

Using Encapsulated-Lens Reflective Sheeting on Overhead Highway Signs

R. N. Robertson and J. D. Shelor, Virginia Highway and Transportation Research Council, Charlottesville

This paper summarizes a study on the use of encapsulated-lens reflective sheeting on overhead signs without external illumination. The existing signs on the Interstate and many primary highways in Virginia were inventoried to determine the percentage of them that would meet the criteria for visibility-recognition distance so that their illumination could be eliminated if they were refurbished with encapsulated-lens sheeting. The plans for several proposed sign-lighting projects were also reviewed for the same criteria. Data relative to the installation, energy, and maintenance costs for lighting overhead signs were also collected. It was concluded that illumination could be eliminated on approximately 45 percent of the existing signs and 50 percent of the proposed ones. The anticipated benefits include monetary and energy savings, reduction in the exposure of maintenance personnel to hazardous working conditions, and improved services to motorists.

The brightness of encapsulated-lens (high-intensity) reflective sheeting is superior to that of the enclosed-lens sheeting that is presently used on overhead traffic signs (1, 2, 3, 4). Consequently, the performance of this material was evaluated by the Virginia Department of Highways and Transportation (VDHT) to determine the feasibility of using it on overhead signs without illumination, and it was concluded that the use of encapsulated-lens sheeting would allow the elimination of the external lighting on many overhead signs without adversely affecting the service to the motoring public (5).

Subsequently, a joint study team from the Office of Engineering and Traffic Operations and Research and Development of the Federal Highway Administration (FHWA) evaluated the performance of encapsulated-lens sheeting in five states (6), and the FHWA removed the use of encapsulated-lens sheeting from the experimental category and established guidelines for the elimination of external lighting on overhead guide signs that are made with encapsulated-lens material.

The use of encapsulated-lens sheeting and the elimination of lighting on many overhead signs should be advantageous to many transportation agencies. Intuitively, the benefits would appear to include monetary savings, energy conservation, increased safety for maintenance personnel, and improved service to motorists. However, the consideration of these probable benefits generates questions such as the following: What percentage of the signs in Virginia meet the criteria for the elimination of lighting? What is the installation cost for lighting? What is the energy cost for lighting an overhead sign? What is the maintenance cost for the lighting on a typical overhead sign?

The purpose of this study was to answer the questions above; it was not intended to provide an economic analysis. The main objectives were to

1. Determine the percentage of existing and proposed overhead signs that meet the criteria for the elimination of lighting by the use of encapsulated-lens materials,
2. Obtain cost estimates for the installation of lighting on a typical overhead sign,
3. Obtain cost estimates for the energy used in illuminating overhead signs, and
4. Obtain cost data for the maintenance of the lighting fixtures on overhead signs.

Because of personnel and time constraints, the study was restricted to the Interstate and primary highway systems. Random samples of statewide data were collected, but it was impossible to obtain complete data on all the overhead signs in the state.

METHODOLOGY AND RESULTS

The first phase of the study was divided into four major tasks.

Sign Survey

One of the criteria established by the earlier study (5) is that the illumination can be eliminated from an encapsulated-lens sign on a freeway that has a straight approach equal to or greater than the visibility-recognition distance. The use of a model developed by Forbes (7) showed that the calculated visibility distance for the overhead signs on a freeway is about 335 to 366 m (1100 to 1200 ft). In terms of time, this allows a motorist traveling at freeway speeds 13.5 s to observe a sign after detecting it. On the assumption that this amount of time is sufficient for the motorist to identify and read the sign, the relationship of speed and visibility distance shown in Figure 1 was developed and used on roadways that had speed limits lower than those on freeways.

All of the overhead signs on the Interstate system, but only a sample of those on the primary and secondary roadways and city streets, were surveyed. The following data were recorded: (a) location of sign structure, (b) number of signs per structure, (c) type and number of lighting fixtures, (d) straight approach distance, (e) type of roadway, and (f) posted speed limit. The existing signs on roadways that are under construction were not inventoried, but the signing plans of several proposed projects were reviewed to estimate the percentage of signs that could be built with encapsulated-lens sheeting and without illumination.

The inventory of existing overhead signs on the Interstate highways given below shows that there are 271 sign structures on which 576 signs are placed.

| Item | Interstate | Other Roadway | |
|---------------------|------------|---------------|-----------|
| | | Counted | Estimated |
| Structures | 271 | 199 | 265 |
| Curved approaches | 149 | 110 | 146 |
| Straight approaches | 122 | 87 | 116 |
| Signs | 576 | 446 | 594 |
| Signs per structure | 2.13 | 2.24 | |

Of these structures, 122 (45 percent) are located on straight roadways and meet the visibility-recognition criterion for the elimination of lighting by the use of encapsulated-lens reflective sheeting.

Approximately 75 percent of the total sign structures on other streets and highways were also surveyed. As shown above, 87 (43.8 percent) of the 199 structures were located on straight approaches.

Since the luminances of signs located on straight roadways are greater than those of signs located on curved roadways, in recent years designers have placed over-

head signs on straight approaches whenever possible. The inventory given below of proposed sign structures on four construction projects shows that 50 percent of them are on straight approaches.

| Item | Interstate (I-495) | Primary Roadway |
|---------------------|--------------------|-----------------|
| Structures | 148 | 10 |
| Curved approaches | 74 | 5 |
| Straight approaches | 74 | 5 |
| Signs | 231 | 21 |
| Signs per structure | 1.56 | 2.1 |
| Light fixtures | 580 | 62 |
| Fixtures per sign | 2.51 | 2.95 |

The inventory given below of lighting fixtures on existing roadways shows the number and variety required (1 m = 3.3 ft).

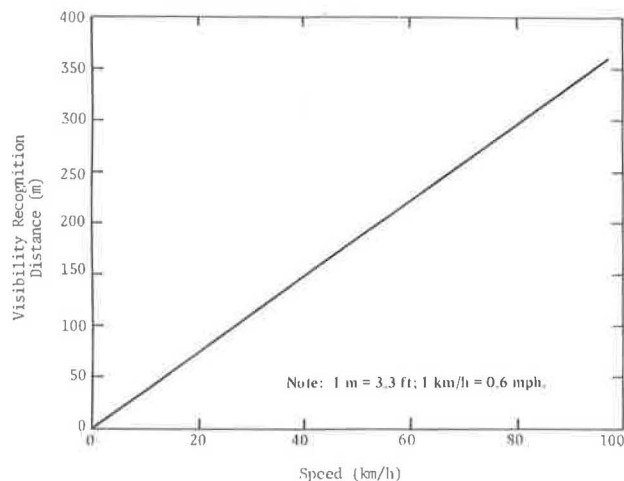
| Type of Fixture | Interstate | Other Roadway | |
|--------------------|------------|---------------|-----------|
| | | Counted | Estimated |
| 1.22 m fluorescent | 1027 | 834 | 1112 |
| 1.83 m fluorescent | 228 | 230 | 306 |
| 2.44 m fluorescent | 23 | 3 | 4 |
| Mercury-vapor | 481 | 240 | 320 |

The number of structures supporting these fixtures and the number of signs lighted by them are given below.

| Type of Fixture | Roadway | Structure | | Signs | |
|-----------------|------------|-----------|-----------|---------|-----------|
| | | Counted | Estimated | Counted | Estimated |
| Fluorescent | Interstate | 158 | — | 392 | — |
| | Other | 142 | 189 | 337 | 449 |
| Mercury-vapor | Interstate | 96 | — | 150 | — |
| | Other | 44 | 59 | 82 | 109 |
| None | Interstate | 17 | — | 34 | — |
| | Other | 13 | 17 | 27 | 36 |

There are about 800 mercury-vapor fixtures and 2700 fluorescent fixtures [totaling 3658 m (12 000 ft)] in service in Virginia. To illuminate the average overhead sign requires 4.35 m (14.3 ft) of fluorescent lighting fixtures or 3.1 mercury-vapor fixtures. The majority of the signs are equipped with fluorescent lighting, but the newer installations include mercury-vapor fixtures because of their better performance characteristics.

Figure 1. Visibility-recognition distance versus speed.



Installation Cost

The majority of the overhead signs in Virginia are installed by an outside agency, and, unfortunately for the purpose of this survey, the payment for the entire structure is made on a lump-sum basis. Obtaining cost estimates for the installation of the lighting only on a typical overhead sign required contacting many sign contractors and consulting engineers and the Traffic and Safety Division of VDHT. The contractors were reluctant to discuss unit prices for lighting fixtures because of the fluctuations among projects and the dates of the work, the increasing costs of materials, and the fact that a small project has a high unit cost but a large project has lower unit costs. However, the contractors did indicate that the VDHT estimate of \$400/fixture was conservative.

If, as shown in the inventory of proposed overhead signs, the average number of fixtures on a proposed sign-installation project is 2.55 and an average of 1.59 signs are planned for each structure, the average cost of lighting each structure will be \$1600.

Overhead sign structures of the 2-pole span type cost an estimated \$738/m (\$225/ft) of span, and those of the cantilever type cost \$800/m (\$250/ft). One-third to one-half of these costs are for the walkways on which the light fixtures are mounted, and since few of the sign-maintenance operations are performed from the walkways, this additional expense is mainly for the mounting and maintenance of the lighting fixtures. Of the 148 structures proposed for I-495, 70 are of the cantilever type, 52 are span structures, and 26 are mounted on bridges. The average lengths of the cantilever, span, and bridge structures are 8.69, 33.2, and 7.01 m (28.5, 109, and 23 ft) respectively. The average cantilever structure will cost \$7125, and the average span structure will cost over \$24 500. (The cost figures for the bridge-mounted signs were not available because these signs require special supports, but their costs are expected to be in the same range as those for the cantilever structures.)

Since 50 percent of the proposed structures on I-495 will be on straight approaches on which encapsulated-lens sheeting without illumination would provide adequate luminances, the elimination of the lighting fixtures would save more than \$402 000 for the structures alone, and there would be an added saving of \$118 000 for the lighting fixtures themselves. The net savings would be approximately \$520 000 on this highway facility or an average of \$7030/structure. These figures are conservative, because they were derived from cost estimates for a project that will require a large number of signs and is in an urban area where electrical service is readily available. The costs of illuminating signs in rural areas increase rapidly because of the long distances to power sources: In remote areas, service cable costs \$6.56/m (\$2.00/ft). Finally, there is an additional saving from the elimination of glare shields, which are not required on encapsulated-lens reflective-sheeting signs.

Energy Cost

Data on the cost of energy for lighting signs in various sections of the state were gathered and analyzed. The data include the annual electrical costs, the suppliers, the locations of structures, the number of signs per structure, and the type and number of lighting fixtures.

The costs of electrical energy varied widely throughout the state. In a few areas, the state government had a special rate that usually (in 1974) was less than 2 cents/kW. Some typical 1974 energy costs are shown in Table 1. At that time, the annual costs for fluorescent lighting on a typical overhead sign in Virginia were between \$35.82

Table 1. Energy costs for overhead sign illumination.

| Location of Structure | Signs on Structure | Lighting Fixtures on Structure | Length of Lighting Fixtures (m) | Annual Cost of Electricity (\$) | Annual Cost of Electricity per Meter of Fixture (\$) |
|--|--------------------|--------------------------------|---------------------------------|---------------------------------|--|
| I-64W at Parham Road, Henrico County | 3 | 11 | 13.4 | 132.00 | 9.85 |
| US-29N at US-15, Culpeper County | 3 | 10 | 12.8 | 334.62 | 26.14 |
| I-95S at Va-619, Prince William County | 3 | 7 | 9.1 | 75.40 | 8.29 |
| I-81S at Va-614, Botetourt County | 3 | 6 | 7.9 | 75.20 | 9.52 |
| I-64W at I-81, Augusta County | 2 | 12 | 14.6 | 380.20 | 26.04 |
| US-29S at Va-739, Amherst County | 2 | 6 | 7.9 | 93.60 | 11.85 |
| US-29N at US-60, Amherst County | 2 | 7 | 9.1 | 96.00 | 10.55 |
| I-81S at Va-381, Bristol | 2 | 4 | 7.3 | 162.87 | 22.31 |
| Total | 20 | 63 | 82.3 | 1349.89 | — |
| Avg | 2.50 | 7.88 | 10.29 | 168.74 | 16.40 |

Note: 1 m = 3 ft.

Table 2. Maintenance costs for overhead sign illumination.

| District | Signs | Person-Hours | Equipment and Labor Costs (\$) | Material Costs (\$) | Total Costs (\$) | Unit Cost per Sign (\$) | Remarks |
|-----------------------------|-------|--------------|--------------------------------|---------------------|------------------|-------------------------|--|
| Culpeper | — | 3846 | 21 300 | 2900 | 24 200 | — | State forces; includes traffic control |
| Salem | 49 | — | 3 300 | 1050 | 4 350 | 89 | State forces; includes traffic control |
| Richmond (I-64) | 63 | 595.4 | 9 500 | 2600 | 12 100 | 192 | Contract; excludes traffic control |
| Suffolk (I-44, 64, and 264) | 142 | 475.0 | 14 100 | 4100 | 18 200 | 128 | Contract; includes traffic control |

and \$113.02, with an average of \$71.35, but these costs have increased greatly since then.

For example, the four 1.8-m (6-ft) fluorescent fixtures on the overhead signs located on I-81 at the Va-381 interchange in Bristol have been replaced by four mercury-vapor fixtures, for which the current electrical cost is \$3.82/light/month and the anticipated annual cost is \$183.36.

Maintenance Cost

Since the VDHT accounting system does not have a specific charge code for sign-lighting costs, the daily work records over a 12-month period in two highway districts were reviewed. The data recorded included the costs of labor, equipment, and materials for maintaining the sign lighting. Data including the number of signs maintained, the number of person-hours required, and labor, equipment, and material expenditures were also collected in two districts in which most of the maintenance operations were carried out by outside contractors.

A review of the daily work records relative to the maintenance cost for the illumination of overhead signs in the Culpeper and Salem Highway districts is given in Table 2. Unfortunately, the number of signs in the Culpeper District was not available, and unit maintenance costs per sign could not be calculated. However, there was an obviously large expenditure for the maintenance of sign lighting, and a three-person crew was assigned to this work. Approximately \$25 000 and 3846 person-hours were expended, but these were not sufficient for an effective sign-illumination maintenance program.

In the Salem District, the maintenance of lighting on 49 signs costs approximately \$4350 with a unit cost per sign of \$89. However, because the majority of the overhead signs in the Salem District are located near the maintenance shops and therefore require little travel time and expense, these costs are considered to be minimal.

The maintenance work on many of the overhead sign lights in the Richmond and Suffolk districts is done by outside contractors, who are compensated for labor and equipment on an hourly basis and provide all traffic control during the maintenance operations. These con-

tractors also bill VDHT for the materials used in the repairs of the sign illumination, and the cost of replacement parts supplied by them is approximately twice the cost usually paid by VDHT for identical items.

The maintenance of the lighting on 63 overhead signs on I-64 in the Richmond District costs more than \$12 000, excluding traffic control. The unit cost per sign was \$192. In the Suffolk District, maintenance of the lighting on 142 signs on I-44, 64, and 264 in the Norfolk area costs \$18 000. The unit cost per sign, including traffic control, was \$128. The other sign lights in these districts were maintained by state forces.

CONCLUSIONS

Because of the limitations of the data, especially those pertaining to the costs of installation, energy, and the maintenance of overhead sign lights, definitive conclusions as to the impacts of the elimination of lighting on encapsulated-lens signs cannot be made. Since the beginning of the energy crisis in the winter of 1973 and the addition of the fuel-adjustment charge, electrical rates have increased so rapidly that the establishment of a true indicator of the energy costs for a typical overhead sign is impossible. The maintenance-cost data were compiled from daily work records and do not necessarily reflect the total cost for maintaining the sign lighting. Frequently, additional crews are required for operations such as traffic control and the replacement of underground cable, and the costs of these activities may not be included in the data presented in this paper. The installation-cost data are also only estimates because contract prices were not available (and the contractors indicated that the estimates were low). Consequently, it is assumed that the foregoing analysis and the following general conclusions are conservative.

The sign survey showed that approximately 45 percent of the existing 1170 overhead signs are located on roadways that have straight approaches and thus that the lighting could be eliminated by the use of encapsulated-lens sheeting.

The annual cost of electricity for and maintenance of the illumination on the typical overhead sign varied between \$124.82 for a sign maintained by state forces in an

area with low electric rates to \$305.02 for a sign maintained by a contractor in an area with high electrical rates. The average annual cost was \$160.35/sign. This annual expense is greater than the additional investment required to build signs with encapsulated-lens reflective materials rather than with the conventional enclosed-lens sheeting. Because the service life of encapsulated-lens materials exceeds 10 years, a benefit-cost ratio greater than 10 to 1 can be anticipated for signs mounted on existing structures and refurbished with encapsulated-lens reflective sheeting.

If the existing 520 signs located on straight approaches were refurbished with encapsulated-lens materials and the lights disconnected, there would be an annual saving of approximately \$83 000 in electrical and maintenance costs. This saving does not include other benefits, such as the reduced exposure of maintenance personnel to traffic, improved services to motorists, the availability of maintenance crews and equipment for other work, and the reduction in time required for night inspections to locate malfunctioning lights.

Eliminating the lighting on new overhead sign structures would result in enormous savings in installation costs. Because overhead signs are usually located on straight sections of roadways, the number of proposed signs that meet the visibility-recognition criterion is increasing. Fifty percent of these signs will be located on straight approaches, where the illumination could be eliminated if they were made with encapsulated-lens sheeting. On the sign project proposed for I-495, the elimination of lights on the overhead structures could save \$7030/structure (less \$400 to \$500 for the additional expense of the encapsulated-lens sheeting). The saving for the entire project would be more than \$500 000, and greater savings per structure could be anticipated on projects that require a small number of signs and in areas where the power sources are long distances from the overhead signs.

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The opinions, findings, and conclusions expressed in this report are those of the author and not necessarily those of the sponsoring agencies.

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Poor Visibility Under Low-Beam Headlights: A Common Cause of Wrong-Way Driving

N. K. Vaswani, Virginia Highway and Transportation Research Council, Charlottesville

Through selected case studies, this paper illustrates the way in which the inadequate visibility of road signs and pavement markings at night contributes to wrong-way driving. A concept termed the key of legibility, which delineates the limits of nighttime visibility under low-beam headlights, is described. The application of the key-of-legibility concept to the placement of signs, markings, and additional devices that help guide the motorist through the intersection of a four-lane divided highway and another road is discussed. Examples of wrong-way entry on roads having poor geometrics are used to emphasize the need for such guidance.

Surveys of wrong-way driving in Virginia since 1970 have shown that most of the wrong-way incidents originated at interchanges and intersections. A driver must be very carefully guided onto the correct ramp at an interchange or around the nose of the median when he or she is making a left turn at an intersection on a divided highway. Many information devices, such as signs and pavement markings, and other features such as curbs, often made conspicuous by color, are used to provide this guidance, but they are often not of maximum effective-