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Abstract
Traffic markings used in Alberta consist primarily of alkyd and waterborne paint. Supplemental delineation such as Snowplowable Raised Pavement Markers (SRPM) may improve driver preview distances at night and in adverse weather conditions in high collision rate areas. A study of SRPM's was undertaken to determine the effectiveness and durability of two types of markers.

In the 2000 construction season Alliant Engineering and Consulting Ltd. was selected to provide contract administration and project management for the installation of the SRPM's at 4 selected test sites.

The types of SRPM's used for this study were the Stimsonite LPCR and the Nightline Pavement Marker (3M). Both of these markers have a low profile design that allows a snowplow blade to easily ride over the marker. The markers consist of a reflector anchored inside cast iron housing.

The markers were evaluated for condition of marker casting and reflector in 2001, 2002, 2003 and 2005. Defects such as cracked, broken and missing reflectors were noted. A nighttime observation of the reflectors was also conducted to determine the effectiveness of the SRPM nighttime reflectivity.

Key Words
Snowplowable Raised Pavement Markers (SRPM)

Reflective Lens
Low Profile
Cracked Lens
Cast Iron Housing
Broken Lens
Missing Lens

Distribution
Unlimited

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DISCLAIMER

TABLE OF CONTENTS

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STUDY OF SNOWPLOWABLE RAISED PAVEMENT MARKINGS

EXECUTIVE SUMMARY

Alberta Infrastructure and Transportation determined that supplementary delineation may be required at collision prone locations such as roads with sharp curves and areas susceptible to fog. The supplementary delineation could be provided by applying SnowPlowable Raised Pavement Markers (SRPM); however concerns were raised regarding the durability of the markings, especially with respect to snowplow operations. This study was conducted to assess these concerns.

SPRM's were introduced as a traffic safety measure to provide better guidance for drivers during inclement weather and low light conditions. These devices have been used as supplemental delineation to improve driver preview distances

SPRM's consist of a polycarbonate or glass lens inserted in a cast iron housing, which is embedded into the asphalt surface using special grinding equipment and held in place with a high strength resin. Snowplow blades ride over the cast iron frame, thus protecting the reflective lens from damage.

In the 2000 construction season, Raised Pavement Markers (SRPM) were installed at four highway test sections near Edmonton. Alliant Engineering & Consulting Ltd. were selected to provide contract administration and project management for the installation of the SRPM's at the test sites. The four test sections comprised of a total of 2080 SRPM's placed on new pavement, old pavement and pavement surfaced with chip seal. Various marker configurations were tried at different sites, such as placing markers on shoulder and centerline or on centerline only. The markers consist of a reflector inside a cast iron housing installed adjacent to painted roadway lines. The SRPM's were evaluated for 4 seasons: 2001, 2002, 2003 and 2005. The following two types of SRPM's were evalauted:

- Stimsonite 101 LPCR
- 3M Nightline Pavement Marker

The SPRM study was comprised of three phases:

1. Evaluate the condition of the marker castings and reflectors.
2. Conduct visual daytime and nighttime observations to determine their effectiveness as a delineator.
3. Document findings

1.0 INTRODUCTION

1.1 Background

Pavement markings play an important role in providing positive guidance to the motorist. Pavement markings and other delineation devices on the road surface contribute to the overall operational efficiency of a roadway, by providing information to the motorist for the appropriate path and speed of their vehicle. In recognizing this importance, Alberta Infrastructure and Transportation annually re-stripes its highways in an effort to maintain good delineation for the motorist.

Since the early 1990's the Department has experimented with Snowplowable Raised Pavement Markers at various test locations in the province. Several of the test projects were completed with limited success. The main concern with SRPM's was susceptibility to damage from snowplow blades which resulted in significant costs for replacement and maintenance. However, it was determined that with care in design and installation, SRPM's can provide an effective means of guidance for vehicles at night.

1.2 Objectives

The objectives of the study are to:

- Determine the effectiveness of the two types of SRPM's (Stimsonite 101 LPCR & 3M Nightline Pavement Marker).
- Monitor the durability and performance of the two products.
- Determine the best configuration for placement of the SRPM's.

2.0 TYPE OF RAISED PAVEMENT MARKERS USED

Stimsonite 101LPCR

The Stimsonite 101LPCR pavement marker has a low profile design to allow a snowplow blade to easily ride over the marker. It consists of a reflector anchored inside a cast iron housing, and extends above the pavement surface approximately 6.55mm.

Nightline Pavement Marker (3M)

The Nightline Pavement Marker also incorporates a low profile design to allow a snowplow blade to easily ride over the marker. The Nightline Pavement Marker is of similar profile to that of the Stimsonite 101LPCR marker, with the exception of a slightly larger (4mm) width.

To withstand the elements, the Stimsonite reflectors contain a glass lens face while the 3M reflectors have a polycarbonate face. Both manufacturers claim that their reflectors provide superior durability.

3.0 SITE SELECTION AND TEST SECTION LOCATION

Four test sites were selected for the testing of the raised pavement markers. These sites were selected on curves and sites with higher collision rates.

The markers were placed on the centerline only for highway 37:04, on the other three sites (highway 21:24, 28:04 and 33:04/06) the markers were placed at centerline and both shoulder lines.

Highway 21:24 utilized both the 3M/Nightline markers and the Stimsonite markers in several different alternating patterns in order to compare their durability. The remaining three sites utilized the Stimsonite markers only.

The following table shows the locations of the Raised Pavement Markers evaluated for this study:

Table 1

Highway No.	Location	Placement of Markers	Marker Type	No. of Markers
37:04	Km 3.51 to Km 6.58	Centerline	Stimsonite	304 yellow
28:04	Km 12.23 to Km 13.83	Shoulders & Centerline	Stimsonite	144 white 124 Yellow
33:04/06	Km 28.22 to Km 0.88	Shoulders & Centerline	Stimsonite	227 white 217 yellow
21:24	Km 16.99 to Km 21.85	Shoulders & Centerline	Stimsonite & 3M	506 white 254 yellow

4.0 PAVEMENT MARKER PLACEMENT

The marker placement consisted of four stages:

1. Marking out the location of markers to be placed
2. Saw-cutting the pavement

3. Cleaning and drying the saw cut
4. Placing the epoxy and marker

Note: ideal temperature for applying epoxy to marker is 15^{o}C.

The first step was to mark the location of the marker using a template. Steps 2 and 3 were conducted together with the saw cutting of the pavement followed by the cleaning and drying of the saw cut. The final stage was to fill the saw cut with epoxy and permanently set the marker in place.

The air temperature influenced the epoxy application time. The application rate was slower at the beginning of the day when the epoxy was cold. When the air temperature increased later in the day the epoxy application rate would speed up.

The marker spacing used at all test sites was 27 meters on straight-aways and 18 meters on curves.

5.0 EVALUATING RAISED PAVEMENT MARKERS

Evaluations of the raised pavement markers were conducted in 2001, 2002, 2003 and 2005 (Appendix 'B'). The markers were not evaluated in 2004. The markers were evaluated for condition of marker casting (shoe) and reflector. Defects such as broken, cracked and missing reflectors were noted as shown on photograph 1, 2 and 3 respectively.

Photo 1

Broken reflector

Photo 2

Cracked reflector

Photo 3

Missing reflector

The following tables summarize the condition/performance of the SRPM's for each year inspected. See Appendix 'I' for tabulated results.

2001

Table 2

(Hwy. 21:24)

	Stimsonite Reflectors		3M Reflectors	
	Centerline	Shoulder	Centerline	Shoulder
% Failure (Broken Lens)	0%	14.5%	0%	0%
% Cracked Lens (Still Functional)	0%	6.3%	0%	0%
% Dislodged Markers (Missing Lens)	0%	2.5%	1.2%	23% (only 30 used)
Totals	0%	23.3%	1.2%	23%

Table 3

(Hwy. 28:04)

	Stimsonite Reflectors	
	Centerline	Shoulder
% Failure (Broken Lens)	0%	1.4%
% Cracked Lens (Still Functional)	0%	1.4%
% Dislodged Markers (Missing Lens)	0%	0%
Totals	0%	2.8%

Table 4

(Hwy. 33:04/06)

	Stimsonite Reflectors	
	Centerline	Shoulder
% Failure (Broken Lens)	0%	3.5%
% Cracked Lens (Still Functional)	0%	10.5%
% Dislodged Markers (Missing Lens)	4.6%	4.9%
Totals	4.6%	18.9%

Table 5

(Hwy. 37:04)

	Stimsonite Reflectors
	Centerline
% Failure (Broken Lens)	0%
% Cracked Lens (Still Functional)	0.7%
% Dislodged Markers (Missing Lens)	0%
Totals	0.7%

2002

Table 6

(Hwy. 21:24)

	Stimsonite Reflectors		3M Reflectors	
	Centerline	Shoulder	Centerline	Shoulder
% Failure (Broken Lens)	0%	21%	0.8%	0%
% Cracked Lens (Still Functional)	0%	22%	0%	0%
% Dislodged Markers (Missing Lens)	0%	2.5%	1.2%	23%
Totals	0%	45.5%	2.0%	23%

Table 7

(Hwy. 28:04)

	Stimsonite Reflectors	
	Centerline	Shoulder
% Failure (Broken Lens)	0%	4.1%
% Cracked Lens (Still Functional)	1.6%	13%
% Dislodged Markers (Missing Lens)	0%	0%
Totals	1.6%	17.1%

Table 8

(Hwy. 33:04/06)

	Stimsonite Reflectors	
	Centerline	Shoulder
% Failure (Broken Lens)	0%	5.3%
% Cracked Lens (Still Functional)	0.5%	17.6%
% Dislodged Markers (Missing Lens)	4.6%	4.9%
Totals	5.1%	27.8%

Table 9

(Hwy. 37:04)

	Stimsonite Reflectors
	Centerline
% Failure (Broken Lens)	1%
% Cracked Lens (Still Functional)	1.3%
% Dislodged Markers (Missing Lens)	0%
Totals	2.3%

2003

Table 10

(Hwy. 21:24)

	Stimsonite Reflectors		3M Reflectors	
	Centerline	Shoulder	Centerline	Shoulder
% Failure (Broken Lens)	0%	28%	1.8%	0%
% Cracked Lens (Still Functional)	0%	26%	0%	0%
% Dislodged Markers (Missing Lens)	0%	3.1%	1.2%	23%
Totals	0%	57.1%	3.0%	23%

Table 11

(Hwy. 28:04)

	Stimsonite Reflectors	
	Centerline	Shoulder
% Failure (Broken Lens)	0%	9.7%
% Cracked Lens (Still Functional)	1.6%	14%
% Dislodged Markers (Missing Lens)	0%	0%
Totals	1.6%	23.7%

Table 12

(Hwy. 33:04/06)

	Stimsonite Reflectors	
	Centerline	Shoulder
% Failure (Broken Lens)	0.9%	9.3%
% Cracked Lens (Still Functional)	1.4%	21%
% Dislodged Markers (Missing Lens)	4.6%	4.9%
Totals	6.9%	35.2%

Table 13

(Hwy. 37:04)

	Stimsonite Reflectors
	Centerline
% Failure (Broken Lens)	2.6%
% Cracked Lens (Still Functional)	2.6%
% Dislodged Markers (Missing Lens)	0%
Totals	5.2%

2005

Table 14

(Hwy. 21:24)

	Stimsonite Reflectors		3M Reflectors	
	Centerline	Shoulder	Centerline	Shoulder
% Failure (Broken Lens)	1.1%	32%	1.8%	0%
% Cracked Lens (Still Functional)	5.6%	37%	0%	0%
% Dislodged Markers (Missing Lens)	0%	3.1%	1.2%	23%
Totals	6.7%	72.1%	3.0%	23%

Table 15

(Hwy. 28:04)

	Stimsonite Reflectors	
	Centerline	Shoulder
% Failure (Broken Lens)	0%	11.1%
% Cracked Lens (Still Functional)	1.6%	16%
% Dislodged Markers (Missing Lens)	0%	0%
Totals	1.6%	27.1%

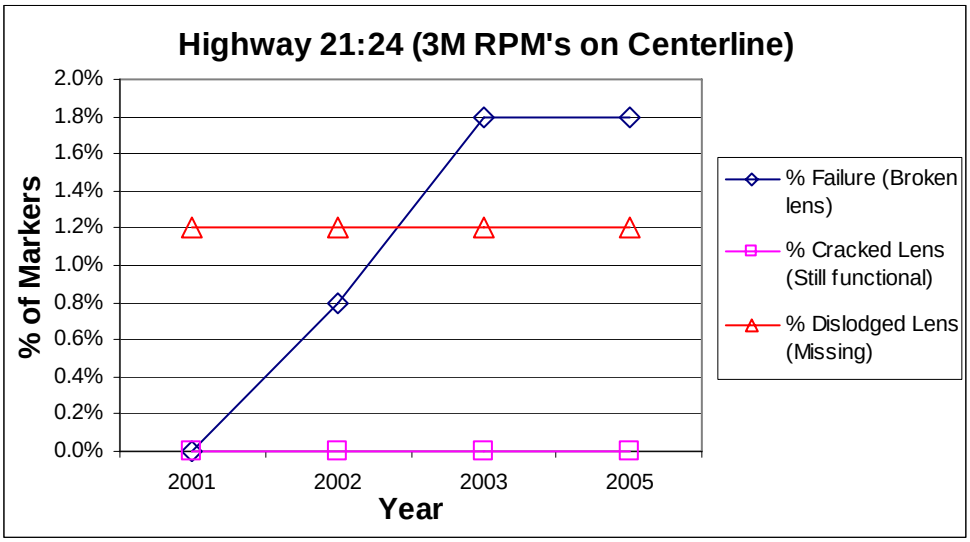
Table 16

(Hwy. 33:04/06)

	Stimsonite Reflectors	
	Centerline	Shoulder
% Failure (Broken Lens)	2.3%	18.5%
% Cracked Lens (Still Functional)	1.8%	33.9%
% Dislodged Markers (Missing Lens)	6.0%	4.9%
Totals	10.1%	57.3%

See Chart 1 to Chart 7 for the graphical plotting of the durability of the SRPM's over the past five years:

Chart 1



Note: There were only 30 3M-raised pavement markers placed on shoulder lines. 7 of the 3M reflectors have become dislodged from the marker shoe some time during the first year of service (see Chart 1).

Chart 2

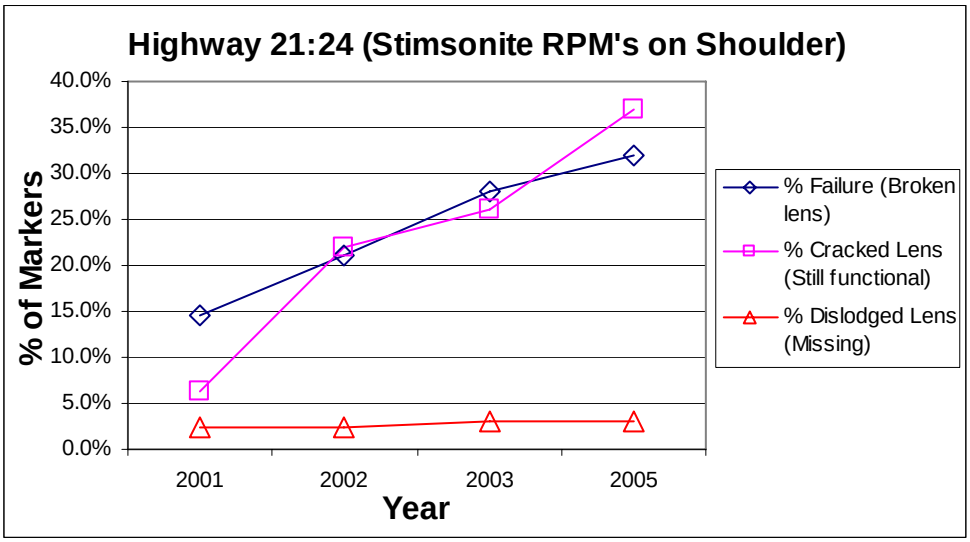


Chart 3

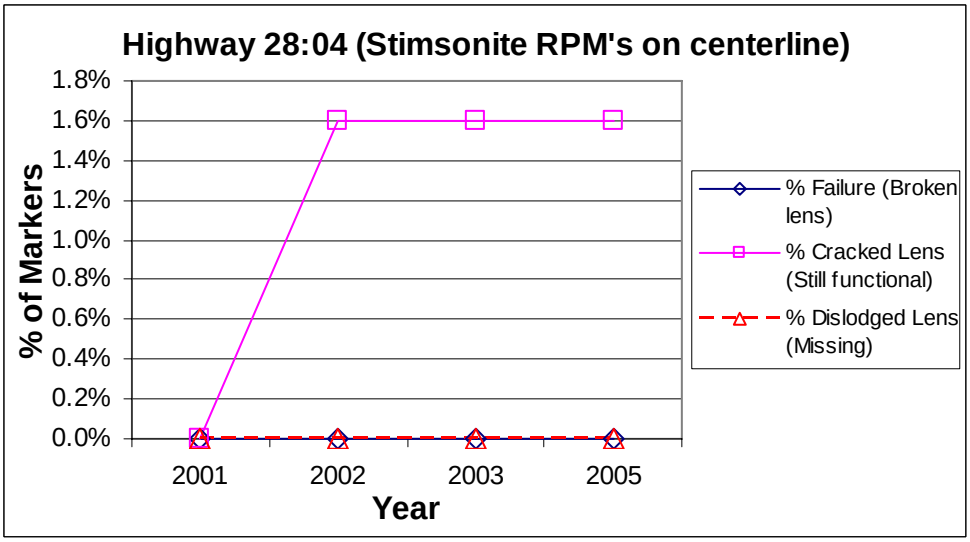


Chart 4

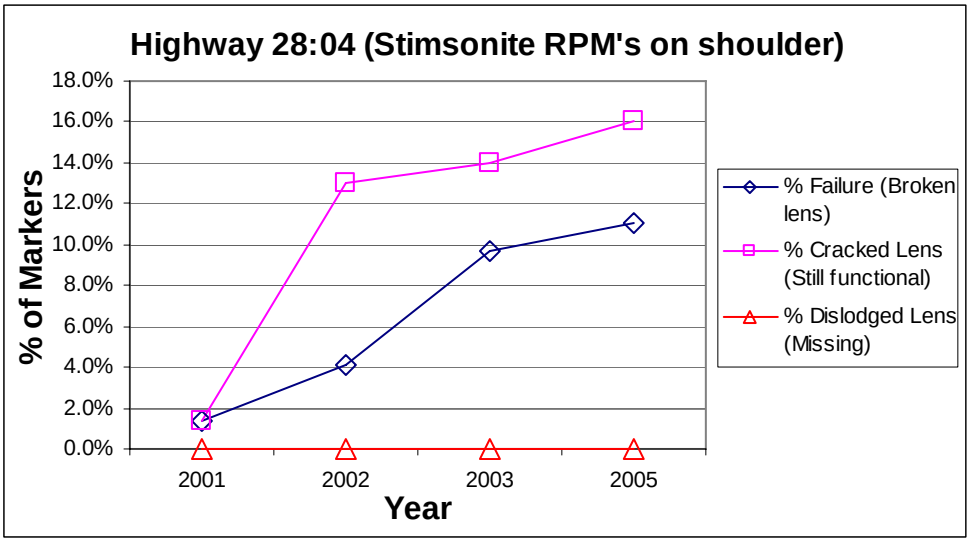


Chart 5

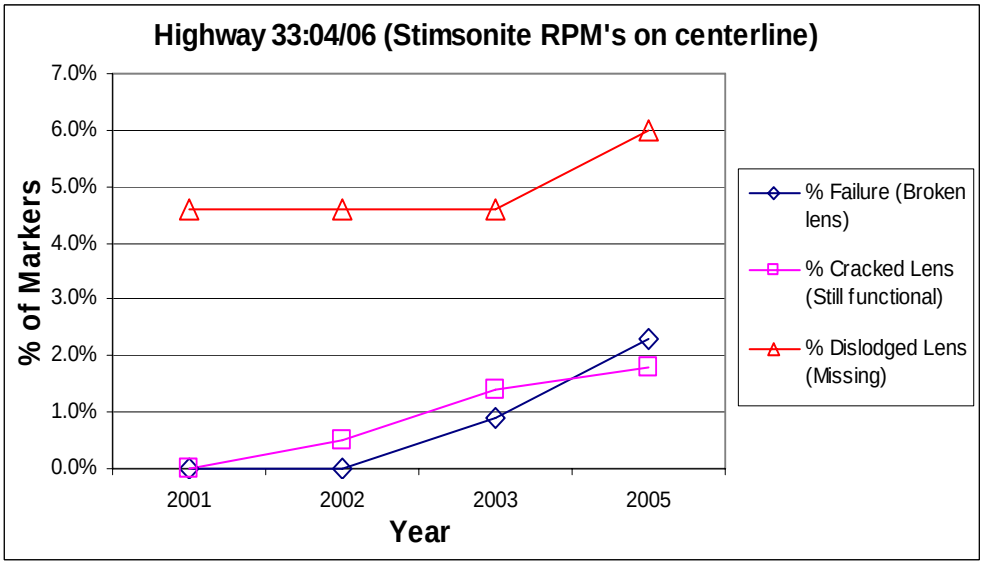


Chart 6

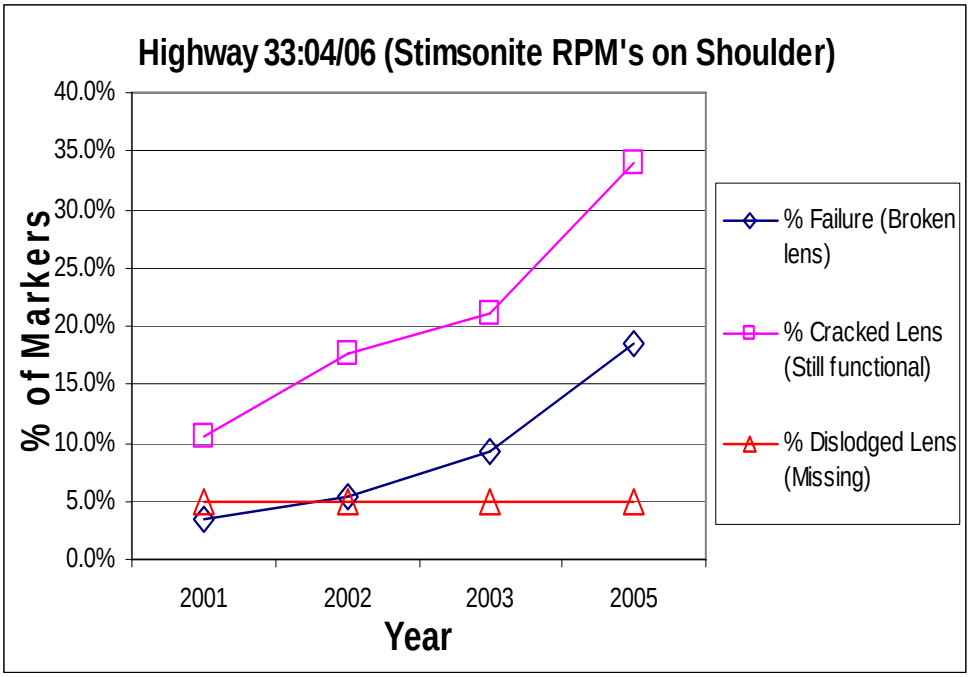
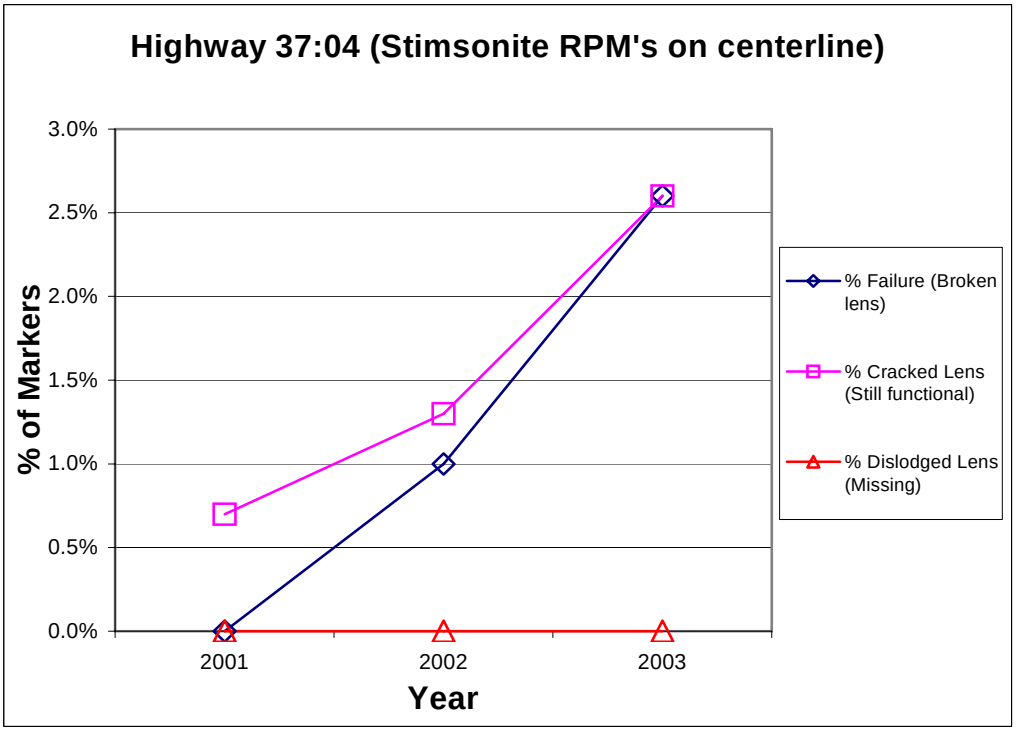


Chart 7



6.0 SERVICEABILITY OF MARKERS

Marker Shoe (cast iron housing)

There were no noted problems with the raised pavement marker shoes adhering to the road surface. The shoes were installed at locations where the pavement was saw cut, cleaned and application of the epoxy and marker. The epoxy used conformed to AASHTO M237 Type 4, Standard Set Epoxy for Blade Deflecting Type Plowable Markers.

Reflective Lens

The reflective lenses were expected to require replacement after 4 to 5 years of service. Many of the reflectors are cracked but are still functional; however the reflectivity of the markers may be reduced. The broken reflectors are no longer effective as the reflectivity of the reflective lens is greatly reduced or non-existent. There were several markers with dislodged lenses. We are unsure of the cause.

7.0 NIGHT-TIME OBSERVATIONS

Raised pavement markers are generally used to supplement and enhance longitudinal pavement markings during dark, rain and fog conditions on curves and areas of high collision rates. The initial observations of the raised pavement markers show they provide very good lane delineation at night.

Initial nighttime observation (October 2000)

A nighttime observation was conducted on Highways 21, 28 and highway 37 during the month of October 2000. The Snowplowable Raised Pavement Markers greatly enhance the travel lane making for better definition of curves at night. Nighttime reflectivity from the markers' reflective lens is very pronounced; several observers commented that the delineation was similar to an airport runway. Nighttime photographs were taken in 2000 and are shown in Appendix 'C'.

Nighttime (Spring 2005)

Highway 21, 28 and 37

A nighttime observation was conducted on Highways 21, 28 and 37 on May 4, 2005. The Snowplowable Raised Pavement Markers are providing good additional delineation on the trial sections of highway 21 and 28. It was evident from this nighttime observation that the markers are definitely effective in enhancing the travel lane especially around curves. The majority of the markers are providing good retro-reflection to the motorist. The effectiveness of the reflectors is not as pronounced as they were in earlier nighttime observations.

Nighttime photographs were taken and are shown in Appendix ‘F’ .
“note” – the photographs do not provide a true representation of the actual reflectivity of the SRPM’s reflective lenses.

Highway 37

This trial section was seal coated in 2004, therefore the majority of the SRPM are obstructed and are not providing good delineation.

8.0 WINTER OBSERVATIONS

Day-Light

The performances of the snowplowable raised pavement markers were observed after snowplow operations in 2002. The majority of the markers observed were clear of snow. There were no noticeable snow ridges along the markers after the snowplow made a pass. The markers did have some snow on them but the reflectors were unobstructed making them visible to the motorist.

Appendix ‘G’ - photographs depict the condition of the snowplowable raised pavement markers after snowplow clearing.

Nighttime (November 2003 and February 11, 2004)

November 2003

On November 6, 2003 a nighttime observation was conducted on highway 28. The Raised Pavement Markers were not as prevalent as the initial observation of October 2000 (part of this is due to the 24% failure rate of the reflectors in 2003 – Chart 9, Appendix ‘I’). The shoulder line markers were not as visible as the centerline markers as there appeared to be more ice and snow build-up on the shoulders. However, the Raised Pavement Markers along the centerline are providing positive supplemental delineation along the centerline which is providing motorist with guidance in maneuvering around curves. Nighttime photographs are shown in Appendix ‘D’.

The observations of the Highway 37 markers were not possible due to the snow and ice built-up along the centerline of this roadway. The performance of the raised pavement markers are hindered due to ice and snow build-up making them ineffective in these conditions. However, due to the ice and snow built-up along the centerline, the paint markings would also be deemed ineffective.

February 2004

On February 11, 2004 a nighttime observation was conducted on highway 28. The majority of the Raised Pavement Markers were visible. The markers provide improved guidance to the motorist in delineating curves on this highway. Some of the marker’s visibility was hindered by the build-up of ice and snow on the reflectors, thus reducing their effectiveness. From a visibility point of view, the markers are functioning as intended. (Photographs are shown in Appendix ‘E’)

Highway 37 was also observed on this night. The centerline raised pavement markers were only visible where there was no snow built-up along the centerline of the roadway. The raised pavement markers at this location are not providing continuous delineation due to the snow build up along the centerline. (Photographs are shown in Appendix 'E')

On February 23, 2004 daytime and nighttime observations were conducted on Highway 21. The markers were all clear of snow or ice. There was some sand/salt residue on the reflectors that may have caused a slight decrease in reflectivity. The Raised Pavement markers on this stretch of highway are providing very good supplemental delineation at night, especially around curves. The markers provide excellent retro-reflection from vehicle headlights.

9.0 COLLISION DATA

Locations with curves and high collision rates were chosen for the Snowplowable Raised Pavement Marker trials. The markers are used for supplemental delineation to the typical painted pavement markings used. Collision data was collected at the trial sites over the past few years and was compared to data prior to the installation of the markers. Collision data from 1997 to 2003 has been summarized and is shown in Appendix "H".

The markers were installed in late 2000; therefore there is only 3 full years (2001 to 2003) of collision data collected during the SRPM trial. The data collected to date is not sufficient to make a general statement on the effects of the markers in reducing collisions.

10.0 DISCUSSION OF RESULTS

Field Results

Visual observations of the markers were conducted for the years 2001, 2002, 2003 and 2005. The visual observations consisted of walking the entire route of the markers on both sides of the highway. The centerline markers were observed from the shoulders and approached from one side between passing vehicles.

The following process was used to review and generate Charts 8 to 11 (Appendix 'I'), showing the yearly deterioration rate of the raised pavement markers:

1. Each raised pavement marker was observed and categorized as one of the following:
    - Cracked Lens
    - Broken Lens
    - Missing Lens

- The cracked reflective lens are considered functional (reflectivity slightly reduced) and will require replacement at some unknown time
- The broken reflective lenses need to be replaced as they are providing very little reflectivity
- The missing reflective lenses need immediate replacement

2. The condition of the marker castings (shoes) was observed for defects. All marker castings are performing very well with no evidence of deterioration.

3. The results of the observations were documented and plotted for each test section. The charts in Appendix 'I' were generated as a result of the field observations and show a graphical deterioration rate (failure rate) of the reflectors:

   Stimsonite 101 LPCR

   A. Chart 8 – Highway 21:24, Shoulder and Centerline markers
   B. Chart 9 – Highway 28:04, Shoulder and Centerline markers
   C. Chart 10 – Highway 33:04/06, Shoulder and Centerline markers
   D. Chart 11 – Highway 37:04, Centerline markers only

   3M Nightline Pavement Markers

   A. Chart 8 – Highway 21:24, Shoulder and Centerline markers

4. Tables 17 and 18 (Appendix I) summarize the findings of the evaluations conducted in 2001, 2002, 2003 and 2005.

   The failure rate of the reflectors is shown in table 17, which includes cracked, broken and missing reflectors. The overall number of broken, cracked and missing reflectors is shown in table 18.

11.0 OBSERVATIONS

Snowplowable Raised Pavement Markings placed on shoulder

Snowplowable raised pavement markings were placed on the shoulder line of highways 21:24, 28:04 and 33:04/06. The shoulder line raised pavement markers exhibited a constant deterioration rate ranging from 10.5% in 2001 to 37% in 2005 for cracked reflectors and 14.5% in 2001 to 32% in 2005 for broken reflectors (charts 2,4 & 6) after five years of service.

Cracked reflective lenses are considered to be still functional, as they still provide reflectivity, however the length of time before total failure is not known. The

broken reflective lenses provide very little to no reflectivity and need replacement. Dislodged reflective lenses have occurred on two of the test locations, highways 21:24 and 33:04/06. The reason for the loss is not known. The number of dislodged lenses increased slightly on highway 21:24 and 33:04/06 from the initial 2001 observations (charts 2 and 5).

Snowplowable Raised Pavement Markings placed on centerline

Snowplowable raised pavement markers were placed on the centerline of highways 21:24, 28:04, 33:04/06 and 37:04. Highway 37:04 encompasses only the centerline SRPM's. The centerline SRPM's exhibited a slight increase in the deterioration rate from the initial observations of 2001. The deterioration rate ranged from 0.7% in 2001 to 2.6% in 2005 for cracked reflectors and 0% in 2001 to 2.7% in 2005 for broken reflectors (charts 1,3,5 & 7). The dislodged centerline reflective lenses have occurred on highways 21:24 and 33:04/06. There has been a slight increase in dislodged reflective lenses on centerline since the initial observations of 2001 on highway 33:04/06 (chart 5).

12.0 SUMMARY OF OBSERVATIONS

In studying the comparative charts of the failure rates for the reflective lenses, (charts 8, 9, 10 & 11 – Appendix 'I') it is evident that the centerline markings are outperforming the shoulder markings. The test sites at highway 33:04/06, 28:04 and 37:04 used only the Stimsonite snowplowable raised pavement markers with Stimsonite reflectors. The highway 21:24 test site used the Stimsonite and Nightline markers along with Stimsonite and 3M reflectors.

There is no evidence of any failures to the marker castings (Stimsonite 101 LPCR or 3M Nightline).

Hwy. 21:24

Highway 21:24 utilized both 3M and Stimsonite reflectors. It is evident from chart 8 (Appendix 'I') that the 3M reflectors incorporating a polycarbonate face outperformed the Stimsonite reflectors incorporating a glass lens face on the shoulder edge lines (23% vs 72% failure rate). However, the failure rate (23%) of the 3M reflectors placed on shoulder edge is based on 7 dislodged reflectors out of a total of 30 placed. The 7 dislodged reflectors were first observed in 2001.

The reflectors placed on centerline are performing very well with very small amounts of failure observed for the Stimsonite reflectors and the 3M reflectors after 5 years of service (6.7% Stimsonite & 3% 3M). It was evident from this trial section that the centerline markers are providing excellent delineation.

Hwy. 28:04

Highway 28:04 utilized the Stimsonite markers for both the shoulder edge and centerline. The failure rate after 5 years was 27% on shoulder and only 1.6% on centerline. The centerline failure rate of 1.6% (chart 9 – Appendix 'I') has not changed since 2002. The Stimsonite raised pavement markers are performing well on this trial section with the centerline markers outperforming the shoulder line markings by a wide margin.

Hwy. 33:04/06

Highway 33:04 utilized the Stimsonite markers for both the shoulder edge and centerline. The failure rate of the Stimsonite reflectors is 57.3% for shoulder edge and 10.1% for centerline. The failure rate for the centerline reflectors has not increased very much since 2001 from 4.6% to 10.1% (chart 10). The centerline reflectors are again performing very well on this trial section.

Hwy. 37:04

Highway 37:04 utilized the Stimsonite markers on centerline only. The failure rate of 5.3% (chart 11) is very low after 3 years of service. The centerline markers on this project are performing very well and providing positive delineation.
Note: Markers on this test site were not evaluated in 2005 due to the road way being seal coated in 2004.

13.0 CONCLUSIONS

1. The marker castings are performing very well with no evidence of damage.

2. The 3M reflectors have outperformed the Stimsonite reflectors on shoulder edge at the highway 21:24 test location.

3. Both of the SRPM products tested perform very well along the centerline and provide excellent delineation.

4. After 5 years of service it is evident that the shoulder edge reflectors have many more defects and are not performing as well as the centerline reflectors. The reflectors were expected to require replacement in approximately 4 to 5 years. Many of the shoulder edge reflectors (as high as 35% - broken & dislodged reflectors) require replacement, as they are no longer effective. It is expected that many of the reflectors will continue to be effective after 5 years.

5. The marker spacing of 27 meters on straight-aways and 18 meters on curves appears to be the proper spacing, giving adequate delineation. However, the NCHRP Report 518 – Safety Evaluation of Permanent Markers; recommends a spacing of 24 meters on straight-aways and 12 meters on curves.

6. The markers on curves are definitely enhancing the painted longitudinal pavement markings during inclement weather and low light conditions. They are definitely effective to the motorist in delineating curves in darkness.

7. The effectiveness of the Raised Pavement Markers in winter can be substantially reduced when snow and ice is built-up on the reflectors.

8. The collision data collected to date is inconclusive in showing that Raised Pavement Markers reduce collisions.

14.0 RECOMMENDATIONS

1. Continue the use of snowplowable raised pavement markers (Stimsonite or 3M reflectors) at locations that have been identified as collision prone such as roads with curves and areas susceptible to fog or whiteout conditions.

   The use of SRPMs as supplemental delineation will provide better road visibility at night and in adverse weather conditions. It is very important that the success of SRPM's is contingent upon regular maintenance and replacement of broken reflectors.

2. On future projects consideration should be given to reducing the marker spacing to 24 meters on straight-aways and 12 meters on curves as recommended in the NCHRP Report 518 – Safety Evaluation of Permanent Markers.

3. The epoxy for adhering the marker shoes to the road surface shall conform to AASHTO M237 Type 4, Standard Set Epoxy for Blade Deflecting Type Plowable Markers.

4. Care is to be taken to prevent reflector contamination during crack sealing and line painting operations.

5. It is recommended that the same colors of the painted roadway lines be used for the SRPMs:

   - Two-way white reflectors for shoulder lines
   - Two-way yellow reflectors for centerline

6. Establish a replacement program for the damaged reflectors:

To be effective, SRPMs must be properly maintained to keep prismatic reflectors in good operating condition. Proper maintenance can be best accomplished by a program, which emphasizes replacement of broken reflectors on a 2 year cycle.

A four-year replacement cycle may prove to be adequate for low volume highways; while heavily traveled highways with high volumes of truck traffic might need reflector replacement on a 2-year cycle.

7. Recommended Installation Guidelines for SRPM's as supplemental delineation devices:

Two-Lane Highways

The SRPM may be used to supplement the line pavement markings on major two-digit highways in the following situations:

- On curved highway sections posted at 80 km/hr or more, where
  - Traffic volumes exceed 3,000 AADT
  - Curve radius does not exceed 3,500 metres
  - Safety record indicates a collision pattern resulting from centerline encroachment

For sharp curves with radii less than 500 metres, the benefits of better delineation with SRPM's may be offset by the increased potential for run-off-road collisions (i.e., due to expected increase in running speed). In these situations, SRPM's should be used with caution; other safety improvements (i.e., grade-widening, curve flattening) may need to be considered in conjunction with SRPM's.

Installation of SRPM's should begin at least 500 metres in advance of the curved section and should continue 500 metres past the curve. This is to reduce the "collision migration" effect and to ensure proper transitioning from the higher level of roadway delineation to a standard delineation.

- On approaches to narrow bridge sites with a significant reduction in pavement width, as an alternative treatment to a standard delineation, where
  - Traffic volumes exceed 500 AADT

- Safety record indicates a pattern of collisions or incidents (typically 3 or more within a five year period) that could be attributed to the minimum geometry of the bridge approaches.

SPRM's should delineate the centerline and both edgelines and should extend for 300 metres along tangent roadway sections in both directions of travel.

Four-Lane Highways

SRPM's may be used to supplement pavement markings on multilane highways in the following situations:

- On curved highway sections posted at 80 km/hr or more, where
  - Traffic volumes exceed 10,000 AADT
  - Curve radius does not exceed 3,500 metres
  - Safety record indicates a collision pattern resulting from encroachments to the side of the travel lane (i.e., higher than the provincial average collision rate or higher number of collisions per kilometer per year).

References

Performance report for the installation of Raised Snowplowable Pavement Markers in Alberta. December 2000.

APPENDIX ‘A’

History of Pavement Markers Tried on Alberta Highways

History of Pavement Markers tried on Alberta Highways

May, 1981

Introduction

Raised reflective pavement markers (non-snowplowable) for improving traffic operations and safety within limits of a construction zone detour were evaluated for their effectiveness and performance.

A total of 450 Stimsonite Life-Lite 88A markers were installed at three meter spacings along the centerline of detour on highway 28 near Namao.

Product Performance

Day and night inspections were conducted on a monthly basis to evaluate marker effectiveness and record marker losses. Over the three-month duration of this project, 94 of the 450 markers (21%) became dislodged.

The markers were found to perform very well at night, even during inclement weather conditions. Comments received by RCMP and the general public confirmed this observation.

Conclusion

It was determined from the subjective evaluations conducted that the raised reflectorized markers were effective in improving delineation's of the detour and facilitating limits. From a safety aspect, the detour was considered significantly improved under nighttime and inclement weather conditions.

Aug. 1987

Introduction

A total of 50 EZC retractable pavement markers were installed along a curve at Diamond City on highway 25. The EZC marker features a retractable retro-reflective marker supported by rubber cushioning and encased in a steel casting.

Product Performance

After one snowstorm in December of 1987, snowplowing vehicles had damaged 20 of the 50 markers, with 4 markers being destroyed. Castings showed severe scarring which suggested that the markers failed to retract properly when struck by snowplows.

Conclusion

The EZC retractable pavement marker is not durable enough and does not retract adequately to withstand impact from snowplows.

August, 1982 & September, 1983

Introduction

Stimsonite 96 snow-plowable markers were installed on highway 2 & 2A in 1982 –83. The markers were evaluated for their ability to withstand impact by snowplows. The following sites were chosen:

1) Hwy. 2 (near 50 St. overpass at Leduc)
2) Hwy. 2 (south of Leduc)
3) Hwy. 2A (near Kavanagh)

These sites were selected because of specific safety problems such as interference from background lighting or poor horizontal alignment.

It was also decided to test the effectiveness of this product in high accident areas as per the following:

1) Hwy. 2A (near Kavanagh)
2) Hwy. 13 (west of Wetaskiwin)
3) Hwy. 2 (near Clyde)

Highway 2A is one of the original test sites used for evaluating the durability of this product.

Product Performance

The reflectors do provide operational guidance during night time (when clean and undamaged) and may have aided in reducing the number of nighttime collisions.

From a durability standpoint the stimsonite 96 product has been effective. Of the 99 markers installed, only two were damaged in the first year by snowplows. Field inspection of devices at both Kavangh and Wetaskiwin in 1987 revealed approximately 30% of the devices has been damaged or destroyed and approximately 75% have been partially or totally painted over.

Conclusion

The stimsonite 96 snowplowable product seems to have fairly good longevity and retain their reflectivity for the life of the product (3 to 5 years). However, this is contingent upon regular maintenance and replacement of broken reflective strips. If dirt is allowed to collect or broken reflective strips are not replaced, the effectiveness drops off quickly.

Summary of Findings

Earlier Trials of Raised Pavement Markers

Raised pavement markers (snowplowable) have been evaluated on Alberta highways since 1981. The Department has tested and evaluated several types of raised pavement markers with favorable results. The Stimsonite 96 snowplowable pavement marker product provided the best results.

Raised Pavement Marker Test Sections (2000)

Alliant Engineering and Consulting Ltd. were involved with the installation of raised pavement markers at four test locations. Two brands of pavement markers were involved in this project, Stimsonite and Nightline.

The sites at Hwy. 33:04/06, 28:04 and 37:04 used Stimsonite snowplowable raised pavement markers with Stimsonite reflectors. The site at Hwy. 21:24 served as a test section for the Stimsonite and Nightline markers along with Stimsonite and 3M reflectors.

There was no evidence of any failure to the castings (Stimsonite 101LPCR or Nightline). However, after only 1 year in service and a mild winter many of the reflectors have failed. The reflectors were expected to require replacement in approximately 4 to 5years. The following is a breakdown of the test sections along with the percentage of failed reflectors:

Hwy. 21:24	24% failure (Stimsonite) 7% failure (3M)
Hwy. 28:04	1.5% failure (Stimsonite)
Hwy. 33:04/06	12% failure (Stimsonite)
Hwy. 37:04	Less than 1% failure (Stimsonite)

The centerline markers showed very minimal failure at all sites inspected. It appears that the majority of failures to the reflectors are at the shoulder lines. Of the four test locations, highway 21:24 showed high reflector damage (24%). Highway 33:04/06 had 12% damage and both highways 37:04 and 28:04 showed negligible damage.

Based on these observations, highways 21:24 and 33:04/06 has not performed as expected (approx. 4 years to replacement). Highways 28:04 and 37:04 have performed adequately as there is only minimal damage to the reflectors.

Highway 21:24, (test site for Stimsonite and 3M reflectors) the 3M reflectors appear to have out performed the Stimsonite reflectors. Of the 120 - 3M reflectors looked at, there were no damages recorded; however 9 reflectors were dislodged.

In conclusion, it is recommended that the Raised Pavement Markers be monitored for long term effect over the next 4 to 5 years. This is required to determine the durability of the markers and the required level of maintenance. A question that may have to be answered is do we replace the damaged marker reflectors? Damaged markers are no longer effective as the reflectivity of the reflector is reduced or non-existent. Night time evaluation may be required.

Prepared by: Joe Filice

APPENDIX 'B'

Field inspections

Snowplowable Raised Pavement Markers

In the 2000 construction season, Raised Pavement Markers were installed at four highway test sections near Edmonton. The markers consist of a reflector inside a cast iron housing installed adjacent to painted roadway lines. The markers are to provide better road visibility at night and in adverse weather conditions. Two types of low profile pavement markers were used with Stimsonite and 3M reflectors:

- Stimsonite 101LPCR
- Nightline Pavement Markers

The initial observations of the pavement markers were very positive. A nighttime evaluation was conducted on Nov. 2, 2000; the markers appeared to be brighter and visible for longer distances than the painted roadway lines.

The four highway test sections chosen are as per the following:

- Highway 37:04 (km 3.51 to km 6.58)
- Highway 28:04 (km 12.23 to km 13.83)
- Highway 33:04 (km 27.22 to km 0.88)
- Highway 21:24 (km 16.99 to km 21.67)

Field observations of raised pavement markers (2001)

Highway 21:24

A total of approximately 600 raised pavement markers were looked at on September 10, 2001. The markers are broken down as per the following:

	Stimsonite		3M	
	White	Yellow	White	Yellow
Total inspected	476	89	30	165
Damaged reflective markers				
Broken markers	69			
Cracked markers	30			
Dislodged markers (missing)	12		7	2

Summary

Of the 565 Stimsonite reflective markers, 111 (23%) were damaged or dislodged (see above breakdown). These markers were installed on October 16, 17 & 18 of 2000.

There were no visual damage observed to the 3M reflective markers. However there are 9 – 3M (3.5%) reflective markers dislodged from the cast iron housing. The centerline markers are out performing the edge line markers, only 2 centerline markers are dislodged with no centerline marker damage observed.

Photographs of reflective markers on Hwy. 21:24

Damaged Stimsonite marker

Cracked Stimsonite marker

Broken Stimsonite marker

3M Marker in good shape

3M reflective marker dislodged from nightline shoe

Stimsonite broken marker

Highway 28:04

Highway 28:04 markers were evaluated on September 07, 2001. There are a total of 268 Stimsonite markers placed on this stretch of highway. The markers are in very good shape and functioning as intended. Several markers had minor scuffmarks and only 4 shoulder (1.5%) is damaged. No centerline markers are damaged.

Photographs of reflective markers on Hwy. 28:04

Scuff mark on Stimsonite marker

Cracked Stimsonite marker

Stimsonite centerline yellow markers
Showing crack sealant

Broken Stimsonite marker

Highway 33:04/06

Highway 33:04/06 markers were evaluated on September 14, 2001. A total of 444 Stimsonite raised pavement markers were inspected. The markers are located at both shoulder lines and centerline and are broken down as per the following:

	Stimsonite
Total inspected	444
Damaged reflective markers	
Broken markers	8
Cracked markers	24
Dislodged markers (missing)	21 (10 centerline and 11 shoulder)

Summary

Of the 444 Stimsonite reflective markers, there are 53 damaged or dislodged markers (see above breakdown). It has been approximately 1 year since the markers were installed (Oct. 10, 11 & 12, 2000), our observations show that 12% of the raised pavement markers are damaged or dislodged. The centerline markers are out performing the edge line markers.

Photographs of reflective markers on Hwy. 33:04/06

Stimsonite Dislodged reflectors

Stimsonite Broken marker

Highway 37:04

Highway 37:04 markers were evaluated on September 14, 2001. A total of 304 Stimsonite raised pavement markers were inspected. The markers were all placed on centerline, no markers on the edge line. The markers are broken down as per the following:

	Stimsonite
Total inspected	304
Damaged reflective markers	
Broken markers	0
Cracked markers	2
Dislodged markers (missing)	0

Summary

Of the 304 Stimsonite reflective markers, there are only 2 damaged (cracked) markers (see above breakdown). These markers were installed in September 18, 25 & 26, 2000, our observations show that the markers on this highway have proven very successful after one year in service.

File: 8190-5-3
Date: September 5, 2002

Field observations of raised pavement markers (2002)

Highway 21:24

A total of 760 raised pavement markers were evaluated on July 18, 2002. These markers were installed on October 16, 17 and 18 of 2000. The damaged markers are broken down as per the following:

	Stimsonite housing		Nightline housing	
	White	Yellow	White	Yellow
Total inspected	476	89	30	165
Damaged reflective markers				
Broken markers	100			
Cracked markers	105			
Dislodged markers (missing)	12		7	2

The raised pavement markers installed on the Hwy. 21:24 site served as a test section for the 3M reflectors/Nightline markers as well as the Stimsonite markers and reflectors. Both 3M/Nightline and Stimsonite markers were used in several different alternating patterns at this site in order to compare their durability directly. The detailed breakdown of the locations of each type of marker is outlined in the following table:

Section	Stations	Centerline	Shoulder
A	-6 to 38	Stimsonite	Stimsonite
B	39 to 66	Alternating between Stimsonite and 3M reflectors; Stimsonite castings.	Alternating between Stimsonite and 3M reflectors; Stimsonite castings.
C	67 to 103	Alternating in fives (i.e. 5 Stimsonite, 5 3M/Nightline, etc.)	Stimsonite
D	104 to 234	3M/Nightline	Stimsonite
E	235 to 245	None	Stimsonite

The following table shows condition of the markers in each section of this test site:

Section	Centerline		Shoulder		Missing Reflectors	
	Broken	Cracked	Broken	Cracked	Centerline	Shoulder
A	None	None	11 (Stim.)	20 (Stim.)		
B	None	None	3 (Stim.)	5 (Stim.)		
C	None	None	20 (Stim.)	12 (Stim.)		
D	2 (3M)	None	60 (Stim.)	60 (Stim.)	2(3M)	12(Stim.) 7(3M)
E	None	None	6 (Stim.)	8 (Stim.)		

Summary

- The centerline markers are performing very well with very few defects noted.
- The shoulder line markers have not performed as well as expected. The manufactures suggested that the reflectors would last for 4 years before requiring replacement. However, after only 2 years in service, 45% of these markers have defects as noted.

	Stimsonite Reflectors		3M Reflectors	
	Centerline	Shoulder	Centerline	Shoulder
% Failure (Broken Lens)	0%	21%	0%	0%
% Cracked (Still Functional)	0%	22%	0%	0%
% Failure (Missing)	0%	2.5%	1.2%	4.2%

- It is interesting to note that while there are some centerline marker defects noted for the 3M product but none for the Stimsonite product the reverse is true for the shoulder line markers. All the defective shoulder line markers are Stimsonite reflectors.

Highway 28:04

A total of 268 Stimsonite markers were evaluated on August 21, 2002. These markers were installed on September 27 and 28 of 2000. The markers are located at both shoulder lines and centerline and damages are broken down as per the following:

	Stimsonite White (shoulder)	Stimsonite Yellow (centerline)
Total inspected	144	124
Damaged reflective markers		
Broken markers	6	
Cracked markers	21	
Dislodged markers (missing)	none	

Stimsonite housing and reflectors were installed on this site. The following table shows the condition of the markers at this test site:

Centerline		**Shoulder**		**Missing Reflectors**	
Broken	**Cracked**	**Broken**	**Cracked**	**Centerline**	**Shoulder**
None	2	6	19	None	None

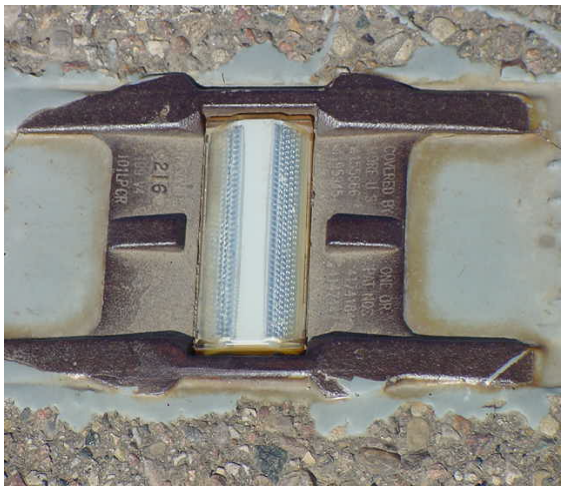
Summary

- The centerline markers are performing very well with minimal defects noted.
- The shoulder line markers have not performed as well as the centerline markers but are in fairly good shape and functioning as intended. However, 10% of all markers have defects as noted in the following table:

	Stimsonite Reflectors	
	Centerline	Shoulder
% Failure (Broken Lens)	0%	4%
% Cracked (Still Functional)	1.6%	13%
% Failure (Missing)	0%	0%

- One centerline marker was covered with crack sealant.

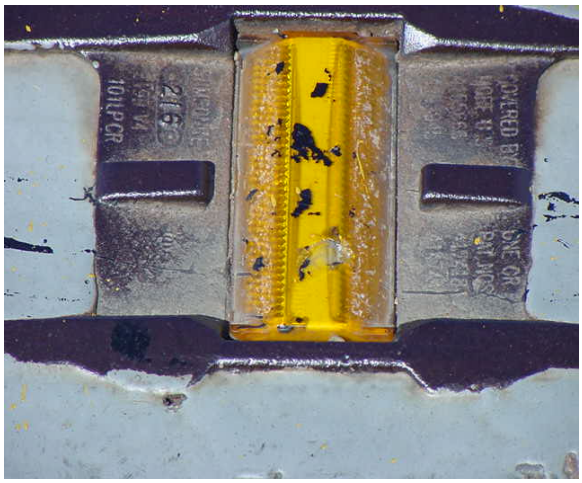
Photographs of reflective markers on Hwy. 28:04



Intact Stimsonite marker and reflector at shoulder

Damaged Stimsonite reflector

Intact Stimsonite markers at centerline



Centerline marker with chip and crack sealer

Centerline marker covered with crack sealer

Broken stimsonite marker at shoulder

Highway 33:04/06

A total of 444 Stimsonite markers were evaluated on August 22, 2002. These markers were installed on October 10, 11, and 12 of 2000. The markers are located at both shoulder lines and centerline and damages are broken down as per the following:

	Stimsonite White (shoulder)	Stimsonite Yellow (centerline) Reflectors
Total inspected	227	217
Damaged reflective markers		
Broken markers	12	
Cracked markers	41	
Dislodged markers (missing)	21 (10 centerline and 11 shoulder)	

Of the 444 Stimsonite housing and reflectors, there are 74 damaged or dislodged markers (see above breakdown). It has been approximately 2 years since the markers were installed, our observations show that 17% of the raised pavement markers are damaged or dislodged. The centerline markers are out performing the edge line markers, there are 10 markers on centerline that are dislodged and 1 that is cracked. The following table shows the condition of the markers at this test site:

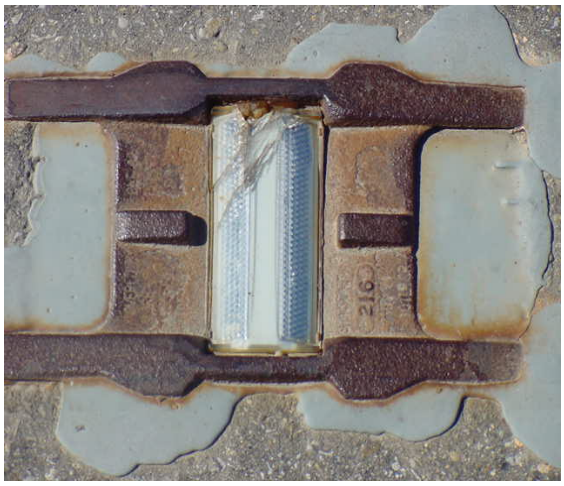
Centerline		**Shoulder**		**Missing Reflectors**	
Broken	**Cracked**	**Broken**	**Cracked**	**Centerline**	**Shoulder**
None	1	12	40	10	11

Summary

- The centerline markers are performing very well with the exception of 10 missing reflectors and some minor defects.
- The shoulder line markers have many defects as noted above and are not performing as well as the centerline markers. The following table shows the % of defects noted on the raised pavement marker reflectors:

	Stimsonite Reflectors	
	Centerline	Shoulder
% Failure (Broken Lens)	0%	5.3%
% Cracked (Still Functional)	0.5%	17.6%
% Failure (Missing)	4.6%	4.9%

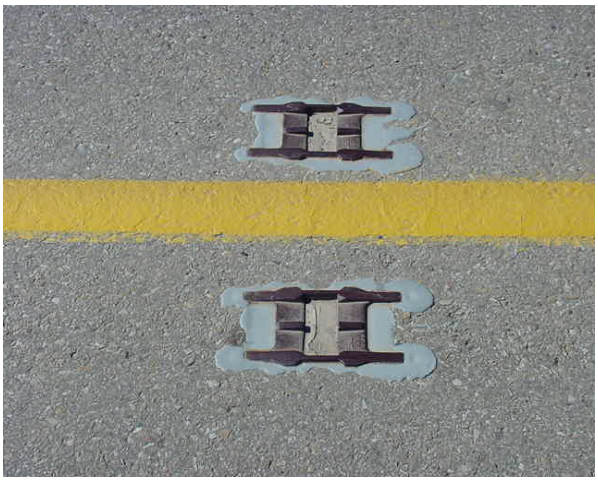
Photographs of reflective markers on Hwy. 33:04/06



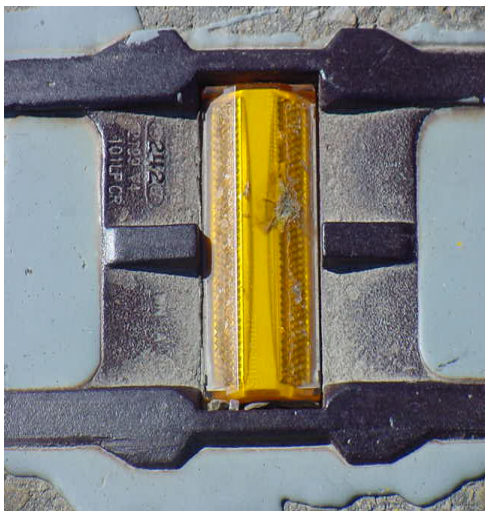
Cracked shoulder reflector

Broken shoulder reflector

Missing shoulder reflector



Missing centerline reflectors



Chip in centerline reflector

Cracks in centerline reflector

Highway 37:04

A total of 304 Stimsonite markers were evaluated on August 22, 2002. These markers were installed on September 18, 25 and 26 of 2000. The markers were all placed on centerline; no markers placed on the edge lines. The following is a damage breakdown of the markers:

Stimsonite Yellow (centerline) Reflectors

Total inspected	304
Damaged reflective markers	
Broken markers	3
Cracked markers	4
Dislodged markers (missing)	none

Of the 304 Stimsonite housing and reflectors, there are 3 broken and 4 cracked reflectors. These markers were installed in September 2000, our observations show that the markers on this highway have proven successful after one year in service. The following table shows the condition of the markers at this test site:

Centerline		**Missing Reflectors**	
Broken	**Cracked**	**Centerline**	**Shoulder**
3	4	none	NA

Summary

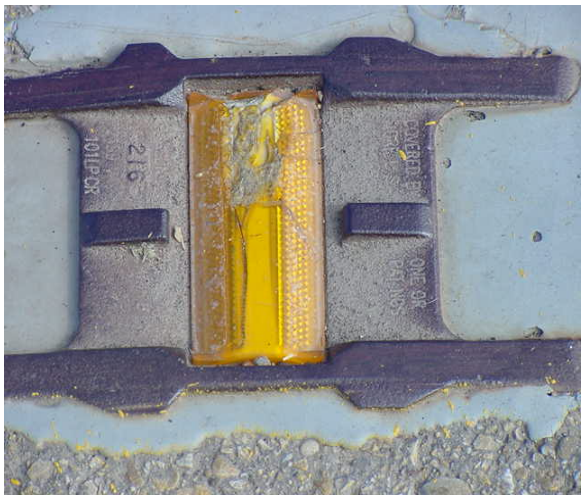
- The centerline markers are performing very well with the exception of 3 broken and 4 cracked reflectors.
- The following table shows the % of defects noted on the raised pavement marker reflectors:

	Stimsonite Reflectors
	Centerline
% Failure (Broken Lens)	1%
% Cracked (Still Functional)	1.3%
% Failure (Missing)	none

Photographs of reflective markers on Hwy. 37:04

Centerline markers

Cracked centerline marker



Broken centerline marker

Summary of Findings

The following is the breakdown of the test sections along with the percentage of failed reflectors for the last two years:

Test Section	% Failure			
	2001		2002	
	Centerline	Shoulder	Centerline	Shoulder
Hwy. 21:24	0%(Stim.) 1.2% (3M)	23%(Stim.) 23%(3M)	0% (Stim.) 1.2% (3M)	46%(Stim.) 23%(3M)
Hwy. 28:04	0% (Stim.)	2.8%(Stim.)	1.6% (Stim.)	17% (Stim.)
Hwy. 33:04/06	1.8% (Stim.)	21% (Stim.)	5% (Stim.)	28% (Stim.)
Hwy. 37:04	0.7% (Stim.)	NA	2.3% (Stim.)	NA

Note: Failure includes cracked, broken and missing reflectors

Prepared by Joe Filice

Field observations of raised pavement markers (2003)

Highway 21:24

A total of 760 raised pavement markers were evaluated on July 31, 2003. These markers were installed on October 16, 17 and 18 of 2000. The damaged markers are broken down as per the following:

	Stimsonite housing		Nightline housing	
	White	Yellow	White	Yellow
Total inspected	476	89	30	165
Damaged reflective markers				
Broken markers	132		3	
Cracked markers	125			
Dislodged markers (missing)	15		7	2

Highway 28:04

A total of 268 Stimsonite markers were evaluated on August 12, 2003. These markers were installed on September 27 and 28 of 2000. The markers are located at both shoulder lines and centerline and damages are broken down as per the following:

	Stimsonite White (shoulder)	Stimsonite Yellow (centerline)
Total inspected	144	124
Damaged reflective markers		
Broken markers	14	
Cracked markers	20	2
Dislodged markers (missing)	none	

Highway 33:04/06

A total of 444 Stimsonite markers were evaluated on August 28, 2003. These markers were installed on October 10, 11, and 12 of 2000. The markers are located at both shoulder lines and centerline and damages are broken down as per the following:

	Stimsonite White (shoulder)	Stimsonite Yellow (centerline) Reflectors
Total inspected	227	217
Damaged reflective markers		
Broken markers	21	2
Cracked markers	48	3
Dislodged markers (missing)	11	10

Highway 37:04

A total of 304 Stimsonite markers were evaluated on October 15, 2003. These markers were installed on September 18, 25 and 26 of 2000. The markers were all placed on centerline; no markers placed on the edge lines. The following is a damage breakdown of the markers:

	Stimsonite Yellow (centerline) Reflectors
Total inspected	304
Damaged reflective markers	
Broken markers	8
Cracked markers	8
Dislodged markers (missing)	none

Field observations of raised pavement markers (2005)

Highway 21:24

A total of 760 raised pavement markers were evaluated on May 25, 2005. These markers were installed on October 16, 17 and 18 of 2000. The damaged markers are broken down as per the following:

	Stimsonite housing		Nightline housing	
	White	Yellow	White	Yellow
Total inspected	476	89	30	165
Damaged reflective markers				
Broken markers	151	1	3	
Cracked markers	177	5		
Dislodged markers (missing)	15		7	2

Highway 28:04

A total of 268 Stimsonite markers were evaluated on May 25, 2005. These markers were installed on September 27 and 28 of 2000. The markers are located at both shoulder lines and centerline and damages are broken down as per the following:

	Stimsonite White (shoulder)	Stimsonite Yellow (centerline)
Total inspected	144	124
Damaged reflective markers		
Broken markers	16	
Cracked markers	23	2
Dislodged markers (missing)	none	

Highway 33:04/06

A total of 444 Stimsonite markers were evaluated on June 10, 2005. These markers were installed on October 10, 11, and 12 of 2000. The markers are located at both shoulder lines and centerline and damages are broken down as per the following:

	Stimsonite White (shoulder)	Stimsonite Yellow (centerline) Reflectors
Total inspected	227	217
Damaged reflective markers		
Broken markers	42	5
Cracked markers	77	4
Dislodged markers (missing)	11	13

Highway 37:04

This highway was seal coated in 2004, the Snowplowable Rasied Pavement Markers are now obstructed.

APPENDIX ‘C”

Nighttime Photographs (October 2000)

Hwy 21 - Nighttime observations October 2000

Hwy 28 - Nighttime observations October 2000

Hwy 37 - Nighttime observations October 2000

APPENDIX ‘D’

Nighttime Photographs (November 2003)

Highway 28 – shoulder markers obstructed by snow/ice

Highway 28 – shoulder markers obstructed by snow/ice

APPENDIX ‘E’

Nighttime Photographs (February 2004)

Hwy. 28 – Centerline and shoulder markers are visible.

February 11, 2004

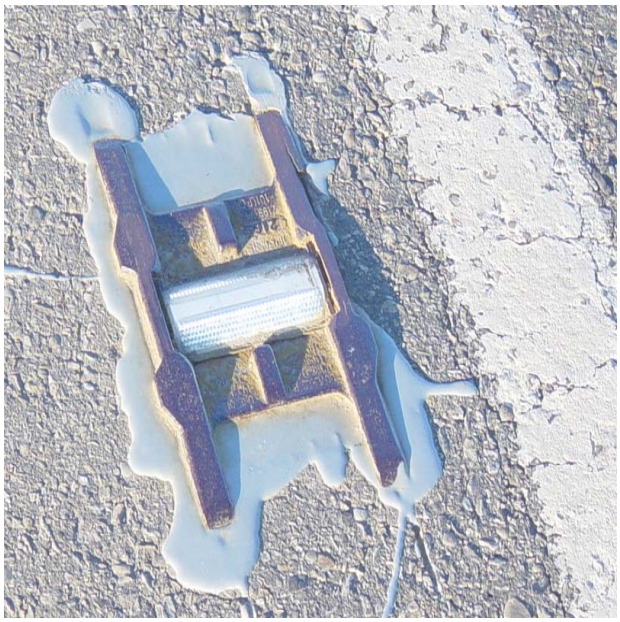
Hwy. 28 – centerline marker is visible. Shoulder marker not fully visible due to ice/snow on reflective lens, thus reducing its reflectivity.

February 11, 2004
Hwy. 37

Hwy. 37 centerline markers are visible and providing guidance to the motorist. However there are many markers that were obstructed by the buildup of snow/ice.

Hwy. 37 centerline marker is visible. There are double centerline markers on this project, at this particular location only one is reflective. The marker on the right is obstructed by ice/snow buildup on the reflective lens.

February 23, 2004 (Day-time and Nighttime observation)
Hwy. 21:24



The reflectors are clear of ice/snow. There are traces of sand residue on the reflectors which may reduce the retro reflective properties of the reflectors.

Reflectors are providing positive delineation at night.

It is evident that when driving through this stretch of highway 21, the raised pavement markers are providing very good retro reflectivity which assists the motorists in maneuvering around curves in low light conditions.

APPENDIX ‘F’

Nighttime Photographs (May 2005)

Hwy 21 – Nighttime observations May 2005

SRPM are providing good additional delineation on the highway 21 trial section. Majority of the Markers are reflective with the exception of some of the broken markers. When compared to normal paint line delineation the SRPM markers definitely improve preview distances and guidance to motorist in low light conditions. Photographs are not providing a true representation of the reflectivity of the SRPM's.

Hwy 28 – Nighttime observations May 2005

SPRM on centerline and edge line are providing very good additional delineation on this trial section. Markers are highly visible as you approach this trial section. Photographs are not providing a true representation of the reflectivity of the SRPM's.

Hwy 37 – Nighttime observations May 2005

SPRM on this trial section are not visible at a distance, they are only visible prior to crossing them. A closer examination concluded that this stretch of highway was seal coated in 2004 therefore the majority of the markers are obstructed.

APPENDIX ‘G’

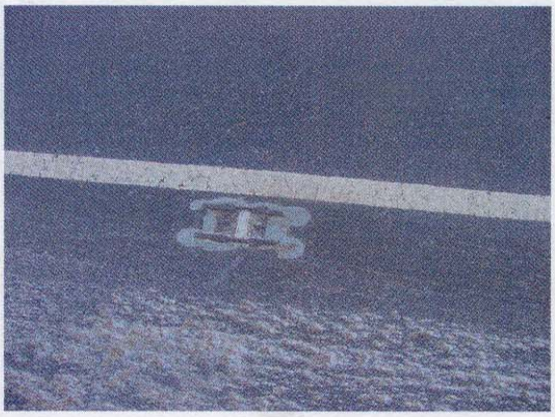
Snowplowable Raised Pavement Markings after snowplow clearing

Note to File

File: 8190-5-13

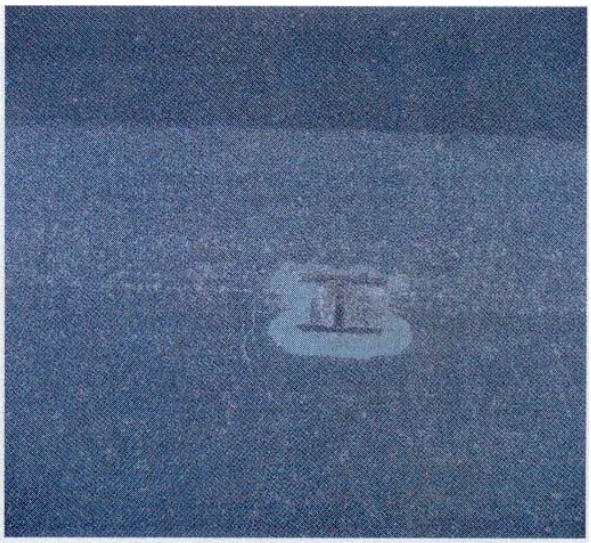
Re: Raised Pavement Markers
(Performance during Snowplowing)

On November 28, 2001, I visited the Highway 21 site to observe the performance of the markers after snowplow operations. The majority of the markers were clear of snow; there were no noticeable snow ridges along the markers after the snowplow made a pass. The markers had snow on them but the reflectors were unobstructed which would make them visible at night. The following photographs depict the condition of the raised pavement markers after snowplow clearing:



Markers are clear of snow

Snow along edge of markers
Reflectors are visible



Centerline markers are clear

Joe Filice

Cc: Terry Willis
Robert Duckworth
Richard Chow

APPENDIX 'H'

Collision Data

HIGHWAY 33:04

KM 0.00 to KM 0.88

	1997	1998	1999	2000	2001	2002	2003
Opposite Direction	0	0	0	0	0	0	1
Same Direction	0	0	1	1	0	2	0
Angle	1	0	0	1	0	0	0
Left Turn Across Path	0	0	0	0	0	0	0
Passing on Left Turn	0	0	0	0	0	0	0
Run-Off-Road	0	0	0	0	0	1	2
Pedestrian	0	0	0	0	0	0	0
Animal	2	0	0	2	0	1	0
Miscellaneous	0	0	0	0	0	0	0
Total	3	0	1	4	0	4	3

HIGHWAY 33:04

KM 28.22 to KM 30.02

	1997	1998	1999	2000	2001	2002	2003
Opposite Direction	0	0	0	0	1	0	0
Same Direction	0	0	0	0	0	0	0
Angle	0	0	0	0	0	0	0
Left Turn Across Path	0	0	0	0	0	0	0
Passing on Left Turn	0	0	0	0	0	0	0
Run-Off-Road	0	0	3	0	0	0	0
Pedestrian	0	0	0	0	0	0	0
Animal	4	1	2	1	6	2	2
Miscellaneous	0	0	0	0	0	0	0
Total	4	1	5	1	7	2	2

HIGHWAY 37:04

KM 3.51 to KM 6.58

	1997	1998	1999	2000	2001	2002	2003
Opposite Direction	0	1	0	0	1	1	0
Same Direction	0	0	0	0	1	1	0
Angle	1 (1 f)	0	0	0	0	1	0
Left Turn Across Path	0	0	0	0	0	0	0
Passing on Left Turn	0	0	0	0	0	0	0
Run-Off-Road	0	2	1	1	1	1	0
Pedestrian	0	0	0	0	0	0	0
Animal	2	8	5	3	2	1	1
Miscellaneous	0	0	1	0	0	0	0
Total	3	11	7	4	5	5	1

HIGHWAY 28:04

KM 12.23 to KM 13.83

	1997	1998	1999	2000	2001	2002	2003
Opposite Direction	0	1	0	0	0	0	1
Same Direction	1	0	0	1	0	1	1
Angle	0	0	0	0	0	1	0
Left Turn Across Path	0	0	0	0	0	0	0
Passing on Left Turn	0	0	0	0	0	0	0
Run-Off-Road	1	1	1	3	3	5	1
Pedestrian	0	0	0	0	0	0	0
Animal	0	2	1	0	3	3	0
Miscellaneous	0	1	0	0	0	0	0
Total	2	5	2	4	6	10	3

HIGHWAY 21:24

KM 16.99 to KM 21.85

	1997	1998	1999	2000	2001	2002	2003
Opposite Direction	0	0	1	0	0	0	2
Same Direction	0	0	0	0	0	0	3
Angle	0	1	0	0	1	0	0
Left Turn Across Path	0	0	0	0	0	0	0
Passing on Left Turn	0	0	0	0	0	0	0
Run-Off-Road	1	0	1	0	3	1	0
Pedestrian	0	0	0	0	0	0	0
Animal	2	1	3	5	3	6	6
Miscellaneous	0	0	0	0	0	0	0
Total	3	2	5	5	7	7	11

APPENDIX 'I'

Observation of Results

Table 17

Summary of % Failure

Test Section	% Failure							
	2001		2002		2003		2005	
	Centerline	Shoulder	Centerline	Shoulder	Centerline	Shoulder	Centerline	Shoulder
Hwy. 21:24	0%(Stim) 1.2%(3M)	23%(Stim) 23%(3M)	0% (Stim) 1.2% (3M)	46%(Stim) 23% (3M)	0% (Stim) 3% (3M)	57% (Stim) 23% (3M)	6.7%(Stim) 3% (3M)	72% (Stim) 23% (3M)
Hwy. 28:04	0% (Stim)	2.8%(Stim)	1.6%(Stim)	17% (Stim)	1.6%(Stim)	24% (Stim)	1.6%(Stim)	27%(Stim)
Hwy. 33:04/06	4.6%(Stim)	19% (Stim)	5.0%(Stim)	28% (Stim)	6.9%(Stim)	35% (Stim)	10%(Stim)	57%(Stim)
Hwy. 37:04	0.7%(Stim)	-	2.3%(Stim)	-	5.3%(Stim)	-		

Note: Failure includes cracked, broken and missing reflectors

Table 18

Number of Broken, Cracked and Missing Reflectors

Test Section	Centerline		Shoulder		Missing Reflectors	
	Broken	Cracked	Broken	Cracked	Centerline	Shoulder
Hwy. 21:24						
2001			69(Stim)	30(Stim)	2(3M)	12(Stim) 7(3M)
2002			100(Stim)	105(Stim)	2(3M)	12(Stim) 7(3M)
2003	3(3M)		132(Stim)	125(Stim)	2(3M)	15(Stim) 7(3M)
2005	3(3M) 1(Stim)	5(Stim)	151(Stim)	177(Stim)	2(3M)	15(Stim) 7(3M)
Hwy. 28:04						
2001			2(Stim)	2(Stim)		
2002		2(Stim)	6(Stim)	19(Stim)		
2003		2(Stim)	14(Stim)	20(Stim)		
2005		2(Stim)	16(Stim)	23(Stim)		
Hwy. 33:04/06						
2001			8(Stim)	24(Stim)	10(Stim)	11(Stim)
2002		1(Stim)	12(Stim)	40(Stim)	10(Stim)	11(Stim)
2003	2(Stim)	3(Stim)	21(Stim)	48(Stim)	10(Stim)	11(Stim)
2005	5(Stim)	4(Stim)	42(Stim)	77(Stim)	13(Stim)	11(Stim)
Hwy. 37:04						
2001		2(Stim)				
2002	3(Stim)	4(Stim)				
2003	8(Stim)	8(Stim)				

Chart 8

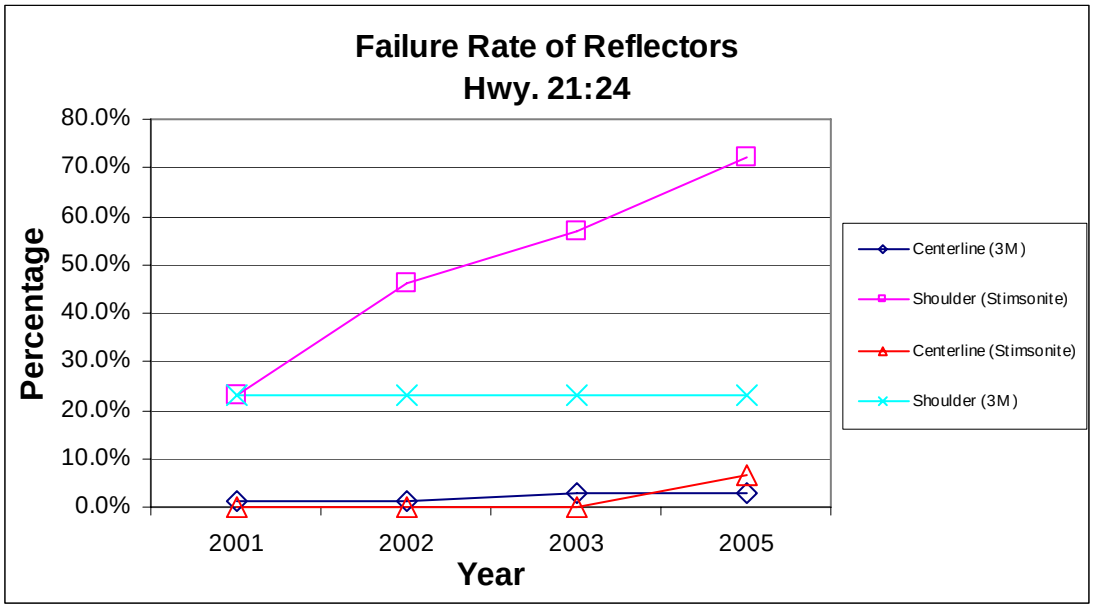


Chart 9

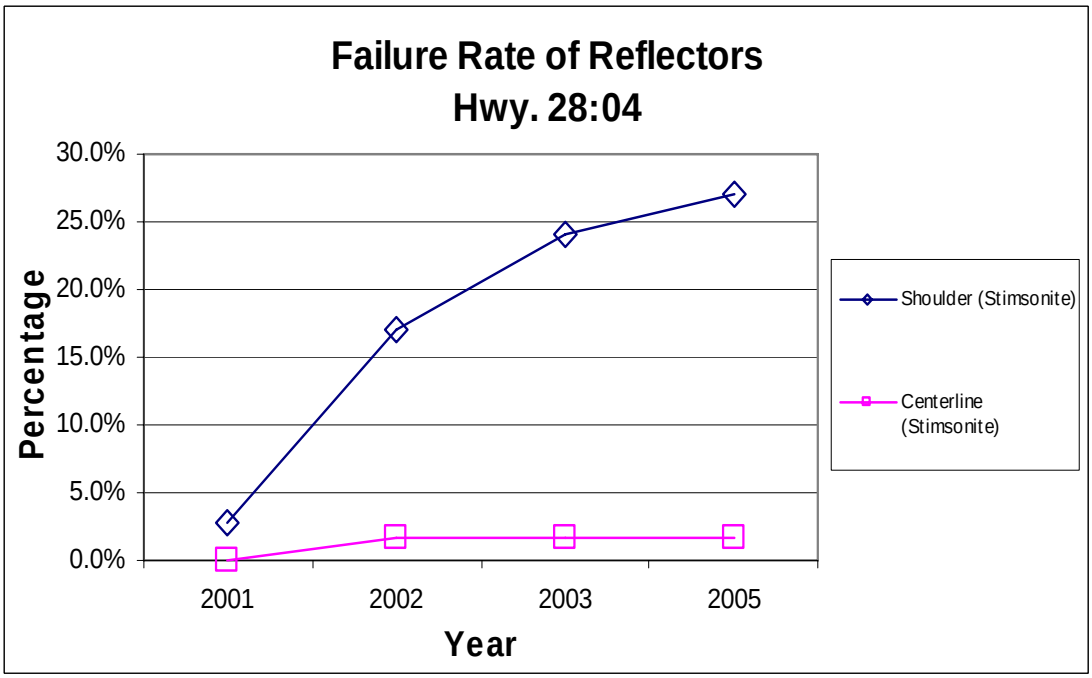


Chart 10

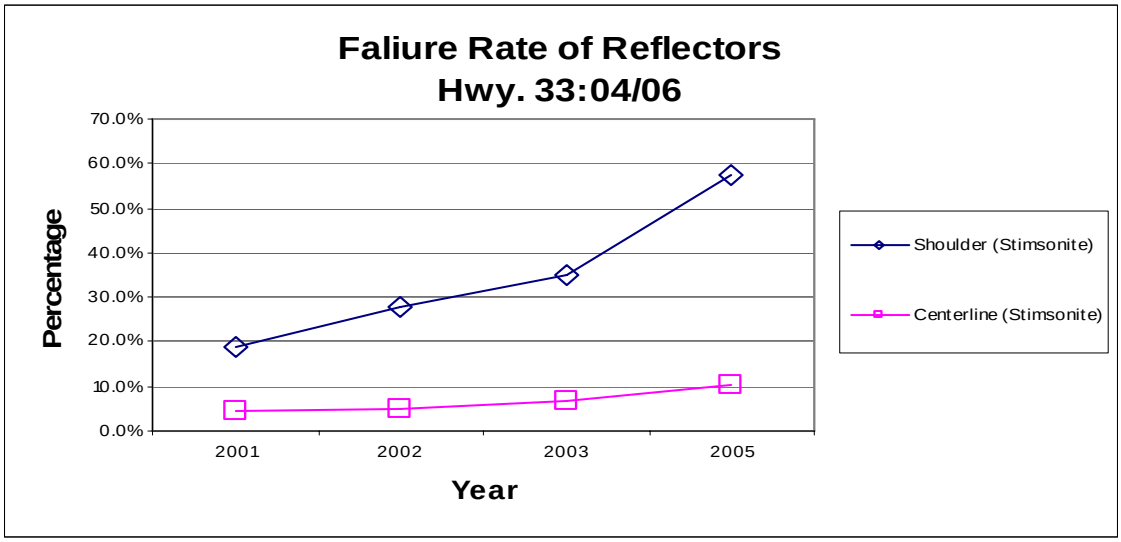
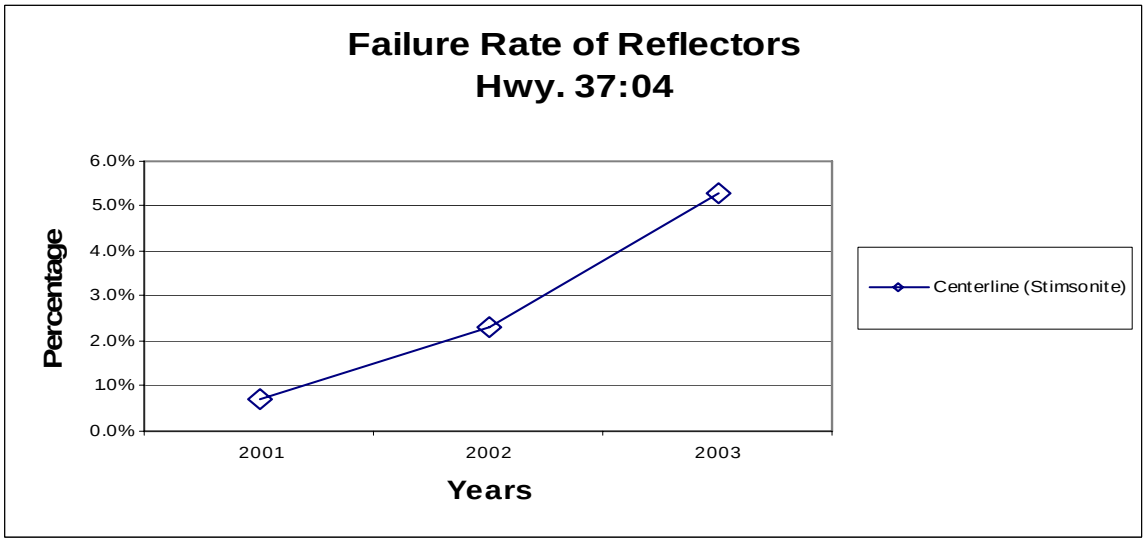


Chart 11



Note: Markers on this test site were not evaluated in 2005 due to the road way being seal coated in 2004.