

**NORTH DAKOTA
DEPARTMENT OF TRANSPORTATION**

**MATERIALS AND RESEARCH
DIVISION**

Experimental Study ND 2011-01

Evaluation of Grooved Pavement Markings

Final Evaluation

SIM-6-029(091)136

October 2014

Prepared by

**NORTH DAKOTA DEPARTMENT OF TRANSPORTATION
BISMARCK, NORTH DAKOTA
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Written by
Matthew Luger

Disclaimer

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EXPERIMENTAL PROJECT REPORT

| | | | | | | | | | | |
|-------------------------------------|---|-------------------------|---------------------------|-------------|-------------------------------------|----------------------|--|-------------------------------------|-----------------------------|--|
| EXPERIMENTAL PROJECT | EXPERIMENTAL PROJECT NO. | | | | | CONSTRUCTION PROJ NO | LOCATION | | | |
| | 1 | STATE ND | YEAR 2011 | NUMBER - | SURF 01 | 8 | SIM-6-029(091)136 I-29 Grand Forks County 28 | | | |
| | EVALUATION FUNDING | | | | | NEEP NO. | PROPRIETARY FEATURE? | | | |
| | 1 | HP&R | | 3 | DEMONSTRATION | | <input type="checkbox"/> | X Yes | | |
| | 48 | 2 | X CONSTRUCTION | 4 | IMPLEMENTATION | | 49 | 51 No | | |
| SHORT TITLE | TITLE 52 Evaluation of Grooved Pavement Markings | | | | | | | | | |
| THIS FORM | DATE 140 | MO. October | YR. -- | 2014 | REPORTING | | | | | |
| | | | | | 1 INITIAL | 2 ANNUAL | 3 X FINAL | | | |
| KEY WORDS | KEY WORD 1 | | | | KEY WORD 2 | | | | | |
| | 145 Wet-Reflective Elements | | | | 167 Pavement Marking | | | | | |
| | KEY WORD 3 | | | | KEY WORD 4 | | | | | |
| | 189 Grooved | | | | 211 | | | | | |
| | UNIQUE WORD | | | | PROPRIETARY FEATURE NAME | | | | | |
| | 233 | | | | 255 3M All Weather Pavement Marking | | | | | |
| CHRONOLOGY | Date Work Plan Approved | | Date Feature Constructed: | | Evaluation Scheduled Until: | | Evaluation Extended Until: | | Date Evaluation Terminated: | |
| | 277 January 2011 | | 281 Fall 2011 | | 285 Fall 2014 | | 289 | | 293 | |
| QUANTITY AND COST | QUANTITY OF UNITS (ROUNDED TO WHOLE NUMBERS) | | | UNITS | | | | UNIT COST (<i>Dollars, Cents</i>) | | |
| | Groove 151,496 | | | | | | | \$0.50 | | |
| | Water-Borne Wet-Ref. 34,479 | | | | | | | \$0.38 | | |
| | Water-Borne Control 34,478 | | | 1 X LIN. FT | | | | \$0.13 | | |
| | Epoxy Wet Refl. 68,136 | | | 2 SY | | | | \$0.54 | | |
| | Epoxy Control 84,480 | | | 3 SY-IN | | | | \$0.34 | | |
| | | | | 4 CY | | | | | | |
| | 297 | | | 305 | | | | 306 | | |
| AVAILABLE EVALUATION REPORTS | CONSTRUCTION | | | PERFORMANCE | | | FINAL | | | |
| | 315 | | | | | | X | | | |
| EVALUATION | CONSTRUCTION PROBLEMS | | | | PERFORMANCE | | | | | |
| | 1 | X | NONE | | | 1 | EXCELLENT | | | |
| | 2 | SLIGHT | | | 2 | GOOD | | | | |
| | 3 | MODERATE | | | 3 | SATISFACTORY | | | | |
| | 4 | SIGNIFICANT | | | 4 | MARGINAL | | | | |
| | 318 | 5 | SEVERE | | | 319 | UNSATISFACTORY | | | |
| APPLICATION | 1 | ADOPTED AS PRIMARY STD. | | | 4 | PENDING | | | | |
| | 320 | 2 | PERMITTED ALTERNATIVE | | | 5 | REJECTED | | | |
| | | 3 | ADOPTED CONDITIONALLY | | | 6 | NOT CONSTRUCTED | | | |
| | <i>(Explain in remarks if 3, 4, 5, or 6 is checked)</i> | | | | | | | | | |
| REMARKS | 321 The objective of this project was to compare the performance of surface applied pavement markings and grooved pavement markings using water based paint and epoxy, paired with standard glass beads and 3M AW Elements | | | | | | | | | |

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Definitions

Standard Water-based Paint - Water-based paint for pavement marking applications conforming to section 880 of the North Dakota Standard Specifications.

Standard Epoxy - Epoxy paint for pavement marking applications conforming to section 880 of the North Dakota Standard Specifications.

3M All Weather Paint (AWP) - A high-build water based paint manufactured by 3M for use with 3M AW Elements.

Standard Glass Beads - Glass beads for pavement marking paint conforming to section 880 of the North Dakota Standard Specifications (1.5 Refractive Index).

3M AW Optics - A material that provides wet-night retroreflectivity with 3M Pavement Marking Products.

3M AW Elements - A material that consists of 3M AW optics bonded to a central core. Used to apply wet-night retroreflectivity to liquid markings.

Standard Preformed Patterned Tape (Standard Tape) - A preformed patterned tape conforming to section 880 of the North Dakota Standard Specifications.

Evaluation of Grooved Pavement Markings

Purpose and Need

The harsh weather conditions of North Dakota demand frequent replacement of pavement markings. Water based pavement markings are replaced every year. Epoxy pavement markings are constructed with the expectation that they will last for 3-5 years when applied to the surface with proper application techniques. However, epoxy pavement markings may not last the projected 3 to 5 years primarily because of snow plow activity. This study will compare the performance of surface applied and grooved liquid pavement markings, based on presence and retroreflectivity. The benefits of constructing pavement markings in a groove is that the marking will be protected from snow plow damage. Possible negatives are that water and dirt may collect in the groove.

Objective

The objective of this project is to compare the performance of surface applied pavement markings and grooved pavement markings using water-based paint and epoxy. This project will also supplement the previous project *Evaluation of Wet-Reflective Elements for Pavement Markings*, ND 2010-01, by evaluating the effectiveness of 3M AW Elements in a groove.

Location

NDDOT constructed research segments as part of project SIM-6-029(091)136. This project is located near Grand Forks on I-29.

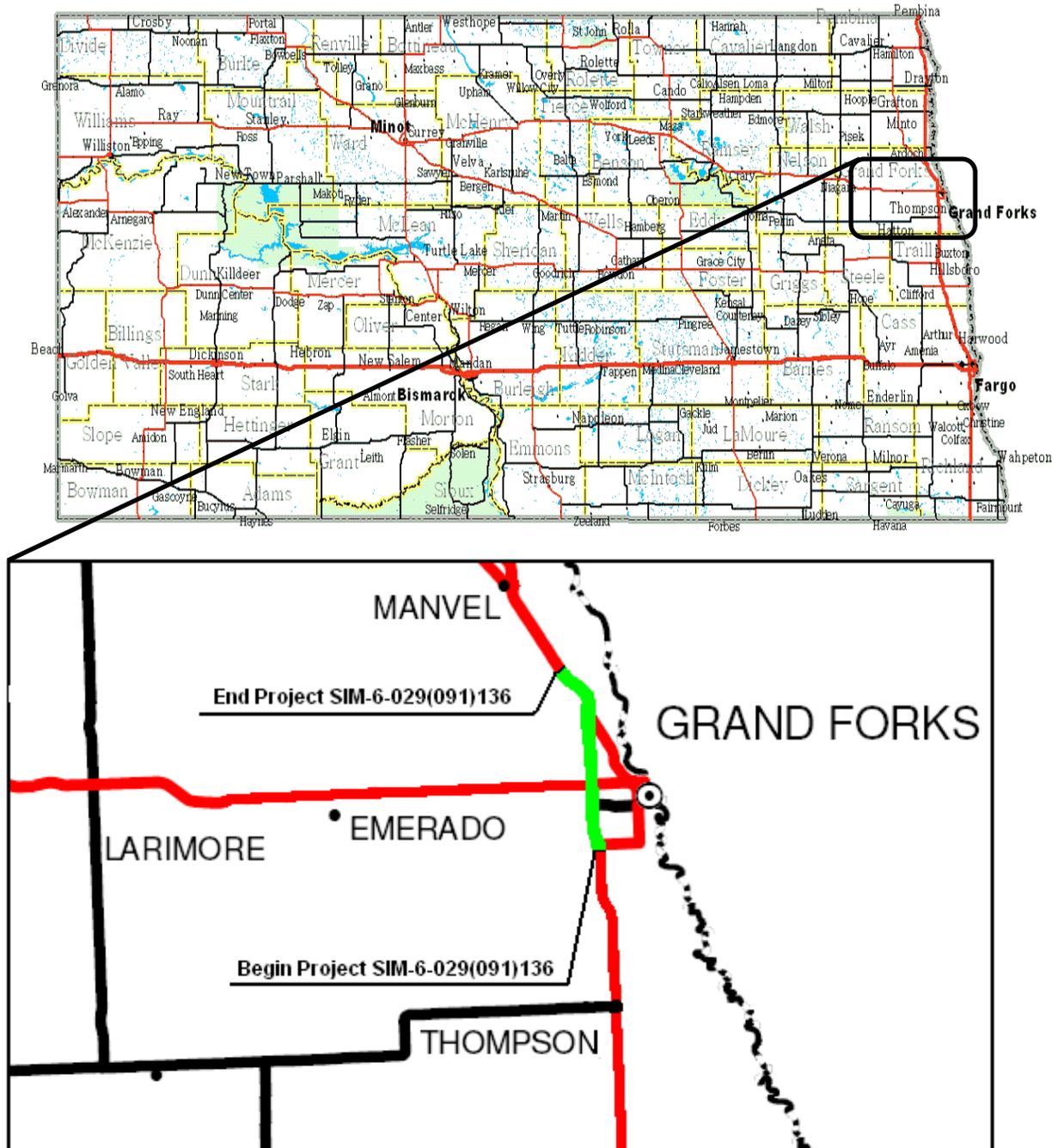


Figure 1 – Project Location

Design

This project consists of concrete pavement repair (CPR) of approximately 20 miles of I-29. The project limits are from RP 136.888 to RP 147.226 in the NB lanes and from RP 136.766 to RP 147.226 in the SB lanes.

The yellow and white edge-lines were divided into segments and constructed according to the following table.

| Pavement Marking Layout | | | | | |
|-------------------------|--|--------------------------|----------------------------|---|---------------------|
| Segment | Location | Length (feet) | Type | Material | Groove Depth (mils) |
| 1A | RP 136.888 to RP 138 (NB) RP 136.766 to RP 138 (SB) | 5,872 (NB) 6,516 (SB) | White and Yellow Edge-line | Water Based Paint with Standard Glass Beads | 40 ±5 |
| 1B | RP 138 to RP 140 (NB&SB) | 10,560 | White and Yellow Edge-line | Water Based Paint with 3M AW Elements | 40 ±5 |
| 2A | RP 140 to RP 142 (NB&SB) | 10,560 | White and Yellow Edge-line | Epoxy with Standard Glass Beads | 40 ±5 |
| 2B | RP 142 to RP 144 (NB&SB) | 10,560 | White and Yellow Edge-line | Epoxy with 3M AW Elements | 40 ±5 |
| 3A | RP 144 to RP 146 (NB&SB) | 10,560 | White and Yellow Edge-line | Epoxy with Standard Glass Beads | N/A |
| 3B | RP 146 to RP 147.226 (NB&SB) | 6,474 | White and Yellow Edge-line | Epoxy with 3M AW Elements | N/A |

Table 1 – Pavement Marking Layout

Grooving equipment and tolerances met the requirements of NDDOT Standard Specification 762.03 B & 762.04 B with a modified groove depth of 40 +/- 5 mils. The groove depth was selected based on recommendations from 3M for the installation of their AW Elements. To have consistent sections for evaluation, the same groove depth was selected for all of the grooved materials.

Construction Evaluation

The striping portion of SIM-6-029(091)136 was completed on October 21, 2011 by Swanston Equipment Co. A 3M representative was onsite to ensure proper application of the AW markings. A truck-mounted Data Logging System (DLS) captured the details of pavement marking application. The DLS verified that proper temperature, wind speed, and application speed were within the requirements of the NDDOT Specifications. A summary of the application rates collected by the DLS are included in Table 2.

| Pavement Marking Application Rates | | | | | | | | | | | | |
|---|--|--------|-------------|--------|--|--------|-------------|--------|-----------------------|--------|-------------|--------|
| Material | Grooved Water Based Paint (40 +/- 5 mil Groove) | | | | Grooved Epoxy (40 +/- 5 mil Groove) | | | | Surface Applied Epoxy | | | |
| | Standard Glass | | AW Elements | | Standard Glass | | AW Elements | | Standard Glass | | AW Elements | |
| Color | White | Yellow | White | Yellow | White | Yellow | White | Yellow | White | Yellow | White | Yellow |
| Wet Mil Thickness | 16 | 16 | 26 | 26 | 20 | 19 | 21 | 20 | 20 | 19 | 21 | 20 |
| Glass Bead Application Rate (lbs/gal) | 6.2 | 6.2 | 4.6 | 4.4 | 37.8 | 21.9 | 31.2 | 31.5 | 37.8 | 21.9 | 31.2 | 31.5 |
| 3M AW Elements Application Rate (lbs/gal) | - | - | 2.1 | 2.1 | - | - | 4.9 | 5.1 | - | - | 4.9 | 5.1 |

Table 2 –Pavement Marking Application Rates

The specified wet mil thickness is 16 mils for standard water-based paint, 25 mils for AWP, and 20 mils for epoxy. The specified application rate of glass beads are 6lb/gal for water-based pavement markings and 25 lbs/gal for epoxy pavement markings. The DLS data also shows the double drop system associated with the application of AW Elements.

Prior to placement of any pavement marking materials, the entire project was diamond ground to remove faulting and improve the ride. This affected the surface (in relation to pavement markings) in two ways. First, the diamond grinding provides a surface texture on the road consisting of small ridges across the pavement. The depth and spacing of these ridges are specified in the NDDOT Standard Specifications. These ridges provide a good surface texture for liquid pavement marking adhesion. Second, the diamond grinding process necessitates multiple passes to grind the full width of the roadway. In some places (not all), a ridge was created in-between passes of the grinder. Photo 1 & 2 show some of the different ways the ridge can affect the pavement marking. In Photo 1, taken at the time of construction, the ridge is adjacent to the pavement marking. While in theory this is good for the survivability of pavement marking, it is problematic for a research control section because the marking will be uncharacteristically protected from snowplows. Photo 2 shows the same ridge but this time the pavement marking is placed directly on top of it. In this case, half of the line is protected and the other half is exposed to snowplows.



Photo 1: Ridge from two adjacent passes of the diamond grinder above the surface applied epoxy.



Photo 2: Surface applied epoxy placed on top of the ridge from two adjacent passes of the diamond grinder.

The thickness of the pavement marking (as a system) is also important. The epoxy was applied at 20 mils when paired with both standard glass beads and AW Elements. The standard water-based paint with standard glass beads was applied at 16 mils and the AWP with AW Elements was applied at 25 mils. The maximum size of the standard glass beads is approximately 25 mils, and the AW Elements average 50 mils. Assuming 50% embedment of the reflective media, the average thickness of the pavement marking system is approximately 32.5 mils for the epoxy with standard glass beads, and 45 mils for epoxy with AW elements, 28.5 mils for standard water-based paint with standard glass beads, and 50 mils for AWP with AW Elements. This leaves very little room for error and places the marking so close to the surface (and snowplows) that the effectiveness of the grooves may be marginalized.

Final Evaluation

This project was evaluated after construction and each spring for three years. The criteria for evaluating the markings are visual appearance and retroreflectivity. For the purposes of evaluation, the project will be considered as 3 different segments: surface applied epoxy, grooved epoxy, and grooved water-based paint. The evaluation considers two characteristics of the pavement marking, presence and retroreflectivity.

The current standard application of liquid markings is surface applied. Therefore, the surface applied epoxy is considered the control section for this project. Its performance is the best baseline by which the grooved epoxy and grooved water-based marking can be compared against.

Surface Applied Epoxy

After 3 winters, the visual appearance of the surface applied epoxy has a few general characteristics. Marking that was protected by the aforementioned ridges is, as expected still intact. However, the areas in which the ridges did not protect the marking are also still intact, albeit with some distresses. The visible distresses are distinctly from the snowplows, evidenced by damage/removal of the reflective media (both glass beads and 3M elements) and scarifying of the top few mils of the epoxy. In isolated locations, a few square inches of material have lost adhesion and have been completely removed; but only three or four of these locations have been identified. Photo 3 shows the most common type of distress observed (loss of reflective media and scarification of upper mils of epoxy). In Photo 3, the ridge between grinding passes is in the center of the marking with most of the distress occurring on top of the ridge.



Photo 3: Surface applied epoxy with standard glass beads after 3 winters.

Photo 4 is a magnified view of surface applied yellow epoxy with standard glass beads. The area in the center of the magnification shows that some of the glass is no longer present on the marking.

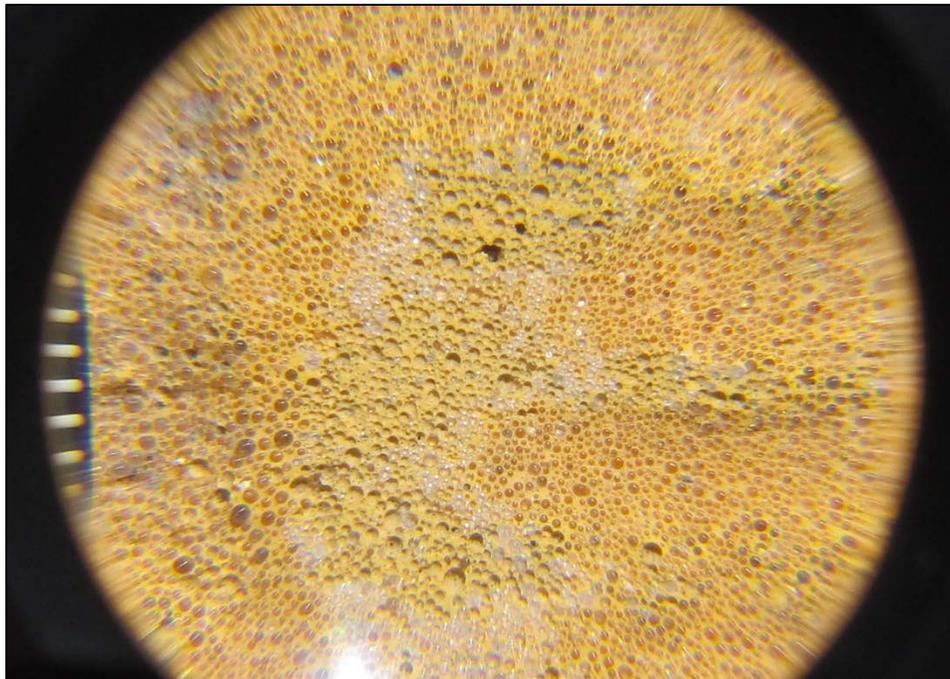


Photo 4: Magnified surface applied epoxy with standard glass beads after 3 winters.

Photo 5 is a magnified view of surface applied white epoxy with AW elements. The oval discolorations are AW elements that have been sheared by snowplows. Also, most of the glass beads are no longer present.

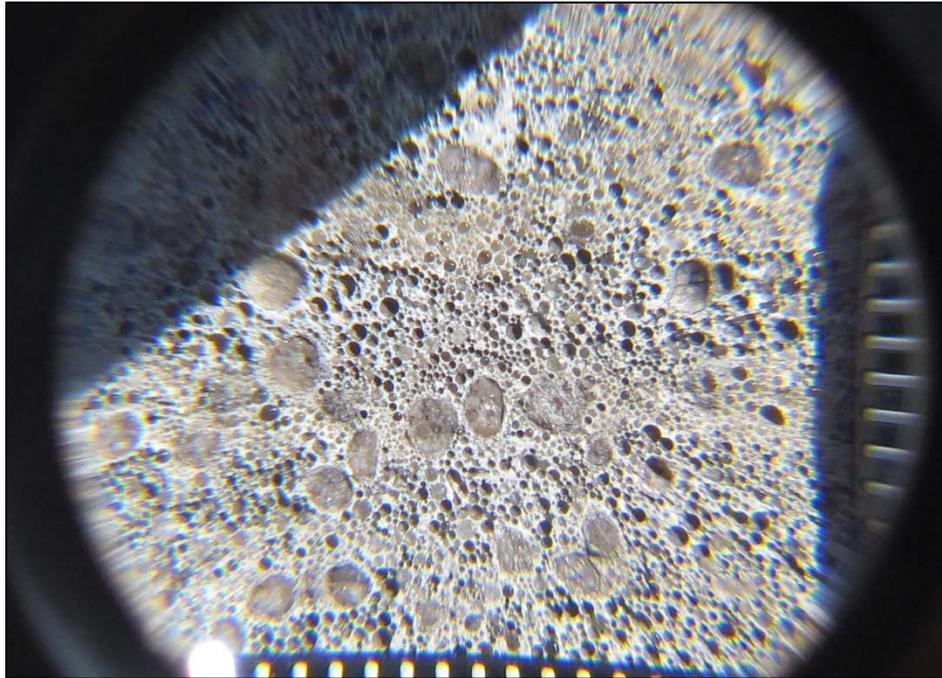


Photo 5: Magnified surface applied epoxy with AW Elements after 3 winters.

Grooved Epoxy

Photo 6 shows a grooved epoxy stripe with standard glass beads after 3 winters. This stripe shows no visual distress.



Photo 6: Grooved epoxy with standard glass after 3 winters.

Photo 7 is a magnified view of the stripe in Photo 6. The epoxy and glass are in-place and undamaged.



Photo 7: Magnified grooved epoxy with standard glass after 3 winters.

Photo 8 is a magnified photo of grooved epoxy with AW elements. The AW Elements are still all in place but the outer coating (which contains the AW Optics) is damaged and/or missing from some of the AW Elements.

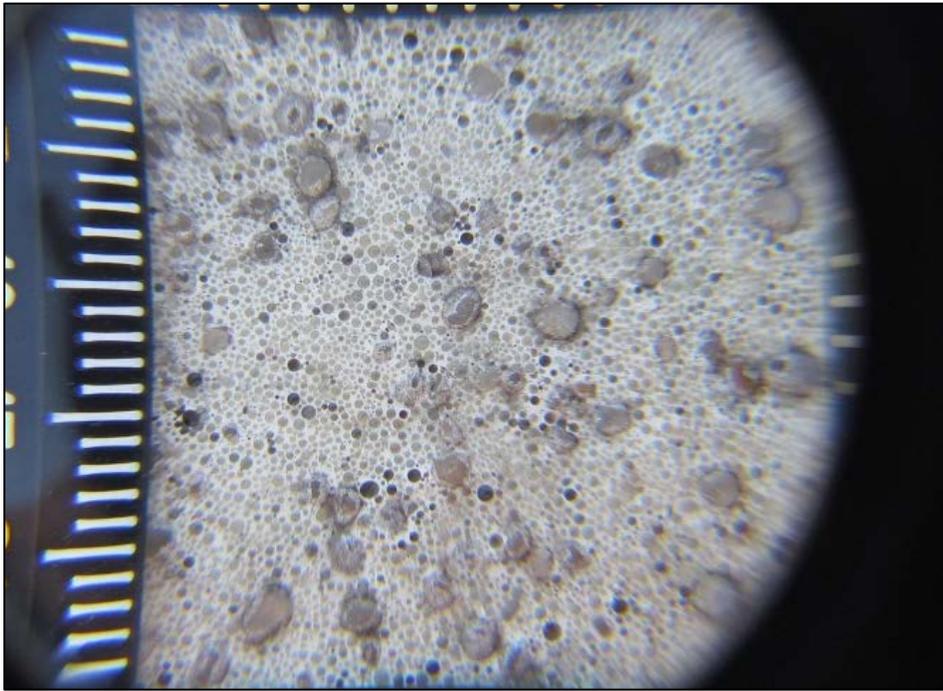


Photo 8: Magnified grooved epoxy with AW Elements after 3 winters.

Photo 9 is an epoxy stripe that was improperly positioned. About 1 inch of the stripe was placed outside of the groove. This photo shows the additional damage that line has sustained when placed outside of the groove.



Photo 9: Grooved epoxy with improper placement after 3 winters.

Grooved Water-based Paint

The groove depth for the grooved water-based pavement markings is the same (40 +/-5 mils) as for the grooved epoxy. Photo 10 shows a grooved standard water-based pavement marking with standard glass beads. Photo 11 shows grooved AWP with AW Elements. Both markings are experiencing some loss of material. The standard water-based paint is experiencing more loss than the AWP. The increased performance could either be attributed to the properties of the AWP or the increased thickness of the pavement marking. After 2 winters, the water-based pavement markings were restriped, and the evaluation of the water-based paint sections was concluded.

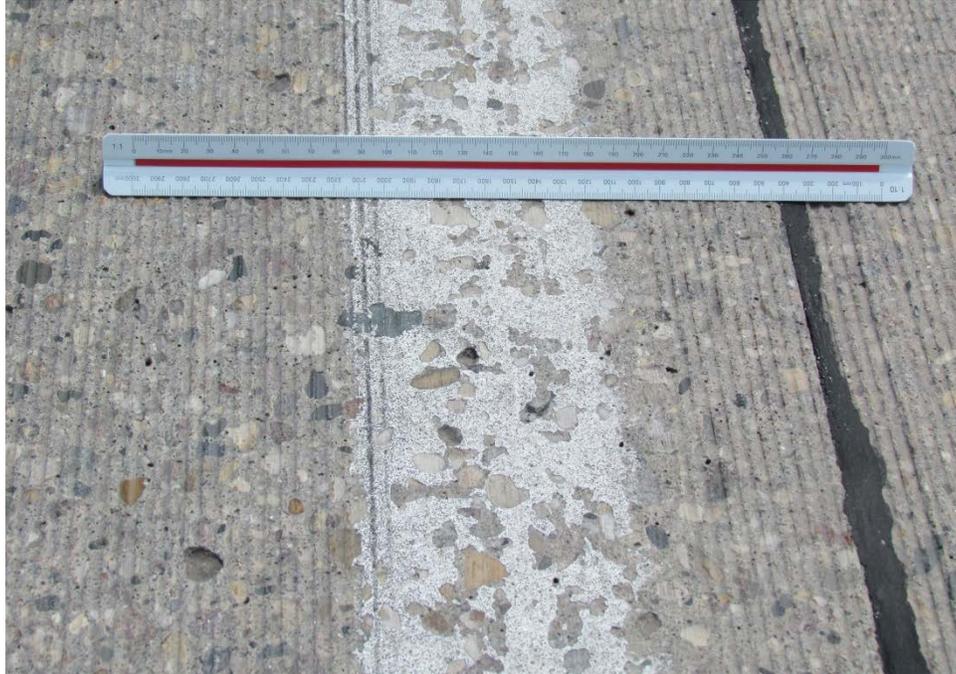


Photo 10: Grooved standard water-based paint with standard glass after 2 winters.



Photo 11: Grooved AWP with AW Elements after 2 winters.

Photo 12 shows grooved AWP with AW Elements. The type of paint loss observed occurred on both standard water-based paint and AWP. The pavement marking has less adhesion to the exposed rock faces than to the concrete paste.



Photo 12: Grooved AWP with AW Elements after 2 winters.

Additional photos of all marking types, colors, and locations are provided in the appendix.

Retroreflectivity

Retroreflectivity data was collected after construction and each spring for 3 years. Each line type has a northbound and a southbound segment. Each segment was two miles long. Retroreflectivity data was collected from the middle of each test segment. Ten readings were collected on each segment in a dry condition. Five readings were collected on each segment in a wet-recovery condition according to ASTM E 2177. The average retroreflectivity results (by reflective media type) are summarized in Table 3 and 4.

| Average Retroreflectivity with Standard Glass Beads | | | | | | | | | | | | |
|---|---------------------------------|-----|---------------|-----|---------------------------|-----|---------------------------------|-----|---------------|-----|---------------------------|-----|
| Date Tested | White Edge-line | | | | | | Yellow Edge-line | | | | | |
| | Surface Applied Epoxy (Control) | | Grooved Epoxy | | Grooved Water-based Paint | | Surface Applied Epoxy (Control) | | Grooved Epoxy | | Grooved Water-based Paint | |
| | Dry | Wet | Dry | Wet | Dry | Wet | Dry | Wet | Dry | Wet | Dry | Wet |
| Initial (Fall 2011) | 331 | 44 | 331 | 23 | 364 | 3 | 203 | 19 | 221 | 29 | 205 | 12 |
| Spring 2012 | 168 | 13 | 178 | 4 | 239 | 2 | 103 | 3 | 188 | 10 | 141 | 3 |
| Spring 2013 | 146 | 8 | 154 | 9 | 196 | 3 | 106 | 3 | 123 | 3 | 143 | 4 |
| Spring 2014 | 152 | 7 | 191 | 4 | * | * | 140 | 7 | 203 | 9 | * | * |

Table 3 – Average Retroreflectivity with Standard Glass Beads

*The water-based markings were restriped during the 2013 construction season.

The retroreflectivity with standard glass beads from Table 3 is compared as percent retained each year in the list below:

- **After One Winter Season**

White Edge-line

- Surface applied epoxy retained 51% of its dry retroreflectivity.
- Grooved epoxy retained 54% of its dry retroreflectivity.
- Grooved water-based paint retained 66% of its dry retroreflectivity.

Yellow Edge-line

- Surface applied epoxy retained 51% of its dry retroreflectivity.
- Grooved epoxy retained 85% of its dry retroreflectivity.
- Grooved water-based paint retained 69% of its dry retroreflectivity.

- **After 2 Winter Seasons**

White Edge-line

- Surface applied epoxy retained 44% of its dry retroreflectivity.
- Grooved epoxy retained 47% of its dry retroreflectivity.
- Grooved water-based paint retained 54% of its dry retroreflectivity.

Yellow Edge-line

- Surface applied epoxy retained 52% of its dry retroreflectivity.
- Grooved epoxy retained 56% of its dry retroreflectivity.
- Grooved water-based paint retained 70% of its dry retroreflectivity.

- **After 3 Winter Seasons (Water-based Paint Restriped)**

White Edge-line

- Surface applied epoxy retained 46% of its dry retroreflectivity.
- Grooved epoxy retained 58% of its dry retroreflectivity.

Yellow Edge-line

- Surface applied epoxy retained 69% of its dry retroreflectivity.
- Grooved epoxy retained 92% of its dry retroreflectivity.

| Average Retroreflectivity with AW Elements | | | | | | | | | | | | |
|--|---------------------------------|-----|---------------|-----|-------------|-----|---------------------------------|-----|---------------|-----|-------------|-----|
| Date Tested | White Edge-line | | | | | | Yellow Edge-line | | | | | |
| | Surface Applied Epoxy (Control) | | Grooved Epoxy | | Grooved AWP | | Surface Applied Epoxy (Control) | | Grooved Epoxy | | Grooved AWP | |
| | Dry | Wet | Dry | Wet | Dry | Wet | Dry | Wet | Dry | Wet | Dry | Wet |
| Initial (Fall 2011) | 573 | 212 | 600 | 78 | 544 | 190 | 429 | 261 | 390 | 171 | 208 | 59 |
| Spring 2012 | 230 | 28 | 331 | 8 | 205 | 25 | 221 | 37 | 297 | 40 | 123 | 22 |
| Spring 2013 | 195 | 25 | 211 | 11 | 128 | 6 | 193 | 29 | 272 | 55 | 70 | 7 |
| Spring 2014 | 173 | 11 | 170 | 4 | * | * | 216 | 12 | 278 | 16 | * | * |

Table 4 – Average Retroreflectivity with AW Elements

*The water-based markings were restriped during the 2013 construction season.

The retroreflectivity with AW Elements from Table 4 is compared as percent retained each year in the list below:

- **After One Winter Season**

White Edge-line

- Surface applied epoxy retained 40% of its dry and 13% of its wet retroreflectivity.
- Grooved epoxy retained 55% of its dry and 10% of its wet retroreflectivity.
- Grooved AWP retained 38% of its dry and 13% of its wet retroreflectivity.

Yellow Edge-line

- Surface applied epoxy retained 51% of its dry and 14% of its wet retroreflectivity.
- Grooved epoxy retained 76% of its dry and 23% of its wet retroreflectivity.
- Grooved AWP retained 59% of its dry and 37% of its wet retroreflectivity.

- **After 2 Winter Seasons**

- White Edge-line

- Surface applied epoxy retained 34% of its dry and 12% of its wet retroreflectivity.
 - Grooved epoxy retained 34% of its dry and 14% of its wet retroreflectivity.
 - Grooved AWP retained 24% of its dry and 3% of its wet retroreflectivity.

- Yellow Edge-line

- Surface applied epoxy retained 45% of its dry and 11% of its wet retroreflectivity.
 - Grooved epoxy retained 70% of its dry and 32% of its wet retroreflectivity.
 - Grooved AWP retained 34% of its dry and 12% of its wet retroreflectivity.

- **After 3 Winter Seasons (Water-based Paint Restriped)**

- White Edge-line

- Surface applied epoxy retained 30% of its dry and 5% of its wet retroreflectivity.
 - Grooved epoxy retained 28% of its dry and 5% of its wet retroreflectivity.

- Yellow Edge-line

- Surface applied epoxy retained 50% of its dry and 5% of its wet retroreflectivity.
 - Grooved epoxy retained 71% of its dry and 9% of its wet retroreflectivity.

Cost

The bid items related to pavement marking for this project are in Table 5 below. Typically, the cost of a groove is included in the cost of striping for a grooved pavement marking. However, 'PAVEMENT MARKING GROOVE' was a separate bid item for this project.

| Bid Item | PAVEMENT MARKING GROOVE | EPOXY PVMT MK 4IN LINE | EPOXY PVMT MK 4 IN LINE - WET REFLECTIVE | PVMT MK PAINTED 4 IN LINE | PVMT MK PAINTED 4 IN LINE - WET REFLECTIVE |
|---------------|-------------------------|------------------------|--|---------------------------|--|
| Quantity (LF) | 151,496 | 84,480 | 68,136 | 34,478 | 34,479 |
| Price/LF | \$0.50 | \$0.34 | \$0.54 | \$0.13 | \$0.38 |
| Total | \$75,748.00 | \$28,723.20 | \$36,793.44 | \$4,482.14 | \$13,102.02 |

Table 5 – Pavement Marking related Bid Items.

Summary

The objective of this project was to compare the performance of surface applied pavement markings and grooved pavement markings using water based paint and epoxy, paired with standard glass beads and 3M AW Elements. The grooved depth suggested by the manufacturer of the AW Elements was 40 +/- 5 mils. The test segments were constructed on PCC pavement on I-29 near Grand Forks, ND after CPR work. After the CPR work was complete, the entire surface was ground with a diamond grinder to improve ride.

The two evaluation criteria were visual condition of the marking material and retroreflectivity. The visual condition and retroreflectivity may have been affected in unpredictable ways for the following reasons:

- Surface texture from the diamond grinding provided a good surface for adhesion of surface applied pavement marking
- Multiple passes of the diamond grinder left a ridge on the surface that may have protected surface applied markings from the effects of snowplows
- The 40+/- 5 mil groove may not have been of sufficient depth to fully protect the pavement marking
 - New standards from the manufacturer of the AW Elements recommend a groove depth of 60 to 80 mils.

The pavement markings exhibited the following general characteristics:

- The white and yellow grooved water-based paint and epoxy, both with standard glass beads, had higher dry retroreflectivity than the surface applied epoxy with standard glass after two winters.
- The white and yellow grooved epoxy with standard glass beads, had higher dry retroreflectivity than the surface applied epoxy with standard glass after three winters.
- The white and yellow grooved AWP with AW elements had less dry retroreflectivity than the surface applied epoxy with AW elements after 2 winters.

- The reflective media is in better condition in the grooved epoxy sections than the surface applied epoxy sections
- Grooved white epoxy with AW elements had nearly equal dry retroreflectivity as surface applied white epoxy with AW after three winters.
- Grooved yellow epoxy with AW elements had higher retroreflectivity than the surface applied yellow epoxy with AW elements after three years.

Additional observations from this research project:

- Surface texture promotes increased adhesion, and possibly some protection of the pavement marking.
- The surface texture of the bottom of the groove may be too smooth for the adhesion of water-based paint.
- Depth of the groove is an important design consideration.
- Texture of the bottom of the groove is also an important design consideration.
- Position of the pavement marking in the groove is critical.
- Increased thickness of water-based paint in a groove may improve durability.
- Build-up of dirt in the groove was not observed.

Appendix A – Photos - Construction (Fall 2011)

Segment 1A - Grooved Paint with Standard Glass Beads



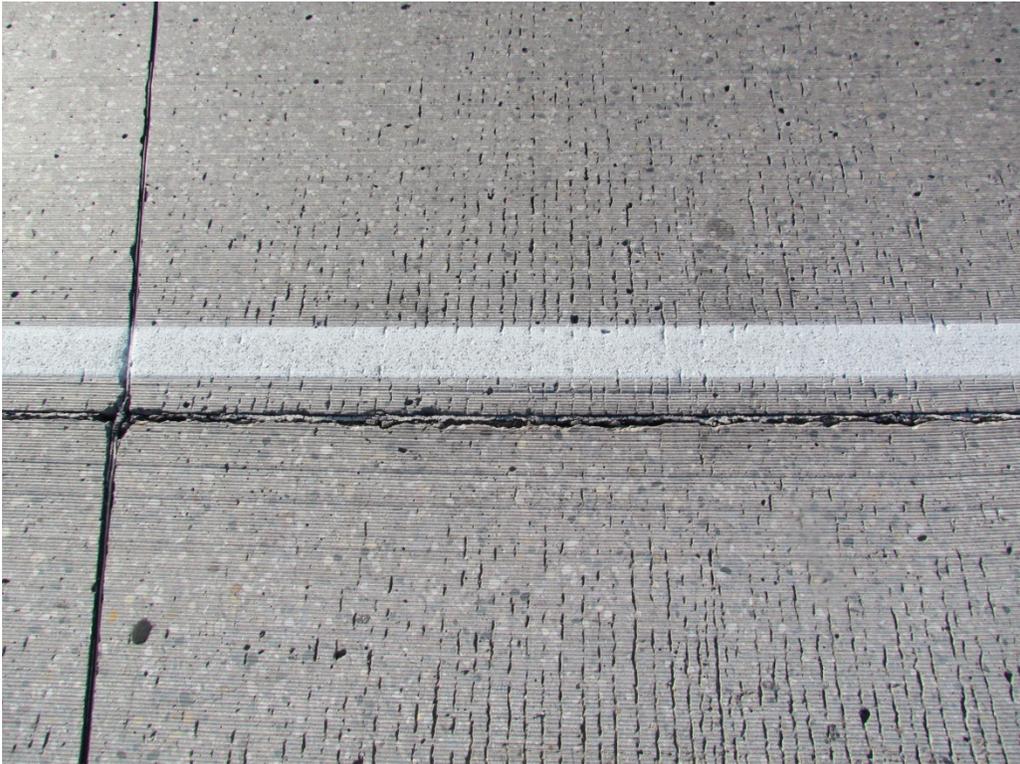
Segment 1B - Grooved Paint with 3M AW Elements



Segment 2A - Grooved Epoxy with Standard Glass Beads



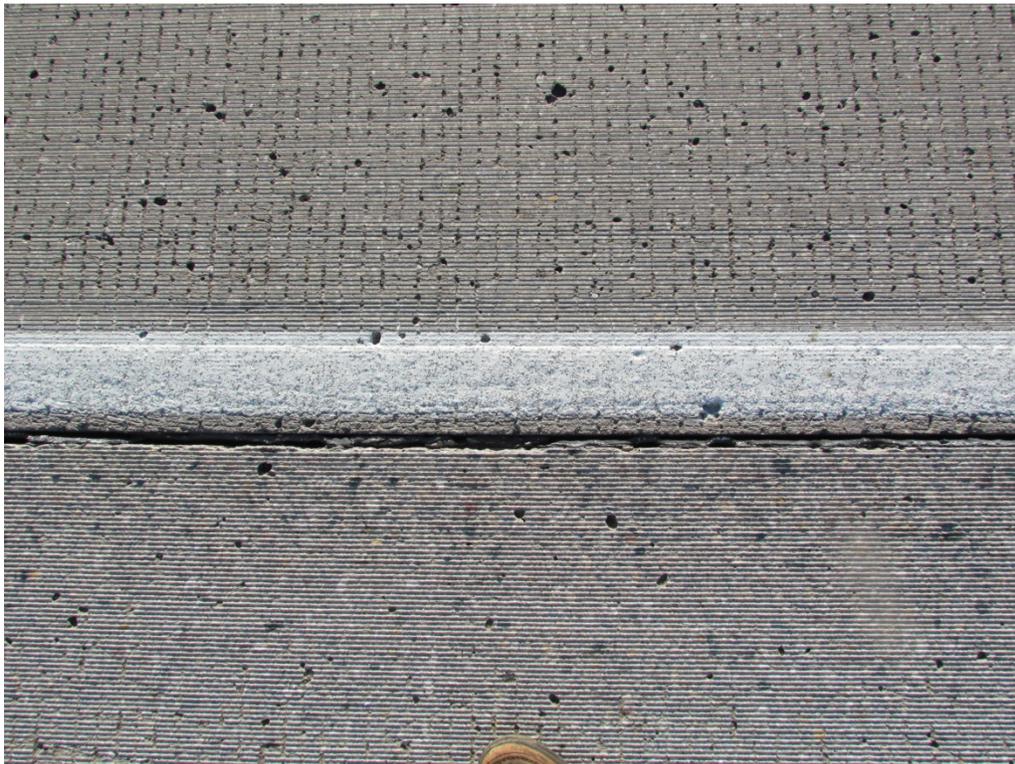
Segment 2B - Grooved Epoxy with 3M AW Elements



Segment 3A - Surface applied Epoxy with Standard Glass Beads



Segment 3B - Surface applied Epoxy with 3M AW Elements



Appendix B – Photos - After One Winter Season

Segment 1A – North Bound (NB) White Grooved Paint with Standard Glass Beads



Segment 1B - NB White Grooved Paint with 3M AW Elements



Segment 2A - NB White Grooved Epoxy with Standard Glass Beads



Segment 2B - NB White Grooved Epoxy with 3M AW Elements



Segment 3A - NB White Surface applied Epoxy with Standard Glass Beads



Segment 3B - NB White Surface applied Epoxy with 3M AW Elements



Segment 1A – South Bound (SB) White Grooved Paint with Standard Glass Beads



Segment 1B - SB White Grooved Paint with 3M AW Elements



Segment 2A - SB White Grooved Epoxy with Standard Glass Beads



Segment 2B - SB White Grooved Epoxy with 3M AW Elements



Segment 3A - SB White Surface applied Epoxy with Standard Glass Beads



Segment 3B - SB White Surface applied Epoxy with 3M AW Elements



Segment 1A - NB Yellow Grooved Paint with Standard Glass Beads



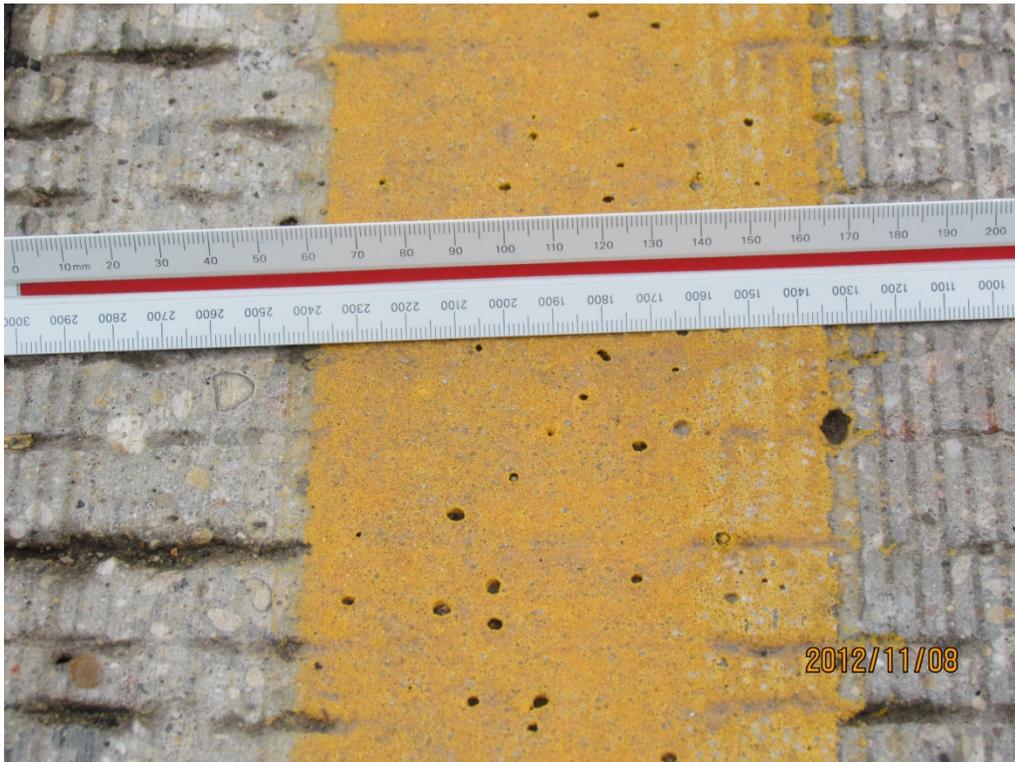
Segment 1B - NB Yellow Grooved Paint with 3M AW Elements



Segment 2A - NB Yellow Grooved Epoxy with Standard Glass Beads



Segment 2B - NB Yellow Grooved Epoxy with 3M AW Elements



Segment 3A - NB Yellow Surface applied Epoxy with Standard Glass Beads



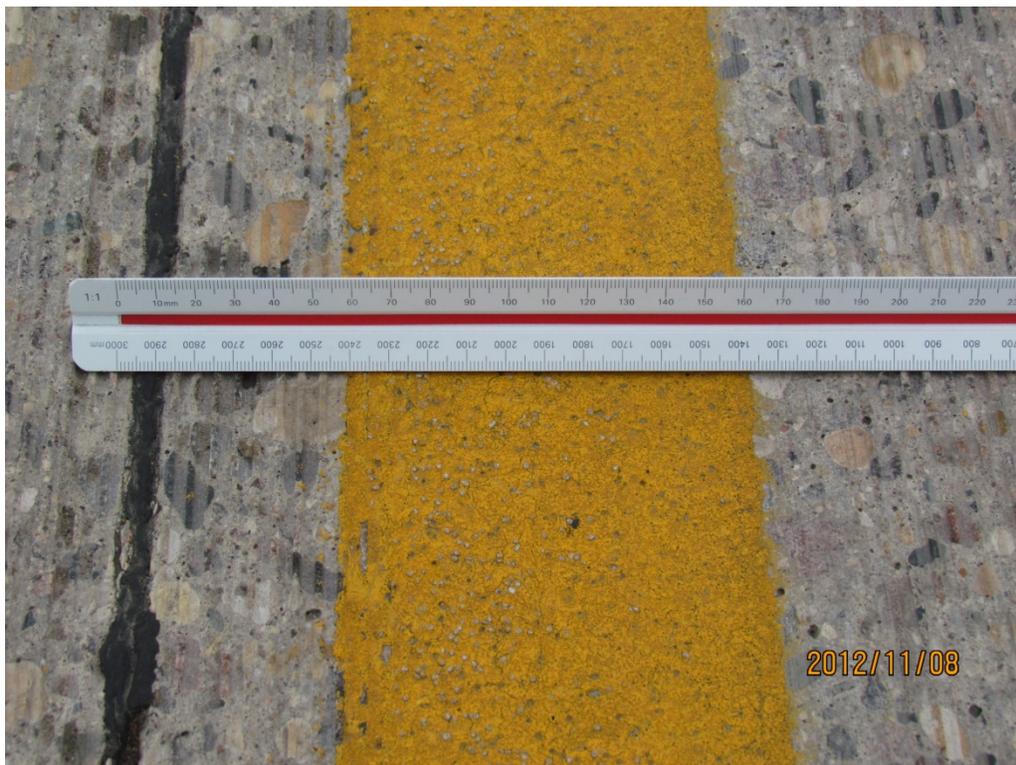
Segment 3B - NB Yellow Surface applied Epoxy with 3M AW Elements



Segment 1A - SB Yellow Grooved Paint with Standard Glass Beads



Segment 1B - SB Yellow Grooved Paint with 3M AW Elements



Segment 2A - SB Yellow Grooved Epoxy with Standard Glass Beads



Segment 2B - SB Yellow Grooved Epoxy with 3M AW Elements



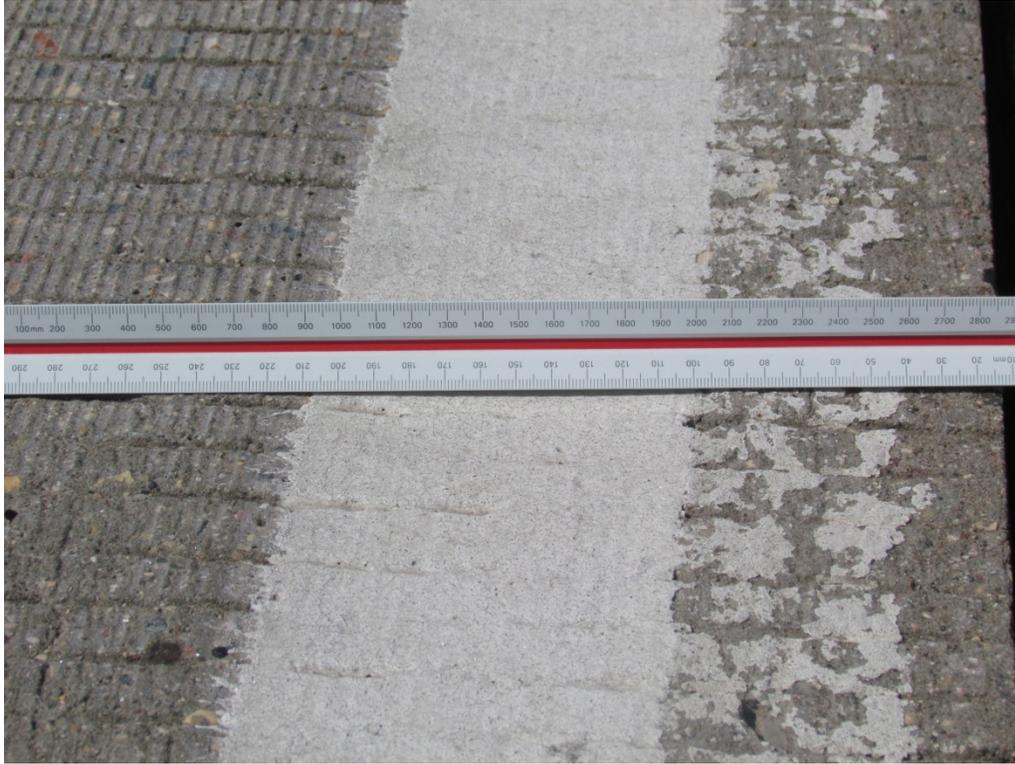
Segment 3A - SB Yellow Surface applied Epoxy with Standard Glass Beads



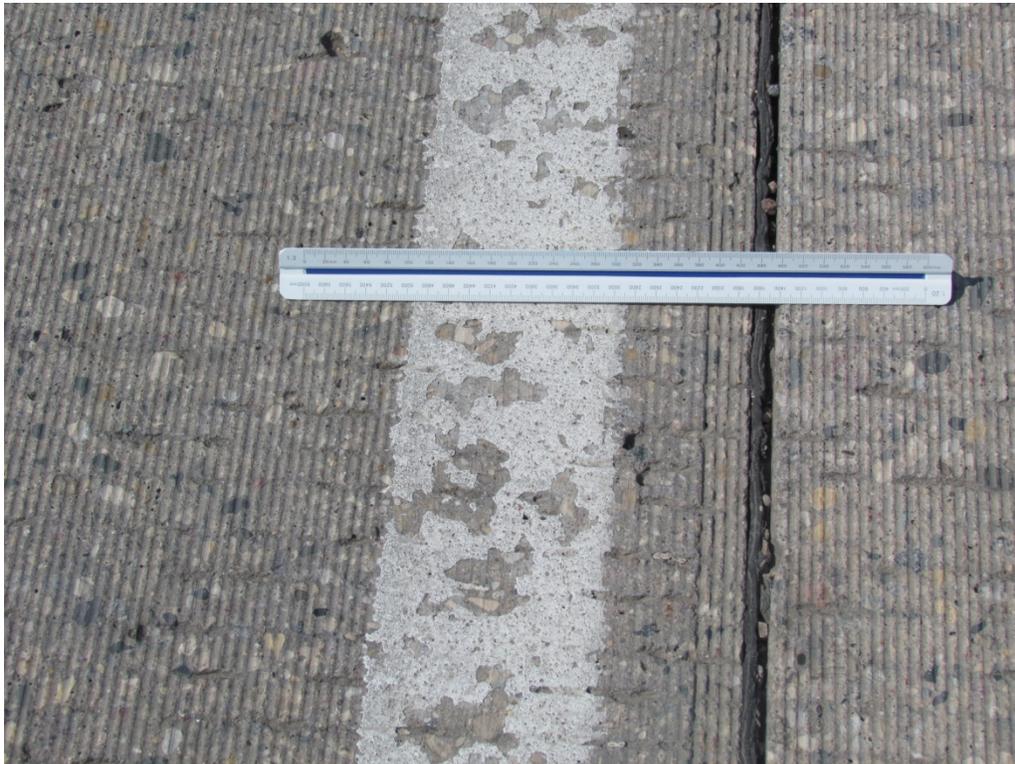
Segment 3B - SB Yellow Surface applied Epoxy with 3M AW Elements



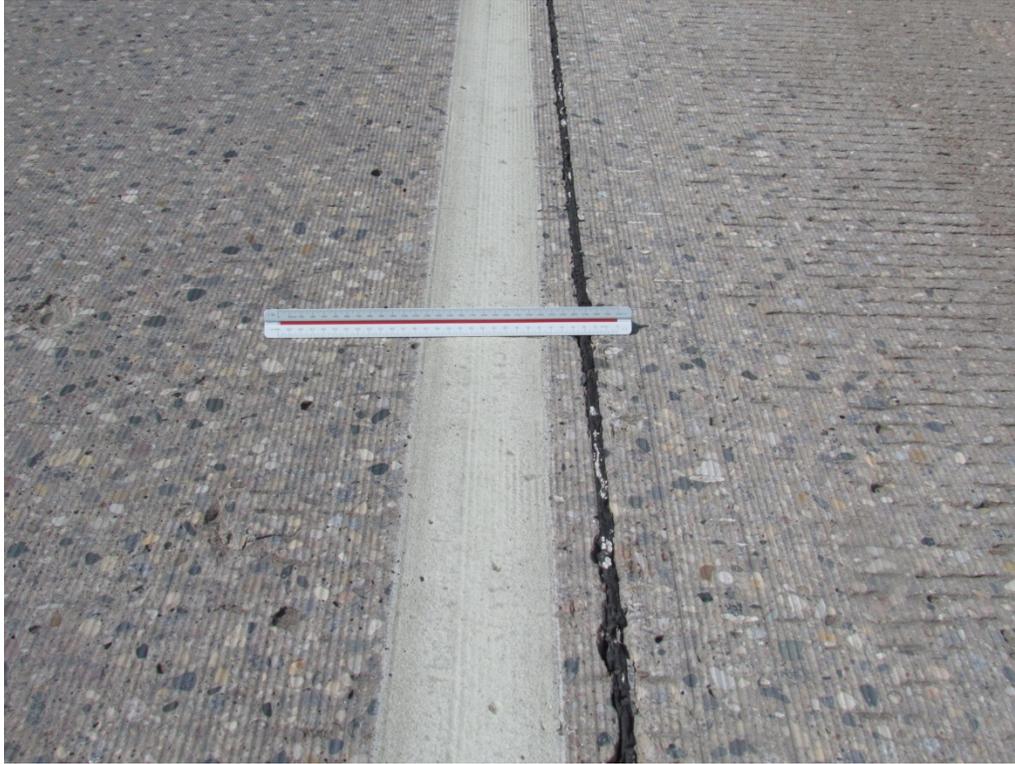
Appendix C – Photos – After 2 Winter Seasons



Segment 1A - NB White Grooved Paint with Standard Glass Beads – RP 137



Segment 1B - NB White Grooved Paint with 3M AW Elements – RP 139



Segment 2A - NB White Grooved Epoxy with Standard Glass Beads – RP 141



Segment 2B - NB White Grooved Epoxy with 3M AW Elements – RP 143



Segment 3A – NB White Surface Applied Epoxy with Standard Glass Beads – RP 145



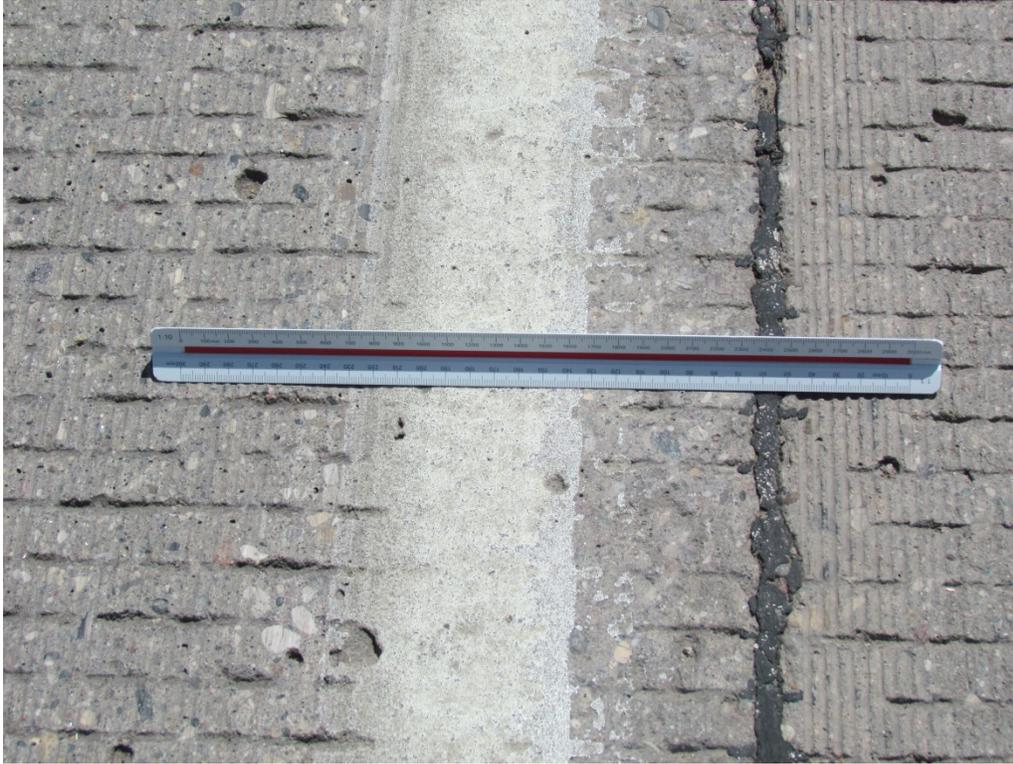
Segment 3B – NB White Surface applied Epoxy with 3M AW Elements – RP 147



Segment 1A - SB White Grooved Paint with Standard Glass Beads – RP 137



Segment 1B - SB White Grooved Paint with 3M AW Elements – RP 139



Segment 2A - SB White Grooved Epoxy with Standard Glass Beads – RP 141



Segment 2B - SB White Grooved Epoxy with 3M AW Elements – RP 143



Segment 3A - SB White Surface applied Epoxy with Standard Glass Beads – RP 145



Segment 3B - SB White Surface applied Epoxy with 3M AW Elements – RP 147



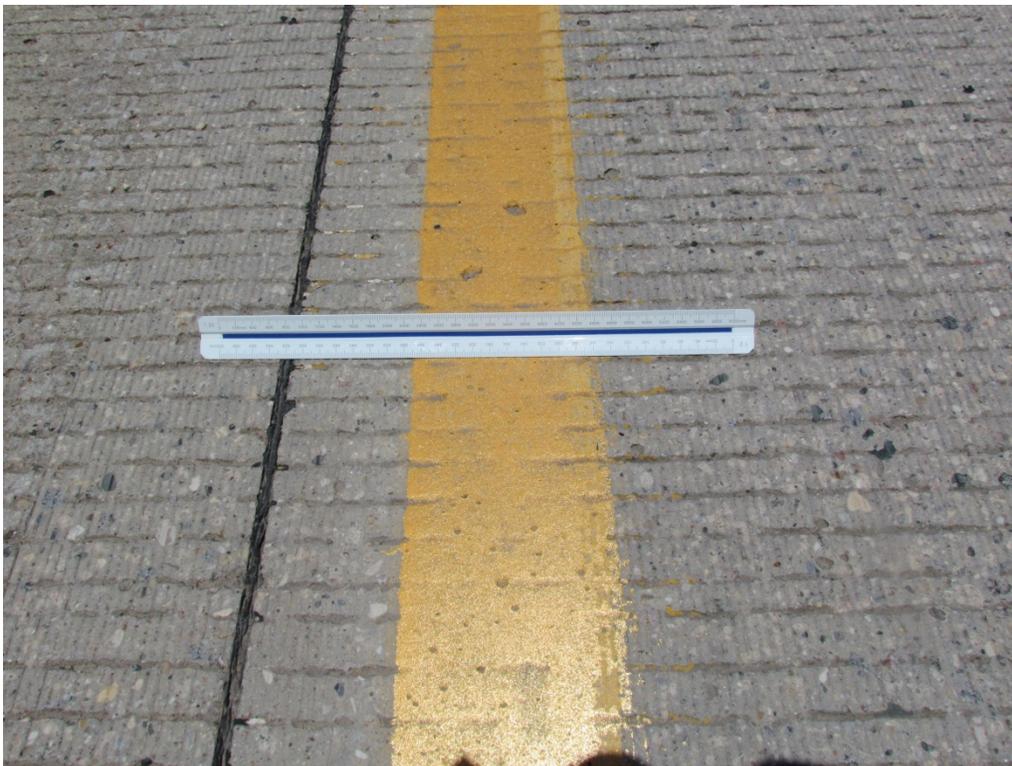
Segment 1A - NB Yellow Grooved Paint with Standard Glass Beads – RP 137



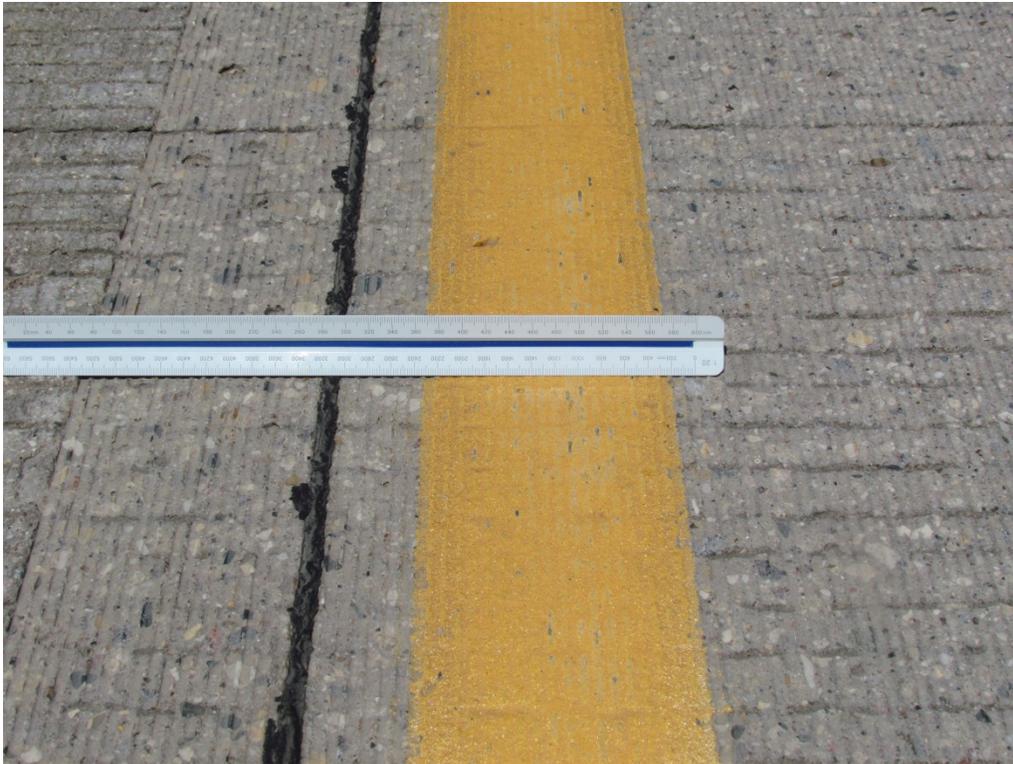
Segment 1B - NB Yellow Grooved Paint with 3M AW Elements – RP 139



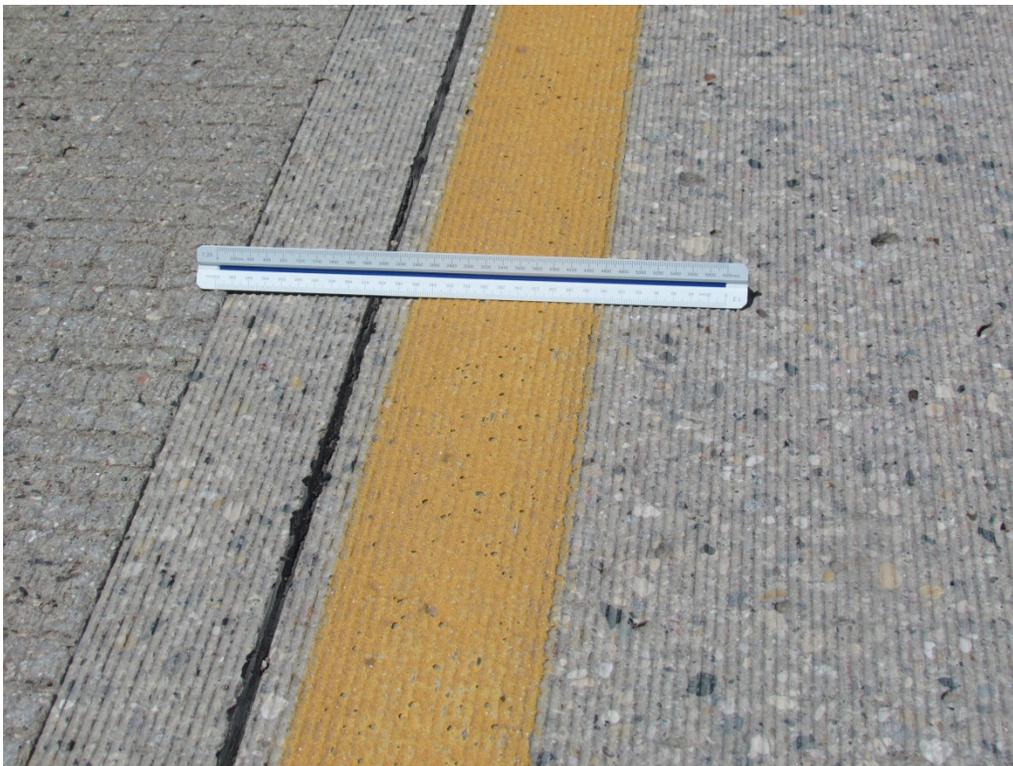
Segment 2A - NB Yellow Grooved Epoxy with Standard Glass Beads – RP 141



Segment 2B - NB Yellow Grooved Epoxy with 3M AW Elements – RP 143



Segment 3A - NB Yellow Surface applied Epoxy with Standard Glass Beads – RP 145



Segment 3B - NB Yellow Surface applied Epoxy with 3M AW Elements – RP 147



Segment 1A - SB Yellow Grooved Paint with Standard Glass Beads – RP 137



Segment 1B - SB Yellow Grooved Paint with 3M AW Elements – RP 139



Segment 2A - SB Yellow Grooved Epoxy with Standard Glass Beads – RP 141



Segment 2B - SB Yellow Grooved Epoxy with 3M AW Elements – RP 143



Segment 3A - SB Yellow Surface applied Epoxy with Standard Glass Beads – RP 145



Segment 3B - SB Yellow Surface applied Epoxy with 3M AW Elements – RP 147

Appendix D – Photos – After 3 Winter Seasons



Segment 2A - NB White Grooved Epoxy with Standard Glass Beads – RP 141



Segment 2B - NB White Grooved Epoxy with 3M AW Elements – RP 143



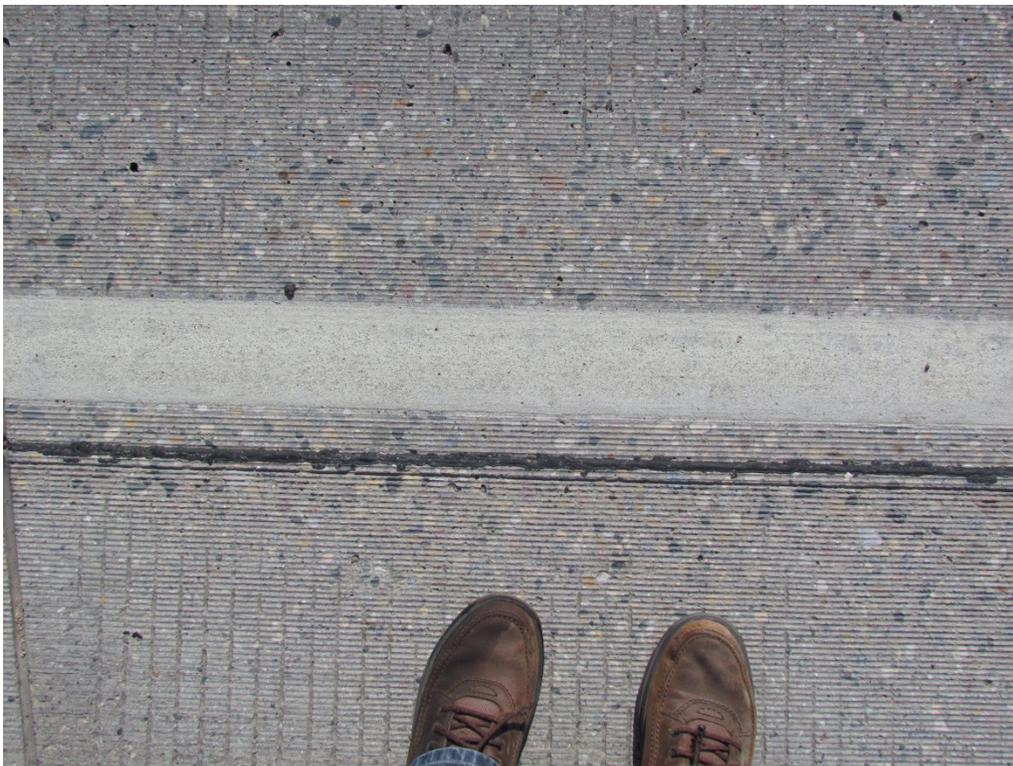
Segment 3A - NB White Surface Applied Epoxy with Standard Glass Beads – RP 145



Segment 3B - NB White Surface applied Epoxy with 3M AW Elements – RP 147



Segment 2A - SB White Grooved Epoxy with Standard Glass Beads – RP 141



Segment 2B - SB White Grooved Epoxy with 3M AW Elements – RP 143



Segment 3A - SB White Surface applied Epoxy with Standard Glass Beads – RP 145



Segment 3B - SB White Surface applied Epoxy with 3M AW Elements – RP 147



Segment 2A - NB Yellow Grooved Epoxy with Standard Glass Beads – RP 141



Segment 2B - NB Yellow Grooved Epoxy with 3M AW Elements – RP 143



Segment 3A - NB Yellow Surface applied Epoxy with Standard Glass Beads – RP 145



Segment 3B - NB Yellow Surface applied Epoxy with 3M AW Elements – RP 147



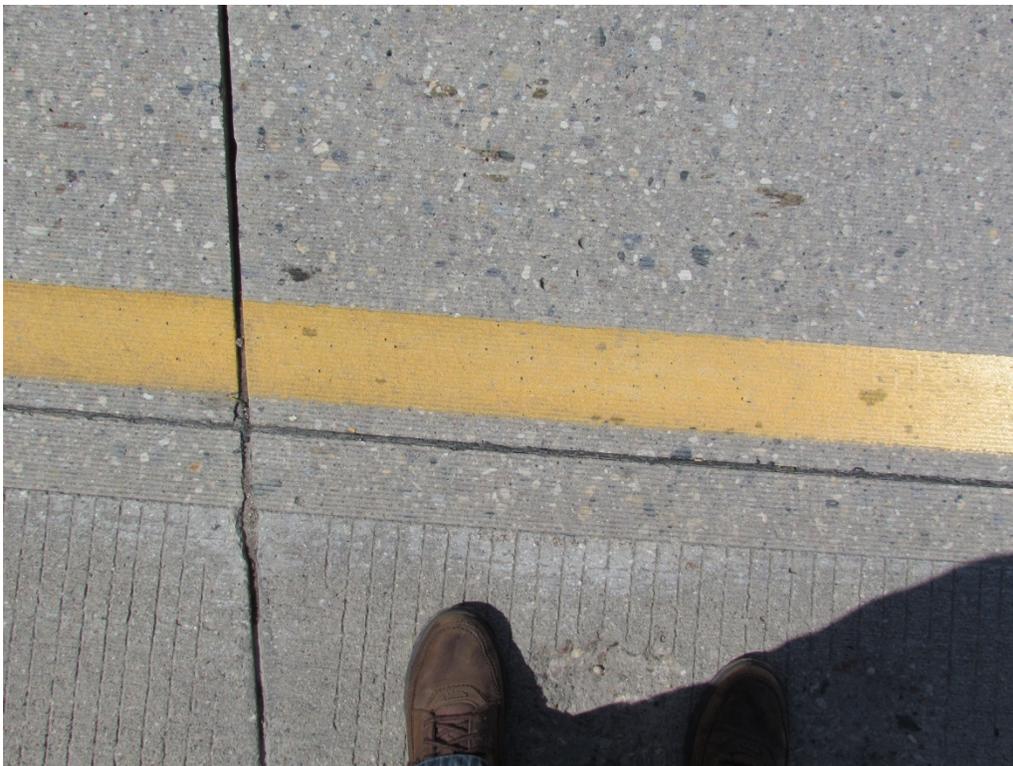
Segment 2A - SB Yellow Grooved Epoxy with Standard Glass Beads – RP 141



Segment 2B - SB Yellow Grooved Epoxy with 3M AW Elements – RP 143



Segment 3A - SB Yellow Surface applied Epoxy with Standard Glass Beads – RP 145



Segment 3B - SB Yellow Surface applied Epoxy with 3M AW Elements – RP 147