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Field Evaluation of Snowplowable Pavement Markers

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The objective of this study was to evaluate available snowplowable markers under similar traffic and snowplow operations. Five different markers were tested: Stimsonite 96, Dura-Brite, recessed, Kingray, and Prismo roadstud. The evaluation revealed that the Stimsonite 96, Dura-Brite, and recessed markers were acceptable snowplowable markers, because all three had adequate reflectivity during both dry and wet nighttime conditions. This reflectivity was maintained over the test period, and the markers proved to be durable when subjected to snowplow operations. Nevertheless, considering all available input, the recessed marker is recommended as the most functional and cost-effective marker.

Raised pavement markers have proved to be an effective delineation treatment during wet nighttime and poor visibility conditions, especially in states outside of the snowbelt. Nevertheless, the problems that result from snowplow operations are particularly severe, and marker applications are limited. Even in a border state such as Kentucky, where more than 1 million raised pavement markers have been installed, only one winter of heavy snow and resultant snowplow operations can destroy a significant part of the installations.

In an attempt to provide wet nighttime delineation by using the concept of raised pavement markers, considerable effort has been devoted to developing snowplowable pavement markers. The most widely used and most successful approach to the development of a snowplowable marker has been to retain the reflective unit of a raised pavement marker and attempt to protect it from snowplows. Usually the reflective unit is encased or surrounded by a material that is resistant to snowplow blades. Consistently mixed results, particularly with regard to the cost-effectiveness of the markers, have been the rule in almost all experimental and large-scale installation projects.

Several types of snowplowable markers have been field tested in the past few years. These tests have been conducted independently under different field conditions. The objective of this study was to evaluate all available snowplowable markers under similar traffic and snowplow operations.

BACKGROUND

A recent survey (1) of the use of snowplowable markers indicated that the majority of existing markers were the Stimsonite marker--either the Stimsonite 96 model or the older Stimsonite 99 model (see Figure 1). This marker consists of an iron casting with an attached prismatic retroreflector. Both ends of the castings are shaped to deflect a snowplow blade. This marker has been evaluated (2-4), but it had not been compared directly with other markers.

The survey indicated that several states experimented with a recessed marker (1). The installation in this study involved placing a regular or low-profile raised marker into a groove cut into the pavement so that the top of the marker was flush with the pavement surface. A recessed marker, which used a regular raised marker in the groove, was included in this study. Some installations have used a groove with a cross section that had several peaks and valleys (5,6). However, this study used a full-width groove similar to installations in Tennessee and South Carolina. The Stimsonite 911 marker (Figure 2) was installed in the groove.

In an effort to include all other available snowplowable markers in the test, various manufacturers were contacted. As a result, two additional markers were included in the original installation, and a small number of another marker were installed shortly thereafter. The new markers were the Dura-Brite (Figure 3), Kingray (Figure 4), and Prismo roadstud (Figure 5) markers. The Dura-Brite marker includes a steel frame set in precast concrete. The replaceable reflector is mounted between the two steel runners that protrude above the pavement surface. The runners are shaped so that the marker can be plowed at an angle. The Kingray marker involves placing the reflective lens in an insert that is depressed in an outer sleeve when struck by a tire or a snowplow blade. The Prismo roadstud is a die cast aluminum marker that provides an anchor stem for additional durability.

A few other potential snowplowable markers were investigated. However, the development or marketing of these markers had either stopped or was progressing so slowly that they were not available for testing.

The lane-delineation survey also obtained information about installation costs (1). The average cost of numerous installations of Stimsonite markers was approximately $16 per marker, but a more accurate current cost would be close to $20 per marker when installed in large quantities. Cost data were not available for the Dura-Brite marker at the time of the survey, but estimates place the cost of this marker to be similar to the Stimsonite markers. No cost figures are available for large installations of the Kingray marker, but its cost would not be less than that of the Stimsonite or Dura-Brite markers. The most inexpensive snowplowable marker installed to date has been the recessed marker, which has a reported cost per marker in the $8 to $9 range. The cost for a regular, raised pavement marker is approximately $3 per marker.

INSTALLATION

Four of the test marker types were installed in December 1980. The fifth type, the Prismo roadstud, was installed by the manufacturer in January 1981. A contract was awarded for the installation of 150 each of the Stimsonite 96, recessed, Dura-Brite, and Kingray markers. The contract was for $31,371.12, or $52.29 per marker. Installation of such a small number of markers resulted in this extremely high cost. Fifty-two of the Prismo markers were installed at the expense of the manufacturer.

Two test locations were selected. Both locations were four-lane divided highways. One location (US-68 in Fayette County) had a portland cement concrete pavement, whereas the other (US-27 in Jessamine and Garrard Counties) had a bituminous pavement. The following criteria were used when selecting the test locations:

1. The roadway could be plowed with any type of snowplow blade that is used in normal snowplow operations;
2. A minimum annual average daily traffic (AADT) of 15,000 was preferable;
3. Part of one test section should be in a high weave area; and
4. Test sections should not have roadway lighting.

The markers were only to be installed on skip lines.

All snowplow operations were performed with a steel blade. In the past, rubber-tipped blades have been used on roadways that had raised markers. Also, virtually all multilane highways in Kentucky that did not have roadway lighting have had raised markers added. This meant that the snowplowable markers had to replace regular raised markers. For practical reasons, isolated, short sections of mul-

Figure 1. Stimsonite 96 marker.

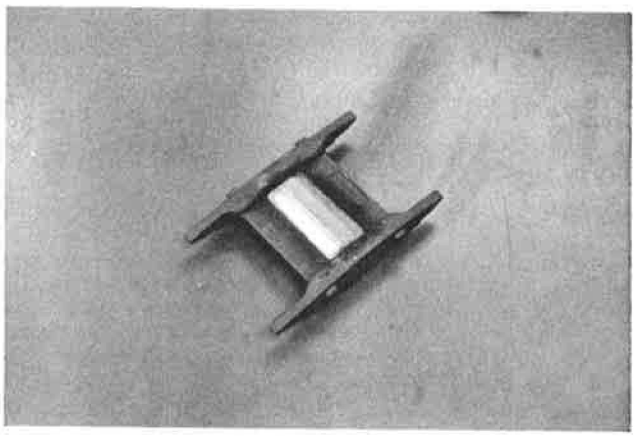


Figure 2. Stimsonite marker used as a recessed marker.

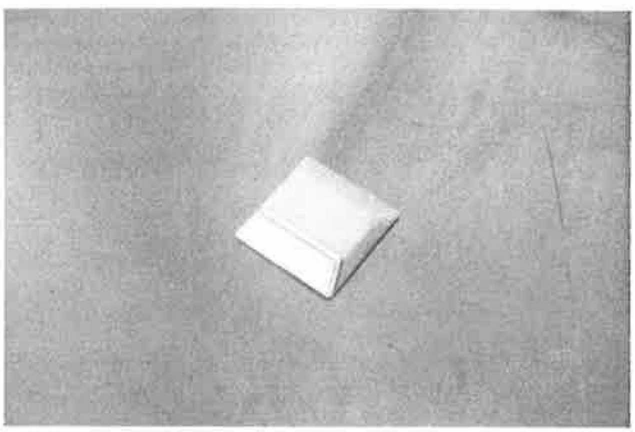


Figure 3. Dura-Brite marker.

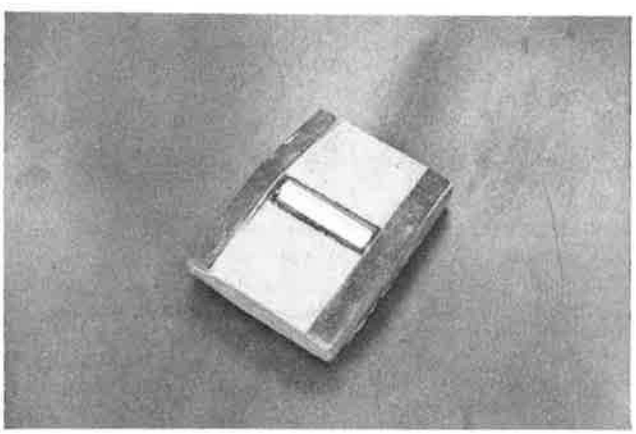


Figure 4. Kingray marker.

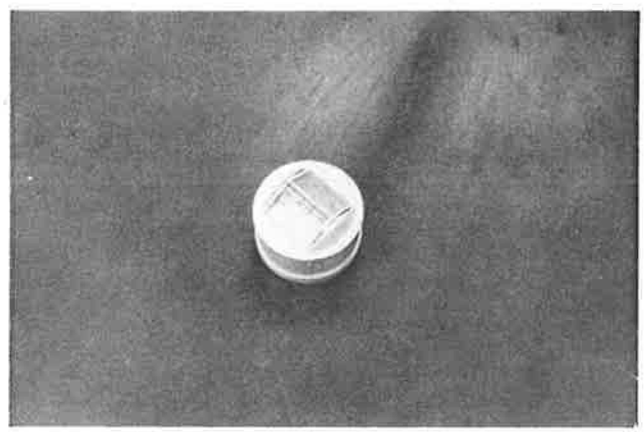
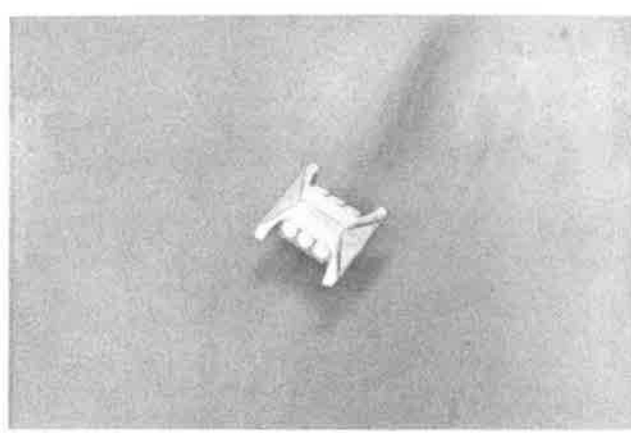


Figure 5. Prismo marker.



tilane highways had to be found for the test installation because maintenance personnel could not be expected to use a different snowplow blade for a short section of a long multilane highway. Arrangements were made with maintenance personnel to assure that the two short sections of highway would be plowed with the normal steel blade.

Both test sections were in areas that did not have roadway lighting. The Fayette County location was adjacent to an interchange and contained several access points, which generated a significant amount of lane changing. The 1980 AADT of the Fayette County location was 16,400, whereas the AADT at the Jessamine-Garrard County location was 7,000. The Jessamine-Garrard County location included a section with a substantial grade. Markers were placed on both the uphill and downhill grade. The old regular markers were removed before the installation of the snowplowable markers.

In general the installation pattern involved alternating the markers so that every fourth or fifth marker was the same. The exception was one direction at the Fayette County location where several of each marker type (22 or 23) were placed together. This was done so that a comparison between the number of markers visible in a line could be made. Also, a regular Stimsonite 911 marker was placed in the pattern in one direction at the Fayette County location. All markers were installed at a 40-ft spacing.

Installation of each of the markers required either a saw cut or a drilled hole in the pavement. The cuts for the Stimsonite 96, recessed, and Dura-Brite markers were made by using diamond-tipped sawblades. The Kingray and Prismo markers required drilling holes in the pavement. The average times for cutting or drilling, installing the marker, and for the adhesive material to dry are given in Table 1. Sawing or drilling time for the Stimsonite 96, recessed, and Prismo markers should be representative of larger installations. However, sawing and drilling time for the Dura-Brite and, in particular, the Kingray markers would be less on larger installations where better procedures could be used.

Table 1. Installation times.

Type of Marker	Time (sec) to Saw or Drill: Concrete	Time (sec) to Saw or Drill: Bitumin	Time to Install Marker (sec)	Time for Adhesive to Dry (min)
Stimsonite 96	12	9	60	60
Recessed	40	25	20	60
Dura-Brite	40	25	90	15
Kingray	720	360	300	10
Prismo	90	90	30	10

Figure 6. Installation at Garrard County, southbound (order of markers is Kingray, Stimsonite 96, Dura-Brite, recessed, and Prismo).

The time needed to install the markers in the prepared cut would also be less in a large-scale operation. The time needed to install the markers was longest for the Kingray markers and shortest for the recessed markers. The factor that contributed most to the longer time to install the Kingray marker was a requirement that the marker be held in position until the bitumen hardened enough such that the marker would not rotate out of alignment. The longest drying times were for the Stimsonite 96 and recessed markers where epoxy was used. Much shorter drying times were found for the Kingray and Prismo markers, which used a bituminous material, and for the Dura-Brite marker, which used a material called SET-45 (a magnesium phosphate cement).

RESULTS

The results consisted of an evaluation of the reflectivity and durability of the markers. The markers were evaluated for a 16-month period after installation. Day and night inspections were conducted quarterly. Additional inspections were made after snowplow operations. There was no significant snowfall requiring snowplows in the first winter, so a snowplow test on wet pavement was made over a portion of the test installation. There were snowplow operations during the second winter, which resulted in the markers being subjected to a total of six to eight snowplow passes. The visual inspections were supplemented with photographs.

Reflectivity

Nighttime observations were made immediately after installation and then on a quarterly basis. Photographs were taken during each inspection.

The first inspection of the four original markers, which was done immediately after installation, indicated that all markers were extremely effective. Observations of the Prismo markers indicated that this marker was also effective. Although the Prismo marker was not as reflective as the others, it still provided adequate delineation and was particularly effective on curved sections.

Results of the periodic nighttime evaluations of reflectivity indicated that most of the marker types maintained satisfactory reflectivity during the test period. The only marker that suffered a substantial loss of reflectivity was the Kingray marker because dirt and water apparently penetrated into the clean air space behind the lens, which resulted in the lens having a foggy appearance. The loss of reflectivity occurred after only a few months. The manufacturer indicated that this problem was overcome by increasing the weld zone of the lens to the backplate and by improving the flow of polypropylene material. However, new markers with this improved feature were not available for testing.

Installing the markers in the alternating pattern allowed comparisons of relative reflectivity. Photographs taken at the southbound Garrard County installation at periodic intervals during the evaluation period give a comparison of all five markers (Figure 6). The Kingray marker had lost its reflectivity visibility, and the Prismo marker was the least reflective marker. The remaining marker types (Stimsonite 96, Dura-Brite, and recessed) demonstrated similar reflectivity.

A photograph of the southbound Fayette County installation gives a comparison of the Stimsonite

96, recessed, and Dura-Brite markers with a regular Stimsonite 911 marker placed on the pavement surface (Figure 7). The comparison indicated that each of these three snowplowable markers had a reflectivity similar to the regular, raised pavement marker.

Observations during wet nighttime conditions were made, and the same general conclusions were found. Particular attention was paid to whether the groove in which the recessed marker was placed would fill with water during wet weather conditions. If this occurred, a loss of reflectivity would result. In all but heavy rains the groove remained relatively dry because of the effect of vehicles passing the marker and the water being vacuumed or blown out. The groove did maintain a level of water for a short time during heavy rains, but this only caused a problem when the geometry of the roadway was such that the marker was on the downhill end of a groove. Overall, it appears that there was no significant problem with the groove becoming filled with water during wet weather conditions.

The visibility of the recessed markers during snow and ice conditions was also observed. After a snowplow operation the groove would be filled with snow and ice. The snow and ice would usually melt in a relatively short period of time, and the resulting water would be swept from the groove by traffic. Some inspections found the groove to be partly filled during these conditions. Approximately the top third of the marker would be cleansed by tires, but the bottom portion would be obscured. This reduced nighttime visibility, but the markers could still be seen. Overall, it was concluded that the recessed marker remained effective during snow and ice conditions. Special attention was directed to the visibility of recessed markers; however, it was noted that light snowfall and ice did not inhibit the performance of the other marker types.

In April 1982, after 16 months in service, the reflective lens of three each of the Stimsonite 96, Dura-Brite, and recessed markers were removed from the field sites for laboratory tests. These reflectors would have initially met the reflectivity requirements in Kentucky for a highly reflectorized marker. The minimum specific reflectivity requirement for a silver-white lens at a 0.2° divergence angle and 0° incidence angle is 2.7 candlepower per footcandle per unit marker. Laboratory tests revealed that the average specific reflectivity for the markers after slightly more than 1 year in service, given in terms of candlepower per footcandle per unit marker, was 2.5 for the recessed reflector, 2.1 for the Dura-Brite reflector, and 1.3 for the Stimsonite 96 reflector. The Dura-Brite and Stimsonite 96 markers use the same reflector. These readings are in agreement with the observed durability of the reflectors in these markers. The lens in the recessed and Dura-Brite markers received little damage, whereas the Stimsonite 96 had some damage. This damage was probably related to the higher profile of the Stimsonite 96 marker. Nighttime observations indicated that all three markers maintained satisfactory reflectivity after 16 months in service. Because of the difficulty of removing the reflective units and their damaged condition after 16 months, neither the Kingray nor the Prismo marker was tested.

Durability

Evaluation of the durability of the markers involved two areas. First, an effort was made to determine the effect of traffic on marker durability, and second, the effect of snowplow operations was evaluated. Most of the markers were not involved in snowplow operations for slightly more than 1 year after installation, which enabled researchers to make an assessment of the effect of traffic on the durability of the markers.

Traffic Wear

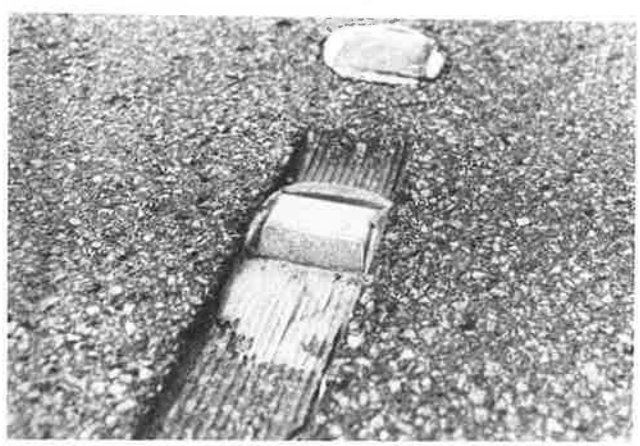
Photographs of the various markers after almost 1 year in service are shown in Figures 8-12. These photographs were taken before the second winter and therefore show the effects of traffic wear only. The summary of marker damage which follows applies to the effect of approximately 1 year of traffic wear with no snowplow damage.

The recessed marker is shown in Figure 8. This marker demonstrated satisfactory durability. Minor damage to the top of the lens was found on seven markers (5 percent). Inspections during the year revealed that the groove remained relatively free of debris, and approximately the top half of the lenses remained clean. The bottom half of the lenses was not satisfactorily cleaned by tires. Also, the abrasive coating on the top half of the lenses was chipped more than the other snowplowable markers.

The Dura-Brite marker is shown in Figure 9. The durability of the Dura-Brite marker to traffic wear was satisfactory. The lenses remained clean, and there was less chipping to the abrasive coating than with the other markers. In some instances the adhesive holding the lens flowed up the covered part

Figure 7. Installation at Fayette County, southbound (order of markers is Kingray, Stimsonite 911, Stimsonite 96, recessed, and Dura-Brite).

Figure 8. Recessed marker after approximately 1 year of service (before snowplow operations).



of the lens. This was caused by the use of butyl tape, which was too thick. The thickness of this tape has since been reduced by the manufacturer. It was also noted that the lens was loose in two markers.

The durability of the Stimsonite 96 marker after being subjected to traffic was also satisfactory (Figure 10). Minor damage to the lens was noted on 13 markers (9 percent). As shown in Figure 10, this damage was minor and did not adversely affect reflectivity. The lens remained clean, but there was minor chipping of the abrasive coating.

Several problems were found with the Kingray marker (Figure 11). The bitumen material holding the marker cracked, and in many instances a large amount of this material was lost, which reduced the bond of the marker to the pavement. A possible reason for the loss of bitumen was failure to heat the hole to a sufficiently high temperature during the installation process. Six markers (4 percent) were missing after almost 1 year in service. The lens also tended to remain dirty because tires would depress and not clean the lens. It was found that rain was necessary to clean the lens. Because the lens did depress on impact, it sustained less abrasive damage to the lens surface than the other markers. About 15 percent of these markers had damage either to the lens or marker. All but two of the markers still recoiled as designed.

Figure 9. Dura-Brite marker after approximately 1 year of service (before snowplow operations).

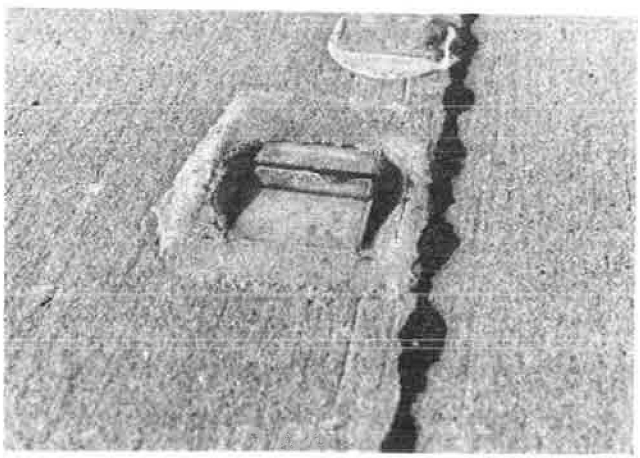
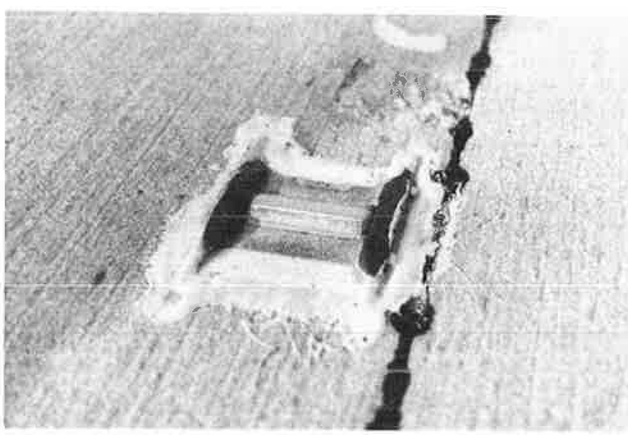


Figure 10. Stimsonite 96 marker after approximately 1 year of service (before snowplow operations).



The Prismo markers at the Fayette County site were removed by snowplows, but observations of the markers at the Garrard County site were made (Figure 12). Five of the markers (17 percent) were missing. The remaining markers were generally in satisfactory condition. Several had minor damage to some of the glass lenses.

Twenty Stimsonite 911 markers were installed at the Fayette County site as a comparison to the snowplowable markers. After almost 1 year of service one of these markers was missing and one had major damage to the lens. There was significant chipping of the abrasive coating on the markers, but they generally remained in satisfactory condition.

Snowplow Damage

During December 1981 and January 1982 between six

Figure 11. Kingray marker after approximately 1 year of service (before snowplow operations).

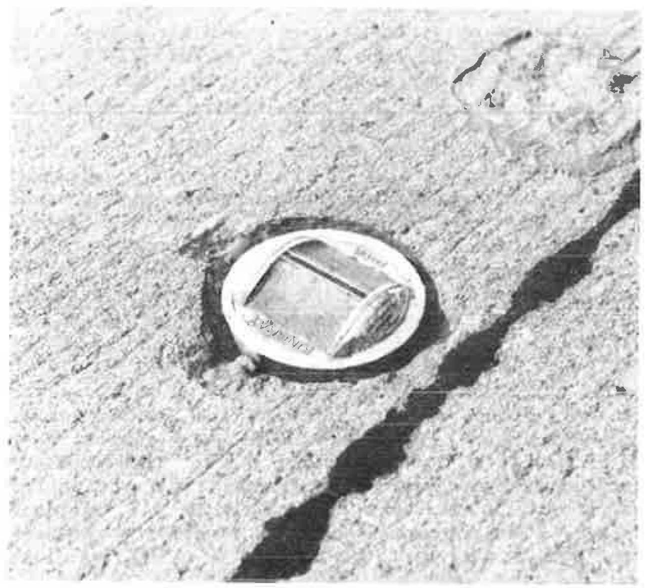
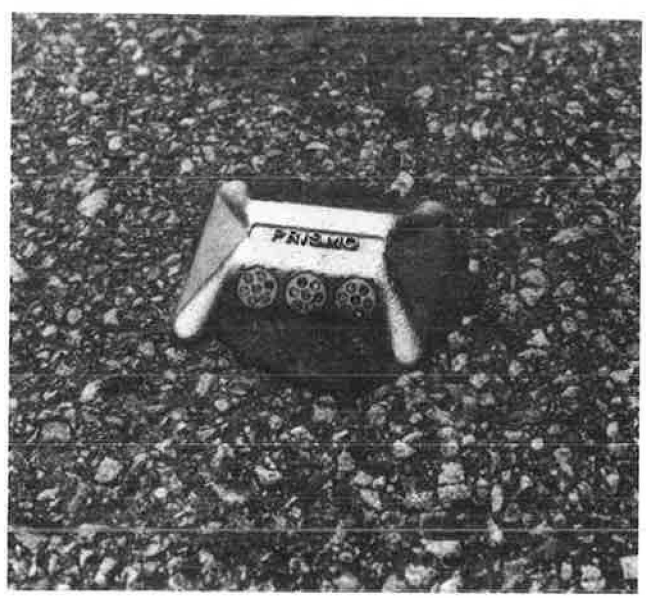


Figure 12. Prismo marker after approximately 1 year of service (before snowplow operations).



and eight snowplow passes were made over the various test sections of markers. A steel blade was used during all operations. The only other snowplow tests were made during January 1981 when two passes were made on the northbound Fayette County location on a wet pavement. In the January 1981 test the Prismo markers were removed and there was damage to three of the Kingray markers (14 percent), whereas the Stimsonite 96, Dura-Brite, and recessed markers proved to be snowplowable, and there was no damage.

A summary of the performance of the markers as a result of the snowplow operations during December 1981 and January 1982 follows. The final inspection was conducted in April 1982 after approximately 16 months in service. The recessed marker was filled with snow after the snowplow operations, but the snow melted and the marker was visible again within a few hours. The recessed marker sustained no additional damage as a result of snowplow operations. Neither the Stimsonite 96 nor Dura-Brite markers sustained any damage to either the lens or the marker housing unit from the snowplow operations. The final inspection indicated that 13 Stimsonite 96 markers and 1 Dura-Brite marker had minor damage to the lens, which was the result of traffic wear. Also, in two of the Dura-Brite markers the lens was missing.

The test indicated that the Prismo marker was not snowplowable. The snowplow sheared the marker off the pavement at the top of the anchor stem. Virtually every Prismo marker involved in the snowplow operation was removed. Also, all of the regular Stimsonite 911 markers that were placed on top of the pavement were severely damaged.

The Kingray markers were also damaged by snowplow operations. Even before the snowplows were used, several of the Kingray markers were either missing or damaged. An inspection after the snowplow operations revealed that 71 Kingray markers (47 percent) were missing, 43 (29 percent) were severely damaged, and 20 (13 percent) were moderately damaged. Only 11 percent were undamaged, and these remaining markers still recoiled as designed.

Another feature of the markers relative to snowplow operations was their interference with snowplow operations. This involved discomfort to the snowplow operator, which resulted from the jolt of hitting the marker, as well as damage to the snowplow blade. The Stimsonite marker, which had the highest profile above the pavement, caused the most interference. The snowplow blade would jump several inches above the pavement after striking a Stimsonite marker. The lower-profile Dura-Brite marker caused less interference. The Kingray and, in particular, the recessed markers caused no interference. The test section was not long enough to show damage to the snowplow blade, but the potential for such damage was demonstrated.

SUMMARY

Installation

All of the markers were installed with relatively few problems. The Stimsonite 96 marker required the shortest saw or drill time. The lengthy drilling time for the Kingray marker would be shortened substantially with better equipment. A more efficient procedure for installing the Dura-Brite markers has been developed by the manufacturer, but it was not used because of the small installation. The time needed to install the markers was highest for the Kingray markers and shortest for the recessed markers. The Stimsonite 96 and recessed markers required longer adhesive drying time because epoxy was used.

Reflectivity

The Stimsonite 96, recessed, and Dura-Brite snowplowable markers maintained their reflectivity during the evaluation period, and each of these markers provided excellent delineation. Although the Prismo marker was less reflective than these markers, it maintained its reflectivity and provided satisfactory delineation. The Kingray marker suffered a severe loss of reflectivity. A subjective rating of the reflectivity of these markers revealed that the Stimsonite 96 marker was the best overall. The reflectivity of the recessed marker varied somewhat with roadway geometry, but it could be rated as second. Because the Dura-Brite marker was a lower-profile marker (rising only 0.25 in. above the pavement surface), the test results indicated that it had slightly lower reflectivity, and it was given a subjective rating of third. Nevertheless, the Dura-Brite marker still provided more than adequate delineation, and the low profile of this marker provides some durability advantages. A new Stimsonite marker, which was recently introduced, is also a low-profile marker and will probably be similar to the Dura-Brite in reflectivity. It should also be noted that all of the marker types performed satisfactorily during light snow and ice conditions.

Durability

Considering only traffic wear, the Kingray and Prismo markers were the only markers that experienced any significant damage. The Dura-Brite and recessed markers received the least amount of damage. The Stimsonite 96 sustained minor damage to the lens in a few markers.

Evaluation of the snowplow operations revealed that the Stimsonite 96, Dura-Brite, and recessed markers qualify as snowplowable markers. None of these markers sustained any noticeable damage as a result of the limited number of snowplow operations. The evaluation revealed that the Prismo markers were not snowplowable, and the Kingray markers sustained significant damage as a result of snowplow operations.

Another factor that should be considered is the relative snowplowability of the markers. The concept used in the design of the Stimsonite 96 and the Dura-Brite markers is to retain the reflective unit of a raised pavement marker and attempt to protect it by using a snowplow-resistant encasement. Nevertheless, the tests indicated that an encasement sufficiently sturdy to resist snowplow damage will likely interfere with snowplow operations because of severe vibrations and will probably damage the blade. Of the markers evaluated in this study, only the recessed and Kingray markers would present a sufficiently low profile (or characteristics that cause them to function like a low-profile marker) to not interfere with snowplow operations.

RECOMMENDATION

The Stimsonite 96, Dura-Brite, and recessed markers should be considered as acceptable snowplowable markers. All three had adequate reflectivity, which was maintained during the test period, and proved to be durable when subjected to snowplow operations. Nevertheless, considering all available input, the recessed marker is recommended as the most functional and cost-effective marker. This recommendation is based on the following characteristics of the recessed marker: (a) ease of installation, (b) high retention of reflectivity, (c) durability when subjected to snowplow operations, (d) relative cost of the marker and its installation, and (e) lack of interference with normal snowplow operations. Specifications for an installation contract of snowplowable markers could allow for use of any of these three markers (Stimsonite 96, Dura-Brite, and recessed), but considering available cost data, the recessed marker should provide the lowest cost.

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Evaluation of the Effect of Natural Brine Deicing Agents on Pavement Materials

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Laboratory tests were conducted to analyze and compare the effects of natural brines and traditional deicing chemicals on bituminous concrete, portland cement concrete, and two types of steel. The effects of 100 freeze-thaw cycles on bituminous concrete immersed in distilled water, a sodium and calcium chloride solution, and a natural brine solution were evaluated by testing specimens for Marshall stability, flow, and weight changes. Two separate 100-cycle freeze-thaw experiments—a surface degradation test, and compressive strength and pulse velocity tests—were conducted to evaluate the effects of distilled water, a sodium and calcium chloride solution, and a natural brine solution on concrete performance. A 100-cycle wet-dry immersion test, where specimens of A-36 and SAE-1010 steel were subjected to a sodium and calcium chloride solution and a natural brine solution, was used as an accelerated corrosion test. Corrosion was measured by weight loss. In general, the effects of natural brines on bituminous concrete were no different than the effects of traditional deicing agents. In terms of the surface deterioration of portland cement concrete, natural brine performed slightly better than traditional deicing agents. Potential discoloration of concrete from brines with high iron content was indicated. The effect of natural brine on concrete compressive strength was no different from that of water or sodium and calcium chloride deicing agents. Specimens of automobile-body steel demonstrated less corrosion in natural brine than in a sodium and calcium chloride solution; however, specimens of structural steel demonstrated opposite results.

As expenditures for snow- and ice-control materials continue to increase, highway agencies are seeking ways to minimize the use of traditional deicing materials and, where possible, are substituting less-costly deicing agents for sodium and calcium chloride. The use of naturally occurring salt brines, which are by-products of oil and gas production, as deicing agents is either a reality in some locations or is being studied in a number of locations. Natural brines are widespread geographically; their existence is not limited to oil and gas fields. The oil and gas industry considers brine as a waste product because there is no apparent use for the liquid, which may be several times stronger than sea water.

The major ions found in most brines are sodium, calcium, magnesium, and chloride. Lower levels of constituents such as potassium, iron, sulfate, and bicarbonate are also usually present. In addition, brines may contain a number of minor or trace ionic species, including bromide, iodide, barium, lead, arsenic, zinc, cadmium, and chromium.

Brines are difficult to dispose of in an environmentally acceptable manner; thus they represent a major problem for the oil and gas industry. For example, more than 100 million gallons of brine are produced annually in West Virginia. Several large brine producers make use of injection wells for brine disposal. In addition to being an expensive disposal method, there is the possibility that increased concern about groundwater contamination may result in legislation that will limit deep well injection. An unknown but significant quantity of waste brine is discharged directly onto the ground or into surface waters, which results in contamination. Eck and Sack (1) have presented a more detailed discussion of brine characteristics and current disposal practices.

The use of natural brines for deicing purposes would appear to solve several problems simultaneously. The oil and gas industry could dispose of an unwanted by-product, and highway agencies could acquire a deicing material at minimal cost. However, before advocating a major deicing program that uses natural brines, a number of issues need to be evaluated. For example, the quantity of brine available for highway deicing in a given geographical area must be assessed. Brine quality from the major producing formations must be determined, including both the major salts and the minor trace elements, in order to assess potential water pollution problems. It would be desirable to compare various brines with commercial deicing agents relative to melting, skid resistance, and refreezing of roadway surfaces. Also, the transportation and storage costs of brine must be estimated. Similarly, comparisons are needed as to the relative effect of brines and commercial deicing agents with respect to corrosion of steels as well as the deterioration characteristics of portland cement concrete (PCC) and bituminous pavement.

A comprehensive research project is in progress at West Virginia University (WVU) to address these