Evaluation of Ultra Hydrophast with Rhoplex Fastrack HD-21A
Final Report

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State of Vermont
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16. Abstract

In an effort to extend the service life of waterborne markings while reducing the overall cost of labor and equipment, the Vermont Agency of Transportation applied an experimental marking material, known as Ultra Hydrophast with Rhoplex Fastrack HD-21A, an acrylic polymer. This substrate is reported to provide multi-year performance by providing a tight, strong anchor to glass beads and road surfaces. In addition to an examination of the binder, Visibeads consisting of glass spheres three to four times larger than conventional beads, were also dropped onto the marking material during application an effort to assess sustainability as studies have shown a greater likelihood of dislodging due to greater protrusion above the marking binder.

Following the placement of the markings, data collection, including retroreflectivity and wear readings, was conducted using uniform methods. All of the white and yellow HD-21A markings were found to be in compliance with ASTM 6359, “Minimum Retroreflectance of Newly Applied Pavement Marking Using Portable Hand-Operated Instruments”. While both the experimental and control traffic marking materials continued to decay as would be expected, the HD-21A markings decayed more readily with considerably lower retroreflectivity readings as compared to the control waterborne. During the spring of 2008, the retroreflectivity readings collected from the HD-21A substrate were half that of the standard marking material. In accordance with a cost analysis, the HD-21A was found to be less cost effective as compared to standard waterborne paint traffic markings. Overall, the application of HD-21A is not recommended as it appears to be far more susceptible to snow plow damage, with both the Visibeads readily sheared off as well as the paint material itself.

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TABLE OF CONTENTS

1.0 INTRODUCTION

Pavement markings provide an important means of communication for all roadway users and must be capable of conveying information during inclement weather and evening hours when there may be little to no contribution from overhead lighting. Longitudinal markings delineate driving lanes, segregate traffic in opposing directions and indicate where passing is permissible. Like most traffic control devices, pavement markings deteriorate over time due to a number of factors including natural constituents (sun exposure, dirt, etc.), vehicular impacts (abrasion from studded tires and winter maintenance practices) and material properties (hardness, bond strength, etc). Therefore, traffic markings must be reapplied periodically to maintain acceptable visibility.

Standard waterborne traffic markings are typically applied to all Interstates, Vermont and US Routes as part of an annual statewide marking program. In accordance with the Agency's specifications, standard waterborne traffic paint is to be comprised of acrylic binder with an applied dry film thickness of 15 mils (or .015 inch). As determined by a recent assessment of various types of traffic markings statewide, waterborne has an approximate service life of 9 months most likely attributed to Vermont's harsh winter climate with an annual average snowfall rate of 100" and associated winter maintenance activities. However, it may be surmised that a higher film build thickness would result in a longer service life.

In addition to key properties of traffic markings, such as durability and retroreflectivity (or luminance), which influence the service life of markings, it is also important to consider material, equipment and labor costs associated with application. For example, as of 2006, standard waterborne markings cost the least amount to apply at an approximate cost of $0.14/LF while surface polyurea markings cost roughly $1.00/LF. These costs include material, equipment and labor. However, if a more expensive traffic marking maintains a longer service, the overall life cycle cost may be competitive with that of a less expensive traffic marking. In this example, with an assumed service life of 9 months and 17 months for the waterborne and polyurea markings respectively, the life cycle cost of the referenced markings is $0.02/LF per month and $0.06/LF per month, respectively, reducing the initial differential cost of the two traffic markings.

In an effort to extend the service life of waterborne markings while reducing the overall cost of labor and equipment, the Vermont Agency of Transportation applied an experimental marking material, known as Ultra Hydrophast with Rhoplex Fastrack HD-21A, an acrylic polymer. This substrate is reported to provide multi-year performance by providing a tight, strong anchor to glass beads and road surfaces. In addition to an examination of the binder, Visibeads consisting of glass spheres three to four times larger than conventional beads were also dropped onto the marking material during application in an effort to assess sustainability, as studies have shown a greater likelihood of dislodging due to a greater protrusion above the marking binder.

The following final report assesses the overall performance of Ultra Hydrophast with Rhoplex Fastrack HD-21A in comparison to standard waterborne traffic markings in terms of durability and retroreflectivity. In addition, the report contains information pertaining to laboratory results in order to quantify the unique characteristics of the experimental material as well as a summary of surveillance and testing measures and their associated results.

2.0 PROJECT DETAILS

The Vermont Agency of Transportation's Traffic Shop personnel applied the Ultra Hydrophast with Rhoplex Fastrack HD-21A, or experimental traffic markings, to the Berlin State Highway, Airport Road and Fisher Road in the town of Berlin. Berlin State Highway is a three lane roadway with a posted speed limit of 50 mph and an average annual daily traffic (AADT) of 7600. This roadway segment also consists of a large curved alignment including a 9% grade. Airport and Fisher Rd. are both characterized as federal aid urban streets. Airport Rd. is considered a two lane minor arterial with a reported AADT of 4100. Fisher Rd. is classified as a two lane collector with a reported AADT between 5800 and 9300. Both locations consist of relatively flat grade and straight alignment. A summary of each roadway segment is provided in Table 1. In accordance with the work plan and manufacturers specifications, the Traffic Shop applied a minimum thickness of 26 wet mils. This represents a greater application rate as compared to the standard 15 wet mils the control waterborne was applied at, as will be described later.

Test Site Description - Ultra Hydrophast with HD-21A					
Designation:	Functional Classification	Number of Lanes	Minimum AADT:	Maximum AADT:	Notes:
Berlin State Highway	Minor Arterial	3	7600	-----	Curved Alignment at 9% grade
Airport Rd.	Minor Arterial	2	4100	-----	Flat grade and alignment
Fisher Rd.	Collector	2	5800	9300	Flat grade and alignment

Table 1 – Summary of Roadway Characteristics

3.0 PRODUCT DETAILS

According to the manufacturer of the Ultra Hydrophast with HD-21A, Franklin Paint Company, Inc. from Franklin, Massachusetts, this waterborne traffic paint is both lead free and VOC compliant. Rhoplex Fastrack HD-21A is manufactured by Rohm and Haas of Springhouse, PA. It is marketed as a fast drying paint marking material that provides a multi-year performance similar to thermoplastic and epoxy markings. As stated above, it is reported to provide a tight, strong anchor to glass beads. The manufacturer states that the experimental marking material displays high initial and sustained long-term retro reflectivity. According to the manufacturer's specifications, this marking material is to be applied at a wet thickness of 25 mils. At this application rate, the paint marking material is expected to dry within 15 minutes. This is recognized as a deviation from a 10 minute track-free condition in accordance with the American Society for Testing Materials (ASTM) D-711, "Test Method for No-Pick-Up Time of Traffic Paint." A minimum application temperature of 50^{o}F is recommended.

Visibeads, produced by Potters Industry, are reported to enhance driver's nighttime visibility, particularly in rain, fog or melting snow, for dramatic improvements in mobility and highway safety. According to Potters, Visibeads are manufactured in a proprietary process that creates glass marking spheres that are three to four times the diameter of conventional highway safety marking spheres. Therefore, they sit higher above the marking material as compared to standard glass beads allowing for additional delineation. Visibeads are compatible with waterborne or solvent based paint, epoxy, polyester, thermoplastic and polyurea markings. Please note that both Visibeads Plus II and standard glass beads (in compliance with AASHTO M247, "Standard Specification for Glass Beads Used in Traffic Paints") were utilized in a double drop application.

4.0 LABORATORY TESTING

As stated within Work Plan 2007-3, several laboratory tests were conducted in order to 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 13.91 lbs per gallon and the yellow pigmented paint was found to have a density of 13.63 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 93 ku. This also met the viscosity specification of 78 to 95 ku which is universal for both colors of marking paint. Please see Appendix A and B for a copy of the laboratory testing results for the white and yellow 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, "Test Method for No-Pick-Up Time of Traffic Paint." This laboratory test seeks to evaluate the amount of time needed to fully cure under varying ambient conditions with consideration to temperature and humidity. In general, the white experimental marking material was found to dry within 14 minutes at an ambient air temperature of 72^{o}F and humidity of 50% while the yellow marking paint was found to dry in 15 minutes at an ambient temperature of 72^{o}F and humidity of 49%. As stated above, this deviates from a no track time of 10 minutes.

Finally, the experimental glass beads, Visibeads Plus II, were examined for roundness in accordance with ASTM D 1155, "Standard Test Method for Roundness in Glass Spheres," and gradation in accordance with ASTM D 1214, "Standard Test Method for Sieve Analysis of Glass Spheres." The roundness test results revealed a 91 (Visibeads) and 95 (AASHTO Type I) percent of spheres were in compliance. Studies have shown that both roundness and gradation have a direct influence on the initial and long term retroreflectivity of traffic markings. Beads must be round to provide retroreflectivity, otherwise known as luminance. It may be surmised that a greater percentage of spheres provides for greater retroreflectivity. Gradations are important in consideration to bead embedment, application equipment and wet mil thickness. In order to attain a preferred embedment depth of 50 to 60% of the bead's diameter, larger glass beads require greater mil thickness. Generally, beads are subject to compliance with AASHTO specification M 247, Type I designation, which states a maximum gradation of 850um. Table 2, provided below contains the gradations and roundness for both the Visibeads Plus II and standard Type I glass beads. Please note that the Visibeads were collected onsite directly from the spreader nozzle which is not standard testing protocol. Therefore the reliability of the data set may be moderate.

Lab Data of Glass beads		
	Visibead Plus II	M 247 Type I
Sieve #:	% Passing	% Passing
10	100	---
12	0.2	---
14	12.2	---
16	71.6	---
18	16.1	---
20	0.2	100
30	---	75-95
40	---	---
50	---	15-35
80	---	---
100	---	0-5
	% SPHERES: 91%	**% SPHERES: 95%**

Table 2 – Visibead Plus II and M247 Gradation and Roundness

5.0 INSTALLATION AND OBSERVATIONS

On Tuesday, August 14, 2007, personnel from the Materials and Research Section accompanied by the Painting Crew from the Traffic Shop, as well as employees from Rohm and Haas and Potters Industries Inc., observed the application of the experimental marking material, Ultra Hydrophast with HD-21A and reflective elements, standard glass beads and Visibeads. Application of the marking materials began at 12:38 PM to the Berlin State Highway in the town of Berlin in order to allow the pavement surface to dry properly prior to application. According to weatherunderground.com, the ambient air temperature was approximately 68°F with a wind speed of 8 mph and 50% humidity.

Prior to installation, the Traffic Shop's paint truck was modified for a double drop application. First, a 500 lb bead tank was added for the larger Visibeads. There was a need for two separate tanks because the smaller standard size beads would fall to the bottom if the two beads are mixed together. Then a separate air line was connected to the new 500 lb tank to pressurize the beads for a consistent bead drop. A bead delivery hose was connected from the bottom of the tank to a Visigun. This gun allows for even distribution of the larger beads, which may be adjusted to deliver a smaller or larger volume. The existing guns for the standard glass beads were moved to the back of the Visigun for a double drop application.

The Paint Crew did not perform any special surface preparations to the roadway prior to installation, such as the removal of any dirt or debris. The previously applied preexisting pavement markings were observed to be in poor to fair condition with visible wear from tire treads and snow plow operations. The experimental marking material was applied at a relative wet thickness of 26 mils along with a double drop of standard glass beads and Visibeads.

Observations with regards to relative humidity, temperature, wet mil thickness and approximate dry time were recorded for the experimental markings. Actual wet thicknesses appeared to range from 24 to 28 mils. This will have an effect on the overall observed drying time as a thinner line is expected to dry more quickly while a thicker line is suspected to dry more slowly. Please note however, that all wet mil thicknesses in relation to dry time were recorded. Table 3, provided below, depicts the relationships between marking type, dry time, ambient air temperature and relative humidity. Extended drying times were anticipated due to greater application rates (26 wet mils for the HD 21A vs. 15 wet mils for standard waterborne markings).

Field Drying Time of HD-21A Berlin State Highway							
Type of Paint	Color	Direction	Dry to Touch Time Minutes	Air Temperature Deg. F	Relative Humidity %	Pavement Temperature F	Comments
HD-21A W/Visibead Plus II	White	Up Hill	30	70	39	100	At 1st driveway On the right.
HD-21A W/Visibead Plus II	White	Up Hill	>30	70	39	78	In the shade Up Hill. On right.

Table 3 – Summary of Field Drying Time

In examining Table 1, the conditions were optimal and the drying time was longer than tested in the Materials and Research lab. The lab dry time tested at 72ºF for 15 wet mils was approximately 14 to 15 minutes.

5.1. Control Section

Unfortunately, a control section consisting of standard waterborne paint could not be applied during the same time frame due to the modifications of the paint truck and site constraints. In an effort to comparatively evaluate the experimental and standard paint markings, similar wear and environmental conditions were warranted. Therefore, the Materials and Research Section requested to be notified when standard waterborne paint markings were applied in the area. According to Russ Velander, standard waterborne paint markings at a thickness of 15 wet mils were applied to the remainder of Airport

Road on Wednesday, August 29th. The ambient air temperature was 83^{o}F with a relative humidity of 51% and wind speed of 6.9 mph as reported by weatherunderground.com at approximately 1 PM. This is an approximate temperature differential of 15^{o}F as compared to experimental marking application ambient conditions. Cure times are often reduced with increasing temperature and decreasing humidity, generally resulting in a greater bond strength between the underlying pavement and glass beads.

6.0 SURVEILLANCE AND TESTING:

A total of seven 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". Five test sites, denoted as TS 1 through 5, were established along the Ultra Hydrophast with HD-21A traffic marking length, as well as two along the standard waterborne markings, specified as TS 6 and 7. 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 would be collected from the same location.

Retroreflectivity readings were collected utilizing an 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. Initial site visits concerning the experimental markings were conducted on Friday, August 17th and Tuesday, August 28th, 3 and 14 days following application, respectively. All pavement markings were found to be intact. A summary of initial experimental retroreflectivity readings can be found below in Tables 5 and 7. Please note that most of the experimental 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 mcd/m^2/lx for white marking and 175 for yellow markings within 14 days of application. Any readings below the referenced ASTM standard are highlighted in red.

For the standard waterborne paint that was applied on Wednesday, August 29th, initial retroreflectivity readings were taken 14 days following the application on Wednesday, September 12th. Two test sites were established on Airport Rd. A summary of initial control readings is provided in Tables 6 and 8 below. All of the standard waterborne markings were found to be in compliance with ASTM 6359.

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 4. For the Berlin State Highway, Airport Road and Fisher Road the speed limits are all 50 mph and classified as a Non-Freeway road. In these cases the white markings need to have a minimum retroflectivity of 100 while the yellow pavement markings must be 65. Any readings that fall below the FHWA recommendations are highlighted in red.

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 4 –FHWA Recommendations

6.1. White Edge Lines

The FHWA recommendation of 100 mcd/m^2/lx for minimum retroreflectivity was selected as a benchmark for the white lines. Tables 5 and 6, as shown below, contain a summary of average reflectance for each composition of white edge lines. Please note that any readings below 100 are highlighted in red. All of the data summary tables display all readings taken for each test site, along with the associated overall averages for each test site for each date. Standard deviations are also shown for each average in order to give a general sense of the overall variability in the data.

White experimental material was not placed on the northbound lanes at test site 4 or test site 5, therefore no readings were taken. Any readings marked in red fall below the FHWA recommended for a non-highway categorized road with a 50 mph speed limit. As can be seen, all readings for the White HD-21A pavement markings that were taken on April 21, 2008 fall below this threshold. These readings were the first measurements performed following the winter plowing season. From this it is evident that durability and effectiveness of these sets of markings were greatly affected by winter maintenance activities.

Ultra Hydrophast with Rhoplex Fastrack HD-21A White Edge Lines						
	Date:	**8/17/2007**	**8/28/2007**	**10/2/2007**	**11/8/2007**	**4/21/2008**
	Days since application:	**3**	**14**	**49**	**86**	**251**
TS 1	Uphill	389	345	355	373	22
		384	338	365	418	20
		330	355	370	395	19
		350	325	439	433	23
		342	347	419	404	20
	Downhill	477	406	365	212	22
		491	406	344	221	21
		444	406	381	272	19
		394	373	319	227	21
		447	395	349	260	17
	Avg:	405	370	371	322	20
	Std:	57	32	35	91	2
TS 2	Uphill	403	246	474	503	35
		404	373	414	477	34
		364	369	362	453	26
		390	388	478	515	58
		388	399	385	466	45
	Downhill	367	345	418	436	64
		388	339	387	411	49
		382	389	401	428	38
		337	299	432	434	63
		385	318	422	426	54
	Avg:	381	347	417	455	47
	Std:	20	48	37	35	13
TS 3	Uphill	378	379	459	470	43
		355	338	464	437	78
		349	419	424	465	54
		397	375	391	446	71
		371	376	433	438	71
	Downhill	363	286	393	237	42
		350	299	410	244	40
		322	321	409	282	43
		323	298	361	292	33
		325	303	383	307	40
	Avg:	353	339	413	362	52
	Std:	25	45	33	97	16
TS 4	Uphill	263	293	325	313	36
		295	344	319	306	30
		284	312	345	282	32
		266	322	338	295	33
		312	312	340	319	32
	Avg:	277	289	327	285	35
	Std:	93	87	108	70	9
	Overall Average:	**354**	**336**	**382**	**356**	**38**

Table 5 – Retroreflectivity readings for white HD-21A markings.

Control Waterborne White Edge Lines						
		Date:	9/12/2007	10/2/2007	11/8/2007	4/21/2008
		Days since application:	14	34	71	236
TS 6	East		332	311	345	108
			326	300	361	142
			371	350	339	131
			350	296	342	97
			341	326	393	89
	West		286	251	297	138
			290	255	280	155
			291	283	286	171
			281	271	296	124
			294	288	296	148
Avg:			316	293	324	130
Std:			32	31	38	26
TS 7	East		333	281	338	82
			309	261	363	76
			313	282	361	76
			310	291	391	57
			301	273	390	39
	West		313	277	273	93
			310	85	244	51
			371	216	271	71
			355	325	249	89
			382	296	232	89
Avg:			330	259	311	72
Std:			29	67	63	18
Overall Average:			323	276	317	101

Table 6 – Retroreflectivity readings for white control markings.

The control pavement marking for this project was the white edge line comprised of waterborne paint in test sites 6 and 7. This performed better with respect to retroreflectivity values after the winter season in comparison to the white HD-21A as evidenced by the fact that not every reading taken failed to meet the FHWA recommendation of 100 mcd/m^2/lx. In some cases many passed and others just barely missed reaching the recommended threshold. While both traffic markings decay as expected, the HD-21A white pavement marking retroreflectivity was only half that of the waterborne as of the April 2008 measurements. The summaries provided indicate that the white edge waterborne pavement markings perform better in terms durability to plowing in comparison to the HD-21A.

6.2. Yellow Center Lines

A similar analysis was performed with the yellow pavement markings with a minimum FHWA acceptable retroreflectivity of 65 mcd/m^2/lx as displayed in Tables 7 and 8. Please note that any readings below 65 are highlighted in red.

Ultra Hydrophast with Rhoplex Fastrack HD-21A Yellow Centerlines						
	Date:	**8/17/2007**	**8/28/2007**	**10/2/2007**	**11/8/2007**	**4/21/2008**
Days since application:		**3**	**14**	**49**	**86**	**251**
TS 1	Uphill	269	328	324	294	17
		284	329	322	309	20
		305	323	373	404	27
		293	287	358	337	12
		314	262	313	360	19
	Downhill	377	297	360	345	17
		356	313	328	321	14
		295	312	368	355	10
		279	343	315	342	14
		284	366	291	339	14
Avg:		306	316	335	341	16
Std:		35	29	28	30	5
TS 2	Uphill	209	211	206	220	32
		211	219	209	228	47
		232	231	232	243	50
		213	206	235	220	49
		190	184	210	240	65
	Downhill	238	183	286	300	49
		273	309	298	290	44
		288	247	298	286	26
		276	264	318	284	69
		289	321	215	299	65
Avg:		242	238	251	261	50
Std:		37	48	44	34	14
TS 3	Uphill	208	224	232	217	31
		204	204	231	249	30
		203	223	221	248	28
		216	209	213	234	40
		192	190	218	259	51
	Downhill	184	221	301	241	30
		203	245	230	213	46
		204	213	212	219	31
		180	225	225	265	70
		290	290	199	239	32
Avg:		208	224	228	238	39
Std:		31	27	28	18	13
TS 4	NB	245	270	258	354	32
		230	293	288	270	70
		271	286	298	346	49
		233	278	273	332	38
		247	299	261	313	30
	SB	264	270	261	264	37
		277	254	279	264	35
		251	289	249	288	33
		276	249	255	261	27

		272	268	259	276	28
Avg:		257	276	268	297	38
Std:		18	16	16	36	13
TS 5	NB	306	335	399	254	17
		174	284	299	165	26
		155	397	277	103	15
		309	417	334	345	16
		330	348	398	285	18
	SB	205	317	306	293	27
		248	310	301	336	44
		294	299	298	330	23
		278	304	325	323	18
		278	327	331	282	27
Avg:		258	334	327	272	23
Std:		60	43	42	79	9
Overall Average:		**254**	**277**	**282**	**282**	**33**

Table 7 – Retroreflectivity readings for yellow HD-21A markings.

Control Waterborne Yellow Centerlines					
Date:		**9/12/2007**	**10/2/2007**	**11/8/2007**	**4/21/2008**
Days since application:		**14**	**34**	**71**	**236**
TS 6	East	190	210	238	87
		222	211	242	83
		225	232	228	86
		229	199	231	81
		219	202	241	70
	West	254	240	219	97
		243	236	223	104
		242	219	241	104
		238	233	227	89
		232	236	227	78
Avg:		229	222	232	88
Std:		18	15	8	11
TS 7	East	193	208	233	25
		249	224	206	23
		238	221	230	26
		245	228	235	18
		245	220	211	21
	West	260	207	134	20
		252	234	213	22
		256	243	172	19
		257	205	198	36
		240	207	181	21
Avg:		244	220	201	23
Std:		19	13	32	5
Overall Average:		**236**	**221**	**217**	**56**

Table 8 – Retroreflectivity readings for yellow control markings.

Performance of the experimental yellow HD-21A markings resembles that of the white HD-21A markings. The performance of both drastically fall between the November and April measurements, indicating that they have difficulty in withstanding the harsh Vermont winter and plowing seasons. All the readings taken on April 21, 2008 for the yellow HD-21A traffic markings are marked in red since none passed the recommended mcd/m^2/lx for FHWA pavement markings. As was the case for the white markings, the yellow waterborne readings were on average nearly twice as high as those for the experimental marking

6.3. Graphical Representation

Plots of the average values for white and yellow markings for each product were developed and can be seen in Figures 1 and 2. Also plotted in each graph is the FHWA recommended minimum values, represented as a dashed horizontal line. The graphical representation clearly shows how harsh the winter plowing season was on all lines, not only in this study but statewide. In both cases the experimental marking started with, and maintained, substantially higher retro values throughout the fall, but retained slightly higher values during the winter.

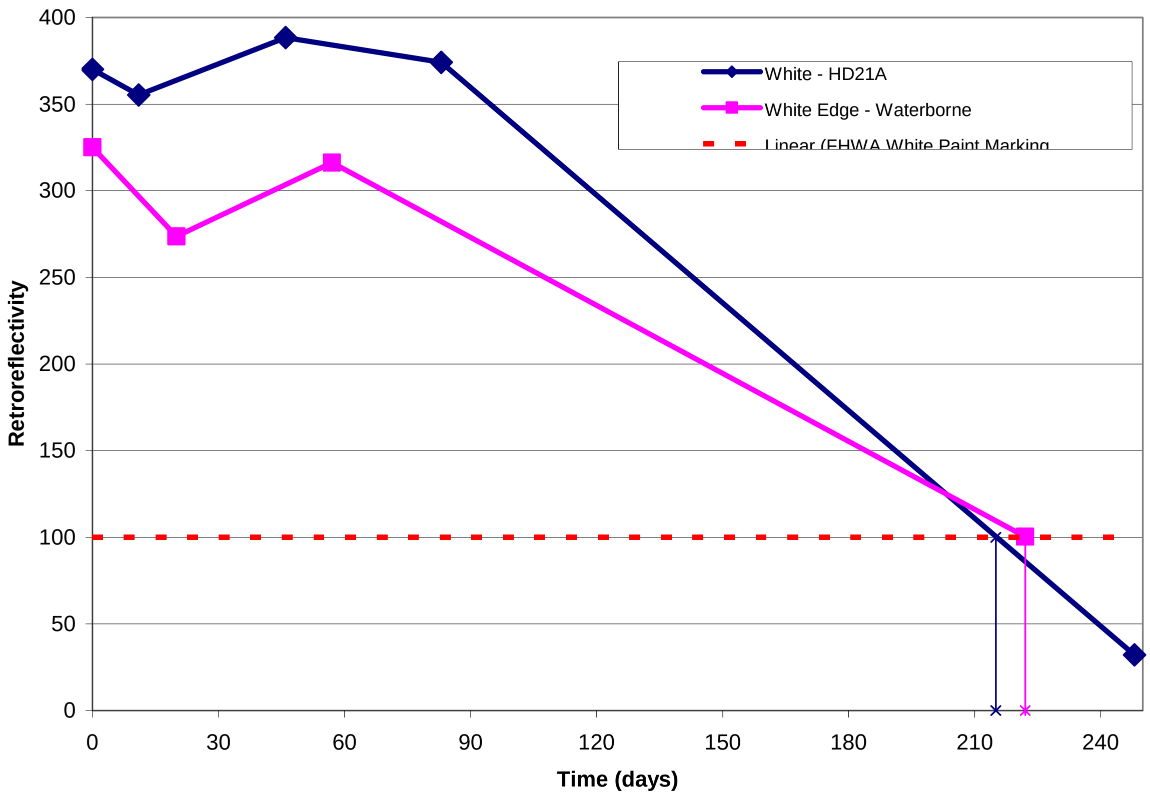

Figure 1. Comparison of retroreflectivity values versus time for white markings.

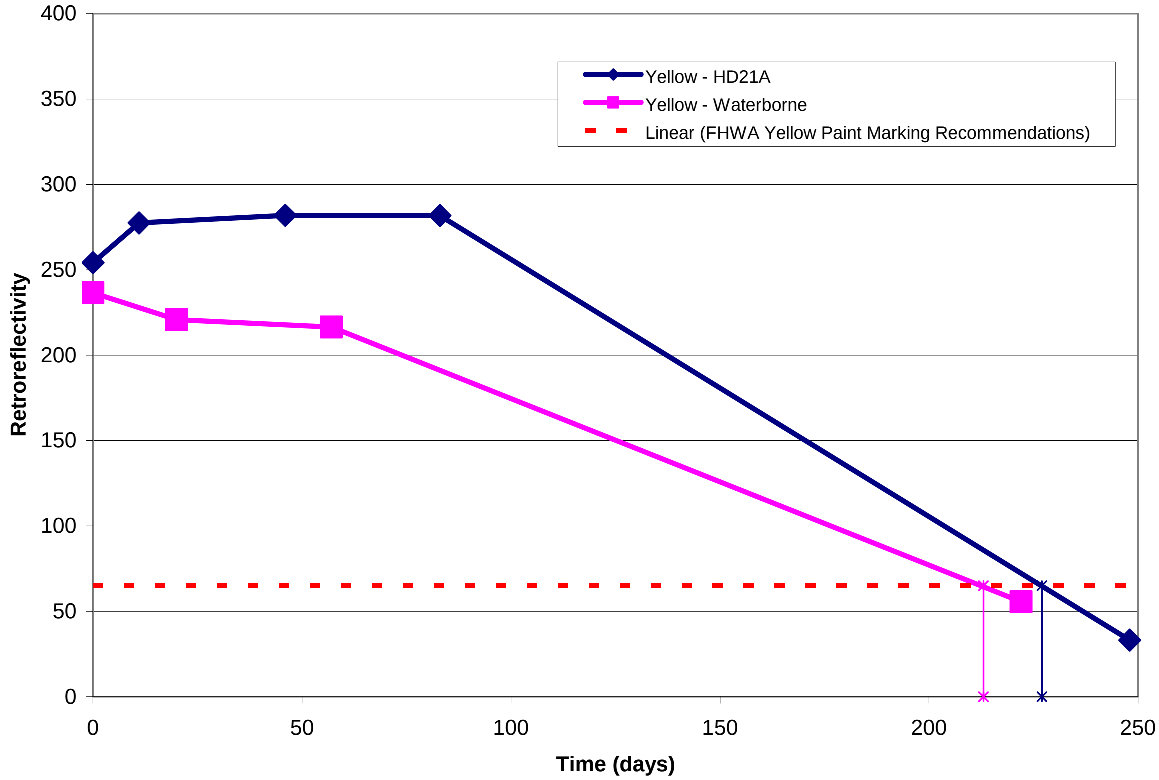

Figure 2. Comparison of retroreflectivity values versus time for yellow markings.

6.4. Cost Analysis

While this is still considered an experimental marking material by the manufacturer, the current cost for Ultra Hydrophast with HD-21A is $10 for a gallon of white or yellow marking paint. This price is higher than standard waterborne traffic paint, which is normally $5.00 a gallon. At a wet mil thickness of 25 mils and width of four inches, each gallon is projected to cover approximately 190 linear feet for an approximate material cost of $0.05 per foot. Table 9 provides a cost comparison between the HD-21A and standard waterborne markings.

Berlin State Highway Material Cost Comparison					
Material	Age in Months	Cost ($/LF)	Labor and Equipment ($/LF)	Total Cost ($/LF)	Cost/Month ($/LF)
Standard	8	$0.016	$0.12	$0.136	$0.0170
HD-21A	8	$0.053	$0.12	$0.173	$0.0216

Table 9 – Material Cost Comparison

Cost per month values were based on the current age of the markings, which is approximately eight months for all markings. According to a representative from Potters Industries, standard Type I glass beads cost roughly $0.25 to $0.30/lb whereas Visibeads Plus II cost $0.55 to $0.60/lb. Franklin Paint and Potters Industries supplied all materials to the Traffic Shop for application.

In accordance with the cost estimate provided in Table 9, it appears that the standard paint markings are slightly more cost effective and just as durable and effective compared to the experimental HD-21A marking material. The HD-21A costs roughly 27% more for material and installation per foot than the standard waterborne does, yet measurements indicate its retroreflectivity is only around half as much after the first winter season.

A second methodology to compare the cost effectiveness of a marking material is to determine its net benefit to the user over its lifespan with consideration to increased retroreflectivity and older drivers. A study conducted by the University of North Carolina at Charlotte concluded “that nighttime luminance levels provided by pavement markings that may be adequate for younger drivers may be less that adequate for older drivers” [Graham, et.al.]. Therefore, rather than examining the amount of time until retroreflectivity levels fall below a minimum recommended level, the following assessment accounts for the retroreflectivity readings over time above minimum recommended levels as a net benefit. The net benefits are calculated by determination of the area under the retroreflectivity lines in Figures 1 and 2.

Between the installation of the standard waterborne on August 29 and the date of the final fall readings on November 8, 70 days elapsed. The net benefits of the materials and the benefit per initial cost per foot are summarized in Table 10.

Material		Benefit (mcd/lx/m^2*days)	Benefit Per Cost/Foot
HD-21A	White	19250	111272
	Yellow	14980	86590
Standard Waterborne	White	13720	100882
	Yellow	10990	80809

Table 10 – Net benefit to user values for 70 days.

Over this timeframe, the HD-21A displayed a greater benefit per cost value of 10.3% and 7.2% as compared to the standard white and yellow waterborne traffic markings, respectively. This represents a marked increase over the standard markings. It is important to note that the total benefit for a marking in Vermont is directly related to how early in the marking season a line is placed. If it is placed at the beginning of the season the public has the entire season to benefit from superior performance, while if a marking is placed towards the end of the season it normally is quickly degraded with the onset of the plowing season, making the marking far less beneficial with respect to safety and life cycle cost..

7.0 SUMMARY AND CONCLUSIONS

With just over eight months of service it is clear that, in general, waterborne markings do not hold up well to winter service periods. Table 11 shows the average retroreflectivity values for all white and yellow readings for each pavement marking type, by the dates the readings were taken. Please note that readings for the waterborne markings were collected over a period of four site visits as opposed to five for the experimental marking as they were applied 26 days after the experimental markings..

Reading Dates	HD-21A:	Aug 17	Aug 28	Oct 2	Nov 8	April 21
	Waterborne:	Sept 12		Oct 2	Nov 8	April 21
HD-21A White		367	349	390	370	37
Waterborne White		323		276	317	101
HD-21A Yellow		254	277	282	282	33
Waterborne Yellow		237		221	217	56

Table 11 – Summary of average retroreflectivity values.

Retro values for the HD-21A markings start off higher, and remain higher, than the standard waterborne throughout the summer and fall months. This is an advantageous property of the experimental marking material as a marking with greater retroreflectivity will be easier to identify during evening hours with little to no ambient lighting. The increase from standard to experimental is between 10 and 40% depending on the site visits at which the readings were taken. After the winter months and plowing season, however, the retro values for the experimental markings fell below those of the standard, resulting in a decrease in values of 50% on average for both colors combined.

There can be two sources for the dramatic decrease in HD-21A retroreflectivity values. The first being the glass beads getting sheared off by snow plows and the second being the actual marking material itself being sheared off. During site visits, durability readings were determined. All markings received values of 9 or 10 (out of 10) throughout the summer and fall months. For the April site visit, HD-21A's durability average was a 3.3, while that for the standard waterborne was 5.3. Neither value is even reasonably acceptable, since they represent a substantial loss in marking material from the road surface, however the 3.3 that the HD-21A received indicates that far more of that material was now missing as compared to the standard. Of the areas that were still in tact, glass beads were found prominently on some areas while not on others. This would indicate that plowing in actuality did both; it sheared off only glass beads in some areas and the entire marking in others. As stated previously, larger glass beads, known as Visibeads, were applied to the experimental markings. While the initial increase in retroreflectivity may be attributed in part to these larger glass beads, they also may be more susceptible to snow plow damage as a larger glass bead most likely protrudes from the marking material.

In addition with the recorded decrease in retroreflectivity and durability, the material and installation costs were also unfavorable for the HD-21A. According to cost data provided by the manufacturers and the State Traffic Shop, the HD-21A cost was 17.3 cents per linear foot, while the cost of the standard waterborne was 13.6 cents per foot; this represents a 27% higher cost for HD-21A. With the net benefit taken into account, the HD-21A was about 10% more effective overall during the fall timeframe. When the increased cost, decreased performance, and the need for slight equipment modifications are taken into account, the HD-21A cannot be recommended for use based upon the findings of this research project.

8.0 REFERENCES

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