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14. Supplementary Notes			
15. Abstract Purpose and Need The North Dakota DOT has revised the design manual to include grooved epoxy pavement markings. The addition of a groove allows the department to explore the use of high-performance optics. High-performance optics can provide additional dry-retroreflectivity when used in addition to AASHTO Type I beads. In addition, some high-performance optics can provide wet-retroreflectivity. Objective The objective of this experimental project is to evaluate the performance of two different high-performance optics: 3M All Weather Elements and Potters Visibeads. Summary The initial data shows that the two pavement markings perform similarly. In the first year, the 3M markings have higher wet-reflective properties, but by year 2, both marking types have very little wet-reflective properties left. By year 3, both the wet-reflective and dry-reflective properties had diminished, and the physical striping presence had deteriorated to a point where restriping was necessary.			
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**NORTH DAKOTA
DEPARTMENT OF TRANSPORTATION**

**MATERIALS AND RESEARCH
DIVISION**

Experimental Study ND 2015-01

Evaluation of Conglomerate Optics

Final Evaluation

IM-1-094(181)162

July 2019

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Evaluation of Conglomerate Optics

Purpose and Need

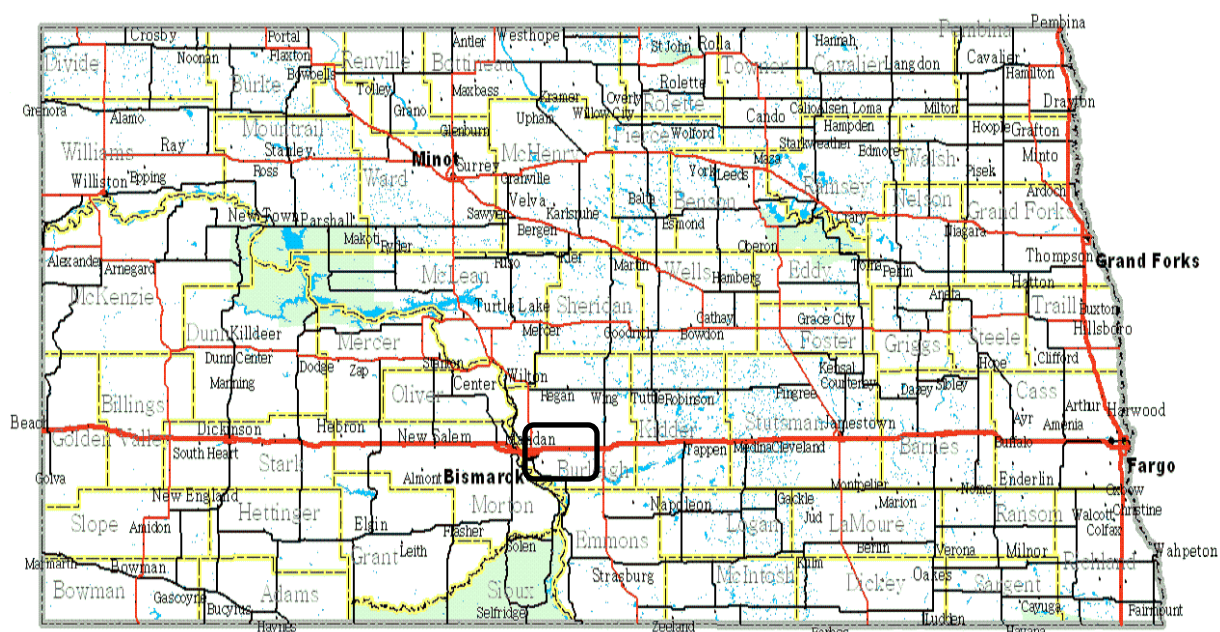
The North Dakota DOT has revised the design manual to include grooved epoxy pavement markings. The addition of a groove allows the department to explore the use of high-performance optics. Most high-performance optics have a much larger diameter than the AASHTO Type I beads in our current specifications, making the groove imperative to their use. High-performance optics can provide additional dry retroreflectivity when used in addition to AASHTO Type I beads. In addition, some high-performance optics can provide wet retroreflectivity.

Objective

The objective of this experimental project is to evaluate the performance of two different high-performance optics: 3M All Weather Elements and Potters Visibeads.

Location

The experimental features are incorporated in a microsurfacing project on I-94, project number IM-1-094(181)162, PCN 20905. The project was constructed in the 2016 construction season. The experimental features are located East of Bismarck from RP 162.630 to RP 182.868.



Design

The experimental pavement marking segments will be placed on the centerline of I-94 in both the EB and WB direction. The centerline will be white epoxy and will be placed in a 100 mil groove (+/-10 mils). The project will be divided into four test segments. Each experimental feature will have two test segments, one in each direction according to Table 1:

Design Details										
Segment	Direction	Begin (RP)	End (RP)	Length (Miles)	Type	Binder	Dry Film Thickness (mils)	Quantity of Retroreflective Media		
								Type 1 Glass Beads (lb/gal)	3MAW Elements (lb/gal)	Potters Visimax (lb/gal)
1	EB	162.367	173.000	10.633	White Center-Line	Epoxy	20	6	-	6
2	EB	173.000	182.868	9.868	White Center-Line	Epoxy	20	20	5.3	-
3	WB	182.874	173.000	9.874	White Center-Line	Epoxy	20	6	-	6
4	WB	173.000	162.360	10.640	White Center-Line	Epoxy	20	20	5.3	-

The design details above were recommended by the manufacturers of the retroreflective media. A representative from each manufacturer will be onsite during construction to facilitate proper installation methods.

Evaluation Criteria

The project will be evaluated annually for three years, or until replacement if it is determined that the condition of the marking warrants replacement before the end of the evaluation period. Materials and Research will also retain the option to extend the evaluation period if the marking's performance is such that it does not warrant replacement after three years. The project will be evaluated on the following criteria each Spring:

- Determine the Coefficient of Retroreflective Luminance (R_L) using a portable retrometer.
- Retroreflectivity data will be collected at 10 locations in each test segment.
- Four readings will be collected at each location in a dry condition.
- Four readings will be collected at each location 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.

Cost

The pavement marking grooves and the different pavement marking types were each bid separately. The low bid for the pavement marking grooves was \$0.37. The low bid for both the 3M markings and the Potters markings was \$1.75. The low bid for epoxy pavement marking (as a control section for cost purposes) was \$0.26.

Line Type	Low Bid Price		
	Groove	4 IN Line (LF)	Total
Control (Epoxy with Type 1 Beads)	\$ 0.37	\$ 0.26	\$ 0.63
Special #1 (Epoxy with 3M All Weather Elements)	\$ 0.37	\$ 1.75	\$ 2.12
Special #2(Epoxy with Potters Visibeads)	\$ 0.37	\$ 1.75	\$ 2.12

Initial Evaluation

The Potters Visibead Section was constructed on 7/28/2016, and the 3M Element Section was constructed on 8/2/2016. A representative from each manufacturer was onsite to ensure proper application of the experimental materials. Both manufacturers aided the contractor to make adjustments to installation equipment in the field. The adjustments included modifications amount of Type 1 glass, angle of drop, and application pressure in order to acquire proper embedment of the proprietary optics. Photos 1-4 below show the finished products after installation.



Photo 1 – Epoxy Centerline with 3M All-Weather Elements

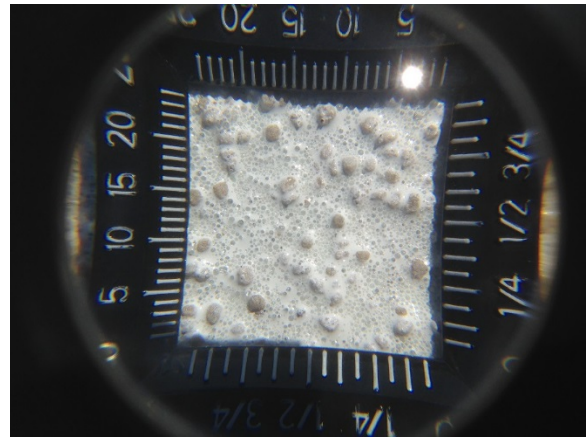


Photo 2 – Close-up of 3M All Weather Elements



Photo 3 – Epoxy Centerline with Potters - Potters' Visibead

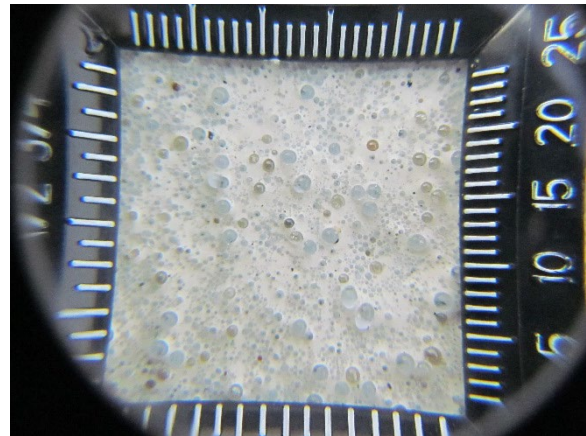


Photo 4 – Close-up of Potters' Visibead

Final Evaluation

Retroreflectivity data was collected after installation and in the springs of 2017, 2018 and 2019. The average dry and wet retroreflectivity at each test location is shown graphically in Figure 1. The data is presented in Table 1 below. The pavement markings were also evaluated visually for distresses and durability.

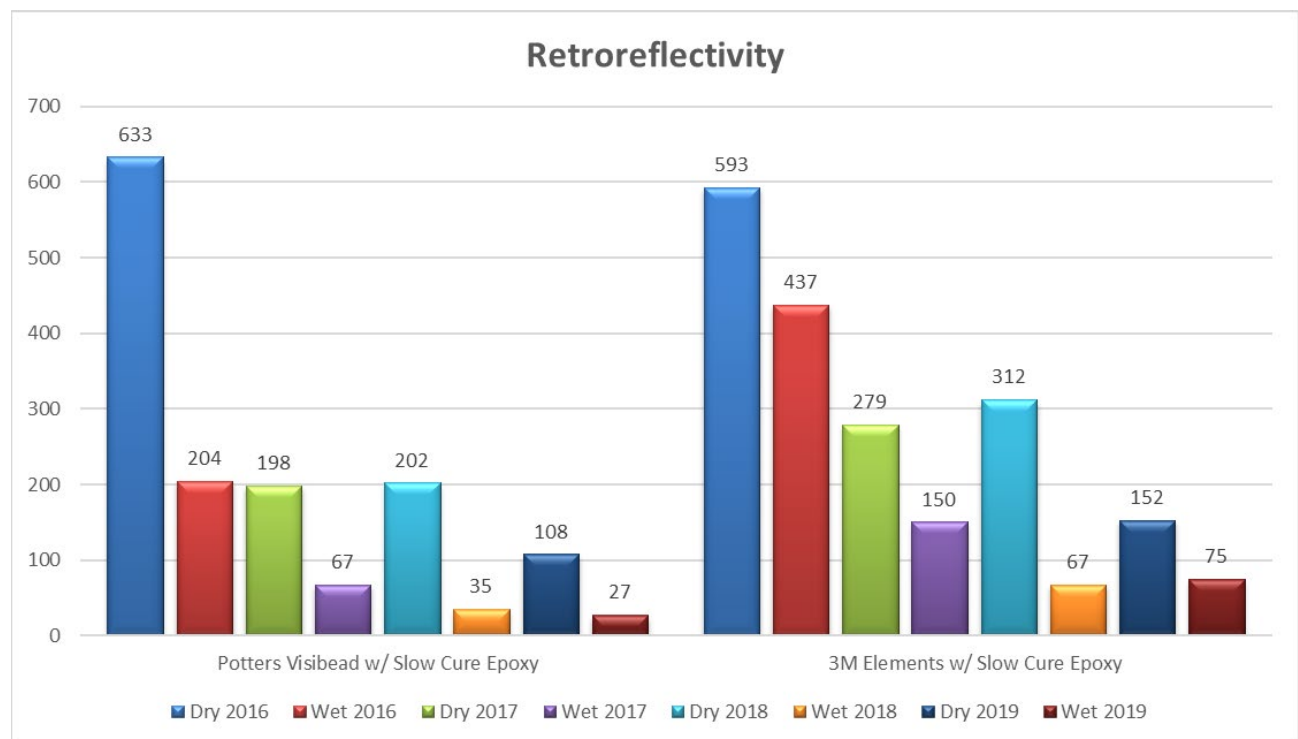


Figure 1 –Retroreflectivity Chart

Retroreflectivity			
Material	Year	Dry Retro-Reflectivity	Wet Retro-Reflectivity
Potters Visibead (w/ Slow Cure Epoxy)	2016	633	204
	2017	198	67
	2018	202	35
	2019	108	27
3M Elements (w/ Slow Cure Epoxy)	2016	593	437
	2017	279	150
	2018	312	67
	2019	152	75

Table 1 – Retroreflectivity Data

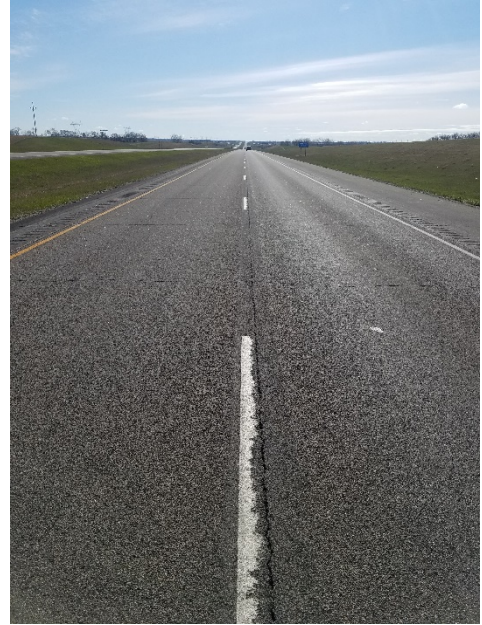


Photo 5 & 6 – Good condition markings at RP 169.0; Typical condition of pavement marking along project corridor (Potters Visibead)

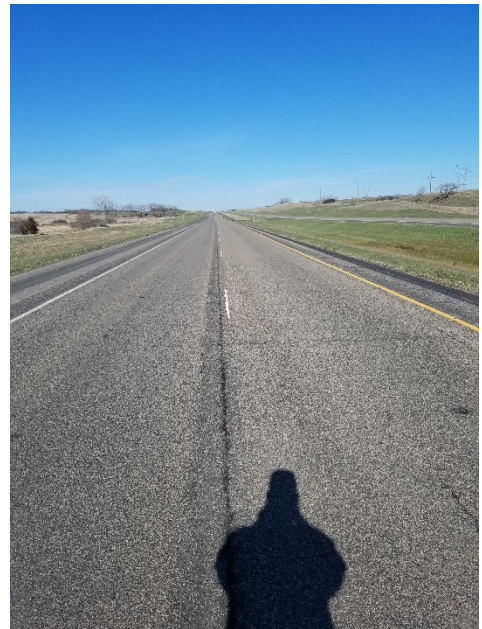


Photo 7 & 8 – Damaged markings at RP 168.0 (Potters Visibead)

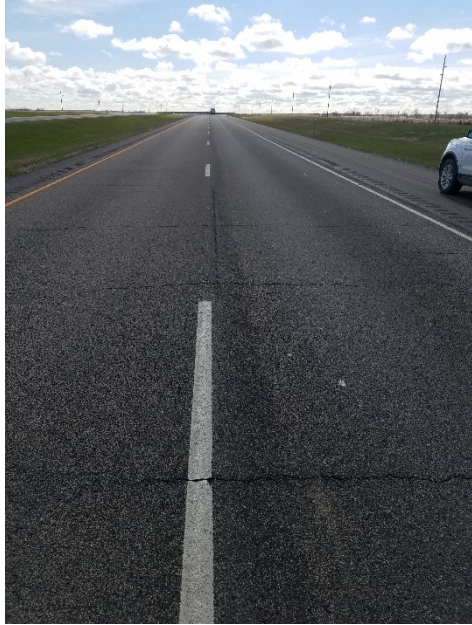


Photo 9 & 10 – Good condition markings at RP 179.0; Typical condition of pavement markings along project corridor (3M AW Elements)

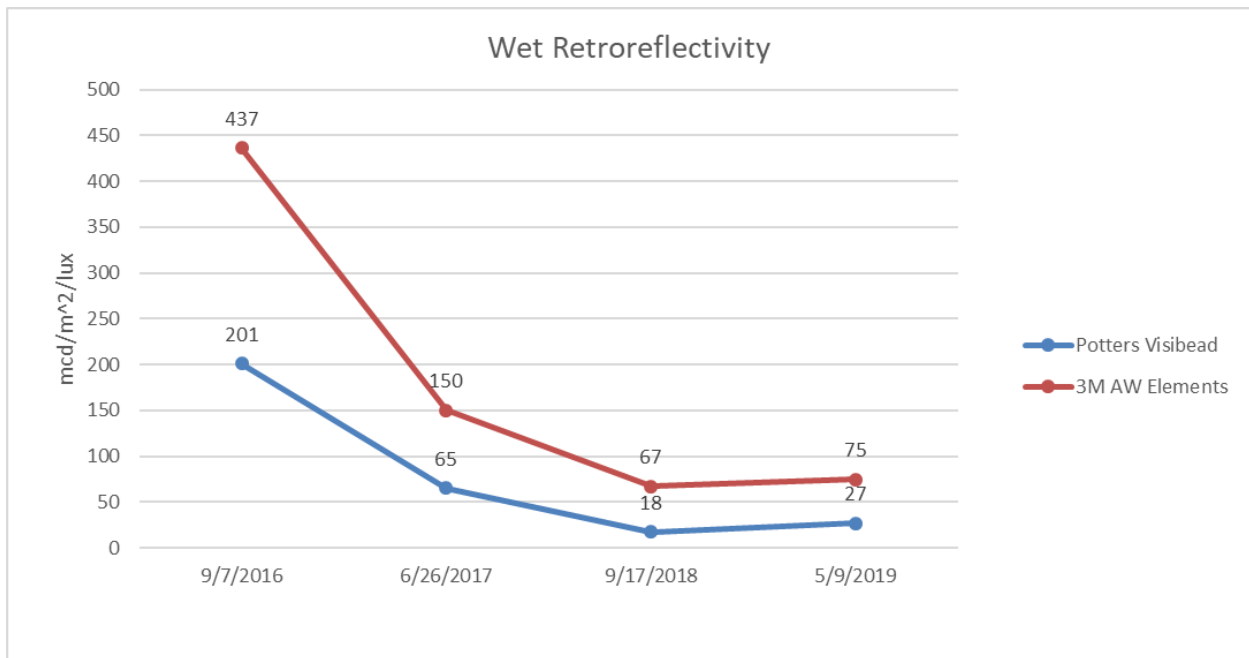
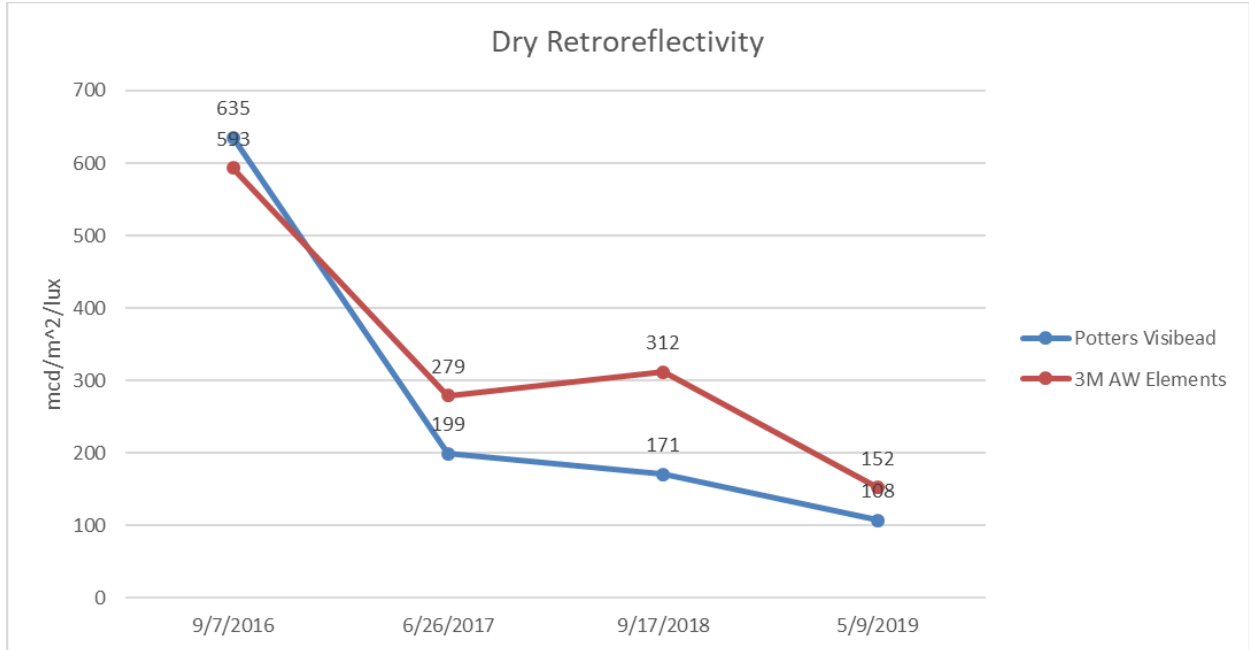


Photo 11 & 12 – Damaged markings at RP 180.0 (3M AW Elements)

Conclusions

The initial data shows that the two wet-reflective pavement markings perform similarly. In the first year, the 3M AW markings have higher wet-reflective properties, but by year 2, both marking types have very little wet-reflective properties left. The dry-reflective properties in year 3 retained approximately 50% of the reflectivity values from year 2. While the dry-reflective values of the 3M AW Elements / Potters Visibead markings were comparable to that of the dry-reflective blends, the dry values for 3M AW Elements were approximately 1.4x that of Potters Visibead at the end of the annual evaluations. The wet-reflective values for 3M AW Elements were approximately 2.8x that of Potters Visibead at the end of the annual evaluations. The comparison values can be seen in the chart / graphs below:

	9/7/2016		6/26/2017		9/17/2018		5/9/2019	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Potters Visibead (w/ Slow Cure Epoxy)	635	201	199	65	171	18	108	27
Ratio initial	1	1	0.31	0.32	0.27	0.09	0.17	0.13
Retro loss ratio compared to prev. yr			0.69	0.68	0.14	0.73	0.37	-0.54
3MAW Elements(w/ Slow Cure Epoxy)	593	437	279	150	312	67	152	75
Ratio initial	1	1	0.47	0.34	0.53	0.15	0.26	0.17
Retro loss ratio compared to prev. yr			0.53	0.66	-0.12	0.55	0.51	-0.11
= 3MAW Elements vs. Potters Visibead	0.9	2.2	1.4	2.3	1.8	3.8	1.4	2.8



The durability of the wet-reflective pavement markings is somewhat lacking due to conglomerate optic bead sizing. The loss attributed to the snowplows can be present as embedded bead loss, bead shearing at the top of groove, and total marking material loss. The bead loss / shearing is difficult to quantify due to traffic level safety concerns while the overall pavement marking condition is visually assessable. The 3M AW Elements markings performed better after several winters compared to Potters Visibead, but both pavement markings did not stand up as well as typical pavement marking sections. While visually inspecting the project corridor, there were sections which were lacking the pavement markings completely (though these sections did not fall on our RP test locations for retroreflectivity values). While the dry-reflective values were nearing the 100 mcd/m²/lux threshold value which MUTCD states as the minimum value of retroreflectivity for longitudinal markings on roads \geq 55mph, the current condition of total presence loss on certain segments along the project corridor warranted the replacement for safety reasons.