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14. Supplementary Notes			
15. Abstract <u>Purpose and Need</u> Durability of pavement markings is challenge in North Dakota due to climate conditions, salt/sand application, and snow plow activities. Durability improvements may be realized if paint or epoxy markings were installed in a groove. <u>Objective</u> The objective of this project is to evaluate the performance of liquid markings in a grooved, rumbled surface, as well as the effectiveness of wet-reflective elements to mitigate water collection in the grooves and rumble strips <u>Summary</u> The retroreflectivity data shows that the water based paint and epoxy with AW elements has outperformed the water based paint and epoxy with standard glass. However, all segments were heavily impacted by a significant loss of pavement marking material due a delamination of a fog seal.			
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**NORTH DAKOTA
DEPARTMENT OF TRANSPORTATION**

**MATERIALS AND RESEARCH
DIVISION**



Experimental Study ND 2013-01

**Evaluation of Grooved, Rumbled
Pavement Markings**

Final Evaluation

HES-HRR-1-999(021)

December 2015

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Evaluation of Grooved Pavement Markings

Purpose and Need

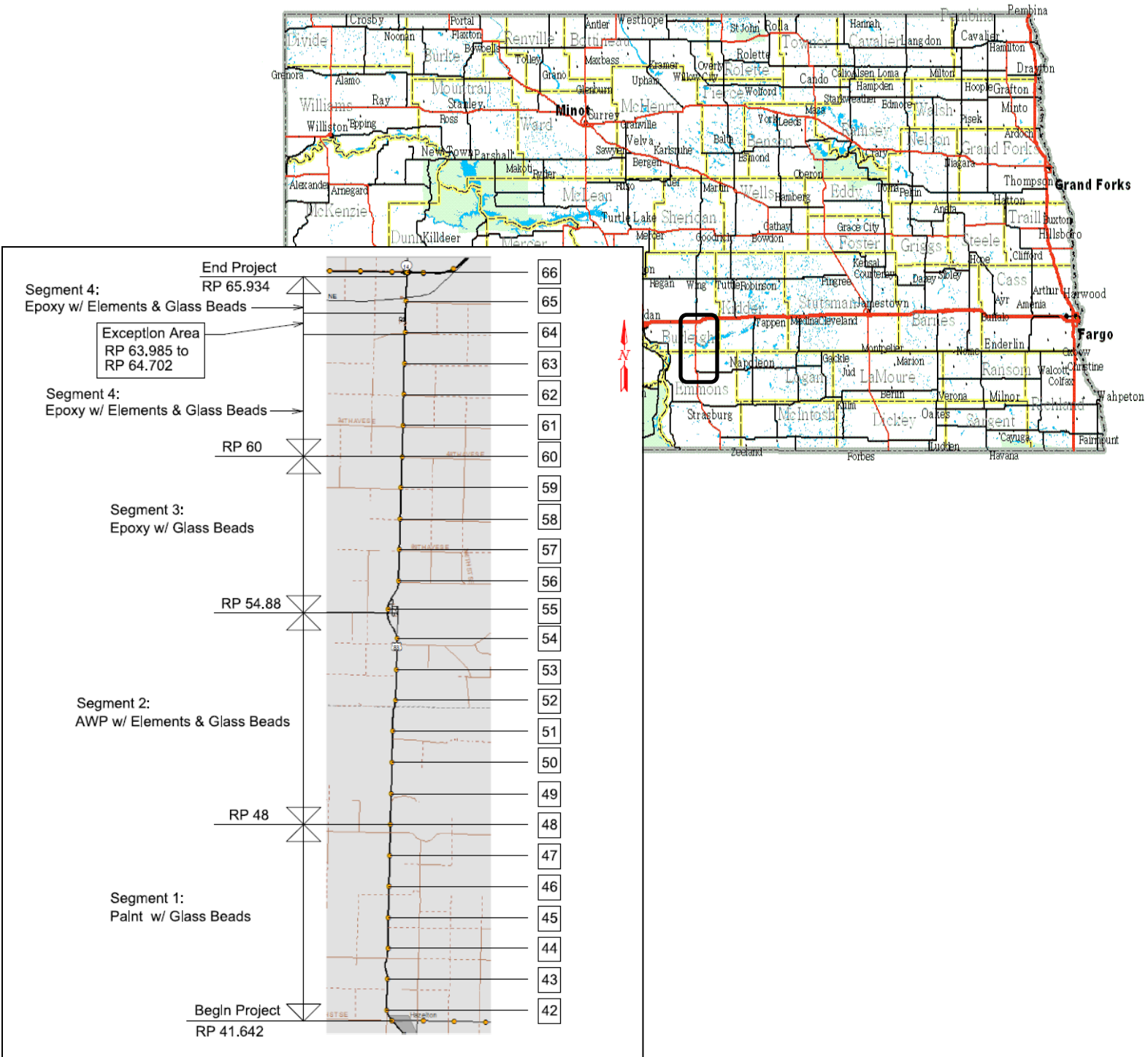
Durability of pavement markings is challenge in North Dakota due to climate conditions, salt/sand application, and snow plow activities. Waterborne pavement markings are require replacement every 1 to 2 years. Epoxy pavement markings are more durable than waterborne markings, and are expected to last 3 to 5 years (NDDOT Design Manual). Grooved preformed patterned tape in a groove is effective in avoiding snowplow damage to and has an expected life span of 7 to 10 years (NDDOT Design Manual). Durability improvements may be realized if paint or epoxy markings were installed in a groove.

Objective

The objective of this project is to evaluate the performance of liquid markings in a grooved, rumbled surface, as well as the effectiveness of wet-reflective elements to mitigate water collection in the grooves and rumble strips. Four types of marking will be evaluated: standard water based paint with standard glass beads, standard epoxy with standard glass beads, 3M AW Paint with a double drop of 3M Elements and standard glass beads, and standard epoxy with a double drop of 3M Elements and standard glass beads.

Location

The experimental features are incorporated in the district wide striping project HES-HRR-1-999(021) to be constructed in 2013. The experimental feature is located on US 83 from RP 41.642 to RP 65.934 between Hazelton and Sterling ND.



Design

As indicated by the map on the previous page this project will be divided into four test segments. The experimental pavement marking segments will be placed on the center-line. The existing pavement marking on this section of US 83 is grooved preformed pattern tape. The original groove was cut to a depth of 100 mils. After the marking was placed, the markings were masked and a chip seal was applied to the roadway surface. The chip seal increased the groove depth by 100 +/- 50 mils.

Prior to the application of the new pavement marking, the existing preformed patterned tape will be removed. The approximate groove depth will be 200 +/- 50 mils. Following the removal of the existing tape, center-line rumble strips will be installed. The rumble strips will follow standard drawing D-760-3. The pavement marking will be applied with the following design details:

Design Details									
Segment	Begin (RP)	End (RP)	Length (Miles)	Type	Liquid Material	Dry Film Thickness (mils)	Retroreflective Media	Quantity of Retroreflective Media	
								Glass Beads (lb/gal)	3M Elements (lb/gal)
1	RP 41.6	RP 48.0	6.4	Yellow Center-Line	AW (water based) Paint	16	Glass Beads	6	-
2	RP 48.0	RP 54.9	6.9	Yellow Center-Line	AW (water based) Paint	25	3M Elements & Glass Beads	20	2.12
3	RP 54.9	RP 60.0	5.1	Yellow Center-Line	Epoxy Paint	20	Glass Beads	25	-
4	RP 60.0	RP 65.9	5.9	Yellow Center-Line	Epoxy Paint	20	3M Elements & Glass Beads	6	5.3

The design details above were developed with recommendation by the manufacturer. A 3M representative will be onsite during construction to facilitate proper construction methods for the wet-reflective segments.

Evaluation Criteria

The project will be evaluated annually for 3 years, or until replacement if it is determined that the condition of the marking warrants replacement before the end of the evaluation period. The evaluations will be in the spring. The project will be evaluated on the following criteria:

- Determine the Coefficient of Retroreflective Luminance (R_L) with an LTL 2000 Retrometer.
 - Retroreflectivity data will be collected at the mile points in each segment.
 - Five readings will be collected on each line type in a dry condition
 - Three readings will be collected on each line type in a wet-recovery condition 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*.
 - Baseline data will be collected 2 weeks after construction according to NDDOT Standard Specification 762.04 E4.
- Visual Inspection
 - The project will be examined visually to assess any durability issues.
 - Visual observations will be documented with photographs.
 - Materials and Research will attempt to view the markings in a wet-night condition.

Materials and Research will publish an annual report documenting the observations of this project.

Evaluation

The pavement marking of all four sections were constructed during a span of two days, starting on September 19, 2013. The first section striped was section 3, All Weather Paint and 3M Wet Reflective Elements. The temperature for most of the day was in the mid 50's with cloudy skies. The contractor originally planned to construct all 4 segments in one day but because of equipment delays and a temperature drop that evening, Section 1 was delayed until the following morning.

The project was evaluated in the spring of 2014 and 2015. Each segment was showing signs of distress at the time of the 2015 evaluation. In the fall of that year, the entire project was restriped due to deterioration of the pavement marking.

Segment 1

Segment 1 is a water based control section. This segment was constructed according to all NDDOT standards with the exception of a 200mil+ groove. The paint is 16 mils thick and has 6lbs/ gallon of AASHTO M 247 Type I Glass Beads. After 2 years in service the water based marking was still present. Some of the marking lost adhesion to open rock faces. In all locations the marking was fractured (see Photo 1), likely from thermal stresses on the coating. However, most of the glass beads were still present.

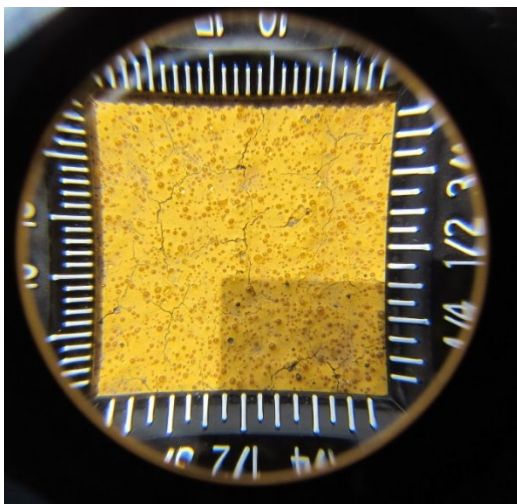


Photo 1 – Cracks in Water based marking



Photo 2 – General Condition of Segment 1

Segment 2

Segment 2 is water-based marking with 3M All Weather Elements. This paint is 25 mils thick with a double drop of reflective media (20 lbs per gallon of AASHTO M 247 Type 1 and 2.12 lbs per gallon of 3M All Weather Elements). The marking and reflective media are both still present. Similar cracking in the paint to the control section was observed, but no loss of adhesion to the open rock faces.



Photo 3 – Cracks in Water-based Marking



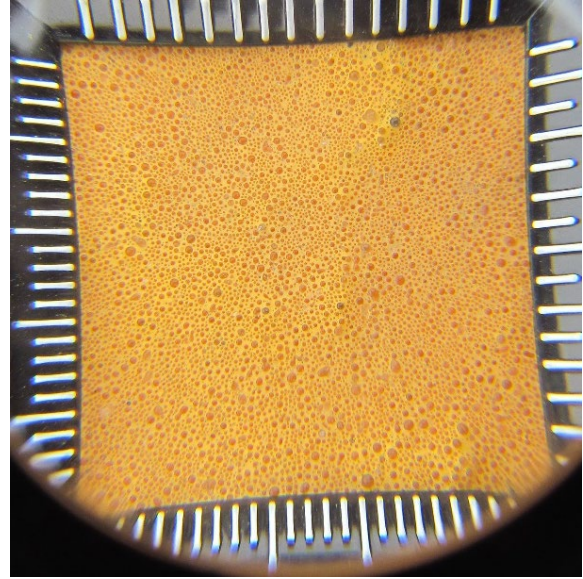
Photo 4 – General Condition of Segment 2

Segment 3

Segment 3 was a control section of epoxy pavement marking 20 mils thick with 25 lbs of AASHTO Type 1 glass beads. This segment can be divided into two distinct categories: Marking that were completely intact and marking that was mostly delaminated. Photos 5, 6, and 7 on the following page are examples of intact and delaminated epoxy stripes.



Photo 5 – Segment 3 – Epoxy Marking Intact



**Photo 6 – Segment 3 Epoxy Marking Intact
(Magnified)**



Photo 7 – Segment 3 Delamination

The reason for the delamination is the construction sequence trapped an uncured fog seal between two layers of temporary water based paint. After the old pavement marking was removed, an application of temporary paint was applied, as the centerline of the road cannot be left unstriped overnight without other means of traffic control. The temporary paint was in place until the rumble stripes were cut. Next, the rumble strips

are cut (also removing some of the original temporary marking). Then the rumble strips are covered with a fog seal. The fog seal is covered with a temporary stripe the same day, again because the centerline cannot be left unstriped. Finally, the permanent stripe is placed. A cross section of this marking is shown in figure 2:

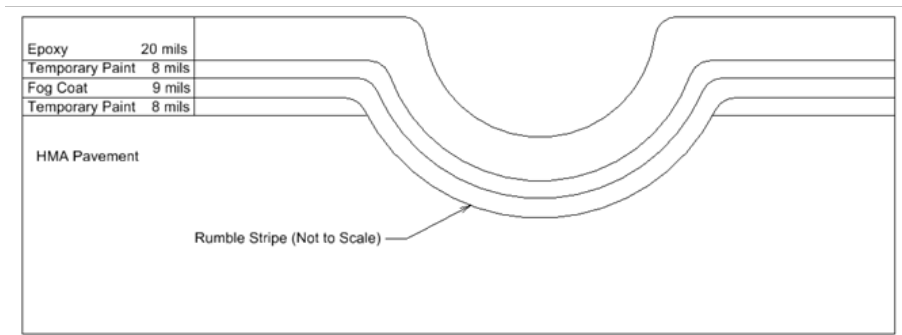


Figure 2 – Longitudinal Cross section of pavement marking system.

Further examination of the delamination of this pavement marking system showed that when the upper pavement marking layers were removed, fog seal remained both on the pavement and on the back of the delaminated material. This indicates that the break is occurring within the fog coat. When this pavement marking system is impacted by the snowplow, it will break within the weakest layer of the system. If we look again at the cross section, what’s currently visible is the first layer of temporary paint, under the remaining fog seal.



Photo 10 – Delaminated areas appear to show HMA Underneath.



Photo 11 – After cleaning, temporary paint visible underneath, indicating that the black material is fog seal.

Therefore the cross section of the remaining paint system would look as follows:

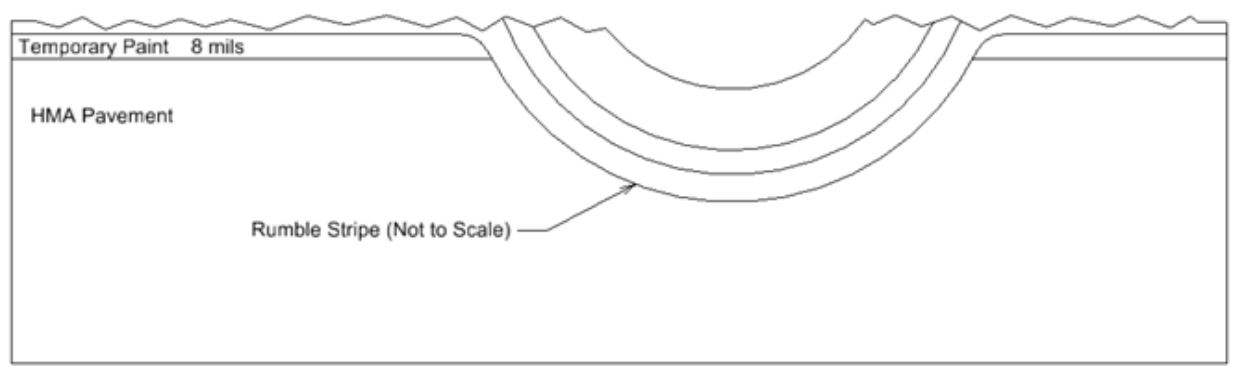


Figure 3 – Longitudinal Cross section of pavement marking system after delamination.

Segment 4

Segment 4 is an epoxy pavement marking with 3M Elements. This segment had the same delamination issues as segment 3, see Photos 8 and 9.



Photo 8 – Segment 4 – Delamination

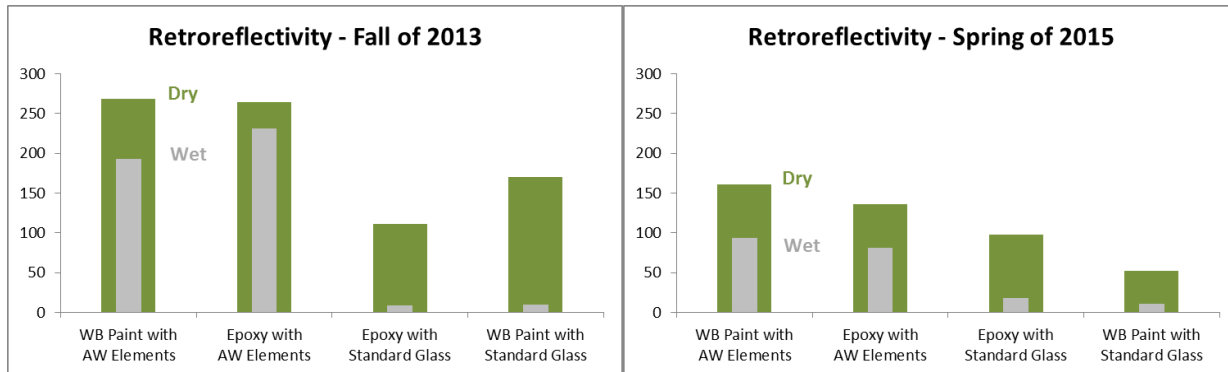


Photo 6 – Segment 4 Delamination

The early failures of segment 3 and 4 are the same mechanism, and have nothing to do with the use of 3M elements.

Retroreflectivity:

Retroreflectivity data was collected in 2013, 2014, & in the spring of 2015 prior to restriping.



The retroreflectivity data shows that the water based paint and epoxy with AW elements has outperformed the water based paint and epoxy with standard glass. However, all segments were heavily impacted by a significant loss of pavement marking material due to the afore mentioned fog seal issue.