



# Horizontal Curve Safety

An Online Continuing Education Course for Engineers

**Course Number: T-3019**

**Credit: 3 Hours / 3 PDH / 3 CPD**

# Horizontal Curve Safety

## CHAPTER 1. INTRODUCTION

Nearly 25 percent of people who die each year on the Nation's roadways are killed in vehicle crashes at curves. About 75 percent of all fatal crashes occur in rural areas, and more than 70 percent are on two-lane secondary highways, many of which are local roads. Furthermore, the average crash rate for horizontal curves is about three times that of other highway segments. And, 76 percent of the curve-related fatal crashes involve single vehicles leaving the roadway and striking trees, utility poles, rocks, or other fixed objects or overturning. Another 11 percent are head-on crashes, the result of one vehicle drifting into the opposing lane when a driver tries to cut the curve or redirect the vehicle after having run onto the shoulder. Strategies to address specific safety problems at horizontal curves are designed to achieve the following objectives:

1. Reduce the likelihood of a vehicle leaving its lane and either crossing the roadway centerline or leaving the roadway at a horizontal curve.
2. Minimize the damaging consequences of a vehicle leaving the roadway at a horizontal curve.

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<sup>1</sup> Key references are italicized and listed at the end of the course.

There are numerous strategies or treatments engineers can apply to a single horizontal curve or a winding road section to address a safety problem. This course includes only those engineering treatments that are relatively low cost, as compared to reconstructing the curve or road section to improve the geometric design features, such as degree and length of curve, superelevation, cross section, and shoulders.

## ABOUT THE MUTCD

Throughout this course, you will see references to the *MUTCD*. Shorthand for the *Manual on Uniform Traffic Control Devices*, the *MUTCD* defines the standards for all traffic control devices (signs, signals, and pavement markings) road managers install and maintain to help regulate, warn, and guide drivers safely on the Nation's roadways and streets. The *MUTCD* is published by the FHWA. All States are required to adopt either the Federal *MUTCD* or a State *MUTCD* that is in substantial conformance to the Federal *MUTCD*. Some States adopt the Federal *MUTCD* with a State Supplement. State laws regarding traffic control devices should be consulted.

The *MUTCD* also defines conditions about what, where, and how a device is to be placed or installed. In different chapters of this course you may see a treatment and the designation that the *MUTCD* states it shall be used. Shall means something is a standard—a practice or device that is specifically required or mandated—or explicitly prohibited. The *MUTCD* may designate other treatments as guidance, which tells the road manager that a practice or device is recommended

and should be used in typical situations, with modifications allowed for a specific location if an engineering study or engineering judgment indicates the deviation to be appropriate. Finally, the MUTCD provides for options, which are presented as may statements.

A few comments about the course content:

- The treatments discussed are intended to improve the safety of a single curve or a winding section. It is assumed that the agency has identified the location as an existing or potential safety problem.
- Some traffic control devices or applications described in this course do not comply with the MUTCD and are considered “experimental.” Any road agency wanting to use a noncompliant device on a public road must request and receive FHWA approval for testing. The MUTCD refers to this as experimentation. MUTCD Section 1A.10 outlines the procedure for experimentation.
- Where evaluation information is available, the course includes estimates of the effectiveness of the treatment in reducing crashes. However, agencies should not expect to obtain these crash reduction values at a specific location, as the actual observed effectiveness of a treatment will vary from site to site.
- Several treatments discussed in this course are signs or other devices placed on supports or posts, which makes them a hazard. The MUTCD states that roadside sign supports in the clear zone shall be breakaway, yielding, or shielded with a longitudinal barrier or crash cushion.

## CHAPTER 2. BASIC TREATMENTS FOR HORIZONTAL CURVES

There are several traffic control devices road agencies can and, in many situations, should consider installing at a horizontal curve, especially curves that data or experience identify as a safety problem location. These devices are considered “basic” treatments that are found in the *MUTCD*. They include:

1. Centerline
2. Edge line
3. Horizontal Alignment signs: Turn (W1-1), Curve (W1-2), Reverse Turn (W1-3), Reverse Curve (W1-4), Winding Road (W1-5), Hairpin Curve (W1-11), or Loop (W1-15) as an advance warning sign depending on the geometry of the curve(s)
4. Advisory Speed Plaque (W13-1) (with any of the Horizontal Alignment signs)
5. One-Direction Large Arrow (W1-6) sign
6. Combination Horizontal Alignment/Advisory Speed (W1-1a or W1-2a) sign
7. Curve Speed (W13-5) sign
8. Chevron Alignment (W1-8) sign
9. Delineators

Agencies should base selection of one or more of the devices on an engineering study or engineering judgment. Factors to consider include:

- The difference in the posted speed limit and the 85th percentile speed (or a 16-degree ball-bank reading<sup>2</sup>).
- Geometric features of the curve to include its length, radius, shoulders and roadside features.
- Sight distance to and around the curve.
- Unexpected geometric features within the curve, such as an intersection or change in curve radius.
- Traffic volume.

Many curves require nothing more than the standard centerline and edge line (if paved) or one of the basic horizontal alignment warning signs. The decision to add one or more of the other devices listed will be influenced by the factors noted above. Additional consideration is necessary when the curve has been identified as a safety concern or recognized safety problem.

The following discussion provides guidelines for using each device. All example signs and markings are from the *MUTCD*.

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<sup>2</sup> See *Traffic Control Devices Handbook* for use of a ball bank indicator.

## CENTERLINE



*Centerline for No Passing on horizontal curve.*

The centerline pavement marking is the minimal treatment to apply to a curve section, assuming the road is paved and has sufficient width and volume, as noted in the table below. A marked centerline helps drivers keep their vehicles on the correct side of the road and further delineates the roadway alignment. For any section of two-way, two-lane roadway, where passing is allowed in both directions, the basic centerline marking is a broken (dashed) yellow line. On some curves, the horizontal curvature, vertical curvature, or other conditions reduce the passing sight distance for one or both directions of travel below the minimum values given in Part 3 of the *MUTCD*. Use a solid yellow line to advise motorists of the no-passing regulation where the restriction exists for each direction of travel. For segments where passing is prohibited in both directions, use a solid yellow line for both directions, which provides a double yellow centerline. The *MUTCD* permits use of a centerline to specific locations, such as around a curve, so it need not be for the entire roadway section, unless a centerline is required for the entire roadway.

## Application Guideline

The table below summarizes *MUTCD* requirements for centerline marking of two-way roads.

### MUTCD Requirements for Centerline Markings on Paved Two-Way Streets.

	Area type	Road Class		Lanes	ADT	Travel Width (ft)
REQUIRED	Urban	Collectors	Arterials	2	6000 +	20+
	All	All		3+		
RECOMMENDED	Urban	Collectors	Arterials	2	4000+	20+
	Rural	Collectors	Arterials	2	3000+	18+
MAY CONSIDER	Any	Any		2	Any	16+

The *MUTCD* also states that “Engineering judgment should be used in determining whether to place centerline markings on travel ways less than 16 ft wide because of the potential for traffic encroaching on the pavement edges, traffic being affected by parked vehicles, and traffic encroaching into the opposing lane.” Therefore, when an agency identifies a curved section as a potential safety problem, and the road segment does not have a centerline, this should be the first, minimal treatment applied. When the curve carries a low traffic volume (fewer than 200 vehicles per day) and/or the pavement is less than 16 ft wide, consider using post delineators, chevrons, or curve warning signs, even though the centerline is not deemed appropriate.

### Centerline Materials

Road agencies commonly use a variety of paint-based materials and thermoplastic for the centerline markings. The specific material to be used depends on what an agency normally uses for its pavement marking applications. In general, thermoplastic markings are more cost-effective as they last much longer than paint materials. However, their higher initial costs may rule out their use on low-volume rural roads.

Other materials agencies can use for centerlines include a variety of raised pavement markers and “profile” thermoplastics. Chapter 3 discusses these supplemental devices. Also, chapter 5 discusses the use of rumble strips as a supplement to centerline pavement markings.

### Centerline Width

The standard width for each stripe of a centerline stripe is 4 in to 6 in, with the 4-in line more common. A wide line is simply twice the width of a standard line. There is no known safety benefit to having a wider centerline other than it provides a larger visual marking for motorists. When a double line is called for, such as when passing is not allowed, the normal practice in

most jurisdictions is to separate the two lines by a measure approximately equal to the width of a single line—4 in to 6 in.

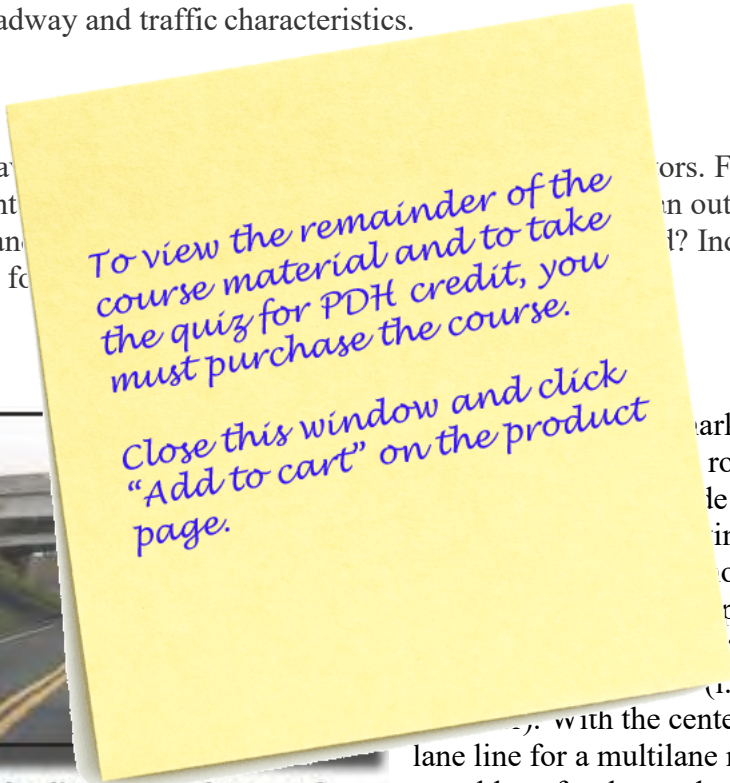
### Effectiveness

A 1996 Kentucky study estimated that including centerline markings reduced crashes by 35 percent. However, this study considered entire roadway sections, not individual curves. Other studies report much smaller benefits. These varying results suggest that agencies can expect safety benefits from installing centerline markings but that the magnitude of the benefits will vary based upon roadway and traffic characteristics.

### Cost

The cost to apply pavement material used—paint or thermoplastic—perform the work; and agencies are aware of their costs for

For example, the cost of an outside contractor? Individual agencies are



### EDGE LINE



*Centerline and edge line for two-lane road.*

centerline, edge lines can be applied just prior to and within the curved section, although it typically is applied to an entire section of roadway when used.

markings define or roadway. It provides a le motorists and helps ing onto the shoulder horizontal curves, be, edge line te line at the right (i.e., not including any

with the centerline, or adjacent lane line for a multilane road, it defines the travel lane for the road user. As with the

### Application Guidelines

The *MUTCD requires* (STANDARD) edge lines only for “. . . rural arterials with a traveled way of 20 ft or more in width and an average daily traffic (ADT) of 6,000 vehicles per day or greater.” They are *recommended* (GUIDANCE) for “. . . rural arterials and collectors with a traveled way of 20 ft or more in width and an ADT of 3,000 vehicles per day” or any other paved road where an engineering study identifies a need for edge line markings.