Measures of Snowplowable Raised Pavement Marker Reflector Wear

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Measures of amount of wear sustained by snowplowable raised reflective pavement markers are recommended to encourage the use of objective measures and provide a basis for standardization of wear measures. Such an evaluation was carried out on NJ-29 and NJ-31 in 1984–1985 and on US-1 in 1974–1975 after two successive winters of use. The effect and extent of various types of physical wear were checked. The scope of this effort allowed determination of which measures were useful in classifying average functional reflective surface area and average visibility distance from year to year, marker to marker, and route to route, so that a statistical analysis of differentiation between the items of comparison could be performed at a high level of significance. There is an increasing need to establish a scientific relationship between the day and night measures, which could be generated by future research work.

Night driving is not only more hazardous than daytime driving, but the percentage of fatalities is increasing. The primary factor is thought to be inadequate visibility *(1)*. There is a need to have and keep adequate night visibility and provide proper delineation during all seasons and types of weather.

Stimsonite Model 96 snowplowable raised reflective pavement markers are becoming widely used for dry and wet night delineation. However, no specific, uniform, and systematic procedure is available for a periodic survey and evaluation of the functionality of these markers. A first step is taken toward providing uniform measures of wear. The purpose of this paper is to encourage the use of suggested measures of wear and to provide a beginning for the standardization of such measures. Measures of wear have been inadequate in the past when information on wear was compared among states and agencies and are needed to satisfy the following objectives: *(a)* to check the durability of new products for delineation and compare them with an existing product being used, *(b)* to evaluate modifications in the existing product, and *(c)* to establish new replacement criteria because of changes or exceptions in conditions causing wear.

Measures of wear and their documentation are described. The importance of each measure and which wear measures have been found useful to satisfy these objectives are discussed. A procedure is given to estimate the condition and visibility of the markers. A technique has been described to estimate night visibility of the markers. It is beyond the scope of this effort to come up with a much-desired link between day and night measures of wear, which should be established through future research work.

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DAYTIME MEASURES

Each marker casting and a reflector insert were closely examined for the following types of wear or condition:

1. Cracking: The acrylic reflector was checked for any cracks, either external on the acrylic shell or internal in the hard core.
2. Breaking: A reflector was noted as broken if any part of the sides or the top was observed to be broken.
3. Delamination: The acrylic surface was inspected for any delamination between the core and the shell of the reflector.

All of the foregoing measures are nominal in nature, allowing their documentation as cracked, broken, or delaminated. Figure 1 shows a perfect reflector, and Figure 2 shows a cracked reflector with top delamination. Delamination of a part of the top as well as the side and cracks are shown in Figure 3; and in Figure 4 a part of the top and side is shown with a crack through the core.

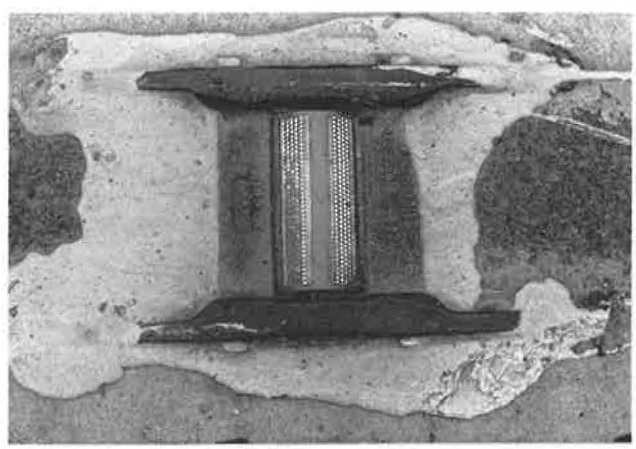

FIGURE 1 Perfect reflector.

The following measures are more quantitative in nature:

1. Percent reflective surface: The retroreflective surface of the reflector was divided into north and south faces for evaluation purposes. NJ-29 and NJ-31 and US-1 run in a north-south direction. Each face was given a "percent functioning" surface rating in 5-percent increments between zero and 100 percent, which provides a measure of the proportion of the total reflector face remaining reflective after cracking, breaking, and delamination are accounted for.

FIGURE 2 **Cracked reflector with top delamination.**

FIGURE 3 **Cracked reflector with top and side delamination.**

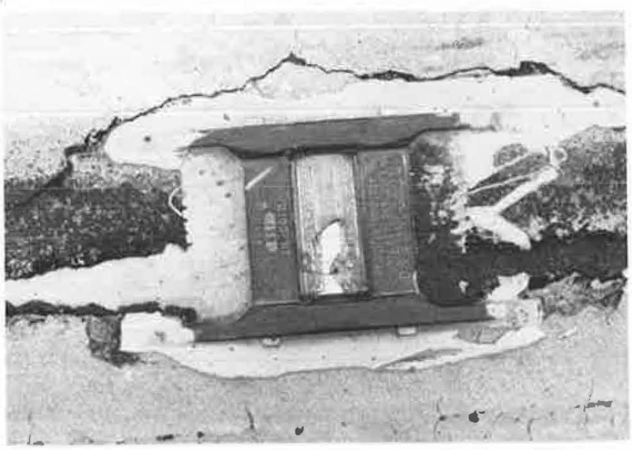

FIGURE 4 **Broken reflector.**

2. Percent epoxy: This is the measure of the amount of the reflective surface accidentally covered by the epoxy use for installation of the casting. It was noted in 5-percent increments what percentage of the total reflector face was covered with epoxy.

3. Percent paint: Some markers were painted over by mistake when the pavement was restriped. The percentage of the paint-covered surface, which was not available for reflectorization, was estimated.

4. Percent top: The top of the reflector, which is nonreflective, was observed for cracks, delamination, and any part that was broken. Percent of the top broken, in increments of 5 percent, was determined approximately.

5. Missing reflector or casting: A missing reflector insert or a missing casting was documented.

Method of Observation

Observations were made on foot in the daylight; all markers were inspected closely, and any reflector surface covered with mud or dirt was cleaned with a brush for a better view of the wear. Necessary safety precautions were taken while inspection of the markers was in progress.

Data Collection and Treatment

All measures were recorded on standard preformatted forms. Each marker was given a specific number, which could easily be traced for subsequent comparison or in case any information was missing. The data collected were analyzed by generating a mainframe data base using a RAMIS II system. Those markers covered with epoxy, painted over, and missing castings were excluded from the analysis because reflector wear was obscured from view.

DIFFERENT USES OF DAY MEASURES

Stimsonite Model 96 snowplowable raised reflective pavement markers, both regular profile and low profile, were installed on NJ-29 in September 1983. One hundred eighty regular-profile and 215 low-profile markers were placed at intervals of 80 ft on the tangent section and 40 ft on curves greater than 3 degrees. The objectives of this installation were *(a)* to observe the different types of wear after each winter, *(b)* to determine which measures of wear were statistically sensitive in a comparison, and *(c)* to see whether there is a distinction between regular- and low-profile markers for reflector insert durability. The markers were surveyed each year for two winters. The snowfall for 1983–1984 was 26.5 in. and for 1984–1985 was 25 in.

The only controlled variable for analysis was a casting type distinguished by a regular and a low profile. The uncontrolled variables included traffic wear, volume of traffic, type of vehicle, amount of snowfall, snowplow wheel and steel-blade passes, and weather conditions; however, these conditions were quantified and documented whenever possible.

In Table 1 physical wear is classified as percent cracked (C), broken (B), or delaminated (D) when these are not mutually exclusive. In the last column the percentage of the reflective surface that shows any or all of these forms of wear is given. Low-profile markers show less physical wear, and the percentage of broken and delaminated reflective surface was significantly different between regular- and low-profile markers at least at the 95 percent confidence level.

A cracked, broken, or delaminated reflector is an imperfect reflector, but these measures of wear are mainly an indication of the cause of damage.

It was observed that at a point on the 6-mi stretch of NJ-29 where markers were installed, almost all trucks carrying rocks

TABLE 1 PHYSICAL WEAR OF REFLECTOR SURFACES, NJ-29

	Percentage of Wear			
Profile	Cracked	Broken	Delaminated	C, B, or D
Regular	59.4	76.9[a]	72.9[b]	92.2
Low	63.3	70.1[a]	52.0[b]	87.1

[a]Significant at the 95 percent confidence limit.
[b]Significant at the 95, 99, and 99.5 percent confidence limits.

from a quarry were going south, dividing the low-profile section of markers. The phenomenon of heavy trucks going south was considered an important variable affecting the statistical analysis of differentiation between regular- and low-profile markers. The wear on reflectors when the influence of heavy trucks was eliminated, or when only the markers north of the quarry were analyzed, is shown in Table 2. A "good" reflective surface was characterized as one in which 50 percent or more of the reflective surface was functioning. This is an arbitrary measure used by several states to check the usability of the marker and is also incorporated into criteria for replacement, discussed later. Average percent functioning surface indicates the amount of intact reflective area remaining.

Low-profile markers were significantly differentiated from regular-profile markers in having more functioning reflective surface and top durability.

Top damage is the beginning of damage to the marker and can serve as the precursor of reflective surface damage.

TABLE 2 REFLECTIVE SURFACE WEAR, NJ-29

Profile	"Good Surface" (%)	Avg Percentage Functioning Surface	Avg Percentage Top Intact
Regular	55.3[a]	55[b]	47[a]
Low	77.9[a]	69[b]	70[a]

NOTE: Results are for markers north of quarry (see text).
[a]Significant at the 95, 99, and 99.9 percent confidence limits.
[b]Significant at the 95 percent confidence limit.

REFLECTOR WEAR AMONG DIFFERENT ROUTES

In September 1984, 270 regular-profile markers were installed on NJ-31 and were surveyed after the first winter to estimate the annual wear. The method of observation was similar to that adopted for NJ-29 except that every fourth marker was inspected for wear. A 1976 report by M. V. Jagannath and A. W. Roberts on evaluation of snowplowable raised pavement markers in New Jersey *(2)* contained the rating of reflector loss and damage to Stimsonite Model 99 markers on US-1 during the winters of 1973–1974 and 1974–1975. The objective of this comparison was to see the effect of traffic and snowplowing on marker wear.

The average percentage of functioning reflective surface remaining is compared for NJ-29, NJ-31, and US-1 in Table 3. It was noted that the wear on reflective surfaces was higher on NJ-31 after the first winter and on NJ-29 after the second winter than on US-1 since installation. It should be noted that traffic volume and characteristics were different on all three routes and the castings on US-1 were slightly different from those used on NJ-29 and NJ-31.

NIGHT MEASURES

Day measures of wear provide physical type and extent, whereas night measures are estimates of what a motorist sees. It is not advisable to make observations during the day on some highways because of personal safety, but it can be more convenient to do so.

An estimate was made of the dry-night visibility of markers on NJ-29 in May 1985 after 2 years of wear. The number of markers visible approximately every 0.4 mi was noted from a moving vehicle, and slides were taken using ASA 400 film in a camera with an $F/1.2$ lens at 1/60 sec. Because the distance between the markers at all points was known, the average visibility of both regular-profile and low-profile markers was calculated to be 260 ft. The availability of data for night measures was limited because of heavy-truck traffic, so the establishment of statistical significance at the 95 percent level of confidence was not possible. It is suggested that at least 30 measures of visibility for each type of marker would be needed in both directions for a proper statistical analysis. It was not possible to relate the night visibility to daytime wear measurement because of the scope of the effort, but this should be done in a separate research project.

DISCUSSION

Daytime Measures of Wear

The daytime measurement of available functional reflective surface could be carried out in two ways. One of the best methods is to register the functional area in increments of 5 percent, as described earlier. In some states the criterion for a

TABLE 3 AVERAGE PERCENTAGE FUNCTIONING REFLECTIVE SURFACE

		After First Winter		After Second Winter		
Test Site	Type of Road	Remaining Reflective Surface (%)	Snowfall (in.)	Remaining Reflective Surface (%)	Snowfall (in.)	Annual Avg Daily Traffic
NJ-31	Two lanes with shoulders	73	25	NA	NA	13,280[a]
NJ-29	Two lanes without shoulders	86	26.5	54	25	8,390[a]
US-1	Six lanes, divided, with shoulders	82	20.2	59	16.4	60,000[b]

[a]In 1983. [b]In 1976.

"good" reflector is that it have 50 percent or more functioning reflective area. Hence, the reflective surface area available could be classified either "50 percent or more" or "less than 50 percent." The advantages of this method are that it is probably faster, it makes calculating the "adequately" functioning reflectors easier, and it helps in quick maintenance decision making. However, an estimate of average functioning reflective surface for the installation cannot be obtained with this simple method.

The measures of physical damage to the reflector, such as cracking, breaking, and delamination, give an estimate of the extent of overall damage to the reflector. These measures should not be used as criteria for replacement of the reflectors. However, they help in understanding the severity of each type of damage and the cause of damage and in determining how many reflectors are simply "damaged" or "not damaged."

Nighttime Measures of Wear

It is not always possible to collect data on daytime measures of wear on heavily traveled, four-lane highways and freeways. A feasible solution would be to resort to the night measures, such as visibility range, and how many of them are perceivable. A night measure of the visibility of the markers under clean and dry conditions could be substituted as a check on reflector wear level. A measure of wet-night visibility would be the ultimate for a replacement criterion because provision of wet-night visibility is the primary purpose of using the markers.

It is advisable to photograph the markers at night because estimating visibility of the markers from a moving vehicle could cause error. A fast film—ASA 400 or higher—may be used in a 35-mm camera fitted with an $F/1.2$ lens at a speed of 1/60 sec; high beams are used, which simulates low beams in a photograph. Slides taken from a moving car approximately reproduce the scene viewed from a stopped car. The slides could then be viewed by one or two persons to determine the visibility of the markers and their contribution toward providing adequate nighttime delineation.

Both day and night measures of wear are useful in comparing types of markers and in selecting durable markers. Wear measures from year to year could provide a rate of wear on a route, which in turn could be used to plan the maintenance of the markers. The measures of wear are, in general, applicable to any kind of road.

Formation of Replacement Criteria

A criterion for replacement of the reflectors can be formulated based on either day or night wear measures, or both. For example, it would be wrong to state the replacement policy using day measures as follows: "When 25 percent of the markers have less than 50 percent reflective surface remaining, replacement of reflectors should be planned for the whole installation." This criterion allows an average functioning reflective area to be as low as 37.5 percent or as high as 87.5 percent, which forms outer limits of tolerance. It could allow an installation having much more than 50 percent average functioning reflective surface area to be replaced or one with much less than 50 percent average functioning reflective surface area to go unreplaced.

When both day and night measures are used, the replacement policy could be worded as follows: "Installations in service for 3 years or longer should be evaluated, and if it is determined that the average of the functioning reflective surface area in an installation is less than 50 percent, or the average visibility of the reflectors at night in an installation is less than 240 ft using low beams, then all the reflectors in an installation should be replaced." As compared with the previous wording, this statement allows only 50 percent as a lower limit for average functioning reflective area. The measurement of reflective area should be registered in small increments, such as 5 percent, to encourage more accurate data collection.

It should be noted that making observations from a moving vehicle during the day and counting imperfect markers would provide a grossly inaccurate measure of wear. It was calculated that for NJ-29 in the second year after installation, the amount of perfect (devoid of any damage) regular markers was only 7.3 percent, whereas the amount of average functioning reflective surface was 55 percent (Table 2). This is evidence that the amount of physical damage should not be used as a replacement criterion.

It is not always possible to measure wear accurately because of safety considerations during observation. For example, standing or stopping in the middle of the road can be hazardous under certain conditions. But experience and evaluation could lead from an approximate measure, such as daytime wear, to a substitute measure that would be easier to use in planning maintenance schedules. For reasons of safety and for uniformity in data collection, training of personnel is necessary before they go out into the field.

FINDINGS AND RECOMMENDATIONS

Daytime measures of physical wear of reflectors provide an estimate of the extent of such marker wear. The measure of percentage of functioning reflective surface area allows calculation of either the average functioning reflective area for the installation or of the number of markers that have less than 50 percent of the reflective area remaining. A measure of visibility of markers at night would provide an indication of what the driver sees at an installation. Criteria for replacement of reflectors for regular maintenance can be formulated by using both day and night measures.

Low-profile markers are more durable and have superior wear resistance against cracking, breaking, and delaminating. Regular-profile markers suffered more wear compared with low-profile markers after the same time since installation and under similar operating conditions.

Low-profile markers have significantly more functioning reflective area after 2 years of wear compared with reflectors placed in regular castings.

The type of traffic, such as heavy trucks, has a significant effect on reflector wear. A research study is needed for better prediction of the effects of variables such as weather, volume of traffic, types of vehicles, snowplow wheels, road geometry, and amount of snowfall. This would help to determine and evaluate the wear on the reflectors due to each variable separately.

A separate research project should be carried out to develop a predictable relationship between the physical wear and damage and the appearance of markers evaluated during daylight and the visibility of the markers at night.

After the recommended studies have been completed and an adequate reflector visibility standard has been determined, a satisfactory maintenance schedule can be planned.

FUTURE RESEARCH NEEDS

The measures of wear used for NJ-29 and NJ-31 are reliable for keeping track of reflector damage. The observation or inspection is carried out during daylight and covers almost every aspect of the reflector. However, there is a need to define the relationship between a daylight measure and night visibility so that one variable can be predicted as a function of the other. An adequate night visibility standard for the markers should be determined in a separate research project. This information can then be used to frame the maintenance cycle for the replacement of the reflectors so that adequate night visibility is provided continuously. It can also help in budgeting and planning by predicting the service life of the reflectors fairly accurately; thus, proper allocation of funds and manpower would be made for regular maintenance.

The effects of uncontrolled variables such as temperature, use of abrasives and chemicals, amount of snowfall, volume of traffic, type of vehicle, and characteristics of snowplow wheels and blades, which might be related to reflector deterioration, could not be estimated separately by the process of wear measurement described earlier. Research in wear measurement is necessary to determine the individual contributions of these variables to physical wear and damage. Methods or techniques to make the reflectors less prone to damage or to allow less damage to occur could then be addressed in further research.

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