Montana Department of Transportation
Research Programs
May 2016

EXPERIMENTAL PROJECTS CONSTRUCTION AND EVALUATION REPORT

CENTERLINE CONTRAST STRIPING AND THE ADDITION OF HIGH-VISIBILITY STRIPING MATERIAL FOR ADDED CONSPICUITY IN NIGHTTIME AND WET DRIVING CONDITIONS

Location:	Missoula/Missoula County: North Reserve St. Highway 93 (N 92) – Reference Point 0.0-5.4
Project Name:	Pavement Markings – Reserve St.
Project Number:	NH 92-1(12)0
Experimental Project No.	MT-14-07
Type of Project:	Enhanced Pavement Markings
Principal Investigator:	Craig Abernathy: Experimental Project Manager (ExPM)
Technical Contact:	Gabe B. Priebe, P.E.: Traffic Project Engineer
Date of Installation:	September 2015

Description

Human vision is tuned to detect edges of contrasting color or brightness. Concrete pavements are so light in color that during the day and at night (especially during wet conditions), white pavement markings appear to blend in with the pavement surface. To improve the visibility of pavement markings on light-colored pavements, markings are applied over the top of a compatible black marking material. The underlying black stripe is applied at a greater width than the actual marking so that it provides a contrasting border around the marking, basically to give the driver an increased preview distance.

This project will apply a white on black centerline boxed contrast epoxy stripe to portland cement concrete pavement (PCCP) within a diamond grind (recessed) groove. In addition; to add 3M Ceramic Elements and Visimax Plus striping beads to be blended with conventional Type 2 glass bead. The subject beads are claimed to provide increased retro-reflectivity and radiance during wet, nighttime conditions.

1. 3M Elements Reflective dual-optic beads (1.9 and 2.4 reflective-index bead blend) are microcrystalline ceramic beads embedded on a center core to provide added reflectivity for pavement markings under wet and rainy conditions, as described by the manufacturer.

2. The Potters VISIMAX Plus combines three to four times the diameters of conventional beads with high-clarity glass spheres coated with high index beads to allow for maximum retroreflectivity in wet conditions as described by the manufacturer.

Additional technical information on the products being tested may be found at:

Potters VISIMAX:

http://www.pottersbeads.com/hs/NorthAmerica/Products/VISIMAXVISIMAXPLUSHwySafetyMarkingSpheres.aspx

3M Reflective Elements:

http://multimedia.3m.com/mws/mediawebserver?mwsId=66666UgxGCuNyXTtoxMVlxT_EVtQEcuZgVs6EVs6E666666--&fn=Elements%20flyer.pdf

Experimental Design

Remove existing skip lane line by grind and install a 9/15 striping design (9' strip/15' gap) on a grooved centerline application.

Beads used on the project will be a blend consisting of 3M Reflective Elements and Type 2 glass beads, a blend consisting of Potters Visimax Plus and MDT Type 2 glass beads, and a control segment using MDT's standard application rate of Type 2 glass beads. The beads will be applied to 20 mil thick epoxy striping placed in a 140 mil +/- 10 mill groove in a grooved area 1-inch (25 mm**)** ± 1⁄8-inch (3 mm) wider and 4 inches (100 mm) ± 1-inch (25 mm) longer than the designed pavement marking within the groove.

This grooving schematic will allow the use of a white on black contrast bordered epoxy stripe. Only the white stripe will receive the standard glass beads and added wet reflective materials by a double drop application.

The blend ratio of retro-reflective elements to MDT Type 2 glass beads will be established based on supplier recommendations. The project parameter will be limited to the lane skip lines.

The following is a detailed breakout of the project sections and bead proportions:

Section 1: RP 0.0 to RP 1.82	10 lbs. per gallon Visimax Plus Elements
	10 lbs. per gallon Type 2 Glass Beads in accordance with Section 620
***Section 2**: RP 1.82 to RP 3.64	6 lbs. per gallon 3M Wet Reflective Ceramic Elements
	20 lbs. per gallon Type 2 Glass Beads in accordance with Section 620
Section 3: RP 3.64 to RP 5.40	25 lbs. per gallon Type 2 Glass Beads in accordance with Section 620

*Due to a scheduled lane reconfiguration between River Rd and. Mullan Rd. (RP 2.72-3.37) located in section 2 (see layout diagram page 20). Applying a recessed groove would not be practical at this time. The decision was made to apply contrast striping without a recess grind and only type 2 glass beads.

Evaluation Procedures

Research will document the installation for best practice and any constructions concerns germane to the performance of the striping placement. Semi-annual inspections will report on markings durability and any other measurable outcomes.

Additional site inspections may supplement the semi-annual visits based on need. Monitor and report on long-term performance. Documentation of actual nighttime wet-rainy/dry conditions may supplement the reporting. Before and after safety data will be added to the report as that becomes available.

Construction Documentation: Will include information specific to the installation events of the pavement markings.

Post Documentation: Will entail semi-annual visual inspections of the pavement marking durability.

The purpose of an in-service experimental features report is to document the phases and events of any given project to gain the reader an understanding of the overall activities required to install or incorporate the research element into an active construction or maintenance project. This report also establishes a baseline for defining performance for any given feature under actual conditions to determine its relative merits.

This report and other information may be found at:
http://www.mdt.mt.gov/research/projects/bead_technology.shtml

Evaluation Schedule

Research will monitor performance for a minimum period of five years annually, with every year up to ten years (informally). This is in accordance with the Department's "Experimental Project Procedures". Delivery of a construction/installation report, interim, annual or semi-annual reports is required as well as a final project report (responsibility of Research).

2015:	Installation/Construction Report
2016-2019:	Semi-Annual Inspections/ Annual Evaluation Reports
2020:	Final Evaluation/Final Report

Initial Remarks (September 2015)

Several application issues have been identified by District staff and will be highlighted in the Issues section of this report (page 11). Specifically:

-Overspray of the white stripe (lack of well-defined delineation between white to black stripe).
-Pavement markings applied outside of the recess grind (mainly associated with the white epoxy strip).
-Apparent uneven bead distribution of the Visamax Plus Spheres to the white epoxy stripe (Section 1).

The District will present these issues to the contractor and determine if remedial actions may be required and to what extent. If a corrective action is required this report will be updated to that effect.

With in-service evaluations such as this project, it may be difficult to quantitatively determine if these issues may affect the short or long term efficacy of the contrast striping and/or bead effectiveness.

Performance to Date (May 2016)

District staff reported that, soon after installation, delamination (or debonding) of the epoxy white stripe to the black underlying stripe was being observed. Research was informed of the stripe durability issue and conducted a site inspection in late February 2016; the inspection was then followed up with another inspection in late March 2016.

The main failure characteristic was a delamination (or debonding) of the white stripe from the black stripe. Field observations show the white epoxy stripe being removed in flakes or chunks by vehicle tire contact. Specifically, the current areas with the most affected contrast stripes are intersections with a high level of traffic coupled with turning movements that offer the greatest contact with tire to stripe.

As observed, a vehicle (i.e. making a right, or left turn on to the two-lane) will sometimes overcorrect and make contact with the center stripe or move to the outer travel lane crossing the center line. Some vehicles will change lanes progressing away from the intersection. The contrast stripe closest to the intersection has almost 100% complete removal of the top white stripe and varying percentage of loss of the top stripe further away from the intersection.

This currently is the main element of failure occurring on the project as noted to date. There are sections of the project, however, where top stripe delamination is transpiring in areas not associated with intersections. Conversely, there are intact contrast stripe sections on the project as well.

With approximately 10.5 centerline miles it is difficult to apply a value on the amount of total top-to-bottom-stripe delamination and to the varying partial stripe delamination on the project. During the inspection conducted on February 29, affected stripe (full or partial delamination) is estimated at 5%.

District staff in early May did conduct a thorough inventory of the project and has estimated 10% of the contrast stripe now exhibits the white stripe delamination from the black epoxy binder.

Even though the majority of the project contrast striping is intact, the current distress of the stripe due to this delamination may continue over time with the traffic, through this corridor, eventually impacting all areas of the project.

The mechanism of failure is unknown at this time. No issue during the epoxy stripe application phase of the project, which may be attributed to the contrast stripe durability, has been reported.

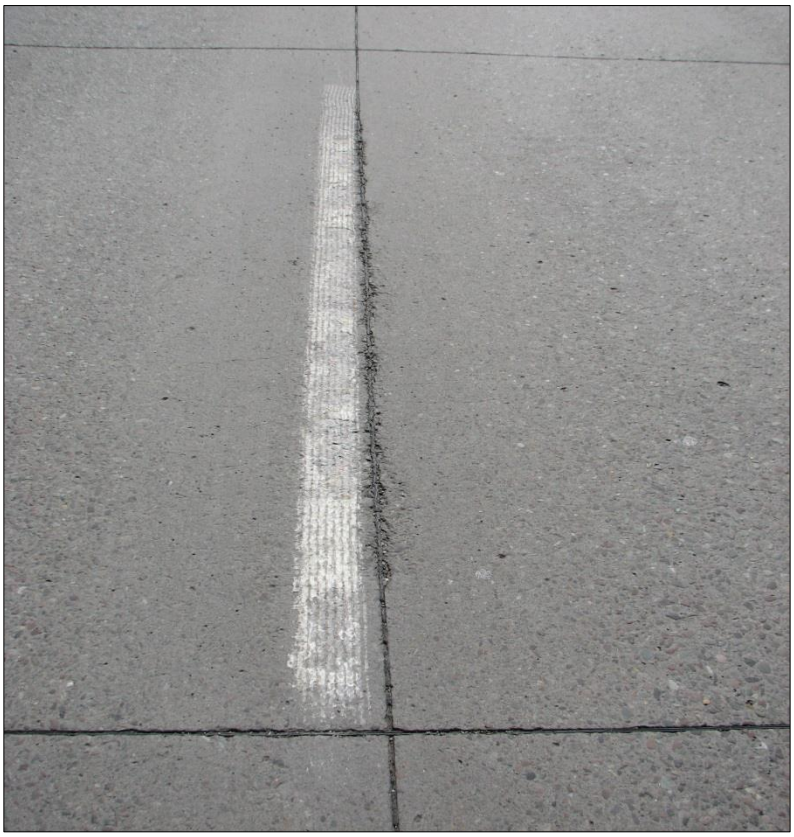
Assuming the contractor used compatible epoxies for the contrast stripe, adhesion of epoxy layers depends on adequate polymerization and/or a sufficient mechanical bond.

It was reported that the application time between the top and bottom layers averaged at twelve (12) hours. Others states' practice of employing contrast striping is to apply the top layer immediately after the bottom stripe is placed. Whether the break between layers may have introduced an element to deactivate the bonding process is difficult to quantify at this time.

Another item to note is currently, the black epoxy stripe appears to have a strong bond to the PCCP; and is intact throughout the project.

The following images are representative of the practice regarding the contrast striping installation and performance to date. Due to changes in the contractor's schedule, Research was unable to capture the actual striping phase.

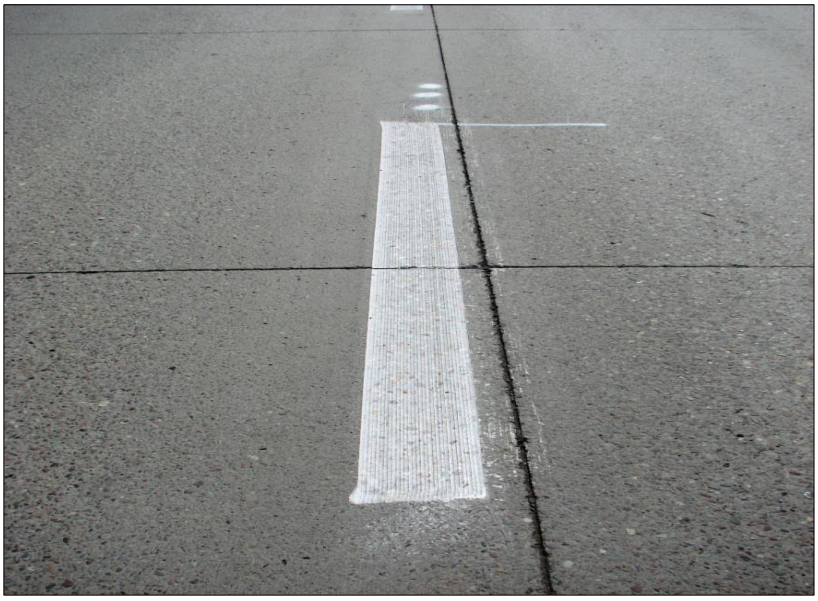
<u>September & October 2015 Project Images: Grinding Phase</u>



⬅⬇ Representative images of the existing stripe after the grinding phase.

Consistency of the amount stripe removed from pavement varied throughout the project.

🡸 Image of Highmark's Model 3-410 grooving truck used on the project.



🡸 Representative image of completed diamond grind groove.

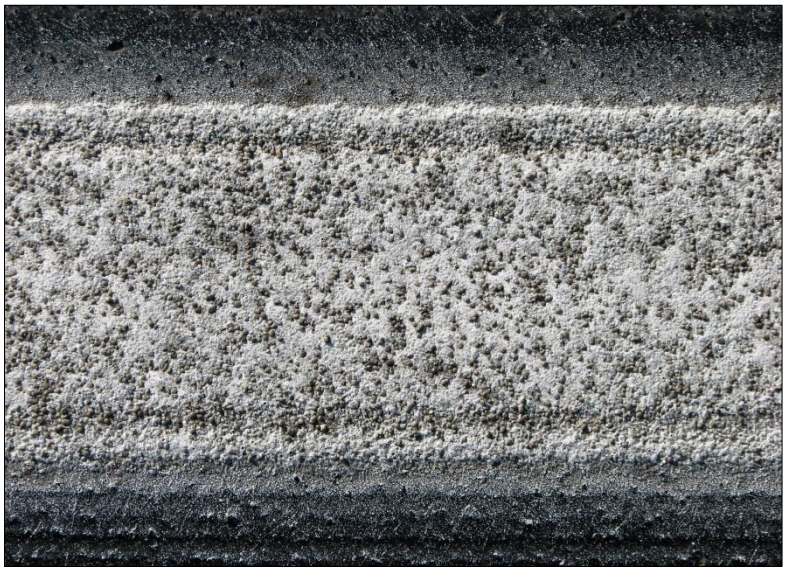
🡸 Close-up of diamond grind. Groove relief represents a quality cut and clean definition.

Completed Striping

⬆ General representation of completed white on black epoxy box contrast (9') stripe relative to all sections within the project.

Section Close-ups of Bead on Epoxy Stripe

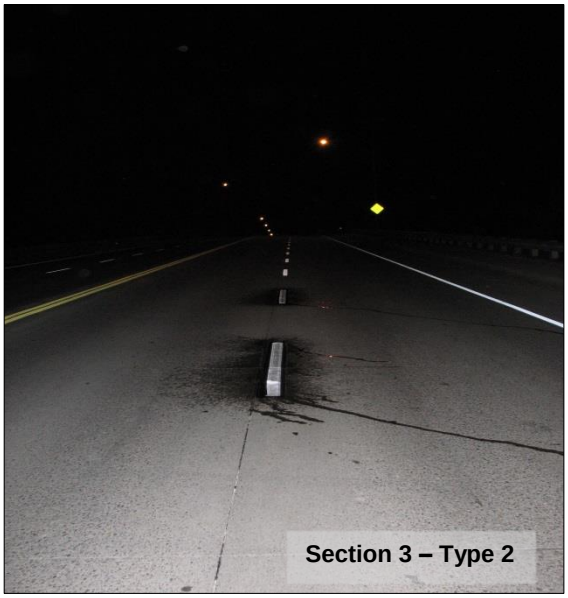
🡸 Section3: Type 2 Glass Bead (RP 3.64 – 5.40), Union Pacific St. to I-90.

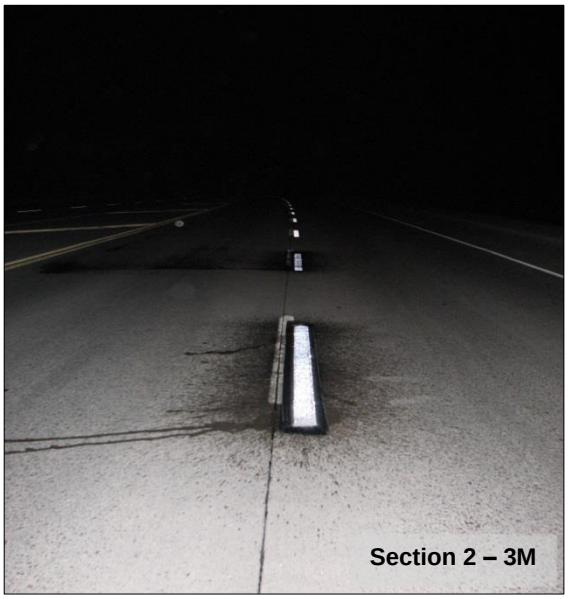


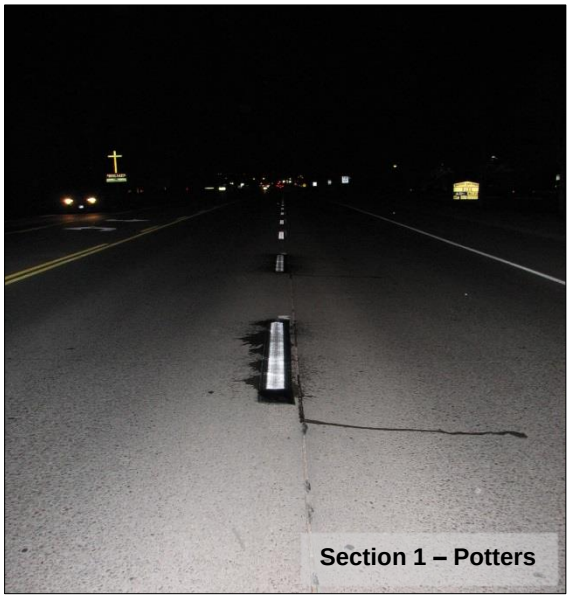
🡸 Section 2: 3M Reflective Elements (RP 1.82 – 3.64), Seventh St. to Union Pacific St.

🡸 Section1: Potters Visimax Plus (RP 0.0 – 1.82) Brooks St. to Seventh St.

Comparing Contrast of the Sections during Wet, Nighttime Conditions







🡸 🡻 The intent of incorporating the 3M & Potters marking materials in sections 2 and 1 was to improve driver conspicuity.

Based on their individual designs, these new marking additives, when blended with conventional beads, offer potential greater contrast from the target (the stripe itself) from its background as perceived from the driver's perspective during wet and nighttime conditions.

What you see in these images was the (simplistic) attempt to compare each treatment by wetting down several of the skips during darkness with the vehicle lights aimed directly center of the travel lane approximately 100' behind the skips.

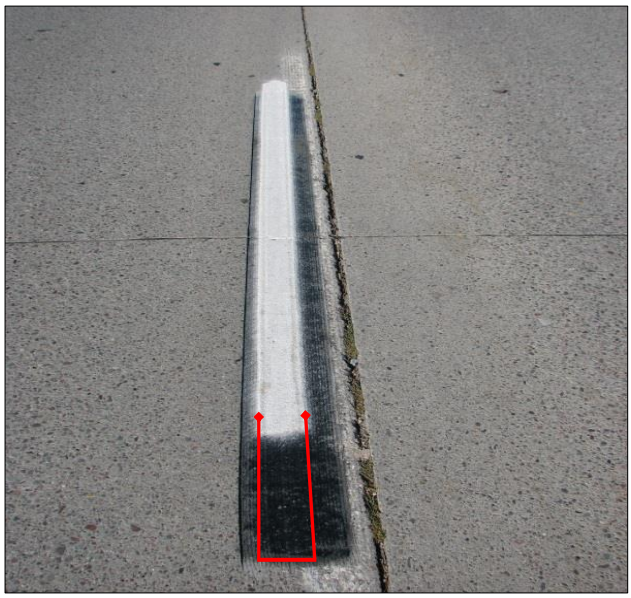
The top image is section 3 using only type 2 glass beads. A coating of water on type 2 beads has a reduced effect on retroreflectivity.

Although subjective, sections 2 & 1, with the added wet reflective material, appear visually to have greater luminesce than the control section 3.

Installation Issue: White Epoxy Overspray

⬅⬇ Representative images of overspray of the white stripe to underlying black stripe which may reduce clarity of the contrasting colors.

Installation Issue: Poor Pavement Marking Alignment to Prepared Groove



⬅⬇ Sample images of poor calibration during striping phase.

Some installations both stripes missed the recessed groove and in other skips the white stripe extended beyond the groove.

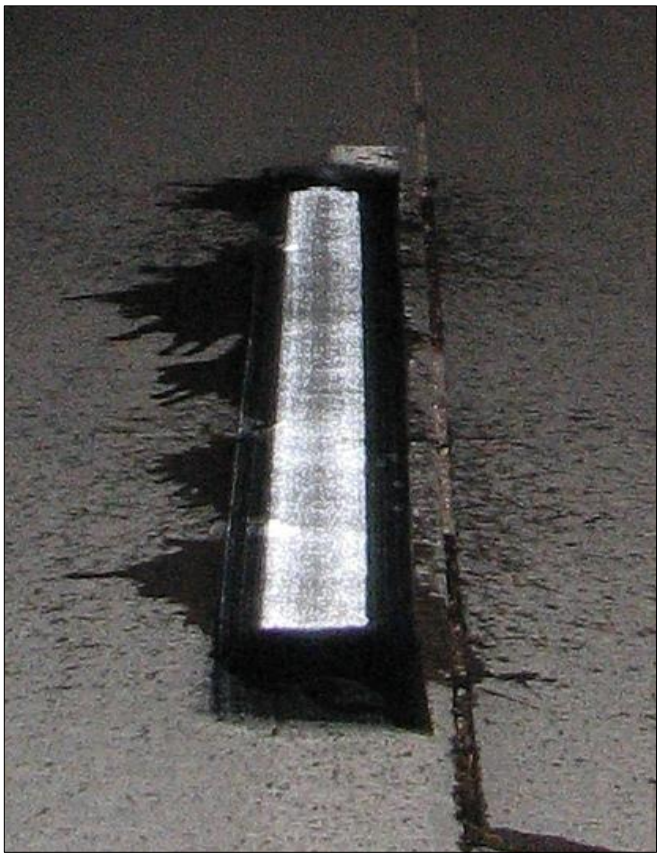
In addition, the contractor had a difficult time keeping the top stripe aligned equal side distance on the base stripe (center image example).

As compared to the total number of skip markings to the project, these anomalies of practice are statistically small but to a level of occurrence that requires documentation.

Installation Issue: Inadequate Bead Distribution - Potters Visimax: Section1

- By visual examination, Visimax bead population distribution was applied at a higher percentage near the edges of the stripe than the interior. Also, due to this edge clustering, may not have adequately embedded the bead to the binder and possibly will be a performance issue in the future.

Supplemental: Effect of Poor Bead Distribution on Wet/Nighttime Luminosity



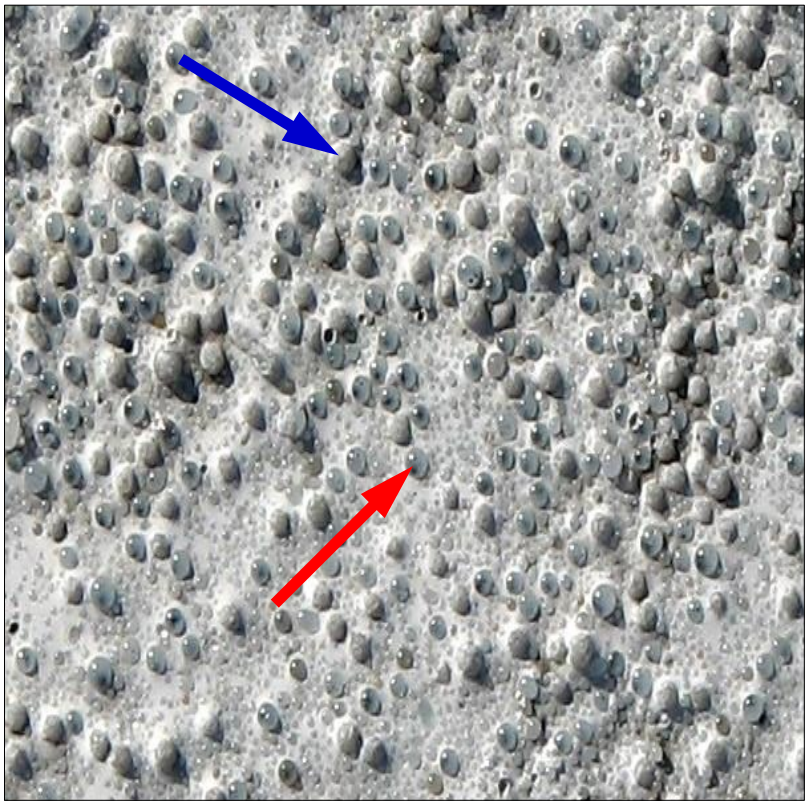
Section1-Potters Visimax: The top image was a skip line taken at night with water poured within the recessed groove.

As shown, the darker shade, predominantly through the center of the white stripe, is due to an inadequate distribution of the Visimax beads. This is compared to the edges of the stripe, which display greater luminosity.

The lower image is a sample of the bead distribution within the stripe.

This may be an indication of improper calibration of the bead gun.

Close-up Description of Experimental Pavement Marking Reflective Beads



🡸 Visimax Plus Blended Beads:

The blend consist of larger type 4 beads (red arrow).

The blue arrow denotes spheres that have thousands of high index beads laminated to an outer shell.

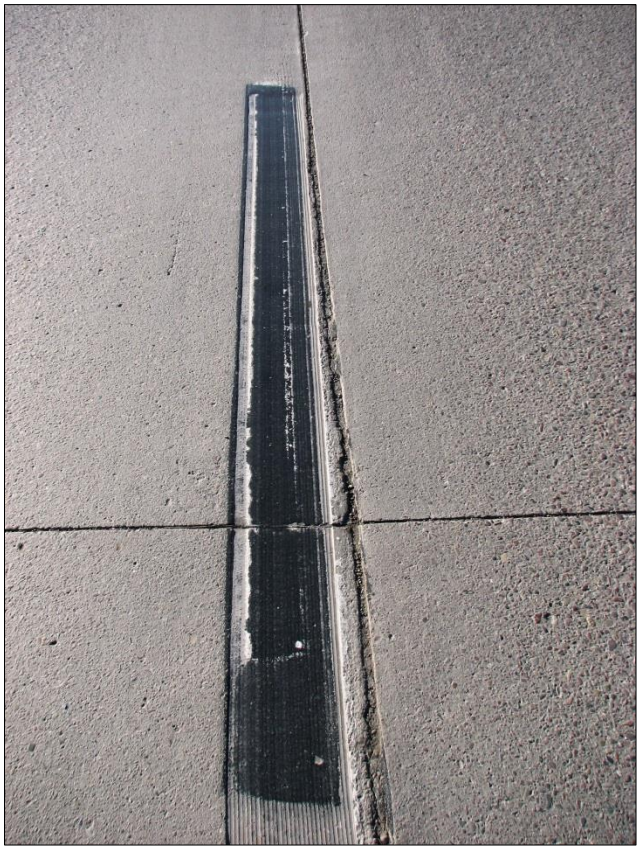
The proportion of blend with Type 2 beads is approximately 50/50.

🡸 3M Reflective Elements:

The elements consist of microcrystalline ceramic beads embedded on a center core (red arrow).

The proportion of blend with Type 2 beads is approximately 30/70.

Post Documentation: Late February & March 2016



← Representative image of the contrast stripe with almost 100% of the top white stripe removed.

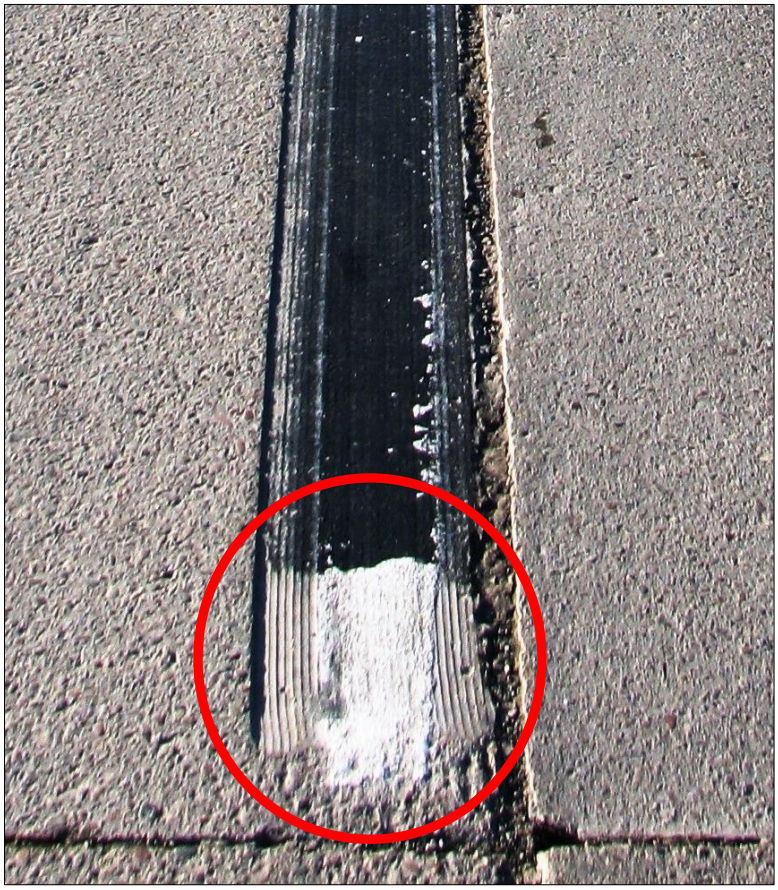
← Southbound of South St. – View North: About 14 skips lacking white stripe.

🡸 Close up of partial white to black epoxy binder delamination.

🡸 In observing actual traffic driving over the contrast striping, this section was seen to pop off as a vehicle tire drove over it.

The underlying black epoxy was smooth to the touch, as well as the underside of the white epoxy.

No indication of mechanical bond was evident.



⬅ Contrast stripe with complete removal of top layer, note the white epoxy remains adhered to the grooved pavement (red circle).

⬅ As stated previously in the report, the majority of the project contrast striping is intact. However, due to the current performance trend the delamination issue may continue.

Supplemental

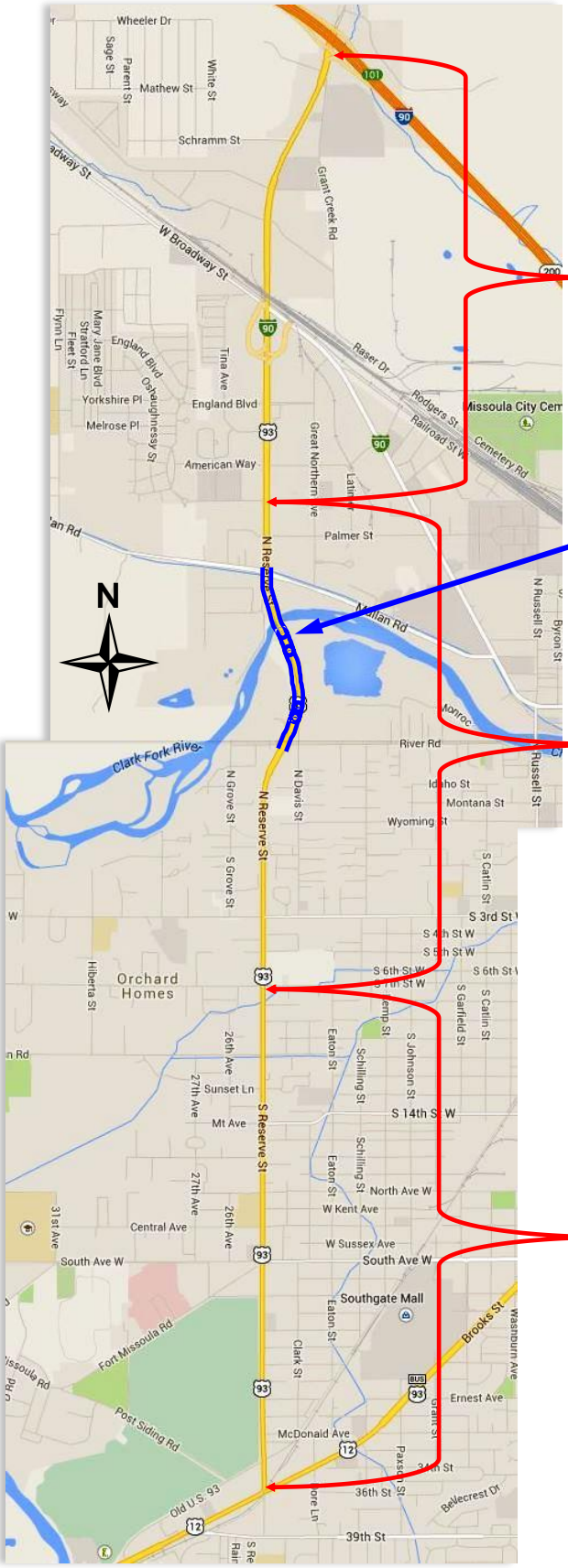
← Image of pop-out of entire contrast stripe from grooved concrete pavement.

Location: Southbound lane; south of Schramm St. adjacent to the Marriot Courtyard Hotel.

This was the only full removal of stripe located on the project as of March 2016.

←Pop-out closer view.

*Experimental Project Sections: Missoula/Reserve St. /NH 92-1(12)0 – RP 0.0-5.40



Note: All sections received white on black contrast epoxy striping within an average grove depth of 140 mils except the blue section.

Section 3 - Control: Type 2 Glass Bead – Reference Point 3.64 (Union Pacific St.) to 5.40 (Interstate 90).

Blue Section: From Reference Point 2.72 (River Rd.) to 3.37 (Mullan Rd.) – Contrast striping without recessed groove. Only Type 2 beads applied.

Section 2: 3M Wet Reflective Ceramic Elements: Reference Point 1.82 (Seventh St.) to 3.64 (Union Pacific St.).

Section 1: Potters Visamax Plus Elements: Reference Point 0.00 (Brooks St.) to 1.82 (Seventh St.).

*Not to Scale: All values are approximate

Disclaimer

The use of a product and/or procedure in the course of an evaluation does not constitute an endorsement by the Department nor does it imply a commitment to purchase, recommend, or specify the product in the future.

Data resulting from the project is public information and will not be considered privileged. The MDT may, at its discretion, release all information developed during and after the evaluation.