Horizontal Curvature

At a horizontal curve, the centrifugal force a vehicle travelling around that curve is generally counteracted by a combination of 2 factors: friction between the tyres and the road surface, and superelevation of the carriageway, where the carriageway is constructed such that the outside carriageway edge is higher than the inside carriageway edge. Traditionally, the design approach has been to combine these factors to ensure that a vehicle can travel around a bend without reducing speed or without causing significant discomfort to the occupants of the vehicle. Where a horizontal alignment along a street requires changes in direction, the curves between straight sections should have radii in accordance with Table 4.3.

Crossfall

Designers should also consider superelevation where one side of the road is designed to be higher than the other in order to resist the centrifugal effect of turning a corner. As the aim of superelevation is to assist drivers to maintain higher speeds around curves, its use is inappropriate where the design is intended to achieve a moderate or low speed environment. As also noted in the *Manual for Streets 2* (2010), superelevation is also difficult to implement in urban areas with frequent junctions and points of access.[36]

However a crossfall of 2.5% is generally provided on carriageways to assist in drainage, which would tend to result in adverse camber at horizontal curves. Consequently, in order to assist in achieving lower vehicle speeds through a more restrictive horizontal alignment, there is a need to provide sharper horizontal curves that do not have the benefit of high levels of superelevation to counteract the centrifugal force. Designers should refer to Table 4.3 for minimum radius with adverse camber of 2.5%.

Where the introduction of radii less than those for minimum radius with adverse camber of 2.5% is unavoidable, a reasonable level of superelevation may be introduced to eliminate adverse camber and introduce a favourable crossfall. Minimum curve radii for a superelevation rate of 2.5% are also presented in Table 4.3, and may be used in such circumstances.

HORIZONTAL CURVATURE

Design Speed (km/h)	**10**	**20**	**30**	**40**	**50**	**60**
Minimum Radius with adverse camber of 2.5%	-	11	26	56	104	178
Minimum Radius with superelevation of 2.5 %	-	-	-	46	82	136

VERTICAL CURVATURE

Design Speed (km/h)	**10**	**20**	**30**	**40**	**50**	**60**
Crest Curve K Value	N/A	N/A	N/A	2.6	4.7	8.2
Sag Curve K Value	N/A	N/A	2.3	4.1	6.4	9.2

Table 4.3: Carriageway geometry parameters for horizontal and vertical curvature.

Vertical Alignment

A vertical alignment consists of a series of straight-line gradients that are connected by curves, usually parabolic curves. Vertical alignment is less of an issue on urban streets that carry traffic at moderate design speeds and changes in vertical alignment should be considered at the network level as a response to the topography of a site.

The required envelope of forward visibility in the vertical plane is illustrated in Figure 4.67 below. The envelope should encompass the area between a driver eye height in the range of 1.05 metres to 2.00 metres, and an object height in the range of 0.6 metres to 2.00 metres

Vertical Curvature

Where changes in gradient are required along an alignment, vertical curves are introduced, such that the appropriate SSDs are achieved, and an adequate level of driver comfort is provided. Ordinarily in urban areas where it can be expected that vehicle speeds will reduce in response to changes in alignment, it will be sufficient to design vertical curves such that the minimum SSD is provided.

Vertical curves can take the form of Crest or Sag curves, the length of a vertical curve, L, is the critical design parameter, and is determined by multiplying the K Values set out in Table 4.3 by the algebraic change of gradient expressed as a percentage, that is:

$$L = Ka$$

Where:

K = The constant of curvature
a = The algebraic change in gradient.

Vertical Crest Curve Design

At crest curves visibility can be obstructed by the road surface itself. Crest curve, accordingly, should be designed such that the curvature is sufficient to maintain an adequate FSD and SSD for a driver. In urban areas, where vehicle speeds are low and gradients are generally modest, the design of vertical crest curves can be simplified as follows:

- For very low design speeds (i.e. less than 40 km/h), and where the algebraic difference in gradient between straight sections is less than 12%, it will generally not be necessary to specifically design a vertical crest curve; however the carriageway should be shaped to avoid an abrupt change in vertical alignment.
- For design speeds of 40 km/h and above, and again where the algebraic difference in gradient is modest, up to a maximum of 12 %, it will normally be sufficient to provide a vertical curve with a length determined using the K-values presented in Table 4.3.

In exceptional circumstances where the algebraic difference in gradient exceeds these limits, it will be necessary for the designer to determine a crest curve length suitable for the circumstances from first principles.

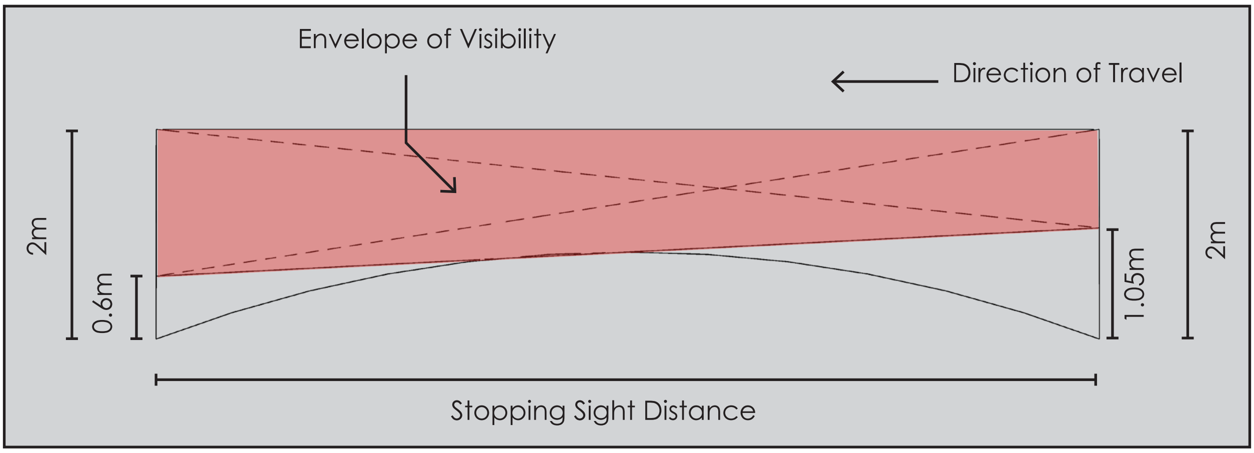

Figure 4.67: Visibility envelope in vertical plane.