Methods for Maintaining Pavement Marking Retroreflectivity

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16. Abstract
In response to a Congressional directive, the FHWA is working to establish minimum maintained pavement marking retroreflectivity levels that will be incorporated into the Manual on Uniform Traffic Control Devices (MUTCD). One of the concerns expressed by agency personnel responsible for being in conformance with required minimum levels is the potential increase in tort exposure. The FHWA has investigated and described retroreflectivity maintenance methods that, when implemented as intended, provide agencies with a flexible means of being in conformance with required minimum retroreflectivity levels and provide protection from potential tort claims. Other properly supported methods (i.e., through the completion of an engineering study showing a tie to the minimum levels) may also be used to maintain pavement markings at the required minimum retroreflectivity levels. Agencies can use the information in this report to help determine which retroreflectivity maintenance method or combination of methods best suits their needs.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

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CHAPTER 1. INTRODUCTION

Background

Improving safety throughout the transportation network is the primary goal of the Department of Transportation.(1) The intent of this proposed rule is to advance this safety strategy in regard to nighttime visibility on our Nation's roads. In 2012, 33,561 people died in motor vehicle traffic crashes in the United States.(2) While only a quarter of travel occurs at night,(3) about one-half of traffic fatalities occur during nighttime hours.(4) This translates into a nighttime fatality rate that is approximately three times greater than that of daytime. There are many reasons for this disparity such as alcohol and fatigue, but no one factor can be singled out for all nighttime traffic crashes. It is, however, reasonable to expect that pavement markings be visible to drivers at night to facilitate safe nighttime driving.

Pavement markings play one of the most important safety functions on our roads. They are widely accepted as being beneficial to drivers in that they communicate the intended travel path for short-range operations and the roadway alignment for long-range delineation. To ensure consistent application of pavement markings, their characteristics and warranting criteria are described in the *Manual on Uniform Traffic Control Devices* (MUTCD),[(5)] which sets the national standard for traffic control devices.

Pavement markings have been repeatedly shown to reduce crashes. Recent crash studies as well as those more than a half-century old have conclusively shown that adding edge lines to rural two-lane highways can reduce crashes and fatalities. Findings from a recent paper demonstrate that the benefits from pavement marking edge lines can be achieved with narrow pavement widths (18 feet or less) and traffic volumes as low as 1,000 vpd.[(6)]

While the presence of pavement markings has been consistently shown to reduce crashes, the nighttime crash rate (as described in the opening paragraph) remains out of proportion compared to the daytime crash rate. Retroreflection (more commonly referred to as retroreflectivity) is a property of the pavement marking that can be measured and is a key indicator of the nighttime visibility of pavement markings. Maintaining pavement marking retroreflectivity is consistent with the FHWA's goal of improving safety on the Nation's streets and highways, and many safety and operational strategies depend on pavement marking visibility that meets the needs of drivers. Furthermore, recent research confirms the value of maintaining longitudinal pavement marking retroreflectivity.[7,8]

After having analyzed and considered technical research results as well as input from participants of FHWA-sponsored workshops, FHWA has developed proposed minimum maintained pavement marking retroreflectivity levels for the MUTCD.[9] Improvements in pavement marking visibility will also support the FHWA's efforts to be responsive to the needs of older drivers whose visual capabilities are declining. This is important because the number of older drivers is expected to increase significantly in the coming years. As of 2008, 32.2 million drivers in the United States were at least 65 years old. It is estimated that by 2020, there will be more than 40 million licensed drivers 65 years and older.[10]

The importance of pavement marking retroreflectivity is recognized in the current MUTCD, which includes the following standard statement regarding pavement markings:

> "Markings that must be visible at night shall be retroreflective unless ambient illumination assures that the markings are adequately visible. All markings on Interstate highways shall be retroreflective." [5]

However, there are no specific performance requirements in the MUTCD regarding pavement marking retroreflectivity levels needed by nighttime drivers. To address this, the United States Congress, as part of the 1993 Department of Transportation Appropriations Act (Pub. L. 102-388; October 6, 1992), directed the Secretary of Transportation to revise the MUTCD to address minimum retroreflectivity standards for signs and pavement markings. The Congressional directive stated that:

> "The Secretary of Transportation shall revise the MUTCD to include a standard for a minimum level of retroreflectivity that must be maintained for traffic signs and pavement markings which apply to all roads open to public travel."

The opening statements of the MUTCD define the purpose of traffic control devices and the principles for their use. Traffic control devices, including pavement markings, are meant to promote highway safety and efficiency by providing for the orderly movement of all road users.[5] (Note: The MUTCD is incorporated by reference in 23 CFR 655.601. It is available the FHWA's Web site at http://mutcd.fhwa.dot.gov.) The MUTCD provisions for pavement marking visibility apply to each agency or official responsible for managing and operating roadways open to public travel.

On December 21, 2007, the FHWA published in the *Federal Register* a final rule amending the 2003 Edition of the MUTCD to include standards, guidance, options, and supporting information relating to maintaining minimum levels of retroreflectivity for traffic signs. The 2009 Edition of the MUTCD also includes the same sign retroreflectivity language.

It is generally believed that maintaining the daytime performance of pavement markings (i.e., placement and color) is more easily accomplished than maintaining the nighttime performance. Nighttime performance of pavement markings can be more difficult to maintain for a variety of reasons. One of the primary differences between daytime and nighttime pavement marking performance is a material property called retroreflection. Retroreflection is a special type of reflection that redirects incident light, such as that from headlights, back toward the source. Pavement markings are made out of many different materials (water-based paints, solvent-based paints, thermoplastic, and epoxy, to name a few); are placed on different pavement types (asphalt and concrete); and are different colors (primarily yellow and white). As a result, the ability of the pavement marking to redirect headlamp illumination back toward the vehicle, thereby making the marking visible for the nighttime driver, varies. The commonly accepted practice for determining pavement marking retroreflectivity is measured at a standard 30-meter geometry and expressed in units of millicandelas per square meter per lux ($mcd/m^2/lx$). A standard protocol including sampling requirements is defined in ASTM D7585, *Standard Practice for Evaluating Retroreflective Pavement Markings Using Portable Hand-Operated Instruments*. [(11)]

The nighttime visibility of pavement markings provided through retroreflectivity is difficult to assess during daytime conditions using visual inspection methods. Furthermore, the retroreflective properties of all pavement marking materials may be initially inconsistent due to installation practices, then degrade over time, making pavement markings continuously less visible (i.e., less bright) at night. Environmental conditions, such as radiation from the sun, moisture, and pollutants, cause a substantial amount of deterioration in retroreflective performance. However, loss of retroreflectivity can also occur due to traffic, roadway debris, and snowplowing activities.

As pavement markings degrade and become less retroreflective, their effectiveness in communicating the intended travel path and roadway alignment to road users at night diminishes. If left unattended, pavement marking retroreflectivity can diminish to the point that the markings cannot be seen in time for nighttime drivers to react properly. Thus, to maintain nighttime effectiveness, pavement markings must be replaced before they reach the end of their useful retroreflective life. Until recently, little information was available about the levels of retroreflectivity necessary to meet the needs of drivers and thereby define the useful life of pavement markings. Research has led to the development of recommended minimum maintained levels of pavement marking retroreflectivity for longitudinal pavement markings considering currently available materials, vehicle fleet characteristics, and the capabilities of a significant majority of the driving population.(12)

One of the key concerns identified during the agency workshops held in the summer of 2007, when the FHWA first started developing potential MUTCD language for minimum pavement marking retroreflectivity levels, was that the rule needs to provide flexibility for agencies to adopt various pavement marking maintenance methods without having to measure the retroreflectivity of all their pavement markings. (9) In this report, the FHWA has outlined maintenance methods that agencies can implement to maintain minimum pavement marking retroreflectivity levels in conformance with the proposed MUTCD requirements. As the proposed rulemaking states, agencies will need to implement pavement marking maintenance methods that incorporate the consideration of minimum retroreflectivity levels to provide for nighttime visibility. This document describes methods for maintaining minimum pavement marking retroreflectivity levels.

Pavement Marking Materials and Standards

There is currently no nationally accepted specification or standard containing established minimum retroreflectivity levels for pavement markings, including newly installed markings or markings at the end of their service life. For many years, ASTM D6359 included a requirement that new pavement markings had a minimum initial retroreflectivity of 250 mcd/m^2/lx for white and 175 mcd/m^2/lx for yellow.(13) However, ASTM D6359 was last updated in 1999 and was withdrawn in 2006 because of onerous sampling requirements. In 2010, ASTM D6359 was replaced with ASTM D7585,[11] which includes a new, easier to use sampling protocol but eliminates the retroreflectivity requirements for newly installed markings.

Agencies have started to move toward warranty and performance-based pavement marking specifications with specific thresholds for retroreflectivity levels. The benefits of these types of contracts are better pavement marking performance and quality, protection against premature failure, reduced lane-occupancy for repairs, and life-cycle savings. Some warranty contracts include performance criteria out to 6 years. Most include minimum requirements for retroreflectivity. More information about warranty and performance-based pavement marking specifications can be found in NCHRP Synthesis 408.[14]

Report Organization

The FHWA has outlined maintenance methods that are intended to provide agencies with a flexible means of conformance with the proposed MUTCD requirements for minimum retroreflectivity of pavement markings. The primary purpose of this report is to describe the methods that can be used to maintain minimum retroreflectivity levels.

Chapter 2 covers the objectives of the maintenance methods. Approved maintenance methods are introduced and defined. In addition, other pavement marking inspection techniques are identified and described.

Chapter 3 describes the calibrated pavement markings procedure for the visual nighttime inspection method. A description of the visual nighttime inspection method using this procedure is included as well as identified advantages and disadvantages.

Chapter 4 describes the consistent parameters procedure for the visual nighttime inspection method for pavement markings. Instructions for conducting the visual nighttime inspection method using this procedure are described as well as the advantages and disadvantages.

Chapter 5 includes a description of the measured pavement marking retroreflectivity method. This chapter includes information an agency needs to be familiar with if they are planning to use retroreflectivity measurements of their pavement markings to be in compliance with the proposed MUTCD language.

Chapter 6 describes the expected service life method and how an agency can use this method to maintain their pavement marking retroreflectivity levels. The information an agency needs to know in order to use expected service life to maintain their markings can be found in this chapter.

Chapter 7 describes the blanket replacement method, which is a form of the expected service life method with less administrative requirements, but perhaps more waste.

Chapter 8 includes a list of questions and answers to support the pavement marking retroreflectivity methods.

Appendix A contains the language that the FHWA has proposed for the Supplemental Notice of Proposed Amendment for the 2009 MUTCD to add language regarding minimum pavement marking retroreflectivity levels.

CHAPTER 2. RETROREFLECTIVITY MAINTENANCE METHODS

Introduction

Traditionally, it has been up to agencies to manage and maintain their pavement markings in accordance with the MUTCD standards. As a result, agencies have implemented different methods to manage pavement markings that reflect local conditions, needs, and priorities. These management methods, as well as the ones described herein, are understood to incorporate both monitoring and replacing the markings.

The management process begins with agency policies and practices regarding the use of pavement marking materials. Agency policies have often been driven by the costs of the various marking materials. Once new pavement markings have been installed, there is a need to monitor the markings to ensure they provide the intended delineation in both daytime and nighttime conditions. By and large, the most common method used to trigger the upgrade of pavement marking retroreflectivity by restriping or replacement has been visual inspection. However, other methods have been tested and implemented including measuring retroreflectivity and re-applying markings based on anticipated service life (e.g., waterborne paint is typically thought to have an expected service life of one year and is therefore commonly re-applied on an annual basis).

The proposed MUTCD language regarding minimum maintained pavement marking retroreflectivity levels is similar to the MUTCD language for minimum sign retroreflectivity in that it requires agencies to adopt one or more acceptable methods designed to maintain retroreflectivity at or above the appropriate threshold. This provision was intended to assure that agencies use methods that will be effective in maintaining nighttime visibility for their pavement markings.

The concept of a minimum pavement marking retroreflectivity standard has raised concerns among State and local agencies. One of the main concerns is associated with the potential increase in tort exposure once numerical values are established. The FHWA sponsored two workshops in the summer of 2007.[(9)] The workshops included participants from State and local agencies from around the country. The goal of the workshops was to obtain input from public agencies regarding efforts to establish a minimum retroreflectivity requirement for pavement markings. Similar to the comments expressed during the sign retroreflectivity rulemaking, the stakeholders at the workshops in 2007 expressed concern over tort liability claims.

In order to minimize the risk to an agency of being found negligent in meeting the requirements for minimum pavement marking retroreflectivity, FHWA proposes a pavement marking retroreflectivity maintenance method be developed and implemented in order to ensure the nighttime visibility of markings. The FHWA has also addressed special circumstances where maintenance of pavement marking retroreflectivity would be naturally difficult and provided an explanation of how compliance with the MUTCD can be achieved.

There have also been concerns that the implementation of new methods would impose new burdens on agencies. Workshop participants noted that the MUTCD should provide flexibility for agencies in terms of complying with minimum maintained pavement marking retroreflectivity levels. The maintenance methods described in this report are intended to provide that flexibility for agencies to minimize their burdens while remaining compliant with the forthcoming standards.

Objectives of Retroreflectivity Maintenance Methods

The intent of these methods is to provide a systematic means for agencies to maintain longitudinal pavement marking retroreflectivity at or above minimum retroreflectivity levels. The FHWA has determined that agencies that use an approved method to maintain pavement marking retroreflectivity are in conformance with the minimum maintained retroreflectivity requirements as proposed in the MUTCD.

Compliance with the proposed MUTCD language is achieved by having a method in place to maintain the minimum retroreflectivity levels. This implies the use of the method(s) chosen to monitor, schedule, and replace deficient markings in a timely manner. Compliance does not require or guarantee that every inch of pavement marking will meet or exceed the minimum retroreflectivity levels at every point in time. However, agency methods and replacement schedules should be designed to replace markings before they fall below the minimum levels.

For example, if an agency chooses to implement the calibrated pavement marking visual nighttime inspection method, there is no guarantee that the retroreflectivity of all pavement markings will be satisfied during the entire period that they are in service. Assuming that an agency successfully completes periodic nighttime visual nighttime inspections in accordance with guidelines set forth in this report, and that markings failing the subjective evaluation or markings rated as marginal are scheduled for replacement within a reasonable time period, then there is clearly a period of time when these markings (or some portion thereof) might be below the minimum retroreflectivity levels while the markings are awaiting replacement or reassessment. Having a method in place to maintain the minimum retroreflectivity levels is a valuable way for agencies to prioritize how to spend limited resources on those markings that should be replaced sooner, ultimately contributing to improved safety for the motoring public.

There are other conditions where markings might be rated as being satisfactory while temporarily falling below the minimum retroreflectivity levels. For example, water and snow on pavement markings can significantly reduce their visibility. In addition, while research has shown that the visual nighttime inspection is a reasonable method in terms of identifying pavement markings that need to be replaced because of inadequate retroreflectivity, the nighttime visual inspection method is not 100 percent reliable,[(15)] nor is any other method.

Regardless of which maintenance method is adopted by an agency, documentation of the pavement marking retroreflectivity maintenance process is important in assisting agencies to achieve conformance with the proposed MUTCD standard to maintain minimum retroreflectivity levels. Written procedures ensure that agency personnel properly follow the selected method, while maintenance records provide the agency with a systematic process for scheduling replacements and justification for the allocation of limited resources. As an example, measurements of pavement marking retroreflectivity might show that certain markings are near or below the MUTCD thresholds of minimum retroreflectivity before they reach the end of their expected life. The records provide documentation that an appropriate maintenance method was followed and permit the agency to assess and revise, if necessary, the expected service life for a given type or group of markings. As long as an agency has a reasonable method in place to manage or assess its markings and establishes a reasonable schedule for marking replacement as needed, the agency will be considered to be in conformance.

Documentation of the pavement marking retroreflectivity maintenance process can include a variety of information and levels of detail. It is understood that a diverse array of resources often contribute to maintenance marking processes including, but not limited to, on-call service contracts for restriping, consultant services for monitoring, material performance contracts, resurfacing contract work with marking replacement, and bartering services/materials/equipment with neighboring agencies/public officials. The form and extent of documentation are up to the discretion of the individual agency. Moreover, FHWA does not intend to hold official review and approval processes for agency policy or documentation regarding implementation of minimum pavement marking retroreflectivity programs. However, some of the items an agency may want to consider in a program or documentation are described below.

- The proposed SNPA language provides an exception for maintained marking retroreflectivity for roadways with less than 6,000 ADT per day. The minimum retroreflectivity levels are also based on the speed limit of the roadway. Therefore, agencies should include a feature in their pavement marking retroreflectivity maintenance program that can adapt to volume and speed changes as needed.
- The proposed SNPA language provides an exception for maintained marking retroreflectivity for roadways where ambient illumination assures that the markings are adequately visible. Intersection or safety lighting, where isolated areas of a roadway are lighted, do not qualify for this exemption. The intended type of lighting that qualifies is continuous roadway lighting or high-mast lighting, typically used at interchanges. A recent report from Alaska shows that when continuous lighting is used along stretches of highway with pavement marking retroreflectivity levels less than those proposed in the SNPA, the pavement marking visibility remains adequate.[16]

  There are two primary documents used in the United States to describe roadway minimum lighting criteria: ANSI/IESNA RP-8-00 and the AASHTO Roadway Lighting Design Guide (AASHTO Guide).[17, 18] The American National Standard Practice for Roadway Lighting published by the Illuminating Engineering Society of North American (IESNA) is commonly used by public agencies as the basis for establishing the appropriate lighting level design values for roadway lighting. This publication has been approved by the American National Standards Institute (ANSI) and is commonly referred to as RP-8. The RP-8 lighting design criteria parallels the lighting criteria found in the AASHTO Guide, with the exception of the general land-use parameter. The RP-8 criteria are based on an assessment of the roadway classification and pedestrian conflict area classification rather than the general land-use classification found in the AASHTO Guide.

- There may be occasions when a roadway or roadway segment is planned for rehabilitation or resurfacing but the existing pavement markings are known to have inadequate retroreflectivity levels. In such cases, a decision needs to be made regarding the effectiveness of restriping the roadway given that it will soon be resurfaced. In its documentation of the pavement marking retroreflectivity maintenance process, an agency may choose to set a maximum time-frame between identification of inadequate pavement marking retroreflectivity and resurfacing. If more time than the maximum is expected, one or more of the following may be needed: a low-cost temporary pavement marking (e.g. conventional waterborne paint and AASHTO M247 Type I beads) restriping contract or a provision within the resurfacing contract which conveys the maintenance of the markings to the contractor once the project is let for construction. Agencies can use a wide array of resources to maintain their pavement marking retroreflectivity.

Resources will change over time and unexpected events will occur. It will be important to establish documentation and make revisions as necessary. When extraordinary resources are used or events and circumstances outside the control of the agency occur, documentation can be advantageous. Repetitive use of such resources or events impacting the ability to comply with the minimum retroreflectivity levels should be addressed by revision to the documented method. Examples of documentation needs that address these uses or occurrences could be 1) revisions to standard operating procedures to accelerate replacement schedules in high-wear areas, 2) inclusion of new resources in lieu of or in combination with agency resources, and 3) characterizing procurement rule changes that impact material deliveries.

If sections of roadways are found to have less than the minimum retroreflectivity levels, agencies will be considered to be in compliance provided they are actively implementing a method as described herein and they take a reasonable course of action to restore the markings in a timely manner. There is no official definition of "in a timely manner." The limits can be set by each agency or set by precedence if no definition is established prior to legal actions.

Pavement Marking Visibility and Retroreflectivity

The ability to see a pavement marking at night is not solely a function of the retroreflective characteristics of the pavement marking, but is dependent upon several factors, including the:

- Amount and pattern of light produced by a vehicle's headlights,
- Amount of light reaching the pavement marking,
- Retroreflective characteristics of the pavement marking, and
- Visual characteristics of the observer.

A key factor in determining the visibility of a pavement marking is the contrast between the marking and the adjacent pavement surfaces. During daylight hours, marking visibility is achieved through ambient light striking the marking surface and scattering in all directions, some of which reaches the driver's eyes. However, in dark environments at night (without roadway lighting), vehicle headlamps produce most of the light striking a pavement surface, and therefore the retroreflective properties of the pavement marking govern the amount of light that reaches the driver's eyes. While the retroreflective performance of pavement markings is primarily provided by optics such as glass beads, there are also other factors that contribute to the retroreflective performance. These include the properties of the binder material (color, pigment type and amount, type, thickness), characteristics of the optics, which are usually glass beads, pavement surface roughness, and the amount of debris and dirt on the marking.

Pavement Marking Retroreflectivity Maintenance Methods

During the agency's initial efforts to develop recommended MUTCD language for the minimum retroreflectivity levels, the FHWA hosted workshops around the country to solicit city, county, and State transportation agency input regarding minimum pavement marking retroreflectivity levels.[9] One of the main points was that a "one-size-fits-all" policy would not be practical and that the FHWA needed to provide flexibility in terms of meeting the minimum retroreflectivity levels. Therefore, the FHWA established methods that agencies could choose from to maintain their markings at or above the minimum levels. Again, though mainly descriptive of the evaluation and monitoring processes, all methods below and described in Chapters 3-7 include the work of replacing or restriping longitudinal markings that do not meet the minimum retroreflectivity criteria. The methods and a brief description of each are provided below.

Visual Nighttime Inspection Methods

There are two visual nighttime inspection procedures allowed by the FHWA. Both procedures are meant to be conducted during dry nighttime conditions. The procedures have common elements such as:

- The use of low beam headlamp illumination,
- Inspections to be conducted at prevailing nighttime speeds,
- The use of trained inspectors, and
- The dependence on subjective evaluations.

Calibrated Pavement Markings Procedure of the Visual Nighttime Inspection Method

With this procedure, a trained inspector views "calibrated pavement markings" at night prior to conducting a nighttime visual inspection. Calibrated pavement markings have known retroreflectivity levels at or above minimum levels. These pavement markings are set up where the inspector can view them in a manner similar to the conditions of the nighttime visual inspections. The markings can be in a maintenance yard, along a service road, or on a road open to public travel. The inspector uses the visual appearance of the calibrated pavement markings to establish an evaluation threshold for that night's inspection activities. An example of calibrated markings is shown in Figure 1.

Figure 1. Photo pavement markings with known retroreflectivity levels

(This photo shows an example of markings with known retroreflectivity (shown in yellow). It is not necessary to include multiple markings like shown when using the calibrated marking method. These markings are 30-meters from the observer, representing the standard 30-meter measurement geometry used as a standard for pavement marking retroreflectivity)

Chapter 3 provides additional details pertaining to the calibrated nighttime visual inspection procedure.

Consistent Parameters Procedure of the Visual Nighttime Inspection Method

The consistent parameter inspection procedure is based on factors similar to those that were used in the research to develop the minimum retroreflectivity levels. It is similar to the calibrated pavement marking visual nighttime inspection procedure described above except that no calibrated pavement markings are needed and therefore no retroreflective measurements are needed either. Instead, this method relies on the judgment of an inspector who is aged 60 years or older.

Chapter 4 contains more details about this procedure.

Measured Retroreflectivity Method

In this method the pavement marking retroreflectivity is measured and directly compared to the minimum levels as shown in Appendix A. The retroreflectivity measurements can either be made with handheld devices or mobile devices, as long as they are measured using the standard 30-meter geometry. Inspectors should follow the instructions provided by the manufacturer to obtain reliable retroreflectivity readings, including periodically calibrating the equipment.

Chapter 5 contains procedures to implement the measured retroreflectivity inspection method.

Expected Service Life Method

In this method, pavement markings on a given stretch of roadway are replaced before they reach the end of their service life (i.e., the length of time the markings can remain in service before they reach the minimum retroreflectivity levels and need to be re-applied). Service life is typically established through research or monitoring of pavement marking test decks. Alternatively, if an agency does not know the service life of its markings, it can begin to establish service life values by measuring a representative sample of pavement markings. Service life must be determined using the replacement retroreflectivity levels at or above the minimum retroreflectivity levels shown in Appendix A. This method should include a system for tracking similar groups of pavement markings based on installation date, color, type of materials, and other characteristics such as traffic volume. Chapter 6 contains procedures to implement the service life method.

Blanket Replacement Method

With this method, an agency replaces all of the pavement markings in an area, corridor, and/or of a given marking material type, at pre-selected time intervals based on the relevant expected service life (using the MUTCD minimum levels shown in Appendix A). The replacement intervals are based on historical retroreflectivity data for specific roadways and types of marking material. The replacement intervals are based on when the shortest lived marking in that group/area/corridor approaches the minimum retroreflectivity levels. This method typically requires that all of the designated pavement markings within a replacement area, or of the particular pavement markings type, be replaced, even if segments of markings were recently installed—following a resurfacing project, for instance.

Chapter 7 contains procedures to implement the blanket replacement method.

Other Methods

Agencies can choose from the methods described in this chapter, combine them, or develop other methods based on engineering studies. It is important, however, that if an agency develops a different method, it must be based on an engineering study and must be tied to the minimum levels shown in Appendix A.

Pavement Marking Retroreflectivity Inspection Techniques Not Included as Approved Maintenance Methods

During the 2007 workshops and upon further review of the literature (referenced accordingly), several pavement markings assessment techniques were identified and considered. These have not been included with the recommended methods in this document because they could not be tied to minimum retroreflectivity levels or for some other concern. These techniques are described below. Future technologies and research may demonstrate that the techniques listed below or other innovative techniques can be successfully used to maintain pavement marking retroreflectivity levels to the proposed levels for the MUTCD.

Sun Over the Shoulder Technique

The sun-over-shoulder test (Figure 2) is an evaluation of pavement marking retroreflectivity normally used to assess the general quality of freshly installed pavement markings. This test is conducted during daylight hours and is a quality control method that is often used during the pavement marking installation process. The sun-over-shoulder test is not considered a suitable pavement marking

Figure 2. Photo showing sun over the shoulder technique

management method to determine if and when longitudinal pavement markings have reached the end of their useful service life. This is noted in Test Method Tex-828-B "Determining Functional Characteristics of Pavement Markings," where the sun-over-shoulder method is recommended for use during striping operations "only as a guide to determine the nighttime appearance of the markings, not for final acceptance." (19)

Comparison Panel Technique

The comparison panel technique involves placing a comparison panel with a retroreflective level at or above the minimum retroreflectivity level next to an in-service pavement marking. An inspector views the combination at a specified distance (e.g., 30 meters). If the comparison panel appears brighter than the pavement marking, the marking needs to be replaced. This technique would have to be conducted at night and with traffic control for safety reasons. While this method may be acceptable for the airfield markings for which it was developed, workshop participants deemed it unsafe for roadways as it requires too much risk for the inspectors.

Figure 3. Daytime comparison samples for visual inspection of pavement marking.

Lane Line Count Technique

To use this technique, trained inspectors must count the number of lane lines visible from the driver seat of a static test vehicle. This count of visible lane lines is multiplied by the lane line length and spacing to calculate visibility distances. While it is possible to tie the minimum retroreflectivity levels to a visibility distance, the need to have the inspection vehicle in a static position on the road places the inspectors at risk when properly performing the test for in-service markings. It is not feasible to count the lane lines from a moving vehicle.

Control Markings Technique

A maintenance method described in the MUTCD for maintaining traffic sign retroreflectivity is called the “control sign method” and involves monitoring a subsample of traffic signs to determine their service life based on minimum sign retroreflectivity levels. As the control signs near the end of their retroreflective life, they are scheduled for replacement along with the other in-service signs of the same age and materials. The control signs can be signs in a maintenance yard or in-service signs.

The pavement marking version of this maintenance technique is limited to only in-service markings. It is classified under the expected service life method in Chapter 6. The expected service life method allows an agency to use the method if they already have the necessary supporting data or if they choose to start monitoring a sample of their markings to determine the most appropriate service life based on their local conditions.

Because pavement marking retroreflectivity is so closely tied to pavement marking type, pavement surface types, and traffic volumes, the control method is not appropriate when the control markings are installed at a low volume facility such as a maintenance yard. This is acceptable for sign degradation, but not for pavement marking degradation.

Windshield Marking Technique

With this technique, a mark (using tape) is placed on the windshield at the line of sight for the particular inspector. This mark coincides with a visibility distance derived from a preview time of 2.2 seconds and the posted or prevailing nighttime speed of the roadway. The inspector then drives the roads at appropriate speed (the mark would need to be adjusted for speed) and disqualifies any segments where the pavement marking cannot be seen at the appropriate distance. This technique is not directly tied to the minimum pavement marking retroreflectivity levels. In addition, there is concern that minor changes in the driver position (e.g. slouching) would affect the accuracy of this system. This technique would require a research study to determine if it would be an effective technique.

Comparison Light Box Technique

A comparison light box is a hand-held device that performs a daytime check of pavement marking retroreflectivity. The device is similar in size to a pavement marking retroreflectometer, but significantly less expensive. The device is composed of a box with a mirror and a light to show the appropriate geometry as the inspector looks directly down into the box. The image that the inspector sees is a side-by-side comparison of the in-service marking and a calibrated marking (placed within the device) that is set to a specific retroreflectivity level. While this device provides a good side-by-side comparison, it needs to be used the same way as a hand-held pavement marking retroreflectometer. While both devices are used by placing them on the pavement marking to be inspected, the retroreflectometer can be operated with a trigger pull and does not require the inspector to glance away from the roadway. The comparison light box, on the other hand, requires that the inspector look down into the device, focus, and then make a decision, demanding the inspector to look away from the roadway for a significant period. The comparison light box technique will work if it is used in a safe location such as with the appropriate traffic control. However, the hand-held retroreflectometer provides a more objective measure of retroreflectivity and reduces user risk by allowing the user to scan traffic. The hand-held retroreflectometer is more expensive, but it is preferred over the comparison light box.

CHAPTER 3. CALIBRATED PAVEMENT MARKING PROCEDURE – VISUAL NIGHTTIME INSPECTION METHOD

Introduction

The calibrated visual inspection method can be used by agencies to conduct nighttime visual inspections as long as a few initial steps are taken to calibrate the inspector's perception of the pavement marking visibility threshold. The MUTCD currently includes language that encourages agencies to undertake periodic daytime and nighttime visual sign inspections (see Section 2A.22). In addition, Section 2A.09 lists visual inspection as an approved method to maintain traffic sign retroreflectivity. Adding pavement markings to a nighttime sign inspection program is an effective method as long as the necessary steps are followed.

Using this approach, it is possible to assess more than just the retroreflectivity of pavement markings. Other damage may be identified such as excessive wear from turning movements or loss of presence (i.e. when some of the pavement marking material is missing), which may not be identified with spot retroreflective measurements alone.

This method requires little investment of resources on the part of the agency, although there is a need for a record-keeping system for inspection data and the potential for higher labor costs where overtime pay is required (because the inspection is performed at night). The significant up-front resource needed is a retroreflectometer to measure the calibrated pavement markings to assure they are at the intended retroreflectivity levels. However, agencies do not necessarily need to purchase their own instruments. Some agencies share devices or use loaners from Local Technology Assistance Program (LTAP) offices.

While nighttime visual inspections will reveal visibility problems not discernable under daytime conditions, they are subjective and hence more difficult to tie to a benchmark value of retroreflectivity. As a result, agencies using visual inspections must establish procedures to provide consistency in inspections. This implies the need for training programs and inspector certification.

Background

Probably the most common type of assessment method used to evaluate pavement marking retroreflectivity has been some form of the nighttime visual inspection method. Despite the subjectivity and reliability concerns of the visual nighttime inspection method, recent research has shown visual assessment techniques can be used to assess the relative brightness of pavement markings, but not necessarily the retroreflectivity level of pavement markings.(15) Therefore, it is important to have trained inspectors who follow the process outlined in this section when conducting nighttime visual inspections of pavement markings. While there is no nationally recognized training course or certification for pavement marking inspectors, agencies should provide some form of training before nighttime inspections are performed. The FHWA will provide inspection training tools to the Local Technical Assistance Program (LTAP) and Tribal Technical Assistance Program (TTAP) Centers.

One way to perform the training is to have the inspectors observe sample pavement markings at a variety of known retroreflectivity levels, including levels near the minimum levels, before conducting the inspections. This type of training helps the inspector understand the differences between various retroreflectivity levels. Training is also necessary for the inspector to understand what the objectives are for the inspection and to ensure an understanding of the critical inspection elements, cautions for improper techniques, and safety procedures. Inspectors should view the sample pavement markings under conditions similar to those under which they will perform inspections. This includes using the low beam headlamps of the inspection vehicle so that the calibration pavement markings are located in positions that replicate most typical field applications. The inspector should also be trained on agency guidelines and procedures for conducting nighttime inspections, including any necessary documentation.

General Procedures

The calibrated visual inspection procedure uses trained personnel to observe pavement markings during nighttime conditions to assess the overall appearance of the markings and determine if they meet the required minimum retroreflectivity level. If the inspector believes a marking appears to be less bright than the calibration marking viewed earlier, then the markings should be replaced. The observation is typically made through the windshield of the vehicle at or near the speed limit of the roadway.

The preferred technique for inspecting pavement markings at night is to use a two-person crew. While the driver focuses on the driving task, the trained passenger evaluates the pavement markings and records the appropriate information. An alternative to a two-person crew is one person using a tape recorder or mounted camcorder for recording notes (to review later for determining the condition of the markings).

Details

To get started, an agency should develop a step-by-step set of instructions for consistency of inspections. This procedure requires a sample of pavement markings at or near the appropriate proposed minimum retroreflectivity levels in the MUTCD. These markings will be designated as the calibration markings. Depending on the agency specifications, the retroreflectivity levels of the calibration markings may be at the minimum levels outlined in Appendix A, or they may be higher than the minimum levels but not lower than the minimum levels. It is possible to install pavement markings at a desired level of retroreflectivity or to use in-service pavement markings. It is also possible that pavement marking manufacturers may produce sections of pavement markings with retroreflectivity levels consistent with the minimum levels. In any case, the pavement marking retroreflectivity will need to measured and documented to ensure it is near the desired level.

The calibration markings should be both yellow and white and positioned accordingly (e.g., for a two-lane two-way roadway, white on the right and yellow on the left). If the calibration pavement markings are installed specifically for this purpose, the contractor or installer will have to make special provisions to apply pavement markings near the desired level. This may take some trial and error but can generally be achieved by controlling truck speed and bead load rates. The retroreflectivity can also be lowered by applying a clear coat polyurethane or other similar product.

The calibration markings should be evaluated before the inspection begins. Since the markings need to be seen for a preview distance of 2.2 seconds, the length of the calibration markings will vary by speed. The calibration markings must be at least 10 feet long. They must be viewed from the inspection vehicle but they can be viewed in a static position or a moving position. If they are to be viewed in a static position, Table 1 shows the preview distances that should be used depending on the posted speed limit of the roadways to be inspected.

When viewing the calibrated the markings, the inspector should try to commit to memory the appearance of the calibrated markings. The inspector will use the appearance of the calibrated markings as a benchmark to determine if in-service markings are brighter or less bright than the calibrated markings. Those that are less bright, and those at about the same brightness level, should be scheduled for replacement.

Table 1. Calibrated pavement marking viewing distances.

Speed (mph)	Distance (ft)	Number of Lane Lines
40	130	4
50	160	5
60	195	5
70	230	6
80	260	7

Once a set of pavement markings that are representative of those installed within the agency's jurisdiction has been installed or identified, the retroreflectivity levels should be measured and documented. ASTM Test Method D7585[11] includes a description of the appropriate test method for hand-held pavement marking retroreflectometers. A mobile pavement marking retroreflectometer can be used, as well.

Any type of vehicle can be used for the calibrated pavement marking visual inspection procedure. The low-beam headlamps of the inspection vehicle should be checked for proper alignment, and inspections should only be conducted with the low beam headlamps The ambient conditions must be dark, at least 30 minutes beyond sunset. The conditions of the pavement must be dry during the calibration and during the inspection. At least one pass of the markings should be made, but more than one may be beneficial. It is helpful either to locate the calibrated pavement markings in a centralized area or to plan the night inspection route so that the calibrated markings can be observed several times throughout the night.

Linking to Minimum Retroreflectivity Levels

Minimum retroreflectivity levels are incorporated into this method by training the inspectors and using procedures that allow them to correlate their inspection observations through the use of calibrated pavement markings with known retroreflectivity levels (at or above the minimum levels in the MUTCD). A good practice is for inspectors to observe the calibrated pavement markings prior to and intermittently throughout each nighttime inspection. The use of appropriate calibrated pavement markings at or near minimum retroreflectivity levels is a key element that links the nighttime visual inspection method to the minimum retroreflectivity levels.

Advantages

One of the major benefits of using the calibrated nighttime visual inspection procedure is that it has low administrative and fiscal burdens. Many agencies already perform some type of periodic pavement marking inspection, although not all inspections are performed at night, and few are actually linked to any retroreflectivity level. This procedure also has a unique feature in that the pavement markings are viewed in their natural surroundings. Thus, the overall appearance of the pavement marking and the ability of the pavement markings to provide information to the driving public can be assessed.

Another advantage of the calibrated nighttime visual inspection method is that it has a low level of unnecessary pavement marking replacement and waste. Only those pavement markings identified as needing to be replaced because of low retroreflectivity levels are replaced, assuming that the inspection frequency is appropriate.

Concerns

While this procedure may be more subjective than other methods, research has shown that subjective ratings can be made of pavement marking visibility that can be used as surrogates for retroreflectivity (i.e., using qualitative ratings such as *poor*, *marginal*, and *desired* rather than specific retroreflectivity levels such as 110 or 115 mcd/m^2/lx). There is some risk involved while performing these inspections, particularly if the driver is also the evaluator and recorder. Ideally, nighttime inspections should be conducted by two people for safety reasons. Including additional inspections by different inspectors has been shown to increase the reliability of visual inspections.

Using this procedure will require agencies to establish a protocol that fits their conditions, including the frequency of inspections and the frequency of replacing calibrated markings. Calibrated markings will need to be monitored so that they do not fall below the minimum levels established in the MUTCD. Since pavement markings tend to lose their retroreflective performance over time, it is important to measure the calibrated markings periodically to ensure that they are at or above the minimum levels outlined in the MUTCD.

Visual inspections of pavement markings supplemented with raised pavement markers (RRPMs) can be difficult. The brightness of the RRPMs is usually much greater than that of the pavement markings, and therefore it can be difficult to judge the pavement marking retroreflectivity.

Pavement markings on either side of the inspection vehicle can be evaluated during a visual inspection. However, pavement markings that are not adjacent to the inspection vehicle cannot be evaluated during a visual inspection. As a result, for multilane highways, more than one pass is needed to inspect all of the longitudinal markings (per direction).

CHAPTER 4. CONSISTENT PARAMETERS PROCEDURE – VISUAL NIGHTTIME INSPECTION METHOD

Introduction

The consistent parameters nighttime visual inspection maintenance procedure can be used by agencies to conduct nighttime visual inspections without requiring the need for specific markings or retroreflectivity measurements. Rather than using calibrated pavement markings, the consistent parameters nighttime visual inspection procedure relies on the judgment of an inspector that is at least 60 years old. The minimum retroreflectivity levels outlined in the MUTCD are based on research that is based on the visibility performance of older drivers. Therefore, the pavement marking visibility viewed by an inspector who is at least 60 years old can be thought of as a surrogate for minimum maintained retroreflectivity.

Using this procedure, it is possible to assess more than just the retroreflectivity of pavement markings. Inspectors may identify other damage, such as excessive wear from turning movements. In addition, they can examine current pavement markings to be sure they continue to meet MUTCD and other policy requirements.

This procedure requires a minimal investment of resources on the part of the agency, although there is a need for a record-keeping system for inspection data and the potential for higher labor costs where overtime pay is required. While visual inspections will reveal night visibility problems not discernable under any other method, they are subjective and hence more difficult to tie to a benchmark value of retroreflectivity. As a result, agencies using visual inspections must establish procedures to provide consistency in inspections. This implies the need for training programs and inspector certification.

Background

The consistent parameter procedure is a visual inspection method that shares some elements of the calibrated visual inspection procedure. The main difference is the inspector's age and ability to perform the method without calibrated markings or a retroreflectometer to measure the calibrated markings.

This consistent parameters procedure uses inspectors aged 60 years or older to observe pavement markings during the nighttime to assess the overall pavement markings appearance and determine if they need to be replaced. The observation is typically done through the windshield of the vehicle at or near the speed limit of the roadway. It is desirable to have a dedicated driver so that the inspector can concentrate on the markings.

The key to this procedure is having trained inspectors. While there is no nationally recognized training course or certification for pavement marking inspectors, agencies should provide some form of training before nighttime inspections are performed. The FHWA will provide inspection training tools to the LTAP and TTAP Centers.

One way to perform the training is to teach the inspector (particularly if an agency is using a layperson) what types of markings to evaluate. The MUTCD does not require that all pavement markings meet the minimum retroreflectivity levels. The minimum retroreflectivity levels only apply to certain white and yellow markings as described in Appendix A. Training should also cover the agency’s guidelines and procedures for conducting nighttime inspections, including any necessary documentation. This helps facilitate an inspector’s preparation before beginning the nighttime inspections.

General Procedures

The consistent parameters procedure is conducted using a two-person crew. While the driver focuses on the driving task, the inspector (aged 60 years or more) evaluates the pavement markings and records the appropriate information. Those markings judged by the inspector not to meet his/her driving needs should be replaced (i.e., Can the “older driver” see the markings far enough in advance to make appropriate decisions and maneuvers?). Although not recommended, an alternative to a two-person crew is to use one person with a tape recorder or mounted camcorder for recording notes. The condition assessments need to be made at the time of the inspection, so any video recording should not be used later for determining the condition of the markings. Video technology is not yet available that can provide the necessary quality to be used in assessing retroreflectivity.

Details

A policy should be developed by the agency for consistent inspections. Unlike the calibration markings procedure, this procedure requires no equipment like a retroreflectometer. The only requirement is that the inspector is at least 60 year old and the inspection takes place at night. In addition, the inspection vehicle headlamps should be properly aimed and set to low beams during the evaluation. The inspection vehicle can be any type of passenger vehicle, although a passenger car is preferred as it most closely matches the research parameters. The inspections should occur at or below posted speed limits and from the travel lanes.

It is helpful to plan the routes and frequency of inspections early and to document as much of the process, including the inspection results, as possible. As noted earlier, this can help alleviate agencies' concerns over tort liability.

Linking to Minimum Retroreflectivity Levels

Minimum retroreflectivity levels are incorporated into this procedure by using inspectors of the same age as those who participated in the supporting research used to develop the minimum pavement marking retroreflectivity levels in the MUTCD. An objective of the MUTCD language is to establish minimum levels of nighttime pavement marking performance based on the visibility needs of nighttime drivers, especially older nighttime drivers, and this procedure provides a technique to do just that.

Advantages

One of the major benefits of using the consistent parameters nighttime visual inspection procedure is that it has the lowest equipment, administrative, and fiscal burdens. Many agencies already perform some type of periodic pavement marking inspection, although not all inspections are performed at night. This procedure also has a unique feature in that the pavement markings are viewed in their natural surroundings. Thus, the overall appearance of the pavement marking and the ability of the pavement markings to provide information to the driving public can be assessed.

Another advantage of the consistent parameters nighttime visual inspection procedure is that it has a low level of unnecessary replacement and waste. Only those pavement markings identified as needing to be replaced because of low retroreflectivity levels are replaced, assuming that the inspection frequency is appropriate.

Concerns

This procedure relies on the judgment of the inspector. It is the most subjective of all approved methods. While it can be used effectively, it may be challenging to use this method to enforce contracted minimum retroreflectivity levels that come with disincentives if the markings fail a specific threshold before a set period of time.

Visual inspections of pavement markings supplemented with raised pavement markers (RRPMs) can be difficult. The brightness of the RRPMs is usually much higher than the pavement markings and therefore it can be difficult to judge the pavement marking retroreflectivity.

Pavement markings on either side of the inspection vehicle can be evaluated during a visual inspection. However, pavement markings that are not adjacent to the inspection vehicle cannot be evaluated during a visual inspection. Therefore, for multilane highways, more than one pass is needed to inspect all of the longitudinal markings (per direction).

CHAPTER 5. MEASURED RETROREFLECTIVITY METHOD

Introduction

In general, there are two ways that pavement marking retroreflectivity can be measured in the field: with hand-held instruments or with mobile instruments. Hand-held instruments require the measurement device to be set on the pavement marking. Mobile instruments are attached to a vehicle and measure the pavement marking retroreflectivity as the instrumented vehicles passes by at typical roadway speeds. Both techniques provide objective retroreflectivity values that can be used in direct comparison to the minimum retroreflectivity levels. The use of the measurement method as an exclusive process to maintain pavement marking retroreflectivity has not historically appealed to agencies, as will be discussed in the following sections. However, when combined with another method, the measured pavement marking retroreflectivity method adds an element of objectivity to the overall maintenance program. This combination of methods may maximize maintenance budgets and provide additional protection from tort claims.

Background

There are several commercially available hand-held retroreflectometers that can be used to measure pavement marking retroreflectivity. While both the hand-held measurement instruments and the mobile measurement instruments provide similar results related to measurement bias, repeatability, and reproducibility,(20) using hand-held instruments can be time consuming if there are many roadways with miles of pavement markings to be sampled. Mobile pavement marking retroreflectivity measurement devices offer flexibility and speed-up the measurement process. However, mobile measurement devices necessitate a relatively high level of capital investment for those agencies interested in purchasing their own. Alternatively, there are companies that specialize in pavement marking measuring services using both hand-held and mobile measurement devices.

The minimum retroreflectivity levels specified in the MUTCD are specified at what is called 30-meter geometry.(21) Essentially, retroreflective measurements made under 30-meter geometry simulate the retroreflective performance of the pavement marking at a distance 30 meters in front of the vehicle (using entrance and observation angles of 88.76 and 1.05 degrees, respectively). Measurements of pavement marking retroreflectivity that are used to determine compliance with the MUTCD minimum levels must be made with instruments that are designed to measure retroreflectivity at 30-meter geometry.

When the pavement marking measurement method is implemented, many ask how many readings are needed. For handheld retroreflectometer measurements, ASTM has developed a standardized practice, *ASTM D7585 / D7585M-10, Standard Practice for Evaluating Retroreflective Pavement Markings Using Portable Hand-Operated Instruments*.[11] Currently, there is not a national standard for mobile retroreflectometer measurements.

Pavement marking retroreflectivity measurements are typically averaged, and the average value is compared to a threshold. More elaborate mathematical processes can also be used, such as considering the variability in the measurements, or determining the percentage of the measurements above some secondary threshold. For yellow pavement markings on centerlines, it is common to measure the retroreflectivity in both directions and use the lowest results.

More information about retroreflectometers can be found on the following Web sites:

Hand-Held Devices

- Delta LTL-X, http://www.flinttrading.com
- Roadvista Stripemaster 2, http://www.roadvista.com
- Zehntner ZRM 6014, http://www.zehntner.com/en/products/categories/retroreflection/zrm-6014

Mobile Devices

- Roadvista Laserlux, http://www.roadvista.com/laserlux-cen-30-mobile-retroreflectometer/
- Zehntner ZDR 6020, http://www.zehntner.com/products/categories/retroreflection/zdr-6020

Note that the FHWA does not endorse the use of any specific instrument or service provider. While the above list is, to the authors' best knowledge, complete as of the date of publication, other instruments and services may be available or may become available in the future. Each agency is encouraged to review the specifications for the various instruments and determine for themselves which instrument is most appropriate for their application.

General Procedures

Measuring retroreflectivity using a hand-held instrument should be performed in safe conditions with the appropriate traffic control. Measuring retroreflectivity using a mobile instrument provides relief from the need for traffic control. Using either type of instrument, the measurements must be made under dry conditions (pavement marking retroreflectivity can be measured under wet recovery and wet continuous conditions, but the minimum maintenance levels in the MUTCD pertain only to dry conditions). It is important to maintain a record of the measurements, when they were made, and other related information as deemed appropriate. If the measured retroreflectivity value is less than the minimum level, the markings should be replaced.

Handheld vs. Mobile Units

Pavement marking retroreflectometers come in two basic types: handheld and mobile. Examples of both types of retroreflectometers are shown in Figures 4 and 5. Handheld retroreflectometers are much less expensive than mobile units, are much easier to use, and require less training. However, handheld units are inconvenient when a large number of measurements are required or when measuring on roads with high-traffic volumes. There are also safety issues related to the use of handheld units as workers are often exposed to traffic while measuring the retroreflectivity of a marking. Taking handheld measurements often requires lane closures, increasing delay to motorists.

Figure 4. Typical Hand-Held Pavement Marking Retroreflectivity Measurement Device

Figure 5. Typical Mobile Pavement Marking Retroreflectivity Measurement Device

Mobile units on the other hand are much more expensive than handheld units and require a significant amount of training and maintenance. However, mobile retroreflectometers produce a very large number of measurements and allow for measurements to be taken at highway speeds without exposure of personnel to traffic or lane closures. Some state transportation agencies own mobile retroreflectometers, although most agencies hire qualified contractors to perform mobile retroreflectivity measurements.

Current Practice

Some States such as North Carolina and Michigan have been systematically measuring pavement marking retroreflectivity for many years as part of their pavement marking management program. Other States such as Iowa and Wisconsin use hand-held pavement marking retroreflectivity devices to monitor pavement marking retroreflectivity.

Linking Measurements to Minimum Retroreflectivity Levels

This method uses measured retroreflectivity as the basis for the decision of whether or not pavement markings meet the required minimum level of retroreflectivity. The measured retroreflectivity values are compared to the minimum retroreflectivity levels specified in the MUTCD. Pavement markings should be scheduled for replacement if the measured retroreflectivity is at or very close to the minimum required level. This method provides the most direct comparison of in-service pavement marking retroreflectivity relative to the minimum maintained retroreflectivity levels.

Advantages

Retroreflectivity measurements can be made during the day. Measurements provide the most direct means of monitoring pavement marking retroreflectivity levels and reduce the uncertainty that exist in other methods. However, a limit must be established on how close a pavement marking's retroreflectivity levels can be to the required minimum levels before the markings must be replaced. Measurement uncertainty and the variance between the retroreflectivity at the prescribed measurement geometry versus the retroreflectivity at the actual observation geometry may result in a pavement marking that meets the minimum requirements but does not meet the needs of the driver, and vice versa.

Concerns

The main disadvantages of using this method is that measuring pavement markings can be time consuming and cost prohibitive, depending on the amount of pavement markings to be measured and the measurement technique. Measured retroreflectivity may be best used to support one of the other methods.

Another disadvantage is that using the retroreflectivity of the pavement marking as the only indicator of whether or not a re-marking should be initiated may result in other attributes of the marking's overall appearance being neglected. Other factors should be considered, including the daytime and nighttime color, the presence of the marking material, and the uniformity of the nighttime appearance. Finally, agencies need access to the measurement devices and trained personnel to use this method (or the measurement services of a third party).

The measurement bias, repeatability, and reproducibility limits of retroreflectivity measurements are also an important consideration when using measurements to determine compliance with a threshold such as the MUTCD minimum pavement marking retroreflectivity levels. ASTM has recently updated the repeatability and reproducibility limits for pavement marking retroreflectivity measured with a 30-m geometry hand-held instrument (see ASTM E1710-11).[21]

CHAPTER 6. EXPECTED SERVICE LIFE METHOD

Introduction

With this method, pavement marking installations are recorded and, using historical data or research results, a schedule for replacing the markings before they fall below the MUTCD minimum levels is established. If historical data or research results are not available, pavement markings installed with the same materials on similar roadways (pavement surfaces and vehicular volumes) can be monitored to determine their service life (i.e., their in-service life before falling below the MUTCD minimum levels).

Procedures

Although there are many variations to this method, the basic idea is that the installation of pavement markings is tracked so that agencies know when the markings were installed and on what roadway (so that they may track at least the key factors such as pavement marking type, pavement surface, and traffic volumes). Research has routinely shown that pavement marking type, pavement surface, and traffic volumes are important factors needed to understand the longevity of pavement marking retroreflectivity.[22, 23]

To track the installation of the markings, it can be useful to use a computerized management technique, but that does not mean an expensive off-the-shelf system. A spreadsheet listing the roads, the markings on the road, the type of pavement, and the traffic volumes would be appropriate. On the other hand, fully featured GIS systems could also be developed. Either way, pavement markings of similar type can be grouped with roadways of similar surface types and traffic volumes. Then, using a specific roadway section representing other roadways sections with similar characteristics, the agency could track the retroreflectivity of the specific roadway section. The roadway section should be long enough to accommodate the selected method used to assess the retroreflectivity along that section of roadway (calibrated visual inspection, consistent parameters, or measured retroreflectivity). The selected section of roadway should include as many features and characteristics of the common grouping as feasible. For instance, it should include center lines and edge line if the common group is mostly two-lane roadways.

When this method is used, the management technique allows the agency to track and even predict (within reasonable limits), when the monitored pavement marking retroreflectivity will reach the end of its life. Before the marking reaches that point, the agency can begin planning to re-apply or replace all the markings that the monitored markings represent.

If an agency monitors pavement markings on a continuous basis, this method can help an agency determine if the degradation is occurring as expected. If the degradation is not occurring as fast as expected, then the pavement markings service life can be extended. Conversely, if the deterioration is occurring faster than expected, the agency can schedule the markings for replacement sooner. Monitoring changes in degradation can help ensure better nighttime visibility and increase the overall life cycle of an agency's pavement markings, resulting in cost savings.

Current Practice

The use of service life based on monitored markings as a maintenance method is currently being employed in a variety of States. Pennsylvania and Florida use a combination of subjective inspection, test deck data, manufacturers' information, past experience, and retroreflectivity measurements. North Dakota, Iowa, and Oregon have detailed retroreflectivity measurement programs to track pavement marking service life.

Linking Expected Service Life to Minimum Retroreflectivity Levels

Either historical data or research results can be used with an expected service life method. Regardless of which is used, the service life period must be based on the MUTCD minimum levels (or higher). If pavement markings are to be monitored, they must be assessed at specified intervals to determine how they are performing with respect to the minimum pavement marking retroreflectivity levels. The trending retroreflectivity levels from the monitored markings can be used to trigger pavement marking replacement or reapplication.

Advantages

While this method does not require as much inspection of markings in the field, it does require that agencies track when and where their pavement markings were installed. Using this method, agencies can also develop a more thorough understanding of pavement marking retroreflectivity durability and make adjustments to their policies as field data and pavement marking costs indicate.

Compared to measuring pavement marking retroreflectivity for all longitudinal markings, this method minimizes exposure of the inspector. In order to implement this method, agencies must determine how best to group similar pavement markings and other key factors such as pavement surface types and traffic volumes. In addition, agencies must determine the sampling procedures for the monitored markings (such as those outlined in ASTM D7585[(11)]) as well as the frequency of inspections (perhaps once per year at a minimum).

Concerns

It is important to understand that this method relies on either known service life values (from historical data or research) or can be used by agencies to begin tracking their markings of similar type to develop service life values, so that this method is feasible in the future. When an agency knows the service life values for pavement markings, it should still consider monitoring some markings to validate and adjust those values. Service life values based on transversely applied test decks or warranty information may not be as reliable as service life values obtained from long line test decks.

When an agency uses this method to determine service life values based on monitored markings, an important aspect is that the markings selected to be monitored must be markings installed on roadways representative of the agency’s jurisdiction. They cannot be markings installed in the maintenance yard or another convenient area without traffic. Because pavement marking retroreflectivity is so closely tied to pavement surface types and traffic volumes, the control method as described and permitted for maintenance of traffic sign retroreflectivity is not an appropriate method for maintaining pavement marking retroreflectivity.

CHAPTER 7. BLANKET REPLACEMENT METHOD

Introduction

The blanket replacement method is essentially a version of service life method, but rather than being executed for each pavement marking, it is executed on a larger spatial or strategic basis. In this method all pavement markings of a certain type or within a certain corridor are replaced at specific intervals. Using this method, the agency does not need to assess the visibility of pavement markings or track all pavement marking installations. It is, however, necessary to record the date of each replacement cycle so that a transportation agency can determine when to repeat the process.

This method should only be used where agencies have historical data or research findings showing the life of their longitudinally applied in-service pavement markings as a function of key variables such as pavement marking system, pavement surface type, and traffic volumes. The service life data should be available to support the service life estimates.

Procedures

The following factors apply to the use of this procedure:

- The replacement cycle is based on the expected service life of the markings given factors such as the marking type, surface type of the roadway, and traffic volume.
- Replacement zones can be based on an area, corridor, or pavement marking type (e.g., edge line, center line, and lane line).
- All markings within the replacement zone are replaced as they near the end of the cycle regardless of the condition of the marking.

Current Practice

Several State transportation agencies use the blanket replacement method to manage pavement marking retroreflectivity. Among them are New Hampshire, Alaska, and Maine. In New Hampshire and Maine, all the highways are restriped each summer with a waterborne paint. In Alaska, all roadways without a durable striping product are re-striped annually with low-VOC paint. Some agencies even restripe with paint twice per year because for them it is the most cost effective way to maintain their markings.

A literature review and agency surveys have shown that the expected service life of pavement markings varies considerably across the United States.[24] The range of values for assorted pavement marking types is shown in Table 3. Caution should be exercised in using the values shown in Table 3 as these are based on research reports, telephone interviews, and reviews of State transportation agency websites. In some instances, data were only from one State. In other cases, the range represents data from several States.

Table 2. Range of pavement marking service life estimates.[25]

Pavement Marking Material Type	Range of Service Life (years)
Water-based paints	0.5 to 3.0
Alkyl-based paints	0.25 to 3.0
Epoxy	2.0 to 5.0
Thermoplastics	1.0 to 7.0
Preformed tapes	2.0 to 8.0
Methyl methacrylate	2.0 to 7.0
Polyurea	3.0 to 4.0

Linking Blanket Replacement to Minimum Retroreflectivity Levels

The minimum retroreflectivity levels provide the initial basis for the expected life criteria, but an understanding of the actual degradation rates of in-service pavement markings is required to set appropriate triggers as retroreflectivity levels approach the minimum requirements. Under this method, retroreflectivity levels of pavement markings are not assessed in the field, and opportunities for capturing data that may be useful in adjusting service lives, trigger points, or maintenance strategies are limited.

Advantages

The major benefit of using this method is that there is no need to conduct field inspections once the service life estimates are generated. However, the key drawback is that a management system needs to be implemented so that the installation and replacement cycles can be properly administered.

For agencies with heavy winter maintenance activities that make annually striping their entire network a necessity, this method can be quite effective. Many northern agencies currently practice this maintenance method—restriping certain highway systems each year with waterborne paint. However, these agencies need to prioritize their restriping programs so that they bring their markings up to the minimum retroreflectivity levels as soon as practical after winter conditions.

Concerns

One of the issues with this method is that the replacement times can vary depending on the marking type, pavement surface type and condition, and traffic volumes. Having reliable service life numbers is important for obtaining the maximum benefit from this method. In addition, regional climate plays a critical role in the expected service life. Having local or regional service life data is important.

To use this method with durable markings, an agency has to have many years of in-service pavement marking retroreflectivity data available to estimate the life of the markings based on factors such as the pavement markings type, the pavement surface, and the traffic volume. Many agencies have conducted in-house test decks or contracted with researchers to design and monitor test decks. These types of activities are time consuming but essential in order to properly estimate the service life of durable pavement markings.

CHAPTER 8. FREQUENTLY ASKED QUESTIONS

Is a retroreflectometer required to meet the new MUTCD requirements? Not for all methods, although there are methods that do require the use of a retroreflectometer. There are alternatives to purchasing retroreflectometers, however; for instance, retroreflectometers are available for loan through some LTAP centers and are also available for rent from the manufacturers.

Is a computer inventory is required? No inventory is required. However, there are many benefits of having an inventory as described in the report.

Must you have a 60 year old for any nighttime inspection? There are two different visual nighttime inspection methods that can be used. The procedure that FHWA calls "consistent parameters" does require an inspector to be at least 60 years of age. The other visual nighttime inspection method (calibrated pavement markings) does not have criteria on the age of the inspector.

Can I use any vehicle for the nighttime inspection methods? Yes. There is much less vehicle size sensitivity related to pavement marking brightness compared to sign brightness. When using the consistent parameters method, a sedan is preferred, since this most closely matches the research parameters. It is less critical for the calibrated inspection method, because the inspector calibrates his/her eyes in the same vehicle being used during the inspection.

Are annual inspections frequent enough? Typically yes, although it may depend on the amount of traffic. In general, it is good practice to inspect markings as soon as practical in the late winter or early spring so that a priority can be given to markings that need to be refurbished.

What if I cannot restore all markings according to the replacement schedule? The MUTCD requires the use of "a method designed to maintain retroreflectivity at or above…" If your implementation of the maintenance method is designed to maintain your markings above the minimum values, you would be considered to be in compliance with the standard. Unanticipated events may occur that cause delays in reapplication. If unanticipated events occur, compliance with the standard is still considered to be achieved as long as a reasonable course of action is taken to restore such markings in a timely manner (See paragraph 6 of MUTCD Section 3A.03)

How detailed should my documentation be? The FHWA does not require agencies to submit documentation. An agency may choose to document their method and maintenance activities for their own purposes, such as scheduling, budgeting resources, defense against litigation, etc

Am I allowed to use resources or take actions outside my written or documented method and still be considered in compliance? An agency is responsible for maintaining pavement markings regardless of whether or not the method is documented. While detailed documentation is useful for business practices and consistency, it is unlikely to address every event or circumstance. For example, an agency would be prudent to schedule reapplication of markings on sections of abnormal wear that are discovered during inspections or routine maintenance, even if that is not part of their written procedure or typical practice.

APPENDIX A. MUTCD LANGUAGE ASSOCIATED WITH THE SUPPLEMENTAL NOTICE OF PROPOSED AMENDMENT FOR THE 2009 MUTCD

Section 3A.03 Maintaining Minimum ~~Pavement Marking~~ Retroreflectivity

Standard:

01 Except as provided in Paragraph 5, a method designed to maintain retroreflectivity at or above 50 mcd/m^2/lx shall be used for longitudinal markings on roadways with statutory or posted speed limits of 35 mph or greater.

Guidance:

02 Except as provided in Paragraph 5, a method designed to maintain retroreflectivity at or above 100 mcd/m^2/lx should be used for longitudinal markings on roadways with statutory or posted speed limits of 70 mph or greater.

03 The method used to maintain retroreflectivity should be one or more of those described in "Methods for Maintaining Pavement Marking Retroreflectivity" (see Section 1A.11) or developed from an engineering study based on the values in Paragraphs 1 and 2.

Support:

04 Retroreflectivity levels for pavement markings are measured with an entrance angle of 88.76 degrees and an observation angle of 1.05 degrees. This geometry is also referred to as 30-meter geometry. The units of pavement marking retroreflectivity are reported in mcd/m^2/lx, which means millicandelas per square meter pre lux.

Option:

05 The following markings may be excluded from the provisions established in Paragraphs 1 and 2:

A. Markings where ambient illumination assures that the markings are adequately visible;
B. Markings on roadways that have an ADT of less than 6,000 vehicles per day;
C. Dotted extension lines that extend a longitudinal line through an intersection, major driveway, or interchange area (see Section 3B.08);
D. Curb markings;
E. Parking space markings; and
F. Shared-use path markings.

Support:

06 The provisions of this Section do not apply to non-longitudinal pavement markings including, but not limited to, the following:

A. Transverse markings;
B. Word, symbol, and arrow markings;
C. Crosswalk markings; and
D. Chevron, diagonal, and crosshatch markings.

07 Special circumstances will periodically cause pavement marking retroreflectivity to be below the minimum levels. These circumstances include, but are not limited to, the following:

A. Isolated locations of abnormal degradation;
B. Periods preceding imminent resurfacing or reconstruction;
C. Unanticipated events such as equipment breakdowns, material shortages, contracting problems, and other similar conditions; and
D. Loss of retroreflectivity resulting from snow maintenance operations.

When such circumstances occur, compliance with Paragraphs 1 and 2 is still considered to be achieved if a reasonable course of action is taken to restore such markings in a timely manner.

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