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Signs for Curves and Turns

By Laura Melendy, Director, Technology Transfer Program

Rural roads often have unique safety issues stemming from the fact that few of them were ever engineered; their geometry, signing and marking simply evolved over time. Many roads still in use in the United States were once paths for wagons or stagecoaches. They have undergone various combinations of grading, widening, graveling and chip sealing, and their alignments, curve radii, grades and crowns were established only by the eye of the equipment operator.

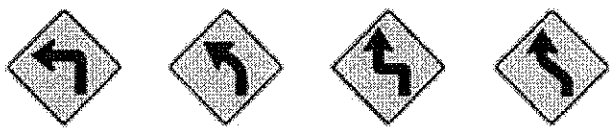
Sharp turns, hairpin curves, broken back S-curves and other "non-standard" geometries that "good engineers" would avoid designing are out there on our rural roads. Curves and turns on rural roads can often be tricky for drivers to negotiate, as the safe speed may be considerably lower than the safe speed on the straightaway approaching the curve. As a vehicle approaches a curve, we hope the driver will slow to an appropriate speed to safely negotiate the curve. However, this isn't always the case. The most frequently reported crashes and the most serious crashes on rural roads occur at curves and turns. These are usually a single vehicle run-off-the-road crash involving a driver entering the curve at excessive speed and losing control.

Standardized, consistent signage can improve safety on these curves—by improving driver expectation of what's coming up ahead. If the same type of curves are always marked the same way, and if the advisory speeds are set in a consistent manner, then drivers know what lies ahead when they encounter those signs. Think about the fable of the boy who cried wolf: if all of the speed advisory signs along a roadway were posted at 25 mph, but a driver actually safely negotiates the curves at 45 mph, how do you think that driver will behave when he approaches another 25 mph advisory sign posted on a curve that really does need to be driven at 25 mph?

Curve and Turn Warning Signs

The official category of signs used to warn drivers of upcoming curves and turns is Horizontal Alignment Signs, which are informally called Curve and Turn Warning Signs. Like all warning signs, they are always black-on-yellow. Information on the signs that are approved for use in California is found in the California MUTCD, Sections 2C.06, 2C.07 and 2C.08. Signs W1-1 through W1-5, W1-11, and W1-15 (illustrated in Figure 1) provide visual information about the nature of the curve the driver is approaching, letting the driver know whether it's a gradual curve, a sharp turn, a hairpin turn or some combination. Whenever the advisory speed for the curve is lower than the posted speed limit, an advisory speed message should be added either directly on the face of the curve or turn warning sign, or on a supplemental plaque below the warning sign. Information on Advisory Speed on Curve and Turn Warning Signs can be found in the California MUTCD, Section 2C.101(CA). If the curve can be driven at the posted speed limit without discomfort, there is normally no need for a sign.

Figure 2C-1. Horizontal Alignment Signs



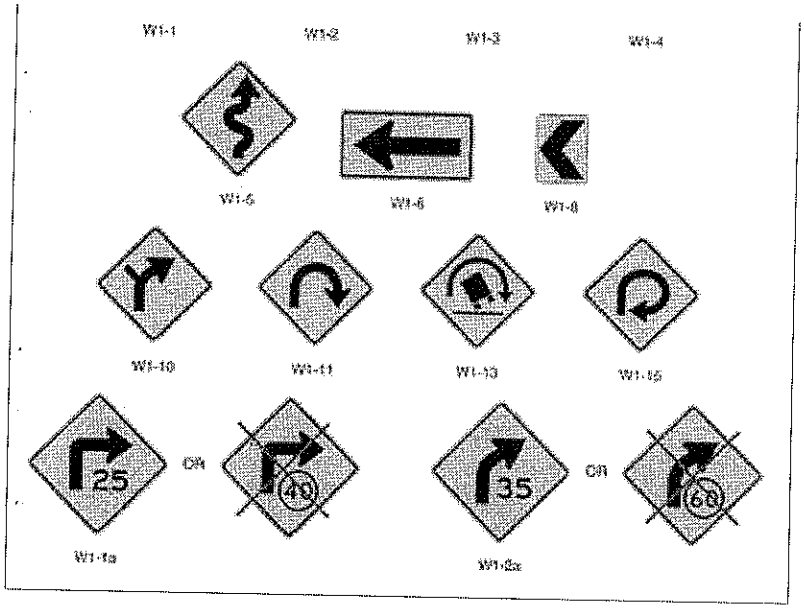


Figure 1

Determining the Advisory Speed

The safe advisory speed for a curve is the maximum speed which will permit the vehicle to travel around the curve in its own lane without causing an uncomfortable side force to its passengers. The advisory speed is NOT the safe speed for every vehicle, driver and pavement condition —it's just an indication that alerts drivers to the need and relative extent to which they should slow down.

To determine the recommended advisory speed, we could carefully measure the maximum super-elevation of the curve. However, if there are any bumps or depressions, they may be missed by such a survey. In addition, these surveys can take lots of time to conduct (especially with proper traffic control in place the entire time). A faster, safer and easier method is to use either a mechanical or electronic Ball Bank Indicator. A Ball Bank Indicator is an inclinometer that measures the overturning force (side friction, measured in degrees) on a vehicle negotiating a horizontal curve. In a Ball Bank Indicator, a ball held in fluid moves along a channel in response to lateral acceleration caused by traveling around the curve. The goal of a ball bank study is to determine the speed of travel where the ball stays below a defined maximum reading.

To determine the safe advisory speed using a ball bank indicator, follow the directions below in "How to Use a Ball Bank Indicator." The actual speed posted on the advisory sign should be the highest speed of travel at which the ball bank reading stays below the limiting value, rounded down to the nearest 5 mph increment.

In California, the limiting ball bank indicator values are 15 degrees for speeds up to 30 mph, approximately 12.5 degrees for speeds from 25 mph through 30 mph, and 10 degrees for speeds of 35 mph and greater. (see the limit line in Figure 2 for illustration).

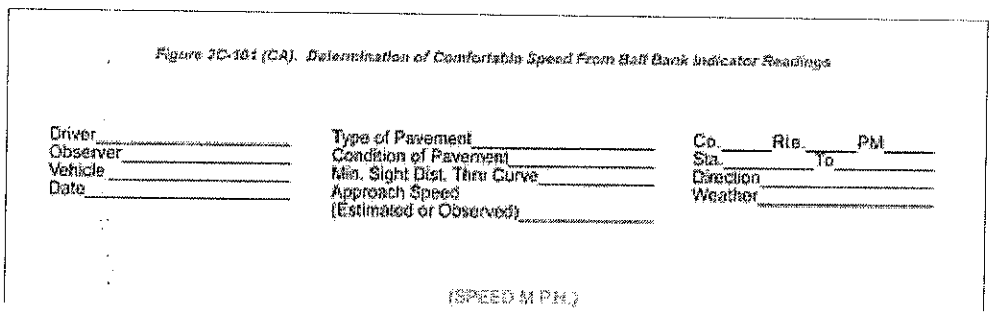


Figure 2C-101 (CA). Determination of Comfortable Speed From Ball Bank Indicator Readings

Driver_____
Observer_____
Vehicle_____
Date_____

Type of Pavement_____
Condition of Pavement_____
Min. Sight Dist. Thru Curve_____
Approach Speed
(Estimated or Observed)_____

Co._____Rte._____PM_____
Sta._____To_____
Direction_____
Weather_____

(SPEED M P H.)

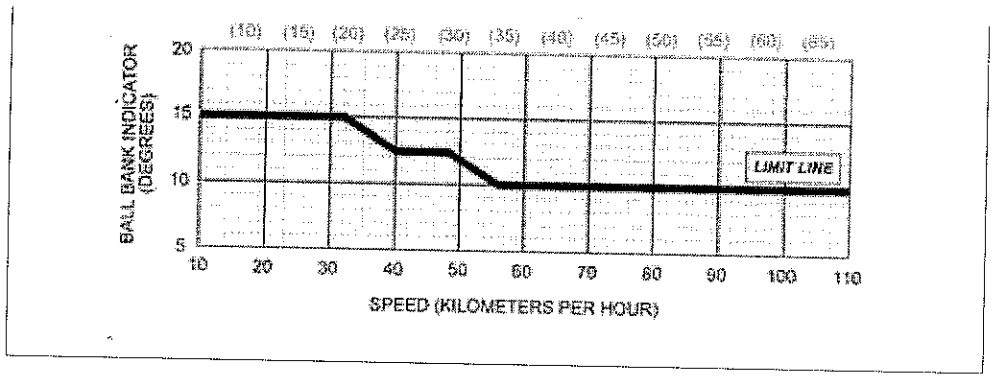


Figure 2

Determining Which Sign to Place

The choice of which warning sign to place on a curve depends upon several different factors. The number of curves in the series, the advisory speed of the sharpest corner and the alignment of the first curve serve as a guide to determining which sign to place. Follow the steps below and consult the California MUTCD, Table 2C-5 (see Table 1) to identify which sign to use in a given situation.

Table 2C-5. Horizontal Alignment Sign Usage

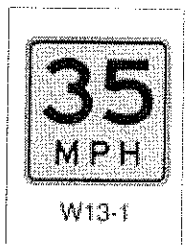
Number of Alignment Changes	Advisory Speed	
	≤ 50 km/h (≤ 30 MPH)	> 50 km/h (> 30 MPH)
1	Turn (W1-1)[1]	Curve (W1-2)[1]
2[1]	Reverse Turn[1] (W1-3)	Reverse Curve[1] (W1-4)
3 or more[1]	Winding Road[1] (W1-5)	

Table 1

First, determine the number of alignment changes. When deciding whether to group curves as part of a series, determine if they have the same alignment (for example, two curves to the left or two to the right). If two curves have the same alignment and are separated by more than 200 feet of straightaway, sign them separately. If two curves have opposite alignments (for example, one to the left and then one to the right) and the distance between them is less than 600 feet, group them together. Sequential curves can always be signed separately if needed, just be sure that the sign placement is not confusing to motorists. Use the Turn (W1-1) and Curve (W1-2) signs for signing a single curve; use the Reverse Turn (W1-3) and Reverse Curve (W1-4) signs for signing a series of two curves; use the Winding Road (W1-5) sign for a series of three or more curves. If there are more than four curves in a row, additional signs are warranted in the middle of the series.

Next, use the advisory speed of the sharpest corner and the direction of the first curve to determine which sign—curve or turn—to place. If the advisory speed is 30 mph or less, post a Turn sign (W1-1 and W1-3); if the advisory speed is greater than 30 mph, post a Curve sign (W1-2 and W-4). An "L" (left) or "R" (right) designation is used to indicate the direction of the first curve.

Finally, post the advisory speed directly on the turn or curve sign (as in W1-1a and W1-2a) or mount a separate advisory speed plaque (W13-1) directly below the turn or curve sign. Information on advisory speed plaques is found in Section 2C.46 of the California MUTCD. For an example, see Figure 3.



W13-1

How to Use a Ball Bank Indicator

1 - **Mount and level the ball bank indicator.** Mount the ball bank indicator on the dashboard of the test vehicle. The indicator can be mounted temporarily with rubber suction cups or permanently affixed. The ball should rest at the zero degree position when the vehicle is level; if it doesn't then the indicator should be leveled according to the manufacturer's instructions. The indicator should be checked periodically to ensure it remains level. A good time to check and level the indicator is when filling the gas tank—the concrete pad at the gas station is typically a level surface. (Note: The test vehicle should be representative of vehicles used by the general public; sports cars, trucks, and SUVs with heavy-duty suspensions are not recommended for use as the test vehicle.) *Figure 3*

2 - **Take a series of ball bank readings at various speeds.** Have one person drive the test vehicle and another observe and record the ball bank indicator readings. The curve should be driven several times (at least three) at a uniform speed and the highest observed reading should be plotted on the chart in Figure 2. The vehicle should be in the center of the lane throughout the curve and the driver should drive smoothly and at a uniform speed. Additional runs should be made, increasing the speed 5 mph for each set of readings, until the maximum recommended speed is found. An additional run above the maximum recommended speed indication may be done (if the pavement is dry and it is safe to do so) to confirm the results of the previous reading. The highest speed of travel at which the ball bank indicator reading falls below the limit line in Figure 2, rounded down to the nearest 5 mph increment, is the advisory speed.

3 - **Be sure to check the curve in both directions of travel.** The posted speed may be different in opposite directions. If so, post each direction separately.

Adapted with permission from the Fall 2007 issue of *Nuggets and Nibbles*, a quarterly newsletter produced by the Cornell Local Roads Program. The original article was titled "Determining the Safe Speed for Curves" and was written by David P. Orr, PE, Senior Engineer, Cornell Local Roads Program and Jim Mearkle, PE, Engineer, Albany County, New York, Department of Public Works.

All tables and figures in this article are reprinted from the California MUTCD.

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