NRA TD 9/00

ROAD LINK DESIGN

AMENDMENT No. 1
June 2001

Incorporating NRA TA 43/00 and Amendment No. 1
(Guidance on Road Link Design)

NRA Standard NRA TD 9/00 - Road Link Design – dated December 2000 is amended as follows. The amendments revise the requirements for crest curves on single carriageway roads.

1. Pages 1/7 and 1/8 (Paragraphs 1.25 to 1.27) dated December 2000 are replaced with the revised Pages 1/7 and 1/8 dated June 2001 as enclosed. **Paragraphs 1.24A and 1.24B have been added**.

2. Pages 4/1 and 4/2 (Chapter 4) dated December 2000 are replaced with the revised Pages 4/1 and 4/2 dated June 2001 as enclosed. **Paragraphs 4.6A and 4.17 have been revised**.

3. Pages 7/1 to 7/6 (Paragraphs 7.1 to 7.19) and 7/9 to 7/12 (Paragraphs 7.29 to 7.41) dated December 2000 are replaced with the revised Pages 7/1 to 7/6 and 7/9 to 7/12 dated June 2001 as enclosed. **Paragraphs 7.5, 7.13, 7.19 and 7.30 have been revised**.

4. This Amendment shall be implemented forthwith in accordance with Paragraph 0.8 of NRA TD 9/00.

5. All technical enquiries or comments on this Amendment or NRA TD 9/00 should be sent in writing to:

Head of Project Management and Engineering
National Roads Authority
St Martin's House
Waterloo Road
Dublin 4

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E O'CONNOR
Head of Project Management and Engineering

INSTRUCTIONS FOR USE

1. Remove existing cover sheet, contents page and pages 1/7, 1/8, 4/1, 4/2, 7/1 to 7/6 and 7/9 to 7/12.
2. Insert the replacement pages as enclosed.
3. Insert this Amendment sheet between the contents page and the cover sheet.

NATIONAL ROADS AUTHORITY
An tÚdarás um Bóithre Náisiúnta

Road Link Design

Incorporating NRA TA 43/00 and Amendment No. 1

(Guidance on Road Link Design)

June 2001

Headquarters St. Martin's Hse., Waterloo Road, Dublin 4. Tel: 01 660 2511 Fax: 01 668 0009

Summary :

This Standard sets out the elements of design for use in the geometric design of roads. It also sets out the principles for co-ordinating the various design elements so as to ensure that the three dimensional layout as a whole is acceptable. Single carriageway design is given particular emphasis in order to provide clearly identifiable sections for overtaking.

Note:

The layout and format of this Standard are modelled closely on the UK Highways Agency's Standard TD 9/93. Wherever practicable, paragraph and figure numbering follows that of TD 9/93.

Published by the National Roads Authority, Dublin
2001

VOLUME 6	**ROAD GEOMETRY**
SECTION 1	**LINKS**

PART 1

NRA TD 9/00
and Amendment No.1

ROAD LINK DESIGN

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Chapter

1.24A A Crest Curve Relaxation of one Design Speed step below Desirable Minimum will generally result in a reduction in Stopping Sight Distance to a value one Design Speed step below Desirable Minumum, the adoption of which would also require a Relaxation. With the exception of the case described in Paragraph 1.24B, this is not a permitted combination of Relaxations and should be treated as a Departure.

1.24B If a Crest Curve Relaxation of one Design Speed Step below Desirable Minimum is being used to avoid dubious overtaking conditions on a straight or nearly straight section of single carriageway in accordance with Paragraph 7.30, the combination of this Relaxation with a one step Relaxation of Stopping Sight Distance is permitted and should not be treated as a Departure.

1.25 Relaxations are not permitted for either of the overtaking sight distance parameters given in Table 3.

1.26 The Relaxations below Desirable Minimum in stopping sight distance and vertical curvature for crest curves and more than 1 Design Speed step below Desirable Minimum for sag curves described in Paragraphs 2.8 to 2.13 inclusive and 4.9 to 4.17 inclusive are **NOT** permitted on the immediate approaches to junctions, because the majority of accidents occur in the vicinity of junctions. For the purposes of this Standard the immediate approaches to a junction shall be:

a. For at grade major/minor junctions without diverge and merge tapers, those lengths of carriageway on the minor roads between a point 1.5 times the Desirable Minimum Stopping Sight Distance upstream of the Stop line or Yield line and the Stop line or Yield line itself, and those lengths of carriageway on the mainline between a point 1.5 times the Desirable Minimum stopping sight distance from the centre line of the minor road and the centre line itself.

b. For roundabouts, those lengths of carriageway on the approach to the roundabout between a point 1.5 times the Desirable Minimum stopping sight distance from the Yield line and theYield line itself.

c. For diverges, that length of carriageway from a point 1.5 times the Desirable Minimum stopping sight distance upstream of the start of the diverge taper to the back of the diverge nose.

d. For merges, that length of carriageway from a point 1.5 times the Desirable Minimum stopping sight distance upstream of the back of the merge nose to the end of the merge taper.

Departures

1.27 In situations of exceptional difficulty which cannot be overcome by Relaxations, it may be possible to overcome them by adoption of Departures, the third tier of the hierarchy. Proposals to adopt Departures from Standard must be submitted to the National Roads Authority for approval before incorporation into a design layout to ensure that safety is not significantly reduced.

4. VERTICAL ALIGNMENT

Gradients

4.1 Maximum Gradients: The Desirable Maximum gradient for design shall be:

	Desirable Max Grade
Motorways	3%
AP Dual Carriageways	4%
AP Single Carriageways	5%

However, in hilly terrain steeper gradients will frequently be required, particularly where traffic volumes are at the lower end of the range.

4.2 Effects of Steep Gradients: In hilly terrain the adoption of gradients steeper than Desirable Maximum could make significant savings in construction or environmental costs, but would also result in higher user costs, i.e. by delays, fuel and accidents. Slightly steeper gradients may, therefore, be permitted as Relaxations. There is, however, a progressive decrease in safety with increasingly steeper gradients. Departures from standards will, therefore, be required for any proposals to adopt gradients steeper than the following:

	Max Grade with Relaxation
Motorways	4%
AP Dual Carriageways	5%
AP Single Carriageways	6%

4.3 Minimum Gradients: For effective drainage with kerbed roads a minimum gradient of 0.5% should be maintained wherever possible. In flatter areas, however, the vertical alignment should not be manipulated by the introduction of vertical curvature simply to achieve adequate surface water drainage gradients. Drainage paths must be provided by false channel profiles with minimum gradients of 0.5%. False channels may be avoided by using over-edge drainage (to filter drains or surface channels or ditches) where kerbs are inappropriate, eg. in rural areas.

Vertical Curves

4.4 General: Vertical curves shall be provided at all changes in gradient. The curvature shall be large enough to provide for comfort and, where appropriate, sight distances for safe stopping at Design Speed. The use of the permitted vertical curve parameters will normally meet the requirements of visibility. However stopping sight distance should always be checked because the horizontal alignment of the road, presence of crossfall, superelevation or verge treatment and features such as signs and structures adjacent to the carriageway will affect the interaction between vertical curvature and visibility.

4.5 K Values: Curvature shall be derived from the appropriate K value in Table 3. The minimum curve lengths can be determined by multiplying the K values shown by the algebraic change of gradient expressed as a percentage, ie. +3% grade to -2% grade indicates a grade change of 5%. Thus for a Design Speed of 120 km/h, the length of a crest curve would be:-

Desirable Min = 5 x 182 = 910m

One step below Des Min = 5 x 100 = 500m

4.6 Crest Curves: There are two factors that affect the choice of crest curvature, visibility and comfort. At all Design Speeds in Table 3 the Desirable Minimum crest in the road will restrict forward visibility to the Desirable Minimum stopping sight distance before minimum comfort criteria are approached, and consequently Desirable Minimum crest curves are based upon visibility criteria.

4.6A The use of crest curves in the range from Desirable Minimum up to FOSD Overtaking Crest on single carriageway roads, in combination with a straight or nearly straight horizontal alignment (such that the section of road could form part of a Two-lane Overtaking Section in the horizontal sense), is a Departure from Standards (see Paragraph 7.19).

4.7 Sag Curves: Daytime visibility at sag curves is usually not obstructed unless overbridges, signs or other features are present; this also applies to night-time visibility on roads that are lit. However, sag curvature does affect night-time visibility on unlit roads. The Desirable Minimum sag curves are based on a conservative comfort criterion (0.21 m/sec^3 maximum rate of vertical acceleration); the resultant sag curves approximate to those using headlamp visibility criteria assuming a 1.5^o upward spread of the light beam. The sag curves for 1 Design Speed step below Desirable Minimum are based on the conventional comfort criterion of 0.3 m/sec^3 maximum rate of vertical acceleration. The adoption of this approach results in the sag curve K values being less than or equal to the equivalent crest curve K values at all the Design Speeds in Table 3.

4.8 Grass Verges: Where, at crests, the sight line crosses the verge, consideration shall be given to the design of a lower verge profile in order to allow for an overall height of grass of 0.5m.

Relaxations

4.9 Crest Curves: In the circumstances described in Paragraphs 1.15 to 1.26, Relaxations below the Desirable Minimum values may be made at the discretion of the Designer. The number of Design Speed steps permitted below the Desirable Minimum are normally as follows:

motorways	band A	1 step
motorways	band B	2 steps
all-purpose roads	bands A and B	2 steps

However, in the circumstances listed in Paragraphs 4.10, 4.11 and 4.12 the scope for Relaxations shall be extended or reduced as described, provided that the resultant Relaxations do not exceed 2 Design Speed steps.

4.10 At or near the top of up gradients on single carriageways steeper than 4% and longer than 1.5 km, the scope for Relaxations may be extended by 1 step due to reduced speeds uphill.

4.11 The scope for Relaxations shall be reduced by 1 Design Speed step immediately following an Overtaking Section on single carriageway roads (see Paragraphs 7.5 to 7.16).

4.12 For band A roads when the crest curve is within a straight section the scope for Relaxations may be extended by 1 Design Speed step.

4.13 Relaxations below Desirable Minimum are not permitted on the immediate approaches to junctions as defined in Paragraph 1.26.

4.14 Sag Curves: In the circumstances described in Paragraphs 1.15 to 1.26, Relaxations below the Desirable Minimum values may be made at the discretion of the Designer. The number of Design Speed steps permitted below the Desirable Minimum are normally as follows:

motorways	band A	1 step
motorways	band B	2 steps
all-purpose roads	bands A and B	2 steps

However, in the circumstances listed in Paragraph 4.16, the scope for Relaxations shall be extended or reduced as described, provided that the resultant Relaxations do not exceed 2 Design Speed steps.

4.15 (Not used.)

4.16 The scope for Relaxations shall be reduced by 1 Design Speed step immediately following an Overtaking Section on single carriageway roads (see Paragraphs 7.5 to 7.16).

4.17 Relaxations more than one Design Speed step below Desirable Minimum are not permitted on the immediate approaches to junctions as defined in Paragraph 1.26.

7. SINGLE 2 LANE CARRIAGEWAY ROADS

General Principles

7.1 Single 2 lane carriageways up to 10m wide (running width) shall be designed with the objectives of safety and uncongested flow in mind. This Chapter gives methods of achieving these objectives. Although they are to some extent related, for instance frustrated traffic tends to lead to unsafe conditions, it is important to identify some other aspects which if not taken into account in the design may lead to a higher than average proportion of serious accidents. Amongst these are:

a. Continuous flowing alignments, (Paragraphs 7.25 and 7.28);

b. Treatment of grade separation on single carriageways (Paragraph 7.35);

c. Single carriageway alternating with dual carriageway (Paragraphs 7.16, 7.36, 7.39, 7.40 and 7.41);

d. Staged construction (Paragraphs 7.37, 7.38, 7.47 and 7.48).

7.2 Clearly identifiable Overtaking Sections for either direction of travel are required to be provided frequently throughout the single carriageway, so that vehicles can maintain the Design Speed in off-peak conditions. In peak conditions overtaking opportunities will be rare; nevertheless steady progress will be possible for the majority of vehicles if junctions are carefully designed, and if climbing lanes are provided wherever the forecast traffic demand is sufficient to justify a climbing lane according to Paragraph 5.2.

7.3 In easy terrain, with relatively straight alignments, it may be economically feasible to provide for continuous overtaking opportunity by means of consistent provision of Full Overtaking Sight Distance (FOSD). Where significant curvature occurs or the terrain becomes increasingly hilly, however, the verge widening and vertical crest requirements implicit in this design philosophy will often generate high cost and/or environmentally undesirable layouts. The alternative philosophy of clearly identifiable Overtaking Sections, including climbing lanes, interspersed with clearly Non-overtaking Sections, will frequently result in a more cost effective design provision. The trade-off between alternative alignments of the construction and user costs, including accidents, should be tested by cost/benefit analyses.

7.4 In the coordination of vertical and horizontal alignments, many of the principles contained in Paragraph 8.7 (Category 5A and 7A dual carriageways) are equally applicable to the design of single carriageway roads. However, the overriding need to design for adequate overtaking will frequently supersede the general desirability for full coordination of vertical and horizontal alignments, with design concentrating upon the provision of straight Overtaking Sections. At sags and crests, however, designs should still be checked to ensure that the road in perspective does not take on a disjointed appearance.

Overtaking Sections

7.5 Overtaking Sections are sections of road where the combination of horizontal/vertical alignment, visibility, or width provision is such that clear opportunities for overtaking will occur.

Overtaking Sections, which are fully defined in Paragraphs 7.7 to 7.16, comprise:

a) Two-lane Overtaking Sections
b) Climbing Lane Overtaking Sections
c) Downhill Overtaking Sections at Climbing Lanes
d) Dual or S4 Overtaking Sections

It is necessary for the calculation of Overtaking Value (Paragraph 7.20) to define the method by which the lengths of Overtaking Sections are assessed, and the method of measurement for each category of Overtaking Section is described in the following paragraphs. In general, they will commence whenever either FOSD on a straight (or nearly straight) or right hand curve is achieved, or the width provision is sufficient for overtaking without crossing the dividing line between opposing lanes. They will terminate either at a point where sight distance reduces to FOSD/2m when approaching a Non-overtaking Section, or at a distance of FOSD/4m prior to an obstruction to overtaking. (The detailed measurement of single lane downhill sections opposite climbing lanes, however, is described in Paragraph 7.13).

7.6 The method of measurement described in the following paragraphs is based upon curvature/visibility relationships for S2 roads. Whilst the additional road width of a WS2 provides much greater flexibility for overtaking, largely independent of curvature, the following design rules should still be used to achieve an optimal overtaking design.

7.7 <u>Two-lane Overtaking Sections</u>: Two-lane Overtaking Sections are sections of single two lane carriageways, with normal centre of carriageway road markings providing clear opportunities for overtaking. They consist of straight or nearly straight sections affording overtaking in both directions (with horizontal radius of curvature greater than that shown in Table 5) and right hand curves, the commencement of which are provided with at least FOSD. The section, which is shown in Figure 19, is measured as follows:

7.8 <u>Commencement</u>: At the point on a straight (or nearly straight) or right hand curve where FOSD is achieved, either within or without the road boundary.

7.9 <u>Termination:</u>

a) At a point FOSD/4m prior to the tangent point or centre of transition of a left hand curve

b) The point on a right hand curve where sight distance has reduced to FOSD/2m

c) A point FOSD/4m prior to an obstruction to overtaking (see Paragraph 7.18).

Design Speed km/h	100	85	70	60	50
Minimum Radius of Straight or nearly Straight sections (m)	8160	5760	4080	2880	2040

Table 5: Minimum Radii for Two-lane Overtaking Sections

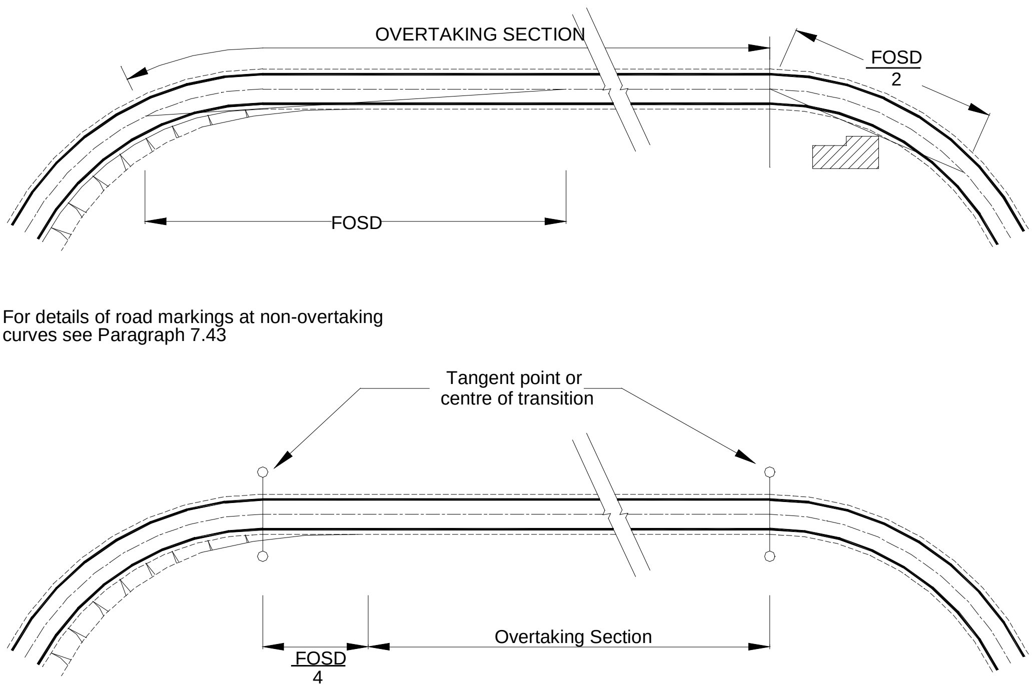


Figure 19 : Two-lane Overtaking Sections

7.10 Climbing Lane Overtaking Sections: Climbing Lane Overtaking Sections are sections where priority uphill overtaking opportunities are provided by means of two uphill lanes, separated from the opposing downhill lane by means of a double line, (either double continuous or continuous/broken). The section, which is shown in Figure 20, is measured as follows:

7.11 Commencement: A point in the centre of the commencing taper.

7.12 Termination: A point FOSD/4m prior to the centre of the finishing taper. However, if the following section is an Overtaking Section, it should be assumed to be contiguous with the climbing lane section.

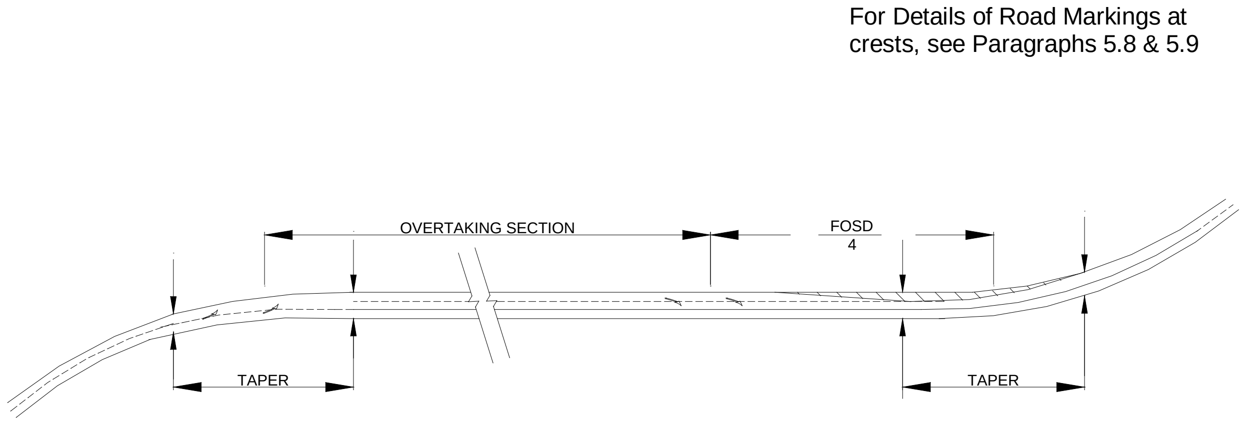


Figure 20 : Climbing Lane Overtaking Sections

7.13 Downhill Overtaking Sections at Climbing Lanes: Downhill Overtaking Sections at Climbing Lanes are sections of a single downhill lane, opposite a climbing lane, constrained by a continuous/broken double line, where the combination of visibility and horizontal curvature provide clear opportunities for overtaking when the opposing traffic permits. They consist of straight or nearly straight sections, and right hand curves with radii greater than those shown in Table 6.

Design Speed km/h	100	85	70	60	50
Minimum Radius (m)	2880	2040	1440	1020	720

Table 6: Minimum Radii of Right Hand Curve Downhill Overtaking Sections at Climbing Lanes

The sight distance naturally occurring within the normal road boundaries at the radii shown in Table 6 will be sufficient for downhill overtaking, and thus, for Downhill Overtaking Sections at Climbing Lanes, verges shall not be widened to give FOSD. However, these sections should only be considered as Overtaking Sections on straight grades or sag configurations, or when the crest curve K value is large enough that the road surface is not obscured vertically within FOSD – this will require the use of a crest curve K value of double the value given in Table 3 for FOSD Overtaking Crest K Value.

The section, which is shown in Figure 21, is measured as follows:

7.14 Commencement: The point where the right hand curve radius achieves the requisite value from Table 6.

7.15 Termination: A point FOSD/4m prior to the end of the requisite radius.

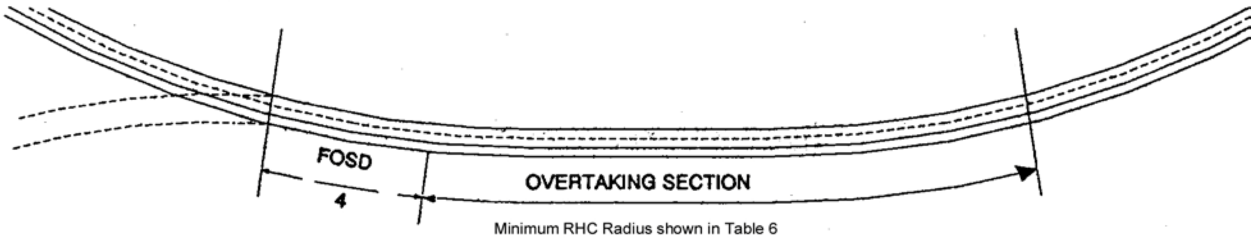


Figure 21 : Downhill Overtaking Sections at Climbing Lanes

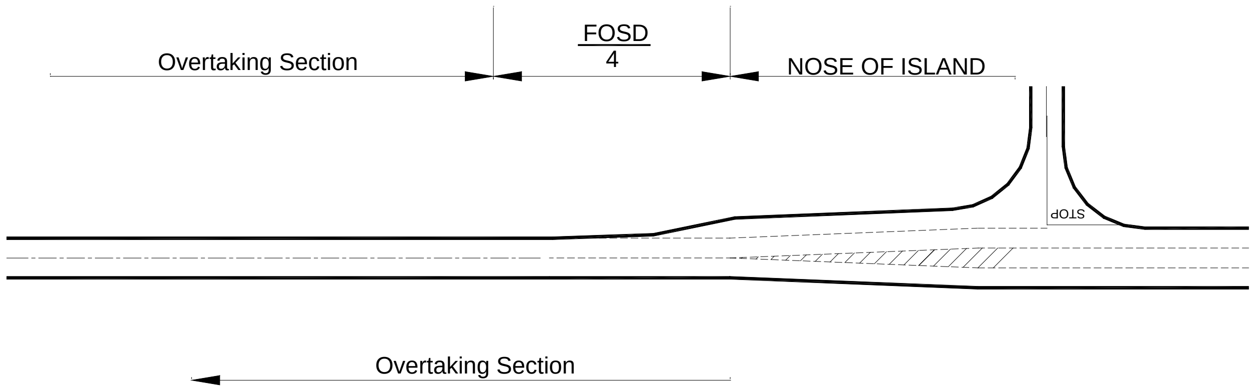
7.16 Dual Overtaking Sections: Dual Overtaking Sections are sections with dual carriageways, which provide overtaking opportunities throughout their length. They should, however, only be provided in cases where the most economic method of improvement of a section of existing single carriageway is to provide a second carriageway alongside the first. Dual Overtaking Sections within otherwise single carriageway roads shall be subject to the same overtaking length criteria as climbing lane sections shown at Paragraph 7.10. S4 Overtaking Sections (where space is limited) should be considered equivalent to Dual Overtaking Sections in terms of assessment of overtaking.

Non-overtaking Sections

7.17 Non-overtaking sections are all left or right hand curves on two-lane sections or single downhill lanes opposite climbing lanes that do not conform with the requirements of Paragraphs 7.7 to 7.16 (see also Non-overtaking crests, Paragraph 7.19).

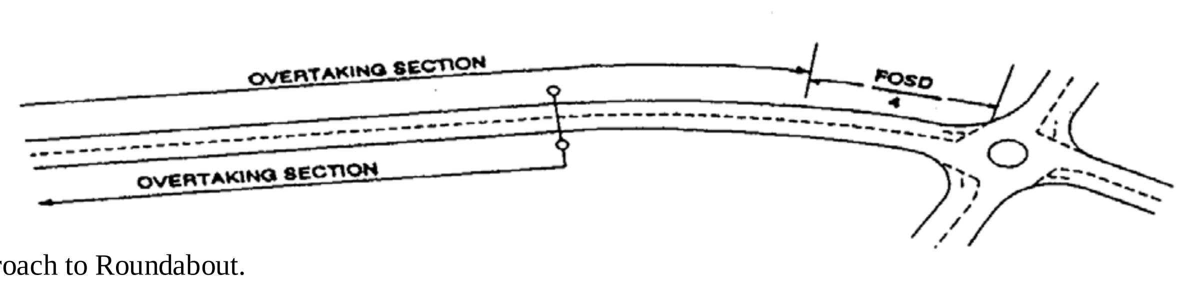
Obstructions to Overtaking

7.18 At Grade Junctions: Major/minor junctions with ghost islands or single lane dualling and roundabouts should be considered as obstructions to overtaking if they are sited within an otherwise Overtaking Section. The Overtaking Section shall terminate at a distance of FOSD/4m prior to the nose of the ghost or physical island, or the roundabout Yield line, as shown in Figure 22. Similarly, the Overtaking Section shall commence at the end of the nose of the ghost or physical island at a priority junction. The commencement at a roundabout shall be in accordance with the requirements for a Two-lane Overtaking Section (see Paragraph 7.8). Simple junctions and accesses, however, with no central ghost or physical islands can be ignored for the purpose of determining Overtaking Sections.



Note: a simple priority junction with no ghost island layout can be ignored for the purposes of determining Overtaking Sections.

a. Approach to Priority Junction (with ghost or solid island).



b. Approach to Roundabout.

Figure 22 : Obstructions to Overtaking

Non-overtaking Crests

7.19 A crest with a K value less than that shown in Table 3 for FOSD Overtaking Crest K Value should be considered as a Non-overtaking crest. The Overtaking Section within which it occurs should be considered to terminate at the point at which sight distance has reduced to FOSD/2, as shown in Figure 23. However, when the horizontal alignment of the Overtaking Section is straight or nearly straight, the use of Desirable Minimum crest K values will result in a continuous sight distance only slightly above FOSD/2, and thus, theoretically, the Overtaking Section will be continuous over the crest. The use of crest K values in the range from Desirable Minimum up to FOSD Overtaking Crest in combination with a straight or nearly straight horizontal alignment (such that the section of road could form part of a Two-lane Overtaking Section in the horizontal sense) is not, therefore, recommended for single carriageway design (see Paragraph 7.30), and is considered to be a Departure from Standards.

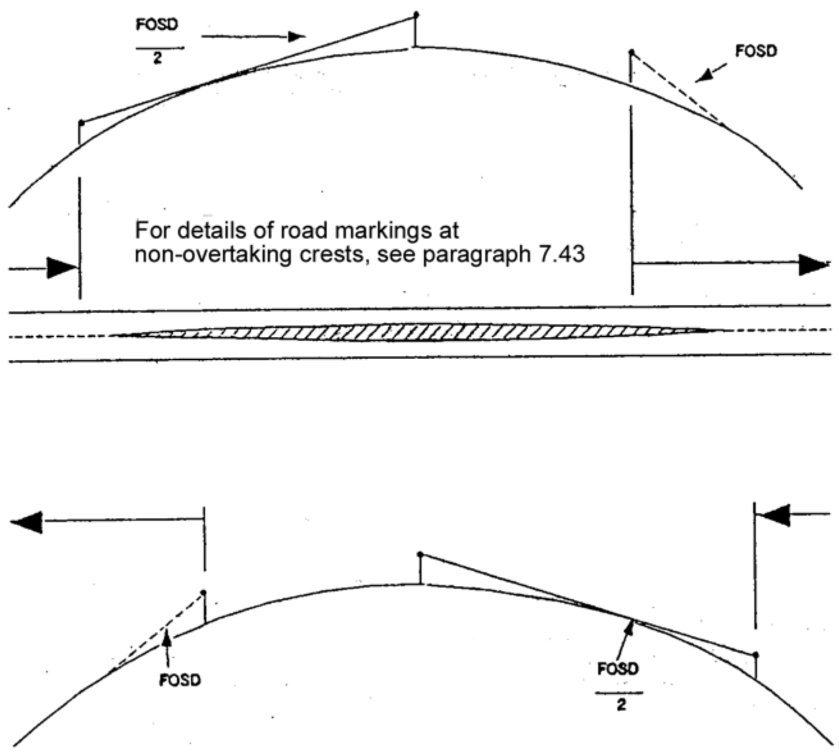
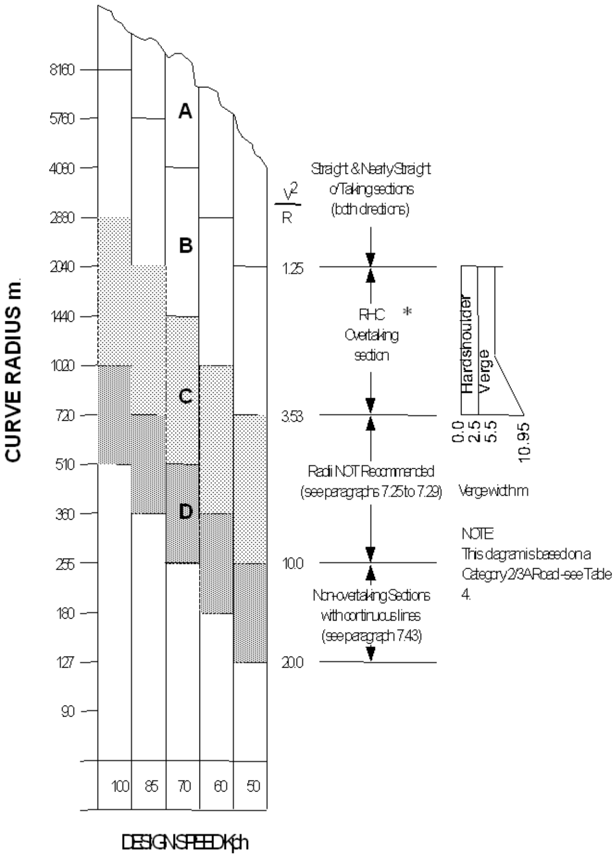


Figure 23 : Non-overtaking Crest



* Note: Verge widening may be necessary. See Paragraph 7.27.

Figure 24 : Horizontal Curve Design

7.29 Non-overtaking Sections should be designed using the radii shown in Band D (V^2/R = 10-20), where the radius is sufficiently small to represent a clearly Non-overtaking Section. Radii of Non-overtaking Sections should be chosen around the centre of Band D (V^2/R = 14) to strike a balance between providing clear Non-overtaking Sections and avoiding steep superelevation.

Vertical Curve Design

7.30 The vertical alignment shall be coordinated with the horizontal alignment to ensure the most efficient overtaking provision. On Two-Lane Overtaking Sections, the vertical curvature shall be sufficient to provide for FOSD in accordance with Paragraphs 2.3 to 2.5. However, for Non-overtaking Sections and climbing lanes, the use of large crest curves is quite unnecessary and is not recommended. On a road with a straight or nearly straight horizontal alignment (such that the section of road could form part of an Overtaking Section in the horizontal sense), unless a vertical curve can have a large enough K value to provide FOSD (thus forming an Overtaking Section) a long section of dubious visibility would result (see Paragraph 7.19). Therefore, in such circumstances on a Two-lane Overtaking Section in the horizontal sense, the crest K value should not be greater than that for one Design Speed step below Desirable Minimum. The use of crest K values in the range from Desirable Minimum up to FOSD Overtaking Crest in combination with a straight or nearly straight horizontal alignment (such that the section of road could form part of a Two-lane Overtaking Section in the horizontal sense) is not recommended for single carriageways, and is considered to be a Departure from Standards. The use of crest curves in that range would be counter productive, simply increasing costs, increasing the length of dubious crest visibility, and reducing the length of clear Overtaking Sections that could otherwise be achieved.

7.31 Horizontal and vertical visibility shall be carefully coordinated to ensure that sight distance at curves on crests is correlated. For example, it would be unnecessary to acquire additional verge width to provide for Desirable Minimum stopping sight distance in the horizontal sense, when the crest only provides a stopping sight distance of one Design Speed step below Desirable Minimum.

Junction Strategy

7.32 The aim should be to provide drivers with layouts that have consistent standards and are not likely to confuse them. On lengths of inter-urban road, sequences of junctions should not therefore involve many different layout types. For example, a length of route containing roundabouts, single lane dualling, ghost islands, simple priority junctions and grade separation would inevitably create confusion and uncertainty for drivers and cause accidents on that account. The safest road schemes are usually the most straightforward ones that contain no surprises for the driver.

7.33 Major/minor junctions with ghost islands or local single lane dualling and roundabouts represent an obstruction to overtaking. To achieve maximum overtaking efficiency, therefore, straight Overtaking Sections should be located wherever possible between junctions, which can be located in Non-overtaking Sections. Visibility to the junction shall be a minimum of Desirable Minimum Stopping Sight Distance.

7.34 Use of a roundabout will enable a change of alignment at a junction, thus optimising the Overtaking Sections either side. As an alternative to continuing large radius curves into the roundabout with only unidirectional overtaking, it is preferable to utilise a straight section followed by a non-overtaking radius as the final approach, in order to optimise the use of two directional overtaking straights, as shown in Figure 25.

7.35 Designs involving grade separation of single carriageway roads should be treated with caution. Some grade separated crossings will be necessary for undesirable side road connections and for agricultural purposes. Experience has shown that frequent overbridges and the resulting earthworks create the impression of a high speed road, engendering a level of confidence in the road alignment that cannot be justified in single carriageways, where opposing traffic travels on the same carriageway. The provision of regular at grade junctions with ghost islands, local dualling or roundabouts will maintain the impression of a single carriageway road. Where crossing flows are high, or local topographical conditions would suggest the need for a grade separated junction, the single quadrant link with a conventional ghost island junction, as shown in Figure 26, will maintain the impression of a single carriageway road, with conventional single carriageway turning movements and minimise the disruptive right turn movement onto the major road. The link should be located in the quadrant that will ensure the larger turning movements become left turns onto and right turns off the major road. With the highest levels of traffic flow, it may be necessary to provide roundabouts at one or both ends of the link road. The use of slip merges can be confusing on single carriageways and create problems with merging into a single lane. They destroy the overall impression of a single carriageway, and shall not be used.

Changes in Carriageway Width

7.36 Changes from dual to single carriageways are a potential hazard situation and the aim in new construction should be to provide continuity of road type, either single or dual carriageway layout, on any major section of a route which carries consistently similar traffic, subject to satisfactory economic and environmental assessments. Exceptions are described below. Where it is not possible to achieve an adequate Overtaking Value by means of Two-lane Overtaking Sections or climbing lanes, the impression of a single carriageway road shall be maintained by utilising Standard S2 or WS2 sections with hard shoulders at suitable locations (see Paragraph 7.24), or short sections of S4, rather than introducing sections of dual carriageway.

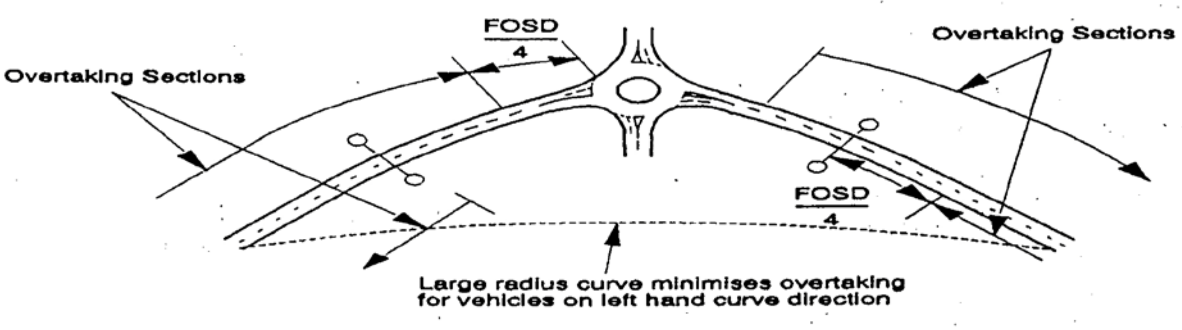


Figure 25 : Use of Roundabout to Change Alignment

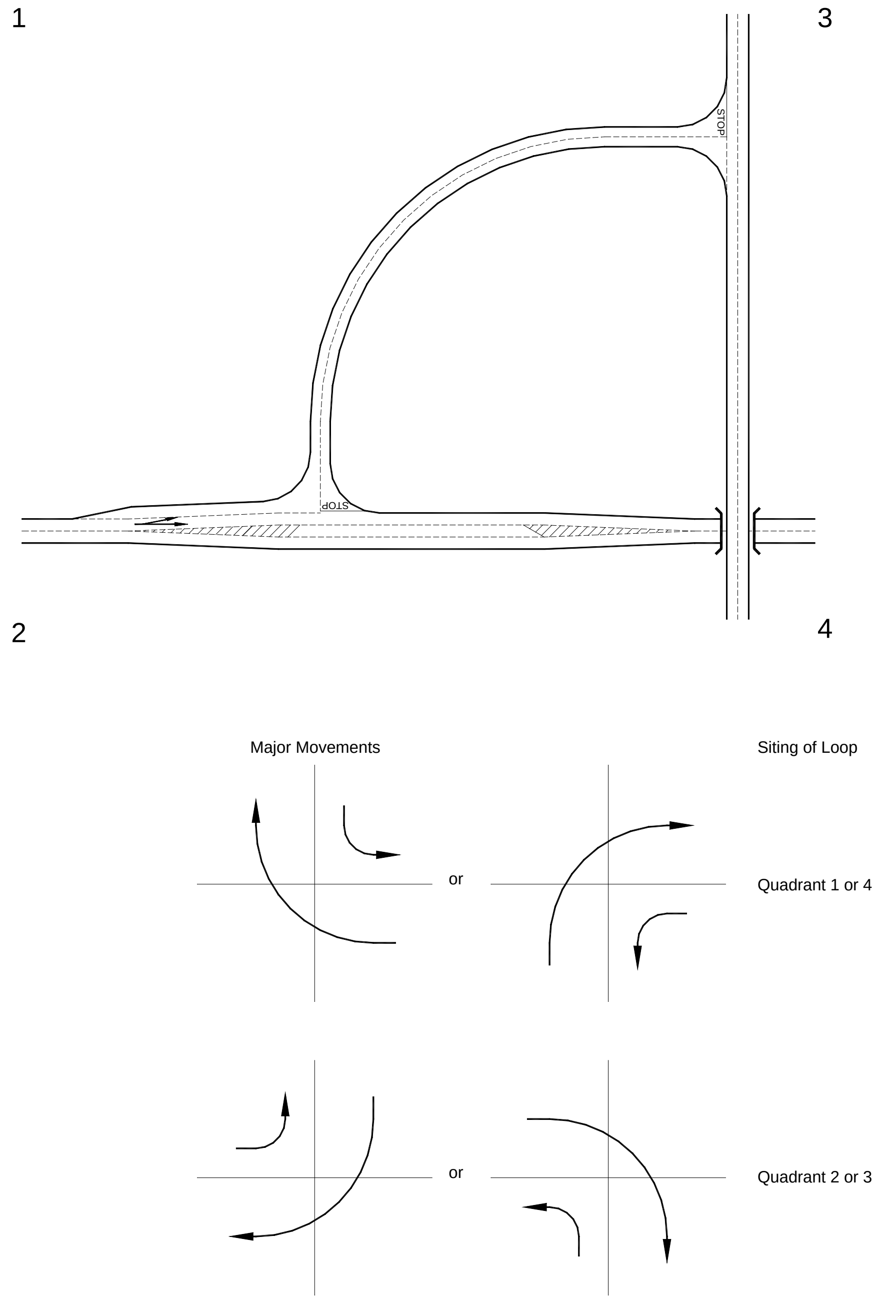


Figure 26 : Single Quadrant Link

Where it is appropriate to change from dual to single carriageway, careful consideration should be given to the use of a roundabout as a terminal junction to indicate to drivers the significant change in road standard.

7.37 Single carriageways of a type containing wide verges and extensive earthworks prepared for eventual dualling create the illusion of driving on a dual carriageway, which leads to abnormally high serious accident rates. Where staged construction is part of the design or there are safety problems at existing sites, provision shall be made to avoid giving drivers an illusion that they are on a dual carriageway rather than on a single carriageway such as

a) Fencing of a permanent appearance at a verge width (normally 3.0m) from the channel of the constructed carriageway on the side reserved for the future carriageway.

b) Clear signing and marking indicating the existence of two way traffic.

c) Where a changeover occurs at a roundabout, a narrow physical splitter island not less than 50 metres long on the single carriageway side of the roundabout followed by hatching.

7.38 Where there is an overbridge designed for an eventual second carriageway, the illusion of a second running carriageway shall be removed by planting and earth mounds as shown in Figure 27.

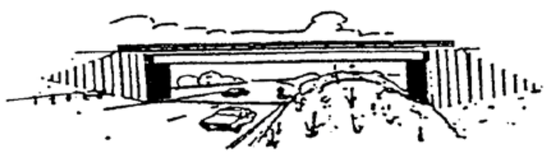


Figure 27

7.39 Where a lighter trafficked bypass occurs within an otherwise dual carriageway route, a single carriageway may be acceptable provided the terminal junctions such as roundabouts give a clear indication to drivers of changed Standards (see Figure 28, Paragraph 7.36 and Paragraph 7.37 b and c).

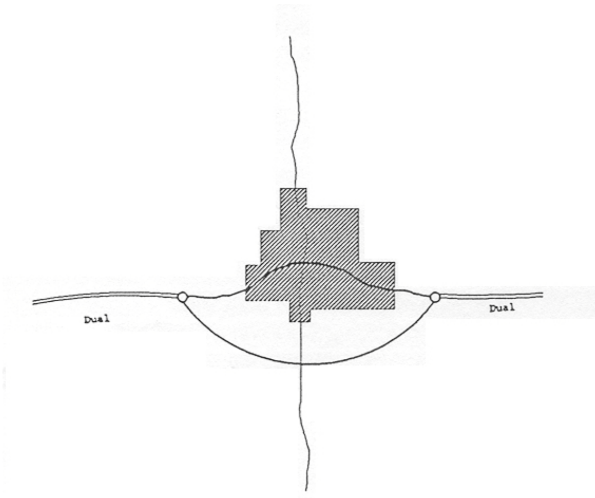


Figure 28

7.40 In circumstances where a length of new carriageway alongside an existing single carriageway provides the most suitable and economic means of achieving a dualled Overtaking Section and where such a dual carriageway returns to single carriageway width or in any other case, the change in width shall be made abundantly clear to drivers by:

a) Signing and marking indicating the existence of the single carriageway

b) Providing a length of central reserve in advance of the taper such that drivers approaching the single carriageway can see across it, to have a clear view of the approaching traffic moving on to the dual carriageway.

7.41 If lengths of dual carriageway within a generally single carriageway road or vice-versa are unavoidable they shall be at least 2km in length and preferably 3km, and major/minor junctions shall be avoided within 1 kilometre of the end of the central reserve on either type of carriageway, see Paragraph 7.39.

NRA TA 43/00

GUIDANCE ON ROAD LINK DESIGN

AMENDMENT No. 1
June 2001

NRA Advice Note NRA TA 43/00 – Guidance on Road Link Design – dated December 2000 is amended as follows. The amendments revise the guidance for crest curves on single carriageway roads.

6. Pages 4/3 to 4/6 (Paragraphs 4.3.2 to 4.4.5) dated December 2000 are replaced with the revised pages 4/3 to 4/6 dated June 2001 as enclosed. **Paragraph 4.3.3A has been added and 4.3.7 has been revised**.

7. Pages 6/3 and 6/4 (Paragraphs 6.3.1 to 6.5.2) dated December 2000 are replaced with the revised pages 6/3 and 6/4 dated June 2001 as enclosed. **Paragraph 6.5.2 has been revised**.

8. This Amendment shall be implemented forthwith.

9. All technical enquiries or comments on this Amendment or NRA TA 43/00 should be sent in writing to:

Head of Project Management and Engineering
National Roads Authority
St Martin’s House
Waterloo Road
Dublin 4

....

E O’CONNOR
Head of Project Management and Engineering

INSTRUCTIONS FOR USE

4. Remove existing cover sheet, contents page and pages 4/3 to 4/6, and 6/3 and 6/4.
5. Insert the replacement pages as enclosed.
6. Insert this Amendment sheet between the contents page and the cover sheet.

Volume 6 Section 1
Part 1A

NRA TA 43/00
and Amendment No.1

NATIONAL ROADS AUTHORITY
An tÚdarás um Bóithre Náisiúnta

Guidance on Road Link Design

June 2001

Headquarters St. Martin's Hse., Waterloo Road, Dublin 4. Tel: 01 660 2511 Fax: 01 668 0009

Summary :

This Advice Note gives recommendations for the geometric design of new roads and improvements with regard to traffic operation and safety. It should be read in conjunction with Standard NRA TD 9 – Road Link Design.

Published by the National Roads Authority, Dublin
2001

VOLUME 6 ROAD GEOMETRY
SECTION 1 LINKS

PART 1A

NRA TA 43/00
and Amendment No.1

GUIDANCE ON ROAD LINK DESIGN

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the difference between (a) and (b) would become significant, but comfort criteria will override. In these latter cases, a maximum vertical acceleration of $0.3m/s^2$ is taken as the limit for comfortable design.

4.3.2 Design Criteria. For practical purposes therefore, situation (b) above can be ignored and the formulae for vertical crest curve length can be resolved to:

Visibility Criterion $L = \dfrac{S^2A}{200\,(a+b+2\sqrt{a}\sqrt{b})}$

Comfort Criterion $L = \dfrac{V^2A}{389}$

where:

- L = Curve length (m)
- S = SSD at the Design Speed (m)
- A = Algebraic difference in grades (%)
- a = Eye height above road surface (m)
- b = Object height above road surface (m)
- V = Design Speed (km/h)

4.3.3 Interrelation with SSD. The lower boundary of the visibility envelope for SSD (Paragraph 2.1.2) represents visibility between an eye height of 1.05m and an object height of 0.26m. Figure 22 shows the object height visible from a 1.05m eye height at the SSD with varying vertical crest radii. The SSD's derived in Paragraph 2.1.8 each bear a constant relationship to each other. Thus, if at a given radius an object of 0.26m height can be seen at the Desirable SSD for the Design Speed, an object of 1.05m height can be seen at an SSD one step below the Desirable value providing there is no horizontal interference to the visibility envelope. This object height of 0.26m includes the stop/indicator lamps of a vehicle, probably the most important criterion, and also significant low objects on the carriageway.

4.3.3A A consequence of this interrelation is that (for situation (a) in Paragraph 4.3.1) the adoption of a Crest Curve one Design Speed step below Desirable Minimum inevitably reduces SSD (to the 0.26m object height) to a value one Design Speed step below Desirable Minimum. Thus, a one step Crest Curve Relaxation generally results in a one step SSD Relaxation. Unless the circumstances described in Paragraph 1.24B of NRA TD9 apply, this is not a permitted combination of Relaxations (see Paragraphs 1.24 and 1.24A of NRA TD9); it should therefore be treated as a Departure.

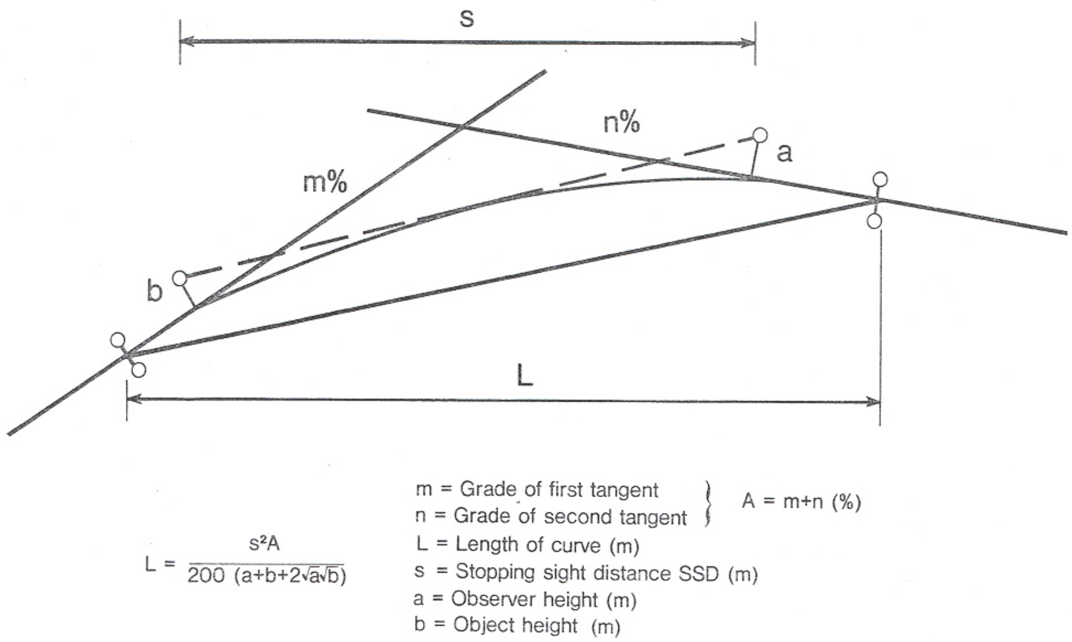


Figure 21 : Relationship between Vertical Curvature and Visibility

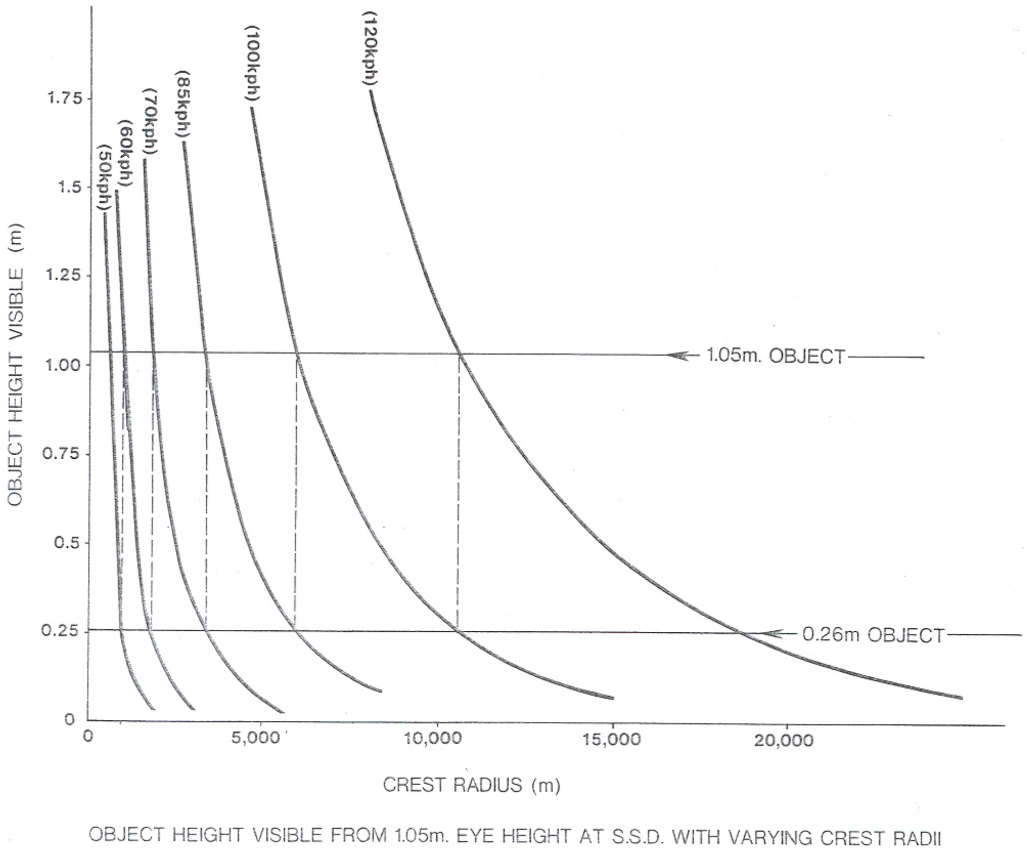


Figure 22 : Crest Curves

4.3.4 Design Formula. The Desirable Minimum SSD crest curve provides Desirable SSD to an object of 0.26m height. The crest curve for one Design Speed Step below Desirable Minimum provides an SSD of one Design Speed step below Desirable Minimum to an object height of 0.26m and this is equivalent to Desirable SSD to an object height of 1.05m. By substituting an eye and object height of 1.05m and 0.26m respectively the equation for stopping visibility crest length becomes:

$$L = \frac{S^2A}{471}$$

or for Design Speeds below 60kph, where SSD is unaffected by the crest curve, the comfort criteria will override, i.e:

$$L = \frac{V^2A}{389}$$

4.3.5 Design Values. Table 11 shows the relevant K values for Design Speed related minimum crest curves. It can be seen that at Design Speeds of 60km/h and above, the visibility criterion will take precedence over the comfort criterion, whilst for 50km/h (and below) comfort criteria will override. For minor changes of grade, however, visibility will not be obstructed and comfort criteria will be the minimum requirement. The Design K values for crest curvature for general use are therefore as in Table 12.

Design Speed (km/h)	120	100	85	70	60	50
Visibility Criteria Desirable Minimum K	182.4	99.2	54.6	30.4	17.2	9.8
One Design Speed Step Below Desirable Minimum K	99.2	54.6	30.4	17.2	9.8	5.7
Comfort Criteria Minimum K	37.0	26.2	18.5	13.1	9.3	6.5

Table 11 : K Values for Different Criteria in the Design of Crest Curves

Design Speed (km/h)	120	100	85	70	60	50
Desirable Minimum K	182	100	55	30	17	10
One Design Speed Step Below Desirable Minimum K	100	55	30	17	10	6.5

Table 12 : K Values for the Design of Crest Curves

4.3.6 Dual Carriageways. The cost implications of providing Desirable Minimum SSD crest curvature, which produces Desirable SSD to a 0.26m object, are minimal where the terrain is easy and where grade changes are relatively minor.

On dual carriageways where grade changes exceed about 4% it will rarely be feasible to consider the use of Desirable Minimum SSD crest curvature and relaxations should be considered in appropriate cases. Relaxations below Desirable Minimum are not permitted where junctions or accesses are sited beyond the crest, (but see Paragraph 2.1.10).

4.3.7 Single Carriageways. On single carriageway roads, the need for clear identification of non-overtaking sections will override (see Paragraphs 6.4.2 and 6.5.2). When the horizontal alignment is straight or nearly straight (such that the section of road could form part of a Two-lane Overtaking Section in the horizontal sense), Desirable Minimum K value should be avoided with lesser values being used (see Paragraphs 6.5.2 and 6.5.3).

4.4 Sag Curves

4.4.1 Design of sag curves has, in the past, been based upon considerations of headlamp visibility whereby a headlamp, 0.6m above the surface of the road with an upward spread of the light beam of 1 degree, would illuminate the road surface for a distance ahead equivalent to the Design Speed related SSD. The following formula can be derived for length of curve in situations when S < L:

$$L = \frac{S^2A}{200\,\alpha\, S + 120}$$

where:

L = Length of sag curve (m)
S = SSD at Design Speed (m)
A = Algebraic difference in grades (%)
α = Angle of upward spread of light beam (radians)

4.4.2 New Criteria. In applying this formula, four aspects need to be appreciated:

(a) The formula is extremely sensitive to the assumption of a 1 degree upward spread of the light beam;

(b) The philosophy assumed that headlamps are capable of illuminating objects up to 300m distance, which is considerably beyond the reach of headlamps;

(c) Many drivers drive on dipped headlamps which considerably reduces the effect of the beam;

(d) On horizontal curves the headlamp beam does not illuminate the road surface at even shorter distances ahead.

Whilst, in relatively flat terrain, relaxations of the SSD related values would have no significant effect, in difficult topography, with gradients of more than about 4%, the minimum sag curve derived from the above formula can have a very severe effect on cost and environmental impact, eg. height of embankment or viaduct. Reliance upon the tenuous headlamp beam parameters in these situations, therefore, cannot be sustained and it is more realistic at the higher Design Speeds to design in relation to the effects of the sag curve on comfort.

4.4.3 Design Values. Data from international practice suggests that the maximum desirable vertical acceleration for comfort is 0.3m/sec² for which:

$$L = \frac{V^2 A}{389} \quad \text{or} \quad K \text{ value} = \frac{V^2}{389}$$

where: L = Length of curve (m)
V = Design Speed (km/h)
A = Algebraic difference in grades (%)

Table 13 shows the relevant K values for Design Speed related sag curves.

4.4.4 UK practice is to use comfort criteria for high Design Speeds (more than 70km/h), but the lower of the two headlamp visibility criteria for low Design Speeds (less than 70km/h) in unlit areas. In lit areas, it is considered acceptable to use comfort criteria for all Design Speeds. All values are considered to be 1 Design Speed step below Desirable Minimum.

4.4.5 A result of this practice is that, at low Design Speeds in unlit areas, minimum crest curve K values are smaller than minimum sag curve K values. A framework of sag curve K values has therefore been developed which both overcomes this anomaly and provides Desirable Minimum values; these are shown in Table 14.

Design Speed (km/h)	120	100	85	70	60	50
Headlamp Visibility K to provide Desirable SSD	75.0	53.3	37.8	26.6	18.6	12.9
K to provide 1 step below Desirable SSD	53.3	37.8	26.6	18.6	12.9	8.9
Comfort K	37.0	26.2	18.5	13.1	9.3	6.5

Table 13 : K Values for Different Criteria in the Design of Sag Curves

Design Speed (km/h)	120	100	85	70	60	50
Des Min Sag K Value	53	37	26	20	13	9
One Design Speed Step Below Des Min K Value	37	26	20	13	9	6.5

Table 14 : Minimum K Values to be Used for Sag Curves

6.3 Overtaking Value

6.3.1 Attention is particularly drawn to the final sub-paragraph of Paragraph 7.24 in NRA TD 9, where the minimum Overtaking Value cannot be reached. This is of particular relevance in short by pass situations and often the best solution will be to widen as described in Paragraph 7.24e. Departures from "Overtaking Value" standard and/or carriageway width standard will be considered on either "level" roads or in climbing lane situations.

6.4 Horizontal Curve Design

6.4.1 The objective should be to evolve a design using Band A, Figure 24 of NRA TD 9, with the upper range of Band B where it cannot be avoided, keeping verge widening minimal. Where this is not possible Band D radii have to be used but not the non recommended Band C.

6.4.2 Non-Overtaking Radii – Design Considerations. Non-overtaking curves in Band D should be utilised only when constraints make this unavoidable. There are both advantages and disadvantages in their use. Radii towards the lower end of this non-overtaking band shorten the length of a curve thereby increasing the amount of overtaking alignment available; they also enhance driver perception of what is a non-overtaking curve. These radii have relatively less sight distance available within the road boundary; Paragraph 7.43 of NRA TD 9 describes the use of hatched markings which are recommended. On the other hand, lower Band D radii will lead to higher sideways forces on vehicles and less than Desirable Minimum Stopping Sight Distance (DMSSD) unless there is excessive verge widening. These effects are illustrated in Table 15 by comparing the difference between the situation for a single 7.3m carriageway at Desirable and one Design Speed Step Below Desirable Minimum Radius (Figure 24) for Design Speeds of 100 km/h or less.

6.4.3 Recommended Radii. There is no unique answer to the conflicting questions posed in Table 15 and in any case too much precision would be spurious in view of two further factors:

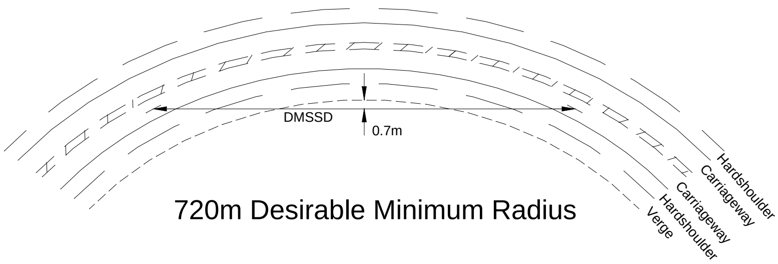
(a) The Design Speed is not in itself an exact assessment, and on lengths of road having Band A curvature/straight characteristics which exceed 2 kilometres in length the design of the first Band D curve should be considered very carefully with safety in mind;

(b) There may be a tendency for speeds to continue to increase with the passage of time.

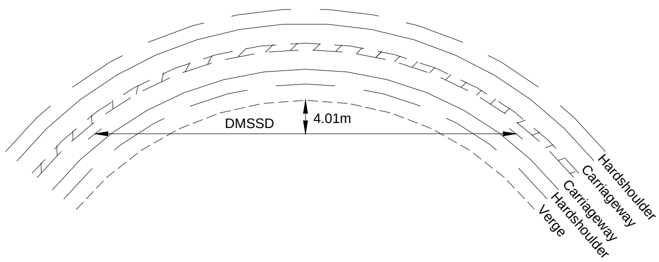
It is better to err on the side of safety when making decisions and as a general guide, to keep near Desirable values of Radius and Sight Distance for all Design Speeds.

Aspect of Design	Desirable Minimum Radius (DMR) $V^2/R=14$	One Design Speed Step below Desirable Minimum Radius $V^2/R=20$
Amount of adjacent overtaking section used up	Mid-way between maximum and minimum	Superior to DMR
Driver perception of what is a non-overtaking curve	Good, well away from Bands B&C, the zone of dubious overtaking	High, superior to DMR
Sideways Force (Design Vehicle)	0.11g half the threshold of discomfort	0.16, inferior to DMR
Is visibility DMSSD?	Yes, 0.7m of verge widening would be required on a Standard (7.3m) Single Carriageway to obtain DMSSD for a Design Speed of 100 km/h	Yes, 4.01m of verge widening would be required on a Standard (7.3m) Single Carriageway to obtain DMSSD for a Design Speed of 100 km/h

Table 15 : Design Considerations for Non-Overtaking Horizontal Curves



720m Desirable Minimum Radius



510m One Step Below Desirable Minimum Radius

Figure 24 : Horizontal Curve Verge Widening for a 100 km/h Design Speed

6.4.4 Application in Design. When designing horizontal curves consideration should be given to all the factors contained in Paragraphs 6.4.2 and 6.4.3 and any other factors which may be relevant such as length and importance of route being considered. Full attention must be paid to these considerations, including the road markings, at the earliest stage of design. At the later stages unsatisfactory compromises almost always have to be made and poor designs result.

6.5 Vertical Curve Design

6.5.1 The objective should be to co-ordinate the design of vertical curves with the horizontal alignment to provide the maximum overtaking provision. To illustrate principles, the vertical non-overtaking crest curve on a straight alignment is considered.

6.5.2 Non-Overtaking Radii Design Considerations. Non-overtaking crest curves should be utilised whenever the provision of a FOSD or greater curve creates heavy earthworks and inordinately high cost. Sharper crest curves serve to minimise loss of some overtaking section, maximise driver perception of what is a non-overtaking curve and reduce the length of road given over to prohibitory continuous road markings. On the other hand such curves will lead to the provision of less than Desirable Minimum Stopping Sight Distance (DMSSD). However, if the vertical curve is on a straight, Stopping Sight Distance appropriate to one Design Speed step below Desirable Minimum to a low object (0.26m) gives DMSSD to a 1.05m object. (See Paragraph 4.3.3). Comparing this with the horizontal curve case where SSD for one Design Speed step below Desirable Minimum to the low object does not always give DMSSD to the 1.05m object, it is clear that on crests there is relatively greater sight distance at one Design Speed step below Desirable Minimum when the road is straight or nearly straight compared with one Design Speed step below Desirable Minimum on purely horizontal curves. In Table 16, three conceivable alternatives for a non-overtaking crest curve on a single carriageway with a Design Speed of 100 km/h are examined to illustrate the above points (Figure 25).