Traffic Engineering & Highway Safety Bulletin

Military Surface Deployment and Distribution Command Transportation Engineering Agency

Bldg. 661 Sheppard Place, Ft. Eustis, VA 23604

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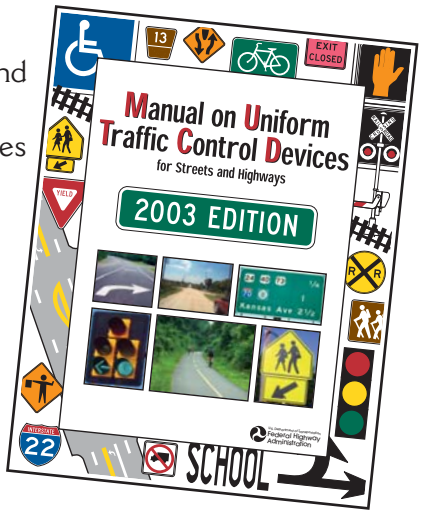
Markings

Did You Know?

Most people understand the term "pavement markings," but traffic engineers generally use the shorter but more encompassing term, "markings." "Markings" includes not only pavement markings such as center lines, stop bars, pavement legends, and arrows; but also curb markings, delineators, and channelizing devices.

Like traffic signs and signals, markings should always conform to the Federal Highway Administration's (FHWA's) *Manual on Uniform Traffic Control Devices* (*MUTCD*). Specifically, Part 3 of the *MUTCD* addresses markings, and is available at http://mutcd.fhwa.dot.gov/pdfs/2003r1r2/ch3.pdf.

Markings frequently supplement signs or traffic signals to provide guidance on roadway alignment, no-passing zones, turn restrictions, and stopping locations. And, like other types of traffic control devices, markings should meet the following five basic requirements:



- ✓ Fulfill a need;
- ✓ Command attention;
- ✓ Convey a clear, simple meaning;
- ✓ Command respect from road users; and
- ✓ Give adequate time for proper response.

"Pavement markings" are the most common type of "markings" and, as the name implies, they are always on the physical surface of a roadway or the shoulder. Unlike other traffic control devices, pavement markings are visible to drivers without requiring them to take their eyes off the roadway.

Pavement markings typically consist of waterborne paints and thermoplastic tape. Inlaid blocks, bricks, and metal strips should not be used as pavement markings.

IN THIS ISSUE:

Pavement markings may be categorized into two primary groups:

- ✓ Longitudinal markings help facilitate vehicle guidance and location.
- ✓ Transverse markings provide warning and regulatory information to the motorist.

Both types of pavement markings provide vital information to the vehicle operator. Therefore, they must be uniform in design, position, and application.

Longitudinal Markings

Longitudinal markings are the primary source of information for positioning vehicles on the roadway. It is important that markings be uniform so they can be recognized and understood instantly by all drivers. The *MUTCD* provides the basic principles to which all pavement markings should adhere.

Proper installation and maintenance of pavement markings is important since longitudinal construction joints can sometimes be falsely interpreted as pavement markings. When markings become worn, drivers tend to follow these joints, particularly in adverse weather or at night.

Longitudinal markings should have a minimum width of 4 inches, although wider lines are helpful both day and night. Examples of pavement marking dimensions are shown in the illustration below.

What is Wrong with This Picture?

Answer on Page 10

Exhibit 1 shows basic types of longitudinal markings. Warrants for the use of pavement markings are contained in the *MUTCD*. Exhibit 2 outlines the *MUTCD* warrants for center lines and edge lines.

Center line pavement markings should be solid yellow longitudinal lines unless passing is permitted for traffic in the lane adjacent to the line. Moreover, passing is only permitted if there is adequate sight distance in accordance with the warrants in the MUTCD.

TYPICAL DIMENSIONS

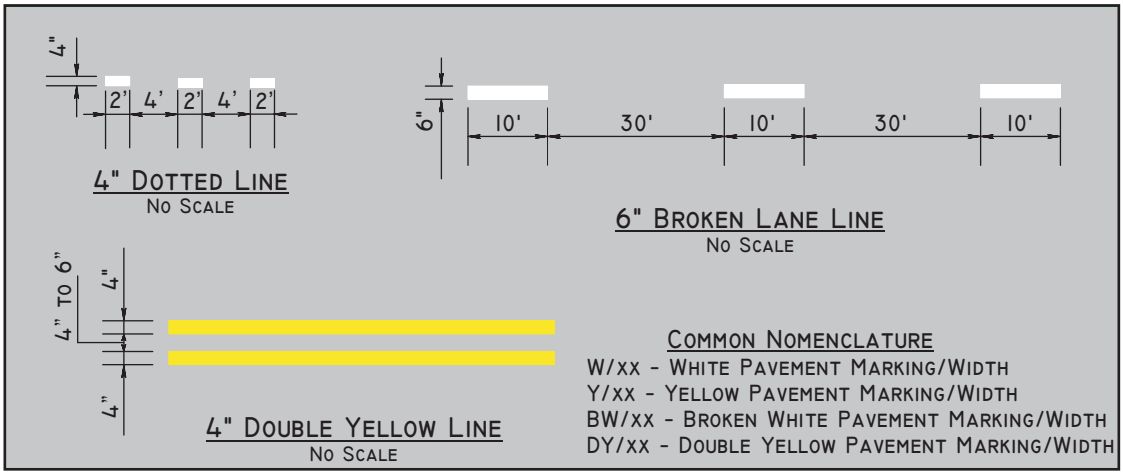
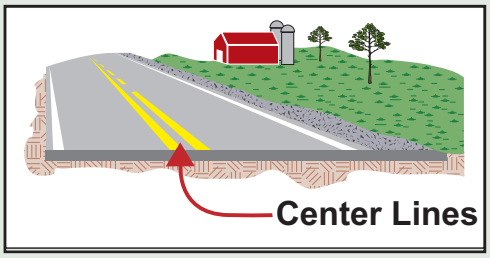
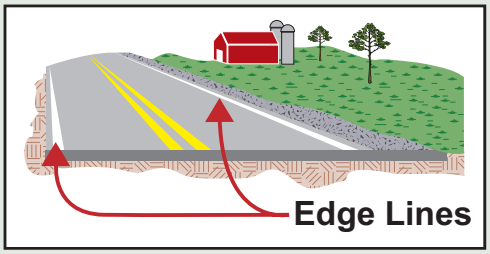


Exhibit 1: Primary Longitudinal Pavement Markings

SOLID YELLOW LINE	The solid yellow line indicates a no-passing zone applying to traffic with the solid line to its immediate left. Used alone, a single solid yellow line is only used to define the median of a freeway or divided roadway, or the left edge of a one-way roadway.
DOUBLE SOLID YELLOW LINE	A double solid yellow line divides lanes of traffic flow in opposing directions where passing is prohibited in both directions.
BROKEN YELLOW LINES	A broken yellow line defines the center of a two-lane, two-way roadway where passing is permitted in both directions.
COMBINATION SINGLE SOLID/BROKEN YELLOW LINE	This combination is used when passing is permitted in one direction (adjacent the broken yellow), and prohibited in the other (adjacent the single solid).
BROKEN WHITE LINES	A broken white line is used to delineate lanes for travel in the same directions. Lane changing is permitted.
SOLID WHITE LINE	A solid white line is used to mark the right edge of the roadway, and to mark lanes for travel in the same direction where lane changing is discouraged. Its normal application is as a lane line on multilane approaches to intersections and, particularly, to delineate left- and right-turn lanes.
DOUBLE SOLID WHITE LINE	The double solid white line is used for travel in the same direction, but crossing the double line is prohibited. For example, a double solid white line may be used on a bridge to prevent lane changing.
DOTTED LINES	The dotted line delineates the extension of pavement markings through an intersection or interchange area. It should be the same width and color as the line it extends.

Source: FHWA, *MUTCD*

Exhibit 2: Warrants for Pavement Markings

TYPE, PURPOSE, AND APPLICATION	*MUTCD* CRITERIA	BENEFITS
CENTER LINES  ✓ Provides separation of traffic traveling in opposite directions ✓ Provides delineation of separation	Standards: ✓ Mandatory for all paved urban arterials and collectors with a travel way width of 20 feet or more and an ADT of 6,000 or more ✓ Mandatory for all paved two-way streets or highways that have three or more traffic lanes Guidance: ✓ Should be placed on all urban arterials and collectors with a travel way of 20 feet or more and ADT of 4,000 or more ✓ Should be placed on all paved rural arterials with a travel way width of 18 feet or more and an ADT of 3,000 or more ✓ May be placed on paved travel ways less than 16 feet wide if a traffic engineering assessment indicates	✓ 30% reduction in head-on crashes
EDGE LINES  ✓ Provides an edge of pavement guide for drivers ✓ May result in lower speeds since travel lanes appear narrower	Standard: ✓ Mandatory for freeways, expressways and paved rural arterials with travel way widths of 20 feet or more and an ADT of 6,000 or more Guidance: ✓ Should be placed on all rural arterials and collectors with a travel way of 20 feet or more and an ADT of 3,000 or more Options: ✓ May be placed where center lines are not present ✓ May be used to minimize driving on shoulders	✓ 11 to 25% reduction in run-off-the-road crashes

Source: FHWA, *MUTCD*

Raised Pavement Markers

Raised Pavement Markers (RPMs) can be used to increase the visibility of pavement markings. They should be the same color as the pavement markings they supplement (except on divided roadways, where the backside facing wrong-way traffic may be red).

RPMs can be used in snow zones, but it is necessary to specify a more expensive snowplowable model that is partially embedded into the road surface. To protect the retroreflective surfaces, these special RPMs have metal rails on both sides of the unit to lift the snowplow blade up and over the retroreflectors.

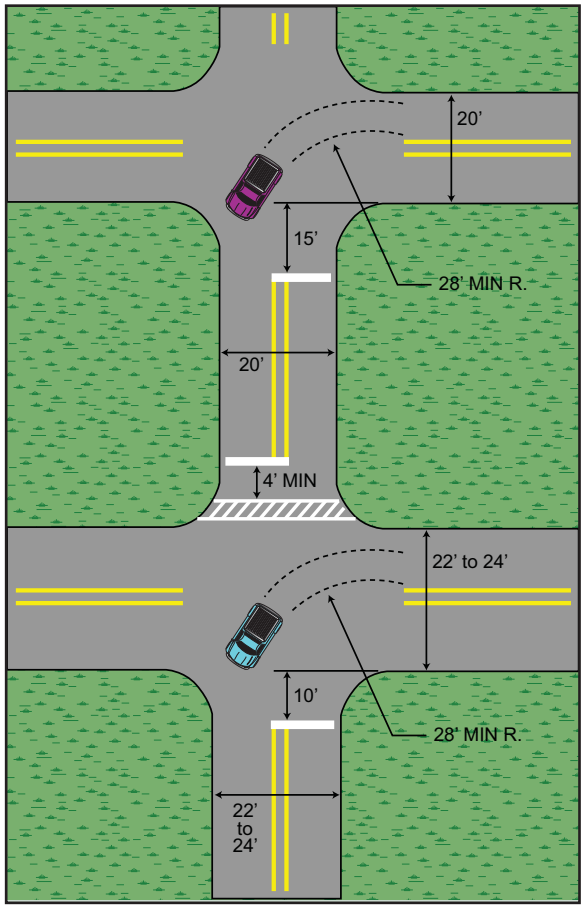
Transverse Markings

Transverse markings may indicate a command to stop at an intersection, to advise caution for pedestrians in a crosswalk, or to advise against travel within boundaries defined by crosshatching or painted islands. Transverse markings include:

- ✓ Stop lines and yield lines
- ✓ Word and symbol markings
- ✓ Crosshatch lines
- ✓ Crosswalks

Stop lines supplement STOP signs and traffic signals. When used, the location of the stop line is determined primarily by the geometry of the intersection, road width, sight distance, and the design-vehicle turn radius. This is illustrated in the figure below. The stopping point should be positioned on the approach leg such that it will not conflict with vehicles turning left from the cross street.

STOP LINE PLACEMENT

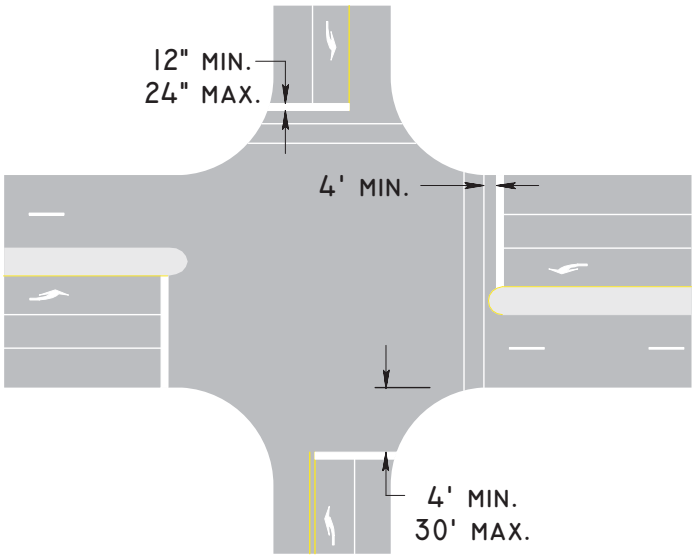


Although stop lines are not necessary at all stop locations, they should be provided where crosswalks are present, and at signalized intersections.

Locate the stop line a minimum of 4 feet in advance of the nearest crosswalk marking. In the absence of a marked crosswalk, locate the stop line at the desired stopping point, but in no case less than 4 feet or more than 30 feet from the edge of the intersecting roadway. The location of the stop line is independent of the location of the STOP sign.

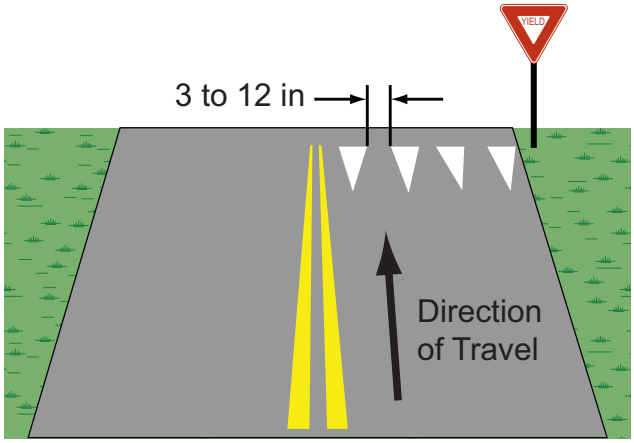
The stop line is retroreflective white and is no less than 12 nor more than 24 inches wide. The width depends on the speed of the roadway and/or the presence of hazardous conditions.

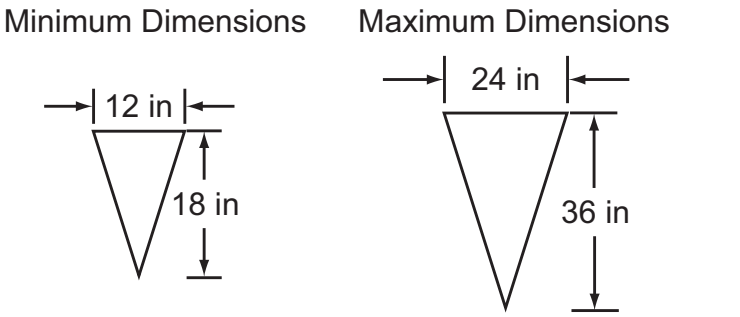
STOP LINE PLACEMENT



Similarly, yield lines may supplement YIELD signs or Yield Here To Pedestrian signs. Determining their location is similar to determining the location of stop lines. When used, yield lines consist of a row of solid white isosceles triangles pointing toward approaching vehicles extending across lanes to indicate the point at which drivers are to yield. Yield line placement examples are illustrated on page 6. The individual triangles should have a base of 12 to 24 inches, and a height equal to 1.5 times the base. The space between the triangles should be 3 to 12 inches.

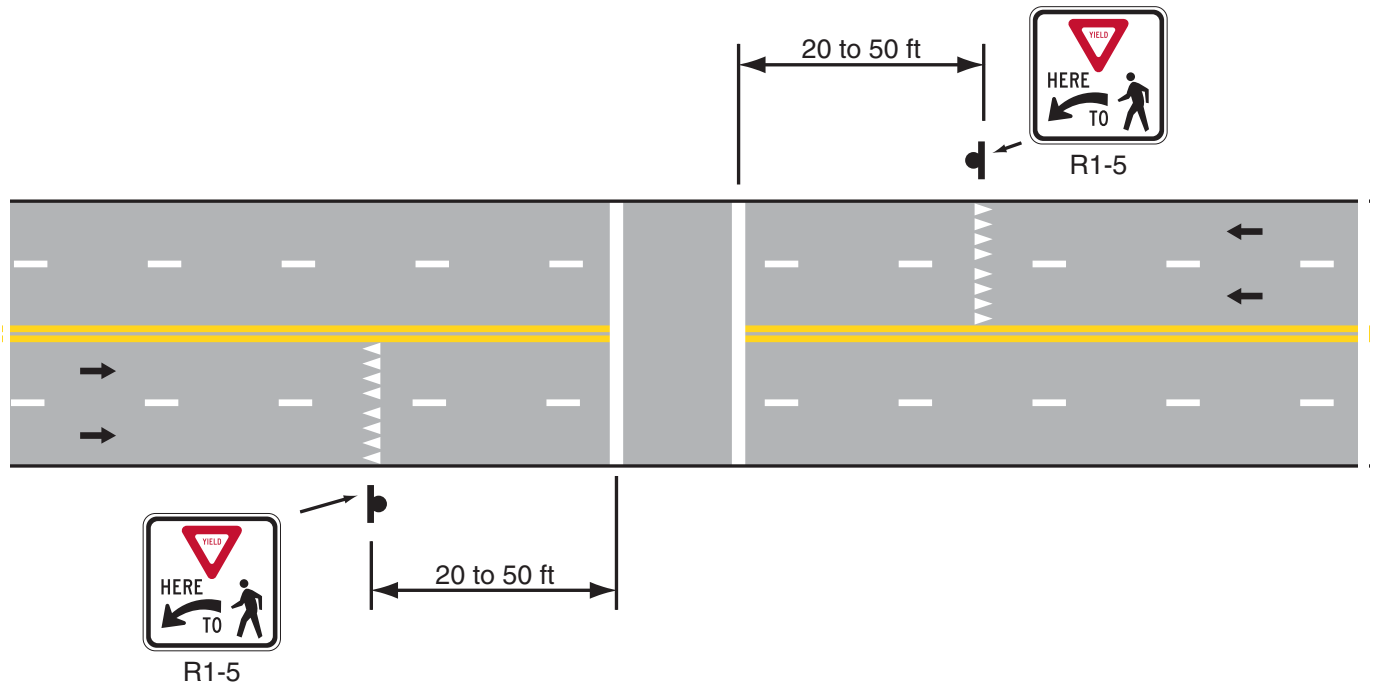
TYPICAL YIELD LINE PLACEMENT





Note: Triangle height is equal to 1.5 times the base dimension.

OPTIONAL USE OF YIELD LINES AT UNSIGNALIZED MID-BLOCK CROSSWALKS



A common mistake is placing stop or yield lines too far away from the intersecting road where drivers do not have a clear view of traffic on the crossing road. As a result, drivers sometimes enter the intersection without proper clearance because they had inadequate sight distance.

Therefore, it is very important to check sight distance to both the left and the right before finalizing the location of a stop or yield line. Keep in mind that a driver's eyes will typically be about 10 feet behind the line and at an elevation about 3.5 feet above the pavement.

Word and Symbol Markings

Pavement word and symbol markings may be used for guiding, warning, or regulating traffic. They are generally used at intersections for lane assignment, or on roadways when special situations exist where additional guidance to the motorist is required. In such cases, they should be limited to no more than three lines of information and shall be white with retroreflective properties.

Although multiple lane approaches to intersections may be marked with lane-use arrows, it can often be difficult for motorists to determine which lane to use at an intersection. This can become more difficult at nighttime, in wet conditions, and when pavement markings become worn. To supplement pavement markings, lane-use control signs should be installed on multiple lane approaches. The *MUTCD* provides guidelines for the installation of these signs.

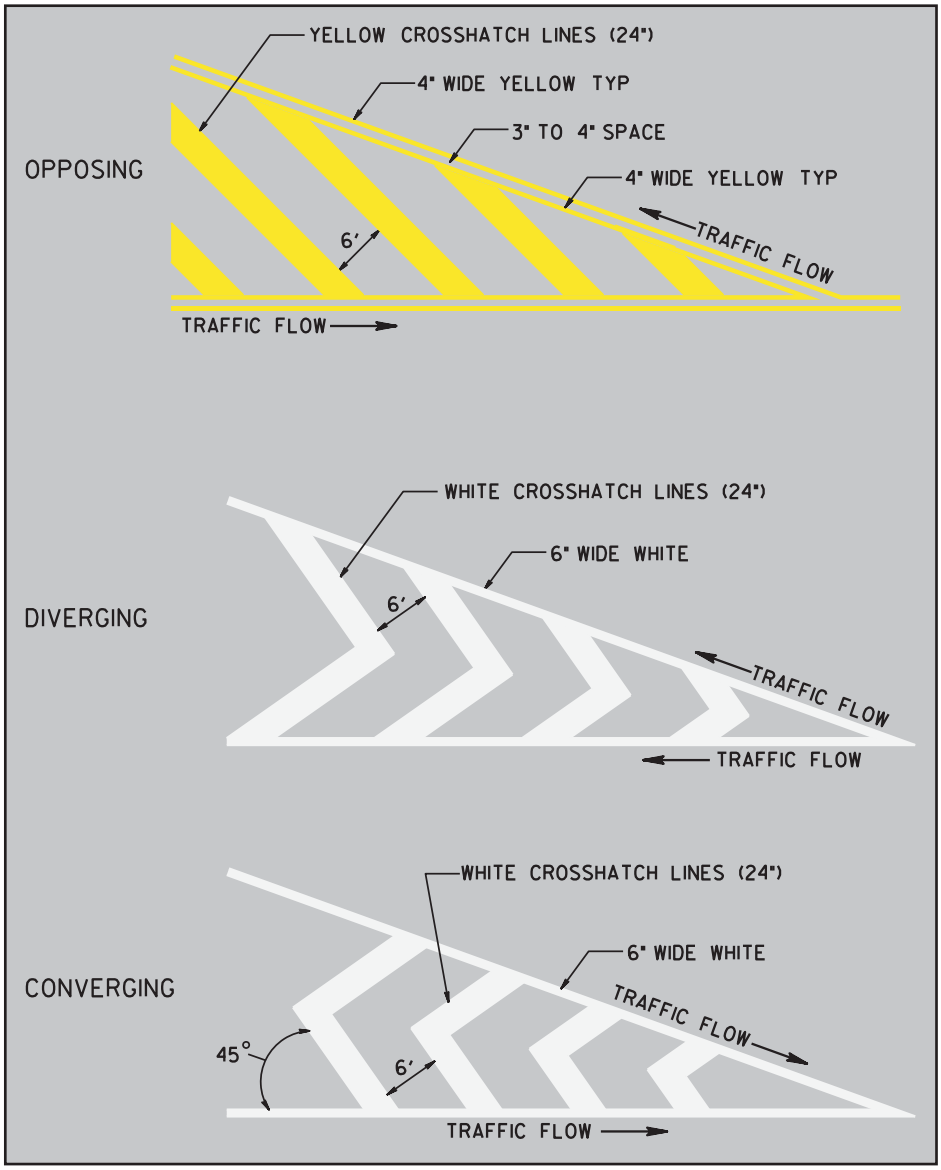
Crosshatch Lines

Crosshatch lines indicate an area, within defined boundaries, over which vehicular traffic should not travel. They may be used in conjunction with divisional and channelizing islands, on approaches to obstructions, and on paved shoulders. However, prudent use of these lines is recommended. Crosshatch lines should be sloped in the direction of traffic flow. Within a particular area they may all slant in one direction, or, if traffic passes on more than one side, they may slope in various directions.

Crosshatch lines are commonly used at the following locations:

- ✓ Wide medians (yellow lines)
- ✓ Channelization islands at intersections (white or yellow lines)
- ✓ Shoulders (white lines, except yellow on the left side of one-way roads)
- ✓ ECF areas, around ID check islands (white or yellow lines)

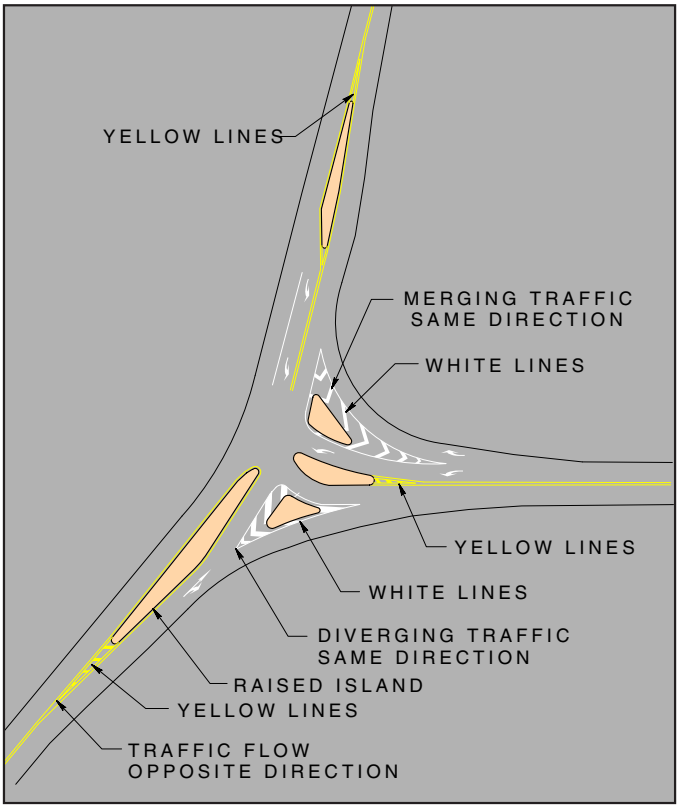
TYPICAL CROSSHATCHING



Painted Islands

Islands may be formed with pavement markings to channelize traffic. Where travel in the same direction is permitted on both sides, an 8-inch-wide or double solid white line should be used to mark the channelizing island. Where islands separate travel in opposite directions, double yellow lines should be used. For added emphasis, painted crosshatching may be placed within the island, in which case the crosshatch markings should be the same color as the lines that outline the island.

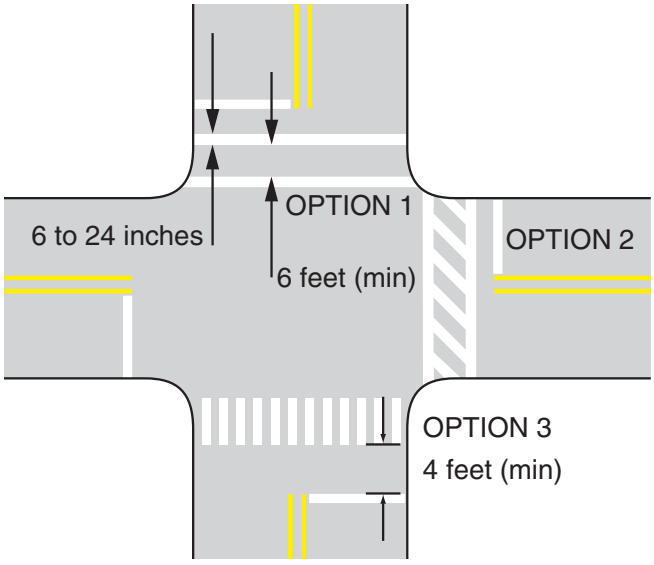
PAINTED ISLANDS



Crosswalks

When crosswalk lines are used, they should be solid white lines and should not be less than 6 inches nor greater than 24 inches in width (OPTION 1). For added visibility, the area of the crosswalk may be marked with white diagonal lines at a 45-degree angle to the line of the crosswalk (OPTION 2) or with white longitudinal lines parallel to traffic flow (OPTION 3).

CROSSWALK MARKING OPTIONS



If used, the diagonal or longitudinal lines should be 12 to 24 inches wide and spaced 12 to 60 inches apart.

These types of markings may be used at locations where:

- ✓ Substantial numbers of pedestrians cross without any other traffic control device.
- ✓ Physical conditions are such that added visibility of the crosswalk is desired.
- ✓ A pedestrian crosswalk might not be expected.

Crosswalks should be at least 6 feet wide, with wider crosswalks where pedestrian demand is high.

Most people believe that marked crosswalks improve safety. However, research indicates that adding marked crosswalks generally increases the number of pedestrian crashes unless at an intersection where traffic is controlled by a traffic signal or a STOP sign, or at a location where additional safety precautions were implemented. Therefore, before installing new crosswalks, an engineering study is needed to determine whether the location is suitable for a marked crosswalk.

The study should consider traffic and pedestrian volumes, vehicle mix, vehicle speeds, sight distance, and other factors. The engineer should also consider providing raised medians or islands, reducing the street width, adding other traffic calming measures, and installing pedestrian-type signs, street lighting, etc.

As a general rule, marked crosswalks should not be considered on uncontrolled roadways that have any of the following:

- ✓ A speed limit greater than 45 mph.
- ✓ Four or more travel lanes without a raised median.
- ✓ Traffic volume greater than 15,000 vehicles a day.

Applying Pavement Markings

The most common pavement marking material is waterborne paint, which is really a latex paint. During the past few years, there were significant improvements in the quality and durability of waterborne paint; and in most cases, the better paints will now last at least 2 years.

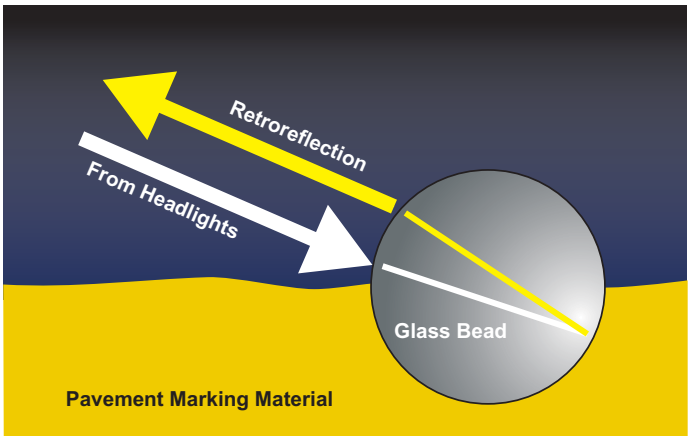
Waterborne paints are generally applied at a wet thickness of 15 mils (i.e., 0.015 inch), which translates to one gallon of paint for every 321 linear feet of 4-inch wide line. These paints will generally dry within about 2 minutes.

All pavement markings need to be retroreflective, since non-retroreflective markings are useless at night.

Almost without exception, all pavement-marking materials rely on round glass beads embedded into the surface of the pavement marking material to make them retroreflective. When a vehicle's headlights illuminate a glass bead, the light:

- ✓ Refracts or bends as it enters the bead;
- ✓ Reflects off the backside of the bead if this part of the bead is embedded in the pavement marking material;
- ✓ The reflected light becomes the color of the pavement marking material;
- ✓ Refracts again as it leaves the glass bead; and
- ✓ Returns to the general vicinity of the headlights and the driver.

PAVEMENT MARKING RETROREFLECTIVITY



Contact Us	
Phone:	DSN: 826-7418 ✦ Richard Quesenberry, P.E., PTOE Telephone: (757) 878-8654 E-mail: Richard.Quesenberry@sddc.army.mil ✦ Rick Sumrak Telephone: (757) 878-7418 E-mail: Richard.Sumrak@sddc.army.mil
Fax:	Commercial: (757) 878-7885
E-mail:	Traffic@sddc.army.mil
Mailing Address:	SDDCTEA Attn: SDTE-SA Bldg. 661 Sheppard Place Fort Eustis, VA 23604

It is essential that the proper type and quantity of glass beads are added to the paint before it solidifies. Specify at least 7 pounds of glass beads for every gallon of paint. Pavement markings should be inspected annually to ensure they are in acceptable condition.

The performance of pavement marking materials is dependant on the type of road surface, the quality of the application, and winter maintenance. Therefore, in order to specify the best materials, military installations are encouraged to review material specifications with the local highway department.

Channelizing Devices

Traffic cones or vertical panels can be used effectively for temporary channelization of traffic during lane reversal and lane closures. And if struck, they generally cause no damage.

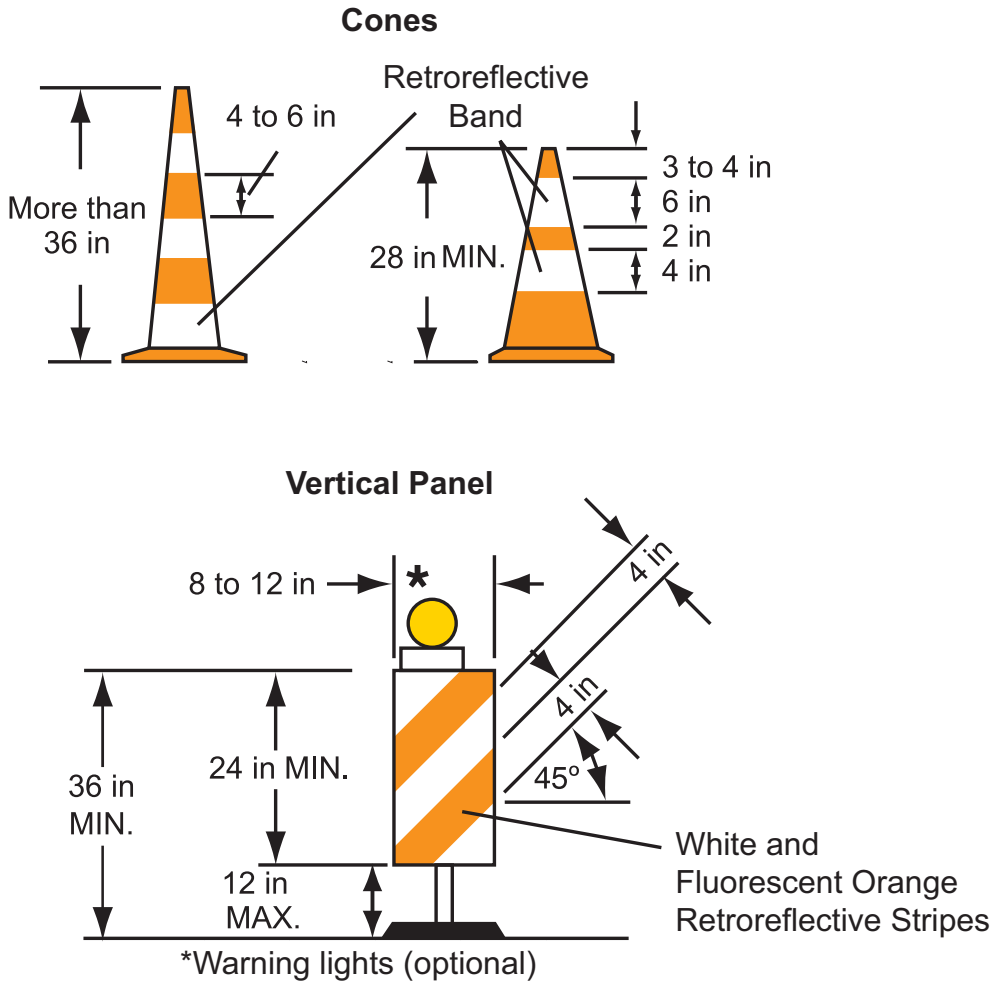
These devices are convenient since, unlike steel drums, they can be quickly placed and removed. Storage is also convenient, as traffic cones can nest one on top of another, and vertical panels can usually be collapsed or the top part can be removed from their base.

Answer from Page 2

Although the pavement markings are in good condition, the stop line is about 35 feet from the near edge of the cross street. If drivers stop at the stop line, their line of vision would be blocked by the sign and the line of trees.

Therefore, it is important to review sight distance when selecting the location of the stop line.

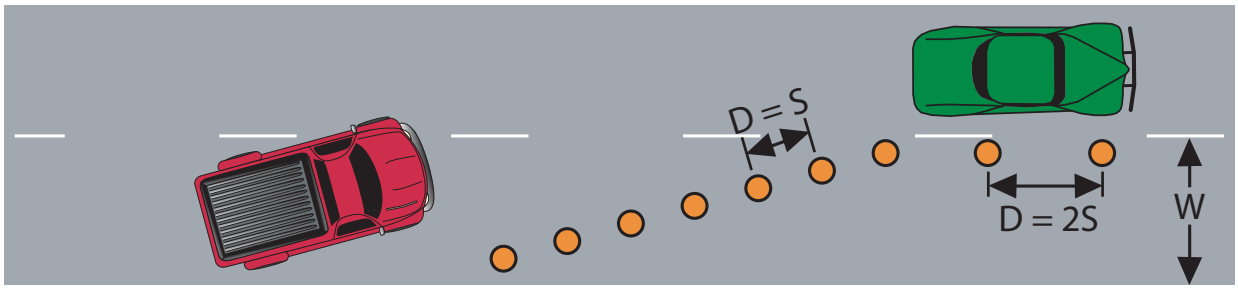
TYPICAL CHANNELIZING DEVICES



Within transitions, the distance between these devices in feet should equal the posted speed limit in miles per hour. For example, if the posted speed limit is 25 mph, the maximum spacing should be 25 feet. At other locations, such as adjacent to closed lanes, the distance between devices in feet may be double the speed limit in miles per hour.

The use of traffic cones and vertical panels should follow standard transition requirements and should not result in an abrupt change in traffic patterns. As a general rule, the taper length in feet should equal $WS^2/60$ for a speed limit of 40 mph or less, or WS for speed limits greater than 40 mph (where W is the width of the shift in feet and S is the posted speed limit in miles per hour) or 100 feet, whichever is greater.

LANE REDUCTION TAPER LENGTHS



W = Width of Shift (feet)
S = Posted Speed Limit (mph)
L = Length of Transition (feet)
D = Distance Between Channelizing Devices (feet)

$$L = \frac{WS^2}{60} \quad \text{(For } S \leq 40 \text{ mph)}$$

$$L = WS \quad \text{(For } S > 40 \text{ mph)}$$

Additional Types of Markings

The *MUTCD* also includes guidance for some other less common markings, including the following:

- ✓ Two-way left-turn lanes
- ✓ Reversible lanes
- ✓ Preferential lanes
- ✓ Speed measurement markings
- ✓ Speed humps
- ✓ Roundabouts (i.e., traffic circles)
- ✓ Highway-rail grade crossings

Common Problems on Military Installations

1. Non-retroreflective pavement markings because of improper application or inadequate maintenance.
2. Installing wrong color markings.
3. Installing stop lines too far away from an intersecting roadway.
4. Using a single broken or solid yellow line when a double solid yellow center line is proper.
5. Using traffic cones at night without white retroreflective collars.
6. Using a substandard taper length for lane reduction tapers.

REFERENCE LIST

- U.S. Department of Transportation, Federal Highway Administration. *Manual on Uniform Traffic Control Devices*. Washington, D.C. 2003 Edition (www.mutcd.fhwa.dot.gov).
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- Institute of Transportation Engineers. *Traffic Engineering Handbook*. Washington D.C. 1999.
- www.fhwa.dot.gov
- www.tea.army.mil
- www.ite.org

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Prepared with the assistance of Gannett Fleming

Michael K. Williams
Director, SDDCTEA

DEPARTMENT OF THE ARMY
Military Surface Deployment and
Distribution Command Transportation
Engineering Agency
Bldg. 661 Sheppard Place
Ft. Eustis, VA 23604

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