New Hampshire DOT

Research

Airport Pavement Paint Study Implementation & Evaluation

Final Report

Prepared by Jacobs Engineering Group, Inc., for the
New Hampshire Department of Transportation, in cooperation with the
U.S. Department of Transportation, Federal Highway Administration

Technical Report Documentation Page

1. Report No.	2. Gov. Accession No.	3. Recipient's Catalog No.
FHWA-NH-RD-26962T		

4. Title and Subtitle	5. Report Date
Airport Pavement Paint Study - Implementation & Evaluation	July 2020
	6. Performing Organization Code

7. Author(s)	8. Performing Organization Report No.
Sandra Baumann, E.I.T, John Gorham, P.E.	

9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
Jacobs Engineering Group, Inc. Two Executive Park Drive Bedford, New Hampshire 03110	
	11. Contract or Grant No. 26962T, A004(708)

12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
New Hampshire Department of Transportation Bureau of Materials & Research Box 483, 5 Hazen Drive Concord, New Hampshire 03302-0483	FINAL REPORT (2017-2020)
	14. Sponsoring Agency Code

15. Supplementary Notes

Conducted in cooperation with the U.S. DEPARTMENT OF TRANSPORTATION, FEDERAL HIGHWAY ADMINISTRATION

16. Abstract

Staining of airfield markings is a safety problem. On airport pavement, white paint markings indicate that the pavement is a runway; yellow paint indicates the pavement is a taxiway or aircraft parking apron. Maintaining this difference in color is critical for the safety of all airport users. Iron, which is present in the sand and stone (aggregate) within the bituminous pavement, stains the airfield paint a yellowish-brown shade, which is particularly noticeable on the white paint. This staining affects compliance with the color standards required by the Federal Aviation Administration (FAA) and Department of Defense (DoD). The results of a 2015 NHDOT study determined that airport pavement aggregate that contains iron, as evidenced by rust-colored aggregate in the pavement surface, is present at some NH airports including Laconia Municipal Airport in Laconia, NH, resulting in rust staining of the runway paint. The current study implemented and evaluated the performance of various pavement marking paint options at Laconia Airport and found that a stain resistant additive extended the service life of the white paint markings and that paint markings on seal coated areas experienced reduced paint discoloration.

17. Key Words	18. Distribution Statement
Airport runways, Pavement markings, Traffic paint, Reflectivity,	No Restrictions. This document is available to the public through the National Technical Information Service (NTIS), Springfield, Virginia, 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
UNCLASSIFIED	UNCLASSIFIED	97	

Airport Pavement Paint Study - Implementation & Evaluation

Prepared by:

Jacobs Engineering Group, Inc.
Bedford, New Hampshire

Prepared for:

New Hampshire Department of Transportation
Bureau of Materials & Research
Concord, New Hampshire

DISCLAIMER

Acknowledgments:

NHDOT:

Beran Black
Wade Footer
Deirdre Nash P.E.
Carol Niewola P.E.
Ann Scholz P.E.
William Stanfield

Laconia Municipal Airport:

Marv Everson

Jacobs Engineering Group Inc.:

Sandra Baumann, E.I.T
John Gorham P.E.

Sightline LLC: Donna

Speidel

Table of Contents

Figures

Tables

Executive Summary

Funded in part through a grant under the Federal Highway Administration's (FHWA) Statewide Planning and Research (SPR) program and New Hampshire Department of Transportation (NHDOT) funds, this research study sought to 1) conduct in-place trials of various pavement paint types to compare rust staining of the paint; 2) evaluate service-life of paint beads in various paint thicknesses; and 3) to provide recommendations for follow-on studies or actions.

Staining of airfield markings is a safety problem. On airport pavement, white paint markings indicate that the pavement is a runway; yellow paint indicates the pavement is a taxiway or aircraft parking apron. Maintaining this difference in color is critical for the safety of all airport users. Iron, which is present in the sand and stone (aggregate) within the bituminous pavement, stains the airfield paint a yellowish-brown shade, which is particularly noticeable on the white paint. This staining affects compliance with the color standards required by the Federal Aviation Administration (FAA) and Department of Defense (DoD).

Iron staining has occurred within six months to a year of paint application at many New Hampshire airports[1]. As funds are available, airports correct the staining by repainting or a combination of removal and repainting. Sometimes, it may be years before an airfield repainting project can be funded. This study observed various paint types with and without stain and rust inhibitors over a 24-month period.

Glass beads installed with the paint improve visibility in low-lighting by reflecting the paint color. The larger bead increases the conspicuity of the paint and thereby increases safety. However, larger beads require thicker paint to achieve the proper embedment. The study observed the bead retention and reflectivity of various paint types over a 24-month period.

The study was carried out at Laconia Municipal Airport – an aggressive environment for both markings and glass beads but very typical of New Hampshire airports. The airport pavement's aggregate contains iron as evidenced by rust-colored aggregate in the pavement surface[2]. This has resulted in rust staining of the runway paint. Additionally, the airport experiences numerous snow and ice removal events that require the use of snow plows and blowers. This equipment's cutting edges ride over the pavement and paint. Glass beads embedded in the paint can be scraped off by the snow removal equipment.

The FAA specification P-620 paint and beads specifications were used as the baseline for this study. Five areas were prepared with combinations of Type II and III paint, Type I and III beads, different paint thickness, and bare pavement and seal coat surface conditions. Stain resistant and rust inhibitor additives were included in certain study areas. Areas adjacent to but outside the study areas were painted with Type III paint and beads at the minimum FAA specification thickness and used to compare the study area color performance.

The study found that the stain resistant additive extended the service life of the white paint markings. Additionally, paint markings on seal coated areas experienced reduced paint discoloration. The study found that that the smaller Type I beads applied in the FAA specification paint thickness yielded higher reflectivity than the Type III beads in the FAA specified thickness or thicker Type III paint. The bottom-up rust spot stains were mitigated by the rust inhibitor and pavement seal coat. It was found that the rust spot stains do little to impact the pilot's use of the paint as a visual indicator of the runway environment. Recommendations for further studies or actions are presented at the end of this report.

[1] Pouliot, Michael. NHDOT, 2011, Project meeting notes.
[2] Laconia Municipal Airport Pavement Evaluation Preliminary Report, Dr. David Gress Ph.D., P.E., March 2012, p. 2.

1) Study Objectives

The study had three objectives:

1) To conduct in-place trials of various pavement paint types to compare rust staining.
2) To evaluate the service life of paint beads in various paint thicknesses.
3) To provide recommendations for follow-on studies or actions.

The first study objective compared control samples placed adjacent to the field painted surfaces. Control samples consisted of aluminum sheets, one for each area that were painted over during the 2017 installation of the study's pavement markings. The control samples were not exposed to sunlight or weather over the study period. This objective also evaluated bottom up rust spot stains that were observable on the surface of the paint and were counted in each of the sample areas.

Figure 1: Control Sample Comparison

Figure 2: Bottom-up Rust Spot Stain Counting

The second study objective, paint bead performance, was evaluated by field reflectivity readings. Reflectivity readings were conducted using trained staff from the NHDOT and their retroreflectometer at the same time the color comparison and rust spot stains counts were made. A second analysis of the bead performance was the measurement of bead loss. Bead loss was measured from magnified photographs of the field samples. 'Craters' in the paint surface where a bead had been embedded were counted from magnified photographs in an office setting.

Figure 3: Retroreflectometer Measurement

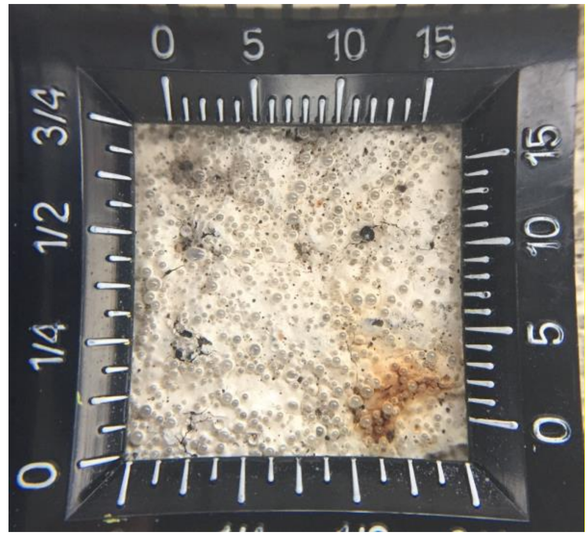


Figure 4: Bead Loss Counting Photograph

The third study objective, recommendations for follow-on studies or actions, is based on observations during this study. The recommendations seek to improve the study's results through controlling the paint applications and the procedures for conducting the field measurements that will aid in future airfield pavement marking decisions for affected airports.

2) Methodology

2.1 Study Location

2.1.1 Laconia Municipal Airport – Runway 8-26

Laconia Municipal Airport's Runway 8-26 was selected as the location for the study for multiple reasons. The first is that the pavement surface has rust-forming iron aggregates and the runway paint is subjected to rust-staining. In addition, prior to the study, the runway paint had a history of turning from white to brownish color from rust staining.

A second reason the airport was selected was because a portion the runway had received a sealant (FAA specification P-608) just prior to this study. It was hypothesized that a sealant would provide an additional barrier reducing the staining of the white paint by the rust-inducing aggregates.

A third reason is that the frequent snow and ice removal operations resulted in snow removal equipment blades creating shear forces over the paint to challenge the bead embedment and performance.

The study area locations on the airport are provided in Figure 9.

2.1.2 Runway 8-26 Pavement

At the beginning of the study, the runway's bituminous pavement was 11 years old[3]. The pavement section includes 4 inches of bituminous pavement over 12 inches of reclaimed aggregate base course. The inner 80-foot width of the runway is grooved.

The runway pavement condition index (PCI) values were obtained in 2012. The PCI study indicated low to moderate raveling of the pavement aggregates. The raveling is shown in Figure 5. In the figure, the dark spots in the pavement are the small holes (i.e., raveling) where the pavement aggregate has eroded. The raveling is attributed to deleterious pre-weathered aggregates in the bituminous concrete surface[4]. These aggregates decomposed when exposed to the elements. The result of the aggregate weathering are small pockets or holes in the pavement surface. In the Runway 26 seal coat area of the study (area G), the 2012 PCI was estimated at a 46 rendering the pavement in fair condition prior to application of the seal coat. In study areas 1 through 4, the PCI ranged from 74 to 95. These values describe a very good pavement condition.

[3] Steven J. Smith Associates Inc., Runway Rehabilitation Project, Typical Sections Drawing, March 2006.
[4] Laconia Municipal Airport Pavement Evaluation Preliminary Report, Dr. David Gress Ph.D., P.E., March 2012, p. 25.

Figure 5: Loss of Aggregate in Runway Surface

2.2 Frequency and Duration of Testing

The study was conducted over a 24-month period. The first observations were made in December 2017, approximately 2 to 3 months after the study areas were painted and before any snow or ice removal events. Including December 2017, eight observations were made approximately every 3 months with the last observation date in September 2019.

2.3 Materials

2.3.1 Paint

Federal Specification TT-P-1952E paint was selected based on the FAA P-620 specification. The TT-P-1952E is a low volatile organic compound (VOC), ready mixed, one-component, 100% acrylic waterborne airfield and traffic marking paint.[5]

Five paint types were selected. Because of the pavement's proximity to Lake Winnipesaukee, and the potential increased humidity and mold on the paint, two areas (1 and 2) were selected to use an FAA specification P-620 paint with stain resistant (SR) additive. Two additional areas were intended to use the P-620 paint with a rust-inhibitor (RI) additive to mitigate against the presumed rusting. However, due to availability, only area 3 received the RI paint. Area 4 was painted with standard FAA P-620 Type II paint with no additives. The fifth area was selected to evaluate P-620 paint without additives on

[5] www. http://everyspec.com/FED_SPECS/T/TT-P-1952E_7387/

a seal-coated asphalt surface. The FAA recommends 30-days of seal coat cure time before painting to allow the water and volatiles to be released from the seal coat.[6] The P-608 seal coat was applied on June 1, 2017, 115 days before the area G study paint was applied allowing for ample curing time prior to applying the study's paint.

The rest of the runway, outside of the test locations, were painted with a standard FAA P-620 Type III paint with no additives. This allowed comparison of the paint with additives and without at the boundaries of the test areas shown in Figure 9.

The paint data is summarized below in Table 1.

Table 1: Paint Data

Area	Type	Manufacturer	Batch/Product No.
1	II SR	Safety Coatings	BO7728
2	III SR	Safety Coatings	BO7726
3	III RI	Sherwin Williams	Not available[1]
4	II	Sherwin Williams	0.0TM2152-20
G & Outside Test Areas	III	Sherwin Williams	275TM2538-61

[1] October 19, 2017 report notes Type III paint with rust inhibitor used.

2.3.2 Paint Beads

Federal specification TT-B-1325D, Type I and III beads manufactured by Swarco Industries Inc. were used. Type III beads are larger in diameter and provide higher reflectivity than Type I beads. Type III and I bead maximum diameters are 1.180 and 0.850 millimeters, respectively[7].

The FAA recommended that airports that re-mark their pavements on a frequent basis (every 6 months) use a Type I bead[8]. Both bead types were used in the study's test areas. The paint thickness was increased over the FAA specification in area 2 to evaluate if the thicker paint increased the bead embedment and reduced the bead loss.

[6] Federal Aviation Administration, AC 150/5370-10H, 620-3.5, p. 532.
[7] Swarco Airport Glass Beads Products Data, www.Swarco.com/northamerical
[8] FAA Specification AC 150/5370-10G, p. 430 and AC 150/5370-10H, p. 529.

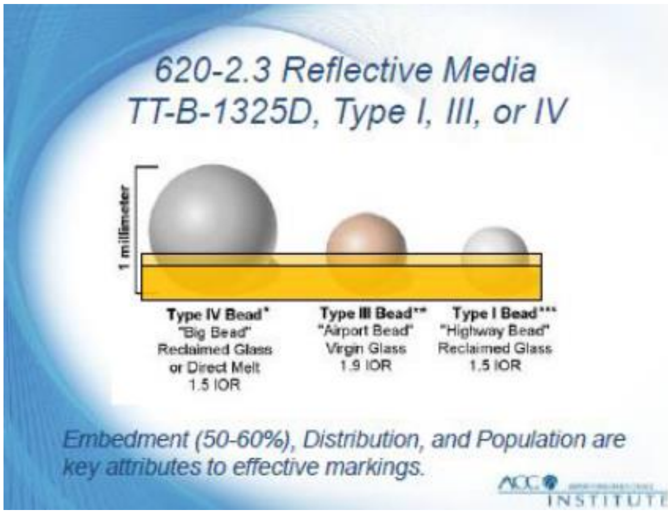


Figure 6: Bead Diameters

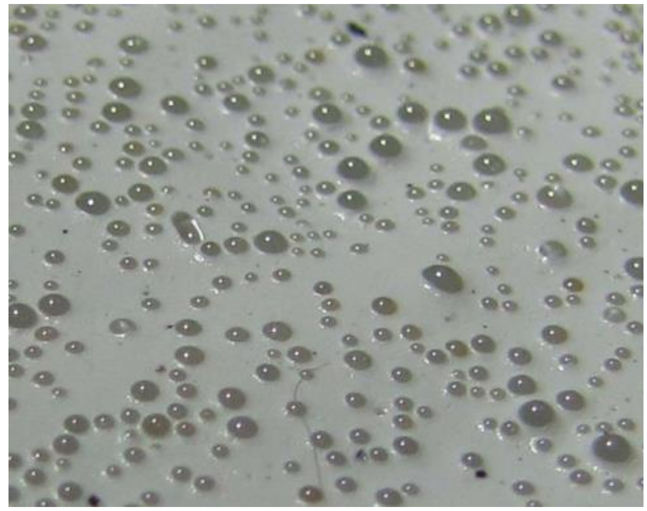


Figure 7: Beads Embedded in Paint

2.4 Paint Installation

2.4.1 Marking Selection - Runway Edges Stripe

The runway's white edge marking was selected as the location for the study. The edge markings consist of 4 stripes that are 4 to 6 inches in width separated by a 4 to 6 inch space.

Of all the runway markings, the edge stripes have the largest volume of stormwater flowing over them. The runway is normally crowned with the high point along the runway centerline. The edge stripes start 47 feet away from the runway centerline and the pavement at the edge stripes is 6 inches lower than the runway centerline. This makes it a worst-case location as it has the highest rust loading from the stormwater flowing over one half the width of the runway pavement as well as the opportunity for bottom up rust spot staining. Additionally, if the study paint resulted in significant color changes, the edge stripes were considered as lower priority markings on the runway and therefore a lower safety issue.

The location of the edge stripes is on un-grooved pavement. The runway is grooved with grooves extending 40 feet on both sides of the centerline. The runway grooves expose the aggregates in the pavement from the saw blade cuts. This exposure causes direct contact between the iron in the aggregates and the stormwater. This contact increases the opportunity for the rust to become a solute in the stormwater and flow over the study's paint in areas 1-4. Area G's runway grooves were coated with the P-608 seal coat which reduced the concentration of rust in the stormwater flowing over the area G paint.

Figure 8: Relationship of Runway Centerline to Edge Stripes

2.4.2 Runway Locations

Five test areas of runway edge markings were selected. Areas 1 through 4 were selected in proximity to each other so the paint was applied to the same bituminous pavement materials. The bituminous asphalt pavement in areas 1 through 4 were constructed at the same time. The pavement materials in these areas were from the same source resulting in the same potential for rust-producing aggregates.

Area G ('G' for the Gilsonite in P-608) or the fifth area was selected for its application on the seal-coated surface. The black seal coat is evident in Figure 8. Area G is approximately 900 feet east of the areas 1 through 4 and was paved under the same project as areas 1 through 4.

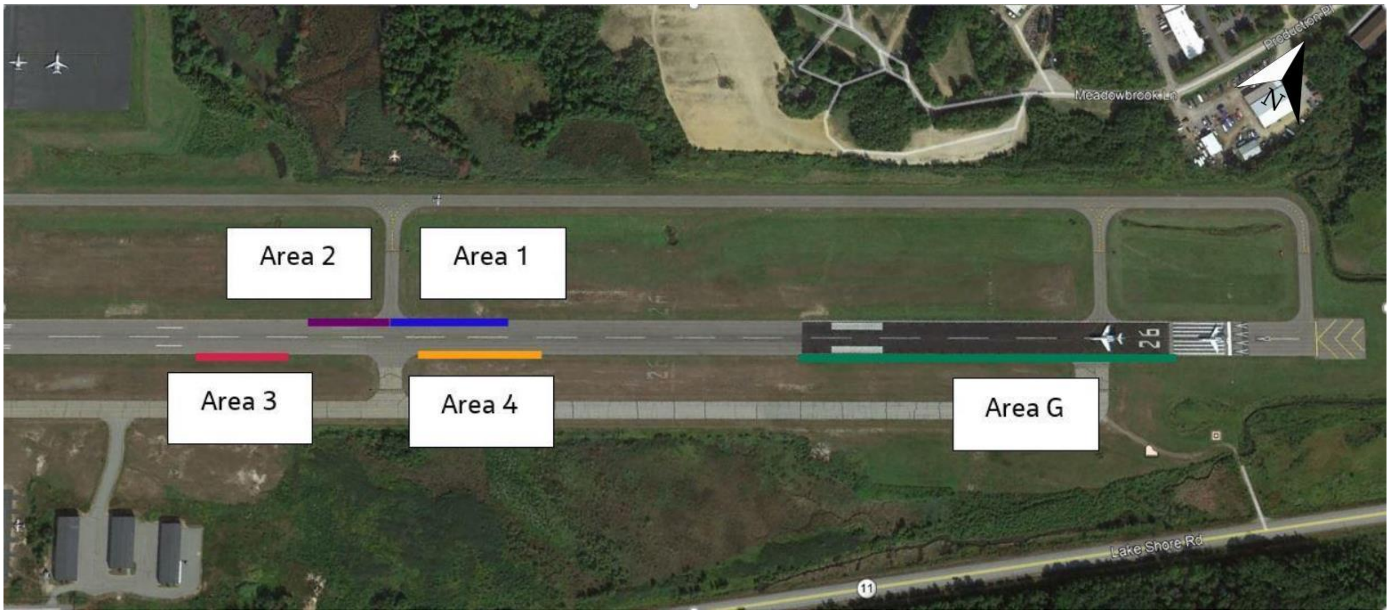


Figure 9: Paint Area Locations at Laconia Municipal Airport

The study sought to compare the performance of the paint in each area to a comparable paint summarized in Table 2. A Type II paint with stain resistant (SR) additive in area 1 is compared to the same type of paint with no additives in area 4. The Type III SR in area 2 is compared to the paint in area 3 with a rust inhibitor (RI) additive. A Type III paint with no-additives applied to a pavement seal coat in area G is compared to the control. As a control, the paint areas outside the study areas, where Type III paint with no additives were placed, were evaluated against the all the study's test areas.

Table 2 Paint Type Comparisons

Comparisons	**Paint to Paint Type**
Area 1 to 4	II SR[1] to II
Area 2 to 3	III SR[1] to III RI[1]
Area G to Control	III (on seal coat) to III (on pavement)

[1] Paint additive added to paint at factory.

Two bead types and three thicknesses of paint were used to study the bead performance. Type III beads were applied in Type II paint at the FAA application rate of 115 SF/Gal in area 1. This tested the theory that that the larger diameter Type III beads would not achieve the embedment depth in a shallower paint depth of the Type II paint and dislodge at a larger percentage. Additionally, Type III beads were installed in Type III paint at the FAA standard 90 SF/Gal application rate (areas 3 and G) and at the thicker 75 SF/Gal rate (area 2) to compare bead retention.

Table 3 below summarizes the paint and bead type testing combinations as well as the sample length, application data, and surface type to which the paint was applied.

Table 3: Paint Application Information by Area

Sample Location	Paint Type	Bead size	Length	Application Rate	Application Date	Surface
Area 1	II SR	III	300 ft	115 SF/Gal	9/9/2017	Bituminous
Area 2	III SR	III	200 ft	75 SF/Gal[1]	9/9/2017	Bituminous
Area 3	III RI	III	240 ft	90 SF/Gal	10/19/2017	Bituminous
Area 4	II	I	315 ft	115 SF/Gal	10/19/2017	Bituminous
Area G	III	III	1050 ft	90 SF/Gal	9/25/2017	Seal Coat
Control[2]	III	III	N/A	90 SF/Gal	8/15/2017	Bituminous

[1] Thicker application than FAA P-620 minimum application specification of 90 SF/Gal.
[2] Control area is considered the paint outside of but adjacent to the study areas.

2.4.3 Installation

Axtell's Pavement Solution LLC (APS) was the installer. APS was under contract with the airport to paint the entire runway. The paint study areas were a small portion of the project of which the study only paid for APS's additional materials and labor needed to implement the study's paint areas. APS installed the study's paint areas by a change order funded by this SPR2-funded paint implementation study.

In all study areas, only one-coat of paint with glass beads was applied. No temporary paint was applied prior to the study paint.

In study areas 1 through 4, the bituminous surfaces were prepared by grinding the existing paint. The surfaces where the paint was removed were further prepared by sweeping and blowing prior to painting. In area G, the existing paint was removed by grinding and then seal coated with the FAA Specification P-608 seal coat by APS under the airport-contracted project. The seal coat cured 115 days before the study's paint was applied, well beyond the FAA P-620 30-day typical cure time.

Figure 10: Runway Paint Removal

The minimum sample area length of 200 feet was considered to allow time for the paint applicator and equipment to simulate the longer lengths installed during construction projects.

Sightline LLC's Donna Speidel and Jacobs Engineering's Tim Buzinski observed the installation of the paint in areas 1 and 2 on September 9, 2017. Area G's paint was installed on September 25, 2017 and observed by Tim Buzinski. Areas 3 and 4 were installed on October 19, 2017 and observed by Jacobs Engineering's John Hehir. The installation reports are provided in Appendix B.

Prior to the installation each paint applicator was calibrated to the specified paint and bead application rates on the airport's abandoned runway pavement. Paint was installed with self-propelled, ride-on Graco paint machines that were equipped with automatic, pressurized glass bead dispensers.

Figure 11: Paint and Bead Installation

Figure 12: Paint and Bead Application Equipment Calibration

Control panels, used for the follow-on color comparisons, were created during the installation. The control panel consisted of a 4-inch wide by 8-inch by 1/8-inch aluminum sheet. The control panel was placed in the painting path during the installation within the study areas on Runway 8-26 to obtain a representative sample. The control panels were protected from sunlight and humidity over the period of the study by storing in protective envelope in Jacobs' office.

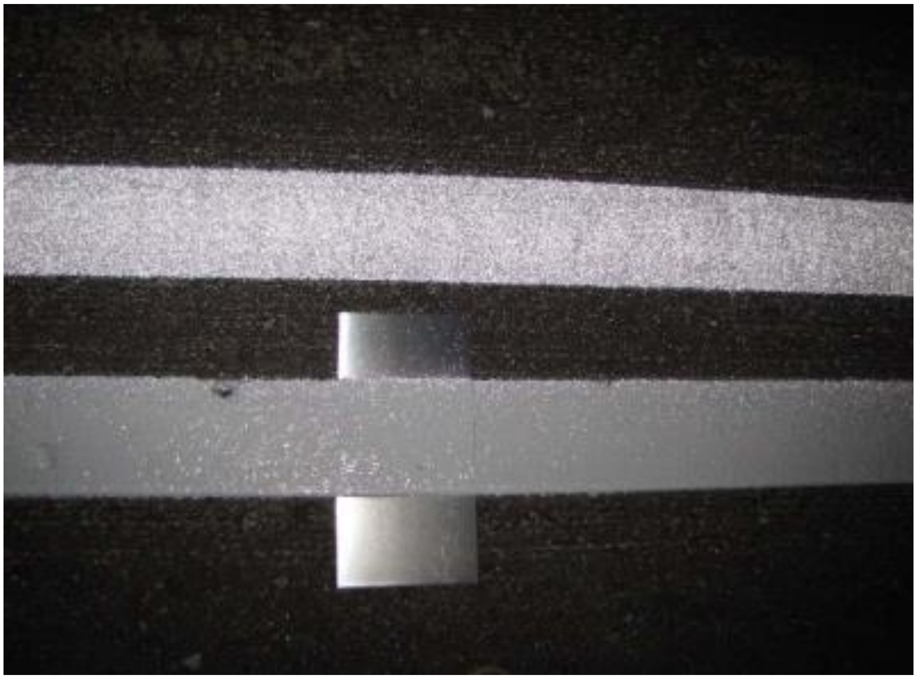


Figure 13: Aluminum Control Panel Placement - Area 1 – 9/9/2017

2.5 Field Measurements

2.5.1 Locations

After the paint had been applied, the first task was to establish the study's paint sample locations. The process attempted to ensure that each field measurement that occurred every three months was taken in the same sampling location. This was especially important when measuring reflectivity and taking magnified images for use in counting bead loss. Marking paint and pavement PK nails (driven flush with the pavement) were used to identify the locations. The nails did not contribute to the paint staining.

In selecting the sampling locations within each study area, random numbers were used to identify unbiased sample locations. After each study area's length was divided in two, the half-length was multiplied by a random number to determine two sample locations in each half-length. This resulted in two sample locations in each half of the study area for a total of four sample locations per study area. The random sample location calculations for each study area are provided in Appendix A. Figure 14 shows the locations of each study area and each sample location (see Table 4 for the figure's legend).

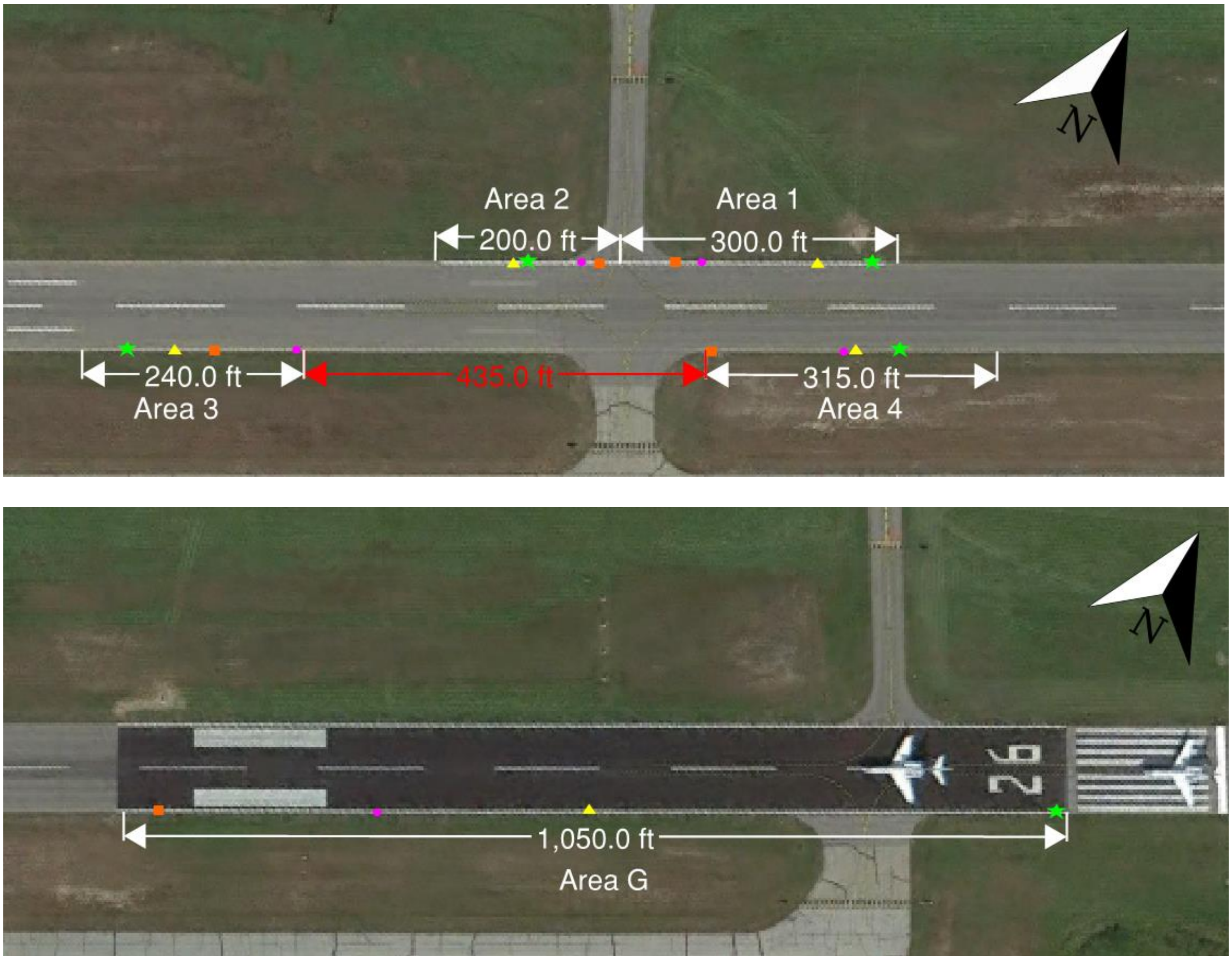


Figure 14: Locations of Random Sampling Within Each Study Area

Table 4: Random Sample Location Color Code Legend in Figure 14

Sample #	**Shape**
1	Circle
1A	Square
2	Triangle
2A	Star

All sample locations were taken on the first line of the runway edge markings. This not only helped to simplify the data collection, but as previously mentioned the first in-board line stripe of the runway edge marking receives the greatest concentration of rust-laden stormwater. The rust particles cling to the pores in the paint. This results in each subsequent downhill stripe receiving a smaller concentration of rust as the uphill markings capture the rust particles.

A challenge occurred after the first year of the study. The first in-board stripe of the runway edge marking became severely abraded by the snow plow activity. At the end of the first year a significant physical loss of paint was noted and was considered to negatively impact all the measurements in the second year. Therefore, the sample point was moved to the adjacent out-board line beginning on December 20, 2018. The abrasion of the paint can be seen in Figure 15 on the in-board line used for the first year of sampling. The out-board line was used for the second year of sampling. The loss in continuity of data resulting from the location change is described in Section 3.

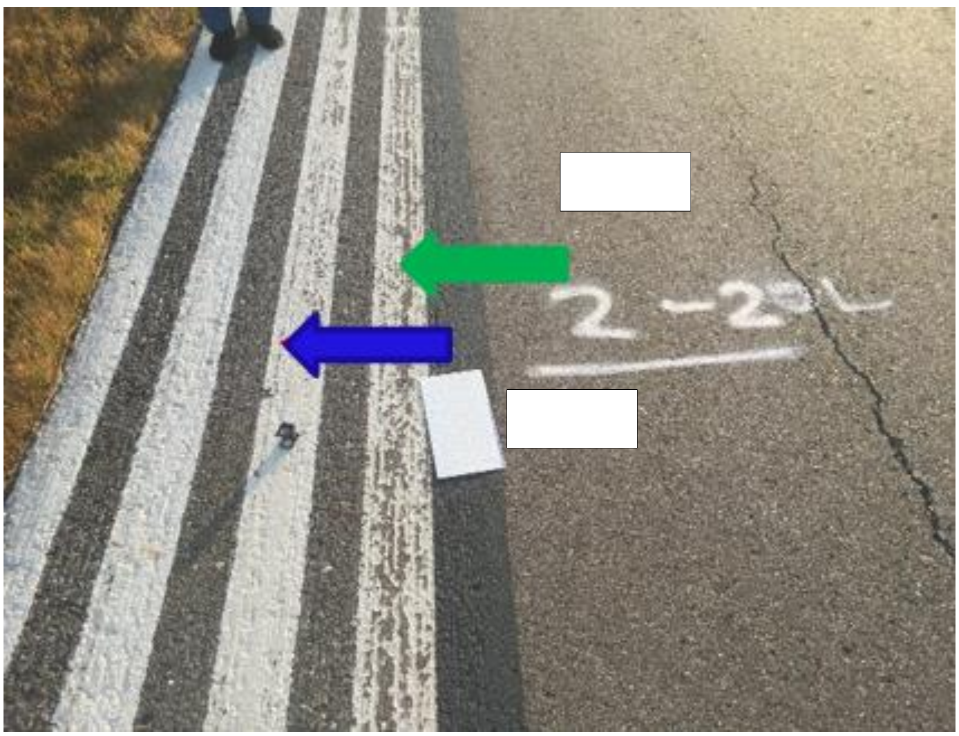


Figure 15: Sample Locations – In-board and Out-board Lines

2.5.2 Dates

Data was collected approximately every 3 months over a period of 24 months. The intent of this interval was to collect enough data points to establish data trends. The duration was selected as it was anticipated the paint characteristics would degrade over this period and anecdotally, the rust staining was known to occur within just a few months of painting the pavement. The data collection dates are presented in Table 5.

Table 5: Data Collection Dates

Date	Approximate months since installation in September and October 2017
12/5/2017	3
3/23/2018	6
6/21/2018	9
9/20/2018	12
12/20/2018[1]	15
4/11/2019	19
7/2/2019	22
9/26/2019	24

[1] Partial data collection this date due to limited access to the runway because of traffic and lack of day light due to late start in sampling on this day.

2.5.3 Paint Color

At each visit the paint color was photographed using an iPhone 6. The control panel collected during the paint installation was brought in its protective envelope from Jacobs' office to the field. The sample was placed on the pavement next to the sample paint location and photographed. Each area had its own control sample for that area's paint and bead type. The same sample was placed at all four sample locations in each area. The time of year and time of day provided different light intensities for the photographs. Some photographs with less than optimum lighting appear darker. The less than optimum lighting did not impact the study comparisons when the photographs are compared over the 24-month study period.

Figure 16: Control Sample Placed Next to Field Paint

2.5.4 Bottom-up Rust Spot Stains

Bottom-up rust spot stains were counted along the first in-board stripe of each area. The count was made by walking the line and if a rust spot stain could be observed at eyelevel, it was counted. The size ranged from the diameter of a pencil eraser to a U.S. nickel. A typical bottom-up rust spot stain can be seen in Figure 17.

Figure 17: Bottom-up Rust Spot Stain

2.5.5 Reflectivity

Reflectivity readings were taken at each sample location using a retroreflectometer. This method of evaluating reflectivity performance was selected for the study as it is common industry practice to use this equipment. In addition, the NHDOT offered the use of the equipment at no additional cost to the study. Trained personnel from the NHDOT Bureau of Materials and Research operated the calibrated retroreflectometer and provided the readings. The retroreflectometer used was LTL-X Mark II manufactured by DELTA. The NHDOT readings are provided in the Appendix D.

Figure 18: Retroreflectometer Reading

2.5.6 Bead Retention

Bead retention was measured by photographing ¾ inch by ¾ inch square at each sample location with an iPhone 6. The location was identified using a rust-proof survey nail set adjacent to the sample area. A ruler was placed on the nail and perpendicular to the paint stripe. The ¾ inch by ¾ inch square area was centered on the paint stripe using the ruler dimensions.

To calculate bead retention, the ¾ inch by ¾ inch square image was imported into AutoCAD® and magnified. Each recession in the paint (crater) where a bead had been was marked and counted. The number of beads lost was equivalent to the craters counted in each sample area. The AutoCAD red dots on Figure 19 represents the craters. When considering bead loss in context with the number beads within the magnified area, it is noted that at the beginning of the study a Type III paint with Type III beads had approximately 550 beads per ¾ inch by ¾ inch square area.

The counting of craters became an issue when the paint was chipped away or when beads had been scraped off as can be seen in the lower left corner of Figure 19. Where paint was missing or scraped, the bead loss was extrapolated to include the number of beads lost on the area of missing or scraped paint, based on how many beads were lost on the rest of the sample area. For example, if ¾ of the area of paint was intact and 120 craters were counted, then it was extrapolated that on the missing ¼ of the paint that 40 beads (120/3 = 40) would have been lost had the paint been present. Thus, in total the study estimated 160 beads (120+40) lost on the entire ¾ inch by ¾ inch square sample area.

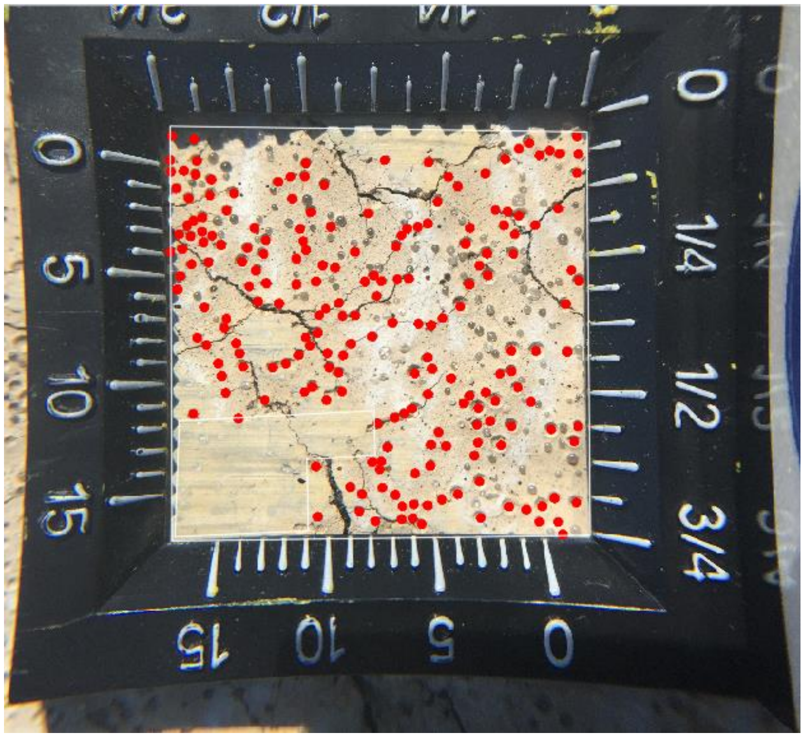


Figure 19: Sample Magnification Area with Bead Loss Count in Red

2.5.7 Rust Removal Test

After the first year of field observations, the study's inspectors noticed the discoloration of the paint was becoming darker with time. Various sources of contamination from dirt, algae and rust were considered. To prove the source of contamination, select sites in each area were scrubbed with soap and water or a rust remover was applied. As soap and water made no change to the paint discoloration, the soil and algae contamination possibilities were eliminated. The application of a commercially available rust remover (Figure 20) resulted in a rapid removal of the contamination on the paint, confirming that the paint contamination was rust. Figure 21 shows the white paint next to where the rust remover was applied. It is noted that the rust staining is only on the surface of the paint. The rust is not within and did not damage the paint. Additionally, the bottom-up rust spot stains were removed with the rust remover.

Figure 20: Rust Remover

Figure 21: Soap and Water vs. Rust Remover

3) Analysis

Based on the data collected, images and readings were compiled and tabulated. The analysis of the study's first two objectives, to compare the rust staining of various paints and evaluate the service life of the paint beads, is described below.

3.1 Color Comparison

The paint color was analyzed by comparing the applied paint with a paint test panel. The color comparison analysis is subjective to the viewer's eye. As previously mentioned, the time of day and time of year affected the lighting and could make some of the pictures appear darker. However, when one looks at the overall trend, the contrast between the control sample and the field paint is evident.

It was observed that over the 24-month period all paint test areas' color deteriorated, changing from white to brown undertones. The paint stripes observed on September 26, 2019, the last observation at the end of the 24-month study period, for each area can be seen below in Figures 22 through 26 along with their associated control panels:

Figure 22: Area 1 II SR/III

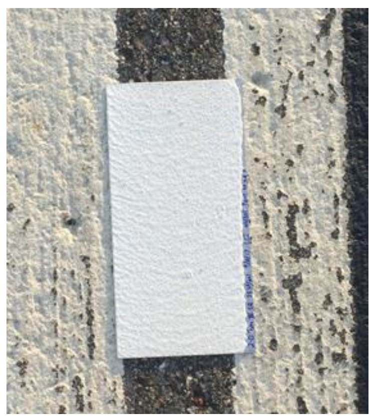


Figure 23: Area 2 III SR/III

Figure 24: Area 3 III RI/III

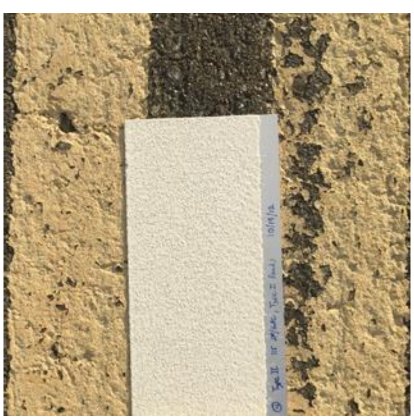


Figure 25: Area 4 II/I

Figure 26: Area G III/III

Legend: Paint type/Bead type
SR – Stain Resistant Additive
RI – Rust Inhibitor Additive

The change in color was also noticed, or not, at the interface between the test area and the control areas adjacent to but outside the test areas. This perspective confirmed the performance of the paint that aged under similar conditions. The paint outside the test areas was the FAA P-620 specification Type III paint with Type III beads. Area G has black seal coat under the white marking. The contrast between the paint and the dark pavement in area G is evident. Representative comparisons of each study area are shown below in Figures 27 through 31 (all control sections are labelled III/III for the standard FAA Type III paint with Type III beads).

The color comparison pictures from the other data collection dates can be found in Appendix C.

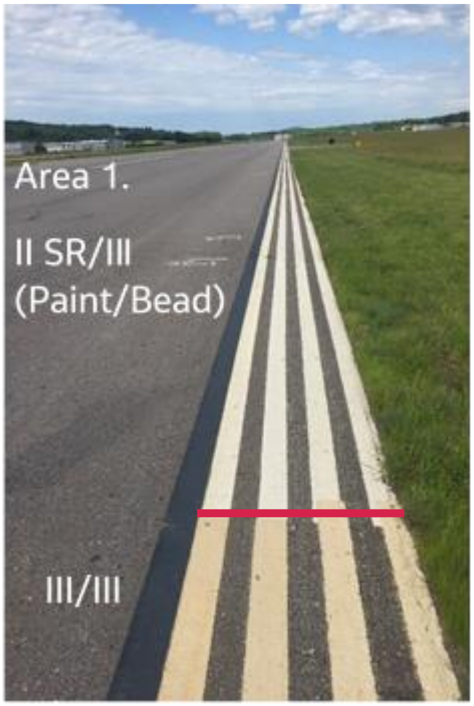


Figure 27: Comparison Area 1 – 7/2/2019

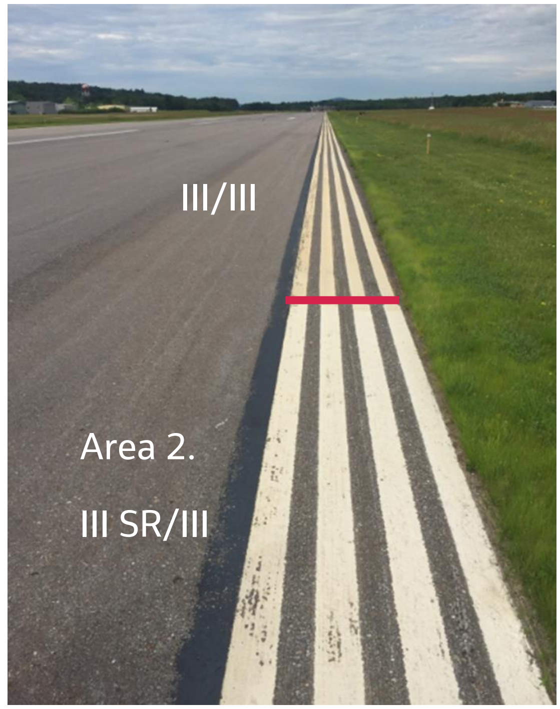


Figure 28: Comparison Area 2 – 7/2/2019

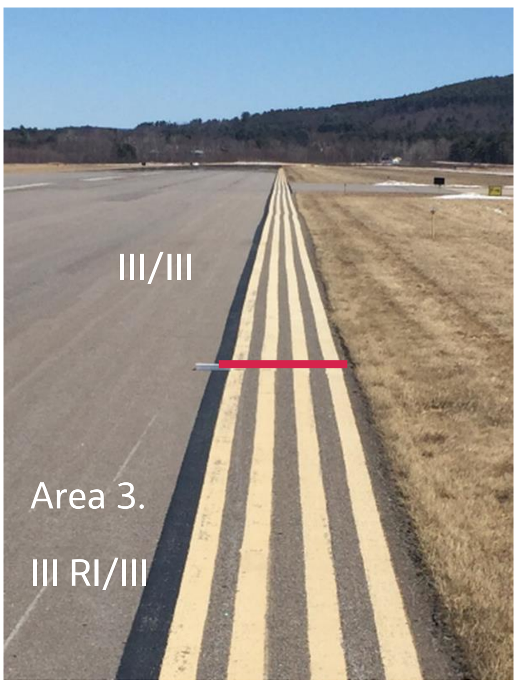


Figure 29: Comparison Area 3 – 4/11/2019

Figure 30: Comparison Area 4 – 9/26/2019

Legend: Paint type/Bead type
SR – Stain Resistant Additive
RI – Rust Inhibitor Additive

Figure 31: Comparison Area G – 9/26/2019

Summary – Color Comparison:

As can be seen in the images, the entire length of the paint discolors indicating rust staining from stormwater runoff across the markings. The areas that have the most discoloration are areas 3 (Type III RI paint) and 4 (Type II paint without additives). The rust inhibitor is an additive to the paint's formulation. The inhibitor does not mitigate the rust particles adhering to the porous paint surfaces during a storm event. The paint with rust inhibitor discolored like the paint without rust inhibitor. However, the paint with the rust inhibitor had the least amount of bottom-up rust spot stains as discussed in the next section.

The paint placed on the seal coated surface in area G, where a rust inhibitor was not used, also exhibited a rust discoloration. The rust discoloration can be seen in Figure 38 of this report. Though the contrast of the rust discoloration next to the black pavement makes the discolored paint appear whiter.

The areas that performed the best were areas 1 and 2 where the stain resistant paint additive was used. The additive makes the surface of the paint less porous which prevents rust from clinging to the paint and alter the paint's color. Area 2 (III SR/III) performed slightly better and had a whiter appearance than area 1 (II SR/III).

3.2 Bottom-up Rust Spot Stains

The number of bottom-up rust spot stains were plotted as stains per 100 feet, as each area had a different length. The average number of rust spot stains counted during the 24-month period is shown in Figure 33. These stains are not related to the rust laden stormwater sheet-flowing over the paint. These rust spot stains originate from below the paint.

Figure 32: Rust Spot Stain in Area G

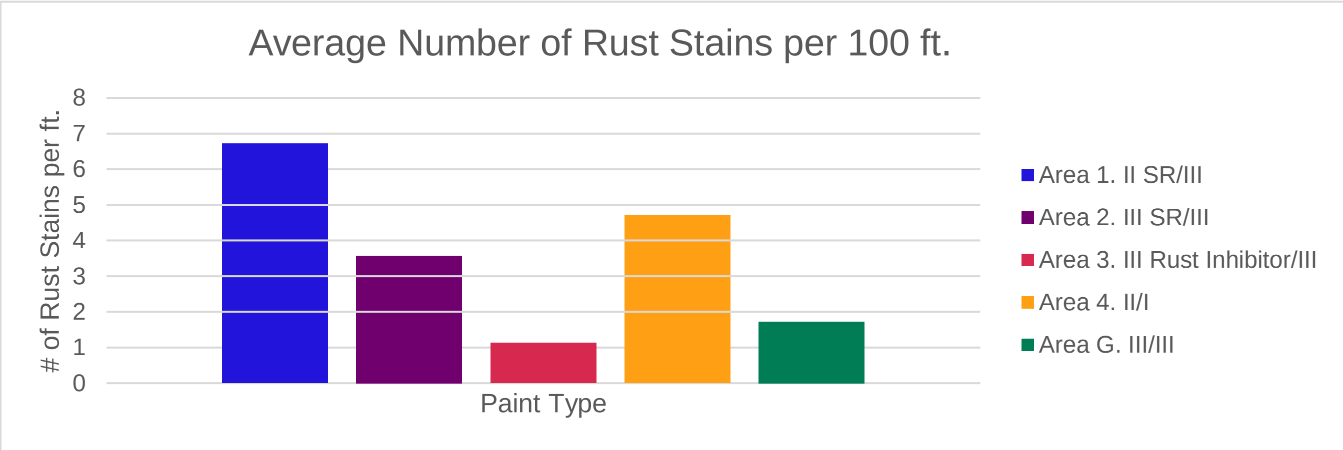


Figure 33: Average Number of Bottom-Up Rust Spot Stains per 100 ft

Summary – Bottom-up Rust Spot Stains:

Area 3 with a Type III RI paint had the lowest number of unique bottom-up rust spot stains. Area G with a standard Type III paint on the seal coat surface was close in number to Area 3 likely due to the seal coating over the iron-laden aggregates in the pavement surface. The Type III SR paint in area 2 did not perform as well as areas 3 (Type III RI) and G (Type III). The Type II paints in areas 1 and 4 had higher number of rust stains per 100 linear feet of paint. The study did not count the bottom-up rust spot staining in the control areas outside of the study areas. The control areas were used for color comparison purposes and not bottom-up rust stain spot counting.

Areas 2, 3 and G that used the high-build Type III paint with 100% cross-linking acrylic latex were installed in a thicker application than areas 1 and 4. High-build coatings are coating materials formulated so that a single application can cover surfaces with relatively thick films that don't sag or run.[9] The added paint thickness and chemical structure of the Type III paint may have prevented water from moving vertically through the paint layer to the iron aggregates in the pavement and thereby reduced the bottom-up rust spot stains.

When area 2 and 3 are compared, the one difference is the use of the rust inhibitor additive in area 3. Even with area 2 having a thicker application, area 3 had fewer bottom-up rust spot stains. From this

[9] www.corrosionpedia.com

comparison it is reasoned that the paint's rust inhibitor additive prevented the bottom-up rust spot stains.

Area G performed well, with the second fewest rust spot stains. This area's paint was placed on the seal coat. The paint in area G was also observed to have more cracking than areas 2 and 3 with similar type III paint. The cracking provides more pathways for stormwater to enter the paint. Without the seal coat the added moisture would allow more rust to form from the iron aggregates. However, the seal coat appeared to have reduced the rust forming as the number of bottom-up rust spot stains are lower than comparable study areas.

The counting of unique rust spot stains was objective and prone to human error. Not all the same rust spot stains were counted each time the data was collected, likely due to the contrast between the paint and the rust stains. Some rust spot stains might have been overlooked if they blended in with the browning background paint. This might explain why there isn't a continuous increase in rust spot stains over time and why more rust spot stains were counted on areas 1, 2 and G (see Table 6), which had a whiter color, compared to areas 3 and 4, which were more discolored. Additionally, paint scraped off in the sample areas after the first year would result in bottom-up rust spot stains along with the paint being removed.

The study noted that while the rust spot stains discolor the paint, they are more of a nuisance than a major factor in the discoloration of the paint caused from rust-laden stormwater runoff. From a pilot's perspective hundreds of feet away, the rust spot staining slightly compromises the paint color recognition.

Table 6: Bottom-Up Rust Spot Stains by Area and Date

Paint/Bead Type	Sample Length	12/5/2017	3/23/2018	6/21/2018	9/20/2018	4/11/2019	7/2/2019	9/26/2019
Area 1 II SR/III	300'	12	20	29	29	24	17	10
Area 2 III SR/III	200'	0	2	4	11	3	4	26
Area 3 III RI/III	240'	0	3	4	4	3	2	3
Area 4 II/I	315'	16	16	16	16	14	12	14
Area G III/III	1,050'	0	2	30	30	25	15	25

Note: The December 2018 rust spot stains were not counted due to lack of availability of the runway and inclement weather conditions.

3.3 Reflectivity

The reflectivity values obtained from the retroreflectometer were averaged for each area by collection date and plotted in Figure 34. The raw reflectivity data is provided in Appendix D.

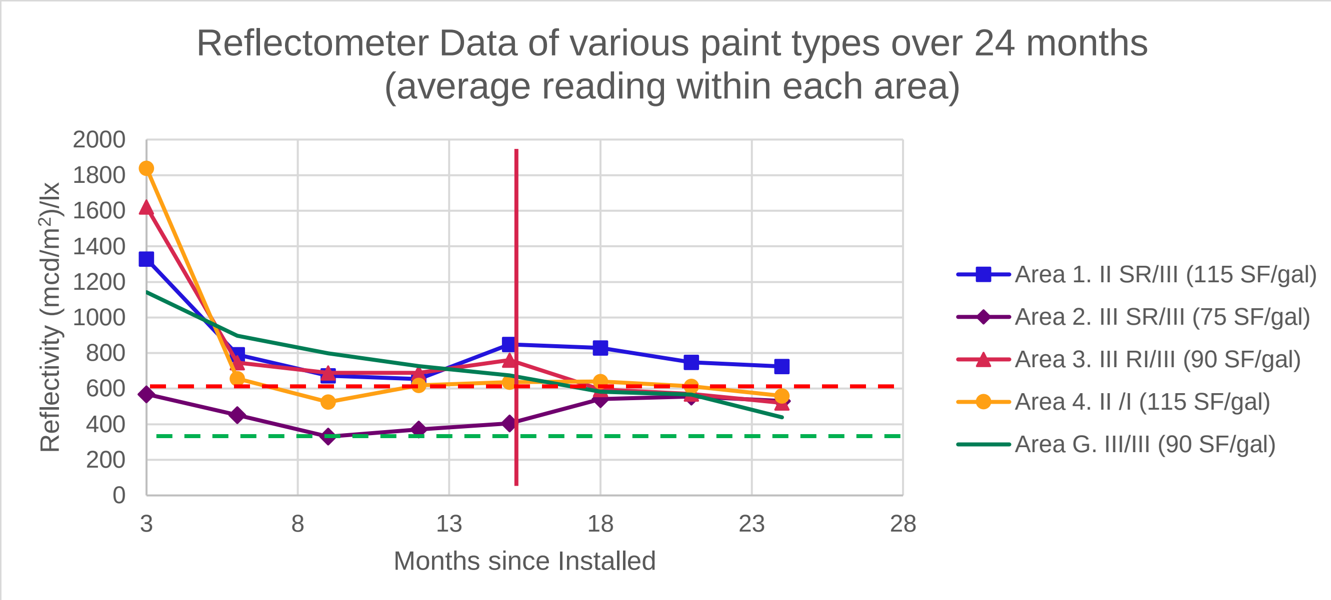


Figure 34: Average Reflectometer Readings

Summary - Reflectivity

The reflectivity readings yielded high results compared to the FAA minimum specifications; however, the similar values at the end of the study provided no significant basis of ranking one bead type over another.

After the first reading there is a significant drop in reflectivity, which is commonly seen in paint reflectivity readings[10]. As can be seen in the graph at month 15 (see vertical red line Figure 34) the values increase because, due to abrasion of the in-board stripe, the reflectivity reading was moved to the out-board stripe as discussed in section 2.5.1. The out-board stripe had less paint scraped off which resulted in more paint and beads within the test sample and higher reflectivity values. This resulted in resetting the reflectivity readings in Figure 34 at 15 months.

At the end of the 24 months, area 1 had the highest reflectivity reading at 725 mcd/m^2, followed by area 4 at 559 mcd/m^2, area 2 at 530 mcd/m^2, area 3 at 520 mcd/m^2 and area G had the lowest reading at 439 mcd/m^2. All the readings are relatively close with the average being 555 mcd/m^2 with a standard deviation of 105 mcd/m^2.

After 3 months the reflectivity readings are much higher than the minimum requirements in FAA specification P-620. According to the specification, Type I beads should have a reflectivity of 300 mcd/m^2 (see dashed green line Figure 34) at installation and Type III beads should have a reflectivity of 600 mcd/m^2 (see dashed red line Figure 34) at installation. Overall, all the areas have high end readings and exceed FAA's minimum specification requirements for paint reflectivity.

Areas 1 and 2 that used a stain resistant additive had some of the highest overall reflectivity readings. These areas are also the ones that appeared to have the least paint chipping.

It is assumed that the reflectivity of the paint is a function of the whiteness of the paint surrounding the glass bead. A stained paint would reduce the reflectivity reading. However, since areas 3 and 4 had

[10] NHDOT, Wade Footer.

some of the highest discoloration and yet sustained reflectivity readings, it is likely that the beads are not affected by the rust. Though not part of this study, the hard, smooth surface of the bead likely sheds the rust and does not impede the light refraction through the bead.

The hypothesis that the thicker paint would retain the beads longer and therefore would sustain reflectivity is not present in the data. Areas 1 and 4 with the highest readings are both Type II paints applied at the thinner FAA specified rate than the other study areas. In addition, area 4 with a smaller Type I bead and higher staining than area 2 with Type III beads resulted in better reflectivity readings. Area 2, with paint applied thicker than the FAA P-620 minimum, had some of the lowest readings. The larger bead embedment may have reduced the area the light can refract through the bead thereby reducing the light reflection.

The change in reflectivity was calculated by comparing the paint reflectivity at month three to reflectivity at month 24 (see Figure 35).

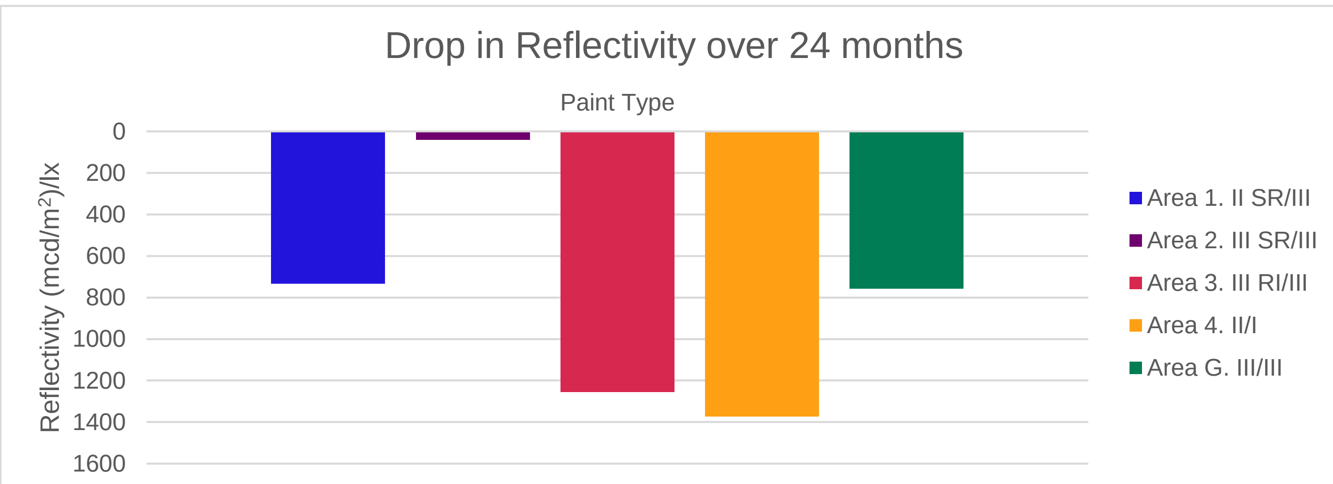


Figure 35: Drop in Reflectivity over 24 months

Area 2, the whitest paint at 24 months and the thickest application, had the least drop in reflectivity and had readings that stayed very constant over the 24-month sampling period. All other areas had noteworthy drops in reflectivity with area 4 having the highest drop. The drop in reflectivity between the areas is not very telling as the end reflectivity for all areas cluster closely together, between 750 mcd/m^2 and 400 mcd/m^2 and are near or exceed the FAA's minimum specification requirements at installation even after 24 months of exposure.

3.4 Bead Loss

The beads lost per area were averaged for each collection date and plotted to find trends in Figure 36. The raw bead loss data can be found in Appendix E.

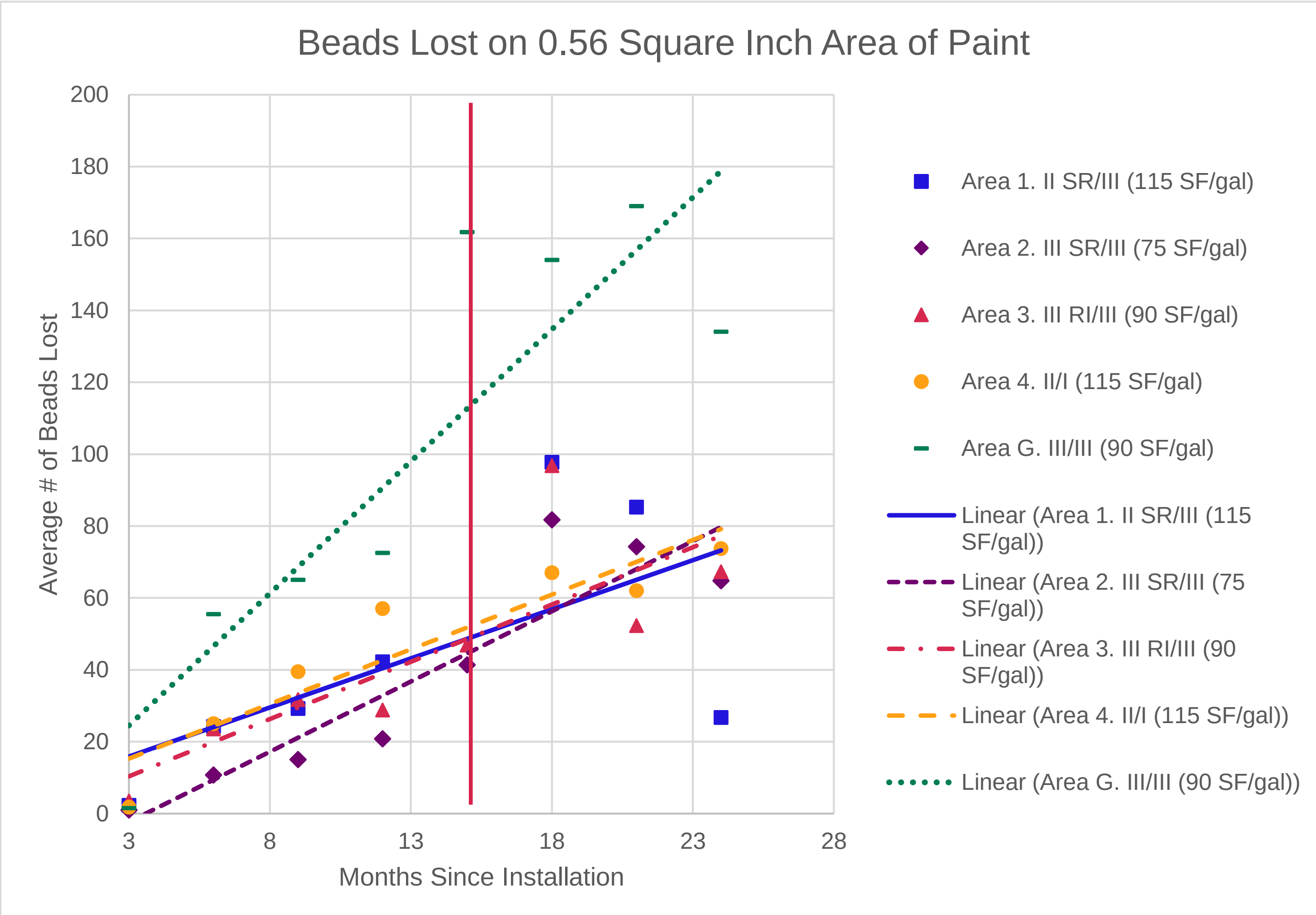


Figure 36: Average Bead Loss per Area

Summary – Bead Loss

Area G experienced the highest bead loss as noted by the steep trend line in comparison to the other areas. The area G paint had a significant amount of cracking and paint chipping which most likely contributed to the loss of beads and resulted in a higher bead loss than the other areas. It is also noted that area G had poor bead embedment at application. The first sampling date in December 2017, a few months after the paint and bead installation, is shown in Figure 37. The figure indicates the poor bead embedment with numerous craters in the paint surface. When reviewing the bead loss data, area G's paint cracking and poor bead embedment at placement should be considered.

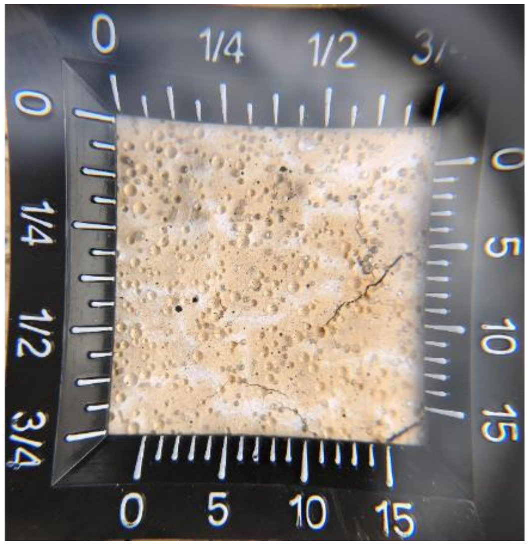
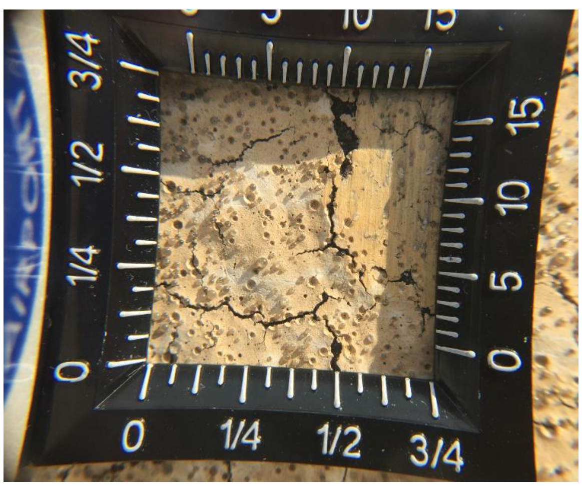


Figure 37: Area G - Sample 1A – 12/5/2017

To further illustrate the poor bead embedment in area G, a comparison of areas G and 1 are shown in the Figures 38 and 39 below. Area G has numerous missing bead craters as compared to area 1 with the beads mostly intact.



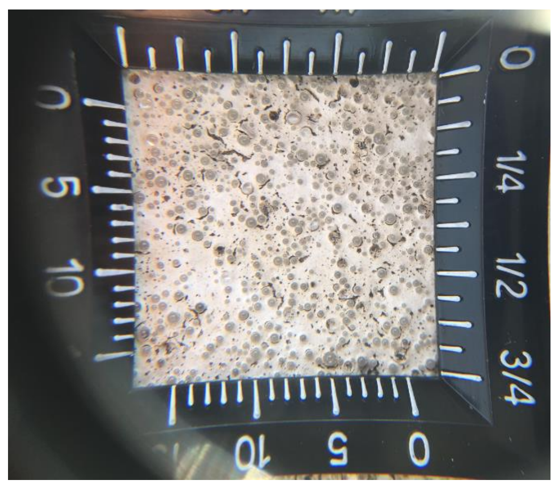


Figure 38: Area G - Sample 2 – 9/26/19

Figure 39: Area 1 - Sample 2A – 9/26/2019

As Figure 36 indicates, areas 1 through 4 tend to have a similar amount of bead loss when looking at the trend lines as the lines cluster together at the end of 24 months and all trend lines are a similar slope. A review of the data indicates that areas 1 through 4 had adequate bead embedment at placement. This can be seen in Figures 40-43.

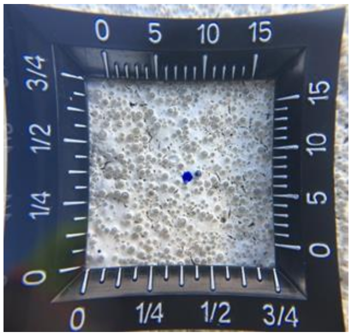


Figure 40: Area 1 - Sample 1 – 12/5/2017

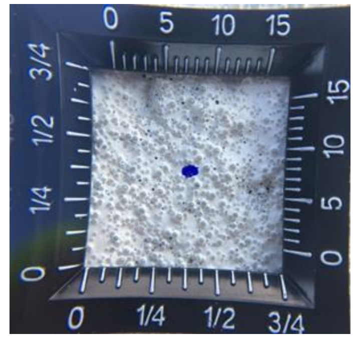


Figure 41: Area 2 - Sample 1A – 12/5/2017

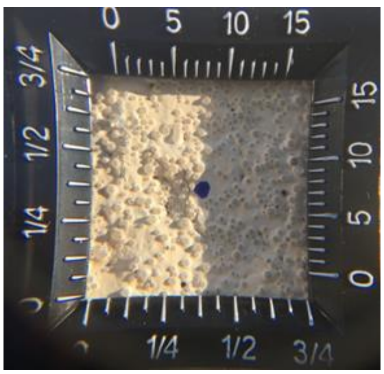


Figure 42: Area 3 - Sample 1 – 12/5/2017

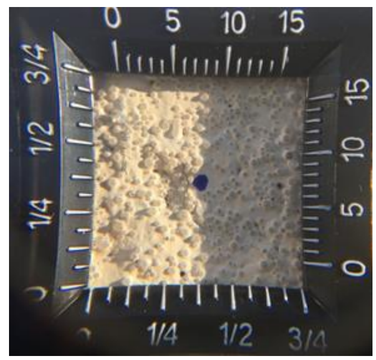


Figure 43: Area 4 - Sample 2A – 12/5/2017

After month 15 (see vertical red line Figure 36) there is a noticeable scatter in the data. The individual data points for each month are no longer on a constant upward trend. This was attributed to the fact that after month 15 the study started looking at the out-board stripe (see section 2.5.1), which was less deteriorated, and therefore those samples may have had more beads. Additionally, even with careful placement, the magnified images were not always taken at the same location. Therefore, each data collection date image might be at a slightly different location on the paint area explaining why the number of beads lost doesn't always increase. The blurriness of some images also made it difficult to determine where bead loss (craters) were in the sample. These factors made measurement and analysis of bead loss more subjective and prone to human error compared to the reflectivity readings.

Up until month 15, area 2 has the lowest bead loss out of all areas. This correlates with the fact that it was the area with the thickest application of paint at 75 SF/Gal. The thicker the paint, the deeper the bead embedment, and the more likely the beads are retained. This can also be seen when looking at data points for area 3 applied at 90 SF/Gal. Area 3 bead loss was almost always lower than that of areas 1 and 4 which both had a thinner paint application at 115 SF/Gal. Areas 2 and 3 used Type III paint which is less susceptible to cracking and therefore improves bead retention. Area G had poor bead embedment from the initial placement, as described above, therefore the values trend higher than the other study areas. The area G data indicates the bead loss outpaces the other areas. One hypothesis is that the cracking and resulting lifting of the area G paint may have contributed to the loss of the beads

3.5 NHDOT Laboratory Analysis

The NHDOT was provided the liquid paint samples in January 2020 for each of the 5 study areas. The samples were delivered in quart size containers obtained in 2017. From 2017 to 2020 the samples were stored in Jacobs office. The idea to test the paint was presented at the end of the study during the study working group review meeting.

The paint applied in areas 1 and 2, with the stain resistant additives, had hardened from the 30-month storage period and, therefore, was not sampled. This may be related to the stain resistant additive as only samples 1 and 2 had hardened. Paint from areas 3, 4, and G had not hardened and were able to be tested.

The NHDOT Materials Testing Lab performed the paint analysis per the state's testing specifications as this was their standard protocol for testing. The FAA's P-620 federal specification TT-P-1952F tests were identified and where the NHDOT's ASTM tests were the same, the NHDOT test results were evaluated against the TT-P-1952F criteria. The NHDOT test result values are provided in Appendix F.

Based on the NHDOT's testing, the paint passed the TT-P-1952F criteria, except for pigment content on sample 3 with a value of 62.4% as compared to the upper limit of 62%. This difference is not considered to be significant in the performance of the paint.

Per the NHDOT requirements, the percent Non-Volatile Vehicle test failed for samples from areas 4 and G. The NHDOT laboratory notes this could affect the dry film thickness of the paint and its ability to hold onto the beads as the paint gets thinner over time.[11] This is confirmed by the study that noted area G had the highest loss of beads.

[11] NHDOT, B. Black, 24 January 2020 email.

4) Conclusions

4.1 Color Comparison

This degradation in the whiteness of the paint is attributed to iron-laden stormwater flowing over the top of the paint and adhering to the porous surface of the paint. Area 2 that used paint Type III with a stain resistant additive and bead Type III retained its white color the best. Using paint Type II or III doesn't seem to make much difference when comparing color, as both area 1 and area 2 maintained their white color over the study period. The paint in area G discolored slightly more than area 1 and 2 and did not discolor as much as the areas with rust-inhibitor additive or with the standard FAA P-620 specification. Additionally, the off-white paint color in area G stands out when contrasted with the adjacent black seal coat.

4.2 Bottom-up Rust Spot Stains

Paint with rust inhibitor additive reduces the number of bottom-up rust spot stains that originate beneath the painted marking and emerge on the top of the painted surface as a rust spot. Area 3 paint, the only area with a rust inhibitor additive, had the fewest number of stains. Area 3 was applied at a lower thickness than area 2 with the stain resistant additive and therefore, thickness does not appear to be the mitigating factor. The chemical constituents in the rust inhibitor additive likely mitigated the rust stains. Additionally, Type II paint that is less flexible as compared to the Type III paint appears to be more prone to bottom-up rust spot stains. This could be due to the cracking and intrusion of moisture through the paint strata to the underlying aggregates. Area G had the next fewest bottom-up rust stain spots likely do to the pavement seal coat.

Bottom-up rust spot stains are a nuisance and are not generally able to be observed by a pilot. The overall pavement marking color, as described above in the Color Comparison conclusion, is more important to the paint performance.

4.3 Reflectivity

The bead reflectivity for all the areas at 24 months was close to or exceeded what the FAA specifies at installation: 600 mcd/m^2 for Type III and 300 mcd/m^2 for Type I beads. Therefore, the different types of beads and paint thicknesses did not affect the ranking of one bead type over another.

The highest reflectivity at the end of 24 months was attained by area 1 with a reflectivity of 725 mcd/m^2 followed by area 4 with a reflectivity of 559 mcd/m^2. Both these areas used Type II paint and had the least amount of paint chipping. The remaining areas also performed well and fell within a reflectivity range of 400 to 600 mcd/m^2. As reflectivity is a measure of the whiteness of the paint and the number of beads, it makes sense that area 1, which retained its color well and had the second lowest average bead loss, exhibited higher reflectivity readings than the other areas.

4.4 Bead Loss

It was determined that the thicker the paint the better beads are embedded and retained. Area 2 had the thickest paint application (75 SF/Gal) and on average the least bead loss, followed by area 3 which had the next thickest paint application (90 SF/Gal). Area G also applied at 90 SF/Gal had poor bead placement during installation and should not be considered in the data.

There is a correlation between bead loss and paint application rate. The thickness of the paint can have an impact on how much paint is chipped off when a snow plow runs over the marking. Areas 1 and 4 which had the thinnest paint application had the least amount of paint chipping.

4.5 Summary of Findings

The stain resistant additive extended the white color of the paint. Additionally, paint on seal coat reduced the paint stain discoloration. Reflectivity and bead loss are not correlated. This does not seem intuitive. The higher bead retention would seem to result in a higher reflectivity. Areas 1 and 4 with smaller Type I beads outperformed the reflectivity of the Type III beads in the thicker paint. The bottom-up rust spot stains are mitigated by the rust inhibitor and pavement seal coat. Though the rust spot stains, when in infrequent distribution over the paint, do little to impact the pilot's use of the paint as a visual indicator of the runway environment. A summary of the findings is provided in Table 7.

Table 7: Study Conclusions

Characteristic	Top 2 Performers	Summary
Color Comparison	Area 2; Area 1	Both paints used stain resistant additive
Bottom-Up Rust Spots	Area 3; Area G	Area 3 rust inhibitor; Area G on seal coat
Reflectivity	Area 1; Area 4	Both Type II paint at 115 SF/gallon
Bead Loss	Area 2; Area 3	Paint thickness assisted in bead retention

A comparison of each area is provided in Table 8. It is important to note that each criterion is not equally weighted. The highest weight should be considered for Color Comparison and Reflectivity as these are the measures of the whiteness of the paint and low light visibility, the characteristics important to the pilots. Bottom-up Rust Spots are of less importance than Color Comparison as the rust spot stains are more of nuisance than an impact to the visibility of the paint. Also Bead Loss is of lesser importance than Reflectivity, as the loss of beads did not correlate to the reflectivity values. When Color Comparison and Reflectivity characteristics are considered alone, areas 1, 2 and G provide the best results. Area G includes the added expense of a seal coat. For many airports this added expense is not feasible. The remaining two high-performing study areas are areas 1 and 2. Area 2 was slightly whiter than Area 1 while both areas had some of the highest reflectivity values. The comparison in Table 8 further supports the use of the stain resistant additive at or greater the thickness of the FAA P-620 specification.

Table 8: Area Comparison

Area	1	2	3	4	G
Paint/Bead Type	IISR/III	IIISR/III	IIIRI/III	II/I	III(sealed)/III
Application (SF/Gal)	115	75	90	115	90
Color Comparison	+	+	-	-	+
Bottom-Up Rust Spots	-	-	+	-	+
Reflectivity	+	+	+	+	+
Bead Loss	+	+	+	+	-

5) Recommendations

5.1 Additional Studies

Additional studies should consider the following:

1) The installation of pavement markings and beads should be performed by the interested party. The installation by a party with a vested interest in the quality of the sample areas will provide installation quality equality between the sample sections.
2) Include photographic documentation from the pilot's perspective approaching the runway. This will provide the users perspective of the various paint types and beads. Data collected from the ground observations produces details, such as bottom-up rust spot stains, that may not be relevant to pilots.
3) Confirm the paint with a stain resistant additive supports the conclusions that the stain resistant paint maintains the paint whiteness better than paints with rust inhibitor additive or no additive. This study is one data set. Conduct additional studies to confirm this study and add to the data set.
4) Increase the number of combinations of paint type, with and without additives, bead types and paint thicknesses. This will assist in isolating the purpose of the sample area. This study had overlapping purposes in one sample area (ex. Area 2's SR paint installed thicker than the FAA specification).
5) Consider each paint type (II, III, IISR, IIISR, IIRI, IIIRI) installed with each bead type (I, III) and at the FAA P-620 specification minimum thickness and at a thickness equal to 60% of the bead diameter depth. These combinations result in twenty-four (24) sample areas. Recommend two sets of each be installed for comparison purposes. The second set will increase the total study's sample areas to forty-eight (48).
6) Conduct laboratory testing of the paint prior to application. Tests shall be made in accordance with the Federal Specification stated in the current FAA Advisory Circular 150/5370-10 specification P-620 "Runway and Taxiway Marking". Samples shall be provided with the manufacturer, date of manufacture, lot number, and paint product code.
7) Perform color comparison with standardized paint chips such as SAE International's AMS-STD-595. This study used the subjective visual perception of the paint color. Utilizing standard paint chips will provide objective values.
8) Include redundant sampling locations that are less likely to be damaged by snow plows at the start of the study. This study relocated sample points in the middle of the study period. For instance, at the beginning of the study it is advised to select redundant locations to collect data on from the beginning of the study in the event the primary locations become damaged from plow activity. This will result in a continuity of data from the same location.
9) Ensure the pavement is properly prepared before the paint application. Establish agreed upon protocol so that each area is prepared equally. While each area in the study was prepared by grinding and cleaning the pavement, the duration and intensity of the cleaning was not the same between each area.
10) Utilize supplemental light source when photographing sample areas. Samples were taken at varies times of the year, times of the day and cloud cover. This led to shadowing in the photographs. Additionally, utilize a tripod to stabilize the camera and improve the magnified image quality.
11) Conduct a cost-benefit analysis of the recommendations as compared to more frequent runway marking.

5.2 Proposed Activities

The study's outcomes indicate there are activities that can be implemented to increase the longevity of the paint's white color. These activities are listed below.

1) Observe paint for discoloration. The gradual change in color may not make the paint discoloration apparent to the airport operator as it occurs slowly over time. The operator would create control paint samples like this study and conduct comparisons every 6-months. If the paint is turning a yellow-brown color (or already has), test the area with a rust remover to confirm the presence of rust.

2) If staining is found at the airport, utilize the FAA P-620 paint specification with a stain resistant additive to the Type II or III paint. The stain resistant additive has proven by this study to maintain its whiteness over a 24-month period. For Airport Improvement Program projects, the sponsor will have to seek the FAA approval to add the stain resistant additive to the paint. FAA approval typically would be in the form of a Modification of Standard. A sample of a modified P-620 specification as of July 2020 is included in Appendix G. The specification can also be found on the NHDOT's website at https://www.nh.gov/dot/org/aerorailtransit/aeronautics/documents.htm.

3) Inspect beads based on operational use. Paint that appears operational during the daytime may have little reflective potential if beads are absent in the paint. In absence of a retroreflectometer, the night-time runway landing and roll-out observations would assist in gauging the paint reflectivity performance and the need to re-paint and re-bead the runway.

4) Specify a heavy application rate of no less than 90 square feet per gallon of Type III paint. The thicker paint application and flexibility of the paint tends to have less paint cracking and longer in-place performance.

5) Installation should be closely monitored for best-management practices. These include temperature and weather considerations, surface preparation and cleaning, calibration of paint and bead dispensers, monitoring quantity of paint to the markings required, limiting the number of installation crews to the number of inspectors, performing paint thickness measurements, and checking as-installed reflectivity readings.

Appendix A. Random Sampling Data

JACOBS

RANDOM SAMPLING

Lot # 1

PROJECT: NHDOT Paint Study

SUBJECT:

JOB No. E2X79001

By: JWG Date: 12/04/17

Sublot Locations: Sta. from ___ 'RT to 03+00.00 'RT

Lot Length: 300 LF

Lot Width: ___ LF

Area: ___ SY

Sample #

TEST AREA # 1

CALCULATIONS FOR TEST LOCATIONS

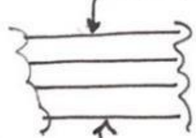
CHANGE ONLY THE BLUE CELLS

	SUBLOT #	RAND #	SUBLOT LENGTH	STATION	RAND #	SUBLOT WIDTH	OFFSET	Dry Density #/CF	% Compaction	% Moisture
			Sample Locations					Test Results		
1	1	0.576	150.0 LF	00+86.36	0.684					
			Elev.							
1A	1	0.387	150.0 LF	00+58.08	0.895					
			Elev.							
2	2	0.380	150.0 LF	02+07.07	0.765					
			Elev.							
2A	2	0.799	150.0 LF	02+69.79	0.907					
			Elev.							

4N 12/4/17

℄ RW

SAMPLE ON THIS LINE (INNER) AT CENTER OF 4"-5" HART.



← EDGE LINES

RW EDGE

207
− 86
121

JACOBS

RANDOM SAMPLING

Lot # 2

PROJECT: NHDOT Paint Study

SUBJECT:

JOB No. E2X79001

By: JWG Date: 12/04/17

Sublot Locations: Sta. from 'RT to to 02+00.00 'RT

Lot Length: 200 LF
Lot Width: LF
Area: SY

Sample #
TEST AREA # 2

CALCULATIONS FOR TEST LOCATIONS

CHANGE ONLY THE BLUE CELLS

	SUBLOT #	RAND #	SUBLOT LENGTH	STATION	RAND #	SUBLOT WIDTH	OFFSET	Dry Density #/CF	% Compaction	% Moisture
	Sample Locations							Test Results		
1	1	0.418	100.0 LF	00+41.81	0.804					
			Elev.							
1A	1	0.223	100.0 LF	00+22.27	0.839					
			Elev.							
2	2	0.215	100.0 LF	01+21.53	0.762					
			Elev.							
2A	2	0.014	100.0 LF	01+01.37	0.649					
			Elev.							

JACOBS

RANDOM SAMPLING

Lot # 3

PROJECT: NHDOT Paint Study

JOB No. E2X79001

SUBJECT:

By: JWG Date: 12/04/17

Sublot Locations: Sta. from 'RT to to 02+40.00 'RT

Lot Length: 240 LF
Lot Width: LF
Area: SY

Sample #
TEST AREA #3

CALCULATIONS FOR TEST LOCATIONS

CHANGE ONLY THE BLUE CELLS

	SUBLOT #	RAND #	SUBLOT LENGTH	STATION	RAND #	SUBLOT WIDTH	OFFSET	Dry Density #/CF	% Compaction	% Moisture
	Sample Locations							Test Results		
1	1	0.038	120.0 LF	00+04.53	0.607					
			Elev.							
1A	1	0.809	120.0 LF	00+97.08	0.095					
			Elev.							
2	2	0.202	120.0 LF	01+44.28	0.655					
			Elev.							
2A	2	0.404	120.0 LF	01+68.50	0.230					
			Elev.							

JACOBS

RANDOM SAMPLING

Lot # 4

PROJECT: NHDOT Paint Study

JOB No. E2X79001

SUBJECT:

By: JWG Date: 12/04/17

Sublot Locations: Sta. from 'RT to to 03+15.00 'RT

Lot Length: 315 LF
Lot Width: LF
Area: SY

Sample #
TESTAREA #4

CALCULATIONS FOR TEST LOCATIONS

CHANGE ONLY THE BLUE CELLS

	SUBLOT #	RAND #	SUBLOT LENGTH	STATION	RAND #	SUBLOT WIDTH	OFFSET	Dry Density #/CF	% Compaction	% Moisture
	Sample Locations							Test Results		
1	1	0.948	157.5 LF	01+49.23	0.303					
			Elev.							
1A	1	0.041	157.5 LF	00+06.49	0.351					
			Elev.							
2	2	0.011	157.5 LF	01+59.22	0.608					
			Elev.							
2A	2	0.295	157.5 LF	02+04.04	0.839					
			Elev.							

JACOBS

RANDOM SAMPLING

Lot # 5

PROJECT: NHDOT Paint Study

JOB No. E2X79001

SUBJECT:

By: JWG Date: 12/04/17

Sublot Locations: Sta. from 'RT to to 10+50.00 'RT

Lot Length: 1050 LF
Lot Width: LF
Area: SY

Sample # GSB 88

CALCULATIONS FOR TEST LOCATIONS

CHANGE ONLY THE BLUE CELLS

	SUBLOT #	RAND #	SUBLOT LENGTH	STATION	RAND #	SUBLOT WIDTH	OFFSET	Dry Density #/CF	% Compaction	% Moisture
	Sample Locations							Test Results		
1	1	0.536	525.0 LF	02+81.43	0.058					
			Elev.							
1A	1	0.069	525.0 LF	00+36.07	0.700					
			Elev.							
2	2	0.047	525.0 LF	05+49.42	0.831					
			Elev.							
2A	2	0.982	525.0 LF	10+40.31	0.693					
			Elev.							

Appendix B. Field Installation Reports

Sightline, LC | Airport Marking Consultants
15483 Enterprise Way Culpeper, VA 22701 (540) 825-9660 tel (540) 825-9088 fax www.sightline.us

Project Title:	**Airfield Marking Evaluation** **Installation of Test Lines**
Project Location:	Laconia Municipal Airport
Project Dates:	September 8-10, 2017
Organization:	Jacobs Engineering Group, Inc. John Gorham, P.E. 2 Executive Park Drive, Suite 205 Bedford, NH 03110
Submitted By:	Donna J. Speidel President 15483 Enterprise Way Culpeper, VA 22701 540-825-9660, ext. 302 540-226-2656, Cell donna@sightline.us

Installation of Test Lines

As a follow up to the report submitted in July when initial work began at LCI, the striping contractor, Axtell, acquired the stain resistant paint from Safety Coatings, of Foley, AL. The contractor had also procured TT-P-1952E, Type III rust resistant paint, but did not have it on site at the time of this test.

I traveled to LCI on Friday, September 8th, and arrived at 7:30 pm. It had rained and work was postponed until 10pm when conditions would be reassessed and a determination made as to the advisability of working. No work was done that night.

The next morning, the contractor and Tim Buzinski from Jacobs Engineering were on the project painting taxiway markings, all with ride-on Graco paint machines that were equipped with automatic, pressurized glass bead dispensers. The enhanced taxiway centerline on the east end of the taxiway had been painted by the contractor. They applied the yellow markings first, and then bordered with black. The result of this sequence was that the yellow was overpainted, reducing the width from the required 6-inches to less than 5-1/2 inches. It was recommended that the black background be applied first, and the yellow applied afterward.

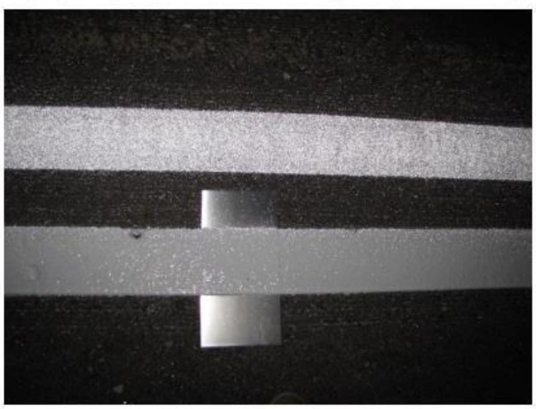
Access to the runway would be allowed as traffic permitted; so the crews continued to paint taxiway markings and enhancements. By 3:30 pm and after repeated delays in acquiring the runway, it was decided to stop work until 7:30 pm, at which time the traffic would have diminished and work could proceed.

At 7:30 pm, people began to arrive. A crew began removing the areas of runway edge markings that would receive the test lines, equipment was loaded with material, and the paint machine was calibrated for the TT-P-1952E, Type II stain-resistant paint from Safety Coatings, Batch Number BO7728. A 1 quart sample was taken and given to Tim Buzinski to retain for the period of the NHDOT test. Jeremy Cunningham, the striping machine operator, determined his speed to be 1.5 mph when 15 mils wet film thickness was achieved. The glass bead guns were then calibrated to collect 150 ml of TT-B-1325D, Type III glass beads in a 10-second drop for the 5-inch line. Once the bead guns were both calibrated, the equipment was taken out to the runway. The area that had been removed was checked to ensure it was clean enough to paint, and additional blowing and sweeping had to be done to remove the majority of the residue left in the depressions in the pavement. The crews held a string line for the length of the test area east ~~west~~ of Taxiway F on the north ~~south~~ side of the runway; and Jeremy painted the first two of four 5-inch lines. During the first run, it was noticed that the bead guns were not adjusted properly to drop the majority of the beads on the painted lines. Jeremy adjusted them to get more of the beads on the lines, seen in Pictures 1 and 2 below.

Picture 1 – glass beads spreading too wide.

Picture 2 – glass bead guns adjusted.

Jeremy had painted the outer two lines first, and then had to let them dry before the other two could be painted; so the crew proceeded to the east end of the runway to paint threshold markings, using the project-specified TT-P-1952E, Type III paint with Type III beads. That equipment was not calibrated.



Picture 3 – first test line had bead gun clog.

Picture 4 – glass beads applied over line.

Once the initial test lines were dry, Jeremy proceeded to apply the other two of four 5-inch test lines using the Type II stain resistant paint. Tim Buzinski collected the two panels that were placed along the test lines that would be retained for the duration of the research project. The first test line that was applied had a clogged glass bead gun (Picture 3). Jeremy recognized it, stopped, then went back to the beginning and applied beads over the unbeaded line (Picture 4). The second panel was placed longitudinally along the line closest to the grass, seen in Picture 5. The streaks seen in the line next to the outermost line were from the string line that rolled across the freshly painted line.

Picture 5 – Test panel placed longitudinally along outer line closest to the grass.

Once the first test was complete, Jeremy and Donna returned to the staging area to drain the Type II paint and load the Type III Stain Resistant paint from Safety Coatings, Batch No. BO7726. When the Type II paint was drained, there was approximately 3 gallons out of 10 gallons remaining. The additional paint that was used beyond the planned 5 gallons was used during all of the test lines during calibration.

Calibration of the equipment to 75 SF per gallon determined the equipment speed to be 1 mph. Based on that speed and for a 5-inch line, we calibrated each of the two glass bead guns to apply 200 ml in a 10 –second drop. Once calibration was complete, we proceeded back out to the runway and applied the TT-P-1952E, Type III, Stain Resistant paint at 75 SF per gallon on the west ~~east~~ side of Taxiway F on the north ~~south~~ side of the runway. This time, the innermost two 5-inch lines were applied first to avoid having to wait for the paint to dry.

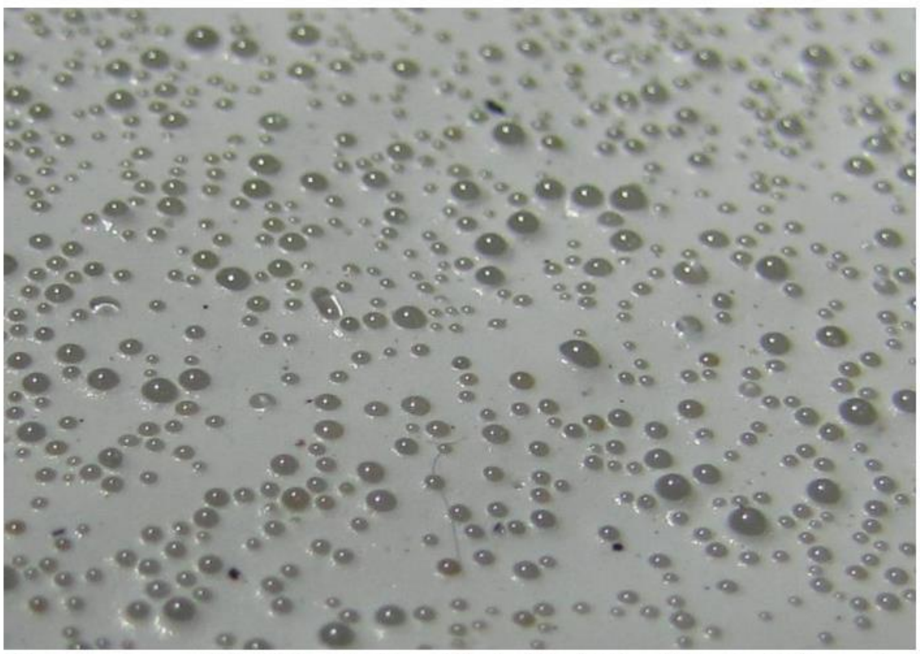
Direction edit note:
Reverse directions 180 degrees. Photos on 26 September 2017 show the south side of the runway not yet painted.
Inspection report on 19 October 2017 notes painting 2 test sections on the south side of the runway. (Jacobs)

Picture 6 – Test line east of Taxiway F

Picture 7 – Test line east of Taxiway F

The second set of 5-inch lines was then painted. The second panel seen in Picture 7 was impacted by the string line when it bounced across the newly painted panel; however, enough of the panel was intact to serve the purpose of the study.

A close up of the 25 mil marking showed excellent glass bead embedment, distribution, and population seen in Picture 8.



Picture 8 – close up of 25 mil Type III, stain resistant paint with Type III beads at 10# per gallon.

It is expected that NHDOT will gather retro-reflectivity data from the test lines in order to establish reflectivity readings at installation.

Color will be monitored throughout the study from the test panels collected during installation of the two test lines.

Since the other paint was not available, Tim Buzinski would take responsibility for overseeing calibration of the material when it arrived and the installation of the test lines.

It was later determined that the contractor could not acquire the Type II paint with the rust inhibitor; so it was decided that they would apply standard Type II paint with Type I glass beads.

Respectfully submitted,

Donna J. Speidel
President

JACOBS

DAILY INSPECTION REPORT

Page 1 of 1

Laconia Municipal Airport –
A.I.P. No. SBG 09-11-2016
Jacobs Project No. E2X73701

PROJECT TITLE **Airport Marking, RW 26 Seal Coating, RW Distance Remaining (RDR) signs & TW Crack Sealing – Laconia Municipal Airport,**	
CONTRACTOR Axtell – GC	
DATE 9/25/17	WORK HOURS 8pm – 6:30 am
RESIDENT ENGINEER TMB	

DAY	Su	M	Tu	W	Th	F	Sat
		x					

	A.M.	P.M.
WEATHER	calm	calm
TEMPERATURE	75 F	63 F
WIND	6 mph	6 mph
HUMIDITY	55	84

REPORT NO.	11
NUMBER OF CONTRACT DAYS	13
NUMBER OF DAYS USED	11
NUMBER OF DAYS REMAINING	2

Contractor & Subcontractors	Supts.	Foreman	Operators	Laborers	Drivers	Electrical	Visitors	Management	TOTAL
Axtell		1		5					6

Paint machine	Blower	Shot blaster	Mini Excavator		Trucks			Compressor	Skidsteere	TOTAL
3	1				4					8

Item	**Description/Location**
1	Work on the airfield started at 8:00, setting up and calibrating paint machines. During this shift contractor focused on runway; painting edge lines white and all of the temporary markings permanent on the GSB88 area. ILS hold bar also painted along with black around CL markings. (P-620-1, P-620-3)

TO THE BEST OF MY KNOWLEDGE, THE WORK IS IN CONFORMANCE WITH THE CONTRACT PLANS AND SPECIFICATIONS, UNLESS OTHERWISE SPECIFIED ON THIS REPORT.

SIGNATURE:______________________________ DATE:___

JACOBS

DAILY INSPECTION REPORT

Laconia Municipal Airport –
A.I.P. No. SBG 09-11-2016
Jacobs Project No. E2X73701

PROJECT TITLE **Airport Marking, RW 26 Seal Coating, RW Distance Remaining (RDR) signs & TW Crack Sealing – Laconia Municipal Airport,**	
CONTRACTOR Axtell – GC	
DATE 10/19/17	WORK HOURS 8am – 4pm
RESIDENT ENGINEER JMH	

DAY	Su	M	Tu	W	Th x	F	Sat
WEATHER				**A.M.** clear		**P.M.** clear	
TEMPERATURE				**A.M.** 61		**P.M.** 58	
WIND				**A.M.** 3		**P.M.** 3	
HUMIDITY				**A.M.** 80		**P.M.** 80	
REPORT NO.						13	
NUMBER OF CONTRACT DAYS						13	
NUMBER OF DAYS USED						13	
NUMBER OF DAYS REMAINING						0	

Contractor & Subcontractors	Supts.	Foreman	Operators	Laborers	Drivers	Electrical	Visitors	Management	TOTAL
Axtell	1	1		3					5
Jacobs							1		
Laconia Airport								1	1

Paint machine	Blower	Shot blaster	Mini Excavator		Trucks			Compressor	Skidsteere	TOTAL
3	1									4

Item	**Description/Location**
1	Completed items on "LCI Punch List" updated October 17, 2017. All items were completed as shown on the plan. See pictures below.
2	GSB88 applied via hand method. Sand applied with sealant. (P-608-1)
3	2 separate paint study applications on the south edge of the runway. One location (3) was Type III w/ Rust Inhibitor at 90 SF/Gal w/ Type III beads. Other location (4) was Type II at 115 SF/Gal with Type I Beads. Samples were taken of both. Ran out of rust inhibitor paint for location 3 and had to complete with Type III w/ Type III Beads. Existing markings removed prior to application of new paint. (P-620-1, P-620-4)
4	FAA Aiming Markings painted at the request of the FAA. Location determined in the field to line up with stakes in the grass and centerline aiming point marking. See pictures below.
5	Two pictures at the end of attached pictures show the discoloration occurring between markings painted today and markings painted earlier in the project.

TO THE BEST OF MY KNOWLEDGE, THE WORK IS IN CONFORMANCE WITH THE CONTRACT PLANS AND SPECIFICATIONS, UNLESS OTHERWISE SPECIFIED ON THIS REPORT.

SIGNATURE:____________________________ DATE:___

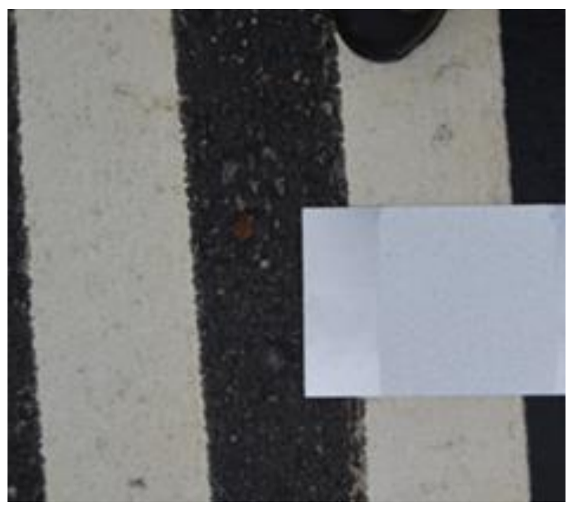
Appendix C. Color Comparison Photographs

December 5, 2017

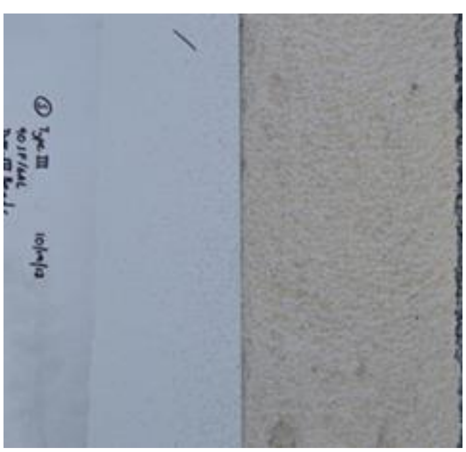
Area 1- II SR/III

Area 2 – III SR/III

Area 3 – III RI/III



Area 4 – II/I

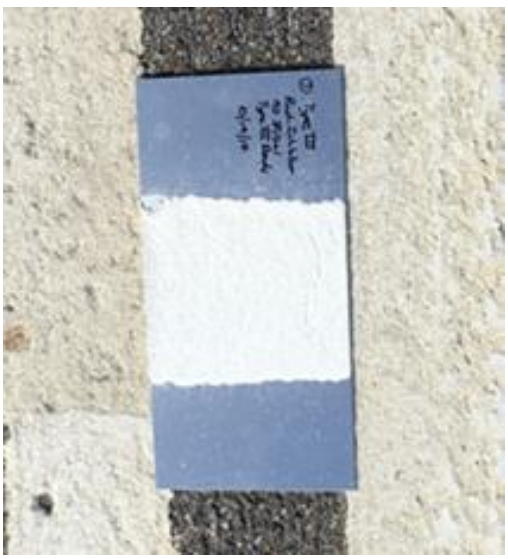


Area G – III/III

March 23, 2018

Area 1- II SR/III

Area 2 – III SR/III



Area 3 – III RI/III

Area 4 – II/I

Area G – III/III

June 21, 2018


Area 1- II SR/III


Area 2 – III SR/III

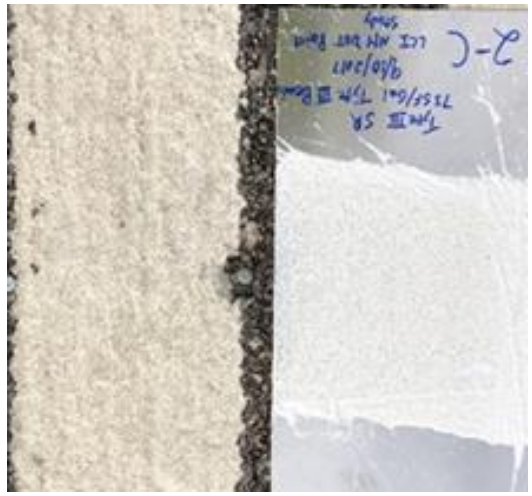

Area 3 – III RI/III


Area 4 – II/I


Area G – III/III

September 20, 2018

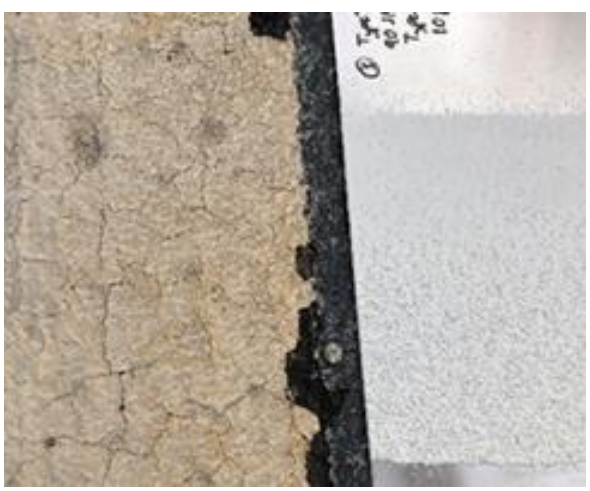
Area 1- II SR/III



Area 2 – III SR/III

Area 3 – III RI/III

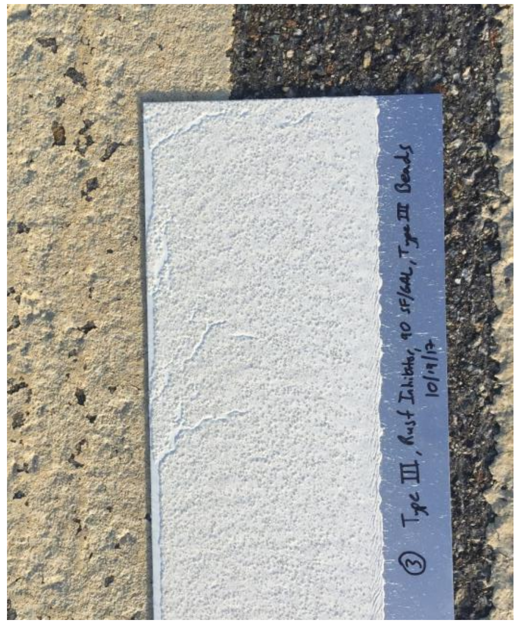
Area 4 – II/I



Area G – III/III

December 20, 2018

Area 2 - III SR/III

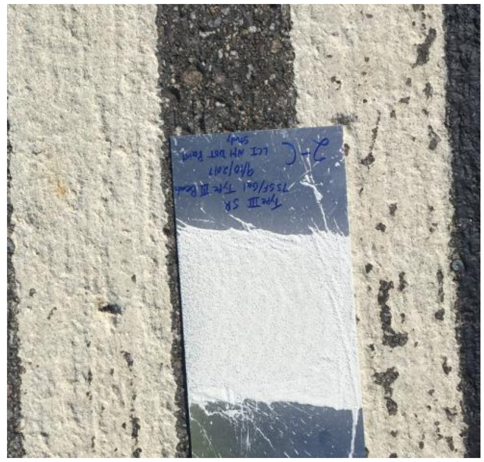


Area 3 – III RI/III

Area G – III/III

April 11, 2019


Area 1- II SR/III

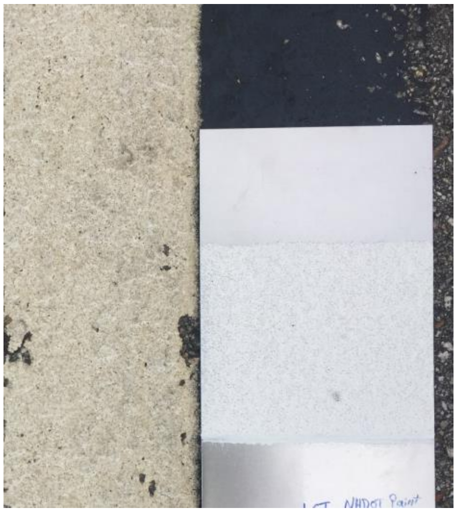

Area 2 – III SR/III


Area 3 – III RI/III


Area 4 – II/I

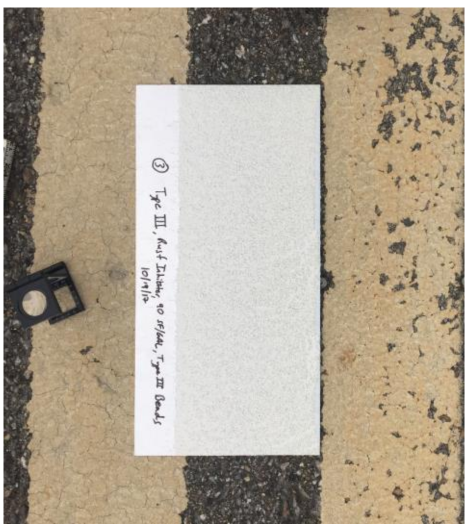

Area G – III/III

July 2, 2019



Area 1- II SR/III

Area 2 – III SR/III

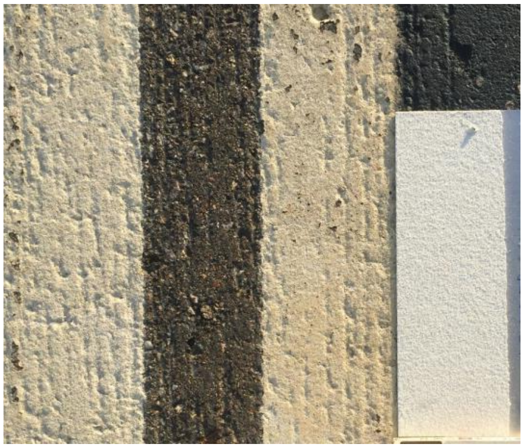


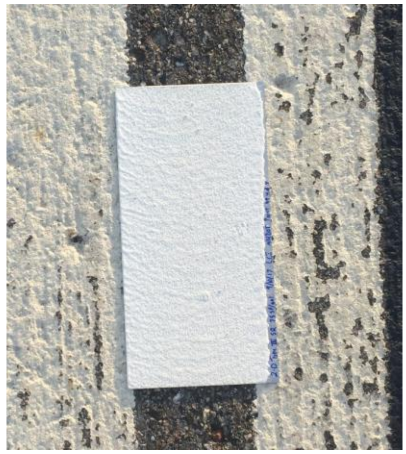
Area 3 – III RI/III

Area 4 – II/I

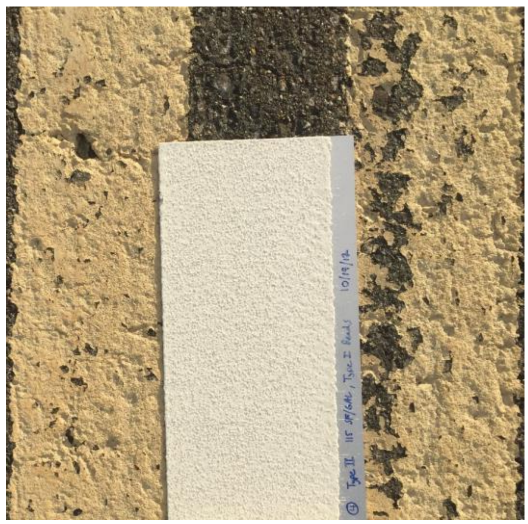
Area G – III/III

September 26, 2019


Area 1- II SR/III


Area 2 – III SR/III


Area 3 – III RI/III


Area 4 – II/I


Area G – III/III

Appendix D. Reflectivity Data

Reflectivity was measured using LTL-X Mark II, all units in $(mcd/m^2)/lux$.

	Sample ID	12/5/2017	3/23/2018	6/21/2018	9/20/2018	12/20/2018	4/11/2019	7/2/2019	9/26/2019
Area 1 - II SR/III	1-1	1244	817	775	502	1117	966	829	885
	1-1A	1374	583	470	542	559	285	280	263
	1-2	1060	565	210	537	1145	1155	1003	948
	1-2A	1637	1201	1235	555	572	883	780	633
	1-1B				289	622	656	590	637
	1-2B				740	1034	1059	966	947
	1-1C				525	395	294	268	321
	1-2C				1542	1350	1333	1266	1167
Area 2 - III SR/III	2-1	650	593	475	514	382	651	614	538.00
	2-1A	591	474	332	401	288	719	731	638
	2-2	592	465	213	269	408	474	420	360
	2-2A	444	278	302	204	625	504	625	616
	2-1B				498	407	502	553	634
	2-2B				178				
	2-1C				571	319	401	397	398
	2-2C				324				
Area 3 - III Rust Inhibitor/III	3-1	1695	1235	980	1098	1321	787	887	766
	3-1A	1586	419	412	563	654	487	493	469
	3-2	1621	424	426	438	462	881	834	746
	3-2A	1583	906	935	1046	1097	268	218	203
	3-1B				913	948	792	818	770
	3-1C				286	284	959	805	747
	3-2B				259	296	332	276	259
	3-2C				911	1018	259	225	201
Area 4 - II/I	4-1	1908	577	428	410	508	384	366	359
	4-1A	1850	392	347	366	385	1298	1214	1214
	4-2	1816	556	495	512	563	354	332	307
	4-2A	1785	1101	829	930	1034	853	809	653
	4-1B				424	425	403	363	319
	4-1C				556	557	201	212	189
	4-2B				749	687	538	511	442
	4-2C				999	942	1099	1094	992
Area G - III/III	G-1	1185	660	752	701	605	819	680	508
	G-1A	1009	1116	918	935	920	523	611	491
	G-2	1254	593	423	491	452	752	792	692
	G-2A	1120	1220	1100	992	943	782	688	500
	G-1B					691	195	187	149
	G-1C				384	366	176	217	162
	G-2B				603	612	784	758	645
	G-2C				979	801	626	603	365

Appendix E. Bead Loss Data

	Sample ID	12/5/2017	3/23/2018	6/21/2018	9/20/2018	12/20/2018	4/11/2019	7/2/2019	9/26/2019
Area 1 - II SR/III	1-1	0	1	2	3		77	10	16
	1-1A	8	20	37	99		33	88	55
	1-2	1	7	7	10		21	39	12
	1-2A	0	69	71	57		260	204	24
Area 2 - III SR/III	2-1	2	28	21	12	17	40	19	11
	2-1A	0	1	18	61	36	137	120	40
	2-2	0	7	13	4	103	120	142	127
	2-2A	2	7	8	6	18	30	16	81
	2-1B					56			
	2-1C					18			
Area 3 - III RI/III	3-1	0	15	14	7		11	5	9
	3-1A	14	14	15	8	3	119	53	31
	3-2	0	22	36	27	18	179	63	115
	3-2A	0	43	62	73	105	78	88	114
	3-2B					79			
	3-2C					5			
	3-1C					71			
Area 4 - II/I	4-1	0	27	55	61		92	95	115
	4-1A	0	18	17	62		66	44	64
	4-2	0	27	36	62		47	44	54
	4-2A	7	28	50	43		63	65	62
Area G - III/III	G-1	0	37	32	103	148	98	120	59
	G-1A	3	82	92	109	218	225	243	184
	G-2	0	44	69	27	112	139	148	159
	G-2A	3	59	67	51	190	154	165	134
	G-2B					83			
	G-1B					137			
	G-1C					244			

Appendix F. NHDOT Laboratory Data

New Hampshire DOT Department of Transportation

Test Report
White Traffic Paint
Sample ID: 3311 – Area #3

Contract: 10892 - MATERIALS & RESEARCH (DEFAULT)
Federal No: NON-FEDERAL
Item: 2570 - PAINT WHITE WB

Sample Date: 12/26/2019
Sampled By: BERAN BLACK

Remarks: From Airport Research Study

Source: unknown
Plant: unknown

Lot: MPO-887KZ 00273DXF
CA:

Test Name: Paint Traffic_1
Methods: ASTM D562, ASTM D1475, ASTM D711, ASTM D2369, ASTM D3723, ASTM D2805
Facility: NHDOT

Test Date: 12/26/2019
Tested By: JULIA FOWLER

	Result	Unit of Measure	Min	Max	Violation
Viscosity ASTM D562	85.9	KU	80	92	
Density Standard ASTM D1475	13.85	lb/gal	13.7	14.3	
Density Metric	1,662.14	kg/l	1644	1716	
Dry Time NPU ASTM D711	10	min		10	
Uniform Surface Dry	Pass				
Total Solids ASTM D2369	78.9	%	76		
% Pigment ASTM D3723	62.4	%	58	62	FAIL
% Vehicle D3723	37.6	%	38	42	FAIL
% Non-Volatile Vehicle ASTM D2369/3723	44.0	%	42		
Dry Opacity ASTM D2805	0.95		0.96		FAIL
pH Paint	9.98		9.6		
Color	Pass				

Comments: opacity 0.9543
dry time <10

Test Validated By: BERAN BLACK

Validated Date: 1/16/2020

Standard Note:

TT-P-1952F Requirements as referenced in the FAA Specification P-620:

The criterion on the previous page is based on the NHDOT specifications. The criteria below is taken from the TT-P-1952F that correlate with the FAA P-620 specification. There are additional tests in the TT-P-1952F. The similar tests in TT-P-1952F that were performed by the NHDOT are reported below.

Characteristic	Value	Units	Min	Max	Violation
Viscosity ASTM D562 (Consistency)	85.9	KU	80	90	
Dry Time	<10	Min		10	
Pigment	62.4	%	60	62	Failed
Opacity	0.95		.92	-----	

New Hampshire DOT
Department of Transportation

Test Report
White Traffic Paint
Sample ID: 3312 – Area #4

Contract: 10892 - MATERIALS & RESEARCH (DEFAULT)
Federal No: NON-FEDERAL
Item: 2570 - PAINT WHITE WB

Sample Date: 12/26/2019
Sampled By: BERAN BLACK

Remarks: From Airport Research Study

Source: unknown
Plant: unknown

Lot: unknown
CA:

Test Name: Paint Traffic_1
Methods: ASTM D562, ASTM D1475, ASTM D711, ASTM D2369, ASTM D3723, ASTM D2805
Facility: NHDOT

Test Date: 12/26/2019
Tested By: JULIA FOWLER

	Result	Unit of Measure	Min	Max	Violation
Viscosity ASTM D562	81.5	KU	80	92	
Density Standard ASTM D1475	14.09	lb/gal	13.7	14.3	
Density Metric	1,690.37	kg/l	1644	1716	
Dry Time NPU ASTM D711	10	min		10	
Uniform Surface Dry	Pass				
Total Solids ASTM D2369	76.3	%	76		
% Pigment ASTM D3723	60.2	%	58	62	
% Vehicle D3723	39.8	%	38	42	
% Non-Volatile Vehicle ASTM D2369/3723	40.5	%	42		FAIL
Dry Opacity ASTM D2805	0.95		0.96		FAIL
pH Paint	9.86		9.6		
Color	Pass				

Comments: opacity 0.9514
dry time <10
Test Validated By: BERAN BLACK
Standard Note:

Validated Date: 1/16/2020

TT-P-1952F Requirements as referenced in the FAA Specification P-620:

The criterion on the previous page is based on the NHDOT specifications. The criteria below is taken from the TT-P-1952F that correlate with the FAA P-620 specification. There are additional tests in the TT-P-1952F. The similar tests in TT-P-1952F that were performed by the NHDOT are reported below.

Characteristic	Value	Units	Min	Max	Violation
Viscosity ASTM D562 (Consistency)	81.5	KU	80	90	
Dry Time	<10	Min		10	
Pigment	60.2	%	60	62	
Opacity	0.95		.92	-----	

New Hampshire DOT Department of Transportation

Test Report
White Traffic Paint
Sample ID: 3313 – Area G

Contract: 10892 - MATERIALS & RESEARCH (DEFAULT)
Federal No: NON-FEDERAL
Item: 2570 - PAINT WHITE WB

Sample Date: 12/26/2019
Sampled By: BERAN BLACK

Remarks: From Airport Research Study

Source: unknown
Plant: unknown

Lot: unknown
CA:

Test Name: Paint Traffic_1
Methods: ASTM D562, ASTM D1475, ASTM D711, ASTM D2369, ASTM D3723, ASTM D2805
Facility: NHDOT

Test Date: 12/26/2019
Tested By: JULIA FOWLER

	Result	Unit of Measure	Min	Max	Violation
Viscosity ASTM D562	89.1	KU	80	92	
Density Standard ASTM D1475	13.97	lb/gal	13.7	14.3	
Density Metric	1,676.06	kg/l	1644	1716	
Dry Time NPU ASTM D711	10	min		10	
Uniform Surface Dry	Pass				
Total Solids ASTM D2369	76.2	%	76		
% Pigment ASTM D3723	60.2	%	58	62	
% Vehicle D3723	39.8	%	38	42	
% Non-Volatile Vehicle ASTM D2369/3723	40.2	%	42		FAIL
Dry Opacity ASTM D2805	0.96		0.96		
pH Paint	9.87		9.6		
Color	Pass				

Comments: opacity 0.9576
dry time <10
Test Validated By: BERAN BLACK
Standard Note:

Validated Date: 1/16/2020

TT-P-1952F Requirements as referenced in the FAA Specification P-620:

The criterion on the previous page is based on the NHDOT specifications. The criteria below is taken from the TT-P-1952F that correlate with the FAA P-620 specification. There are additional tests in the TT-P-1952F. The similar tests in TT-P-1952F that were performed by the NHDOT are reported below.

Characteristic	Value	Units	Min	Max	Violation
Viscosity ASTM D562 (Consistency)	89.1	KU	80	90	
Dry Time	<10	Min		10	
Pigment	60.2	%	60	62	
Opacity	0.96		0.92	-----	

Appendix G. Sample Modified FAA P-620 Paint Specification

DISCLAIMER: THE MODIFICATIONS TO THIS SPECIFICATION MUST BE APPROVED BY THE FAA FOR USE ON AIRPORT IMPROVEMENT PROJECTS.

Modifications are in **blue, bold, underlined text**.

Item P-620 Runway and Taxiway Marking

DESCRIPTION

620-1.1 This item shall consist of the preparation and painting of numbers, markings, and stripes on the surface of runways, taxiways, and aprons, in accordance with these specifications and at the locations shown on the plans, or as directed by the Resident Project Representative (RPR) **or inspector**. The terms “paint” and “marking material” as well as “painting” and “application of markings” are interchangeable throughout this specification.

MATERIALS

620-2.1 Materials acceptance. The Contractor shall furnish manufacturer’s certified test reports, for materials shipped to the project. The certified test reports shall include a statement that the materials meet the specification requirements. This certification along with a copy of the paint manufacturer’s surface preparation; marking materials, including adhesion, flow promoting and/or floatation, **stain resistant and/or rust inhibitor additives; and** application requirements must be submitted and approved by the Resident Project Representative (RPR) prior to the initial application of markings. The reports can be used for material acceptance or the RPR may perform verification testing. The reports shall not be interpreted as a basis for payment. The Contractor shall notify the RPR upon arrival of a shipment of materials to the site. All material shall arrive in sealed containers that are easily quantifiable for inspection by the RPR.

620-2.2 Marking materials.

Table 1. Marking Materials

Paint[1]				Glass Beads[2]	
Type	**Color**	**Fed Std. 595 Number**	**Application Rate Maximum**	**Type**	**Application Rate Minimum**
*	*	*	*	*	*
*	*	*	*	*	*

[1] See paragraph 620-2.2a

[2] See paragraph 620-2.2b

****

Make the appropriate selections for paint type, color, Fed Std 595 number, application rates, and glass bead type and application rates and inserted into Table 1. Asterisks denote insert points.

****

a. Paint. Paint shall be **[** waterborne **] [** epoxy **] [** methacrylate **] [** solvent-base **] [** and **] [** preformed thermoplastic **]** in accordance with the requirements of this paragraph. Paint colors shall comply with Federal Standard No. 595. **[___]**

****

The Engineer must specify paint type (s), colors and glass beads to be used for the project and populate that information above in Table 1. When more than one paint type is specified, the plans should clearly indicate paint type, paint color and bead type required for each marking.

Select type of paint.

Types: Waterborne, Epoxy, Methacrylate, solvent-base, or preformed Thermoplastic

For waterborne or solvent based paints, specify Type I, II, or III:

- **Type I intended for locations where slower tracking is not a problem.**
- **Type II intended for locations where faster curing is desirable.**
- **Type III intended for locations that require a thicker, more durable coating.**

1. **Select paint color(s) from the following Table:**

Paint Color	Fed Std. No 595 Color Number
White	**37925**
Red	**31136**
Yellow	**33538 (**deleted 33655)
Black	**37038**
Pink	**1 part 31136 to 2 parts 37925**
Green	**34108**

Waterborne or solvent base black paint should be used to outline a border at least 6 inches (150 mm) wide around markings on all light-colored pavements. Preformed thermoplastic markings shall have a non-reflectorized black border integral to the marking.

Select appropriate application rates for type of paint and bead selected:

Application Rates for Paint and Glass Beads for Table 1

Paint		Glass Beads		
Type	**Application Rate Maximum**	**Type I, Gradation A[1] Minimum**	**Type III Minimum**	**Type IV[1] Minimum**
Waterborne Type I or II	115 ft^2/gal (2.8 m^2/l)	7 lb/gal (0.85 kg/l)	10 lb/gal (1.2 kg/l)	--
Waterborne Type III	90 ft^2/gal (2.2 m^2/l)	7 lb/gal (0.85 kg/l)	8 lb/gal (1.0 kg/l)	
Waterborne Type III[2]	55 ft^2/gal (1.4 m^2/l)		6 lb/gal (.8 kg/l)	5 lb/gal (.7 kg/l)
Solvent Base	115 ft^2/gal (2.8 m^2/l)	7 lb/gal (0.85 kg/l)	10 lb/gal (1. 2 kg/l)	--
Solvent Base	55 ft^2/gal (2.2 m^2/l)	--	--	5 lb/gal (.7 kg/l)
Epoxy	90 ft^2/gal (2.2 m^2/l)	15 lb/gal (1.8 kg/l)	20 lb/gal (2.4 kg/l)	16 lb/gal (1.9 kg/l)
Methacrylate	45 ft^2/gal (1.1 m^2/l)	15 lb/gal (1.8 kg/l)	20 lb/gal (2.4 kg/l)	16 lb/gal (1.9 kg/l)
Methacrylate Splatter-Profile	24ft^2/gal. (0.6 m^2/l)	8 lb/gal. (0.1 kg/l)	10 lb/gal. (1.2 kg/l)	10 lb/gal (1.2 kg/l)
Temporary Marking Waterborne Type I or II	230 ft^2/gal (5.6 m^2/l)	No beads	No beads	No beads

[1]Glass bead application rate for Red and Pink paint shall be reduced by 2 lb/gal (0.24 kg/l) for Type I and Type IV beads.

[2]Engineer may consider thicker application to improve bead embedment in the paint surface.

The Engineer shall specify the time period in paragraph 620-3.5 in order to allow adequate curing of the pavement surface. The Engineer should contact the paint manufacturer to determine the wait period. A 24- to 30-day waiting period is recommended for all types of paint used for pavement marking. The final application should occur after the waiting period has passed. The final marking application must be at a rate equal to 100% of the full application rate with glass beads.

It is recommended that any previously unmarked pavement or pavement that has had no previous paint or had the paint removed shall receive a primer coat of paint (50% of the specified application rate) to seal the unmarked surface. Glass beads will not adhere well at the low application rates for the primer coat. After at least 24 hours of curing of the primer coat, a full coat of paint with glass beads may be applied.

Markings may be required before paving operations are complete. The Engineer may wish to specify waterborne or solvent-based materials for temporary markings at 30% to 50% of the specified application rates. Glass beads will not adhere well at the low application rates for temporary markings.

CAUTION: Prior to reopening pavements at Part 139 airports verify that all markings comply with Part 139 requirements. Temporary markings not in compliance with AC 150/5340-1 will require a NOTAM regarding any non-standard marking be issued. For example, temporary markings without beads.

When painting Porous Friction Course, the paint should be applied to the pavement in two coats from opposite directions. The first coat should be applied at a rate equal to 50% of the full application rate with no glass beads. The second coat should be applied from the opposite direction at a rate equal to 100% of the full application rate with glass beads.

Preformed thermoplastic pavement markings shall yield at least 225 mcd/m^2/lux on white markings at installation and at least 100 mcd/m^2/lux on yellow markings at installation.

Retroreflectivity shall be measured by a portable retroreflectometer according to ASTM E1710 and the practices in ASTM D7585 shall be followed for taking retroreflectivity readings with a portable retroreflectometer and computing measurement averages. A vehicle-mounted retroreflectometer may also be used.

****

[Waterborne. Paint shall meet the requirements of Federal Specification TT-P-1952F, **[** Type I **] [** Type II] **[** Type III **]** **[with approved stain resistant additive] [with approved rust inhibitor additive]. Paint additives with at least 2 years of approved service life will be approved by the Engineer. The Contractor shall provide written evidence of the paint additive service life including location installed, quantity installed, type of paint installed, date installed and name & phone number of the project representative with knowledge of the paint performance at least 2 years after application. The service life documentation provided to the Engineer shall match the type of paint used in the project**. The non-volatile portion of the vehicle for all paint types shall be composed of a 100% acrylic polymer as determined by infrared spectral analysis. **[** The acrylic resin used for Type III shall be 100% cross linking acrylic as evidenced by infrared peaks at wavelengths 1568, 1624, and 1672 cm-1 with intensities equal to those produced by an acrylic resin known to be 100% cross linking. **]** **Material manufacturers shall certify in writing that the paint complies with these tests.**

****

For white paint markings that are subject to rust color change (yellowing or browning of paint over time) over the entire area of the markings, the Engineer may specify Stain Resistant additive be added to the above Type I, II and III paints. The Stain Resistant additive has demonstrated ability to reduce staining and cracking of the paint. The Engineer will consult the approved paint manufacturers for the additive type and recommended rate of mixing with the paint.

For white paint markings that area subject to rust spot staining, the Engineer may specify Rust Inhibitor additive be added to the above Type I, II and III paints. Consult paint manufacturers for the additive type and rate of mixing with the paint. The Engineer will consult the approved paint manufacturers for the additive type and recommended rate of mixing with the paint.

****

[**Epoxy.** Paint shall be a two component, minimum 99% solids type system conforming to the following:

(1) Pigments. Component A. Percent by weight.

(a) White:

- Titanium Dioxide, ASTM D476, type II shall be 18% minimum (16.5% minimum at 100% purity).

(b) Yellow and Colors:

- Titanium Dioxide, ASTM D476, type II shall be 14 to 17%.
- Epoxy resin shall be 75 to 79%.
- Organic yellow, other colors, and tinting as required to meet color standard.

(2) Epoxy content. Component A. The weight per epoxy equivalent, when tested in accordance with ASTM D1652 shall be the manufacturer's target ±50.

(3) Amine number. Component B. When tested in accordance with ASTM D2074 shall be the manufacturer's target ±50.

(4) Prohibited materials. The manufacturer shall certify that the product does not contain mercury, lead, hexavalent chromium, halogenated solvents, nor any carcinogen as defined in 29 CFR 1910.1200 in amounts exceeding permissible limits as specified in relevant federal regulations.

(5) Daylight directional reflectance.

(a) White: The daylight directional reflectance of the white paint shall not be less than 75% (relative to magnesium oxide), when tested in accordance with ASTM E2302.

(b) Yellow: The daylight directional reflectance of the yellow paint shall not be less than 55% (relative to magnesium oxide), when tested in accordance with ASTM E2302. The x and y values shall be consistent with the federal Hegman yellow color standard chart for traffic yellow standard 33538, or shall be consistent with the tolerance listed below:

x	.462	x	.470	x	.479	x	.501
y	.438	y	.455	y	.428	y	.452

(6) Accelerated weathering.

(a) Sample preparation. Apply the paint at a wet film thickness of 0.013-inch (0.33 mm) to four 3 × 6-inch (8 × 15 cm) aluminum panels prepared as described in ASTM E2302. Air dry the sample 48 hours under standard conditions.

(b) Testing conditions. Test in accordance with ASTM G154 using both Ultra Violet (UV-B) Light and condensate exposure, 72 hours total, alternating four (4) hour UV exposure at 140°F (60°C), and four (4) hours condensate exposure at 104°F (40°C).

(c) Evaluation. Remove the samples and condition for 24 hours under standard conditions. Determine the directional reflectance and color match using the procedures in paragraph 5 above. Evaluate for conformance with the color requirements.

(7) Volatile organic content. Determine the volatile organic content in accordance with 40 CFR Part 60 Appendix A, Method 24.

(8) Dry opacity. Use ASTM E2302. The wet film thickness shall be 0.015 inch (0.38 mm). The minimum opacity for white and colors shall be 0.92.

(9) Abrasion resistance. Subject the panels prepared in paragraph 620-2.2b(6) to the abrasion test in accordance with ASTM D968, Method A, except that the inside diameter of the metal guide tube shall be from 0.747 to 0.750 inch (18.97 to 19.05 mm). Five liters (17.5 lb (7.94 kg)) of unused sand shall be used for each test panel. The test shall be run on two test panels Both baked and weathered paint films shall require not less than 150 liters (525 lbs (239 kg)) of sand for the removal of the paint films.

(10) Hardness, shore. Hardness shall be at least 80 when tested in accordance with ASTM D2240. **]**

[Methacrylate. Paint shall be a two component, minimum 99% solids-type system conforming to the following:

(1) Pigments. Component A. Percent by weight.

(a) White:

- Titanium Dioxide, ASTM D476, type II shall be 10% minimum.
- Methacrylate resin shall be 18% minimum.

(b) Yellow and Colors:

- Titanium Dioxide, ASTM D476, type II shall be 1% minimum.

  Organic yellow, other colors, and tinting as required to meet color standard.
- Methacrylate resin shall be 18% minimum.

(2) Prohibited materials. The manufacturer shall certify that the product does not contain mercury, lead, hexavalent chromium, halogenated solvents, nor any carcinogen as defined in 29 CFR 1910.1200 in amounts exceeding permissible limits as specified in relevant federal regulations.

(3) Daylight directional reflectance:

(a) White: The daylight directional reflectance of the white paint shall not be less than 80% (relative to magnesium oxide), when tested in accordance with ASTM E2302.

(b) Yellow: The daylight directional reflectance of the yellow paint shall not be less than 55% (relative to magnesium oxide), when tested in accordance with ASTM E2302. The x and y values shall be consistent with the federal Hegman yellow color standard chart for traffic yellow standard 33538, or shall be consistent with the tolerance listed below:

x	.462	x	.470	x	.479	x	.501
y	.438	y	.455	y	.428	y	.452

(4) Accelerated weathering.

(a) Sample preparation. Apply the paint at a wet film thickness of 0.013-inch (0.33 mm) to four 3 × 6-inch (8 × 15 cm) aluminum panels prepared as described in ASTM E2302. Air dry the sample 48 hours under standard conditions.

(b) Testing conditions. Test in accordance with ASTM G154 using both Ultra Violet (UV-B) Light and condensate exposure, 72 hours total, alternating four (4) hour UV exposure at 140°F (60°C), and four (4) hours condensate exposure at 104°F (40°C).

(c) Evaluation. Remove the samples and condition for 24 hours under standard conditions. Determine the directional reflectance and color match using the procedures in paragraph 3 above. Evaluate for conformance with the color requirements.

(5) Volatile organic content. Determine the volatile organic content in accordance with 40 CFR Part 60 Appendix A, Method 24.

(6) Dry opacity. Use ASTM E2302. The wet film thickness shall be 0.015 inch (0.38 mm). The minimum opacity for white and colors shall be 0.92.

(7) Abrasion resistance. Subject the panels prepared in paragraph 620-2.2c(4) to the abrasion test in accordance with ASTM D968, Method A, except that the inside diameter of the metal guide tube shall be from 0.747 to 0.750 inch (18.97 to 19.05 mm). Five liters (17.5 lb (7.94 kg)) of unused sand shall be used for each test panel. The test shall be run on two test panels Both baked and weathered paint films shall require not less than 150 liters (525 lbs (239 kg) of sand for the removal of the paint films.

(8) Hardness, shore. Hardness shall be at least 60 when tested in accordance with ASTM D2240.

(9) Additional requirements for methacrylate splatter profiled pavement marking. Pavement markings of this type shall comply with all above requirements for methacrylate paint, except as noted below:

(a) The thickness of the marking will be irregular ranging from 0.000 to 0.250 inches (0.00 to 6.4 mm), applied in a splatter pattern which comprises a minimum of 80% of the visible line (when traveling at 5 mph the line appears to be solid.).

(b) The hardness shall be 48 Shore D minimum. **]**

[Solvent-Base. Paint shall meet the requirements of Commercial Item Description **[** A-A-2886B Type I, Type II, and Type III **].]**

[Preformed Thermoplastic Airport Pavement Markings. Markings must be composed of ester modified resins in conjunction with aggregates, pigments, and binders that have been factory produced as a finished product. The material must be impervious to degradation by aviation fuels, motor fuels, and lubricants.

(1) The markings must be able to be applied in temperatures as low as 35°F without any special storage, preheating, or treatment of the material before application.

(a) The markings must be supplied with an integral, non-reflectorized black border.

(2) Graded glass beads.

(a) The material must contain a minimum of 30% intermixed graded glass beads by weight. The intermixed beads shall conform to Federal Specification TT-B-1325D, Type I, gradation A and Federal Specification TT-B-1325D, Type IV.

(b) The material must have factory applied coated surface beads in addition to the intermixed beads at a rate of one (1) lb (0.45 kg) (±10%) per 10 square feet (1 sq m). These factory-applied coated surface beads shall have a minimum of 90% true spheres, minimum refractive index of 1.50, and meet the following gradation.

Preformed Thermoplastic Bead Gradation

Size Gradation		Retained, %	Passing, %
U.S. Mesh	µm		
12	1700	0 - 2	98 - 100
14	1400	0 - 3.5	96.5 - 100
16	1180	2 - 25	75 - 98
18	1000	28 - 63	37 - 72
20	850	63 - 72	28 - 37
30	600	67 - 77	23 - 33
50	300	89 - 95	5 - 11
80	200	97 - 100	0 - 3

(3) Heating indicators. The material manufacturer shall provide a method to indicate that the material has achieved satisfactory adhesion and proper bead embedment during application and that the installation procedures have been followed.

(4) Pigments. Percent by weight.

(a) White:

- Titanium Dioxide, ASTM D476, type II shall be 10% minimum.

(b) Yellow and Colors:

- Titanium Dioxide, ASTM D476, type II shall be 1% minimum.
- Organic yellow, other colors, and tinting as required to meet color standard.

(5) Prohibited materials. The manufacturer shall certify that the product does not contain mercury, lead, hexavalent chromium, halogenated solvents, nor any carcinogen as defined in 29 CFR 1910.1200 in amounts exceeding permissible limits as specified in relevant federal regulations.

(6) Daylight directional reflectance.

(a) White: The daylight directional reflectance of the white paint shall not be less than 75% (relative to magnesium oxide), when tested in accordance with ASTM E2302.

(b) Yellow: The daylight directional reflectance of the yellow paint shall not be less than 45% (relative to magnesium oxide), when tested in accordance with ASTM E2302. The x and y values shall be consistent with the federal Hegman yellow color standard chart for traffic yellow standard 33538, or shall be consistent with the tolerance listed below:

x	.462	x	.470	x	.479	x	.501
y	.438	y	.455	y	.428	y	.452

(7) Skid resistance. The surface, with properly applied and embedded surface beads, must provide a minimum resistance value of 45 BPN when tested according to ASTM E303.

(8) Thickness. The material must be supplied at a nominal thickness of 65 mil (1.7 mm).

(9) Environmental resistance. The material must be resistant to deterioration due to exposure to sunlight, water, salt, or adverse weather conditions and impervious to aviation fuels, gasoline, and oil.

(10) Retroreflectivity. The material, when applied in accordance with manufacturer’s guidelines, must demonstrate a uniform level of nighttime retroreflection when tested in accordance to ASTM E1710.

(11) Packaging. Packaging shall protect the material from environmental conditions until installation.

(12) Preformed thermoplastic airport pavement marking requirements.

(a) The markings must be a resilient thermoplastic product with uniformly distributed glass beads throughout the entire cross-sectional area. The markings must be resistant to the detrimental effects of aviation fuels, motor fuels and lubricants, hydraulic fluids, deicers, anti-icers, protective coatings, etc. Lines, legends, and symbols must be capable of being affixed to asphalt and/or Portland cement concrete pavements by the use of a large radiant heater. Colors shall be available as required.

(b) The markings must be capable of conforming to pavement contours, breaks, and faults through the action of airport traffic at normal pavement temperatures. The markings must be capable of fully conforming to grooved pavements, including pavement grooving per advisory circular (AC) 150/5320-12, current version. The markings shall have resealing characteristics, such that it is capable of fusing with itself and previously applied thermoplastics when heated with a heat source per manufacturer’s recommendation.

(c) Multicolored markings must consist of interconnected individual pieces of preformed thermoplastic pavement marking material, which through a variety of colors and patterns, make up the desired design. The individual pieces in each large marking segment (typically more than 20 feet (6 m) long) must be factory assembled with a compatible material and interconnected so that in the field it is not necessary to assemble the individual pieces within a marking segment. Obtaining multicolored effect by overlaying materials of different colors is not acceptable due to resulting inconsistent marking thickness and inconsistent application temperature in the marking/substrate interface.

(d) The marking material must set up rapidly, permitting the access route to be re-opened to traffic after application.

(e) The marking material shall have an integral color throughout the thickness of the marking material. **]**

]

****

Thermoplastic airport markings will be subject to an Engineering life-cycle cost analysis prior to inclusion in specifications.

****

b. Reflective media. Glass beads for white and yellow paint shall meet the requirements for Federal Specification TT-B-1325D **[** Type I, Gradation A **] [** Type III **] [** Type IV, Gradation A **]**.

Glass beads for red and pink paint shall meet the requirements for **[** Type I, Gradation A **] [** Type IV, Gradation A **]**.

Glass beads shall be treated with all compatible coupling agents recommended by the manufacturers of the paint and reflective media to ensure adhesion and embedment.

Glass beads shall not be used in black and green paint.

Type III glass beads shall not be used in red and pink paint.

****

The Engineer should insert all that will be used in the project. When more than one bead type is specified, the plans should indicate the bead type for each marking.

Federal Specification TT-B-1325D, Type I, gradation A shall be used when remarking on a frequent basis (at least every six months), and typically yield 300 mcd/m²/lux on white markings at installation and 175 mcd/m²/lux on yellow markings at installation.

Federal Specification TT-B-1325D, Type III. Initial readings typically yield 600 mcd/m²/lux on white markings and 300 mcd/m²/lux on yellow markings at installation and once in service, the reflectance values are approximately the same as Type I beads.

Federal Specification TT-B-1325D, Type IV, gradation A shall be used with TT-P-1952F, Type III paint. The glass beads are larger than either Type I or Type III, thus requiring more of the coating material to properly anchor. The Engineer should consult with the paint and bead manufacturer on the use of adhesion, flow promoting, and/or flotation additives.

Preformed thermoplastic pavement markings should yield at least 225 mcd/m^2/lux on white markings at installation and at least 100 mcd/m^2/lux on yellow markings at installation.

****

CONSTRUCTION METHODS

620-3.1 Weather limitations. Painting shall only be performed when the surface is dry, and the ambient temperature and the pavement surface temperature meet the manufacturer's recommendations in accordance with paragraph 620-2.1. Painting operations shall be discontinued when the ambient or surface temperatures does not meet the manufacturer's recommendations. Markings shall not be applied when the wind speed exceeds 10 mph unless windscreens are used to shroud the material guns. Markings shall not be applied when weather conditions are forecasts to not be within the manufacturers' recommendations for application and dry time.

620-3.2 Equipment. Equipment shall include the apparatus necessary to properly clean the existing surface, a mechanical marking machine, a bead dispensing machine, and such auxiliary hand-painting equipment as may be necessary to satisfactorily complete the job.

The mechanical marker shall be an atomizing spray-type or airless type marking machine with automatic glass bead dispensers suitable for application of traffic paint. It shall produce an even and uniform film thickness and appearance of both paint and glass beads at the required coverage and shall apply markings of uniform cross-sections and clear-cut edges without running or spattering and without over spray. The marking equipment for both paint and beads shall be calibrated daily.

620-3.3 Preparation of surfaces. Immediately before application of the paint, the surface shall be dry and free from dirt, grease, oil, laitance, or other contaminates that would reduce the bond between the paint and the pavement. Use of any chemicals or impact abrasives during surface preparation shall be approved in advance by the RPR. After the cleaning operations, sweeping, blowing, or rinsing with pressurized water shall be performed to ensure the surface is clean and free of grit or other debris left from the cleaning process.

a. Preparation of new pavement surfaces. The area to be painted shall be cleaned by broom, blower, water blasting, or by other methods approved by the RPR to remove all contaminants, including PCC curing compounds, or other debris, minimizing damage to the pavement surface.

b. Preparation of pavement to remove existing markings. Existing pavement markings shall be removed by rotary grinding, water blasting, or by other methods approved by the RPR minimizing damage to the pavement surface. The removal area may need to be larger than the area of the markings to eliminate ghost markings. After removal of markings on asphalt pavements, apply a fog seal or seal coat to 'block out' the removal area to eliminate 'ghost' markings.

c. Preparation of pavement markings prior to remarking. Prior to remarking existing markings, loose existing markings must be removed minimizing damage to the pavement surface, with a method approved by the RPR. After removal, the surface shall be cleaned of all residue or debris.

Prior to the application of markings, the Contractor shall certify in writing that the surface is dry and free from dirt, grease, oil, laitance, or other foreign material that would prevent the bond of the paint to the pavement or existing markings. This certification along with a copy of the paint manufactures application and surface preparation requirements must be submitted to the RPR prior to the initial application of markings.

****

Loose markings should always be removed prior to remarking, whether or not existing markings need to be removed is up to the Engineer and the Airport Operator. The type of removal method used depends upon whether you need to remove loose markings or all existing markings.

****

620-3.4 Layout of markings. The proposed markings shall be laid out in advance of the paint application. The locations of markings to receive glass beads shall be shown on the plans. **All markings to be maintained shall also be checked for proper alignment, dimension and placement prior to applying more paint.** **[** The locations of markings to receive silica sand shall be shown on the plans. **]**

****

Glass beads improve conspicuity and the friction characteristics of markings. At a minimum, the Engineer shall indicate the locations to receive glass beads per AC 150/5340-1, Standards for Airport Markings.

****

620-3.5 Application. A period of **[___]** days shall elapse between placement of surface course or seal coat and application of the permanent paint markings. Paint shall be applied at the locations and to the dimensions and spacing shown on the plans. Paint shall not be applied until the layout and condition of the surface has been approved by the RPR.

****

Select timeframe between placement of surface course or seal coat and application of the paint based on type of surface course or seal coat in the project and environment at the project location. The typical timeframe is 30-days for volatiles and moisture vapor to dissipate.

****

The edges of the markings shall not vary from a straight line more than 1/2 inch (12 mm) in 50 feet (15 m), and marking dimensions and spacing shall be within the following tolerances:

Marking Dimensions and Spacing Tolerance

Dimension and Spacing	Tolerance
36 inch (910 mm) or less	±1/2 inch (12 mm)
greater than 36 inch to 6 feet (910 mm to 1.85 m)	±1 inch (25 mm)
greater than 6 feet to 60 feet (1.85 m to 18.3 m)	±2 inch (50 mm)
greater than 60 feet (18.3 m)	±3 inch (76 mm)

The paint shall be mixed in accordance with the manufacturer's instructions and applied to the pavement with a marking machine at the rate shown in Table 1. The addition of thinner will not be permitted.

Glass beads shall be distributed upon the marked areas at the locations shown on the plans to receive glass beads immediately after application of the paint. A dispenser shall be furnished that is properly designed for attachment to the marking machine and suitable for dispensing glass beads. Glass beads shall be applied at the rate shown in Table 1. Glass beads shall not be applied to black paint or green paint. Glass beads shall adhere to the cured paint or all marking operations shall cease until corrections are made. Different bead types shall not be mixed. Regular monitoring of glass bead embedment and distribution should be performed.

620-3.7 Qualifications. The Contractor shall have at least one individual on site at all times during the painting operation who has achieved an airfield marking certificate. The individual shall be from the Contractor's staff or the Contractor's subcontractor staff. Training shall include information relative to FAA AC 150/5340-1 and the best practices outlined in the Airfield Marking Handbook.

620-3.8 Crew Size. The Contractor shall coordinate the number of painting crews or on-site teams with the Engineer 72 hours prior to the start of a painting operation. The Engineer shall have the right to reduce the number of crews to the available number of RPRs.

620-3.9 Application--preformed thermoplastic airport pavement markings.

[Preformed thermoplastic pavement markings not used. **]**

[To ensure minimum single-pass application time and optimum bond in the marking/substrate interface, the materials must be applied using a variable speed self-propelled mobile heater with an effective heating width of no less than 16 feet (5 m) and a free span between supporting wheels of no less than 18 feet (5.5 m). The heater must emit thermal radiation to the marking material in such a manner that the difference in temperature of 2 inches (50 mm) wide linear segments in the direction of heater travel must be within 5% of the overall average temperature of the heated thermoplastic material as it exits the heater. The material must be able to be applied at ambient and pavement temperatures down to 35°F (2°C) without any preheating of the pavement to a specific temperature. The material must be able to be applied without the use of a thermometer. The pavement shall be clean, dry, and free of debris. A non-volatile organic content (non-VOC) sealer with a maximum applied viscosity of 250 centiPoise must be applied to the pavement shortly before the markings are applied. The supplier must enclose application instructions with each box/package. **]**

****

The Engineer will make the appropriate selection for thermoplastic markings.

****

620-3.10 Control strip. Prior to the full application of airfield markings, the Contractor shall prepare a control strip in the presence of the RPR **for each paint and bead applicator equipment used in the project.** The Contractor shall demonstrate the surface preparation method and all striping equipment to be used on the project. The marking equipment must achieve the prescribed application rate of paint and population of glass beads (per Table 1) that are properly embedded and evenly distributed across the full width of the marking. Prior to acceptance of the control strip, markings must be evaluated during darkness to ensure a uniform appearance. **In addition, prior to acceptance of the control strip, the thickness of the paint shall be measured for acceptance. Typical "wet" mil thicknesses are as follows: 30 mils at 55 SF/gal, 25 mils at 75 SF/gal; 20 mils at 90 SF/gal and 15 mils at 115 SF/gal.**

620-3.11 Retro-reflectance. [Reflectance shall be measured with a portable retro-reflectometer meeting ASTM E1710 (or equivalent). A total of 6 reading shall be taken over a 6 square foot area with 3 readings taken from each direction. The average shall be equal to or above the minimum levels of all readings which are within 30% of each other.

Minimum Retro-Reflectance Values

Material	Retro-reflectance mcd/m^2/lux		
	White	Yellow	Red
Initial Type I	300	175	35
Initial Type III	600	300	35
Initial Thermoplastic	225	100	35
All materials, remark when less than[1]	100	75	10

[1] ‘Prior to remarking determine if removal of contaminants on markings will restore retro-reflectance][not used]

****

Include tests of retro-reflectance at Part 139 airports, recommend testing at least 2 times per day. Enter Not Used at all other locations.

****

620-3.12 Protection and cleanup. After application of the markings, all markings shall be protected from damage until dry. All surfaces shall be protected from excess moisture and/or rain and from disfiguration by spatter, splashes, spillage, or drippings. The Contractor shall remove from the work area all debris, waste, loose reflective media, and by-products generated by the surface preparation and application operations to the satisfaction of the RPR. The Contractor shall dispose of these wastes in strict compliance with all applicable state, local, and federal environmental statutes and regulations.

METHOD OF MEASUREMENT

620-4.1a The quantity of surface preparation shall be measured by **[** the number of square feet (square meters) for each type of surface preparation specified in paragraph 620-3.3 **][** lump sum **]**.

620-4.1b The quantity of markings shall be paid for shall be measured **[** by the number of square feet (square meters) of painting **] [** by lump sum **]**.

620-4.1c The quantity of reflective media shall be paid for by **[** the number of pounds (km) **]** **[** lump sum **]** of reflective media.

620-4.1d [The quantity of temporary markings to be paid for shall be **[** the number of square feet (square meters) of painting **][** lump sum price **]** performed in accordance with the specifications and accepted by the RPR. Temporary marking includes surface preparation, application and complete removal of the temporary marking. **][** Temporary markings not required. **]**

[620-4.1e The quantity of preformed markings to be paid for shall be **[** the number of square feet (square meters) of preformed markings **][** lump sum **]]**.

****

Separate pay items for surface preparation, marking, and reflective media is recommended, however on small jobs, lump sum pay items is acceptable.

****

BASIS OF PAYMENT

620-5.1 This price shall be full compensation for furnishing all materials and for all labor, equipment, tools, and incidentals necessary to complete the item complete in place and accepted by the RPR in accordance with these specifications.

620-5.1a Payment for surface preparation shall be made at the contract price for **[** the number of square feet (square meters) for each type of surface preparation specified in paragraph 620-3.3 **][** lump sum **]**.

620-5.2b Payment for markings shall be made at the contract price for **[** the number of square feet (square meters) of painting and the number of pounds (km) of reflective media **][** by the number of square feet (square meters) of painting **][** by lump sum **]**.

620-5.3c Payment for reflective media shall be made at the contract unit price for **[** the number of pounds (km) of reflective media **][** lump sum **]**.

620-5.4d Payment for temporary markings shall be made at the contract price for **[** the number of square feet (square meters) of painting **][** lump sum price **]**. This price shall be full compensation for furnishing all materials and for all labor, equipment, tools, and incidentals necessary to complete the item. **[** Temporary markings are not required. **]**

[620-5.5e Payment for preformed markings shall be made at the contract price for **[** the number of square feet (square meters) of preformed markings **][** lump sum price **]**. **]**

Payment will be made under:

Item P-620-5.1a	Surface Preparation **[** per square foot (square meter) **][** lump sum **]**
Item P-620-5.2b	Marking **[** per square foot (square meter) **][** lump sum **]**
Item P-620-5.3c	Reflective Media **[** per pound (km) **][** lump sum **]**
Item P-620-5.4d	Temporary runway and taxiway marking **[** per square foot **][** per square meter **][** lump sum **]**.
[Item 620-5.5e	Preformed markings per **[** the number of square feet (square meters) of preformed markings **][** lump sum price **]**. **]**

REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

ASTM International (ASTM)

ASTM D476	Standard Classification for Dry Pigmentary Titanium Dioxide Products
ASTM D968	Standard Test Methods for Abrasion Resistance of Organic Coatings by Falling Abrasive
ASTM D1652	Standard Test Method for Epoxy Content of Epoxy Resins
ASTM D2074	Standard Test Method for Total, Primary, Secondary, and Tertiary Amine Values of Fatty Amines by Alternative Indicator Method
ASTM D2240	Standard Test Method for Rubber Property - Durometer Hardness
ASTM D7585	Standard Practice for Evaluating Retroreflective Pavement Markings Using Portable Hand-Operated Instruments
ASTM E303	Standard Test Method for Measuring Surface Frictional Properties Using the British Pendulum Tester
ASTM E1710	Standard Test Method for Measurement of Retroreflective Pavement Marking Materials with CEN-Prescribed Geometry Using a Portable Retroreflectometer
ASTM E2302	Standard Test Method for Measurement of the Luminance Coefficient Under Diffuse Illumination of Pavement Marking Materials Using a Portable Reflectometer
ASTM G154	Standard Practice for Operating Fluorescent Ultraviolet (UV) Lamp Apparatus for Exposure of Nonmetallic Materials

Code of Federal Regulations (CFR)

40 CFR Part 60, Appendix A-7, Method 24	Determination of volatile matter content, water content, density, volume solids, and weight solids of surface coatings
29 CFR Part 1910.1200	Hazard Communication

Federal Specifications (FED SPEC)

FED SPEC TT-B-1325D	Beads (Glass Spheres) Retro-Reflective
FED SPEC TT-P-1952F	Paint, Traffic and Airfield Marking, Waterborne
FED STD 595	Colors used in Government Procurement

Commercial Item Description

A-A-2886B	Paint, Traffic, Solvent Based

Advisory Circulars (AC)

AC 150/5340-1	Standards for Airport Markings
AC 150/5320-12	Measurement, Construction, and Maintenance of Skid Resistant Airport Pavement Surfaces

END OF ITEM P-620