AECOM

Roads Bitesize 2022

Overview Of Horizonal and Vertical Alignment Design

Ian Bamforth

Personal Introduction

Ian Bamforth

Chartered Civil Engineer
24 years experience in the design and implementation of major highways schemes in the UK
Technical Director in Highways team based in Chesterfield

1. Introduction
2. Applicable Design Standards
3. Determination of Design Speed
4. Horizontal Alignment Design
5. Vertical Alignment Design
6. Further Design Considerations
   – Visibility
   – Cross Section
   – Alignment Phasing
7. Discussion

Note: Presentation is not going to cover 3D modelling and software use

Introduction

Geometric design of a highways covers many different types of projects eg motorways, dual carriageway bypasses, single carriage urban roads, major new junctions or minor junction improvements.

Starting point of geometric design is creation of a horizontal and vertical alignment, from which other features are added.

Geometric design has a direct impact on:

- Operation and Capacity
- Driver perception and ‘comfort’ factor
- Safety
- Environmental Impact
- Cost

Design Standards

Geometric design typically based on design standards in Design Manual for Roads and Bridges https://www.standardsforhighways.co.uk/dmrb/

Applicable to strategic roads in England, Scotland, Wales and Northern Ireland.

Likely to be applicable or basis of design standards for local highways authorities.

Adopted or basis for design internationally, other examples include AASHTO, Austroads.

Principals across design are similar-developed to provide for safe operation based on a hierarchy of design parameters linked to speed.

DMRB-CD109 Highway Link Design (formally TD9)

Design Speed

Design Speed v Operational Speed/Speed Limit

Drivers regulate their speed along a road in accordance with the physical characteristics and their perception of what lies ahead.

Design Speed is the estimate of the speed traffic will adopt for a given alignment and layout constraints

Design Speed is defined as the 85%ile speed ie 85% of drivers will be travelling at this speed or less.

See Chapter 2 of CD109

Design Speed

Determination of Design Speed, for rural roads is a reactive process

If a road alignment needs to be bendy for environmental for environmental of physical reasons, the curvature and visibility standards can also be lower, reflecting the lower speed traffic will adopts.

Each Design Speed is divided into Bands A and B to avoid a sudden jump in design standards. More flexibility in design is available in each Band B.

For urban roads designs Design Speed is selected with refence to speed limit, but note design speeds are higher than the speed limit and permit a small margin for vehicle speed in excess of the speed limit.

Speed limit		Design speed
Mph	Kph	Kph
30	48	60B
40	64	70A
50	80	85A
60	96	100A

Design Speed Related Parameters Table 2.10 CD109

Design speed kph	120	100	85	70	60	50	V2/R
Stopping sight distance (metres)							
Desirable minimum	295	215	160	120	90	70	-
One step below desirable minimum	215	160	120	90	70	50	-
Horizontal curvature (metres)							
Minimum R* with adverse camber and without transitions	2880	2040	1440	1020	720	520	5
Minimum R* with superelevation of 2.5%	2040	1440	1020	720	510	360	7.07
Minimum R* with superelevation of 3.5%	1440	1020	720	510	360	255	10
Desirable minimum R (superelevation 5%)	1020	720	510	360	255	180	14.14
One step below desirable Minimum R (superelevation 7%)	720	510	360	255	180	127	20
Two steps below desirable minimum radius (superelevation 7%)	510	360	255	180	127	90	28.28
Vertical curvature							
Desirable minimum* crest K value	182	100	55	30	17	10	-
One step below desirable min crest K value	100	55	30	17	10	6.5	-
Desirable minimum sag K value	37	26	20	20	13	9	-
Overtaking sight distances							
Full overtaking sight distance FOSD (metres)	-	580	490	410	345	290	-
FOSD overtaking crest K value	-	400	285	200	142	100	-
* Not recommended for use in the design of single carriageways (see Section 9)							
The V^2/R values shown above simply represent a convenient means of identifying the relative levels of design parameters, irrespective of design speed.							

Horizontal Alignment

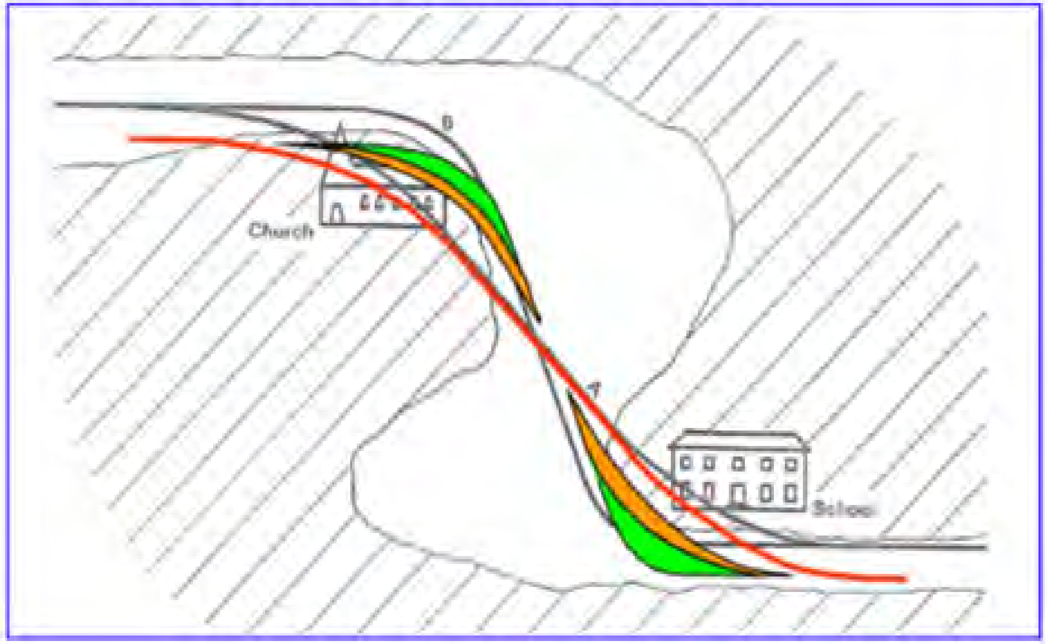
Horizontal control line for the road, typically the road centreline.

Combination of circular curves, straights and transition curves.

Determine constraints on the alignment and prepare an initial design based on Desirable Minimum Standards.

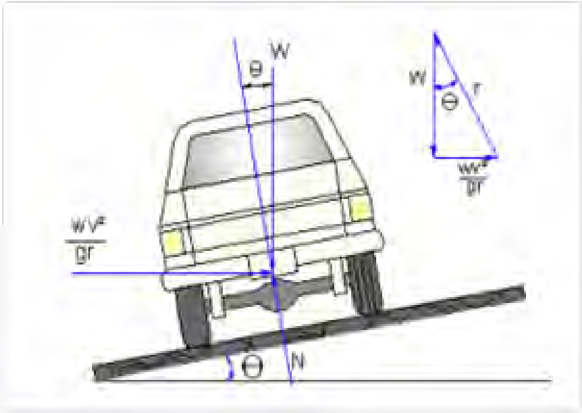
Introduce *Relaxations* and *Departures from Standard* introduced where necessary to satisfy alignment constraints.

Transition curves-cubic spirals are included between elements to provide a smooth change in direction and provide a means of applying changes in superelevation.



Horizontal Alignment

Superelevation balances the dynamic forces experienced around a curve. Maximum centrifugal acceleration acceptable for comfort and safety is 0.22g.



Superelevation is applied to curves with radii less than desirable minimum for design speed.

Superelevation Equation $S = \frac{V^2}{2.828R}$

Generally, superelevation should not exceed 7% on rural areas or 5% in urban areas.

Roll over of superelevation, check for flat spots and channel gradients in carriageways resulting in drainage issues.

Horizontal Alignment

Transition curves are provided on curves with radii less than desirable minimum for design speed.

Calculation of basic transition length L= $\frac{V^3}{46.7qR}$

q=Rate of increase of centripetal acceleration (m/sec^3)

Q shall not exceed 0.6m/sec^3-relaxation to 0.3m/sec^3

Check against $\sqrt{24R}$

Round transitions to nearest 10m design speeds >85kph and 5m for design speeds <85kph.

Vertical Alignment

Combination of vertical curves and longitudinal gradients. Choice of curve will impact visibility and comfort.

Limits to longitudinal gradients Table 5.1 CD109

	Desirable maximum	Permitted relaxations
Motorways	3%	4%
All-purpose dual carriageways	4%	8%
All-purpose single carriageways	6%	8%

Minimum channel gradients of 0.5% should be maintained for effective drainage, particularly on kerbed roads.

Vertical Alignment

Vertical sag and crest curves-aim for Desirable Minimum Standards, take particular note of obstructions such as safety fences and parapets which can impact on sight line requirements.

Good practice to provide vertical visibility one design step higher than the horizontal radius on dual carriageways. Single carriageways are a special case due to full overtaking sight distance requirements.

Desirable Minimum crest curves provide Desirable Minimum stopping sight distance (SSD). More to follow

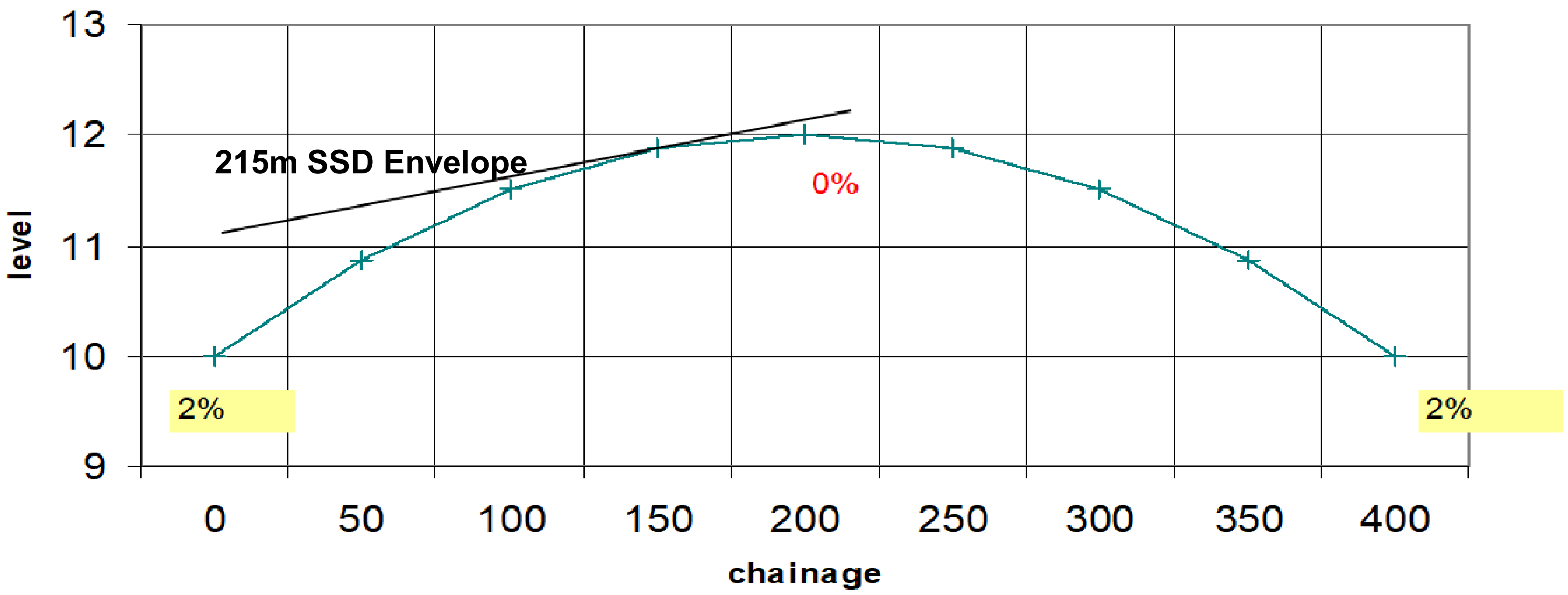
Vertical curves specified as K value where R=100K

K is the length of curve required to change the gradient by 1%

Vertical Alignment

Example:

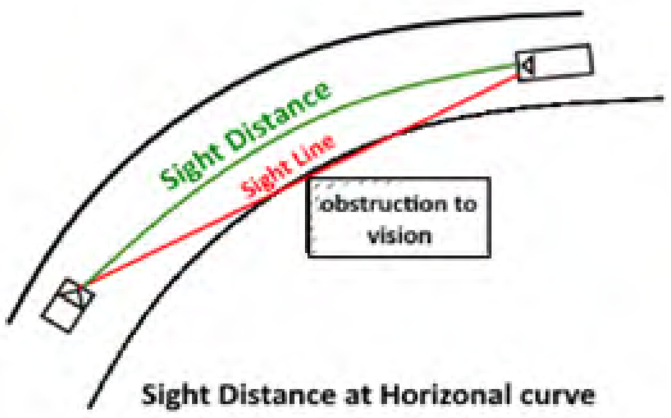
- Design Speed 100kph
- Minimum SSD 215m
- Desirable Minimum Crest Curve 100k

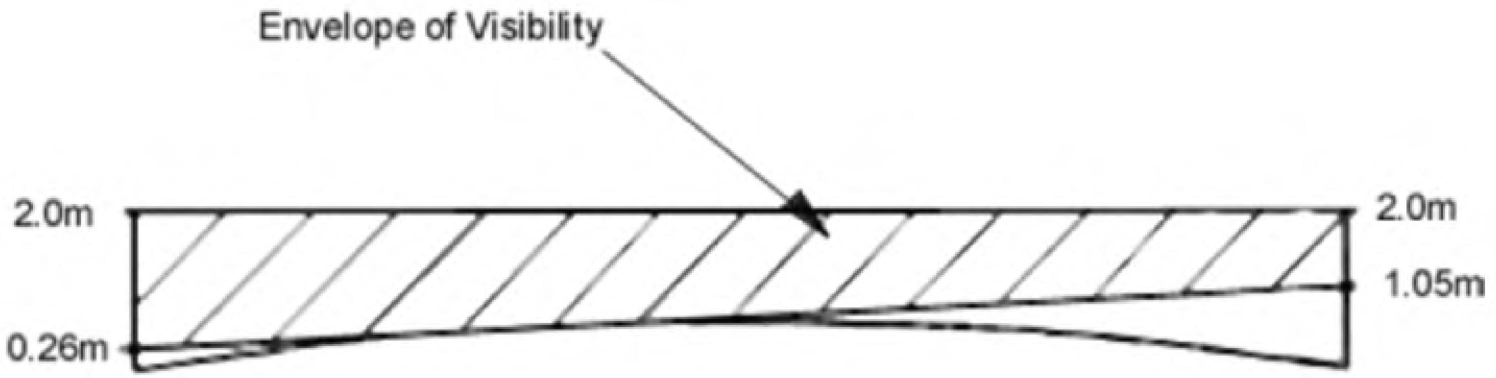


Further Design Considerations

Visibility

- Horizontal SSD measured between any two points from the centre of the lane.
- Vertical SSD envelope of visibility measured from a drivers eye height of between 1.05m and 2.00m to an object height of between 0.26 and 2.00m above the road surface.



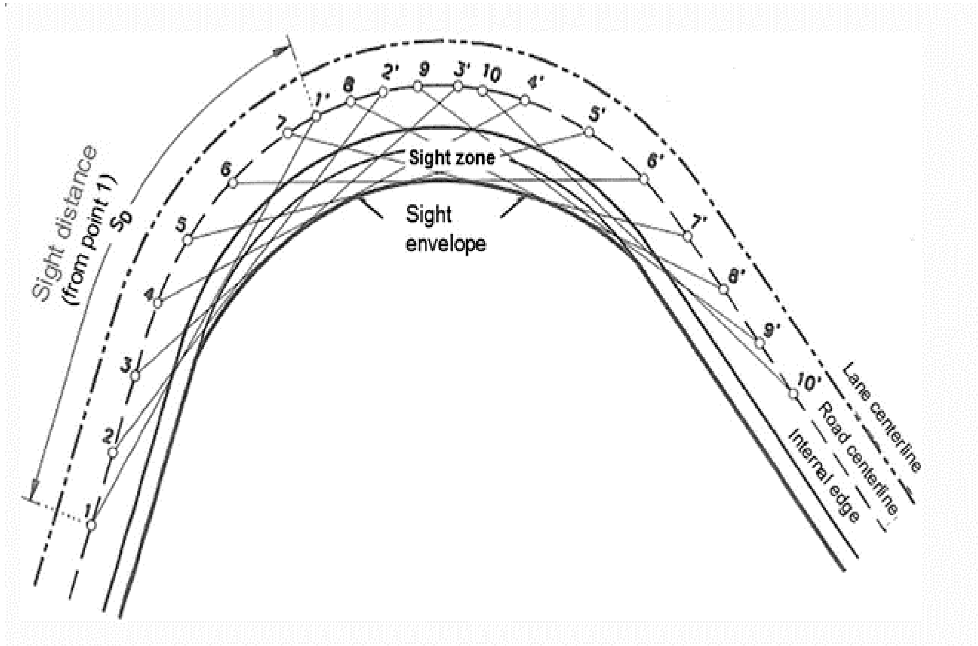


- Overall distance perception distance, reaction distance and breaking distance

Further Design Considerations

Cross Section

- Cross Section design standards are set out in CD127 Cross-sections and headrooms.
- Widening requirements for verges and central reserves
- Curve widening requirements on single carriageways CD109



Further Design Considerations

Alignment Phasing

- Coordination of horizontal and vertical elements
- Aesthetics of how the road is integrated into the landscape-both the view of the road and view from the road .
- Safety and comfort factor as to how the road user perceives the road ahead
- Horizontal and vertical tangent points coincide with horizontal slightly in advance of vertical curves, horizontal and vertical curves of similar length.

Further Design Considerations

Alignment Phasing

Further Design Considerations

Alignment Phasing

Discussion

Thank you

Delivering a better world

aecom.com