Evaluation of Snowplowable Marker Installations

Kenneth R. Agent*  Jerry G. Pigman†

*University of Kentucky, ken.agent@uky.edu
†University of Kentucky, jerry.pigman@uky.edu
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### Technical Report Documentation Page

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<td>The first large-scale contracts for the installation of snowplowable markers were awarded in 1984 and 1985. Stimsonite 96 and recessed markers were installed. The objective of this study was to evaluate the performance of the installations. Durability and reflectivity results show that both the recessed markers and Stimsonite 96 markers have performed effectively as snowplowable markers. The recessed markers should continue to be used only on four-lane highways constructed to high geometric standards with the Stimsonite 96 markers installed on the majority of highways.</td>
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EVALUATION OF SNOWPLOWABLE MARKER INSTALLATIONS

by

Kenneth R. Agent
Transportation Research Engineer

and

Jerry G. Pigman
Transportation Research Engineer

Kentucky Transportation Research Program
College of Engineering
University of Kentucky
Lexington, Kentucky

in cooperation with
Kentucky Transportation Cabinet
Commonwealth of Kentucky

and

Federal Highway Administration
US Department of Transportation

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John Luttrell, Chairman, Division of Traffic
Kentucky Department of Highways

Bob Payne, Federal Highway Administration

E. B. Drake, Division of Design,
Kentucky Department of Highways

Tom Stockton, Jefferson County,
Transportation Engineering Division

Andrew Terwilleger, Lexington-Fayette County,
Traffic Engineering Division

George A. Yates, Division of Traffic,
Kentucky Department of Highways
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EXECUTIVE SUMMARY

The first large-scale contracts for the installation of snowplowable markers in Kentucky were awarded in 1984 and 1985. The Stimsonite 96 and recessed markers were installed. The objective of this study was to evaluate the performance of these installations.

Contracts for the installation of about 109,000 recessed markers over 800 miles and about 311,000 Stimsonite 96 markers over 2,200 miles had been awarded through the end of 1985. Total installed unit costs were in the range from $6.26 to $8.29 for the recessed markers and from $15.39 to $17.50 for the Stimsonite 96 markers. Inspections of installations of both types of markers revealed they were installed properly.

After an average of about one year in service, the detailed inspections revealed only 1.0 percent of the recessed markers had over 50 percent lens damage while another 4.2 percent had under 50 percent damage. For the Stimsonite 96 markers, only 1.6 percent of the Stimsonite 96 markers had over 50 percent lens damage while another 8.0 percent had under 50 percent damage.

No problem was detected relative to dirt accumulation in the groove used for the recessed marker. The groove was not observed to cause damage to the pavement. The major problem with the recessed markers concerned the accumulation of water in the groove for short periods of time during periods of heavy rainfall. The paint skipping device used in conjunction with the Stimsonite 96 markers was noted to work properly in all but a few instances. For both the recessed markers and Stimsonite 96 markers, chipping of the abrasive coating of the marker lens was noted, but this did not cause any durability problem or loss in reflectivity.

After an average of about one year in service, the nighttime inspections revealed 3.7 percent of the recessed markers had over 50 percent loss of the reflective surface compared to 1.1 percent for the Stimsonite 96 markers. Both types of markers provided excellent nighttime delineation.

An accident analysis at locations where recessed markers were installed revealed that, considering control locations, there were statistically significant reductions in the percentage of all nighttime and wet-nighttime accidents. There was also a large reduction in the percentage of these accidents at Stimsonite 96 locations, but a very similar reduction was found at the Stimsonite 96 control locations.

The conclusion of the study was that both the recessed marker and Stimsonite 96 marker had performed effectively as snowplowable markers and there continued use was warranted. However, the use of recessed markers should be limited to four-lane highways constructed to high geometric standards with the Stimsonite 96 markers installed on the majority of highways. It was recommended that the 40-foot spacing used for the Stimsonite 96 marker be increased to 80 feet on tangents and curves having a degree of curvature of six degrees or less.
INTRODUCTION

Raised pavement markers have been used across the country as an effective delineation treatment, especially during wet-nighttime and poor visibility conditions. Specifications were first developed in Kentucky for surface-mounted raised pavement markers in 1975 (1). Over one million surface-mounted markers were placed in Kentucky between 1975 and 1979. An evaluation indicated the markers to be cost effective with good durability except for damage resulting from snowplows (2).

Because of snowplow damage, the use of snowplowable markers has increased in recent years. A 1980 survey revealed that the large majority of snowplowable markers were the Stimsonite marker with several states experimenting with a recessed marker (3).

An evaluation of several types of snowplowable markers was conducted in 1981 and 1982 (4). The Stimsonite 96, Dura-Brite, and recessed markers were observed to be acceptable snowplowable markers. However, considering all available input, the recessed marker was recommended as the most functional and cost-effective.

The first large-scale contracts for the installation of snowplowable markers in Kentucky were awarded in 1984 and 1985. The Stimsonite 96 and recessed markers were installed. The objective of this study was to evaluate the performance of these installations.

INSTALLATIONS

Summaries of snowplowable marker contracts are presented in Tables 1 and 2. As shown in Table 1, four contracts have been awarded through 1985 for the installation of recessed markers for a total of about 109,000 markers over approximately 800 miles. The first recessed markers were placed in September 1984. The cost of sawing the groove has varied from $4.44 to $5.79 per groove and the cost per marker has varied from $1.82 to $2.50 for a total installed unit cost of $6.26 to $8.29. Contracts were awarded in 1986 for the installation of about 20,000 additional recessed markers.

As shown in Table 2, five contracts have been awarded through 1985 for the installation of Stimsonite 96 markers for a total of about 311,000 markers over approximately 2,200 miles. The first Stimsonite 96 markers were installed in October 1984. The installed unit costs have ranged from $15.39 to $17.50. Contracts were awarded in 1986 for the installation of approximately 197,000 additional Stimsonite 96 markers.

The most recent specifications for the markers are contained in Special Provision No. 74C(85) of the Kentucky Department of Highways, which are included in Appendix A. The recessed marker consisted of a 48-inch long groove having a width of 4-1/2 inches and a constant depth of 1/2 inch. The marker was placed at the downstream end of the groove except on downhill grades where it could be moved up a few inches from the end to allow water to pool behind the marker. The Stimsonite 947 low-profile marker was placed in the groove using epoxy. A straightedge was placed across the groove during placement of the marker so that the top of the installed marker was flush with
the pavement surface. The specifications required that markers extending above the pavement surface or more than 1/8 inch below the pavement surface be removed and replaced with correctly installed markers. Photographs of sawing the groove and placement of the marker are shown in Figure 1.

The Stimsonite 96 marker consisted of a cast-iron housing having the same reflective unit used in the recessed marker. A specially designed concrete saw was used to cut the pavement to recess the marker and then the sawed area was partially filled with epoxy and the marker was placed. The saw cut for the marker and an installed marker are shown in Figure 2. The marker is designed so that the snowplow blade rides over the tapered housing and does not contact the reflector. The housing has a low-profile six-degree slope to a 7/16 inch maximum height to reduce the effect of the snowplow blade.

The two types of snowplowable markers were installed on different types of roadways. The recessed markers were installed only on multilane highways, primarily interstates. This allowed the marker to be placed at the back of the groove. Also, the roadway geometrics for these roadways would be better than for two-lane highways. These factors would allow for optimum viewing of the recessed markers. The Stimsonite 96 markers were installed almost completely on two-lane roadways. Most of the installations were in rural areas.

PROCEDURE

The evaluation consisted of 1) detailed and nighttime inspections of both types of markers and 2) before-and-after accident analyses on those installed in 1984. The detailed inspection involved closely inspecting for damage and proper installation (especially the recessed markers). A total of 20 recessed marker locations (listed in Table 3) and 30 Stimsonite 96 locations (listed in Table 4) were included in the detailed inspections. Twenty-five markers were inspected at each location so that a total of 500 recessed markers and 750 Stimsonite 96 markers were included in the detailed inspection. For the recessed markers, installation data concerning the groove length, groove depth, distance from the top of the marker to the pavement surface, and marker placement were obtained along with information concerning lens damage. For the Stimsonite 96 markers, damage to the lens, marker, housing, and pavement were examined along with the installation of the marker.

Nighttime inspections involved driving sections of roadway and counting each marker lens by category based on the percentage of the lens visible. Listings of the roadways inspected are contained in Tables 5 and 6 for recessed and Stimsonite 96 markers, respectively. About 12,000 recessed markers and 14,600 Stimsonite 96 markers were included in the survey.

Two sets of inspections were performed. The first was in the summer and fall of 1985 and the second was in the spring and summer of 1986. This allowed each section to have either one or two winters in use so that all the markers had been snowplowed.

To have a full year of after accident data available, only sections of roadway that had markers installed in 1984 were included in the accident analysis. One year of after data (1985) was compared to two years of before
A total of 122 miles of recessed markers and 565 miles of Stimsonite 96 markers was used in the analysis. Changes in total accidents, nighttime accidents, and wet-nighttime accidents were analyzed. Sections of similar types of highways where no markers were installed were selected as a control to compare to the sections where snowplowable markers were installed.

RESULTS

DETAILED INSPECTIONS

Detailed inspections were conducted at 20 recessed marker locations. Twenty-five markers were inspected at each location providing a total of 500 markers included in this part of the survey.

The initial inspection included several measurements relating to installation. The results are shown in Table 7 by location and summarized in Table 8. The average groove length at all locations was 50 inches compared to the 48-inch groove designated in the specifications. The average groove length, by location, varied from 47 inches at two locations to a maximum of 55 inches. About 60 percent of all grooves measured were within plus or minus 2 inches of the 48-inch standard and about 83 percent were within plus or minus 4 inches. The shortest groove measured was 40 inches and the longest was 61 inches.

As shown in Table 8, the average groove depth was 0.48 inch compared to the 0.5-inch depth designated in the specifications. The average groove depth at the various locations varied from 0.43 to 0.54 inch. About 88 percent of all grooves measured were within plus or minus 1/16 inch of the 1/2-inch specified. The measured groove depth varied from 1/4 inch to 5/8 inch.

A concern in the installation process was placement of the marker such that the top of the marker was flush with the pavement surface. The specifications required that the top of the marker not extend above the pavement surface or be more than 1/8 inch below the pavement surface. As shown in Table 8, only 5.4 percent were found to extend above the pavement and only 2.6 percent were greater than 1/8 inch below the pavement surface.

The specifications also stated that, on downhill grades, the marker should be installed several inches from the end of the groove to reduce water pooling in front of the marker. Measurements indicated, as shown in Table 7, that the markers were being placed farther from the end of the groove when placed on a grade.

The groove width was specified to be 4-1/2 inches. Average groove widths varied from 4.3 to 4.5 inches. The average groove width was 4-7/16 inches.

A summary, by location, of the damage to the lens of the recessed marker as noted in the detailed inspections is given in Table 9. The data are summarized in Table 10 for the 1985 and 1986 inspection periods. The date of inspection, days in service, and traffic exposure are presented along with the lens damage observed. The damage was classified as either under or over 50 percent of the lens damaged (missing) or where the lens was cracked with none.
of it missing. This percentage (50 percent) was selected as the point at which the marker lost a substantial amount of its effectiveness. That is, in a replacement program, markers having more than 50 percent of their lens missing should be replaced. As may be noted, only a small percentage of the markers, 0.2 percent in 1985 and 1.3 percent in 1986, had more than 50 percent of their lens missing. The markers inspected in 1986 had been in service for an average of 332 days, or almost one year. The average daily traffic (ADT) at those locations was about 14,400. As may be noted, the detailed inspections revealed the recessed markers to be in good condition after about one year in service.

The typical condition of a recessed marker after an average of about one year in service is shown in Figure 3. The markers were typically in good condition with minor chipping to the abrasive coating on the lens. The typical damage noted on a recessed marker is shown in Figure 4. The damage was usually to the top, with some of the lens damaged. The results of placing the marker so that its top was slightly above the pavement is shown in Figure 5. This marker was placed with the top 1/16 inch above the pavement and appears to have been damaged by snowplows. This marker also shows what may happen when only a small portion of damage to the top of the lens occurs, that is, discoloration to a large portion of the lens. In several instances, while only a small percentage of the lenses were damaged, water was allowed to get behind the lenses due to damage to the tops of the markers and the markers' reflectivity was lost. This was evident from the nighttime inspections.

A question regarding the recessed markers was whether the grooves would lead to damage to the pavement. However, no such problem was noted. Even when the groove was placed where the pavement was previously cracked, there was usually no problem, as illustrated in Figure 6. The exception was when the groove was placed on a pavement that was in very poor condition. As shown in Figure 7, if the pavement was excessively cracked, sections of the pavement in the groove failed, resulting in loss of the marker in some instances.

There was no problem with pavement failure noted when the groove was placed in a portland cement concrete (PCC) pavement. There was concern that there might be damage since the groove would be close to the pavement joint. The groove was usually placed one to two inches from the joint as shown in Figure 8, but, even when placed next to the joint, as shown in Figure 9, no damage was noted.

Another question pertaining to the recessed marker was whether dirt would accumulate in the groove. However, as illustrated by the previous photographs of recessed markers, this was not observed to be a problem. Traffic kept the grooves clear of debris.

The major problem observed with the recessed markers during the inspections did not relate to durability. Some inspections were made shortly after substantial amounts of rainfall and collection of water in the groove as shown in Figure 10 was noted. This groove is on a level section of roadway. If the groove was on an upgrade, water would accumulate away from the marker (Figure 11) but, if there was a downgrade, water would tend to cover the marker (Figure 12). The water would be blown out of the groove fairly quickly by the traffic, especially on the high volume and speed interstates having a
large percentage of truck traffic. The length of time the water remained in
the groove was also related to the pavement type. Water remained longest in a
groove on a portland cement concrete pavement and shortest on an open-graded
asphaltic concrete pavement where it could also drain readily through the
pavement.

A summary, by location, of the results of the detailed inspections of the
Stimsonite 96 markers is given in Table 11. The data are summarized in Table
12 for the 1985 and 1986 inspection periods and by the year the marker was
installed (1984 or 1985). As with the recessed marker inspection, the date of
inspection, days in service, traffic exposure, and numbers having damaged
lenses was listed. In addition, the numbers having damaged steel housing and
either paint or epoxy on the lenses were summarized.

Only one of the 750 markers was observed to have steel housing damage
and, as shown in Figure 13, this marker had been torn out of the pavement
(probably by a snowplow). Observations of other installations revealed this
occurrence to be very rare. The markers appeared to be installed properly, so
there should be no damage to the steel housing.

Several lenses were observed to be partially covered with paint as shown
in Figure 14. The paint striper was equipped with a device that allowed the
metal marker to be detected, which cut off the paint spray temporarily so the
marker would not be painted. This device worked well in almost all instances
as illustrated in Figure 15. The 1986 inspection revealed less problem with
painted lenses compared to the 1985 inspection. No additional markers had
been painted and the paint had started to wear off the lenses painted in 1985
(Figure 16). The Stimsonite 96 markers were placed with epoxy and, in a very
few instances, an excess amount of epoxy was used, allowing it to cover part
of the lens.

As with the recessed marker inspections, only a small percentage of the
lenses had more than 50 percent missing (1.6 percent in the 1986 inspection
compared to 1.0 percent for the recessed marker). The 1986 inspection
revealed another 8.0 percent having under 50 percent missing compared to 4.2
percent for the recessed marker. The 1986 inspection revealed another 5.1
percent with the lenses cracked compared to 1.2 percent of the recessed
markers. As may be noted, while the damage to the Stimsonite 96 marker was
not great, there was more damage than that observed for the recessed markers.
This difference could be partially explained due to the greater number of days
in service of the Stimsonite 96 markers (an average of 436 days compared to
332 days for the recessed markers). However, the average traffic exposure was
higher for the recessed marker locations (4.82 million vehicles) than for the
Stimsonite 96 locations (1.82 million vehicles) due to the higher average ADT
(14,400 at the recessed marker locations and 4,100 at the Stimsonite 96
locations). Also, since the Stimsonite 96 markers were placed on the narrower
two-lane roadways compared to the four-lane, interstate-type highways for the
recessed markers, there would be a greater tendency for traffic to run over
the Stimsonite 96 marker.

Most Stimsonite 96 markers appeared as shown in Figure 17, with the only
wear being the chipping of the abrasive coating of the marker lenses. A
photograph of the damage due to a cracked lens is shown in Figure 18. The
typical damage is shown in Figure 19 and severe damage is shown in Figure 20.
The reflective element in the Stimsonite 96 marker is the same low-profile marker that is placed in the groove. It is attached to the housing with an adhesive pad. The entire marker was not found to be missing at any of the detailed inspection locations. However, failure of proper adhesion between the marker pad and housing was noted in a few instances, as illustrated in Figure 21.

NIGHTTIME INSPECTIONS

A summary, by location, of the data obtained in the nighttime inspections at recessed marker locations is given in Table 13. The numbers of markers surveyed, the date of inspection, approximate days in service, and traffic exposure are listed along with the amount of damage observed. The damage was classified according to the percentage of the lenses damaged.

The data for the recessed marker nighttime inspections are summarized in Table 14. Results of the 1985 and 1986 inspections are summarized separately as well as the installations made in 1984 and 1985. Considering all data, the percent of markers having 50 percent or more loss in reflective surface was 1.5 percent in the 1985 survey and 3.7 percent in the 1986 survey. The percentage having a loss in reflective surface of less than 50 percent of the lens was 2.2 percent in the 1985 survey and 6.6 percent in the 1986 survey. Therefore, the nighttime survey revealed that about 10 percent of recessed markers had some loss in the reflective surface after an average of about one year in service. This percentage was higher than that noted in the detailed survey. One explanation would be the larger traffic exposure at the nighttime inspection locations when the average ADT, weighted to consider the length of each location, was about 21,700. Another explanation would be that damage to only a small portion of the lenses may result in lack of reflectivity to a larger portion of the lenses if water is allowed behind the lenses.

Observations during the 1986 nighttime inspections indicated the recessed markers to still be providing excellent delineation at the 80-foot spacing on the type of roadway where they were installed. Several markers were usually visible with no fewer than three visible even at locations such as hill crests and curves. Nighttime photographs of two recessed marker locations are shown in Figure 22. The only problem with reflectivity occurs when there is a very heavy rainfall. At some locations, depending on roadway geometrics, visibility may be limited to one marker and some markers became obscured for a short period of time.

A summary by location of data obtained in the nighttime inspections at the Stimsonite 96 locations is given in Table 15, and the data are then summarized in Table 16. The same types of data and summaries are presented as for the recessed markers.

Considering all data, the percent of lenses having 50 percent or greater loss of reflective surface was 0.9 percent in the 1985 survey and 1.5 percent in the 1986 survey. The percentage having a loss in the reflective surface of less than 50 percent was 1.1 percent in the 1985 survey and 3.8 percent in the 1986 survey. Therefore, the nighttime survey revealed that about 5.6 percent of Stimsonite 96 markers had some loss in the reflective surface after an average of about 490 days in service. The percentage of lenses having a loss
of reflectivity was less for the Stimsonite 96 than for the recessed markers. An explanation would be that, even though the Stimsonite 96 locations had been in place longer, the traffic exposure was much higher at the recessed marker locations due to the higher traffic volume (a weighted value considering length of location of 21,700 at the recessed marker locations compared to 4,200 at the Stimsonite 96 locations).

Observations revealed that the Stimsonite 96 markers placed at a 40-foot spacing provided very good delineation. Daytime and nighttime photographs of a straight section of two-lane roadway are shown in Figure 23. A nighttime photograph of the Stimsonite 96 markers through a curve is shown in Figure 24. Observations revealed that the 40-foot spacing could be decreased to an 80-foot spacing on tangents but should be maintained on curves.

ACCIDENT ANALYSIS

To estimate the effect the snowplowable markers have had on traffic accidents, a before-and-after accident analysis of snowplowable marker installations and control locations was conducted. The results are presented in Table 17. The analysis was limited to locations installed in 1984 so that a one-year after period could be obtained. Recessed markers were installed on about 122 miles of roadway in 1984 (all on interstate highways). Stimsonite 96 markers were installed on about 566 miles of roadway in 1984. Accident data for 1982 and 1983 were used for the before data and data for 1985 were used as the after data. As control sections for the recessed markers, about 71 miles of interstate highways were selected where recessed markers had not been installed before the end of 1985. Approximately 322 miles of highways, similar to the type where Stimsonite 96 markers were placed but where no markers were installed, were selected as control sections for the Stimsonite 96 installations.

In Table 17, total accidents and the percent of all nighttime and wet-nighttime accidents are listed for the Stimsonite 96 marker and recessed marker installations and control sections. The percentages of nighttime and wet-nighttime accidents were used because the total number of accidents increased substantially in 1985 compared to 1982 and 1983. Nighttime and wet-nighttime accidents are the types that would be expected to be affected by the installation of snowplowable markers. The accident data showed a dramatic decrease in these types of accidents at the Stimsonite 96 markers and recessed marker locations. There was not such a reduction at the recessed marker control locations. A statistical analysis indicated that, considering the control locations, there was a reduction in the percentage of nighttime accidents at the recessed marker locations with a significance level of 0.99 while there was a reduction in the percentage of wet-nighttime accidents with a significance level of 0.90 (5). However, the Stimsonite 96 control locations showed a very similar reduction in the percentage of nighttime and wet-nighttime accidents as the Stimsonite 96 installation locations. Therefore, no statistical accident benefit from the installation of the Stimsonite 96 markers could be documented. The types of highways on which the Stimsonite 96 markers are installed were constructed to lower design standards than the highways on which the recessed markers were installed, so the Stimsonite 96 markers have the potential for a greater benefit. The percentages reduction in nighttime and wet-nighttime accidents were actually
greater at the Stimsonite 96 than the recessed marker locations. However, for an unknown reason, the Stimsonite 96 control locations also experienced a large reduction in nighttime and wet-nighttime accidents.

SUMMARY

1. Contracts for the installation of about 109,000 recessed markers over 800 miles and about 311,000 Stimsonite 96 markers over 2,200 miles had been awarded through the end of 1985.

2. Total installed unit costs were in the range from $6.26 to $8.29 for the recessed markers and from $15.39 to $17.50 for the Stimsonite 96 markers.

3. Inspections of installations of both types of markers revealed they were installed properly. Specifically, for the recessed marker, the groove length, depth, width, marker placement, and distance from the pavement surface to the top of the marker were checked and found to meet specifications in most instances.

4. After an average of about one year in service, the detailed inspections revealed only 1.0 percent of the recessed markers had over 50 percent lens damage while another 4.2 percent had under 50 percent damage and another 1.2 percent had the lens cracked. There was no damage to 93.6 percent of the markers.

5. After an average of over one year in service, the detailed inspections revealed only 1.6 percent of the Stimsonite 96 markers had over 50 percent lens damage while another 8.0 percent had under 50 percent damage and another 5.1 percent had the lens cracked. There was no damage to 85.3 percent of these markers.

6. No problem was detected relative to dirt accumulation in the groove used for the recessed marker. Traffic kept the groove free of debris.

7. The groove that was installed for placement of the recessed marker was not observed to cause damage to the pavement.

8. The paint skipping device used in conjunction with the Stimsonite 96 markers was noted to work properly in all but a few instances.

9. For both the recessed markers and Stimsonite 96 markers, chipping of the abrasive coating of the marker lens was noted, but this did not cause any durability problem or loss in reflectivity.

10. After an average of about one year in service, the nighttime inspections revealed 3.7 percent of the recessed markers had over 50 percent loss of the reflective surface while another 6.6 percent had under 50 percent loss.

11. The nighttime inspections revealed that the recessed markers provided excellent delineation at the 80-foot spacing on the type of roadway where they were installed.
12. The major problem with the recessed markers concerned the accumulation of water in the groove for short periods of time during periods of heavy rainfall. This would limit visibility to only one or two markers or, depending on the roadway geometry, the recessed marker could be obscured by the water.

13. After an average of over one year in service, the nighttime inspections indicated 1.1 percent of the Stimsonite 96 markers had over 50 percent loss of the reflective surface while another 3.8 percent had under 50 percent loss.

14. The nighttime inspections revealed that the 40-foot spacing used for the Stimsonite 96 markers provided very good delineation and could be decreased to an 80-foot spacing on tangents; however, the 40-foot spacings should be maintained on horizontal curves.

15. An accident analysis at locations where recessed markers were installed revealed that considering control locations, there were statistically significant reductions in the percentage of all nighttime and wet-nighttime accidents. There was also a large reduction in the percentage of these accidents at Stimsonite 96 locations, but a very similar reduction was found at the Stimsonite 96 control locations.

IMPLEMENTATION

The durability and reflectivity results show that both the recessed markers and Stimsonite 96 markers have performed effectively as snowplowable markers. The only problem found with either marker was the accumulation of water in the recessed marker groove for short periods of time during heavy rainfall. The installed cost of the recessed marker has remained about one-half that of the Stimsonite 96 marker. The use of recessed markers should be limited to four-lane highways constructed to high geometric standards with the Stimsonite 96 markers installed on the majority of highways. The spacing of the Stimsonite 96 markers should be increased from 40 feet to 80 feet on tangents and shallow curves. A spacing of 40 feet should continue to be used on sharp curves. This change in spacing should serve to alert the motorist of the change in alignment and insure a minimum number of markers being kept in view. The 40-foot spacing should be used when the design speed of the curve is less than 55 mph. Therefore, the 40-foot spacing should be used on curves having a degree of curvature greater than six degrees. A field procedure for the measurement of horizontal curvature is given in Appendix B.

REFERENCES


### TABLE 1. SUMMARY OF RECEESSED MARKER CONTRACTS

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<th>CONTRACT</th>
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* Contracts awarded through 1985.

** Includes estimate of markers to be installed in two sections that have not been completed.

### TABLE 2. SUMMARY OF STIMSONITE 96 MARKER CONTRACTS*

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<td>16,500</td>
<td>Conc</td>
<td>Dec 1984</td>
</tr>
<tr>
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<td>Harl, Larue, Herdin</td>
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<td>61.2</td>
<td>90.5</td>
<td>NB</td>
<td>20,900</td>
<td>Bit</td>
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</tr>
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<td>McCracken, Marshall</td>
<td>I 24</td>
<td>4.3</td>
<td>41.6</td>
<td>EB</td>
<td>12,600</td>
<td>Bit</td>
<td>Nov 1984</td>
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<td>US 62</td>
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<td>9.4</td>
<td>EB</td>
<td>6,900</td>
<td>Bit</td>
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<tr>
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<td>Lyon</td>
<td>US 62</td>
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<td>4.8</td>
<td>WB</td>
<td>6,900</td>
<td>Bit</td>
<td>June 1985</td>
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* Average ADT for total length of location.

** Combination of PCC and bituminous.

---

### TABLE 6. LOCATIONS FOR STIMSONITE 96 MARKERS NIGHTTIME INSPECTIONS

<table>
<thead>
<tr>
<th>LOCATION NUMBER</th>
<th>COUNTY</th>
<th>ROUTE</th>
<th>BEGINNING MILEPOINT</th>
<th>ENDING MILEPOINT</th>
<th>ADT*</th>
<th>TYPE</th>
<th>INSTALLED</th>
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<td>Henry</td>
<td>US 421</td>
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<td>2,200</td>
<td>Bit</td>
<td>Sept 1985</td>
</tr>
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<td>Jessamine</td>
<td>US 27</td>
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<td>19,600</td>
<td>Bit</td>
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</tr>
<tr>
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<td>Jessamine</td>
<td>US 27</td>
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<td>6,800</td>
<td>Bit</td>
<td>Oct 1984</td>
</tr>
<tr>
<td>Garrard</td>
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<td></td>
<td></td>
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<td>Bit</td>
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</tr>
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<td>Bit</td>
<td>Oct 1984</td>
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* Average ADT for total length of location.
TABLE 7. RECESSED MARKERS DETAILED INSPECTIONS DATA RELATING TO INSTALLATION

DISTANCE FROM PAVEMENT SURFACE TO TOP OF MARKER (INCH)

<table>
<thead>
<tr>
<th>NUMBER</th>
<th>LOCATION</th>
<th>LENGTH (INCHES)</th>
<th>DEPTH (INCH)</th>
<th>AVERAGE GROOVE</th>
<th>AVERAGE GROOVE</th>
<th>AVERAGE MARKER</th>
<th>AVERAGE GROOVE</th>
<th>PLACEMENT WIDTH</th>
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<td>4.4</td>
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<td>17</td>
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<td>4.5</td>
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<td>7</td>
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<td>17</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>4.3</td>
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</tbody>
</table>

* Top of marker above pavement surface.
** Distance from back of marker to end of groove.
*** Markers were placed on a grade.
TABLE 8. SUMMARY OF INSTALLATION DATA FOR RECESSED MARKERS DETAILED INSPECTIONS

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<thead>
<tr>
<th></th>
<th>Number</th>
<th>Percent</th>
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</tr>
<tr>
<td>Average Groove Depth</td>
<td>0.48</td>
<td></td>
</tr>
<tr>
<td>Average Marker Placement</td>
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</tr>
<tr>
<td>Average Groove Width</td>
<td>4.44</td>
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</table>

Distance from Pavement Surface to Top of Marker

<table>
<thead>
<tr>
<th>Distance from Pavement Surface to Top of Marker</th>
<th>Number</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>-1/8 Inch</td>
<td>3</td>
<td>0.6</td>
</tr>
<tr>
<td>-1/16 Inch</td>
<td>24</td>
<td>4.8</td>
</tr>
<tr>
<td>Flush</td>
<td>227</td>
<td>45.4</td>
</tr>
<tr>
<td>1/16 Inch</td>
<td>157</td>
<td>31.4</td>
</tr>
<tr>
<td>1/8 Inch</td>
<td>76</td>
<td>15.2</td>
</tr>
<tr>
<td>3/16 Inch</td>
<td>10</td>
<td>2.0</td>
</tr>
<tr>
<td>1/4 Inch</td>
<td>3</td>
<td>0.6</td>
</tr>
</tbody>
</table>

* Distance from back of marker to end of groove.
<table>
<thead>
<tr>
<th>LOCATION NUMBER</th>
<th>DATE OF INSPECTION</th>
<th>DAYS IN TRAFFIC</th>
<th>TRAFFIC EXPOSURE*</th>
<th>PERCENT OR MORE CRACKED</th>
</tr>
</thead>
<tbody>
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<td>60</td>
<td>1.03</td>
<td>1</td>
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<tr>
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<td>6.19</td>
<td>4</td>
</tr>
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<td>361</td>
<td>12.71</td>
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<td>6-03-85</td>
<td>361</td>
<td>12.71</td>
<td>2</td>
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<tr>
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<td>54</td>
<td>1.90</td>
<td>0</td>
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<tr>
<td>9</td>
<td>6-03-85</td>
<td>367</td>
<td>9.87</td>
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<td>8-23-85</td>
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* Million vehicles over test section.
### TABLE 10. SUMMARY OF LENSES DAMAGE TO RECESSED MARKERS (DETAILED INSPECTIONS)

<table>
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<th>Inspection Date</th>
<th>1985*</th>
<th>1986**</th>
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<tr>
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</tr>
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<td>Over 50 Percent Damaged</td>
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</tr>
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<td>Lenses Cracked</td>
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<td>0.8</td>
</tr>
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</table>

*Average of 94 days in service and average traffic exposure of 0.91 million vehicles.

**Average of 332 days in service and average traffic exposure of 4.82 million vehicles.
<table>
<thead>
<tr>
<th>LOCATION NUMBER</th>
<th>DATE OF INSPECTION</th>
<th>DAYS IN SERVICE</th>
<th>TRAFFIC EXPOSURE*</th>
<th>LENSES DAMAGE</th>
<th>STEEL</th>
<th>LENSES PAINTED</th>
<th>LENSES PARTIALLY COVERED WITH EPOXY OR TAR</th>
</tr>
</thead>
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<tr>
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<td>LOCATION DATE</td>
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<td>50 PERCENT OR MORE</td>
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* Inspections conducted in 1985. Average of 193 days in service and average traffic exposure of 0.80 million vehicles.

** Inspections conducted in 1986. Average of 436 days in service and average traffic exposure of 1.86 million vehicles.
# TABLE 13. RECESSED MARKERS NIGHTTIME INSPECTIONS

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<td>0.0</td>
</tr>
<tr>
<td></td>
<td>5-21-86</td>
<td>320</td>
<td>2.21</td>
<td>278</td>
<td>0</td>
<td>4</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

* Number of marker lenses having given damage.

** Number of vehicles (in millions).
**TABLE 14. SUMMARY OF DATA FOR RECESSION MARKERS NIGHTTIME INSPECTIONS**

<table>
<thead>
<tr>
<th>YEAR INSTALLED</th>
<th>TOTAL MARKERS</th>
<th>DAYS IN TRAFFIC SERVICE</th>
<th>AVERAGE TRAFFIC EXPOSURE**</th>
<th>NO DAMAGE</th>
<th>NOT VISIBLE</th>
<th>PERCENTAGE OF LENSES DAMAGED</th>
<th>50 PERCENT OR GREATER</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>UNDER 25</td>
<td>25-49</td>
<td>50-74</td>
<td>75-99</td>
</tr>
<tr>
<td>1984***</td>
<td>3,102</td>
<td>375</td>
<td>5.14</td>
<td>2,913</td>
<td>18</td>
<td>85</td>
<td>29 29 29</td>
</tr>
<tr>
<td>1985***</td>
<td>8,438</td>
<td>140</td>
<td>1.89</td>
<td>8,728</td>
<td>53</td>
<td>53</td>
<td>51 20 33</td>
</tr>
<tr>
<td>ALL***</td>
<td>12,040</td>
<td>180</td>
<td>2.48</td>
<td>11,641</td>
<td>71</td>
<td>138</td>
<td>80 49 61</td>
</tr>
<tr>
<td>1984****</td>
<td>3,102</td>
<td>560</td>
<td>8.13</td>
<td>2,704</td>
<td>47</td>
<td>149</td>
<td>51 28 33</td>
</tr>
<tr>
<td>1985****</td>
<td>8,930</td>
<td>333</td>
<td>7.50</td>
<td>8,136</td>
<td>145</td>
<td>360</td>
<td>108 98 91</td>
</tr>
<tr>
<td>ALL****</td>
<td>12,040</td>
<td>371</td>
<td>7.60</td>
<td>10,930</td>
<td>192</td>
<td>509</td>
<td>159 126 124</td>
</tr>
</tbody>
</table>

* Number of marker lenses with given damage.

** Number of vehicles (in millions).

*** Inspections conducted in 1985.

**** Inspections conducted in 1986.
### TABLE 15. STIMSONITE 96 NIGHTTIME INSPECTIONS

<table>
<thead>
<tr>
<th>LOCATION NUMBER</th>
<th>MARKERS SURVEYED</th>
<th>DATE OF INSPECTION</th>
<th>DAYS IN SERVICE</th>
<th>TRAFFIC EXPOSURE***</th>
<th>NO DAMAGE</th>
<th>NOT VISIBLE</th>
<th>DAMAGE</th>
<th>PERCENTAGE OF LENSES DAMAGED</th>
<th>PERCENT WITH 50 PERCENT OR GREATER DAMAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5,211</td>
<td>11-18-85</td>
<td>60</td>
<td>132</td>
<td>10,398</td>
<td>3</td>
<td>11</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>6-17-86</td>
<td></td>
<td>270</td>
<td>594</td>
<td>10,126</td>
<td>18</td>
<td>179</td>
<td>44</td>
<td>37</td>
</tr>
<tr>
<td>2</td>
<td>667</td>
<td>11-21-85</td>
<td>210</td>
<td>4,116</td>
<td>1,318</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>6-12-86</td>
<td></td>
<td>410</td>
<td>8,036</td>
<td>1,271</td>
<td>8</td>
<td>37</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>3</td>
<td>2,200</td>
<td>11-21-85</td>
<td>390</td>
<td>2,652</td>
<td>4,282</td>
<td>20</td>
<td>27</td>
<td>26</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>6-12-86</td>
<td></td>
<td>590</td>
<td>4,012</td>
<td>4,138</td>
<td>24</td>
<td>149</td>
<td>36</td>
<td>31</td>
</tr>
<tr>
<td>4</td>
<td>279</td>
<td>11-21-85</td>
<td>390</td>
<td>1,950</td>
<td>541</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>6-12-86</td>
<td></td>
<td>590</td>
<td>2,950</td>
<td>515</td>
<td>3</td>
<td>27</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>5</td>
<td>1,500</td>
<td>11-21-85</td>
<td>390</td>
<td>1,755</td>
<td>2,919</td>
<td>6</td>
<td>24</td>
<td>20</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td>6-07-86</td>
<td></td>
<td>580</td>
<td>2,610</td>
<td>2,803</td>
<td>20</td>
<td>97</td>
<td>41</td>
<td>28</td>
</tr>
<tr>
<td>6</td>
<td>1,460</td>
<td>11-25-85</td>
<td>390</td>
<td>468</td>
<td>2,841</td>
<td>10</td>
<td>17</td>
<td>15</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>6-07-86</td>
<td></td>
<td>580</td>
<td>696</td>
<td>2,728</td>
<td>11</td>
<td>106</td>
<td>30</td>
<td>31</td>
</tr>
<tr>
<td>7</td>
<td>1,048</td>
<td>11-25-85</td>
<td>30</td>
<td>60</td>
<td>2,073</td>
<td>8</td>
<td>10</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>6-15-86</td>
<td></td>
<td>230</td>
<td>460</td>
<td>2,059</td>
<td>8</td>
<td>23</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>1,576</td>
<td>12-04-85</td>
<td>400</td>
<td>1,640</td>
<td>3,120</td>
<td>5</td>
<td>12</td>
<td>6</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>6-15-86</td>
<td></td>
<td>590</td>
<td>2,419</td>
<td>2,950</td>
<td>9</td>
<td>123</td>
<td>38</td>
<td>30</td>
</tr>
<tr>
<td>9</td>
<td>656</td>
<td>12-04-85</td>
<td>400</td>
<td>1,120</td>
<td>1,098</td>
<td>18</td>
<td>92</td>
<td>50</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>6-15-86</td>
<td></td>
<td>590</td>
<td>1,652</td>
<td>1,072</td>
<td>20</td>
<td>108</td>
<td>52</td>
<td>32</td>
</tr>
</tbody>
</table>

* Number of marker lens having given damage. Each marker had two lens.

** Number of vehicles (in thousands).
### Table 16. Summary of Data for Stimsonite 96 Nighttime Inspections

<table>
<thead>
<tr>
<th>YEAR</th>
<th>TOTAL MARKERS</th>
<th>DAYS IN TRAFFIC</th>
<th>AVERAGE MARKERS PERIOD</th>
<th>AVERAGE DAYS IN TRAFFIC</th>
<th>EXPOSURE**</th>
<th>DAMAGE NO.</th>
<th>VISIBLE NO.</th>
<th>PERCENTAGE OF LENSES DAMAGED</th>
<th>PERCENT WITH 50 PERCENT OR GREATER LENS DAMAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1984***</td>
<td>7,671</td>
<td>390</td>
<td>1.60</td>
<td>14,801</td>
<td>62</td>
<td>176</td>
<td>119</td>
<td>130</td>
<td>54</td>
</tr>
<tr>
<td>1985***</td>
<td>6,926</td>
<td>100</td>
<td>1.44</td>
<td>13,789</td>
<td>15</td>
<td>25</td>
<td>8</td>
<td>11</td>
<td>6</td>
</tr>
<tr>
<td>ALL***</td>
<td>14,597</td>
<td>300</td>
<td>1.54</td>
<td>28,590</td>
<td>75</td>
<td>201</td>
<td>127</td>
<td>141</td>
<td>60</td>
</tr>
<tr>
<td>1984****</td>
<td>7,671</td>
<td>590</td>
<td>2.39</td>
<td>14,206</td>
<td>87</td>
<td>610</td>
<td>200</td>
<td>159</td>
<td>80</td>
</tr>
<tr>
<td>1985****</td>
<td>6,926</td>
<td>300</td>
<td>3.03</td>
<td>13,456</td>
<td>34</td>
<td>239</td>
<td>56</td>
<td>47</td>
<td>20</td>
</tr>
<tr>
<td>ALL****</td>
<td>14,597</td>
<td>490</td>
<td>2.60</td>
<td>27,662</td>
<td>121</td>
<td>849</td>
<td>256</td>
<td>206</td>
<td>100</td>
</tr>
</tbody>
</table>

* Number of marker lenses having given damage. Each marker had two lenses.
** Number of vehicles (in millions).
*** Inspections conducted in 1985.
**** Inspections conducted in 1986.
TABLE 17. BEFORE AND AFTER ACCIDENT ANALYSIS AT SNOWPLOWABLE MARKER INSTALLATIONS AND CONTROL LOCATIONS

<table>
<thead>
<tr>
<th></th>
<th>BEFORE*</th>
<th>AFTER**</th>
<th>PERCENT CHANGE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stimsonite 96 Installations</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Accidents</td>
<td>1,478</td>
<td>1,769</td>
<td>+20</td>
</tr>
<tr>
<td>Percent Total Nighttime Accidents</td>
<td>29</td>
<td>24</td>
<td>-17</td>
</tr>
<tr>
<td>Percent Wet-Nighttime Accidents</td>
<td>7.8</td>
<td>4.0</td>
<td>-49</td>
</tr>
<tr>
<td><strong>Stimsonite 96 Control Locations</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Accidents</td>
<td>779</td>
<td>960</td>
<td>+23</td>
</tr>
<tr>
<td>Percent Total Nighttime Accidents</td>
<td>30</td>
<td>23</td>
<td>-23</td>
</tr>
<tr>
<td>Percent Wet-Nighttime Accidents</td>
<td>8.2</td>
<td>4.2</td>
<td>-49</td>
</tr>
<tr>
<td><strong>Recessed Marker Installations</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Accidents</td>
<td>319</td>
<td>404</td>
<td>+27</td>
</tr>
<tr>
<td>Percent Total Nighttime Accidents</td>
<td>46</td>
<td>39</td>
<td>-15</td>
</tr>
<tr>
<td>Percent Wet-Nighttime Accidents</td>
<td>7.2</td>
<td>4.7</td>
<td>-35</td>
</tr>
<tr>
<td><strong>Recessed Marker Control Locations</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Accidents</td>
<td>294</td>
<td>341</td>
<td>+16</td>
</tr>
<tr>
<td>Percent Total Nighttime Accidents</td>
<td>41</td>
<td>41</td>
<td>0</td>
</tr>
<tr>
<td>Percent Wet-Nighttime Accidents</td>
<td>6.8</td>
<td>6.5</td>
<td>-4</td>
</tr>
</tbody>
</table>

* Average of 1982 and 1983 accident data.
** 1985 accident data.
Figure 1. Installation of Recessed Marker.
Figure 2. Steps in Installation of Stimsonite 96 Marker.
Figure 3. Typical Condition of Recessed Marker after About One Year in Service.

Figure 4. Typical Type of Damage to Recessed Marker.
Figure 5. Damage to Recessed Marker Installed with Top Slightly above the Pavement Surface.

Figure 6. Lack of Pavement Damage from Groove Even when Groove Placed Where Pavement was Cracked.
Figure 7. Failure Resulting When Recessed Marker was Placed on Pavement in Very Poor Condition.

Figure 8. Typical Placement of Groove Adjacent to Joint in Portland Cement Concrete Pavement.
Figure 9. Lack of Damage when Groove Placed Next to Joint in Portland Cement Concrete Pavement.

Figure 10. Accumulation of Water in Groove.
Figure 11. Accumulation of Water in Groove on Upgrade.

Figure 12. Accumulation of Water in Groove on Downgrade.
Figure 13. Stimsonite 96 Marker Torn Out of Pavement by Snowplow.

Figure 14. Painting over Portion of Stimsonite 96 Marker.
Figure 15. Typical Operation of Paint Striper where Paint Stripe Skipped Stimsonite 96 marker.

Figure 16. Paint Wearing Off Lens of Stimsonite 96 Marker.
Figure 17. Typical Condition of Stimsonite 96 Marker after Over One Year in Service.

Figure 18. Cracked Lens on Stimsonite 96 Marker.
Figure 19. Typical Type of Damage to Stimsonite 96 Marker.

Figure 20. Severe Damage to Stimsonite 96 Marker.
Figure 21. Reflective Element of Stimsonite 96 Marker Missing.
Interstate 24 (Lyon County)

Interstate 64 (Scott County)

Figure 22. Nighttime Delineation Provided by Recessed Markers.
Figure 23. Daytime and Nighttime Photograph of Stimsonite 96 Markers Installed on a Tangent Section (US 460 in Scott County).
Figure 24. Nighttime Delineation Provided by Stimsonite 96 Markers Installed on a Curve (US 460 in Scott County).
APPENDIX A

PAVEMENT MARKER SPECIFICATIONS
This Special Provision shall apply when indicated on the plans or in the proposal. Section references herein are to the Department's 1985 Standard Specifications for Road and Bridge Construction.

I. DESCRIPTION

This Special Provision covers requirements for permanent pavement markers, temporary pavement marking, and temporary lane marking tape. All requirements of the standard drawings and the 1985 Standard Specifications shall apply except as specifically modified or superseded herein. Markers will be classified in types, as follows:

Type III - Large highly reflectorized marker with glass shield.

Type IV - Small highly reflectorized marker with glass shield; may be installed on the pavement or in a groove cut into the pavement surface as required by the plans or proposal.

Type V - Snowplowable marker consisting of a cast iron frame enclosing a Type IV marker, installed in slots cut into the pavement surface.

Type VI - Reflectorized marker designed to be easily installed and removed for temporary use.

II. MATERIALS

A. Type III Markers. Type III markers shall conform to requirements in Section 840.04.

B. Type IV Markers and IVA Markers (Figure No. A-1)

1. Type IV Markers. Type IV markers shall comply with the requirements of Section 840.05, except markers installed in Type V iron castings shall be laminated to an elastomeric pad and adhesively attached to the casting.

2. Type IVA Markers. Type IVA markers shall comply with the requirements of Section 840.05, except for dimensions. Each Type IVA marker shall be 4.7 inches by 2.3 inches with a plus or minus 0.25 inch tolerance on length and width. Height of Type IVA markers shall be 0.52 inch, plus or minus 0.10 inch.

C. Type V Markers. Type V markers shall consist of an iron casting to which is attached a Type IV marker (mono- or bi-directional as specified elsewhere). Both ends of the casting shall be shaped to deflect a snowplow blade. The casting shall be designed so the Type IV marker may
be removed and replaced when needed to restore reflectivity in the future. The design of Type V markers shall be approved by the Department before use. Markers which generally incorporate the typical features specified herein and depicted in Figure No. A-2 will be approved, provided evidence satisfactory to the Engineer of acceptable performance in actual service on a roadway pavement is submitted. Deviations from previously approved designs will be cause for rejection of markers at any time.

(1) Dimensions. Overall dimensions shall be approximately 9.25 inches long by 5.86 inches wide by 1.74 inches high. Installed height shall be approximately 0.41 inch above the road surface.

(2) Casting material. The casting shall be nodular iron conforming to ASTM A 536-77, Grade 72-45-05, hardened to 52-54 RC.

(3) Surface. The surface of the keel and web shall be free of scale, dirt, rust, oil, grease, or any other contaminant which may reduce its bond to the epoxy adhesive.

(4) Weight. Approximately 4.6 pounds.

(5) Identification. Each casting shall be marked with manufacturer's name and manufacturer's model number of marker.

D. Certification and Acceptance. Each shipment of markers shall be accompanied by a certification from the manufacturer that the markers furnished meet all requirements of this specification. Each shipment shall be sampled in accordance with Section 840.06 and the Department's Manual of Field Sampling and Testing Practices.

Type V Markers are not required to be on the Department's list of approved markers.

Markers shall be approved before use. Approval will be based on both the certification and the results of testing by the Department.

Adhesive shall be certified as specified in Section 840.06.

E. Type VI Markers (Temporary Pavement Markers). Temporary pavement markers shall be on the list of Approved Temporary Pavement Markers on file in the Division of Materials.

F. Removable lane Tape. Removable lane tape shall be on the list of Approved Removable Lane Type on file in the Division of Materials.

G. Strength Test. Contrary to Section 840.05(d), the rate of application of the test load shall be 0.03 inch per minute.

III. CONSTRUCTION REQUIREMENTS

A. Type III, Type IV, and Type IVA Markers.
(1) Type III and Type IV Markers. Type III and Type IV Markers installed on the pavement shall be installed as specified in Section 740.03.

When required by the plans or proposal, Type IV markers shall be installed in a groove cut into the pavement, as shown in Figure No. A-1. The groove shall not be cut until the pavement has cured sufficiently for the cutting to be performed without excessive tearing or ravelling of the pavement.

The area within the groove to receive the marker shall be cleaned or otherwise prepared as recommended by the marker manufacturer. After applying adhesive, the markers shall be pressed into place using a straightedge placed across the groove, so that the top of the installed marker is flush with the pavement surface. Installed markers extending above the pavement surface or more than 1/8 inch below the pavement surface shall be removed and replaced with correctly installed markers. If the pavement groove is too deep, the bottom of the groove shall be raised with epoxy cement so the installed marker is correctly positioned. If the groove depth is greater than 3/4 inch, the bottom of the entire groove shall be raised to the correct depth with epoxy cement.

On downhill grades, the marker shall be installed up to 3 inches from the end of the groove to reduce water ponding in front of the marker, when directed by the Engineer.

(2) Type IVA Markers. On new construction, Type IVA markers may be substituted for Type IV markers at the Contractor's option, with the following conditions and exceptions:

(a) When new markers are to be installed in a groove and the Contractor elects to furnish Type IVA markers, the groove shall be cut 5 inches wide and 0.6 inches deep to accommodate the Type IVA marker, at no additional cost to the Department.

(b) When Type IV markers are to be installed in existing grooves, the Contractor may install Type IVA markers provided the end of the groove is widened and deepened, by sawing, as necessary to accommodate the Type IVA marker.

(c) The marker attached to Type V iron castings, either new or as a replacement, shall be a Type IV marker.

B. Type V Markers. Type V Markers shall be installed in slots cut into the pavement, as shown in Figure A-2. The slots shall not be cut until the pavement has cured sufficiently for the cutting to be performed without excessive tearing or ravelling of the pavement. To facilitate the cutting of the two parallel slots and intervening concaved surface simultaneously, it is recommended that an arbor and saw blades assembly be used. For additional details and tolerances of the casting and arbor-saw assembly contact the casting manufacturer.
After applying adhesive, the markers shall be pressed into place so the height of the installed marker is 0.45 inch or less above the pavement.

C. Location and Spacing. Markers shall be installed as specified on the plans or standard drawings. Type IV markers placed in a groove or Type V markers shall not be installed on bridge decks unless otherwise specified.

Markers installed at double yellow centerlines shall be placed between the two lines. Markers installed along an edge line or channelizing line shall be placed so that the near edge of the casting is no more than 1 inch from the near edge of the line. Markers installed along a lane line or dashed yellow centerline shall be placed between and in line with the dashes. Markers shall not be placed over the line except where the lines deviates visibly from their correct alignment, and then only with the approval of the Engineer.

D. Type VI Markers (Temporary Pavement Markers).
Type VI markers shall be used only when and as designated in the plans or proposal.

Type VI markers shall be installed in accordance with the manufacturer’s recommendations and shall be maintained by the Contractor throughout the duration of the application. Missing or damaged temporary markers shall be replaced within 3 days at no additional cost the the Department.

Type VI markers are reusable provided they are not damaged. The Engineer may require either new or used Type VI markers depending upon availability and cost effectiveness.

After completion of the work, the markers shall be removed, including primer, and will become the property of the contractor.

E. Removable Lane Tape.
Removable lane tape shall be used when and as designated in the plans or proposal. This material is intended for use when lane lines, edge lines, or other pavement markings are necessary for certain phases of the construction, but must be relocated to different positions on the same pavement during other phases of construction.

This material is not intended as a permanent marking nor should it be used in situations where it will be covered with other pavement prior to its removal.

Removable lane tape shall be maintained by the Contractor throughout the duration of the application. Missing or damaged tape shall be replaced at no additional cost to the Department.

IV. METHOD OF MEASUREMENT

Pavement markers will be measured in individual units of each type acceptably furnished and installed.
Grooves for Type IV markers will be measured in individual units acceptably cut into the pavement surface.

No separate measurement or payment will be made for slots necessary to install Type V markers.

Type VI markers will be measured in individual units acceptably furnished, installed, maintained, and removed.

Type VI markers (Reused) will be measured in individual units acceptably installed, maintained, and removed; each installation of a previously used marker will be measured for payment.

When included in the contract as a bid item, Removable Lane Tape acceptably furnished, installed, maintained, and removed will be measured in linear feet.

V. BASIS OF PAYMENT

Each marker will be paid for at the contract unit price each, which payment shall be full compensation for all labor, equipment, materials, and incidentals necessary to complete the work.

Grooves for Type IV markers will be paid for at the contract unit price each, which payment shall be full compensation for all labor, equipment, materials, and incidentals necessary to cut the grooves, including disposal of the cuttings.

Type VI Markers, Type VI Markers (Reused), and Removable Lane Tape will be paid for at their contract unit price, which shall be full compensation for all labor, equipment, materials, and incidentals necessary to furnish, install, maintain, and acceptably remove these items as specified in the contract.

Payment will be made under:

<table>
<thead>
<tr>
<th>Pay Item</th>
<th>Pay Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pavement Marker (Type, mono- or bi-directional, color)</td>
<td>Each</td>
</tr>
<tr>
<td>Groove for Marker</td>
<td>Each</td>
</tr>
<tr>
<td>Pavement Marker Type VI (Reused)</td>
<td>Each</td>
</tr>
<tr>
<td>Removable Lane Tape</td>
<td>Linear Foot</td>
</tr>
</tbody>
</table>
Figure A-1. Groove for Type IV Marker.

Figure A-2. Type V Snowplowable Marker.
APPENDIX B

FIELD MEASUREMENT OF HORIZONTAL CURVATURE
Horizontal curve radius (r) is calculated from the middle ordinate (M) of a 50 foot or 100 foot chord (C) where:

\[
r = \frac{3C^2}{2M} + \frac{M}{24}
\]

C = Chord length (feet),
M = Middle ordinate (inches), and
r = curve radius (feet).

The radius is then divided by 5730 to determine the degree of curve. For example, if you laid out a 100 foot tape on the ground and measured a mid-ordinate of 30 inches, the curve radius would be:

\[
r = \frac{3(100)^2}{2(30)} + \frac{30}{24} = 501 \text{ feet}
\]

The degree of curve (D) would be:

\[
D = \frac{5730}{501} = 11 \text{ degrees}
\]