Evaluation and Comparison of
Cold Weather Waterborne Traffic Paint with XSR
Middlesex/Moretown VT 100B
Final Report

August, 2007

Report 2007 – 12
Reporting on Work Plan 2006-R-3

State of Vermont
Agency of Transportation
Materials and Research Section

Prepared by:

Kat Patterson
Transportation Researcher

Jennifer M. V. Fitch, EI
Research Engineer

Reviewed by:

William E. Ahearn, PE
Materials and Research Engineer

Date: August 29, 2007

TABLE OF CONTENTS

INTRODUCTION …… 1
PRODUCT DETAILS …… 1
PROJECT DETAILS …… 2
INSTALLATION …… 2
LABORATORY TESTING …… 4
SURVEILLANCE AND TESTING …… 4
WHITE EDGE LINES …… 9
YELLOW EDGE LINES …… 10
SERVICE LIFE …… 12
COST ANALYSIS …… 13
FINDINGS …… 14
REFERENCES …… 15

APPENDIX A …… 16
APPENDIX B …… 18
APPENDIX C …… 20
APPENDIX D …… 22

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
2007-12		

4. Title and Subtitle	5. Report Date
Cold Weather Waterborne Traffic Paint With XSR	July 2007
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Kat Patterson, Jennifer Fitch	2007- 12
9. Performing Organization Name and Address	10. Work Unit No.
Vermont Agency of Transportation Materials and Research Section National Life Building Drawer 33 Montpelier, VT 05633-5001	11. Contract or Grant No.
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Federal Highway Administration Division Office Federal Building Montpelier, VT 05602	Final (2006-2007)
	14. Sponsoring Agency Code

15. Supplementary Notes
Reporting on Work Plan 2006-R-3, Research Report 2006-7

16. Abstract
In an effort to extend the striping season, the Vermont Agency of Transportation applied an experimental pavement marking material, known as Cold Weather Waterborne Paint with XSR, to a preexisting roadway on VT 100B in the town of Moretown in October of 2006 when ambient air and pavement temperatures ranged from 28^{o}F to 48^{o}F with a dew point of 22^{o}F. In accordance with the manufacturer's specifications, the experimental marking material is reported to dry within 9 minutes at an ambient air temperature of 35^{o}F and rising.

Following the placement of the markings, data collection, including retroreflectivity and wear readings, was conducted using uniform methods. All of the white XSR marking and the majority of the yellow XSR markings were found to be in compliance with ASTM 6359, "Minimum Retroreflectance of Newly Applied Pavement Marking Using Portable Hand-Operated Instruments" which requires a minimum retroreflectivity of 250 mcdl for white marking and 175 mcdl for yellow markings within 14 days of application. While both traffic marking materials continued to decay as would be expected, the standard traffic markings decayed more readily with considerably lower retroreflectivity readings as compared to the experimental markings. During the spring of 2007, the retroreflectivity readings collected from the XSR substrate were twice that of the standard marking material.

In accordance with a cost analysis, the Cold Weather Paint with XSR was found to be more cost effective as compared to standard waterborne paint traffic markings. Overall, the application of Cold Weather Paint with XSR is recommended for late season striping when ambient air temperatures are below 50^{o}F.

17. Key Words	18. Distribution Statement
XSR Waterborne Paint Traffic Markings	No restrictions

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. Pages	22. Price
Unclassified	Unclassified	23	

INTRODUCTION:

Vermont's construction season typically ranges from five to eight months and specialty work, such as line striping, often occurs at the end of the construction season during the decline of ambient air temperatures. In accordance with the Vermont Agency of Transportation "2006 Standard Specifications for Construction", 646.04(c), during the application of waterborne paint markings, "the temperature of the surface to be painted shall be a minimum of 10^{o}C (50^{o}F) and the ambient air temperature shall be 10^{o}C (50^{o}F) and rising. As most residents are aware, the weather in Vermont is highly variable and often unpredictable. Ambient air temperatures towards the end of the construction season may not meet the requirements referenced within the specifications, making the completion of the application of pavement markings difficult. However, an experimental pavement marking known as Cold Weather Waterborne Traffic Paint with XSR, an acrylic resin, is reported to allow application at 35^{o}F and rising with a drying time of 9 minutes.

The following final report assesses the overall performance of an experimental cold weather waterborne paint marking material with XSR and standard waterborne traffic markings in terms of durability and retroreflectivity, otherwise known as luminance. This report also contains information related to the experimental method of placement and summarizes all surveillance and testing methods, data collection results and associated findings.

PROJECT DETAILS:

The Vermont Agency of Transportation's Traffic Shop personnel applied the Cold Weather Waterborne Traffic Paint, or experimental traffic markings, to VT Route 100B in Moretown, a two lane roadway with a posted speed limit of 50 mph and an AADT, or Average Annual Daily Traffic, of 2500. This location was selected by personnel from the Traffic Shop and the Materials and Research Section due to proximity from the Laboratory. Please note that all control and experimental pavement markings were applied over recently installed waterborne pavement markings that appeared to be in relatively good condition. Pavement markings were applied as shown with Table 1.

Cold Weather Paint with XSR Limits of Application				
	Mile Marker		Total	
Descrition	To	From	Miles	Notes
Experimental White Pavement Markings	1.50	7.50	6.00	Shoulder of the southbound lane
Experimental Yellow Pavement Markings	5.80	7.50	1.70	Both solid and skip lines
Control White Pavement Markings	6.20	7.50	1.30	Shoulder of the northbound lane

Table 1 - Installation Details

Please refer to Appendix A for layout of all experimental and control pavement markings. In accordance with the work plan and manufacturers specifications, the Traffic Shop applied a minimum thickness of 15 wet mils. This was proven to be an important variable in relation to dry time, as discussed below.

PRODUCT DETAILS:

According to the manufacturer, the Franklin Paint Company, Inc. from Franklin, Massachusetts and the associated MSDS, or Material Safety Data Sheet, the referenced waterborne traffic paint is a lead free and VOC compliant material. It is marketed as a fast drying paint marking material that can be applied at a minimum temperature of 35^{o}F and rising due to a particular polymer known as Rhoplex Fastrack ^{tm} XSR ^{tm}, which is manufactured by Rohm and Haas of Houston, Texas. Cold Weather Waterborne Traffic Paint is currently being produced in both white and yellow marking materials with a reported high level of durability and good retention of retroreflectivity. At 35^{o}F and a wet thickness of 15 mils, the marking material is expected to dry within 9 minutes.

INSTALLATION:

On November 3, 2006, personnel from the Materials and Research Section accompanied by the Painting Crew from the Traffic Shop observed the installation of the experimental marking material, or Cold Weather Waterborne Traffic Paint with XSR, and the control marking material, or standard waterborne paint. Application of the marking materials began at 9:45 AM to Route 100B in the town of Moretown at MM 7.5 in order to allow the pavement surface to dry properly prior to installation. The Paint Crew explained that there may be some residual standard waterborne paint residing within hoses and that it was suspected that there would be some mixing of the control and standard marking materials within the first ½ mile of application. This information was considered during the selection of test sites.

The Paint Crew did not perform any surface preparations to the roadway prior to installation, such as the removal of any dirt or debris. As stated previously, the recently applied preexisting waterborne pavement markings appeared to be in good condition with little wear from traffic. After following the installation of the experimental white marking material along the shoulder of the southbound lane, the Traffic Shop proceeded to apply the yellow experimental marking material. A control section, comprised of standard waterborne paint, was applied along the shoulder of the northbound lane. It is suspected that there may have been some mixing of the experimental and control traffic markings along this location.

Following application and proper dry time, the overall appearance of the experimental paint markings appeared to be much better in comparison to the standard waterborne paint as the cold weather paint retained a consistent texture and greater dry thickness.

Observations with regards to relative humidity, temperature, wet mil thickness and approximate dry time was recorded for both the experimental and control markings. It should be noted that while the associated Category II work plan called for a wet thickness of 15 mils, an uneven surface roughness prevented a consistent application. Actual wet thicknesses appeared to range from 10 to 20 mils. This will have an effect on the overall observed drying time as a lower-film-thickness line is expected to dry more quickly while a thicker line is known to dry more slowly. Please note however, that all wet mil thicknesses in relation to dry time were recorded. Table 2, depicting the relationships between marking type, dry time, ambient air temperature and relative humidity is provided below.

Field Drying Time of XSR and Standard Waterborne Paint VT Route 100B, Moretown							
Type of Paint	Color	Direction	Dry to Touch Time Minutes	Air Temperature Deg. F	Relative Humidity %	Pavement Temperature F	Comments
XSR MM 7.00 TS 1	Yellow	Center	13.5	48	31	40	Uneven pavement blotchy line
XSR MM 6.20 TS 2	White	SB	9	44	34	43	Smooth pavement, consistent thickness
XSR MM 5.7	White	SB	>30	38	33	28	Near graveyard Moretown Village
Standard Waterborne TS 4	White	NB	>25	46	33	42	Same location as TS 2 above

Table 2 - Field Drying Time for XSR and Standard Waterborne Paint

The information with regards to MM 5.7, in Table 1, was not a test site but rather an area that was selected in order to assess drying time in a shaded low lying area. Localized conditions that exacerbate drying time were specifically selected to determine the drying characteristics in less favorable conditions

In examining the Table 1, it is difficult to verify or refute the drying time specifications provided by the manufacturer. As stated above, the experimental markings are intended to dry within 9 minutes at an ambient air temperature of 35^{o}F and rising. Only the markings applied at Test Site 2 dried within 9 minutes, however the ambient air and pavement temperature were well above 35^{o}F. There are potential interferences to drying when ground temperatures are below the dew point. As shown in the table above, the surface of the pavement was consistently colder than the ambient air condition potentially causing condensation on the pavement surface resulting in increased drying time. It is promising though to compare the drying times of Test Site 2 and 4 as they were applied under similar ambient conditions with highly varying dry times. Additionally, the influence of direct sunlight is also reflected within the table as the cold weather paint took much longer to dry under shaded conditions

LABORATORY TESTING:

As stated within the work plan, several laboratory tests were conducted in order examine the material properties of the experimental pavement marking. For application purposes, it is important that the paint is light enough to flow readily and that the pigment is smooth enough as to not clog the painting apparatus. The assessment began with an examination of the pigment of the paint in accordance with ASTM D 1475, "Density of Liquid Coatings." The white pigmented paint was found to have a density of 13.76 lbs per gallon and the yellow pigmented paint was found to have a density of 13.45 lbs per gallon well within the specifications of 13.7 to 14.3 lbs per gallon for the white pigment and 13.3 to 13.9 lbs per gallon for the yellow pigment. In order to assess the viscosity of the traffic paint marking material with regards to potential clogging of spray nozzles, both the white and yellow paint was tested in accordance ASTM D 562, "Consistency of Paints Using the Stormer Viscometer." The white and yellow marking material was found to have a kinematic viscosity of 95 ku and 88 ku, respectively. This also met the viscosity specification of 78 to 95 ku which is universal for both colors of marking paint. Please see Appendix B and C for a copy of the laboratory testing results for the yellow and white marking paint, respectively.

In addition to an examination of the characteristics of the experimental materials, a third assessment was performed in accordance with ASTM D 711, "No Pick Up Time." This laboratory test seeks to evaluate the amount of time needed to fully cure under varying ambient conditions with consideration to temperature and humidity. Table 3, as provided below, contains a summary of results. Please note that this test was modified as the test specification calls for testing under the following conditions: an ambient air temperature between 70^{o}F to 77^{o}F and a humidity level between 45 to 55%.

Laboratory Drying Time of XSR Paint (ASTM D711.Mod.) VT Route 100B, Moretown			
Color	Temperature ^{o}F	Relative Humidity %	No-Pick-Up Time ASTM D711. Mod.
White	73	57	5.0 Minutes
Yellow	73	57	5.0 Minutes
White	46	45	9.5 Minutes
Yellow	46	45	9.0 Minutes
White	38	60	>20 Minutes
Yellow	38	60	18.5 Minutes
Yellow	58	69	15.0 Minutes

Table 3 – ASTM D 711.mod. Laboratory Tests

SURVEILLANCE AND TESTING:

A total of five test sites were established throughout the length of the project in order to collect retroreflectivity readings in accordance with ASTM E 1710-97, "Standard Test Method for Measurement of Retroreflective Pavement Marking Materials with CEN-Prescribed Geometry Using a Potable Retroreflectometer", and durability, in accordance with ASTM D 913-03, “Evaluating Degree of Resistance to Wear of Traffic Paint”. Each test site was established in an area with good sight distance on a straight away and consisted of a total length of 40 feet with data collection conducted at 10 foot intervals starting from the beginning of the test site. Each data collection location was identified with white marking paint along the shoulder of the driving lane in order to ensure that all future readings will be collected from the same location. Please note that Test Site 1 through 3, consist of readings collected on the experimental markings along the shoulder of the southbound lane and centerline markings and Test Site 4 and 5 consist of readings collected on the control markings along the shoulder of the northbound lane. Please refer to Appendix A for a layout of all test site locations.

Retroreflectivity readings and visual assessments were collected on a periodic basis through the summer of 2007 utilizing a LTL 2000 retroreflectometer which employs 30 meter geometry. Photographic documentation was also gathered at individual test site locations during each field visit. All retroreflectivity and durability readings were recorded onto the appropriate field forms and then compiled into a dedicated spreadsheet. The data collection process was carried out year round, including winter months when the ambient air temperature fell below the minimum temperature specified within the ASTM testing procedures of 40^{o}F. However, care was taken to maintain the testing equipment above the minimum specifications during travel and between test sites. Where warranted, the pavement markings were cleaned with a mixture of water and windshield washer fluid to remove any salt, dirt or other debris and then thoroughly dried prior to data collection in accordance with the “Protocol for the Cleaning of Line Striping to Test for Retroreflectivity.” A copy of the protocol is provided in Appendix D.

Initial site visits were conducted on November 3rd and November 9th, immediately and 6 days following application, respectively. All pavement markings were found to be intact. A summary of initial retroreflectivity readings are provided below in Table 4 and Table 5. Please note that most of the epoxy markings were not found to be in compliance with ASTM 6359, “Minimum Retroreflectance of Newly Applied Pavement Marking Using Portable Hand-Operated Instruments” which requires a minimum retroreflectivity of 250 mcdl for white marking and 175 mcdl for yellow markings within 14 days of application. Any readings below the referenced ASTM standard are highlighted in red. The * in Table 3 denotes that no readings were taken at that site because of an obstruction.

Cold Weather Waterborne Paint with XSR VT Route 100B, Moretown						
	South Bound White		South Bound Yellow		North Bound Yellow	
Test Site ID:	**11/3/2006**	**11/9/2006**	**11/3/2006**	**11/9/2006**	**11/3/2006**	**11/9/2006**
TS 1 123' south of MM 7.00	346	367	149	158	187	188
	349	368	195	161	175	183
	333	351	207	157	187	161
	366	337	200	153	196	153
	367	342	191	96	193	159
Average	352	353	188	145	188	169
Std. Dev.	14	14	23	28	8	16
TS 2 MM 6.20	409	350	179	152	79	177
	378	336	171	172	92	174
	379	337	163	143	168	181
	422	*	191	144	167	172
	370	361	172	147	174	100
Average	392	346	175	152	136	161
Std. Dev.	23	12	10	12	46	34
TS 3 ends at MM 5.80	379	346	199	149	215	203
	384	359	201	134	210	204
	401	364	217	161	213	200
	386	351	181	170	222	189
	404	359	206	107	217	176
Average	391	356	201	144	215	194
Std. Dev.	11	7	13	25	5	12
Overall Average:	**378**	**352**	**188**	**147**	**180**	**175**

Table 4 – Initial Experimental Retroreflectivity Readings

Standard Waterborne Paint VT Route 100B, Moretown		
	North Bound White	
Test Site ID:	11/3/2006	11/9/2006
TS 4 110' north of MM 6.20	347	318
	403	280
	395	297
	384	353
	402	384
Average	386	326
Std. Dev.	23	42
TS 5 MM 6.80	388	186
	393	193
	393	186
	373	174
	372	187
Average	384	185
Std. Dev.	11	7
Overall Average	**385**	**256**

Table 5 – Initial Control Retroreflectivity Readings

In examining the data sets provided in Table 3 and 4, roughly 36% of the readings from the experimental markings and 25% of the readings from the control markings were found to be below the minimum standards of ASTM D 6359. However, it is important to note that all of the white experimental markings were found to be in compliance with the referenced standard. Conversely, 62% of the experimental yellow markings were found to be below compliance. In comparing the initial retroreflectivity results from both the experimental and standard white traffic markings, it does appear that the waterborne traffic markings with XSR initially outperformed the standard marking paint with a greater initial reading of 356 mcdl for the experimental markings and 256 for the control markings six days following application. Standard deviations are relatively low for both marking types indicating consistency in the materials and application techniques. The average standard deviations are 13.5 and 21 mcdl for the white XSR and standard markings, respectively.

The initial drop in retroreflectivity is also important to examine as it relates to proper curing. If properly cured, both the binder and the beads retain higher bond strength to all surrounding substrates and should be less susceptible to wear and tear from tire treads. Over a six day period, the initial retroreflectivity readings of the standard markings decreased by an average of 129 mcdl while the XSR marking decreased by 35 mcdl, suggesting that the experimental markings cured more readily at lower temperatures. As stated previously, wear readings were also collected. Wear reading are a visual assessment of the amount of substrate remaining and are rather subjective. This variable is dependent on several parameters, including proper application, wear from tire treads and winter maintenance practices, and ultraviolet radiation. Figures 1 through 4 display the marking materials immediately and seven months following application.

Figure 1 – XSR 11/09/06

Figure 2 – XSR 06/20/07

Figure 3 – Waterborne 11/09/06

Figure 4 – Waterborne 06/20/07

In addition to verifying initial retroreflectivity compliance with ASTM D 6359, all markings were monitored for performance over time. The service lives of pavement markings were used to compare durability and degradation rates to a predefined benchmark in order to evaluate and determine life cycle costs. To date, the Federal Highway Administration, or FHWA, and other federal and state authorities have not established a minimum requirement for retroreflectivity of pavement markings. However, FHWA has compiled recommended retroreflectivity guidelines for white and yellow pavement marking for different classes of roads as shown in Table 6.

1998 FHWA Research-Recommended Pavement Marking Values			
Type	**Non-Frwy**	**Non-Frwy**	**Freeway**
Option 1	<= 40 mph	>= 45 mph	>= 55 mph
Option 2	<= 40 mph	>= 45 mph	>= 60 mph, >10K ADT
Option 3	<= 40 mph	45-55 mph	>= 60 mph
White	85	100	150
Yellow	55	65	100

Table 6 – FHWA Recommendations

WHITE EDGE LINES:

As seen in Table 6 the recommendation by FHWA, is a minimum retroreflectivity of 100 mcdl was selected as the benchmark. Table 7 and 8, as shown below, contains a summary of average reflectance for each composition of white edge lines. Please note that any readings below 100 mcdl are highlighted in red. The * denotes that no readings were taken at that site because of an obstruction.

Cold Weather Waterborne Paint with XSR VT Route 100B, Moretown Southbound White Edge Line							
Date:	**11/3/2006**	**11/9/2006**	**11/30/2006**	**1/4/2007**	**5/7/2007**	**6/20/2007**	**8/1/2007**
Days since application:	**0**	**6**	**27**	**62**	**185**	**229**	**271**
TS 1 123' south of MM 7.00	346	367	167	141	181	77	145
	349	368	156	139	158	154	122
	333	351	183	129	81	125	68
	366	337	106	99	121	86	165
	367	342	189	131	121	169	159
Average	352	353	160	128	132	122	132
Std. Dev.	14	14	33	17	38	41	39
TS 2 MM 6.20	409	350	252	224	172	145	138
	378	336	264	234	168	138	128
	379	337	233	212	132	90	111
	422	*	267	165	61	44	61
	370	361	238	169	69	74	91
Average	392	346	251	201	120	98	106
Std. Dev.	23	12	15	32	53	43	31
TS 3 Ends at MM 5.80	379	346	221	147	80	23	80
	384	359	207	139	72	45	63
	401	364	240	151	44	47	46
	386	351	243	149	50	68	42
	404	359	233	120	22	78	22
Average	391	356	229	141	54	52	51
Std. Dev.	11	7	15	13	23	21	22
Overall Average:	**378**	**352**	**213**	**157**	**102**	**91**	**96**

Table 7 – Experimental White Retroreflectivity Summary

Standard Waterborne Paint VT Route 100B, Moretown Northbound White Edge Line							
Date:	**11/3/2006**	**11/9/2006**	**11/30/2006**	**1/4/2007**	**5/7/2007**	**6/20/2007**	**8/1/2007**
Days since application:	**0**	**6**	**27**	**62**	**185**	**229**	**271**
TS 4 100' north of MM 6.20	347	318	107	246	121	89	84
	403	280	105	169	41	42	44
	395	297	96	156	41	64	72
	384	353	132	205	52	50	57
	402	384	156	219	139	138	123
Average	386	326	119	199	79	77	76
Std. Dev.	23	42	25	37	47	39	30
TS 5 MM 6.80	388	186	120	26	18	18	16
	393	193	134	59	14	15	12
	393	186	112	54	23	15	16
	373	174	134	80	17	18	15
	372	187	123	47	19	19	15
Average	384	185	125	53	18	17	15
Std. Dev.	11	7	9	20	3	2	2
Overall Average:	**385**	**256**	**122**	**126**	**49**	**47**	**45**

Table 8 – Standard White Retroreflectivity Summary

The summaries provided above do indicate greater performance in terms of luminance of the XSR marking material over time. While both traffic marking materials continue to decay as would be expected, the standard traffic markings decay more readily with considerably lower retroreflectivity readings as compared to the experimental markings. During the spring of 2007, the retroreflectivity readings collected from the XSR substrate are twice that of the standard marking material. Once again, standard deviations are relatively low indicating consistency within the data sets and materials.

YELLOW EDGE LINES:

A similar analysis was performed with the yellow pavement markings with a minimum FHWA acceptable retroreflectivity of 65 mcdl as displayed in Table 9 and 10. Please note that any readings below 65 mcdl are highlighted in red. The * denotes that no readings were taken at that site because personnel was unable to collect the data due to winter cleaning protocol as well as traffic volume. Data was not collected on Thursday, January 4th due to traffic volume and safety concerns.

Cold Weather Waterborne with XSR VT Route 100B, Moretown						
Northbound Yellow Center Line						
	11/3/2006	**11/9/2006**	**11/30/2006**	**5/7/2007**	**6/20/2007**	**8/1/2007**
Test Site ID:	**0**	**6**	**27**	**185**	**229**	**271**
TS 1 123' south of MM 7.00	187	188	147	79	56	66
	175	183	151	71	61	66
	187	161	148	88	82	65
	196	153	164	65	87	70
	193	159	161	62	77	67
Average	188	169	154	73	73	67
Std. Dev.	8	16	8	11	13	2
TS 2 MM 6.20	79	177	124	*	68	57
	92	174	116	*	65	44
	168	181	126	59	65	43
	167	172	70	47	64	73
	174	100	60	77	47	68
Average	136	161	99	61	62	57
Std. Dev.	46	34	32	15	8	14
TS 3 ends at MM 5.80	215	203	170	32	69	67
	210	204	178	81	70	48
	213	200	181	77	64	60
	222	189	166	91	64	39
	217	176	150	106	51	56
Average	215	194	169	77	64	54
Std. Dev.	5	12	12	28	8	11
Overall Average:	**179**	**174**	**140**	**72**	**66**	**59**

Table 9 – Northbound Yellow Center Lines

Cold Weather Waterborne Yellow Paint with XSR VT Route 100B, Moretown						
Southbound Yellow Center Line						
	11/3/2006	**11/9/2006**	**11/30/2006**	**5/7/2007**	**6/20/2007**	**8/1/2007**
Test Site ID:	**0**	**6**	**27**	**185**	**229**	**271**
TS 1 123' south of MM 7.00	149	158	87	68	72	78
	195	161	163	101	81	59
	207	157	154	*	64	65
	200	153	147	88	72	109
	191	96	142	*	103	75
Average	188	145	139	86	78	77
Std. Dev.	23	28	30	17	15	19
TS 2 MM 6.20	179	152	99	88	81	79
	171	172	90	87	79	83
	163	143	75	66	97	73
	191	144	73	109	103	102
	172	147	78	91	78	86
Average	175	152	83	88	88	85
Std. Dev.	10	12	11	15	12	11
TS 3 ends at MM 5.80	199	149	146	122	68	86
	201	134	164	92	49	52
	217	161	146	77	59	58
	181	170	134	76	60	68
	206	107	155	59	64	53
Average	201	144	149	85	60	63
Std. Dev.	13	25	11	24	7	14
Overall Average:	**188**	**147**	**124**	**86**	**75**	**75**

Table 10 –Southbound Yellow Center Lines

SERVICE LIFE:

Service life estimates for the white line pavement marking could not be determined due to the large extent of time between data collection events. Therefore, a scatter plot of the data was generated in order to establish the approximate amount of elapsed time before retroreflectivity values fell below 100 mcdl, as shown in Figure 5. Please note that only white lines are modeled for this analysis due to the inherent variability of yellow pavement markings.

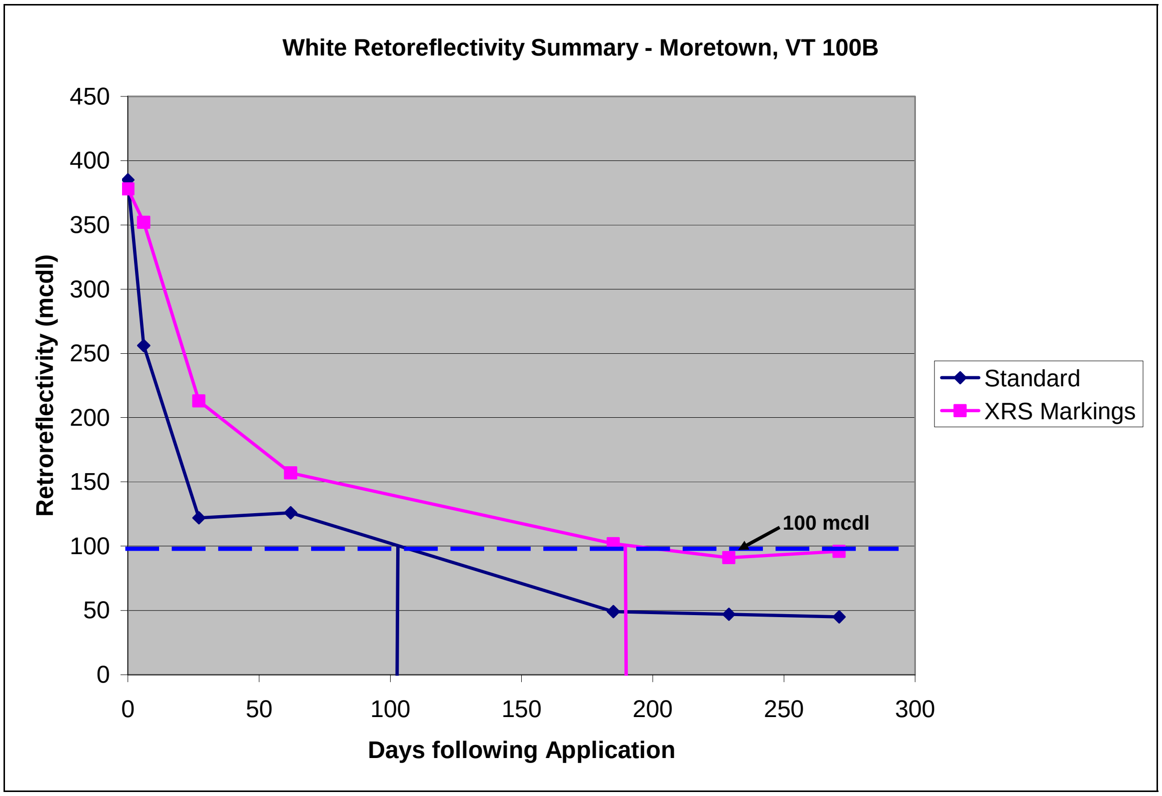


Figure 5 – XSR and Standard Marking Comparison

Estimated service lives for the white pavement markings are as follows:

- Cold Weather Waterborne Paint with XSR – 188 days
- Standard Waterborne Traffic Marking Paint – 110 days

COST ANALYSIS:

The projected cost for the Cold Weather Traffic Paint is $7.10 for a gallon of white marking paint and $7.00 for a gallon of yellow marking paint. This price is slightly higher than regular waterborne traffic paint that is normally $5.00 a gallon. Each gallon covers 300 lineal ft using a four inch line at 15 wet mils. Franklin Paint supplied three drums of 50 gallons each of each of paint in both white and yellow, which covered approximately 4 ¼ miles. According to a local contractor, standard waterborne paint costs approximately $0.08 to $0.20/LF for material, labor and equipment. For purposes of the cost analysis, a mean cost of $0.14/LF was utilized. Please note however, that this includes all associated costs. A calculated amount of $0.017/LF for standard waterborne paint was subtracted from $0.14/LF for an equivalent cost of $0.123/LF to represent the cost of equipment and labor. This was a constant for both markings and has been reflected in the Table 11 below. The cost per month for each marking was calculated by dividing the total cost of application per linear foot by the estimate service lives in months.

Moretown, VT 100B Material Cost Analysis						
Material	Elapsed Time		Material Cost ($/LF)	Labor and Equipment	Total Cost	Cost/Month
	Days	Months				
XSR	188	6	$0.024	$0.123	$0.147	$0.025
Standard	110	4	$0.017	$0.123	$0.140	$0.035

Table 11 – Cost Estimate

In accordance with the cost estimate provided in Table 11, it appears that the Cold Weather Paint with XSR is slightly more cost effective as compared to standard marking material.

FINDINGS:

In an effort to extend the striping season for both the Operations and Program Development Divisions, the Vermont Agency of Transportation applied an experimental pavement marking material, known as Cold Weather Waterborne Paint with XSR, to a preexisting roadway on VT 100B in the town of Moretown in October of 2006 when ambient air and pavement temperatures ranged from 28^{o}F to 48^{o}F with a dew point of 22^{o}F. In accordance with the manufacturer's specifications, the experimental marking material is reported to dry within 9 minutes at an ambient air temperature of 35^{o}F and rising. This product is compatible with standard waterborne paint which means that flushing of the hoses and storage tanks is not required. Feedback from the Traffic Shop was positive with regards to ease of application.

Following the placement of the markings, data collection, including retroreflectivity and wear readings, was conducted using uniform methods. All of the white XSR marking and the majority of the yellow XSR markings were found to be in compliance with ASTM 6359, "Minimum Retroreflectance of Newly Applied Pavement Marking Using Portable Hand-Operated Instruments" which requires a minimum retroreflectivity of 250 mcdl for white marking and 175 mcdl for yellow markings within 14 days of application. While both traffic marking materials continued to decay as would be expected, the standard traffic markings decayed more readily with considerably lower retroreflectivity readings as compared to the experimental markings. During the spring of 2007, the retroreflectivity readings collected from the XSR substrate were twice that of the standard marking material.

In consideration to laboratory testing, results indicate that the paint is sufficiently viscous to flow readily and the pigment is smooth enough as to not clog the painting apparatus as it was found to meet the specifications within ASTM D 1475, "Density of Liquid Coatings" and ASTM D 562, "Consistency of Paints Using the Stormer Viscometer." In addition to an examination of the characteristics of the experimental materials, a third assessment was performed to evaluate the amount of time needed to fully cure under varying ambient conditions with consideration to temperature and humidity. As the temperature drops and humidity increases, dry time also increases. In addition, laboratory testing does not verify the reported dry time from the manufacturer of 9 minutes at an ambient air temperature of 35^{o}F and rising. However, please keep in mind that the paint is not heated for testing purposes while it is in the field prior to application. The material is expected to dry more quickly once it has been heated.

A cost analysis was performed with consideration to FHWA's minimum recommended retroreflectivity. Service lives were found to be 188 and 110 days for the XSR and control markings, respectively. While the initial cost of the XSR markings is slightly higher at $7.10/gallon as compared to $5.00/gallon for white markings, the cost analysis indicated that the XSR markings are more cost effective over the life of the marking materials, which was postulated to be less than one year.

Overall, the application of Cold Weather Paint with XSR is recommended for late season striping when ambient air temperatures are below 50^{o}F.

References:

ASTM D 711, "Test Method for No-Pick-Up Time of Traffic Paint" American Society for Testing and Materials

American Association of State Highway and Transportation Officials' (AASHTO) specification M 247 "Glass Beads Used in Traffic Paint

ASTM E 1710-97, "Standard Test Method for Measurement of Retroreflective Pavement Marking Materials with CEN-Prescribed Geometry Using a Portable Retroreflectometer

ASTM D 6359-99, "Minimum Retroreflectance of Newly Applied Pavement Marking Using Portable Hand-Operated Instruments"

ASTM D 913-03, "Evaluating Degree of Resistance to Wear of Traffic Paint".

Appendix A

VTrans Working to Get You There

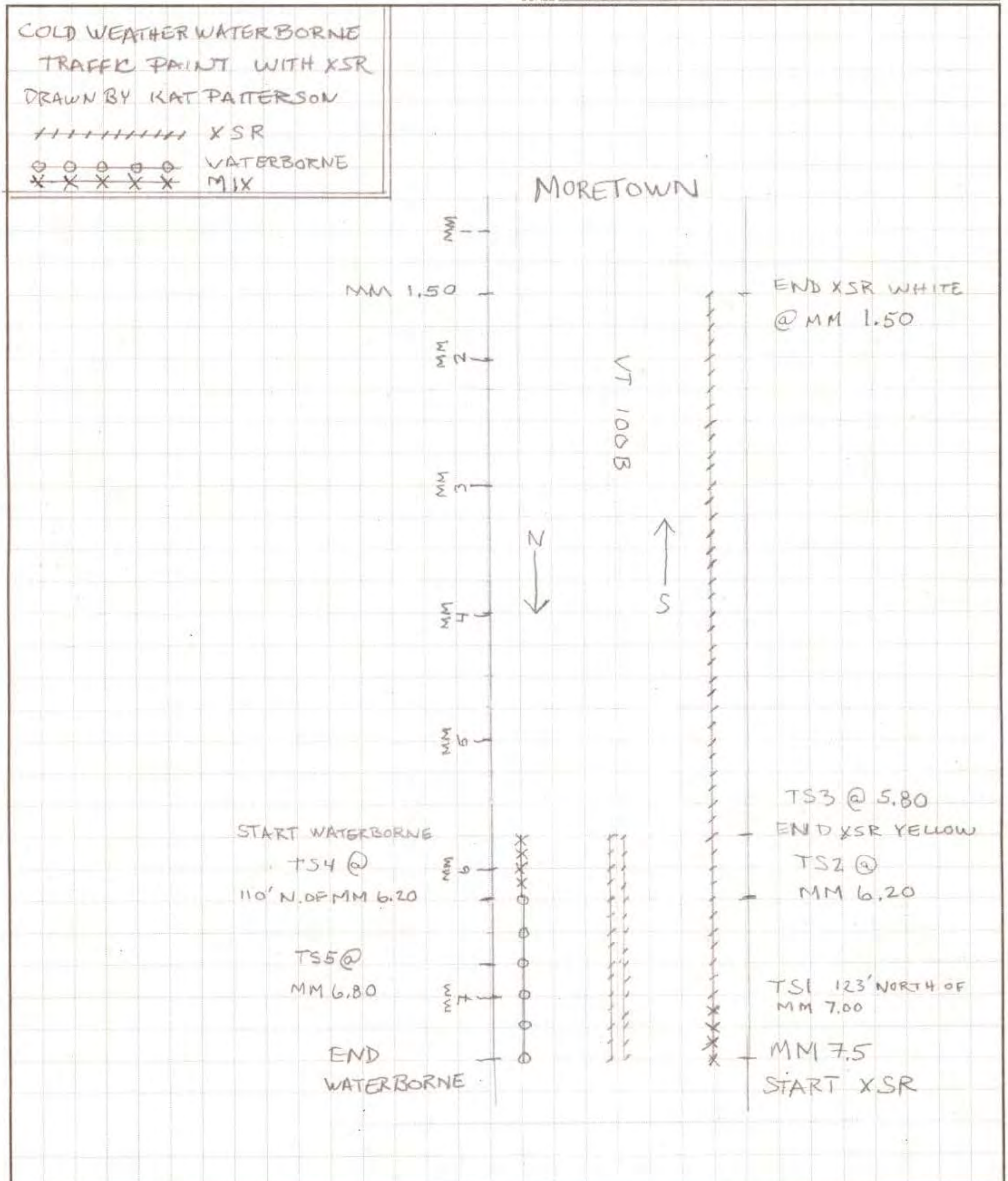
JOB COLD WEATHER WATERBORNE PAIT W XSR

SHEET NO. 1 OF 1

CALCULATED BY ______ DATE ______

CHECKED BY ______ DATE ______

SCALE NOT TO SCALE



Appendix B

Vermont Agency of Transportation
Materials & Research Laboratory
Paint Test Report

Lab No. 2006- 105 Project Name & No. EXPERIMENTAL

Pay Name ____ Pay Item ____

Sample Type: Traffic Shop ____ Acceptance ____ Investigative X Other ____

Material Description YELLOW 'XSR' COLD WEATHER WATERBORNE PAINT

Material Source FRANKLIN PAINT CO. Manufacturer FRANKLIN PAINT CO.

Lot No. N/A Date of Manufacture 10-22-06

Date Received 10-24-06 Date Tested 10-27-06 Tested by JERRY MCMAHAN

Temperature (Specification = 23±2°C) 22.8 Humidity (Specification = 50±5%) 55

	SPECIFICATION REQUIREMENTS	RESULT
No-Pick-Up Time ASTM D-711	10 Minutes	5.0
Pounds per Gallon ASTM D-1475	Yellow 13.3min. – 13.9max. White 13.7min. – 14.3max.	13.45
Viscosity ASTM D-562	78ku min. – 95ku max.	88

Results within specifications? YES

Comments ____

Analyst ____ Supervisor ____

Appendix C

Vermont Agency of Transportation
Materials & Research Laboratory
Paint Test Report

Lab No. 2006-104 Project Name & No. EXPERIMENTAL

Pay Name ______ Pay Item ______

Sample Type: Traffic Shop ____ Acceptance ____ Investigative X Other ____

Material Description WHITE 'XSR' COLD WEATHER WATERBORNE PAINT

Material Source FRANKLIN PAINT CO. Manufacturer FRANKLIN PAINT CO.

Lot No. N/A Date of Manufacture 10-22-06

Date Received 10-24-06 Date Tested 10-27-06 Tested by JERRY MCMAHAN

Temperature (Specification = 23±2°C) 22.8 Humidity (Specification = 50±5%) 55

SPECIFICATION REQUIREMENTS		RESULT
No-Pick-Up Time ASTM D-711	10 Minutes	5.0
Pounds per Gallon ASTM D-1475	~~Yellow 13.3min. – 13.9max.~~ White 13.7min. – 14.3max.	13.76
Viscosity ASTM D-562	78ku min. – 95ku max.	95

Results within specifications? YES

Comments ______

______

Analyst ______ Supervisor ______

Appendix D

APPENDIX D - PROTOCOL FOR THE CLEANING OF LINE STRIPPING FOR RETROREFLECTIVE READINGS

Equipment needed:

1. Windshield washer fluid
2. Water
3. Two liquid dispensers
4. Towels or rags
5. Squeeze mop and/or sponges
6. Gas powered leaf blower

PROCEDURE

Step 1 – Mix ½ water and ½ windshield washer fluid into the first liquid dispenser. The other liquid dispenser should have water only.

Step 2 – Thoroughly clean the lines with the windshield washer fluid mixture using the dispenser to spray away as much salt, dirt and other debris as possible.

Step 3 – Thoroughly clean the lines with the water dispenser, spraying away the windshield washer mixture. * Note: Make sure you start at the highest point of the surface to be cleaned and wash down to the lowest point.

Step 4 – Using the squeeze mop and sponges clean away as much excess water as possible. Wipe the line surfaces with a towel or rag to get the surfaces as dry as possible.

Step 5 – Utilizing a gas powered leaf blower or similar device blow the lines off until completely dry.

Step 6 – Begin Reflectometer Testing.