Overhead Signs Without External Illumination

Donald L. Woods and Neilon J. Rowan, Texas Transportation Institute

The basic objective of this research was the evaluation of high-intensity reflective sheeting for use on overhead sign installations without external illumination. The effects of height above the roadway and angle of sign tilt with respect to the vertical, headlight configuration, and vehicle approach speed to sign legibility distance were measured for both an externally illuminated sign and a high-intensity reflective sheeting sign. It was concluded that the nighttime legibility distance of overhead signs was not appreciably affected by increases in mounting height in the range of 5.5 to 7.0 m (18 to 23 ft), by changes in angle of the sign with respect to the vertical in the range of -5 to +5 deg, or by vehicle approach speed. Headlight configuration, as expected, was the dominant factor in the legibility distance of the unilluminated high-intensity sign. Further, the high-intensity sheeting can be used without external illumination for overhead sign installations in spite of the observed difference in legibility distances. The average legibility distance is 19 percent less with low beams and 5 percent more with high beams on the high-intensity sheeting without external illumination than on the standard installation without illumination.

Providing the necessary information to keep the driver fully informed regarding the geometric conditions and required maneuvers is the goal of every traffic operation engineer. Often, the information is located above the roadway to permit the proper association of the sign message with the geometric condition and to place a critical message in the direct line of sight of the driver. Usually, overhead sign installations are externally illuminated to be effective. The installation to get power to the site, the amount of power required, and the routine maintenance are costly. The lack of information at night due to a power failure or lamp outage is an additional problem.

A recently developed reflective sheeting, commonly referred to as high-intensity sheeting, shows considerable promise for use on overhead signs without external illumination. Field installations using this product indicate satisfactory performance and a high degree of public acceptance. There are some indications that the legibility distance is less for sign installations with high-intensity sheeting than for those with externally illuminated flat-top sheeting. This project was undertaken to evaluate the degree of legibility distance reduction and to study the effects of several design parameters on the legibility of overhead signs.

STUDY OBJECTIVES

This study compared the legibility characteristics during nighttime conditions for two overhead signs constructed of different materials. One sign used a kelly green flat-top (enclosed-lens) reflective-sheeting background with letters fabricated in accordance with overhead guide sign standards used by the Texas State Department of Highways and Public Transportation. This sign was externally illuminated and had white, 40.6-cm (16-in), series E letters arranged in accordance with Texas State Department of Highways and Public Transportation spacing standards.

The legibility distance for this assembly was compared to a similar sign constructed of high-intensity (encapsulated-lens) reflective sheeting. Both the green background and silver letters were of the high-intensity material. In this case, no external illumination was provided. Letter height and stroke were the same for both signs. Letter spacings conformed with those recommended by the Institute of Traffic Engineers. Specific research objectives are outlined as follows:

1. To compare legibility distances using the two signs described above, and
2. To investigate some of the effects on legibility distance associated with angle of sign tilt with respect to the vertical and mounting height of sign.

EXPERIMENTAL DESIGN

The qualitative variables included in the study were sign material (2) and headlight configuration (2). The quantitative variables were

1. X_1 = sign mounting height, 5.6, 6.2, and 6.8 m (18.5, 20.5, and 22.5 ft),
2. X_2 = angle of tilt, -5, 0, and +5 deg, and

Publication of this paper sponsored by Committee on Visibility.

3. X_3 = approach speed, 56, 72, and 89 km/h (35, 45, and 55 mph).

A full factorial design that involves measurement of all combinations of variables (2 × 2 × 3 × 3 × 3) would require 108 observations. To reduce the number of observations needed and make inferences concerning the statistical reliability of the findings, a composite experimental design was recommended by Hartley (1) and was chosen for the study. Hartley (1) gives a detailed description of the principles involved in the experimental design.

The desired response for this experiment is legibility distance (Y). To use the composite design method, the response variable is fitted to a second order law consisting of coefficients (B or Beta) in combination with qualitative input variables (X_1, X_2, and X_3). The equation for legibility distance is defined as follows:

$$Y = B_0 + \sum_{i=1}^{n} B_i X_i + \sum_{i=1}^{n} B_{ii} X_i^2 + \sum_{i<j}^{n} B_{ij} X_i X_j \qquad (1)$$

The composite design is a combination of the star and fractional factorial designs. The schedule of observations for the star design section is

X_1	X_2	X_3	X_1	X_2	X_3
0	0	0	0	1	0
-1	0	0	0	0	-1
1	0	0	0	0	1
0	-1	0			

where

-1 = lowest level of measurement,
0 = intermediate level, and
+1 = upper or highest level of measurement.

The number of response surfaces equals the product of the number of qualitative variables (2 × 2 = 4). For each of the 4 combinations of the 2 sign materials with the 2 headlight configurations, a separate response relationship to the quantitative variables is computed (X_1, X_2, and X_3). Accordingly, 28 tests (4 × 7) are required by the star design.

The fractional factorial design section is combinations of the extreme values in the star design section. The schedule of observations for the fractional design section is

X_1	X_2	X_3	X_1	X_2	X_3
1	-1	-1	-1	-1	1
-1	1	-1	1	1	1

A total of 16 tests (4 × 4) is required for this part of the experiment.

When the tests from the two sections are combined (28 + 16), the total number of tests for the composite design is 44. To gain greater reliability for the results obtained, a complete replication of the extreme ends of the star design is desirable. This amounts to an additional 24 tests, or a total of 68 tests in all.

For purposes of reproducibility, more than one test subject was recommended to obtain the legibility distance measurements. This is not only important for statistical reliability, but it also reduces the problems of fatigue and becoming overly familiar with the testing sequence. Accordingly, three test subjects were chosen for the study.

METHOD OF STUDY

Whenever human response is involved, it is desirable to test in an environment that matches the actual situation as closely as possible. Care must also be exercised to prevent the test subject from being influenced by factors other than those being tested. Every effort was made to have this research conform to the normal driving task and to ensure that only the variables being studied were influential on the outcome.

This research was conducted at the highway test facilities of the Texas A&M University Research Annex. A 914.4-m (3000-ft) test road section was striped for a 3.8-m (12.5-ft) traffic lane approaching an overhead sign structure. The approach, with 0 percent grade, gave the appearance of a highway traffic lane with an overhead sign centered in the distance. No abnormal conditions were visible to the driver. Figure 1 is a diagram of the test assembly.

To measure the effects of mounting height and angle of tilt, the test sign backgrounds were mounted on specially designed supports. These supports were prefabricated so that manual adjustments could be made in short time intervals. The test vehicle was a 1969 Plymouth, four-door sedan, equipped with automatic transmission and a manual steering mechanism. Each subject served as the vehicle operator and was assigned a given approach speed and headlight configuration to maintain throughout the test. The subject responded by reading the word presented on the sign at the moment the legend was understood. In case the word was misread, the subject was instructed to follow through and correct his reading accordingly.

Legibility distances were recorded by an experimenter in the test vehicle. For measurement purposes, an event recorder was attached to a mechanism on the vehicle that automatically recorded an event mark every 17.3 m (56.8 ft). Manual event record marks were placed on the tape at the time the subject read the message and again at the sign structure. Distances were measured on the strip chart from the mark where the sign was read to the mark associated with the sign structure.

Three young male subjects with equal static visual acuities of 20/13 were used. The visual acuity for each subject was measured at 4.2 cd/m^2 (14.5 ft-L) of background brightness, and none of the subjects showed signs of night sight defects or other abnormal visual problems. A series of tests for constant mounting heights was conducted for each of the three nights. The test subjects were rotated in order, and the sequence of legends was preassigned on a random basis for each subject.

ANALYSIS OF DATA

The legibility study was designed so that any analysis of variance and of regression could be used to determine the statistical significance of the coefficients of the variables tested and their interactions. Analysis of variance principles included in most statistical references will not be discussed in great detail in this paper.

Briefly, the purpose of the statistical analysis is to estimate the effect of all quantitative and qualitative variables on the legibility distance. More specifically, these statistical estimates are based on (a) analysis of regression (for the effective coefficients, B_0, B_i, and B_{ij}, of the quantitative variables) and (b) analysis of variance (for the qualitative variables). All experimental variables were assumed to remain fixed and were predetermined to satisfy the normal range of actual applications.

The data collected were tabulated and arranged in a manner suitable for analysis of variance. A computer regression program was used to analyze the statistical significance of the data and to determine coefficients for the regression equation previously mentioned. Tabular and graphical methods for representation of the test results were selected for presentation and analysis purposes.

DISCUSSION OF RESULTS

Before proceeding with a detailed description and analysis of study objectives, we should clarify the concept of word legibility as opposed to legibility of individual letters comprising the words.

Individuals have a tendency to recognize groupings of letters or words without reading each letter involved. In addition, some common groupings are more easily recognizable than others. Research in the area of word legibility is somewhat limited to date and, therefore, must be treated to some extent before proper inferences can be made concerning the findings of this study. Words used for test purposes were selected from previous studies by Forbes (2) and Allen (3). In these studies, words were grouped according to differences in relative legibility of the letters that comprise them.

It was suggested by members of the Texas Transportation Institute staff and later became apparent that different words result in different legibility distances. To estimate the differences in legibility associated with the words used in this study, an indexing procedure was formulated as given in Table 1. Legibility distance measurements were obtained from three subjects (not the same three used in the basic legibility studies) who approached the overhead sign at very low speed under daylight conditions. Their observations were averaged, and the word that was the most legible at the average legibility distance was used as the base value and assigned an index of 1.00. The index for all other words was computed by dividing average legibility distance of each word by the average legibility distance of the most legible word. These indexes were then used to adjust the observed legibility distances from the basic study so that the comparison of the two signs would be on a common basis. It would have been desirable to use words of relatively common legibility; however, data are not readily available in the literature. Therefore, the selection of the words based on the legibility of the individual letters appeared to be a reasonable alternative. As given in Table 1, as much as 26 percent variation in the legibility distance could be associated with the difference in words, and it is apparent that letters of similar legibility do not combine to form words of similar legibility. The variability among words is greater than the expected variability among the other parameters studied.

Measured response distances for the variables tested are given in Tables 2, 3, 4, and 5. In view of the preceding observations concerning word indexes, the observed legibility distances (Y) were adjusted to the values indicated in the last column of Tables 2 through 5. These adjusted figures were used for analysis purposes, since it is believed that they permit a more accurate assessment of the effect of the quantitative and qualitative variables with which this study is concerned.

Analysis of variance summaries and calculated correlation values were obtained as previously described. From these tabulations, the statistical significance of variables tested and their interactions were determined by using the t-statistic at the 0.100 level. Inspection of these summaries revealed that none of the variables was significant at the 0.100 level. The multiple R-square (correlation value) associated with the four test conditions ranged from a low of 0.28 for the high-intensity sign with high beams to a high of 0.49 for the kelly green sign with low beams. The multiple R-square values measured the strength of the linear relation exhibited by the test results; for predictive purposes, the values should be a minimum of 0.80 to 0.85. Since correlation results were low, the data recorded by these tests do not lend themselves to regression by the second order equation or response surface previously described. This does not suggest that anything is faulty with the data or the regression model; however, no acceptable fit could be obtained by using this model.

The analysis of variance indicated that none of the quantitative variables was significant. However, the specific effects of the variables tested, descriptions of each, and their interactions with other variables are given in the following paragraphs.

Effects of Headlights

Since headlight configurations were defined as qualitative variables, they were not analyzed for statistical significance by the analysis of variance and regression operations. However, the headlight effects on the test outcome for both sign materials are shown in Figure 2. A sizable reduction in the relative legibility distance occurred for high- and low-beam configurations for the high-intensity sign. In comparison, the kelly green sign showed little variation in legibility distance for the two headlight configurations. The results can be explained by the characteristics of the signs and their reflectance qualities. The high-intensity sign is completely dependent on the vehicle headlight source, whereas the kelly green sign is provided with a constant external light source.

Effects of Mounting Height

The effects of mounting height on sign legibility distances are presented in Figure 3. The height measurements extended from ground level to the bottom of the sign panel. Since the legends were placed near the center of the signs, the sign was mounted an additional 0.9 m (3 ft) so the driver could read the bottom of the letters. When mounting heights were changed, a somewhat greater variation in legibility distance occurred for the kelly green sign than for the high-intensity sign. However, the analysis of variance revealed that mounting height was not a significant variable within the range of mounting heights studied. Observations during the field studies indicated that there is little change in legibility when signs are lowered or raised within the limits tested. In most cases, a higher range of heights is more desirable for highway clearance purposes. However, higher mountings can result in certain adverse effects and create the need for stronger supports.

Effects of Angle of Tilt

The effects of tilting the sign with respect to the vertical are shown in Figure 4. Between tilt angles of -5 and +5 deg, the kelly green sign appears to have a somewhat larger degree of variation. Since the external light source on this sign remained constant for the three angles tested, reflectance could have been influential. By changing the angles of incident and the reflectance for headlight illumination, the sign brightness would change as the vehicle approaches the sign. After these variables were adjusted for both the high-intensity sign and the kelly green sign, the variability of the legibility distances was relatively small. Angles of tilt within the range tested do not appear to offer significant effects.

Figure 1. Schematic diagram of test arrangement.

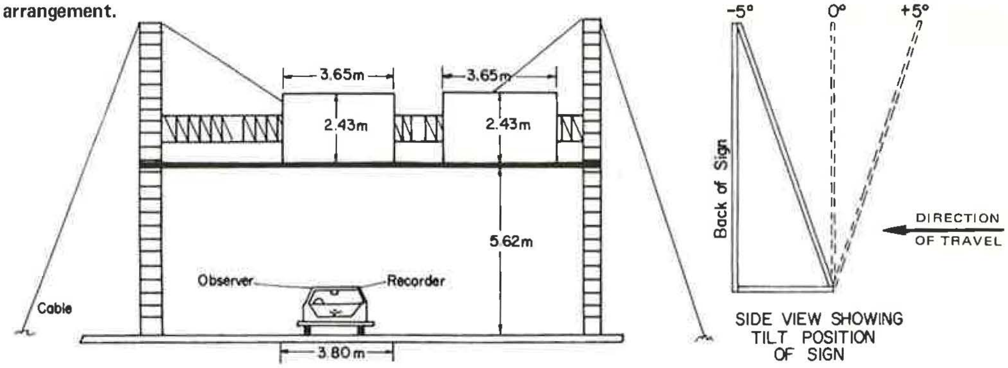


Table 1. Relative legibility of words.

Test	Sign	Legend	Legibility Distance (m) Subject 1	Subject 2	Subject 3	Average	Word Index
1	HI	REAR	235	354	290	293	0.75
2	HI	STAY	322	361	354	345	0.88
3	KG	CITY	360	385	427	390	1.0
4	HI	ROAD	NA	NA	NA	NA	NA
5	KG	BOOK	278	338	305	307	0.79
6	KG	BOAT	303	303	337	314	0.81
7	KG	ROAD	302	355	363	340	0.87
8	HI	GONE	286	329	306	307	0.79
9	HI	SAME	239	287	335	287	0.74
10	KG	CLAY	328	384	425	379	0.97
11	HI	COME	277	321	323	307	0.79
12	KG	ROCK	306	334	335	325	0.83

Note: 1 m = 3.28 ft.

Table 2. Summary of night sign legibility tests for externally illuminated kelly green sign with low beams.

		Quantitative Factor			Legibility Distance Factor		
Test	Legend	Height (m)	Tilt (deg)	Speed (km/h)	Word Index	Observed (m)	Adjusted (m)
1	CLAY	6.3	0	72	0.98	347	354
2	BOOK	6.3	-5	72	0.79	265	335
3	ROAD	6.3	-5	72	0.88	448	509
4	BOAT	6.3	+5	72	0.80	277	346
5	CLAY	6.3	+5	72	0.98	360	367
6	ROCK	6.3	0	56	0.84	424	505
7	CLAY	6.3	0	56	0.98	338	345
8	CITY	6.3	0	89	1.00	283	283
9	CITY	6.3	0	89	1.00	478	478
10	CITY	5.6	0	72	1.00	427	427
11	ROCK	5.6	0	72	0.84	360	429
12	ROCK	5.6	+5	56	0.84	491	584
13	BOOK	5.6	-5	89	0.79	320	405
14	BOOK	6.9	0	72	0.79	375	475
15	BOOK	6.9	0	72	0.79	293	370
16	ROAD	6.9	-5	56	0.88	375	426
17	ROAD	6.9	+5	89	0.88	439	499

Note: 1 m = 3.28 ft and 1 km/h = 0.622 mph.

Table 3. Summary of night sign legibility tests for externally illuminated kelly green sign with high beams.

		Quantitative Factor			Legibility Distance Factor		
Test	Legend	Height (m)	Tilt (deg)	Speed (km/h)	Word Index	Observed (m)	Adjusted (m)
1	CLAY	6.3	0	72	0.98	479	489
2	ROAD	6.3	-5	72	0.88	293	333
3	ROAD	6.3	-5	72	0.88	323	367
4	BOAT	6.3	+5	72	0.80	421	526
5	ROCK	6.3	+5	72	0.84	252	300
6	BOAT	6.3	0	56	0.80	335	419
7	CLAY	6.3	0	56	0.98	479	489
8	CITY	6.3	0	89	1.00	372	372
9	BOOK	6.3	0	89	0.79	351	444
10	CITY	5.6	0	72	1.00	466	466
11	ROCK	5.6	0	72	0.84	341	406
12	CITY	5.6	+5	56	1.00	396	396
13	BOOK	5.6	-5	89	0.79	427	541
14	ROCK	6.9	0	72	0.84	302	360
15	BOAT	6.9	0	72	0.80	475	594
16	ROAD	6.9	-5	56	0.88	326	370
17	CLAY	6.9	+5	89	0.98	369	377

Note: 1 m = 3.28 ft and 1 km/h = 0.622 mph.

Table 4. Summary of night sign legibility tests for high-intensity sign with low beams.

		Quantitative Factor			Legibility Distance Factor		
Test	Legend	Height (m)	Tilt (deg)	Speed (km/h)	Word Index	Observed (m)	Adjusted (m)
1	ROAD	6.3	0	72	0.83	366	441
2	COME	6.3	-5	72	0.79	213	270
3	ROAD	6.3	-5	72	0.83	268	323
4	STAY	6.3	+5	72	0.89	399	448
5	SAME	6.3	+5	72	0.73	180	247
6	GONE	6.3	0	56	0.81	283	344
7	REAR	6.3	0	56	0.75	299	399
8	ROAD	6.3	0	89	0.83	232	280
9	STAY	6.3	0	89	0.89	290	326
10	REAR	5.6	0	72	0.75	265	353
11	GONE	5.6	0	72	0.81	204	252
12	REAR	5.6	+5	56	0.75	207	276
13	SAME	5.6	-5	89	0.73	296	405
14	COME	6.9	0	72	0.79	244	309
15	COME	6.9	0	72	0.79	347	439
16	REAR	6.9	-5	56	0.75	232	309
17	ROAD	6.9	+5	89	0.83	305	367

Note: 1 m = 3.28 ft and 1 km/h = 0.622 mph.

Table 5. Summary of night sign legibility tests for high-intensity sign with high beams.

		Quantitative Factor			Legibility Distance Factor		
Test	Legend	Height (m)	Tilt (deg)	Speed (km/h)	Word Index	Observed (m)	Adjusted (m)
1	COME	6.3	0	45	0.79	335	424
2	COME	6.3	-5	45	0.79	454	575
3	ROAD	6.3	-5	72	0.83	238	287
4	SAME	6.3	+5	72	0.73	341	467
5	GONE	6.3	+5	72	0.81	341	421
6	STAY	6.3	0	56	0.89	253	284
7	REAR	6.3	0	56	0.75	384	512
8	SAME	6.3	0	89	0.73	451	618
9	GONE	6.3	0	89	0.81	308	380
10	ROAD	5.6	0	72	0.83	430	518
11	GONE	5.6	0	72	0.81	448	553
12	REAR	5.6	+5	56	0.75	341	455
13	COME	6.9	-5	89	0.89	323	363
14	COME	6.9	0	72	0.79	350	443
15	SAME	6.9	0	72	0.73	277	379
16	STAY	6.9	-5	56	0.89	448	503
17	ROAD	6.9	+5	89	0.83	338	407

Note: 1 m = 3.28 ft and 1 km/h = 0.622 mph.

Figure 2. Effects of headlight on legibility.

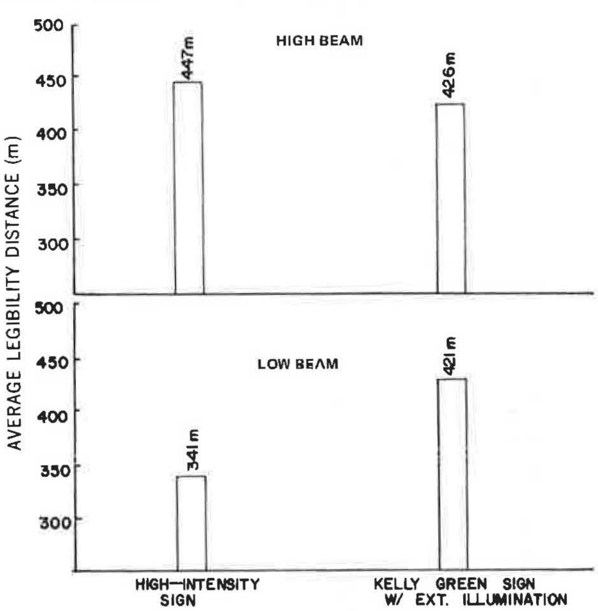


Figure 3. Effects of mounting height on legibility.

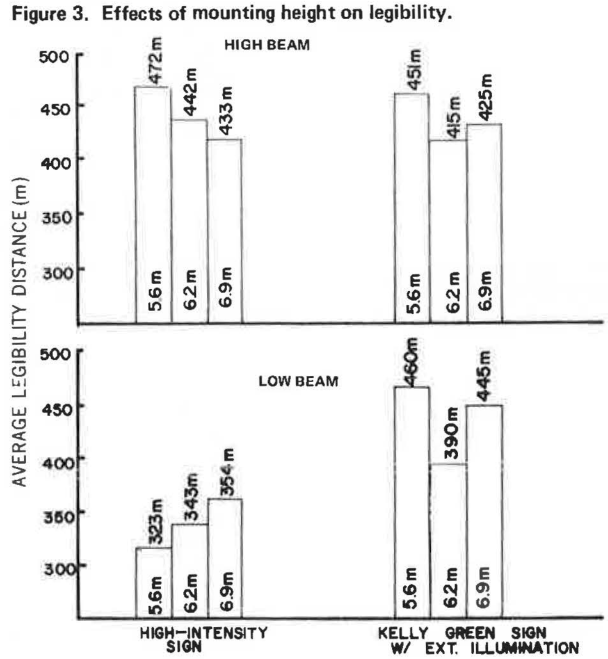


Figure 4. Effects of angle of tilt on legibility.

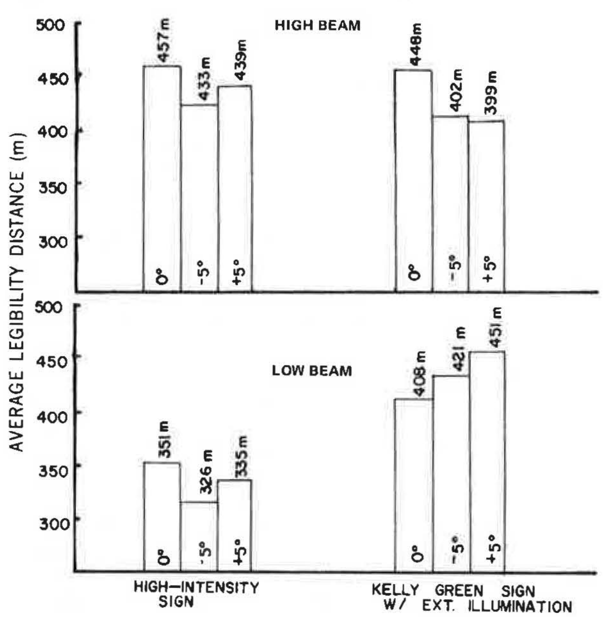
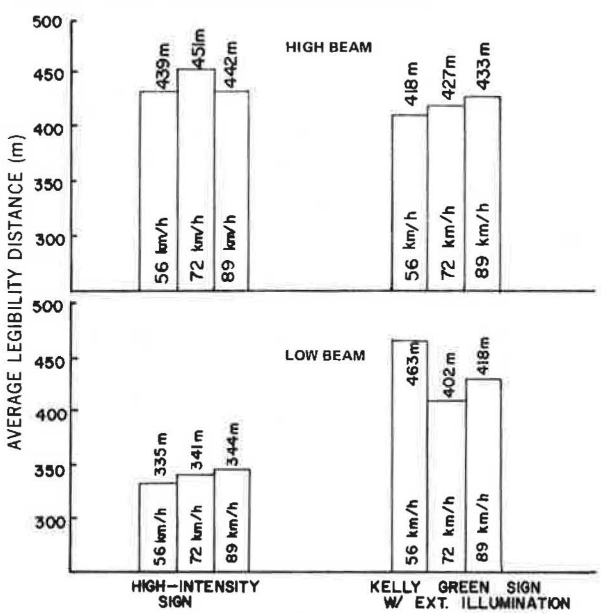


Figure 5. Effects of approach speed on legibility.



Effects of Approach Speed

Approach speed showed little effect on legibility distance. Figure 5 shows the average legibility distances recorded during this series of tests for the three approach speed levels involved, 56, 72, and 89 km/h (35, 45, and 55 mph). The results are substantiated by the fact that drivers tend to recognize words and not individual letters and that the time involved for recognition purposes is small. In fact, as many as three small words can be read at a single glance (5). Accordingly, the speed within the range specified and the driver's fast perception time account for little change in legibility distance.

STATISTICAL COMPARISON OF LEGIBILITY DISTANCES

One of the primary purposes of this study was to determine how the two types of signs compare from a legibility standpoint; therefore, a statistical analysis is needed to draw final conclusions. The mean legibility distances shown in Figure 2 were statistically compared by using an average value determined from all grouped data for each respective sign material. The difference between two means when the standard deviations are unknown but assumed to be equal can be tested by using the t-statistic (4). The equation for the t-statistic is

$$t = (\bar{Y}_1 - \bar{Y}_2)/S_p\sqrt{(1/N_1) + (1/N_2)} \quad (2)$$

where

$\bar{Y}_1$ and $\bar{Y}_2$ = mean legibility distances afforded by the kelly green sign and the high-intensity sign respectively,
N_1 and N_2 = number of observations conducted on the kelly green sign and the high-intensity sign respectively, and
S_p = pooled standard deviation for each set determined by

$$S_p^2 = \sum_{i=1}^{2} V_i S_i^2 \Big/ \sum_{i=1}^{2} V_i \quad (3)$$

where

V_i = degrees of freedom of the ith date set, and
S_i^2 = variance of legibility distances for each respective sign and headlight configuration.

To use this method of analysis, it is necessary to ascertain that the standard deviations of the compared signs are equal. This is accomplished by using the F-test, which is a test of variance but can also be used to test standard deviations. The ratio of the two variances is compared with an F-distribution chart by using a predetermined confidence limit. A 95 percent confidence limit was chosen; this limit is commonly used for studies of this type. The null hypothesis assumes that there are no significant differences in the variance for each data set and the pooled variance of the combined data.

The equation to determine if the variances are equal is

$$F_{MAX} = (MAX\ S^2/MIN\ S^2) = (14\,475.0/6778.3) = 2.135 \quad (4)$$

By using a 5 percent significance level the critical F-value is 8.44. Since the value of the test statistics is less than 8.44, there is no evidence that the variances are different for the four treatment groups.

The error mean squares for the analysis are presented below:

Sign	Headlight Beam	Variable	Error Mean Square
Kelly green	High	S_1^2	9 113.4
	Low	S_3^2	7 483.2
High intensity	High	S_2^2	14 475.0
	Low	S_4^2	6 778.3

The pooled variance of all four headlight and sign configurations is

$$S_p^2 = [7(9113.4) + 7(7483.2) + 7(14\,475.0) + 7(6778.3)]/28 = 26\,4949.3/28 = 9462.48 \quad (5)$$

The mean values of all data for each sign-headlight configuration are as follows:

Sign	Headlight Beam	Variable	Mean of Data (m)
Kelly green	High	$\bar{Y}_1$	426
	Low	$\bar{Y}_3$	421
High intensity	High	$\bar{Y}_2$	447
	Low	$\bar{Y}_4$	341

The averages for high and low beam are respectively 437 m (1433 ft) and 381 m (1249 ft).

The test to determine if there is a significant difference in the mean legibility distances for high-beam configuration is

$$t_1 = (\bar{Y}_1 - \bar{Y}_2)/S_p\sqrt{(1/N_1) + (1/N_2)} = (427 - 447)/97.27\sqrt{2/17} = -20/33.36 = -0.60 \quad (6)$$

The t-value (0.05) for 28 degrees of freedom is 2.05. Since the computed value (-0.60) is less than the tabulated value, there is no significant difference in the two sign materials under the high-beam headlight configuration (i.e., the null hypothesis is accepted).

The test for the low-beam configuration is

$$t_2 = (\bar{Y}_3 - \bar{Y}_4)/S_p\sqrt{2/N_p} = (421 - 341)/97.27\sqrt{2/17} = 80/33.36 = 2.40 \quad (7)$$

Since the t-value (0.05) for 28 degrees of freedom (2.05) is less than the computed value (2.40), the null hypothesis is rejected, and the significant difference between the two sign materials under the low-beam headlight configuration is indicated.

In summary, it appears that the high-intensity sign with high-beam legibility distance is not significantly greater in a statistical sense than the kelly green engineer-grade sign with external illumination, which is significantly less effective under the low-beam configuration. The differences are, however, small when compared to the magnitude of the observed legibility distance.

FINDINGS

The reduction in legibility distance under the low-beam and high-intensity sign configuration is undoubtedly cause for some concern. However, the legibility distance provided is sufficient to read a complex message. For example, a 345-m (1130-ft) legibility distance at 89 km/h (55 mph) provides 14 s of reading time at a visual acuity of 20/13. Even by adjusting to the 20/40 visual acuity, a 4.5-s reading time is provided. Considering that the target value of the high-intensity sign is high and thus prepares the driver to read the message, and considering that field installations have been relatively successful, it seems reasonable to conclude that high-intensity overhead sign installations without external illumination can be effectively used when the background brightness is not excessive and when the minimum direct line of sight to the sign installation is at least 450 m (1500 ft).

In support of this conclusion, the Louisiana Department of Highways in September 1975 issued a directive that overhead signs fabricated of high-intensity sheeting should not be externally illuminated. This decision was reached after a field test period of more than 3 years.

As a result of this study, the following conclusions can be made.

1. There is no substantial effect on legibility distance associated with increasing the height of overhead signs from 5.6 to 6.8 m (18.5 to 22.5 ft).
2. The angle of tilt of the sign with respect to the vertical, in the range of -5 to +5 deg, does not appear to affect substantially the legibility distance of overhead signs. A tilt of several degrees forward (top is farther forward than the base) would be desirable to reduce the problem of bird droppings marring the face of the sign.
3. Vehicle approach speed does not produce a significant effect on the legibility distance of overhead signs within the speed ranges tested.
4. The headlight configuration does not appreciably affect the legibility distance on the externally illuminated flat-top sheeting sign.
5. The legibility distance for the high-intensity sheeting installation is 24 percent less with low beams than with high beams.
6. The observed legibility distance is 19 percent less with low beams and 5 percent more with high beams on the high-intensity sheeting without external illumination than on the standard installation with external illumination. All legibility distances recorded (actual observed values) exceeded 179.3 m (590 ft), and this magnitude of change would not appreciably affect traffic operations.

REFERENCES

1. H. P. Hartley. Smallest Composite Designs for Quadratic Response Surfaces. Biometrics, Vol. 15, No. 4, Dec. 1959, pp. 611-624.
2. T. W. Forbes and R. R. Holmes. Legibility Distance of Highway Destination Signs in Relation to Letter Height, Letter Width, and Reflectorization. Proc., HRB, Vol. 19, 1939, pp. 321-255.
3. T. M. Allen. Night Legibility Distance of Highway Signs. HRB, Bulletin 191, 1958, pp. 33-40.
4. I. Miller and J. E. Freud. Probability and Statistics for Engineers. Prentice-Hall, Englewood Cliffs, N.J., 1965.
5. T. M. Matson, W. S. Smith, and F. W. Hurd. Traffic Engineering. McGraw-Hill, New York, 1955, pp. 312-319.