Indirect Factors Affecting Reflective Sign Brightness

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The effectiveness of traffic sign materials at night has been investigated in numerous studies and has resulted in recommended luminances for recognition and legibility. The importance of adequate sign luminance is of particular interest owing to threshold levels that must be satisfied for certain situations. In numerous field studies (1), we have noted unusual luminance enhancement during stream traffic when other vehicles are placed immediately ahead of or behind the driver. Under this circumstance, the contribution of other head lamps is easily measured, but vehicle spacing and head-lamp aim are usually unknown for all of the vehicles involved. Similar enhancement has been occasionally observed in rainfall.

DESIGN OF EXPERIMENT

The experiment simulated volumes of 300, 600, and 1500 vehicles/lane/h on a test road. All vehicles in all tests employ low-beam head lamps since common use of lower beams is well documented and is the rule with high volumes. Upper beams generally produce quite adequate sign luminance; however, lower beams on unlighted overhead guide signs provide only threshold values for legibility for single vehicles. Therefore, increases that may derive from a common operational circumstance would be very beneficial.

The test road is 670 m (2200 ft) long and was designed to represent a one-way tangent section of an Interstate highway. Measurements were made from five distances that ranged from 457 to 91 m (1500 to 300 ft). The road surface is made of a comparatively fine-textured asphaltic concrete. While single-vehicle sign luminance measurements were proceeding, unexpected rain produced a thoroughly wet road surface. A set of readings were taken under this condition, which approximated an estimated 25-mm/h (1-in/h) rate. The road surface condition and sign luminance readings were subsequently reproduced with a sprinkling truck.

Luminance measurements were made from a full-sized station wagon, which had untinted glass and was equipped with a telephotometer at the driver's eye position. The vehicle head lamps conformed to the Society of Automotive Engineers (SAE) recommended standard for photometrics and aim.

The sign materials studied are representative of silver-white retroreflective materials employed for traffic control signs. The materials used were as follows:

Material	Description	Illuminance (lx)	Angle (deg) Divergence	Angle (deg) Incidence
A	Encapsulated-lens reflective sheeting	2 691	0.2	-4
B	Enclosed-lens reflective sheeting	861	0.2	-4
C	Cube corner button	23 250	0.1	0
D	Cube corner reflective sheeting	10 763	0.2	-4

Panels 0.6 by 0.6 m (2 by 2 ft) were used for reflective sheeting, and a 457-mm (18-in) capital letter was used for material C and was positioned to represent the center of typical sign placement specified in the Manual on Uniform Traffic Control Devices (2).

Three densities of stream traffic were simulated by positioning 3, 6, and 15 vehicles at equal distances and by staggering the vehicles on the left and right lanes. These densities are representative of traffic volumes of 300, 500, and 1500 vehicles/lane/h.

RESULTS AND CONCLUSIONS

The luminance readings are given in Table 1 and shown in Figure 1. For unlighted overhead signs, the single vehicle with low beams produced luminances of 3.4 to 6.9 cd/m^2 (1 to 2 ft-L). With 3 vehicles spaced at 152-m (500-ft) increments, sign luminance for the test vehicle increased from 3.8 to 9.6 cd/m^2 (1.1 to 2.8 ft-L). With 6 vehicles spaced at 91-m (300-ft) increments, sign luminances for the test vehicle increased from 9.3 to 14.0 cd/m^2 (2.7 to 4.1 ft-L). For 15 vehicles spaced at 15-m

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(50-ft) increments, corresponding to near capacity for an average facility, sign luminances for the test vehicle increased from 26.7 to 28.4 cd/m^2 (7.8 to 8.3 ft-L); the greatest increase occurred at 366-m (1200 ft) increments. The increase from 3.4 to 4.1 cd/m^2 (1 to 1.2 ft-L) to approximately 24 to 27 cd/m^2 (7 to 8 ft-L) occurred at longer distances. For a 183 to 91-m (600 to 300-ft) range, sign luminance nearly doubled as compared with sign luminance for the single vehicle.

The improvement at the longer distance appears to be due to the close angular proximity of the adjacent headlights. This comparison is given in Table 1 and is shown in Figure 2. An approximation of the overhead sign luminance I may be expressed as follows:

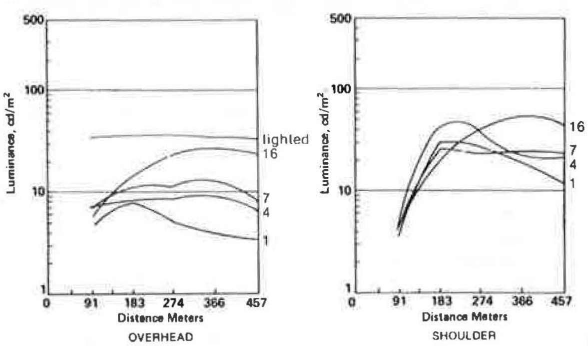
$$I \cong I_1 \times (Vn + 1)/2 \qquad (1)$$

Table 1. Nighttime luminance of silver-white retroreflective sign materials in stream traffic with vehicles on low beam.

No. of Vehicles in Traffic Stream	Material	Overhead Sign Luminance (cd/m^2) by Distance From Vehicle					Shoulder-Mounted Sign Luminance (cd/m^2) by Distance From Vehicle				
		457 m	366 m	274 m	183 m	91 m	457 m	366 m	274 m	183 m	91 m
15	A	26.7	28.4	24.7	15.4	6.2	47.0	61.7	36.3	21.2	4.8
	B	15.1	16.4	13.0	10.3	5.5	25.7	32.6	23.6	12.7	5.1
	C	11.6	12.7	13.4	7.5	3.8	20.6	39.4	22.6	15.8	4.4
	D	60.0	64.1	60.0	33.6	12.3	106.3	120.0	85.7	44.2	13.0
6	A	9.3	14.0	12.7	12.0	4.1	25.0	26.4	24.0	27.4	3.8
	B	6.2	8.2	6.2	5.1	2.7	8.6	12.3	12.0	13.7	3.4
	C						8.6	9.2	12.0	12.0	3.4
	D	22.6	28.1	25.4	22.3	9.6	54.8	49.7	48.0	56.6	11.0
3	A	6.9	9.6	9.3	8.9	4.4	22.3	21.6	39.8	40.4	4.8
	B	5.1	4.4	4.1	4.4	3.1	10.3	10.3	33.6	23.0	4.1
	C						10.3	12.3	32.9	36.0	5.1
	D	15.1	20.0	18.2	18.8	10.6	41.1	42.8	72.0	99.4	13.0
1[a]	A	3.4	4.1	5.8	7.5	5.5	13.7	18.2	27.4	26.7	5.5
	B	1.2	1.5	2.4	3.2	4.1	6.2	8.9	13.0	13.0	4.1
	C						8.9	11.0	19.2	10.3	3.1
	D	5.3	8.9	11.3	14.0	9.9	27.1	35.3	59.0	55.5	13.0
1[a,b]	A	34.3	36.0	38.7	39.8	39.1	10.6	16.8	21.6	24.3	3.1
	B	41.1	41.8	42.8	44.6	45.6	4.8	8.6	10.6	13.7	3.1
	C	37.7	36.0	39.4	44.9	49.0	7.5	13.0	15.8	22.3	3.8
	D	34.3	29.1	30.8	32.6	29.1	21.9	32.6	49.7	60.0	8.6

Notes: 1 m = 3.28 ft and 1 cd/m^2 = 0.291 ft-L.
[a]Test vehicle. [b]Additional luminance from roadway and sign lights.

Figure 1. Nighttime luminance of material A for stream traffic, single vehicle, and lighted sign conditions for overhead and shoulder-mounted guide signs.



Note: 1 m = 3.28 ft and 1 cd/m^2 = 0.291 ft-L.

Figure 2. Improved luminance ratio of overhead sign in stream traffic.

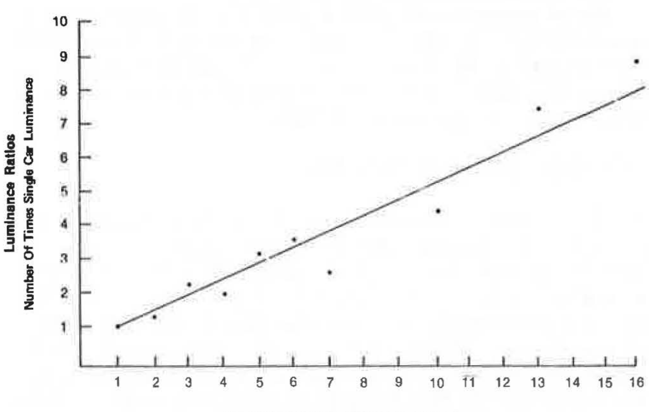


Figure 3. Improved luminance ratio of shoulder-mounted and overhead signs under dry and wet conditions.

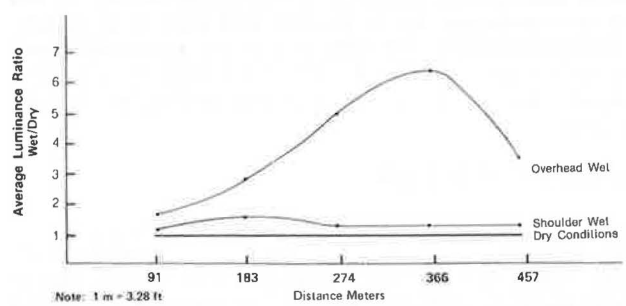


Table 2. Nighttime luminance of silver-white retroreflective sign materials under wet and dry conditions with vehicles on low beam.

Distance to Sign (m)	Material	Overhead Sign Luminance (cd/m^2)			Shoulder-Mounted Sign Luminance (cd/m^2)		
		Wet	Dry	Wet/Dry Ratio	Wet	Dry	Wet/Dry Ratio
457	A	8.2	3.4	2.38	16.4	16.4	1.00
	B	7.2	1.2	6.00	6.5	6.2	1.08
	D	20.2	5.3	3.81	36.0	35.0	1.03
366	A	18.8	4.1	4.40	32.6	23.3	1.40
	B	12.7	1.5	6.89	11.0	9.6	1.16
	D	48.0	8.9	5.49	70.3	47.3	1.49
274	A	27.4	5.8	4.70	42.8	36.7	1.17
	B	13.0	2.4	5.0	17.1	14.7	1.18
	D	60.0	11.3	5.30	109.7	75.4	1.45
183	A	17.5	7.54	2.32	72.0	54.8	1.31
	B	11.6	3.3	3.57	12.2	23.0	1.42
	D	48.0	14.0	3.41	171.4	89.1	1.93
91	A	6.8	5.5	1.21	19.2	19.2	1.00
	B	5.1	4.1	1.25	12.7	12.0	1.07
	D	12.3	9.9	1.22	32.9	31.5	1.04

Notes: 1 m = 3.28 ft and 1 cd/m^2 = 0.291 ft-L.
No reading for material C at that location.

where

I_1 = overhead sign luminance for a single vehicle on low beams, and
Vn = number of vehicles between test vehicle and sign.

For shoulder-mounted signs, lower beam sign luminances were 13.7 to 54 cd/m^2 (4 to 16 ft-L) with the reflective sheeting material A for a single car. Additions for stream traffic are less beneficial and increased only 1.2 to 1.8 times for low to high volumes of vehicles respectively as compared with the test vehicle only. For the other materials tested, luminous increases were of a similar order.

During the experiment with 15 cars, the test vehicle switched off the lower beam lamps to determine for the overhead sign positions the luminance contribution attributable exclusively to other vehicles. Results of this comparison showed that, for all materials and distances, an average of 19 percent of the sign luminance comes from the driver's head lamps. Since the lone vehicle can comfortably switch to upper beams to provide sign luminances 10 times greater than with lower beams, this is not likely to happen in traffic so the effects of adjacent vehicle lights are beneficial.

A general opinion prevails that sign visibility deteriorates under rainfall conditions at night; however, the measurements made in rainfall conditions display generally higher luminances as shown in Table 2 and Figure 3. For shoulder-mounted signs, the ratios appear to maximize at the 183-m (600-ft) distance by a factor of approximately 1.4. Luminances of overhead signs increased an average of 3.8 times for all materials at all distances with rainfall. At longer distances, the improvement was 2.8 to 4 times for 457 m (1500 ft); at shorter distances, the improvement averaged 1.2 to 3 times the dry values. The greatest benefits occurred in the 274 to 366-m (900 to 1200-ft) distances where single-vehicle, low-beam overhead sign luminances increase from 4.8 to 6.9 times with rainfall.

REFERENCES

1. W. P. Youngblood and H. L. Woltman. A Brightness Inventory of Contemporary Signing Materials for Guide Signs. HRB, Highway Research Record 377, 1971, pp. 69-91.
2. Manual on Uniform Traffic Control Devices for Streets and Highways. Federal Highway Administration, U.S. Department of Transportation, 1971.