Volume 6 Section 1
Part 1

NRA TD 9/07

Road Link Design

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St. Martin's House, Waterloo Road, Dublin 4. Tel:+353 1 660 2511 Fax +353 1 668 0009
Email : info@nra.ie Web : www.nra.ie

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.

NRA TD 9/07 includes a revision of Table 4, which rationalises the menu of road types for use on national routes and removes the reference to road categorisation. Two new road types are introduced, namely the Type 2 dual carriageway and the Type 3 dual carriageway. The High Quality dual carriageway has been renamed as Type 1 dual carriageway. The wide single WS2 carriageway road type has been removed.

A new design parameter, namely Absolute Minimum Vertical Curve length is introduced for roads with design speeds of greater than 100 km/h in Table 3 and Chapter 4.

This standard contains an extension of Chapter 8 to include requirements for the provision of Emergency Accesses as part of the motorway and dual carriageway national road network. It also includes requirements for the widening of central reserve barriers and the associated change of road cross section in advance of obstacles such as bridge piers and gantries.

This standard includes a major revision to Chapter 10, which introduces the concept of categorisation of minor improvements to existing national roads and introduces the NRA Interim Advice Note 85/06 and a new Chapter 11 that gives requirements in relation to the design of single carriageway non-national roads constructed or improved as part of a national road scheme.

Note:

The layout and format of this Standard are modelled closely on the UK Highways Agency's Standard TD 9/93. Except in Chapters 5, 8, 10 and 11, paragraph and figure numbering follows that of TD 9/93 wherever practicable.

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VOLUME 6 ROAD GEOMETRY
SECTION 1 LINKS

PART 1

NRA TD 9/07

ROAD LINK DESIGN

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0. FOREWORD

Introduction

0.1 This Standard applies to both single and dual carriageway roads in both urban and rural areas. It shall be used to derive the Design Speed, and the appropriate values of geometric parameters for use in the design of the road alignment. It states the basic principles to be used for coordinating the various elements of the road layout, which together form the three-dimensional design of the road.

0.1A This Standard supersedes NRA TD 9/05 dated January 2005. The principal changes from the previous Standard are:

a) The revision of Table 4 rationalises the menu of road types for use on national routes and removes the reference to road categorisation. Two new road types are introduced, namely the **Type 2** and **Type 3** dual carriageway. The High Quality dual carriageway has been renamed as **Type 1** dual carriageway. The wide single WS2 carriageway road type has been removed.

b) A new design parameter, namely Absolute Minimum Vertical Curve length is introduced for roads with design speeds of greater than 100 km/h in Table 3 and Chapter 4.

c) The extension of Chapter 8 to include requirements for localised central reserve widening and the associated change of road cross section in advance of obstacles such as bridge piers or gantries, and the provision of Emergency Accesses as part of the motorway and dual carriageway national road network;

d) A major revision to Chapter 10 which introduces the concept of categorisation of minor improvements to existing national roads and introduces the NRA Interim Advice Note 85/06;

e) A new Chapter 11, which outlines the design approach applicable to single carriageway non-national roads, constructed or improved as part of a national road scheme.

0.2 An Advice Note – NRA TA 43, Guidance on Road Link Design – accompanies this Standard. It provides background information and explains the general design philosophy of the layout standards.

Definitions

0.3 For the definitions of the general road terms used in this Standard, such as components of the road (central reserve, verge, hard shoulder and hard strip, etc.), see BS 6100: Subsection 2.4.1.

0.4 Particular terms used in this Standard are defined as follows:

All purpose road:- A road for the use of all classes of traffic (e.g. not a motorway).

Motorway:- A divided multi-lane road as defined in Section 43 of the Roads Act

D2M or D3M:- Dual two-lane (or dual three-lane) motorway.

Central reserve:- The area which separates the carriageways of a dual carriageway or motorway. Note that this <u>includes</u> any offside hard strips

Hard Shoulder:- Surfaced strip, greater than 1.5m wide, adjacent to a carriageway intended for use by vehicles in the event of a difficulty or during obstruction of the carriageway. A hard shoulder does <u>not</u> form part of the verge.

Hard Strip:- Surfaced strip, not more than 1.5m wide, that abuts a carriageway. A hard strip forms part of the verge.

Type 1 Dual Carriageway;-:- A divided all-purpose road with two lanes in each direction constructed to the geometric standards of NRA TD 9 and TD 22

Type 2 Dual Carriageway;-:- A divided all-purpose road with two lanes in each direction constructed to the geometric standards of NRA TD 10/07 ‘Type 2 and Type 3 dual carriageways’

Type 3 Dual Carriageway;-: A divided all purpose road with two lanes in one direction of travel and one lane in the other direction, constructed to the geometric standards of NRA TD 10/07 'Type 2 and Type 3 dual carriageways'. The two-lane section alternates with a one-lane section at intervals of 2km approximately.

Roads: Urban and Rural: An **Urban Road** is a road which is in a built-up area and has either a single carriageway with a speed limit of 40mph or less, or has a dual carriageway (including motorways) with a speed limit of 50mph or less (60km/h and 80km/h respectively post January 2005). All other roads are **Rural Roads.**

S2:- Two-lane single carriageway road with lane widths of up to 3.75m.

Verge:- The part of a road cross-section alongside a carriageway but not including embankment or cutting slopes. Note that this includes hard strips but not hard shoulders.

0.5 (Not used)

0.6 (Not used)

0.7 The principal design parameters for the layout of road links are based on "Desirable Minimum" values. Values of parameters below the Desirable Minimum are expressed in terms of the number of Design Speed steps below the Desirable Minimum. However, some other DMRB Standards refer to Absolute Minimum values of parameters in this Standard. Where this occurs, the reference shall be taken to mean one Design Speed step below the Desirable Minimum value.

Implementation

0.8 This Standard shall be used for the design of all new or improved national roads. Unless otherwise agreed with the relevant Road Authority. All roads affected by National Roads projects shall be designed in accordance with this Standard. The design of local roads which are constructed or improved as part of a National Road Scheme shall be designed in accordance with Chapter 11. The Standard should be applied to the design of schemes already being prepared unless, in the opinion of the National Roads Authority, application would result in significant additional expense or delay progress. In such cases, Design Organisations should confirm the application of this Standard to particular schemes with the National Roads Authority.

0.9 If this Standard is to be used for the design of local road schemes, the designer should agree with the relevant Road Authority the extent to which the document is appropriate in any particular situation.

Scope

0.10 A major objective of this Standard is to ensure that designs achieve value for money without any significant effect on safety. The design systems that have been developed in relation to both Design Speed and the related geometric parameters will result in greater flexibility to achieve economic design in difficult circumstances. In addition, detailed attention is given to the design of single carriageway roads, where the recommendations allow flexibility for design, with particular emphasis upon the coordination of design elements to improve safety and overtaking conditions. Overall, the flexibility for design introduced by this Standard will enable economic designs to be prepared, minimising both the construction costs and the impact of new roads and road improvements on the environment.

0.11 Throughout this Standard, there are continual references to the use of cost/benefit analyses. These should be used at all stages to test the economic performance of alternative scheme designs.

Interpretation

0.12 The standards contained in this document represent the various criteria and maximum/minimum levels of provision whose incorporation in the road design would achieve a desirable level of performance in average conditions in terms of traffic safety, operation, economic and environmental effects. In most cases, with care, designs can be achieved which do not utilise the lowest levels of design parameters given. At some locations on new roads or major improvements, however, it may not be possible to justify even the lowest levels of design parameters in economic or environmental terms, due to high costs, low traffic levels, and environmental damage, etc. In such cases, sufficient advantages might justify either a Relaxation within the standards or, in more constrained locations, a Departure from the standards. The various parameters quoted in this Standard are not, therefore to be regarded as sacrosanct in all circumstances. Relaxations and Departures should be assessed in terms of their effects on the economic worth of the scheme, the environment, and the safety of the road user. Further details on the use of Relaxations are given in Chapters 1 to 4.

0.13 Designers should always have regard to the cost effectiveness of the design provision. However, the implications, particularly in relation to safety may not be quantifiable and the designer must apply the judgement of experience in proposing a Relaxation or Departure.

0.14 When issued in the United Kingdom in 1981, this Standard introduced the concept of a hierarchy of permitted values for geometric layout parameters (visibility, horizontal curvature and vertical curvature). This hierarchy was based upon Desirable Minimum standards, with lower values being known progressively as Relaxations and Departures. Values equal to or higher than Desirable Minimum give consistently safe alignments and minimise journey times. However, research had shown that in many situations safety was no worse with values lower than the rigid requirements of the previous standards. The hierarchy of values enabled a flexible approach to be applied where the strict application of Desirable Minimum requirements would lead to disproportionately high construction costs or severe environmental impacts upon people, properties and landscapes. Successive levels in the hierarchy invoked more stringent consideration in line with the need to consider safety carefully.

0.15 During the years since 1981 there have been many advances in road layout design. The procedures for the assessment of safety and operational aspects have improved. Further research has strengthened the understanding of driver behaviour. Safety audits and other initiatives in the mechanics of assessing and checking scheme layouts have made the design process more rigorous and reliable.

0.16 Since 1981, experience has been gained in the application of this hierarchy of values and this indicates that the environmental and financial benefits gained from increased flexibility can be considerable. Against this background, the scope for Relaxations has been set so as to allow designers to consider alignment parameter values that would generally be approved if they were put to the National Roads Authority as Departure proposals. The designer is required to consider carefully the benefits and any potential disadvantages of Relaxations. Guidance is included in Chapter 1, describing the approach to be taken to assessing Relaxations. Relaxations are considered to conform to standards.

1. DESIGN SPEED

General

1.1 The road alignment shall be designed so as to ensure that standards of curvature, visibility, superelevation, etc. are provided for a Design Speed which shall be consistent with the anticipated vehicle speeds on the road. A relatively straight alignment in flat country will generate higher speeds, and thus produce a higher Design Speed, than a more sinuous alignment in hilly terrain or amongst dense land use constraints. There is, therefore, always an inherent economic trade-off between the construction and environmental costs of alternative alignments of different Design Speeds, and their user benefits.

Factors Affecting Speed

1.2 Speeds vary according to the impression of constraint that the road alignment and layout impart to the driver. This constraint can be measured by the three factors given in Paragraphs 1.3 to 1.5.

1.3 Alignment Constraint, Ac: This measures the degree of constraint imparted by the road alignment, and is measured by:

Dual Carriageways: Ac = 6.6 + B/10

Single Carriageways: Ac = 12 - VISI/60 + 2B/45

where:

B = Bendiness (total angle the road turns through), degrees/km;

VISI = Harmonic Mean Visibility, m (see Annex A).

1.4 Layout Constraint, Lc: This measures the degree of constraint imparted by the road cross section, verge width and frequency of junctions and accesses. Table 1 shows the values of Lc relative to cross section features and density of access, expressed as the total number of junctions, laybys and direct accesses (other than single field accesses) per km (see TD 41), summed for both sides of the road, where:

L = Low Access numbering up to 5 per km;

M = Medium Access numbering 6 to 8 per km;

H = High Access numbering 9 or more per km.

Table 1: Layout Constraint, Lc km/h

Road Type	S2											D2M		D3M
Carriageway Width (ex. hard strips)	6m		7.0m		7.3m		Dual 7.0m		Dual 7.5m		Dual 10.5m or 11.25m	Dual 7.0m	Dual 7.5m	Dual 10.5m or 11.25m
Degree of Access and Junctions	H	M	M	H	M	L	M	L	M	L	L	L	L	L
With hard shoulders					21	19	10	9	8	7	5	5	4	0
Without hard shoulders:														
With 3.0m Verge	(29)	(26)	25	23	(23)	(21)	(12)	(11)	(10)	(9)	(6)			
With 1.5m Verge	(31)	(28)		(27)			( ) : Non-standard cross-section							
With 0.5m Verge	(33)	(30)	There are no research data available for 4 lane Single Carriageway roads between 12 and 15m width. In the limited circumstances for their use described in this document, Design Speed should be estimated assuming a normal D2AP with a Layout Constraint of 15 - 13km/h.												

1.5 Mandatory Speed Limits: On rural derestricted roads, i.e. with national speed limits of:

	km/h
Motorways and Type 1 Dual Carriageway	120
National Roads (Single, Type 2 and Type 3 Dual Carriageway)	100
Non-national Roads	80

Vehicle speeds are constrained only by the physical impression of the road alignment, as described by Ac and Lc. The use of mandatory speed limits (together with more confined urban cross-sections), however, restricts speeds below those freely achievable, and will act as a further constraint on speed in addition to that indicated by Lc.

Selection of Design Speed

1.6 New Rural Roads: Design Speed shall be derived from Figure 1, which shows the variation in speeds for a given Lc against Ac. The Design Speeds are arranged in bands, i.e. 120, 100, 85 km/h etc., within which suffixes A and B indicate the higher and lower categories of each band.

1.6A An initial alignment to a trial Design Speed should be drawn up, and Ac measured for each section of the route demonstrating significant changes thereof, over a minimum length of 2 km. The Design Speed calculated from the ensuing Ac and Lc should be checked against the initial choice, to identify locations where elements of the initial trial alignment may be relaxed to achieve cost or environmental savings, or conversely where the design should be upgraded, according to the calculated Design Speed. If any changes to road geometry result, then the Design Speed should be recalculated to check that it has not changed.

1.6B The Design Speed calculated in accordance with the above procedure may be greater than the mandatory speed limit for the road. In such cases, the following rules shall apply:

a) On motorways and dual carriageways with a speed limit of 100km/h or greater, the Design Speed shall be as calculated;

b) On single carriageways with a speed limit of 80km/h or greater, the Design Speed should be as calculated or 100km/h, whichever is the lesser;

c) On other roads (i.e. those with speed limits less than indicated in Paragraphs a and b for the relevant road type), the Design Speed should be as calculated but need not be greater than the Design Speed indicated in Table 2 for the relevant speed limit.

1.6C However, where a proposed layout has isolated sub-standard features, the imposition of a mandatory speed limit (where one would otherwise not be needed) should not be used to justify those features: Departures from Standard should be sought instead (see Paragraph 1.31).

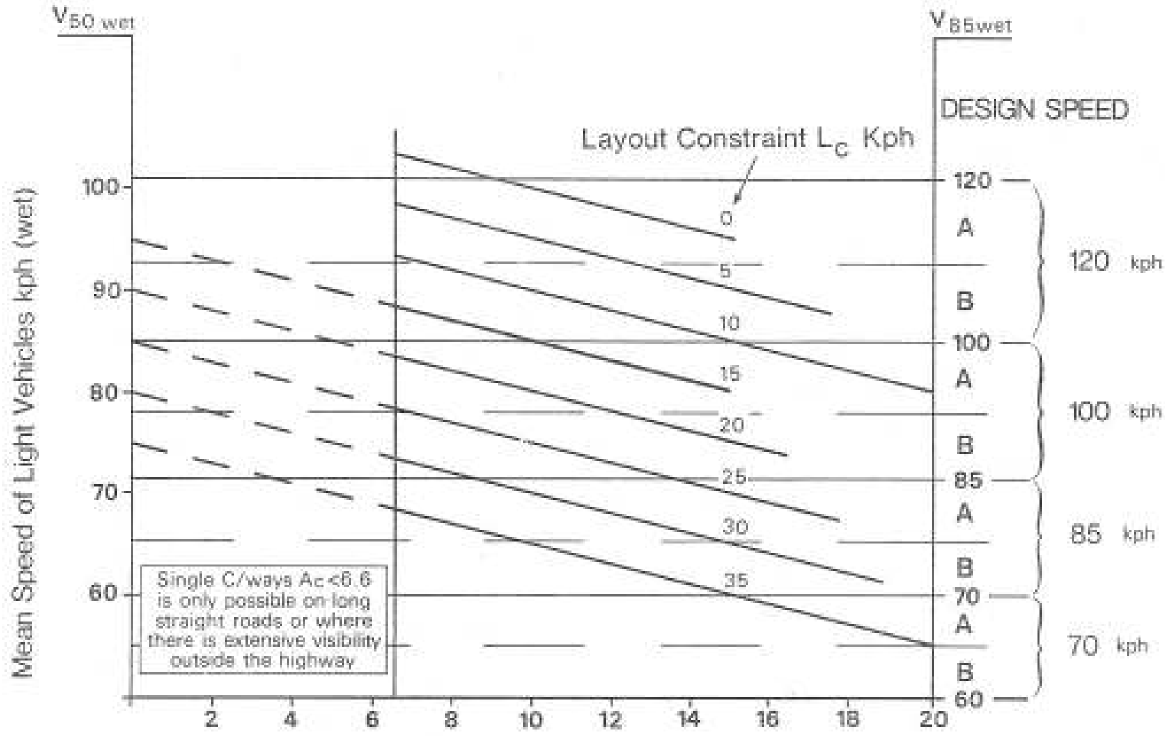
1.7 Existing Rural Road Improvements:

- National Roads: Minor improvements on National Roads have been categorised into three categories and the design speeds should be derived in accordance with Categories 1, 2 and 3 as defined in Chapter 10 of this Standard;
- Local Roads constructed or improved as part of a national road scheme: Design speeds are to be derived in accordance with Chapter 11;
- For all other road improvements, Design Speed shall be derived in a similar manner to Paragraphs 1.6 to 1.6B above, with Ac measured over a minimum length of 2 km incorporating the improvement, provided there are no discontinuities such as roundabouts. The strategy for the contiguous sections of road, however, must be considered when determining Ac and the cross-sectional design. It might be unnecessary to provide a full standard cross-section for a minor re-alignment within a low standard route, unless it represented an initial stage of a realistic improvement strategy.

1.8 Urban Roads: Low speed limits (30-50 km/h) may be required due to the amount of frontage activity, but also where physical restrictions on the alignment make it impractical to achieve geometry relative to a higher Design Speed. Design Speeds shall be selected with reference to the speed limits envisaged for the road, so as to permit a small margin for speeds in excess of the speed limit, as shown in Table 2.

Table 2: Maximum Design Speeds for Mandatory Speed Limits

Speed Limit km/h	Design Speed km/h
30	50B
50	60B
80	85A



ALIGNMENT CONSTRAINT A_C km/h

for Dual C/ways = 6.6 + B/10
for Single C/ways = 12 – VISI/60 + 2B/45

Figure 1: Selection of Design Speed (Rural Roads)

Design Speed Related Parameters

1.9 The Design Speed bands 120, 100, 85 km/h etc. dictate the minimum geometric parameters for the design according to Table 3. This shows Desirable Minimum values and values for certain Design Speed steps below Desirable Minimum. Desirable Minimum values represent the comfortable values dictated by the Design Speed.

Table 3: Design Speed Related Parameters

DESIGN SPEED (km/h)	120	100	85	70	60	50	V^2/R
STOPPING SIGHT DISTANCE m							
Desirable Minimum Stopping Sight Distance	295	215	160	120	90	70	
One Step below Desirable Minimum	215	160	120	90	70	50	
Two Steps below Desirable Minimum	160	120	90	70	50	50	
HORIZONTAL CURVATURE m							
Minimum R* without elimination of Adverse Camber and Transitions	2880	2040	1440	1020	720	510	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 with Superelevation of 5%	1020	720	510	360	255	180	14.14
One Step below Desirable Min R with Superelevation of 7%	720	510	360	255	180	127	20
Two Steps below Desirable Min R with Superelevation of 7%	510	360	255	180	127	90	28.28
VERTICAL CURVATURE – CREST							
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	
Two Steps below Desirable Min Crest K Value	55	30	17	10	6.5	6.5	
VERTICAL CURVATURE – SAG							
Desirable Minimum Sag K Value	53	37	26	20	13	9	
One Step below Desirable Min Sag K Value	37	26	20	13	9	6.5	
Two Steps below Desirable Min Sag K Value	26	20	13	9	6.5	6.5	
** Absolute Minimum Vertical Curve Length	120	100					
OVERTAKING SIGHT DISTANCES							
Full Overtaking Sight Distance FOSD m.	N/A	580	490	410	345	290	
FOSD Overtaking Crest K Value	N/A	400	285	200	142	100	

Notes

* Not to be used in the design of single carriageways (see Paragraphs 7.25 to 7.30).

The V2/R values simply represent a convenient means of identifying the relative levels of design parameters, irrespective of Design Speed.

K Value = Desirable Minimum curve length divided by algebraic change of gradient (%). Or Desirable Minimum curve length multiplied by the algebraic change of gradient (%) = K Value
See Paragraph 4.5.

** Where the Desirable Minimum Vertical Curve length calculated, is less than the Absolute Minimum Vertical Curve length indicated in Table 3, the Absolute Minimum Vertical curve length shall be used.

Changeover of Design Speed Standards

1.10 Transitions between sections with different Design Speeds shall be designed carefully so as not to present the driver suddenly with low radius curves, shorter sight distances etc. Where an alignment changes from a higher to a lower Design Speed, Relaxations should be avoided adjacent to the interface on the length of road with the lower Design Speed.

Connection to Existing Roads

1.11 Care shall be taken where an improved section rejoins an existing road, that the existing standard of curvature and sight distance at the interface shall be subject to the same restrictions as would be relevant for the Design Speed of the improvement. Figure 2 shows the connection of an improvement to an existing road. Care must be taken that the curvature and sight distance at C is adequate for the approach Design Speed which has increased due to the improvement between A and B. Refer Chapter 10 with regards to route consistency for minor improvements on National Roads.

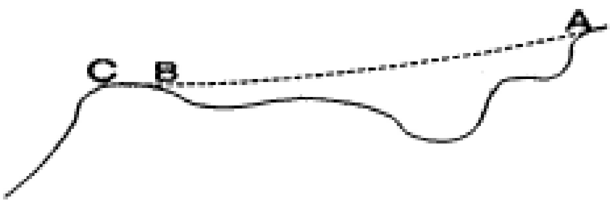


Figure 2: Connection to Existing Road

Selection of Parameter Values

1.12 Designers should normally aim to achieve at least Desirable Minimum values for stopping sight distance, horizontal curvature and vertical curvature. For single carriageways there are certain horizontal and vertical curve values which, although exceeding the Desirable Minimum values, are not recommended: in some cases Departures from Standards would be required. See Paragraphs 7.25 to 7.31 inclusive.

1.13 Numerous accident studies have been carried out and it has always proved difficult to correlate accident rates with causal factors. The reason is that an accident is a rare, random event where people have failed to cope with the situation; often exacerbated by one or more influences from a large selection of contributory factors. Serious injury accidents are rarer still, with the majority being primarily attributable to driver error. It is estimated that road layout is a main contributory factor in only a small proportion of injury accidents, indicating that accident rates are unlikely to be significantly affected by small or even moderate reductions in design parameters.

1.14 Studies carried out on rural all-purpose roads in the United Kingdom for the development of the UK version of this Standard aimed to correlate personal injury accident rates with horizontal curvature, gradient, and sight distance. Results were consistent with those of other studies, showing that values of these layout parameters below Desirable Minimum values were associated with slightly increased accident rates, but that the increase did not become significant until the difference from the Desirable value was considerable.

Relaxations

1.15 This Standard defines a sequence of parameter values in the form of a hierarchy of geometric design criteria related to Design Speeds. This three tier hierarchy enables a flexible approach to be applied to a range of situations where the strict application of Desirable Minimum standards would lead to disproportionately high construction costs or severe environmental impacts upon people, properties or landscapes. Designs with at least Desirable Minimum standards will produce a high standard of road safety and should be the initial objective. However, the level of service may remain generally satisfactory and a road may not become unsafe where these values are reduced. This second tier of the hierarchy is termed a Relaxation.

1.16 The limit for Relaxations is defined by a given number of Design Speed steps below the Desirable Minimum. Relaxations vary according to the type of road - motorway or all-purpose -

and whether the Design Speed is band A or band B. Details for sight distance are given in Chapter 2, for horizontal alignment in Chapter 3, and for vertical alignment in Chapter 4.

1.17 Relaxations may be introduced at the discretion of the designer, having regard to the advice given in this document and all the relevant local factors. Careful consideration must be given to layout options incorporating Relaxations, having weighed the benefits and any potential disbenefits. Particular attention should be given to the safety aspects and the environmental and/or cost benefits which would result from the use of Relaxations. The design organisation shall record the fact that a Relaxation has been used and the corresponding reason for its use. The record shall be endorsed by the design organisation's senior engineer responsible for the scheme. The design organisation shall report all Relaxations incorporated into the design as part of the project report at the end of each project management phase (refer to the National Roads Project Management Guidelines). The preferred option should be compared against options that would meet Desirable Minimum standards.

1.18 A number of layout options might be feasible for a scheme, with each containing Relaxations. This Standard gives examples of locations where some options can be expected to be safer than others. For example, Desirable Minimum Stopping Sight Distance could be provided to a junction, at the expense of a Relaxation to less than desirable values of horizontal or vertical curvature at a location away from that junction. The Relaxation then becomes isolated in that only one feature is below desirable value on a given length of road, and that length does not contain the complication of a junction. In this manner the accident potential of a constrained alignment has been minimised by applying layout design principles based upon the knowledge currently available.

1.19 A list of principles to follow when preparing options that include Relaxations is as follows. It is equally a list of factors to be taken into account when considering the merits of options.

1.20 The designer should consider whether, and to what degree, the site of the proposed Relaxation is:

- isolated from other Relaxations;
- isolated from junctions;
- one where drivers have Desirable Minimum Stopping Sight Distance;
- subject to momentary visibility impairment only;
- one that would affect only a small proportion of the traffic;
- on straightforward geometry readily understandable to drivers;
- on a road with no frontage access;
- one where traffic speeds would be reduced locally due to adjacent road geometry (e.g. uphill sections, approaching roundabouts and major/minor junctions where traffic has to yield or stop etc.), or speed limits.

1.21 The designer should also consider whether the following should be introduced in conjunction with any Relaxation:

- accident prevention or mitigation measures (e.g. increased skidding resistance, safety barriers, etc.);
- warning signs and road markings to alert the driver to the layout ahead.

1.22 The designer should have regard to the traffic flows carried by the link. High flows may carry a greater risk of queues and standing traffic approaching junctions in the peak period. Conversely lower flows might encourage higher speeds.

1.23 Values for sight distance, horizontal curvature and vertical curvature shall not be less than those given in Table 3 for each Design Speed and the appropriate number of Design Speed steps.

1.24 Only Stopping Sight Distance, horizontal curvature, vertical curvature, superelevation and gradient shall be subject to Relaxations.

1.25 At any one location, combinations of Relaxations of the alignment standards set out in Chapters 1 to 5 of NRA TD 9 are not permitted except in the following circumstances:

a) Stopping Sight Distance Relaxations of up to one Design Speed step below Desirable Minimum may be coincident with horizontal curvature Relaxations of up to one Design Speed step below Desirable Minimum.

b) The use of a crest curve K value of one Design Speed step below Desirable Minimum to avoid dubious overtaking conditions on a straight or nearly straight section of single carriageway in accordance with Paragraph 7.30, is not regarded as a Relaxation. Such a curve will generally result in a one step Relaxation of Stopping Sight Distance. This arrangement is permitted.

c) A vertical curve K value of up to one Design Speed step below Desirable Minimum may be used at the end of a steep gradient with a permitted Relaxation. However, there shall be no Relaxation in the Stopping Sight Distance at such locations, except as permitted by Paragraph 1.25(b).

d) Stopping Sight Distance Relaxations to the low object at central reserve safety barriers (see Paragraph 2.7A) may be coincident with other Relaxations, provided Desirable Minimum Stopping Distance is obtained to a 1.05m high object.

e) A Relaxation (or permitted combination of Relaxations) of one of the geometric parameters in NRA TD 9 is permitted in combination with a Relaxation from another current design standard in the NRA Design Manual for Roads and Bridges.

No other combinations of Relaxations are permitted. If used, they shall be treated as Departures.

1.26 A crest curve K value 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 Minimum, the adoption of which would also require a Relaxation. With the exception of the case described in Paragraph 1.25(b), this is not a permitted combination of Relaxations and shall be treated as a Departure.

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

1.28 The following Relaxations are **NOT** permitted on the immediate approaches to junctions, because the majority of accidents occur in the vicinity of junctions:

a) Relaxations below Desirable Minimum Stopping Sight Distance other than Relaxations to the low object at central reserve safety barriers (see Paragraphs 2.7A to 2.13);

b) Relaxations below Desirable Minimum in vertical curvature for crest curves (see Paragraphs 4.9 to 4.13). This requirement takes precedence over the requirements of Paragraphs 7.19 and 7.30;

c) Relaxations more than one Design Speed step below Desirable Minimum for sag curves (see Paragraphs 4.14 to 4.17).

1.29 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 the Yield 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.

1.30 For the purposes of this Standard the term 'junction' shall include a lay-by (see NRA TA 69). Furthermore, Relaxations below Desirable Minimum Stopping Sight Distance are not permitted on the immediate approaches to a vehicular access other than an individual field access (see TD 41). The immediate approaches to a vehicular access are as defined for a junction in Paragraph 1.29.

Departures

1.31 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.

2. SIGHT DISTANCE

Stopping Sight Distance

2.1 Table 3 shows the Stopping Sight Distance (SSD) appropriate for each Design Speed.

2.2 Stopping Sight Distance shall be measured from a driver's eye height of between 1.05m and 2.00m, to an object height of between 0.26m and 2.00m both above the road surface, as shown in Figure 3. It shall be checked in both the horizontal and vertical planes, between any two points in the centre of the lane on the inside of the curve (for each carriageway on dual carriageways).

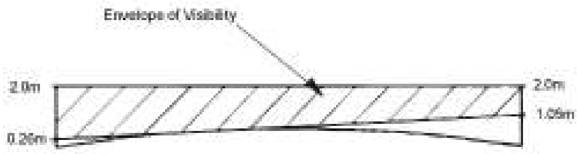


Figure 3: Measurement of Stopping Sight Distance

Full Overtaking Sight Distance

2.3 Table 3 shows for each Design Speed the Full Overtaking Sight Distance (FOSD) required for overtaking vehicles using the opposing traffic lane on single carriageway roads. Sufficient visibility for overtaking shall be provided on as much of the road as possible, especially where daily traffic flows are expected to approach the maximum design flows. FOSD is not required on motorways or dual carriageways.

2.4 FOSD shall be available between points 1.05m and 2.00m above the centre of the carriageway as shown in Figure 4, and shall be checked in both the horizontal and vertical planes throughout the full length of the overtaking section. The vertical height from the underside of the 1.05m sight line to the road surface must not be more than 1.05m at any point within this section.

2.5 FOSD is considerably greater than Stopping Sight Distance, and can normally only be provided economically in relatively flat terrain where the combination of vertical and horizontal alignments permits the design of a flat and relatively straight road alignment.

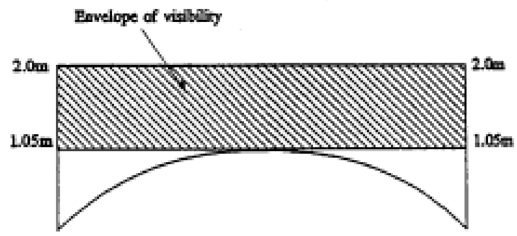


Figure 4: Measurement of FOSD

Coordinated Design of Single Carriageways

2.6 It will frequently be more economic to design a single carriageway road so as to provide clearly identifiable Overtaking Sections with FOSD in relatively level areas and with climbing lanes at hills, interspersed with Non-overtaking Sections where constraints on the alignment would result in high cost or environmental implications. The detailed standards and design considerations regarding the coordinated design of such links are given in Chapters 6 and 7. Designs which provide the driver with obvious lengths for overtaking have been found to reduce the frequency of serious accidents occurring on roads with continuous large radius curves. There is always an inherent economic trade-off between the construction and environmental costs of alternative alignments and their user benefits.

Obstructions to Sight Distance

2.7 Care shall be taken to ensure that no substantial fixed obstructions interrupt the sightlines, including road furniture such as traffic signs. However, isolated slim objects such as lamp columns, sign supports, or slim footbridge supports of width 550mm or under can be ignored. Lay-bys should, wherever possible, be sited on straights or on the outside of curves, where stopped vehicles will not obstruct sightlines.

2.7A Long bridge parapets or safety barriers on horizontal curves may obscure Stopping Sight Distance to the 0.26m object height, although the appropriate sight distance to the tops of other vehicles, represented by an object 1.05m high, will be obtained above the parapet or safety barrier. Relaxations below the Desirable Minimum Stopping Sight Distance to the low object may be appropriate in such situations.

Relaxations

2.8 In the circumstances described in Paragraphs 1.16 to 1.28, Relaxations below the Desirable Minimum Stopping Sight Distance values may be made at the discretion of the designer. The numbers of Design Speed steps permitted below the Desirable Minimum are normally as follows:

Motorways and Type 1 dual carriageways:		
	band A	1 step
	band B	2 steps
Other all-purpose roads:		
	bands A and B	2 steps

However, in the circumstances listed in Paragraphs 2.9 to 2.12, the scope for Relaxations shall be extended or reduced as described, provided that the resultant Relaxations do not exceed 2 Design Speed steps.

2.9 For band A roads where the Stopping Sight Distance is reduced by bridge piers, bridge abutments, lighting columns, supports for gantries and traffic signs in the verge or central reserve which form momentary obstructions, the scope for Relaxations may be extended by 1 Design Speed step.

2.10 For band A roads the scope for Relaxation of Stopping Sight Distance to the 0.26m object height, for sight lines passing in front of long obstructions such as bridge parapets or verge safety barriers, may be extended by 1 Design Speed step, provided the Desirable Stopping Sight Distance is available to the high object (see also Paragraph 2.7A).

2.11 On or near the bottom of long grades on dual carriageways steeper than 3% and longer than 1.5km, the scope for Relaxations shall be reduced by 1 Design Speed step. Conversely, at or near the top of up gradients on single carriageways steeper than 4% and longer than 1.5 km, the scope for Relaxation may be extended by 1 step due to reduced speeds uphill.

2.12 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).

2.13 Relaxations below Desirable Minimum Stopping Sight Distance, other than Relaxations to the low object at central reserve safety barriers (see Paragraph 2.7A), are not permitted on the immediate approaches to junctions as defined in Paragraph 1.29.

3. HORIZONTAL ALIGNMENT

Road Camber

3.1 On sections of road with radii greater than that shown in Table 3 for Minimum R without elimination of adverse camber & transitions (i.e. $V^2/R < 5$), the crossfall or camber should be 2.5%, normally from the centre of single carriageways, or from the central reserve of dual carriageways to the outer channels. At junctions other than roundabouts, the cross-section of the major road shall be retained across the junction, and the side road graded into the channel line of the major road. On horizontal curves, adverse camber shall be replaced by favourable crossfall of 2.5% or more when the radius is less than that shown in Table 3 for 'Minimum R without elimination of adverse camber & transitions' (i.e. $V^2/R > 5$). However, it will frequently be necessary to eliminate adverse camber on larger radii for aesthetic or drainage reasons.

3.1A On minor roads where the quality of road pavement laying is unlikely to be high, the minimum crossfall should be 3%.

Superelevation

3.2 On radii less than those shown in Table 3 for Minimum R with superelevation of 2.5% (i.e. $V^2/R > 7.07$), superelevation shall be provided, such that:

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

where :

V = Design Speed, km/h

R = Radius of Curve, m

S = Superelevation, %.

On Rural Roads superelevation shall not exceed 7%. On Urban Roads with at-grade junctions and accesses, superelevation shall be limited to 5%.

Figure 5 shows the appropriate superelevation for the range of Design Speeds. Sharper radii than the Desirable Minimum values shown in Table 3 result in steep crossfalls which should be avoided if possible. It is essential to maintain adequate skidding resistance and good drainage at all superelevations.

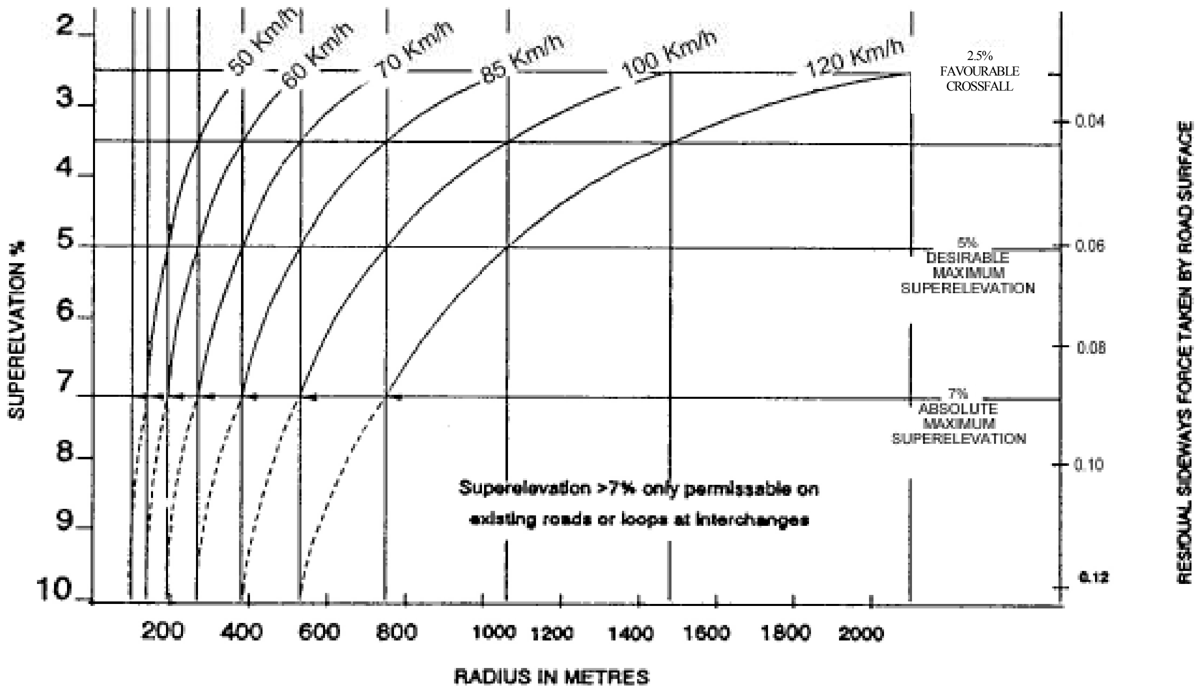


Figure 5: Superelevation of Curves

Desirable Minimum Radius

3.3 The Desirable Minimum radii, corresponding to a superelevation of 5% (i.e. $V^2/R = 14.14$) are shown in Table 3.

Relaxations

3.4 In the circumstances described in Paragraphs 1.16 to 1.28, Relaxations of up to 2 Design Speed steps below the Desirable Minimum values may be made at the discretion of the designer for all road types. However, for roads in Design Speed band B in the circumstances listed in Paragraphs 3.5 and 3.6, the scope for Relaxations shall be extended or reduced as described, provided that the resultant Relaxations do not exceed 2 Design Speed steps.

3.5 On or near the bottom of long grades on dual carriageways steeper than 3% and longer than 1.5km the scope for Relaxations shall be reduced by 1 Design Speed step. Conversely, 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.

3.6 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).

Appearance and Drainage

3.7 Superelevation shall not be introduced, nor adverse camber removed, so gradually as to create large almost flat areas of carriageway, nor so sharply as to cause discomfort or to kink the edges of the carriageway. A satisfactory appearance can usually be achieved by ensuring that the carriageway edge profile does not vary in grade by more than about 1% from that of the line about which the carriageway is pivoted, and by ample smoothing of all changes in edge profile. In general on motorways and dual carriageways, a smoother edge profile should be provided by reducing the variation in grade of the edge profile to a maximum of 0.5% where feasible, i.e. where local drainage conditions permit. Care should be taken to ensure that a minimum longitudinal gradient of at least 0.5% is maintained wherever superelevation is to be applied or reversed. However, in some difficult areas even the above requirements can lead to drainage problems, e.g. where the superelevation is applied against the longitudinal gradient. It may be necessary to modify the horizontal alignment thereby moving the superelevation area, to increase the variation in grade of the edge profile, or to apply a rolling crown. Areas susceptible to such drainage problems should be identified at an early stage in the design process, before the horizontal alignment is fixed.

Application of Superelevation

3.8 Progressive superelevation or removal of adverse camber shall generally be achieved over or within the length of the transition curve from the arc end (see also Paragraph 3.17). On existing roads without transitions, between ½ and $^2/_3$ of the cant shall be introduced on the approach straight and the remainder at the beginning of the curve.

Widening on Curves

3.9 Pavement widening at curves on links and on the main line through junctions is required on low radius curves to allow for the swept path of long vehicles.

3.10 For carriageways of standard width (with lane widths of 3.5m, 3.65m or 3.75m depending on the road type), each lane shall be widened to 3.95m when the radius is between 90m and 150m.

3.10A For carriageways of standard width, an increased width of 0.15m per lane shall be applied when the radius is between 150m and 1,000m. However, at these radii lane widths do not need to be widened beyond 3.65m.

3.11 For carriageways less than the standard widths, widening shall be:

a) 0.6m per lane where the radius is between 90m and 150m, subject to maximum carriageway widths of 3.95m, 7.9m, 11.9m and 15.8m (for 1, 2, 3 and 4 lanes respectively).

b) 0.5m per lane where the radius is between 150m and 300m, subject to maximum carriageway widths of 3.95m, 7.9m, 11.9m and 15.8m (for 1, 2, 3 and 4 lanes respectively).

c) 0.3m per lane, where the radius is between 300m and 400m, subject to maximum carriageway widths of 3.95m, 7.9m, 11.9m and 15.8m (for 1, 2, 3 and 4 lanes respectively).

3.12 Radii less than 90m on the mainline are Departures from Standard. For these and all other junction elements, widening should be in accordance with TD 42.

3.13 The extra width should be applied uniformly along the transition curve. In the improvement of existing curves the widening should generally be made on the inside of curves.

Lane Width Reductions at Pinch Points

3.14 At points of particular difficulty on Wide Dual Carriageways, where full lane widths cannot be achieved, a reduction from 3.75m to 3.50m is permitted as a Relaxation provided that the radius of curvature exceeds 1,000m. Points where such a Relaxation is likely to be most applicable are around the urban fringe, at sites with difficult topography or in historic or conservation areas. This Relaxation shall not apply on new single carriageway roads.

Transitions

3.15 Transition curves shall be provided on any curve the radius of which is less than that shown in Table 3 for Minimum R without elimination of adverse camber and transitions (i.e. $V^2/R < 5$).

3.16 Length of Curve: The basic transition length shall be derived from the formula:

$$L = \frac{V^3}{46.7 \times q \times R}$$

where:

L = Length of transition (m)

V = Design Speed (km/h)

q = Rate of increase of centripetal acceleration (m/sec^3) travelling along curve at constant speed V

R = Radius of curve (m).

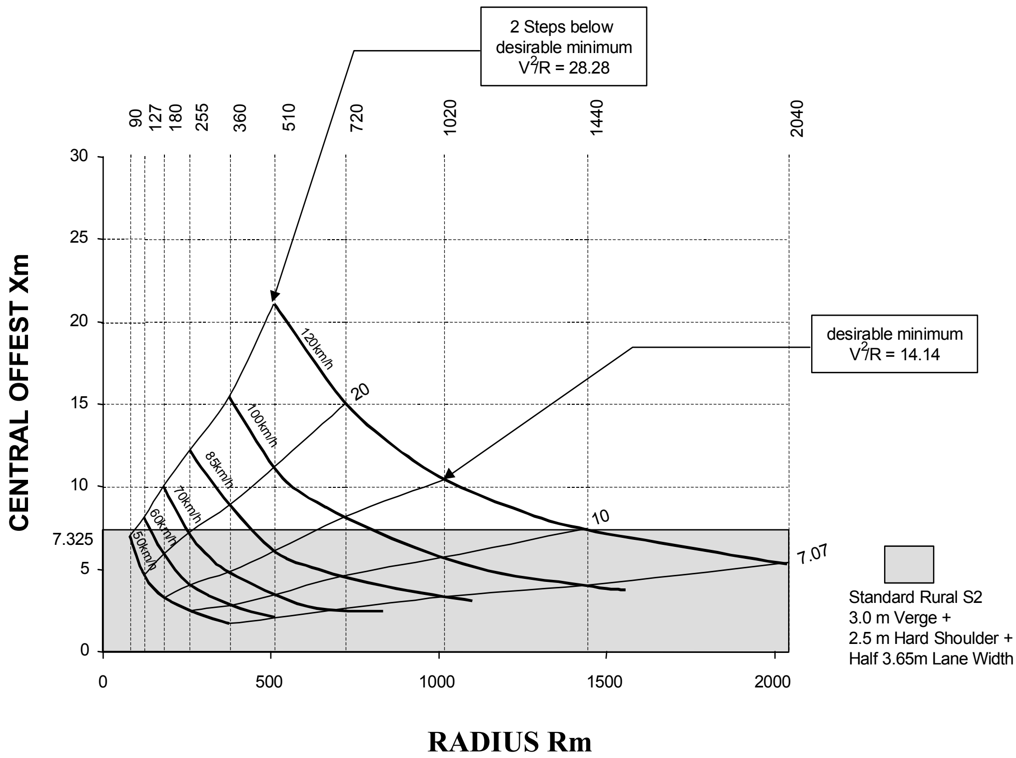
q should normally not exceed $0.3 m/sec^3$. However, in difficult cases the value of q may be increased up to $0.6\ m/sec^3$ as a Relaxation. On curves which are sub-standard for the appropriate Design Speed, the length of transition should normally be limited to $\sqrt{(24R)}$ metres.

3.17 Application of Superelevation: Superelevation or elimination of adverse camber shall generally be applied on or within the length of the transition curve from the arc end. The basic transition appropriate to the Design Speed, however, will often result in insufficient transition length to accommodate superelevation turnover: in such cases longer transitions should be provided to match the superelevation design.

The Effect of Sight Distance at Horizontal Curves

3.18 Stopping Sight Distance: When the road is in a cutting, or at bridge crossings, it may be necessary to widen verges or increase bridge clearances to ensure that the appropriate Stopping Sight Distance is not obstructed. Figure 6 shows the maximum central offset required with varying horizontal curvature, in order to maintain the Design Speed related Stopping Sight Distances. It can be seen that extensive widening of verges and structures, or central reserves with hedges or safety barriers, would be required to maintain Desirable Stopping Sight Distances on horizontal radii below Desirable Minimum. Where a road is on embankment, however, visibility will be available across the embankment slope. However, it must be ensured that the sight distance is not obscured by landscape planting.

3.19 Full Overtaking Sight Distance: Figure 7 shows the maximum central offset required with varying horizontal curvature, in order to maintain the Design Speed related FOSDs. It can be seen that the higher requirements of FOSD result in extensive widening of verges for all but relatively straight sections of road.



The values of X shown are the maxima and apply where SSD < curve length. Land for visibility should be checked from the plans.

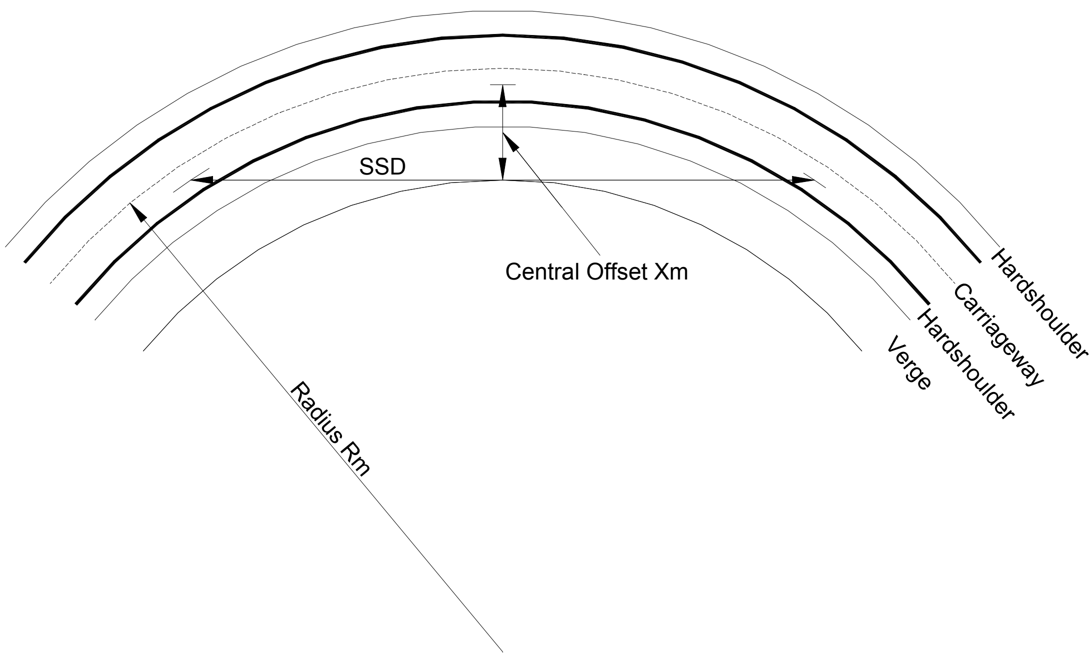
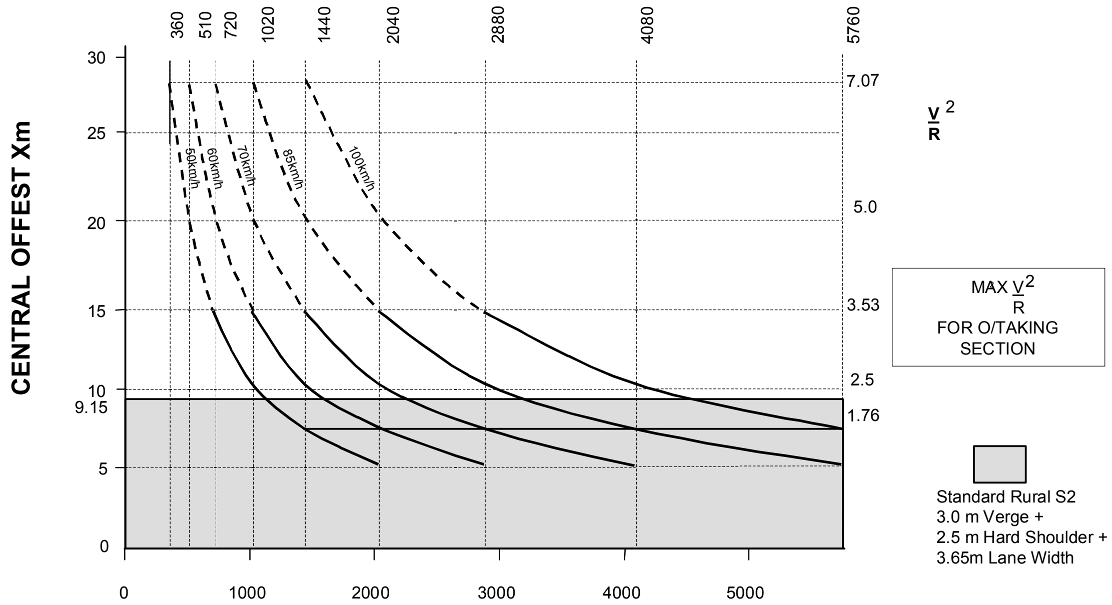


Figure 6: Verge Widening for Desirable Minimum Stopping Sight Distance



RADIUS Rm

The values of X are the maxima and apply where FOSD < curve length.
Land for visibility should be checked from the plans.

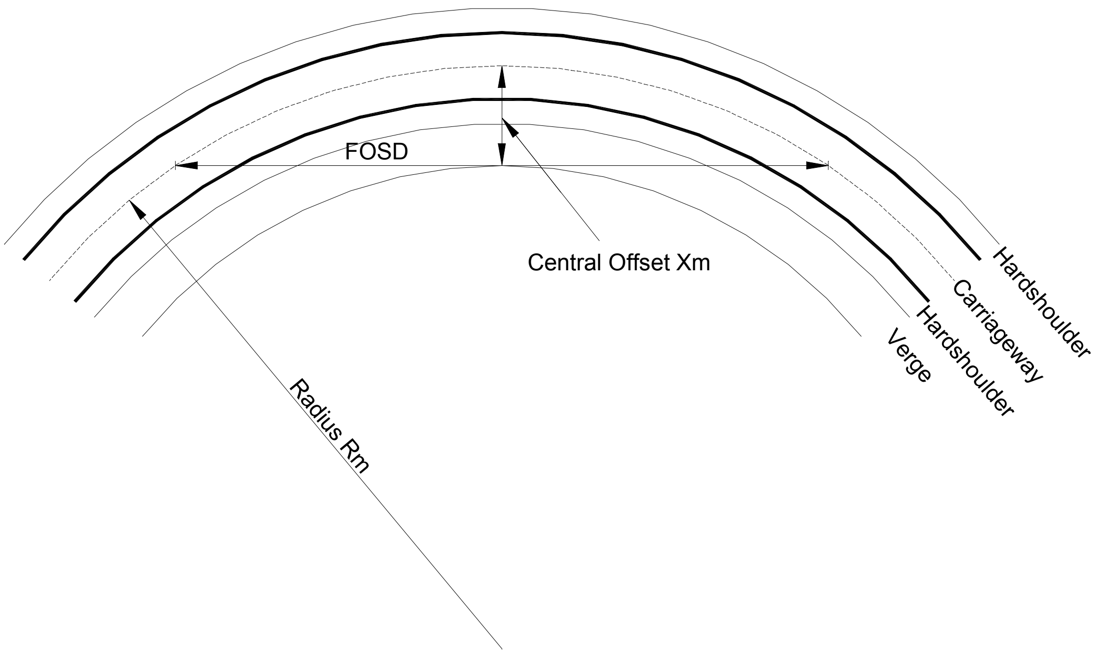


Figure 7: Verge Widening for Full Overtaking Sight Distance

4. VERTICAL ALIGNMENT

Gradients

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

	Desirable Max Grade
Motorways and Type 1 Dual Carriageways	3%
Type 2 & 3 Dual Carriageways	4%
Single Carriageways:	
National and Regional Roads	5%
Local Roads	6%

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 are, therefore, 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 and Type 1 Dual Carriageways	4%
Type 2 & 3 Dual Carriageways	5%
Single Carriageways:	
National and Regional Roads	6%
Local Roads	8%

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, e.g. 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, e.g. +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:- L= K value A

Desirable Min = 182 x 5 = 910m

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

Where the Desirable Minimum Curve length calculated is less than the Absolute Minimum curve length indicated in Table 3, the Absolute Minimum curve length shall be used to avoid localised kinks in the vertical alignment.

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 the Desirable Minimum crest curves are based upon visibility criteria.

4.6A The use of crest curves with K values greater than Desirable Minimum but less than 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^2 maximum vertical acceleration); the resultant sag curves approximate to those using a headlamp visibility criterion 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^2 maximum 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 1.16 to 1.28, 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 and Type 1 dual carriageways:

	band A	1 step
	band B	2 steps

Other all-purpose roads:

	bands A and B	2 steps.

However, in the circumstances listed in Paragraphs 4.10 to 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 Design Speed 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 1.29.

4.14 Sag Curves: In the circumstances described in Paragraphs 1.16 to 1.28, 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 and Type 1 dual carriageways:

	band A	1 step
	band B	2 steps

Other all-purpose roads:

	bands A and B	2 steps.

However, in the circumstances listed in Paragraph 4.16, the scope for Relaxations shall be reduced as described.

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 1.29.

5. CLIMBING LANES

Introduction

5.1 A climbing lane is an additional lane added to a road in order to improve capacity and/or safety because of the presence of a steep gradient. The steep gradient is the primary reason for adding the lane. On single carriageways climbing lanes provide two lanes for uphill traffic whilst the opposing traffic is partially or fully confined to one lane: they, therefore, provide overtaking opportunities. On dual carriageways the need for climbing lanes is less, since overtaking opportunities are greater, but they can alleviate congestion at higher traffic flows.

5.2 This chapter outlines the design principles and other factors which should be considered by designers for the introduction of climbing lanes into new or existing carriageways.

5.3 On single carriageway roads, a climbing lane should be considered if it can be justified (see Paragraphs 5.11 and 5.12) on hills with gradients greater than 2% and longer than 500m. Justification is unlikely to be achieved where the traffic flows are less than 4,000 Annual Average Daily Traffic (AADT) in the design year.

5.4 On dual carriageway roads (including motorways), a climbing lane should be considered if it can be justified (see Paragraphs 5.11 and 5.12) on hills with gradients greater than 3% and longer than 500m. Justification is unlikely to be achieved where the traffic flows in the design year are less than 75% of the capacity given in Table 4 for the relevant category of road.

5.4A (Not used)

5.5 In some cases a detailed scheme appraisal, as outlined in Paragraphs 5.6 to 5.17, may provide justification for a climbing lane even when the above criteria are not met.

Scheme Appraisal

5.6 Consideration of the need for and justification of a climbing lane should form an integral part of the development of a scheme. Assessment, consultation and design should be an iterative process, considering the appropriateness and significance of impacts measured against the scheme objectives. Appraisal of the effects of a climbing lane should consider:

- Economy: reduction in travel times, vehicle operating costs and journey time reliability;

- Environment: effects on environmental intrusion, reduction in driver frustration, noise and air pollution;

- Safety: reduction in accidents.

5.7 Climbing lanes add another optional element to the treatment of vertical alignment. They may allow steeper, shorter gradients to be considered, which would reduce earthworks, be less intrusive to the local environment, and offset the cost of the wider road. However, from a traffic benefit viewpoint, the option of flattening gradients may often be preferable. The implications of long steep gradients on the downhill carriageway should also be considered.

5.8 Assessment of Impacts: The provision of an additional uphill lane should provide benefits to travellers by diminishing delays caused by slow-moving traffic. The effect of adding a lane is two-fold: some traffic is able to move over to a faster lane, thereby gaining a significant speed advantage, and the consequent reduction in traffic in the left-hand lane can enable speeds to increase in this lane. Where traffic flows are approaching capacity, gradients without climbing lanes can be pinch points where congestion starts. Where flows are less, the economic benefits are likely to be less substantial but the climbing lane can also be viewed as a safety measure, creating a safer overtaking opportunity and reducing driver frustration.

5.9 Where a climbing lane is to be added to an existing carriageway, data should be collected and "Before" surveys carried out if appropriate.

5.10 On a new road, the introduction of a steep gradient with a climbing lane should be compared with an alternative with lesser gradients and no climbing lane. The latter may have greater costs and impacts due to the need for more extensive earthworks.

5.11 Economy: The criteria for provision of climbing lanes (see Paragraphs 5.18 and 5.19 for single carriageway roads and Paragraph 5.39 for dual carriageway roads) will ensure that the climbing lane is economically justified in most cases, provided there are no high cost elements along the relevant length of road.

5.12 Where there are high cost elements or other factors which make economic appraisal appropriate, an economic appraisal should be undertaken, considering a Do Something (climbing lane) option against the Do Nothing (no climbing lane), as well as an assessment of alternative climbing lane lengths and slope configurations. The method of economic appraisal to be adopted should be agreed with the National Roads Authority.

5.13 Environment: Climbing lanes can have an impact on the environment in a number of ways and environmental issues need to be considered as an integral part of the design and appraisal process. The likely impact on, for example, wildlife will be neutral or negative if additional land-take is necessary. However, the impact may be positive if an increased gradient with diminished earthworks leads to less land-take and reduced visual intrusion.

5.14 Driver frustration should form part of the environmental appraisal process for single carriageway roads. Whilst useful engineering data relating to driver frustration are scarce, careful consideration should be given to the provision of adequate overtaking opportunities (see Paragraphs 7.5 to 7.24).

5.15 Safety: Climbing lanes help to relieve driver frustration and provide a safer overtaking environment, particularly on single carriageway roads. As a guide, the presence of a climbing lane on a single carriageway road can be expected to reduce the accident rate by 25%.

5.16 Factors which tend to make the road less safe and which, therefore, should be avoided include: sharp bends, poorly marked and located junctions, short climbing lane sections, and short or unusual entry or exit tapers. In particular, the exit taper should not be located in the vicinity of junctions or sharp bends.

5.17 Where the criteria of Paragraphs 5.11 and 5.12 are not met, an assessment should be made, taking all factors into account, including the effects on the road user. Whilst the quantifiable economic benefits of the climbing lane may not be quite sufficient to justify its provision, the resulting loss of Net Present Value may be only minor, and thus a small price to pay for the unquantifiable benefits the climbing lane would provide to traffic, such as relieving the frustration of platoons caused by slow moving heavy goods vehicles (see Paragraph 7.24). An example of a situation where such a situation may occur is a hill slightly shorter than 500m where a climbing lane would provide a useful overtaking opportunity.

Single Carriageways

5.18 Criteria for Provision: On single carriageway roads on hills with gradients (G = 100H/L) greater than 2% and longer (L) than 500m the following criteria may be used to determine the justification for a climbing lane as an alternative to economic appraisal:

a) On single carriageways without hard shoulders (or with narrow hard shoulders), Figure 5/1 may be used. The solid curves in Figure 5/1 show the height risen, H, of a hill required to justify the provision of a climbing lane, according to the design year traffic forecast. The figure assumes the standard cost of a climbing lane in relatively easy terrain.

b) On single carriageways with full width hard shoulders (2.5m or more), the climbing lane should replace the hard shoulder, with little or no additional width (see Paragraph 5.22). As the cost of provision of the climbing lane in such cases will be small, climbing lanes should generally be provided on gradients greater than 2% wherever the risen height (H) exceeds 15m and the traffic flow will exceed 6,000 AADT in the design year. This is shown by the dashed line in Figure 5/1.

In both cases, the height risen (H) and length (L) shall be calculated between two standard points on the hill as illustrated in Figure 5/2.

5.19 On single carriageways without hard shoulders, where there are high cost elements involved such as heavy earthworks, bridgeworks or environmental effects (which would invalidate the average cost assumptions of Figure 5/1), it may be uneconomic or undesirable to make full provision. It may be preferable to adopt a Departure from Standards, by providing the climbing lane partially within the normal verge width/marginal strip to reduce the high cost implications, rather than omit the climbing lane altogether.

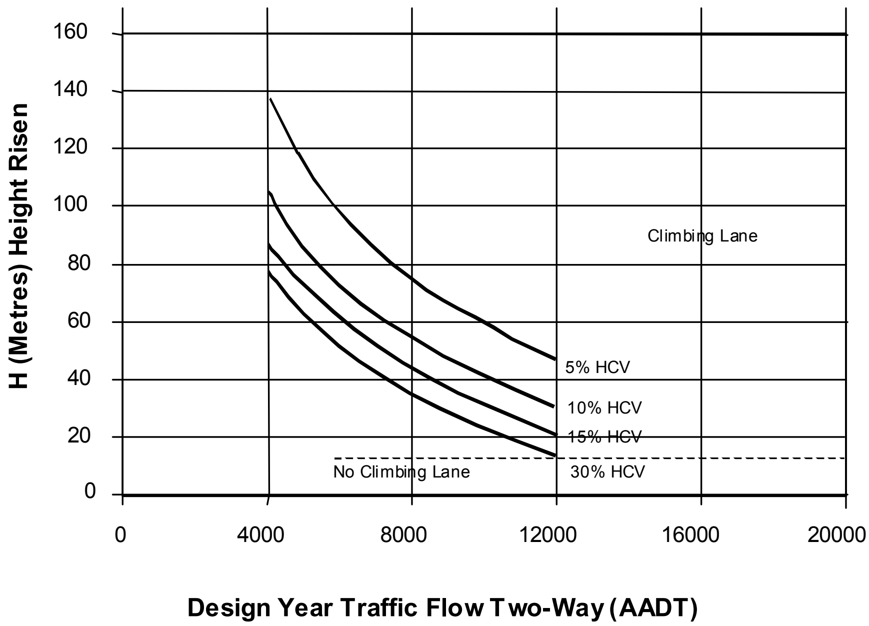


Figure 5/1: Single Carriageway Climbing Lanes

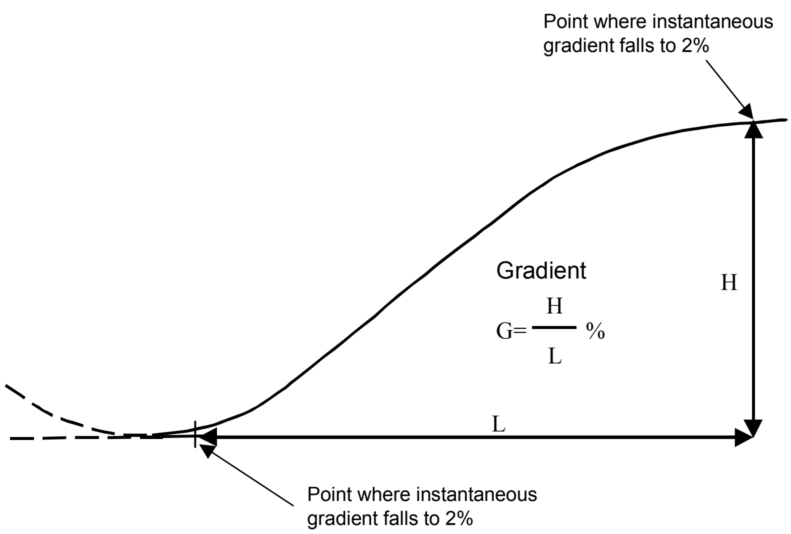
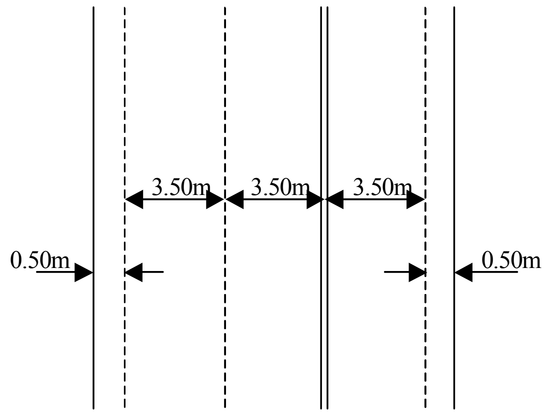


Figure 5/2: Definitions for Climbing Lanes

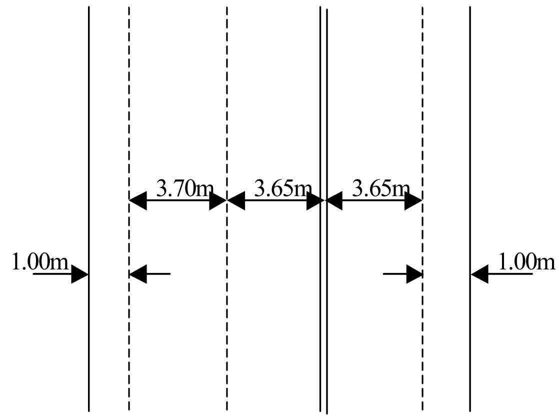
5.20 Length of Climbing Lanes: A climbing lane should not be provided unless the length of full width climbing lane section is a minimum of 600m. This length will normally be provided where the length 'L', the distance with gradients in excess of 2%, is 500m or more. Where a climbing lane is being provided on a shorter hill, for example to provide an overtaking section, it should be extended to a minimum of 600m. However, care should be taken with the design of the end taper, since the speed of vehicles in the climbing lane will increase as the hill flattens. Short climbing lanes have a higher accident risk that is exacerbated by bends in the road. High accident rates are associated with average bendiness (irrespective of the climbing lane length) in excess of 50degs/km.

5.21 Climbing lane road markings tend to confine downhill traffic to a single lane, unless there is ample forward visibility unobstructed by slow moving vehicles in the climbing lane. Where the length of a climbing lane exceeds about 3 km, therefore, it is important that some sections are provided with a straight or large radius right hand curvature in order to provide an Overtaking Section for downhill traffic (see Paragraph 7.13).

5.22 Lane Widths: The cross-sections of single carriageways including climbing lanes shall be as shown in Figures 5/3(a), (b) and (c).



(a): On Reduced Single Carriageway



(b): On Standard Single Carriageway

Notes:

1. For standard road cross-sections, see NRA TD 27.
2. The overall width of paved surface in case (c) should be equal to that without a climbing lane but including hard shoulders.

Figure 5/3: Climbing Lanes on Single Carriageways

5.23 Layout at Start of Climbing Lane: The full width of the climbing lane shall be provided at a point 'S', 100m uphill from the 2% point of sag curve, and preceded by a taper of 1/50, as shown in Figure 5/4. The length of the taper shall be such that traffic in the lane which is required to experience the greatest lateral shift over the length of the taper does so at 1/50. The alignment at the commencement of the climbing lane shall encourage drivers to follow the nearside channel unless overtaking. The taper shall therefore provide a smooth transition, by utilising the road curvature to develop the extra width, wherever possible. Where the curvature is used in this way, the length of taper may be reduced to 1/40. Specific signing of the climbing lane will not be necessary.

5.24 Climbing lanes may also be inserted directly into the exit lane of a roundabout where appropriate.

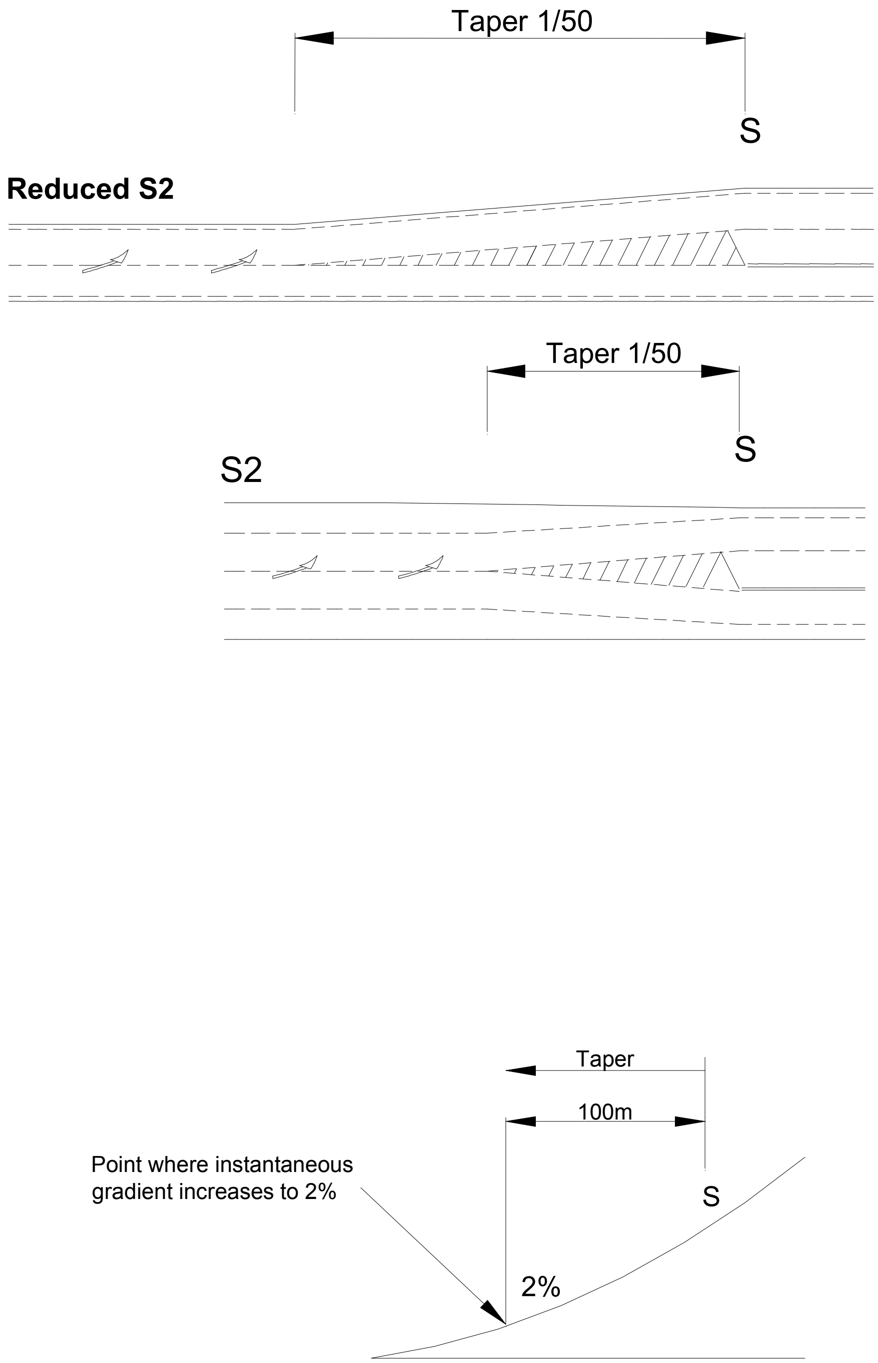


Figure 5/4: Start of Climbing Lane

5.25 Layout at End of Climbing Lane: The full width of the climbing lane shall be maintained until a point ‘F’, at least 220m beyond the point at which the gradient reduces to 2% at the crest curve. After point F the carriageway width shall be tapered back to the normal two-lane width at a taper of 1:70 for the lane marking which has the greatest lateral shift, as shown in Figure 5/5. On a reduced single carriageway, the full width of the paved surface (including hard strips) shall be maintained up to the end of the taper. A 200m length of hard shoulder shall then be provided on the climbing lane side of a reduced S2, followed by a taper of 1:70 to the normal paved width (see Figure 5.5).

5.26 The alignment at the end of the climbing lane shall place the onus on the driver in the right –hand lane to rejoin the continuing lane. The taper shall provide a smooth transition in the same manner as that at the start of the climbing lane. Where the road curvature is used to provide a smooth transition, the lengths of tapers may be reduced to 1:40 as a Relaxation. Advance warning signs shall be provided as shown in Figure 5/5. Care should be taken to ensure that the return to a single lane does not coincide with junctions or a sharp curve.

5.27 Consideration should be given to extending the distance between the 2% point and point F, the end of the full width climbing lane, in the following circumstances:

a) Where an extension enables traffic to merge more safely;

b) If an existing junction is in the vicinity of the end taper area;

c) If the climbing lane is part of an overall route strategy for overtaking (see Paragraphs 7.20 to 7.24) and the climbing lane is extended to maximise overtaking opportunities;

d) If a high proportion of HCVs or slow moving vehicles currently cause problems at the end taper of an existing climbing lane, the lane may be extended where heavy vehicles are picking up speed as the road begins to descend from the crest of the hill.

5.28 Where the climbing lane is extended the taper arrangement at the end of the lane shall be as shown in Figure 5/5.

5.29 The climbing lane may terminate at a roundabout where appropriate, with the overtaking lane becoming the right hand entry lane into the roundabout. If the climbing lane would terminate within 500m of the roundabout, it should be continued to the roundabout.

5.30 Junctions: Careful consideration should be given with respect to the location of junctions along the length of the climbing lane. On new roads, junctions shall not be provided within the length of the climbing lane (including the tapers): any proposal for such a junction would require a Departure from Standard. On existing roads, junctions within the length of the climbing lane should be closed where possible and accesses and side roads should be re-routed.

5.31 Signing: Clear signing and road markings at the end of a climbing lane are very important, to ensure that drivers are aware of the potential ‘change of lane’ manoeuvres that will be taking place ahead. This is important for both safety and the efficient operation of the climbing lane.

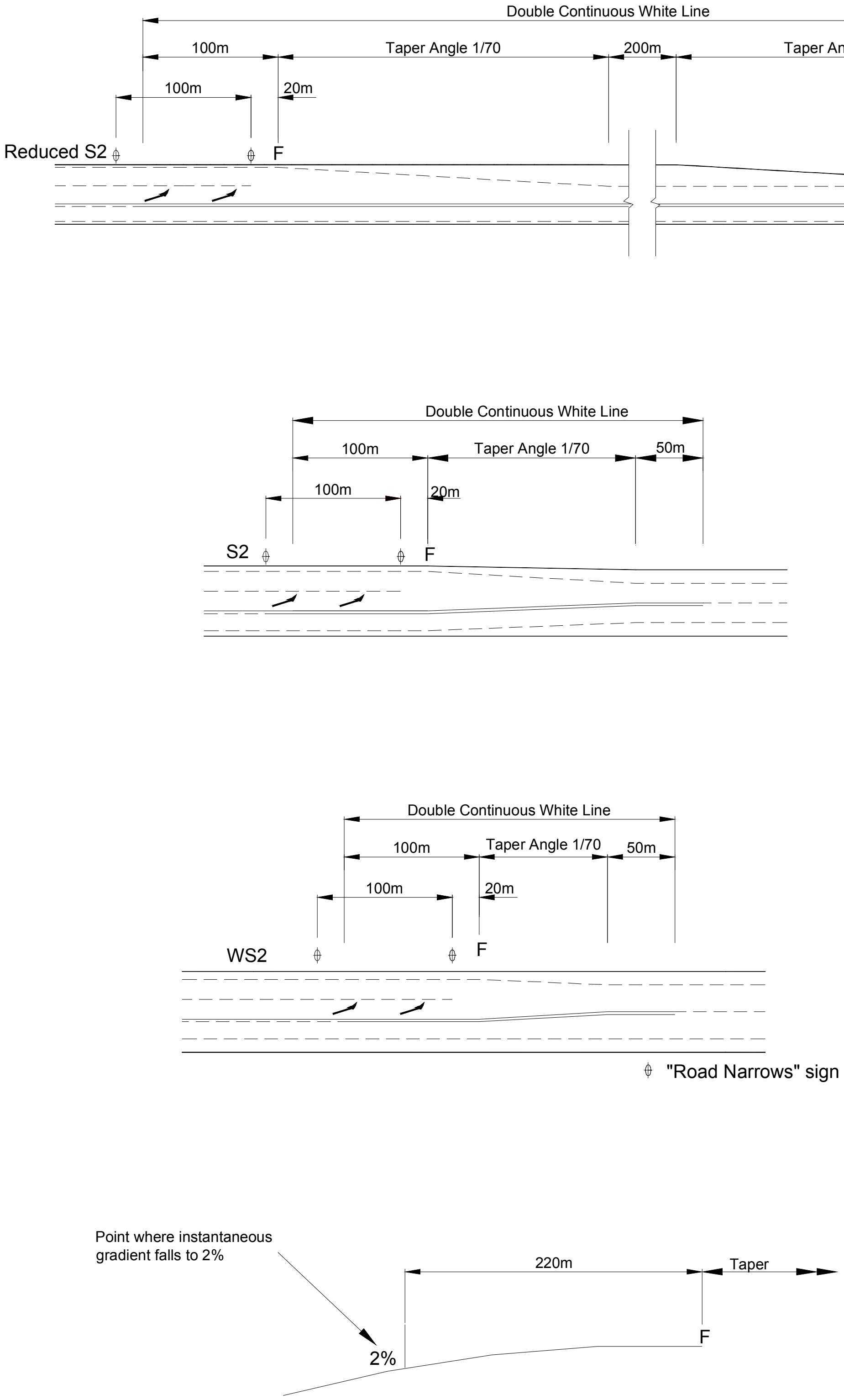
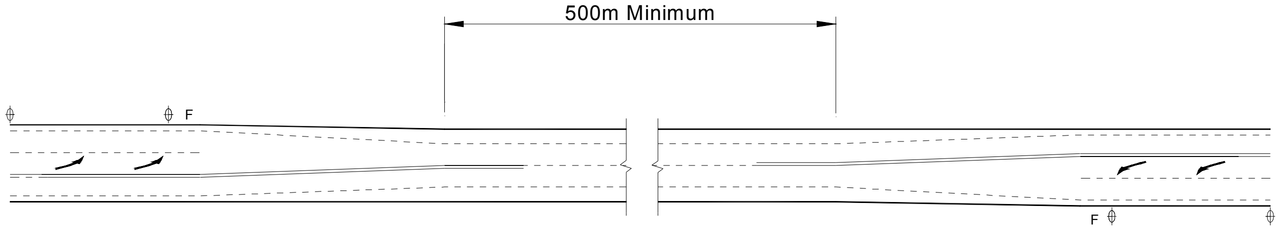
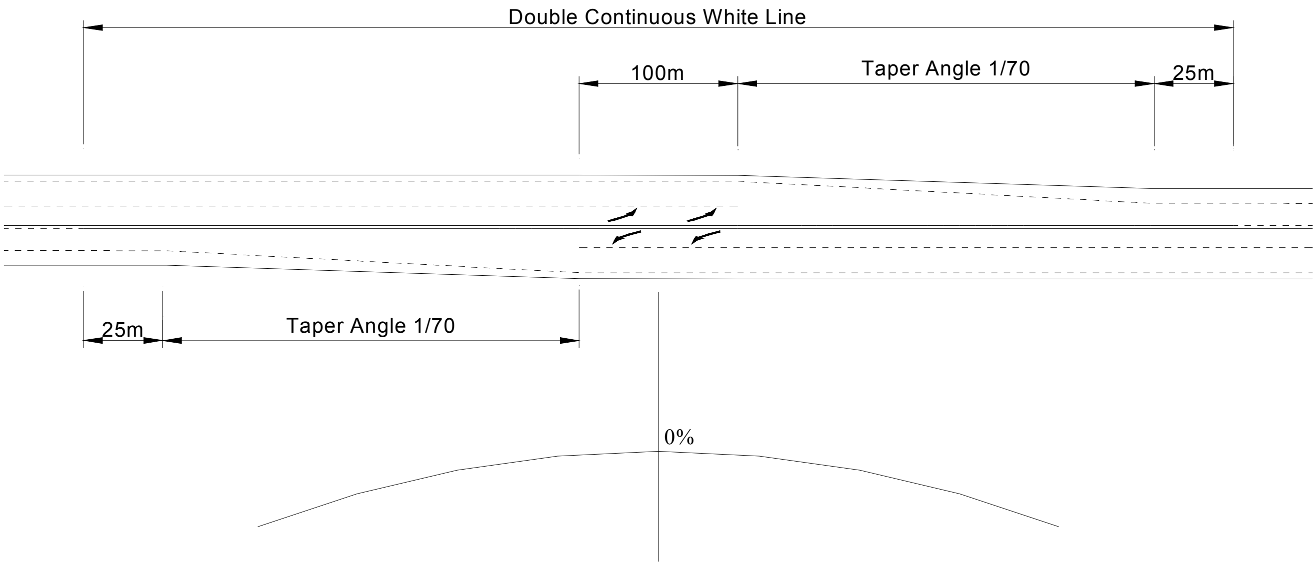


Figure 5/5: End of Climbing Lane

5.32 Layout at crests: Where there are climbing lanes on both sides of the hill, and profile conditions would lead to a conventional road layout between ends of tapers of less than 500m in length (see Figure 5.6a), the climbing lanes shall be extended to provide a length of four lane road at the summit: the detailed layout of a four lane crest is shown in Figure 5/6b. The overlap of the full width climbing lanes should not be less than 100m. The treatment of lanes, hard shoulders and hard strips should follow Figures 5/3 and 5/5 for the appropriate carriageway standard.



(a): Crest Curve Between Separated Climbing Lanes



(b): Crest Curve With Overlapping Climbing Lanes

Figure 5/6: Crest with Two Climbing Lanes

5.33 Layout at Sags: Where there are climbing lanes either side of a sag curve, and profile conditions would lead to a conventional 2 lane road layout between starts of tapers of less than 500m in length, the climbing lanes shall be extended downhill until they meet, as illustrated in Figure 5/7. The treatment of lanes, hard shoulders and hard strips should follow Figure 5/3 for the appropriate carriageway standard.

5.34 Sight Distance Requirements: Climbing lanes on single carriageways do not require Full Overtaking Sight Distance, but the Desirable Minimum Stopping Sight Distance shall be provided throughout. In difficult circumstances a one step Relaxation below Desirable Minimum SSD may be provided. Care should be taken, however, in the design of the crest curve. If vehicles on the crest approaching the downhill section are provided with a high visibility crest curve, there is a possibility of subsequent abuse of the priority rule. The crest curve should be designed to a K value of (or slightly more than) one Design Speed step below Desirable Minimum. A double continuous line marking should be provided as in Figure 5/5 to establish clearly the climbing lane priority. If sight distance increases beyond the crest, the marking should then become continuous/broken to permit some overtaking in the downhill direction.

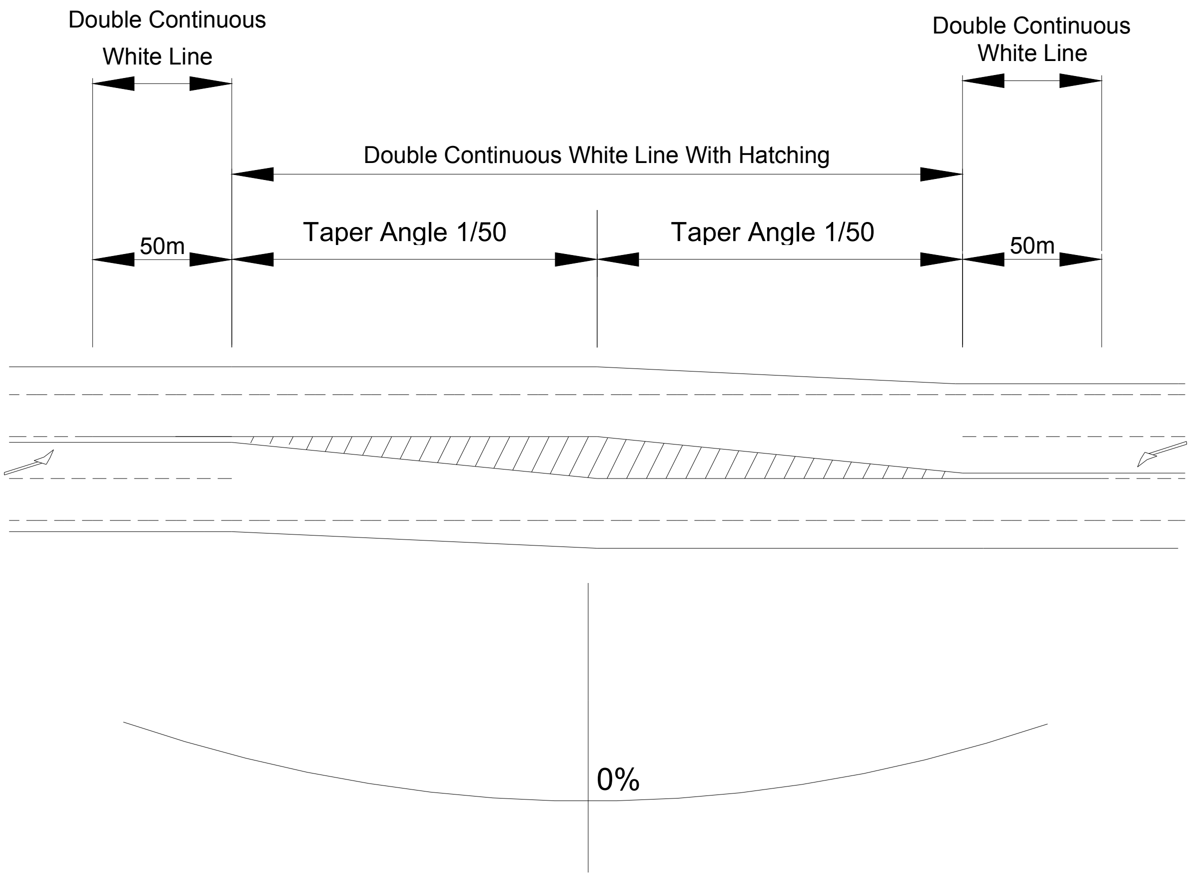


Figure 5/7: Sag between Two Climbing Lanes

5.35 Marking of Climbing Lanes: A three-lane hill is marked with a lane line separating the two uphill lanes and a double white line separating the uphill lanes from the downhill lane. The double white line will feature a continuous line for uphill traffic in all cases and a continuous line for downhill traffic except where the criteria for a broken line are satisfied (see the Traffic Signs Manual).

5.36 To avoid frequent changes of pattern on long hills, or for safety reasons, the designer may use a downhill continuous line even where the visibility criteria for a broken line are satisfied. However, the use of a prohibitory line on long straight sections should be avoided if possible.

5.37 The markings at the start of the climbing lane should be designed to encourage uphill drivers to keep to the left-hand lane unless overtaking (see Figure 5/4). In order to avoid a potential conflict at this point between uphill and downhill drivers, a length of double continuous line should be provided after (uphill of) the start taper for a distance 'W' (see Table 5/1) according to the Design Speed of the road. This ensures that any downhill overtaking vehicle will be returned to its own lane before coming into conflict with an uphill vehicle. In addition, the double white line may be extended along the length of the taper in order to prevent overtaking by downhill traffic. However, if visibility over this length is good, a warning line may be more effective.

Table 5/1: Length of Double Continuous Line

Design Speed (km/h)	Double Continuous Line Length 'W' metres
100	245
85	205
70	175
60	145

5.38 Typical layouts for the markings at the end of a climbing lane are indicated in Figures 5/5 and 5/6.

Dual Carriageways and Motorways

5.39 Criteria for Provision: On dual carriageway roads and motorways on hills with gradients (G = 100H/L) greater than 3% and longer (L) than 500m, as an alternative to economic appraisal, a climbing lane should generally be provided wherever the predicted traffic flow in the design year is expected to exceed 75% of the capacity given in Table 4 for the relevant category of road. The height risen (H) and length (L) shall be calculated between two standard points on the hill as illustrated in Figure 5/2.

5.40 Lane Widths: In general, a full lane width climbing lane shall be provided, although in difficult areas, where structural or environmental costs are high, the cross-section may be reduced by using narrow lanes down to 3.25m, i.e. a carriageway width of 9.75m (D2), or 13.00m (D3). Such reductions shall be considered as Departures.

5.41 Provision of Climbing Lanes: On motorways and Type 1 dual carriageways, climbing lanes shall be formed by the addition of an extra lane, with a full width hard shoulder alongside. On other dual carriageways, a 3.5m wide climbing lane and a 1.0m wide hard strip shall replace the normal hard shoulder. The transition from hard shoulder to hard strip, or vice versa, should take place over the length of the taper in carriageway width.

5.42 Layout at Start of Climbing Lane: The full width of the climbing lane shall be provided at a point 'S' in a similar manner to that described for single carriageway roads (Paragraph 5.23), as shown in Figure 5/8. Wherever possible the additional width should be developed by using the road curvature to provide a smooth transition.

5.43 Climbing lanes may not be inserted directly at the exit from a roundabout, but should allow for a distance of at least 100m before the start of the entry taper to avoid conflicting traffic movements on exiting the roundabout. The entry taper can be reduced to 1/40 owing to the reduced vehicle speeds close to the roundabout.

5.44 Layout at End of Climbing Lane: The carriageway width shall be maintained up to a point F, in a similar manner to that described for single carriageway roads (Paragraph 5.25), followed by a taper of 1/70. A smooth transition should be used wherever possible.

5.45 The climbing lane may terminate at a roundabout where appropriate, with the overtaking lane becoming the right hand entry lane into the roundabout. If the climbing lane would terminate within 500m of the roundabout, it should be continued to the roundabout.

5.46 <u>Signing of Climbing Lanes</u>: To distinguish the commencement of a climbing lane on a dual carriageway from a change of carriageway standard, "Slow Lane" signing should be provided in accordance with the Traffic Signs Manual.

5.47 <u>Sight Distance Requirements with Climbing Lanes</u>: As the speeds of vehicles using the climbing lane will be less than those on the rest of the dual carriageway, the Stopping Sight Distance measured from the centre of the climbing lane may be the distance for one Design Speed step below that for the road. However, the Stopping Sight Distance measured from the centres of the nearside and offside lanes of the original carriageway shall be in accordance with the requirements of Chapter 2 for the Design Speed of the road.

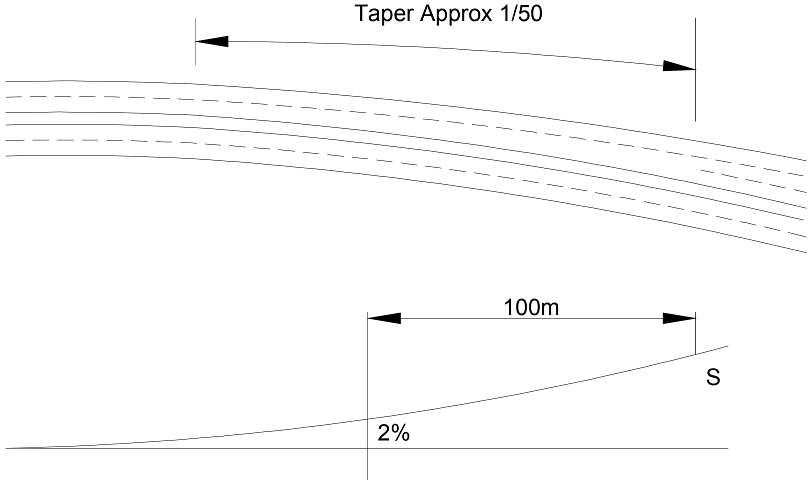


Figure 5/8: Start of Dual Carriageway Climbing Lane

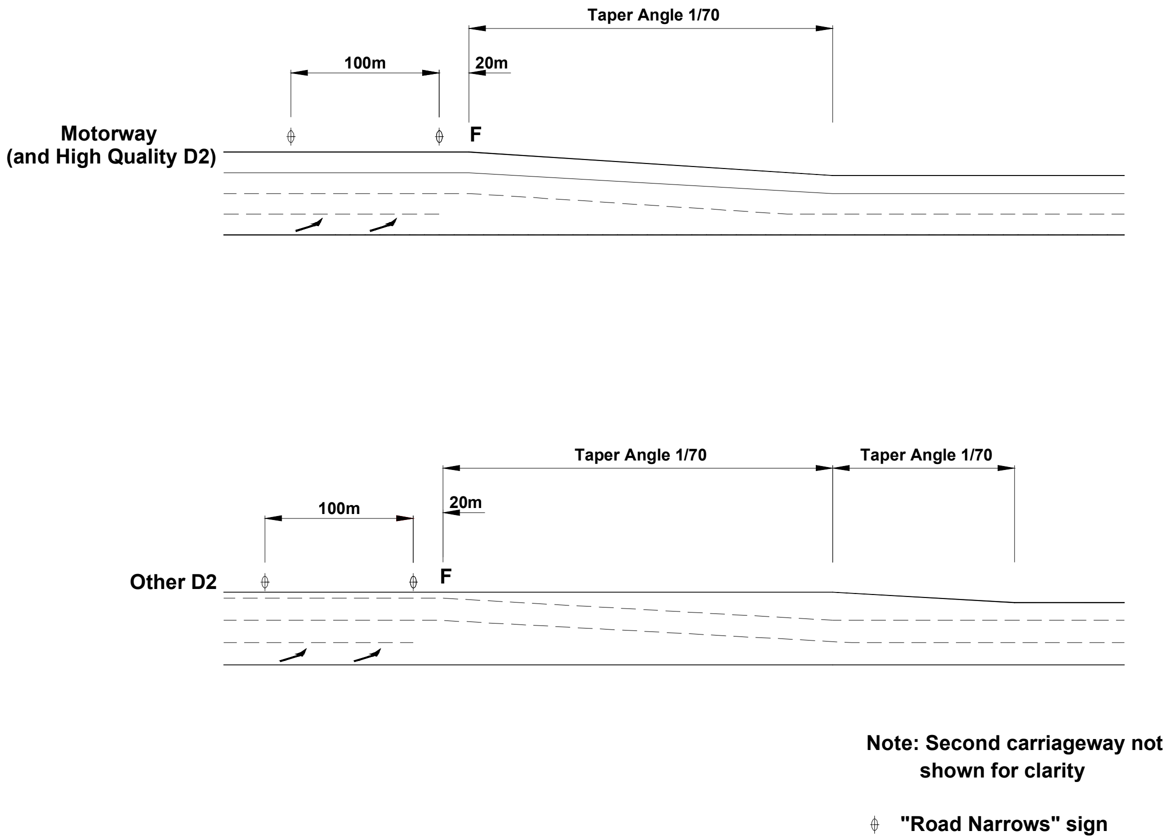


Figure 5/9: End of Dual Carriageway Climbing Lane

6. INTRODUCTION TO COORDINATED LINK DESIGN

General

6.1 The various elements detailed in this Standard shall be coordinated, together with cross-section and junction layouts, so as to ensure that the three dimensional layout as a whole is acceptable in terms of traffic safety and operation, and economic/ environmental effects. Single carriageway design is given particular emphasis due to the problems of driver understanding and provision for overtaking.

Rural Roads

6.2 A general guide to the layout features appropriate for various types of road is given in Table 4. The table recommends edge treatments, access treatments and junction types that would be suitable in broad terms for each type of road. For details of the standard road cross-sections, see NRA TD 27.

6.2A The vehicle flows (Annual Average Daily Traffic) given in Table 4 represent the approximate two-way flows which correspond to Level of Service D in reasonably level terrain. This is the level of service at which passing becomes extremely difficult, with ‘shock waves’ beginning to affect the overall flow. For further details of the level of service, see NRA TA 43.

Urban Roads

6.3 It is not possible to tabulate overall layout characteristics for roads in urban areas in the same way as for rural areas, as the constraints of the existing urban fabric will result in designs tailored to meet the site-specific requirements. Urban Standards (embracing mandatory speed limits, Design Speeds generally 85km/h and below, and reduced cross-section design), are more conducive to safe conditions where the surrounding development is very much of an urban nature. Urban standards should not normally be used for roads which present an open aspect (e.g. passing through parkland, recreational areas, non-built up waste land, etc.), other than for short lengths.

6.4 In urban areas there will usually be less scope for coordinating the geometric features than in rural areas, although wherever economically and environmentally practicable every effort should be made to do so. The demands of accommodating the road within the urban fabric will frequently predominate.

6.5 A single two-lane carriageway S2 urban road, with no frontage access, no standing vehicles and negligible cross traffic, would normally represent a radial or orbital bypass or new town distributor. The design considerations in respect of Overtaking Sections in Chapter 7 should be applied to such a road wherever economically and environmentally practicable, although the constraints of the urban area will frequently not permit the flexibility of alignment required. In some cases, extra road width (i.e. 4 lane single carriageway) can be used to provide overtaking opportunities if economically feasible.

6.6 Single two-lane carriageways S2 with frontage development, side roads, bus stops, etc. with the paramount need to create safe conditions for pedestrians, are likely to be modest projects in an area where comprehensive traffic management has been carried out on the existing network and the new road is required to extend or improve that management. It is unlikely that the coordinated design aspects contained hereafter will be applicable in these cases. Further advice is given in the NRA Guidelines on Traffic Calming.

Table 4: Recommended Rural Road Layouts

Type of Road [1.]	Capacity (AADT) for Level of Service D	Edge Treatment	Access Treatment	Junction Treatment at Minor Road	Junction Treatment at Major Road
Reduced Single (7.0m) Carriageway S2	8,600	0.5m hard strips. Footways where required	Minimise number of accesses to avoid standing vehicles and concentrate turning movements.	Priority junctions, with ghost islands where necessary.	Ghost islands
Standard Single (7.3m) Carriageway S2	11,600	2.5m hard shoulders	Minimise number of accesses to avoid standing vehicles and concentrate turning movements.	Priority junctions, with ghost islands where necessary.	Ghost islands or roundabouts [2.]
Type 3 Dual [3.] (7.0m + 3.5m) Divided 2+1 lanes Primarily for retro fit projects	14,000	1.0m hard strips.	Minimise the number of accesses to avoid standing vehicles and concentrate turning movements.	Restricted number of left in/left out or ghost priority junctions.	Priority junctions or at-grade roundabouts.
Type 2 Dual [3.] Divided 2 +2 Lanes Carriageways. (2x7.0m)	20,000	0.5m hard strips	Left in / Left out	No gaps in the central reserve.	At-grade roundabouts and compact grade separation
Type 1 Dual Divided 2+2 Lanes Carriageways (2x7.0m)	38,100	2.5m hard shoulders	Left in / Left out	No gaps in the central reserve.	Left in / Left out and grade separation.
Standard Dual Divided 2 +2 Lane (2X7.0m) Motorway (D2M)	44,100	2.5m hard shoulders	Motorway Regulations	No gaps in the central reserve.	Motorway standards Full-grade separation.
Wide Dual Divided 2+2 Lane (2X7.5m) Motorway (D2M)	55,500	3m hard shoulders	Motorway Regulations	No gaps in the central reserve	Motorway standards Full-grade separation.

Notes:
1. For details of the standard road cross-sections, see NRA TD 27 and NRA TD 10 'Type 2 and Type 3 Dual Carriageways'
2. Single lane dualling may be appropriate in some situations, but would be a Relaxation (see TD 42).
3. See NRA TD 10 'Type 2 and Type 3 Dual Carriageways'

7. SINGLE TWO-LANE CARRIAGEWAY ROADS – NATIONAL AND REGIONAL ROADS

General Principles

7.1 Chapter 7 shall be used for the design of single two-lane carriageway national and regional roads up to 7.3m wide (running width) with the objectives of safety and uncongested flow in mind. This Chapter gives methods of achieving those objectives. Although they are to some extent related, for instance frustrated traffic tends to lead to unsafe conditions, it is important to identify 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 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 in accordance with Chapter 5.

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 the construction and user costs, including accidents, should be tested for alternative alignments by cost/benefit analyses.

7.4 In the coordination of vertical and horizontal alignments, many of the principles contained in Paragraph 8.7 (Categories 5B and 6B 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. Nevertheless, designs should still be checked at sags and crests 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 and 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 Single 4-lane Overtaking Sections.

It is necessary for the calculation of Overtaking Value (see 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, Overtaking Sections 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/2 when approaching a non-overtaking section, or at a distance of FOSD/4 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 Standard S2 roads. The decreased road width of a reduced S2 provides reduced flexibility for overtaking; however the following design rules should still be used to achieve an optimal overtaking design.

7.7 Two-lane Overtaking Sections: 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 Commencement: At the point on a straight (or nearly straight) or right hand curve where FOSD is achieved, either within or without the road boundary.

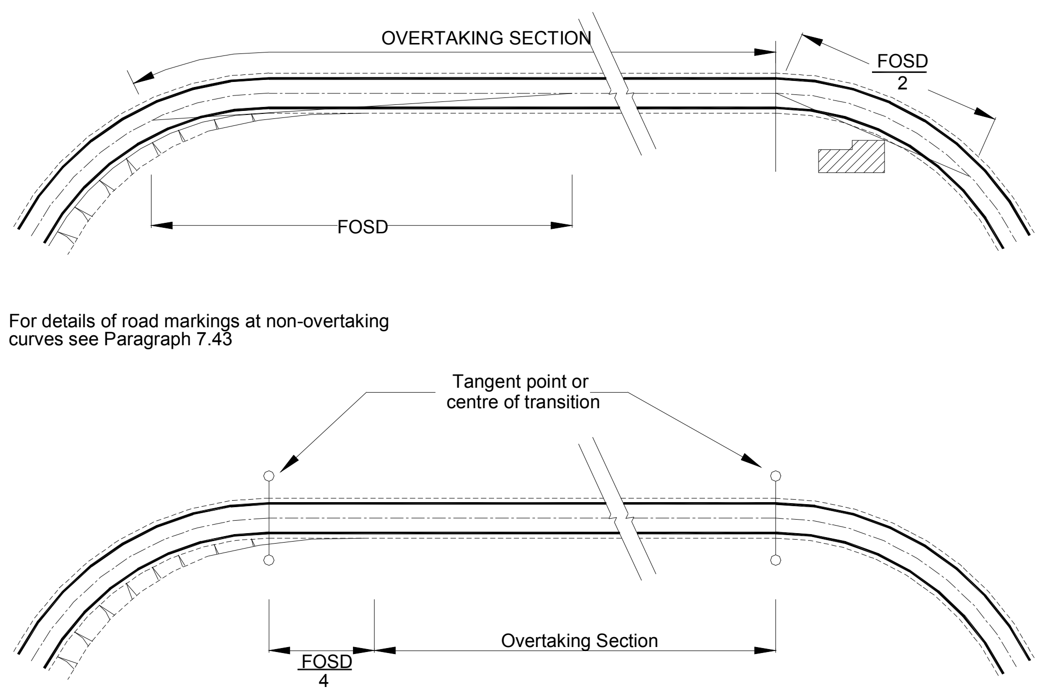
7.9 Termination:

a) At a point FOSD/4 prior to the tangent point or centre of transition of a left hand curve; or
b) The point on a right hand curve where sight distance has reduced to FOSD/2; or
c) A point FOSD/4 prior to an obstruction to overtaking (see Paragraph 7.18).

Table 5: Minimum Radii for Two-lane Overtaking Sections

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

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/4 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.

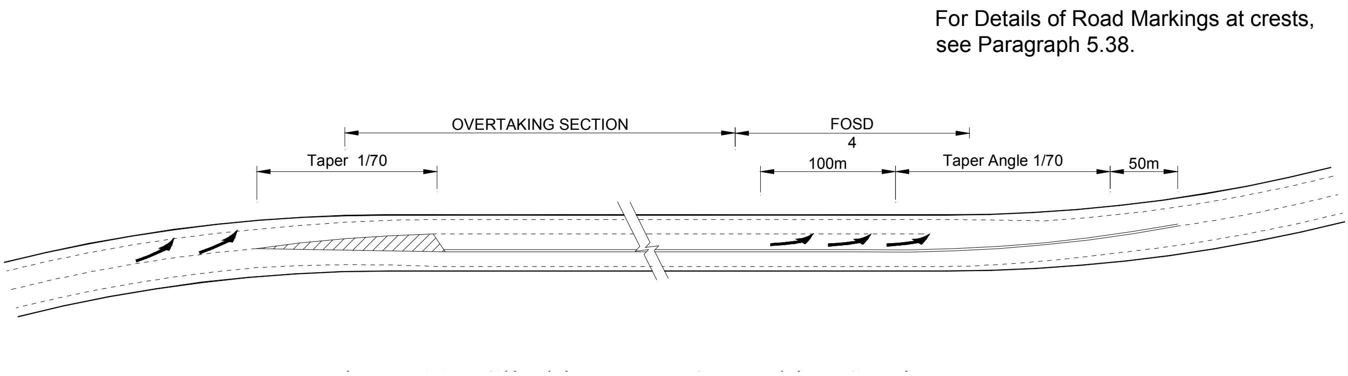


Figure 20: Climbing Lane Overtaking Sections

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 provides 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.

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

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

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/4 prior to the end of the requisite radius or a point FOSD/4 prior to the centre of the finishing taper, whichever is the earlier.

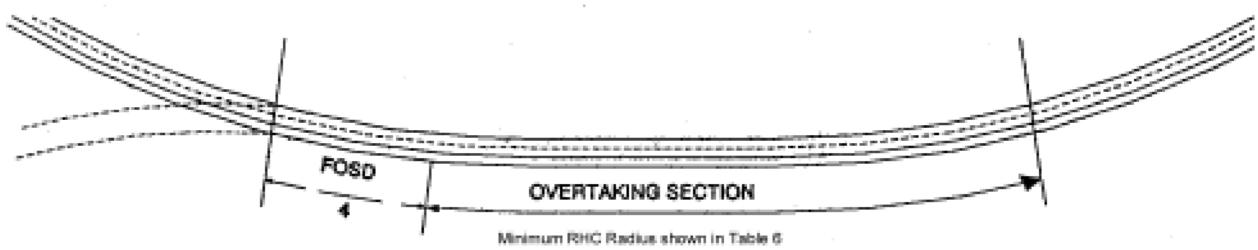


Figure 21: Downhill Overtaking Sections at Climbing Lanes

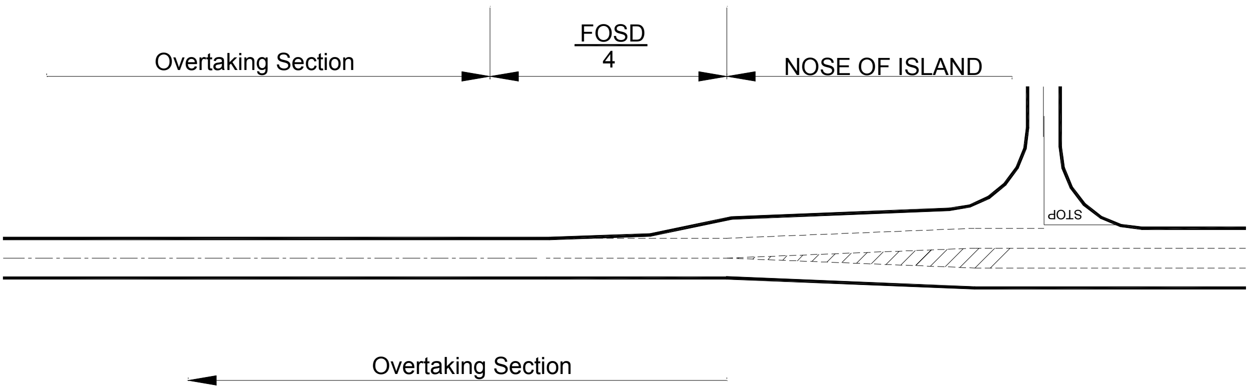
7.16 Dual Overtaking Sections: Dual Overtaking Sections are sections with dual carriageways, which provide overtaking opportunities throughout their length. They should, however, only be provided in cases where the most economic method of improvement of a section of existing single carriageway is to 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. Single 4-lane 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 lengths of single carriageway roads that do not conform with the requirements of Paragraphs 7.7 to 7.16. These will generally be left or right hand curves on two-lane sections, single downhill lanes opposite climbing lanes, or approaches to junctions (see also Non-overtaking crests, Paragraph 7.19).

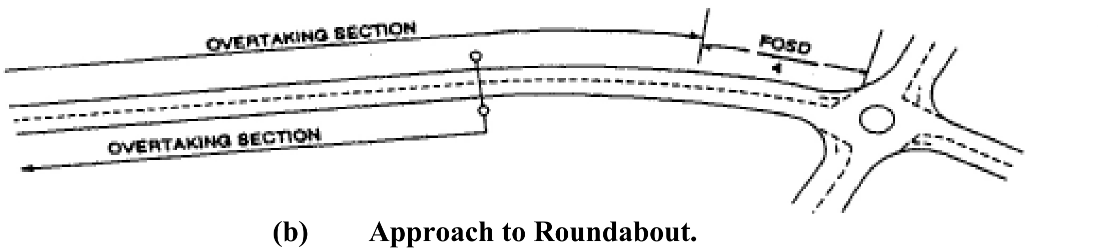
Obstructions to Overtaking

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/4 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). However, simple junctions and accesses 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: At Grade Junctions

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 would result in a continuous sight distance only slightly above FOSD/2, and thus, theoretically, the Overtaking Section would be continuous over the crest. The use of crest K values greater than Desirable Minimum but less than 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. An exception to this is on the approach to a junction: it is important for Desirable Minimum Stopping Sight Distance to be provided at the junction, so the requirements of Paragraph 1.28 take precedence.

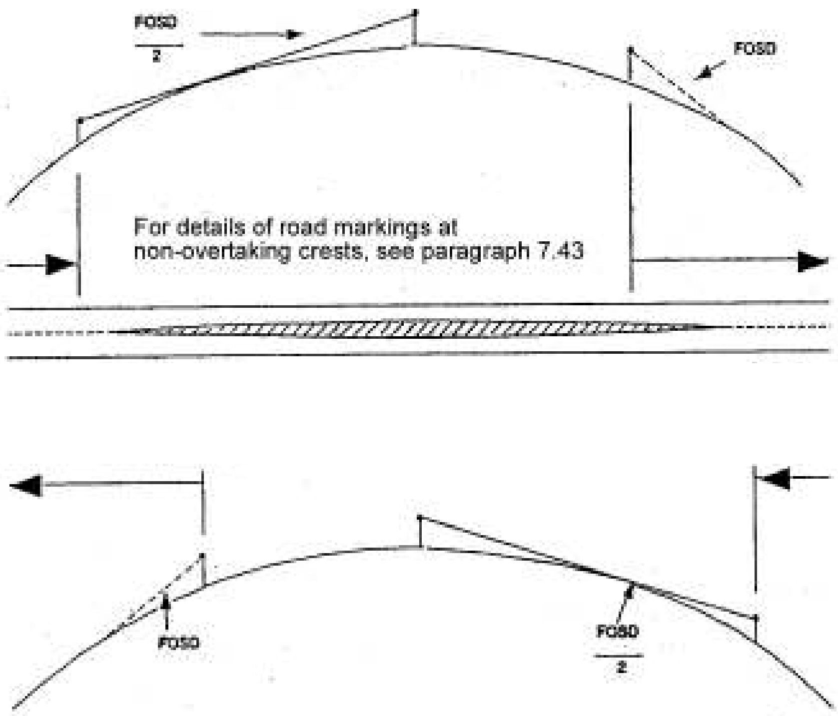


Figure 23: Non-overtaking Crest

Overtaking Value

7.20 On Rural Roads, a sight distance analysis shall be carried out for each direction of travel to ensure that there are sufficient and effective Overtaking Sections at frequent intervals along the scheme. The total length of Overtaking Sections for each direction shall be summed and divided by the total length of the road improvement to obtain the "Overtaking Value" in each direction, expressed as a percentage. The minimum Overtaking Values for the different road types which are thought to provide a reasonably safe road in most circumstances are given in Table 7. An Overtaking Value is not required on single carriageway Urban Roads.

Table 7: Overtaking Value

Rural Road Type	Overtaking Value
Reduced Single	15%
Standard Single S2	30%

The table applies to new construction and new schemes exceeding 2km. Overtaking sections should be distributed along a length of road such that no Non-overtaking Section exceeds 3km. The results of the sight distance analysis should be plotted on the engineering drawings, with the system of road markings to be adopted along the route included below the plot (see Paragraphs 7.7, 7.10, 7.13, 7.19, 7.29, 7.30 and 7.43). This is to ensure that the significance of the various interacting parameters has been taken account of at an early date. Generally speaking it is an advantage from a safety point of view to provide as much overtaking distance as possible, but the amount of provision above the minimum in each scheme must be a matter of judgement according to the particular circumstances.

7.21 The Overtaking Sections along a scheme, which may comprise combinations of the various types shown in Paragraphs 7.5 to 7.16, should be provided by the most economic means. In some instances it may be suitable to use a few long sections, whilst in other cases more frequent shorter sections, linked with Non-overtaking Sections, would provide the most economic strategy to achieve the appropriate Overtaking Value. Alternative designs should be tested by cost benefit analyses.

7.22 The Overtaking Values shown shall be regarded as a minimum level of provision. Using the principles described in this standard it should be possible in the majority of cases to obtain these values without significant extra expenditure on alignment. Detailed guidance is given in Paragraph 7.24. It must be appreciated, however, that a single carriageway will never provide an equal "level of service" to a dual carriageway. There will always be greater interactions between fast and slow moving vehicles on single carriageways, and overtaking manoeuvres will always be hazardous, involving difficult decisions by drivers, whereas dual carriageways permit continuous overtaking without interference with opposing traffic. These implications, however, result in reduced speeds and increased accident rates on single carriageways that are already implicit in the cost/benefit trade-off of alternative standards of design, although the "level of service" or driver-comfort differentials cannot be costed. Provided the requisite Overtaking Values are achieved, therefore, a satisfactory single carriageway design will result. Any additional measures to increase Overtaking Values beyond the requisite levels, such as the provision of additional climbing lanes, straightening route sections, or elimination of junctions, should be justified in economic and environmental terms.

7.23 <u>Schemes Less Than 2km In Length</u>: Schemes less than 2km in length shall be integrated with the contiguous sections of existing road to provide the best overtaking opportunities that can economically be devised. Where contiguous sections afford little or no overtaking opportunity, it is essential that the requisite Overtaking Value be achieved for the scheme. On short improvement schemes this will result in the need to provide at least one Overtaking Section in either direction. However, where contiguous sections provide good overtaking opportunities, a check on the Overtaking Value for a length of, say 3km including the improvement scheme, may relieve the necessity to provide the requisite Overtaking Value for the improvement.

7.24 <u>Means of Improving Overtaking Value</u>: As well as ensuring sufficient overtaking opportunities, the design method outlined above also controls the spacing of junctions. If the criteria are not met initially for any alignment it may be necessary to:

a) Modify the junction strategy by stopping up, bridging or diverting some side roads;

b) Adjust the alignment to produce more straight sections;

c) Introduce climbing lanes on hills previously not considered justified because of low traffic flow;

d) Introduce roundabouts at the more heavily trafficked priority junctions to create sharper changes of direction and improve Overtaking Section lengths;

e) On lengths of existing road without hard shoulders, introduce lengths of Standard S2 or WS2 road with hard shoulders at suitable locations. Whilst this will not improve the Overtaking Value according to the formal methods described in Paragraphs 7.5 to 7.16, such sections will nevertheless, by the extra road width, increase flexibility and reduce frustration; or

f) Introduce more extensive sections of single 4-lane or dual carriageway.

Alternative means of improving Overtaking Values should be tested by cost/benefit analyses to determine their economic implications. This will take into account any changes in user costs due to increased junction delays, diversion costs, or increased speeds due to increased road width, etc. The minimum overall additional cost of improving Overtaking Values in terms of loss of Net Present Value (NPV) should be identified, and an assessment made taking all factors into account, including the effect on the road user.

The extra cost of provision of extra road width to provide a climbing lane at a hill previously considered unjustified (or a section of wider road cross-section on a constrained level road alignment) may be justified on the total balance of advantage. As the wider road will also provide some improved benefits, the resulting loss of NPV may only be minor and thus a small price to pay for the unquantifiable benefits to traffic of improving the Overtaking Value.

Horizontal Curve Design

7.25 The use of mid-large radius curves is counter productive, inhibiting the design of clear Overtaking Sections. Such curves produce long dubious overtaking conditions for vehicles travelling in the left hand curve direction, and simply reduce the length of overtaking straight that could otherwise be achieved. Figure 24 shows a curve selection chart for horizontal curves which illustrates the bands of radii (relative to Design Speed) and their applicability to the design of single carriageways.

7.26 Wherever possible, Overtaking Sections (including climbing lanes) should be provided as straight or nearly straight sections (Band A), thus providing an Overtaking Section for both directions of travel ($V^2/R < 1.25$).

7.27 Where straight sections are not possible, lower radii (Band B) will result in right hand curve (RHC) Overtaking Sections:

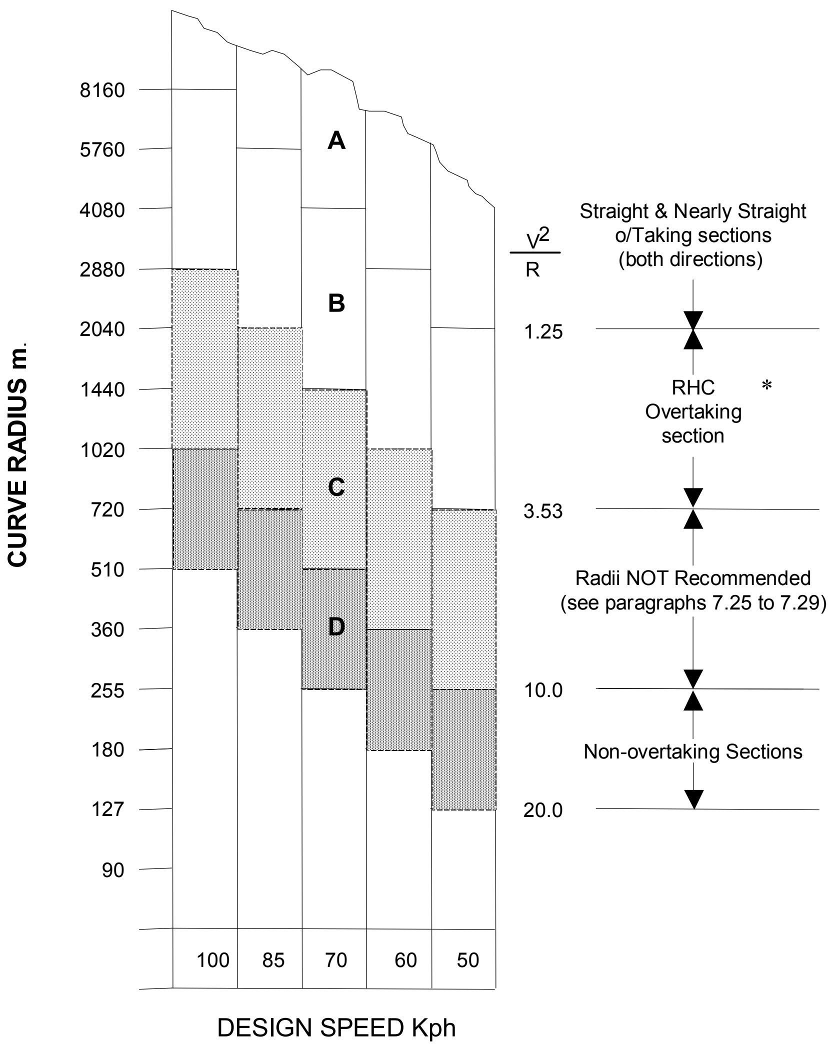
a) On two-lane sections following the achievement of FOSD (see Figure 19); and

b) On single lane downhill sections opposite climbing lanes (see Figure 21).

The lower limit of Band B ($V^2/R = 3.53$) shown for RHC Overtaking Sections should be considered as the minimum radius for use in designing Overtaking Sections. At this level a maximum verge width of 8.45m (plus the 2.5m hard shoulder) would be required on a Standard Single Carriageway to maintain FOSD within the road cross-section for RHC traffic. Left hand curves with radii in Band B should not be considered to be part of Two-Lane Overtaking Sections or Downhill Overtaking Sections at climbing lanes.

7.28 The use of radii in Band C ($3.53 > V^2/R < 10$) is not recommended, as they, in common with Band B, provide long sections with dubious overtaking conditions for LHC traffic. Where visibility is constrained within the road cross-section, either excessive verge widening would be required to maintain FOSD for RHC traffic, or the natural visibility without verge widening at these radii would result in dubious overtaking conditions. It is a paramount principle, therefore, that design should concentrate only on Bands A and B for clear Overtaking Sections, and Band D for clear Non-overtaking Sections. The use of radii in Band C is a Departure from Standards (see Paragraph 1.31).

7.29 Non-overtaking Sections should be designed using the radii shown in Band D (V^2/R = 10 to 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.



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

Figure 24: Horizontal Curve Design

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 (refer to Figure 24 above) and climbing lanes, the use of large crest curves is quite unnecessary and is not recommended. On a road with a horizontal alignment that permits overtaking in one or both directions (Figure 24, Bands A and B), the use of a crest curve that was large but not sufficient to provide FOSD would result in a long section of dubious visibility (see Paragraph 7.19). Therefore, the following standards shall apply for crest curves on single carriageway roads 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):

a) Unless FOSD is provided, the crest K value should not be greater than that for one Design Speed step below Desirable Minimum;

b) The use of crest K values greater than one Design Speed step below Desirable Minimum and up to Desirable Minimum is not preferred, but may be used as a Relaxation;

c) The use of crest K values greater than Desirable Minimum but less than FOSD Overtaking Crest is not recommended and is considered to be a Departure from Standards. The use of crest curves in that range would be counter productive, increasing the length of dubious crest visibility, and reducing the length of clear Overtaking Sections that could otherwise be achieved;

d) Notwithstanding (a) to (c) above, the crest curve K value on the immediate approaches to junctions shall be not less than the Desirable Minimum, in accordance with Paragraph 1.28.

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.

7.31A On sections of road where the alignment allows overtaking, “blind spots” must be avoided. These occur when the road disappears from view over a crest or around a bend and reappears in view again further on. Vertical blind spots, or ”hidden dips”, occur where there is a sag between two crests on a straight road; horizontal blind spots occur where reverse horizontal curves are used on a straight grade. These, plus a combination of horizontal and vertical geometry, could cause the road to disappear from view such that a car coming around a bend or over one crest can see the road ahead (on the far crest) but may not be able to see an oncoming car in the intervening space. As blind spots can be the cause of overtaking accidents, FOSD must be provided both horizontally and vertically in each direction of travel on these sections of road.

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 bi-directional overtaking straights, as shown in Figure 25.

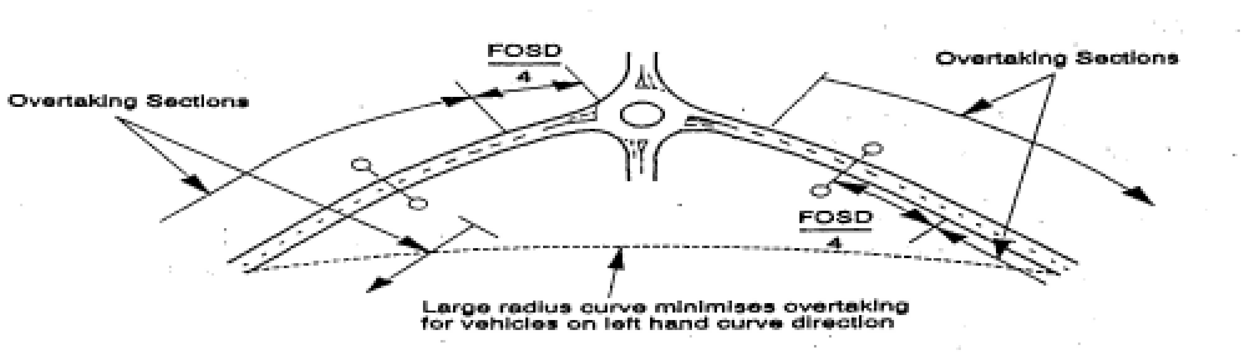


Figure 25: Use of Roundabout to Change Alignment

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. This layout can also 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 with acceleration lanes 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 potential hazards: the aim in new construction should be to provide continuity of road type, either single or dual carriageway, 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 sections with hard shoulders at suitable locations (see Paragraph 7.24), rather than introducing sections of dual carriageway.

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. Whatever layout is adopted, adequate advance signing will be required.

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: this leads to abnormally high serious accident rates. Where staged construction is part of the design, or where 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. Appropriate measures are:

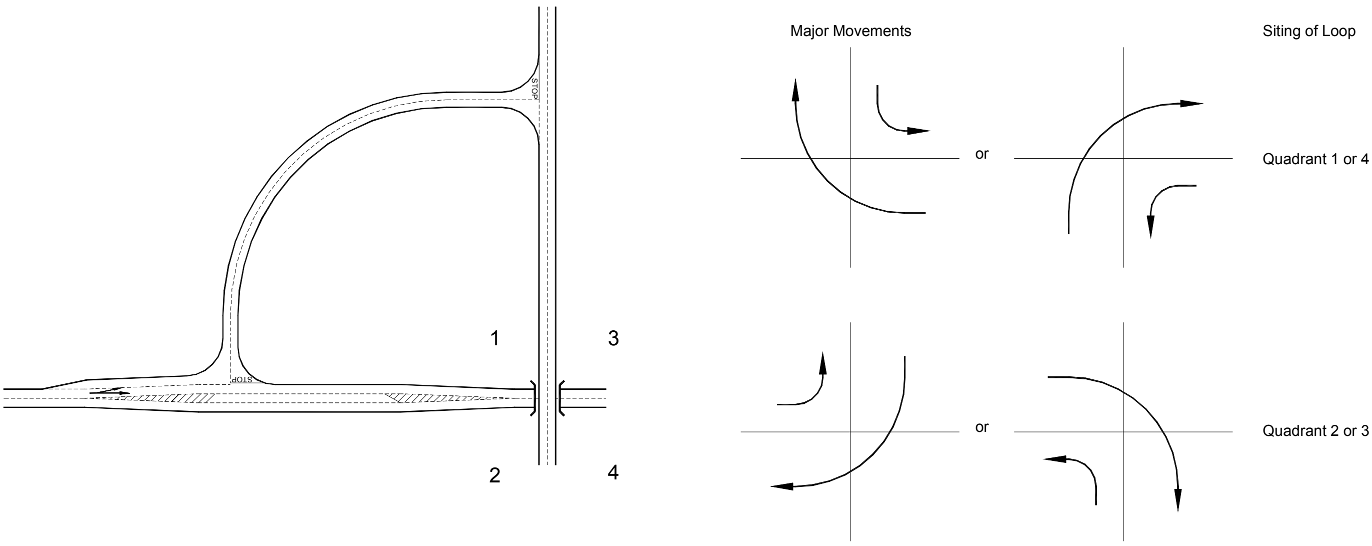


Figure 26: Single Quadrant Link

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; or

c) Where a changeover from dual to single carriageway occurs at a roundabout, provision of 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.

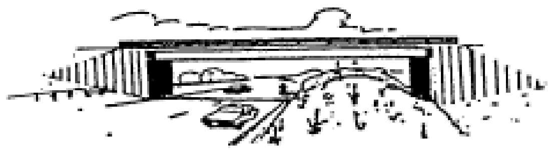


Figure 27

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 and Paragraphs 7.36 and 7.37 b and c).

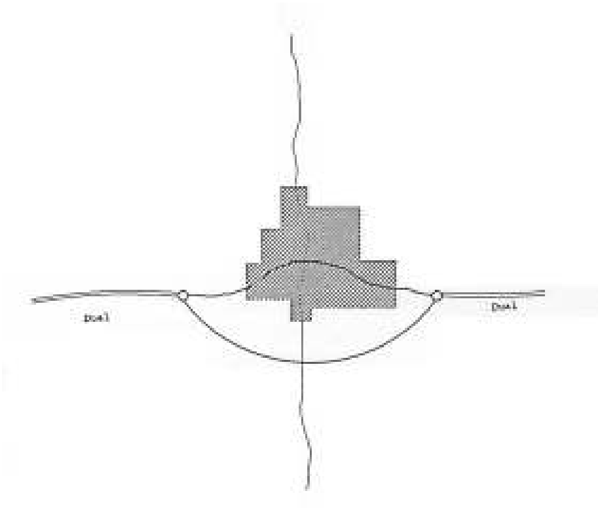


Figure 28

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; and

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 onto 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.

Road Markings

7.42 (Not used.)

7.43 At non-overtaking horizontal curves and crests (see Paragraph 7.30), double continuous line markings should be provided where the visibility (measured in the same way as for FOSD, see Paragraph 2.4) is less than the relevant distance stated in the Traffic Signs Manual. The markings may be strengthened with a hatched marking in accordance with the Traffic Signs Manual, as shown in Figure 29, especially following Overtaking Sections, in order to make clear to drivers the presence of undesirable overtaking conditions.

Existing Single National and Regional Carriageway Improvements

7.44 The design standards contained in the preceding paragraphs apply generally to lengths of new single carriageway construction, from short bypasses and diversions to extensive new single carriageway routes. When dealing with existing rural national and regional roads, the need for improvements will frequently be dictated by evident dangerous bends, junctions, narrow sections, hills, etc. For the improvement of such features the standards shown in Chapters 1 to 5 should be applied. For the minor improvement of national roads the standards shown in Chapter 10 should be applied

7.45 Where, however, the need for improvement arises from congested conditions, or from a restricted alignment providing an unsatisfactory regime of flow, attention should be focused upon the provision of adequate Overtaking Sections, as in Paragraphs 7.20 to 7.24. One of the most economic methods of improving Overtaking Value is the provision of climbing lanes (or a second carriageway added to the first) on hills, where slow moving vehicles create severe congestion and consequent delays. This can be considerably more economic than a major realignment to create a Two-Lane Overtaking Section elsewhere.

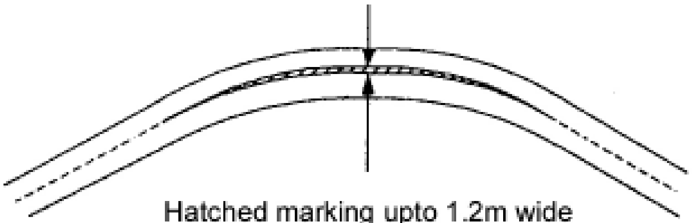


Figure 29: Hatched Road Marking at Non-overtaking Curves and Crests

7.46 On a long length carrying consistently similar traffic which has been defined for major improvement, it is important to have a comprehensive strategy to maintain an acceptable level of service and safe conditions. Ways of implementing the strategy in stages must be evolved to suit expenditure profiles. The techniques contained throughout Chapters 6 and 7 should be used when formulating the overall strategy, which, after elimination of dangerous bends, junction improvements, etc., should concentrate upon the provision of adequate Overtaking Sections. Whilst the vertical and horizontal alignments shall be coordinated in accordance with the preceding paragraphs for all newly constructed diversions and bypasses, there will frequently be little necessity for such coordination on the remaining sections which, although not conforming to formal standards, may not demonstrate any operating problems.

Staged Construction

7.47 Where a single carriageway is being considered as a first stage of an eventual dual carriageway improvement, the single carriageway shall be designed in accordance with the coordinated design aspects shown in Chapter 7. This will ensure that the impression of an essentially at-grade single carriageway road is maintained. Where it is economic to carry out some earthworks or bridgeworks for the dual carriageway in the first stage, care must be taken to ensure that the wider formation and bridges do not create the illusion of a dual carriageway. At bridges, such an illusion can be avoided by the methods described in Paragraph 7.38, and generous planting can reduce the overall impression of space.

7.48 The overriding requirements for clear Overtaking Sections in the first stage design will mean that the flowing alignment requirements for dual carriageways (as shown in Paragraph 8.7) will not be possible or desirable. However, first stage designs should be checked to ensure that the horizontal and vertical alignments are phased sufficiently to eliminate any areas where misleading visual effects in perspective might occur: for example, broken back alignments.

8. DUAL CARRIAGEWAYS AND MOTORWAYS

General Principles

8.1 All-purpose dual carriageways and motorways shall be designed to permit light vehicles to maintain the Design Speed. Subject to traffic conditions, light vehicles can overtake slower moving vehicles throughout, without conflict with opposing traffic, and drivers are free to travel at a speed controlled only by the constraints described in Chapter 1. Unlike single carriageways, therefore, there is no limitation upon the use of horizontal or vertical curves in excess of the values for one Design Speed step below Desirable Minimum values, and the coordination of design elements will mainly involve the design and optimisation of aesthetic alignments.

8.2 In the coordination of vertical and horizontal alignments, the principles contained in Paragraph 8.7 are generally desirable for all dual carriageway designs. However, for the lower categories of design, with consequently lower traffic flows, a high standard of aesthetic design may frequently not be justifiable, particularly where the dual carriageway represents an alternative to a single carriageway.

All Purpose Dual Carriageways

8.3 <u>Type 3 Dual Carriageway – (Table 4)</u>: This is the lowest category of all-purpose dual carriageway; it represents an alternative layout option to single carriageway types S2 for traffic flows indicated in Table 4 and its use will be primarily for retrofit projects.

The <u>Type 2 Dual Carriageway</u> is the next category of all-purpose dual carriageway for traffic flows indicated in Table 4. (See NRA TD 10 'Type 2 and Type 3 Dual Carriageways')

8.4 The vertical alignment of a Type 2 dual carriageways should follow the topography closely, with the horizontal alignment phased to match. Junctions should generally be at-grade, with roundabouts at the more heavily trafficked locations and compact grade separated solutions elsewhere.

8.5 Major/minor junctions on dual carriageways are a source of accidents, but collecting together side roads or providing grade separation may be economically justified. Furthermore, where the dual carriageway is being assessed as an alternative option to a single carriageway, the additional costs of higher standards of junction or alignment provision, together with the resulting higher overall earthworks and structural implications, may well cause the dual carriageway option to be so costly as to be uneconomic, in spite of its inherently superior performance in terms of link accidents and user costs.

8.6 <u>Type 2 and Type 3 Dual Carriageways to be used where agreed with the National Roads Authority.</u>

8.7 <u>Type 1 Dual Carriageway – (Table 4)</u>: The higher category of all-purpose dual carriageway is to accommodate the traffic flows indicated in Table 4. All intersections, both major and minor (other than left in/left out minor junctions), should be grade separated, and no accesses are permitted. A smooth flowing alignment is required for sustained high speeds. The following are the principles to be followed in securing a satisfactory alignment:

a) Care should be taken to ensure that embankments and cuttings do not make severe breaks in the natural skyline.

b) When negotiating a ridge in cutting or passing through a broad stretch of woodland, the road should be on a curve whenever possible so as to preserve an unbroken background.

c) Short curves and straights should not be used. Adjacent curves should be similar in length.

d) Small changes of direction should not be made, as they give the perspective of the road ahead a disjointed appearance.

e) Curves of the same or opposite sense which are visible from one another should not be connected by a short straight. It is better to introduce a flat curve between curves of the same sense, or to extend the transition curves to a common point between curves of the opposite sense.

f) Changes in horizontal and vertical alignment should be phased to coincide whenever possible. This is very important with horizontal curves sharper than 2,000m radius and vertical curves of less than 15,000m radius.

g) Flowing alignment can most readily be achieved by using large radius curves rather than straights.

h) The profile of the road over bridges must form part of the easy flowing alignment.

i) At the start of horizontal curves superelevation must not create large flat areas on which water would stand.

j) Horizontal and vertical curves should be made as generous as possible at interchanges in order to enhance sight distances.

k) Sharp horizontal curvature shall not be introduced at or near the top of a pronounced crest. This is hazardous especially at night because the driver cannot see the change in horizontal alignment.

l) The view of the road ahead should not appear distorted by sharp horizontal curvature introduced near the low point of a sag curve.

Motorways

8.8 The high standard of motorway design results in high speeds throughout, by complete elimination of access other than at interchanges and service areas, prohibition of usage by pedestrians and certain vehicle types, coupled with the generous flowing alignment for traffic flows indicated in Table 4.

8.9 The relevant alignment standards are given in Chapters 2 to 5 and the rules in Paragraph 8.7 shall be followed. Additionally:

a) Horizontal and vertical curves should be as generous as possible throughout.

b) To relieve the monotony of driving on a road with such good extensive forward visibility, long sections of the road should be aligned to give a view of some prominent feature ahead.

Central Reserve Barrier Widening

8.10 Where the central reserve barrier varies in width, e.g. localised widening in advance of bridge piers or gantries, the change of road cross section should take place over a minimum 1:200 taper length and the length of barrier bifurcation shall ensure a maximum and minimum set back to the median barrier of 1.5m and 1.0m respectively (See NRA TD 27)

Provision of Emergency Accesses

8.11 This section describes the requirements to provide emergency access and egress from motorways and dual carriageways on the national road network. It is necessary to ensure that emergency vehicles are able to access the location of an incident and to provide egress opportunities to other road users whose vehicles become trapped when one, or both, carriageways are obstructed.

8.12 On sections of motorway or dual carriageway national road an emergency access facility should be provided for emergency incidents to the minimum frequency shown in Table 8/1. Special emergency access must be provided either as:

- a break in the central reserve barrier as an Emergency Crossing Point (ECP) or
- an Emergency Access Link (EAL) to connect the motorway/dual carriageway to the side road network in the vicinity of a side road crossing.

Proposals to change the frequency or omit ECP's or EAL's must be submitted as a Departure Application to the National Roads Authority.

8.13 In any route emergency access strategy special consideration must be given to tunnel portals and the provisions made for tunnel operational, emergency and maintenance purposes. These should be incorporated as part of the overall emergency access provision.

8.14 Central reserve emergency crossing points and emergency access links shall be provided to facilitate route specific emergency access and egress procedures in accordance with the requirements of this Chapter.

Emergency Crossing Points

8.15 Central reserve openings to facilitate Emergency Crossing Points must be secured with a section of vehicle restraint that is easily removed and replaced, and is in line with the requirements of clause 8.20.

8.16 The crossing point must be able to be quickly and effectively opened and closed by trained operatives when required and be of suitable width to enable vehicles to pass through at low speeds and on to the opposing carriageway. A standard detail of such a solution is provided in Figure 8/1.

8.17 The crossing point must be designed to a minimum length of 16m and a maximum length of 25m. Greater lengths may create operational difficulties. To determine the dimensional requirements of the crossing point, a location specific swept path analysis should be undertaken for articulated and rigid design vehicle.

8.18 Solutions must comply with the requirements of NRA TD 19.

8.19 Where a central reserve barrier is already in-situ, or is to be installed, a removable section, approved to EN1317, specifically designed to match the profile of the central reserve barrier must be provided.

8.20 The full length of central reserve barriers in central reserve crossing points must achieve the performance specification, as set out in paragraph 8.20, as a minimum.

Table 8/1: Minimum Frequency for Emergency Access Provision

Design Year AADT	Distance between Junctions (km)						
≥50,000		<5	≥5<10	≥10<15	≥15<20	≥20<25	≥25<30
	Emergency Access Provisions	1	2	3	4	5	6
<50,000		<5	≥5<10	≥10<15	≥15<20	≥20<25	≥25<30
	Emergency Access Provisions	0	1	2	3	4	5

8.21 When designing a removable central reserve barrier the following should be considered as a minimum:

- The minimum level of containment must be N2 or the equivalent standard of the adjacent barrier, whichever is greater;
- The equipment to remove the central reserve barrier must be lightweight and suitable to be transported in a standard Traffic Corp Gardai or emergency services vehicle;
- The opening of the crossing point should only necessitate a closure of the outside lane in the secondary carriageway;
- The crossing point must be able to be opened within 20 minutes and closed within 60 minutes by suitably trained operatives, using non-specialist equipment.

Network Operation

8.22 One principal mode of operation for a removable central reserve barrier would be to enable trapped vehicles to perform a U turn onto the opposing carriageway and exit the network via the next junction. This is a complex operation which would require a significant amount of resource and training to perform safely and successfully. Figure 8/1 below indicates possible operational modes.

Siting

8.23 Where possible a central reserve crossing point should be provided in conjunction with widening/ hardening of the verge to facilitate the turning of large vehicles within the width of the carriageway. These emergency turnaround areas should be no more than 500m downstream of a central reserve crossing point. An indicative layout is given in Figure 8/1 and Fig 8/2 below. Where lay-bys are to be constructed consideration should be given to their location to facilitate an emergency turnaround area as part of the route emergency access strategy.

8.24 An Emergency Crossing Point may be located where the central reserve is of sufficient width to accommodate turning vehicles. Any hardened areas should be suitable for being trafficked without damage.

8.25 Crossing points at locations with a wider section of central reserve will be better able to facilitate the turning circles of larger vehicles.

8.26 Emergency crossing points shall be sited no closer that 2km apart on any given link to ensure they serve the purpose of traffic management without compromising the safety of the road users.

8.27 Where possible central reserve crossing points should be located on lit sections of the network.

Routine Maintenance

8.28 Full consideration must be given to the maintenance implications of the installation of a removable central reserve barrier. This is to include the maintenance requirements of any moving parts such as wheels, hinges etc. This is unlikely to have any additional barrier maintenance requirements (in terms of lane closures and exposure of operatives to live traffic) over and above that already undertaken on existing metal central reserve barriers.

Emergency Access Links

8.29 Ideally emergency access links should be provided at the mid-point between interchanges and should be located on both sides of the motorway/dual carriageway. If a choice of locations exists the higher classification/ standard of side road should be selected.

8.30 Links should be constructed with junctions at right angles to the national primary road and local road, Figure 8/3 refers, and be provided with a lockable barrier adjacent to both the national primary and local roads. Galvanised heavy duty chains (minimum section 5mm) shall be provided at the top and bottom of the link to prevent use by the general public.

8.31 The proposed horizontal alignment should limit necessary land take and discourage excessive speed of any vehicle using the link. The vertical alignment (maximum gradient of 8%) is intended to further limit/discourage the speed of a vehicle using the link.

Geometry

8.32 Design standards for Emergency Access Links are shown in Table 8/2. The design shall ensure that forward visibility to the stop line within the link junctions shall be at least equal to the stipulated stopping sight distance shown.

8.33 The visibility "x" distance to be used at the ends of the link shall be 2.4m back from the edge of the carriageway. The stopping sight distances shall, accordingly, be appropriate for the design speed of the local road. If no design is available then an assessment should be undertaken to establish a design speed in the vicinity of this junction. Guidance on sight distance and visibility standards are given in NRA TD42. The need for additional signing identifying the emergency access location should be considered.

8.34 Adoption of vertical curves terminating at the edges of the primary and secondary roads ensures that the 5.0m length immediately adjacent to the public road shall have a maximum gradient of plus or minus 3%.

Table 8/2 - Design Standards for Emergency Accesses

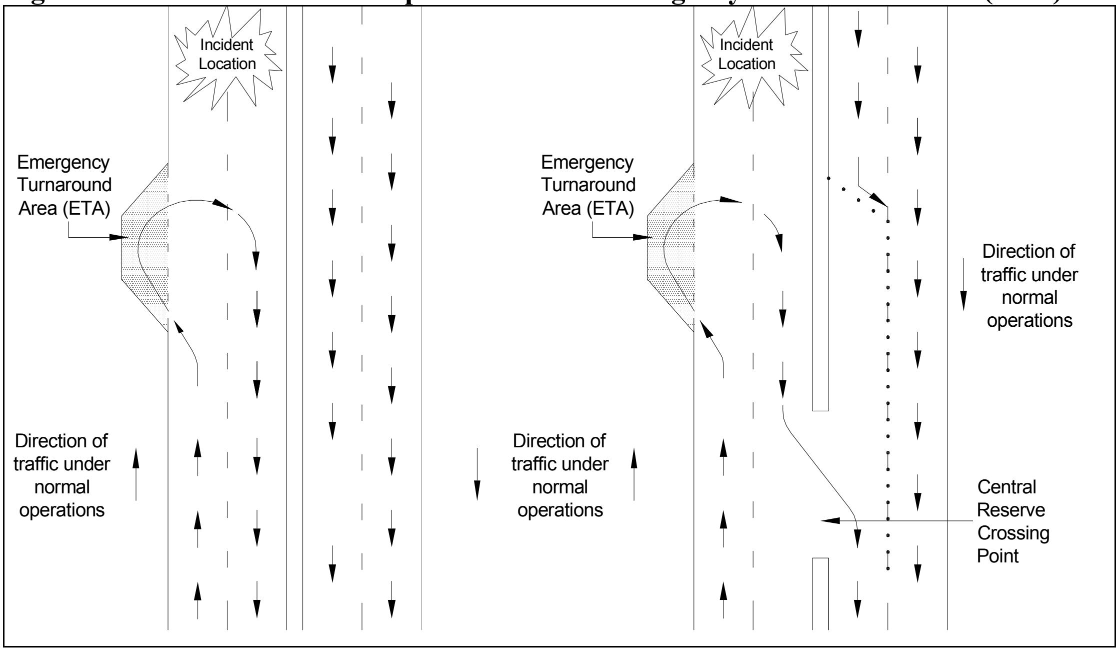
HORIZONTAL CURVATURE Minimum radius (m) (to nearside channel)	10
VERTICAL CURVATURE Minimum Crest K Minimum Sag K	 3.0 2.0
GRADIENTS Maximum Gradient	 8%
STOPPING SIGHT DISTANCE Minimum Stopping Sight Distance (m)	 50
JUNCTION RADII Minimum radius (m) of each channel	 10

Typical Cross Section

8.35 The emergency access carriageway shall have a minimum cross-section width of 4.0m with 1.0m soft verges on either side, compatible with Road Construction Detail RCD/700/6.

8.36 Design of the Emergency Access Links shall require analysis of the swept path of the design vehicle (8m rigid vehicle) to ensure widening of the surfaced road is provided where necessary.

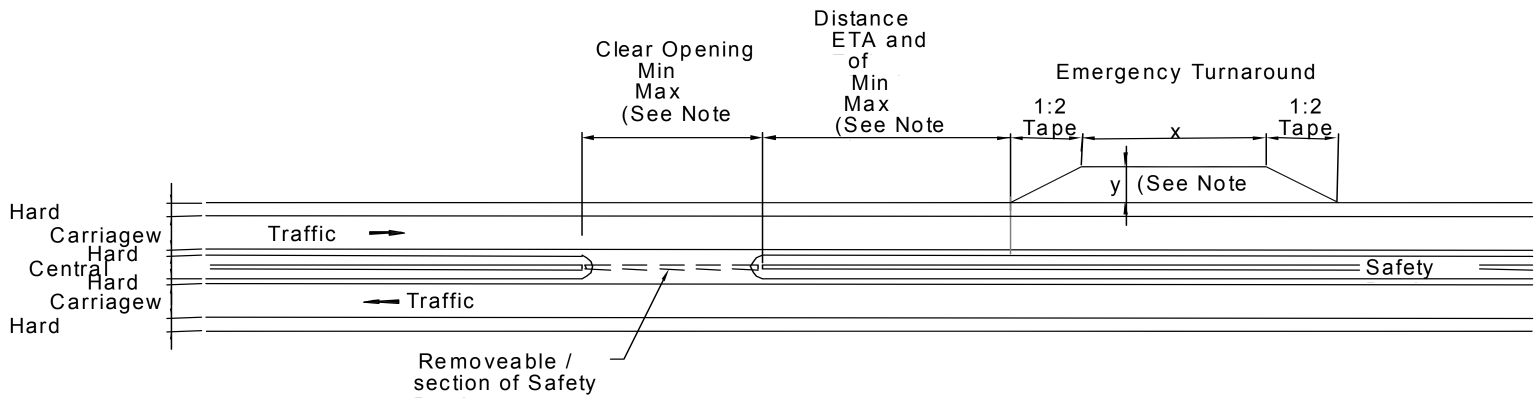
Figure 8/1 Potential Modes of Operation for an Emergency Turnaround Area (ETA)



Use of ETA for Vehicle Egress On same carriageway

Use of ETA for Vehicle Egress via opposing carriage

Figure 8/2 Central Reserve Crossing Point and Emergency Turnaround Area (ETA)



KEY

▭ Cellular grass system or

SUGGESTED MINIMUM DIMENSIONS (SINGLE U MANOEUVRE OF VEHICL

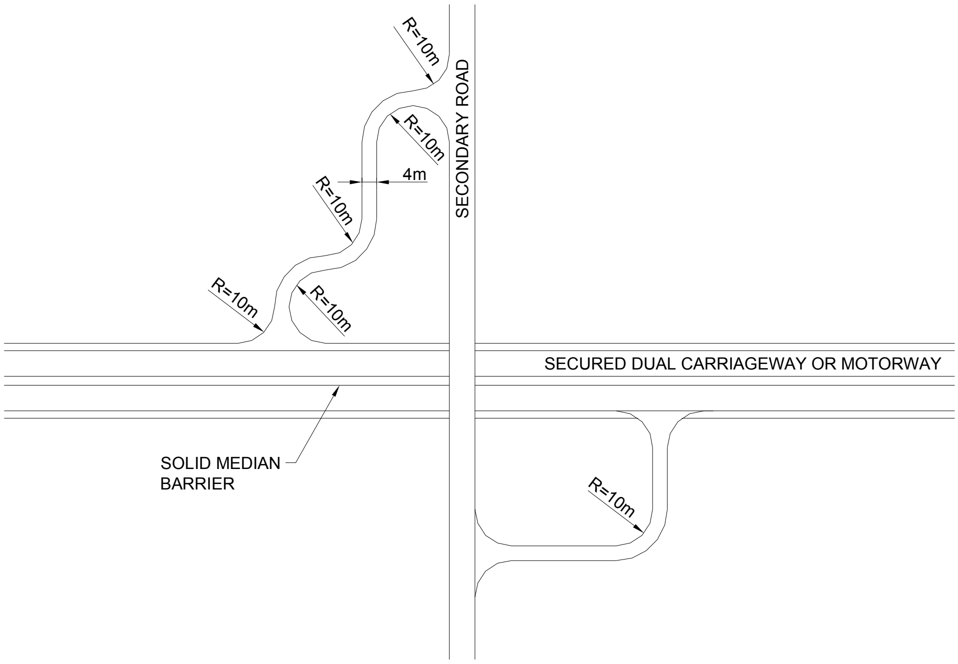
ROAD	x	y
2 Hard	15m	7m
3 Hard	15m	5m

(See note

NOTE

1. Exact dimensions to be determined during local swept path
   Designers should note the dimensions are minimums, several vehicles including large rigid HGVs and difficulty turning in the space provided depending on The minimum dimensions may need to be increased if coach numbers are
2. The 25m safety barrier opening has a design speed slower operational speed should be considered during smaller opening is to be
3. It is recommended that the length of removeable / barrier is restricted to 25m to ensure ease of operation speeds during
4. Offset between end of barrier and start of ETA to be basis of preferred mode of egress
5. ETA
   Depth of cellular grass system to be designed to HA
   Minimum sand blinding layer of
   A minimum depth of 150mm Type B granular sub-bas
   For CBR values of less than 4% an additional depth o 75mm per 1% reduction is
   Exact layby construction depths to be determined following site investigations and CBR
6. Details and background data abstracted from HA IAN 68/06.
7. Where a Type 1 lay-by (NRA-TA69/03) is to be utilise the raised segregation island should be replaced by a flush with the existing

Figure 8/3 Typical Layouts for Emergency Access Links



9. (Not Used)

10. MINOR IMPROVEMENTS TO EXISTING NATIONAL ROUTES

General

10.1 The majority of the existing national road network pre-dates the current NRA Design Manual for Roads and Bridges and includes many design elements such as tight bends or poor forward visibility.

10.2 Any works that are generally less than 2km in length or are less than the NRA threshold in cost are deemed minor improvements. When considering low cost minor improvements, Designers may have difficulty in achieving current NRA DMRB design criteria within the existing physical, economic or environmental constraints, whilst also maintaining a high degree of route consistency for the driver.

Categorisation

10.3 To assist Designers in achieving the above objectives set out in NRA IAN 85/06, minor improvements for National Roads have been divided into three categories as detailed in Table 3/1 of the NRA IAN 85/06. A minor improvement scheme may comprise a combination of these (or other) individual measures, and shall be designed in accordance with the highest applicable category. For example if both Category 1 and 2 apply, then the Scheme shall be designed to Category 1.

Category 1

10.4 Category 1 Minor Improvements as outlined in Table 3/1 of NRA IAN 85/06, shall conform to the current standards of NRA TD 9. Category 1 Minor Improvements should, where possible, meet desirable minimum standards, however this may not be achievable in all instances and in such circumstances it may be necessary to consider Relaxations or Departures from Standard. The procedures set out in Paragraph 1.15 to 1.31 above should be used for considering options, recording relaxations and applying for Departures. These procedures should be applied for all remaining or proposed features, which are less then Desirable Minimum.

Category 2

10.5 Category 2 Minor Improvements as outlined in Table 3/1 of NRA IAN 85/06, shall be designed to maintain the existing route consistency of the road taking into account the existing road geometry 2km either side of the proposed scheme. The design speed should then be calculated using the Alignment Constraint and Layout Constraint as set out in NRA IAN 85/06.

Category 3

10.6 Category 3 Minor Improvements as outlined in Table 3/1 of NRA IAN 85/06, are noted as minimal changes and do not contain any geometric changes and therefore the use of the current NRA DMRB Standards are not applicable.

Junction Treatment

10.7 All accesses, excluding field accesses and individual residential accesses, affected by Category 1 and 2 Minor Improvements are to be reviewed in accordance with the current NRA DMRB using the appropriate design speed selected above.

Signage

10.8 The provision of signs and line markings shall fulfil the requirements of the Traffic Signs Manual. Addition temporary signage should be provided advising change to road layouts and/or new junctions if appropriate.

Safety Barriers

10.9 Designers must consider the requirements for roadside Safety Barriers for all Category 1 and 2 road improvements in accordance with NRA TD

19. Where the design speed is less than 85km/h provision of safety barriers should be considered on a case-by-case basis to mitigate the risk of particular safety hazards.

10.10 For all Categories of Minor Improvements, Designers must also review the operational characteristics of the existing barriers to comply with NRA TD 19.

10.11 Where the Desirable Minimum standards pertaining to safety barriers cannot be achieved, it may be necessary to consider Relaxations or Departures from Standard.

11 SINGLE TWO-LANE CARRIAGEWAY ROADS - LOCAL ROADS

Introduction

11.1 This Chapter shall be used for the design of local single two-lane carriageway roads which are constructed or improved as part of a national road scheme.

11.2 The principles of design given within this Chapter allow lower design speeds for local roads.

Selection of Design Speed

11.3 Local Roads greater than 2km Long: Where the new or improved length of a local road is over 2km or is newly constructed, the speed of traffic will depend on the design standards selected. The Design Speed should be not greater than the value indicated in Table 11/1 for the stated mandatory speed limit.

Table 11/1: Design Speeds for Mandatory Speed Limits

Mandatory Speed Limit km/h	Design Speed km/h
30	42
50	60
60	70
80	85

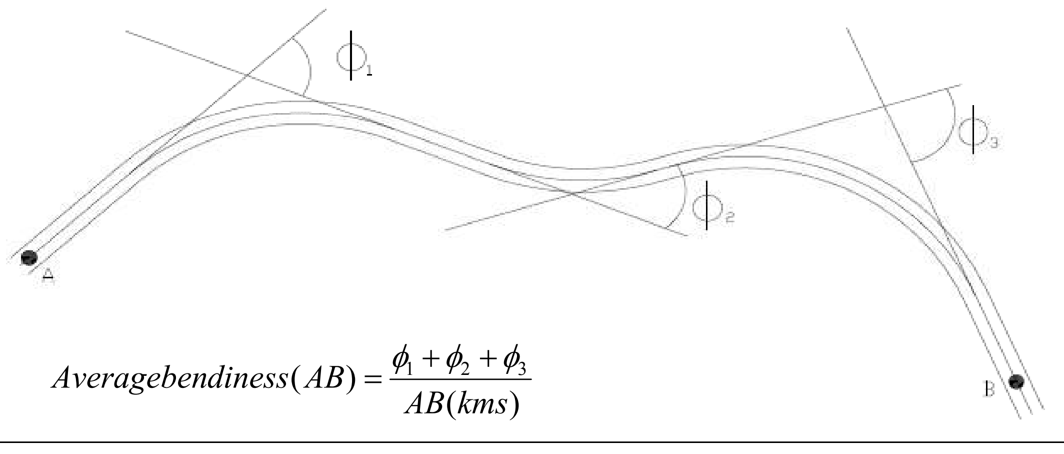
11.4 Local Rural Roads Less Than 2km Long: Where the improved length of local road is less than 2km, the Design Speed shall be derived using the Alignment Constraints (Ac) and Layout Constraints (Lc) measured over a minimum length of 2km which includes the length of improvement as set out below. Where a new length of local road is less than 300m e.g. short link roads and culs-de-sac, an appropriate design speed shall be chosen to correspond to the anticipated speed.

11.5 Alignment constraint (Ac) measures the degree of constraint imparted by the road alignment, and is measured for single carriageways by:

Ac = 12 – VISI/60 +2B/45

And where, B is the Bendiness, which is measured as the total angle the road turns through per kilometre length. It is important to realise that the design speed is not dependent on the radius of curvature of individual curves per se but on the total of degrees turned through per km bendiness (see figure 11.1) and that Bendiness must be calculated as the average value over the section to be improved and 2km either side of the proposed scheme. The bendiness should be calculated using 1:2500 scale OS digital mapping.

And where, VISI is the Harmonic Mean Visibility as calculated in Annex A.



$$Average bendiness(AB) = \frac{\phi_1 + \phi_2 + \phi_3}{AB(kms)}$$

Figure 11.1: Bendiness

11.6 Layout Constraint (Lc) measures the degree of constraint imposed by the road cross-section, verge width and frequency of junctions and accesses. Table 11.2 shows the values of Lc relative to cross section features and density of access, expressed as the total number of junctions, laybys and direct accesses (other than single field accesses) per km (see TD 41), over a distance of 2km, where:

M = Medium Access numbering 6 to 8 per km;
H = High Access numbering 9 or more per km.

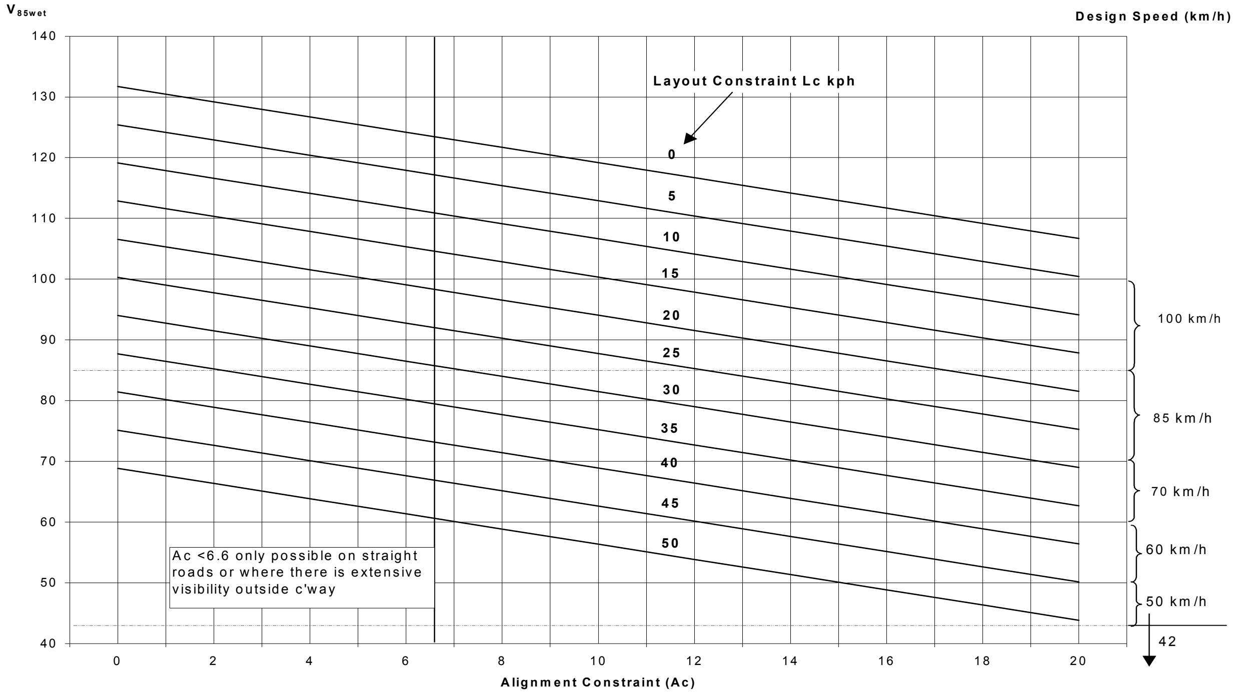
Table 11.2: Layout Constraint, Lc km/h

Carriageway width (ex. Hard strips)	4.0m		5.0m		6.0m	
Degree of access and junctions	H	M	H	M	H	M
With 3m verge (no hard shoulder)	39*	32*	33*	29*	29	26
With 1.5m verge (no hard shoulder)	41*	34*	35*	31*	31	28
With 0.5m verge (no hard shoulder)	43*	36*	37*	33*	33	30
No verge (no hard shoulder)	45*	38*	39*	35*	35*	32*

* These values were interpolated from Table 1 of this Standard.

11.7 The Design Speed is then derived from the ensuing Ac and Lc values using figure 11/1 below (Figure 11/1 has been interpolated from Figure 1 of this standard). The strategy for the continuous section of road however must be considered when determining Ac and the cross-sectional design.

Figure 11/1: Selection of Design Speed for Local Roads



11.8 The adopted Design Speed is round up to the next related design speed parameter and dictates the minimum geometric parameters for the design.

For Design Speeds on Local Roads the geometric parameters stated in Table 11/3 of this Standard shall apply.

Table 11/3: Design Speed Related Parameters

LOCAL ROAD DESIGN SPEED (km/h)	85	70	60	50	42	V^2/R
STOPPING SIGHT DISTANCE m						
Desirable Minimum Stopping Sight Distance	160	120	90	70	50	
One Step below Desirable Minimum	120	90	70	50	40	
Two Steps below Desirable Minimum	90	70	50	40	30	
HORIZONTAL CURVATURE m						
Minimum R without elimination of Adverse Camber and Transitions	1440	1020	720	510	360	5
Minimum R with Superelevation of 2.5%	1020	720	510	360	255	7.07
Minimum R with Superelevation of 3.5%	720	510	360	255*	180*	10
Desirable Minimum R with Superelevation of 5%	510	360**	255**	180*	127*	14.14
One Step below Desirable Min R with Superelevation of 7%	360	255**	180**	127*	90*	20
Two Steps below Desirable Min R with Superelevation of 7%	255	180**	127**	90*	65*	28.28
VERTICAL CURVATURE – CREST						
Desirable Minimum Crest K Value	55	30	17	10	6.5	
One Step below Desirable Min Crest K Value	30	17	10	6.5	5	
Two Steps below Desirable Min Crest K Value	17	10	6.5	5	5	
VERTICAL CURVATURE – SAG						
Desirable Minimum Sag K Value	26	20	13	9	6.5	
One Step below Desirable Min Sag K Value	20	13	9	6.5	5	
Two Steps below Desirable Min Sag K Value	13	9	6.5	5	5	
OVERTAKING SIGHT DISTANCES						
Full Overtaking Sight Distance FOSD m.	490	410	345	***	***	
FOSD Overtaking Crest K Value	285	200	142	***	***	

Notes

The V2/R values simply represent a convenient means of identifying the relative levels of design parameters, irrespective of Design Speed.

K Value = curve length divided by algebraic change of gradient (%).

* For local roads of design speeds 50km/h and less, a maximum superelevation of 3.5% shall apply.

** For local roads of design speeds 60 km/h and 70km/h, a maximum superelevation of 5% shall apply.

*** Missing FOSD parameters - refer to Section 11.9 below.

11.9 To seek to improve safety, overtaking is discouraged for Local Roads with a design speed ≤ 50km/h. Accordingly, allowable Overtaking Sight Distances are not included in Table 11/3 and any design should not seek to provide for overtaking manoeuvres.

11.10 For maximum allowable vertical gradients on local roads the parameters stated in paragraphs 4.1 and 4.2 shall apply.

Relaxations and Departures

11.11 In general the policy with regard to Relaxations and Departures shall be that adopted for National Roads as set out in this Standard. Paragraphs 11.12 to 11.14 set out exceptions to the Relaxations and Departures that will apply to local roads.

Any variation in that policy (e.g. in amending the policy in relation to acceptance of numbers of Relaxations) shall be specifically agreed by the road authority.

The road authority shall be either the local authority or the National Road Authority or their appointed agent.

Exceptions

11.12 A crest curve K value 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 Minimum, the adoption of which would also require a Relaxation. This arrangement is permitted and will not require a departure when applied on a local road.

11.13 In situations where site-specific circumstances dictate, transitions may be omitted from the design of the new local road at low design speeds (≤ 60km/h) and recorded as a Relaxation.

11.14 Progressive superelevation or removal of adverse camber shall generally be achieved over or within the length of the transition curve from the arc end (see also paragraph 3.17). On new and existing roads without transitions, between ½ and ⅔ of the superelevation shall be introduced on the approach straight and the remainder at the beginning of the curve.

12. REFERENCES

BS 6100 : Subsection 2.4.1, Glossary of Building and Civil Engineering Terms: Highway Engineering. British Standards Institution.

NRA Design Manual for Roads and Bridges (NRA DMRB):

NRA TA 43 (NRA DMRB 6.1.1A) – Guidance on Road Link Design.

NRA TA 69 (NRA DMRB 6.3.3) – The Location and Layout of Lay-bys.

NRA TD 19 (NRA DMRB 2.2.8A) – Safety Barriers.

TD 22 (DMRB 6.2.1) – Layout of Grade Separated Junctions.

NRA TD 27 (NRA DMRB 6.1.2) – Cross-Sections and Headroom.

TD 40 (DMRB 6.2.5) – Layout of Compact Grade Separated Junctions.

TD 41 (DMRB 6.2.7) – Vehicular Access to All-Purpose Roads.

TD 42 (DMRB 6.2.6) – Geometric Design of Major/Minor Priority Junctions.

Guidelines on Traffic Calming for Towns and Villages on National Routes. National Roads Authority.

National Roads Project Management Guidelines. National Roads Authority.

Road Traffic (Signs) Regulations.

Traffic Signs Manual. Department of the Environment and Local Government.

13. ENQUIRIES

13.1 All technical enquiries or comments on this Standard should be sent in writing to:

Head of Engineering Operations
National Roads Authority
St Martin's House
Waterloo Road
Dublin 4

………………………………………………………
E O'CONNOR
Head of Engineering Operations

ANNEX A: HARMONIC MEAN VISIBILITY

A1 The Harmonic Mean Visibility VISI shall be measured over a minimum length of about 2km in the following manner. Measurements of sight distance shall be taken in both directions at regular intervals (50m for sites of uneven visibility, 100m for sites with good visibility) measured from an eye height of 1.05m to an object height of 1.05m, both above the centre line of the road surface. Sight distance shall be the true sight distance available at any location, taking into account both horizontal and vertical curvature, including any sight distance available across verges and outside the road boundary wherever sight distance is available across embankment slopes or adjoining land, as shown in Figure A1.

A2. Harmonic Mean Visibility is the harmonic mean of individual observations, such that:

$$VISI = \frac{n}{\frac{1}{V_1} + \frac{1}{V_2} + \frac{1}{V_3} \ldots + \frac{1}{V_n}}$$

where:-

n = number of observations
V1 = sight distance at point 1, etc.

A3. For existing roads, an empirical relationship has been derived which provides estimates of VISI given in bendiness and verge width (applicable up to VISI = 720m), i.e.

Log_{10} VISI = 2.46 + VW/25 - B/400

where:

VW = Average width of verge, plus hard shoulder where provided (m, averaged for both sides of the road)

B = Bendiness (degrees per km, measured over a minimum length of about 2 km).

This relationship is valid for most existing roads. However, on long straight roads, or where sight distance is available outside the highway boundary, significant underestimates of VISI will result.

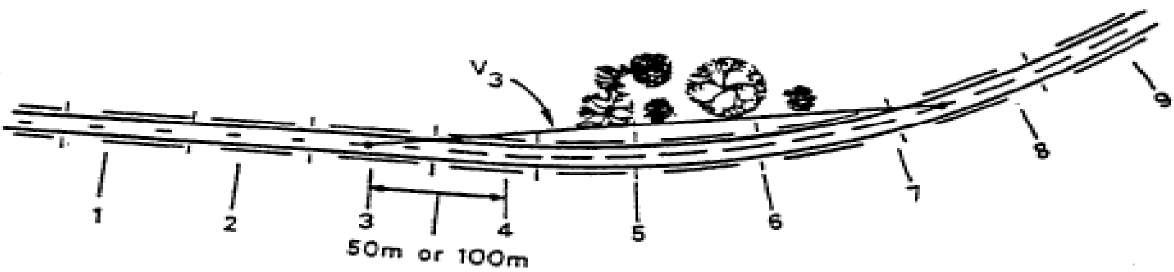


Figure A1: Measurement of Harmonic Mean Visibility

A4. For preliminary route analysis, where detailed measurements of sight distance are not available, the following typical values should be used:

a) On long virtually straight roads, or where the road is predominantly on embankment affording high visibility across embankment slopes or adjoining level land:

VISI = 700m

b) If a new road is designed with continuous overtaking visibility, with large crest K values and wide verges for visibility:

VISI = 500m

c) Where a new road is designed with frequent Overtaking Sections, but with stopping sight distance provision at all sharp curves:

VISI = 300m

d) Where an existing single carriageway contains sharp bends, frequent double continuous line sections, narrow verges etc.:

VISI = 100 to 200m

However, the empirical formula shown in Paragraph A3 can be used if Bendiness is available.