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Design Manual Part 2 Highway Design

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2.2 VERTICAL ALIGNMENT

As with other design elements, the characteristics of vertical alignment are influenced greatly by basic controls related to design speed, highway functional classifications and the terrain conditions. Within these basic controls, there are several general controls for vertical alignment that should be considered:

1. A smooth gradeline with gradual changes, as consistent with the type of highways, roads or streets and the character of terrain, should be sought for in preference to a line with numerous breaks and short lengths of grades.

2. The "roller-coaster" or the "hidden-dip" type of profile should be avoided.

3. Undulating gradelines involving substantial lengths of momentum grades should be evaluated for their effect on traffic operation.

4. A broken-back gradeline (two vertical curves in the same direction separated by a short section of tangent grade) generally should be avoided, particularly in sags where the full view of both vertical curves is not pleasing.

5. It may be preferable, on long grades, to place the steepest grades at the bottom and flatten the grades near the top of the ascent or to break the sustained grade by short intervals of flatter grade.

6. Where at-grade intersections or railroad-highway grade crossings occur on roadway sections with moderate to steep grades, it is desirable to reduce the grade through the intersection or railroad-highway grade crossing.

7. Sag vertical curves should be avoided in cuts unless adequate drainage can be provided.

For additional information concerning general and design considerations for vertical alignment and additional presentations on the practical application of the relevant criteria, refer to the 2011 AASHTO Green Book, Chapter 3, Section 3.4.6, "Vertical Curves", "General Controls for Vertical Alignment".

2.3 CONTROLS FOR COMBINATION HORIZONTAL AND VERTICAL ALIGNMENTS

Horizontal and vertical alignments represent permanent design elements which warrant thorough examination and study. They should not be designed independently, but should complement each other to avoid alignment deficiencies. Excellence in the design of combination horizontal and vertical alignments enhances vehicle control, encourages uniform speed and improves appearance.

The proper combination of horizontal and vertical alignment is obtained through engineering studies with consideration given to the following general guidelines:

1. Curvature and grades should be in proper balance. Tangent alignment or flat curvature at the expense of steep or long grades and excessive curvature with flat grades both represent poor design. A logical design that offers the best combination of safety, capacity, ease and uniformity of operation and pleasing appearance within the practical limits of terrain and area traversed is a compromise between these two extremes.

2. Vertical curvature superimposed on horizontal curvature, or vice versa, generally results in a more pleasing facility, but such combinations should be analyzed for their effect on traffic. Successive changes in profile not in combination with horizontal curvature may result in a series of humps visible to the driver for some distance which represents an undesirable condition.

3. Sharp horizontal curvature should not be introduced at or near the top of a pronounced crest vertical curve. This condition is undesirable because the driver may not perceive the horizontal change in alignment, especially at night. The disadvantages of this arrangement are avoided if the horizontal curvature leads the vertical curvature, i.e., the horizontal curve is made longer than the vertical curve. Suitable designs can also be developed by using design values well above the appropriate minimum values for the design speed.

4. Sharp horizontal curvature should not be introduced near the bottom of a steep grade approaching or near the low point of a pronounced sag vertical curve. Because the view of the road ahead is foreshortened, any horizontal curvature other than a very flat curve assumes an undesirable, distorted appearance. Further, vehicle speeds, particularly for trucks, are often high at the bottom of grades and erratic operations may result, especially at night.

5. On two-lane roads and streets, the need for passing sections at frequent intervals and including an appreciable percentage of the length of the roadway often supersedes the general guidelines for combinations of horizontal and vertical alignment. In such cases, it is appropriate to work toward long tangent sections to assure sufficient passing sight distance in design.

6. Horizontal curvature and profile should be made as flat as practical at intersections and at railroad-highway grade crossings where sight distance along both roads or streets is important and vehicles may have to slow or stop.

7. On divided highways and streets, variation in width of median and the use of independent profiles and horizontal alignments for the separate one-way roadways are desirable. Where traffic justifies provision of four lanes, a superior design without additional cost generally results from such practices.

8. In residential areas, the alignment should be designed to minimize nuisance to the neighborhood. Generally, a depressed facility makes a highway less visible and less noisy to adjacent residents. Minor horizontal adjustments can sometimes be made to increase the buffer zone between the highway and clusters of homes.

9. The alignment should be designed to enhance scenic views of the natural and human-made environment, such as rivers, rock formations, parks and outstanding structures. The highway should head into, rather than away from, those views that are outstanding; it should fall toward those features of interest at a low elevation and it should rise toward those features best seen from below or in silhouette against the sky.

Coordination of horizontal and vertical alignment should begin with preliminary design, at which time adjustments in either or both can be made jointly to obtain the desired coordination. The design criteria contained in Chapter 1 and the elements of design covered in this Chapter should be kept in mind. Design speed may require adjustment during the process to conform to variations in speeds of operation due to changes in alignment characteristics needed to accommodate unusual terrain, railroad-highway grade crossings or right-of-way controls. All aspects of terrain, traffic operation and appearance should be considered and the horizontal and vertical lines should be adjusted and coordinated before the calculations and the preparation of construction plans to large scale are started.

For highways with gutters, the effects of superelevation transitions on gutter line profiles should be examined. This can be particularly significant when flat grades are involved and can result in local depressions. Slight shifts in profile in relation to horizontal curves can sometimes eliminate the problem.

For additional information on the controls and general considerations for the combination of horizontal and vertical alignment, refer to the 2011 AASHTO Green Book, Chapter 3, Section 3.5, "Combinations of Horizontal and Vertical Alignment".

2.4 SIMPLE CURVE COMPUTATIONS

The changes in direction along a highway are basically accounted for by curves consisting of portions of a circle. The simple curve computation method shall be used for all curve computations as indicated in Figure 2.1.