Research Report
KTC-11-22/SPR330-07-2I

KENTUCKY TRANSPORTATION CENTER

EVALUATION OF LONG-TERM PAVEMENT MARKING PERFORMANCE

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Research Report
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EVALUATION OF LONG-TERM PAVEMENT MARKING PERFORMANCE

by

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in cooperation with

Kentucky Transportation Cabinet
Commonwealth of Kentucky

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16. Abstract

The objective of the investigation was to evaluate the useful life of pavement markings. The Manual on Uniform Traffic Control Devices (MUTCD) provides general guidelines for the application and installation of pavement markings. However, performance requirements for various types of pavement markings are not included. Retroreflectivity data were collected throughout Kentucky on various longitudinal pavement markings using mobile and manual techniques. Data were collected on one-year, two-year and three-year-old lines. The retroreflectivity levels were analyzed and the several recommendations were made. Minimum levels of retroreflectivity should be set for determining what roads to restripe annually. These values should be lower than the passing/bonus thresholds used in the Quality Control/Quality Assurance (QA/QC) program. It is recommended that yellow lines should be above 100 mcd/m^2/lux and white lines should be above 150 mcd/m^2/lux. Retroreflectivity measurements should be collected and used to determine which roads should be painted each year. The current Maintenance Rating Program (MRP) can be used to facilitate this process. An inventory of striped roads should be maintained to allow a determination of when specific roadway sections were last restriped.

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

The evaluation also led to a methodology to determine what roadways should be restriped each year in Kentucky.

This research is a continuation of a study completed in 2008 in which a total of 480 locations were selected across the state with 40 in each highway district. In each highway district, 30 locations were selected that had been painted one year before data collection and 10 locations that had been painted two years prior to data collection. The one-year data were not available for all locations. For this study, a sample of the locations from the previous study were retested. The time frame was based on the line that was randomly selected for each site; therefore the time since painted may not be accurate for all lines. It was assumed that each line was painted in the same year.

The data clearly show that striped lines can still produce passing retroreflectivity levels after two years. However, after three years there is evidence that some line types fail to maintain passing levels. White lines maintain levels above bonus after one year and above passing after two years. Yellow lines maintain levels near the passing limit after one year and just under passing after two years. Sixty percent of all lines striped had passing levels after one year, nearly half of all lines striped had passing levels after two years and nearly twenty percent of all lines striped had passing levels after three years. The levels maintained show that it is not necessary to restripe many roads annually.

ACKNOWLEDGMENTS

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1.0 INTRODUCTION

The Manual on Uniform Traffic Control Devices (MUTCD) provides general guidelines for the application and installation of pavement markings. However, performance requirements for various types of pavement markings are not included. Kentucky's Standard Specifications for Road and Bridge Construction and all pavement marking projects contain certain material composition requirements as well as performance measures for retroreflectivity that are evaluated after a "proving period" that varies by material type. The performance measures are used for contract payment purposes to ensure the markings are applied in an acceptable and consistent manner. Other markings are installed with a specified "warranty" period which requires that the material maintain minimum retroreflectivity levels and other measures of effectiveness for a specified period of time. However, minimum maintained retroreflectivity levels and other performance measures are not currently used to determine material selection for specific applications or to predict the useful life of different materials under different conditions. Some installations of pavement markings have been observed to prematurely fail or deteriorate at an accelerated pace. Others exhibit exceptional levels of performance and last much longer than anticipated. Overall, there is a need to understand the useful life of various pavement markings including paints, thermoplastics, and tapes. Issues to be addressed should include material specifications, application procedures, useful life, and costs.

The objective of the investigation was to evaluate the useful life of pavement markings. The evaluation should lead to a methodology to determine what roadways should be restriped each year in Kentucky. The initial study (completed in 2008) evaluated data up to two years in service. This study included locations with three years in service.

The Kentucky Transportation Cabinet (KYTC) rates pavement markings based on retroreflectivity. Retroreflectivity is a measure of an object's ability to reflect light back toward its source, along the same axis from which it strikes the object, with a minimal scattering of light. In order to achieve this type of reflection, glass beads are embedded into painted pavement markings.

The contractors are paid based on a Quality Control/Quality Assurance (QC/QA) system as an incentive to ensure that minimum retroreflectivity readings are met. The contractors can adjust the retroreflectivity by changing the number of gallons of paint applied per mile, and the number of beads per gallon of paint. Thirty to sixty days after the line has been painted, the contractor tests retroreflectivity levels at randomly selected zones using a handheld device (QC). Data for higher volume roads are measured using a mobile collection technique provided by Precision Scan. These readings are used to determine if the line fails, passes, or bonuses. Twenty percent of the QC locations are tested by a district representative (QA). A KYTC representative from the Division of Materials is contacted if there is a discrepancy between QC and QA results. These specifications are outlined in Kentucky Methods 64-202-08 for handheld measurements and KM 64-203-08 for mobile readings (see http://transportation.ky.gov/materials/KYMethods.htm). The contractors had the opinion that the mobile readings are typically lower than the handheld readings.

2.0 LITERATURE SEARCH

A literature review was conducted relating to research of longitudinal retroreflective pavement markings. Most of the available literature focuses on the effectiveness and durability of pavement markings under wet or nighttime conditions. There is also extensive research on specific pavement marking materials: retroreflective tape, thermoplastic materials, lead-based vs. water-based paints, small vs. large glass beads, etc, as well as their effectiveness on specific roadway materials: concrete, asphalt, and seal coat.

One study evaluated New Jersey's three-year fixed-schedule restriping strategy to determine if it is consistent with the actual service life of the pavement markings (1). The results suggested that the threshold value of an acceptable versus unacceptable level of retroreflectivity was between 80 and 130 mcd/m^2/lux for drivers younger than 55 and between 120 and 165 mcd/m^2/lux for drivers older than 55. These results are consistent with conclusions reached by other investigators in similar research, where results generally ranged between 70 and 170 mcd/m^2/lux. The study indicates that minimum levels of retroreflectivity could be used for yellow centerlines and white lanelines. Furthermore, the study suggested that restriping lines with values less than 165 mcd/m^2/lux would produce the greatest relative increase in driver satisfaction (all drivers).

Other studies suggest lower retroreflectivity levels may be acceptable. An NCHRP report from 1996 found that 85% of test subject 60 and older found a retroreflectivity of 100 mcd/m^2/lux to be adequate or more than adequate (2). A Transportation Research Report from 1998 analyzed pavement marking visibility related to crash data. This research study found that a threshold of 150 mcd/m^2/lux was recommended from a safety standpoint.

3.0 PROCEDURE

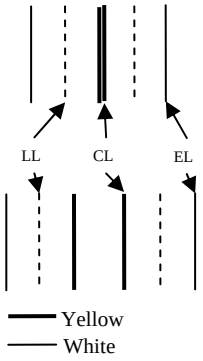
The 2009 QC/QA data were obtained from each highway district in which data were taken. Each QC/QA sheet contained up to five average retroreflectivity readings and the dates painted and checked for a location on the state-maintained system. This information, as well as the line color and type, was collected from each sheet and compiled into a database. Additionally, the percentage of how many readings passed the minimum requirement was added to the database. The database was examined to ensure that each record has a valid location and retroreflectivity reading. This database was matched to the Highway Performance Monitoring System (HPMS) to obtain roadway geometrics and traffic volumes for each location. HPMS is a system used to inventory the roadway characteristics of Kentucky’s state highways. Approximately 2,500 locations were matched to HPMS. The same process was used for the 2005 QC/QA data resulting in approximately 1,000 matching locations.

For the 2008 study, ten 2006 locations and thirty 2007 locations were randomly selected from each of the twelve highway districts. It was verified that the random sample represented the

state's highway system classifications adequately. Not all highway districts were represented since 2006 data were unavailable for districts 3, 5, 6, 10 and 11. For this study, lines which were tested in 2008 were retested to find retroreflectivity levels three years after having been painted.

Data were collected in the fall of 2009 using a Delta Optics LTL-X Pavement Marking Retroreflectometer. The meter obtains reflectivity in millicandelas per square meter per lux ($mcd/m^2/lux$). In this report, retroreflectivity, whether referred to as levels or readings, will be in units of $mcd/m^2/lux$. Twenty readings were collected on each line type. Data were collected as close to the measured location as possible. However, the collection area was moved, if necessary, to ensure that the roadway was straight and data were not collected in areas of poor pavement conditions. In addition, areas with auxiliary lanes and driveways or access roads were avoided.

Data were collected using the form presented in Appendix A. Data were collected for up to three line types at each location. For undivided highways, data were collected on the white edgeline, white laneline and yellow centerline. For divided highways, data were collected on the white edgeline, white laneline and yellow edgeline at the median (this was categorized as a centerline for consistency). The following diagram shows these lines.



Data could be collected in either travel direction as long as it was collected in the same direction as it was painted. For all lines except centerlines, this is always in the direction of travel. Therefore, the direction in which the centerline was painted was determined from the QC/QA data sheets. In the event that directional data were unavailable for a given segment, the line was sampled in both directions and the higher reflectivity readings were used. Since locations were selected from a list of QC/QA data records, it was ensured that data be collected consistent with the QC/QA data. For example, if the random site was based on a white edgeline reading in the northbound direction, data were collected on the northbound white edgeline. This effort was to ensure that data were collected on the same line for which data was available. A sample of the QA/QC data sheet is shown in Appendix B.

Daily work reports for 2009 were obtained from the contractors for Highway Districts 2, 7, 9 and 10. A sample of a daily work report is shown in Appendix C. Each report outlined the county, route and milepoint range painted that day. In addition, the paint color, line type, line width (four or six inch) and road type (MP or RS) were shown. The total mileage for each road type is

calculated on the form. The total paint (in gallons) and the number of beads were shown for daily report. This information was used to calculate beads per gallon and gallons per mile for each day.

4.0 RESULTS

Data Collection

For the previous study, sites were selected which had been painted either one year or two years prior to data collection. For this study, wherever possible sites where the previously tested lines had not been repainted were revisited. Below is a table summarizing the number of lines in each district. Up to three lines were collected at each site.

	Number of Lines YEAR*	
District	**2-Year**	**3-Year**
2	74	-
7	-	21
9	36	20
10	52	-
Total	162	41

*The time frame was based on the line that was randomly selected for each site; therefore the time since painted may not be accurate for all lines. It was assumed that each line was painted in the same year.

Line Types

Data were collected on up to three lines at each site: centerlines, edgelines and lanelines. White lines are either edgelines or lanelines. Yellow lines are edgelines on divided highways, centerlines on undivided highways and essentially lanelines on roads with two-way left turn lanes (TWLTL). The following table shows the count of collected data by line type.

		Count	
Color	**Type**	**2-Year**	**3-Year**
White	Edgeline	69	11
	Laneline	11	2
Yellow	Edgeline	7	-
	Centerline	75	29
	All	**162**	**41**

As previously noted, contractors are paid based on passing and bonus retroreflectivity readings. These limits differ for yellow and white lines. The following table shows the passing and bonus limits for yellow and white in Kentucky Standard Specifications when the lines included in this report were installed.

Lowest Retroreflectivity Readings Needed

Color	Pass	Bonus
Yellow	175	225
White	250	300

The average retroreflectivity is shown by line type in the following table.

Color	Type	QC	QA	1-Year	2-Year	3-Year
White	Edgeline	379	364	353	288	251
	Laneline	378	349	362	306	231
	All White	379	363	354	290	248
Yellow	Edgeline	233	248	205	203	-
	Centerline	268	277	248	186	113
	All Yellow	267	276	244	187	113

The data are also presented, graphically, in Appendix D. Lines marking the top and bottom of the passing range are shown.

Graphs were made representing the percent of readings that passed, were at or above bonus, and failed versus time-since-painted. The retroreflectivity readings from the QC/QA datasheets were taken 30 to 60 days since the lines were painted. The 2006 (three years since painted), the 2007 (two years since painted) and the 2008 (one year since painted) were also used. These graphs were prepared for all data as well as for each line type and are giving in Appendix E.

5.0 CONCLUSIONS

The data clearly show that striped lines can maintain passing retroreflectivity levels even after two years, but after three years there is evidence that retroreflectivity levels begin to approach failing levels. White lines maintain levels above bonus after one year and above passing after two years. After three years roughly 80 percent of the lines tested in this study were at or near the failure level. Yellow lines maintain levels near the passing limit after one year and just under passing after two years. After three years ninety percent of yellow lines were considered failing. Sixty percent of all lines striped had passing levels after one year and nearly half of all lines striped had passing levels after two years. The levels maintained show that is not necessary to

restripe many roads annually.

The latest Kentucky Standard Specifications have increased the passing and bonus levels by 50. The levels are:

2009 Standard Specifications
Lowest Retroreflectivity Readings Needed

Color	Pass	Bonus
Yellow	225	275
White	300	350

Studies show that retroreflectivity levels less than current passing levels can provide adequate visibility. Furthermore, some research indicates that the same levels could be used for yellow and white lines. Retroreflectivity ranging from 70 to 170 have been found to provide adequate visibility in various studies.

6.0 RECOMMENDATIONS

1. Minimum levels of retroreflectivity (lower than the passing/bonus thresholds used in the QC/QA program) should be set for determining roads to restripe annually. It is recommended that yellow lines should be above 100 mcd/m^2/lux and white lines should be above 150 mcd/m^2/lux.

2. Retroreflectivity measurements should be collected and used to determine which roads should be painted each year. The current Maintenance Rating Program (MRP) can be used to facilitate this process.

3. An inventory of striped roads should be maintained to allow a determination of when specific roadway sections were last restriped.

7.0 REFERENCES

1. Parker, N. and M. Meja. Evaluation of Performance of Permanent Pavement Markings. In *Transportation Research Record 1824*, TRB National Research Council, Washington, D.C., 2003 pp. 123-132.

2. Graham, J.R., J.K. Harold, and L.E. King. Pavement Marking Retroreflectivity Requirements for Older Drivers. In *Transportation Research Record 1529,* TRB National Research Council, Washington, D.C., 1996, pp. 65-70.

APPENDIX A

Retroreflectometer Data Sheet

RETROREFLECTOMETER DATA SHEET

Collector's Name:_____ Date:_____

Location ID:_____ Yellow Dir: _____ Time:_____

County:_____ Route:_____ MP:_____

Location Description:_____ Parking: _____

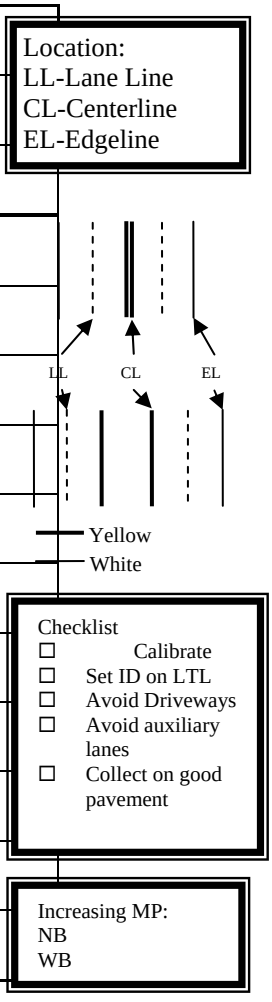
# of Lanes:_____ Lane Width:_____ Shoulder Width:_____

Divided / Undivided / TWLTL Rumble Strips ☐ Shoulder Type:_____

Dir	
Loc	
Color	
LTLID:	

Dir	
Loc	
Color	
LTLID:	

Dir	
Loc	
Color	
LTLID:	



Previous Reading: **(Be sure to collect data on the same line as below)**

Retro:_____ Date:_____ Direction: _____ Color:_____ Location:_____

APPENDIX B

Sample QAQC Data Sheet

STRIPING REFLECTIVITY TEST

WHITE

DATE PAINTED: 05/20/06 FIRST DATE TO TEST: 06/19/06 LAST DATE TO TEST: 07/19/06

TEST SITE:	SEGMENT #1			SEGMENT #2			SEGMENT #3			SEGMENT #4			SEGMENT #5		
ZONE:	#1	#2	#3	#1	#2	#3	#1	#2	#3	#1	#2	#3	#1	#2	#3
DATE CHKD:	07/06/2006			07/06/2006			07/06/2006			07/06/2006			07/06/2006		
COUNTY:	Lincoln			Lincoln			Lincoln			Lincoln			Lincoln		
ROUTE:	27			39			39			39			39		
SEGMENT MP:	17.9			0			7.6			14.6			7		
ZONE MP:	18.4			0.6			8.1			14.1			6.6		
LOCATION:	NBEL			NBEL			NBEL			SBEL			SBEL		
READING NO:	READING	READING	READING	READING	READING	READING	READING	READING	READING	READING	READING	READING	READING	READING	READING
1	263			342			332			365			384		
2	285			338			342			332			357		
3	289			357			347			341			395		
4	309			348			348			313			405		
5	338			342			348			355			396		
6	335			353			388			332			394		
7	330			335			387			343			402		
8	321			346			410			330			411		
9	294			355			417			331			389		
10	300			374			414			344			412		
11	275			359			429			355			397		
12	305			376			446			360			412		
13	302			378			414			340			417		
14	299			395			404			330			424		
15	288			383			419			354			424		
16	294			409			410			336			435		
17	300			381			432			334			415		
18	305			363			429			331			409		
19	306			377			411			364			437		
20	300			377			408			344			396		
	20	20	100%	20	20	100%	20	20	100%	20	20	100%	20	20	100%

REFLECTIVITY REQUIREMENTS	
MINIMUM:	250
BONUS:	300

LEGEND:

EL=EDGELINE
CL=CENTERLINE
WBL=WESTBND LANE
EBL=EASTBND LANE
SBL=SOUTHBND LANE
NBL=NORHTBND LANE

MILES STRIPED M P	
CH NO.	MILES
	37.750
R S	
CH NO.	MILES

* 40% PAID WHEN PASSING PAINT REPORT RECEIVED

Number Of Segments Tested 5
Number Of Segments Failed 0
SECTION PASSES

TEST BY: Teresa Harrison
RESIDENT ENGINEER

Initial Pay 60%				
CH NO:				
MILES:	22.650			

	RAND. # 1	RAND. # 2	RAND. # 3
SEGMENT LENGTH:	7.6	7.6	7.6
RANDOM INSPECTION #:	0.5	1.3	5.5

362.06

Pay 40% Upon Reflectivity Acceptance				
CH NO:				
MILES:	15.100			

MEAN	MEAN	MEAN	MEAN	MEAN	MEAN	MEAN	MEAN	MEAN	MEAN	MEAN	MEAN	MEAN	MEAN	MEAN
301.9	0	0	364.4	0	0	396.75	0	0	341.7	0	0	405.55	0	0

QA MEAN	QA MEAN	QA MEAN	QA MEAN	QA MEAN	QA MEAN	QA MEAN	QA MEAN	QA MEAN	QA MEAN	QA MEAN	QA MEAN	QA MEAN	QA MEAN	QA MEAN

% DIFF.	% DIFF.	% DIFF.	% DIFF.	% DIFF.	% DIFF.	% DIFF.	% DIFF.	% DIFF.	% DIFF.	% DIFF.	% DIFF.	% DIFF.	% DIFF.	% DIFF.
#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

APPENDIX C

Sample Daily Work Report

Daily Work Report

4" YELLOW

Date 08/19/2008 Truckno. BRUTUS Driver JASON REYNOLDS Striper MIKE SHELTON

District 8 Precipitation Temperature (AM/PM) Road Conditions

Time	County	Road	MP	RS	DIR	LINE	Milepost From - To	Lineal Feet MP	Miles MP	Lineal Feet RS	Miles RS
	ADAIR	61	X		N	CL	0-.1	1362	0.26		0.00
									0.00		0.00
	ADAIR	61	X		N	CL	0-21.9	183840	34.84		0.00
	ADAIR	768		X	W	CL	12.79-17.47		0.00	47252	8.95
	ADAIR	768		X	W	CL	21-27		0.00	58820	11.14
									0.00		0.00
									0.00		0.00
									0.00		0.00
									0.00		0.00
									0.00		0.00
									0.00		0.00
									0.00		0.00
									0.00		0.00
									0.00		0.00
							TOTALS	185202	35.09	106072	20.09

	MP	PAID MP		RS	PAID RS	
Total miles of stripe	35.09318182			20.08939394		
60% TOTAL	21.06			12.05		
40% TOTAL	14.04			8.04		

MATERIALS USED	QUANTITY	BATCH NO.
PAINT		
BEADS		

LEGEND:

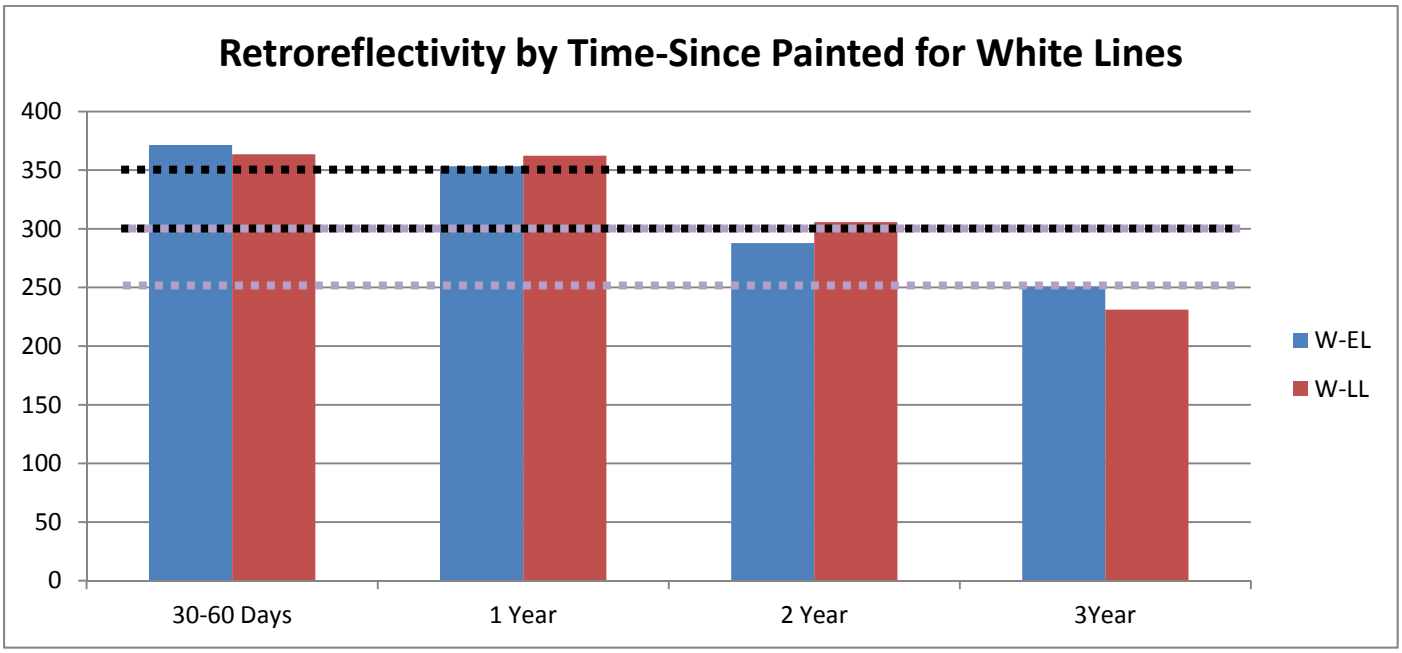
EL=EDGELINE CL=CENTERLINE
SK=SKIP
WBL=WESTBND LANE
EBL=EASTBND LANE
SBL=SOUTHBND LANE
NBL=NORHTBND LANE

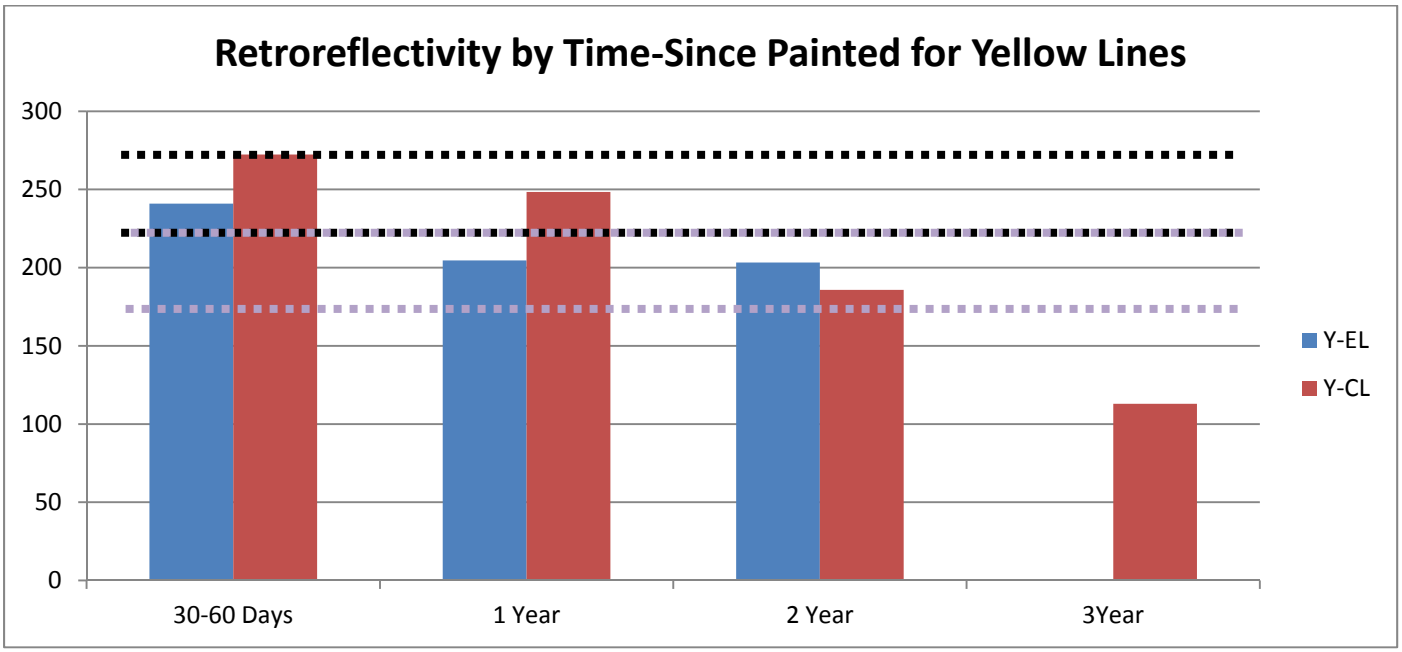
NOTES:

16.72629426

APPENDIX D

Retroreflectivity by Time-Since-Painted for Each Line Type



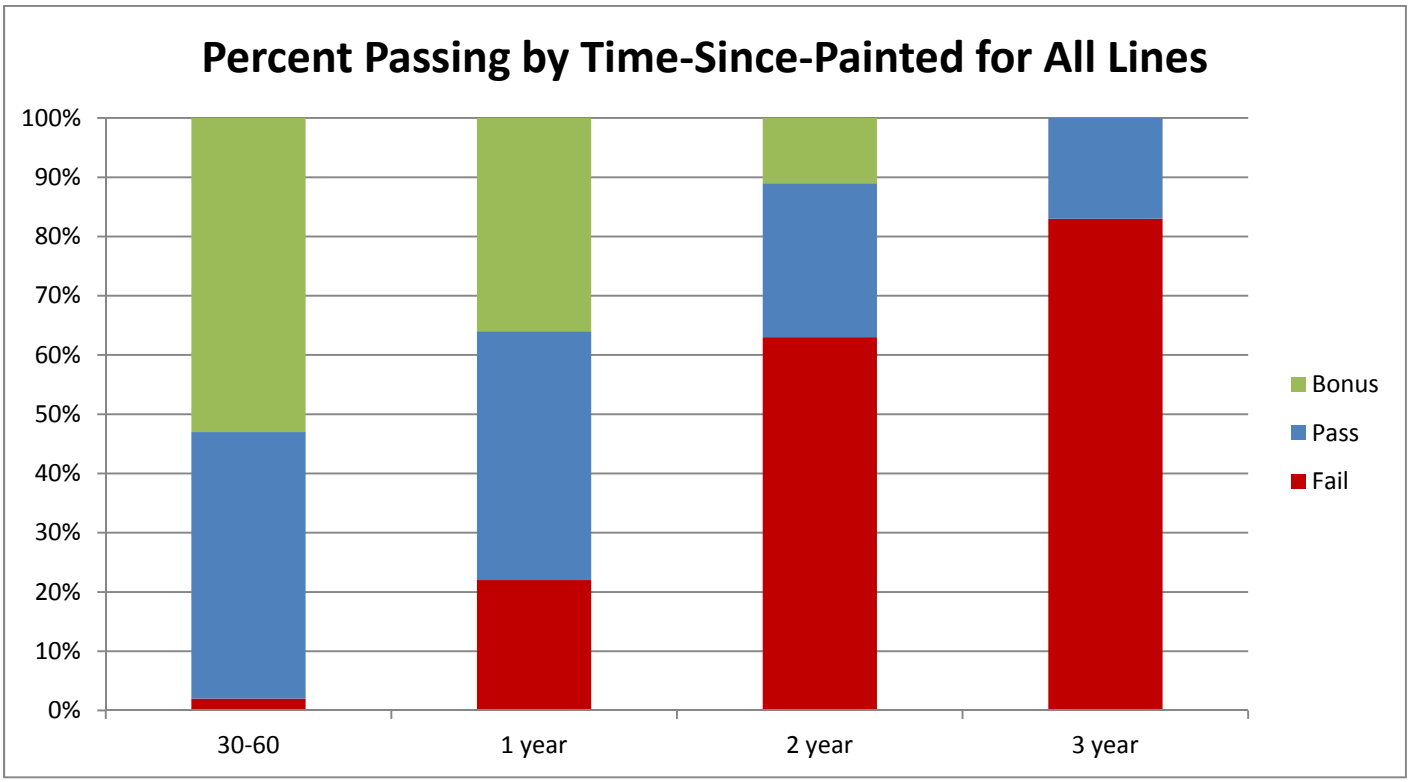


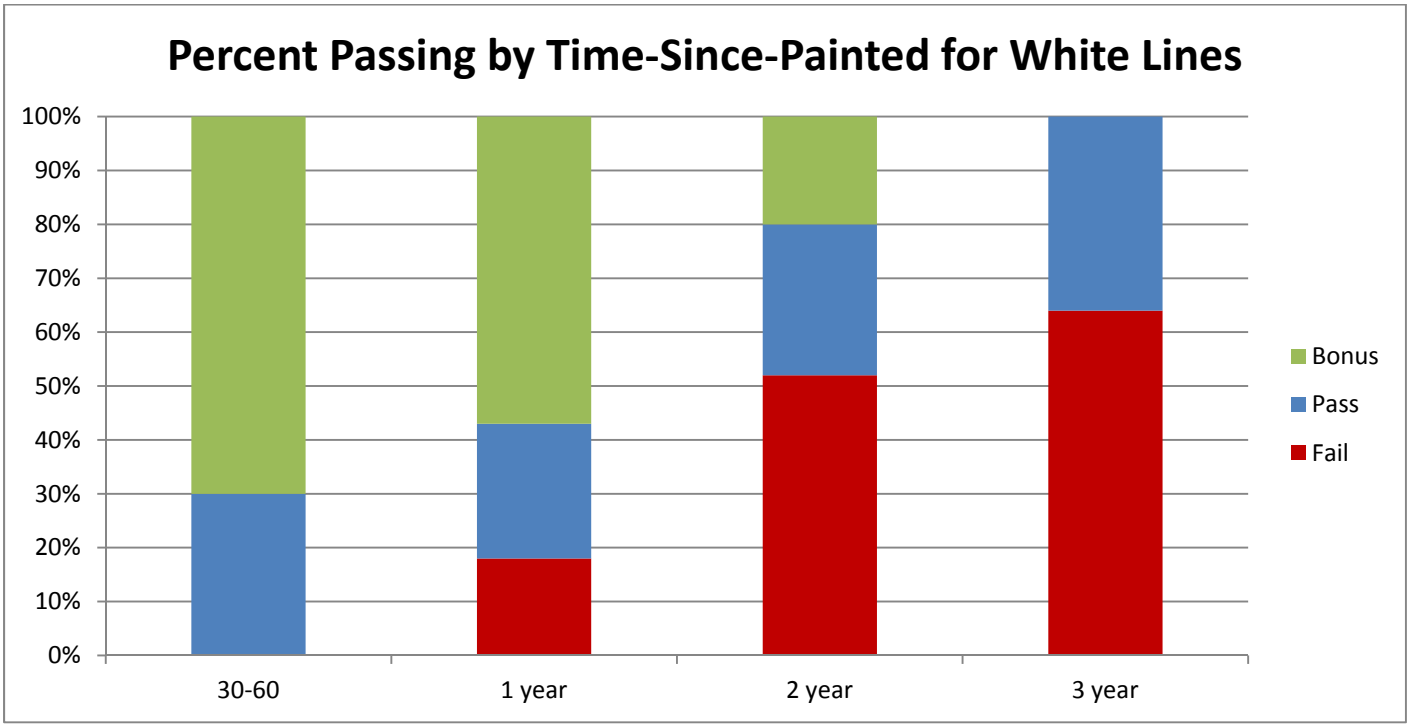
*Black dashed lines represent the current passing threshold (lower) and bonus threshold (upper) assigned by the 2009 Standard Specifications

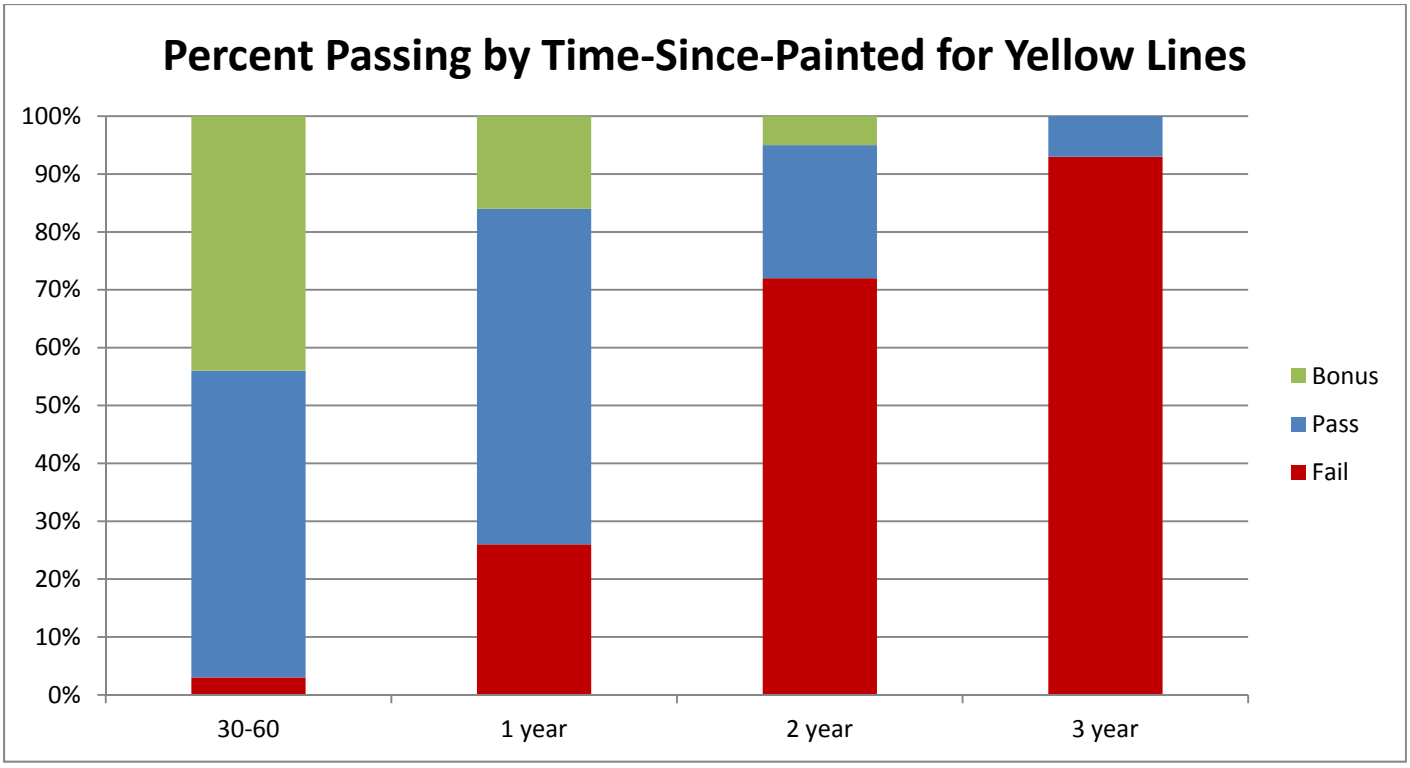
**Purple dashed lines represent the previous passing and bonus thresholds assigned by the 2003 Standard Specifications

APPENDIX E

Percent Passing, Bonus and Failing


Percent Passing by Time-Since-Painted for All Lines
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
30-60
1 year
2 year
3 year
Bonus
Pass
Fail


Percent Passing by Time-Since-Painted for White Lines
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
30-60
1 year
2 year
3 year
Bonus
Pass
Fail



Bonus, passing and failing levels as assigned by the 2009 MUTCD

For more information or a complete publication list, contact us at:

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