Polyester Marking Material Study

August 2006

DOT/FAA/AR-TN06/33

U.S. Department of Transportation
Federal Aviation Administration

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Technical Report Documentation Page

1. Report No. DOT/FAA/AR-TN06/33	2. Government Accession No.	3. Recipient's Catalog No.
4. TITLE AND SUBTITLE POLYESTER MARKING MATERIAL STUDY		5. Report Date August 2006
		6. Performing Organization Code ATO-P R&D
7. Author(s) Holly M. Cyrus and Renee Frierson*		8. Performing Organization Report No.
9. Performing Organization Name and Address Federal Aviation Administration William J. Hughes Technical Center Airport and Aircraft Safety Research and Development Division Airport Technology Research and Development Branch Atlantic City International Airport, NJ 08405	*Hi-Tec Systems 500 Scarborough Dr., Suite 108 Egg Harbor Twp., NJ 08234	10. Work Unit No. (TRAIS)
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address U.S. Department of Transportation Federal Aviation Administration Office of Aviation Research and Development Washington, DC 20591		13. Type of Report and Period Covered Technical Note
		14. Sponsoring Agency Code AAS-100

15. Supplementary Notes

Messrs. Paul Jones, James Patterson, and Donald Gallagher of the FAA William J. Hughes Technical Center assisted in the evaluation of the pavement markings. A special thanks to Traci Stadtmueller, a summer intern, who setup all of the graphs and took countless hours of data.

16. Abstract

This research was conducted to determine if polyester marking material would be an acceptable addition to the existing paint materials specified in the Federal Aviation Administration (FAA) Advisory Circular 150/5370-10A Item P-620, Runway and Taxiway Painting. The polyester marking material was applied on the FAA William J. Hughes Technical Center at the FAA ramp, Pangborne Road, and the Pavement Test Facility for an evaluation period of 1 year starting in August 2004. Three different types of pavement were used during the tests: Hot-Mix Asphalt, Aged Portland Cement Concrete, and New Portland Cement Concrete. The chromaticity, retro-reflectivity, baseline, pull-off strength, and friction tests were performed on the polyester marking material.

Based on the test results, the polyester marking material maintained its retro-reflectivity, but the chromaticity level for yellow was not acceptable. When simulated in a high-traffic airport environment, the polyester marking material failed (disintegrated) after less than a day's worth of operations. Therefore, the polyester marking material is not suitable for the airport environment.

17. Key Words Retro-reflectivity, Chromaticity, Polyester, Friction test, Baseline test, Pull-off strength test, Glass beads	18. Distribution Statement This document is available to the public through the National Technical Information Service (NTIS), Springfield, Virginia 22161.		
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 29	22. Price

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LIST OF ACRONYMS AND ABBREVIATIONS

AC	Advisory Circular
FAA	Federal Aviation Administration
ICAO	International Civil Aviation Organization
IOR	Index of Refraction
NAPTF	National Airport Pavement Test Facility
PCC	Portland cement concrete
psi	Pounds per square inch
R&D	Research and development

EXECUTIVE SUMMARY

Maintenance of pavement markings is a common problem for airports due to the frequency of repainting and life cycle cost. As a result, airports have been looking for alternative paint materials that will be able to withstand the varied environmental conditions of an airport rather than the standard paint materials that are specified in the Federal Aviation Administration (FAA) Advisory Circular (AC) 150/5370-10A Item P-620, Runway and Taxiway Painting. One possible candidate, a polyester marking material, was presented to the FAA for consideration. In the past, polyester marking material was used for paint markings on aircraft and for highway pavement markings.

This research effort was conducted to determine if polyester marking material would be an acceptable addition to the existing paint materials specified in the FAA AC 150/5370-10A Item P-620, Runway and Taxiway Painting.

The polyester marking material was applied at the FAA William J. Hughes Technical Center at the FAA ramp, Pangborne Road, and the Pavement Test Facility for an evaluation period of 1 year starting in August 2004. Three different types of pavement were used during the tests: Hot-Mix Asphalt, Aged Portland Cement Concrete, and New Portland Cement Concrete.

Based on the test results, the polyester marking material maintained its retro-reflectivity, but the chromaticity level for yellow was not acceptable. When simulated in a high-traffic airport environment, the polyester marking material failed after less than a day's worth of operations. Therefore, the polyester marking material is not suitable for an airport environment.

INTRODUCTION

PURPOSE.

This research effort was conducted to determine whether or not polyester marking material would be an acceptable marking material for the airport environment. The Airport Technology Research and Development (R&D) Branch evaluated the polyester marking material.

OBJECTIVE.

The objective of this evaluation was to determine if polyester marking material would be an acceptable addition to the existing paint materials specified in the Federal Aviation Administration (FAA) Advisory Circular (AC) 150/5370-10A Item P-620, Runway and Taxiway Painting.

BACKGROUND.

Maintenance of pavement markings is a common problem for airports due to the frequency of repainting and life cycle cost. As a result, airports have been looking for alternative paint materials that will be able to withstand the varied environmental conditions of an airport. One possible candidate, a polyester marking material, was presented to the FAA for consideration. In the past, polyester marking material was used for paint markings on aircraft and for highway pavement markings. Manufacturers have been postulating that the durability of the polyester marking material surpasses current paint marking materials; however, polyester marking material has not been used in an airport environment and required testing.

In March 2004, Lambert-St. Louis International Airport requested a deviation from FAA standards in order to install polyester marking material on a new runway under construction. Consequently, the FAA Airport Engineering Division office requested that the Airport Technology R&D Branch conduct a formal evaluation of the polyester marking material.

Additionally, the Airport Engineering Division office requested that various reflective media (glass beads) be tested for compatibility with the polyester marking material. Glass beads are used in paint markings to reflect light toward the pilot, giving the pilot better visual acquisition of the paint marking during nighttime operations. Glass beads are characterized by their Index of Refraction (IOR), which is a scale index of the rate at which a material refracts light toward the source. The characteristics of the IOR vary depending on the type of glass used, whether it is virgin (never been used), or recycled. Virgin beads produce a higher IOR than recycled beads because recycled beads retain some color from previous use. Depending on the paint material used, glass beads incorporated within the paint may exhibit rapid failure when not properly embedded. Three types of beads are detailed in the Federal Specification TT-B-1325C, i.e., Type I (1.5 IOR) low-index recycled glass bead, Type III (1.9 IOR) high-index virgin glass bead, and Type IV (1.5 IOR) low-index direct-melt glass. The Type I bead is commonly referred to as a highway bead, and the Type III bead is commonly referred to as an airport bead. The glass beads evaluated in this study were Type I and Type III.

DISCUSSION.

The polyester marking material was applied at the FAA William J. Hughes Technical Center for an evaluation period of 1 year starting in August 2004. The polyester marking material was applied on Hot-Mix Asphalt on Pangborne Road, on Aged Portland Cement Concrete at the FAA ramp, and on New Portland Cement Concrete in the National Airport Pavement Test Facility (NAPTF) at the FAA William J. Hughes Technical Center. The polyester marking material was applied to the pavement using an extrusion method. The extrusion method requires equipment that continually mixes the polyester coating with a peroxide catalyst solution. The mixture is then poured into a form that helps to ensure the uniform shape of the line being applied to the pavement. Airports do not use the extrusion method to apply pavement paint markings; normally a spray method is used. The polyester marking material was applied at a thickness of 15 mil for each line tested. In addition, as a part of determining the acceptance of this material, the compatibility of standard Type I and Type III beads were examined. Table 1 shows the pavement type, color, type of bead, and tests conducted on the polyester marking material.

TABLE 1. POLYESTER MARKING MATERIAL LOCATIONS

<table>
<tr><th>Pavement Type</th><th>Color</th><th>Type of Bead</th><th>Tests Conducted</th></tr>
<tr><td rowspan="4">Asphalt
(figures 1and 2)</td><td>2 white stripes</td><td>Type I, Type III</td><td rowspan="4">Chromaticity, retro-reflectivity, pull-off strength, friction, baseline</td></tr>
<tr><td>White centerline</td><td>Type I</td></tr>
<tr><td>2 yellow stripes</td><td>Type I, Type III</td></tr>
<tr><td>Yellow centerline</td><td>Type I</td></tr>
<tr><td rowspan="2">Aged Portland
Cement Concrete
(figure 3)</td><td>2 white stripes</td><td>Type I, Type III</td><td rowspan="2">Chromaticity, retro-reflectivity</td></tr>
<tr><td>2 Yellow stripes</td><td>Type I, Type III</td></tr>
<tr><td rowspan="2">New Portland
Cement Concrete
(figure 4)</td><td>Yellow</td><td>Type I, Type III</td><td rowspan="2">Chromaticity, retro-reflectivity</td></tr>
<tr><td>White</td><td>Type I, Type III</td></tr>
</table>

*Installed at the NAPTF at the FAA William J. Hughes Technical Center, which has the capability to simulate a high-traffic volume airport of Boeing 747s and 777s. The test vehicle did 20 passes over the polyester marking material, which amounted to less than a day's worth of operations. The polyester marking material failed after 20 passes and was removed.

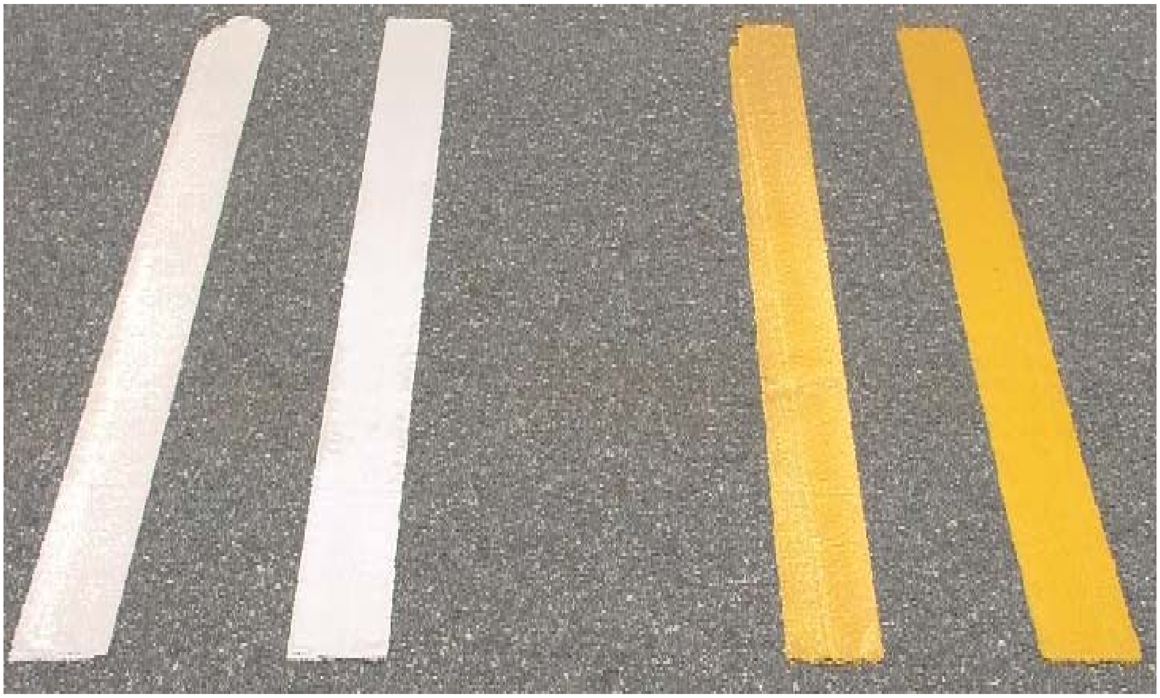

FIGURE 1. POLYESTER MARKING MATERIAL ON ASPHALT WITH TYPE I AND TYPE III BEADS

FIGURE 2. CENTERLINE POLYESTER MARKING MATERIAL ON ASPHALT WITH TYPE I BEADS

FIGURE 3. POLYESTER MARKING MATERIAL ON AGED PORTLAND CEMENT CONCRETE WITH TYPE I AND TYPE III BEADS

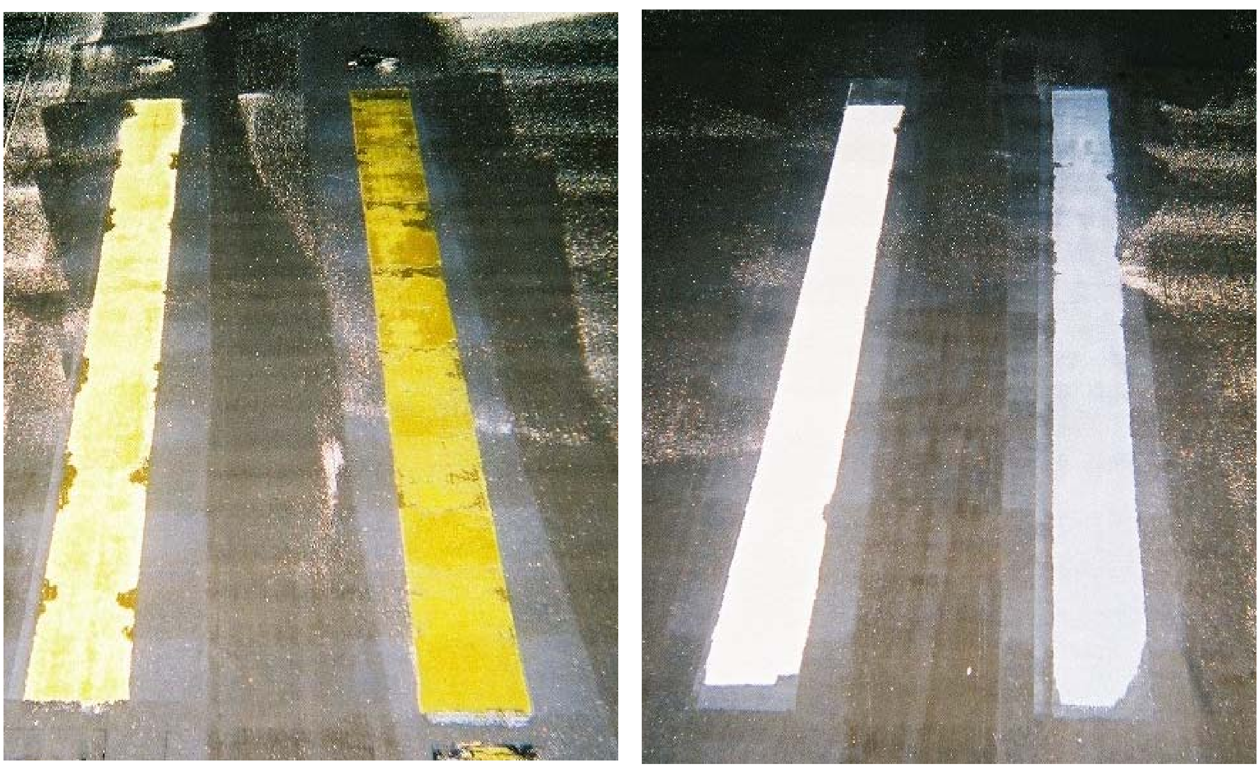

FIGURE 4. POLYESTER MARKING MATERIAL ON NEW PORTLAND CEMENT CONCRETE WITH TYPE I AND TYPE III BEADS

RELATED DOCUMENTS.

Related documents dealing with this evaluation project are:

- ASTM E 2380-05, “Standard Test Method for Measuring Pavement Texture Drainage Using an Outflow Meter”
- ASTM D 2177-01, “Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers”
- ASTM E 2177-01, “Standard Test Method for Measuring the Coefficient of Retro-reflected Luminance (R_L) of Pavement Markings in a Standard Condition of Wetness”
- DOT/FAA/AR-TN03/22, “Development of Methods for Determining Airport Pavement Marking Effectiveness,” March 2003
- DOT/FAA/AR-02/128, “Paint and Bead Durability Study,” March 2003
- DOT/FAA/AR-TN96/74, “Follow-On Friction Testing of Retro-Reflective Glass Beads,” July 1996
- DOT/FAA/CT-94/119, “Evaluation of Alternative Pavement Marking Materials,” January 1995
- DOT/FAA/CT-94/120, “Evaluation of Retro-Reflective Beads in Airport Pavement Markings,” December 1994
- FAA Advisory Circular AC 150/5340-1H, “Standards for Airport Markings,” December 1, 2000
- FAA Advisory Circular AC 150.5320-12C, “Measurement, Construction, and Maintenance of Skid-Resistant Airport Pavement Surfaces,” March 18, 1997
- FAA Advisory Circular AC 150/5370-10A, “Standards for Specifying Construction of Airports,” Item P-620, “Runway and Taxiway Painting,” February 17, 1989
- ICAO Annex 14, Volume I, “Aerodrome Design and Operation,” August 9, 2000, pp. 131-132
- Specification TT-B-1325C, “Beads (Glass Spheres) Retroreflective,” June 1, 1993

EVALUATION APPROACH

METHOD.

The Airport Technology R&D Branch team conducted monthly chromaticity and retro-reflective readings at the FAA William J. Hughes Technical Center. Upon initial application of the polyester marking material, outflow water meter, 2-liter water recovery, pull-off strength, friction, and baseline tests were performed. The following is a brief description of equipment used.

- Equipment Description
  - Spectrophotometer, Color guide 45/0, BYK-Gardner USA, 20 mm, 6805-SVC, built by BYK-Gardner of Germany.
  - Retro-Reflectometer, Flint Trading, Inc., 30-meter geometry, LTL 2000 built by Delta Lights and Optics of Denmark
  - Dyna-Meter Z16 Pull-Off Tester
  - Saab Friction Tester ASTM 1551 Tire at 30 pounds per square inch (psi)
- Evaluation Participants
  - Individuals from the manufacturer of the polyester marking material

BASELINE TEST. At initial application, baseline measurements of the polyester marking material were taken for each color (yellow and white) on asphalt and concrete. Once the material was applied to the pavement, chromaticity and retro-reflective readings were taken using a spectrophotometer and a retro-reflectometer.

CHROMATICITY TEST. The chromaticity test was conducted using a spectrophotometer. The readings were taken by placing the instrument on the pavement marking and activating the device. Using the spectrophotometer, two readings per marking were taken. Color readings were performed after initial application of the polyester marking material was completed and continued monthly thereafter for 1 year.

RETRO-REFLECTIVITY TEST. Retro-reflectivity was obtained with the use of a retro-reflectometer. The readings were taken by placing the instrument on the pavement marking and activating the device. Six readings per polyester marking material were obtained using the retro-reflectometer. Prior to each use, the instrument was calibrated and had an accuracy of ±5%. Readings were taken after initial application of the polyester marking material was completed and continued monthly thereafter for 1 year.

PULL-OFF STRENGTH TEST. The pull-off strength test was used to determine the tensile strength of the bond between the polyester marking material and hot-mix asphalt or PCC. Using a Dyna-Meter Z16 Pull-Off Tester, a metal disc was glued down on the polyester marking material while it dried for a period of 24 hours. The Dyna-Meter Pull-Off Tester was connected to the disc via a draw bolt, adjusted to level via adjustable legs, turned on, and the crank was turned until the metal disc separated from the pavement. This test was performed in accordance with ASTM D 4541-02.

FRICTION TEST. Using a Dyna-Test 6850 Runway Friction Tester, multiple test runs were conducted. Testing took place on asphalt at the FAA William J. Hughes Technical Center, where two 150-foot test stripes were located. The friction runs were conducted at 30 psi with the water on.

DATA COLLECTION.

CHROMATICITY TEST. For the chromaticity test, the spectrophotometer produced (Y, x, y) coordinate readings. The readings were compared to the International Commission on Illumination standard illuminant D65 chromaticity chart found in International Civil Aviation Organization (ICAO) Annex 14, Volume I. However, the aviation yellow region was modified to suit the FAA in-service yellow used on airports, since the region for the FAA in-service boundaries of aviation yellow are not the same as for ICAO yellow. The region for FAA in-service yellow was obtained and is documented in figure A-5 in appendix A of DOT/FAA/AR-TN03/22, "Development of Methods for Determining Airport Pavement Marking Effectiveness." The region for white is the ICAO white region. A white data point that falls outside the ICAO white region is considered failed. A yellow data point that falls outside the FAA in-service aviation yellow region is considered failed (see figure 5).

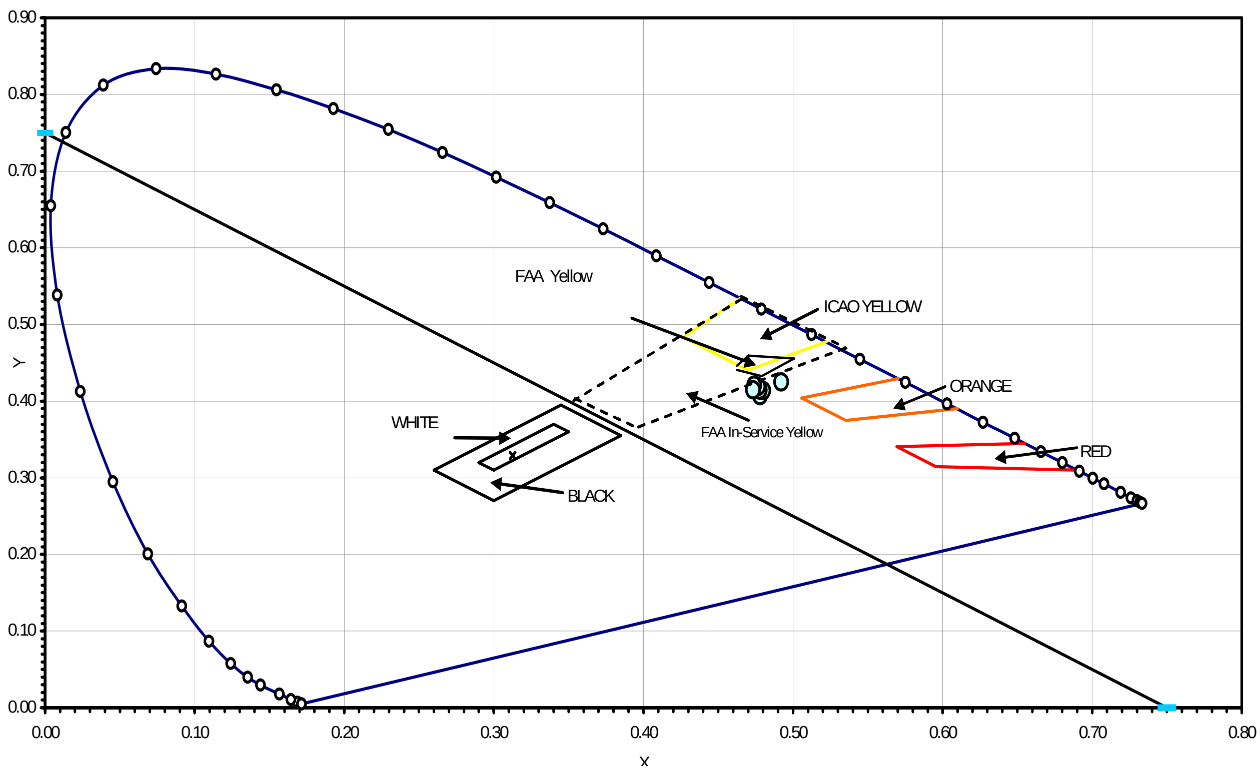

FIGURE 5. SAMPLE COLOR READINGS (YELLOW) TYPE III BEADS ON AGED CONCRETE

RETRO-REFLECTIVITY. The retro-reflectometer produced millicandela per meter squared per lux readings. Currently, the FAA has no standard for retro-reflectivity limits. A paint marking study conducted by the Airport Safety Technology R&D team determined that the recommended minimum was 100 mcd/m^2/lx for white and 70 mcd/m^2/lx for yellow. Additional information can be found in FAA report DOT/FAA/AR-TN03/22.

PULL-OFF STRENGTH TEST. This test determined whether there was an internal failure of the polyester marking material or an external failure of the pavement material (asphalt or concrete). When the polyester marking material fails, there is a cohesive failure, when the asphalt or concrete fails, there is an adhesive failure. The tensile strength readings were measured in psi. The best result should end in a pavement failure (adhesive) rather than a marking material failure (cohesive). To pass, the psi reading should be equal or higher than the baseline.

FRICTION TEST. The data output of the friction tester readings was measured in Mu (μ). The readings for friction can range from 0 to 1 μ, with 1 μ being the best possible friction reading.

TEST RESULTS

BASELINE TEST.

The initial chromaticity readings for white and yellow polyester marking material all fell within their acceptable ranges. (See appendix A for additional data.)

The initial retro-reflectivity readings for Type I and Type III beads were above the recommended minimums of 100 mcd/m^2/lx for white and 70 mcd/m^2/lx for yellow. (See appendix A for additional data.)

CHROMATICITY TEST.

The acceptability range for the white x-coordinate is 0.2895 to 0.3442 and the y-coordinate is 0.3100 to 0.3650. The acceptability range for the yellow x-coordinate is 0.4261 to 0.5266 and the y-coordinate is 0.4300 to 0.5346. A Pass or Fail rating was based on the last data point taken at the end of the study, as shown in table 2. (See appendix A for additional data.)

TABLE 2. PASS/FAIL RATE FOR CHROMATICITY TEST

Surface Material	Color	Total Evaluated	Pass	Fail
Asphalt	White	3	3	0
	Yellow	3	0	3
Aged Concrete	White	2	2	0
	Yellow	2	0	2

RETRO-REFLECTIVITY TEST.

The recommended minimum is 100 mcd/m^2/lx for white and 70 mcd/m^2/lx for yellow. Table 3 shows the average retro-reflectivity readings for Type I beads, and table 4 shows the average retro-reflectivity readings for Type III beads.

TABLE 3. AVERAGE RETRO-REFLECTIVITY READINGS FOR TYPE I BEADS

Color	Surface Material	September 2004* (mcd/m^2/lx)	July 2005 (mcd/m^2/lx)	Percent Remaining
White	Asphalt	516	363	70
White	Asphalt	520	323	62
Yellow	Asphalt	161	101	63
Yellow	Asphalt	139	59	42
White	Aged Concrete	535	562	105
Yellow	Aged Concrete	146	121	83

*Due to the polyester marking material covering most of the beads at initial application, readings from the second month were collected instead of the first month for a more accurate reading.

TABLE 4. AVERAGE RETRO-REFLECTIVITY READINGS FOR TYPE III BEADS

Color	Surface Material	September 2004* (mcd/m^2/lx)	July 2005 (mcd/m^2/lx)	Percent Remaining
White	Asphalt	657	428	65
Yellow	Asphalt	296	87	29
White	Aged Concrete	798	998	125
Yellow	Aged Concrete	344	276	80

*Due to the polyester marking material covering most of the beads at initial application, readings from the second month were collected instead of the first month for a more accurate reading.

PULL-OFF STRENGTH TEST.

As a comparison for polyester marking material, a past study (DOT/FAA/AR-02/128) was conducted on waterborne paint in which yellow waterborne paint had an average tensile strength of 77 psi and white waterborne paint had an average tensile strength of 86 psi. Both markings were tested on asphalt (see table 5).

TABLE 5. PULL-OFF STRENGTH TEST

Surface Material	Tensile Strength (psi)	Cohesive/Adhesive
Asphalt	214	Adhesive
Concrete	13	Cohesive

FRICTION TEST.

The readings for friction can range from 0 to 1 μ, with 1 μ being the best possible friction reading. The only friction readings taken were on asphalt (see table 6).

TABLE 6. FRICTION TEST (ASPHALT)

Description	Average (μ)	Average Speed (mph)
Baseline (dry pavement)	0.55	30
Yellow/White Centerline (Type I)	0.12	30

SUMMARY

One of the markings for yellow polyester on asphalt with Type I beads failed during the 1-year evaluation with a final reading of 59 mcd/m^2/lx and a reduction of 42%. In addition, for Type III beads, one marking failed with a final reading of 87 mcd/m^2/lx and a reduction of 29%. All white polyester markings passed for retro-reflectivity.

Of the ten markings, only one marking failed with Type I beads and one marking failed with Type III beads.

For chromaticity, yellow polyester marking material failed to maintain its color for the duration of the test with all markings failing at the end of 1 year. The white polyester marking material maintained its color for the duration of the test.

The pull-off strength test indicates that polyester marking material, if applied correctly on asphalt, provides a better bond than waterborne marking material.

Friction test results indicated that the polyester marking material did not provide sufficient resistance with an average reading of 0.12 at 30 mph on asphalt.

Based on the test results, the polyester marking material maintained its retro-reflectivity, but the chromaticity level for yellow was not acceptable. When simulated in a high-traffic airport environment, the polyester marking material disintegrated after less than a day's worth of operations. Therefore, the polyester marking material is not suitable for the airport environment.

APPENDIX A—DATA COLLECTED

TABLE A-1. BASELINE TEST FOR CHROMATICITY READINGS ON ASPHALT

Color	Type of Bead	X-Reading	Y-Reading
White	Type I	0.3356	0.3549
White	Centerline Type I	0.3358	0.3549
White	Type III	0.3396	0.3598
Yellow	Type I	0.5161	0.4299
Yellow	Centerline Type I	0.5230	0.4343
Yellow	Type III	0.5046	0.4270

TABLE A-2. BASELINE TEST FOR CHROMATICITY READINGS ON AGED PORTLAND CEMENT CONCRETE

Color	Type of Bead	X-Reading	Y-Reading
White	Type I	0.3278	0.3484
White	Type III	0.3394	0.3570
Yellow	Type I	0.5237	0.4365
Yellow	Type III	0.4780	0.4073

TABLE A-3. BASELINE TEST FOR RETRO-REFLECTIVITY ON ASPHALT

Color	Type of Bead	Initial Reading
White	Type I	240
Yellow	Type I	163
White	Centerline Type I	462
Yellow	Centerline Type I	139
White	Type III	430
Yellow	Type III	293

TABLE A-4. BASELINE TEST FOR RETRO-REFLECTIVITY ON AGED PORTLAND CEMENT CONCRETE

Color	Type of Bead	Initial Reading
White	Type I	321
Yellow	Type I	170
White	Type III	309
Yellow	Type III	269

TABLE A-5. COLOR READINGS (WHITE) FOR TYPE I BEADS ON ASPHALT

Month	Acceptability Range (0.2895-0.3442) X-Readings	Acceptability Range (0.3100-0.3650) Y-Readings
August	0.3356	0.3549
July	0.3349	0.3511

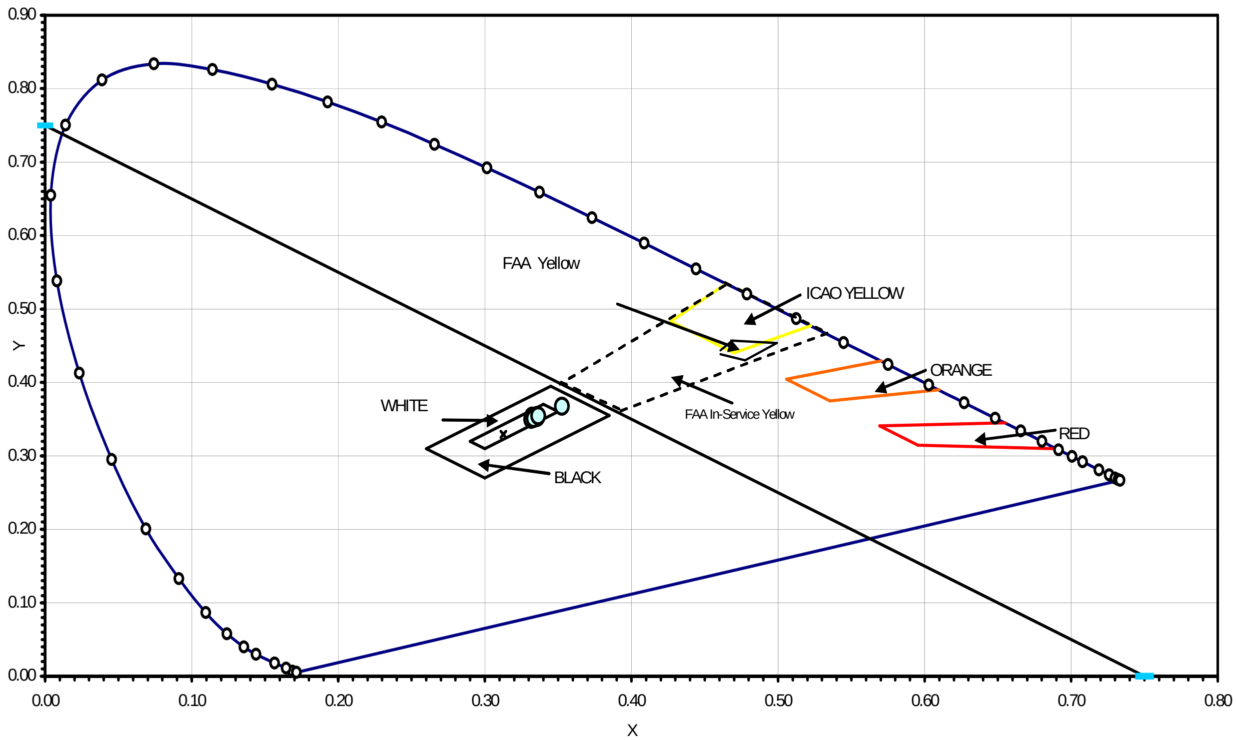

FIGURE A-1. COLOR READINGS (WHITE) TYPE I BEADS ON ASPHALT

TABLE A-6. COLOR READINGS (YELLOW) TYPE I BEADS ON ASPHALT

Month	Acceptability Range (0.4261-0.5266) X-Readings	Acceptability Range (0.4300-0.5346) Y-Readings
August	0.5161	0.4299
July	0.4933	0.4186

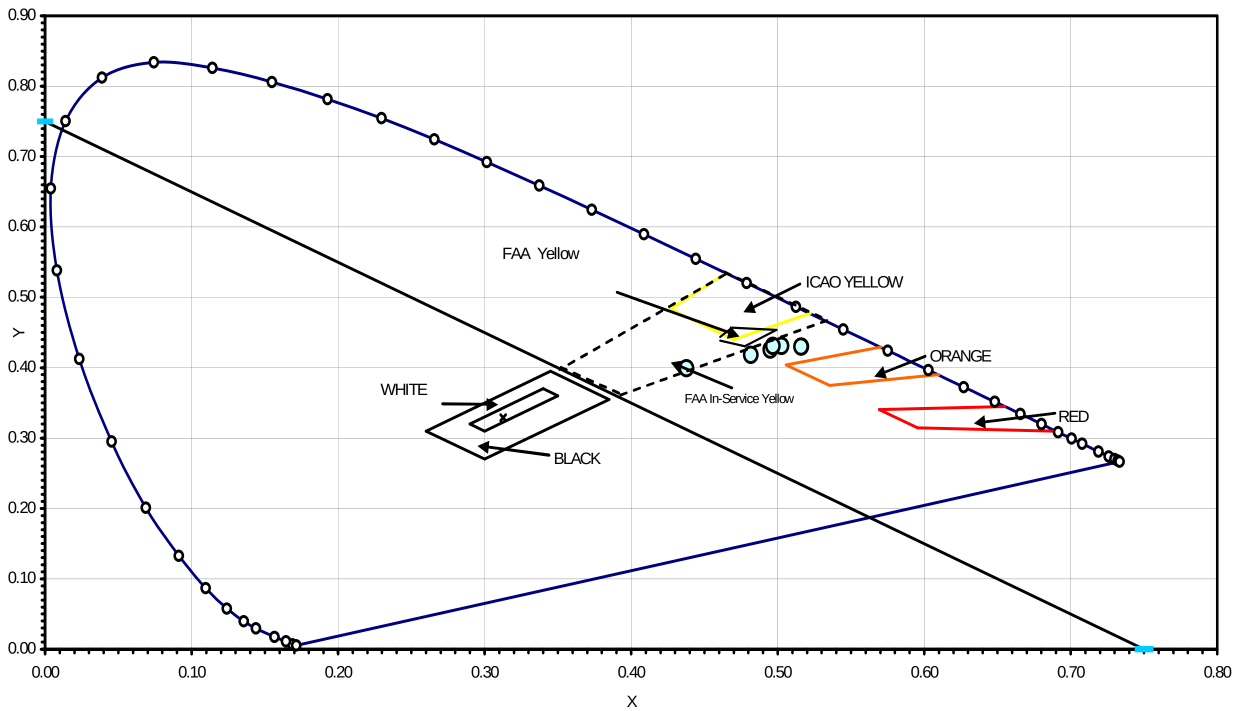

FIGURE A-2. COLOR READINGS (YELLOW) TYPE I BEADS ON ASPHALT

TABLE A-7. COLOR READINGS (WHITE) TYPE III BEADS ON ASPHALT

Month	Acceptability Range (0.2895-0.3442) X-Reading	Acceptability Range (0.3100-0.3650) Y-Reading
August	0.3396	0.3598
July	0.3335	0.3497

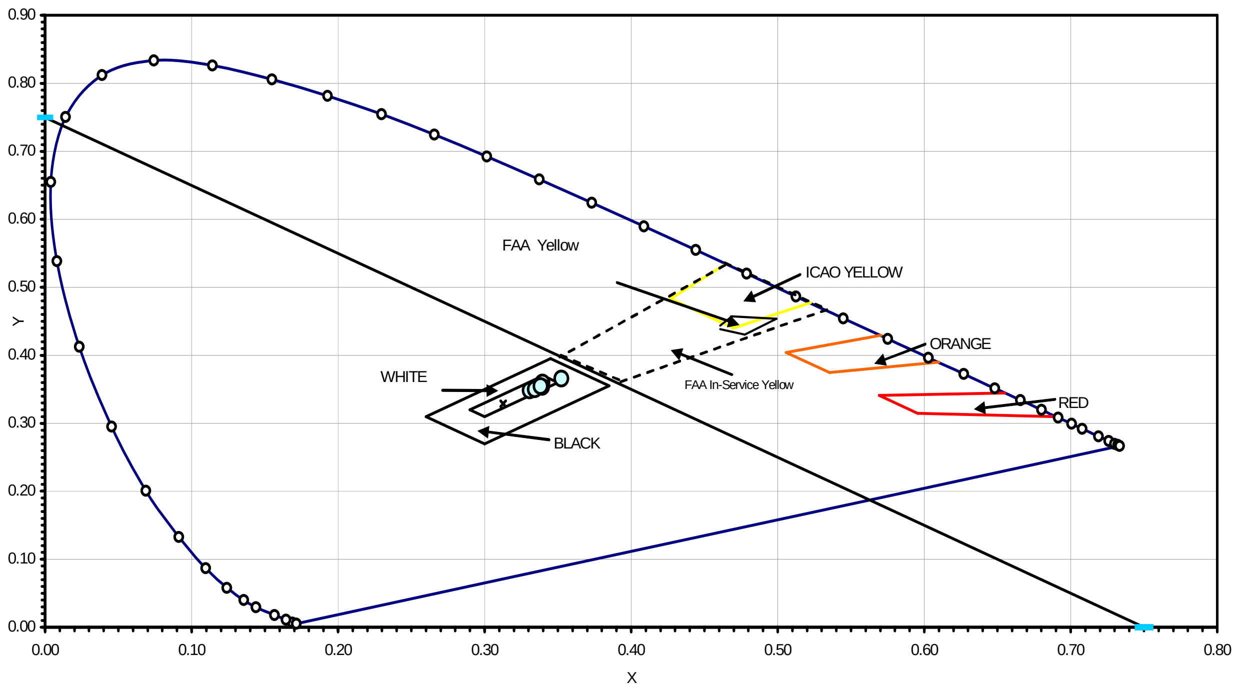

FIGURE A-3. COLOR READINGS (WHITE) TYPE III BEADS ON ASPHALT

TABLE A-8. COLOR READINGS (YELLOW) TYPE III BEADS ON ASPHALT

Month	Acceptability Range (0.4261-0.5266) X-Readings	Acceptability Range (0.4300-0.5346) Y-Readings
August	0.5046	0.4270
July	0.4701	0.4089

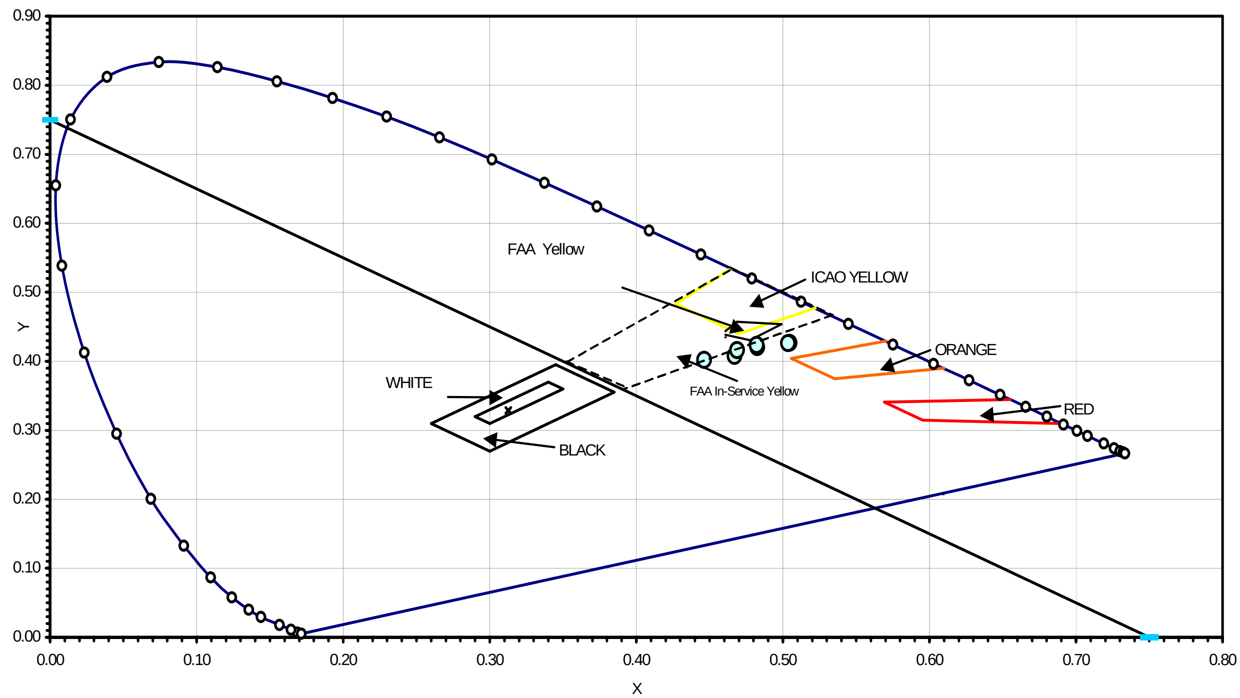

FIGURE A-4. COLOR READINGS (YELLOW) TYPE III BEADS ON ASPHALT

TABLE A-9. COLOR READINGS (WHITE) CENTERLINE TYPE I ON ASPHALT

Month	Acceptability Range (0.2895-0.3442) X-Reading	Acceptability Range (0.3100-0.3650) Y-Reading
August	0.3358	0.3549
July	0.3360	0.3510

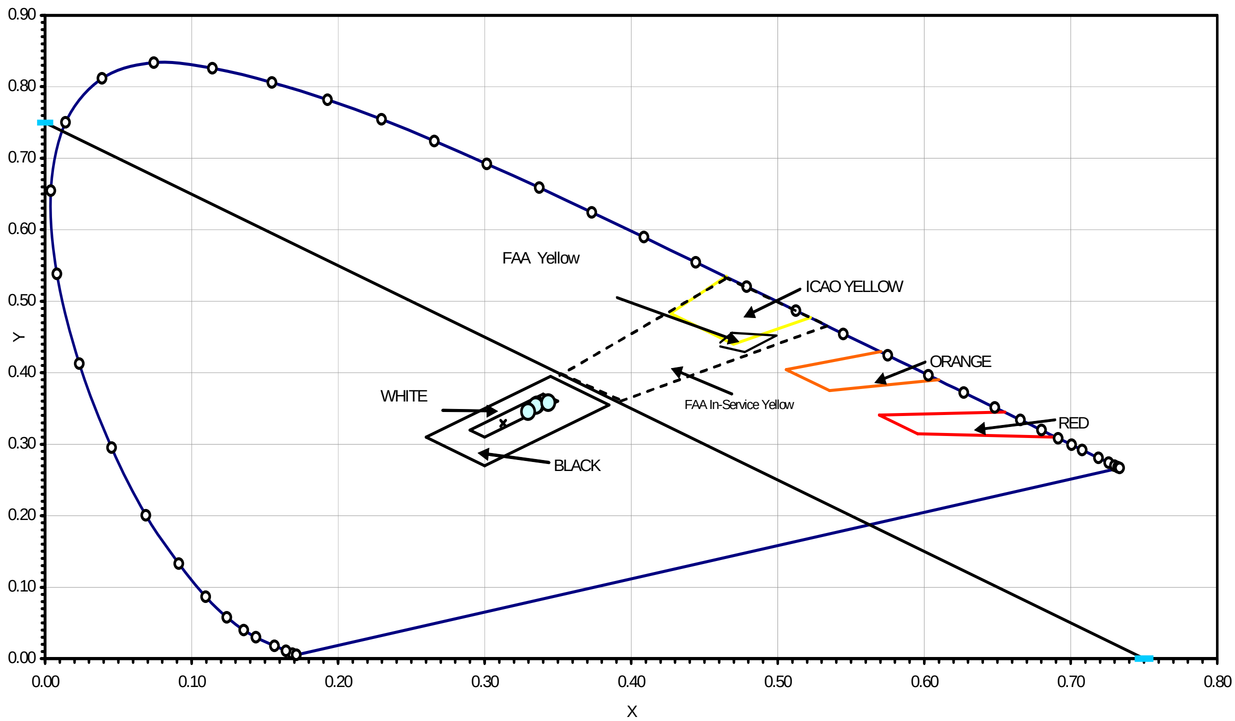

FIGURE A-5. COLOR READINGS (WHITE) CENTERLINE TYPE I ON ASPHALT

TABLE A-10. COLOR READINGS (YELLOW) CENTERLINE TYPE I ON ASPHALT

Month	Acceptability Range (0.4261-0.5266) X-Reading	Acceptability Range (0.4300-0.5346) Y-Reading
August	0.5230	0.4343
July	0.4846	0.4158

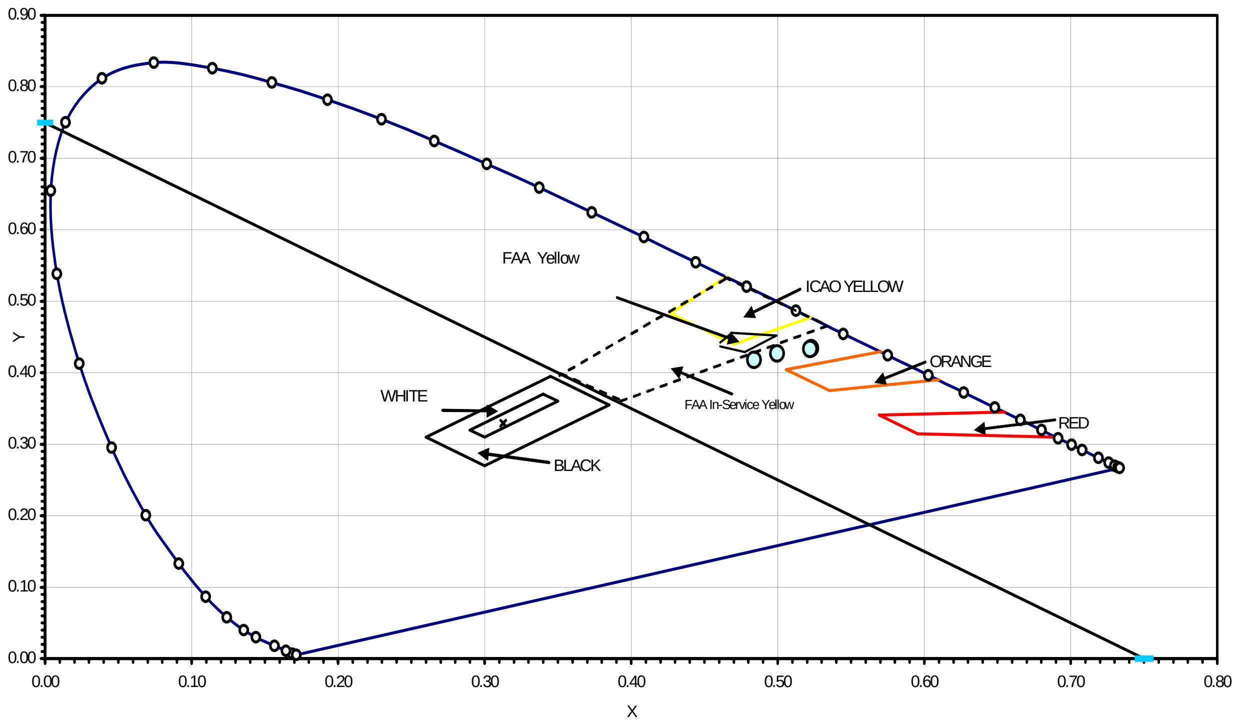

FIGURE A-6. COLOR READINGS (YELLOW) CENTERLINE TYPE I ON ASPHALT

TABLE A-11. COLOR READINGS (WHITE) TYPE I BEADS ON AGED CONCRETE

Month	Acceptability Range (0.2895-0.3442) X-Reading	Acceptability Range (0.3100-0.3650) Y-Reading
August	0.3278	0.3484
July	0.3325	0.3481

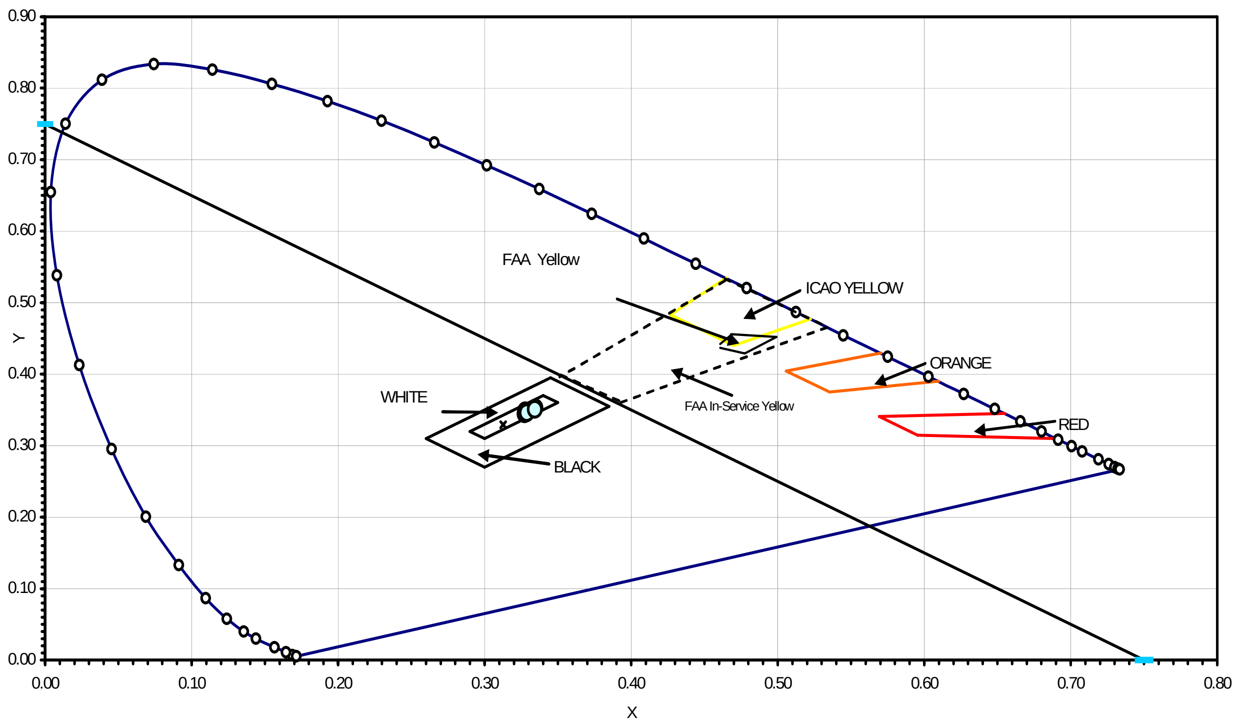

FIGURE A-7. COLOR READINGS (WHITE) TYPE I BEADS ON AGED CONCRETE

TABLE A-12. COLOR READINGS (YELLOW) TYPE I BEAD ON AGED CONCRETE

Month	Acceptability Range (0.4261-0.5266) X-Reading	Acceptability Range (0.4300-0.5346) Y-Reading
August	0.5237	0.4365
July	0.5027	0.4248

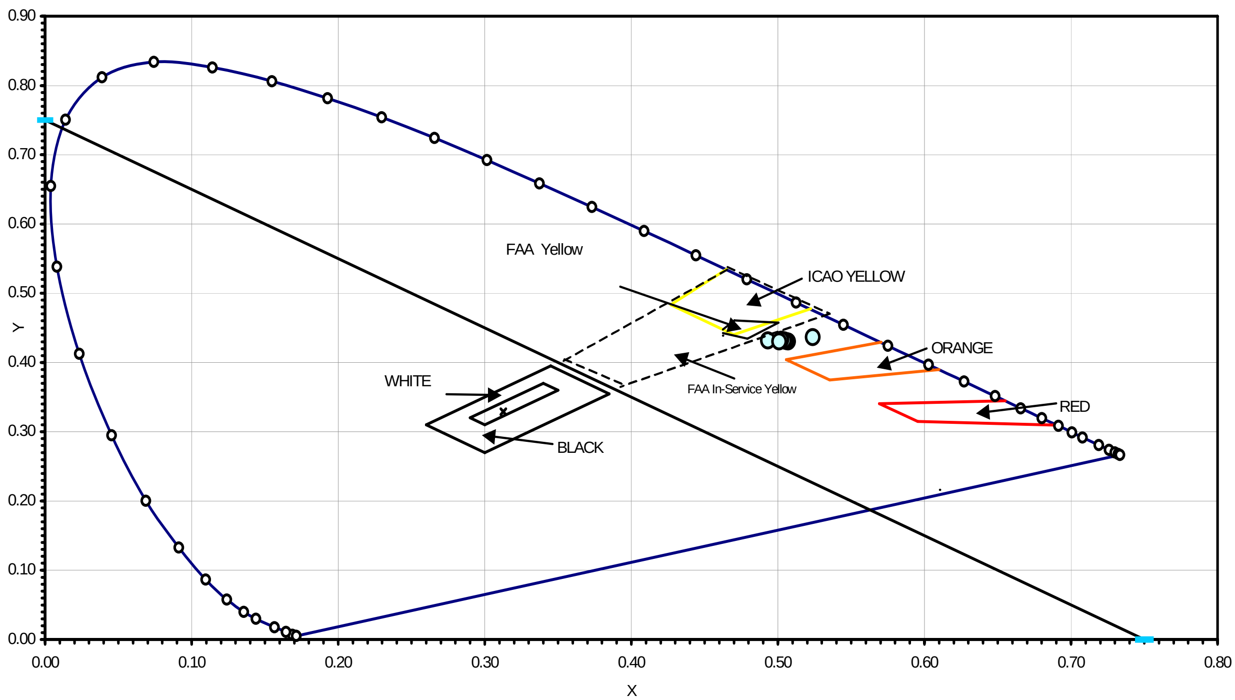

FIGURE A-8. COLOR READINGS (YELLOW) TYPE I BEAD ON AGED CONCRETE

TABLE A- 13. COLOR READINGS (WHITE) TYPE III BEADS ON AGED CONCRETE

Month	Acceptability Range (0.2895-0.3442) X-Reading	Acceptability Range (0.3100-0.3650) Y-Reading
August	0.3394	0.3570
July	0.3351	0.3489

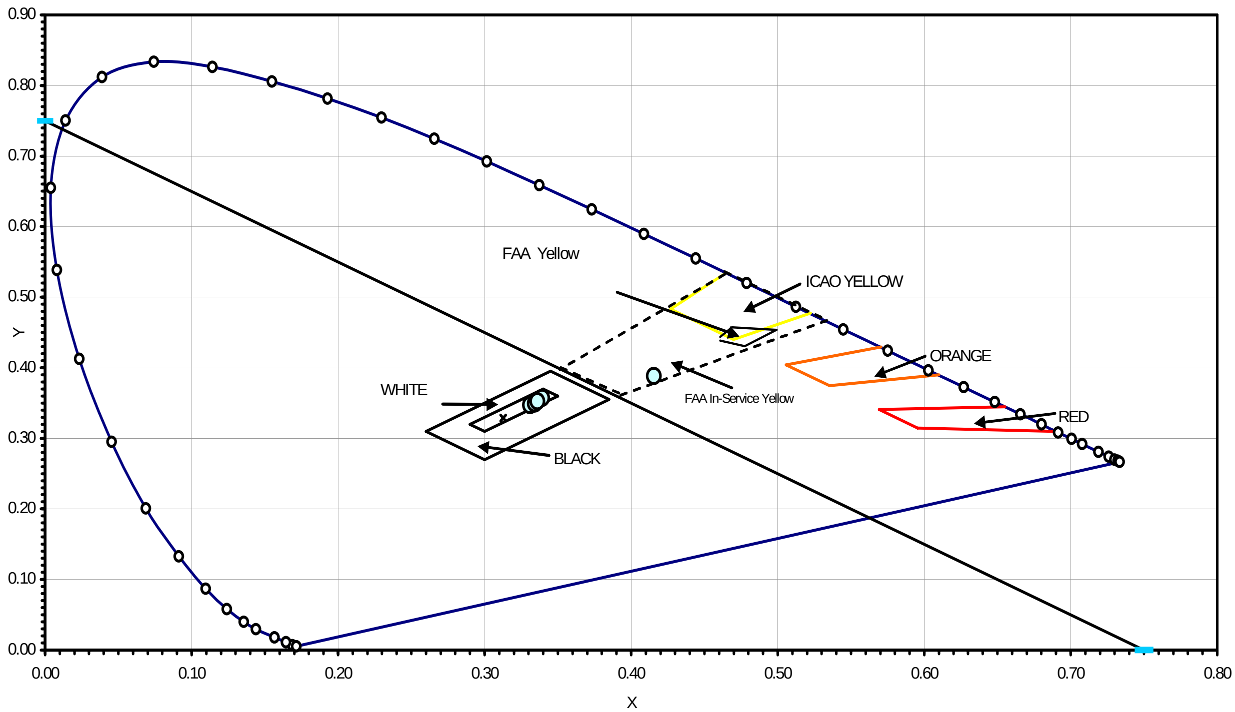

FIGURE A-9. COLOR READINGS (WHITE) TYPE III BEADS ON AGED CONCRETE

TABLE A-14. COLOR READINGS (YELLOW) TYPE III BEADS ON AGED CONCRETE

Month	Acceptability Range (0.4261-0.5266) X-Reading	Acceptability Range (0.4300-0.5346) Y-Reading
August	0.4780	0.4073
July	0.4732	0.4178

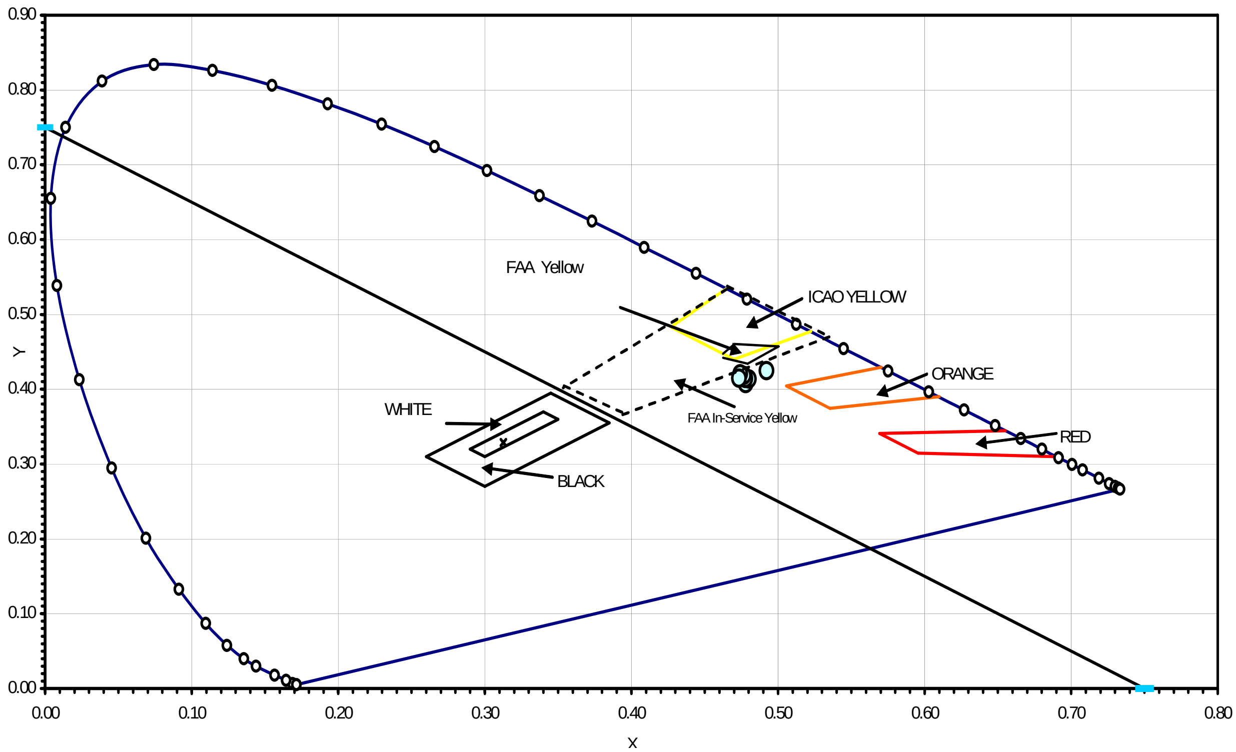

FIGURE A-10. COLOR READINGS (YELLOW) TYPE III BEADS ON AGED CONCRETE