TRAFFIC ENGINEERING & HIGHWAY SAFETY BULLETIN 15-02
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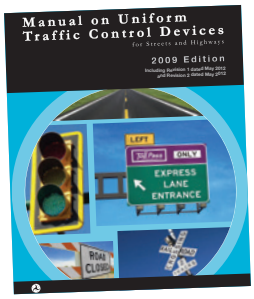
Pavement Marking Materials

Definitions and Overview

Pavement markings are markings on the physical surface of a roadway or shoulder that provide guidance and information to road users. Unlike other traffic control devices, pavement markings are visible to drivers without requiring them to take their eyes off the roadway. Because they provide visual guidance, providing pavement markings is an effective, low-cost strategy to prevent vehicles from encroaching on the roadside or other travel lanes and has been shown to reduce run-off-the-road (roadway departure) and cross-over-the-centerline crashes.



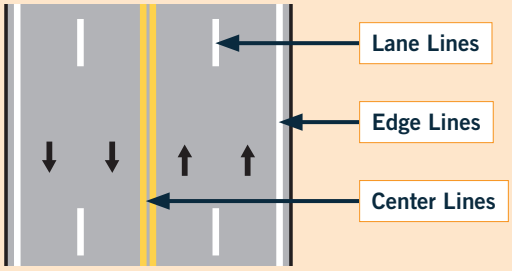
Part 3 of the Federal Highway Administration's (FHWA's) *Manual on Uniform Traffic Control Devices* (MUTCD) includes standards and guidance for pavement markings as well as other "markings" including delineators, channelizing devices, islands, and rumble strips. These standards include warrants for installation of various types of longitudinal markings such as center lines, lane lines, and edge lines. Additional guidance is contained in Chapter 3 of SDDCTEA Pamphlet 55-14, "Traffic Engineering for Better Signs and Markings," and Chapter 6 of SDDCTEA Pamphlet 55-17, "Better Military Traffic Engineering."

While these manuals clearly detail standards for installation of pavement markings, the primary challenge facing most agencies is the maintenance of existing markings. In order to be effective, it is critical that pavement markings be made of durable material and well maintained or replaced as needed.

Pavement Marking Categories

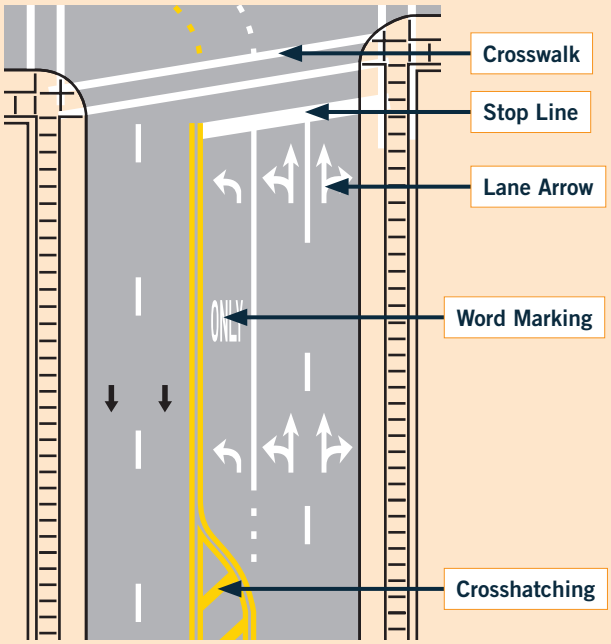
Longitudinal Markings

Help facilitate vehicle guidance and location. Example:



Transverse Markings

Provide warning and regulatory information to the motorist. Example:



In This Issue

Types of Pavement Marking Materials

Many different types and classes of pavement marking materials are available today. Common types of materials used in the United States for pavement markings include:

Waterborne paint	• Sprayable latex paint with embedded glass beads • Typically heated prior to application • Most common and lowest cost material for longitudinal lines • Generally less durable than other materials • Less sensitive to changes in temperature and moisture than thermoplastics
Preformed (cold) thermoplastic	• Preformed, ready to position thermoplastic markings with partially embedded glass beads • Applied with a propane heat torch • Most common material for transverse markings and other labor-intensive markings
Hot thermoplastic	• Four-component material consisting of thermoplastic binder, pigment, glass beads, and filler • Most commonly sprayed but also can be extruded • Provides high durability and good retroreflectivity when applied properly • Well suited for use on asphalt surfaces • Relatively low cost • Frequently used for longitudinal markings in high-traffic areas
Preformed plastic tape	• Cold applied (preformed) polymer tape with no drying or curing time • Applied by removing adhesive backing and pressing onto the pavement with a roller or truck tire • Significantly higher initial cost • Highly durable and abrasion-resistant with excellent retroreflectivity • Frequently used for transverse markings or longitudinal markings in high-traffic areas
Epoxy	• Sprayable epoxy resin paint • Exceptional adhesion to both bituminous and concrete surfaces with good abrasion resistance and retroreflectivity • More expensive than waterborne paints and about the same or slightly more expensive than thermoplastics
Methyl methacrylate (MMA)	• Non-hazardous, two-component material that can be sprayed or extruded • Has been shown to provide much longer service life than waterborne paint and perform well in cold weather climates • Bonds well to concrete pavements and is resistant to common surface chemicals such as oil and antifreeze • Cost comparable to epoxy materials • Requires special equipment for application
Polyurea	• Sprayable, two-component material • Marketed as durable material that provides exceptional color stability, resistance to abrasion, and adhesion to all pavement surfaces with less sensitivity to pavement surface moisture and temperature • Some materials must be applied by special striping apparatus while others can be applied with standard epoxy truck

Source: TxDOT Pavement Marking Handbook

Installations should use ONLY those materials that are approved for use in the State in which the installation is located. In addition, inlaid blocks, bricks, and metal strips should never be used for pavement markings.

Application Considerations

Not all pavement-marking materials are compatible with each other or with some road surfaces or climates. Both the Texas Department of Transportation's (TxDOT's) *Pavement Marking Handbook* and the Minnesota Department of Transportation's (MnDOT's) *Pavement Marking Field Guide* contain detailed guidance regarding the application of various pavement marking materials. Because pavement marking material performance is so dependent upon proper application, these manuals contain troubleshooting guides for each material to address issues including thickness, width, coverage, adhesion, retroreflectivity, smearing/tracking, and discoloration.

The following are application considerations for two of the most common pavement marking materials:

Waterborne paint	• The pavement surface must be dry and free of dirt, dust, and other contaminants, including poorly adhered old markings and glass beads. • The air and pavement temperatures must be above the dew point and at least 40°F. • There must be no serious threat of rain within 4 hours after application.
Thermoplastics	• The pavement surface must be dry and free of dirt, dust, and other contaminants, including poorly adhered old markings and glass beads. • Pavement and air temperatures must be at least 50°F and 55°F, respectively. • Do not apply on top of any existing marking materials other than thermoplastic. Loose thermoplastic should be removed, and any oxidized old thermoplastic should be scraped to expose fresh surface material.

Pavement type and age should be considered during material selection. Many State DOTs have recommended material types and application specifications for certain pavement types. These specifications will vary by agency, but the following are some common considerations:

New asphalt pavements	• Waterborne paint may dissolve road oils and cause a discoloration of the pavement marking. A double application may be necessary to achieve proper color and is sometimes specified. • Nearly all thermoplastic materials are well-suited for new asphalt surfaces given the thermal bond that is formed via heat fusion. • Permanent tape can be inlaid into freshly placed bituminous surfaces.
Old asphalt pavements	• Asphalt surfaces wear and become more brittle through traffic exposure and oxidization over time. In order to aid in forming a thermal bond, primers are recommended prior to application of thermoplastics on asphalt surfaces that are older than a specified threshold (typically 2-3 years), heavily oxidized, or have exposed aggregates. • Permanent tape can be grooved into older bituminous surfaces while temporary tape can be glued into place. However, permanent tape is not typically a cost-effective choice for older asphalt pavements given the higher cost of the tape and the potential for roadway resurfacing. • Waterborne paint may be used on older asphalt pavements without primer.
Concrete pavements	• Thermoplastics are generally undesirable on concrete surfaces due to the potential for premature de-bonding of the material since a thermal bond is not possible. Therefore, primers are recommended prior to application of hot thermoplastics on all concrete surfaces (particularly those that are new) to enable a mechanical bond between the liquid thermoplastic and the pores of the concrete. • Permanent tape can be grooved into concrete surfaces while temporary tape can be glued into place. • Waterborne paint may be used on concrete pavements without primer. • Epoxies are commonly used by State DOTs and do not require a primer application on any road surfaces.

Maintenance and Service Life

Service Life: **The time required for a pavement marking to become ineffective due to having lost its luster, lost its retroreflectivity, or worn completely from the pavement.**

The performance of pavement marking materials is dependent on the type of road surface, the quality of application, and winter maintenance. Some materials work better in the colder adverse weather conditions than other products, but there is no guarantee that these materials will be the best in warm climates. Military installations are encouraged to review their material specifications with the local State DOT.

Pavement marking materials are tested and certified by the American Association of State Highway and Transportation Officials' (AASHTO's) National Transportation Product Evaluation Program (NTPEP) using the American Society for Testing and Materials (ASTM) Specification D 713, the Accelerated Wear Test, for various pavement surface types under various traffic volume levels and environmental conditions. NTPEP reports for various manufacturers and materials are available on AASHTO's website.

Source: Kimley-Horn

Pavement markings can reach the end of service life because of loss of material due to chipping and abrasion or loss of pigment/color change resulting in reduced daytime visibility, as well as, because of bead loss resulting in poor nighttime retroreflectivity. Pavement markings should be inspected annually to ensure that they are in acceptable condition, and installations should generally expect to replace markings every two years or less.

Although waterborne paint is typically the most cost-effective pavement marking material, it is generally the least durable. While past research has shown that expected service life for waterborne paint is often 1 year or less, significant improvements have been made in recent years; and in most cases, the better quality waterborne paints will last at least 2 years. Many State DOTs recommend waterborne paint for use only on lower volume highways (less than 10,000 vehicles per day average daily traffic [ADT]).

According to the TxDOT *Pavement Marking Handbook*, thermoplastic pavement markings have been known to last from 5 to 8 years—depending on traffic volumes—when properly formulated for a given roadway surface and correctly applied. However, research has shown that usual service lives range from 3 to 4 years depending on traffic volumes. It is especially well-suited for asphalt pavements.

Epoxy is another durable material that adheres well to both asphalt and concrete surfaces and has been known to provide service lives in excess of 5 years. Tape (preformed) is a very durable material that has been known to last up to 8 years. Numerous agencies have conducted research on expected service lives of various materials, including Texas Transportation Institute, Indiana DOT, and Idaho DOT. The following matrix presents general materials selection considerations.

Material	Relative Cost	Traffic Volumes			Pavement Material			Marking Type		Service Life (in years)
		Low (<10,000 ADT)	Medium (10,000-50,000 ADT)	High (>50,000 ADT)	New Asphalt	Old Asphalt	Concrete	Longitudinal	Transverse	
Waterborne paint	$	✓			✓	✓	✓	✓		0.5-1
Preformed (cold) thermoplastic	$$	✓	✓	✓	✓	✓*	✓*		✓	3-5
Hot thermoplastic	$$	✓	✓		✓	✓*	✓*	✓	✓	3-5
Preformed plastic tape	$$$		✓	✓	✓	✓*	✓*	✓	✓	4-8
Epoxy	$$	✓	✓	✓	✓	✓	✓	✓		3-5
MMA	$$	✓	✓	✓	✓		✓	✓		2-4
Polyurea	$$	✓	✓	✓	✓	✓	✓	✓		3-5

* *with primer application*

Retroreflectivity

According to FHWA, about half of all fatal crashes occur at night. Considering that only about one quarter of travel occurs after dark, the crash rate is approximately three times higher at this time than during the day. To improve highway safety, nighttime driver visibility should be increased through the use of roadway lighting and/or retroreflective signs and pavement markings. The retroreflectivity of pavement markings makes them visible to drivers at night when their vehicle's headlights reflect off the material.

Paint and most other pavement marking materials rely on round glass beads embedded into the surface of the material to make them retroreflective. Proper application and drying time, if applicable, are critical to achieving good levels of retroreflectivity for pavement markings. In addition, because the retroreflective properties of markings deteriorate over time, pavement markings need to be actively maintained to ensure that they are clearly visible at night.

MINIMUM LEVELS OF RETROREFLECTIVITY

In 1993, Congress directed the U.S. Secretary of Transportation to revise the *MUTCD* to include minimum levels of retroreflectivity for both traffic signs and pavement markings, and after extensive research, FHWA adopted minimum retroreflectivity values for traffic signs in 2007. Although FHWA has not adopted minimum retroreflectivity for pavement markings, Section 3A.02 of the *MUTCD* currently states, "Markings that must be visible at night shall be retroreflective unless ambient illumination assures that the markings are adequately visible." In April 2010, FHWA published a proposed change to Section 3A.03 of the *MUTCD* to include minimum retroreflectivity values for pavement markings. Refer to SDDCTEA Pamphlet 55-14 for these proposed minimum retroreflectivity values.

Source: MnDOT

The minimum values are proposed to apply to center lines, lane lines, and edge lines that are either required or recommended in the *MUTCD* (Section 3B). The requirements are significantly higher for two-lane roads with only center line markings than for all other roads (such as those with edge lines). FHWA also proposes two exceptions to the requirements:

- Where raised retroreflective pavement markers (RRPMs) are used to supplement or substitute for longitudinal lines and are maintained such that at least three are visible from any position along that line during nighttime conditions
- Where continuous roadway lighting assures that the markings are visible

FHWA is proposing several ways for agencies to manage minimum retroreflectivity levels and plans to publish the details of these methods in a future report, *Methods for Maintaining Pavement Marking Retroreflectivity*. The SDDCTEA team recognizes a number of challenges with maintaining proposed minimum levels of retroreflectivity for pavement markings, as summarized in Pamphlet 55-14 and reiterated below:

Concerns with any Future Minimum Retroreflectivity Values

1.	Most markings are "manufactured" on location under varying temperature and humidity conditions, applied over existing surfaces that may be less than ideal (e.g., rough texture due to surface treatment, oil contaminants, etc.), and sometimes vehicles drive on the markings before they are cured, all of which have a negative effect on the retroreflectivity.
2.	Some properly-applied markings deteriorate much faster than other markings because vehicles frequently ride on or cross over the markings (e.g., longitudinal lines in heavy weaving areas, around curves, and at intersections). In addition, the asphalt in bituminous roadways sometimes bleeds and the material may track onto the markings, causing discoloration and loss of retroreflectivity.
3.	Snowplows, sanding, chemicals, and tire studs and chains cause markings to deteriorate very quickly during the winter months within many areas, and blowing sand may also cause similar problems in other areas.
4.	If markings wear out during the winter, it may not be possible to replace them for several months.

Removal of Pavement Markings

When traffic patterns change or travel lanes are modified, it is important to remove the old pavement markings and apply new ones in the proper location. A common problem on military installations has been the improper removal of markings, which can have a number of undesirable effects:

- Black paint has been used in the past to cover existing markings, but the paint eventually wears thin and causes the unwanted marking to become visible again. In addition, black painted lines can be compelling during the day and are often more visible on a wet night than the real pavement markings.
- The scars left by some removal methods (such as grinding) also may appear like additional pavement markings.
- Markings may be only partially removed.
- If conflicting markings exist due to any of the above improper methods, it can create a hazardous condition for motorists by confusing drivers and increasing the potential for driver error and, therefore, crashes.

Markings that are no longer applicable for roadway conditions or restrictions and that might cause confusion for the road user shall be removed or obliterated to be unidentifiable as a marking as soon as practical.

Source: MUTCD (Section 3A.02)

All pavement marking removal methods have drawbacks, but the goal is to effectively remove the existing marking while at the same time minimizing damage to the pavement. Although grinding has been used to remove old markings, this process creates permanent scars that will frequently exist for the life of the pavement. Therefore, unless the pavement will be overlaid, grinding should not be used. Another method is high-pressure blasting with water or an abrasive such as sand or shot. Thermoplastic markings cannot withstand abrasive blasting because the heat generated by the process melts the thermoplastic. Hydro-blasting with water can cause slick pavements in the wintertime. TxDOT's *Pavement Marking Handbook* indicates that permanent tapes (especially those that are inlaid) can only be removed by a small number of methods that are often destructive to the pavement surface (such as grinding). Because tape must always be removed prior to the placement of new markings, the challenging removal of this material is a major drawback to its use.

SDDCTEA's preferred eradication method to remove old markings is high-pressure water blasting. The *MUTCD* also allows markings to be temporarily masked with tape (not paint) that is approximately the same color as the pavement until they can be removed or obliterated. MnDOT's *Pavement Marking Field Guide* notes that lines and scars from line removal may look different at night and recommends nighttime inspections to determine that the obsolete pavement markings are not visible and that the correct markings are understandable under both day and night conditions.

Source: MnDOT

Active Vehicle Barrier Markings and Delineation

Per the Unified Facility Criteria (UFC), an active vehicle barrier (AVB) is required at the end of the threat response zone to provide containment in the event that an installation's entry control facility (ECF) security is compromised by a potential threat. AVBs should function such that they can be opened/lowered (or kept in the open/down position) to allow vehicles entering the installation to traverse them under normal conditions. AVBs should be properly delineated to ensure that they are visible to drivers when closed/raised.

Various types of AVBs are used and have different considerations for delineation, as described in Chapter 8 of SDDCTEA's Pamphlet 55-15, "Traffic and Safety Engineering for Better Entry Control Facilities":

Nets	Span multiple lanes but have limited surface area for delineation
Wedges	Fixed object providing significant surface area for delineation
Bollards	Have limited surface area for delineation
Crash Beams	Have limited surface area for delineation
Spikes	Best as a secondary AVB

AVB Markings

Improper Orientation and Colors

Correct Orientation and Colors

Source: SDDCTEA Pamphlet 55-15

AVBs are often improperly delineated using the wrong colors and/or orientation for markings. The use of red and white stripes is appropriate because of the stop condition that is required for the impact hazard. Additionally, since these devices are typically centered within the travel way, striping should be oriented vertically, similar to automatic gate arms for railroad crossings as specified in the *MUTCD* (Section 8C.04). The backside of barriers also should be delineated to the extent possible with the same vertical configuration.

As specified in SDDCTEA Pamphlet 55-15, the markings used to delineate the AVBs should be durable to withstand daily traffic, satisfy FHWA retroreflective requirements for warning signs, and maintain retroreflectivity based on expected traffic for a minimum of 2 years. Only State DOT approved and tested materials and application procedures should be used. When designing AVB markings, installation personnel should consult SDDCTEA and the local State DOT for a list of manufacturers that may be able to provide markings that satisfy all requirements. Potential materials to consider include retroreflective sheeting, retroreflective paint, and permanent tape.

TRAFFIC ENGINEERING & HIGHWAY SAFETY BULLETIN

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Sources

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Prepared with the assistance of Kimley»Horn