

**NORTH DAKOTA  
DEPARTMENT OF TRANSPORTATION**

**MATERIALS AND RESEARCH  
DIVISION**

Experimental Study ND 2010-01

**Evaluation of Wet-Reflective Elements for  
Pavement Markings**

**Evaluation 2**

IM-6-029(075)129 & SNH-6-002(079)337

January 10, 2013

Prepared by

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Written by  
Matthew M. Luger



## **Disclaimer**

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EXPERIMENTAL PROJECT REPORT

|                                     |   |                              |               |                                |                                     |                                       |   |                                       |        |   |       |
|-------------------------------------|---|------------------------------|---------------|--------------------------------|-------------------------------------|---------------------------------------|---|---------------------------------------|--------|---|-------|
| <b>EXPERIMENTAL PROJECT</b>         | EXPERIMENTAL PROJECT NO.  |                              |               |                                | CONSTRUCTION PROJ NO                |                                       |   | LOCATION                              |        |   |       |
|                                     | 1   | STATE<br>ND                  | Y EAR<br>2010 | NUMBER<br>- 01                 | SURF                                | IM-6-029(075)129<br>SNH-6-002(079)337 |   | I-29/US 2 Grand Forks<br>County<br>28 |        |   |       |
|                                     | EVALUATION FUNDING  |                              |               |                                |                                     |                                       | NEEP NO.  | PROPRIETARY FEATURE?                  |        |   |       |
|                                     | 48  | 1                            | HP&R          |                                | 3                                   | DEMONSTRATION                         |   | <input type="checkbox"/>              | X Yes  |   |       |
|                                     | 2   | X                            | CONSTRUCTION  |                                | 4                                   | IMPLEMENTATION                        |   | 49                                    | 51 No  |   |       |
| <b>SHORT TITLE</b>                  | TITLE 52 Evaluation of Wet-Reflective Elements for Pavement Markings      |                              |               |                                |                                     |                                       |   |                                       |        |   |       |
| <b>THIS FORM</b>                    | DATE<br>140   | MO.<br>February              | YR.<br>2013   | REPORTING                      |                                     |                                       |   |                                       |        |   |       |
|                                     |   | --                           |               | 1                              | INITIAL                             |                                       | 2   | X                                     | ANNUAL | 3 | FINAL |
| <b>KEY WORDS</b>                    | KEY WORD 1  |                              |               |                                | KEY WORD 2                          |                                       |   |                                       |        |   |       |
|                                     | 145 Wet-Reflective Elements   |                              |               |                                | 167 Pavement Marking                |                                       |   |                                       |        |   |       |
|                                     | KEY WORD 3  |                              |               |                                | KEY WORD 4                          |                                       |   |                                       |        |   |       |
|                                     | 189   |                              |               |                                | 211                                 |                                       |   |                                       |        |   |       |
|                                     | UNIQUE WORD   |                              |               |                                | PROPRIETARY FEATURE NAME            |                                       |   |                                       |        |   |       |
|                                     | 233   |                              |               |                                | 255 3M All Weather Pavement Marking |                                       |   |                                       |        |   |       |
| <b>CHRONOLOGY</b>                   | Date Work Plan<br>Approved  | Date Feature<br>Constructed: |               | Evaluation<br>Scheduled Until: |                                     | Evaluation<br>Extended Until:         |   | Date Evaluation<br>Terminated:        |        |   |       |
|                                     | 277 January 2010  | 281 Fall 2010                |               | 285 Fall 2013                  |                                     | 289                                   |   | 293                                   |        |   |       |
| <b>QUANTITY AND COST</b>            | QUANTITY OF UNITS<br>(ROUNDED TO WHOLE NUMBERS)                           |                              |               | UNITS                          |                                     |                                       | UNIT COST ( <i>Dollars, Cents</i> )                     |                                       |        |   |       |
|                                     | Water-Borne Wet Refl. US 2 169,417  |                              |               |                                |                                     |                                       | \$0.44  |                                       |        |   |       |
|                                     | Water-Borne Control US 2  |                              |               |                                |                                     |                                       | \$0.09  |                                       |        |   |       |
|                                     | Water-Borne Wet Refl. I-29 85,952   |                              |               | 1 X LIN. FT                    |                                     |                                       | 5 TON   |                                       |        |   |       |
|                                     | Water-Borne Control I-29  |                              |               | 2 SY                           |                                     |                                       | 6 LBS   |                                       |        |   |       |
|                                     | Preformed Tape Wet Refl. I-29 9,833                                       |                              |               | 3 SY-IN                        |                                     |                                       | 7 EACH  |                                       |        |   |       |
|                                     | Preformed Tape Control I-29   |                              |               | 4 CY                           |                                     |                                       | 8 LUMP SUM  |                                       |        |   |       |
|                                     | 297   |                              |               | 305                            |                                     |                                       | 306   |                                       |        |   |       |
| <b>AVAILABLE EVALUATION REPORTS</b> | CONSTRUCTION  |                              |               | PERFORMANCE                    |                                     |                                       | FINAL   |                                       |        |   |       |
|                                     | 315   |                              |               | X                              |                                     |                                       |   |                                       |        |   |       |
| <b>EVALUATION</b>                   | 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                        |   |                                       |        |   |       |
| <b>APPLICATION</b>                  | 1 ADOPTED AS PRIMARY STD.   |                              |               | 4 PENDING                      |                                     |                                       | <i>(Explain in remarks if 3, 4, 5, or 6 is checked)</i> |                                       |        |   |       |
|                                     | 2 PERMITTED ALTERNATIVE   |                              |               | 5 REJECTED                     |                                     |                                       |   |                                       |        |   |       |
|                                     | 3 ADOPTED CONDITIONALLY   |                              |               | 6 NOT CONSTRUCTED              |                                     |                                       |   |                                       |        |   |       |
| <b>REMARKS</b>                      | 321<br>This project will continue to be evaluated for an additional year. |                              |               |                                |                                     |                                       |   |                                       |        |   |       |



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## **Definitions**

**Standard Paint** - Water-based 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 within its wet reflective pavement marking systems.

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

**3M Optics** - A material that provides wet-night retroreflectivity with 3M water-based materials (combination of 1.9 and 2.4 refractive index).

**3M Elements** - A material that consists of 3M optics bonded to a central core. Used to apply wet-night retroreflectivity to liquid markings (combination of 1.9 and 2.4 refractive index).

**Standard Preformed Patterned Tape (Standard Tape)** - preformed patterned tape conforming to section 880 of the North Dakota Standard Specifications (1.5 Refractive Index).

**3M All Weather Tape** - A preformed patterned tape manufactured by 3M with wet reflective properties (combination of 1.9 and 2.4 refractive index).



# Evaluation of Wet-Reflective Elements for Pavement Markings

## Purpose and Need

Water on the surface of pavement markings typically reduces the marking's retroreflectivity and may cause pavement markings to become nearly invisible during wet conditions at night. Water on the surface of pavement markings reflects light away from its source and does not allow the glass beads in the pavement marking to reflect light back toward its source. This condition is referred to as "wet-night" and the retroreflectivity during this condition is referred to as "wet-night retroreflectivity". To improve a marking's wet-night retroreflectivity, 3M Company has developed wet-reflective optics to provide retroreflectivity in both dry and wet pavement conditions. These elements can be applied to all types of pavement markings.

## Objective

The objective of this experimental project is to evaluate the performance of 3M Company's Wet Reflective Optics as part of their All Weather (AW) Pavement Marking Systems, on a roadway in North Dakota in wet and dry conditions. The project will be evaluated annually for three years or until the markings are replaced.

## Background<sup>1,2</sup>

Light is refracted, or bent, as it enters a new medium (such as traveling through air and entering a glass bead). The amount that the light is refracted is known as the refractive index. The most commonly used pavement marking beads have a refractive index of 1.5. The optimum refractive index for dry pavement marking beads is 1.9. However, in order to achieve a higher refractive index, the hardness of the bead must be increased. This can make the glass more brittle and subject to damage. Because of this, AASHTO requirements for glass beads for liquid pavement markings are to have a refractive index between 1.50 to 1.55. The current North Dakota specifications follow these AASHTO Guidelines.

Water also has a different refractive index (1.33) than air, and therefore a bead for pavement marking will need a different refractive index to retroreflect light when wet.

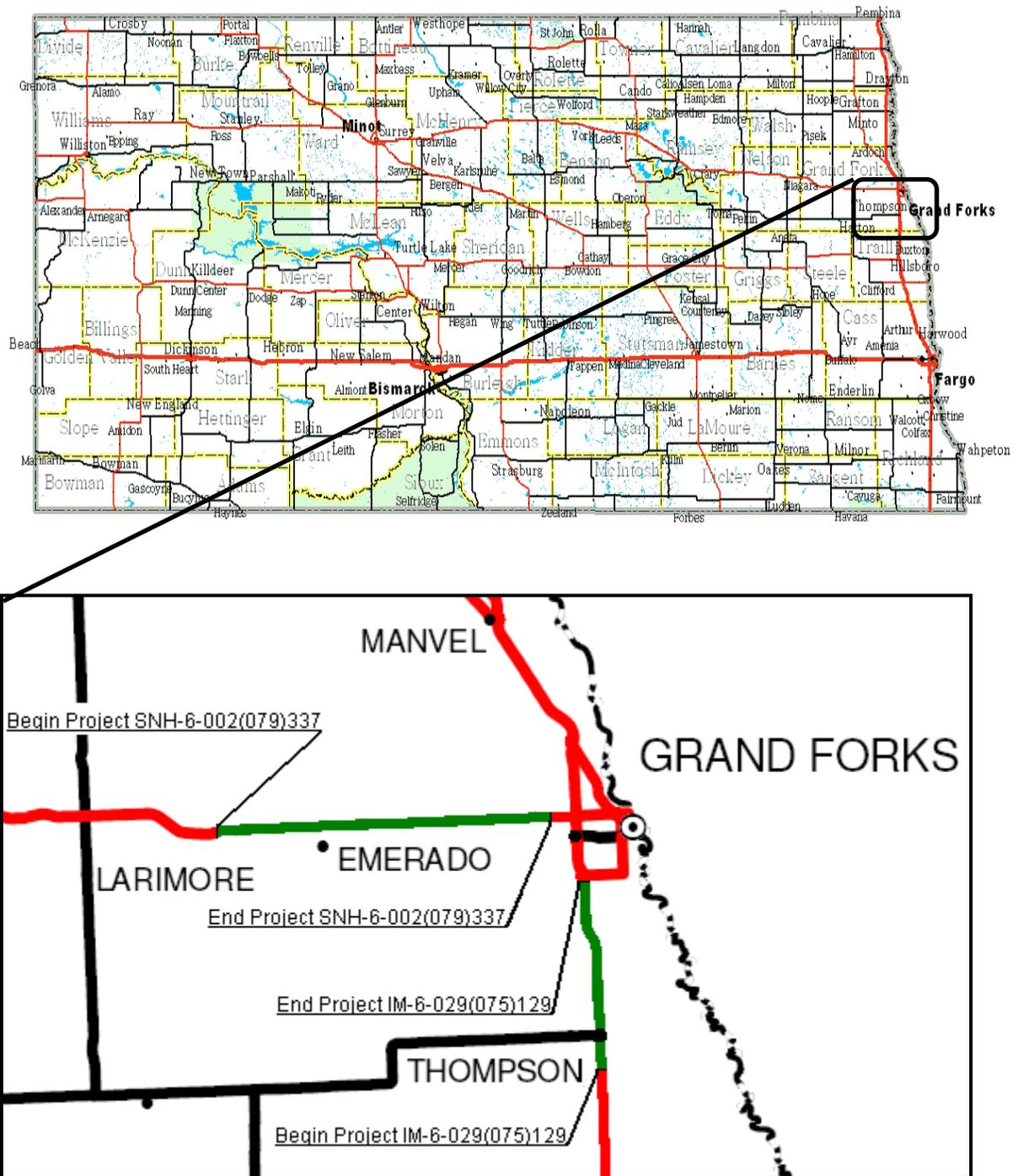
The optimum refractive index for a pavement marking bead designed to retroreflect when wet is between 2.4 and 2.5. These high refractive indices cause concern because of the previously mentioned durability issues. 3M Company has developed wet reflective optics that are microcrystalline ceramic material instead of glass to achieve a refractive index of 2.4 while maintaining durability.

<sup>1</sup> TRB No. 2015. 2007

<sup>2</sup> 3M Technology Bulletin

## Location

NDDOT plans to incorporate wet reflective optics as part of project IM-6-029(075)129 and SNH-6-002(079)337. These projects are located near Grand Forks on I-29 and US 2 respectively. This report will be split into two sections to discuss each project separately.



## **IM-6-029(075)129**

### **Design**

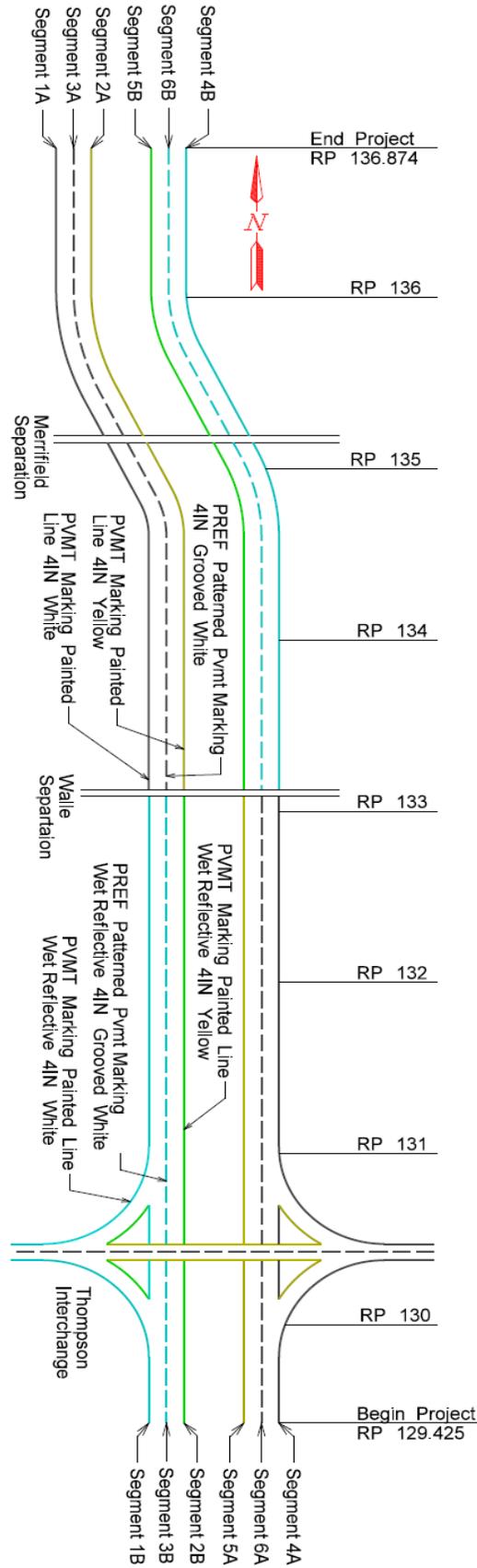
This project consists of the reconstruction of 7.4636 miles of Interstate from RP 129.425 to RP 136.874 on the south bound roadway in 2010. In 2009 the adjacent north bound roadway was also reconstructed. The north bound roadway will be used to carry head to head traffic during the construction of the southbound roadway. Therefore, temporary pavement markings were placed on the north bound roadway. Permanent pavement markings will be placed on both roadways at the end of the 2010 construction season as part of project IM-6-029(075)129. Both roadways are constructed with PCC pavement. Grooved preformed patterned pavement markings will be placed on the centerline, and surface applied painted pavement markings will be placed on the edge lines.

NDDOT intends to compare 3M All Weather Optics to current standard NDDOT pavement marking materials according to Section 880 of the North Dakota Standard Specifications. To provide the comparison, each roadway will be divided in half at RP 133 near the Walle Separation. Markings will be applied according to Table 1 on the following page.

| Roadway                | Location                | Segment  | Marking Type      | Bid Item (Marking Material)                                | AADT   |
|------------------------|-------------------------|----------|-------------------|--|--------|
| I-29<br>North<br>Bound | RP 129.4 to<br>RP 133.0 | 6A Glass | White Center-line | PREF Patterned Pvmt Marking 4 IN<br>Grooved                | 11,100 |
|                        |                         | 4A Glass | White Edge-line   | PVMT Marking Painted Line 4IN                              | 11,100 |
|                        |                         | 5A Glass | Yellow Edge-line  |  |        |
|                        | RP 133.0 to<br>RP 136.9 | 6B AW    | White Center-line | PREF Patterned Pvmt Marking Wet<br>Reflective 4 IN Grooved | 12,800 |
|                        |                         | 4B AW    | White Edge-line   | PVMT Marking Painted Line Wet<br>Reflective 4IN            | 12,800 |
|                        |                         | 5B AW    | Yellow Edge-line  |  |        |
| I-29<br>South<br>Bound | RP 136.9to<br>RP 133.0  | 3A Glass | White Center-line | PREF Patterned Pvmt Marking 4 IN<br>Grooved                | 6,620  |
|                        |                         | 1A Glass | White Edge-line   | PVMT Marking Painted Line 4IN                              | 6,620  |
|                        |                         | 2A Glass | Yellow Edge-line  |  |        |
|                        | RP 133.0 to<br>RP 129.4 | 3B AW    | White Center-line | PREF Patterned Pvmt Marking Wet<br>Reflective 4 IN Grooved | 6,620  |
|                        |                         | 1B AW    | White Edge-line   | PVMT Marking Painted Line Wet<br>Reflective 4IN            | 6,620  |
|                        |                         | 2B AW    | Yellow Edge-line  |  |        |

**Table 1 - I-29 Pavement Marking Design Details**

The table above is illustrated on the following page. Details for the installation of the experimental features were included in the plans by a plan note.



## **Construction Evaluation**

This project was awarded to the Strata Corporation. The pavement marking work was subcontracted to Swanston Equipment Company. The pavement marking application process began on September 24, 2010 on the south bound roadway. At the time of construction, these lanes were still under a lane closure. The pavement markings on this project consisted of both water-based paint and preformed patterned tape.

The curing compound from the new concrete pavement was removed prior to the application of water-based paint. The contractor elected to use a rotomilling machine to accomplish this task. The rotomilling machine has the ability to remove the curing compound and other surface debris without cutting a groove into or otherwise damaging the new pavement. Photo 1 below shows the pavement surface with the curing compound removed where the edge line would be placed.



A 3M technical representative, Jason Elsen, was on site to oversee the paint application. Striping for the standard glass bead segments used a truck mounted spraying apparatus equipped with a data logging system. Paint was applied at a 16 mil thickness with a single drop application of standard glass beads (1.5 refractive index). The All-Weather (AW) segments used the same truck to apply the paint as the standard

glass bead segments. The water-based paint was applied at a 25 mil thickness for these segments. A 'double drop' application was used to apply the retroreflective elements. The first drop is an application of standard glass beads. This application will provide reflectivity in a dry condition. The second drop is an application of 3M Company's All Weather Elements. These elements consist of a blend of 1.9 refractive index and 2.4 refractive index microcrystalline ceramic beads bonded to a central core. These elements will provide additional dry retroreflectivity as well as retroreflectivity in a wet condition. Photo 2 on the following page shows a white stripe of a water-based paint with standard glass beads; and Photo 3 shows a white stripe of water-based paint with 3M Elements. The table below details the construction dates and application rates of the painted segments.

**Table 2 - Construction details of painted segments.**

| Paint Application  |                      |             |                      |             |                      |             |                      |             |
|--|----------------------|-------------|----------------------|-------------|----------------------|-------------|----------------------|-------------|
| Segment  | 1A                   | 1B          | 2A                   | 2B          | 4A                   | 4B          | 5A                   | 5B          |
| Direction  | South                | South       | South                | South       | North                | North       | North                | North       |
| Type   | Standard Glass Beads | 3M Elements |
| Color  | White                | White       | Yellow               | Yellow      | White                | White       | Yellow               | Yellow      |
| Date Constructed   | 9/27                 | 9/27        | 9/29                 | 9/29        | 10/14                | 10/15       | 10/12                | 10/12       |
| Paint application Rate (ft/gal)                            | 297.09               | 195.65      | *                    | *           | 299.75               | 191.03      | 299.52               | 193.95      |
| Average Thickness Wet (mils)                               | 16.01                | 24.90       | *                    | *           | 16.05                | 25.19       | 16.05                | 24.81       |
| Approximate Average Thickness Dry (Mils)                   | 10.57                | 14.94       | *                    | *           | 10.59                | 15.11       | 10.59                | 14.89       |
| Average Glass Bead Application Rate (lbs /gal)             | 8.01                 | 6.46        | *                    | *           | 8.62                 | 8.11        | 8.50                 | 6.03        |
| Average 3M All Weather Elements Application Rate (lbs/gal) | 0.00                 | 3.24        | *                    | *           | 0.00                 | 3.50        | 0.00                 | 3.32        |

†Segments 3A, 3B, 6A, and 6B are preformed patterned tape

\*Information is not available for these segments.



**Photo 2 : Southbound White Edge-line with Standard Glass Beads**



**Photo 3 : Southbound White Edge-line with 3M Optics**

Preformed patterned tape application is the same for both standard tape segments and the 3M All Weather Tape segments. First a groove is cut into the existing pavement at 100 mils +/- 10 mils. Then the groove is swept or blown to remove debris left behind from the grooving process and the tape is applied. Both standard tape and 3M All Weather Tape have adhesive already on the bottom side of the tape when purchased. However since temperatures were cool, (approx 70° F) it was recommended by the manufacturer to apply additional adhesive before placing the tape. The adhesive was applied to the groove with a spray nozzle and allowed a few seconds to become tacky, at which time the tape was laid in the groove. The truck that carried the material was used to apply pressure to insure proper adhesion. The retroreflective elements embedded on the All Weather Tape consist of a blend of 1.9 refractive index and 2.4 refractive index microcrystalline ceramic elements.

The following photos show a comparison of the two preformed patterned tape materials. There is pearlescent ring around the patterns on the 3M All Weather Tape (difficult to see in the photo). This ring contains the wet reflective properties. However the pearlescent ring can cause the tape to have a similar appearance to concrete pavement during the day.



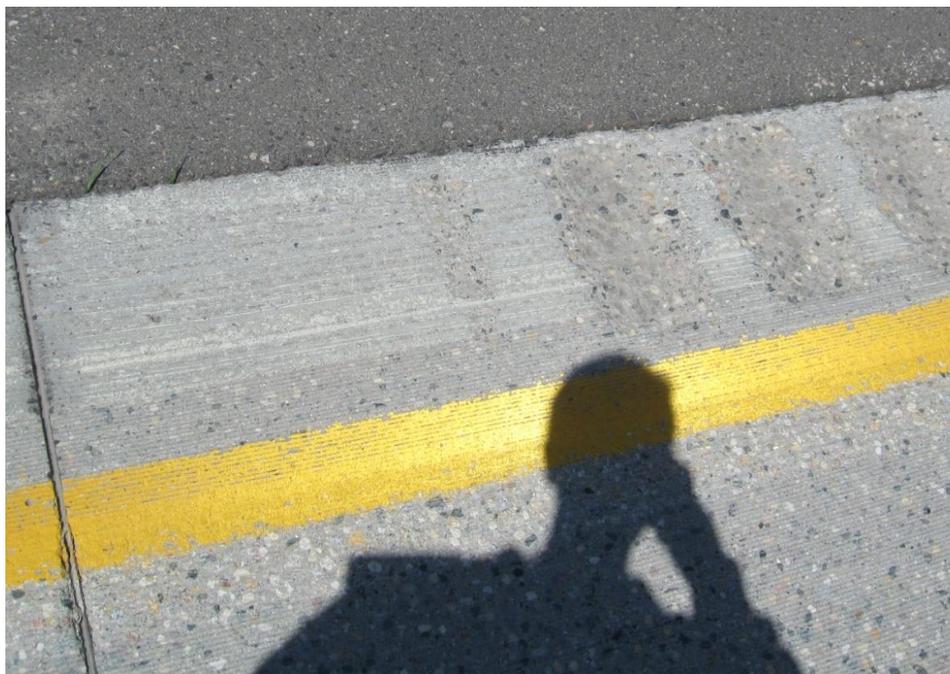
**Photo 4 : Southbound Standard Tape**



**Photo 5 : Southbound 3M All Weather Tape**

## **Evaluation 1**

The I-29 project was evaluated for the first time on May 19, 2011. This allowed the markings to be exposed to winter conditions, (snow, ice, salt, sand, and snow plows). The painted lines have performed well. The only damage/loss of material has occurred at the 'peaks' of the surface profile where the line is most susceptible to traffic and snow plow damage, see photo 6 below:



**Photo 6 : Loss of Material on Peaks of Surface Profile**

This profile was the result of a rotomilling machine which was used to remove the curing compound from the roadway surface. The grooved centerline preformed patterned tape markings show no wear in either standard tape or 3M All Weather Tape segments.

## **Evaluation 2**

The I-29 project was evaluated for the second time on June 5, 2012. After two winter seasons, the surface applied water-based markings are beginning to show distress. The photos below illustrate the loss of material of the painted lines.



**Photo 7 - Yellow Edge-line with Standard Glass Beads**



**Photo 8 - Yellow Edge-line with 3M Optics**



**Photo 9 - White Edge-line with Standard Glass Beads**



**Photo 10 - White Edge-line with 3M Optics**

The previous photos also show the difference in the distresses that are accumulating on the painted control markings vs. the 3M AW painted markings. About 50% of the paint was gone from the white edge-line in the south bound direction from RP 135 to RP 136. As described earlier, this segment was slightly damaged during other construction

activities on the project. Under a magnifying glass, it appears that about 25% to 50% of the beads are missing from both standard glass and AW segments. Also, some AW Elements were gone completely while others experienced some loss of the 3M Optics from the ceramic core.

The preformed patterned tape continues to show no signs of distress in both the control and AW sections. Both of these lines are still early in their life cycles.

## **Retroreflectivity**

Retroreflectivity readings were collected with a Delta Light and Optics LTL 2000 Portable Retrometer. This device conforms to ASTM D 4061 *Standard Test Method for Retroreflectance of Horizontal Coatings*. Readings were collected in a dry condition, as well as a wet condition. Wet readings were collected according to ASTM E 2177 *Standard Test Method for Measuring the Coefficient of Retroreflected Luminance ( $R_L$ ) of Pavement Markings in a Standard Condition of Wetness*. This test involves spraying the markings with water until saturated (30 sec) and waiting a specified amount of time (45 sec) before taking a reading. An effort was made to allow the markings to be in place for at least two weeks before collecting initial readings.

### **IM-6-029(075)129**

Data was collected at three reference points in each segment of the I-29 project. Ten dry readings and five wet readings were collected at each reference point.

The following charts show the retroreflectivity data for the white and yellow edge-lines. The charts allow the reader to compare wet to dry readings of each line type. The charts also allow the reader to observe how the retroreflectivity values change over time. Other states use a dry reading of 100 mcd/m<sup>2</sup>/lux as a typical value to begin considering replacement of the line. For certain types of marking within the NDDOT a value of 180 mcd/m<sup>2</sup>/lux for yellow and 275 mcd/m<sup>2</sup>/lux for white is the minimum acceptable value for a new marking. Any value over 500 mcd/m<sup>2</sup>/lux is excellent; any values higher than that become difficult for the eye to distinguish an increase in retroreflectivity.

| Average Retroreflectivity of White Edge-line Paint on I-29 (mcd/m <sup>2</sup> /lux) |                |     |             |     |                |     |             |     |
|--|----------------|-----|-------------|-----|----------------|-----|-------------|-----|
| Date Tested  | North Bound    |     |             |     | South Bound    |     |             |     |
|  | Standard Glass |     | 3M Elements |     | Standard Glass |     | 3M Elements |     |
|  | Dry            | Wet | Dry         | Wet | Dry            | Wet | Dry         | Wet |
| 10/13/2010   | 478            | 30  | 557         | 252 | 302            | 14  | 510         | 186 |
| 5/19/2011  | 296            | 6   | 341         | 33  | 130            | 5   | 304         | 39  |
| 6/5/2012   | 144            | 2   | 192         | 14  | 73             | 2   | 173         | 12  |

| Average Retroreflectivity of Yellow Edge-line Paint on I-29 (mcd/m <sup>2</sup> /lux) |                |     |             |     |                |     |             |     |
|---|----------------|-----|-------------|-----|----------------|-----|-------------|-----|
| Date Tested   | North Bound    |     |             |     | South Bound    |     |             |     |
|   | Standard Glass |     | 3M Elements |     | Standard Glass |     | 3M Elements |     |
|   | Dry            | Wet | Dry         | Wet | Dry            | Wet | Dry         | Wet |
| 10/13/2010  | 339            | 13  | 503         | 111 | 225            | 31  | 362         | 303 |
| 5/19/2011   | 233            | 13  | 337         | 101 | 192            | 22  | 348         | 145 |
| 6/5/2012  | 141            | 5   | 261         | 40  | 124            | 8   | 234         | 58  |

The above charts show that the due to traffic and snow plow activities, the retroreflectivity of the painted markings decrease over time.

The following chart shows the retroreflectivity data for the white center-line tape with standard glass beads and with 3M All Weather Elements.

| Average Retroreflectivity of White Center-Line Tape on I-29 (mcd/m <sup>2</sup> /lux) |               |     |                     |     |               |     |                     |     |
|---|---------------|-----|---------------------|-----|---------------|-----|---------------------|-----|
| Date Tested   | North Bound   |     |                     |     | South Bound   |     |                     |     |
|   | Standard Tape |     | 3M All Weather Tape |     | Standard Tape |     | 3M All Weather Tape |     |
|   | Dry           | Wet | Dry                 | Wet | Dry           | Wet | Dry                 | Wet |
| 10/13/2010  | 832           | 66  | 766                 | 406 | 338           | 46  | 302                 | 376 |
| 5/19/2011   | 1005          | 68  | 831                 | 514 | 1000          | 41  | 1107                | 333 |
| 6/5/2012  | 918           | 51  | 713                 | 299 | 845           | 44  | 500                 | 119 |

This chart shows an increase in retroreflectivity after the first year. There may have been some type of coating on the marking that caused reduced initial values that traffic was able to remove without damaging the line. These markings are protected from snow plow activities by a groove.

## **SNH-6-002(079)337**

### **Design**

This project consists of a hot bituminous overlay of 17.399 miles of westbound US 2 from Arvilla to Grand Forks. This project is divided into four test segments. All of the pavement marking is surface applied paint and will be applied according to Table 3 below. Details for the installation of the experimental features were included in the plans by a plan note.

| Roadway | Location                                    | Marking Material                              | Marking Type   | AADT  |
|---------|---|---|--|-------|
| US 2    | Beginning of Project (RP 337.325) to RP 340 | Pavement Marking Paint                        | Yellow Edge-line, White Center-line, White Edge-line, 8in White Channel Line, & Messages | 4,440 |
|         | RP 340 to RP 347                            | 3M AWP with Series 90 Wet Reflective Elements | Yellow Edge-line, White Center-line, White Edge-line, 8in White Channel Line, & Messages | 4,440 |
|         | RP 347 to RP 351                            | Pavement Marking Paint                        | Yellow Edge-line, White Center-line, White Edge-line, 8in White Channel Line, & Messages | 4,440 |
|         | RP 351 to End of Project (RP 354.724)       | 3M AWP with Series 90 Wet Reflective Elements | Yellow Edge-line, White Center-line, White Edge-line, 8in White Channel Line, & Messages | 4,440 |

**Table 3 - US 2 Pavement Marking Design Details**

## **Construction Evaluation**

This project was awarded to Central Specialties Inc. of Alexandria MN. The pavement marking work was subcontracted to Swanston Equipment Company. The pavement markings were applied during the week of August 15, 2011. Jason Elsen of 3M Co. was again available during construction to ensure that the wet reflective elements were applied correctly. All segments on this project were surface applied paint. The table below details the construction dates and application rates as recorded by the data logging system on-board the striping truck.

| Paint Application US 2                                     |                 |                                 |                   |                  |                  |
|--|-----------------|---------------------------------|-------------------|------------------|------------------|
| Line Type  | White Edge-line | White Edge-line/<br>Center-line | White Center-line | Yellow Edge-line | Yellow Edge-line |
| Reflective Material  | All Weather     | Control                         | All Weather       | Control          | All Weather      |
| Date Constructed   | 8/18            | 8/18                            | 8/17              | 8/19             | 8/16             |
| Paint application Rate (ft/gal)                            | 271             | 296                             | 166               | 299              | 196              |
| Average Thickness Wet (mils)                               | 25.6            | 16.1                            | 28                | 16.6             | 25.8             |
| Average Glass Bead Application Rate (lbs /gal)             | 9.03            | 6.5                             | 6.72              | 6.26             | 6.42             |
| Average 3M All Weather Elements Application Rate (lbs/gal) | 3.15            | –                               | 2.85              | –                | 2.17             |

**Table 4 - US 2 Pavement Marking Application Details**

Only two issues that may affect life of the striping occurred during construction. The first was a section of about 0.25 miles on the yellow edge-line as it passes beneath the Emerado Interchange. At this location the rumble strips were out of alignment. This caused the support wheels of the paint and bead gun apparatus to roll over the rumble strips. This in turn caused the spray apparatus to bounce which may cause uneven thickness in paint and distribution of beads and Elements. The other issue was tracking of approximately 1,000 ft of the white edge-line near RP 354. This location was avoided when retroreflectivity readings were collected. With the exception of the above issues, the construction of the markings occurred without incident. The markings appear

uniform and no defects could be detected visually. Photos 11 and 12 below show a typical yellow line and a typical white line from this project.



**Photo 11: Westbound Yellow AW Paint with AW Elements**



**Photo 12: Westbound White AW Paint with AW Elements**

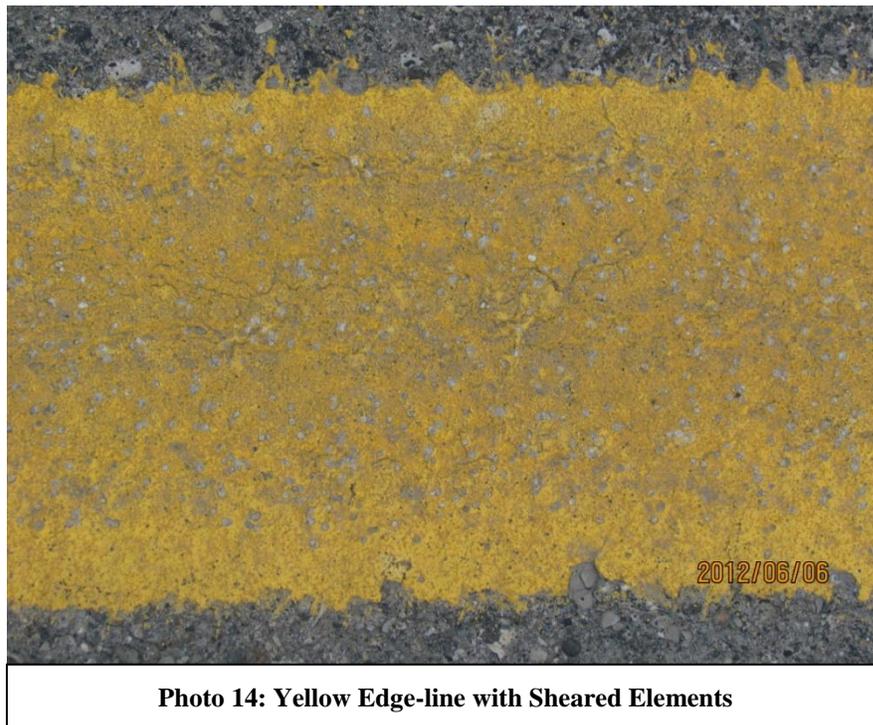
## **Evaluation 1**

The US 2 project was evaluated for the first time on June 5, 2012. After one winter the pavement markings are showing distress. As shown in photo 13 below, a segment of the white edge-line was nearly undetectable. The remaining portions of the white edge-line were also damaged to a degree that it was recommended to restripe it and terminate the research on the white edge-line.



**Photo 13: Damaged White Edge-line**

The white center-line and yellow edge-line are showing signs of distress. Photo 14 below shows a segment of yellow edge-line with 3M Elements. The white/cream dots on the line are what remains of the 3M Elements. The 3M Elements were sheared in half from the snow plows, exposing the white ceramic core of the Elements.



This occurrence was common in the segments with 3M Elements. All line types are showing some loss of paint.

### **Retroreflectivity**

Initial retroreflectivity readings were collected approximately one month after construction. Retroreflectivity readings were collected after one winter on June 5, 2012. Twelve reference points were selected for testing on this project. Six reference points are located in the control segments and six reference points are located in segments with 3M Elements. Five dry readings and three wet readings were collected on the edge-lines. Four dry readings and two wet readings were collected on the center-lines. The average readings for each line type are shown in the following tables.

| Average Retroreflectivity of White Edge-line Paint<br>(mcd/m <sup>2</sup> /lux) |                |     |             |     |
|---|----------------|-----|-------------|-----|
| Date Tested   | Standard Glass |     | 3M Elements |     |
|   | Dry            | Wet | Dry         | Wet |
| 9/15/2011   | 357            | 33  | 452         | 356 |
| 6/5/2012  | 165*           | 6*  | 174*        | 21* |

\*Tests were not taken at each reference point due to damage to the line.

| Average Retroreflectivity of Yellow Edge-line Paint<br>(mcd/m <sup>2</sup> /lux) |                |     |             |     |
|--|----------------|-----|-------------|-----|
| Date Tested  | Standard Glass |     | 3M Elements |     |
|  | Dry            | Wet | Dry         | Wet |
| 9/15/2011  | 265            | 18  | 372         | 247 |
| 6/5/2012   | 127            | 6   | 161         | 14  |

| Average Retroreflectivity of White Center-line Paint<br>(mcd/m <sup>2</sup> /lux) |                |     |             |     |
|---|----------------|-----|-------------|-----|
| Date Tested   | Standard Glass |     | 3M Elements |     |
|   | Dry            | Wet | Dry         | Wet |
| 9/15/2011   | 324            | 21  | 488         | 176 |
| 6/5/2012  | 125            | 9   | 190         | 19  |

The data shows that initially, the marking in segments with 3M All Weather Elements performed better than the markings with standard glass beads in both a wet and dry condition. However, after one winter the segments with 3M All Weather Elements seem to have lost their wet-night retroreflective properties. Also the segments with 3M All Weather Elements currently provide only slightly higher retroreflectivity in a dry condition.

## **Cost**

The All Weather Elements and All Weather Tape are advanced pavement marking systems. They have properties that cannot be achieved with conventional markings. With these added properties also comes additional cost. Another purpose of this research is to weigh the benefits of these systems versus the cost. A cost comparison is shown in the Table 5 below.

| <b>Location</b>     | <b>SNH-6-002(079)337</b> |                         | <b>IM-6-029(075)129</b> |                         |               |                     |
|---------------------|--------------------------|-------------------------|-------------------------|-------------------------|---------------|---------------------|
| Reflective Material | Standard Glass           | 3M AWP with AW Elements | Standard Glass          | 3M AWP with AW Elements | Standard Tape | 3M All Weather Tape |
| Marking Material    | 4 IN Paint               | 4 IN Paint              | 4 IN Paint              | 4 IN Paint              | 4 IN Tape     | 4 IN Tape           |
| Bid Price (\$/LF)   | \$0.09                   | \$0.44                  | \$0.19                  | \$0.31                  | \$3.28        | \$3.28              |
| Quantity (feet)     | 79,297                   | 169,417                 | 88,749                  | 82,952                  | 9,833         | 9,833               |
| Total Cost          | \$6,898.84               | \$73,696.40             | \$16,862.31             | \$25,715.12             | \$32,252.24   | \$32,252.24         |

**Table 5 - Cost from Bid Prices**

It should be noted that part of the increased cost of the All Weather markings in water-based paint is an increase in the quantity of material. That is, the standard glass segments used 16 mils of paint while the All Weather segments used 25 mils of paint.

## **Summary**

The goal of this project is to evaluate the performance of 3M All Weather Pavement Markings on two different projects in the Grand Forks District. Due to changes in the bid opening schedule, the I-29 project was constructed in 2010, and the US 2 project was constructed in 2011.

When construction was completed, initial retroreflectivity values were collected on segments with standard glass beads and segments with 3M All Weather Elements in both wet and dry conditions. Initially, the segments with 3M All Weather Elements

performed better than the markings with standard glass beads in both a wet and dry condition. The improved initial performance characteristics were seen on both projects.

After snow plow activities it appears that the water based segments with 3M All Weather Elements have lost some of their capability to provide wet-night retroreflectivity. The segments with 3M All Weather Elements still out-perform the control segments in a dry condition but the margin has been reduced by snow plow activities.

The preformed patterned tape is performing well in both the control segments with standard tape and the segments with 3M All Weather Tape. Tape is considered a durable marking and it also has the benefit of being placed in a groove. The 3M All Weather Tape may lose some daytime visibility when placed on a concrete surface.

