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14. Supplementary Notes			
15. Abstract Purpose and Need The NDDOT has begun to use water-borne pavement marking paints instead of solvent-borne paints. The NDDOT desires to compare the performance of different water-borne products to the performance of solvent-borne paints. Objective To compare the performance and cost-effectiveness of different types of pavement marking paint. Scope Test sections were constructed on ramp sections with similar traffic counts and were located on both asphalt and portland cement concrete (PCC) pavement surfaces. The striping test section installed on concrete was located on the northwest ramp of the intersection of I-94 and Centennial Road. The striping test section installed on asphalt was located on the northeast ramp of the intersection of I-94 and Hwy 83 in Bismarck. The types of pavement marking paints tested were: water-borne acrylic latex (E-2706) - white and yellow, water-borne acrylic latex (E-3427) - white and yellow, and solvent-borne - white and yellow. The test sections were evaluated after approximately 26, 66, and 261 days of exposure to traffic. The test sections were evaluated for appearance, resistance to wear, and retroreflectivity on the final evaluation. The different paints were also evaluated for relative cost of application. Summary Test stripes located on PCC Pavement Observations during the first evaluation indicated that the yellow latex E-3427 paint appeared to be performing better on a PCC surface when compared to the yellow latex E-2706 paint. However, by the second evaluation, (approximately 66 days after installation), both the E-2706 and E-3427 paint were worn away. During the third evaluation, (approximately 261 days after installation), only traces of the striping were observed near the edges of the pavement. Test stripes located on AC Pavement At the second evaluation, (approximately 66 days after installation), the test stripes containing the two water-borne paint systems and the solvent-borne paint system were still performing moderately well. Although all of the paint systems were showing signs of wear and fading, it appeared that there was no significant difference in performance between any of the paint systems. At the third evaluation, (approximately 261 days after installation), all systems continue to show wear and fading. Members of the research team commented that the roughness of the asphalt surface contributed to the better performance of all paint systems. Recommendations Given the benefit of a slight increase in wearability over the yellow latex E-2706 paint, it is doubtful whether the latex E-3427 paint would warrant any decrease in the frequency of striping operations. Also as previously mentioned the cost of the E-3427 material was more per gallon than the E-2706 material. At this point, it is would not be advantageous to replace the E-2706 paint system currently used on North Dakota projects with the latex E-3427 paint system.			
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**NORTH DAKOTA
DEPARTMENT OF TRANSPORTATION**

**MATERIALS AND RESEARCH
DIVISION**

Experimental Study MR 98-01

Evaluation of Water-Borne Pavement Marking Paints

Final Report

October 2001

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Disclaimer

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Evaluation of Water-Borne Pavement Marking Paints

Objective

To compare the performance and cost-effectiveness of different types of pavement marking paint.

Scope

In order to achieve the objective, several different types of pavement marking paints were applied to two test sections.

The types of pavement marking paints tested were:

1. Water-borne acrylic latex (E-2706) - white and yellow
2. Water-borne acrylic latex (E-3427) - white and yellow
3. Solvent-borne - white and yellow

The water-borne acrylic latex (E-3427) is a new product manufactured by Rohm-Haas.

The pavement marking test sections were located on both asphalt and portland cement concrete (PCC) pavement surfaces.

A total of 24 stripes were applied at each test section (four of each type and color). Of the four test stripes installed, two of the stripes received an application of glass beads. The test stripes were aligned perpendicular to the oncoming traffic.

The test sections were constructed on ramp sections with similar traffic counts. A layout of the test deck is shown on the following page.

Location

The striping test section installed on concrete is located on the northwest ramp of the intersection of I-94 and Centennial Road. The striping test section installed on asphalt is located on the northeast ramp of the intersection of I-94 and Hwy 83 in Bismarck.

Paint Test Deck
Applied 9-24-98
Flex-o-lite 70/30 dual coated beads - Brite Blend
East Bismarck Interchange
NW quadrant - on ramp - concrete Surface
From east to west:
(2) stripes E-3427 w/o beads - white
(2) stripes E-3427 w/beads - white
(2) stripes E-2706 w/o beads - white
(2) stripes E-2706 w/beads - white
(2) stripes E-3427 w/o beads - yellow
(2) stripes E-3427 w/beads - yellow
(2) stripes E-2706 w/o beads - yellow
(2) stripes E-2706 w/beads - yellow
(2) stripes solvent borne w/o beads - white
(2) stripes solvent borne w/beads - white
(2) stripes solvent borne w/o beads - yellow
(2) stripes solvent borne w/beads - yellow
US 83 & I 94 Interchange
NE quadrant - off ramp - asphalt surface
From west to east:
(2) stripes E-3427 w/o beads - white
(2) stripes E-3427 w/beads - white
(2) stripes E-2706 w/o beads - white
(2) stripes E-2706 w/beads - white
(2) stripes solvent borne w/o beads - white
(2) stripes solvent borne w/beads - white
(2) stripes E-3427 w/o beads - yellow
(2) stripes E-3427 w/beads - yellow
(2) stripes E-2706 w/o beads - yellow
(2) stripes E-2706 w/beads - yellow
(2) stripes solvent borne w/o beads - yellow
(2) stripes solvent borne w/beads - yellow

Construction

On September 24, 1998 two pavement marking test sections were installed. Traffic Safety Services Inc (TSS) applied all of the water-borne paint and NDDOT maintenance forces applied the solvent-borne paint.

Test Stripes on PCC Pavement

Photo 1 depicts TSS applying the latex E-3427 and the glass beads. The method used to apply the glass beads resulted in uneven application.



Photo 1 - Contractor applying white latex E-3427 paint stripes followed by glass beads. Stripes installed on PCC surface.

Photo 2 depicts NDDOT maintenance forces applying white solvent-borne paint followed by the glass beads. Maintenance force's method of applying the glass beads resulted in a more uniform distribution. The beads used for this experimental project were Flex-o-lite 70/30 dualcoated beads - Brite Blend.



Photo 2 - Maintenance forces applying white solvent-borne paint stripes followed by glass beads. Stripes installed on PCC surface.

Photo 3 shows eight test stripes located in the concrete test section taken immediately after construction. The four yellow stripes on the left side of the photo are painted with solvent-borne paint and the four white stripes on the right are painted with solvent-borne paint. For each set of four stripes the left two stripes has an application of glass beads.



Photo 3 - Eight test stripes on concrete test section. Four yellow solvent-borne paint stripes (left side). Four white solvent-borne paint stripes (right side).

Photo 4 depicts the middle eight stripes located in the same concrete test section taken immediately after construction. The four yellow stripes on the left side of the photo are painted with latex E-2706 and the four yellow stripes on the right are painted with latex E-3427.



Photo 4 - Middle eight stripes on concrete test section. The four yellow latex E-2706 stripes (left side). Four yellow latex E-3427 stripes (right side).

Photo 5 depicts the final eight test stripes located in the concrete test section taken immediately after construction. The four white stripes on the left side of the photo are painted with latex E-2706 and the four white stripes on the right are painted with latex E-3427. The latex E-2706 was applied too heavy because the contractor was having problems with the sprayer.



Photo 5 - Final eight test stripes on concrete test section. Four white latex E-2706 stripes (left side). Four white latex E-3427 stripes (right side).

Test Stripes on AC Pavement

Photo 6 depicts eight white test stripes applied to an asphalt pavement. This photo was taken immediately after construction. The four stripes on the left side of the photo are painted with latex E-3427 and the four on the right are painted with latex E-2706. For each set of four stripes, the right two stripes, have an application of glass beads.



Photo 6 - Four latex E-3427 stripes (left side). Four latex E-2706 stripes (right side). Stripes installed on AC surface.

Photo 7 depicts the middle eight stripes located in the same asphalt test section taken immediately after construction. The four white stripes on the left side of the photo are painted with solvent-borne paint and the four yellow stripes on the right are painted with latex E-3427. Notice on the yellow latex stripes the excess application of beads.



Photo 7 - Middle eight stripes of asphalt test section. Four white solvent-borne paint stripes (left side). Four yellow latex E-3427 stripes (right side).

Photo 8 depicts the final eight test stripes located in the asphalt test section taken immediately after construction. The four yellow stripes on the left side of the photo are painted with solvent-borne paint and the four yellow stripes on the right are painted with latex E-2706.



Photo 8 - Final eight test stripes on asphalt test section. Four yellow solvent borne paint stripes (left side). Four yellow latex E-2706 paint stripes (right side).

Evaluation

Personnel from the NDDOT have evaluated the test stripes on three separate occasions. The first evaluation was conducted on October 10, 1998. The initial report detailing the findings of the first evaluation was published in November of 1998. The second evaluation was conducted on November 23, 1998. The interim report was published in January of 1999. The third (final) evaluation was conducted on June 11, 1999. Photos from the first, second, and third evaluation are presented for comparative purposes.

Test Stripes on PCC Pavement - (White Water-Borne Materials)

The first, second, and third evaluations were conducted after approximately 26, 66, and, 261 days of exposure to traffic. Photo 9, (taken during the first evaluation), depicts the four latex E-2706 stripes (left hand) and the four latex E-3427 stripes on the concrete pavement 26 days after installation.. The E-2706 material appeared to be holding up, however, the thick application rate, as previously mentioned, may have had some bearing on the performance. The latex E-3427 stripes also appeared to be in good condition.



Photo 9 - First evaluation of stripes on concrete test section. 26 days after installation. Four white latex E-2706 (left), and four white latex E-3427 (right) test stripes.

Photo 10, (taken during the second evaluation), depicts the same test stripes approximately 66 days after installation. The white latex E-2706 and the E-3427 material have completely worn away except near the edges of the PCC pavement.



Photo 10 - Second evaluation of E-2706 (left), and E-3427 (right), white latex test stripes. 66 days after installation.

Photo 11, (taken during the third evaluation), depicts the test stripes approximately 261 days after installation. The photo indicates that only minor traces of the white latex E-2706 and the E-3427 material remain near the edges of the PCC pavement.



Photo 11 - Third evaluation of E-2706 (left), and E-3427 (right), white latex stripes. 261 days after installation.

Test Stripes on PCC Pavement - (Yellow Water-Borne Materials)

Photo 12 (during the first evaluation), depicts the yellow latex E-2706 (left four stripes) and the yellow latex E-3427 stripes in the PCC pavement 26 days after installation. During this time the E-3427 (right) material appeared to be performing better than the E-2706 (left) material.



Photo 12 - First evaluation of stripes on concrete test section. 26 days after installation. Four yellow latex E-2706 (left), and four yellow latex E-3427 (right) test stripes.

Photo 13, (during the second evaluation) depicts the test stripes approximately 66 days after installation. As with the white water-borne materials, both the yellow latex E-2706 and the yellow latex E-3427 material have completely worn away except near the edges of the PCC pavement.



Photo 13 - Second evaluation of E-2706 (left), and E-3427 (right), yellow latex test stripes. 66 days after installation.

Photo 14, (taken during the third evaluation), depicts the test stripes approximately 261 days after installation. The photo indicates that only minor traces of the yellow latex E-2706 and E-3427 material remain near the edges of the PCC pavement.



Photo 14 - Third evaluation of E-2706 (left), and E-3427 (right), white latex test stripes. 261 days after installation.

Test Stripes on PCC Pavement - (White and Yellow Solvent-Borne Materials)

Photo 15, (taken during the first evaluation) depicts the solvent-borne yellow and solvent-borne white material as they appeared during the first evaluation. During this time it appeared that both of the paints were experiencing limited wear, however, some of the darker areas exhibited was mud stuck to the pavement surface. It was also apparent that the latex E-3427 material appeared comparable in performance to the solvent-borne material.



Photo 15 - First evaluation of yellow and white solvent-borne test stripes. 26 days after installation.

Photo 16, (taken during the second evaluation), depicts the test stripes approximately 66 days after installation. Both solvent-borne materials have completely worn away except near the edges of the pavement.



Photo 16 - Second evaluation of yellow and white solvent-borne test stripes. 66 days after installation.

Photo 17, (taken during the third evaluation), depicts the test stripes approximately 261 days after installation. The photo indicates that only minor traces of the solvent-borne material remain near the edges of the PCC pavement.

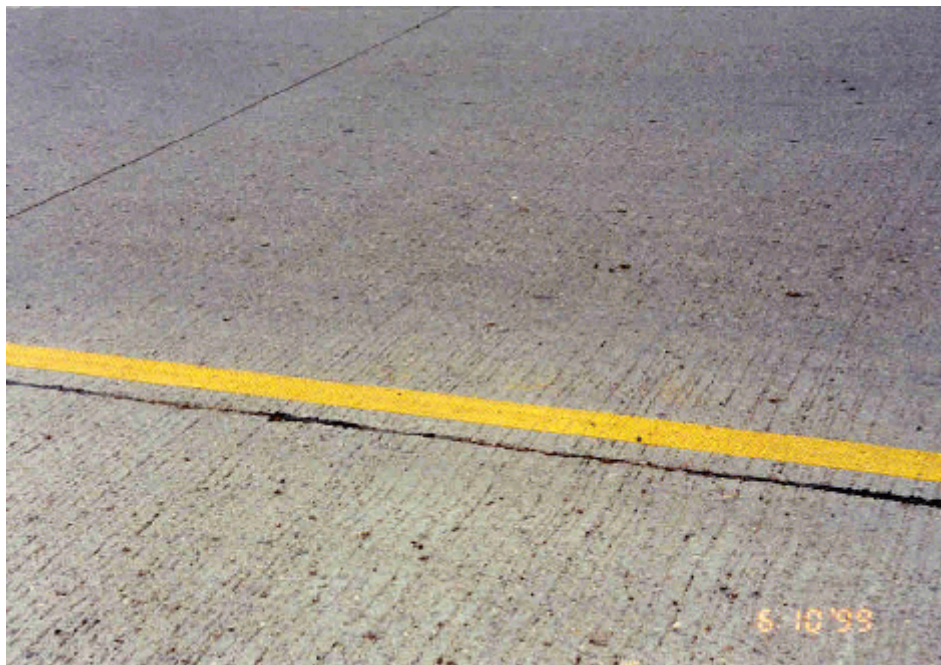


Photo 17 - Third evaluation of yellow and white solvent-borne test stripes. 261 days after installation.

Test Stripes on AC Pavement (Yellow Water-Borne and Solvent-Borne Material)

The first, second, and third evaluations were conducted after approximately 26, 66, and, 261 days of exposure to traffic.

Photo 18, (taken during the first evaluation), depicts a view of all of the yellow paint stripes in the asphalt test section 26 days after installation. Beginning from the left, the photo depicts the first four latex E-3427 stripes, the middle four latex E-2706 stripes, and the final four solvent-borne stripes. During this time it appeared, from a distance, there was no significant difference in performance from a wearing standpoint. However, upon closer inspection, the solvent-borne material exhibited isolated areas of wear on the tops of some of the larger aggregate chips more subject to traffic. The color of the solvent-borne yellow appeared to stand out slightly more than the both latex materials which appeared to fade.



Photo 18 - First evaluation of yellow paint stripes on the asphalt test section. 26 days after installation.

Photo 19, (taken during the second evaluation), depicts the test stripes approximately 66 days after installation. The photo indicates that although there is no significant difference in performance between the different paint systems; all of the yellow test stripes have begun to wear and fade.



Photo 19 - Second evaluation of yellow paint stripes on the asphalt test section. 66 days after installation.

Photo 20, (taken during the third evaluation), depicts the test stripes approximately 261 days after installation. The photo indicates that all yellow stripes can be observed. Ranking the materials by visual observation; (1) E-2706 latex stripes, (2) solvent-borne stripes, and (3) E-3427 latex stripes. Retroreflectivity readings were taken to compare the current condition of the paint systems. The data is included in Appendix A.



Photo 20 - Third evaluation of yellow paint stripes on the asphalt test section. 261 days after installation.

Test Stripes on AC Pavement (White Water-Borne and Solvent-Borne Material)

Photo 21, (taken during the first evaluation), depicts all of the white test stripes located on the asphalt section as they appeared approximately 26 days after installation. The photo depicts, beginning from the left, the first four latex E-3427 stripes, the middle four latex E-2706 stripes, and the final four solvent-borne stripes.



Photo 21 - First evaluation of white paint stripes on the asphalt test section. 26 days after installation.

The first evaluation indicated no significant difference in performance from a wearing standpoint. However, upon closer inspection, the solvent-borne material exhibited isolated areas of wear on the tops of some of the larger aggregate chips that are more subject to traffic.

Photo 22, (taken during the second evaluation), depicts the test stripes approximately 66 days after installation. The photo indicates that, (similar to the yellow materials on this test section), although there is no significant difference in performance between the different paint systems, all of the white test stripes have begun to wear and fade.



Photo 22 - Second evaluation of white paint stripes on the asphalt test section. 66 days after installation.

Photo 23, (taken during the third evaluation), depicts the test stripes approximately 261 days after installation. The photo indicates that all white stripes can be observed. Ranking the materials by visual observation; (1) E-2706 latex stripes, (2) solvent-borne stripes, and (3) E-3427 latex stripes.



Photo 23 - Third evaluation of white paint stripes on the asphalt test section. 261 days after installation.

Although initial retroreflectivity readings were not acquired, final readings were obtained during the third evaluation for the striping on the asphalt test section. This was done to obtain a relative ranking of the present condition of the striping. The complete data is included in Appendix A.

Cost

The cost of latex E-3427 paint is approximately \$0.40 to \$0.45 more per gallon than the latex E-2706.

Summary

Test stripes located on PCC Pavement

Observations during the first evaluation indicated that the yellow latex E-3427 paint appeared to be performing better on a PCC surface when compared to the yellow latex E-2706 paint. However, by the second evaluation, (approximately 66 days after installation), both the E-2706 and E-3427 paint were worn away.

During the third evaluation, (approximately 261 days after installation), only traces of the striping were observed near the edges of the pavement.

Test stripes located on AC Pavement

At the second evaluation, (approximately 66 days after installation), the test stripes containing the two water-borne paint systems and the solvent-borne paint system were still performing moderately well. Although all of the paint systems were showing signs of wear and fading, it appeared that there was no significant difference in performance between any of the paint systems.

At the third evaluation, (approximately 261 days after installation), all systems continue to show wear and fading.

Members of the research team commented that the roughness of the asphalt surface contributed to the better performance of all paint systems.

Recommendations

Given the benefit of a slight increase in wearability over the yellow latex E-2706 paint, it is doubtful whether the latex E-3427 paint would warrant any decrease in the frequency of striping operations. Also as previously mentioned the cost of the E-3427 material was more per gallon than the E-2706 material. At this point, it would not be advantageous to replace the E-2706 paint system currently used on North Dakota projects with the latex E-3427 paint system.

Appendix A

The analysis of the retroreflectivity readings, (obtained from stripes on the AC Test Section), indicates that, approximately 261 days after installation, the average retroreflectivity of the materials can be ranked as follows:

White Stripes:

Yellow Stripes:

1) E-2706 w/beads	70		1) E-2706 w/beads	38
2) E-3427 w/beads	31		2) E-3427 w/beads	19
3) E-2706 w/o beads	25		3) Solvent-borne w/beads	13
4) Solvent-borne w/beads	19		4) Solvent-borne w/o beads	10
5) E-3427 w/o beads	15		5) E-2706 w/o beads	9
6) Solvent-borne w/o beads	12		6) E-3427 w/o beads	7

In theory, the retroreflectivity reading obtained from striping w/o glass beads should be very low. The higher than expected reading obtained from the white E-2706 w/o glass beads stripes could be attributed to problems during application as referred to earlier in this report. Wind conditions during construction may have spread excess beads, thus contaminating adjacent stripes.

In general, these results appear to support the conclusion that the water-borne striping w/glass beads performs better than the solvent-borne striping w/glass beads, when used on asphalt surfaces.

Based on final retroreflectivity comparison of the stripes on the AC surface, the latex E-2706 paint w/glass beads remains more visible, (regardless of color), than the latex E-3427 paint.

Experimental Study MR 98-01 Evaluation of Water-Borne Pavement Marking Paints June 11, 1999 US 83 and I-94 Interchange - NE Quadrant-off-Ramp - Asphalt (West To East) Retroreflectorometer Readings											
Color	Paint Type (WB, SB)	Paint #	Stripe #, (Mirolux Location)	Glass Beads (Y/N)	Mirolux 12 Reading	Color	Paint Type	Paint #	Stripe #	Glass Beads (Y/N)	Mirolux 12 Reading
White	WB	E-3427	1-N	N	11	Yellow	WB	E-3427	13-N	N	0
"	WB	E-3427	1-C	N	0	"	WB	E-3427	13-C	N	2
"	WB	E-3427	1-S	N	25	"	WB	E-3427	13-S	N	15
"	WB	E-3427	1-AVG	N	12	"	WB	E-3427	13-AVG	N	5
"	WB	E-3427	2-N	N	8	"	WB	E-3427	14-N	N	4
"	WB	E-3427	2-C	N	3	"	WB	E-3427	14-C	N	2
"	WB	E-3427	2-S	N	40	"	WB	E-3427	14-S	N	17
"	WB	E-3427	2-AVG	N	17	"	WB	E-3427	14-AVG	N	5
"	WB	E-3427	3-N	Y	25	"	WB	E-3427	15-N	Y	1
"	WB	E-3427	3-C	Y	14	"	WB	E-3427	15-C	Y	4
"	WB	E-3427	3-S	Y	45	"	WB	E-3427	15-S	Y	40
"	WB	E-3427	3-AVG	Y	25	"	WB	E-3427	15-AVG	Y	15
"	WB	E-3427	4-N	Y	19	"	WB	E-3427	16-N	Y	2
"	WB	E-3427	4-C	Y	21	"	WB	E-3427	16-C	Y	8
"	WB	E-3427	4-S	Y	60	"	WB	E-3427	16-S	Y	57
"	WB	E-3427	4-AVG	Y	33	"	WB	E-3427	16-AVG	Y	22
"	WB	E-2706	5-N	N	16	"	WB	E-2706	17-N	N	1
"	WB	E-2706	5-C	N	18	"	WB	E-2706	17-C	N	2
"	WB	E-2706	5-S	N	42	"	WB	E-2706	17-S	N	24
"	WB	E-2706	5-AVG	N	25	"	WB	E-2706	17-AVG	N	9
"	WB	E-2706	6-N	N	11	"	WB	E-2706	18-N	N	1
"	WB	E-2706	6-C	N	17	"	WB	E-2706	18-C	N	4
"	WB	E-2706	6-S	N	45	"	WB	E-2706	18-S	N	21
"	WB	E-2706	6-AVG	N	24	"	WB	E-2706	18-AVG	N	8
"	WB	E-2706	7-N	Y	74	"	WB	E-2706	19-N	Y	27
"	WB	E-2706	7-C	Y	106	"	WB	E-2706	19-C	Y	12
"	WB	E-2706	7-S	Y	59	"	WB	E-2706	19-S	Y	76
"	WB	E-2706	7-AVG	Y	80	"	WB	E-2706	19-AVG	Y	38
"	WB	E-2706	8-N	Y	32	"	WB	E-2706	20-N	Y	23
"	WB	E-2706	8-C	Y	56	"	WB	E-2706	20-C	Y	13
"	WB	E-2706	8-S	Y	89	"	WB	E-2706	20-S	Y	76
"	WB	E-2706	8-AVG	Y	59	"	WB	E-2706	20-AVG	Y	37
"	SB	---	9-N	N	8	"	SB	---	21-N	N	5
"	SB	---	9-C	N	8	"	SB	---	21-C	N	2
"	SB	---	9-S	N	26	"	SB	---	21-S	N	21
"	SB	---	9-AVG	N	14	"	SB	---	21-AVG	N	8
"	SB	---	10-N	N	9	"	SB	---	22-N	N	4
"	SB	---	10-C	N	6	"	SB	---	22-C	N	1
"	SB	---	10-S	N	16	"	SB	---	22-S	N	25
"	SB	---	10-AVG	N	10	"	SB	---	22-AVG	N	10
"	SB	---	11-N	Y	11	"	SB	---	23-N	Y	2
"	SB	---	11-C	Y	13	"	SB	---	23-C	Y	3
"	SB	---	11-S	Y	44	"	SB	---	23-S	Y	30
"	SB	---	11-AVG	Y	23	"	SB	---	23-AVG	Y	12
"	SB	---	12-N	Y	8	"	SB	---	24-N	Y	6
"	SB	---	12-C	Y	5	"	SB	---	24-C	Y	5
"	SB	---	12-S	Y	29	"	SB	---	24-S	Y	28
White	SB	---	12-AVG	Y	14	Yellow	SB	---	24-AVG	Y	13

Paint Type: WB = Water-Borne
SB = Solvent-Borne

Stripe #: X
Mirolux 12 Location: X-N = North
X-C = Center
X-S = South