trips through the study area. The individual vehicle-speed study method measured speeds of individual vehicles through several sections of roadway, including the channelized section.

Study Procedures.—Test Car Method—The test car was equipped with a Galvanic Skin Response (GSR) dermograph (1) to measure and record driver tension responses as the drivers traveled through the study area. The test car was also equipped with a recording speedometer to provide a continuous record of vehicle speed.

Four drivers were selected to drive the test car through the study section four times each as a through vehicle and four times as a left-turning vehicle. These drivers, all male college students, were young and experienced. None of the drivers were especially familiar with the study section, and they were not aware of the geometric conditions that existed at the study site before the tests were begun for each condition.

Individual Vehicle Speed Study Method (2)—Studies were conducted to evaluate any differences in the speed characteristics of the vehicles in the normal traffic stream before and after the installation of channelization. The study section was divided into four separate control sections or sectors (Fig. 11). An event recorder actuated by road tubes measured the time required for each vehicle to drive the length of each of the designated sectors. The average speeds for each sector were calculated from the time intervals.

Discussion of Results

GSR Study.—To evaluate differences in driver behavior for each of the three conditions of channelization, the GSR responses occurring in the section extending from the center of the intersection to a point 1,000 ft in advance of the intersection were selected

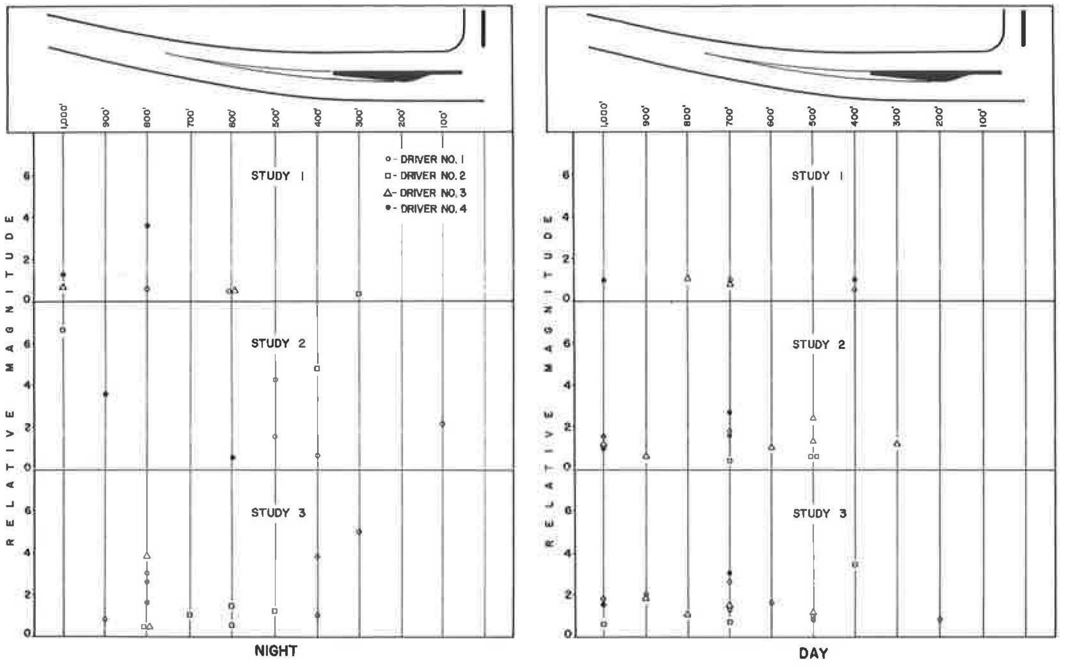

Figure 12. GSR tension responses, through vehicle runs.

for a comparative analysis. The GSR responses of all drivers were examined on the basis of total frequency and total magnitude to determine any differences in driver behavior.

The results of the GSR studies (Fig. 12) indicate a relatively small number of tension responses in all of the studies for both day and night. The number of responses per study ranged from 6 for Study 1 (no channelization-day) to 17 for Study 3 (channelization with special approach-end treatment). These responses were observed during four runs made by four drivers, or a total of 16 runs for each study. Also, two drivers were more responsive than the other two and contributed approximately 65 percent of the responses. In view of the relatively small number of responses and the existent variability in drivers, it was felt that comparisons should not be interpreted as definite conclusions, but only as general indicators of driver behavior.

A greater number of responses were recorded in Study 3 for both day and night runs (Fig. 12). These responses were distributed along the general area of the delineation line but showed a greater concentration at a point 800 ft from the intersection, corresponding to the beginning of the delineation line. These patterns and the increased number of responses indicate that the special approach-end treatment did serve to forewarn the driver of the introduced channelization and the intersection ahead.

Test Car Speed Profiles.—No meaningful comparison could be made of test car speed profiles because of the great variation.

Individual Vehicle Speed Study.—The speeds observed for the before and after conditions of channelization are shown comparatively in Figure 13 for the eastbound direction only. Statistical tests showed significant differences in the mean or average speeds in sectors A and C but not in sectors B and D (Fig. 11). The difference observed in sector A indicated that channelization and the special approach-end treatment caused traffic to reduce speed at a greater distance from the intersection. The speed reduction in sector C indicated that drivers were made more aware of the potential hazard at the intersection and did not return to normal speed until they were clear of the channelized section. Before channelization was installed, the drivers returned to normal speed

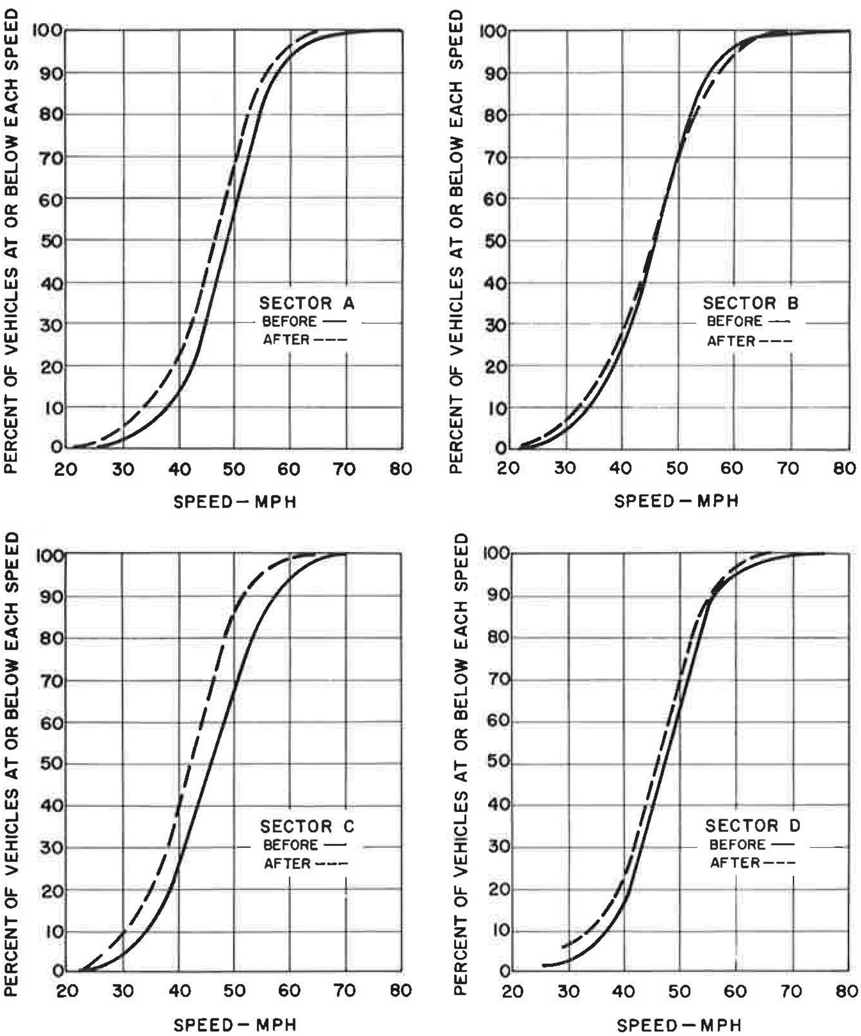

Figure 13. Speed distribution curves for before and after conditions of channelization.

immediately after clearing the intersection. According to these results, channelization has, in effect, extended the intersection area to the limits of channelization and increased its significance.

Evaluation of the Approach-End Treatment

Delineation Line.—The design of the delineation line was intended to provide a natural path around the channelizing island. To establish its effectiveness in providing a smooth transition around the channelizing island, general observations were made of the placement of 382 vehicles classified as (a) vehicles that encroached on the delineation line; (b) vehicles that approached but did not encroach; and (c) vehicles that remained approximately the same distance from the line throughout its length.

The results showed that 28.5 percent of the observed vehicles changed their placement with respect to the delineation line and 8.1 percent of these actually encroached. However, only a few of those encroaching remained on the line any length of time due to the noise produced when the tires struck the buttons. No vehicles were in any danger of striking the island at any time.

CONDITION I - NO CHANNELIZATION

CONDITION 2 - CHANNELIZATION

CONDITION 3 - DELINEATION LINE

CONDITION 3 - RUMBLE STRIP

CONDITION 3
NIGHT VIEW OF
DELINEATION LINE

Figure 14. Views of Elgin Study.

Although the delineation line did accomplish its purpose of guiding traffic around the island, it apparently did not provide a completely natural path as indicated by the high percentage of vehicles changing their placement with respect to the line. It is possible that a smaller degree of curvature, a spiral curve, or a tangent section would have provided a more natural path.

Rumble Strip.—The $^5/_8$-in. aggregate did not produce the desired noise level, especially at lower speeds. Also, the color contrast provided by natural aggregate colors was not satisfactory.

Curb Delineation.—The island curb delineation provided by the prismatic reflectors was considered to be very effective. Figure 14 shows the relative brightness produced by the delineators.

SUMMARY OF FINDINGS

Because the total number of GSR tension responses observed in the driver behavior study was low, the results of that portion of the research were interpreted as general indications rather than definite conclusions. The results of the studies of driver behavior and traffic speeds in a channelized area are summarized as follows:

1. Both conditions (2 and 3) of channelization indicated an influence on driver behavior by an increase in tension responses at night. These tension responses were considered as indications that the drivers were responsive to the warning produced by the channelization.
2. The special approach-end treatment (condition 3) produced greater tension responses than either of the other two conditions, particularly at a point 800 ft in advance of the intersection. This point was coincidental with the beginning of the special approach-end treatment.
3. The installation of channelization with an adequate approach-end treatment caused drivers of the normal traffic stream to reduce speed at a greater distance before the intersection than where the channelization was not present. Also, drivers did not begin to accelerate until they had cleared the channelized area, whereas under unchannelized conditions, they began to accelerate immediately on passing the intersection.

CONCLUSIONS

The following conclusions were drawn from the results of this research:

1. In the tests conducted under controlled conditions, the prismatic reflectors exhibited excellent visibility characteristics and were far superior to curb coating-type materials in delineating channelizing island curbs.
2. The prismatic reflectors performed satisfactorily as curb delineators under actual traffic conditions in rural areas. However, in some urban areas the efficiency of the reflectors was substantially reduced by splash or road film. The reduction in efficiency occurred in the approach-end taper section where the roadway was not well drained and high traffic volumes passed very close to the reflectors.
3. In the tests of KEEP RIGHT signs, the internally illuminated sign provided greater visibility and legibility distances than all other signs tested. However, much of this superiority must be attributed to the fact that the sign legend was composed of 7-in. letters and only 4-in. letters were used on the prismatic reflector sign and 5-in. letters on all others.
4. The prismatic reflector type, externally illuminated, and the reflective sheeting type signs provided good visibility and legibility characteristics. When compared to the internally illuminated sign, they had relative visibilities of 80 percent to 70 percent, respectively.
5. The introduction of channelization with special approach-end treatment caused traffic to reduce speed at a greater distance from the intersection and continue at a reduced speed through the channelized section. A further reduction in speed in the immediate intersection area indicated that the channelization increased the significance or importance of the intersection.

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